Geology and Uranium Deposits of the Caribou Area, Boulder County Colorado

GEOLOGICAL SURVEY BULLETIN 1030-N

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By F. B. MOORE, W. S. CAVENDER, *and* E. P. KAISER

CONTRIBUTIONS TO THE GEOLOGY OF URANIUM

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GEOLOGY AND URANIUM DEPOSITS OF THE CARIBOU AREA, BOULDER COUNTY, COLORADO

By F. B. Moore, W. S. Cavender, and E. P. Kaiser

ABSTRACT

The Caribou silver-mining area is underlain by schists and gneisses of the Idaho Springs formation and the Boulder Creek granite, both units of Precambrian age, and monzonite of Tertiary(?) age. Most of the uranium occurs in mesothermal lead-silver veins which cut the monzonite in an area less than a half mile square; a few lead-silver veins and a few gold veins occur in the Idaho Springs formation but are relatively unimportant. The total value of metals produced from the area is estimated to be about $6,000,000.

The lead-silver deposits occur in two sets of interconnecting fractures: (1) a northeast-striking series of shear fractures which parallel the regional trend, and (2) a west-striking series of tension fractures. The deposits occur in shoots localized chiefly at junctions of veins occupying the fractures but to a lesser extent where strike and dip of the fractures change. Few of the veins have been worked to depths of more than 300 feet.

In the Caribou area pitchblende in quantities of more than trace amounts has been found only in the Radium vein in two ore shoots at depths between 900 and 1,140 feet. The larger shoot has a horizontal dimension of 75 feet along the vein and extends from the 920 level to the 1140 level; the smaller shoot has a horizontal dimension of 35 feet along the vein and extends upwards 70 feet from the 1040 level. In both shoots pitchblende occurs in a ⅛ to 6-inch-wide streak along the footwall side of the vein. Most of the pitchblende is soft and sooty, but in places sooty pitchblende encloses small quantities of a hard botryoidal pitchblende. Silver, lead, zinc, and carbonate minerals are in contact with but are not intermixed with the pitchblende. There is no apparent difference in mineralogy, other than the presence of pitchblende, between the uranium-bearing veins and other lead-silver veins at Caribou.

INTRODUCTION

Pitchblende was discovered in the Caribou mine of the Consolidated Caribou Silver Mines, Inc., in Boulder County, Colo., during the reopening of the 1040 level in 1948. Since then a small quantity of pitchblende has been produced from the Radium vein in this mine during exploratory work that was done under contract with the U. S. Atomic Energy Commission. The underground workings of the present Caribou mine, primarily a silver mine, expose five veins, the Caribou, No Name, Poorman, Sherman, and Silver Dollar, that formerly were worked through separate shafts. Three other veins, the Radium, Elmer, and Nelson, are exposed only in the Caribou mine at and below the 920 level.

The general geology of the Caribou area has been discussed by Bastin (1917) and more recently by Lovering and Goddard (1950). In 1937, a detailed study of the petrography of the Caribou stock was made by Smith (1938). In 1948 and 1949, R. U. King (1952) of the U. S. Geological Survey examined the Caribou mine to evaluate the uranium occurrence. In 1951 the U. S. Geological Survey began a detailed investigation of the Caribou area on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission, the principal purpose of which was to evaluate the uranium occurrences in the area. The study was begun by E. P. Kaiser and W. S. Cavender, who established a triangulation net, using a base line in Caribou Park for horizontal control and a U. S. Geological Survey bench mark on the top of Caribou Hill for vertical control. Kaiser left the project in August 1951, and the investigation was continued until November 1951 by F. B. Moore and W. S. Cavender. During the study of the district, a geologic map was prepared at a scale of 1:1,200 of an area covering about one square mile. The mapped area includes most of the mines in the Caribou district and embraces the eastern half of Caribou Hill and adjacent areas to the east and north. In addition, all accessible underground workings were mapped at a scale of 1:480. Surface mapping was done by planetable methods. For underground mapping, a compass and tape were used in conjunction with base maps furnished by the Consolidated Caribou Silver Mines, Inc.

The writers wish to acknowledge the cooperation of the staff of the Consolidated Caribou Silver Mines, Inc., who made the Caribou mine available for examination at all times and who furnished maps and suggestions that were of great assistance. Mr. A. E. Blakesley, owner of the Comstock mine, was also most cooperative in making possible the examination of his mine. Thanks are due Dr. E. E. Wahlstrom of the University of Colorado and to the Boulder Daily Camera for the use of their files, which contain information on the Caribou mine.

LOCATION AND GENERAL FEATURES

The Caribou area is in sec. 8, T. 1 S., R. 73 W., sixth principal meridian, in the Grand Island mining district, in the southwest part of Boulder County, Colo. (fig. 176). The now almost completely abandoned town of Caribou, 17 miles west of Boulder and 4 miles northwest of Nederland, is readily accessible by means of an improved gravel road from Nederland.

The Caribou lead-silver mines are at an altitude of about 10,200 feet on the northeast side of Caribou Hill. Klondike Mountain is on the west and Boulder County Hill on the east (fig. 177). Although the relief in the area mapped is nearly 1,000 feet, both Caribou and

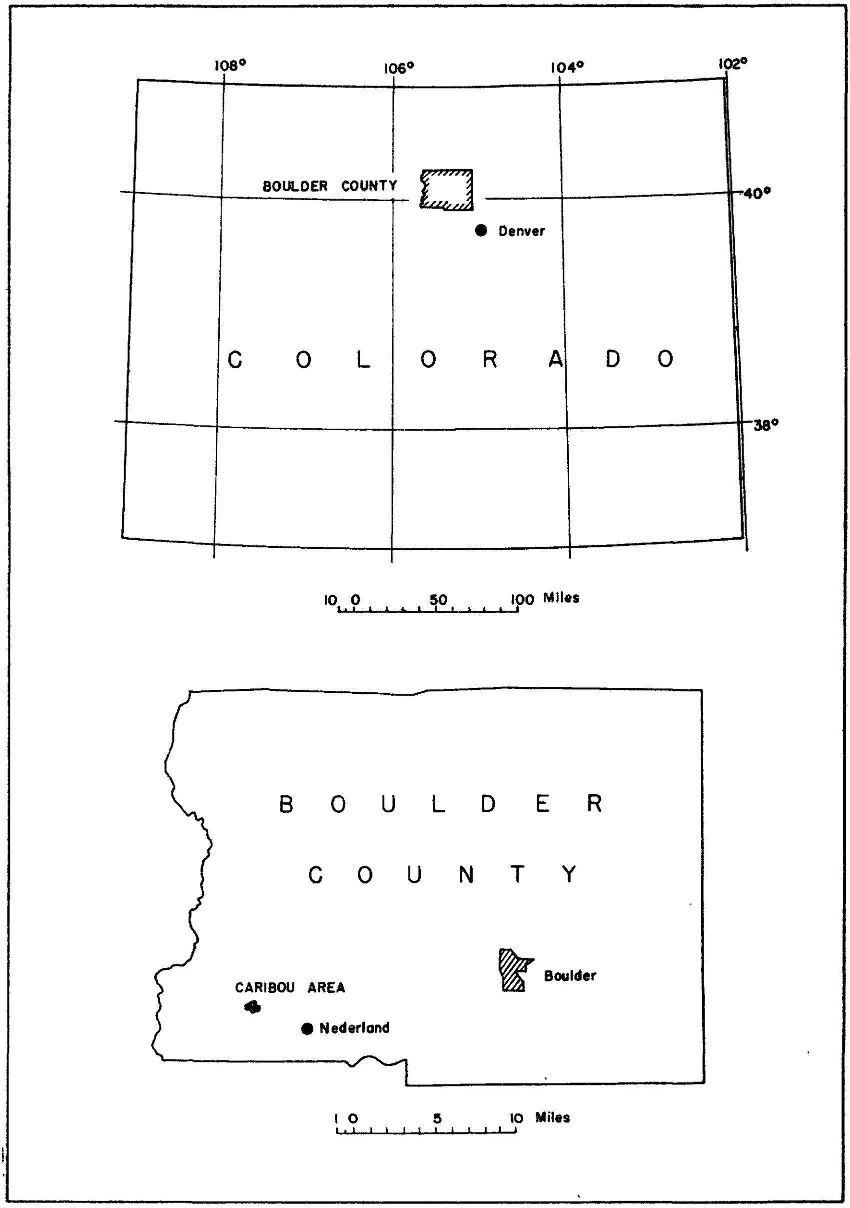

FIGURE 176.—Index maps showing location of Caribou area, Boulder County, Colo.

