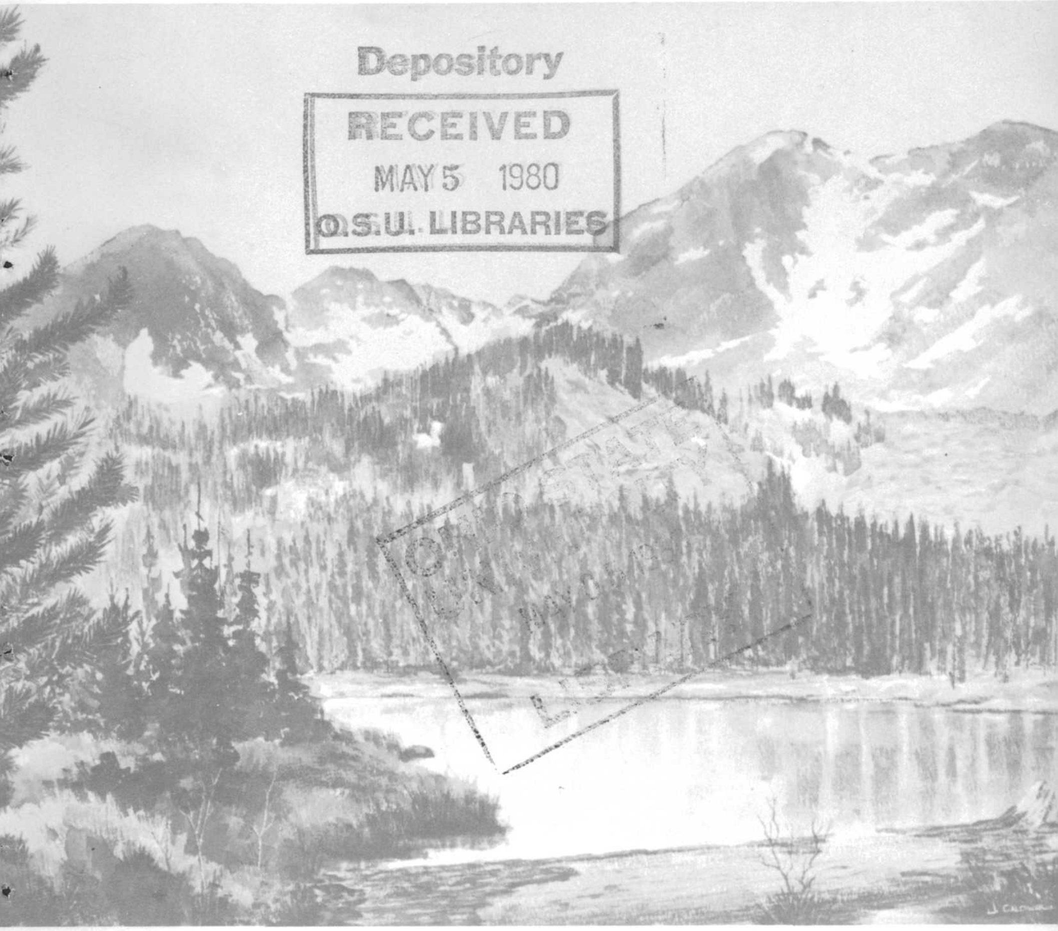
STUDIES RELATED TO WILDERNESS



INDIAN PEAKS STUDY AREA, COLORADO

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

GEOLOGICAL SURVEY BULLETIN 1463

Mineral Resources of the Indian Peaks Study Area, Boulder and Grand Counties, Colorado

By ROBERT C. PEARSON, U.S. GEOLOGICAL SURVEY,
and by U.S. BUREAU OF MINES
With a section on INTERPRETATION OF AREOMAGNETIC DATA,
By GORDON JOHNSON, U.S. GEOLOGICAL SURVEY

STUDIES RELATED TO WILDERNESS

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An evaluation of the mineral potential of the area

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

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STUDIES RELATED TO WILDERNESS

WILDERNESS AREAS

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

UNITED STATES DEPARTMENT OF THE INTERIOR

CECIL D. ANDRUS, *Secretary*

GEOLOGICAL SURVEY

H. William Menard, *Director*

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STUDIES RELATED TO WILDERNESS

MINERAL RESOURCES OF THE INDIAN PEAKS STUDY AREA, BOULDER AND GRAND COUNTIES, COLORADO

By ROBERT C. PEARSON, U.S. Geological Survey, and by U.S. BUREAU OF MINES

SUMMARY

A mineral survey of the Indian Peaks study area, Colorado, which is being considered for inclusion in the National Wilderness Preservation System, was made in 1972 and 1973 by the U.S. Geological Survey and the U.S. Bureau of Mines. An aeromagnetic survey of the area was made in 1967 by the Geological Survey. The area studied consists of about 130 mi^2 (340 km^2) of the Indian Peaks study area and about 15 mi^2 (39 km^2) of adjoining land. The area lies astride the Front Range in central Colorado just south of Rocky Mountain National Park about 30 mi (48 km) northwest of Denver.

The geologists and engineers spent about 22 man-weeks in field work making a reconnaissance geologic map, collecting samples, and investigating mineralized areas and mining claims. Foot traverses through the area by the geologists were spaced about 0.5 to 1 mi (1 to 1.5 km) apart. Rock samples were collected from all the different rock units to characterize them geochemically. Rocks that showed evidence of hydrothermal alteration or mineralization were sampled and analyzed, and samples of active stream sediment were collected at intervals from all streams, although most were collected from small, unbranched tributaries. Panned concentrates and soils were collected in a few places. In all, about 1,100 samples were collected and analyzed. About one-fourth of these were fresh rock, one-fourth were stream sediments, and the rest were mostly altered and mineralized rock from the study area and from nearby mines and mining districts. All samples were analyzed by semiquantitative spectrographic analysis. Selected samples were also analyzed by fire assay for gold and silver. Stream-sediment samples were tested for cold-extractable copper and citrate-soluble heavy metals. Most mineralized and altered rock samples collected by the U.S. Geological Survey were analyzed for arsenic, antimony, tellurium, and zinc by colorimetric methods, for gold by atomic absorption, and for mercury by an instrumental technique.

The rocks of the area are preponderantly gneisses and granitic rocks of Precambrian age that have been intruded by stocks, sills, and dikes of Laramide (Late Cretaceous to early Tertiary) and possibly younger age. The oldest rocks are an in-

terlayered sequence chiefly of pelitic gneiss, a few thin layers of amphibolite, and some granitic and granodioritic gneisses that are probably of igneous origin, some of them possibly volcanic. All these rocks were strongly folded before and during regional metamorphism to the amphibolite facies. Plutons of Boulder Creek Granodiorite intruded the gneisses before the end of the plastic folding and metamorphism; Silver Plume Granite, part of a batholith and many satellite bodies, intruded the gneisses post-tectonically. The Bryan Mountain, Caribou, and Audubon-Albion stocks of Laramide age lie on the north-trending line in the eastern part of the area. Sills and dikes intrude the Precambrian rocks in the vicinity of the stocks and northward, mostly on the east side of the range. Faults of the breccia-reef type that have broken all these rocks trend mainly northwest to west-northwest. The north-northeast-trending Ranch Creek fault intersects west-northwest-trending faults and ends in the southern part of the area.

The Indian Peaks study area lies along the north edge of the Colorado Mineral Belt, which encompasses most of the mining districts in the state. The Ward, Boulder County tungsten, Caribou, Eldora, and Lost Lake districts all lie less than 4 mi (6.4 km) from the study area. The Laramide stocks in the eastern part of the area generally have been considered to be part of the Mineral Belt. The area has been extensively prospected, and exploratory diggings dot the surface in several areas where mineralized rock—principally in veins—has been found. Twenty-one patented mining claims are within the area, and approximately 700 unpatented claims are within or adjacent to it. Three mines in the study area have recorded mineral production, all prior to 1915. The greatest production was from the Snowy Range vein in the Lake Albion area which produced 482 tons (437 t) of lead-silver concentrates. The other recorded shipments are 11 tons (10 t) of copper-silver ore from the head of Roaring Fork and 115 tons (104 t) of base- and precious-metal ore from the Fourth of July mine.

Some ore probably remains in the Lake Albion area, although the amount and grade are unknown. In addition, an inferred resource of a few hundred short tons of copper per hundred feet of depth is in the vein in upper Roaring Fork, and a few thousand short tons of rock containing 0.1 to 0.2 percent uranium is evident at the prospect in Wheeler Basin. No geologic evidence was discovered to indicate the existence of any deposit of minable proportions at these localities.

Of the many other widely scattered mineralized areas, three may be worth exploring for sizable ore bodies. Disseminated sulfides in the Audubon-Albion stock between Blue and Mitchell Lakes contain some copper and gold and suggest the possibility of ore deposits at greater depth. Similarly, granitic rocks in the cirque west of Rainbow Lakes contain many joints that are coated with limonite and narrow veins that contain sulfide minerals. Stream sediments below both of these occurrences are highly anomalous in copper. Narrow gold and silver-telluride veins along the lower part of Jasper Creek on the boundary of the study area are believed to define an area of low potential for deep ore bodies.

Many parts of the area show evidence of weak mineralization. Many fracture zones, small areas of altered rock, and narrow quartz veins contain small amounts of one or more metals, particularly copper, lead, zinc, molybdenum, gold, and silver. The stream-sediment samples also reflect this widespread weak mineralization, as anomalous samples come from many drainages that contain little rock that is visibly mineralized. However, other factors may contribute to anomalous metal contents of stream sediments, such as man-caused contamination and the high organic content of some samples.

Small resources of peat, modest amounts of sand and gravel, and substantial amounts of decorative stone are in the area. The area contains no evidence of a geothermal energy resource, and no possibility exists for discovery of coal or petroleum.

INTRODUCTION

The Front Range of Colorado is the impressive row of high mountain peaks visible from the cities and towns of north-central Colorado. The range towers above the western edge of the Great Plains, and clearly marks the eastern front of the Rocky Mountain ranges. It extends from Wyoming southward through more than half of Colorado, and it is 30 mi (48 km) wide at its narrowest part. Some peaks rise to over 14,000 ft (4,200 m) above sea level. The Indian Peaks study area (fig. 1) lies near the middle of the Front Range. The Continental Divide, along the crest of the range through the middle of the area, separates the streams on the western slope that are tributary to the Colorado River from the streams on the eastern slope that drain into the South Platte River. Most of the crest of the range is high above timberline and has a rugged serrate outline resulting from intense glaciation. The study area adjoins Rocky Mountain National Park and shares some of the outstanding mountain scenery that characterizes the park.

This report discusses the results of an investigation of the mineral resources of the Indian Peaks study area, a part of the Arapaho and Roosevelt National Forests that is being considered for inclusion in the National Wilderness Preservation System. The boundary shown on plate 1 and in figure 1 encompasses the approximate area that is presently (1978) managed by the U.S. Forest Service as wilderness. Studies were extended beyond this boundary in some places to include mineralized areas or to investigate geologic relations that might bear on mineral resources within the area. Some samples were collected outside the boundary in order to complete certain sampling patterns or to gather geochemical information that might suggest geologic relationships.

The study area extends south from Rocky Mountain National Park for 21 mi (34 km) along both flanks of the range as far as Rollins Pass. It is a triangular area of about 85,000 acres (34,400 ha) that narrows irregularly southward from a width of 19 mi (30 km) at the north end to about 3 mi (5 km) at the south end. It includes almost all the high rocky and tundra country above timberline and a narrow fringe of the lower timbered slopes and valleys on either flank.

The Indian Peaks study area is readily accessible by numerous logging and mine roads that impinge on the boundary at several points, by the automobile road across Rollins Pass, and by numerous foot and stock trails, four of which cross the Continental Divide. The Rollins Pass road, which is just south of the study area (fig. 1), follows the old grade of the Denver, Northwestern, and Pacific Railway (now a part of the Denver and Rio Grande Western

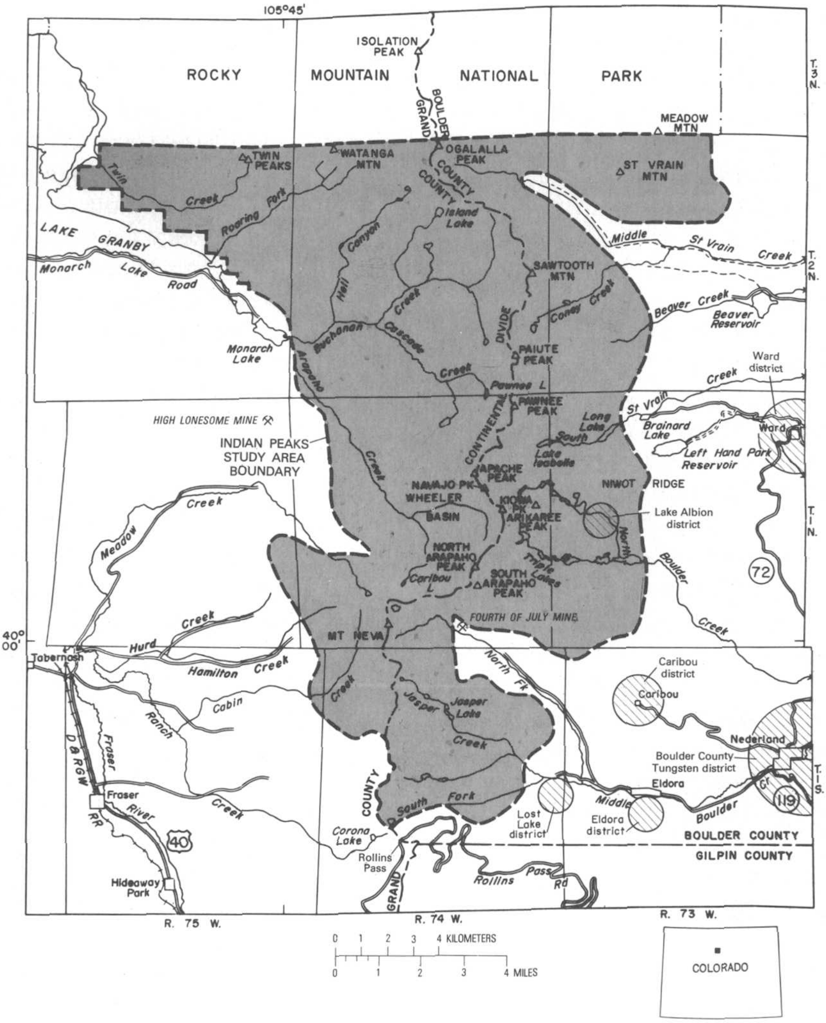

FIGURE 1.—Index map showing Indian Peaks study area (shaded) and mining districts (lined).

Railroad); this grade was used by the railroad from 1904 until the Moffat Tunnel was completed in 1928. The road is now used by sightseers and recreationists only in summer, for it is blocked by snow most of the year; in 1973, the road was not plowed free of snow until late July. Several roads lead west from State Highways 119 and 72 (fig. 1). From Nederland, passenger cars may be driven west through the town of Eldora and up the North Fork Middle Boulder Creek to within 2 mi (3.2 km) of the Continental Divide. Another road from Nederland leads to the old mining camp of Caribou, just east of the study area. From about 4 mi (6.4 km) south of Ward, a gravel road heads west from Highway 72 to a campground at Rainbow Lakes, and from Ward a hard-surface road goes to Brainard Lake, the most heavily used access to the Indian Peaks study area. Farther north, one four-wheel-drive trail follows Middle St. Vrain Creek and another lies along the moraine south of the Middle St. Vrain from Beaver Reservoir to Coney Creek. On the west side of the range, the principal access is by way of the road along the south side of Lake Granby to Monarch Lake. The southwestern part of the area is accessible from Fraser and Tabernash on U.S. Highway 40 by old logging roads up Meadow, Hurd, Hamilton, and Ranch Creeks. These roads are interconnected by a more modern road that follows an aqueduct and provides access to water-diversion structures on these and other streams. The three principal trails cross the range at Arapaho Pass (11,906 ft; 3,631 m), Pawnee Pass (12,541 ft; 3,825 m), and Buchanan Pass (11,837 ft; 3,610 m). A fourth trail, across Devils Thumb Pass, crosses the divide at an elevation of about 12,000 ft (3,660 m) at a point about 0.5 mi (0.8 km) south of its location as shown on the base map (pls. 1, 2).

On both sides of the Continental Divide the high crestal part of the area is characterized by numerous cirques (figs. 2 and 3). Adjacent cirques are separated by spur ridges that extend out from the divide. The longest of these is Niwot Ridge, which ends about 5 mi (8 km) from the divide at an altitude of 11,471 ft (3,499 m) at Niwot Mountain. The only extensive area without cirques is along the west side of the divide near the south end of the area. Here and on other smaller alpine slopes that have not been glaciated, the surface is blanketed with frost-riven rock, most of which has moved downslope as solifluction sheets and lobes. Many of the cirque and glaciated valley walls are a series of cliffs broken here and there by fractures that produce couloirs with talus cones below. Typically, an apron of talus along the lower valley sides grades into Neoglacial moraines and rock glaciers in some high cirques, but otherwise the glaciated valleys lack extensive surficial deposits within the study area. Timberline varies from 10,500 to 11,000 ft (3,200–3,350 m), depending on exposure and effects of glaciation. Except for some of the scrubby trees near timberline—mainly limber pine—the forests are open and clear of brush. They consist mainly of lodgepole pine, which grows best on the dry soils of moraines with sunny exposure, and Engelmann spruce and subalpine fir, which are adapted to moister soils.

Except for scattered prospect pits, the crumbling remains of prospector's cabins, and the few well-used trails, practically the only evidence of human activity is in connection with water storage. The North Boulder Creek drainage, including all drainage of Arapaho

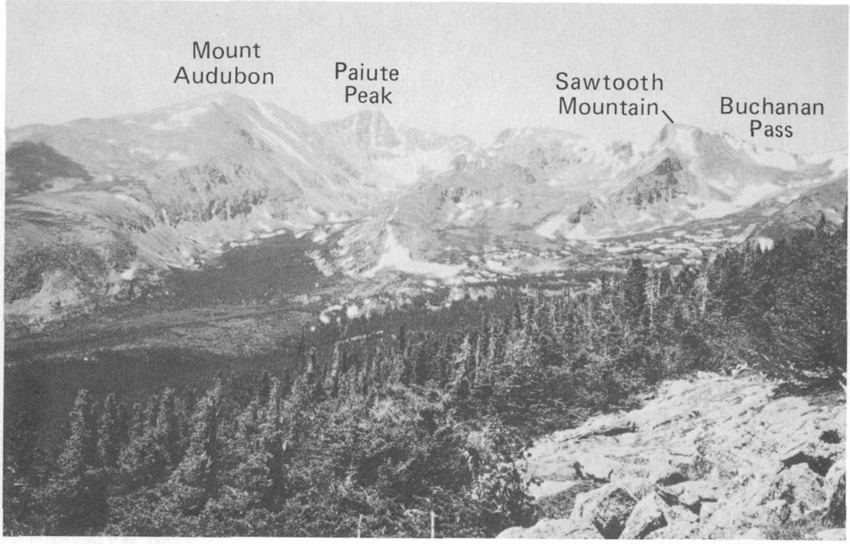

FIGURE 2.—Crest of Front Range viewed to southwest across Middle St. Vrain Creek. The top of Mount Audubon (13,222 ft; 4,033 m) is the north end of the Audubon-Albion stock. Paiute Peak, much of Mount Audubon, and rock in foreground are Silver Plume Granite. Most of divide area north of Paiute Peak is biotite gneiss. Cirques north and south of Sawtooth Mountain probably were glaciated slightly or not at all in Pinedale time, but next valley to south (Coney Creek) was occupied by a large Pinedale glacier. The large lateral moraine of Middle St. Vrain Creek that extends from center of photograph to left edge is of Bull Lake and Pinedale age.

Glacier, is known as the Boulder watershed. This area of several square miles is owned by the city of Boulder, Colo., and the surface runoff is used as a municipal water supply. For completeness, the area was included in this study, with permission of the city of Boulder. Most of the natural lakes in the Boulder watershed have been enlarged by dams that are accessible by roads. Other lakes in the study area that have been dammed include Skyscraper Reservoir, Woodland Lake, and Jasper Lake in the Middle Boulder Creek drainage; Isabelle and Long Lakes in the South St. Vrain Creek drainage; and Monarch Lake in the Arapaho Creek drainage.

PREVIOUS STUDIES

Most of the studies of geology and mineral resources that relate to the Indian Peaks study area concerned the eastern part of the area near mining camps of the Colorado Mineral Belt such as Ward, Caribou, Eldora, and Lake Albion. The geology of the Audubon-Albion stock and the Lake Albion mining district was mapped by Wahlstrom (1933, 1940b). The northern part of the area was mapped

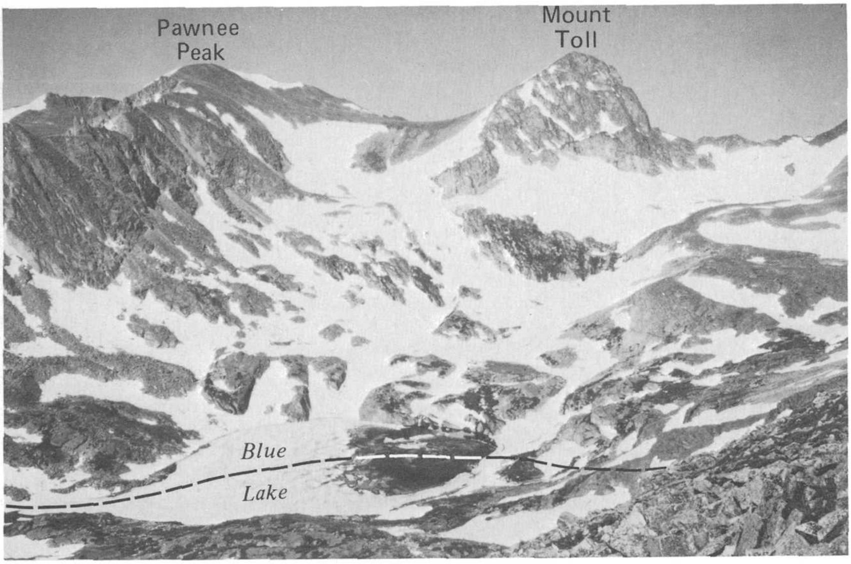

FIGURE 3.—View west across Blue Lake to Pawnee Peak and Mount Toll. Photo shows large compound cirque south of Mount Audubon. Dashed line indicates contact between Audubon-Albion stock in foreground and Longs Peak-St. Vrain batholith of Silver Plume Granite in background. Photograph taken July 10, 1973.

in rapid reconnaissance in 1938 for the U.S. Geological Survey by T. S. Lovering and E. N. Goddard in connection with a proposed extension of Rocky Mountain National Park. Unpublished data resulting from that study were provided by Ogden Tweto, who assisted in the work. Lovering and Goddard (1950) also compiled much detailed information on mines and geology of the Front Range, including the southern and eastern parts of the Indian Peaks study area. Geologic mapping by Gable (1969) in the Nederland quadrangle, and by Gable and Madole (1976) in the Ward quadrangle bears on the Indian Peaks study and was used freely. Other reports that refer to geology or mineral resources are discussed in appropriate sections of this report.

PRESENT INVESTIGATION

During the summers of 1972 and 1973 a mineral survey was made of the Indian Peaks study area; known mineral occurrences were studied, a geologic map was prepared, and more than 1,000 samples were collected and analyzed.

The records of mining claims and the economics of mineral resources were primarily the responsibilities of the U.S. Bureau of Mines. C. N. Speltz, assisted by J. B. Armstrong, and P. D. Blumenstein, Jr., searched the county records in Hot Sulphur Springs (Grand County) and Boulder (Boulder County) for evidence of claim locations. They obtained information on patented mining claims from records of the U.S. Bureau of Land Management in Denver. They also compiled data on mineral production. All mining claims, prospect workings, and mineralized areas that could be found were studied. A total of 117 samples of mineralized rocks was collected. The samples were prepared for analysis in Denver and were analyzed in the Bureau's Reno Metallurgy Research Center, Reno, Nev. Final compilation of the Bureau of Mines' contribution to this report was done by other members of the Bureau's Intermountain Field Operations Center staff.

The geologic map accompanying this report was prepared mainly from mapping done by R. C. Pearson and J. C. Ratté, with some information adapted from mapping mentioned under "Previous studies." Pearson covered the southeastern part of the area in about 20 days in the summer of 1972, and Pearson and Ratté, with the capable assistance of R. S. Kuhlman and E. M. Pokras, covered the rest of the area in about six weeks in the summer of 1973. The work was greatly facilitated in 1973 by use of a helicopter that transported parties to peaks and ridges to begin foot traverses and returned them to base camp near Sawmill Meadow west of the area.

The analytical work on the 950 samples collected by the U.S. Geological Survey party was performed in the field and at base laboratories by Geological Survey personnel under the immediate supervision of J. M. Motooka. Semiquantitative spectrographic analyses were made by Motooka and J. A. Domenico with the assistance of R. N. Babcock using the methods described by Grimes and Marranzino (1968). Chemical analyses were performed by R. L. Turner, C. A. Curtis, J. G. Frisken, R. B. Carten, and R. L. Miller, who used the atomic-absorption method of Ward and others (1969), the colorimetric tests of Ward and others (1963), and the mercury vapor detection method of Vaughn and McCarthy (1964). Uranium and thorium analyses were made by H. G. Millard, P. J. Aruscavage, and A. G. Bartel.

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

The aeromagnetic map, which with the geology is shown on plate 1, was made by the U.S. Geological Survey in 1967.

A preliminary version of this report was released in 1975 as U.S. Geological Survey Open-File Report 75-500 (Pearson and Speltz, 1975).

ACKNOWLEDGMENTS

We are grateful to Mr. Don I. Campbell, U.S. Forest Service, for providing space and facilities in 1972 at the Rollinsville Ranger Station and to him and his staff in the Boulder District office for many other courtesies. To Mr. Dean Rasmussen and Mr. Ben Beauregard, also of the Forest Service, we extend thanks for assistance in connection with our field camp near Sawmill Meadow. Officials of the city of Boulder, Colo., specifically Mr. V. A. Hollar, kindly permitted access to the Boulder watershed, and Mr. Tom Platt provided information and assistance in gaining access to this restricted area.

GEOLOGY

GEOLOGIC SETTING

The Indian Peaks study area lies in the high central part of the Front Range in a terrane of Precambrian crystalline rocks. The Front Range, one of the largest of the Rocky Mountain ranges, is about 35 mi (55 km) wide at the latitude of the Indian Peaks study area, and it is part of an expanse of Precambrian rocks that is continuously exposed north and south for well over 300 mi (500 km). The range is a broad flat-topped anticline, "* * * like a plateau bounded by oppositely facing monoclines" (Tweto, 1968). East of the area, at the edge of the range, upper Paleozoic sedimentary strata lie in depositional contact on the Precambrian rocks. These strata and the succeeding Mesozoic strata are upturned into a monocline at the edge of the range, thus separating the Great Plains from the Rocky Mountains. To the west, the Front Range is bordered by Middle Park, one of the intermontane basins of the Rocky Mountains.

Metamorphosed sedimentary and volcanic(?) rocks of predominantly high metamorphic grade, which are widely distributed between plutons of igneous rock, are the oldest rocks in the Front Range. They are strongly deformed and, where mapping has been done in detail, it is evident that they have been affected by at least two, and probably three, periods of folding. Granitic rocks of three general ages are widespread in the Front Range. The oldest, the Boulder Creek Granodiorite, about 1,710 m.y. old (Precambrian X), is named for a medium-sized batholith east of the Indian Peaks study area. Many other small plutons of generally correlative rocks are known throughout the Front Range, as well as in most other Precambrian exposures in Colorado. The Boulder Creek was emplaced during the period of high-grade metamorphism and the major folding. The Silver Plume Granite and its widespread correlatives, about 1,450 m.y. old (Precambrian Y), constitute the next younger group of granitic rocks.

It was emplaced, in part at least, during a period of more localized deformation that is marked by rather small-scale folding and cataclasis, which have not been recognized in the Indian Peaks area. The youngest of the major granites, the Pikes Peak Granite, is about 1,050 m.y. old (Precambrian Y); it does not crop out within 25 mi (40 km) of the Indian Peaks study area.

The Paleozoic and Mesozoic history of the central Front Range can be pieced together from relationships outside the Indian Peaks study area. Following a long period of erosion of the Precambrian rocks, marine strata were deposited in most, if not all, the periods of the Paleozoic through the Mississippian. These thin formations, mostly clean sandstones and carbonates, are separated from one another by unconformities. In Pennsylvanian time these sedimentary rocks were eroded in response to uplift of the Ancestral Rockies, and much detritus from these beds and from Precambrian crystalline rocks was deposited in adjacent sedimentary basins, mostly as nonmarine red beds. This regime continued through the early Mesozoic as the mountains were gradually eroded. In Cretaceous time thick marine sediments were deposited across the area of the former ancestral Front Range. Within the study area, this 400 m.y. of geologic history, from the Cambrian to the Cretaceous, is represented only by a few sandstone dikes that presumably formed during deposition of one of the Paleozoic sandstones. In Late Cretaceous time, about 70 m.y. ago, uplift was renewed in the same general area as the ancestral Front Range and the sedimentary beds were eroded once again. As the modern Front Range was formed, during the Laramide orogeny, intrusive and extrusive igneous rocks and ore deposits were also formed. Isotopic age determinations have shown that many of the igneous rocks and ore deposits previously thought to be Laramide (Late Cretaceous to early Eocene) are in fact middle Tertiary (Tweto, 1968). Additional details and references to many reports are given by Tweto (1968).

The structure of the Front Range was described by Tweto (1968, p. 566, 567) as follows:

> The Precambrian core of the Front Range, which makes up nearly the entire range, is broken by myriad fractures and faults. Largest and most persistent of these are NNE- to NNW-trending faults such as the Berthoud Pass fault * * *. [Such] faults, as much as a half mile wide, are Precambrian shear zones that underwent much movement in later time. Far more important—and economically more significant—are northwest-trending faults generally known as breccia reefs. These faults also originated in Precambrian time and underwent extensive movement in later time * * *.
>
> The western flank of the Front Range is faulted through much of its length, but remnants of a monoclinal structure—generally more gentle than on the east side of the range—remain in many places.

The Berthoud Pass fault trends north immediately west of the Indian Peaks area, and several of the northwest-trending breccia reefs are in the area.

One of the last events in the geologic history of the Front Range was alpine glaciation in the Pleistocene. Glaciers carved out cirques along the Continental Divide and flowed down preexisting valleys, scouring them out and producing the spectacular scenery present today. Studies in various parts of the Front Range have demonstrated several glacial episodes.

PRECAMBRIAN ROCKS

BIOTITE GNEISS

The oldest rocks in the Indian Peaks study area are a sequence of gneisses that are strongly deformed by folding and the accompanying migmatization. They presumably occupied the whole area originally, but now they remain only as septa, generally 1 mile (1.6 km) to several miles wide, between the numerous granitic plutons (pl. 1). They are exposed mainly in the north-central and west-central parts of the area. The principal rocks in the gneiss sequence are pelitic, are mostly rich in sillimanite, and are here called biotite gneiss. The name "biotite gneiss" has been used by several other authors for virtually identical rocks in nearby areas to the south and east (Sims, 1964; Theobald, 1965; Braddock, 1969; Gable, 1969, 1972). Distinctive layers of granitic and granodioritic gneiss were mapped separately in the part of the area where they are thickest; they are described under separate headings. Biotite gneiss is generally an unfavorable host rock for veins in the mining districts of the Front Range, presumably because it has behaved incompetently where faulted, and the fractures in it are commonly tight and barren.

The biotite gneiss unit consists mainly of gray fine- to medium-grained migmatitic layered rocks that are largely sillimanitic and that are inferred to be of sedimentary origin. The unit also contains a few thin layers and pods of amphibolite, calc-silicate gneiss, and quartz gneiss.

Biotite gneiss is composed mostly of biotite, quartz, and plagioclase, and various amounts of sillimanite, microcline, garnet, and cordierite. Small amounts of muscovite and green spinel are present locally. The spinel is a dark-green variety and is associated with cordierite and magnetite; it is probably similar in its occurrence to the spinel described by Gable and Sims (1969).

The biotite gneisses near the northwest corner of the area differ from those elsewhere in being more granular and feldspathic and, so far as could be determined, by lacking sillimanite, garnet, and cordierite; these rocks are very migmatitic but little is known about them because they are very poorly exposed.

The biotite gneiss exposed for about 1 mi (1-2 km) on both sides of Middle St. Vrain Creek in the northeastern part of the area is very highly migmatitic. Bodies of alaskite a few feet to a few hundred feet thick form an appreciable amount of the biotite gneiss unit in that area—in some parts of it, probably more than 50 percent. The alaskite locally contains garnet and sillimanite, and the associated biotite gneiss also contains widespread cordierite.

