Mineral Resources of the Spanish Peaks Primitive Area, Montana

OLOGICAL SURVEY BULLETIN 1230-B

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

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STUDIES RELATED TO WILDERNESS

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An evaluation of the mineral
potential of the area

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STUDIES RELATED TO WILDERNESS

The Wilderness Act (Public Law 88–577, Sept. 3, 1964) and the Conference Report on Senate bill 4, 88th Congress, direct the U.S. Geological Survey and the U.S. Bureau of Mines to make 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 provided that each primitive area should 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 Spanish Peaks primitive area, Montana. The area discussed in the report corresponds to the area under consideration for wilderness status. It is not identical with the Spanish Peaks primitive area as defined because modifications of the boundary have been proposed for the area to be considered for wilderness status. The area that was studied is referred to in this report as the Spanish Peaks primitive area.

This bulletin is one of a series of similar reports on primitive areas.

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MINERAL RESOURCES OF THE SPANISH PEAKS PRIMITIVE AREA, MONTANA

By George E. Becraft and James A. Calkins, U.S. Geological Survey, and Eldon C. Pattee, Robert D. Weldin, and Joseph M. Roche, U.S. Bureau of Mines

SUMMARY

This report on the Spanish Peaks primitive area, Montana, is the result of a study made by the U.S. Geological Survey and the U.S. Bureau of Mines during the summer of 1965. Most of the primitive area consists of Precambrian metamorphic rocks which, along the southwestern boundary of the area, are in fault contact with folded Paleozoic and Mesozoic sedimentary rocks. The Spanish Peaks area has rugged topography, with altitudes that range from 6,000 feet above sea level near the Gallatin River to 11,015 feet on Gallatin Peak.

Reconnaissance geologic mapping and semiquantitative spectrographic and chemical analyses of nearly 300 samples of stream sediments and bedrock did not indicate any potentially economic mineral deposits within the Spanish Peaks primitive area. Included in the analyzed samples are sediment samples from the major streams and from many small tributaries of these streams in and near the primitive area. Also, several samples of each major rock unit and many samples of the few altered zones in the area were analyzed.

Asbestos occurs in a few places in the eastern part of the area; the largest prospect is on Table Mountain. Examination of the several pits on this prospect indicate the veins are too small, and the asbestos, anthophyllite, is of too poor grade to be economically potential.

Extensive sampling, mineral dressing tests, and assays of dike rock from the Table Mountain asbestos-chromite prospect by the U.S. Bureau of Mines indicated an average Cr_2O_3 grade of 11 percent for the rock. The grade is too low and the deposit too small to be profitably mined at present. The deposit, however, contains submarginal material and is a potential source of chromium. Large altered zones were found along the Spanish Peaks fault and the Deer Creek shear zone, and two small altered zones were found south of Gallatin Peak. Examination and analyses of samples from these zones indicate no mineral deposits.

There has been no production of minerals from the primitive area, and the known deposits within the boundaries cannot be mined profitably at the present time.

LOCATION AND GEOGRAPHY

The Spanish Peaks primitive area is in the Gallatin National Forest of southwestern Montana near the northern end of the Madison Range in Madison and Gallatin Counties. The area is irregular in shape but is elongated in a northwest-southeast direction. The maximum length is 17 miles and the average width is about 4.5 miles.

The rugged Spanish Peaks are bordered by lower mountains of the Madison Range to the north and south. Drainage of the area is eastward and westward by tributaries of the Gallatin and Madison Rivers. Most of these streams flow in broad glaciated valleys with steep walls extending to the ridge crests 1,000 to 3,000 feet above the valley floors. Alpine glaciation has produced a rugged topography with many knife-edge ridges and cirques. All the many lakes in the area occupy cirques, except Lava Lake which has been formed by the damming of a streambed by a large landslide. Near the eastern and western boundaries of the area, glacial erosion was not as severe, and traces of the preglacial rolling topography remain. Altitudes range from about 6,000 feet above sea level near the Gallatin River to 11,015 feet on Gallatin Peak. Timberline is near 9,000 feet. Slopes below are forested with various species of conifers, and several varieties of deciduous trees grow along streambeds. The south slopes of some ridges at lower altitudes are bare, except for sagebrush and grass.

The climate in the basins surrounding the area is semiarid, but the mountains have considerably more precipitation. There are wide variations in daily and seasonal temperatures. Summers are mild, with temperatures seldom above 90°F. Thundershowers in the afternoon are common. Winters are severe, with considerable subzero temperatures. Snow covers the ground from October or November into July; depths of 2 to 6 feet are common.

Several roads provide access to within 2 miles of the wilderness boundary. U.S. Highway 191 follows the canyon of the Gallatin River and skirts the eastern edge of the primitive area (fig. 1). No roads extend into the primitive area but many Forest Service dirt roads and trails extend to near the boundary from U.S. Highway 191 on the east and from State Highway 287 a few miles to the west. A new Forest Service road, under construction in 1965, from the county road along Spanish Creek to the Spanish Creek Ranger Station, will provide easy access to trails that extend into the western part of the area.

The nearest rail shipping points are at Gallatin Gateway and Norris, 14 and 20 miles northeast and northwest, respectively. Bozeman, 32 miles to the northeast, is the nearest source of small mining equipment and most general supplies.

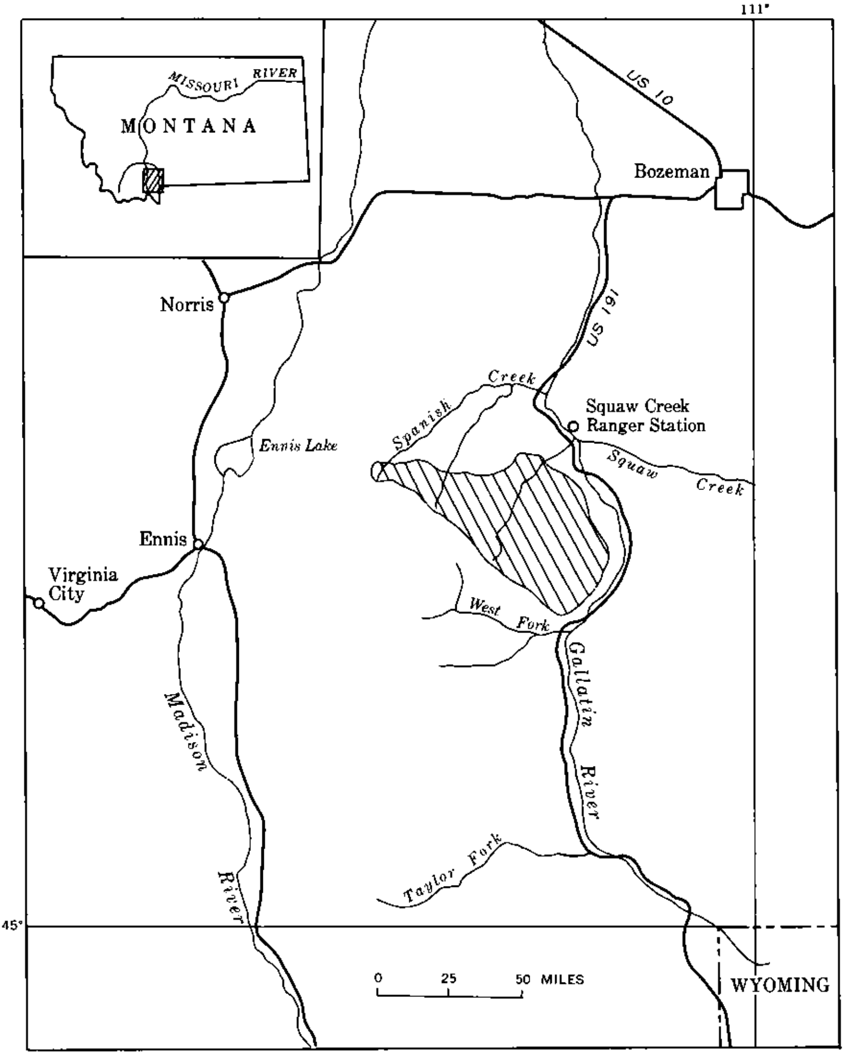


FIGURE 1.—Location of Spanish Peaks primitive area, Montana.

GEOLOGY AND MINERAL RESOURCES

By GEORGE E. BECRAFT and JAMES A. CALKINS, U.S. Geological Survey

INTRODUCTION

This study of the mineral resources of the Spanish Peaks primitive area was made during July and August 1965 by Becraft and Calkins assisted by Mike F. Gregorich and Robert L. Bailey. A reconnaissance geologic map was made of the area. Several stream-sediment samples were collected from each major stream in and near the area, and sediment samples were collected from many small tributaries of the major streams. Many samples of typical rocks of the area were collected for analysis as well as samples of any rock that appeared to be altered in any way. Finally, selected traverses were made, mainly on foot, to evaluate the mineral potential of the area.

All stream-sediment samples were analyzed in the field for selected elements by Gordon Van Sickle and Charles L. Whittington, assisted by Fred H. Marshall, operating with a mobile chemical laboratory. Spectrographic analyses of the stream-sediment samples and most of the rock samples were made in the field by A. P. Marranzino, Gary C. Curtin, Howard W. Knight, and David J. Grimes operating with a mobile spectrographic laboratory. The chemical and spectrographic analytical methods used and the minimum concentrations of each element detectable by these methods are described in detail by Ward, Lakin, Canney and others (1963). The method used for gold analysis is described by Lakin and Nakagawa (1965). A few samples were analyzed in the U.S. Geological Survey laboratory in Denver, Colo., by J. C. Hamilton and Barbara Tobin.

Geology of the Garnet Mountain quadrangle, which includes a little of the eastern part of the Spanish Peaks primitive area, was mapped by McMannis and Chadwick (1964). Edgar W. Spencer and Samuel J. Kozak studied the tectonic style in the Spanish Peaks and very kindly supplied us with a copy of the unpublished manuscript based on that study. Both of these reports aided considerably in the study of the mineral potential of the Spanish Peaks primitive area. A report by Peale (1896) covers the Spanish Peaks but does not include any details of the geology of the primitive area. Swanson (1951) mapped the sedimentary rocks at the south boundary of the area as part of a study of the central Madison Range. Marvin (1952) mapped small areas partly within the primitive area and briefly discussed some of the geology. Reports by Perry (1948) and by Wilson (1948) describe the geology and mineralogy of the Karst asbestos deposit, which is in secs. 35 and 36, T. 5 S., R. 4 E., just east of the primitive area. McMannis and Chadwick (1964) also discuss the geology of this deposit. These reports helped us in our study because the Karst asbestos deposit is similar to the small occurrences of asbestos within the primitive area.

We are indebted to Ralph L. Erickson, U.S. Geological Survey, for his helpful suggestions on the geochemical sampling program and for evaluating the results of the analyses. We thank District Ranger L. O. Peck, U.S. Forest Service, for his generous cooperation and aid. We are particularly grateful to Mr. and Mrs. Robert Keefer, Gallatin Gateway, Mont., who kindly helped us in many ways.

GEOLOGY

Most of the bedrock in the Spanish Peaks primitive area is Precambrian metamorphic rock consisting mainly of various kinds of gneiss, schist, quartzite, amphibolite, and pegmatite. The geology of these rocks is extremely complex in the area, as it is throughout all of southwestern Montana, and no attempt was made to map it in detail. Near the southern boundary of the primitive area, folded Paleozoic and Mesozoic sedimentary rocks, which extend southward about 40 miles, are in fault contact with the Precambrian rocks. A few small remnants of a formerly extensive cover of Tertiary volcanic rocks remain in the eastern part of the primitive area. These volcanic rocks cover a large area east of the Gallatin River (McMannis and Chadwick, 1964). Glacial deposits cover all the valley floors in the area. Two large landslides occurred after the retreat of the glacier in Cascade Creek; the larger, which consists mainly of Tertiary volcanic rocks, dammed the creek and caused Lava Lake to form. The other, about 1 mile north of Lava Lake, consists largely of Precambrian gneiss; a large meadow has formed by filling on the upstream side of this slide.

PRECAMBRIAN ROCKS

The Precambrian metamorphic rocks are a complex mixture of many varieties of rock. They were not mapped in detail, but a conspicuous layer of quartzite and a small body of mafic intrusive rock are shown on plate 1.

Reid (1957, 1963), in two reports on the geology of the Tobacco Root Mountains, and McThenia (1960), in a report on the area north of Ennis, have described the petrography of similar Precambrian rocks in considerable detail. Only a brief discussion of these rocks is given below.

The major rock type is granitic gneiss which ranges from light gray to nearly black depending upon the amount of biotite and amphibole in the rock. It is generally very strikingly foliated with alternate light and dark layers producing a banding that is obvious for considerable distances from the outcrops. In some places, however, particularly where no layers rich in dark minerals are present, the foliation is not as obvious but can be seen on close observation. This poorly foliated type of gneiss is more common in the eastern half of the primitive area but is also present in the western half. The granitic gneiss consists principally of quartz, plagioclase, potassium feldspar, biotite, hornblende, and, in places, muscovite.

Schists of many different compositions are also common in the area; some of the more common types are amphibole-biotite-quartz, muscovite-biotite-quartz, garnet-biotite-quartz, amphibole-feldspar, and muscovite-biotite-feldspar. Sillimanite- and kyanite-bearing quartzitic schists were found in several places. The greatest thickness of kyanite-bearing rocks is on the southeast-trending ridge about 1 mile south of Gallatin Peak. There, biotite-kyanite-quartz schist is interlayered with other schists and gneisses in sequence about 1,500 feet thick. The kyanite, both deep-blue and colorless in crystals about one-half inch long, makes up about 10 percent of a few of the layers.

Amphibolite, a dark-greenish rock—consisting of hornblende, plagioclase, quartz, and locally garnet—is present throughout the entire area but appears to be most common in certain zones. It occurs as irregular masses, lenses, dikes, and in sill-like bodies that may be continuous for as much as a mile. Dikes and sills are particularly well exposed on the west side of Gallatin Peak and on the ridge east and northeast of Mirror Lake. Generally the bodies are only a few feet to a few tens of feet thick, but a few are thicker. Exposures in cirque walls indicate some amphibolite bodies are lenticular vertically as well as horizontally, and as E. W. Spencer and S. J. Kozak suggest in their manuscript (referred to on p. B4), some of these may be boudins (sausage-shaped segments) formed from an originally continuous layer. During folding, the amphibolite layer was less ductile than the surrounding gneiss and was squeezed off. Many of the amphibolite bodies are well foliated; in these, the foliation commonly parallels that in the surrounding gneiss. Other amphibolite bodies appear to have little or no foliation.

Quartzite and schistose quartzite are interlayered with the other rocks in a few places, but only one quartzite unit was persistent enough to be mapped (pl. 1). This unit is about 400 feet thick and was traced about 6 miles along strike. The rock is made up of layers ranging from less than 1 inch to several inches thick. Though the rock is largely quartz, it generally contains a few percent of muscovite and, locally, a small amount of sillimanite. Smaller, discontinuous layers of similar rock occur near the top of the ridge east of Lava Lake and on the ridge south of Jerome Rock Lakes. The quartzite east of Lava Lake contains crystals of green muscovite as much as 0.1 inch long and a few small crystals of kyanite. The layer south of Jerome Rock Lakes is about 6 feet thick and contains a little biotite and kyanite as well as quartz and traces of sillimanite.

Small pegmatite masses occur throughout the area. They are commonly discontinuous dikes and sills ranging in thickness from a few inches to a few feet. In some outcrops several generations of pegmatite can be observed—each generation cutting the earlier ones. The earlier formed pegmatite has vague boundaries and appears to have formed from the gneiss by removal of the dark mafic minerals and concentration of the light-colored minerals. The youngest pegmatite has no foliation and has sharp boundaries and obviously intruded the enclosing rocks late in the last metamorphic episode. It is most common near the axial zones of small folds but also occurs at many other places. The mineralogy of the pegmatites is simple. They consist largely of quartz and potassium feldspar, but contain some plagioclase, biotite, hornblende and minor amounts of muscovite, magnetite, and tourmaline. Some of the pegmatites consist almost entirely of milky quartz and contain potassium feldspar crystals as much as 4 inches long. Some of the potassium feldspar is microcline and much is perthitic.

PALEOZOIC ROCKS

Sedimentary rocks of Paleozoic age occupy an area of less than a square mile in the primitive area near its southern border. They are part of a sequence of sedimentary rocks ranging from Cambrian to Cretaceous in age that is faulted against the Precambrian rocks along the Spanish Peaks fault, a major fault that roughly parallels the southwest side of the primitive area. These rocks have been mapped in the adjacent Garnet Mountain quadrangle and described in detail by McMannis and Chadwick (1964). The total thickness of the rocks is more than 5,000 feet. On plate 1 the sedimentary rocks have been divided into five map units: Cambrian to Mississippian rocks, Quadrant Formation of Pennsylvanian age, Phosphoria Formation of Permian age, Triassic to Jurassic rocks, and Cretaceous rocks. Only the oldest rocks in this sequence, Cambrian to Mississippian in age, are discussed below as they are the only ones within the primitive area. The younger rocks have been described by McMannis and Chadwick (1964).

Rocks of Cambrian to Mississippian age form the northwest-trending ridge between Dudley and North Fork Creeks. They are about 2,500 feet thick and consist predominantly of limestone and dolomite. The lowermost unit adjacent to the Spanish Peaks fault is the Meagher Limestone of Middle Cambrian age. It is dense gray thin-bedded microcrystalline limestone. The Meagher is overlain successively by the Park Shale of Middle Cambrian age and the Pilgrim Limestone of Late Cambrian age. The Pilgrim and Meagher Limestones are similar except that the Pilgrim is partially dolomitized and contains more shale partings.