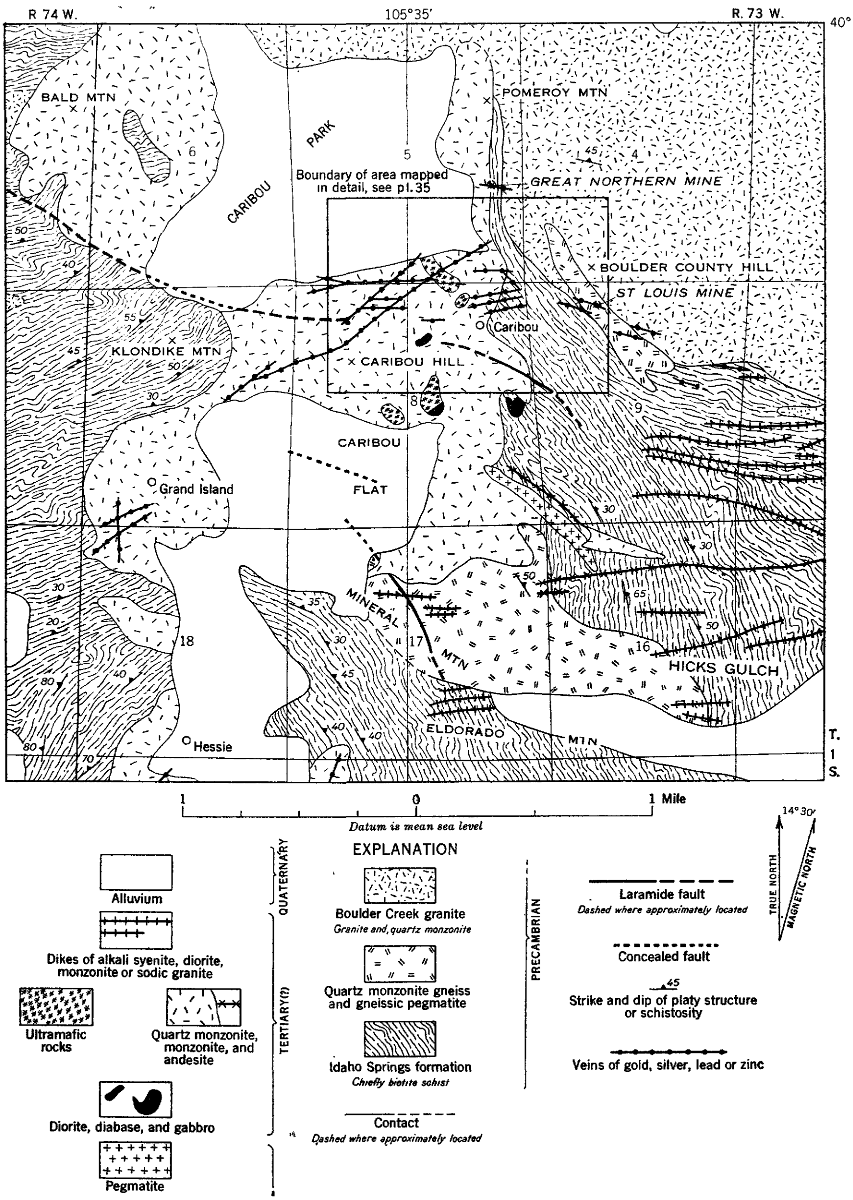

FIGURE 177.—Geologic map of the Grand Island-Caribou mining district, Boulder County, Colo.

Boulder County Hills are well rounded, with moderate slopes. North and south of Caribou Hill are broad, flat, mountain meadows.

HISTORY AND PRODUCTION

The ores of the Caribou Hill "silver-belt" were discovered in 1869 by a party of prospectors led by Samuel Conger, who had prospected Caribou Hill several years earlier without realizing the value of the minerals he found. Claims on the Caribou and the Poorman lodes, two of the richest in the area, were located in 1869 and in the following year the No Name, Native Silver, and Seven-Thirty claims were staked. By the end of 1871, most of the richer lodes on the hill had been found and in 1874, $330,000 worth of ore was shipped from the Caribou, No Name, Poorman, Sherman, Seven-Thirty, and Native Silver mines (Raymond, 1875).

The ore in the upper levels of many of the mines on Caribou Hill was exceedingly rich, as shown by reports in issues of the Rocky Mountain News for the period 1871–1872 and the Mining Review for 1873–1874. Assays of more than 1,000 ounces of silver per ton were not uncommon. The ores mined at that time were divided into four classes: first-class ore, more than $300 per ton; second-class ore, $100–$300 per ton; third-class ore, $50–$100 per ton; and fourth-class ore, less than $50 per ton, which was either discarded or stockpiled to await construction of a mill.

The high value of much of the near-surface ore apparently resulted from supergene enrichment. Native silver and horn silver (cerargyrite), both secondary minerals, are frequently mentioned in early newspaper reports. Gold content was low in the lead-silver veins, and Henderson (1926) records no lead production for Boulder County until 1887, when 593 pounds were produced. Raymond (1875) noted a decrease by 1874 in the grade of the ore from the Caribou mine at a depth of 430 feet. The value of ore from the mine that year totaled $130,000, with an average value of $72 a ton. Many of the mines, from which ore valued at $300 to $1,000 per ton was reported early in the camp's history, failed to yield a large production. This apparent inconsistency could be the result, in part, of the over-enthusiastic reports of individual owners and, in part, to the inability of the owners to work the narrower veins profitably below the oxidized zone. Scattered reports in issues of the Mining Review and the Rocky Mountain News, for the 70's, and Corbett (1879), Fossett (1876), Burchard (1882), and Raymond (1872, 1873, 1874, 1875), when integrated show there was a definite, gradual decline in grade of ore as the mines became deeper.

Ore was produced from the Caribou area until 1893, when a drop in the price of silver forced most of the mines to close. Some of the richer of the gold mines, whose initial production had been completely over-shadowed during the early silver boom, resumed production in 1898. However, from 1900 to 1948, activity in the area was limited to sporadic attempts by individual operators to reactivate certain mines or to mill the material from some of the larger dumps. The production for this period is believed to have been small. In 1948, after the discovery of pitchblende on the dump, the Caribou mine was reopened by the Consolidated Caribou Silver Mines, Inc. This mine, which has workings also intersecting the No Name, Poorman, Sherman, and Silver Dollar veins, was the only one operating in the Caribou Hill area at the time of the investigation in 1951.

The total value of lead and silver produced from the Caribou area before 1924 is estimated, based in part on figures compiled by Henderson (1926) for production from Boulder County, to have been approximately $6,000,000. Of this total, the larger part was furnished by five mines: the Caribou, No Name, Poorman, Native Silver, and Seven-Thirty. No figures are available from which to estimate the value of gold produced, but it is believed to have been small.

The ore currently produced from the Caribou mine is concentrated at the company mill at Lakewood, about five miles east of the mine. From the mill the concentrate is sent by truck to a smelter at Leadville.