Biotite gneiss overlying the granitic gneiss on the north side of Buchanan Creek in the north-central part of the area is a thinly laminated rock composed of quartz-feldspar layers about a half inch (1-2 cm) thick separated by thinner biotite-sillimanite laminae. These rocks weather to a yellowish tan on the north side of Buchanan Creek, but about 2 mi (3 km) to the south on the south side of the Thunderbolt Peak anticline, where comparable strata are presumably present, the rocks are gray and the characteristic weathering color is absent.

Amphibolite and calc-silicate gneiss are uncommon and occur as thin layers and pods in the biotite gneiss unit. The thickest and most continuous sequence of these calcareous rocks generally parallels Buchanan Creek; it continues for more than 10 mi (16 km) from near the mouth of Buchanan Creek northeastward on the north side of the creek to the cirque at the very head of the creek. This sequence is probably no more than about 300 ft (100 m) thick at most, but locally it is absent. Pegmatite is abundant in it. Other thin calcareous units are in the vicinity of the Fourth of July mine, along the Continental Divide and east of the divide south of Ogalalla Peak, and on the spurs east of the divide north of Coney Creek.

GRANITIC GNEISS

Fine- to coarse-grained gneissic granitic rocks crop out in three main parts of the Indian Peaks study area: the northwest corner, the Buchanan Creek area near the center, and the south end.

The granitic gneiss in the northwest corner is forest covered and very poorly exposed. It is known chiefly from small pieces of float and a few outcrops that indicate that the rocks are fine- to medium-grained leucocratic gneiss and pegmatite. They consist dominantly of quartz, microcline, and sodic plagioclase; biotite and magnetite constitute a trace to a few percent. These rocks are evidently part of a body that continues north for several miles, according to David Abbott (oral commun., 1973). The relation of these rocks to the adjacent Boulder Creek Granodiorite and biotite gneiss units is unknown except that the granitic gneiss seems to be interlayered with biotite gneiss.

The granitic gneiss unit in the central part of the area is best exposed along the valleys of Buchanan Creek and Cascade Creek, where it forms one or more layers about 300–1,000 ft (90–300 m) thick that are interlayered with sillimanitic biotite gneiss. The several nearly parallel layers of the gneiss can be interpreted as an isoclinally folded single layer on the northwest flank of the Thunderbolt Peak anticline, as will be described in a subsequent section. The unit consists mainly of well-foliated buff- to reddish-brown-weathering biotite granite and quartz monzonite. Pegmatite that grades into granitic gneiss is abundant, locally forming bodies as much as 300 ft (100 m) across. Here and there the gneiss contains clots and streaks of sillimanite; surfaces of some talus blocks and large outcrops as much as several square meters in area are coated with white sillimanite.

The unit as exposed in the southern part of the area is mainly gneissic alaskite that contains only trace amounts of biotite and magnetite. It consists of layers of the alaskite interlayered with sillimanitic biotite gneiss. These rocks were called quartz monzonite gneiss by Lovering and Goddard (1950, pl. 2). The term "migmatite" is more apt for these rocks than for the rocks included in this unit farther north. Toward the northeast, in Jasper Creek valley, the granitic rocks seem to interfinger with migmatitic biotite gneiss; the contacts between biotite gneiss and granitic gneiss have not been mapped with any great degree of certainty. Some of the veins along lower Jasper Creek cut granitic gneiss layers, but a close association of the mineralization with particular wallrocks is not obvious there.

In nearby areas granitic gneisses generally similar to those in the Indian Peaks study area have been assigned to as many as three different units that have separate ages and origins. Microcline gneiss (Moench, 1964) (also called microcline-quartz-plagioclase-biotite gneiss (Sims, 1964), and quartz monzonite gneiss (Harrison and Wells, 1959)) is a widespread unit that forms concordant layers in biotite gneiss and hornblende gneiss; it has been interpreted by Moench (1964) as a metasedimentary rock. Granite gneiss and pegmatite is a similar rock unit that is more gradational with biotite gneiss; it evidently is a product of extreme migmatization (Harrison and Wells, 1959). Quartz monzonite, a fine-grained late phase of the Boulder Creek Granodiorite (Wells, 1967; Gable, 1972), may be represented by all or part of the granitic gneiss unit in the northwest corner of the study area, but elsewhere it is present in only small bodies that have in general been included in Boulder Creek Granodiorite on plate 1.

GNEISSIC GRANODIORITE

A fairly uniform gneiss of generally granodioritic composition forms folded layers in the northern part of the area, where it is interlayered with biotite gneiss. The principal layer is about 1,500 ft

(450 m) thick along Roaring Fork and in folds among the cliffs between the mouth of Roaring Fork and Monarch Lake. Northeast of Monarch Lake the layer seems to split into at least two layers that thin toward the northeast. In addition, one or more thinner layers crop out (1) between the fold limbs of the principal layer, (2) near the tops of several peaks on the Continental Divide, and (3) at Upper Coney Lake east of the divide. The mapping was not sufficiently detailed to show the extent and structural relation of these layers. Contacts with the enclosing pelitic gneisses are gradational over a few tens of feet. The gneissic granodiorite formed a more competent wallrock for the copper-silver vein in upper Roaring Fork than biotite gneiss and therefore afforded better access to mineralizing solutions.

Gneissic granodiorite is a gray, fine- to medium-grained, well-foliated, unlayered rock that consists mainly of biotite, quartz, and plagioclase, and of various amounts of microcline. The color index (percentage of dark minerals) ranges from about 7 to 20. Although the rock generally has an even-grained appearance, commonly it contains prismatic to lenticular crystals (augen) of andesine or, less commonly, of microcline that are coarser than the groundmass. These augen are about 0.25 in. (5 mm) long and are suggestive of original phenocrysts, although the fabric otherwise is completely metamorphic. Other metamorphic minerals that are present locally are garnet, hornblende, and pyroxene. Orthopyroxene and clinopyroxene occur together in rocks that contain no microcline.

As the name is meant to imply, the gneissic granodiorite is inferred to be a metamorphosed igneous rock. The lack of layering within the units and the relict phenocrysts suggest this. Thin layers covering more than 30 mi^2 (75 km^2) are more suggestive of lava flows than of intrusive bodies. The original character is not clear, however. It is similar in composition to the Boulder Creek Granodiorite, but the relative ages of the two units are not certain.

BOULDER CREEK GRANODIORITE

Two moderate-sized bodies of Boulder Creek Granodiorite are in the Indian Peaks study area; both are about 2 mi (3.5 km) wide and trend northeast. One in the southern part of the area extends from Rollins Pass to Silver Lake, and the other lies near the northwest corner of the area. The two bodies may both be parts of a large body of the Boulder Creek that lies west of the study area (Lovering and Goddard, 1950, pl. 1). The southern body, in turn, may connect with the main Boulder Creek batholith to the east of the study area (Gable, 1969, 1972; Gable and Madole, 1976). The Boulder Creek is important as a host rock for veins in the Boulder County tungsten district and other important districts nearby, but it is not known to be mineralized to any appreciable extent in the Indian Peaks study area.

Boulder Creek Granodiorite in the study area ranges from biotite granodiorite to quartz monzonite, and generally it contains blocky phenocrysts of microcline 0.5-1.5 in. (1-4 cm) long. Hornblende, which is common elsewhere, was not observed; sphene and allanite are common accessories. The color index is estimated to be mostly 10-15.

The rock generally has a pronounced foliation in the border of plutons, but in the interior of plutons the foliation is mostly weak or absent.

Fine-grained foliated biotite quartz monzonite forms small bodies in and near the typically coarser grained porphyritic Boulder Creek. These bodies are not shown separately on plate 1. These rocks resemble the quartz monzonite in the main Boulder Creek batholith described by Wells (1967) and mapped by Gable (1972).

PEGMATITE

Pegmatite occurs in all Precambrian rock units in the area, but is mainly in bodies too small to map. It is distinguished on the map (pl. 1) only along the north shore of Lake Granby, where it seems to be gradational with Boulder Creek Granodiorite. Some of these exposures exhibit a mixture of pegmatite, Boulder Creek, fine-grained gneissic quartz monzonite (probably of Boulder Creek age), and gray biotitic gneisses similar to those mapped as biotite gneiss about 1.2 mi (1.9 km) to the north.

No rare or potentially economic minerals were found in any of the pegmatite in the bodies that were mapped. The rock is composed of alkali feldspars, quartz, biotite, and, locally, muscovite. Uranium associated with pegmatite is described on pages 54-55.

BIOTITE QUARTZ DIORITE, BIOTITE-HORNBLENDE QUARTZ DIORITE, AND HORNBLENDITE

West of Diamond Lake, 0.5-1 mi (0.8-1.6 km), are two small bodies of biotite-hornblende quartz diorite, which grades into hornblendite at the south end of the western body. These rocks are similar in composition to many small bodies in the Front Range that are known to be younger than Boulder Creek Granodiorite and older than Silver Plume Granite.

Two small bodies of biotite quartz diorite lie within the Silver Plume Granite, one at Pawnee Lake, the other 4 mi (6 km) northeast of there. The rocks in these bodies are gray, gneissic, medium-grained, and moderately mafic. The body at Pawnee Lake is definitely cut by Silver Plume Granite, and the other one probably is also. They may be early mafic variants of the Silver Plume and hence of Precambrian Y age, or they may be older than Silver Plume, perhaps of Precambrian X age.

SILVER PLUME GRANITE

A lobe of the Longs Peak–St. Vrain batholith (Boos and Boos, 1934) of Silver Plume Granite projects southwestward into the Indian Peaks area from the main batholith. It occupies most of the northeast and east-central parts of the area. The lobe narrows southwestward to about 2 mi (3.2 km) wide at the Continental Divide, and it continues about 1 mi (1.6 km) southwest of the divide. Numerous small satellitic bodies of granite and pegmatite are scattered through the country rock within about 2.5 mi (4 km) of the main body. West of the area another large body of probable Silver Plume Granite is present on and near Lonesome Peak (pl. 1).

The rocks of the Longs Peak–St. Vrain batholith have been correlated with Silver Plume Granite by Boos and Boos (1934), Lovering and Goddard (1950), and Peterman, Hedge, and Braddock (1968) on the basis of chemical and physical characteristics and isotopic age determinations. The type locality of the Silver Plume is 13 mi (21 km) south of Rollins Pass near the town of Silver Plume. A Rb–Sr isochron plot of samples from the batholith indicates an age of 1,450±30 m.y. (Peterman and others, 1968).

Silver Plume Granite is light-gray binary granite or quartz monzonite that has a color index about 6 and is characterized by tabular microcline crystals in almost parallel arrangement. Muscovite is less conspicuous in the Indian Peaks study area than in most places, though it is evident microscopically. The fabric produced by the parallel microcline crystals generally parallels the contacts, and is regarded by us, as by others, as magmatic flow structure. Locally the microcline phenocrysts attain a length of 1.5 in. (4 cm), which is unusually large for Silver Plume Granite.

The Silver Plume has provided a competent wallrock for veins at several important mining districts in the Front Range. In addition, two occurrences of ore minerals described in this report are probably genetically connected to the Silver Plume. The High Lonesome mine on Lonesome Peak, just west of the area, is at the contact between probable Silver Plume Granite and calcareous layers in the biotite gneiss (Lovering and Goddard, 1950, p. 71). The uranium occurrence in Wheeler Basin is similarly situated in migmatitic biotite gneiss, and the age of uraninite crystals demonstrates the relation of uranium mineralization to the Silver Plume (this report, p. 55).

The contacts of the Silver Plume with the older rocks are sharp and discordant in some places and interfingering at others. On the north and east sides of Mount Audubon the granite complexly interfingers with the biotite gneiss in approximately equal proportions, and the two were not separated in the mapping over an area of about 3 mi^2 (5 km^2). Similar intimate mixtures are common in the Silver Plume elsewhere. (See Theobald, 1965, for example.)

PALEOZOIC(?) SANDSTONE DIKES

For a distance of 2.5 mi (4 km) along the Arapaho Pass fault, which crosses the southern part of the area (pl. 1), sandstone occurs in lenticular or dikelike bodies. Inasmuch as outcrops along the fault zone are discontinuous, the continuity or size of individual sandstone bodies is uncertain; some of the localities shown on the geologic map (pl. 1) represent only float. The largest surface exposure of the sandstone is a highly fractured and mineralized rib that rises above the scree-covered slope on the north side of Arapaho Pass. All surface exposures are fractured by fault movement, and many are mineralized, particularly by introduction of specularite and recrystallization of the original quartz grains. Lead, zinc, and silver minerals are also present in sandstone west of Caribou Pass, which is 1 mile northwest of Arapaho Pass. The surface exposures suggest a thickness for the sandstone bodies of several feet to several tens of feet. The largest exposure, however, is along the drift at the end of the adit of the Fourth of July mine about 1 mi (1.6 km) southeast of Arapaho Pass. It is exposed for 300 ft (92 m) along the drift; crosscuts indicate a thickness of 30 ft (9 m) to more than 60 ft (18 m) (fig. 10). The rock is brecciated by faulting, and its contacts with biotite gneiss and Boulder Creek Granodiorite are sheared so that the original thickness of the sandstone body cannot be definitely determined. The difference in elevation between highest and lowest exposures of the dike is 1,300 ft (400 m).

The sandstone is mostly white, tan, gray, or reddish-brown; some of the colors are caused by introduced iron minerals or their alteration products. The sandstone is petrographically an orthoquartzite consisting dominantly of well-rounded and moderately spherical grains of quartz. Feldspar constitutes several percent of the sand grains. In places, the sandstone contains angular fragments of feldspar, quartz, mica, and granitic rocks as much as 4 in. (10 cm) long. These are presumably fragments of the wallrocks, but none of them are diagnostic as to source. Thus the sandstone consists of components of two totally different regimes. The angular fragments of Precambrian rocks are foreign to the type of environment in which a very mature orthoquartzite would normally form.

Similar sandstone dikes are common in Precambrian rocks in the Front Range southeast of the Indian Peaks, where they are in and near north- to northwest-trending faults. Scott (1963) has summarized the information known on their distribution and discussed the several hypotheses that have been invoked by others to account for their origin: (1) unconsolidated sand was emplaced into open fissures, (2) slices of sandstone were dragged into fault zones during movement in Laramide time, (3) "quicksand-like material" was injected into the upthrown block from sedimentary rocks in the downthrown block during faulting, and (4) the dikes are relict Precambrian sandstone beds. In addition, a mechanism similar to (3) was proposed by Harms (1965). The only one of these hypotheses that seems to be in accord with the characteristics of the dikes in the Arapaho Pass fault is the first: filling of open fissures by unconsolidated sand. Scott (1963) has also concluded that dikes about 60 mi (100 km) to the southeast had a similar origin. If the sand filtered downward into water-filled fissures that were open to the sea floor, and if thereafter the dike never moved downward independent of both walls by faulting, the fissure would have been open to a width of as much as 60 ft (18 m) at a depth of at least 2,100 ft (650 m). The adit level of the Fourth of July mine is 2,100 ft (650 m) to 2,800 ft (860 m) below adjacent (less than 1.5 mi distant) mountain peaks, which would be the lowest possible level for the sea floor.

The maturity of the sand in the dikes suggests that they formed during the Paleozoic. The dikes may correlate with the Cambrian Sawatch Quartzite, the Ordovician Harding Sandstone, or the Devonian Parting Formation, all of which are present about 40–50 mi (65–80 km) west and southwest of Arapaho Pass.

CRETACEOUS AND TERTIARY INTRUSIVE ROCKS

Several stocks and hundreds of dikes and sills of porphyritic to equigranular igneous rocks of Late Cretaceous and Tertiary age have intruded the Precambrian rocks in the Indian Peaks study area. The stocks lie along a line that trends north from the southeast corner of the area, and they include parts of the Bryan Mountain stock and the Caribou stock, all of the Audubon–Albion stock, and several small bodies farther north, the largest of which is at Sawtooth Mountain (pl. 1). The dikes and sills are most abundant near the stocks, but they are also common north and northwest of the stocks, in the Middle St. Vrain Creek drainage. Except for several dikes and sills in the vicinity of Thunderbolt Peak, these bodies are uncommon west of the Continental Divide. More sills and dikes are present than are shown on plate 1, which illustrates only the largest and evidently the most continuous. No attempt was made to "walk out" the bodies in the mapping, as D. J. Gable did in the Nederland and Ward quadrangles (Gable, 1969; Gable and Madole, 1976).

The stocks are composite bodies, and specific rock types in one stock have petrographically similar counterparts in other stocks. The principal rock types in the Audubon-Albion stock are monzonite, quartz monzonite, leucocratic syenite, and syenogabbro (Wahlstrom, 1940b). The Caribou stock, as described by Smith (1938), is "* * * composed chiefly of monzonite but with masses of titaniferous magnetite and bodies of ultramafic and gabbroic rocks." Cree (1948) has described the Bryan Mountain stock as containing mainly quartz monzonite, and also granite, tonalite, and syenogabbro.

Thus, on petrographic grounds, the stocks can be inferred to be comagmatic, and hence about the same age. Though not all consistent, isotopic age determinations indicate that their age is Laramide (Late Cretaceous to early Tertiary). However, numerous porphyry bodies in the Colorado Mineral Belt have a middle Tertiary age (Tweto, 1968). Therefore, some of the inconsistencies in the age determinations may be explained by a heating of the Laramide rocks by younger Tertiary rocks, which so far have not been definitely identified in the Indian Peaks study area. The Bryan Mountain stock has been dated as 54 m.y. old (K-Ar) and 60 m.y. old (Rb-Sr) by Hart (1964), and as 59.1±1.8 m.y. old (K-Ar) by McDowell (1971). The Audubon-Albion stock has been dated as 68 m.y. old by Hart (1961). The Bryan Mountain stock may be older in part than some of these ages suggest, however, for Naeser and Faul (1969) reported fission-track ages of 73±7 m.y. C. W. Naeser (oral commun., 1974) now believes that recent modifications of the technique would revise these fission-track ages downward slightly—perhaps to near the 68-m.y. age measured on the Audubon-Albion stock. The part of the Bryan Mountain stock that is granite has a composition more like that of the mid-Tertiary porphyries, which could be the cause of some of the inconsistencies in the K-Ar ages. The granite lies south of the study area.

The stocks are a part of the Colorado Mineral Belt as it is conceived by most authors (Ball, 1908; Lovering and Goddard, 1950; Tweto and Sims, 1963; Tweto, 1968). Mineral deposits, mostly in the form of veins, are associated with the stocks, but most of the veins are outside the area considered in this report.

Dikes and sills that are present through nearly all of the Indian Peaks study area are of many petrographic types, but two types predominate. Near the stocks and probably related to them, the commonest type in the southern part of the area is hornblende-plagioclase porphyry. From Lake Albion north and northwest, the commonest type is biotite-quartz-plagioclase porphyry. This latter rock forms the large dike at the northwest end of Red Deer Lake, another large dike 1.2 mi (2 km) east-northeast of Monarch Lake, and most of the concordant bodies so well exposed in the cirque walls at the head of Middle St. Vrain Creek. The biotite-quartz-plagioclase porphyry has not been found in contact with the Laramide stocks, and it has no obvious petrographic counterpart in the Laramide stocks. A fission-track age of 52.6±5.6 m.y. was determined by C. W. Naeser (written commun., 1975) on zircon from a sample of the dike at Red Deer Lake.

TERTIARY AND QUATERNARY SURFICIAL DEPOSITS

Surficial deposits cover only about 5 percent of the Indian Peaks study area. They consist predominantly of till in glacial moraines, of solifluction deposits on the smooth slopes above timberline, and of small amounts of alluvium along the valley bottoms. Some bouldery deposits on ridges may be of Tertiary age. All these deposits were mapped as one unit except those that are possibly Tertiary in age.

Glaciers formed at several different times in the cirques at the heads of nearly every valley and then flowed down the valleys depositing till as lateral moraines that are now several hundred feet above the valley floors and as ground moraines on parts of the valley floors and sides. The largest moraine forms Knight Ridge near the northwest corner of the area; it was deposited by a trunk glacier formed by the coalescence of tributary glaciers that drained most of the Indian Peaks study area west of the Continental Divide. Among the major tributaries were the glaciers of the Arapaho, Buchanan, and Roaring Fork drainages. South of Arapaho Creek, glaciers in the Meadow Creek and Cabin Creek drainages merged along the west edge of the area (pl. 1) to form a piedmont glacier that lay at an elevation of about 10,000 ft (3,000 m) for about 6 mi (10 km) from Devils Thumb Park to north of Sawmill Meadow. The moraines of these glaciers represent a complicated glacial history; no detailed study was made of them. The west-facing slope 1 mi (1.6 km) northeast of Sawmill Meadow is covered by a bouldery deposit, possibly till, that is definitely older than the large lateral moraine along Arapaho Creek and, as judged from its surface form, may be pre–Bull Lake in age.

The large lateral moraines on the east side of the area are partly of Bull Lake and partly of Pinedale age (Gable and Madole, 1976). The largest is the lateral moraine along the south side of Middle St. Vrain Creek (visible in fig. 2) at the north edge of the area. Some of the valleys tributary to Middle St. Vrain Creek, such as the one east of Buchanan Pass (fig. 2), were not glaciated during the last major glaciation, which was presumably in Pinedale time. Neoglacial moraines of several ages lie high in the cirques or are a mile at most from the cirque.

Solifluction deposits mantle most of the smooth gentle to moderate slopes above timberline. These deposits are blankets of coarse blocks that have moved downslope for various distances. Solifluction produces a wavy surface on gentle slopes and vertical stripes on moderately steep slopes. Although these deposits, which are probably several feet (a few meters) thick, were not distinguished in most places from the bedrock that they tend to mask, they have locally been included in the Quaternary unit.

Bouldery till-like deposits lie on a few spur ridges 1–2 mi (1.5–3 km) east of the Continental Divide in the east-central part of the area. These deposits have been considered to be pre–Bull Lake till by several investigators (G. M. Richmond, oral commun., 1973). Recent mapping, however, suggests the possibility that they are later Tertiary in age and that they may be of fluvial rather than of glacial origin (Gable and Madole, 1976).

Alluvium along the stream valleys consists of generally small and thin deposits of sand and gravel, but at a few places these deposits may be substantial. One deposit that may be large is in the park along Jasper Creek, near its mouth, and another is in the delta above Monarch Lake. Swamps and deposits of peat and peaty muck as much as several feet (a few meters) thick mask some of these sand and gravel deposits, making determination of their extent difficult.

STRUCTURE

The structural history of the Indian Peaks study area involves plastic folding in probably two separate periods in the Precambrian and faulting in the Precambrian, Paleozoic, Laramide (Late Cretaceous to early Tertiary), and probably later in the Tertiary.

The dominant trend of the rock units and their foliation in the Indian Peaks study area is approximately northeast. The two bodies of Boulder Creek Granodiorite and most lithologic units in the gneiss sequence trend in this direction. In two parts of the area, however, there is a definite northwest to west trend to the foliation and to minor units in the gneiss sequence.

FOLDS

The principal folds recognized in the Precambrian gneiss sequence are upright to overturned and trend N. 50° E. These folds are in the northern part of the area between the large bodies of Silver Plume Granite and Boulder Creek Granodiorite (pl. 1). The dominant structural feature is the Thunderbolt Peak anticline, which was mentioned though not named by Lovering and Goddard (1950, p. 55). Cascade Creek cuts across the anticline at right angles exposing its axial region through a vertical distance of more than 2,600 ft (800 m). At the level of Cascade Creek the anticline is nearly isoclinal and upright, but upward it becomes more open, and along the ridge near Thunderbolt Peak the crest is broad and nearly flat. In that area, dips of foliation barely exceed 20° for a quarter of a mile (0.4 km) on either side of the axis, and these dips are mostly down the plunge to the northeast.

Northwest of Buchanan Creek the granodiorite gneiss outlines a series of anticlines and synclines that parallel the Thunderbolt Peak anticline. The two parallel outcrop bands of granodiorite gneiss, which are about 2 mi (3.2 km) apart, seem to outline a large syncline, but a subsidiary intervening anticline is indicated by exposures on the steep slope above the east end of Lake Granby. This anticline and other possible subsidiary folds have not been mapped through the monotonous sequence of biotite gneiss to the northeast. However, all these folds seem to decrease in amplitude toward the northeast; from the Continental Divide eastward to the Silver Plume Granite batholith the gneisses have a general low homoclinal dip to the east or northeast. Along Middle St. Vrain Creek (fig. 4) an anticline that has low amplitude and plunge may be the Thunderbolt Peak anticline. Just to the west of the area shown in the photograph (fig. 4), on Elk Tooth, are overturned minor folds with amplitudes of at least several tens of feet. The homoclinally dipping gneisses are possibly part of a limb of a large overturned or recumbent fold that trends west or northwest.

Foliation in the biotite gneiss adjacent to the Silver Plume Granite batholith generally parallels the contact of the batholith, though it is markedly discordant in detail. The southwest end of the batholith particularly shows the concordance. For several miles south of the batholith, the biotite gneiss has a dominant trend of west to northwest. Numerous minor folds in this area also plunge northwestward but at various angles, as would be expected if older northwest-trending folds were refolded by the northeast-trending folds.

Elsewhere in the central Front Range three periods of folding in the Precambrian have been demonstrated by Wells (1967), Sheridan, Maxwell, and Albee (1967), and Gable (1969). Of the three, the middle or major period (Tweto, 1968) produced folds that have a north to northeast trend, and in many places these are the only folds that are apparent. The northeast-trending folds in the northern part of the Indian Peaks study area may well belong to the period of major deformation, and the sparse indications of west to northwest-trending

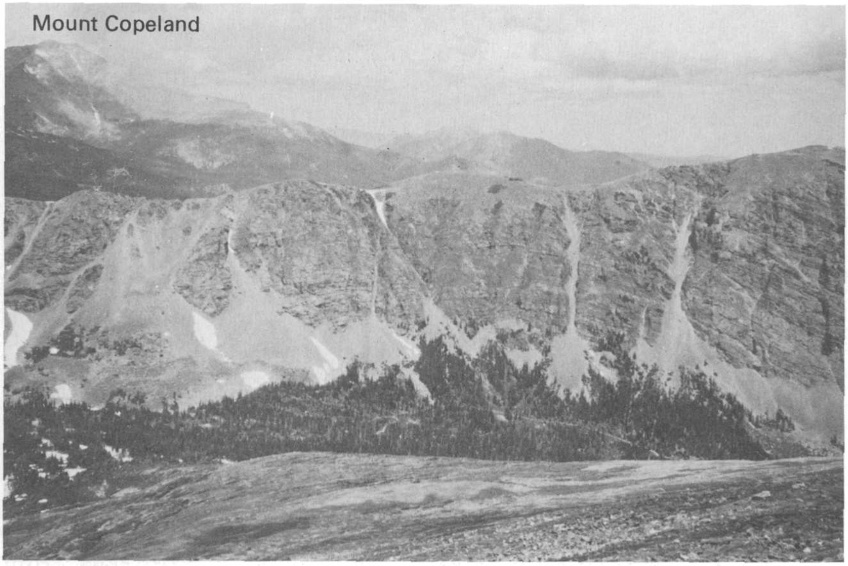

FIGURE 4.—View north across Middle St. Vrain Creek. Shown is gentle anticline in migmatitic biotite gneiss. Mount Copeland on skyline at left is in the Rocky Mountain National Park.

folds may be part of the early deformation. No structural features that could be assigned to the later deformation were found.

FAULTS

The principal faults in the Indian Peaks area are the Ranch Creek fault and the Arapaho Pass fault (pl. 1). Many other faults in the southern part of the area, mostly south of the Arapaho Pass fault, seem to be minor and probably are part of the highly broken block of rock near the intersection of the two principal faults. The few faults recognized in the northern part of the area trend north, northeast, and northwest. The northwest-trending group, of which the Arapaho Pass fault is one, is part of the breccia reef system that is best developed east and southeast of the Indian Peaks area. The Berthoud Pass fault trends north just west of the area. All faults seem to dip steeply.

The Ranch Creek fault extends into the southwest corner of the area at Rollins Pass from the south-southwest. Although this fault has been called the Berthoud Pass fault (Lovering and Goddard, 1950, p. 59, 60), it was named the Ranch Creek fault by Lovering (1932), and Braddock (1969) referred to it by the older name. At Rollins Pass the fault is a broad fault zone consisting of several strands, each containing much crushed and altered rock—mainly

Boulder Creek Granodiorite. Some of these strands diverge from the main fault and become tight, inconspicuous fractures in short distances. The main strand trends N. 40° E. from Rollins Pass. It is a single fault that consists of less than 300 ft (100 m) of breccia and gouge where it crosses Woodland Mountain and consists of one or two narrower strands where it crosses the next ridge to the north. It evidently merges with, or stops against, a N. 75° E.-trending fault that is inferred beneath surficial deposits in the valley of Jasper Creek. The amount of displacement on the Ranch Creek fault is probably large, for Boulder Creek Granodiorite forms the dominant rock west of the fault but is not present east of it except for a small body at Rollins Pass. The Ranch Creek fault is not known to be mineralized in the Indian Peaks study area, although Lovering (1928) mentioned small amounts of copper in it where the fault was exposed in the Moffat Tunnel.

The Arapaho Pass fault trends N. 60° W. completely across the area from the Caribou mining district through Arapaho Pass (fig. 5), through Caribou Pass, and, on the west side of the range, down Meadow Creek where it disappears beneath glacial deposits. Topographic lineaments along the same trend west of the area suggest that it continues at least 6 mi (10 km) beyond the mapped area. At the east edge of the area it may stop against, or be offset by, the same N. 75 E.-trending fault that seems to cut off the Ranch Creek fault. The northwest boundary of the Boulder Creek Granodiorite is offset by the Arapaho Pass fault about 1 mi (1.6 km) left laterally (pl. 1). The Arapaho Pass fault has been prospected by shallow pits and has been explored at depth in the Fourth of July mine, where small amounts of copper, lead, and zinc minerals were found. West of Caribou Pass small veins were prospected by means of several small workings. Movement took place at several times. Tertiary movement is indicated by brecciation of the Caribou stock, which, south of Bald Mountain, is limited to the north side of the fault. Sandstone dikes were emplaced in open fault fissures in Paleozoic time. A Precambrian origin for the Arapaho Pass fault is probable (Tweto and Sims, 1963).

A north-trending bench lies at an elevation of about 10,000 ft (3,000 m) just west of the study area and extends from Devils Thumb Park to Sawmill Meadow (pl. 1). This bench, which is covered by glacial deposits, is evidently the topographic expression of the Berthoud Pass fault. The only outcrop of this fault that was seen is a strong north-trending mylonitic fault zone that crops out 1.5 mi (2.4 km) south of Devils Thumb Park and, according to Braddock (1969, fig. 25, p. 52), farther south also. No mylonite or other evidence of a north-trending fault was found north of the inferred intersection of the Berthoud Pass fault with the Arapaho Pass fault near Sawmill

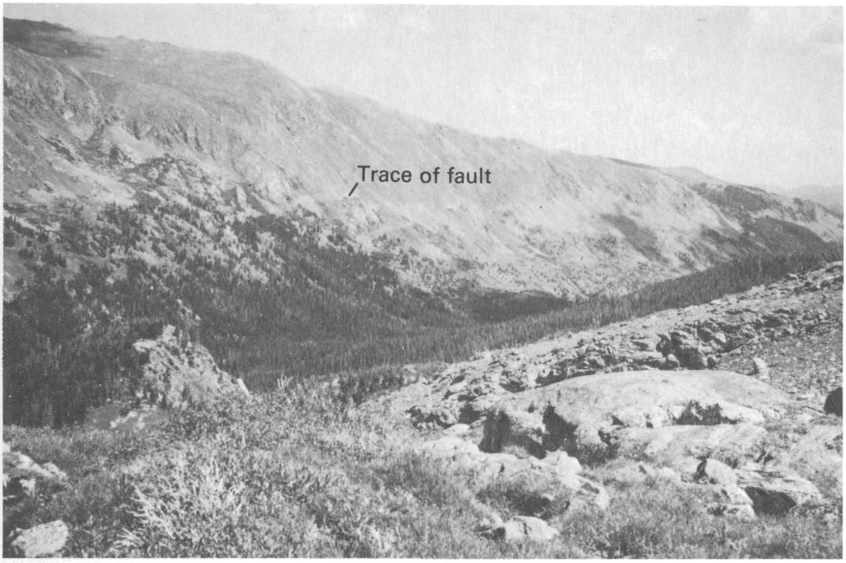

FIGURE 5.—View east across North Fork Middle Boulder Creek showing trace of Arapaho Pass fault in the middle of the slope. Fault is marked by line of small patches of scree and by upper limit of trees at left.

Meadow. This lack suggests that the Berthoud Pass fault is offset left laterally by the Arapaho Pass fault.