Ordovician and Silurian strata are missing in this area, and the Cambrian rocks are overlain disconformably by the Devonian Jefferson Limestone and the Devonian and Mississippian Three Forks Shale. The Jefferson Limestone in this area is mainly white and gray medium-grained, crystalline dolomite; only a few beds of limestone and shaly limestone are present.

Overlying the Devonian and Mississippian strata are the ridge-forming limestones of Mississippian age, which here include the Lodgepole and Mission Canyon Limestone. These two units total about 1,300 feet in thickness and form the crest of the ridge as well as the steep cliffs on the southwest side. The rocks are gray dense medium-bedded limestones, with some oolitic and argillaceous beds. Fossils are abundant and chert nodules are present in places. The upper part of the Mission Canyon Limestone is strongly dolomitized and contains abundant layers and lenses of chert.

TERTIARY ROCKS

Volcanic rocks of Tertiary age are exposed in a few small areas near the eastern margin of the Spanish Peaks primitive area. These are remnants of lava flows that undoubtedly extended eastward to join the thick volcanic sequence mapped by McMannis and Chadwick (1964) east of the Gallatin River. The rocks are very dense porphyritic gray to black andesite.

Many dikes of diabase (dark intrusive rock of about the same composition as the lava flows) cut the Precambrian metamorphic rocks in the eastern and central part of the area. The diabase appears to be unmetamorphosed and most dikes have chilled margins, indicating that the diabase is distinctly younger than the metamorphic rocks. No dikes were observed in contact with the lava flows, but they probably are about the same age. This age has not been fixed closer than early Eocene to late Miocene (McMannis and Chadwick, 1964, p. 22).

STRUCTURE

The structure of the area consists mainly of two unrelated elements of vastly different ages; the first is the fold structure in the Precambrian rocks, and the second includes the fault structure of Laramide age and related folding in the sedimentary rocks and the Deer Creek shear zones.

STRUCTURE OF THE PRECAMBRIAN ROCKS

The overall trend of the foliation in the Precambrian rocks is northeast with a swing toward a more easterly direction in the eastern part of the area. The dip of the foliation is generally steep except in the southeastern part of the area. In detail, the structure of these rocks is much more complex owing to many tight, closely spaced folds which range from tiny crinkles on foliation surfaces to folds that are many tens of feet in wavelength. Some isoclinal folds are only a few feet across, but the limbs can be traced for a few hundred feet. Some rock layers retain evidence of extreme folding, whereas layers on each side show little or no evidence of folding. In many folds, migration of material from the limbs to the axial zones has resulted in extreme thinning and thickening of layers and very complex folds in the axial zone. In other small areas the rocks have actually become molten, and earlier layering has been destroyed. Most of the folding appears contemporaneous with the high-grade metamorphism, but whether there was more than one period of metamorphism and folding was not determined.

SPANISH PEAKS FAULT

The large fault separating Precambrian metamorphic rocks on the northeast from Paleozoic and Mesozoic sedimentary rocks on the southwest has been called the Spanish Peaks fault by McMannis and Chadwick (1964, p. 32). The fault was traced in detail from the Gallatin River northwestward to Beehive Basin, a distance of 9 miles, and projected beyond for several miles. It is strikingly marked topographically by a series of saddles in the ridges and by drainage alinements.

The fault strikes northwestward and it appears to be nearly vertical, as shown by a few direct measurements and its remarkably straight course across the rugged topography. The fault zone ranges in width from 60 to about 150 feet and consists of brecciated sedimentary rocks and gneiss together with kaolinitic clay gouge. The gouge is commonly stained red and brown by iron and manganese oxides. High permeability along the fault in one area is indicated by a large spring along the fault just below U.S. Highway 191 outside the primitive area.

The rocks on the northeast side of the fault have moved upward relative to those on the southwest side. In most places the sedimentary rocks on the south side dip steeply away from the fault; however, in two places where the sedimentary rocks immediately adjacent to the fault are well exposed, they dip toward the fault. Displacement on the fault cannot be determined in the absence of sedimentary rocks on the northeast side, but McMannis and Chadwick (1964, p. 32) suggest that farther southeast the stratigraphic displacement may be as much as 13,500 feet. This large displacement suggests that the sedimentary rocks are not simply dragged against the fault but are part of an original monocline or kink in the bedded rocks and that the fault is a major regional structure.

DEER CREEK SHEAR ZONE

A zone of shearing, brecciation, and alteration—called the Deer Creek shear zone—extends for a known distance of slightly over 1 mile along the lower slopes north of Deer Creek, in and near the southeastern part of the primitive area. Other smaller zones occur on the ridge south of Deer Creek. Considerable prospecting has been done along these zones.

The Deer Creek shear zone strikes about N. 70° E., dips about 70° NW., and ranges in outcrop width from 70 to 400 feet. Westward, the shear zone disappears under the thick alluvium of the Deer Creek Valley and does not crop out elsewhere. Its eastward continuation across the Gallatin River was not investigated.

The rocks in and adjacent to the shear zone are mica-quartz schist, quartz-rich granitic gneiss, and quartzite. The shear zone generally follows the strike of the foliation but cuts sharply across the dip, which typically is only about 30° and in places is as low as 10°. The shear zone is characterized by irregularly spaced fractures that display little evidence of movement. In some places, the altered rock has been intensely brecciated and recemented by quartz, destroying the original fabric of the rock, but in most places the original foliation of the rock has been preserved.

Rocks in the shear zone are stained rusty brown from iron oxides present in stringers, patches, and along fractures. Near the center of the zone, the rocks have been silicified, or replaced by fine-grained quartz or jasperoid, and near the borders they have been partly altered to clays. These features indicate that hot or warm mineralizing solutions moved through the zone, but no ore-bearing veins were found. Results of geochemical sampling in the zone are discussed later in this report. The silicified outcrops of the shear zone stand out in bold relief in an area otherwise scanty of outcrops.

The zones south of Deer Creek are similar, though considerably smaller. They are probably branches of the larger zone, but their northward extensions are covered by the alluvium of Deer Creek.

MINERAL RESOURCES

Several different types of mineral deposits are known in the general area of the Spanish Peaks primitive area. To the northwest in the Tobacco Root Mountains are veins containing lead, silver, zinc, gold, copper, and tungsten. Large gold deposits were found in the gravel of Alder Gulch near Virginia City west of the Spanish Peaks. Also in the vicinity of the primitive area are small deposits of nonmetallic minerals including corundum, mica, talc, kyanite, sillimanite, and asbestos.

No mineral deposits of potential economic value were found in the Spanish Peaks primitive area. Asbestos of poor quality occurs in a few places in the eastern part of the area, but in deposits too small to mine profitably. The largest prospect is on Table Mountain. Large hydrothermally altered zones were found along the Spanish Peaks fault and the Deer Creek shear zone, and two small altered zones were found on the ridge south of Gallatin Peak. An occurrence of secondary copper minerals in an amphibolite dike was found just south of the primitive area in an old roadcut about 100 feet east of U.S. Highway 191 south of Jack Smith bridge in the SW¼ sec. 27, T. 6 S., R. 4 E.

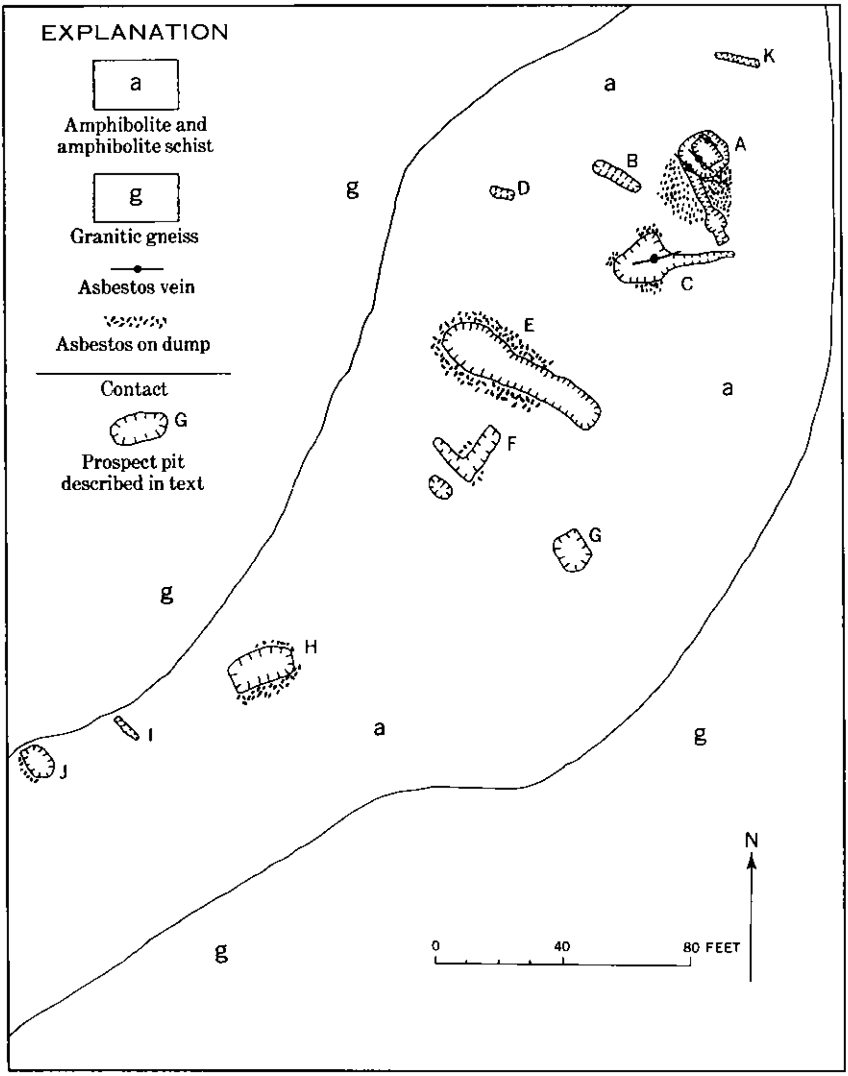
TABLE MOUNTAIN ASBESTOS PROSPECT

The Table Mountain prospect, the best of the small asbestos deposits in the area, is in the NE¼ sec. 8, T. 6 S., R. 4 E. It has been explored by 11 shallow prospect pits. Asbestos was found on the dumps of six of those pits (fig. 2).

The asbestos, of the anthophyllite variety, occurs in small veins that cut an altered mafic dike. Veins were observed in only two pits (A and C). The thickest vein seen in the pits was about 8 inches, but some fibers of the asbestos on the dump of pit A (fig. 2) were as much as 12 inches long. Thus, wider veins must have existed in the pit because the fibers grow normal to vein walls. Much of the asbestos in place is hard and brittle, whereas that on the dump is softer and more flexible owing to weathering. This is similar to the conditions at the Karst asbestos deposit east of the primitive area where, according to Wilson (1948), the asbestos fibers become harsher and of inferior quality at depth because the best are produced by weathering of the anthophyllite. The asbestos on Table Mountain undoubtedly was formed in the same manner as that at the Karst deposit. There the pyroxene mineral enstatite was altered to serpentine (antigorite) by superheated water. The serpentine was altered to asbestos (anthophyllite) by solutions containing calcium, aluminum, and silicon dioxide (Wilson, 1948).

The prospect pits on Table Mountain shown on figure 2 are described in detail in the following paragraphs. All the pits were badly caved, and little bedrock was exposed in them.

Pit A.—The main part of the pit is about 12 feet deep and was originally a little deeper, but the bottom is filled with rubble. A shallow trench about 2 feet deep extends to the southeast. The walls of the pit are mostly altered mafic dike rock, probably originally amphibolite or pyroxenite. In the north corner of the pit are two highly irregular veins of asbestos (shown by one vein symbol on fig. 2). The veins appear to have a general northwest strike and dip 75°–85° NE. The asbestos fibers in the veins are elongated in a general northeast direction. The veins vary greatly in width but average about 8 inches. A third asbestos vein is exposed on the southwest side of the main pit. It parallels those to the north, has about the same width, and is also rather irregular. The asbestos, however,



Mapped by G. E. Becraft and M. F. Gregorich, 1965

FIGURE 2.—Geologic map of the asbestos prospect on Table Mountain.

appears to be much harder and more brittle. The small vein at the junction of the main pit and the trench is only about 2 inches wide. The dumps, southeast and southwest of the main pit, are completely covered by asbestos, some of which is as much as 12 inches long, so there must have been larger veins in the pit than those remaining. The floor and the dumps of the shallow trench extending southeast from the main pit are covered by asbestos and altered wallrock. The trench may have been dug along a narrow vein that strikes northwest. No veins appear to strike northeast, parallel to the general strike of the mafic dike.

Pit B.—The pit is about 4 feet deep, in slightly altered mafic dike rock. Some wallrock contains a little asbestos, but the only vein of asbestos seen was about 1 inch wide and 1 foot long. The few pieces of asbestos on the dump are almost certainly from pit A.

Pit C.—The pit is about 4 feet deep, and a small trench to the east is about 2 feet deep. One vein of asbestos is exposed in the pit. It is about 18 inches wide at its widest point and trends about N. 75° E. Two thin zones of altered wallrock, each less than half an inch wide, divide the vein into three segments at the widest part. On the north side of the trench at the junction with the main pit, the vein splits into several small veins about 1 inch wide and these pinch out to the northeast. The vein does not extend to the west side of the pit. The asbestos is hard and brittle.

Pit D.—Only slightly altered wallrock was observed in this small pit about 3½ feet deep. The rock contains a little asbestos but the few large pieces of asbestos on the dump do not appear to be from this pit.

Pit E.—This large pit is about 7 feet deep near the northwest end and about 2½ feet deep at the southeast end. The walls of the pit are so completely slumped that no bedrock was seen in place. As shown on figure 2, asbestos completely covers the dump of the western part of the pit, but there is none on the dump near the eastern end. Some asbestos fibers are as much as 8 inches long, so at least one vein was that wide. There were probably several veins exposed in the pit, as judged from the amount of asbestos on the dump.

Pit F.—This pit is about 3 feet deep and badly slumped. Though no veins of asbestos were seen in the pit, there is a little asbestos on the dump. The fibers are as much as 4 inches long. If the asbestos on the dump came from veins in this pit, the veins must be very short or there should be considerably more asbestos on the dump.

Pit G.—This pit is very shallow and exposes only unaltered mafic dike rock.

Pit H.—This pit is about 4 feet deep. There is a large amount of asbestos on the dump but none was seen in place. The only rock now exposed is altered wallrock at the southwest end of the pit. The longest fibers on the dump are 8 inches long, indicating at least one vein of that width. The large pieces of asbestos are hard and brittle, but the weathered fibers are soft and flexible.

Pit I.—This small pit is about 2 feet deep and exposes only slightly altered wallrock. There is no asbestos on the dump.

Pit J.—The pit is about 3½ feet deep. There is a little asbestos on the dump on the south side of the pit, but none was seen in place. The vein was probably about 4 inches wide. The remainder of the rock on the dump is altered mafic rock with a little asbestos in the fabric of the rock.

Pit K.—This is the northernmost pit in the vicinity. It is about 1½ feet deep and exposes only unaltered mafic dike rock.

ALTERATION ALONG SPANISH PEAKS FAULT

The rocks along the Spanish Peaks fault have been altered presumably by hydrothermal solutions moving through the highly permeable zone. The alteration is almost totally restricted to the sheared and broken rock in the fault and does not appear to extend into the unbroken wallrock on either side of the fault. The zone has been prospected at many places, generally at points where the fault crosses a ridge.

Many samples from along the zone were analyzed (table 1), but only those from the pits near where the fault crosses U.S. Highway 191, outside the primitive area, contained unusual amounts of metal. One specimen of vein material from the dump of one pit contained 3 percent copper (C77b, table 1). Several pits were dug in this vicinity, but highway construction has obliterated all but three. One pit is a few feet below the highway and about 30 feet north of the spring. The second is uphill and 15 feet from the highway. The third is about 100 feet above the highway. All pits are caved and nearly filled with rubble, but the dumps consist mostly of brown-stained crushed granite gneiss and mica-quartz schist and contain brown carbonate (siderite?) fragments spotted with quartz and white crushed and kaolinized feldspar. Small pieces of vein quartz containing chalcopyrite, pyrite, and malachite are on the dump of the second pit, which evidently is on a small vein. No copper minerals were seen in the other two pits although the dump of the pit about 100 feet above the highway contains some quartz. Scattered pyrite crystals in brown-weathering siliceous clay gouge were found on the dump of the prospect pit on the steep wooded slope west of North Fork Creek in sec. 9, T. 6 S., R. 3 E., but no copper or other ore minerals were noted (see analysis C76b, table 1). All other pits along the Spanish Peaks fault are devoid of ore minerals.

The locations of rock samples collected along the Spanish Peaks fault are shown on plate 2. The results of the analyses of these samples are given on table 1. In addition, several stream-sediment samples were collected from streams crossing the fault. Analyses of these samples are also given on table 1.

MINERALIZATION ALONG DEER CREEK SHEAR ZONE

Several small pits mostly outside the primitive area have been dug on and near the Deer Creek shear zone (described under the section on "Structure") and the smaller zones to the south. Many rock samples from these pits and elsewhere along the zones were analyzed as well as three stream-sediment samples from streams that cross the main zone (table 1). None of the samples contained unusual amounts of metallic elements.