GEOLOGY

The Caribou area, which is part of the Front Range mineral belt, is underlain by Precambrian igneous and metamorphic rocks and, with the exception of unconsolidated Quaternary glacial and stream deposits, is devoid of sedimentary rocks. The Precambrian rocks in the Caribou area and in the adjoining areas to the north and south are intruded by Tertiary(?) igneous rocks which form several small stocks (Lovering and Goddard, 1950, plate 2). The dominant structural feature of the Front Range mineral belt, a series of northeast-trending folds and faults, is reflected in the Caribou area chiefly by northeast-trending mineralized shear fractures, several of which were quite productive of lead and silver. The lead-silver deposits at Caribou, with the exception of one mineral, are similar to many other lead-silver deposits throughout the Front Range mineral belt; the presence of pitchblende in some of the lead-silver ores at Caribou distinguishes these deposits from all but a few in the Front Range.

ROCK UNITS

The three principal rock units in the Caribou area are the Idaho Springs formation and the Boulder Creek granite, both of Precambrian age, and the monzonite of the Caribou stock (fig. 177), of Tertiary (?) age. The Caribou stock also contains small bodies of diorite, gabbro, and ultrabasic rocks.

Minor units include Precambrian quartz monzonite gneiss and pegmatite (fig. 177). All the Precambrian rocks are cut by Eocene(?) dikes of diorite and andesite in the area southeast of Caribou. Because none of the minor rock units occur in the area mapped (pl. 35), they are not described below. Most of the lead-silver veins of the area are in the Tertiary(?) monzonite of the Caribou stock but all the gold veins are in Precambrian rocks.

IDAHO SPRINGS FORMATION

Schists and gneisses of the Idaho Springs formation occupy a large area in the Front Range and are described by Bastin and Hill (1917, p. 26) as follows:

> The predominant rocks of the Idaho Springs formation are light- to dark-grey quartz-biotite schists, in places carrying some hornblende or muscovite. With these are associated lesser amounts of biotite-sillimanite schist, quartzitic gneiss, dark-green hornblende schist and gneiss, and lime-silicate rocks that represent metamorphosed limestones.

In the Caribou area the Idaho Springs formation occupies a narrow belt, about a half mile wide, along the eastern edge of the area mapped (pl. 35); it is bordered on the west by monzonite and on the east by granite. Within this belt, the Idaho Springs formation consists mostly of quartz-biotite schist and injection gneiss and, near its contact with monzonite on Idaho Hill, includes a large amount of pegmatitic rock. This formation is the host rock for most of the known gold veins in the area.

BOULDER CREEK GRANITE

The Precambrian Boulder Creek granite does not crop out in the mapped area, but is mentioned here because it occupies an area of several square miles adjoining the mapped area to the north and east (fig. 177). According to Lovering and Goddard (1950, p. 25): "the Boulder Creek is commonly a dark-gray faintly banded rock that ranges in composition from a quartz monzonite to a sodic granite." In the area near Caribou it contains but few ore-bearing veins.

CARIBOU STOCK

The Caribou stock underlies most of the area mapped (pl. 35). It is not uniform in composition and is described by Smith (1938, p. 161–196) as: "a composite Tertiary(?) intrusive mass composed chiefly of monzonite but with masses of titaniferous magnetite and bodies of ultramafic and gabbroic rocks." Lovering and Goddard (1950) mapped bodies of quartz monzonite, gabbro, and ultramafic rocks within it as part of the stock.

The monzonite, which constitutes about 90 percent of the stock, is a bluish-gray, medium-grained rock composed essentially of biotite, augite, orthoclase, and andesine; locally, fine-grained and porphyritic facies are common. At many places, hornblende forms thin seams along joint planes; in a few places the fresh monzonite shows faint layering which is not apparent on weathered outcrops. Outcrops of monzonite are few, but fresh rock can be found in many prospect pits and on the mine dumps.

Bodies of ultramafic and gabbroic rocks, as much as several hundred feet in diameter, occur at many places in the stock, but Smith (1938, p. 171) points out that "the distribution of the ultramafic and gabbroic bodies is irregular." The ultramafic bodies are chiefly pyroxenite and contain masses of titaniferous magnetite in interlacing veins as much as 5 inches thick. One of the larger ultramafic bodies, known locally as the "Iron Dike," forms the eastern margin of the Caribou Hill lead-silver belt (pl. 35).

STRUCTURE

The dominant structure of the Caribou region is a large north-northeast-trending anticline of Precambrian age which appears to have controlled the intrusion of the Caribou and other nearby stocks. Lovering and Goddard (1950, p. 54) describe this anticline as extending south-southwest from Caribou to Empire, a distance of 12 miles. The Caribou stock and a monzonite stock two miles to the south form an elongate, discontinuous body that coincides with the axis of the anticline.

In the area mapped (pl. 35) the foliation in the Idaho Springs formation wraps around the north end of the anticline and, therefore, in many places the contact with the monzonite is discordant locally. The general distribution of the monzonite bodies in the region, however, is nearly concordant with the regional trend of the Precambrian structures. Such preexisting structures in the Precambrian rocks may have controlled the localization of the stocks in two ways: (1) directly, by forming zones of weakness or layers along which ease-of-access of intruding magmas would be greater than normal, and (2) indirectly, by influencing the trend of later (Laramide) structures, which in turn would control localization of the stocks. No evidence was found during mapping with which to determine which type of control was dominant.

Jointing in the monzonite is common but is not conspicuous. The most prominent set of joints ranges in strike from N. 40° to 60° E. and in dip from 70° to 90° NW., with an average strike of N. 50° E. and an average dip of 85° NW. Much less prominent are sets of steeply dipping north-trending and east-trending joints.

To the east of Caribou, in Boulder County, are a series of northwest-trending major faults (Lovering and Goddard, 1950, pl. 2), and to the south, in the northern parts of Clear Creek and Gilpin Counties are several large northeast-trending faults. Although these faults are not apparent in the Caribou area, they can be traced to within a few miles of Caribou and, if projected along their strikes, would intersect in the Caribou district. These faults may be present at depth, even though no surface indication of the faults exist. Lovering (1932) believes that the northwest-trending faults of Boulder County localized most of the ore deposits in Boulder County.

Three sets of steeply dipping veins—northeast-trending, east-trending, and northwest-trending—occur in the Caribou area. All the veins dip north at angles of 70° or more. The northeast and east-trending veins on Caribou Hill are chiefly in monzonite of the Caribou stock and form an interconnecting vein system (fig. 178 and pl. 36); the east-trending veins are at an angle of about 40° to the more persistent northeast veins. To the east, on Idaho and Boulder County Hills, a few west- and northwest-trending veins, which contain chiefly pyrite, gold, and quartz, form a separate system in the Idaho Springs formation. These veins may be older than the Caribou stock.