Faulting, perhaps in the late Tertiary, also seems to have affected the height of parts of the crest of the range. The northern two-thirds of the area is in general higher than the southern third. From Arapaho Pass northward, nine named peaks are higher than 13,000 ft (3,960 m) above sea level, whereas to the south none of the peaks is that high. The average altitude of the northern segment is about 500 ft (150 m) higher than the southern segment—a difference that is clearly evident from Wondervu, which is located on State Highway 72 about 15 mi (24 km) east of the southern tip of the area, and similar distant vantage points. The southern segment of the range crest may be lower because it is more broken and weakened by faults in a triangular area bounded by the two major faults. The Arapaho Pass fault, in particular, forms the dividing line between the higher and lower segments of the range. The Ranch Creek fault crosses the range at a low angle, and it and numerous other subsidiary faults lie in the area south of the Arapaho Pass fault. The highest peaks in the study area, North Arapaho Peak (13,502 ft; 4,115 m) and South Arapaho Peak (13,397 ft; 4,083 m), lie within 1 mile of the Arapaho Pass fault; and South Arapaho Peak rises very steeply 2,200 ft (670 m) from the fault near the Fourth of July mine. This abrupt acclivity north of the Arapaho Pass fault suggests the possibility of late Tertiary movement on that fault, which may account for the difference in height of the two parts of the range.

The several northwest-trending faults in the northern part of the area are typical of the "breccia reefs" along the east flank of the Front Range. These are marked by many tens of feet of breccia and gouge, by weak chloritic and sericitic alteration of the wallrocks, and by a few veins. The displacements along these faults seem to be very small. The most important mineral deposit in the area is in the disseminated copper in a vein along one of these faults.

The numerous other faults recognized seem to have no particular pattern or significant offset.

INTERPRETATION OF AEROMAGNETIC DATA

By Gordon R. Johnson

In 1967, the U.S. Geological Survey made an aeromagnetic survey of the Indian Peaks study area and surrounding region between lat 39°30′ and 40°15′ N. and long 105°07′50″ and 106°45′ W. (U.S. Geological Survey, 1968). The survey was flown at a constant barometric elevation of 14,000 ft (4,270 m); a fluxgate magnetometer was used to obtain continuous total intensity magnetic profiles along 52 east-west flight lines spaced approximately 1 mi (1.6 km) apart. Contours of relative intensity, initially compiled at a scale of 1:125,000 and at contour intervals of 20 and 100 gammas (γ) were enlarged to a scale of 1:48,000 and are shown superimposed on the geologic map (pl. 1). No laboratory measurements of rock magnetic properties were made.

The Indian Peaks study area stands out as a region of high magnetic intensity that is typical of many mountain ranges that consist of Precambrian crystalline rocks. Within the area the magnetic relief is moderately high owing to topography and differences in magnetic properties within the various rock units. Although mapped rock units, extending to depth, apparently control the distribution of magnetic anomalies, it is also possible, but not likely, that beneath the exposed rocks a basement of highly magnetic rock produces the high magnetic gradients seen at the west and south edges of the mapped area and to some extent along the east edge. The cause of the high gradients at the edges can probably be best explained by the difference in elevation between the high part of the range and the adjacent areas to the east and west. It is also possible that the rocks in the high part of the area are more magnetic. The Boulder Creek Granodiorite seems to be the most magnetic of the Precambrian rocks inasmuch as several small positive anomalies coincide with outcrops of this rock. On a gross scale the biotite gneiss apparently has a magnetic intensity almost as high as the Boulder Creek Granodiorite.

The Silver Plume Granite has a magnetic expression that suggests that this rock may be reversely polarized, as was found by Tweto and Case (1972), who made laboratory measurements on magnetic properties of rocks correlative with the Silver Plume Granite.

Within the Indian Peaks study area an arcuate zone of magnetic highs (pl. 1) trends north to south and culminates in a positive anomaly about 1 mi (1.6 km) southeast of South Arapaho Peak. This anomaly, which has a maximum value of 4,459 γ (based on an arbitrary datum), is the highest in the area and is probably caused by a combination of topography and a large body of Boulder Creek Granodiorite. The high magnetic gradients on the south and southwest sides of the anomaly reflect more than 2,000 ft (600 m) of topographic relief in this area. A northward extension of the magnetic high has a maximum intensity of 4,209 γ near the top of North Arapaho Peak. From there the anomaly is elongated in a northeasterly direction, and it parallels the contact between Boulder Creek Granodiorite and biotite gneiss. The high magnetic values apparently produced by the biotite gneiss are actually an effect of topography, because the magnetic high coincides with a ridge which includes peaks over 13,000 ft (3,960 m) in elevation. The high gradients on the northeast end of the magnetic high are caused partly by topographic effects and perhaps partly by the Laramide Audubon–Albion stock, which is probably less magnetic than the Precambrian rocks.

From North Arapaho Peak the zone of positive anomalies trends northwest, then north, following the outcrop of biotite gneiss to the northern boundary of the mapped area. The shapes and intensities of the magnetic highs are controlled by topographic variations except in the region south of Buchanan Creek where a magnetic saddle exists. Granitic gneiss in this area, which is probably less magnetic than the biotite gneiss, could account for a magnetic low of this type.

A linear northeast-trending zone of low magnetic intensity several miles (km) long cuts across the north-central boundary of the Indian Peaks study area. Because topograpic variations do not seem to control the intensity or trend of the magnetic lows and because these lows occur in an area of magnetic biotite gneiss, some other rock probably occurs at depth. Small outcrops of Silver Plume Granite in several places along the magnetic low may indicate a sizable mass of this rock beneath the ground surface, and inasmuch as the Silver Plume Granite is assumed to be reversely magnetized, probably a linear body of this rock at some intermediate depth produces the zone of magnetic lows. Other possible causes of the linear magnetic low would be either a zone of alteration in the biotite gneiss or the presence of some other weakly magnetic silicic igneous rock that does not crop out.

A cluster of magnetically low anomalies is located in the central to east-central parts of the mapped area, mainly over Silver Plume Granite. Of the three closed negative magnetic anomalies, the northwest low (3,308 γ) is the shallowest, probably because it is near the summit of Paiute Peak, which was only about 1,000 ft (300 m) below the sensing magnetometer. The southwest low (3,291 γ) is also over an area of generally high elevation. The third magnetic low, on the eastern boundary of the mapped area, has two depressions within it. The southernmost depression (3,039 γ) is centered (on one flight line) over an area that is probably underlain by syenite—a leucocratic phase of the Audubon–Albion stock. The area is largely covered by surficial deposits, but scattered outcrops of syenite occur as far east as Brainard Lake, which suggests that the center of the anomaly is at least 0.5 mi (0.8 km) from the contact with Silver Plume Granite. Although a narrow body of syenite extends from the main mass south to Lake Albion, it exhibits no magnetic expression, probably because of its small size.

A short-wavelength magnetic high exists over the east flank of Mount Audubon near the edge of the Audubon–Albion stock. The steep gradients associated with this anomaly and its apparent east-west elongation suggest it may be caused by a near-surface dikelike body. However, there is no obvious surface indication of mafic rocks nearby, nor are there any significant geochemical anomalies in this area. Magnetite-rich rocks similar to those in the Caribou stock could account for this anomaly, but they evidently do not crop out. For these reasons, this magnetic high probably is not useful as a target for mineral exploration in this area.

A closed magnetic high with an amplitude of about 500 γ (4,188 γ maximum intensity), located just outside the southeast boundary of the area in the Caribou mining district, is centered over Caribou Flat and nearly encompasses the Caribou stock (Lovering and Goddard, 1950, pl. 2). The high magnetic gradients suggest that the rock producing this anomaly must be near the surface; possibly the rock is the titaniferous magnetite in the central portion of the stock (Smith, 1938). The anomaly has a southwest-trending nose extending to the Bryan Mountain stock, which lacks a magnetite-rich zone but is otherwise similar petrographically to the Caribou stock. Thus, the aeromagnetic data tend to confirm the indications from geologic mapping (Gable, 1969) that the Bryan Mountain stock is connected to the Caribou stock. There is no clear evidence from the magnetic map that the Audubon–Albion stock a few miles north is connected at depth to the Caribou stock, but the complex magnetic patterns produced by the combination of magnetically contrasting rock units and topographic effects may tend to conceal magnetic evidence of any such connection.

In summary, the aeromagnetic data in general seem to reflect the geology as mapped. In many instances the magnetic trends have a northeast-southwest alinement that is parallel to the strike of the dominant rock units. No hidden features seem to be revealed by the aeromagnetic data that would warrant further geophysical study in the search for mineral resources.

MINERAL RESOURCES

SETTING

The Indian Peaks study area lies along the northwest side of the Colorado Mineral Belt—an area that contains most of the mining districts in Colorado. The mineral belt is a narrow zone that extends southwestward diagonally across the mountain ranges from Jamestown (7.5 mi (12 km) northeast of Ward) near the edge of the Front Range to the San Juan Mountains in the southwestern part of the state. The belt is characterized by intrusive igneous rocks of Laramide and younger age as well as by ore deposits of various types. In the Front Range the mineral belt is about 10–15 mi (16–24 km) wide and is well defined. Its northwest boundary is generally drawn to include the mineralized areas and the Laramide stocks of the eastern part of the Indian Peaks study area. The Jamestown, Ward, Gold Hill, and Caribou districts and the Boulder County tungsten district lie in the mineral belt within 10 mi (16 km) of the study area. In addition, about 15 mi (24 km) south of the study area are the large disseminated molybdenum ore bodies at Urad and Henderson and the base and precious metal veins in the Central City-Blackhawk district, which has had a large production in the past. The minor Lost Lake and Lake Albion districts, partly in the Indian Peaks study area, are here considered to be within the Colorado Mineral Belt. As defined by the presence of Laramide intrusive bodies, the mineral belt would also extend north to include the Audubon-Albion stock. The mining districts and mineralized areas within and near the Indian Peaks study area are shown in figure 6 in relation to Laramide intrusives.

Except for Urad and Henderson, the nearby mining districts are characterized by veins that occupy faults of small displacement largely in Precambrian rocks but partly in Laramide intrusive rocks. Most of the faults are only a few hundred feet long and few exceed 1 mile (1.6 km). The Laramide ore bodies in these and other districts in the mineral belt of the Front Range have been summarized by Tweto (1968, p. 576) as follows:

> The ore deposits in such veins [those in Precambrian rocks] are in ore shoots that have thicknesses of several inches to a few feet, stope lengths of a few tens to a few

hundreds of feet, and pitch lengths from a few tens to 1,000 feet. The ore bodies thus are small in tonnage, and many of them could be worked only because of their rather high grade, which in many cases was 1 to 10 ounces of gold or 50 to 500 ounces of silver per ton. Since the veins are discontinuous and the ore bodies small, the outlook for future production from deposits of this kind is poor, primarily because the cost of discovery is high in proportion to the value of an ore body.

Although exploration and mining activity continue sporadically, particularly during periods of relatively high metal prices, the outlook for mining these veins in the Front Range is still pessimistic.

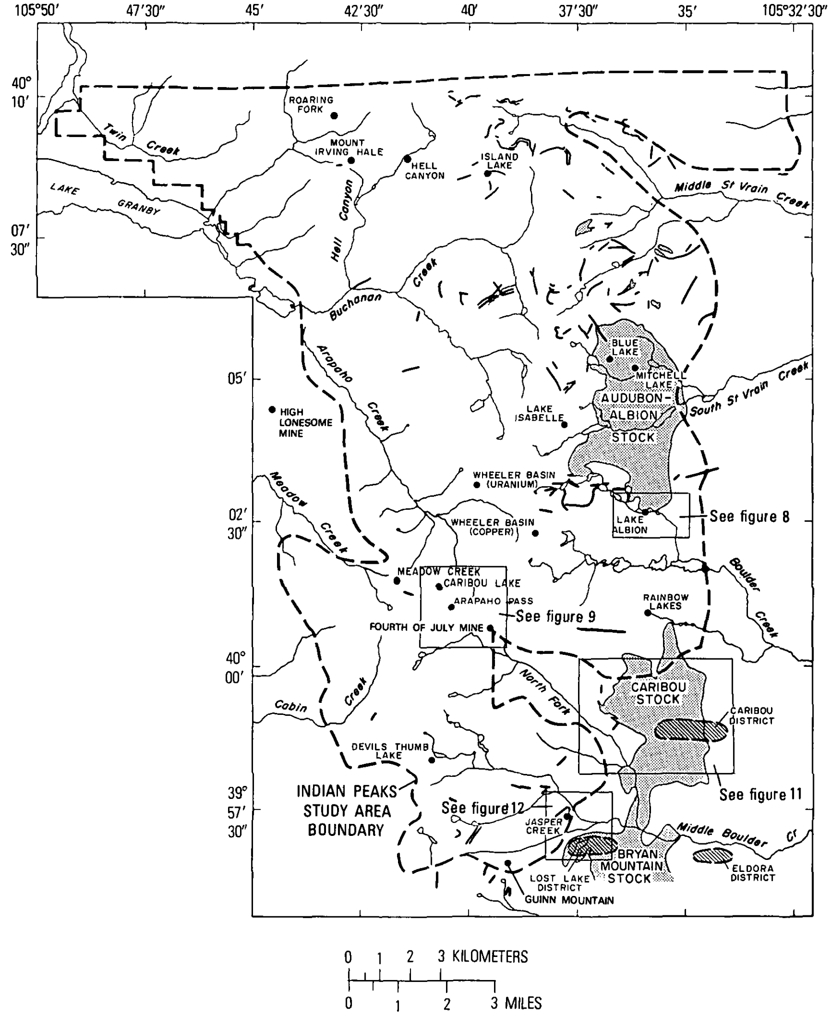

FIGURE 6.—Mineralized areas (dots), mining districts (patterned), and porphyry stocks and dikes (lines) in and near the Indian Peaks study area. Shows areas of detailed maps.

Furthermore, in many of the districts or parts of districts, Caribou and Ward for example, ores near the surface have been enriched by processes associated with weathering. When mining proceeded to depths below this surficial enriched zone, the primary ore still was present but its grade was such that mining was no longer economic. However, some low-grade resources remain in veins that are known, and probably other small veins that could contain high-grade shoots remain undiscovered in all the districts in the central Front Range.

One of the principal findings in recent years that has a bearing on the discovery of ore in Colorado is that ore formed during more than one time in the Tertiary. The traditional view that all the ore deposits and their attendant porphyry intrusives were of Laramide age has been revised with the recognition that some of the largest deposits, such as the molybdenum deposits at Climax, Henderson, and Urad, are of Oligocene age as determined by radiometric ages of associated igneous rocks. Tweto (1968, p. 579) argued, on geologic grounds, that the tungsten and precious-metal telluride ores east and southeast of the Indian Peaks study area are of Oligocene age also, and he pointed out (p. 575) that the Ward district has characteristics of both Laramide and Oligocene mineralization. By extension, Tweto's arguments imply that some telluride veins in the Indian Peaks study area could be Oligocene, although no igneous rocks of that age are known.

HISTORY AND PRODUCTION

Most mining districts in the northeastern part of the Colorado Mineral Belt were organized in the decade following the initial discoveries in 1859. Ore was discovered in the Ward district in 1861, in the Jamestown district in 1865, and in the Caribou district in 1869. Later discoveries were the Eldora and Lost Lake districts in 1896, and the famed Boulder County tungsten district, in which production began in 1900. The Lake Albion mining area was probably discovered a few years later, as some ore was mined there in 1909.

Mining activity was taking place also on the west side of the Front Range in the first decade of the 20th century. Although available information is sketchy, references to promising copper prospects were made by Lindgren (1906), who stated that they were known as early as 1905. They were located 12 mi (19 km) east of Granby, and some of them were owned by the Monarch Mining Co. of Boulder. The following year Naramore (1907), in a discussion of Grand County, wrote, "[In] the Harmon district, at the foot of Mt. Audubon, near the Boulder County line, the Monarch-Smuggler Mining and Reduction Company and the Monarch Consolidated Gold Mining and Milling Company are each carrying on extensive development work on copper mines." Mount Audubon is not in Grand County, of course. Hill (1912) referred to Lindgren (1906) and Naramore (1907), and also stated that the copper is in veins in Precambrian rock. Henderson (1926, pl. 1) showed the Monarch district to be in the vicinity of Monarch Lake, and he showed several mine symbols, one in the vicinity of what is now known as the High Lonesome mine. Henderson (1926, pl. 1) also showed a hydroelectric plant near the mouth of Roaring Fork that was owned by the Monarch Mining Company. Vanderwilt (1946, p. 97-98) discussed Monarch and Harmon together, but he added "* * * it is not certain that the two localities are the same." Lovering and Goddard (1950, p. 71) discussed the High Lonesome mine and a copper prospect at the head of Roaring Fork, which on their plate 4 is labeled "Monarch." Thus, the locations of the Harmon and Monarch mining districts seem to be so poorly known that continued reference to them is of little value.

During this period of discovery, prospectors were exceedingly active in the Front Range. The Indian Peaks area was undoubtedly prospected extensively, as attested to by prospect pits on virtually every mineral showing. These pits are concentrated on the peripheries of known mining districts but are also found in the remotest parts of the area.

Very little of the mineral production from Boulder and Grand Counties has come from the Indian Peaks study area. However, mineral production from Boulder County, which includes the eastern part of the Indian Peaks area, has been appreciable. Through 1970, Boulder County had produced base and precious metals and tungsten valued at about $45 million. Of this, gold accounted for $25,056,350; silver, $8,633,303; lead, $854,900; zinc, $4,583; and tungsten, $10,613,754. Little ore has been mined since 1970. In contrast, Grand County, which includes the western part of the Indian Peaks area, has produced only a few tens of thousands of dollars worth of metals. The only significant amount of ore produced within the study area was from the Lake Albion region in Boulder County, which produced 482 tons (437 t) of lead concentrates in 1909 (Wahlstrom, 1933). Other producers inside the study area are the Copper King mine on Roaring Fork in Grand County, which shipped 12 tons (11 t) of copper-silver ore in 1905, and the Fourth of July mine in Boulder County, which reportedly yielded 115 tons (104 t) of base- and precious-metal ore in 1914.

In addition to metallic ores, various nonmetallic ores and construction materials have been extracted in Boulder and Grand Counties—none from within the Indian Peaks study area, however. Peat has been mined from several bogs east of the Indian Peaks area, the nearest of which are the sites of Left Hand Park Reservoir and

Caribou Park, both about 1 mi (1.6 km) outside the area; another is near Beaver Reservoir, about 3 mi (4.8 km) outside.

MINING CLAIMS

Records of the U.S. Bureau of Land Management list 21 patented mining claims within the Indian Peaks study area; most of these are in the southeastern part near the Lake Albion, Caribou, and Lost Lake mining districts. Several dozen others lie within 1 mi (1.6 km) of the area. All patented claims in the area and many nearby were visited; their locations are shown on plate 2.

The courthouse records of Boulder and Grand Counties list approximately 700 unpatented mining claims in and adjacent to the study area. Many of these claims could not be located during this mineral survey because their descriptions were either vague or inaccurate. The locations of some of the unpatented claims that were examined are shown on plate 2.

METHOD OF STUDY

The investigation of mineral resources and their appraisal in the Indian Peaks study area has been made by geologic mapping, geochemical sampling, detailed investigation of mines and prospects, and interpretation of aeromagnetic data. In the investigation of mines, prospects, and other mineralized areas, the Bureau of Mines collected and assayed samples primarily to determine the monetary value of various bodies of rock. The geochemical samples were collected by the Geological Survey to determine geochemical variations in rocks and structures in different parts of the area.

Geologic mapping has delineated the major rock units and structural features that might have a bearing on the location of ore deposits. The mapping, which can be considered of reconnaissance quality only, was done along traverses spaced about half a mile (about 1 km) apart. In the mapping, considerable reliance was placed on the use of binoculars to interpret geology between traverses by scanning the cliffs in the cirques and glaciated valley walls. In general, bedrock is well exposed, inasmuch as more than half of the area is above timberline, and glaciation has stripped the bedrock bare in most valleys. Glacial deposits are not extensive, but many of the smooth gentle slopes between glaciated valleys and above timberline are covered with solifluction deposits that mask the immediate bedrock to some extent.

GEOCHEMICAL SAMPLE COLLECTION

Nearly 1,000 samples that might be classified geochemical were collected from the 130-mi^2 (337-km^2) area for analysis and laboratory study. Most samples fall into one of three categories: (1) stream sediment, (2) altered and mineralized rock, and (3) fresh rock. The remainder, comprising only a few samples, are of soil and panned concentrates.

The stream-sediment samples were collected from all streams in the area with emphasis on the smaller ones. Samples were collected along the larger streams at intervals of about 0.5–1 mi (0.8–1.6 km), commonly from sites just above the mouths of small streams. Stream-sediment samples consisted of a handful or two of the finest sediment available. An attempt was made to collect mud that would consist of a substantial proportion of silt- or clay-sized sediment, inasmuch as all sediment samples were sieved, and only the minus-80-mesh fraction (<180 μm) was analyzed. In many of these mountain streams the gradient is so great that little fine sediment remains; consequently, a pound or more of sandy or gravelly sediment was collected at many sites in order to get enough of the minus-80-mesh sediment for analysis. Many of the stream-sediment samples have a moderate to high content of organic matter.

Fresh-rock samples were collected for analysis and for petrographic study. An effort was made to collect samples representative of all the geologic units, in crude proportion to their abundance, and also to acquire a fairly even distribution of samples over the whole area. Analyses of fresh rocks provide a baseline against which to evaluate analyses of altered and mineralized rocks. A statistical summary of analytical data on fresh rocks is given in table 1.

Altered and mineralized rocks were sampled wherever they were found in an effort to evaluate each occurrence and to identify any pattern of mineralization that might suggest genetic associations and targets for exploration. As the mineralized and altered rocks are not evenly distributed, these sample localities are clustered in and near the known mineralized areas and along faults. However, most of the rocks in the area are broken by joints or minor fractures that are commonly coated with limonite, chlorite, or other minerals indicative of the passage of hydrothermal solutions. Such indications of a weak mineralizing process have no apparent association with known mineral deposits, however small. They record the passage of solutions related to structural or igneous events possibly as old as Precambrian.

Twenty-five soil samples were collected. Fourteen of these came from one traverse near the Meadow Creek mineralized area and one came from Wheeler Basin. These are discussed in the sections of this

TABLE 1.—*Arithmetic mean and standard deviation of analytical data on major rock units, Indian Peaks study area, Colorado*

[For the calculations, elements detected below the lower limit of determination were assigned arbitrary values equal to one-half of that limit, and elements not detected were given arbitrary values equal to one-tenth of the lower limit. Means shown in italics were computed from data that included at least 20 percent arbitrary values. M, arithmethic mean; SD, standard deviation]

Element	Biotite gneiss (103 samples)		Gneissic granodiorite (16 samples)		Gneissic quartz monzonite (24 samples)		Boulder Creek Granodiorite (18 samples)		Silver Plume Granite (42 samples)		Cretaceous and Tertiary intrusives (46 samples)	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
					Data in percent							
Iron--------	6.2	4.3	4.7	2.9	3.2	2.1	6.3	1.5	2.3	1.3	4.4	2.9
Magnesium---	1.5	2.1	.86	.70	.48	.39	.90	.38	.37	.21	1.1	1.4
Calcium-----	2.1	4.5	2.8	2.7	1.0	1.0	3.0	1.7	.74	.82	4.0	3.2
Titanium----	.32	.21	.33	.19	.25	.24	.58	.24	.16	.10	.21	.13
					Data in parts per million							
Manganese---	450	440	290	240	210	140	520	240	150	100	670	390
Barium------	510	330	530	260	840	460	700	260	430	260	900	440
Beryllium---	*1.3*	1.4	*1.1*	.65	*1.2*	.80	2.0	.91	*.69*	.49	*.97*	.41
Cobalt------	*12*	10	8.6	6.1	*4.5*	4.2	12	4.9	*2.7*	2.5	*7.1*	6.9
Chromium----	110	160	*38*	44	*16*	23	23	14	*7.0*	12	*15*	31
Copper------	*28*	55	*10*	13	*2.6*	3.5	22	22	*7.2*	6.9	*20*	39
Lanthanum---	45	55	60	39	58	46	79	35	68	40	42	30
Nickel------	52	120	*21*	23	*7.1*	7.4	13	11	*3.0*	2.1	*6.0*	12
Lead--------	*16*	14	18	12	23	9.3	23	10	42	36	18	13
Scandium----	13	9.8	10.8	4.5	*6.3*	3.6	11	3.3	*3.9*	2.8	*7.6*	6.0
Strontium---	*130*	130	170	57	170	55	290	160	*110*	57	860	510
Vanadium----	90	62	78	42	37	33	110	46	32	21	94	66
Yttrium-----	23	17	20	9.8	*20*	15	31	11	*15*	8.7	*15*	7.6
Zirconium---	100	71	74	43	77	47	150	80	83	56	75	55
Mercury-----	*.053*	.066	*.051*	.046	*.050*	.070	*.032*	.033	*.036*	.038	*.045*	.053

report concerning those areas. The other soil samples were mostly from widely scattered ridge crests, where mineralized fracture zones were suspected. Except for sample R–235, which was collected on the ridge west of upper Cabin Creek and which contained 20 parts per million citrate-soluble heavy metals, the soil samples contained only small quantities of metals, and none of them will be discussed further.

Gravel from several streams was panned for gold, and eleven samples of the concentrates were analyzed. No gold was detected, and only elements expected to be concentrated by panning, such as iron, titanium, rare earths, and zirconium, were found in quantity. Except for rare earths, the analyses of these samples will not be discussed further.

Sample localities are shown on plate 2.

ANALYSIS OF SAMPLES AND TREATMENT OF DATA

Samples collected by the Bureau of Mines were analyzed spectrographically for 43 elements and by fire assay for gold and silver at the Reno Metallurgy Research Center. Samples that showed anomalously high copper and molybdenum values in the spectrographic analyses were analyzed by atomic absorption for those elements. Analyses of these samples are reported in table 2.

Of the samples collected by the Geological Survey, rock samples and panned concentrates were ground before analysis. Stream-sediment and soil samples were sieved, and the minus-80-mesh fraction (<180 μm) was analyzed. All samples were analyzed by semiquantitative spectrographic analysis for 30 elements, and some samples were analyzed for other elements by different chemical and instrumental techniques. In addition to spectrographic analysis, mineralized rock samples were analyzed for mercury by an instrumental technique; for gold, zinc, and tellurium by atomic absorption; and for arsenic and antimony by colorimetric analysis. Stream-sediment and soil samples were analyzed by the cold-extractable copper test (CxCu) and the citrate-soluble heavy metals test (CxHM); the latter test detects mainly zinc, lead, and copper. All samples were scanned by a scintillator to detect radioactivity; 91 selected samples were checked more carefully for radioactivity, and equivalent uranium (eU) was determined for these samples (table 3). Uranium and thorium were determined for a few samples by an induced-radiation technique.

The geochemical data and various geologic parameters for all samples were stored on magnetic disk in the U.S. Geological Survey's DEC 1070 computer in Denver. Computer printouts of data on selected groupings of samples were perused in an effort to determine geochemical and geological relations. The computer also made certain graphical analyses and mathematical calculations; it produced the printouts of selected analyses that constitute tables 4, 5, and 6 at the back of this report. A computer printout of all the analytical data by Motooka, Turner, and Smith (1975) and the appropriate geographic and geologic parameters that apply to each sample are on file with the National Technical Information Service. A magnetic tape of the data may be purchased from the National Technical Information Service.

STREAM-SEDIMENT SAMPLES

Stream-sediment samples provide the only reasonably systematic geochemical coverage of the Indian Peaks study area. The results seem to be erratic and difficult to interpret. Although many of the samples from streams draining mineralized areas contained one or more metals in quantities high enough to indicate mineralized rock upstream, other samples downstream from known mineralized areas are devoid of such indications. In addition, numerous samples contain anomalous quantities of metal in drainages where mineralized rock was not found and where its existence is doubtful. Such vagaries of stream-sediment sampling are well known but are difficult to explain.

Of the 286 stream-sediment samples collected in this study—an average of about two per square mile—more than one-third (101) are considered to be anomalous in one or more metals (table 4 and fig. 7). Anomalous values are defined arbitrarily to be those in the upper 5-10 percent of the distribution. If a higher cutoff were chosen, some significant samples would likely be eliminated from consideration, and if a lower cutoff were chosen, too many samples would be included that represent merely high background values. In theory, elements dispersed in a stream from an ore deposit should produce a distinct statistical population of stream-sediment samples. In reconnaissance surveys such as this one, however, too few samples of the anomalous population are usually collected to produce the second mode, and hence a cutoff value must be selected. The values selected in this study were based in part on the shape of the distribution, as seen in a histogram, and in part on an empirical comparison of analytical values from streams draining mineralized and nonmineralized ground.