McMannis and Chadwick (1964, p. 43) report copper minerals along a shear zone in Precambrian rocks near the mouth of Deer Creek in the NE¼ sec. 22, T. 6 S., R. 4 E. A hand specimen from a prospect pit in this area at C95 (pl. 2), along a small shear zone, had traces of malachite along narrow fractures in altered and sheared granitic rock. An analysis of a sample of this rock, however, indicated no unusual amount of copper.

A few narrow veins of asbestos about 1 inch wide were seen in a prospect pit in sheared serpentine at locality C2, plate 2. The veins are very irregular and discontinuous.

VEINS SOUTH OF GALLATIN PEAK

Two altered zones, each less than 2 feet wide, were found on the ridges south of Gallatin Peak, near the center of the mapped area (pl. 1). They are located at C82 and C83 on plate 2.

The first zone (C82, pl. 2) contains a vein less than 1 inch wide and parallel to the foliation. The vein contains mostly quartz, epidote, and pyrite, but a sample of vein material found in the float nearby also contained chalcopyrite and malachite. The wallrocks—

granitic gneiss and amphibolite—contain pyrite, quartz, and epidote in veinlets and lining fractures, and are stained rusty brown by iron oxide. The altered zone disappears beneath talus in only a short distance.

The second zone (C83, pl. 2) is similar to the first except that it consists of at least five quartz-epidote-pyrite veins about 1 inch wide, two of which contain a considerable amount of carbonate minerals. The veins are discontinuous; none is longer than 30 feet. No copper minerals were seen in this second zone.

Analyses of samples from these zones are given in table 1. These veins are too small to be economically significant.

COPPER IN ALTERED AMPHIBOLITE

Some amphibolite samples contain slightly more copper than the surrounding metamorphic rocks, but no copper minerals were found in the amphibolite in the primitive area. However, secondary copper minerals, mostly malachite, coat fractures in amphibolite well exposed in a roadcut along U.S. Highway 191 about 1 mile south of the primitive area in sec. 27, T. 6 S., R. 4 E. (B1 on pl. 2). The amphibolite cuts a slightly schistose micaceous quartzite. All the rocks are stained by iron oxide, and are also cut by many small faults with gouge zones less than 1 inch wide. The amphibolite and micaceous quartzite are altered adjacent to some of the small faults. Secondary copper minerals coat these fractures in the amphibolite, but none were seen in the quartzite. Analyses (table 1) of samples from this locality indicate that the unaltered amphibolite has an unusually high copper content. Thus, the copper was probably leached from the amphibolite by solutions and deposited as secondary copper minerals in the fractures nearby. These occurrences of copper minerals are not considered to be of economic significance.

ANALYTICAL DATA

Many rock samples and stream-sediment samples, in addition to those already discussed, were analyzed during the present study. Most were analyzed both chemically and spectrographically in mobile units in the field, using methods described in detail by Ward, Lakin, Canney, and others (1963). A few were analyzed spectrographically in the U.S. Geological Survey laboratories in Denver, Colo.

An attempt was made to sample all major streams and most tributaries of those streams, to obtain several samples of each rock type in the area, and to sample any altered-appearing rock. Analyses of these samples served as a guide to further work in the area.

Analyses of the rock samples given on table 1 show much more variation than the stream sediments, as would be expected. However, none indicated unusual concentrations of metallic elements. Many amphibolites have high chromium content, compared with the surrounding rocks, but chromite commonly occurs in these amounts in rocks of this type in southwestern Montana. None of the amphibolites in the primitive area contain sufficient amounts of chromium to be of economic significance.

Analyses of the stream-sediment samples given on table 1 (locations of these samples are shown on pl. 2) show little variation except for a few samples collected from very small streams draining mafic rocks. For example, sample G1f is high in nickel and chromium, but it is from a small stream that drains only amphibolite—also high in nickel and chromium.

TABLE 1.—*Analyses of samples from the Spanish Peaks primitive area*

[All elements in parts per million except Fe, Mg, and Ca, which are in percent. For sample locations see plate 2. Analysts: A. P. Marranzino, G. C. Curtin, H. W. Knight, D. J. Grimes, J. C. Hamilton, Barbara Tobin, G. Van Sickle, and C. L. Whittington. Abbrevia-

Sample	Semiquantitative spectrographic analyses																	
No.	Ti	Zn	Mn	V	Zr	La	Ni	Cu	Pb	B	Y	Mo	Co	Ag	Be	Ga	As	Sc	Cr
							Spanish Peaks fault												
B2a	200	<200	200	20	7	20	15	7	70	10	5	<2	5	<1	<1	<10	<500	<5	5
B2b	700	<200	150	70	50	<20	20	7	10	<10	5	<2	7	<1	<1	<10	<500	5	700
B2c	1,000	<200	500	70	100	20	70	5	<10	10	10	<2	20	<1	1	10	<500	15	200
B2d	1,500	<200	100	500	7	<20	15	5	<10	20	10	<2	7	<1	<1	20	1,500	7	200
B2e	1,500	700	5,000	300	10	<20	150	10	10	20	20	<2	100	<1	2	50	<500	70	300
B2f	2,000	200	100	200	70	<20	50	10	10	15	10	<2	20	<1	<1	20	<500	5	150
B5a	3,000	300	50	70	100	<20	300	100	20	30	5	3	30	<1	1	30	2,000	<5	200
B5b	5,000	<200	1,000	100	100	20	100	30	10	30	7	<2	20	<1	<1	20	1,000	<5	200
B5c	7,000	<200	1,500	300	70	<20	30	50	<10	10	7	<2	50	<1	<1	20	<500	7	100
C11a	>10,000	<200	500	150	150	20	20	70	<10	15	10	<2	20	<1	<1	20	<500	10	10
C11b	5,000	<200	700	150	200	20	30	50	10	20	15	<2	20	<1	2	20	<500	10	15
C11c	300	<200	200	20	50	<20	20	15	10	10	7	<2	7	<1	1	30	<500	<5	300
C11e	10,000	<200	200	150	70	<20	70	15	15	<10	50	<2	15	<1	<1	15	<500	10	700
C17	3,000	<200	1,500	100	200	20	<2	7	50	10	5	<2	7	<1	1	20	<500	<5	5
C54a	5,000	<200	200	100	100	<20	100	70	<10	20	5	<2	15	<1	1	20	<500	<5	500
C54b	200	<200	500	10	10	<20	15	2	20	<10	<5	<2	<5	<1	<1	20	<500	<5	<5
C54c	1,000	<200	150	15	100	<20	2	2	10	10	5	<2	<5	<1	1	30	<500	<5	5
C54d	300	<200	700	20	7	<20	30	20	10	10	<5	<2	5	<1	<1	<10	<500	<5	15
C70	200		100	20	20	30	20	15					7			10			10
C72a	3,000		1,000	200	70		70	70			20		50			50		20	10
C72b	2,000		50	70	30		150	70			10		20			30		10	200
C73	1,500		200	100	30		30	70			15		10			20		7	150
C74	1,000		200	70	100		70	70	10		10		15			20		5	50
C74a	5,000		200	100	150	150	30	3			20		15			30		10	20
C75	2,000		50	70	30		100	100					15			15	1,500		200
C76a	300		30		30	50	10	100	70							7	1,500		7
C76b	2,000		3	70	50	30	15	50	30							3			100
C77a	700		500	70	30		70	10			10		30			15		10	200
C77b	70		150				30	30,000					5	1					7
C77c	300		150	15	20		30	100	10		10	5	5			10			20
C77d	100		200				15	5,000					30						5
C11d	2,000	<200	700	50	150	20	10	30	70	20	10	<2	10	<1	<1	20	<500	<5	5
C16	7,000	<200	1,500	150	150	20	70	20	15	10	30	<2	30	<1	1	20	<500	20	300
C18	5,000	<200	300	100	200	30	50	50	20	30	10	<2	10	<1	1	20	<500	10	150
C25																			
C26	5,000	<200	1,500	150	100	50	50	20	30	10	50	<2	30	<1	1	20	<500	10	200
C53	3,000	<200	700	200	150	50	70	30	15	10	30	<2	30	<1	<1	30	<500	20	150
C69	700		150	50	20		10	5	20				5			20			30
C80	2,000		500	70	100		50	30	10		15		15			20		10	100
							Deer Creek shear zone												
B8a	2,000	<200	700	100	100	20	70	50	15	10	15	<2	15	<1	1	20	<500	15	50
B8b	2,000	<200	500	70	150	30	150	70	30	10	7	<2	20	<1	1	20	<500	10	150
B8c	500	<200	100	15	100	<20	10	7	20	<10	<5	<2	<5	<1	<1	15	<500	5	5
B9a	1,500	<200	200	30	200	<20	5	20	20	<10	5	2	5	<1	1	20	<500	5	20
B9b	1,000	<200	150	10	100	20	3	10	10	<10	<5	<2	<5	<1	1	10	<500	5	5
B9c	1,000	<200	70	10	50	<20	70	5	10	<10	<5	<2	<5	<1	1	10	<500	5	5
B9d	2,000	<200	300	100	200	30	50	30	20	<10	5	<2	10	<1	<1	15	<500	5	30
B9e	1,500	<200	150	50	100	20	50	5	15	<10	5	<2	15	<1	1	15	<500	5	20
B9f	700	<200	200	70	70	20	50	15	20	<10	7	<2	5	<1	1	15	<500	5	7
B9g	1,000	300	150	20	100	30	30	15	15	10	5	<2	5	<1	2	20	<500	5	15
B9h	1,500	300	500	50	150	<20	70	7	10	10	5	<2	15	<1	1	20	<500	5	150
C2a	1,000	<200	2,000	70	5	<20	1,500	50	<10	15	<5	<2	30	<1	<1	10	<500	10	5,000
C2b	2,000	<200	700	100	70	20	20	30	50	<10	10	<2	10	<1	<1	20	<500	5	100
C2c	700	<200	1,500	70	5	<20	3,000	5	<10	30	<5	<2	50	<1	<1	<10	<500	10	5,000
C3	3,000	<200	300	50	200	20	10	20	30	<10	5	<2	10	<1	1	20	<500	5	5
C4a	3,000	<200	50	20	150	<20	10	10	15	<10	5	<2	<5	<1	1	10	<500	5	30
C4b	3,000	<200	500	30	100	20	50	20	15	<10	5	<2	10	<1	1	<10	<500	5	300
C4c	2,000	<200	1,000	50	70	20	15	15	30	<10	15	<2	5	<1	1	20	<500	5	30
C5	3,000	<200	100	50	100	30	20	15	20	<10	5	<2	<5	<1	2	20	<500	5	30
C6	2,000	<200	500	70	300	30	70	20	20	<10	15	<2	20	<1	2	20	<500	10	10
C7	3,000	<200	1,500	50	200	50	70	20	15	<10	10	<2	30	<1	1	10	<500	5	50
C8	3,000	<200	150	30	150	30	20	10	30	<10	5	<2	5	<1	<1	30	<500	5	5
C8c	1,000		70	20	30		50	30	20		10		10			10		5	700
C9	500	<200	1,500	70	<5	<20	200	10	<10	<10	<5	<2	10	<1	<1	<10	<500	7	3,000
C10	700	<200	500	50	150	<20	200	30	100	15	30	3	30	<1	7	10	<500	10	10

TABLE 1.—*Analyses of samples from the Spanish Peaks primitive area*—Continued

tions: Ls = limestone, alt. = altered, sed. = sedimentary, N. = north, qtzte = quartzite, cpy = chalcopyrite, mal. = malachite, qtz = quartz, sil. = silicified, S. = south, cal. = calcite, bio. = biotite, cxCu = cold-acid-extractable copper]

Sample	Chemical analyses													
			Percent											
No.	Ba	Sr	Fe	Mg	Ca	cxCu	Cu	Pb	Zn	Au	Mo	Co	Ni	Sample Description
						Spanish Peaks fault								
B2a	15	700	<2	5	<20	1	30	75	25	<.03		<20	25	Ls 500 ft S. of fault
B2b	30	<50	1	.5	.1	8	20	25	<25	<.03		<20	25	Alt. sed. rock near fault
B2c	150	50	7	.1	3	<1	10	<25	50	<.03		40	200	Alt. sed. rock in fault
B2d	700	<50	15	.3	1	<1	10	25	<25	<.03		<20		Alt. sed. rock in fault
B2e	200	50	15	.2	.5	<1	20	<25	200	<.03		150	300	FeO-stained gouge near soil
B2f	3,000	200	5	.7	3	<1	10	<25	100	<.03		20	75	FeO-stained gouge below soil
B5a	100	50	10	.2	.1	2	200	25	200	.07		40	800	Alt. sed. rock in fault
B5b	300	100	5	1.5	1.5	2	60	25	75	.05		40	200	FeO-stained soil
B5c	100	100	15	3	3	25	100		25			30	<25	Amphibolite N. of fault
C11a	500	<50	5	1.5	1.5	30	150		50	<.03	2	40	50	Amphibolite from adit
C11b	500	100	5	1	2	8	100		50	<.03		40	50	Fault gouge in gneiss
C11c	1,000	200	1	.7	2	3	60		25	<.03		<20	<25	Fault gouge in gneiss
C11e	500	<50	1	.5	2	3	40		25	<.03		30	150	Alt. rock from adit dump
C17	3,000	2,000	3	1.5	5									Porphyritic dike rock
C54a	100	50	15	.1	.2									FeO-stained fault breccia
C54b	1,500	200	1	.05	.1									Brecciated granitic gneiss
C54c	700	200	1	3	1									Gneiss from pit
C54d	20	70	1.5	10	<20									Alt. ls.breccia from fault
C70	700	200	1.5	.2	.1									Brecciated gneiss
C72a	200	700	5	1	7									Altered gneiss
C72b	70	20	7	.2	.2									Alt. sed. rocks
C73	200	50	3	.2	1.5									Fault breccia
C74	5,000	200	3	.07	.15									Qtzte breccia in fault
C74a	700	700	2	1.5	1									Gneiss N. of fault
C75	300	150	5	.07	.1									FeO-stained gouge
C76a	1,500	100	5	.015	.03									FeO-stained gouge
C76b	500	200	2	.005	.015									Sil. rock with pyrite
C77a	150	30	2	.7	1									Gouge
C77b	30		3	.5	.05									Vein qtz with cpy. & mal.
C77c	500	300	1	.05	.05									Vein quartz
C77d	15		1	.2	.07									Vein qtz with mal.
C11d	200	300	1.5	1	3									Gneiss at adit portal
C16	500	300	7	5	3	3	60		50			20	75	Stream sediment
C18	700	300	3	1.5	3	25	100		25			<20	25	Stream sediment
C25						<1	30		75			<20	25	Stream sediment
C26	500	700	7	7	7	10	60		50			40	100	Stream sediment
C53	500	150	3	2	2		30	25	50					Stream sed. near fault
C69	1,500	1,000	1.5	.5	1									Stream sed. along fault
C80	500	300	2	1.5	1.5									Stream sediment
						Deer Creek shear zone								
B8a	300	150	7	.7	.7	5	60	25	100	<.03		30	75	Residual soil
B8b	700	500	5	1	1	5	70	25	100	<.03		30	300	Residual soil
B8c	1,000	300	1	.1	.5	<1	<5		<25			<20	25	Stained aplite
B9a	1,000	70	1.5	.1	1	1	30		50			<20	75	Alt. gneiss N. of zone
B9b	500	<50	1	.05	.2	3	10		25			<20	25	Jasperoid breccia in zone
B9c	500	<50	.5	.02	.03	<1	10		25			<20	25	Jasperoid breccia in zone
B9d	700	100	2	.03	.05	4	20		50			<20	75	Alt. rock N. of zone
B9e	700	50	2	.02	.03	3	20		50			20	75	Sil. sheared breccia in zone
B9f	700	<50	2	.02	.05	2	10		50			20	75	Alt. rock S. of zone
B9g	1,000	50	1.5	.1	.2	1	5		50			<20	50	Alt. rock S. of zone
B9h	200	<50	3	.1	.1	1	30		75	<.03		<20	150	Sil. boxwork from zone
C2a	70	<50	15	<10	5	25	150		25		<2	120	3,000	Serpentine with asbestos
C2b	1,500	200	1.5	1.5	.7	2	6		<25			<20	75	Qtz-feldspar-chlorite rock
C2c	10	<50	20	<10	1	1	20		100			200	2,500	Sheared serpentinite
C3	1,500	700	1	.5	1	1	30		50			<20	<25	Mica-qtz schist
C4a	700	50	.7	.05	.1	<1	10		<25			<20	<25	Sheared gneiss
C4b	300	50	2	.2	.1	2	30		25			20	<5	FeO-stained gneiss
C4c	2,000	300	1.5	1	7	1	30		25			<20	<25	FeO-stained breccia with cal.
C5	700	<50	1.5	.05	.1	<1	30		25			<20	25	Silicified breccia
C6	3,000	100	10	.05	.1	2	40		100			20	150	FeO-stained vein qtz.
C7	700	<50	5	.05	.1	6	60		50			60	100	Breccia
C8	<5,000	300	2	.2	.1	<1	<5		<25			<20	<25	Breccia from zone
C8c	1,000	20	1.5	.07	.07									Alt. qtz-feldspar schist
C9	70	1,000	7	<10	20	1	<5		50			60	400	Qtz-epidote rock from zone
C10	5,000	70	10	.07	.2	<1	60	300	150			80	800	Breccia along zone