The northeast-trending veins on Caribou Hill are interpreted as occupying shear zones and the east- and west-trending veins are interpreted as occupying tension fractures branching from the shear zones. Although such features as offset geologic contacts were not in evidence to furnish conclusive proof, this interpretation is compatible with most of the geologic data. A northeast-trending shear fracture could be produced either by a compressional force acting nearly in an east or west direction or by a northeast-southwest shearing couple. The

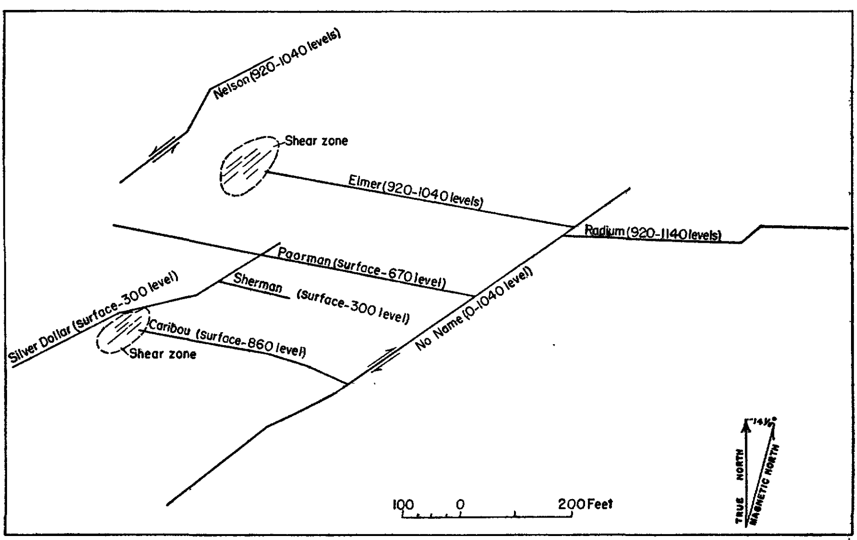

FIGURE 178.—Generalized structure of the Caribou group vein system, Boulder County, Colo.

regional forces producing fracturing in the Front Range mineral belt of Colorado are interpreted by Lovering and Goddard (1950, fig. 81) to have acted in a northeast-southwest direction. If the component of a couple on the northwest side of such a shear fracture moved northeast with respect to the southeast side, any tension fractures produced should trend about east-west, as do the Caribou, Poorman, and Radium veins (fig. 178).

The direction of relative movement of the vein walls is difficult to determine by underground examination. Slickensides are nearly horizontal as seen in the mine workings but the evidence presented by chatter marks is inconclusive. Horizontal movement along the veins was small. There is no apparent displacement of the ultrabasic body—locally called the "Iron Dike"—that is only 100 feet beyond the northernmost workings on the No Name vein (along the strike). What appears to be a displacement of the Radium-Elmer vein (fig. 178) is the fortuitous branching of two separate veins from the No Name vein at nearly the same place. The Radium vein leaves the No Name vein in a smooth curve and is not cut off sharply, as would be true were it displaced by later faulting. Van Diest (1875) stated that the Caribou vein was cut and offset by the No Name vein, with the eastern extension of the Caribou vein being displaced about 10 feet to the southwest. This interpretation seems unlikely, for no ore has been found along such eastern extensions of the Caribou vein, even on the levels where it contained good ore a few feet west of the No Name vein.

Although movement along the No Name vein may have been small, the brecciation and fracturing both of the vein walls and the vein filling show that movement did take place, some of it after the fractures were mineralized. If the walls along the No Name vein moved as indicated in figure 178, ore bodies would be expected in places where the strike changes to a more easterly direction. As intersections with the Caribou vein probably had an equal or greater effect in localizing ore bodies than did changes in strike along the veins, the effects of changes in strike alone will be most noticeable on the levels below the 860-level. On the 920-level and less obviously, on the 1040-level, ore bodies are found along the No Name vein in places where the strike changes to a more easterly direction. The movement along the northeast-trending Nelson vein apparently is in the opposite direction, because the vein widens where the strike is more northerly.

ORE DEPOSITS

Two types of ore deposits—lead-silver veins and gold veins—are present in the Caribou mining district. The lead-silver deposits have been the most important economically, with silver being the most valuable metal recovered. Since 1948 small quantities of uranium have been produced from the lead-silver-bearing Radium vein.

Most of the lead-silver veins are within an area of about one-half square mile on Caribou Hill (pl. 35); a few are on Boulder County and Idaho Hills, half a mile to the east. Almost all are in the Tertiary(?) monzonite but a few occur in the Precambrian rocks. The gold veins occur predominantly in gneisses of the Idaho Springs formation, and none are known in the monzonite, which suggests that the gold veins may have been formed before the fracturing of the Caribou monzonite stock or even before its emplacement, whereas the lead-silver veins were formed after its consolidation. This interpretation is in harmony with Bastin and Hill's (1917) conclusion that in the Central City district the gold mineralization was earlier than the lead-silver mineralization.

GOLD VEINS

The gold veins of the Caribou area are relatively unimportant, both quantitatively and economically. A few were worked in the 1890's (as reported in issues of Rocky Mountain News for 1890–1900), after the silver mines were closed, but their total production is believed to be small. A small group of veins, including the Silver Point, Idaho, Elephant, and Windy Point (pl. 35), which contained both gold and silver minerals (Lovering and Goddard, 1950, p. 202) are discussed in this report with the gold veins, but perhaps these should be classed as composite veins. None of the gold mines were accessible at the time of this survey.

The gold veins are on the west side of Idaho Hill, less than half a mile east of the Caribou mine (pl. 35). Although the shafts of several of these mines are only a few hundred feet east of the monzonite stock, and the veins if extended westward would cut the monzonite, no monzonite was seen on the dumps. Therefore, these veins probably do not extend into the monzonite. The country rock cut by the gold veins is mostly schist and gneiss of the Idaho Springs formation; however, near the contact with the monzonite, large amounts of pegmatitic rock are present.

Although none of the gold veins could be examined, the character of the ore can be determined from a study of the dump material. Samples from the dump of the largest gold mine in the area, the St. Louis, contained quartz, pyrite, chalcopyrite, covellite(?), and minor amounts of galena and sphalerite. Some carbonates (mostly dolomite) and quartz are found in vugs and presumably were deposited later than the ore minerals.

Production figures for the Idaho Hill gold mines are not available and no estimate of the average value of the ore can be made. Bastin and Hill (1917, p. 181), in describing the St. Louis mine, state:

The ore treated was free milling and the value was mainly in gold. Sixteen tons shipped in 1905 are said to have shown an average content of gold, 3.28 ounces; silver, 9 ounces; and silica, 17 percent. Two tons shipped in 1904 are said to have assayed gold, 5.81 ounces; silver 8.5 ounces; silica, 41.7 percent.

LEAD-SILVER VEINS

In all the veins in the Caribou monzonite stock, silver is the most valuable metal and lead the most abundant. The Radium vein also contains pitchblende and therefore is discussed separately. A small quantity of pitchblende was found on the dump of the Great Northern mine, but as this mine now is inaccessible, the vein could not be examined. The vein systems exposed in the Caribou mine and the Comstock mine were the only ones accessible for study in the Caribou area in 1951.

The lead-silver veins of the Caribou area are concentrated in an area about half a mile square, on the east and northeast slope of Caribou Hill (pl. 35); a few veins are present about one mile away to the east, north, and northwest of Caribou Hill. Only the Boulder County vein to the east is believed to have produced more than a small amount of ore and none of these outlying veins is included in the area mapped.

The description of mineralogy and paragenesis of the Caribou lead-silver ores is based largely on the study of samples from the Caribou mine, although samples from the dumps of most of the larger mines in the area also were examined. Listed in approximate sequence of deposition, the primary minerals in the lead-silver ores are quartz, pyrite, sphalerite, galena, chalcopyrite, argentite, ruby silver (pyrargyrite), and carbonates. Secondary minerals include native silver, azurite, malachite, and limonite. Reports by early workers (Mining Review, 1873, Endlich, 1874, Raymond, 1875) indicate that tetrahedrite, cerussite, "brittle silver" (stephanite(?)), "horn silver" (cerargyrite), and barite were present in small amounts in the upper workings.

Quartz, although one of the earliest minerals deposited, was deposited also in minor amounts as a late mineral. It formed either during several stages of mineralization or throughout the entire period of mineralization. The early quartz is massive white "vein quartz," commonly with small amounts of pyrite. Late quartz, in the form of clear crystals, fills vugs and forms veinlets cutting all other vein minerals except the carbonates. Cryptocrystalline quartz with fine-grained pyrite replaces the wall rock near the veins. Fine-grained pyrite is common in all the lead-silver ores but is not abundant.