The metals considered to be of most interest—copper, molybdenum, lead, zinc, and silver—were determined by semiquantitative spectrographic analysis and by CxCu and CxHM, which are wet chemical tests designed for fine-grained samples such as stream sediments. The values of each of the metals that were high enough to

TABLE 2.—*Analyses of selected ore and vein*

[Tr, trace; M, major constituent; -, not detected; ?, not determined. Cu and Mo values for samples M-1 through spectrographic analysis. Cd, Sb, W, Ga, Hf, In, La, Li, Nb,

Sample No.	Remarks	Fire assay (ounces/ton)		Semiquantitative spectrographic analysis (percent)							
		Au	Ag	Al	Ba	Ca	Fe	Mg	Na	Si	Ti
M- 1	Dump sample........	Tr	0.1	5.0	-	0.3	4.0	0.8	1.0	M	0.4
2	..do..............	Tr	.1	M	-	.5	3.0	.8	M	M	.3
3	..do..............	-	.2	M	-	.4	3.0	.8	M	M	.3
4	..do..............	Tr	.3	M	-	1.0	3.0	.8	M	M	.3
5	..do..............	-	-	M	-	.06	3.0	2.0	4.0	M	.2
6	8-ft chip.........	Tr	.3	M	-	.5	4.0	2.	M	M	.2
7	Dump sample........	-	-	5.0	-	.5	3.0	2.0	.3	M	.2
8	..do..............	-	-	M	-	.5	3.0	2.0	M	M	.2
9	20-ft chip.........	Tr	.4	5.0	-	2.0	3.0	3.0	3.0	M	.2
10	Dump sample........	-	.1	>5.0	-	2.0	4.0	3.0	4.0	M	.2
11	..do..............	Tr	.1	M	-	2.0	4.0	.8	4.0	M	.1
12	..do..............	-	.1	>5.0	-	.4	3.0	.2	2.0	M	.2
13	..do..............	-	.1	>5.0	0.1	.3	4.0	.2	2.0	M	.2
14	..do[1].............	Tr	.6	4.0	-	.3	5.0	.2	.4	M	.2
15	..do..............	Tr	Tr	>5.0	.1	.3	2.0	.8	2.0	M	.2
16	Mill sample[1].......	-	3.0	1.0	-	>4.0	M	3.0	3.0	M	.2
17	15-ft channel......	Tr	.5	>5.0	.1	.3	5.0	.8	2.0	M	.2
18	Dump sample........	Tr	.1	>5.0	.1	2.0	5.0	3.0	2.0	M	.7
19	..do..............	Tr	.1	>5.0	-	.4	5.0	2.0	2.0	M	.7
20	15-ft chip.........	Tr	.3	>5.0	.1	.4	5.0	3.0	2.0	M	.7
21	7-ft chip.........	Tr	1.4	>5.0	.2	.3	3.0	.2	1.0	M	.2
22	Dump sample........	Tr	1.2	4.0	.2	.5	5.0	.4	1.0	M	.2
23	..do[1].............	Tr	2.7	4.0	4.0	>4.0	5.0	.7	1.0	M	.2
24	..do[2].............	Tr	1.1	5.0	-	M	7.0	3.0	1.0	M	.4
25	..do..............	Tr	.2	>5.0	1.0	4.0	5.0	2.0	3.0	M	.4
26	..do[2].............	-	1.0	1.0	.1	M	5.0	.8	1.0	M	.05
27	7-ft channel......	-	-	>5.0	-	.2	3.0	2.0	2.0	M	.1
28	Dump sample........	Tr	.1	5.0	-	.1	5.0	.4	.1	M	.2
29	..do..............	Tr	-	5.0	.1	.06	4.0	.6	1.0	M	.1
30	..do..............	Tr	-	>5.0	-	.08	4.0	3.0	4.0	M	.2
31	..do..............	Tr	-	5.0	-	.1	4.0	.4	1.0	M	.2
32	..do..............	Tr	-	4.0	-	.3	4.0	.4	2.0	M	.05
33	..do..............	Tr	-	3.0	-	.3	7.0	.8	-	M	.05
34	..do..............	Tr	-	5.0	-	.3	5.0	2.0	2.0	M	.2
35	..do..............	Tr	-	M	-	.1	4.0	.8	3.0	M	.2
36	..do..............	Tr	-	5.0	-	.3	>7.0	2.0	1.0	M	.2
37	..do..............	Tr	Tr	M	-	.2	4.0	.8	3.0	M	.2
38	..do..............	Tr	-	4.0	-	.3	M	2.0	.5	M	.1
39	..do..............	Tr	-	M	-	.03	7.0	.2	.5	M	.2
40	..do..............	Tr	-	1.0	-	-	.2	.1	.5	5.0	.05
41	..do..............	Tr	Tr	5.0	-	.03	6.0	.4	1.0	M	.1
42	..do..............	Tr	.1	M	-	.2	4.0	.4	4.0	M	.2
43	..do..............	Tr	.3	M	-	.1	3.0	.2	4.0	M	.1
44	..do..............	Tr	.1	5.0	-	.03	3.0	.4	1.0	M	.1
45	..do..............	Tr	-	.3	-	-	.06	.02	-	1.0	.01
46	..do..............	Tr	.4	M	-	.3	4.0	.5	4.0	M	.2
47	..do..............	Tr	.5	M	-	.1	1.0	.2	4.0	M	.1
48	..do..............	Tr	-	4.0	-	.3	1.0	.05	4.0	M	.1
49	..do..............	Tr	-	M	-	.06	4.0	.2	1.0	M	.2
50	..do..............	Tr	-	M	-	.06	4.0	.2	1.0	M	.2
51	..do..............	Tr	-	M	-	.06	3.0	.2	2.0	M	.2
52	..do..............	Tr	-	M	-	.3	3.0	.2	2.0	M	.1
53	..do..............	Tr	.1	3.0	-	.1	4.0	.4	.1	M	.1
54	40-ft random chip..	Tr	-	M	.1	.2	6.0	1.5	2.0	M	.2
55	50-ft random chip..	Tr	Tr	M	.1	1.0	5.0	2.0	.5	M	.1
56	6-ft channel......	Tr	-	3.0	-	.5	6.0	.8	2.0	M	.1
57	Dump sample........	0.01	.1	>5.0	.1	1.0	6.0	1.0	2.0	M	.4
58	..do..............	Tr	.2	M	<.1	1.0	6.0	.8	2.0	M	.2
59	..do..............	-	.1	5.0	.1	.3	6.0	.8	2.0	M	.4
60	..do..............	Tr	.1	M	.1	.5	5.0	.8	4.0	M	.4
61	..do..............	Tr	.2	5.0	-	1.0	6.0	1.0	2.0	M	.2
62	..do..............	.01	.2	>5.0	.1	.2	6.0	1.0	2.0	M	.2
63	6-ft chip.........	.01	.1	M	.1	.3	4.0	.8	4.0	M	.4

samples from the Indian Peaks study area, Colorado

M-11 and M-74 through M-75 determined by atomic absorption. All other values determined by semiquantitative P, Pt, Ta, Te, and Ti were not detected in any samples]

Semiquantitative spectrographic analysis (parts per million)														
Bi	Cu	Mo	Pb	Zn	B	Co	Cr	Mn	Ni	Sc	Sr	V	Y	Zr
-	110	<30	400	-	-	-	200	300	40	-	-	<60	-	100
-	5,400	<30	-	-	-	-	100	500	40	-	-	<60	-	200
-	270	<30	200	-	-	-	100	500	40	-	-	<60	-	300
-	8,200	<30	90	-	-	-	100	500	40	-	-	<60	-	200
-	560	<30	90	-	-	-	200	500	40	-	-	<60	-	100
-	4,100	<30	90	-	-	-	100	500	20	-	-	<60	-	300
-	140	<30	-	-	-	-	70	300	-	-	-	<60	-	200
-	2,000	<30	90	-	-	-	100	300	20	-	-	<60	-	200
-	17,000	<30	-	-	-	-	100	500	20	-	-	<60	-	100
-	350	<30	200	-	-	-	200	500	20	-	-	60	-	300
-	260	<30	300	-	-	-	70	500	-	-	-	<60	-	300
-	100	<20	100	-	-	-	200	1,000	-	-	-	<60	-	100
-	100	<20	1,000	-	-	-	200	1,000	-	-	-	<60	-	70
700	1,000	20	6,000	1,000	-	-	300	2,000	-	-	-	200	-	<70
-	100	<20	400	-	-	-	200	1,000	-	-	-	<60	-	<70
3,000	3,000	<20	70,000	3,000	-	40	500	20,000	20	-	-	400	-	<70
400	1,000	100	10,000	1,000	-	<40	500	8,000	20	-	-	200	-	70
200	600	20	10,000	1,000	-	<40	500	4,000	40	-	-	200	-	300
200	600	70	6,000	1,000	-	<40	500	2,000	40	-	-	200	-	300
200	1,000	70	10,000	-	-	-	500	4,000	40	-	-	200	-	100
400	1,000	4,000	20,000	-	-	-	200	2,000	-	-	-	60	-	600
400	1,000	2,000	50,000	5,000	-	-	200	4,000	-	-	-	100	-	<70
3,000	1,000	2,000	80,000	5,000	-	<40	200	6,000	-	-	-	60	-	<70
500	1,000	100	20,000	3,000	-	-	600	4,000	-	50	<1,000	100	<30	200
400	300	30	6,000	2,000	-	<40	300	2,000	-	-	-	100	-	300
1,000	300	30	50,000	1,000	-	-	100	2,000	-	-	<1,000	60	<30	70
-	50	-	700	-	-	-	100	500	-	-	<1,000	<60	-	70
-	3,000	<20	3,000	-	<100	-	100	2,000	<40	-	-	60	-	<70
-	80	<20	300	-	<100	-	100	500	<40	-	<1,000	<60	10	100
-	40	-	100	-	-	-	300	1,000	40	-	-	<60	-	70
-	80	-	100	-	-	-	70	500	60	-	-	<60	-	70
-	300	-	-	3,000	-	-	30	500	60	-	-	-	-	70
-	300	20	-	-	-	-	100	8,000	-	-	-	<60	-	<70
-	80	<20	300	-	-	-	200	1,000	<20	-	-	<60	-	100
-	600	-	400	-	<100	-	100	500	-	-	-	<60	-	70
-	80	60	200	-	<100	-	100	4,000	-	-	-	<60	-	70
-	80	-	200	-	<100	-	200	2,000	-	-	-	<60	-	70
-	300	20	-	-	-	-	200	8,000	-	-	-	<60	-	<70
-	600	-	100	-	-	-	200	500	60	-	-	<60	-	300
-	30	-	400	-	-	-	-	100	-	-	-	-	-	-
-	200	-	500	-	100	-	100	500	40	-	-	60	-	70
-	200	-	400	-	-	-	100	500	20	-	-	<60	-	300
-	600	-	400	-	<100	-	<230	500	20	-	-	<60	-	70
-	40	-	700	-	-	-	200	500	20	-	-	<60	-	<70
-	20	-	<100	-	<100	-	-	60	-	-	-	-	-	-
-	600	-	400	-	100	-	300	1,000	20	-	-	<60	-	100
-	80	-	3,000	-	100	-	-	100	20	-	-	-	-	70
-	90	-	700	-	-	-	30	300	20	-	-	-	-	-
-	30	-	200	-	-	-	200	500	40	-	-	60	-	100
-	30	-	800	-	<100	-	200	500	40	-	-	60	-	70
-	40	-	600	-	-	-	200	500	40	-	-	<60	-	70
-	80	-	600	-	<100	-	-	500	-	-	-	<60	-	70
-	600	<20	700	-	<100	-	100	300	40	-	-	<60	-	<70
-	80	-	700	-	<100	-	300	500	<40	<10	-	<60	<10	100
-	40	-	200	-	<100	-	200	400	<40	?	-	<60	10	100
-	80	-	700	-	<100	-	100	1,000	<40	-	-	<60	-	70
-	300	-	3,000	-	-	-	100	4,000	-	30	<1,000	<60	-	100
-	80	-	200	-	<100	-	100	2,000	-	-	-	<60	-	<70
-	80	-	100	-	<100	-	300	1,000	-	-	-	<60	-	<70
-	80	-	100	-	<100	-	100	1,000	-	<30	-	<60	-	<70
-	80	-	100	-	-	-	100	1,000	-	30	<1,000	<60	-	100
-	600	-	200	-	-	-	100	500	-	-	<1,000	<60	-	100
-	500	-	100	-	<100	-	100	1,000	-	-	-	<60	-	<70

TABLE 2.—*Analyses of selected ore and vein samples*

Sample No.	Remarks	Fire assay (ounces/ton)		Semiquantitative spectrographic analysis (percent)							
		Au	Ag	Al	Ba	Ca	Fe	Mg	Na	Si	Ti
64	Dump sample	Tr	.1	>5.0	<.1	1.0	6.0	2.0	2.0	M	.2
65	..do	Tr	.2	>5.0	<.1	2.0	5.0	2.0	2.0	M	.2
66	..do	Tr	.2	>5.0	.1	M	M	3.0	4.0	M	.4
67	..do	Tr	.2	>5.0	.1	M	M	4.0	4.0	M	.8
68	..do	Tr	-	5.0	<.1	M	7.0	2.0	1.0	M	.2
69	..do	.01	8.1	M	.1	.5	6.0	.8	1.0	M	.2
70	..do	.01	8.8	M	<.1	.3	5.0	.8	1.0	M	.2
71	..do	Tr	13.9	5.0	<.1	2.0	5.0	1.5	1.0	M	.2
72	..do	.01	4.8	>5.0	-	4.0	5.0	2.0	1.0	M	.2
73	..do	Tr	3.2	>5.0	-	4.0	5.0	2.0	1.0	M	.2
74	1.5-ft chip	Tr	7.9	1.0	-	4.0	6.0	3.0	-	5.0	.4
75	Ore sample	Tr	6.8	>5.0	-	>4.0	7.0	3.0	2.0	M	.4
76	Dump sample	Tr	1.7	M	-	M	4.0	1.0	1.0	M	.02
77	..do	Tr	-	4.0	-	.5	3.0	.8	.2	M	.2
78	..do	Tr	1.4	5.0	-	.5	2.0	.8	.1	M	.1
79	..do	Tr	.6	4.0	-	.5	3.0	.8	.2	M	.02
80	5-ft chip	Tr	7.2	M	-	.03	4.0	.6	.5	M	.05
81	Dump sample	.17	.3	M	<.1	.03	1.0	.3	.5	M	.05
82	..do	.08	.5	M	<.1	.1	5.0	.6	1.0	M	.05
83	..do	.2	3.3	5.0	<.1	1.0	6.0	.8	.5	M	.1
84	..do	Tr	.7	M	<.1	M	7.0	3.0	2.0	M	.006
85	..do	.01	1.3	5.0	.1	1.0	4.0	.8	1.0	M	.1
86	..do	-	.1	>5.0	-	.06	4.0	.4	1.0	M	.2
87	4-ft channel	-	-	M	-	>4.0	M	3.0	-	M	1.0
88	Dump sample	-	-	>5.0	-	.5	6.0	2.0	2.0	M	.8
89	..do	-	-	5.0	-	.1	4.0	.4	-	M	.2
90	..do	-	-	>5.0	-	.5	6.0	.6	-	M	.2
91	..do	-	Tr	>5.0	-	.5	6.0	2.0	2.0	M	.2
92	..do	-	.1	>5.0	-	.5	6.0	2.0	2.0	M	.8
93	..do	Tr	-	M	.4	.5	3.0	.8	4.0	M	.2
94	..do	Tr	.1	>5.0	-	.03	4.0	.8	.5	M	.2
95	..do	Tr	-	M	.2	.02	4.0	.8	.2	M	.1
96	..do	Tr	-	5.0	1.0	.06	4.0	.6	1.0	M	.1
97	..do	Tr	-	5.0	.1	.1	3.0	.4	4.0	M	.05
98	..do	Tr	-	M	-	.5	5.0	.8	4.0	M	.1
99	..do	Tr	Tr	M	.4	.5	4.0	.8	2.0	M	.2
100	..do[3]	Tr	-	3.0	-	.3	6.0	.8	1.0	M	.8
101	..do[3]	.3	Tr	5.0	.1	.2	5.0	.8	1.0	M	.2
102	Ore bin	.05	Tr	4.0	-	.5	4.0	.4	-	M	.1
103	Dump sample	.08	.4	5.0	<.1	.05	2.0	.1	.5	M	.1
104	5-ft channel	.01	.1	M	.1	.1	2.0	.2	1.0	M	.2
105	Dump sample[1]	.02	Tr	M	.1	.1	4.0	.2	2.0	M	.1
106	8-ft chip	Tr	-	M	.4	.3	3.0	.8	2.0	M	.2
107	Dump sample	-	.1	>5.0	.1	.2	3.0	.4	1.0	M	.1
108	..do	Tr	.1	>5.0	.1	.06	4.0	.4	1.0	M	.2
109	..do	.02	.3	4.0	-	.2	M	.4	-	M	.1
110	..do	.01	.2	>5.0	<.1	.06	6.0	.7	.5	M	.2
111	..do	Tr	.1	>5.0	<.1	.06	4.0	.4	1.0	M	.2
112	..do	Tr	.1	>5.0	<.1	.5	3.0	.4	4.0	M	.05
113	..do	Tr	.2	>5.0	.1	.2	4.0	.4	4.0	M	.2
114	..do	-	.2	>5.0	.1	.2	3.0	.2	4.0	M	.1
115	..do	Tr	Tr	>5.0	.1	.3	5.0	.7	2.0	M	.1
116	..do	Tr	.1	>5.0	.1	.3	4.0	.4	2.0	M	.1
117	..do	Tr	.1	>5.0	.1	.3	5.0	.5	2.0	M	.2

[1] Samples M-14, M-16, M-23 contained 40 ppm Sn; Sample M-105 contains 200 ppm Sn. No other samples contained Sn.

be considered anomalous are as follows: copper, 70 ppm; molybdenum, 10 ppm; lead, 100 ppm; CxCu, 10 ppm; and CxHM, 17 ppm. In addition, the content of zinc or silver was considered anomalous if any was detected at all, whether it was above or below the limit of determination. (Detectable amounts that were too small *from the Indian Peaks study area, Colorado*—Continued

Semiquantitative spectrographic analysis (parts per million)														
Bi	Cu	Mo	Pb	Zn	B	Co	Cr	Mn	Ni	Sc	Sr	V	Y	Zr
-	80	-	100	-	-	-	100	1,000	-	30	<1,000	<60	-	<70
-	50	-	<100	-	-	-	100	1,000	-	-	<1,000	<60	<30	<70
-	50	-	<100	-	-	-	100	2,000	-	50	1,000	<60	-	<70
-	50	-	<100	-	-	-	100	3,000	-	50	1,000	<60	-	<70
-	80	-	<100	-	-	-	100	2,000	-	-	<1,000	<60	-	<70
-	600	<20	8,000	2,000	<100	-	60	2,000	<40	10	-	<60	10	100
-	400	<20	6,000	1,000	<100	-	60	2,000	<40	<10	-	<60	<10	100
-	400	<20	6,000	1,000	<100	-	60	1,000	<40	<10	-	<60	10	70
-	200	30	6,000	2,000	-	<40	200	2,000	-	-	-	60	-	100
-	300	30	6,000	2,000	-	<40	100	2,000	-	-	-	60	-	<70
-	440	<30	700	-	-	40	30	500	-	-	-	100	-	100
-	300	<30	10,000	4,000	-	40	100	2,000	40	-	-	100	-	200
-	40	-	3,000	1,000	<100	-	100	2,000	-	<30	-	<60	-	<70
-	80	-	700	-	<100	-	60	500	-	-	-	<60	-	<70
-	80	-	3,000	2,000	<100	-	60	500	-	-	-	<60	-	<70
-	80	-	1,500	1,000	<100	-	60	1,000	-	-	-	<60	-	<70
-	600	-	6,000	1,000	<100	-	60	1,000	-	-	-	<60	-	<70
-	100	70	1,500	-	<100	-	60	500	-	-	-	<60	-	<70
-	100	?	1,500	1,000	<100	-	100	1,000	-	-	-	<60	-	<70
-	200	100	10,000	3,000	<100	-	100	2,000	-	-	-	<60	-	<70
-	500	-	700	-	<100	-	100	2,000	-	-	-	100	-	<70
-	80	-	400	-	<100	-	100	1,000	-	<30	<1,000	<60	-	<70
-	40	-	100	-	-	-	300	500	<20	-	-	<60	-	<70
-	100	-	-	-	-	-	500	2,000	40	-	-	100	-	200
-	40	-	90	-	-	-	300	500	-	-	-	60	-	300
-	60	-	90	-	100	-	100	300	-	-	900	60	-	200
-	80	-	200	-	-	-	100	500	-	-	900	200	-	300
-	80	-	200	-	-	-	100	500	-	-	-	60	-	300
-	80	-	90	-	-	-	100	500	-	-	-	60	-	200
-	80	-	400	-	<100	-	30	5,000	-	-	-	<60	-	70
-	80	-	100	-	-	-	300	500	<20	-	-	<60	-	100
-	80	70	400	-	-	-	100	200	<40	-	<1,000	<60	10	200
-	60	<20	100	-	-	-	100	100	<40	-	<1,000	<60	?	70
-	60	<20	200	-	-	-	100	400	<40	-	<1,000	<60	-	<70
-	60	<20	300	-	-	-	100	500	<40	-	<1,000	<60	-	70
-	80	-	700	-	100	-	<30	1,000	-	-	-	100	-	300
-	60	-	200	-	-	-	<60	1,000	-	-	-	100	-	60
-	60	-	200	-	100	-	<60	1,000	-	-	<1,000	100	-	100
-	80	<20	400	-	100	-	100	1,000	<40	-	-	60	-	<70
-	60	<20	400	-	<100	-	30	200	<40	-	<1,000	100	-	<70
-	40	<20	200	-	<100	-	60	200	<40	-	<1,000	100	-	70
-	1,300	<20	500	-	<100	-	100	300	<40	-	<1,000	100	-	70
-	80	60	400	-	<100	-	70	300	-	-	-	<60	-	70
-	50	-	700	-	-	-	100	500	-	-	-	<60	30	70
-	40	-	100	-	-	-	100	200	-	-	-	<60	<30	100
-	1,000	20	400	-	-	-	100	500	-	-	<1,000	100	30	70
-	200	-	200	-	-	-	100	200	-	-	-	<60	<30	100
-	40	-	100	-	-	-	100	400	-	-	-	<60	<30	<70
-	50	-	100	-	-	-	100	200	-	-	<1,000	<60	-	70
-	50	-	100	-	-	-	100	500	-	-	<1,000	<60	30	70
-	20	-	100	-	-	-	100	500	-	-	<1,000	<60	-	70
-	50	-	100	-	-	-	100	500	-	-	<1,000	<60	-	70
-	50	-	100	-	-	-	100	500	-	-	-	<60	30	70
-	50	-	100	-	-	-	100	500	-	-	-	<60	30	70

[2] Samples M-24 and M-26 contained less than 10 ppm Be. No other samples contained Be.
[3] Samples M-100 and M-101 contained 1,000 ppm As. No other samples contained As.

to quantify are reported as less than (<) the lower limit of determination in table 4.) Analyses of all stream-sediment samples that were anomalous in one or more of these metals are listed in table 4, and the sample localities are shown on plate 2 and in figure 7. Most of the anomalous samples have values that are near these lower limits.

TABLE 3.—*Equivalent uranium determinations of selected rock samples, Indian Peaks study area, Colorado*

[Determinations in parts per million. L, less than 30 ppm]

Sample	eU	Sample	eU	Sample	eU	Sample	eU
222	50	361	60	R-077	40	R-183	70
223	80	362	60	R-078	30	R-184	40
252	70	363	50	R-079	50	R-185	30
261	80	366	L	R-080	30	R-195	70
262	70	367	60	R-088	40	R-196	70
263	40	368	60	R-106	60	R-197	60
265	L	420	50	R-108	50	R-198	40
270	60	424	L	R-109	60	R-199	L
276	70	432	L	R-110	50	R-200	60
277	50	433	L	R-111	60	R-201	60
278	L	435	L	R-112	70	R-202	30
294	140	436	L	R-122	50	R-203	50
295	30	437	L	R-123	L	R-205	70
296	50	441	60	R-124	L	R-206	L
297	60	442	60	R-125	50	R-207	L
313	L	443	30	R-126	70	R-218	60
314	30	444	30	R-156	L	R-219	30
316	L	445	50	R-167	50	R-220	50
317	30	473	L	R-168	L	R-221	500
318	50	R-016	70	R-169	40	R-223	50
320	L	R-074	L	R-170	L	R-224	160
359	90	R-075	40	R-171	L	R-225	90
360	L	R-076	70	R-172	L		

Many of the anomalous values were from samples collected downstream from mineralized areas and presumably reflect that mineralization (fig. 7). Although none of the anomalous samples has led directly to a discovery of mineralized rock, two of them suggest that mineral occurrences may be more important than was judged from the outcrops. Most anomalous samples that are associated with mineralized areas are discussed in appropriate sections later in this report. Perhaps the most significant of these samples is P-005, which was collected east of Blue Lake. It contains 500 ppm copper by spectrographic analysis and 30 ppm CxCu, perhaps indicating that the copper is mostly in detrital grains, probably sulfide minerals. A sample from west of Rainbow Lakes containing 150 ppm copper is also of interest. Several samples in Roaring Fork (387, R-117), Hell Canyon (P-058, P-059, P-060, P-061, P-062), Meadow Creek (326, 452, 453, 454), Devils Thumb Lake (156), Wheeler Basin (K-032, K-034, P-012), the head of Arapaho Creek (P-078), North Fork Middle Boulder Creek (105), Lake Albion (196), and South St. Vrain Creek

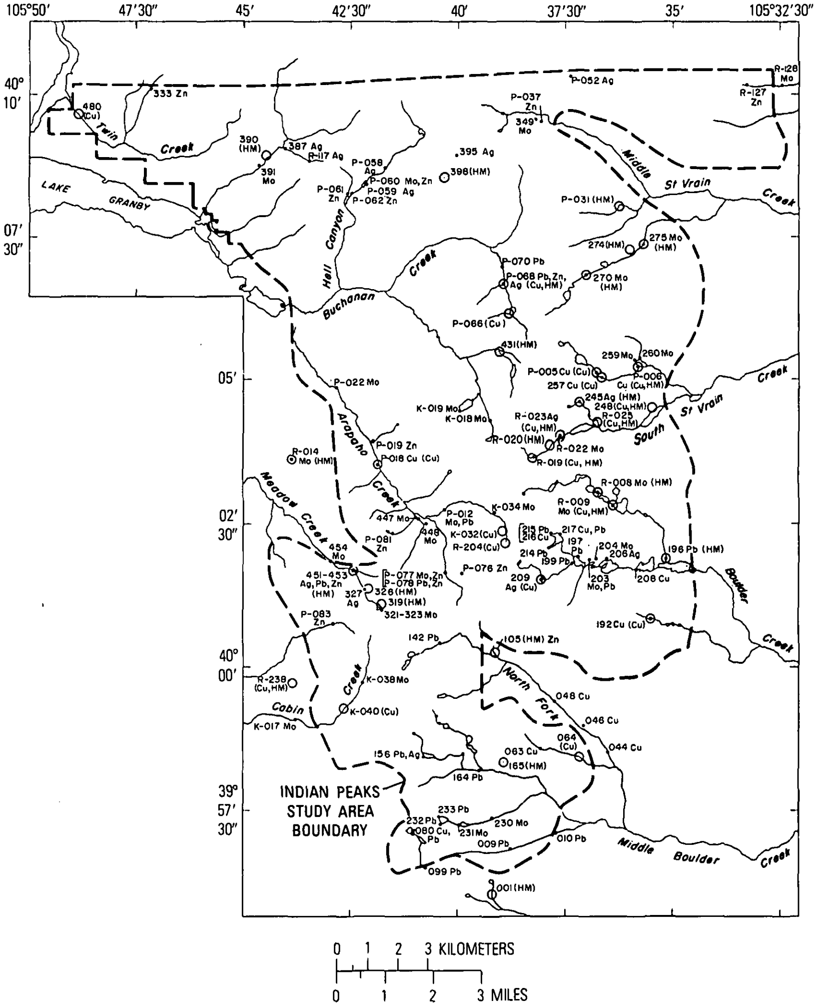

FIGURE 7.—Localities of anomalous stream-sediment samples. Shows sample numbers and anomalous elements. Locality is shown as a solid dot where elements were determined by semiquantitative spectrographic analysis; locality is shown as an open circle where elements were determined by cold-extractable copper technique (CxCu) and citrate-soluble heavy metals technique (CxHM).

(R-022, R-023), evidently reflect the mineralized areas upstream. Many of these anomalous values are barely above background, however, and it would be difficult to distinguish these from the many apparently anomalous samples that are so widespread and that have not been shown to be related to significant mineralized rock.

Streams in some drainages that contain mineralized rock failed to yield anomalous samples. The most striking example is sample 381 (pl. 2) from the small stream that flows along the copper-silver vein in upper Roaring Fork for about a quarter of a mile and that drains only the small cirque through which the vein trends. This sample-not listed in table 4-contains only 15 ppm copper, 5 ppm CxCu, 3 ppm CxHM, and no detectable silver. Sample 385 collected about a mile farther downstream has a similar composition. Higher metal contents were expected in the stream samples because the vein contains a substantial amount of copper and silver. Chemical interactions among ground water, surface water, and stream sediments may account for the low metal content of these and other stream-sediment samples. Perhaps the metals are not being precipitated from the stream water and no detrital ore minerals happened to be in the samples. Scavengers of metals from solution, such as iron and manganese oxides, are not abundant in these samples.

In many drainages where little or no mineralized rock was found, stream-sediment samples were collected that contain metals in amounts that seem to be anomalous. Although these samples could indicate a buried or unrecognized mineral deposit, most of them surely indicate merely false or apparent anomalies. Among the many factors that may account for such anomalies are very diffuse mineralization, organic content, variation in grain size, and man-caused contamination. The known criteria that could distinguish among the factors involve efforts that are beyond the scope of this study.

Perhaps the most significant factor responsible for the apparent anomalies is widespread but very diffuse mineralization similar to that found by Tweto, Bryant, and Williams (1970) in the Gore Range, Colo. The Gore Range not only is similar geologically to the Indian Peaks study area, but it bears an analogous relation to the Colorado Mineral Belt. In the Gore Range nearly every fracture has been mineralized, commonly with a thin metalliferous film or veinlet. The net effect of that pervasive mineralization has been to produce many rather weak stream-sediment anomalies, similar to those found by this study. Although the number of mineralized fractures is probably less in the Indian Peaks study area (and the amount of metal in the samples from the fractures much less), the large number of samples of altered and mineralized rock (tables 5 and 6), and their wide distribution (pl. 2) suggest that a process similar to that in the Gore Range has taken place.

These factors probably account for most of the weakly anomalous stream sediments, but they do not necessarily account for all of them. Any one of these samples could reflect the presence of mineralized rock of importance, but in general, anomalous values higher than those found would be necessary to attract the serious prospector. Any further work should be considered carefully in terms of geologic relations or specific geologic targets.

MINERAL COMMODITIES

The similarities in geologic setting between the Indian Peaks study area and nearby mining districts suggest the possibility that significant vein-type mineral deposits might exist in the study area. Thus far, however, the only production from the Indian Peaks study area consists of one shipment of lead-silver concentrates from Lake Albion, a few tons of copper-silver ore from Roaring Fork, and a little over 100 tons of base and precious metal ore from the Fourth of July mine. If hidden deposits of larger magnitude exist, they are most likely to be of base and precious metals. The nearest mining districts have, with one exception, produced mainly gold and silver. Some of them, such as Eldora and Lost Lake, have produced only gold and silver. At Caribou, the ores were valuable mainly for silver and lead; but gold, copper, zinc, and uranium were also present. At Ward, gold and silver were most important, but base metals were also extracted from some ores. At Nederland, tungsten is the only valuable metal in the veins. Fluorite was mined in moderate amounts in the Jamestown district, but it was much less valuable than gold or silver. Uranium is important in vein deposits in the Ralston Buttes district near the mountain front south of Boulder.

The amount of molybdenum thus far mined in Colorado has had a total value greater than that of any other metallic mineral, and the known reserves indicate it will continue to maintain this preeminent position. The Henderson deposit, 15 mi (24 km) to the south, is a very large molybdenum ore body, in which molybdenite forms narrow veinlets in silicified Precambrian rocks and in a mid-Tertiary porphyry stock. Likewise most other molybdenum deposits in Colorado are associated with mid-Tertiary stocks (Tweto, 1968, p. 574–575). Thus the age of porphyry bodies is a major prospecting tool. Though much remains to be done to determine the age of the various porphyry bodies in the study area, existing information strongly suggests that the youngest porphyries are early Eocene. The apparent lack of Oligocene intrusives or areas of appreciable hydrothermal alteration is good evidence that this area is not favorable for the near surface occurrence of large molybdenum deposits.

The mineral survey of the Indian Peaks area shows the presence of minor or trace amounts of bismuth, tellurium, tungsten, and arsenic, as well as molybdenum, particularly from near Lost Lake and along lower Jasper Creek. The amounts are too small to be of economic interest unless they could be extracted as byproducts from the gold-silver veins in which they occur. These gold-silver veins, however, are probably too narrow and low grade to be mined. The principal importance of these metals is that their presence suggests the possibility of larger deposits at depth, mainly in the Lost Lake area.

Copper has been a relatively unimportant mineral commodity in the Front Range mining districts, but in the Indian Peaks study area it forms one notable deposit and two other interesting occurrences. The Roaring Fork deposit, which will be discussed in a later section of this report, may contain more than 1,000 tons (907 t) of copper in rock that may average a few tenths of 1 percent copper. Because it is relatively inaccessible and because it is unlikely to lead to a large orebody, the deposit is of no value in the foreseeable future. Sulfides disseminated in the Audubon-Albion stock east of Blue Lake contain copper, and stream-sediment samples below it are rather highly anomalous in copper. This locality and the Rainbow Lakes area, which are described in later sections of this report, deserve further investigation. Copper sulfides in vein deposits at several other localities seem to be trivial.

Rare-earth elements in moderate quantity were detected by spectrographic analysis of several samples. Nearly all the samples that contain at least 300 ppm lanthanum or at least 100 ppm yttrium are stream-sediment samples or panned-concentrate samples. Trace amounts of monazite in granites or gneisses probably are the source of the rare earths. Monazite was identified by John W. Adams (oral commun., 1974) in panned concentrates that gave the highest lanthanum and yttrium values; these samples came from Jasper Creek and a tributary to it that flows through Woodland Lake. Samples from these and other streams draining Boulder Creek Granodiorite in part seem to contain more rare earths than other streams. However, samples from a few streams not draining Boulder Creek Granodiorite also contain moderate quantities (300 ppm lanthanum, for example, in sample 405 from Buchanan Creek, which drains mainly biotite gneiss). Some pyritic gneisses (such as sample 488) contain more than 1,000 ppm lanthanum. Rare earths of these quantities could be economic in placer deposits, but no significant quantities of placer gravel exist in the area.

The only significant uranium occurrence known in the Indian Peaks study area is a prospect in Wheeler Basin, which is described in a later section of this report. The uranium is closely associated with pegmatite, probably of Silver Plume Granite age, but the prospect offers little possibility of a significant uranium reserve. Several of the breccia-reef faults that cross the area have features in common with those in the Ralston Buttes district near the mountain front 10–15 mi (16–24 km) south of Boulder, where pitchblende occurs in hydrothermal veins that cut Precambrian rocks in strongly brecciated parts of faults of the breccia-reef system (Sheridan and others, 1967). The pitchblende in the Ralston Buttes district is associated with small amounts of copper, lead, zinc, and silver. The deposits have been found along two of the major breccia-reef faults in places where the faults branch and curve extensively, forming much brecciated rock. Uranium mineralization has evidently been controlled to a large extent by the structural and physical factors that provided open space. The mineralogical or chemical character of the wallrocks may also have localized uranium deposition, for most of the economically important uranium deposits have been found in iron-rich rocks, particularly amphibolite and calc-silicate rocks. In the breccia-reef faults that cross the Indian Peaks study area some of the factors that were important in localizing uranium in the Ralston Buttes district are absent, but the most fundamental controls are present and indicate the possibility of undiscovered uranium deposits there.

Measurements of radioactivity (eU) of 91 samples (table 3) collected during this study indicate that all major rock types and mineralized areas, except for samples from the Wheeler Basin uranium prospect, have low radioactivity (less than 80 ppm eU). Three samples (223, R-224, R-225) of biotite gneiss and Silver Plume Granite from Wheeler Basin and vicinity (but not the uranium prospect) contain 80 to 160 ppm eU, and three samples (261, 294, 359) from specularite-quartz veins in and near bodies of Silver Plume Granite contain 80 to 140 ppm eU. Analyses by the delayed-neutron technique for uranium and thorium show that except for one analysis, thorium accounts for most of the radioactivity in these samples and that the uranium content is generally low. The sample highest in uranium (R-225) contains 68 ppm uranium and the sample next highest contains only 12 ppm uranium. The thorium content of these six samples ranges from 1 to 76 ppm. Sample R-225 was of biotite gneiss collected about 1 mi (1.6 km) west of the Wheeler Basin uranium prospect. None of these samples contains sufficient uranium or thorium to encourage prospecting.

Nonmetallic minerals and rocks that occur in the area include feldspar, sillimanite, peat, and decorative and dimension stone.