TABLE 1.—*Analyses of samples from the Spanish Peaks primitive area*—Continued

Sample No.	Semiquantitative spectrographic analyses																		
	Ti	Zn	Mn	V	Zr	La	Ni	Cu	Pb	B	Y	Mo	Co	Ag	Be	Ga	As	Sc	Cr
Deer Creek shear zone (continued)																			
C78	2,000		200	50	200	70	20	30	15		20		7			20		5	10
C95	200		500	20			100	10					10					5	700
B38	3,000	<200	300	70	300	20	30	7	20	10	10	<2	10	<1	1	20	<500	5	150
B39	5,000	<200	1,500	100	200	70	50	30	20	10	30	<2	20	<1	1	20	<500	15	200
B40	5,000	<200	1,000	100	150	50	50	15	20	10	15	<2	20	<1	<1	20	<500	10	200
Altered zones south of Gallatin Peak																			
C82	2,000	1,500	300	100	50	150	30	1,500	300		15		30	2		50		5	10
C83a	5,000		1,500	200	30		30	100	30		15		20			30		20	7
C83b	3,000		1,000	300	30		30	150	15		15		30			30		30	50
C83c	300		2,000	70			15	150			10		20					7	7
Roadcut in amphibolite																			
B1a	5,000	<200	2,000	300	70	30	70	70	20	10	10	<2	50	<1	<1	30	<500	30	200
B1b	7,000	<200	2,000	300	70	<20	50	150	20	10	15	<2	70	<1	<1	30	<500	30	150
B1c	500	<200	>5,000	70	30	50	20	50	30	<10	20	<2	15	<1	<1	<10	<500	7	5
B1d	2,000	<200	3,000	150	30	<20	300	20	15	15	20	<2	30	<1	<1	20	<500	7	300
B1e	<10,000	<200	2,000	300	100	<20	70	50	15	15	30	<2		<1	<1	50	<500	50	100
B1f	10,000	200	1,000	300	100	<20	150	>5,000	70	20	20	<2	100	10	<1	30	<500	30	70
B1g	1,000	<200	300	20	100	<20	15	15	20	10	<5	<2	15	<1	1	20	<500	<5	<5
B1h	10,000	<200	1,500	300	70	<20	50	150	10	15	50	<2	50	<1	<1	20	<500	30	70
B1i	5,000	<200	500	200	100	20	20	100	30	<10	5	<2	30	<1	1	30	<500	10	30
B1j	7,000	<200	3,000	200	70	20	20	100	10	10	10	<2	30	<1	<1	30	<500	20	50
B1k	<10,000	<200	1,500	300	100	<20	30	150	15	10	15	<2	30	<1	<1	30	<500	30	70
B1m	10,000	<200	2,000	500	100	<20	70	>5,000	10	10	20	<2	50	<1	<1	30	<500	30	100
Spanish Peaks rock samples																			
B3a	5,000	<200	1,000	100	100	20	2	10	20	10	15	<2	15	<1	1	30	<500	5	5
B3b	5,000	<200	700	150	150	20	5	7	20	10	10	<2	15	<1	1	20	<500	7	10
B3c	5,000	<200	1,500	300	30	<20	50	100	10	10	10	<2	70	<1	<1	30	<500	30	30
B3d	700	<200	100	10	100	<20	2	5	<10	10	5	<2	<5	<1	1	15	<500	<5	<5
B4a	300	200	200	30	<5	<20	150	7	10	50	5	<2	15	<1	1	20	<500	<5	20
B6a	1,500	<200	2,000	200	100	<20	500	7	<10	10	5	<2	70	<1	<1	15	<500	20	1,500
B6b	500	<200	1,500	100	<5	<20	300	15	<10	10	<5	<2	50	<1	<1	15	<500	20	1,500
B6c	700	<200	1,000	100	5	<20	200	10	<10	<10	5	<2	50	<1	<1	10	<500	15	1,500
B6d	500	<200	1,500	100	5	<20	300	5	<10	<10	5	<2	30	<1	<1	10	<500	20	1,500
B6e	700	<200	1,500	100	5	<20	300	15	<10	10	5	<2	50	<1	<1	10	<500	15	1,500
B6f	7,000	<200	1,000	200	150	<20	70	100	<10	10	<5	<2	50	<1	<1	30	<500	20	150
B7a	5,000	<200	1,000	150	50	<20	50	20	10	10	5	<2	30	<1	<1	30	<500	<5	150
B10a	1,000	<200	200	20	100	30	5	2	50	10	<5	<2	<5	<1	1	20	<500	<5	15
B10b	500	<200	700	100	100	<20	7	5	50	10	<5	<2	<5	<1	1	30	<500	5	15
B10c	10,000	<200	500	200	150	150	15	3	20	10	10	<2	5	<1	<1	30	<500	<5	20
B13a	100	<200	200	<10	5	<20	<2	<2	<10	10	<5	<2	15	<1	<1	<10	<500	5	<5
B13b	5,000	<200	700	150	200	20	70	30	15	70	20	<2	30	<1	1	50	<500	20	150
B13c	700	<200	300	15	100	100	15	70	70	30	100	<2	20	<1	<1	10	<500	<5	5
B13d	5,000	<200	2,000	30	50	<20	20	5	<10	100	70	<2	10	<1	1	30	<500	10	15
B13e	5,000	<200	2,000	300	20	<20	150	15	<10	10	10	<2	50	<1	1	30	<500	50	700
B16	10,000	<200	1,000	200	150	20	5	20	30	10	20	<2	30	<1	<1	20	<500	15	30
B18	2,000	<200	100	50	300	<20	<2	7	10	<10	<5	<2	<5	<1	<1	<20	<500	<5	70
B23a	2,000	<200	1,000	50	<5	<20	3,000	10	<10	50	<5	<2	70	<1	<1	<20	<500	<5	3,000
B23b	2,000	<200	1,500	300	10	<20	700	5	<10	10	10	<2	30	<1	<1	20	<500	30	3,000
B24	10,000	<200	1,500	300	100	<20	70	150	<10	10	20	<2	70	<1	<1	20	<500	20	150
B25a	10,000	<200	1,500	150	100	<20	10	70	<10	10	30	<2	30	<1	<1	20	<500	<5	5
B25b	10,000	<200	2,000	500	50	<20	100	100	<10	10	10	<2	50	<1	<1	30	<500	30	200
B27	3,000	<200	300	70	30	20	5	10	20	<10	<5	<2	7	<1	1	30	<500	<5	10
B28a	300	<200	2,000	70	<5	<20	3,000	20	<10	20	<5	<2	70	<1	<1	<10	<500	<5	1,000
B28b	2,000	<200	2,000	100	150	<20	15	5	<10	<10	20	<2	30	<1	<1	20	<500	10	10
B28c	700	<200	100	10	100	<20	10	5	50	<10	<5	<2	<5	<1	<1	20	<500	20	5
B29a	1,000	<200	150	30	70	<20	<2	10	30	<10	<5	<2	<5	<1	<1	20	<500	<5	<5
B29b	1,000	<200	150	20	100	<20	5	2	<10	<10	30	<2	<5	<1	<1	30	<500	<5	10
B30a	1,000	<200	1,500	150	10	<20	2,000	3	<10	<10	<5	<2	50	<1	<1	<20	<500	10	>5,000
B30b	1,000	<200	1,000	200	5	<20	1,500	70	<10	<10	<5	<2	50	<1	<1	<10	<500	20	5,000
B34	1,000	<200	1,000	200	5	<20	1,000	2	<10	<10	10	<2	30	<1	<1	10	<500	30	5,000
B41a	7,000	<200	2,000	300	50	<20	50	70	<10	10	10	<2	30	<1	<1	20	<500	30	200
B41b	10,000	<200	2,000	500	70	<20	20	30	<10	10	15	<2	30	<1	<1	20	<500	30	100
B42a	200	<200	1,500	10	<5	<20	2,000	7	<10	10	<5	<2	30	<1	<1	<10	<500	<5	300

TABLE 1.—*Analyses of samples from the Spanish Peaks primitive area*—Continued

Sample	Chemical analyses													
			Percent											
No.	Ba	Sr	Fe	Mg	Ca	cxCu	Cu	Pb	Zn	Au	Mo	Co	Ni	Sample Description
Deer Creek shear zone (continued)														
C78	1,000	70	1.5	.15	.1									Alt. gneiss
C95	20	100	1	2	5									Alt. granitic rock
B38	1,500	700	1.5	1.5	7	<1	20		<25			<20	25	Stream sediment
B39	1,000	300	5	2	5	5	60		75			20	75	Stream sediment
B40	700	300	5	1.5	3	2	40		25			20	50	Stream sediment
Altered zones south of Gallatin Peak														
C82	1,000	700	3	.3	5									Qtz-epidote rock with cpy.
C83a	300	500	5	5	5									Vein quartz
C83b	300	500	5	5	5									Schist with pyrite
C83c	1,500	150	5	3	<10									Cal.-qtz.-epidote vein
Roadcut in amphibolite														
B1a	300	200	10	2	3	15	100	50	125			60	<25	Gouge in alt. amphibolite
B1b	100	150	15	5	5	>60	400	25	25		<2	20	<25	Unaltered amphibolite
B1c	70	700	5	.5	>20	>60	150	50	25	<.03	2	20	<25	Cal. vein in amphibolite
B1d	150	100	10	3	15	8	40	50	25	<.03		40	150	Fault gouge
B1e	200	150	15	3	5	15	70	50	50	<.03		40	<25	Fault gouge
B1f	150	150	15	.2	5	>120	15,000	250	200	.05	4	150	100	Mal. in fault in amphibolite
B1g	700	300	2	5	.5	<1	60	25	25	<.03		60	<25	Clay zone in qtzte
B1h	150	150	10	1	3	>60	400	25	50	<.03	<2	60	<25	Fe-rich gouge in amphibolite
B1i	700	200	7	5	2	50	200	50	150	<.03	<2	30	<25	Fe-rich gouge in qtzte
B1j	300	200	10	1	15	25	150	<25	100		2	40	<25	Amphibolite-qtzte contact
B1k	150	100	10	3	5	30	200	<25	50	<.03	<2	30	25	Amphibolite-qtzte contact
B1m	300	200	15	3	5	>60	15,000	<25	75	<.03	<2	60	75	Mal. in fault in amphibolite
Spanish Peaks rock samples														
B3a	1,500	700	7	.7	3	2	10		50	<.03		20	<25	Volcanic rock
B3b	1,500	1,000	5	1.5	3	2	15		50	<.03		<20	<25	Volcanic rock
B3c	50	200	10	5	7	2	150		25	<.03	2	<20	<25	Amphibolite
B3d	300	300	1	.2	1	1	5		25	<.03		<20	<25	Gneiss
B4a	150	<50	>20	.3	.3	<1	20	40	100	<.03		20	400	Gossan in float over ls.
B6a	20	50	15	7	3	<1	<5		<25			<20	<25	Biotite gneiss
B6b	15	50	10	7	3	5	40		<25	<.03		20	200	Mafic-rich intrusive rock
B6c	20	70	10	7	3	<1	40		<25			<20	25	Soil over intrusive rock
B6d	20	70	7	7	5	<1	15		<25			<20	<25	Mafic-rich intrusive rock
B6e	15	100	10	7	3	5	70		<25	<.03		20	25	Mafic-rich intrusive rock
B6f	1,000	500	10	5	7									Garnet-biotite gneiss
B7a	1,000	150	15	5	5									Garnet rich gneiss
B10a	1,500	1,000	1.5	.3	2									Gneiss
B10b	2,000	1,000	7	.1	2									Hornblende-rich pegmatite
B10c	2,000	3,000	5	2	3									Gneiss with large K-feldspar
B13a	<10	700	.2	3	>20									Limestone
B13b	500	200	10	2	1.5	1	60	25	75	<.03		20	75	Soil over gneiss
B13c	2,000	200	1.5	.1	5	15	200	300	25	<.03	<2	40	<25	Quartz vein in gneiss
B13d	150	<50	15	.5	1.5	1	<5		25			<20	50	Hematite in soil
B13e	200	200	15	>20	10	2	30		50			<20	50	Amphibolite
B16	15	1,500	7	2	3									Volcanic rock
B18	200	<50	.5	.1	.1									Quartzite
B23a	10	50	10	7	1.5									Amphibolite near asbestos vein
B23b	10	70	10	10	20									Amphibolite west of pit
B24	70	100	15	5	7									Volcanic rock
B25a	100	300	10	1.5	7									Foliated amphibolite
B25b	70	200	15	3	5									Non-foliated amphibolite
B27	300	700	2	1.5	2									Sheared gneiss
B28a	100	<50	10	>10	1									Asbestos-bearing amphibolite
B28b	70	70	10	1.5	1									Garnet-bearing aplite
B28c	700	500	.5	.2	2									Biotite-bearing quartzite
B29a	3,000	700	1	1	10									Amphibolite
B29b	3,000	1,000	.2	.5	10									Gneiss
B30a	<10	<50	1	2	7									Schist
B30b	50	<50	15	>10	5									Schist
B34	<10	<50	15	>10	5									Garnet-bearing schist
B41a	150	200	15	5	7									Amphibolite
B41b	200	200	15	5	7									Biotite gneiss
B42a	10	<50	7	>10	.5									Asbestos

TABLE 1.—*Analyses of samples from the Spanish Peaks primitive area*—Continued

Sample No.	Semiquantitative spectrographic analyses																		
	Ti	Zn	Mn	V	Zr	La	Ni	Cu	Pb	B	Y	Mo	Co	Ag	Be	Ga	As	Sc	Cr
								Spanish Peaks rock samples (continued)											
B42b	200	<200	2,000	30	<5	<20	1,000	<2	<10	10	10	<2	30	<1	<1	<20	<500	10	1,500
B42c	>10,000	<200	2,000	300	100	<20	50	15	<10	10	20	<2	50	<1	<1	50	<500	30	150
B42d	5,000	<200	200	500	<5	<20	1,000	5	<10	15	<5	<2	500	<1	<1	10	<500	15	>5,000
B42e	200	<200	1,500	20	<5	<20	1,000	5	<10	<10	5	<2	20	<1	<1	<20	<500	5	1,000
B42f	3,000	<200	3,000	150	30	50	30	15	<10	20	20	<2	30	<1	1	20	<500	20	70
B42g	3,000	<200	700	100	<5	<20	1,500	<2	<10	<10	<5	<2	20	<1	<1	<20	<500	5	>5,000
B42h	5,000	<200	1,000	100	<5	<20	2,000	10	<10	<10	<5	<2	50	<1	<1	<20	<500	10	>5,000
B46a	10,000	<200	300	70	100	<20	15	50	<10	30	20	<2	7	<1	<1	50	<500	15	200
B46b	3,000	<200	50	100	200	<20	20	3	10	<10	<5	<2	5	<1	<1	<20	<500	5	200
B49a	1,500	<200	1,500	100	100	<20	5	7	20	10	10	<2	5	1	1	20	<500	<5	20
B49b	10,000	<200	2,000	200	70	<20	20	15	20	<10	10	<2	30	<1	<1	20	<500	10	50
B50a	1,000	<200	700	20	70	<20	<2	5	50	20	5	<2	<5	<1	1	30	<500	<5	10
B50b	10,000	<200	700	300	100	<20	70	100	<10	<10	7	<2	50	<1	<1	20	<500	10	20
B52b	7,000	<200	1,500	300	150	20	20	30	10	<10	10	2	20	<1	<1	20	<500	20	50
B59a	10,000	<200	2,000	150	150	30	15	20	20	10	30	7	30	<1	1	20	<500	5	10
B59b	1,500	<200	200	50	200	<20	10	20	30	<10	50	<2	10	<1	1	20	<500	5	5
B65	500	<200	1,000	50	70	<20	10	15	<10	30	20	3	5	<1	1	20	<500	<5	50
B66	10,000	<200	700	150	300	70	15	15	30	<10	20	<2	15	<1	1	30	<500	10	30
B69b	10,000	<200	500	500	150	20	50	50	10	<10	10	<2	30	<1	<1	20	<500	30	200
B69c	5,000	<200	1,000	200	70	<20	30	30	<10	<10	10	<2	30	<1	<1	20	<500	15	70
B74	2,000	<200	1,500	100	100	20	50	10	20	10	30	<2	5	<1	<1	20	<500	<5	100
B79b	10,000	<200	1,000	300	150	20	70	70	20	<10	20	<2	50	<1	<1	20	<500	30	200
B79c	10,000	<200	2,000	500	50	<20	70	15	<10	10	20	<2	50	<1	1	20	<500	50	300
B81	700	<200	150	30	100	<20	2	15	10	20	<5	<2	<10	<1	<1	30	<500	5	5
B83b	3,000	<200	100	150	70	30	30	20	15	20	5	<2	10	<1	1	20	<500	7	50
B84	1,000	<200	2,000	50	50	<20	20	15	<10	<10	10	<2	30	<1	1	30	<500	7	50
B85b	7,000	<200	1,000	500	200	30	70	70	20	<10	30	<2	30	<1	<1	30	<500	50	300
B87b	1,000	<200	150	20	10	<20	<2	5	30	<10	<5	<2	<10	<1	<1	20	<500	<5	5
B89a	3,000	<200	500	50	100	20	15	2	20	15	5	<2	10	<1	<1	20	<500	5	10
B89b	10,000	<200	2,000	500	70	<20	70	100	<10	15	5	<2	50	<1	<1	30	<500	30	200
B89c	7,000	<200	2,000	500	50	<20	50	150	<10	10	10	<2	50	<1	<1	20	<500	30	150
B89d	5,000	<200	2,000	100	30	<20	1,000	2	<10	15	5	<2	70	<1	<1	<10	<500	10	1,500
B90a	1,500	<200	300	50	100	<20	20	7	<10	<10	<5	<2	15	<1	<1	20	<500	<5	10
B90b	5,000	<200	2,000	500	50	<20	50	15	15	10	7	<2	70	<1	<1	30	<500	30	5
B91a	3,000		1,000	100	100	30	200	1			20		30			30		15	300
B91b	1,000		200	200	100	50	7	1	15		20					50		10	300
B93	1,000		1,500	300	10		300	1			15		70			<10		30	1,000
B94	700		1,000	150	10		700	1			10		50			10		15	1,500
B102a	7,000		3,000	500	50		200	500			30		50			20		50	300
B102b	10,000		3,000	1,000	70		200	500			30		70			50		70	300
B102c	7,000		2,000	700	70		200	200			30		100			30		70	300
C12	2,000	<200	500	50	200	20	30	10	50	20	7	<2	10	<1	1	20	<500	<5	70
C14	500	<200	>5,000	30	50	<20	20	70	10	10	10	<2	10	<1	<1	30	<500	<5	50
C19	7,000	<200	1,500	500	100	70	100	20	30	20	20	<2	50	<1	1	20	<500	20	300
C20	5,000	<200	1,000	300	100	20	200	2	20	10	10	<2	30	<1	<1	20	<500	20	700
C21a	2,000	<200	700	70	100	30	100	15	20	<10	10	<2	30	<1	<1	50	<500	5	300
C21b	1,500	<200	500	100	100	50	30	5	20	<10	5	<2	20	<1	1	30	<500	<5	70
C21c	300	<200	100	15	70	<20	<2	300	20	<10	<5	<2	<5	<1	1	20	<500	5	<5
C24	3,000	<200	300	50	100	150	10	5	20	<10	5	<2	10	<1	1	20	<500	<5	5
C28	2,000	<200	150	30	100	20	2	5	50	<10	5	<2	<5	<1	1	30	<500	10	<5
C29	2,000	<200	1,000	200	50	50	30	15	20	<10	7	<2	30	<1	<1	30	<500	15	100
C30	500	<200	200	20	30	<20	10	30	30	15	<5	<2	5	<1	1	20	<500	<5	5
C32a	10,000	<200	1,000	300	70	30	7	15	10	<10	10	<2	30	<1	<1	20	<500	20	<5
C32b	5,000	<200	2,000	300	20	<20	50	15	<10	10	15	<2	50	<1	<1	20	<500	<5	300
C33	10,000	<200	1,000	200	300	50	20	20	20	<10	30	<2	20	<1	<1	20	<500	20	30
C51	3,000	<200	700	100	100	100	15	10	20	<10	10	<2	5	<1	<1	30	<500	<5	10
C52	1,500	<200	200	50	100	20	15	15	30	<10	<5	<2	<5	<1	<1	30	<500	<5	20
C57	7,000	<200	700	150	200	50	20	3	20	<10	10	<2	20	<1	<1	50	<500	5	20
C61	5,000	<200	700	100	100	20	50	10	15	<10	7	<2	15	<1	1	30	<500	5	50
C62	300		200	30	30		7	2	50							15			20
C64	1,500	<200	150	50	100	<20	10	15	50	<10	7	<2	<5	<1	1	30	<500	5	20