Galena and sphalerite are closely associated, although sphalerite is sparse at shallow depths, either because of zonal deposition or leaching by ground waters. Both dark sphalerite, "black jack," and yellowish-green sphalerite, "rosin jack," are present in the Caribou mine. Except in one place along the Radium vein at the 1040 level, chalcopyrite occurs only in small amounts. For the most part it appears to be contemporaneous with sphalerite and galena. Carbonates (dolomite and calcite) were the last minerals formed, and carbonate veinlets cut all other minerals.

Distribution of the minerals along the veins shows some variation. Quartz is more abundant in the Caribou vein than in other veins of the Caribou mine. The highly silicified Caribou-vein material formed what was known to the miners as a "hard ore." Sphalerite appears to increase with depth. Chalcopyrite is plentiful only on the 1040 level of the Radium vein. Carbonates are present in all the veins but are more abundant than average along the No Name vein and less so along the Caribou vein. Massive pink carbonate more than a foot in width occurs along the No Name vein on the 500 level.

The upper parts of the veins at the Caribou mine have been greatly enriched in silver in the highly oxidized zone above the 300 level. The workings are inaccessible, but Endlich (1874) reported cerussite, malachite, and native silver from the 210 level and Raymond (1875) reports "horn silver" from the 200 level. The writers found abundant native silver in a veinlet on the 300 level and saw small amounts on the 360 level. The operators of the mine report that some native silver was found in a stope on the 920 level. Raymond (1875) noted a decrease in the silver content of the Caribou ore at a depth of 420 feet.

The presence of the secondary minerals cerussite and "horn silver" in only the oxidized parts of veins, at depths of 300 feet or less; the abundance of native silver at depths of less than 300 feet; and the rapid decreases in grade of ore between 300 and 420 feet indicate that the oxidized zone of secondary enrichment did not extend much below 300 feet. In the oxidized zone, the enrichment was from 3 to 10 fold. Below the oxidized zone, in the zone of secondary sulfides, enrichment is much less pronounced. From the few production figures available, it is estimated that the enrichment in the secondary sulfide zone may have increased the grade of the ore values by as much as 50 percent. The base of the zone of secondary sulfides is believed to be at about 740 feet, where there is a noticeable decrease in iron oxide.

The lower limits of the oxidized and the secondary-sulfide zones are related to position of the water table, which is controlled primarily by the topography (fig. 179). The water table is normally somewhat

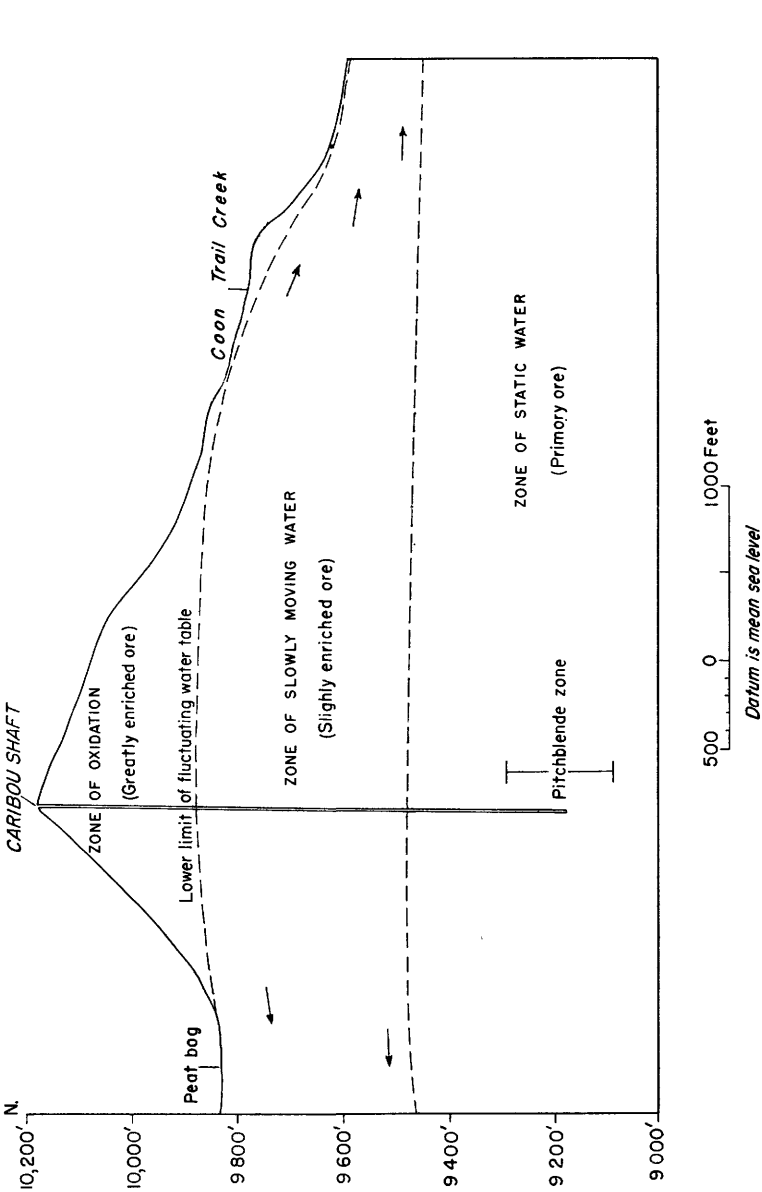

FIGURE 179.—Generalized section of Caribou Hill, Boulder County, Colo., showing relationship of ore enrichment to ground water movement

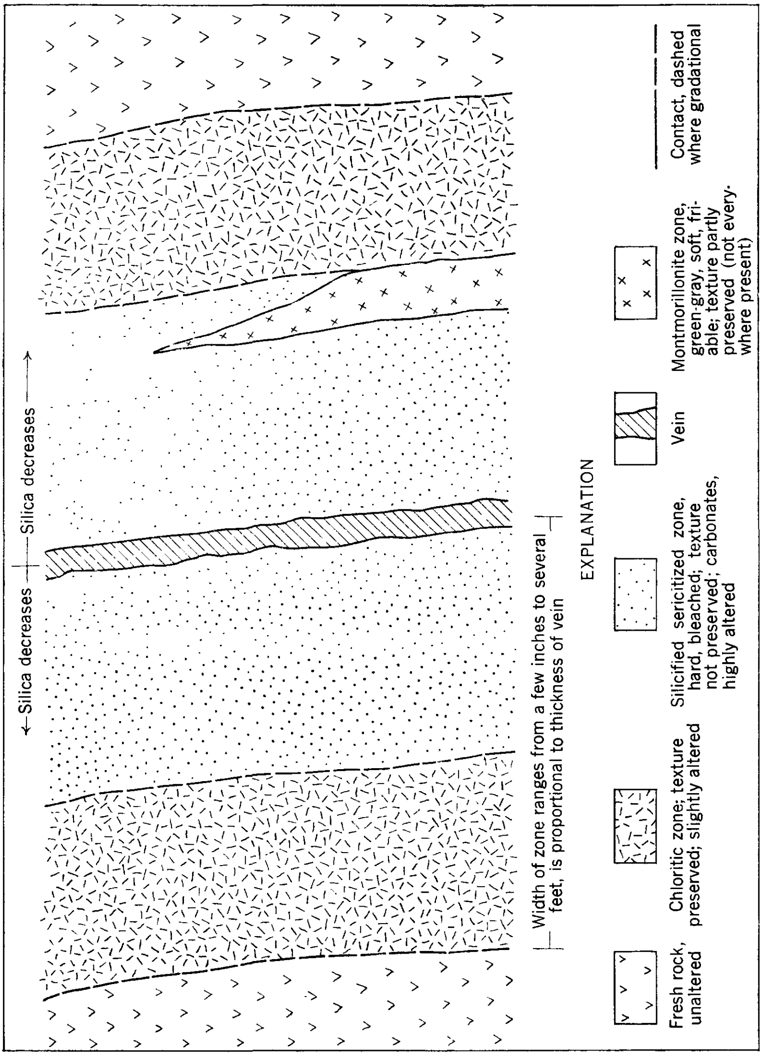

FIGURE 180.—Diagrammatic cross section of vein, showing alteration, Caribou mine, Boulder County, Colo.