Bodies of pegmatite are ubiquitous in the crystalline rocks. They all seem to be simple, unzoned bodies, and none was found to contain beryl, commercial mica, lithium minerals, or other particularly valuable minerals commonly found in pegmatites. Feldspar is, of course, abundant in the pegmatite as well as in other granitic rocks. Because most of the cost of feldspar is in transportation, the remoteness of the Indian Peaks study area makes it an unlikely site for feldspar mining.

Sillimanite is very widespread in the biotite gneiss, but nowhere does it appear to exceed 10 percent of the rock, the grade necessary for it to be considered potentially economic (Espenshade, 1973).

Peat has accumulated to thicknesses of one to several feet along parts of nearly all stream valleys in the area. The largest deposits are in the rolling country between Sawmill Meadow and Devils Thumb

Park along the west side of the area. The boundary of the Indian Peaks study area (pl. 1) passes through this boggy, moraine-covered area, where drainage is poorly integrated and where peat deposits of significant size may be present. Other deposits in the area are probably small by comparison and are much less accessible.

Small to medium-sized deposits of sand and gravel occur at several places near the boundary or just outside the area. In the northwestern part of the area the delta at the confluence of Buchanan and Arapaho Creeks is probably a substantial deposit, as it has a surface area of about 0.25 mi^2 (0.65 km^2). Deposits along Cabin Creek in Devils Thumb Park and along Meadow Creek 1 mi (1.6 km) southeast of Sawmill Meadow may be almost as large. A small deposit of gravel underlies the Jasper Creek valley for about one-fourth of a mile (0.4 km) upstream from its mouth. The thickness of these deposits cannot even be inferred because glaciers have overdeepened portions of the valleys and because till probably forms an uneven blanket beneath some gravel deposits. Even the surface distribution is difficult to determine because of the swamp deposits which cover the sand and gravel in some places. The remoteness from markets renders these deposits uneconomic now and in the foreseeable future.

Most granite in the area is too finely jointed to be suitable for dimension stone. Similar granite is equally widespread outside the area, where its proximity to transportation and to markets would make it more valuable.

Decorative stone in the form of lichen-covered boulders and loose pieces of rock littering the surface of the ground have been gathered in large quantities in recent years and have been sold for building facings, fireplaces, and landscaping purposes. This "moss rock," as it is called, occurs in large quantities in the Indian Peaks study area, but a road network would be necessary for access to it.

The geology of the area virtually precludes the presence of coal, petroleum, oil shale, and the many other mineral products associated with sedimentary rocks. The area shows no surface evidence to indicate a geothermal resource.

DESCRIPTION OF MINERALIZED AREAS

ROARING FORK

Three patented mining claims lie end-to-end along a northwest-trending vein in upper Roaring Fork (sec. 6, T. 2 N., R. 74 W.) (pl. 2). These claims contain what is possibly the most important mineral occurrence known in the Indian Peaks study area. Records of the U.S. Bureau of Mines indicate that in 1905 the Copper King mine, operated by the Monarch Consolidated Gold and Copper Mining and Smelting Co., shipped 12 tons (about 11 t) of ore. Some of the workings on the vein in upper Roaring Fork are probably those of the Copper King. A total of 2 oz (62 g) gold, 22 oz (684 g) silver, and 1,680 lb (760 kg) copper was recovered from the ore. The ore presumably was transported down the Roaring Fork trail on pack animals, as a small pile of abandoned or dumped ore was found off the trail near the falls on Roaring Fork. The Monarch-Smuggler Mining and Reduction Co. also operated in the district; however, no production is attributed to them (Lindgren, 1906; Naramore, 1907; Stevens, 1908).

The vein trends northwest (pl. 1, pl. 2) and ranges from a few feet to as much as 20 ft (6 m) in width. Copper sulfides are generally spotty in an albite, dolomite, and locally quartz gangue. From Roaring Fork the vein trends N. 45° W., but east of the creek it strikes N. 55° W. Although largely covered, it evidently extends from the creek eastward about three-fourths of a mile (1.2 km) to the divide between Roaring Fork and Hell Canyon, and northwestward from the creek at least half a mile (0.8 km). The structure probably continues northwestward into Rocky Mountain National Park, but it is not known if it is mineralized there.

The vein is explored by two adits near the level of Roaring Fork, by a shallow shaft and short adit (both caved) 1,400 ft (430 m) northwest of the creek (pl. 2), and by several small prospect pits. The most mineralized part of the vein is northwest of Roaring Fork where the walls are granodiorite gneiss. In that area the vein is as much as 20 ft (6 m) wide and is composed mainly of albite, iron-bearing dolomite, and bull quartz. It also contains trace amounts of sphene, chlorite, white mica, quartz, and locally euhedral drusy quartz crystals that are coated with copper sulfides. The albite and dolomite evidently replaced the wallrocks, inasmuch as the contacts are gradational in places. The bull quartz cuts the albitic vein material. Copper sulfides, mostly bornite partly replaced by chalcocite and digenite, are disseminated through the albite-dolomite rock. Southeast of Roaring Fork, where the walls are largely biotite gneiss, the copper content of the vein is much less.

Fifty samples were collected from the vein—most of them from the more mineralized part. Some were taken from dumps and others were chipped from outcrops and prospect workings. Sample localities are shown on plate 2, and analyses are included in tables 2, 5, and 6. Analyses of these samples indicate that locally the albite-dolomite vein contains 0.2 to greater than 2 percent copper and up to several parts per million silver. In the shallow shaft at an altitude of about 11,250 ft (3,430 m), six samples (498–504) were chipped, each from a small area at 2-ft (0.6-m) intervals across 11 ft (3.3 m) of vein. They averaged about 1.5 percent (15,000 ppm) copper and 0.26 oz of silver per ton (9 ppm). About 150 ft (46 m) northwest of the shaft, a chip sample (526) across almost 20 ft (6.1 m) of vein contained 0.5 percent (5,000 ppm) copper and 0.08 oz of silver per ton (3 ppm). A similar sample (510) chipped across an outcrop of 20 ft (6.1 m) of vein 1,200 ft (367 m) southeast of the shaft and 125 ft (38 m) west of the adit likewise contained 0.5 percent (5,000 ppm) copper and 0.08 oz of silver per ton (3 ppm). An 8-ft (2.4-m) chip sample (M–6) across the face of the open adit on the northwest side of the creek yielded a trace of gold, 0.3 oz of silver per ton (10 ppm), and 0.41 percent (4,100 ppm) copper. One other outcrop of the vein was found between the shaft and the adit; samples (506–508) from it contained as much as 0.3 percent (3,000 ppm) copper, but the two other samples contained virtually none. A 20-ft (6.1-m) chip sample (M–9) was taken across the vein in an outcrop on the southeast side of the creek. It yielded a trace of gold, 0.4 oz of silver per ton (14 ppm), and 1.7 percent (17,000 ppm) copper. Stream-sediment sample 381 was collected near the mouth of the tributary that flows along the most mineralized part of the vein, yet it contained no metals in unusual quantity.

Inasmuch as the vein is covered by till and soil through most of its length between the shaft and the adit, calculations of tonnage and grade are largely speculative. Nevertheless, a modest submarginal resource of perhaps 100 to 600 tons (91 to 550 t) of copper per 100 ft (30 m) of depth is inferred. The estimates of tonnage were made by assuming a width of 10 ft (3 m), a copper content of 0.2 to 0.5 percent, and a length of 700 to 1,400 ft (215 to 430 m). T. S. Lovering and E. N. Goddard (written commun., 1938) investigated this property briefly and concluded that "* * * most of the vein is too low grade to work and that the ore of commercial grade in the vein is much too scarce to be of commercial importance in such an inaccessible location."

MOUNT IRVING HALE

Prospecting has been done on at least two mineralized fractures about 0.8 mi (1.3 km) north-northeast of Mount Irving Hale and a mile southeast of the Roaring Fork prospect (fig. 6). About 800 ft (245 m) east-northeast of the broad saddle on the ridge, a prospect pit has been dug on a N. 80° E.-trending silicified and altered fracture zone that is more than 10 ft (3 m) thick. Anastomosing quartz-specularite veins are in nearby outcrops. Small amounts of chalcopyrite were found on the dump of the pit. A selected specimen (354) of chalcopyrite-rich rock contained, in addition to copper, 320 ppm zinc, 1,500 ppm lead, and 1,500 ppm silver. T. S. Lovering and E. N. Goddard (written commun., 1938) report an assay of 8.48 oz of silver per ton (291 g/t), 0.12 oz of gold per ton (4 g/t), and 2.5 percent copper from this pit. Another pit about 700 ft (210 m) S. 80° E. from the first is on a fracture zone that is 5-6 ft (1.5-1.8 m) wide, trends N. 45° W., and dips 67° NE. Quartz, fluorite, and locally chalcopyrite, pyrite, hematite, and malachite cement the fracture zone. Selected samples (R-259, R-260, R-261) contain 0.7 to 2 percent copper and 0.7 to 3 ppm silver. T. S. Lovering and E. N. Goddard (written commun., 1938) obtained an assay of 0.11 oz of gold per ton (4 g/t) and 0.22 oz of silver per ton (8 g/t) from this locality. A stream-sediment sample (P-061) from the mouth of the stream that drains these veins was anomalous in zinc (300 ppm). Two stream-sediment samples (387, R-117) from the small stream that flows west from the broad saddle on the ridge contained 0.5 ppm silver, which indicates that the same or another similar vein is probably present west of the saddle. These veins seem to contain only small local concentrations of metals and are not believed to have economic significance.

HELL CANYON

In Hell Canyon (pl. 1, fig. 6) several silicified and pyritized fracture zones trend northwest and northeast in an area from Stone Lake downstream for about 1 mi (1.6 km). They cut biotite gneiss and small bodies of Silver Plume Granite. Iron-stained biotite gneiss is found in several places, as on the cliffs east of Stone Lake, indicating that pyrite is disseminated in certain layers of the gneiss as well as being present in fractures. Several short adits and prospect pits have been dug on the fracture zones. Thirteen samples of these mineralized and altered rocks indicate low values of copper and silver (tables 4, 5, and 6), except for one (R-138) that contained 1,500 ppm copper and 1 ppm silver. The best mineralized structures found in Hell Canyon are one-fourth of a mile (0.4 km) downstream from Stone Lake on the southeast side of the creek, where a 30-ft (9-m) -thick zone of silicified breccia trends N. 40° W.; it is apparently cut off or crossed by a 50- to 70-ft (15- to 18-m) -thick breccia zone that trends N. 65° E. Samples from these zones (R-139 to R-143) contain at most 200 ppm copper, 0.5 ppm silver, and minimal quantities of other metals. A sample from the dump of a caved adit on the northwest side of the creek (sample M-11, table 2) was assayed and was found to contain a trace of gold and 0.1 oz of silver per ton (3.4 g/t). Several stream-sediment samples (P-058, P-159, P-060, P-062) from Hell Canyon contain trace amounts of silver and zinc. Sample P-060 also contains 15 ppm tin. These localities contain rock that is too low in metal content to offer promise for the occurrence of an ore deposit.

ISLAND LAKE

The northwest-trending fault that passes through the north edge of Island Lake (Buchanan Creek drainage) is mineralized on the ridge 0.3 mi (0.5 km) southeast of the lake (fig. 6), where the fault consists of several fractures in a zone 800 ft (240 m) wide (pl. 1). Sixteen selected geochemical samples from this zone (pl. 2) and from other nearby altered and pyritized zones—mainly in biotite gneiss—indicate that the metal values are very spotty; most of these samples do not contain unusual amounts of metals. Sample R-164 (table 6) contained the highest values: 2 percent copper, 300 ppm zinc, 10 ppm silver and 2 ppm gold. A few flakes of molybdenite were also found in the vicinity of sample R-164. Stream-sediment sample 395, from the inlet to Island Lake, contains a trace of silver; and sample 398, from a quarter of a mile (0.4 km) downstream from the lake, contains 17 ppm CxHM (table 4). These values may reflect the weak mineralization along the northwest-trending fault and perhaps along a northeast-trending fracture occupied by the outlet stream below the lake. This area has very low potential for the discovery of an ore deposit.

HIGH LONESOME MINE

The High Lonesome mine is about 1.5 mi (2.4 km) west of the boundary of the Indian Peaks study area in sec. 1, T. 1 N., R. 75 W., and about 2 mi (3.2 km) south of Monarch Lake (plate 2; fig. 6). Lovering and Goddard (1950) briefly discussed the geology of the mine and concluded that ore occurs in a contact zone between a calcareous layer in the Idaho Springs Formation (biotite gneiss of this report) and a large body of granite that strongly resembles Silver Plume Granite. The mine was opened by three adits, now caved at or near the portals, and several prospect pits. No production has been recorded. The ore contained disseminated chalcopyrite, tremolite, epidote, and a little galena (Lovering and Goddard, 1950, p. 71); it also contained the zinc mineral gahnite (William H. Raymond, oral commun., 1978).

Three samples (R-011, R-012, R-013) were collected and analyzed spectrographically. Results indicated no gold and a maximum of 1,000 ppm silver. The three samples yielded 10,000 ppm or more zinc, 1,000-20,000 ppm copper, 700->20,000 ppm lead, and one sample yielded >1,000 ppm bismuth (table 6).

The dumps and the immediately surrounding areas were studied to determine if the ore-bearing contact might extend into the study area, but because the immediate area is heavily forested and covered with soil and till, no evidence of mineralization was found beyond the mine area.

BLUE LAKE-MITCHELL LAKE

About 1,000 ft (300 m) east of Blue Lake (fig. 6), copper-bearing pyritic rocks form a north-trending zone in the Audubon-Albion stock and the adjacent Silver Plume Granite. The zone is 100–200 ft (30–60 m) wide and about 2,500 ft (760 m) long.

Pyrite is distributed sporadically in the zone. The most pyritic rocks are silicified and exposed at the base of the cliffs east of Little Pawnee Peak, along the creek about 700 ft (210 m) southeast of the outlet of Blue Lake, and in the vicinity of a prospect shaft 1,500 ft (457 m) northeast of Blue Lake. Between the first two occurrences the mineralized rock is concealed by a moraine, and between the second two the moderately well-exposed bedrock is sparsely pyritized. The pyrite seems to die out upward at both ends of this zone, suggesting the possibility that only the top of a mineralized body of rock is exposed.

The mineralized porphyry is a fine-grained gray type that contains small inconspicuous phenocrysts. It differs appreciably from the medium-grained porphyritic quartz monzonite that forms most of the stock though it is probably an early phase of the stock. Much of the fine-grained porphyry is sheared, some of it resembling phyllite, and locally it is an intrusion breccia. The shearing is clearly older than the porphyritic quartz monzonite, and the mineralization is probably older also.

Samples from outcrops, some of which are weathered, and from prospect pits show that the metal values are proportional to the pyrite content. The richest, a selected sample (256, table 5) from the dump of the prospect shaft northeast of Blue Lake, contains 5,000 ppm copper, 30 ppm molybdenum, 1 ppm tellurium, and 0.25 ppm gold. Eleven other samples were collected later and are not shown in the tables. Copper content of the eleven samples ranges from 7 to 1,000 ppm; silver was detected in only two of them, at 0.5 and 0.7 ppm; and 70 ppm tungsten was found in one sample. Molybdenum and niobium contents range from below the limit of determination (5 and 20 ppm, respectively) to as much as 50 ppm molybdenum and 30 ppm niobium. Stream-sediment samples (table 4) from the creek below these occurrences contain the highest metal values of any taken in this study (fig. 7). Sample P-005, taken where the creek passes through the altered zone, contains 500 ppm copper; and sample 257, taken 800 ft (250 m) farther downstream, contains 150 ppm copper. These samples each contain 30 ppm CxCu, and sample 257 contains 7 ppm CxHM. Another stream-sediment sample (not shown in table 4) contains 150 ppm copper, a trace of silver, 40 ppm CxCu, and 10 ppm CxHM; it was collected near the mouth of the small gully that drains the northern part of the pyritized area. About 1 mi (1.6

km) farther downstream, at the inlet to Mitchell Lake, stream-sediment sample P-006 contains 50 ppm copper, 15 ppm CxCu, and 20 ppm CxHM. Stream-sediment samples (259, 260) from the mouths of other inlet streams to Mitchell Lake contain 10 ppm molybdenum.

Similar though smaller bodies of pyritic sheared rocks, also in the Audubon-Albion stock, occur almost 1 mi (1.6 km) east of Blue Lake. Sample 258 from the dump of a small prospect pit contains 150 ppm copper and no other metals of apparent interest.

Disseminated sulfides in and near the stock suggest the possibility of a substantial ore deposit at depth, but occurrences of this type can be evaluated only by further work beyond the capability of this study. The area seems worthy of more detailed investigation.

LAKE ISABELLE

In the cliffs northwest of Lake Isabelle (pl. 1, fig. 6), which is about 2 mi (3 km) northwest of Lake Albion, quartz and pyrite have replaced Silver Plume Granite and (to a lesser extent) biotite gneiss, thereby forming a northward-trending intensely altered zone about 500 ft (150 m) wide. On the bench above the cliffs the zone is covered by solifluction deposits consisting of unaltered Silver Plume Granite. Talus at the base of the cliffs, which are in biotite gneiss, covers the south margin of the zone. Rock in outcrops in the valley bottom below the talus is slightly altered. Samples 238 and 240 from the altered zone contained 15 and 5 ppm molybdenum, respectively, and little else of interest. The cliffs east of the quartz-pyrite zone are stained brown by limonite that evidently was formed by weathering of widespread sparse pyrite. Stream-sediment samples R-022 and R-023 (table 4) from South St. Vrain Creek contain a trace of silver and moderate amounts of CxCu and CxHM that may have been derived from this zone. Because of its very low metal content, the quartz-pyrite zone must be considered to have low potential as an exploration target.

WHEELER BASIN

An adit and a prospect trench were dug by uranium prospectors on a west-trending spur about 800 ft (250 m) above the creek on the north side of Wheeler Basin (pl. 1, fig. 6). The workings explored a highly migmatitic and pegmatitic part of the biotite gneiss unit that lies in a triangular reentrant in the contact of the Silver Plume Granite batholith. The granite contact lies a few hundred feet (around a hundred meters) north, east, and south of the prospects, and evidently the migmatitic rocks formed as a contact effect of the batholith. Although we examined the prospect briefly and sampled it,

E. J. Young of the U.S. Geological Survey made a more detailed examination in 1973 and provided much of the information that follows (Young and Hauff, 1975).

The adit, which was dug in 1956 by Jonas Bennett, trends north into the mountain side for 32 ft (10 m). It explored at least two masses of radioactive biotite-rich schist and mixtures of biotite gneiss and pegmatite that lie among fairly discrete bodies of pegmatite 10–20 ft (3–6 m) long. The crumpled biotite-rich schist forms some fairly uniform masses, commonly several feet (1–3 m) wide and 20–30 ft (6–9 m) long, as well as small clots more or less scattered through a matrix of pegmatite. The schist consists almost entirely of black lustrous biotite, which is in flakes mostly 1–5 mm in diameter; it also contains small amounts of quartz, sillimanite, muscovite, and numerous other minerals.

Uraninite in small cubes and anhedral grains less than 0.5 mm across are disseminated irregularly throughout the biotite-rich schist. It is accompanied by hematite, pyrite, monazite, zircon, molybdenite, chalcopyrite, and fluorite, all in trace amounts except monazite, which constitutes as much as 3 percent of one sample. Uraninite has been altered to uranophane, curite, and fourmarierite. The unit-cell size of the uraninite is 5.483 ± 0.002 angstroms, which is indicative of a pegmatitic origin. U–Pb isotopic age determinations on cogenetic monazite and uraninite (Kenneth Ludwig, written commun., 1975) indicate an age of 1,446 ± 20 m.y.—identical to the Rb–Sr isochron age (1,450 m.y.) of the adjacent batholith of Silver Plume Granite.

Analyses of samples from the dump, adit, and outcrops indicate that the radioactive schist ranges widely in uranium content. Although one sample from the dump contained as much as 0.7 percent uranium, the average of eight analyses is about 0.2 percent uranium (Young and Hauff, 1975). Perhaps a few thousand tons of rock that might average 0.1 to 0.2 percent uranium are within a few tens of feet of the surface in the vicinity of the adit; however, the cost of mining and transporting this rock would be far greater than the most optimistic estimate of its value under present circumstances. The occurrence is of interest, though, because it is similar in some respects to the Rössing deposit in South West Africa (von Backström, 1970) and the Charlebois Lake deposits in Saskatchewan (Mawdsley, 1952). The entire migmatized contact zone of the Longs Peak–St. Vrain batholith, as well as other bodies of Silver Plume Granite, should be considered as potential targets for uranium exploration. No other similar biotite-rich schist was seen during this investigation.

Near the head of Wheeler Basin (pl. 1, fig. 6), secondary copper minerals coat foliation and joint surfaces, and sulfides are disseminated in narrow veinlets. The area is at an elevation of about 11,500 ft (3,500 m), 0.65 mi (1.05 km) south-southwest of Arikaree Peak and 0.90 mi (1.45 km) north-northeast of North Arapaho Peak. Copper minerals were found intermittently in outcrop and float along a north-northwesterly line for about 1,000 ft (300 m). Inaccessible cliffs above are coated in places with what are apparently bright-green secondary copper minerals.

The country rock is sillimanitic biotite gneiss that strikes N. 40° W. and dips 60° to 70° NE. The contact with the batholith of Silver Plume Granite, which parallels the foliation in the biotite gneiss, is about 0.3 mi (0.5 km) to the northeast. Many small bodies of Silver Plume Granite and pegmatite have intruded the gneiss in the general vicinity of the copper occurrences.

Chalcopyrite in grains and blebs is scattered through narrow quartz veinlets (less than 1 in. (25 mm) thick) that parallel the foliation in the gneiss. Selected samples (R–198, R–201, and R–203) contain 3,000 to 7,000 ppm copper, and as much as 1.5 ppm silver and 0.1 ppm gold. One sample that is very low in copper contains 70 ppm molybdenum. Some sheared and altered rocks within 1,000 ft (300 m) of the batholith contain as much as 0.7 ppm silver and 0.2 ppm gold (samples R–196 and R–197).

Stream-sediment samples from Wheeler Basin contain weakly anomalous amounts of metals: 10 ppm CxCu (K–032); 15 ppm molybdenum (K–034); and 15 ppm molybdenum, 100 ppm lead, and 30 ppm tin (P–012).

This area is difficult to evaluate because much of the copper-bearing rock is in inaccessible cliffs. The fact that the only copper sulfides recognized are in rather sparse narrow veinlets suggests that the occurrence has little economic significance.

LAKE ALBION MINING DISTRICT

The Lake Albion district (fig. 6) is within the "Boulder watershed"—an area in the extreme western part of T. 1 N., R. 73 W. that is owned by the city of Boulder, Colo., and is used as its municipal water supply. Known mineral production in this district occurred in 1909 when 482 tons (437 t) of lead concentrates averaging 0.07 oz of gold per ton (2.4 g/t), 27 oz of silver per ton (926 g/t), and 41 percent lead were shipped (Wahlstrom, 1933, 1940a). The ore came mainly from the Snowy Range tunnel, which was driven about 700 ft (210 m) along the east-trending Snowy Range vein (pl. 1). Some ore may have come from the Eureka tunnel, which was driven 260 ft (80 m) along the Eureka vein, a northeast-trending branch of the Snowy Range vein.

The geology of the Lake Albion district has been described by

Wahlstrom (1933, 1940a) and Lovering and Goddard (1950). The east-trending Snowy Range vein cuts syenite, monzonite, and quartz monzonite of the Audubon-Albion stock and biotite gneiss both east and west of the stock. The vein dips about 60° N. The fault zone which the vein occupies is only a few inches wide in the Precambrian gneiss but is a breccia zone as much as 30 ft (9 m) wide in the stock. The main vein is as much as 10 ft (3 m) wide in places, but in general is only 3-4 ft (1 m) wide; it is well marked and continuous, although seams and subsidiary veins branch from it in some places forming a mineralized zone as much as 30 ft (9 m) wide. Locally the ore and gangue minerals fill spaces between the breccia fragments. The Eureka vein is about 18 in. (46 cm) wide.

Argentiferous galena is the most important ore mineral of the Lake Albion district; other minerals present are pyrite, sphalerite, chalcopyrite, molybdenite, and tetradymite. The gangue consists of pyroxene, quartz, asbestos, calcite, potassium feldspar, and fluorite.

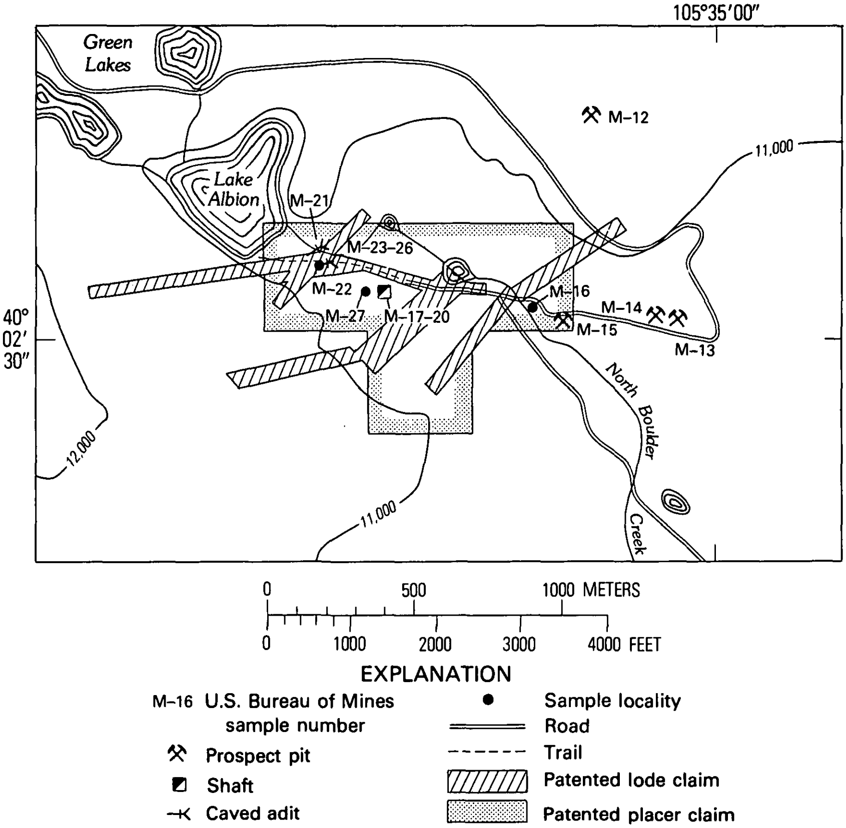

FIGURE 8.—Sample localities and patented claims in the Lake Albion area, Boulder County, Colo.

The veins contain fibrous asbestos, which make the ores extremely difficult to concentrate because the fibers clog the concentrating equipment.

Sixteen samples (M-12 to M-27) were collected from mine dumps, prospect pits, and concentrator stockpiles in the district. Sample localities are shown in figure 8 and assay values are given in table 2. Gold, copper, and zinc values for all samples were negligible; other values ranged from a trace to 3.0 oz of silver per ton (103 g/t), from 0.04 to 8.0 percent lead, and from zero to 0.4 percent molybdenum.

Sample M-16, taken from a small stockpile near a disassembled concentrator, may provide an indication of the grade of ore mined. It contained 3.0 oz of silver per ton (103 g/t), 7.0 percent lead, 0.3 percent copper, and 0.3 percent zinc. Based on metal prices at the end of 1977, the value of these metals was about $65 per ton. As much as 10,000 tons (about 9,100 t) of broken rock exists on the mine dumps from which samples M-22 through M-26 were taken. Average content of these samples is 1.2 oz of silver per ton (41 g/t), 0.07 percent copper, 4.1 percent lead, 0.4 percent zinc, and 0.08 percent molybdenum. Assuming that these samples are representative of the dumps and using 1977 year-end prices, the value of the contained metals is about $40 per ton, or $400,000 for all rock in the dumps.

Some ore may remain in the Snowy Range vein, but information is inadequate to determine if the amount or grade are significant. Wahlstrom (1940a) implied that mining ceased because of the beneficiation problem caused by the asbestos in the ore rather than because the ore was exhausted. Lovering and Goddard (1950, p. 284) reported that the grade of ore mined before 1910 was so low "* * *that the cost of mining and treating the ore just about equaled the returns from its sale." All shafts and adits are caved and the extent of the underground workings is not known. Neither Wahlstrom (1933) nor Lovering and Goddard (1950) indicated whether the 700-ft (210-m) length of the Snowy Range adit explored the full length of the vein that is in the favorable Audubon-Albion stock or whether the vein was stoped above or below the adit level. Nonetheless, the depth that ore extends is probably the most important factor in determining the amount remaining in the vein. Drilling would probably be necessary to determine if that amount is significant.

MEADOW CREEK

The Arapaho Pass fault is weakly mineralized near the head of Meadow Creek west of Caribou Pass. The Meadow Creek area has been prospected by means of at least 20 small prospect pits, 18 of which are shown on plate 1; some are also shown in figure 9.

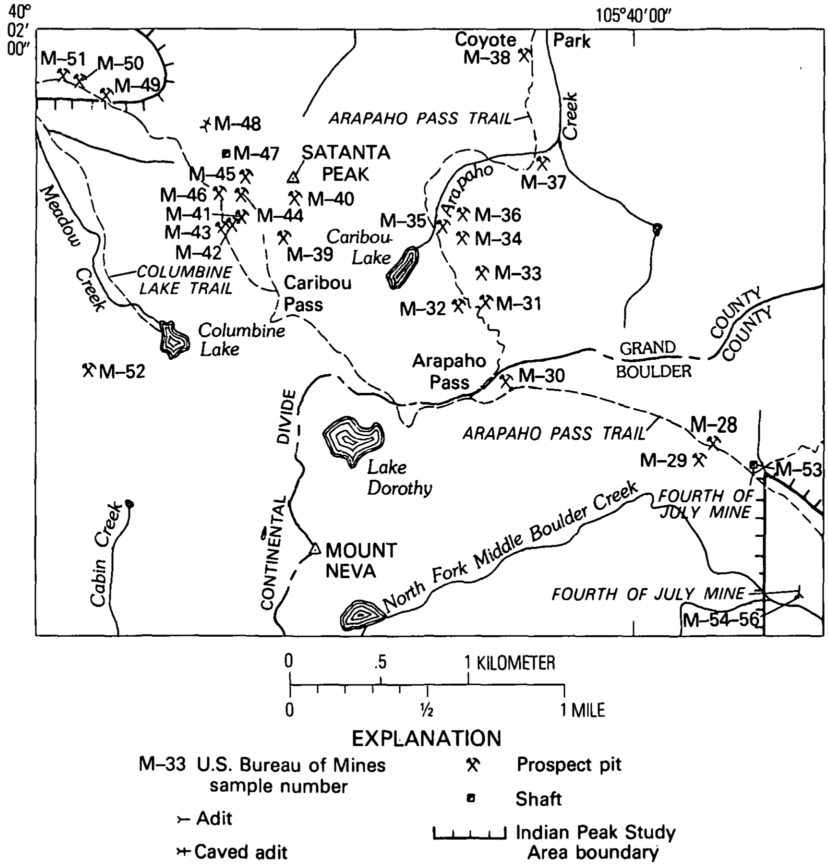

FIGURE 9.—Sample localities in the Arapaho Pass area, Boulder and Grand Counties, Colo.

The country rock is predominantly biotite gneiss that is somewhat migmatitic. The Arapaho Pass fault trends N. 60° W. through this area. It consists of a crushed and altered zone 200-400 ft (60-120 m) wide and several narrower subparallel faults that together form a zone more than 1,000 ft (300 m) wide. Sandstone of probable Paleozoic age from a sandstone dike occurs as float at sample locality 529 and in outcrops near sample locality 532 (pl. 2). The prospected area is mostly covered by glacial deposits and is partly forested.

As is common in most of the mineralized northwest-trending faults, the sulfide minerals are sporadically distributed and, to judge by what is visible in the prospect pits and on the dumps, are present in only small amounts. The selected samples from the dumps contain a few thousand parts per million copper, a few parts per million silver, and most contain a few hundred parts per million lead and zinc. Sample localities are shown on plate 2 and in figure 9, and analyses are listed in tables 2, 4, and 6. The sandstone dike has been mineralized, as is evident from sample 529 (table 6), which contains 3,000 ppm lead, 200 ppm zinc, and 3 ppm silver.

Just west of Caribou Pass, at sample localities 530 and 532 (pl. 2), the sulfide minerals are disseminated in a feldspar-carbonate vein similar to that in upper Roaring Fork except that microcline is present in the vein as well as albite and iron-bearing carbonate. In most other prospect pits the ore minerals are disseminated in chloritized and sericitized biotite gneiss, most of which is impregnated with limonite that probably was formed by weathering of pyrite.