TABLE 1.—*Analyses of samples from the Spanish Peaks primitive area*—Continued

Sample No.	Ba	Sr	Percent			Chemical analyses								Sample Description
			Fe	Mg	Ca	cxCu	Cu	Pb	Zn	Au	Mo	Co	Ni	
						Spanish Peaks rock samples (continued)								
B42b	20	<50	10	>10	3									Mica schist
B42c	70	500	15	3	>20									Garnet-bearing amphibolite
B42d	<10	<50	>20	7	1.5									Amphibole schist
B42e	20	<50	7	7	1									Schist
B42f	30	50	20	3	7									Amphibolite
B42g	<10	<50	7	10	.05									Amphibolite
B42h	30	<50	10	>10	.1									Amphibole schist
B46a	50	150	>20	1.5	.7									Oxidized hnbd-garnet rock
B46b	700	1,500	.5	.2	.1									Green mica-garnet qtzte
B49a	2,000	1,500	5	1	2									Porphyritic dike rock
B49b	5,000	500	15	.5	10									Dike rock breccia with cal.
B50a	2,000	500	1.5	.2	1									Diabase float
B50b	300	700	10	3	3									Amphibolite float
B52b	200	300	10	1	3									Garnet bearing gneiss
B59a	500	150	.5	.1	1									Fe veinlets in qtzte schist
B59b	500	100	7	.1	.5									Oxidized qtzte schist
B65	100	70	20	1.5	2									Oxidized amphibolite
B66	2,000	200	7	1.5	3									Finely layered gneiss
B69b	500	150	7	2	1									Mica schist
B69c	100	200	7	5	5									Biotite-garnet gneiss
B74	3,000	1,500	5	1.5	3									Altered dike rock
B79b	200	150	10	3	7									Garnet-bearing amphibolite
B79c	200	100	15	7	10									Fine-grained amphibolite
B81	700	700	1	.2	3									Granitic gneiss
B83b	300	150	1.5	.2	.5									Gneiss
B84	150	<50	20	1.5	3									Oxidized amphibolite
B85b	1,000	500	5	1.5	3									Biotite gneiss
B87b	1,500	500	1.5	.2	1.5									Amphibolite
B89a	500	300	3	.5	2									Biotite gneiss
B89b	100	200	15	5	10									Pegmatite cutting gneiss
B89c	150	200	15	5	10									Fine-grained amphibolite
B89d	<10	50	10	7	5									Mica-hornblende schist
B90a	1,000	1,000	1.5	.5	1									Porphyritic dike rock
B90b	200	200	15	5	7									Garnet-bearing amphibolite
B91a	30	100	5	>10	5									Amphibolite
B91b	50	1,000	5	.2	>10									Olivine-bearing amphibolite
B93	70	500	>10	>10	5									Coarse-grained amphibolite
B94	7	10	5	>10	5									Amphibolite
B102a	50	150	>10	7	>10									Diabase from dike
B102b	100	300	>10	7	>10									Diabase from dike
B102c	200	300	>10	7	>10									Diabase from dike
C12	500	500	1.5	1.5	3									Schist
C14	500	50	15	5	10									Amphibolite
C19	1,500	3,000	15	7	10									Dioritic gneiss
C20	50	100	15	>10	.7									Actinolite gneiss
C21a	1,500	300	3	5	.5									Biotite gneiss
C21b	500	1,500	2	2	3									Biotite-bearing gneiss
C21c	1,500	500	.5	.2	1									Quartz-feldspar gneiss
C24	2,000	1,500	2	.7	2									Gneiss
C28	700	200	1.5	.2	.7									Granitic gneiss
C29	1,500	2,000	7	2	3									Gneiss
C30	3,000	1,500	1.5	.1	.1									Sheared gneiss
C32a	150	500	15	1.5	3									Layered gneiss and amphibolite
C32b	100	200	15	7	7									Amphibolite
C33	2,000	300	10	1.5	3									Finely laminated gneiss
C51	3,000	3,000	5	1	3									Gneiss
C52	1,500	700	2	.5	2									Gneiss
C57	3,000	3,000	3	2	3									Gneiss
C61	200	300	2	2	2									Gneiss
C62	2,000	700	2	.15	1.5									Pegmatite
C64	1,500	300	1.5	.5	1.5									Gneiss

TABLE 1.—*Analyses of samples from the Spanish Peaks primitive area*—Continued

Sample	Semiquantitative spectrographic analyses																		
No.	Ti	Zn	Mn	V	Zr	La	Ni	Cu	Pb	B	Y	Mo	Co	Ag	Be	Ga	As	Sc	Cr
Spanish Peaks rock samples (continued)																			
C68	7,000	<200	700	150	150	30	5	30	20	15	10	<2	20	<1	<1	30	<500	5	30
C81	500		70	20		30	5	5			10					30			3
C81a	1,000		200	70	70		70	7					10			30		7	300
C87	700		30	50	50		10	10								7			70
C88	1,500		700	100	50		70	70	20		10		20			30			150
C90	500		100	20	20	50	10	7			15					5			50
C91	1,500		700	50	50		5	5	15		10				1	20			7
C92a	1,000		150	15	70	30	3	1	50		10				1	20			5
C92b	1,500		150	20	100		5	5	50		15				1	20		5	7
C93	2,000		1,500	200			1,000	70					100			<10		30	2,000
C94	1,500		1,000	200			1,500	150					100			<10		50	3,000
C94a	300		2,000	50			2,000	70					100			<10			3,000
G1a	1,500	<200	2,000	50	100	20	10	5	20	10	<5	<2	<5	<1	<1	20	<500	<5	50
G1b	1,500	<200	1,500	100	30	<20	3,000	30	<10	15	<5	<2	50	<1	<1	<10	<500	7	>5,000
G1c	10,000	<200	2,000	500	150	30	30	70	10	10	20	<2	30	<1	<1	50	<500	30	150
G1d	1,500	<200	100	50	200	100	10	5	10	<10	<5	<2	<5	<1	<1	30	<500	<5	5
G1e	1,000	<200	2,000	100	30	<20	3,000	20	<10	20	<5	<2	70	<1	<1	20	<500	<5	5,000
G1g	500	<200	2,000	20	<5	<20	2,000	200	<10	10	<5	<2	100	<1	<1	10	<500	<5	300
G1h	2,000	<200	1,000	200	30	<20	500	7	<10	10	10	<2	30	<1	<1	20	<500	20	3,000
B7b	2,000	300	1,000	70	100	<20	2	30	<10	50	10	<2	5	<1	1	30	<500	20	100
Spanish Peaks sediment samples																			
B11	2,000	<200	1,500	150	150	70	70	15	15	10	20	<2	30	<1	1	30	<500	20	300
B12	3,000	<200	700	100	200	70	50	50	20	10	20	<2	20	<1	1	30	<500	15	70
B17	7,000	<200	2,000	150	300	50	30	15	20	10	20	<2	30	<1	<1	30	<500	5	50
B19	10,000	<200	1,500	200	500	50	150	70	15	10	20	<2	50	<1	1	30	<500	10	700
B20	5,000	<200	1,500	200	200	30	100	50	20	10	30	<2	30	<1	<1	30	<500	10	500
B21a	5,000	<200	1,500	200	200	30	100	30	20	10	15	<2	30	<1	<1	30	<500	15	500
B21b	5,000	<200	1,500	200	150	>20	100	15	20	10	15	<2	30	<1	<1	30	<500	15	500
B22	10,000	<200	1,500	200	150	30	150	50	15	10	10	<2	50	<1	<1	30	<500	10	500
B26a	5,000	<200	1,500	150	100	>20	150	30	20	<10	10	<2	50	<1	<1	30	<500	10	500
B26b	5,000	<200	1,500	150	150	30	100	15	20	<10	15	<2	30	<1	<1	20	<500	10	700
B26c	3,000	<200	2,000	100	100	50	70	30	30	10	30	<2	30	<1	<1	30	<500	15	200
B31	5,000	<200	1,000	150	100	<20	70	10	30	10	15	<2	30	<1	<1	30	<500	10	200
B32	3,000	<200	1,000	150	150	<20	70	15	20	10	15	<2	30	<1	<1	20	<500	10	150
B33a	5,000	<200	1,000	150	100	<20	70	15	30	10	10	<2	30	<1	1	20	<500	10	150
B33b	5,000	<200	1,000	150	150	30	100	50	20	15	20	<2	50	<1	1	20	<500	15	300
B35	5,000	<200	1,500	150	100	20	70	20	20	10	15	<2	20	<1	1	30	<500	20	300
B36	10,000	<200	1,500	200	150	20	150	150	10	10	10	<2	50	<1	<1	20	<500	20	300
B37a	10,000	<200	2,000	300	200	<20	100	70	10	10	5	<2	50	<1	<1	30	<500	30	700
B37b	10,000	<200	1,500	200	150	<20	70	50	10	10	7	<2	30	<1	1	20	<500	20	200
B47	10,000	<200	2,000	200	150	20	70	30	20	20	10	<2	30	<1	1	20	<500	30	300
B48	7,000	<200	1,000	150	100	20	100	20	20	20	10	<2	20	<1	1	20	<500	5	300
B50c	7,000	<200	1,500	200	100	50	70	50	30	15	30	<2	30	<1	1	20	<500	20	200
B51a	7,000	<200	1,500	150	300	30	70	20	15	<10	20	<2	30	<1	<1	20	<500	20	300
B51b	7,000	<200	1,500	150	150	30	70	10	15	10	30	<2	20	<1	1	20	<500	20	200
B52a	10,000	<200	2,000	200	150	50	100	100	50	30	30	<2	30	<1	1	20	<500	30	300
B53	10,000	<200	1,500	200	200	50	50	10	50	20	50	<2	20	<1	1	20	<500	20	200
B54	>10,000	<200	2,000	200	200	50	70	15	10	10	50	<2	30	<1	1	30	<500	30	300
B55	7,000	<200	1,500	150	150	50	50	30	30	10	30	<2	20	<1	1	20	<500	20	150
B56	10,000	<200	2,000	200	200	30	50	50	50	20	50	<2	30	<1	1	20	<500	30	150
B57	10,000	<200	2,000	200	1,000	30	50	20	30	10	10	<2	15	<1	1	20	<500	10	150
B60	10,000	700	2,000	150	>1,000	70	150	30	30	10	50	<2	20	<1	1	30	<500	20	150
B61	10,000	<200	1,500	200	>1,000	30	100	30	30	10	30	<2	20	<1	1	20	<500	10	100
B62	7,000	<200	1,000	70	500	50	50	20	30	10	50	<2	20	<1	1	20	<500	10	100
B63	10,000	<200	1,500	200	1,000	50	70	50	50	20	30	<2	30	<1	1	30	<500	10	150
B64	10,000	<200	2,000	200	>1,000	50	100	30	50	10	30	<2	30	<1	1	20	<500	15	150
B67	>10,000	<200	1,500	200	>1,000	50	70	70	30	10	30	<2	30	<1	1	20	<500	20	150
B68	7,000	<200	1,500	150	300	30	50	30	50	10	30	<2	30	<1	1	20	<500	10	100
B69a	10,000	<200	1,500	500	300	50	100	150		10	30	<2	50	<1	1	20	<500	30	200
B70	>10,000	<200	2,000	500	200	50	70	70	50	20	50	<2	30	<1	<1	20	<500	30	200
B71	>10,000	<200	1,500	300	300	30	70	50	20	15	50	<2	50	<1	<1	20	<500	30	150
B72	>10,000	<200	2,000	300	300	20	50	30	20	15	50	<2	50	<1	1	20	<500	30	150
B75	5,000	<200	2,000	150	200	20	50	15	10	<10	15	<2	30	<1	<1	20	<500	15	150
B76	10,000	<200	2,000	200	300	30	50	15	10	<10	20	<2	30	<1	<1	20	<500	15	100
B77	7,000	<200	1,500	150	500	50	70	20	20	10	20	<2	30	<1	1	30	<500	20	100
B78	7,000	<200	1,500	150	200	50	50	15	30	10	20	<2	30	<1	<1	20	<500	10	150

TABLE 1.—*Analyses of samples from the Spanish Peaks primitive area*—Continued

Sample			Percent			Chemical analyses								
No.	Ba	Sr	Fe	Mg	Ca	cxCu	Cu	Pb	Zn	Au	Mo	Co	Ni	Sample Description
						Spanish Peaks rock samples (continued)								
C68	1,500	1,500	7	1.5	5									Volcanic rock
C81	150	30	.5	.3	.15									Sillimanite-kyanite gneiss
C81a	500		2	5	.015									Kyanite-bio.-qtz. schist
C87	30		.2	.03	.2									Mica-sillimanite-qtz. schist
C88	500	700	2	2	5									Gneiss
C90	70		.5	.2	.007									Sillimanite-kyanite qtzte
C91	2,000	700	1.5	.5	2									Fine-grained dike rock
C92a	1,500	150	1.5	.2	.7									Quartz-rich gneiss
C92b	1,500	200	1.5	.2	.7									Fine-grained gneiss
C93	700	70	>10	>10	3									Garnet amphibolite
C94	30	10	>10	>10	>10									Magnetite-bearing amphibolite
C94a	100		>10	>10	.3									Asbestos-bearing mafic rock
G1a	300	700	2	.3	1.5									Amphibolite
G1b	150	150	15	>10	2									Amphibolite
G1c	1,000	700	15	2	7									Volcanic rock
G1d	300	1,000	2	.5	3									Gneiss
G1e	100	100	20	>10	2									Amphibolite
G1g	30	70	15	>10	1									Amphibolite
G1h	50	500	10	10	5									Amphibolite
B7b	15	<50	20	1.5	2	10	100		<25	<.03		<20	<25	Oxidized garnet amphibolite
						Spanish Peaks sediment samples								
B11	700	500	10	5	5	4	60		50			20	100	
B12	700	500	7	2	3	10	60		50			<20	25	
B17	1,000	700	10	2	5	1	20		50			30	25	
B19	500	500	10	7	5	2	100		50			30	75	
B20	500	300	10	5	5	5	60		50			20	75	
B21a	300	200	10	7	7	4	60		50			20	50	
B21b	500	500	10	7	10	3	30		25			<20	25	
B22	300	700	10	7	7	4	60		50			<20	150	
B26a	500	300	7	5	7	4	60		50			<20	200	
B26b	500	300	7	5	5	2	40		50			20	75	
B26c	700	200	7	5	7	10	60		25			20	75	
B31	500	300	5	2	5	1	30		50			20	50	
B32	500	300	5	2	5	1	20		25			<20	25	
B33a	500	300	5	2	5	<1	40		50			<20	25	
B33b	500	200	5	3	3	25	150	<25	50		6	40	150	
B35	700	500	7	5	7	<1	30		50			20	50	
B36	500	300	15	7	5	30	250	<25	75		4	30	100	
B37a	300	500	15	7	15	4	150		50		4	20	50	
B37b	300	500	10	7	10	4	100		50			<20	75	
B47	500	200	10	3	5	<1	60		75			30	50	
B48	500	300	7	2	2	6	40		50			20	100	
B50c	300	300	7	3	3	15	100	40	75			<20	100	
B51a	300	300	10	3	3	6	100	<25	75			<20	75	
B51b	300	500	10	3	3	1	40	<25	50			<20	100	
B52a	700	300	7	5	5	25	100	40	100			30	100	
B53	700	300	7	5	3	2	30	<25	75			<20	75	
B54	300	300	10	5	3	1	30	<25	50			<20	50	
B55	700	300	7	3	3	8	60	25	50			<20	50	
B56	700	300	10	3	3	3	60	40	100			<20	25	
B57	1,000	300	7	2	3	<1	30	<25	75			<20	25	
B60	1,500	300	10	2	5	<1	30		50			<20	50	
B61	1,500	300	7	2	5	<1	15		25			<20	<25	
B62	1,000	200	3	1.5	3	1	15		25			<20	50	
B63	1,000	300	10	2	3	4	30		25			<20	25	
B64	1,500	200	10	2	3	<1	20		50			20	25	
B67	1,500	700	7	2	5	1	30		25			<20	50	
B68	1,000	300	5	1.5	3	<1	15		25			20	25	
B69a	700	200	5	2	3	8	110		75			60	100	
B70	1,000	500	10	7	20	3	60		25			<20	25	
B71	700	300	10	5	5	<1	40		50			20	50	
B72	700	300	10	3	5	<1	40		50			20	<25	
B75	300	200	10	2	2		40		25			<20	50	
B76	300	200	10	2	2		30		50			<20	50	
B77	500	300	10	2	3		60		50			40	50	
B78	500	500	10	2	2		40		50			30	75	