higher than indicated in figure 179 and only during excessively dry periods would be at the level shown. The lowest position of the fluctuating water table marks the base of the oxidized zone and of the highly enriched ore. In the oxidized zone, ground water would move relatively rapidly downward, but in the secondary-sulfide zone it would move much more slowly, because the hydraulic gradient would be controlled by Coon Trail Creek at the same altitude as the 740 level in the Caribou mine. Below the 740 level, in the zone of primary ore, the ground water is nearly static and therefore the ore has not been altered. The boundaries of the oxidized, secondary-sulfide, and primary-ore zones are gradational. The absence or scarcity of pyrrhotite, chalcocite, and similar very active precipitants of silver in the mine make possible the easy transportation of the silver by the ground water.

The effects of supergene enrichment on ore minerals other than those of silver are not well known at the Caribou district but appear to be of minor importance. Because zinc sulfide, a relatively soluble ore mineral, is rarely mentioned in the early accounts of the district, presumably it was leached from the near-surface parts of the veins. The Mining Review (1873, v. 1, no. 6, p. 11) states that the ores of the Caribou mine—then exposed to a depth of 320 feet—contained "but little zinc, arsenic or antimony." Zinc is fairly abundant on the 1040 level but there is no evidence of secondary deposition either here or on the upper levels. Galena is plentiful throughout the veins and, being only moderately soluble, was apparently little affected by ground-water action. The pitchblende in the Radium vein occurs below the oxidized zone and probably was not exposed to secondary processes. If it was present in the oxidized part of the vein, it probably was removed for it is readily soluble in acid solutions.

Most of the wall rock of the Caribou lead-silver veins is medium-grained, gray to dark-gray monzonite. Small masses of diorite, gabbro, pyroxenite, and biotite pyroxenite are exposed in the Caribou mine, but no comparative study of the alteration products of the monzonite and those of the more mafic rocks was made.

The wall rock of the lead-silver veins of the Caribou area has been progressively silicified, argillized, and chloritized for as much as 3 feet outward from the vein. Silica and chlorite occur along all veins. The products of argillization, possibly once extensive, have been partly obliterated by later sericitic alteration; they form a distinct zone at only a few places. The monzonite adjacent to the veins is intensely altered to form an inner zone of hard, bleached, silicified rock in which the original texture has been destroyed. The zone ranges from a few inches to 2 feet in thickness and is characterized by disseminated cryptocrystalline quartz, sericite or illite, or both, and carbonate minerals, as well as by numerous veinlets of fine-grained quartz and carbonate minerals. In most places this intensely altered zone grades into a zone of slightly altered rock characterized by chlorite. This outer, or chloritic, zone ranges from about 6 inches to 2 feet in thickness, grading outward into fresh rock. A middle, or argillized, zone occurs in a few places between the chloritic and silicified zone (fig. 180). Composed of a green-gray, friable rock, the argillized zone contains abundant minerals of the montmorillonite group. This argillized, or montmorillonite, zone is only 6–12 inches thick along the Radium vein, but is several feet thick along the No Name vein on the 500 level. The contacts between the montmorillonite and adjacent zones are sharp.

Assignment of alteration minerals to definite zones is not meant to imply that these minerals are found only in a particular zone or that other alteration minerals are absent from this zone. The zones are named for the most abundant or characteristic alteration minerals, which were originally identified in thin section under a microscope. Recent X-ray studies by E. W. Tooker of the U. S. Geological Survey on the clay minerals of the inner and middle zones have largely confirmed the original identifications. Altered material in the inner or silicified zone believed to be sericite was shown by its X-ray pattern to be a mixture of sericite and illite. Although no determination of the relative distribution of sericite and illite within the zone could be made with the samples available, Tooker (1953, oral communication) states that, in general, the ratio of sericite to illite decreases with an increase in distance from the vein. The distribution of alteration minerals in the three zones are given below, listed according to means of identification:

	Silicified (inner) zone	*Montmorillonite (middle) zone*	*Chloritic (outer) zone*
Microscope	Quartz, sericite, carbonate, some kaolinite.	Montmorillonite, some kaolinite, beidellite, and illite.	Chlorite.
X-ray	Mostly sericite-illite, 10–15 percent kaolinite, 5–10 percent montmorillonite, 5–10 percent halloysite.	Montmorillonite, 10–15 percent kaolinite, some illite-sericite.	Not determined.

H. D. Wright (1950, written communication) in studying the major pitchblende ore shoot in the Radium vein, recognized four zones of alteration which he numbered in order outward from the vein as (1) a 2- to 6-inch hard, compact bleached zone containing sericite, carbonate, and fine-grained quartz, (2) a 2- to 3-inch dark green-gray, friable zone containing iron-stained montmorillonite, some kaolinite, and a little sericite, (3) a discontinuous zone resembling zone 1, but with little silica and containing abundant sericite and small amounts of kaolinite and montmorillonite, which mark the outer limit of argillic alteration; (4) a zone of propylitized rock in which the pyroxenes have altered to chlorite, calcite, and a little epidote. Zones 1 and 3 of Wright correspond to the inner zone of this report. Except where separated by a montmorillonite layer (zone 2 of Wright), they form a single gradational zone.

The most persistent vein in the Caribou area—the No Name vein (pl. 36 and fig. 178)—strikes northeast and has been worked for a horizontal distance of at least 1,000 feet and to a depth of 1,100 feet. This vein marks the eastern boundary of the main productive area on Caribou Hill (pl. 35). Most of the other veins are short—300–400 feet in length—and few have been worked to depths of more than 300 feet. The Caribou vein, which can be traced for 300 feet on the 300 level of the Caribou mine, appears to become shorter as the depth increases. Below the 860 level, it cannot be recognized. Several veins which are known only on the deeper levels—the Elmer, Radium, and Nelson—may actually be deeper parts of outcropping veins that were worked only to shallow depths.

The lead-silver ore bodies of the Caribou mine are vertical or steeply-plunging ore shoots. The larger shoots extend more than 200 feet along the vein and have been followed to depths of more than 700 feet. The veins are as much as 7 feet thick in places but the "pay streak" is rarely more than 18 inches wide.

The veins are mostly fissure fillings, but in places the wall rock has been replaced. Some veins have one well-defined wall; the other is gradational. The ore bodies are almost entirely in monzonite; and where the veins cut mafic rocks, they are weakly mineralized. There are no mines in the mafic rocks.

The ore shoots of Caribou Hill are localized by changes in dip or strike of the vein and by vein junctions. A series of tension fractures that trend west from the No Name vein contain ore shoots near their junction with the No Name vein. The concentration of ore minerals in the tension fractures such as the Caribou vein was in many places greater than in the stronger shear fractures, such as the No Name vein, that trend northeast. Prior to mineralization highly fractured rock partly filled the openings along the No Name vein and locally was cemented by vein minerals. Such brecciation is absent along the subsidiary west-trending tension fractures. Postmineral movement, indicated by crushed vein minerals, is apparent along the northeast-trending shear fractures. No postmineral movement is apparent in vein minerals of the west-trending tension fractures.