About 1 mile (1.6 km) northwest of the mineralized area, 14 soil samples were collected across the till-covered trace of the Arapaho Pass fault, in an attempt to locate the fault and to determine if the fault is mineralized at that place. Analyses of these samples, which were collected about 200–400 ft (60–120 m) apart (pl. 2), indicated little of interest except 17 ppm CxHM in sample R–279 and 0.50 ppm mercury in sample R–283. Inasmuch as the till was derived partly from the known mineralized area, the samples anomalous in CxHM and mercury could reflect transported mineralized rock in the till. However, it is more likely that they reflect the proximity of weakly mineralized strands of the fault.

The mineral occurrences in Meadow Creek are believed to be economically unimportant, and no evidence was found to suggest that significant resources exist there.

CARIBOU LAKE–ARAPAHO PASS

Several prospect pits have been dug in the Arapaho Pass fault about 1,000–1,500 ft (300–450 m) northeast of the trail where it crosses Arapaho Pass (pl. 2, fig. 9). One sample (432) of pyrite-feldspar rock that formed by replacement of pegmatite contains 1,000 ppm cobalt, which is ten times the next highest amount of cobalt detected in any of the more than 1,000 samples analyzed. Analyses of samples 136, 137, and 433 (pl. 2) revealed nothing of economic interest. The amount of pyrite-rich rock at this locality is probably small, although the size of the body cannot be determined because it may be partly covered by scree.

Northeast of Caribou Lake at the head of Arapaho Creek (figs. 6 and 9) several pits have been dug in small pods of garnet-rich skarn. Some pods are inclusions in Silver Plume Granite and other pods are in biotite gneiss. They were presumably calc-silicate gneiss layers or pods in the biotite gneiss unit that were recrystallized and perhaps mineralized by the Silver Plume. Samples 435, 436, 437, and 441, which are sulfide-bearing skarn or limonite weathered from it, contain 1,000 to 3,000 ppm (0.1 to 0.3 percent) copper but little else of apparent interest. The skarn bodies are of no economic importance because of their small size and low metal content. Stream-sediment samples (P-077 and P-078) from downstream are weakly anomalous in molybdenum, lead, zinc, and CxHM.

Dump samples M30-M38 (fig. 9), taken from the Caribou Lake-Arapaho Pass area, do not contain significant amounts of metals (table 2), and no evidence was found to suggest that the area contains significant resources.

FOURTH OF JULY MINE

The Fourth of July mine (figs. 6 and 10) is the most extensive underground development in the Indian Peaks study area. The mine openings consist of a shaft and an adit south and southwest of South Arapaho Peak. U.S. Bureau of Mines production records show that 115 tons (104 t) of ore containing an average of 1.6 oz (50 g) of gold and 3 oz (93 g) of silver was shipped from 1914 to 1937.

The mine was opened by a vertical shaft, now caved, sunk on the Arapaho Pass fault about 1 mi (1.6 km) east-southeast of Arapaho Pass, and by a 1,900-ft (580-m) adit (fig. 10) which crosscuts to the fault from along Middle Boulder Creek almost 600 ft (180 m) below the collar of the shaft. Near the end of the long adit, a drift extends 300 ft (92 m) northwest along the fault toward the shaft, at which point it is caved. However, air movement in the adit suggests that the drift connects with the shaft. According to Seeley[1], the adit was intended to intersect the Fourth of July vein, by which he probably meant the small ore shoot that was evidently encountered in the shaft.

The rocks in the crosscut are mostly biotite gneiss whose foliation strikes west to northwest and dips steeply north (pl. 1). The fault is partly occupied by a sandstone dike that is described on pages 17-18. North of the sandstone dike the crushed wallrock is Boulder Creek Granodiorite, although at the surface the granodiorite is 1,000 ft (300 m) farther east.

Three samples (M-54, M-55, M-56) from the adit represent rock that was judged most likely to contain metal of commercial value. A fourth sample (M-53) was taken from the waste dump at the collar of the shaft; it is the only one that contains more than a trace of metals, namely 0.1 oz of silver per ton (3.4 g/t) (table 2). Analyses of selected dump samples 054, 055, and 056 (table 6) indicate the presence of appreciable amounts of copper, lead, zinc, silver, and gold. Other

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[1] W. L. Seeley, 1906, "Report of Mines and Mineral Resources of Boulder County on Line of Colorado and Northwest Railroad": Corporate report(?), probably privately printed. Copy in U.S. Bureau of Mines library, Denver, Colo.

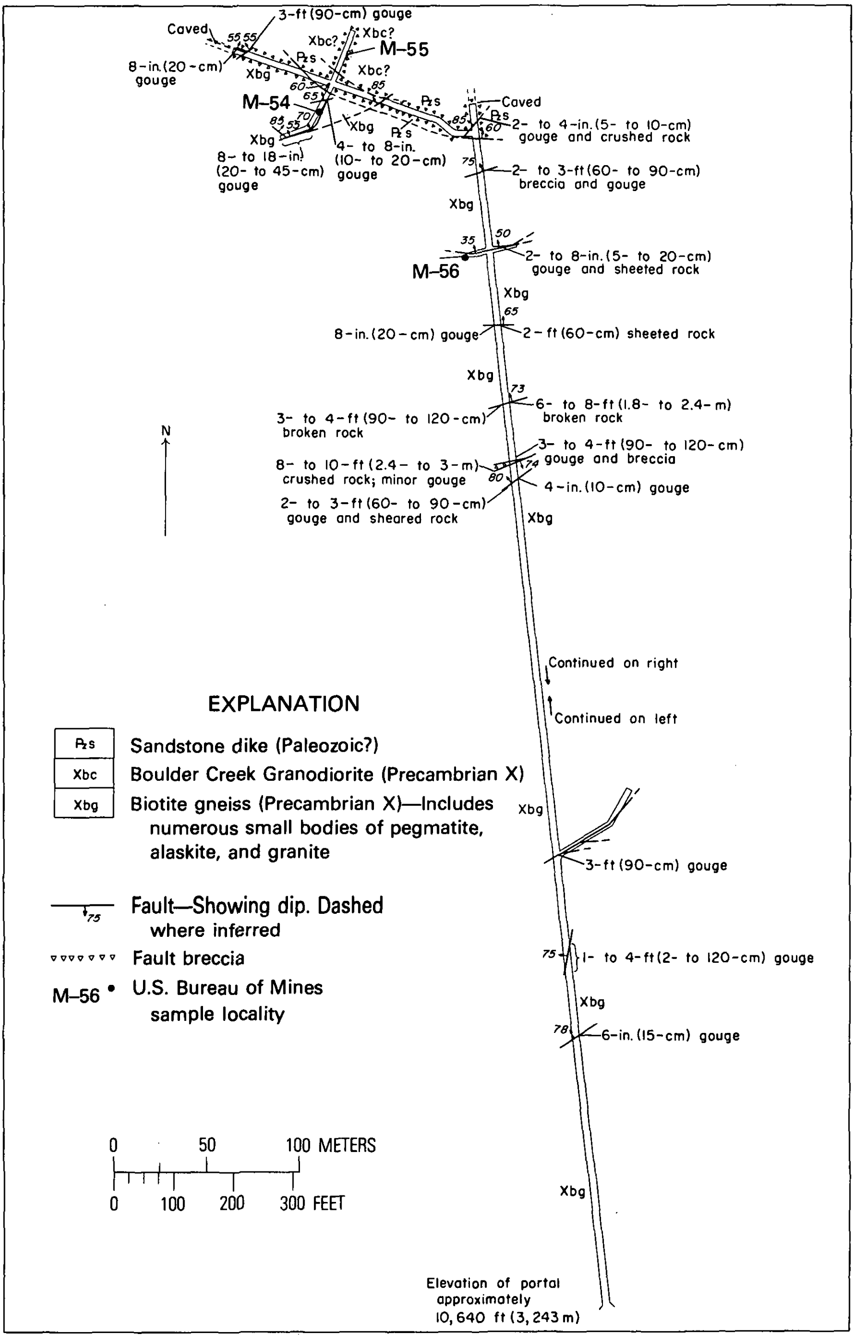

FIGURE 10.—Fourth of July mine adit, North Fork Middle Boulder Creek, Boulder County, Colo. Adit mapped and samples collected by C. N. Speltz. Geology by R. C. Pearson and J. C. Ratté.

elements of interest in these selected samples are bismuth, cadmium, cobalt, mercury, and arsenic. Though not accessible now, the source of these specimens was presumably only a small pocket because production from the mine has been small. No evidence indicates that additional exploration would disclose larger deposits. Stream-sediment sample 105 (fig. 7) from about 0.75 mi (1.2 km) downstream from the shaft contains 200 ppm zinc and 25 ppm CxHM (table 4).

RAINBOW LAKES

Along the east edge of the Indian Peaks study area north of Rainbow Lakes (fig. 6, pl. 1), prospect pits, shafts, and adits have explored quartz veins and mineralized fractures in Boulder Creek Granodiorite. In the cirque west of Rainbow Lakes, evidence of weak mineralization is widespread, and joint surfaces and shear zones are coated with limonite. These mineralized areas evidently fringe the Caribou stock inasmuch as they occur within 1 mi (1.6 km) of the north contact of the stock, which is buried beneath the glacial deposits that surround Rainbow Lakes. The presence of a small plug of quartz monzonite a quarter of a mile north of Rainbow Lakes suggests that the stock continues northward at depth beneath the mineralized areas; it may connect in the subsurface with the Audubon–Albion stock 2 mi (3.2 km) to the north, although the aeromagnetic data do not indicate this connection.

The veins north of Rainbow Lakes are dominantly quartz-pyrite veins that locally contain abundant molybdenite. Selected specimens from dumps show, in addition to molybdenum, moderate-to-high amounts of gold, silver, lead, zinc, copper, bismuth, tin, and manganese. The veins seem to be too small and too sparsely mineralized to be mined profitably, but they could be clues to larger ore bodies at depth.

The cirque west of the lakes also contains abundant evidence of weak mineralization. The Boulder Creek Granodiorite there is moderately to closely jointed, and the joint surfaces are coated by limonite that ranges in thickness from a film to at least 0.1 in. (2 mm). Selected specimens of pyritic quartz veins a few inches (several centimeters) thick from along the north side of the cirque are high in copper, molybdenum, and lead, and contain detectable amounts of silver and tungsten. Stream-sediment sample 192 (fig. 7) collected below the cirque contains 150 ppm copper, 11 ppm CxHM, and 40 ppm CxCu. The veins observed seem to be too small and too few to produce such high metal values in the stream sediments. The joint coatings—probably produced by weathering of sulfides—are a much more likely source, although a sample of granite that contains a thin film of limonite did not contain anomalous amounts of metals.

Because the Caribou stock may be present below the diffuse mineralization in the cirque, more detailed work is warranted to evaluate the chances of locating a deep exploration target. The area is regarded as having a rather low, but definite, potential.

CARIBOU MINING DISTRICT

The Caribou mining district (fig. 6), which is also known as the Caribou-Grand Island district (Lovering and Goddard, 1950), is outside the Indian Peaks study area but was examined because it has been a significant source of gold, silver, and base metals. Although most production occurred in the 19th century, intermittent production has continued to the present. Recorded production for the district through 1970 has been $4.3 million in gold, $1.5 million in silver, $151,000 in lead, $52,000 in copper, and $800 in zinc. Mines, prospects, and sample localities are shown in figure 11. The geology and mines of the area were discussed by Lovering and Goddard

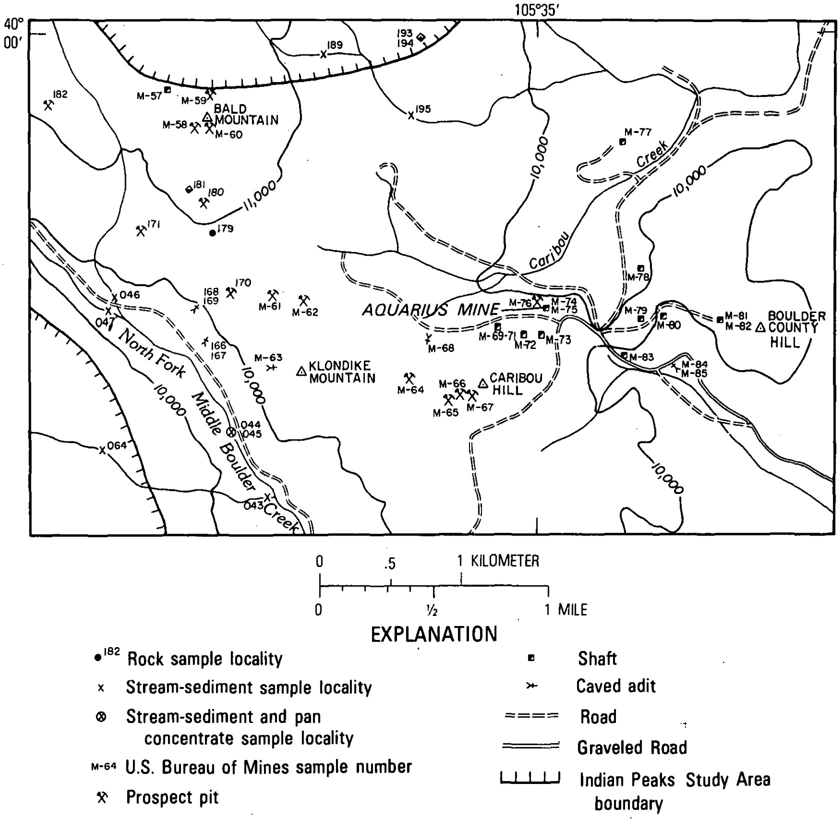

FIGURE 11.—Sample localities in the Caribou area, Boulder County, Colo.

(1950), Bastin and Hill (1917), and Smith (1938). Titaniferous magnetite was reported in the district by these authors and by Harrer and Tesch (1959). The occurrence of uranium (pitchblende) in the veins was discussed by Moore, Cavender, and Kaiser (1957).

Ore occurs in quartz veins within a monzonite porphyry stock that extends west and north from Caribou into the study area. Most mined veins were very rich near the surface, but ore grade diminished rapidly with depth. In most veins a pronounced decrease in ore grade occurred at a depth of about 100 ft (30 m). In a few veins good ore persisted to a depth of 300 ft (90 m) (Lovering and Goddard, 1950). Principal ore minerals in the district were galena, argentite, cerargyrite, native silver, chalcopyrite, and gray copper—all in a quartz gangue. Galena, sphalerite, and chalcopyrite were found on the dumps.

Thirty-one samples (M-57 to M-85) were taken from prospect pits, dumps, and stockpiles in the Caribou district; sample localities are shown on figure 11, and assay results are shown in table 2. Because all workings except the shaft of the Aquarius mine (samples M-74 and M-75) were caved at the time of this investigation, a thorough evaluation of the district could not be made. In general, assays reveal that copper, lead, zinc, and molybdenum are present in negligible amounts except in samples M-75 and M-83. Gold content is also negligible except for sample M-85, from the dump of the St. Louis shaft, and sample M-83, from the dump of the Potosi shaft (fig. 11). Prospect pits on Bald Mountain (fig. 11), 1,000 ft (300 m) or less outside the Indian Peaks study area, were also sampled (samples M-57 to M-60). These samples contain very small amounts of metals.

We conclude that the productive veins of the Caribou district do not extend into the study area, and that the few veins fringing the district near the study area, such as those on Bald Mountain, are small and evidently of low grade.

DEVILS THUMB LAKE

Samples collected at Devils Thumb Lake (fig. 6) indicate the presence of lead and silver in a fault zone. The fault is exposed as crushed and slightly altered rock at least a few tens of feet (around 10 meters) wide on the east bank of the inlet stream south of the west end of the lake. The fault cuts Boulder Creek Granodiorite and a few inclusions of migmatitic biotite gneiss. A selected sample (158) of limonite-stained crushed granite contained 5,000 ppm lead and 15 ppm silver (table 6). Stream-sediment sample 156 (fig. 7) collected at the inlet to the lake just a few hundred feet north of sample locality 158 contains 100 ppm lead and a trace of silver (table 4). We conclude that only small amounts of these metals are in the fault.

LOST LAKE DISTRICT

The Lost Lake mining district is about 2 mi (3.2 km) west of the Eldora district. It lies less than 1 mi (1.6 km) outside the southeastern boundary of the study area (figs. 6 and 12).

In a brief description of the district, Lovering and Goddard (1950) mentioned production from mines south and southeast of Lost Lake. Most of the mining was on small shoots 1-3 in. (2.5-7.5 cm) wide along the Norway, Maude W., and Revenge veins (not shown on fig. 12). These yielded small quantities of telluride ore similar to that

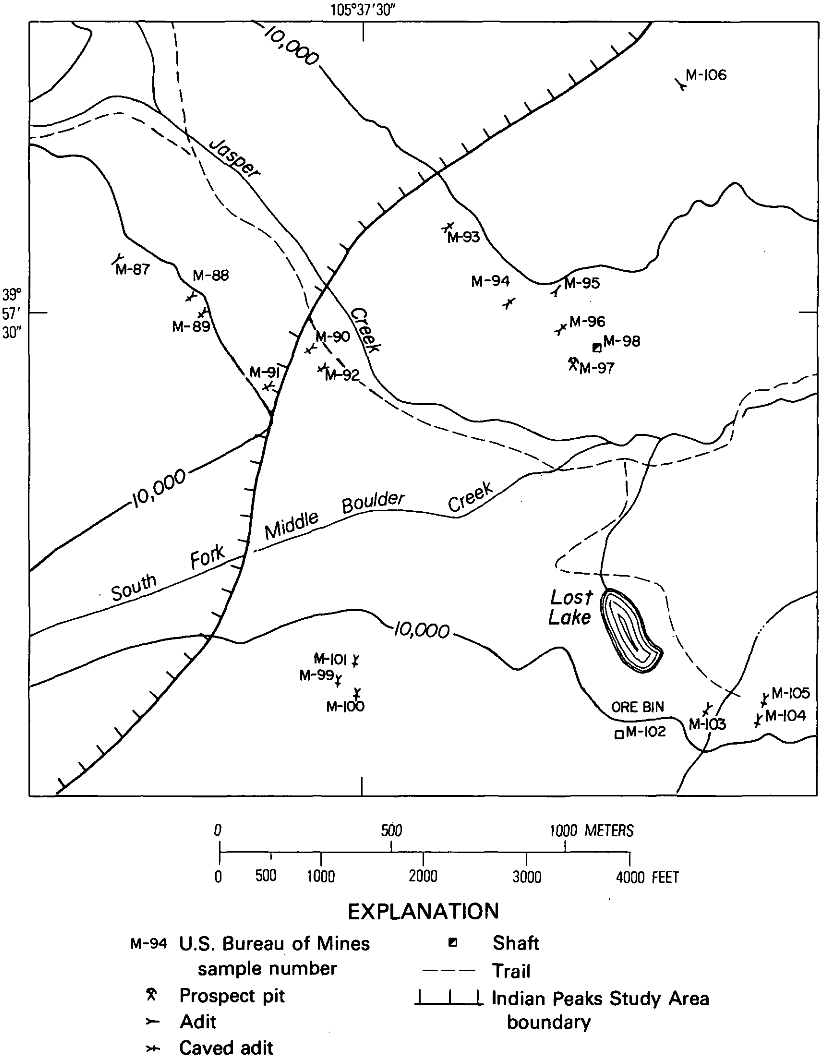

FIGURE 12.—Sample localities in the Lost Lake area, Boulder County, Colo.

described by Lindgren (1907) in the Eldora district. Reported production from 1901 to 1942 totaled less than 3,500 tons (about 3,200 t) of ore of unknown value.

The veins near Lost Lake are in quartz monzonite of the Bryan Mountain stock, but to the west and on Jasper Creek they are in Precambrian rocks that are mainly a mixture of granitic gneiss and biotite gneiss. At least one porphyry dike and small bodies of intrusion breccia, which consists of angular to rounded fragments of Precambrian rock in a matrix of porphyry, crop out among the prospect pits on the southwest side of Jasper Creek. The veins trend northeastward and are generally parallel to the foliation of the wallrocks. Hydrothermal alteration is pronounced in the productive part of the district south of Lost Lake. The dumps of the larger mines are bleached quartz monzonite that weathers yellow indicating envelopes of intense alteration along the veins. In contrast, alteration along the veins in Precambrian rocks on Jasper Creek is weak; minor chlorite, sericite, and pyrite are in and along fractures, and an ankeritic(?) carbonate locally cements breccia.

Samples (M-87 to M-106, fig. 12) were taken from the faces of open adits, from the dumps of caved adits, and from prospect pits. Assay values for samples M-87 to M-106 (table 2) are generally low, except for 0.3 oz of gold per ton (10.3 g/t) in sample M-101. Although about 50,000 tons (45,000 t) of rock is contained in the dumps of the various workings, it is far below commercial grade.

Thirty-nine geochemical samples (pl. 2) collected from dumps of some of the productive mines and from most prospect adits and pits in the Lost Lake-Jasper Creek area indicate that the veins of this group are similar geochemically to the telluride veins at Eldora, where barite and molybdenite are present (Lindgren, 1907). Except for two samples (014 and 067, pl. 2) that contain appreciable quantities (table 6) of copper, lead, and zinc, the veins are characterized by silver, gold, tellurium, molybdenum, tungsten, barium, mercury, and arsenic.

The small amounts of tungsten in the veins of the Lost Lake-Jasper Creek area suggest a possible genetic association with the Boulder County tungsten district, which is about 5 mi (8 km) to the east. Of the more than 1,000 samples collected in this study, 12 of the 15 samples in which tungsten was detected came from the Lost Lake-Jasper Creek area. However, the maximum amount of tungsten contained in any of these samples was 100 ppm, and hence it has no economic importance.

The veins of the Lost Lake-Jasper Creek area have been prospected adequately to demonstrate that they are small and that metallic minerals are distributed intermittently along them. At shallow depths these veins surely contain only minor resources.

However, these near-surface veins and the substantial hydrothermal alteration of the quartz monzonite stock indicate that the area southeast of Lost Lake has potential for ore deposits at depth. Detailed geological and geophysical studies would be needed to determine whether deep drilling is warranted in this area, which is nearly a mile outside the boundary of the Indian Peaks study area. The Jasper Creek area, which is on the boundary of the study area, seems to have a much lower mineral potential than the area southeast of Lost Lake, largely because hydrothermal alteration is meager and the porphyry intrusions consist of only a few small dikes and a small body of intrusion breccia. The geochemical evidence is not completely negative, however, for the suite of metals found in these veins and the presence of the intrusion breccia suggest a slight possibility of larger orebodies at substantial depth.

GUINN MOUNTAIN AREA

The Guinn Mountain area is on the southern boundary of the Indian Peaks study area immediately west of the Lost Lake mining district (fig. 6). Five patented lode claims, one patented placer claim, several prospect pits and the dump of one caved adit were examined.

Ten samples (M–107 to M–117, pl. 2) collected in the area contained only negligible amounts of any metal. Samples from the Avalon placer claim, located on the South Fork Middle Boulder Creek north of Guinn Mountain, and from the creek bottom were collected and panned; no gold was found.

The Guinn Mountain area has little or no economic potential.

CONCLUSIONS

Although the study area has no known economic ore deposits, it does contain many mineral occurrences, some of which we interpret as potential exploration sites. Only at the Roaring Fork copper prospect is enough metal exposed to infer the presence of resources, and even there the grade is submarginal, and the total amount of copper is probably only a few hundred tons per 100 ft (30 m) of depth. The Roaring Fork deposit is not economic now, nor is it likely to be in the foreseeable future. The Snowy Range vein in the Lake Albion mining district probably contains some lead-silver ore, but little information is available on the quantity or grade. Numerous other mineral occurrences scattered widely through the Indian Peaks study area have been prospected without discovery of significant orebodies. The prospect pits, shafts, and adits have disclosed minor showings of copper, lead, zinc, silver, gold, uranium, and traces of tungsten and molybdenum. Geologically, these showings are localized along northwestward-trending faults, in narrow veins trending various directions, disseminated in the Laramide stocks, and, for uranium, associated with pegmatites near a batholith contact. Of these, only the disseminated sulfides in and near the Audubon-Albion and Caribou stocks seem to us to represent attractive sites for future exploration. The large number of samples that contain anomalous quantities of metals is probably the result of diffuse mineralization that may well have failed to form a single important ore deposit.

Except for the Roaring Fork deposit and the Snowy Range vein, the vein deposits and the uranium prospect are interpreted to be of little consequence. The uranium prospect does draw attention to the margin of the Longs Peak-St. Vrain batholith as a site where similar, perhaps larger, deposits of uranium might be found. The Lost Lake mining district, which is about 1 mi (1.6 km) outside the study area, contains much hydrothermally altered rock and an important suite of elements in veins. It is an attractive exploration target for deep drilling. The veins on Jasper Creek, which are on the boundary of the study area, contain the same minor-element suite as the veins near Lost Lake but show only minor hydrothermal alteration. The Jasper Creek veins seem to be fringing the Lost Lake mineralized area and thus do not represent a very attractive exploration target. The Caribou mining district is also about 1 mi (1.6 km) outside the boundary of the Indian Peaks study area, and only a few small veins that fringe the district extend into the study area. The area where these veins crop out offers only slight promise as an exploration target.

Geologic conditions virtually preclude the finding of deposits of coal, oil, natural gas, oil shale, or other mineral commodities associated with sedimentary rocks. Deposits of other nonmetallic mineral products are absent except for peat and construction materials such as sand, gravel, and stone, and these are probably uneconomic at this time. There is no evidence for a source of geothermal energy.

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Tables 4, 5, and 6.—*Analyses of selected stream-sediment (table 4), altered-rock (table 5), and mineralized-rock (table 6) samples from Indian Peaks study area, Colorado*

[See pl. 2 for sample localities. All values in parts per million except Fe, Mg, Ca, and Ti, which are in percent. The usual lower limit of determination for each element or technique is the number shown with "<". CxCu is the copper test using cold-acid extraction; CxHM is the citrate-soluble test for heavy metals, mainly zinc and also copper, lead, and cobalt. Semiquantitative spectrographic analyses are reported to the nearest number in the series 1, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, etc., which represent approximate midpoints of group data on a geometric scale. Symbols: N, element was looked for but not found; <, element was detected but was less than amount shown; ---, not determined; >, greater than amount shown.]

TABLE 4.—*Analyses of selected stream-sediment samples, Indian Peaks study area, Colorado*

Sample	North latitude			West Longitude			Semiquantitative spectrographic analyses											
							(percent)				(parts per million)							
	D	M	S	D	M	S	Fe	Mg	Ca	Ti	Mn	Ag	B	Ba	Be	Co	Cr	Cu
K-017	39	59	5	105	43	48	10.0	0.7	1.00	0.50	300	N	15	700	2.0	7	70	15
K-038	39	59	45	105	42	15	15.0	.5	.70	>1.00	700	N	10	300	1.0	10	150	15
K-040	39	59	16	105	42	39	7.0	1.0	2.00	.70	700	N	<10	1,500	2.0	15	70	30
K018	40	4	16	105	39	16	5.0	.5	.70	.30	150	N	15	300	1.5	<5	30	30
K019	40	4	26	105	39	57	3.0	.3	.70	.50	300	N	20	300	1.5	<5	30	15
K032	40	2	23	105	38	59	5.0	1.0	.50	.30	500	N	15	500	1.5	10	100	50
K034	40	2	43	105	39	11	5.0	.7	.70	.30	700	N	20	500	1.5	7	30	15
P-005	40	5	6	105	36	48	5.0	1.5	7.00	.30	1,000	N	<10	700	1.0	5	30	500
P-006	40	5	13	105	35	49	3.0	.7	5.00	.30	1,000	N	10	700	1.0	5	20	50
P-012	40	2	45	105	40	21	5.0	.7	1.00	.70	500	N	10	700	1.0	10	70	15
P-018	40	3	32	105	41	53	7.0	.7	.50	1.00	500	N	20	700	1.5	10	100	70
P-022	40	2	22	105	45	21	10.0	1.0	.50	.50	500	N	10	700	1.0	10	200	10
P-031	40	8	2	105	36	17	3.0	.7	.70	.30	1,000	N	15	500	1.5	5	50	15
P-049	40	10	28	105	38	54	3.0	1.0	.70	.30	500	N	20	300	2.0	15	100	50
P-052	40	10	18	105	37	22	3.0	.5	.70	.70	500	<.5	20	300	1.5	5	30	20
P-058	40	8	41	105	41	43	2.0	.7	.70	.50	300	<.5	20	700	2.0	7	70	15
P-059	40	8	25	105	42	8	2.0	.7	.70	.50	200	<.5	20	700	2.0	7	70	15
P-060	40	8	28	105	42	7	3.0	.7	.70	.70	500	N	30	1,000	2.0	7	70	20
P-061	40	8	15	105	42	27	3.0	.5	.70	.30	700	N	20	1,000	1.5	7	70	20
P-065	40	6	4	105	38	41	3.0	.7	1.00	.30	700	.5	30	700	1.5	5	50	20
P-066	40	6	8	105	38	47	3.0	1.0	.70	.30	700	N	30	300	1.5	10	70	30
P-068	40	6	40	105	38	58	2.0	.5	.70	.20	200	.5	20	700	2.0	5	50	30
P-070	40	6	58	105	38	59	3.0	.5	.70	.30	500	N	20	300	1.5	5	70	15
P-077	40	1	38	105	40	17	7.0	1.0	.70	.30	1,500	N	15	500	1.0	15	100	15
P-078	40	1	37	105	40	21	7.0	.7	.70	.30	1,500	N	10	500	1.0	10	100	15

Sample	Semiquantitative spectrographic analyses (parts per million)												Chemical analyses (ppm)	
	La	Mo	Nb	Ni	Pb	Sc	Sn	Sr	V	Y	Zn	Zr	CxCu	CxHM
K-017	70	20	<20	20	20	10	<10	200	70	30	N	150	2	3
K-038	200	15	20	30	30	10	N	N	100	1,000	N	700	N	5
K-040	150	N	20	20	30	15	N	300	100	70	N	200	10	4
K018	50	10	<20	15	50	5	N	100	50	20	N	150	4	5
K019	150	15	<20	7	30	5	N	100	50	30	N	200	5	3
K032	50	N	<20	50	30	10	N	100	70	70	N	150	10	3
K034	150	15	<20	20	50	7	N	100	70	30	N	150	4	5
P-005	70	N	N	10	20	15	N	1,000	100	30	N	50	30	14
P-006	50	5	N	5	50	7	N	700	70	20	N	30	15	20
P-012	70	15	<20	20	100	10	30	150	70	20	N	200	4	5
P-018	100	N	<20	30	20	15	<10	100	100	200	N	200	15	3
P-022	200	10	<20	50	15	15	<10	100	150	100	N	70	3	2
P-031	100	<5	<20	10	30	10	N	150	70	30	N	150	2	17
P-049	30	N	<20	50	70	10	N	100	70	20	N	100	10	14
P-052	30	5	N	10	50	10	10	100	50	20	N	100	7	7
P-058	70	N	<20	20	30	10	N	100	70	30	N	100	3	3
P-059	70	N	<20	20	20	10	N	100	70	30	N	200	2	5
P-060	150	10	<20	20	50	10	15	150	70	30	<200	150	2	5
P-061	150	N	<20	20	30	10	N	150	70	70	300	150	2	3
P-065	150	N	<20	10	50	10	N	300	50	30	N	200	7	11
P-066	30	5	<20	20	30	10	N	150	70	30	N	150	11	9
P-068	50	<5	N	20	150	10	N	150	30	30	<200	50	15	40
P-070	100	N	N	20	100	10	30	150	50	20	N	200	5	9
P-077	70	10	<20	50	30	15	N	100	70	20	<200	100	3	14
P-078	50	7	N	30	100	15	50	100	70	30	<200	70	2	7

TABLE 4.—*Analyses of selected stream-sediment samples, Indian Peaks study area, Colorado*—Continued