TABLE 1.—*Analyses of samples from the Spanish Peaks primitive area*—Continued

Sample	Semiquantitative spectrographic analyses																		
No.	Ti	Zn	Mn	V	Zr	La	Ni	Cu	Pb	B	Y	Mo	Co	Ag	Be	Ga	As	Sc	Cr
								Spanish Peaks sediment samples (continued)											
B79a	5,000	<200	2,000	150	150	50	30	20	30	10	20	<2	50	<1	1	20	<500	20	100
B80	7,000	<200	2,000	200	700	30	70	10	20	<10	30	<2	30	<1	1	20	<500	20	150
B82	5,000	<200	1,000	150	200	20	70	30	15	10	20	<2	20	<1	<1	20	<500	15	300
B83a	7,000	<200	1,500	150	200	20	70	20	15	15	20	<2	20	<1	<1	20	<500	15	200
B85a	10,000	<200	5,000	200	200	20	50	20	20	10	50	<2	20	<1	<1	20	<500	50	200
B86	7,000	<200	1,500	200	200	20	30	20	30	15	50	<2	15	<1	<1	20	<500	20	100
B87a	5,000	<200	1,500	150	200	20	50	15	30	10	20	<2	20	<1	<1	20	<500	15	150
B88	7,000	<200	1,000	300	200	<20	50	15	20	10	30	<2	20	<1	<1	20	<500	15	200
C13	7,000	<200	2,000	150	100	20	100	30	20	10	50	<2	30	<1	<1	20	<500	20	1,500
C15	5,000	<200	1,000	150	100	50	70	70	20	10	50	<2	30	<1	<1	20	<500	20	300
C22	5,000	<200	1,500	200	150	50	50	30	50	10	15	<2	30	<1	1	20	<500	15	200
C23	5,000	<200	1,500	200	150	50	30	20	30	10	15	<2	20	<1	1	20	<500	10	100
C31	3,000	<200	700	150	700	20	70	15		15	50	<2	15	<1	1	15	<500	10	200
C34	>10,000	<200	1,500	200	>1,000	30	70	10	30	10	30	<2	20	<1	1	20	<500	20	150
C37	>10,000	<200	2,000	1,000	1,000	70	70	20	30	10	50	<2	50	<1	<1	15	<500	30	500
C38	>10,000	<200	2,000	700	700	70	70	10	<10	30	70	<2	20	<1	1	20	<500	15	500
C39	10,000	<200	2,000	500	300	50	70	20		30	30	<2	30	<1	<1	30	<500	20	500
C40	10,000	<200	1,500	300	300	30	50	20	30	20	20	<2	30	<1	<1	20	<500	15	150
C41	2,000	<200	2,000	100	150	20	50	20	10	15	5	<2	30	<1	1	20	<500	10	150
C42	5,000	<200	2,000	300	500	100	70	15	10	15	20	<2	30	<1	1	30	<500	5	150
C43	5,000	<200	1,500	200	500	100	100	100	10	15	30	<2	50	<1	1	20	<500	10	300
C44	1,500	<200	2,000	150	200	70	50	15	10	15	20	<2	30	<1	<1	30	<500	5	200
C45	5,000	<200	3,000	200	150	20	70	15	10	10	30	<2	30	<1	1	20	<500	15	300
C46	3,000	<200	3,000	200	200	20	150	10	<10	15	30	<2	30	<1	<1	20	<500	30	700
C47	10,000	<200	2,000	200	500	100	100	15	20	10	30	<2	30	<1	<1	20	<500	30	300
C48	10,000	<200	2,000	200	300	50	70	15	15	10	30	<2	30	<1	<1	20	<500	10	150
C49	>10,000	<200	1,000	200	300	150	70	15	20	<10	20	<2	20	<1	1	20	<500	10	150
C50	5,000	<200	2,000	200	150	50	70	20	10	<10	20	<2	30	<1	1	20	<500	20	300
C53	3,000	<200	700	200	150	50	70	30	15	10	30	<2	30	<1	<1	30	<500	20	150
C55	3,000	<200	700	100	200	50	50	30	30	10	10	<2	20	<1	1	30	<500	7	100
C56	5,000	<200	1,500	150	300	20	50	20	15	20	20	<2	30	<1	1	30	<500	10	300
C58	10,000	<200	1,000	200	500	70	70	20	30	10	30	<2	30	<1	1	30	<500	15	150
C59	5,000	<200	1,000	150	100	30	70	30	50	10	15	10	20	<1	1	20	<500	10	200
C60	7,000	<200	1,000	150	200	20	70	10	15	10	10	<2	20	<1	1	30	<500	15	200
C63	10,000	<200	700	150	200	<20	100	15	10	10	15	<2	20	<1	<1	30	<500	10	300
C65	7,000	<200	700	150	200	50	70	50	20	10	20	<2	20	<1	1	30	<500	10	150
C66	7,000	<200	1,000	150	200	20	70	20	20	10	15	<2	20	<1	1	20	<500	10	150
C67	10,000	<200	2,000	200	200	<20	100	20	15	10	15	<2	30	<1	<1	20	<500	15	300
G1F	3,000	<200	1,500	150	30	<20	2,000	30	10	15	<5	<2	70	<1	<1	20	<500	10	>5,000

TABLE 1.—*Analyses of samples from the Spanish Peaks primitive area*—Continued

Sample			Percent			Chemical analyses								
No.	Ba	Sr	Fe	Mg	Ca	cx Cu	Cu	Pb	Zn	Au	Mo	Co	Ni	Sample Description
						Spanish Peaks sediment samples (continued)								
B79a	300	150	10	1.5	2		75		125			80	100	
B80	500	200	10	2	3		20		50			20	25	
B82	300	300	10	2	3		20	25	25					
B83a	300	300	10	2	3		20	25	50					
B85a	300	100	15	3	5		20	25	50					
B86	500	200	10	2	3		20	<25	50					
B87a	500	300	7	2	3		15	<25	50					
B88	300	300	10	2	3		10	<25	50					
C13	300	300	10	7	3	4	60		50			40	200	
C15	500	300	7	5	3	15	100		50			<20	100	
C22	300	1,000	7	3	3	<1	60		50			<20	75	
C23	500	700	5	2	2	<1	60		50			<20	75	
C31	300	300	5	1.5	2	1	30	<25	50			<20	50	
C34	1,500	200	7	2	5	<1	10		25			<20	<25	
C37	1,500	1,500	>20	7	15		30		25			30	50	
C38	300	200	>20	3	2		20		50			<20	75	
C39	700	300	>20	5	3		<5	<25	75			<20	25	
C40	700	1,000	10	5	7		20		25			<20	<25	
C41	700	500	10	2	2		30		25			20	100	
C42	1,000	1,500	10	3	5		30		25			<20	50	
C43	1,000	500	10	3	5		150		50			30	75	
C44	500	300	20	2	3		30		25			20	75	
C45	300	300	10	3	3		60		25			20	100	
C46	200	200	15	5	5		20		25			30	75	
C47	300	700	10	3	3		30		25			20	100	
C48	300	500	10	2	3		60		25			20	75	
C49	300	500	7	3	2		30		25			60	50	
C50	200	500	15	3	2		40		50			20	100	
C53	500	150	3	2	2		30	25	50					
C55	1,000	500	5	2	2		30	25	25					
C56	700	300	2	2	2		40	25	50					
C58	1,000	1,000	7	2	3		20	<25	75					
C59	500	300	5	2	2		60	25	50					
C60	200	300	5	2	3		30	<25	25					
C63	300	500	7	2	3		20	<25	<25					
C65	500	300	5	2	2		40	<25	<25					
C66	500	200	5	2	3		30	<25	50					
C67	300	200	10	3	3		30	<25	25					
G1f	150	300	20	>20	5	15	70	<25	75	<.03		150	1,200	

ECONOMIC APPRAISAL

By ELDON C. PATTEE,[1] ROBERT D. WELDIN,[2] and JOSEPH M. ROCHE,[2] U.S. Bureau of Mines

INTRODUCTION

The U.S. Bureau of Mines searched the county records of Madison and Gallatin Counties to determine the number of mining claims and their location within the primitive area, made a limited aerial reconnaissance of the area, examined the mining claims and known mineral deposits, and made limited mining and marketing studies of some commodities. A total of 25 mining claims at 9 sites is known to have been located within the primitive area, but there is no record of current assessment work in the county records (fig. 3). Publications furnished a total of 13 other leads on mineral deposits within the proposed area which also were investigated. Some deposits were not found because of dense vegetation, lack of workings, or vague description of location. Cursory examinations also were made of some deposits outside but near the proposed boundary.

The cooperation and assistance of personnel of the Gallatin National Forest are gratefully acknowledged.

CHROMITE AND ASBESTOS

Chromite and asbestos are included under one heading because the most significant deposit in the primitive area, the Table Mountain prospect, contains both commodities. Much of the information on the chromite and asbestos industries was obtained from Bureau of Mines publications (Holliday, 1965; Bowles, 1955; Kennedy, 1960).

The mineral chromite is the only commercial source of chromium. Basically it is composed of the oxides of chromium, iron, aluminum, and magnesium in varying quantities. In general, ores containing relatively large amounts of chromium are used in the steel industry; those relatively high in iron are used in making chromium chemicals; and those relatively high in aluminum are used in making refractory bricks.

Virtually all the chromite ore consumed in the United States is imported from the Philippines, the Republic of South Africa, Southern Rhodesia, Turkey, and the U.S.S.R. Consumption of chromite was 1,187,000 short tons in 1963 according to the Minerals Yearbook 1963 (U.S. Bureau of Mines, 1964, p. 379). The world chromite reserves and resources, calculated as shipping ores or concentrates, were estimated (1965) to be 2,660 million long tons, mostly

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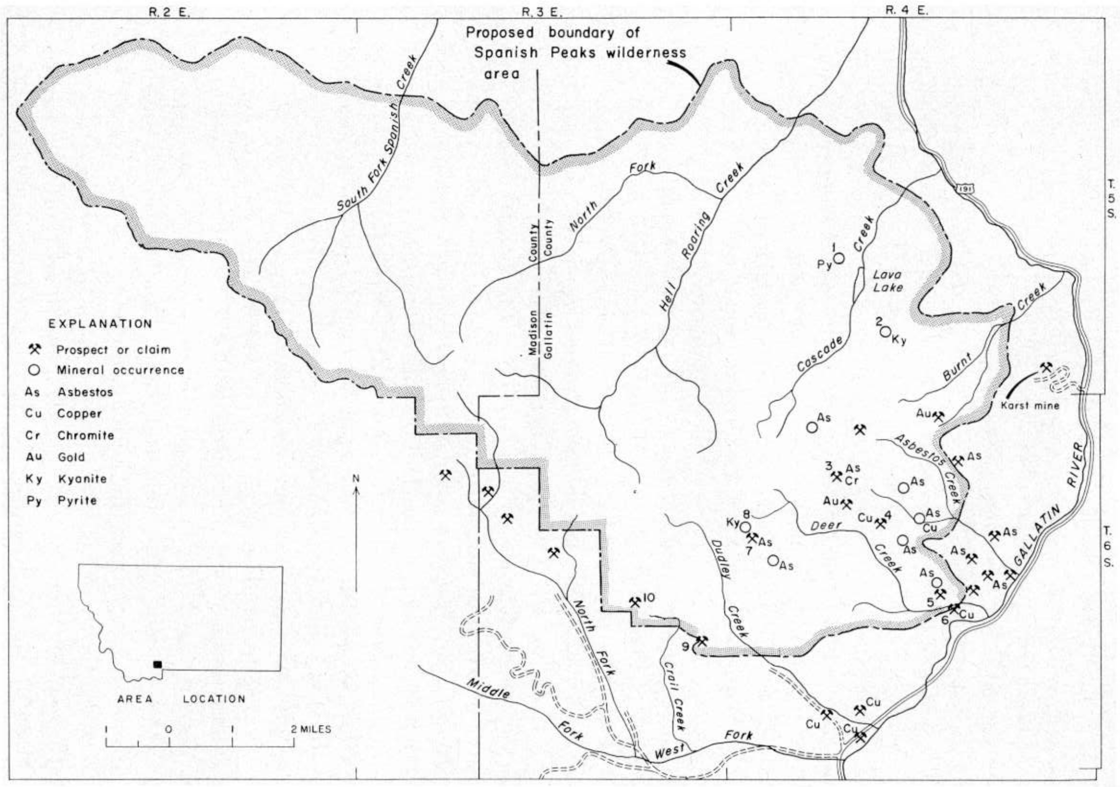


FIGURE 3.—Prospects and mineral occurrences in and near the Spanish Peaks primitive area. The names of prospects are (1) Lava Lake pyrite, (2) Lava Lake kyanite, (3) Table Mountain, (4) Mountain Goat No. 5 claim, (5) Deer Creek shear zone, (6) Deer Creek prospect, (7) Moon Lake asbestos, (8) Moon Lake kyanite, (9) Ridge prospect, and (10) Last Chance prospect.

in Africa. Resources of chromite in the United States were estimated (1965) to be 8 million long tons, and an additional 9 million short tons is in U.S. Government stockpiles. About 14 million long tons of low-grade rock containing 15 to 30 percent Cr_2O_3 is in the Stillwater Complex of Montana.

Prices of chromite ore are determined by negotiation, and no fixed standards apply. The prices paid per long ton f.o.b. Atlantic ports for various imported ores in October 1965 ranged from $35 for high-grade ores to $19 for ore containing 44 percent Cr_2O_3, with no chromium-to-iron ratio specified (Engineering and Mining Journal, 1965). The low-grade ore apparently meets chemical-grade specifications. Known chromite resources in the Spanish Peaks cannot be profitably mined at these prices.

Chromite ores are mined by conventional methods adapted to the peculiarities of individual deposits, and beneficiation methods vary. Mining costs vary greatly; however, total mining and milling costs of low-grade domestic ores are estimated at about $11 to $14 per ton of ore or about $24 to $30 per ton of concentrate.

The predicted annual domestic consumption of chromite by 1980 is estimated at 2.15 million tons. Major changes in supply and use patterns during the next 10 to 20 years will involve the increasing use of fine particles and concentrates, increasing interchangeability of use of the different ore types, and increasing reliance on a relatively few large sources. Known world reserves of metallurgical- and chemical-grade chromite are more than adequate for many decades.

Spectrographic analyses of rock samples from the Spanish Peaks primitive area show some chromium, but only samples from the Table Mountain prospect are significant. The Table Mountain deposit was originally prospected for asbestos, but the work by the Bureau of Mines disclosed significant amounts of chromite. Concentrates from the ore would meet specifications for chemical-grade chromium.

Asbestos is a name applied to a group of naturally fibrous minerals. It has characteristics of silk or cotton but will not burn. No large consistent market has been developed for anthophyllite, the type of asbestos in the Spanish Peaks area, and production has never exceeded a few hundred tons a year in the United States.

The United States is the leading manufacturer of asbestos products, but domestic sources furnish only 9 to 12 percent of the raw asbestos needed. Most of the U.S. supply is chrysotile from Canada. The trend in asbestos consumption follows industrial production and building construction, which will probably increase moderately. The chief suppliers of U.S. markets, Canada and Africa, appear to have adequate reserves for long-range planning. The reserves in the

United States are far from being adequate to meet current or future demands.

Prices of asbestos depend on mineral type and length of fiber. In general, chrysotile is more valuable than other asbestos minerals. Anthophyllite asbestos, similar to that occurring in the primitive area, could be used for some of the same purposes as low-grade chrysotile, which was priced at $42.50 to $46.00 per short ton in 1965.