The ore shoots in the Caribou vein are thicker in the less steeply dipping parts of the vein. This is especially evident on the 360-level where the vein decreases in dip from about 80° to 50° and increases to 10 feet in thickness (pl. 37, section *A–A'*). The Caribou vein steepens at the 800-level and here is too thin to be worth mining; it was not explored below the 860-level. Although the other veins in the Caribou group are not sufficiently well exposed to determine the structure of their ore shoots, it is believed that a similar structural relationship may also control, in part, the localization of ore in other shoots in the Caribou area.

Changes in strike, especially along the northeasterly-striking shear fracture veins, apparently helped influence the localization of ore. The best ore exposed in the Nelson vein is along that portion of the vein in which the strike is more northerly. Along the No Name vein, the junction of that vein with the Caribou vein was the dominant influence in localization of ore, but on the 1040- and 920-levels (pl. 37), the Caribou vein is absent and slight changes in strike to a more easterly direction coincide with the stoped areas. In general, veins occupying the westerly trending tension fractures are straight because the wall rock is homogeneous and the horizontal movement, relative to that of the shear fractures, is small. Accordingly, changes in strike were not important factors in the control of the ore deposition in the tension-fracture veins. The ore shoot localized by a change in strike along the Radium vein (tension-fracture) is small.

Silver is by far the most valuable metal in the lead-silver ores of Caribou Hill area. Gold rarely exceeds 0.1 or 0.2 ounce per ton and gold was not reported present in the lead-silver veins by early newspaper accounts or by Fossett (1879) or Raymond (1872, 1873, 1874, 1875). Lead, which currently is being produced from the Caribou mine, is believed to account for only a small percentage of the total production from the mining district. The earliest recorded production of lead from Boulder County, as reported by Henderson (1926), was in 1887, a time at which the production of ore from the Caribou area was declining rapidly.

The ore, especially in the oxidized zone, was exceedingly rich; assay values of 200 to 300 ounces of silver per ton were not uncommon. However, the bulk of the production came from ore of much lower grade. The Caribou vein, the richest and most productive in the area (about $1,500,000 to 1883), yielded $334,000 worth of ore of an average grade of $70 per ton during 1874 and 1875.

Since the Caribou mine was reopened in 1947, a total of $519,642.19 worth of lead-silver ore has been produced.[1] Most of the ore came

[1] Data furnished by Consolidated Caribou Silver Mines, Inc. Published with permission of the company.

from the 920- and 1040-levels but a small amount came from the 500-level. The largest ore bodies were found along the Nelson vein but the Elmer, No Name, and Radium veins also yielded ore. Some of the ore contains as much as 100 ounces of silver and 10 percent lead. Zinc is less abundant than lead. Analyses of 17 samples taken from the uranium-bearing areas of the Radium vein are shown below.

Analyses of samples from the Radium vein, Caribou mine, Boulder County, Colo.

[Analysts: W. D. Goss and D. L. Skinner for samples CAA-1 to -10; E. C. Mallory and D. L. Skinner for samples FM-5-48 to -56.]

Sample No.	Location, distance from No Name vein (feet)	Length of sample (inches)	U	Pb	Zn	Cu	Ag	Au
			Percent				Ounces per ton	
920 level								
CCA- 1	75	8	0.08	5.85	3.94	0.02	72.07	0.03
2	80	8	.22	2.29	3.78	.04	10.14	.03
5	111	9	.79	4.28	5.27	.02	15.12	.04
6	116	2½	.18	8.29	4.07	.11	76.77	.10
8	121	9	.23	3.01	3.07	.36	75.84	Tr.
9	126	10	1.85	5.20	2.77	.39	217.64	.14
10	131	9	.11	3.96	2.82	.24	38.28	.08
1040 level								
CCA- 3	51	3	.36	22.99	16.73	.01	3.20	Tr.
FM 5-48	271½	6	.49	3.73	5.33	.04	22.31	.05
49	276	7	.04	1.96	1.46	.02	2.76	None
50	280½	12	.36	10.13	4.80	.01	8.87	.03
51	285	13	.08	15.82	7.68	.02	1.64	None
52	285	12	.01	11.84	17.06	.03	4.30	.04
53	293½	13	.15	7.74	3.98	.05	14.05	.02
54	302	12	.19	12.23	2.78	.16	108.40	.07
55	309½	8	.28	6.16	6.61	.02	7.84	.02
56	315	8	.02	.46	.22	<.01	.72	None

URANIUM-BEARING LEAD-SILVER VEINS

Except for the presence of pitchblende, the uranium-bearing veins in the Caribou area do not differ in mineralogy from other lead-silver veins of the area; the two types of veins form one interconnecting vein system. However, the uranium-bearing veins are discussed separately in this section, not because they are considered a separate type of vein, but because they warrant special attention, in view of the strategic importance of uranium.

The only known pitchblende deposits in the Caribou area are in the Caribou mine, but pitchblende is believed to occur in the Great Northern mine. The pitchblende occurs in the Caribou mine along

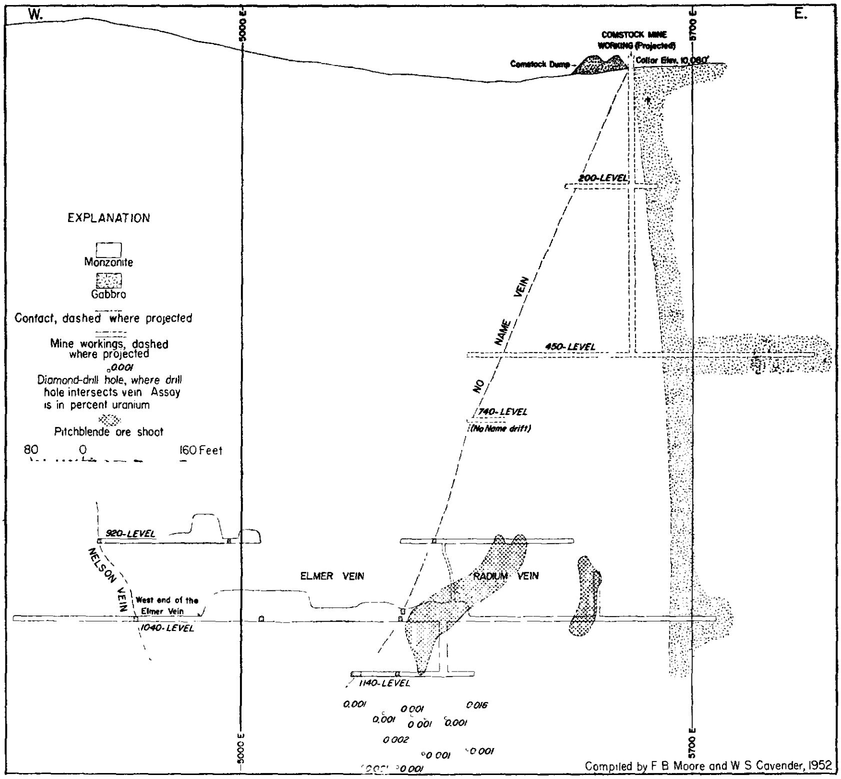

FIGURE 181.—Vertical longitudinal projection of the Radium and Elmer vein workings, showing locations of pitchblende ore shoots, Caribou mine, Boulder County, Colo.

the Radium vein at depths between 900 and 1,140 feet (pl. 37 and fig. 181) and along an unnamed vein, possibly the Nelson vein, on the 500 level (pl. 38). Pitchblende was found on the dump of the Great Northern mine, but because the mine is inaccessible and there is no record of pitchblende having been found in the mine, this occurrence cannot be evaluated.

In the Caribou mine, pitchblende occurs beside galena, sphalerite, and silver minerals along the footwall of the Radium vein. Some of the pitchblende is hard, but most is soft and sooty and coats vugs and fractures. The hard pitchblende occurs as a band, generally less than an inch thick, between sulfides and gouge along the footwall of the vein. In a few places the band is as much as 6 inches thick and locally splits into stringers that form a braided network.