Sample	North latitude			West Longitude			Semiquantitative spectrographic analyses											
							(percent)				(parts per million)							
	D	M	S	D	M	S	Fe	Mg	Ca	Ti	Mn	Ag	B	Ba	Be	Co	Cr	Cu
R-008	40	3	3	105	36	44	3.0	0.7	0.70	0.20	500	N	10	500	1.0	5	50	30
R-009	40	2	48	105	36	23	3.0	.5	.70	.30	500	N	10	300	1.5	10	100	50
R-014	40	3	40	105	43	51	3.0	.5	.50	.30	500	N	15	300	1.5	5	50	15
R-019	40	3	41	105	38	16	3.0	.7	.70	.30	200	N	20	700	1.0	5	50	30
R-020	40	3	53	105	37	51	5.0	1.0	1.00	.30	700	N	20	700	1.5	10	70	50
R-022	40	3	59	105	37	39	7.0	.5	.70	.30	200	N	15	300	1.5	<5	50	20
R-023	40	3	60	105	37	39	7.0	1.0	.70	.30	1,000	<.5	20	700	1.5	15	70	50
R-025	40	4	15	105	36	45	5.0	1.5	3.00	.30	700	N	15	300	1.0	10	100	50
R-105	40	10	20	105	32	46	3.0	.7	.70	.20	200	.5	50	300	3.0	5	50	50
R-117	40	8	49	105	43	28	2.0	.5	.70	.30	500	.5	30	700	2.0	<5	50	20
R-128	40	10	9	105	39	59	2.0	.3	.70	.20	200	N	10	300	1.5	<5	20	10
R-134	40	9	19	105	40	45	5.0	.7	1.00	.30	700	<.5	20	500	2.0	7	70	30
R-216	40	10	27	105	34	48	5.0	.7	.70	.30	500	N	50	500	1.5	7	70	30
R-238	39	59	44	105	43	52	1.5	.2	.70	.15	200	N	15	200	1.5	N	30	10
R204	40	2	12	105	38	53	2.0	.5	.50	.30	300	N	30	300	1.5	5	50	30
001	39	56	3	105	39	2	2.0	.2	.15	.15	200	N	10	150	1.5	5	20	20
009	39	56	48	105	38	47	7.0	.7	1.50	.70	1,000	N	10	300	1.5	15	70	20
010	39	57	7	105	37	42	7.0	.7	1.50	.50	500	N	<10	200	1.5	10	70	30
044	39	58	31	105	36	31	7.0	1.0	1.50	.70	1,500	N	<10	200	1.0	15	150	70
046	39	58	48	105	37	5	7.0	.7	1.50	.70	700	N	10	150	1.5	15	70	30
048	39	59	25	105	37	45	7.0	.7	1.50	.70	1,500	N	<10	200	<1.0	15	100	50
063	39	38	5	105	58	36	7.0	1.0	1.50	.70	1,000	N	10	300	1.0	15	150	70
064	39	37	9	105	58	26	10.0	.7	3.00	>1.00	1,500	N	<10	300	<1.0	10	70	50
080	39	57	6	105	41	3	10.0	1.0	1.00	.70	1,500	N	10	200	1.5	20	100	70
099	39	56	30	105	40	45	5.0	.7	.50	.50	1,000	N	<10	150	1.5	15	30	20

Sample	Semiquantitative spectrographic analyses (parts per million)												Chemical analyses (ppm)	
	La	Mo	Nb	Ni	Pb	Sc	Sn	Sr	V	Y	Zn	Zr	CxCu	CxHM
R-008	70	10	<20	20	50	10	N	200	70	20	N	100	N	25
R-009	50	15	<20	30	30	7	N	150	70	15	N	100	10	40
R-014	50	10	<20	20	20	15	N	100	50	30	N	100	2	30
R-019	50	N	<20	20	30	7	N	200	50	20	N	100	10	17
R-020	70	<5	<20	50	70	10	N	200	100	30	N	100	7	25
R-022	70	10	<20	15	50	7	N	100	50	20	N	100	N	9
R-023	50	7	<20	30	70	10	N	150	100	20	N	100	10	20
R-025	70	5	<20	50	50	15	N	300	100	20	N	100	10	20
R-105	30	5	N	20	30	10	<10	150	50	20	N	70	10	9
R-117	30	N	N	10	30	7	<10	100	50	30	N	100	4	5
R-128	50	15	N	7	20	5	<10	100	30	30	N	70	2	1
R-134	50	5	<20	30	20	15	<10	100	70	30	N	200	4	3
R-216	100	N	<20	20	30	10	N	150	70	30	N	300	11	5
R-238	20	N	N	5	20	5	N	N	30	<10	N	100	10	30
R204	20	N	N	20	50	7	N	<100	50	15	N	100	15	11
001	30	N	N	5	70	7	N	100	70	15	N	100	2	30
009	70	N	<20	10	100	15	N	200	150	30	N	300	4	7
010	100	N	N	10	100	10	N	200	100	70	N	300	4	5
044	100	N	N	30	50	15	N	100	150	50	N	1,000	3	5
046	100	N	N	20	100	15	N	150	150	30	N	300	2	9
048	700	N	N	30	100	15	N	100	150	100	N	1,000	2	6
063	70	N	<20	30	70	15	N	200	200	30	N	700	3	4
064	200	N	N	15	50	15	N	300	200	150	N	1,000	10	3
080	70	N	<20	30	200	15	N	150	150	30	N	300	5	8
099	70	N	N	20	100	15	<10	150	100	30	N	200	3	7

TABLE 4.—*Analyses of selected stream-sediment samples, Indian Peaks study area, Colorado*—Continued

Sample	North latitude			West Longitude			Semiquantitative spectrographic analyses (percent)											
											(parts per million)							
	D	M	S	D	M	S	Fe	Mg	Ca	Ti	Mn	Ag	B	Ba	Be	Co	Cr	Cu
105	40	0	13	105	39	8	7.0	1.0	0.70	0.30	2,000	N	<10	150	1.5	15	150	20
142	40	0	25	105	40	26	7.0	1.0	.50	.30	1,000	N	<10	150	1.5	15	100	30
156	39	58	27	105	40	47	7.0	.7	.70	.70	700	<.5	<10	150	1.5	15	70	30
164	39	58	12	105	39	30	7.0	.7	1.50	.70	1,500	N	<10	200	1.5	15	50	30
165	39	58	21	105	38	56	7.0	.3	1.00	.70	1,500	N	<10	150	1.0	15	30	20
192	40	0	51	105	35	32	2.0	.5	1.50	.70	500	N	<10	150	2.0	7	30	150
196	40	1	54	105	35	9	10.0	.3	1.00	.70	700	N	<10	150	1.0	15	150	20
197	40	1	55	105	37	12	7.0	.7	.50	.70	500	N	<10	150	1.5	15	150	20
199	40	1	51	105	37	18	.7	1.0	.50	.70	1,000	N	<10	150	1.5	20	150	50
203	40	1	53	105	36	57	1.5	.1	.10	.05	20	N	N	30	1.0	N	30	10
204	40	1	53	105	36	48	3.0	.7	.50	.30	500	N	<10	150	1.5	15	100	20
206	40	1	53	105	36	34	5.0	.7	1.50	.70	1,000	<.5	<10	200	2.0	15	70	30
208	40	1	43	105	35	50	3.0	.7	1.50	.70	1,000	N	<10	200	1.5	15	50	70
209	40	1	30	105	38	4	7.0	1.0	.70	.50	700	<.5	<10	200	1.0	20	200	50
214	40	2	5	105	37	54	7.0	1.0	.30	.70	700	N	10	200	1.5	15	200	30
215	40	2	18	105	37	51	5.0	1.0	.30	.50	700	N	10	150	1.5	15	200	50
216	40	2	19	105	37	50	5.0	.7	.50	.30	500	N	<10	150	1.5	15	100	70
217	40	2	19	105	37	38	7.0	1.0	.50	.50	700	N	20	150	2.0	15	150	70
230	39	57	22	105	39	11	3.0	.5	.30	.30	700	N	10	150	1.5	7	70	20
231	39	57	15	105	39	58	2.0	.7	.70	.50	700	N	N	150	2.0	10	50	20
232	39	57	17	105	40	24	3.0	.7	.30	.50	700	N	10	150	1.5	15	70	20
233	39	57	24	105	40	26	3.0	.7	.30	.50	700	N	<10	150	1.5	15	70	20
245	40	4	35	105	37	10	3.0	.5	.50	.20	150	<.5	20	300	1.0	<5	30	20
248	40	4	29	105	36	0	3.0	.5	2.00	.50	500	N	10	500	1.5	5	30	50
257	40	5	0	105	36	40	5.0	1.0	5.00	.30	700	N	<10	700	1.0	10	30	150

Sample	Semiquantitative spectrographic analyses (parts per million)												Chemical analyses (ppm)	
	La	Mo	Nb	Ni	Pb	Sc	Sn	Sr	V	Y	Zn	Zr	CxCu	CxHM
105	70	N	N	30	70	15	N	100	70	30	200	200	2	25
142	30	N	N	30	100	15	N	<100	100	30	N	200	2	5
156	150	5	<20	15	100	15	N	200	150	70	N	200	N	5
164	200	N	<20	20	100	15	N	150	100	50	N	700	1	7
165	100	N	N	10	30	7	N	150	70	30	N	1,000	N	25
192	100	5	N	5	70	10	N	150	70	70	N	500	40	11
196	100	N	<20	30	150	15	N	200	200	100	N	200	2	30
197	300	7	N	50	100	15	N	100	150	70	N	300	1	3
199	100	N	N	50	100	20	N	100	100	30	N	200	4	5
203	N	15	N	5	100	5	N	N	70	30	N	15	N	3
204	70	15	N	30	70	15	N	100	100	20	N	300	N	4
206	150	5	<20	20	70	15	N	200	70	50	N	300	2	9
208	200	5	N	15	70	15	N	200	100	50	N	700	1	7
209	30	N	N	50	50	20	N	100	150	100	N	150	15	3
214	70	N	N	50	100	20	N	100	150	50	N	150	5	6
215	70	N	N	30	150	15	N	150	150	20	N	100	4	6
216	70	N	N	30	70	15	N	150	70	30	N	150	7	5
217	150	N	N	30	100	15	N	150	150	30	N	150	7	9
230	70	10	N	7	50	15	N	150	100	30	N	200	N	2
231	150	10	N	7	50	15	N	150	100	30	N	500	1	7
232	70	N	N	10	100	15	N	150	100	30	N	500	1	5
233	70	N	N	20	100	15	N	150	100	30	N	200	2	5
245	100	<5	<20	7	70	7	N	100	50	30	N	150	2	30
248	50	N	<20	7	30	10	N	500	100	20	N	100	10	20
257	100	5	<20	10	30	10	N	500	100	20	N	100	30	7

TABLE 4.—*Analyses of selected stream-sediment samples, Indian Peaks study area, Colorado*—Continued

Sample	North latitude			West Longitude			Semiquantitative spectrographic analyses (percent)				(parts per million)							
	D	M	S	D	M	S	Fe	Mg	Ca	Ti	Mn	Ag	B	Ba	Be	Co	Cr	Cu
259	40	5	18	105	35	53	3.0	0.5	2.00	0.30	300	N	10	700	1.5	5	20	15
260	40	5	21	105	35	48	3.0	.5	2.00	.30	500	N	15	700	1.5	5	20	20
270	40	6	50	105	37	3	3.0	1.0	1.50	.50	700	N	10	700	1.5	5	50	20
272	40	6	58	105	36	36	3.0	1.0	1.00	.30	500	N	15	700	1.5	5	70	30
274	40	7	17	105	36	0	3.0	.5	.70	.30	1,000	N	20	300	1.5	5	30	15
275	40	7	22	105	35	41	5.0	1.0	2.00	.50	1,000	N	15	700	1.5	7	70	30
319	40	1	4	105	41	45	5.0	.3	.50	.20	300	N	15	300	1.5	5	50	10
321	40	1	0	105	41	44	7.0	1.5	.70	.20	500	N	20	300	1.5	7	200	15
323	40	0	59	105	41	48	7.0	1.5	.50	.30	500	N	15	500	1.5	10	150	15
326	40	1	23	105	42	6	7.0	.3	.50	.20	200	N	20	300	1.5	5	70	15
327	40	1	22	105	42	9	5.0	1.0	1.00	.30	500	<.5	15	300	1.5	7	150	15
349	40	9	34	105	38	43	5.0	.7	.70	.50	700	N	20	500	1.5	7	100	15
387	40	9	2	105	44	2	3.0	.5	.70	.70	500	.5	70	700	1.0	5	150	20
390	40	8	55	105	44	30	1.0	.1	.30	.07	150	N	<10	100	1.5	N	20	10
391	40	8	45	105	44	39	2.0	.5	1.00	.30	300	N	20	500	2.0	5	50	15
395	40	8	55	105	40	1	3.0	.5	.50	.30	200	<.5	30	300	2.0	N	50	20
398	40	8	31	105	40	21	3.0	.5	.50	.20	500	N	30	300	1.5	N	30	30
431	40	5	29	105	39	2	2.0	.2	.70	.15	1,500	N	15	200	1.5	5	20	15
447	40	2	34	105	40	56	3.0	.5	.50	.50	700	N	15	300	1.0	7	50	7
448	40	2	30	105	40	48	5.0	.5	.50	.50	500	N	15	300	1.0	7	100	10
451	40	1	38	105	42	23	7.0	1.0	.70	.30	1,500	<.5	20	500	1.5	15	300	20
452	40	1	38	105	42	21	1.5	.2	.50	.10	150	<.5	30	200	1.5	N	30	15
453	40	1	41	105	42	22	5.0	.5	.50	.20	1,000	1.0	20	700	1.5	5	50	15
454	40	1	51	105	42	59	7.0	.7	.70	.30	700	N	20	700	1.5	15	150	15
480	40	9	38	105	48	50	5.0	.5	.70	.70	700	N	20	300	1.5	5	100	20
493	40	6	35	105	39	15	3.0	.5	.70	.70	500	N	50	700	2.0	5	50	30

Sample	Semiquantitative spectrographic analyses (parts per million)												Chemical analyses (ppm)	
	La	Mo	Nb	Ni	Pb	Sc	Sn	Sr	V	Y	Zn	Zr	CxCu	CxHM
259	30	10	<20	<5	30	7	N	500	70	15	N	70	4	7
260	50	10	<20	7	30	7	N	500	70	20	N	150	7	5
270	70	10	<20	30	50	7	N	200	50	20	N	100	4	150
272	50	<5	<20	30	30	7	N	200	50	15	N	150	4	17
274	20	5	N	7	50	7	N	150	30	15	N	100	N	20
275	50	10	N	30	30	15	N	150	50	30	N	200	4	70
319	30	5	N	10	30	7	N	<100	50	15	N	100	1	17
321	70	30	<20	70	30	10	N	<100	70	30	N	150	4	11
323	150	10	<20	70	20	10	N	100	70	30	N	150	1	3
326	50	N	N	15	30	7	N	<100	30	20	N	100	3	17
327	200	7	N	70	50	7	N	100	70	50	N	100	3	17
349	100	10	<20	20	30	15	<10	100	100	30	N	150	1	3
387	100	N	<20	20	20	10	N	100	70	30	N	150	3	3
390	30	N	N	N	10	N	N	N	N	N	N	20	2	17
391	30	10	N	15	20	10	N	150	50	20	N	200	2	3
395	30	N	N	10	30	7	N	100	30	20	N	100	3	9
398	50	N	N	10	50	7	N	N	30	30	N	70	7	17
431	100	5	N	5	30	5	N	<100	30	20	N	50	1	20
447	150	10	N	10	20	10	N	100	50	150	N	100	1	3
448	50	15	N	20	20	10	N	100	70	20	N	150	1	3
451	200	7	N	70	70	10	N	100	70	50	N	150	4	25
452	20	N	N	7	20	5	N	N	30	<10	N	50	N	17
453	100	N	N	20	100	7	N	100	50	30	<200	150	4	35
454	100	10	<20	50	50	10	N	100	70	100	N	150	2	3
480	50	N	<20	30	15	10	N	<100	70	500	N	150	10	5
493	20	10	<20	20	30	10	N	150	70	30	N	200	10	3

TABLE 5.—*Analyses of selected altered-rock samples, Indian Peaks study area, Colorado*

Sample	North latitude			West longitude			Semiquantitative spectrographic analyses				
							(percent)				(ppm)
	D	M	S	D	M	S	Fe	Mg	Ca	Ti	Mn
R-005	40	3	14	105	37	2	5.0	0.10	3.00	0.007	150
R-006	40	3	14	105	37	2	10.0	1.00	7.00	.150	700
R-007	40	3	2	105	36	46	7.0	1.00	.07	.200	300
R-112	40	10	5	105	31	16	15.0	.50	7.00	.300	200
R-197	40	2	34	105	38	35	15.0	.30	.05	.150	100
R-223	40	2	57	105	39	58	7.0	.50	.07	.200	150
R-249	39	58	21	105	41	60	5.0	.30	.30	.700	150
R-271	40	6	25	105	43	42	15.0	7.00	10.00	1.000	3,000
017	39	56	48	105	37	5	7.0	.30	.10	.200	150
060	38	57	28	105	37	8	1.5	.30	.05	.050	30
065	39	37	49	105	58	49	1.5	.20	<.05	.150	70
116	39	59	19	105	39	42	7.0	.10	<.05	.150	70
154	39	58	0	105	41	16	5.0	.20	1.00	.200	300
170	39	59	2	105	36	30	15.0	.15	.50	.500	700
182	39	59	44	105	37	24	2.0	.20	.05	.030	30
185	40	1	3	105	38	48	7.0	1.00	1.50	.200	300
211	40	1	39	105	38	6	1.5	.20	.07	.070	70
226	40	2	52	105	37	3	7.0	1.50	.10	.300	200
256	40	5	23	105	36	43	5.0	1.00	2.00	.200	500
276	40	4	29	105	43	15	2.0	.30	.30	.150	100
286	40	1	18	105	43	54	7.0	.50	5.00	.500	700
287	40	1	22	105	43	53	3.0	.30	.50	.200	500
309	40	8	33	105	37	0	15.0	1.50	.15	.500	500
445	40	2	50	105	41	52	7.0	1.00	.07	.300	150
465	40	0	59	105	42	12	3.0	.20	.15	.300	300
475	39	59	8	105	44	44	2.0	.05	.50	.100	200
486	40	6	33	105	36	38	7.0	1.00	2.00	.700	100
490	40	6	13	105	40	34	15.0	3.00	7.00	>1.000	1,500
512	40	9	34	105	43	4	7.0	2.00	1.50	.300	500
540	40	7	20	105	35	28	1.5	.50	.50	.150	150
541	40	7	17	105	35	31	1.0	.10	.20	.050	100
543	40	3	18	105	37	0	3.0	1.00	2.00	.300	300

TABLE 5.—*Analyses of selected altered- samples, Indian Peaks study area, Colorado*—Continued

Sample	Semiquantitative spectrographic analyses (parts per million)								
	Ag	B	Ba	Be	Co	Cr	Cu	La	Mo
R-005	0.7	<10	1,500	3.0	70	N	2,000	150	N
R-006	N	<10	200	1.0	15	10	700	20	N
R-007	N	<10	500	3.0	7	150	15	30	N
R-112	.5	<10	1,000	<1.0	7	100	150	300	N
R-197	<.5	<10	300	<1.0	15	70	30	150	N
R-223	.5	<10	700	<1.0	30	30	700	20	70
R-249	1.0	10	1,000	2.0	10	15	70	70	<5
R-271	N	<10	1,000	1.0	30	N	30	70	N
017	.5	15	1,500	2.0	7	10	7	70	10
060	N	N	700	N	N	N	7	30	30
065	2.0	N	300	1.5	5	<10	10	70	<5
116	1.5	<10	500	<1.0	N	30	500	N	<5
154	N	N	700	1.0	15	50	5	150	N
170	1.0	10	700	N	30	50	15	70	N
182	N	N	200	1.5	N	<10	7	20	70
185	N	10	300	2.0	20	20	300	70	N
211	.7	N	700	<1.0	10	N	15	70	N
226	.5	<10	700	2.0	N	150	200	70	10
256	N	<10	1,000	<1.0	7	N	5,000	20	30
276	N	N	300	1.0	<5	N	5	70	N
286	N	15	700	1.0	15	15	N	50	N
287	1.5	20	200	1.5	10	50	15	30	N
309	N	<10	700	1.5	20	150	10	70	N
445	N	<10	700	<1.0	10	70	N	50	N
465	.5	30	500	2.0	<5	N	30	200	7
475	<.5	<10	1,000	<1.0	N	N	N	20	N
486	N	<10	1,000	1.0	10	100	300	100	N
490	N	<10	700	1.0	50	50	100	50	N
512	N	<10	50	N	15	50	15	150	N
540	N	<10	2,000	<1.0	N	15	30	30	100
541	N	<10	700	<1.0	N	<10	10	30	70
543	N	<10	500	1.0	7	50	200	30	N

TABLE 5.—*Analyses of selected altered-rock samples, Indian Peaks study area, Colorado*—Continued

Sample	Semiquantitative spectrographic analyses (parts per million)									
	Nb	Ni	Pb	Sc	Sn	Sr	V	W	Y	Zn
R-005	N	30	30	N	N	1,500	N	N	30	N
R-006	N	20	N	15	N	200	150	N	20	N
R-007	N	50	10	15	<10	<100	150	N	<10	<200
R-112	N	50	30	10	15	3,000	100	N	50	N
R-197	N	20	<10	10	N	N	70	N	50	N
R-223	N	70	10	7	N	N	50	N	<10	N
R-249	<20	7	300	10	N	100	70	N	30	<200
R-271	20	5	30	30	N	700	200	N	50	200
017	30	7	100	10	N	300	150	50	20	N
060	N	<5	10	N	10	100	70	N	N	N
065	N	15	20	5	N	<100	30	N	20	N
116	<20	20	15	15	N	<100	150	N	<10	200
154	N	30	15	15	<10	200	150	N	30	N
170	N	20	15	30	N	<100	150	50	30	N
182	N	5	20	<5	N	N	20	N	N	N
185	N	30	10	15	N	N	100	N	30	<200
211	N	7	20	<5	N	150	20	N	10	N
226	<20	15	20	15	N	150	200	N	30	N
256	N	<5	N	<5	N	1,000	150	N	15	N
276	<20	<5	30	5	<10	100	30	N	20	N
286	<20	7	15	15	N	150	150	N	30	<200
287	<20	20	200	10	N	100	50	N	20	300
309	<20	70	20	30	N	N	150	N	50	200
445	<20	20	10	7	<10	<100	70	N	15	N
465	<20	<5	70	5	N	150	30	N	30	500
475	N	<5	20	5	<10	100	30	N	N	N
486	<20	50	N	15	N	200	100	N	70	N
490	N	100	50	20	N	100	200	N	30	300
512	N	30	N	10	<10	100	50	N	50	N
540	N	<5	20	5	N	700	15	N	10	N
541	N	<5	20	<5	10	100	10	N	<10	N
543	<20	5	30	7	N	700	30	N	15	N

TABLE 5.—*Analyses of selected altered-rock samples, Indian Peaks study area, Colorado*—Continued

Sample	Spectrographic	Atomic absorption analyses			Instrumental	Chemical analyses	
	Zr	Au	Te	Zn	Hg	As	Sb
R-005	10	N	--	--	0.60	--	--
R-006	70	N	--	--	.35	--	--
R-007	70	.10	--	--	.04	--	--
R-112	30	N	--	--	N	--	--
R-197	70	.20	--	--	<.02	--	--
R-223	100	N	2.0	30	.30	N	<1
R-249	150	.05	--	--	.06	--	--
R-271	100	N	--	--	.04	--	--
017	150	.10	<.5	70	1.20	120	20
060	300	N	<.5	10	.08	N	<1
065	200	N	N	25	.06	N	<1
116	150	N	.5	240	.02	30	<1
154	150	N	.5	40	.18	N	1
170	100	N	N	500	.02	N	1
182	700	.05	N	5	.02	N	2
185	150	N	N	150	.02	N	2
211	100	N	N	35	.02	N	<1
226	300	N	<.5	150	.06	N	1
256	30	.25	1.0	15	<.02	<10	N
276	150	<.05	--	--	.24	--	--
286	70	.05	--	--	.10	--	--
287	150	N	--	--	.06	--	--
309	100	N	--	--	.04	--	--
445	50	.10	--	--	.16	--	--
465	150	N	--	--	.06	--	--
475	20	.10	--	--	.06	--	--
486	100	N	--	--	.06	--	--
490	200	<.05	--	--	<.02	--	--
512	150	<.05	--	--	.28	--	--
540	70	N	<.5	20	.02	10	<1
541	70	N	N	10	.02	10	4
543	15	N	N	30	<.02	10	3

TABLE 6.—*Analyses of selected mineralized-rock samples, Indian Peaks study area, Colorado*

Sample	North latitude			West longitude			Semiquantitative spectrographic analyses									
							(percent)				(parts per million)					
	D	M	S	D	M	S	Fe	Mg	Ca	Ti	Mn	Ag	As	Au	B	Ba
R-011	40	4	32	105	44	30	7.00	1.50	>20.00	0.003	1,000	20.0	N	N	N	N
R-012	40	4	32	105	44	30	15.00	2.00	7.00	.070	1,500	10.0	N	N	<10	150
R-013	40	4	32	105	44	30	7.00	5.00	20.00	.005	3,000	1,000.0	N	N	<10	30
R-049	40	4	51	105	35	47	3.00	.30	1.00	.200	700	.7	N	N	<10	1,500
R-050	40	4	51	105	35	47	.50	.02	.05	.005	300	.5	N	N	<10	100
R-085	40	8	18	105	37	31	15.00	3.00	<.05	.700	500	N	N	N	2,000	200
R-102	40	9	2	105	31	34	7.00	2.00	15.00	.200	1,500	N	N	N	30	3,000
R-108	40	10	18	105	31	50	15.00	2.00	.15	1.000	500	N	N	N	<10	300
R-110	40	10	14	105	31	36	10.00	.30	2.00	.100	200	.5	N	N	<10	300
R-135	40	9	6	105	40	51	10.00	1.50	.70	.300	1,500	N	N	N	<10	300
R-138	40	9	4	105	41	10	.70	.70	1.00	.200	150	1.0	N	N	<10	300
R-141	40	8	56	105	38	53	10.00	7.00	20.00	.070	5,000	.5	N	N	<10	20
R-142	40	8	55	105	38	53	5.00	7.00	15.00	.020	500	N	N	N	<10	150
R-144	40	8	39	105	38	60	.15	1.50	2.00	.100	>5,000	N	N	N	<10	70
R-148	40	8	3	105	39	55	5.00	.10	2.00	.100	150	.7	N	N	<10	300
R-153	40	6	55	105	42	52	5.00	.50	.10	.150	70	.5	N	N	<10	500
R-158	40	8	40	105	40	54	5.00	1.50	2.00	.200	200	.5	N	N	<10	1,500
R-160	40	8	40	105	40	52	10.00	1.00	.10	.200	200	.7	N	N	<10	300
R-164	40	8	34	105	39	36	7.00	7.00	10.00	.050	3,000	10.0	N	N	20	2,000
R-165	40	8	34	105	39	36	3.00	1.00	.30	.030	5,000	.5	N	N	<10	150
R-166	40	8	34	105	39	36	15.00	.02	<.05	.150	20	3.0	N	N	<10	<20
R-169	40	8	47	105	39	44	5.00	3.00	.30	.150	150	N	N	N	<10	300
R-170	40	8	45	105	39	46	3.00	.70	.50	.300	150	<.5	N	N	<10	700
R-172	40	8	43	105	39	49	3.00	.70	2.00	.100	200	N	N	N	<10	2,000
R-173	40	8	41	105	39	52	3.00	.50	.20	.300	150	N	N	N	<10	700

Sample	Semiquantitative spectrographic analyses (parts per million)												
	Be	Bi	Cd	Co	Cr	Cu	La	Mo	Nb	Ni	Pb	Sb	Sc
R-011	N	N	100	70	N	20,000	N	N	N	100	700	N	N
R-012	3.0	<10	50	10	N	7,000	N	15	N	<5	700	N	<5
R-013	2.0	>1,000	100	7	N	1,000	N	N	N	<5	>20,000	N	N
R-049	1.5	N	N	<5	N	1,000	30	10	N	<5	20	N	5
R-050	<1.0	N	N	15	N	1,000	N	N	N	<5	N	N	N
R-085	5.0	N	N	50	200	1,500	50	N	20	100	N	N	15
R-102	7.0	N	N	5	100	300	200	10	N	20	<10	N	15
R-108	3.0	N	N	30	700	300	20	N	<20	200	10	N	15
R-110	2.0	N	N	70	10	2,000	70	N	<20	70	N	N	5
R-135	N	N	N	5	70	300	30	N	N	7	15	N	10
R-138	1.5	N	N	50	150	1,500	500	N	N	500	70	N	7
R-141	15.0	N	N	7	N	200	30	5	N	<5	50	N	<5
R-142	1.5	N	N	10	10	200	30	N	N	7	N	N	10
R-144	3.0	N	N	5	50	700	20	N	N	7	N	N	10
R-148	1.0	N	N	N	50	300	100	20	N	30	20	N	<5
R-153	1.5	N	N	N	10	300	20	N	N	<5	20	N	5
R-158	5.0	N	N	7	30	150	100	N	20	20	15	N	10
R-160	3.0	N	N	30	50	1,500	20	<5	N	70	20	N	10
R-164	5.0	20	N	10	N	20,000	30	5	N	<5	30	N	<5
R-165	1.0	N	N	<5	N	3,000	N	15	N	<5	N	N	5
R-166	<1.0	N	N	30	N	15	N	5	N	10	N	N	N
R-169	1.0	N	N	7	20	30	20	7	N	50	N	N	7
R-170	1.0	N	N	7	50	100	20	5	N	50	50	N	7
R-172	5.0	N	N	15	10	200	150	5	N	30	30	N	5
R-173	2.0	N	N	5	50	N	20	N	N	15	10	N	10

TABLE 6.—*Analyses of selected mineralized-rock samples, Indian Peaks study area, Colorado*—Continued

Sample	Semiquantitative spectrographic analyses (parts per million)							Atomic absorption analyses			Instru-mental	Chemical analyses	
	Sn	Sr	V	W	Y	Zn	Zr	Au	Te	Zn	Hg	As	Sb
R-011	N	<100	<10	N	<10	>10,000	N	0.20	--	--	0.02	--	--
R-012	10	<100	30	N	50	10,000	10	.10	--	--	.10	--	--
R-013	15	N	N	100	10	>10,000	N	.10	--	--	.02	--	--
R-049	N	700	150	N	15	<200	30	<.05	<.5	70	.04	10	1
R-050	N	N	N	N	N	N	20	<.05	N	20	.02	<10	N
R-085	N	N	200	N	15	700	150	N	--	--	.06	--	--
R-102	N	3,000	70	N	50	N	100	N	--	--	.06	--	--
R-108	N	N	500	N	<10	700	100	.05	--	--	N	--	--
R-110	N	500	20	N	30	N	10	N	--	--	.10	--	--
R-135	N	100	100	N	30	N	100	.10	--	--	.02	--	--
R-138	N	300	70	N	50	N	50	N	--	--	.12	--	--
R-141	N	150	50	N	30	200	20	N	<.5	25	.04	<10	N
R-142	N	<100	100	N	20	<200	10	N	N	110	<.02	10	N
R-144	N	<100	50	N	30	<200	50	N	--	--	.06	--	--
R-148	N	300	50	N	20	N	50	N	--	--	.07	--	--
R-153	N	N	15	N	20	N	100	N	--	--	.10	--	--
R-158	N	300	70	N	30	N	150	.05	--	--	N	--	--
R-160	N	N	150	N	15	N	50	<.05	--	--	.04	--	--
R-164	<10	700	20	N	20	300	N	2.00	2.0	220	.08	10	1
R-165	N	N	10	N	10	N	10	<.05	<.5	65	.02	10	1
R-166	N	N	20	N	10	N	200	N	3.0	10	.02	<10	1
R-169	N	N	70	N	20	N	30	N	1.0	40	<.02	N	N
R-170	N	100	200	N	20	200	70	N	<.5	250	.04	N	N
R-172	N	1,000	50	N	20	<200	50	N	<.5	100	.06	N	N
R-173	N	100	50	N	10	N	30	.05	--	--	.12	--	--

Sample	North latitude			West longitude			Semiquantitative spectrographic analyses									
							(percent)				(parts per million)					
	D	M	S	D	M	S	Fe	Mg	Ca	Ti	Mn	Ag	As	Au	B	Ba
R-175	40	8	24	105	39	55	7.00	2.00	10.00	0.200	1,500	1.0	N	N	10	70
R-176	40	8	21	105	39	55	10.00	1.50	.50	.300	1,500	N	N	N	10	70
R-185	39	58	10	105	38	20	15.00	.70	10.00	.100	200	1.0	N	N	<10	50
R-188	39	58	41	105	38	24	5.00	.30	7.00	.070	150	1.0	N	N	<10	1,500
R-196	40	2	37	105	38	36	5.00	1.00	.05	.700	150	.7	N	N	<10	700
R-198	40	2	24	105	38	41	7.00	1.50	.15	.700	1,000	<.5	N	N	<10	700
R-199	40	2	24	105	38	41	3.00	1.00	.10	.200	500	N	N	N	<10	500
R-201	40	2	16	105	38	33	7.00	1.50	.30	.500	300	N	N	N	<10	500
R-203	40	2	15	105	38	36	1.50	.10	.05	.007	50	1.5	N	N	<10	300
R-205	40	2	16	105	39	8	5.00	.70	.05	.500	100	N	N	N	<10	1,500
R-209	40	10	8	105	40	55	5.00	.10	2.00	.030	100	.7	N	N	<10	300
R-210	40	10	8	105	40	55	10.00	.30	1.50	.300	150	.5	N	N	<10	2,000
R-230	40	0	41	105	42	8	10.00	.70	.05	.700	500	N	N	N	20	500
R-259	40	8	48	105	42	42	5.00	.30	20.00	.300	100	.7	N	N	<10	500
R-260	40	8	48	105	42	42	10.00	.10	15.00	.020	20	.7	N	N	<10	300
R-261	40	8	48	105	42	42	2.00	1.50	7.00	.150	150	3.0	N	N	<10	200
002	39	56	6	105	38	30	2.00	.20	.10	.150	50	N	N	N	N	300
003	39	56	18	105	38	51	20.00	.10	<.05	.050	50	5.0	N	15	N	100
005	39	57	8	105	37	40	3.00	.20	<.05	.300	30	N	N	N	N	700
013	39	56	49	105	36	47	.50	.20	<.05	.100	20	10.0	N	<10	50	2,000
014	39	56	52	105	36	53	10.00	.30	.10	.150	150	100.0	1,500	N	15	700
016	39	56	2	105	37	2	3.00	.15	.10	.150	100	.7	700	<10	20	1,000
018	39	56	55	105	37	3	3.00	.15	.07	.100	50	<.5	200	N	15	700
019	39	57	22	105	37	32	5.00	.30	1.00	.200	700	<.5	200	N	10	1,000
020	39	57	25	105	37	35	3.00	<.02	.07	.200	20	N	700	N	10	1,500