The Karst mine, which is 0.5 mile east of the proposed boundary, had produced 1,800 tons of anthophyllite asbestos by 1948 valued at $35 per ton (Perry, 1948). The asbestos was mined from open-pit and underground workings in peridotite. Available evidence indicates that the peridotite does not extend into the primitive area. Anthophyllite deposits in this area are associated with amphibolites and schists.

TABLE MOUNTAIN PROSPECT

Table Mountain (fig. 4) is in sec. 8, T. 6 S., R. 4 E., and has a maximum altitude of 9,840 feet. Prospect pits on this flat-topped mountain all are at altitudes less than 50 feet from the top of the mountain. The mountain was known as Jumbo Mountain by early settlers. The top of the mountain is barren of timber but is covered with grass and a few patches of brush. Overburden is from 2 to 4 feet deep, although a few outcrops are visible.

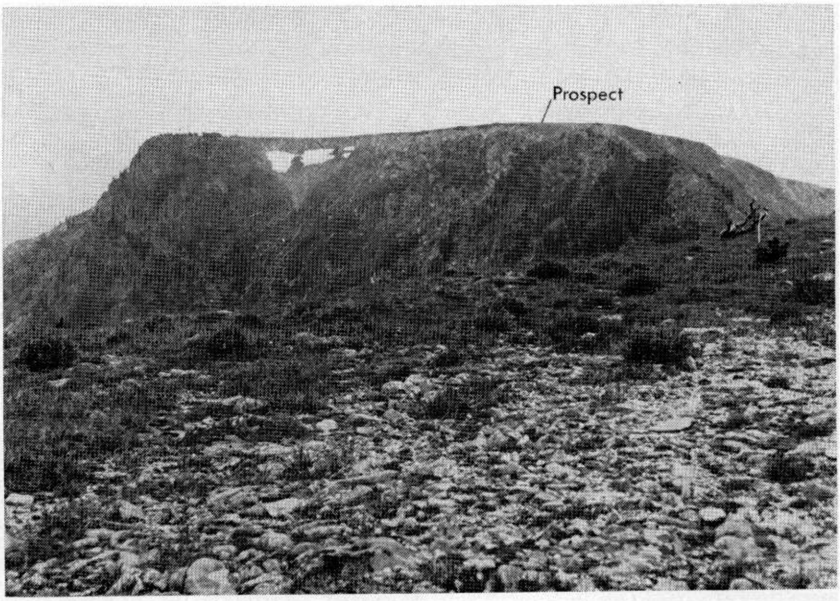


FIGURE 4.—Northeast side of Table Mountain.

The best route to the prospect from Gallatin Gateway, the nearest rail-shipping point, is to travel 25 miles south on U.S. Highway 191 to the mouth of Deer Creek, then about 8 miles by trail up Deer Creek to the top of the mountain. The best road-construction route to Table Mountain would follow the Deer Creek trail. The lower 6 miles of the route could be relatively easily constructed by bulldozing and minor blasting, but the last 2 miles would require considerable rock removal.

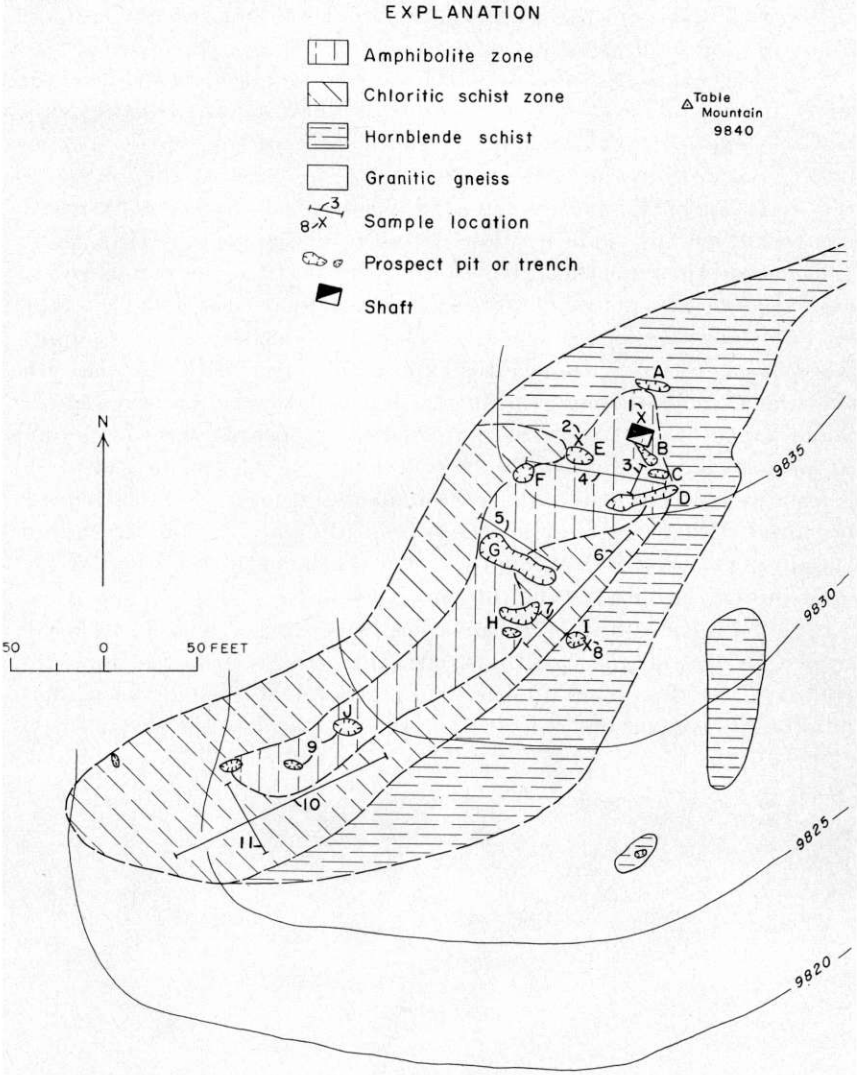
The first mining claims for the prospect were filed in 1914, according to Gallatin County courthouse records. Three claims located by P. F. Karst and T. F. Triplett are recorded as being on top of Jumbo Mountain, the old name for Table Mountain. Apparently the most recent location was made in 1960 by V. J. Hinsberger, Charley Sexton, and Thomas Nash of Culver City, Calif. There is no more recent affidavit of assessment work in the courthouse records.

Rock types on Table Mountain are granitic gneiss, hornblende schist, amphibolite, and chloritic schist. White to gray indistinctly banded granitic gneiss is the predominant rock. The other rock types occur as lenses or bands within the granitic gneiss.

Petrography of the rock surrounding the deposit was studied by Lawrence Brown, U.S. Bureau of Mines. The deposit occurs in a northeast-trending lens of amphibolite and surrounding chloritic schist. These rocks are surrounded by the granitic gneiss. (See fig. 5.) Both chromite and amphibole asbestos (anthophylite) occur in the amphibolite; chromite also occurs in the chloritic schist. The amphibolite lens is 300 feet long and averages 35 feet in width. The chloritic schist averages 35 feet in width on both sides of the amphibolite. It attains a width of 90 feet at the south end but does not continue around the northeast end. Samples indicate the average chromite content of the deposit to be about 11 percent Cr_2O_3.

The amphibolite zone is composed largely of anthophyllite and chromite with small amounts of talc, limonite, cummingtonite, chlorite, actinolite-tremolite, and other altered amphiboles. The rock consists predominantly of short randomly oriented crystals of nonfibrous anthophyllite, although zones, as much as 4 feet wide, containing cross-fiber anthophyllite occur. The amphibolite zone grades to chloritic schist on the east, west, and south but is in contact with hornblende schist on the north end of the exposure.

The chloritic schist is a dark-gray fine-grained rock that grades into the amphibolite and the hornblende schist. The south and west schist–granitic gneiss contact is not well exposed but on the basis of residual material it appears to be rather sharp. At a few points near the amphibolite, the chloritic schist grades to an actinolite-tremolite



Assay data

Sample No.	*Type of sample*	Cr_2O_3 *(percent)*	*Sample No.*	*Type of sample*	Cr_2O_3 *(percent)*	*Sample No.*	*Type of sample*	Cr_2O_3 *(percent)*
1	Grab	8.98	5	Chip	18.76	9	Grab	2.82
2	do	6.67	6	do	17.81	10	Chip	10.95
3	Chip	1.85	7	do	13.52	11	do	8.98
4	do	10.37	8	Grab	0.45			

FIGURE 5.—Table Mountain prospect.

schist with some anthophyllite and smaller amounts of chlorite and limonite.

The best exposure of anthophyllite asbestos is in a 10-foot-deep shaft at the northeast end of the amphibolite zone (fig. 6). The asbestos is exposed in the north and south walls of the shaft. The asbestos exposure in the north wall is 40 inches wide at the bottom of the shaft but only 1 foot wide near the collar. It could not be traced northward on the surface. The exposure in the south wall is about 4 feet wide through the full depth of the shaft. The trends of the asbestos zones are not easily determined because of near-surface distortion of enclosing rock. The asbestos in the south wall trends southward and connects with asbestos exposures in trench B. Apparently the zone extends through the full 20-foot length of this trench and is about 2.5 to 3.0 feet wide, as indicated by exposures and the amount of asbestos on the dump. The trench averages 2.5 feet in width and 3 feet in depth, but the walls are slumped and most of the bedrock is obscured. Pit C near the southeast end of trench B contains no anthophyllite asbestos but exposes the north-south-trending contact between the amphibolite and the chloritic schist.

Another zone of anthophyllite asbestos is exposed here and there in trench D, 25 feet south of the shaft. The trench is 38 feet long and trends S. 85° E. Amphibolite is exposed for 26 feet in the western part of the trench, but chloritic schist is exposed in the eastern part.

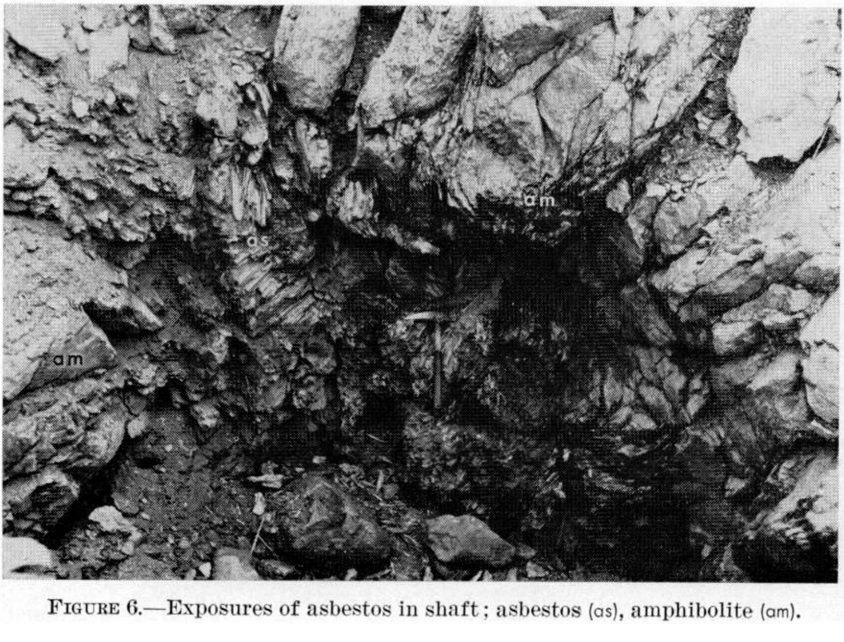


FIGURE 6.—Exposures of asbestos in shaft; asbestos (as), amphibolite (am).

The zone of asbestos is 6 to 13 inches wide and is poorly exposed in the amphibolite. It can be traced by sporadic exposures for 16 feet, but probably extends an additional 10 feet to the chloritic schist.

Anthophyllite asbestos was observed on the dumps of trenches E, F, G, H, and J, but the trenches are partly filled with debris and no asbestos was observed in place. The material on the dumps indicates that the asbestos zones may be up to 12 inches wide.

The Table Mountain deposit is significant because of the chromite, but anthophyllite from the amphibolite might be a coproduct or byproduct. The northwest part of the chloritic schist zone could not be sampled because of a hard-packed snow cover, but a total of 11 samples (fig. 5) from the southeastern side and the amphibolite zone averaged 10.06 percent Cr_2O_3. The samples were composed predominantly of residual fragments of rock. Screening tests of the anthophyllite fibers were made, and results are listed in table 2.

TABLE 2.—*Screen analysis of asbestos samples*

Location of sample	Weight/percent in specified size class			
	Plus ½ inch	½ inch to 4 mesh	4 to 10 mesh	Minus 10 mesh
North wall of shaft	5.4	39.2	27.5	27.9
Stockpile at shaft	3.3	45.9	22.7	28.1
Trench E		57.0	21.0	22.0
Pit-A dump		44.0	25.2	30.8
Pit-K dump	21.2	60.3	10.3	8.2
Average	6.0	49.3	21.3	23.4

Although the data in table 2 indicate good fibrous asbestos, the brittle nature of the anthophyllite limits its use to that of low-quality material.

The entire deposit including the amphibolite zone and the chloritic schist is estimated to contain 140,500 tons of indicated resources averaging 11 percent Cr_2O_3 and 248,000 tons of inferred resources averaging 10.4 percent Cr_2O_3. The resources of asbestos are 60 tons of measured material and 900 tons each of indicated and inferred material. This type of asbestos has found minor applications as cheap fillers and welding-rod coatings. The indicated resources are based on an assumed depth of 75 feet, and inferred resources are based on an estimated depth of 150 feet.

Several samples were composited into three representative samples for preliminary chromite mineral-dressing tests. The samples were crushed and then ground in a ball mill to minus 48 mesh, classified hydraulically, tabled for a rougher concentrate, and retabled for a final concentrate by J. C. White, U.S. Bureau of Mines. The tests showed that most of the chromite was in the 100- to 200-mesh fraction. The composite samples ranged from 17.0 to 25.6 percent chromite, of which between 76.0 and 79.2 percent was recovered in concentrates assaying from 42.3 to 48.3 percent Cr_2O_3. The chromium-to-iron ratios ranged from 1.45:1 to 1.72:1.

Concentrates will meet specifications for chemical-grade material, but will not meet those for metallurgical- or refractory-grade material. The low chromium-to-iron ratio makes the chromite undesirable for metallurgical uses, and the high iron content and low combined Cr_2O_3 plus Al_2O_3 percentages appear to be unsatisfactory for refractory uses. Consumers of metallurgical and refractory grades also prefer hard, dense, nonfriable ore. These adverse factors for metallurgical and refractory uses could probably be compensated for by consumers.

The deposit is not economically feasible to mine at present because of the small size, relatively low grade, location, high waste-to-ore ratio for open-pit mining, severe winter weather, and expensive road construction. In addition, the asbestos would require expensive hand cobbing. If the deposit is developed in the future, there are several locations in the Table Mountain area with adequate water supply for milling and for tailings disposal.

MOON LAKE ASBESTOS

The Moon Lake anthophyllite asbestos occurrence is near the north line of sec. 18, T. 6 S., R. 4 E. In 1892, eight claims were recorded with the following descriptions of location given: "situated on the divide between Deer Creek and Dudly Creek near the head." The asbestos probably occurs on one of these claims. The workings are on the ridge crest and about 8 miles from U.S. Highway 191 by way of the Deer Creek and Hell Roaring Lake trails. The asbestos occurs in amphibolite gneiss, but various metamorphic rocks occur nearby.

Three small pits, each about 4 feet square and partly filled, were excavated along a small asbestos zone. No bedrock is visible, but some asbestos is on the dumps, and float was found nearby. The longest fibers were 3 inches. The three pits are alined N. 65° W. and are spaced over a distance of 120 feet. The only outcrop showing asbestos is in an escarpment about 10 feet east of the northernmost pit. In the outcrop, seven veinlets of cross-fiber asbestos occur over a width of 14 inches; the largest veinlet is about 3/8 inch wide. The material between the veinlets is amphibolite. Asbestos float found here and there between the pits indicates the zone may be continuous.

Another nearby exposure of asbestos and float is described by Marvin (1952, p. 42–43). These occurrences are apparently small and were not found during a search of the area.

MISCELLANEOUS ASBESTOS OCCURRENCES

Asbestos is reported by Marvin (1952, p. 43–44) to occur at six additional locations in the proposed wilderness area. These occurrences are small, and most have not been explored. The fibers are reported to range from 1 to 4 inches in length.

The occurrences are widely scattered (fig. 3), and although thoroughly searched for during the reconnaissance, they could not be found because of dense vegetation and small size. There is no indication that a large potentially commercial deposit of asbestos exists in these areas.

COPPER, GOLD, AND SILVER

Most of the copper deposits being mined at present in the United States are low-grade disseminated sulfide ores or secondary minerals derived from copper sulfides. The price of copper fluctuates but was 35.6 cents per pound in October 1965. According to the 1963 Minerals Yearbook (U.S. Bureau of Mines, 1964), the domestic copper ore mined in 1963 averaged 0.74 percent copper. These ores were practically all from large low-grade deposits mined by open-pit methods with low costs because of large volumes processed. Small deposits would require at least a few percent copper to be profitably mined.