TABLE 6.—*Analyses of selected mineralized-rock samples, Indian Peaks study area, Colorado*—Continued

Sample	Semiquantitative spectrographic analyses (parts per million)												
	Be	Bi	Cd	Co	Cr	Cu	La	Mo	Nb	Ni	Pb	Sb	Sc
R-175	2.0	N	N	10	30	300	30	N	N	50	30	N	15
R-176	30.0	N	N	10	30	70	50	N	<20	7	10	N	15
R-185	2.0	N	N	20	N	3,000	50	N	N	70	N	N	10
R-188	3.0	N	N	7	20	3,000	200	N	N	70	10	N	7
R-196	1.0	N	N	5	100	5	50	N	20	50	10	N	20
R-198	2.0	N	N	20	100	3,000	70	<5	20	50	10	N	20
R-199	<1.0	N	N	20	30	15	20	70	N	20	N	N	15
R-201	<1.0	N	N	20	150	7,000	100	5	<20	70	30	N	20
R-203	N	N	N	<5	N	7,000	N	N	N	20	<10	N	N
R-205	N	N	N	5	100	700	150	N	N	50	30	N	7
R-209	5.0	N	N	10	N	300	70	N	N	30	70	N	N
R-210	<1.0	N	N	5	100	30	70	N	N	15	30	N	10
R-230	1.5	N	N	15	150	N	70	N	20	50	30	N	30
R-259	<1.0	N	N	5	50	10,000	50	N	N	10	10	N	7
R-260	1.0	N	N	5	10	20,000	20	N	N	7	<10	N	5
R-261	<1.0	N	N	7	20	7,000	N	N	N	7	N	N	15
002	<1.0	N	N	N	10	5	100	N	N	5	<10	N	7
003	<1.0	N	N	15	<10	5,000	N	15	N	20	70	N	7
005	<1.0	N	N	N	50	10	200	5	<20	<5	<10	N	10
013	2.0	N	N	<5	N	30	70	200	30	7	700	200	20
014	3.0	N	<20	50	N	3,000	150	100	50	7	3,000	2,000	5
016	1.0	N	N	5	20	50	50	15	<20	10	70	<100	15
018	1.5	N	N	7	<10	15	70	20	20	10	15	<100	7
019	2.0	N	N	10	20	200	150	10	<20	20	30	<100	15
020	2.0	N	N	5	15	30	100	10	N	15	10	<100	7

Sample	Semiquantitative spectrographic analyses (parts per million)							Atomic absorption analyses			Instrumental	Chemical analyses	
	Sn	Sr	V	W	Y	Zn	Zr	Au	Te	Zn	Hg	As	Sb
R-175	N	150	100	N	30	300	70	N	--	--	0.10	--	--
R-176	N	N	70	N	30	200	100	N	--	--	.04	--	--
R-185	N	700	30	N	50	N	150	.10	--	--	.30	--	--
R-188	N	2,000	50	N	30	N	N	<.05	--	--	.06	--	--
R-196	<10	N	100	N	20	N	100	.15	--	--	<.02	--	--
R-198	N	100	100	N	30	N	150	N	<.5	70	.02	<10	1
R-199	N	N	50	N	10	N	50	N	N	40	.10	10	1
R-201	<10	N	150	N	50	200	100	.10	--	--	.02	--	--
R-203	N	N	N	N	<10	N	N	.10	--	--	.02	--	--
R-205	N	200	70	N	20	N	50	<.05	--	--	.08	--	--
R-209	N	500	N	N	30	N	30	N	--	--	.06	--	--
R-210	10	300	100	N	20	300	150	N	--	--	<.02	--	--
R-230	20	N	150	N	15	200	100	N	--	--	.04	--	--
R-259	N	100	50	N	30	N	100	N	<.5	30	<.02	N	N
R-260	N	N	20	N	<10	N	10	N	<.5	5	.10	<10	N
R-261	N	100	70	N	30	N	30	N	.5	45	.02	N	N
002	N	150	30	N	30	N	100	.10	<.5	15	.06	N	1
003	N	N	15	50	10	N	20	30.00	1.0	200	.20	10	1
005	N	150	100	N	30	N	150	.05	<.5	5	.16	10	7
013	N	500	2,000	N	<10	N	150	3.50	5.0	60	2.50	20	200
014	N	300	100	<50	20	500	200	.30	1.0	800	>10.00	1,600	2,000
016	N	N	700	100	10	N	150	7.50	6.5	100	7.00	800	40
018	N	300	150	<50	15	N	100	.10	1.5	40	1.50	400	20
019	N	500	100	N	50	N	200	.05	<.5	140	4.00	200	35
020	N	3,000	150	70	30	N	150	.05	<.5	10	1.30	300	40

TABLE 6.—*Analyses of selected mineralized-rock samples, Indian Peaks study area, Colorado*—Continued

Sample	North latitude			West longitude			Semiquantitative spectrographic analyses									
							(percent)				(parts per million)					
	D	M	S	D	M	S	Fe	Mg	Ca	Ti	Mn	Ag	As	Au	B	Ba
021	39	57	25	105	37	35	2.00	0.70	1.50	0.150	300	N	N	N	N	1,500
023	39	57	22	105	37	43	7.00	.03	.05	.150	30	N	N	N	N	700
024	39	57	21	105	37	40	7.00	1.00	1.50	.200	500	N	N	N	N	700
025	39	57	21	105	37	40	10.00	.20	.15	.300	30	N	200	N	<10	1,500
026	39	57	26	105	37	42	1.00	.15	.50	.100	100	N	<200	N	N	1,000
027	39	57	29	105	37	45	7.00	1.00	2.00	.700	300	N	N	N	N	1,000
029	39	57	24	105	37	46	15.00	1.50	7.00	.015	500	<.5	700	N	<10	200
030	39	57	28	105	37	49	10.00	7.00	7.00	.700	700	<.5	N	N	<10	500
039	39	56	21	105	36	56	1.50	.03	.15	.200	100	N	N	N	N	500
040	39	56	47	105	37	8	3.00	.03	.05	.100	150	1.0	500	N	N	200
042	39	56	37	105	37	60	1.50	.10	<.05	.050	30	.5	N	N	N	2,000
049	39	59	50	105	38	31	10.00	1.50	1.00	.300	700	<.5	N	N	N	300
054	40	0	39	105	39	32	2.00	.10	5.00	.020	100	300.0	N	N	N	300
055	40	0	39	105	39	32	1.50	.30	1.00	.300	70	.7	N	N	N	30
056	40	0	39	105	39	32	7.00	.20	1.50	.070	150	3.0	N	N	<10	50
057	40	0	39	105	39	32	7.00	1.00	.20	.100	1,500	N	N	N	20	200
061	39	37	5	105	57	32	3.00	.70	.10	.200	100	N	N	N	N	500
066	39	56	57	105	37	6	2.00	.05	.07	.070	30	7.0	1,000	30	N	300
067	39	56	57	105	37	6	20.00	.70	1.50	.010	2,000	10.0	N	N	N	200
069	39	56	52	105	37	16	1.50	.10	7.00	.070	100	1.0	500	N	N	500
070	39	56	52	105	37	16	.70	.07	7.00	.070	20	1.5	500	N	N	700
071	39	56	55	105	37	31	7.00	1.00	7.00	.070	2,000	<.5	N	N	10	1,000
072	39	56	56	105	37	34	10.00	1.00	.50	.100	5,000	N	700	N	15	700
073	39	56	57	105	37	31	5.00	1.50	7.00	.030	2,000	N	N	N	10	700
074	39	56	57	105	37	31	7.00	.70	1.50	.150	500	.5	N	N	<10	2,000

Sample	Semiquantitative spectrographic analyses (parts per million)											
	Be	Bi	Cd	Co	Cr	Cu	La	Mo	Nb	Ni	Pb	Sb	Sc
021	1.0	N	N	7	<10	7	70	50	N	10	50	N	7
023	<1.0	N	N	15	10	5	30	30	N	15	10	N	5
024	1.5	N	N	15	15	5	70	N	20	10	N	N	15
025	1.0	N	N	15	15	15	150	15	N	20	30	<100	15
026	N	N	N	N	N	7	100	N	N	<5	15	N	7
027	<1.0	N	N	30	N	15	150	N	20	5	10	N	20
029	1.0	N	N	30	N	7	70	N	N	30	30	N	5
030	N	N	N	70	500	70	N	N	N	150	N	N	20
039	2.0	N	N	N	N	15	150	N	50	<5	N	N	5
040	2.0	N	N	N	N	15	150	10	<20	7	15	<100	7
042	1.5	N	N	N	<10	20	20	10	N	<5	50	N	<5
049	<1.0	N	N	50	70	700	30	N	20	70	15	N	15
054	N	15	100	20	N	20,000	N	N	N	10	20,000	<100	5
055	1.0	N	N	30	30	15	70	5	N	15	100	N	10
056	N	N	N	100	N	3,000	N	N	N	20	300	N	15
057	2.0	N	N	15	70	7	150	N	N	30	10	N	7
061	<1.0	N	N	N	30	7	20	5	20	10	15	N	10
066	2.0	N	N	<5	N	20	70	5	20	15	15	<100	15
067	1.5	N	<20	30	N	15,000	150	N	N	30	100	N	5
069	3.0	N	N	5	N	50	70	10	<20	10	15	100	N
070	3.0	N	N	N	N	30	70	50	<20	<5	20	100	10
071	2.0	N	N	10	N	15	70	N	20	10	10	N	5
072	5.0	N	N	30	<10	20	100	N	<20	30	20	<100	30
073	2.0	N	N	15	<10	10	30	N	N	15	15	<100	7
074	1.5	N	N	30	N	20	70	30	20	20	15	N	7

TABLE 6.—*Analyses of selected mineralized-rock samples, Indian Peaks study area, Colorado*—Continued

Sample	Semiquantitative spectrographic analyses (parts per million)							Atomic absorption analyses			Instrumental	Chemical analyses	
	Sn	Sr	V	W	Y	Zn	Zr	Au	Te	Zn	Hg	As	Sb
021	N	700	70	<50	15	N	150	0.10	<0.5	70	0.18	20	1
023	N	200	20	N	15	N	200	.15	.5	10	.08	N	1
024	N	500	150	N	30	N	150	N	.5	55	.08	N	<1
025	N	300	150	N	30	N	300	.50	.5	<5	.60	100	25
026	N	300	30	N	20	N	N	.10	.5	10	.02	10	<1
027	N	700	150	N	70	N	200	.05	<.5	40	.08	10	<1
029	N	<100	20	N	30	N	50	2.00	1.5	45	3.00	600	2
030	N	300	150	N	30	N	150	.05	<.5	45	.02	N	<1
039	N	300	50	N	15	N	150	<.05	N	30	.45	10	2
040	N	200	150	70	15	N	50	2.50	<.5	100	1.00	300	30
042	N	150	30	N	N	N	30	.30	.5	10	.26	30	3
049	N	150	150	N	15	N	150	N	<.5	100	.06	N	1
054	N	150	20	N	N	3,000	10	7.00	N	6,000	>10.00	120	40
055	N	N	70	N	15	N	200	.05	N	120	.26	N	<1
056	N	N	150	N	N	700	50	.05	N	1,400	2.50	10	2
057	N	N	70	N	20	N	200	.05	.5	75	.08	N	<1
061	N	100	70	N	N	N	200	.10	.5	20	.06	N	<1
066	N	150	1,500	N	10	N	50	53.00	7.5	55	>10.00	1,600	25
067	N	100	50	N	15	1,500	N	.40	.5	2,500	.26	80	9
069	N	300	300	N	30	N	50	1.00	4.0	70	>10.00	300	20
070	N	300	700	N	15	N	100	3.00	4.0	20	5.00	400	45
071	N	100	70	N	20	N	70	.05	N	170	.60	N	1
072	N	150	200	50	50	700	100	.30	<.5	1,000	.28	600	8
073	N	100	70	N	20	700	10	.05	<.5	1,000	.50	60	2
074	N	300	70	<50	30	N	150	.05	.5	45	.08	<10	4

Sample	North latitude			West longitude			Semiquantitative spectrographic analyses									
							(percent)				(parts per million)					
	D	M	S	D	M	S	Fe	Mg	Ca	Ti	Mn	Ag	As	Au	B	Ba
075	39	56	57	105	37	31	7.00	0.50	0.20	0.300	150	0.7	700	N	30	1,500
077	39	56	53	105	37	44	10.00	1.00	<.05	.100	20	1.5	N	N	10	200
078	39	57	34	105	37	18	7.00	.50	<.05	.100	50	3.0	N	N	<10	1,000
110	39	59	7	105	39	40	5.00	.02	.20	.030	20	N	N	N	<10	20
140	40	0	42	105	39	45	7.00	.03	<.05	.070	100	N	N	N	<10	30
158	39	58	24	105	40	48	7.00	.30	.15	.200	150	15.0	N	N	20	70
166	39	58	51	105	36	38	7.00	3.00	.30	.300	500	<.5	N	N	15	300
180	39	59	23	105	36	37	3.00	<.02	<.05	.010	30	5.0	N	N	<10	3,000
181	39	59	24	105	36	42	7.00	.07	<.05	.100	500	3.0	N	N	<10	1,000
191	40	0	24	105	36	8	5.00	.15	.10	.150	70	50.0	N	N	10	150
193	39	59	58	105	35	35	3.00	.30	10.00	.070	1,000	20.0	N	N	<10	300
219	40	2	26	105	36	10	10.00	1.00	.05	.150	150	15.0	N	N	<10	500
220	40	2	26	105	36	10	1.00	.03	<.05	.020	20	.5	N	N	N	100
234	40	0	44	105	39	41	2.00	.50	.10	.300	150	20.0	N	N	N	3,000
240	40	4	16	105	37	47	3.00	.30	N	.200	50	N	N	N	<10	700
242	40	4	18	105	37	23	3.00	.20	N	.200	20	N	N	N	<10	500
252	40	8	16	105	37	54	2.00	.20	.10	.070	100	N	N	N	<10	300
253	40	8	8	105	37	46	7.00	3.00	.20	.700	1,000	N	N	N	<10	500
258	40	5	17	105	36	0	7.00	1.50	7.00	.300	700	N	N	N	<10	1,000
261	40	8	22	105	37	44	2.00	.30	.10	.200	100	1.5	N	N	<10	700
263	40	5	56	105	37	12	2.00	.02	N	.010	20	1.0	N	N	<10	100
266	40	6	44	105	36	26	3.00	.05	N	.007	15	15.0	N	N	<10	70
311	40	1	46	105	42	11	10.00	1.50	7.00	.300	700	1.0	N	N	30	1,500
313	40	1	45	105	44	30	7.00	1.50	15.00	.300	1,500	N	N	N	<10	500
314	40	1	45	105	44	30	10.00	2.00	15.00	.200	2,000	N	N	N	<10	300

TABLE 6.—*Analyses of selected mineralized-rock samples, Indian Peaks study area, Colorado*—Continued

Sample	Semiquantitative spectrographic analyses (parts per million)											
	Be	Bi	Cd	Co	Cr	Cu	La	Mo	Nb	Ni	Pb	Sb	Sc
075	3.0	N	N	7	50	30	150	10	50	15	20	N	15
077	3.0	N	N	20	N	15	70	10	N	20	300	<100	5
078	1.0	N	N	N	<10	10	300	15	N	<5	15	N	10
110	1.0	N	N	N	N	200	N	N	N	5	N	N	7
140	<1.0	N	N	30	<10	10	N	N	N	30	N	N	5
158	2.0	N	N	20	100	70	100	15	<20	30	5,000	N	20
166	3.0	N	N	15	70	<5	700	500	N	30	30	N	15
180	N	N	N	N	<10	1,000	N	70	N	5	3,000	N	<5
181	1.0	N	N	N	10	700	50	100	N	5	3,000	N	10
191	2.0	70	N	N	<10	100	100	30	N	10	1,000	N	10
193	<1.0	N	N	5	<10	150	20	N	N	5	70	N	5
219	7.0	15	N	N	50	100	150	30	N	15	1,000	N	5
220	<1.0	N	N	N	N	10	150	100	N	<5	15	N	<5
234	1.0	20	N	N	50	15,000	70	15	N	15	2,000	N	10
240	1.0	N	N	N	N	N	100	5	<20	<5	10	N	5
242	<1.0	N	N	N	N	N	70	30	N	<5	<10	N	5
252	<1.0	N	N	N	N	50	50	N	N	<5	50	N	N
253	1.5	N	N	<5	100	30	70	N	20	5	20	N	20
258	1.0	N	N	7	50	150	30	N	N	15	10	N	15
261	<1.0	N	N	N	N	10	200	10	N	<5	70	N	5
263	<1.0	15	N	N	N	1,500	30	7	N	<5	300	N	N
266	<1.0	10	N	N	N	50	N	70	N	<5	50	N	N
311	<1.0	N	N	20	20	2,000	50	N	N	20	700	N	15
313	1.5	N	N	20	70	1,500	50	N	<20	70	10	N	20
314	<1.0	N	N	20	30	1,000	30	5	N	70	10	N	15

Sample	Semiquantitative spectrographic analyses (parts per million)							Atomic absorption analyses			Instrumental	Chemical analyses	
	Sn	Sr	V	W	Y	Zn	Zr	Au	Te	Zn	Hg	As	Sb
075	N	1,000	300	50	30	N	150	5.00	4.0	55	9.00	800	30
077	N	2,000	20	<50	20	N	100	1.50	.5	15	1.30	10	6
078	10	N	70	N	70	N	150	.70	3.0	10	.04	20	3
110	N	N	70	N	N	N	N	N	N	15	.04	20	<1
140	N	N	30	N	10	300	150	N	N	300	.08	N	<1
158	N	150	100	N	50	200	150	N	N	270	.24	30	20
166	15	150	100	N	100	N	150	N	N	45	.02	N	1
180	N	150	30	N	10	N	10	15.00	N	130	1.60	N	2
181	N	N	70	<50	30	N	150	7.00	<.5	110	.08	N	2
191	N	N	70	<50	15	N	100	2.00	5.0	25	.06	N	2
193	N	500	30	N	15	<200	30	.20	1.0	170	.75	<10	1
219	N	N	50	<50	10	200	10	.30	N	450	.04	N	1
220	N	N	10	N	10	N	15	.10	<.5	20	.02	N	<1
234	N	N	100	N	20	N	150	.25	N	20	.04	N	2
240	10	N	50	N	20	N	150	N	N	<5	.28	N	N
242	10	N	70	N	20	N	100	N	N	<5	N	N	N
252	N	N	100	N	10	N	50	<.05	1.0	30	<.02	N	<1
253	N	N	150	N	20	<200	100	N	.5	160	.06	<10	N
258	N	500	150	N	20	N	50	N	.5	100	.31	<10	2
261	N	150	150	N	20	N	30	.30	2.0	25	.08	10	N
263	N	N	100	N	N	N	N	1.00	10.0	35	.02	10	2
266	N	N	20	N	N	N	N	1.50	10.0	40	.04	20	<1
311	N	150	150	N	20	300	50	N	--	--	.02	--	--
313	N	200	150	N	50	<200	100	N	.5	70	.10	N	N
314	N	150	100	N	20	200	70	N	1.0	70	.10	N	<1

TABLE 6.—*Analyses of selected mineralized-rock samples, Indian Peaks study area, Colorado*—Continued

Sample	North latitude			West longitude			Semiquantitative spectrographic analyses									
							(percent)				(parts per million)					
	D	M	S	D	M	S	Fe	Mg	Ca	Ti	Mn	Ag	As	Au	B	Ba
315	40	1	43	105	41	50	7.00	0.05	N	0.150	20	1.0	N	N	<10	300
316	40	1	42	105	44	15	10.00	2.00	15.00	.150	2,000	<.5	N	N	<10	300
317	40	1	32	105	44	16	5.00	2.00	7.00	.300	700	15.0	N	N	20	200
354	40	8	41	105	42	51	2.00	.10	.30	.150	20	1,500.0	N	N	<10	2,000
355	40	8	41	105	42	51	3.00	<.02	.15	.030	15	1.0	N	N	<10	30
376	40	9	47	105	43	21	1.00	.07	.05	.070	15	<.5	N	N	<10	50
377	40	9	44	105	43	17	1.50	.30	.70	.070	150	10.0	N	N	<10	30
378	40	9	44	105	43	17	1.50	.30	.70	.300	100	15.0	N	N	<10	50
380	40	9	34	105	43	5	3.00	1.50	2.00	.150	150	3.0	N	N	<10	20
432	40	1	3	105	40	26	7.00	.02	N	.100	10	N	N	N	<10	<20
435	40	1	20	105	40	40	15.00	2.00	1.00	.100	>5,000	N	N	N	<10	100
436	40	1	20	105	40	40	20.00	1.50	1.00	.200	>5,000	N	N	N	<10	300
437	40	1	20	105	40	40	15.00	1.00	1.00	.070	>5,000	N	N	N	<10	70
441	40	1	27	105	40	39	15.00	1.50	1.50	.100	>5,000	N	N	N	<10	<20
484	40	7	7	105	37	3	.15	.02	.05	.005	10	N	N	N	<10	50
488	40	6	18	105	35	58	7.00	.50	10.00	.100	150	<.5	N	N	<10	500
496	40	9	45	105	43	17	2.00	.20	.50	.300	150	.7	N	N	<10	100
498	40	9	44	105	43	16	5.00	1.50	5.00	.300	200	1.5	N	N	<10	70
499	40	9	44	105	43	16	2.00	1.00	5.00	.300	150	7.0	N	N	<10	30
500	40	9	44	105	43	16	3.00	1.00	3.00	.200	150	15.0	N	N	<10	70
501	40	9	44	105	43	16	5.00	1.50	7.00	.700	150	15.0	N	N	<10	50
502	40	9	44	105	43	16	5.00	1.50	7.00	.500	150	10.0	N	N	<10	30
503	40	9	44	105	43	16	10.00	2.00	15.00	.300	500	5.0	N	N	<10	100
504	40	9	45	105	43	17	2.00	.70	.70	.200	150	7.0	N	N	<10	50
506	40	9	37	105	43	9	10.00	.20	7.00	.700	700	1.5	N	N	15	150

Sample	Semiquantitative spectrographic analyses (parts per million)												
	Be	Bi	Cd	Co	Cr	Cu	La	Mo	Nb	Ni	Pb	Sb	Sc
315	N	N	N	15	10	1,500	50	N	N	50	N	N	<5
316	<1.0	N	N	50	50	1,000	20	30	N	70	20	N	15
317	1.0	N	N	20	700	50	50	N	N	500	700	N	20
354	<1.0	<10	N	100	N	>20,000	200	N	N	20	1,500	N	<5
355	<1.0	N	N	N	N	150	N	N	N	<5	<10	N	N
376	<1.0	N	N	N	N	10	N	30	N	<5	N	N	N
377	<1.0	N	N	<5	N	7,000	20	N	N	<5	<10	N	<5
378	<1.0	N	N	<5	30	>20,000	20	N	N	5	<10	N	7
380	<1.0	N	N	5	50	7,000	50	N	N	7	N	N	7
432	N	N	N	1,000	N	N	N	N	N	50	N	N	N
435	<1.0	N	N	5	20	1,000	20	N	N	5	N	N	5
436	<1.0	N	N	5	50	1,500	30	N	N	<5	N	N	10
437	1.0	N	N	5	30	3,000	100	N	N	5	N	N	10
441	<1.0	N	N	30	50	1,500	30	7	N	50	N	N	10
484	<1.0	N	N	N	N	N	N	N	N	<5	N	N	N
488	3.0	N	N	7	50	2,000	>1,000	N	N	50	10	N	5
496	<1.0	N	N	5	15	2,000	100	N	N	5	<10	N	5
498	<1.0	N	N	7	30	2,000	70	N	N	7	N	N	10
499	<1.0	N	N	<5	20	10,000	N	N	N	5	N	N	10
500	<1.0	N	N	5	30	>20,000	20	N	N	10	<10	N	7
501	<1.0	N	N	10	70	>20,000	70	N	N	20	N	N	15
502	<1.0	N	N	10	100	20,000	20	N	N	20	N	N	15
503	<1.0	N	N	15	70	10,000	50	N	N	30	10	N	15
504	<1.0	N	N	5	50	10,000	30	N	N	10	N	N	5
506	2.0	N	N	15	N	3,000	50	N	N	20	<10	N	10

TABLE 6.—*Analyses of selected mineralized-rock samples, Indian Peaks study area, Colorado*—Continued

Sample	Semiquantitative spectrographic analyses (parts per million)							Atomic absorption analyses			Instru-mental	Chemical analyses	
	Sn	Sr	V	W	Y	Zn	Zr	Au	Te	Zn	Hg	As	Sb
315	N	N	50	N	10	N	30	<0.05	--	--	0.35	--	--
316	N	150	100	N	20	200	70	N	1.0	85	.28	N	1
317	N	150	100	N	15	3,000	100	N	N	3,400	.12	<10	N
354	N	N	<10	N	N	200	N	N	N	320	.02	10	N
355	N	N	30	N	N	N	10	N	N	10	.02	N	N
376	N	N	10	N	N	N	20	N	.5	5	N	10	N
377	N	N	15	N	10	N	30	<.05	<.5	30	N	10	N
378	N	N	30	N	30	N	70	.10	3.0	25	.02	N	N
380	N	<100	50	N	20	N	50	N	<.5	50	<.02	<10	2
432	N	N	N	N	20	N	200	N	<.5	5	.55	100	2
435	N	N	50	N	30	N	50	N	<.5	20	.04	N	1
436	N	N	70	N	20	N	70	N	1.0	30	.02	<10	2
437	N	N	30	N	30	N	150	N	1.0	110	.04	<10	N
441	N	N	50	N	30	N	100	N	1.0	25	.20	N	1
484	N	N	N	N	N	N	N	.05	<.5	5	.04	10	N
488	N	5,000	20	N	100	N	N	N	<.5	20	.14	10	<1
496	<10	100	30	N	10	N	100	<.05	--	--	<.02	--	--
498	<10	<100	50	N	30	N	150	N	N	30	<.02	N	N
499	<10	<100	50	N	15	N	50	N	<.5	20	.02	10	N
500	N	<100	30	N	20	N	50	<.05	1.0	25	.22	10	N
501	10	<100	70	N	50	N	70	<.05	.5	40	.04	10	N
502	<10	<100	70	N	50	N	100	N	1.0	35	.10	10	<1
503	<10	<100	100	N	20	N	70	<.05	2.0	90	.06	10	2
504	N	N	30	N	30	N	100	N	<.5	25	.06	30	N
506	N	<100	100	N	20	N	10	<.05	N	30	.08	10	N

Sample	North latitude			West longitude			Semiquantitative spectrographic analyses									
							(percent)				(parts per million)					
	D	M	S	D	M	S	Fe	Mg	Ca	Ti	Mn	Ag	As	Au	B	Ba
510	40	9	35	105	43	5	3.00	0.50	0.15	0.300	150	3.0	N	N	<10	70
513	40	9	34	105	43	4	3.00	1.50	1.00	.300	150	3.0	N	N	<10	50
514	40	9	34	105	43	4	3.00	.50	1.50	.300	150	.5	N	N	<10	70
515	40	9	34	105	43	4	1.50	.30	.50	.150	30	.7	N	N	<10	20
526	40	9	45	105	43	17	3.00	.50	.70	.300	150	3.0	N	N	<10	70
529	40	1	26	105	41	34	1.50	.05	<.05	.020	100	3.0	N	N	<10	1,000
530	40	1	25	105	41	35	5.00	7.00	20.00	.200	1,000	5.0	N	N	10	300
531	40	1	23	105	41	36	15.00	.70	.50	1.000	1,000	N	N	N	150	300
532	40	1	30	105	41	40	5.00	5.00	15.00	.070	700	3.0	N	N	<10	1,000
533	40	1	33	105	41	47	5.00	.70	.15	.300	300	5.0	N	N	15	1,000
534	40	1	33	105	41	47	15.00	1.00	.20	.200	200	2.0	N	N	<10	500
535	40	1	33	105	41	47	10.00	10.00	15.00	.700	1,500	.7	N	N	30	1,500
542	40	7	18	105	35	32	1.50	.15	<.05	.070	30	N	N	N	<10	300
545	40	3	12	105	37	27	1.50	.30	.15	.070	150	30.0	N	N	<10	300
550	40	4	3	105	32	53	5.00	.02	<.05	.015	50	5.0	N	15	<10	70
551	40	3	30	105	33	7	5.00	.20	<.05	.030	70	N	N	N	<10	500
553	40	3	18	105	34	50	.20	.02	<.05	.005	20	N	N	N	<10	70
560	40	3	18	105	37	39	3.00	1.00	.10	.300	200	5.0	N	N	<10	500
561	39	58	42	105	38	14	>20.00	.70	<.05	>1.000	500	N	N	N	N	150

TABLE 6.—*Analyses of selected mineralized-rock samples, Indian Peaks study area, Colorado*—Continued

Sample	Semiquantitative spectrographic analyses (parts per million)												
	Be	Bi	Cd	Co	Cr	Cu	La	Mo	Nb	Ni	Pb	Sb	Sc
510	<1.0	N	N	10	50	5,000	30	N	N	15	N	N	7
513	<1.0	N	N	7	70	10,000	50	N	N	15	N	N	7
514	<1.0	N	N	10	50	300	50	N	N	15	N	N	10
515	<1.0	N	N	<5	30	2,000	50	N	N	5	N	N	7
526	<1.0	N	N	5	30	5,000	30	N	N	7	N	N	7
529	N	N	N	N	20	N	N	N	N	<5	3,000	N	N
530	1.0	N	N	15	150	7,000	30	N	N	50	20	N	15
531	7.0	N	N	50	200	20	30	7	N	150	20	N	20
532	<1.0	N	N	15	20	100	20	N	N	30	70	N	7
533	<1.0	N	N	10	100	5	50	N	<20	30	300	N	10
534	1.0	N	N	10	50	3,000	30	N	N	10	N	N	5
535	1.0	N	N	30	500	100	150	N	N	500	30	N	15
542	<1.0	N	N	N	<10	5	N	100	N	<5	N	N	<5
545	1.0	700	N	5	10	50	150	5	N	7	200	N	<5
550	<1.0	15	N	N	<10	200	N	15	N	<5	10	N	N
551	1.5	N	N	N	<10	15	20	N	N	7	<10	N	<5
553	N	N	N	N	<10	<5	30	700	N	<5	200	N	N
560	<1.0	<10	N	7	10	300	150	15	<20	5	30	N	<5
561	N	N	N	30	5,000	100	70	N	N	150	N	N	15

Sample	Semiquantitative spectrographic analyses (parts per million)							Atomic absorption analyses			Instrumental	Chemical analyses	
	Sn	Sr	V	W	Y	Zn	Zr	Au	Te	Zn	Hg	As	Sb
510	N	N	30	N	20	N	100	<0.05	N	30	<0.02	10	2
513	N	N	50	N	30	N	70	<.05	<.5	45	3.00	10	N
514	N	N	50	N	10	N	30	<.05	N	30	.04	<10	N
515	N	N	15	N	15	N	10	<.05	N	10	.14	10	N
526	N	<100	30	N	30	N	50	<.05	N	35	.02	10	N
529	N	N	N	N	N	200	100	<.05	N	370	.06	<10	1
530	N	200	100	N	30	N	70	<.05	.5	180	.06	80	2
531	N	N	200	N	30	700	100	<.05	N	500	.02	20	2
532	N	200	100	N	15	<200	30	N	N	190	.04	10	<1
533	N	N	70	N	20	200	200	N	N	260	.10	10	2
534	10	N	150	N	50	N	150	<.05	N	180	.04	N	2
535	N	200	150	N	30	200	150	<.05	N	190	.02	20	N
542	15	N	20	N	<10	N	100	N	N	<5	.02	10	N
545	30	100	20	N	20	N	70	N	.5	85	.02	10	<1
550	N	N	<10	N	N	N	10	16.00	10.0	25	.04	10	<1
551	N	N	10	N	50	N	50	N	.5	20	N	N	2
553	N	N	<10	N	N	N	10	N	N	10	<.02	N	N
560	<10	<100	200	N	50	N	200	N	.5	35	N	<10	1
561	N	N	>1,000	N	N	1,500	500	N	.5	180	.02	10	1

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