Numerous copper prospects have been located along the Spanish Peaks fault at the southwestern edge of the area, but no production is known. The fault strikes about N. 60° W. and has been mapped through a length of many miles. The Precambrian gneiss and schist in the primitive area are north of the fault, and sedimentary rocks of various ages occur to the south. About 2 miles of the fault is within the proposed area, but only two prospects—the Last Chance and Ridge prospect—are along this segment (fig. 1). Several prospects are along the fault, but the nearest containing identifiable copper minerals is 2.4 miles southeast from the proposed boundary. Twenty-one samples were taken at various points along the fault and assayed for gold and silver, but only one sample contained more than a trace. Spectrographic analyses were made of six samples, but no unusually high amounts of copper or other metals were noted.

A silicified shear zone (Deer Creek shear zone) near the mouth of Deer Creek at the east edge of the proposed area can be traced for nearly 1.5 miles. The zone has been explored for gold, silver, or copper, but the locations of workings do not correspond with any claim description in county courthouse records. The rock in the zone is intensely brecciated and has been recemented with quartz, calcite, and limonite. No sulfide minerals were observed in outcrops, but a small amount of boxwork indicates that some sulfides have been leached.

An outcrop of the zone along the north side of Deer Creek has been explored with an adit and a trench. These workings are 200 feet north of a point on the Deer Creek trail 1 mile from U.S. Highway 191 and are near a tributary of Deer Creek. The outcrop is 100 feet wide, 70 feet high, and extends for less than 100 feet along the shear zone. The zone, however, can be traced for 120 feet north, making a total width of 220 feet. The adit is caved but extended westward from creek level through talus and mantle rock to the shear zone, a distance of 30 to 35 feet. The trench is at the south side of the exposure and extends 19 feet in a southerly direction. It is partly filled with debris containing some hematite-stained rock.

Samples taken from siliceous material on the adit dump, calcitic rock and siliceous rock above the adit, and hematite-stained material in the trench and a 100-foot chip sample cut across the east end of the outcrop were assayed for gold and silver. All contained only a trace, except the dump sample which assayed 0.1 ounce per ton of silver. The calcitic rock from above the portal and the 100-foot chip sample both contained 0.06 percent copper. Spectrographic analyses were made of the samples from the dump and from the 100-foot chip sample, but no unusually large amounts of metals were detected. Other samples taken along the shear zone but outside the proposed wilderness area did not show unusually high amounts of metals.

The available information indicates that the shear zone has no potential as a source of valuable minerals.

LAST CHANCE PROSPECT

The Last Chance prospect is in the NW¼NE¼ sec. 23, T. 6 S., R. 3 E., Gallatin County, and is in a small saddle near the head of Crail Creek (fig. 3). The best route to the prospect is by 2 miles of trail from the end of the North Fork road.

A pit 13 feet square and 12 feet deep near the Spanish Peaks fault is the only working on the property (fig. 7). The pit was sunk at the contact between partly altered limestone and chlorite schist. The bedding of the limestone and schistosity of the schist strike N. 50° W. and dip 85° NE. Precambrian granitic gneiss crops out 25 feet northeast of the pit, and Madison limestone (Mississippian) crops out 25 feet to the southwest. A 2-foot wide pegmatite occurs 23 feet southwest of the shaft.

Small amounts of hematite and limonite stains occur in the walls of the shaft, but no ore minerals were observed. Spectrographic analysis of samples from the altered limestone and pegmatite showed copper in the range of 0.003 to 0.03 percent but no anomalous amounts of other elements. Samples of limestone and iron-stained rock from the shaft

FIGURE 7.—Last Chance pit; granitic gneiss (gn), schist (sch), and limestone (lms).

and pegmatite were assayed for gold and silver, but only trace amounts were detected.

The deposit has no potential for production of valuable minerals.

RIDGE PROSPECT

The Ridge prospect is in the W½SE¼ sec. 24, T. 6 S., R. 3 E., Gallatin County, and in a small saddle on the ridge between Crail and Dudley Creeks (fig. 3). The best route to the prospect is by 1.5 miles of trail from the end of the Dudley Creek road.

The only working that could be found at the property is a partly filled trench 18 feet long, 12 feet wide, and 4 feet deep (fig. 8). No bedrock is visible in the trench, but Jefferson Limestone (Devonian) crops out 30 feet to the southwest, and Precambrian gneiss crops out 50 feet to the northeast. Debris in the trench consists of hematite-stained quartz, gneiss, and limestone. A grab sample of hematite-stained quartz was assayed for copper, gold, and silver, but none was detected. A spectrographic analysis of the same sample did not reveal unusual amounts of any metal.

The prospect has no potential as a source of copper or other valuable metals.

FIGURE 8.—Ridge prospect; granitic gneiss (gn), limestone (lms).

DEER CREEK PROSPECT

The Deer Creek prospect is in the NE¼ sec. 22, T. 6 S., R. 4 E., Gallatin County, and is 0.7 mile from U.S. Highway 191. Most of the workings are in a saddle on the ridge between Deer Creek and the Gallatin River.

Small amounts of copper minerals occur at points in and near a silicified shear zone in Precambrian quartzite. The shear zone trends N. 74° E. and appears to dip 75° W. The silicified material crops out south of the saddle. This outcrop is 390 feet long, a maximum of 43 feet high, and 80 feet wide. The rock in the outcrop has been brecciated and recemented with quartz, calcite, and limonite. The resulting outcrop is predominantly white to yellow-gray quartz. A small amount of boxwork at points in the outcrop indicates that some sulfides might have been leached. The only copper mineral identified was chalcopyrite which occurs in very small crystals. A 6-foot long chip sample taken above a short caved adit at the northwest edge of the outcrop contained some boxwork. The sample assayed 0.65 percent copper and 0.03 percent nickel. A more representative sample of the outcrop taken for 50 feet along its northeast side, assayed 0.06 percent copper but no nickel. A spectrographic analysis of this sample did not show unusual amounts of other metals. A 12-foot chip sample cut across the south end of the outcrop contained 0.13 percent copper. These samples were also assayed for gold and silver, but only a trace was detected.

There are five small trenches in the saddle about 100 feet northeast of the outcrop. The trenches are in quartzite and are less than 100 feet apart. Samples taken from two of the trenches assayed a trace of gold and silver, and one contained 0.53 percent copper.

The prospect has no potential for development because the copper values are small and sporadic.

MOUNTAIN GOAT NO. 5 CLAIM

The Mountain Goat No. 5 prospect is near the south line of sec. 9, T. 6 S., R. 4 E., about 4 miles by way of the Deer Creek trail from U.S. Highway 191. The location notice for the claim is on the crest of the ridge between Deer Creek and Asbestos Creek and is at an altitude of about 8,500 feet. The claim was located in 1949 by C. A. Lester, address unknown. There is no record of recent assessment work in county courthouse records.

The area is underlain by Precambrian hornblende schist and granitic gneiss. White quartz veins occurring in the hornblende schist were explored in a shallow shaft, a trench, and two small prospect pits. Malachite is reported (Marvin, 1952, p. 46) in one of the pits, but none was observed during this examination.

The discovery pit is partly caved, and no bedrock is exposed. Most of the debris on the dump is schist or gneiss, but some white quartz is present. No sulfides or copper minerals were observed, and a spectroscopic analysis of a sample did not indicate copper.

A partly caved 8-foot-deep shaft is about 850 feet southeast of the discovery pit. A quartz vein in hornblende schist is exposed in the shaft. The vein strikes N. 80° W. and dips 65° N., and is parallel to the schistosity of the schist. The vein is 18 inches wide in the bottom of the shaft but splits into two stringers 12 and 8 inches wide; the 8-inch stringer pinches out below the rim of the pit. A sample of the vein was assayed for gold, silver, and copper, but only traces of gold and silver were detected. Spectrographic analysis of the sample did not show appreciable amounts of any metal.

A small pit 100 feet southeast of the shaft does not expose bedrock. Quartz is present on the dump; no minerals of value were observed.

A white quartz vein averaging 1 foot in width is exposed in a trench 600 feet northwest from the discovery pit and in a nearby outcrop of hornblende schist (fig. 9). The vein strikes N. 50° W. and dips 68° NE., parallel to the schist. A sample of the quartz contained only a trace of gold and silver.

The quartz veins exposed on the claim have no potential for production of valuable minerals.

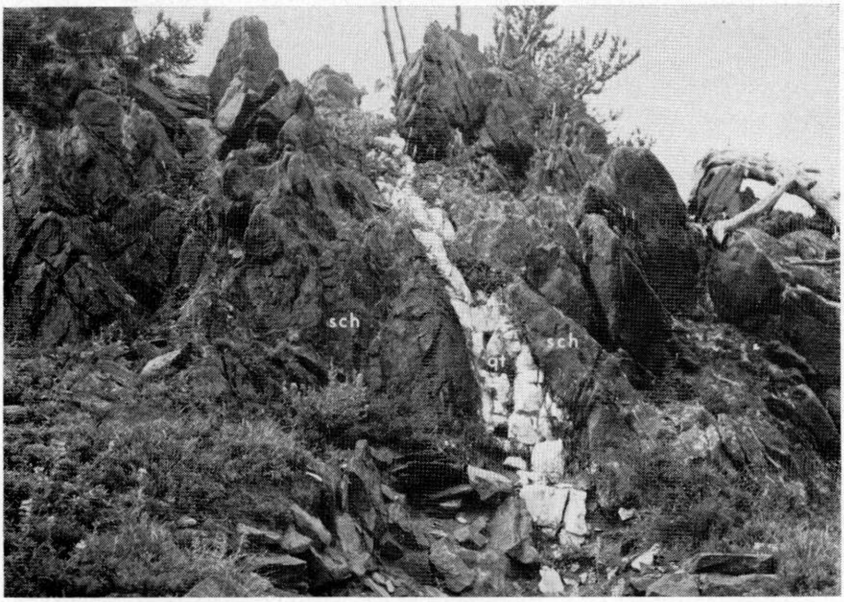


FIGURE 9.—Quartz vein at Mountain Goat No. 5 prospect; hornblende schist (sch), quartz vein (qt).

LAVA LAKE PYRITE

The Lava Lake pyrite occurrence is near the center of the SE¼ sec. 20, T. 5 S., R. 4 E., at an altitude of 8,000 feet on the crest of the ridge northwest of Lava Lake. It is 3 miles from U.S. Highway 191 by way of the Cascade Creek trail.

A wedge-shaped outcrop of diorite is reported by Marvin (1952, p. 47) to contain approximately 2 percent pyrite. The diorite outcrop is 55 feet wide and 60 feet deep near the top of the ridge, and is surrounded by granitic gneiss. Assays of two samples of the pyrite-bearing diorite showed only trace amounts of gold and silver.

The occurrence has no potential for development.

KYANITE

Kyanite is a metamorphic mineral used in making high-alumina refractories and as a sweetener for firebrick, glass, electrical and chemical porcelain, and other ceramic products. Prices of processed domestic kyanite are listed as $47 to $58 per short ton in October 1965 issue of the Engineering and Mining Journal, and high-grade imported material was from $79 to $84 per short ton. The industry at present is centered in the Eastern States, but large undeveloped reserves are available in the Western States.

Two kyanite occurrences have been reported by Marvin (1952, p. 45) in the primitive area (fig. 1), and several were detected by the U.S. Geological Survey. The kyanite described by the U.S. Geological Survey occurs as an accessory mineral in the metamorphic rocks. Although amounts up to 40 percent have been reported, the occurrences are small and have little significance. Only reported occurrences of higher grade material are included in this report.

MOON LAKE KYANITE

Kyanite was reported at the north line of sec. 18, T. 6 S., R. 4 E. The occurrence was described by Marvin (1952, p. 45) as follows:

> The extent of the kyanite deposit is not known, since the mineral was not recognized in the field. The field specimen is a shiny, light-colored, fine-grained, friable rock composed of clear, fine-grained quartz, kyanite, and chlorite with red, medium-sized metacrysts of garnet.
>
> * * * The minerals were found in the following amounts:

Garnet	40 percent
Kyanite	40 percent
Chlorite	15 percent
Quartz	5 percent

The reported locality was searched, but no occurrences of kyanite were disclosed. No deposits of significant size are present.

LAVA LAKE KYANITE

The Lava Lake kyanite occurrence is near the center of the north line of sec. 33, T. 5 S., R. 4 E. The occurrence has been described by Marvin (1952, p. 47, 48) as follows:

> The kyanite is found in light-colored quartzite bands composed of clear, fine- to medium-grained quartz. In one specimen the kyanite is medium grained and a light bluish-green. * * * In another sample the kyanite is colorless and fine-grained.

The kyanite reportedly constitutes 3 and 20 percent, respectively, in the above-mentioned samples.

The area was sampled, and a petrographic study of the sample was made. The quartzite consisted largely of quartz with some chromium muscovite and trace amounts of limonite and rutile. A very few flakes of kyanite were observed in one small section of a specimen.

No deposit of significant size or grade is in the area.

MISCELLANEOUS MINING CLAIMS

Six groups of mining claims within the primitive area were not found. These claims were located between 1892 and 1948, but there is no record of recent assessment work. The areas described in the records were thoroughly searched, and local residents were contacted in an attempt to find the claims. The descriptions of some claims are vague, and others are so old that workings could not be recognized. Some claims were apparently located for asbestos and others, for gold and silver. These claims are believed to have no potential for development because assessment work was discontinued and no deposits were found during a search of their sites.

A few additional claims recorded as being on Jumbo Mountain were not definitely found, but they probably include the workings on Table Mountain which was formerly known as Jumbo Mountain by early settlers. No workings were found on the present Jumbo Mountain.

CONCLUSIONS

The work by the Bureau of Mines included the determination of potential of mining claims and occurrences of chromite, asbestos, kyanite, gold, silver, and copper minerals. This involved consideration of resources, minability, and markets.

Spectrographic analyses of samples from the primitive area contained some chromium, but only samples from the Table Mountain prospect represent a resource. The chromite concentrate produced from samples from this deposit does not meet present marketing specifications for metallurgical and refractory uses but is adequate for chemical-grade uses. The cost of mining, milling, and shipping of concentrates to consumers would exceed present market value of the ore.

The known asbestos occurrences in the proposed area are small and are of no significance, except the source at the Table Mountain deposit which possibly could be recovered as a byproduct with chromite.

Occurrences of gold, silver, and copper minerals are in the proposed area, but deposits are too small or too low in grade to be minable at present or in the foreseeable future.

Several occurrences of kyanite are known in metamorphic rocks within the proposed wilderness area, but deposits are of very small extent or the kyanite is only an accessory constituent. They cannot be economically mined at present and have no potential for future development.

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UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

BULLETIN 1230-B
PLATE 1

Base from U.S. Geological Survey
15' topographic quadrangles: Ennis,
1949, Spanish Peaks, 1950, and
Garnet Mountain, 1955

APPROXIMATE MEAN DECLINATION, 1966

SCALE 1:62 500

1 ½ 0 1 2 3 4 MILES

1 .5 0 1 2 3 4 KILOMETERS

CONTOUR INTERVAL 40 AND 80 FEET
DATUM IS MEAN SEA LEVEL

Geology by G. E. Becraft
and J. A. Calkins, 1965

EXPLANATION

Qls
Quaternary landslide deposits

Tv
Tertiary volcanic rocks

Tertiary(?) diabase dikes
May be related to volcanic rocks (Tv)

Ks
Cretaceous sedimentary rocks

J₨s
Jurassic and Triassic sedimentary rocks

Pp
Permian Phosphoria Formation

₽q
Pennsylvanian Quadrant Formation

M€s
Mississippian to Cambrian sedimentary rocks

p€m
p€q
p€mi
Precambrian metamorphic rocks
p€m, *gneisses, schists, quartzite, pegmatite, and amphibolite*
p€q, *quartzite*
p€mi, *mafic intrusive rock*

Precambrian amphibolite dikes and sills

Contact

Fault
Dashed where approximately located

70
Shear zone, showing dip

45
Axes of minor folds showing bearing and plunge

50 90
Inclined Vertical
Strike and dip of beds

80
Inclined Vertical
Strike and dip of foliation

68
Bearing and plunge of lineation

Vein

Adit

x
Prospect pit

Approximate boundary of primitive area

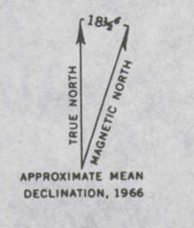
RECONNAISSANCE GEOLOGIC MAP OF THE SPANISH PEAKS PRIMITIVE AREA, MONTANA

215-251 O - 66 (In pocket) No. 1

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

BULLETIN 1230-B
PLATE 2

Base from U.S. Geological Survey 15' topographic quadrangles: Ennis, 1949, Spanish Peaks, 1950, and Garnet Mountain, 1955



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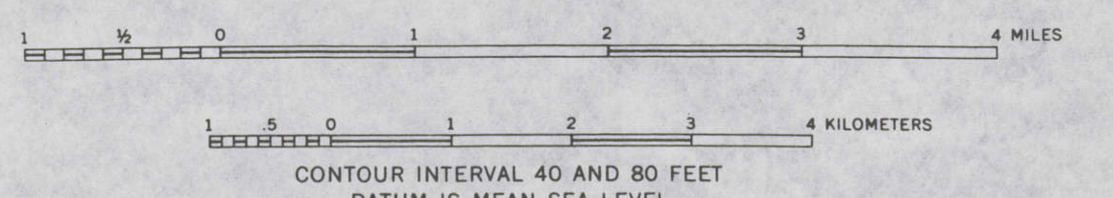

CONTOUR INTERVAL 40 AND 80 FEET
DATUM IS MEAN SEA LEVEL

MAP OF THE SPANISH PEAKS PRIMITIVE AREA, MONTANA, SHOWING SAMPLE LOCATIONS

215-251 O - 66 (In pocket) No. 2