The paragenesis of the minerals constituting the Radium vein was determined by a study of polished sections. Quartz and pyrite (a minor amount) were the earliest minerals. Most of the quartz is white and massive; however, some occurs in vugs as crystals. Sphalerite and galena, apparently contemporaneous, fill vugs and fractures in the quartz. Chalcopyrite, in part contemporaneous with the sphalerite and galena, is also probably younger in part. One specimen shows a chalcopyrite veinlet cutting sphalerite but not galena. A younger age for part of the chalcopyrite is indicated by its occurrence along cleavages in galena and as crystals growing along a sphalerite-galena contact.

The position of the pitchblende in the paragenetic sequence is not definitely known because only small amounts of the hard, lustrous pitchblende are present along the veins, and because the samples that were collected did not show definite age relationships with other minerals. One specimen contains an irregular veinlet of hard pitchblende that cuts pyrite. On the basis of negative evidence, it is believed that the hard pitchblende also is younger than the sphalerite and galena. If the pitchblende were earlier than the galena, evidence that galena cuts pitchblende should be present, owing to the relative abundance of galena in the pitchblende zone. If the pitchblende were contemporaneous with the galena and sphalerite, some of the pitchblende should be intergrown with those minerals. None of the pitchblende contains any appreciable quantity of sulfides nor do the adjacent sulfides contain any visible pitchblende. Autoradiographs of two specimens of sooty pitchblende show that the sooty variety is confined to vugs and fractures and is not intermixed with the sulfides.

H. D. Wright (1950, written communication) in discussing the mineralogy of the Radium vein states:

> The ore minerals recognized in the polished surface are uraninite,[2] pyrite, chalcopyrite, sphalerite, galena, argentite, ruby silver, and native silver. Gangue minerals represented are quartz, carbonate and barite. The existence of two characteristic assemblages of ore minerals suggests two stages of vein formation. In Stage A, which is thought to be earlier, quartz, sphalerite and galena were deposited. Uraninite was deposited early in Stage B. The other minerals of this stage are chalcedony, chalcopyrite, sphalerite, argentite, ruby silver, and native silver.

The hard pitchblende at Caribou occurs as "inclusions" in the soft, sooty variety, suggesting that the sooty pitchblende was deposited by hypogene solutions after the hard pitchblende or that it resulted from the supergene alteration of it. Sooty pitchblende deposited in vugs after deposition of colloform quartz and fine oolitic pyrite in the vugs indicates a late and probably low-temperature stage of deposition.

Although age determinations for the comparison of the relative ages of the soft and hard pitchblende are not available, the field relations show that the soft variety is the younger. Kerr and Kulp

[2] Pitchblende is generally considered to be a noncrystalline form of uraninite.

(1952) give an age of 23 million years (±10 million) for the pitchblende at the Caribou mine. This age determination was probably made on pitchblende of the hard variety and was not corrected for common lead. Phair (1952) recalculated the age of the Caribou pitchblende and determined a possible maximum age of 44 million years. The pitchblende from the nearby Central City district, Colorado, which contains a much higher ratio of hard to soft material and which Bastin (1917, p. 124) believed was contemporaneous with the gold ores, was determined by Nier, Thompson, and Murphey (1941) to be from 57 to 59 million years old.

Kerr (1951, p. 91–92), after studying samples of "uraninite" from Colorado, Canada, and the Belgian Congo, states: "A number of observations indicate that the sooty uraninite may be a later form high in UO_3 that has originated at the expense of earlier hard uraninite, high in UO_2". It is possible that the soft pitchblende is a first step in the chemical alteration of pitchblende to secondary minerals. The absence of any of the typical alteration products (gummite, torbernite, etc.) at Caribou may be due to the limiting factors of the environment. Kerr adds that "although the sooty mineral is later, it is found at such depths that it apparently does not represent a typical surface-weathering product." Two separate stages of primary uranium deposition seem unlikely because, were this true, in some places only hard pitchblende should occur and in others only soft pitchblende. However, the two varieties appear to be coextensive.

Pitchblende has been exposed along the Radium vein on the 920, 1040, and 1140 levels, the only levels that have explored the Radium vein (pl. 37). Two ore shoots containing pitchblende occur about 170 feet apart in the Radium vein on the 1040 level. The larger shoot extends from the 920 level downward to the 1140 level and is more than 70 feet long (fig. 181). The smaller ore shoot extends for 35 feet along the drift and vertically for 70 feet in a raise from the 1040 level. The larger ore shoot plunges steeply to the west; although the smaller one appears to be vertical, it also may plunge steeply to the west.

Within the ore shoots the pitchblende is erratically distributed. Assays vary by as much as 100 to 1 in a distance of 2¼ feet. At places where pitchblende occurs, minerals typical of the lead-silver veins are invariably present, commonly in considerable abundance. Some of the pitchblende-bearing ore is worth mining for lead and silver. The uranium ore, a part containing as much as 7 percent uranium, has been separated from the lead-silver ore and from the gangue by hand sorting. Except for a small shipment for metallurgical purposes, all the uranium ore from the Caribou mine has been stockpiled by the company.

MINE DESCRIPTIONS

The Boulder County claim map for sec. 8, T. 1 S., R. 73 W., shows 100 patented claims in the area mapped; 46 of these claims have been identified with surface workings, and names also have been assigned to an additional 38 unpatented properties. The names of mines and veins shown on plate 35 were determined in large part from a map published in the Engineering and Mining Journal (1877) and in part from information given by Mr. Elmer Hetzer of Boulder, Colo. Many of the smaller mines or prospects could not be identified. About 30 mines were worked to a depth of 100 feet or more, but production figures are available for only a few of the larger properties. The mines described below are believed to be significant because of their production, size of workings, location, or mineralogy. One, the Great Northern, is a few hundred feet beyond the area mapped but its location is shown on figure 177. The Caribou and the Comstock mines were the only ones accessible during this study.

SILVER MINES

Of the silver deposits in the Caribou area, those worked by the Caribou group of mines are the most important; only one other mine is accessible and only one other deposit yields evidence of pitchblende.

The Caribou group consists of eight mines, the Caribou, No Name, Poorman, Silver Dollar, Sherman, Columbia, Spencer, and the Socorro. The Caribou, No Name, Poorman, Silver Dollar, and Sherman veins can be identified on the Caribou mine's 300 level and form an interconnecting vein system. The Columbia and Spencer veins, which parallel the No Name vein, were incorporated in the holdings of the Caribou company as early as 1883. The Socorro vein is parallel to the Caribou vein on the south and may be identical with the South Caribou vein of this report. Recently three more veins, the Radium, Elmer, and Nelson, have been exposed on the 920- and 1040-levels of the Caribou mine but have not been definitely correlated with any of the veins exposed at the surface.

The Caribou group is owned by the Consolidated Caribou Silver Mines, Inc., who reopened the mines in 1948 by means of an adit, the Idaho tunnel, 3,700 feet long (pl. 38) that intersects the Caribou shaft at a depth of 500 feet. In 1951 the ore was being exploited from the No Name, Nelson, Elmer, and Radium veins on the 920 and 1040 levels.

CARIBOU MINE

The Caribou vein, discovered in 1869, is the richest silver vein in the Caribou area. The value of silver ore shipped from the mine before 1880 totaled more than $1,000,000 (Fossett, 1879). Corregan and Lingane (1883) gave the total production of the Caribou and No

Name veins as $2,500,000. Since 1883, the Caribou mine has been operated intermittently. Some of the ore was very rich; assay values of $300 to $500 a ton were common.

A shaft 1,040 feet deep gives access to levels at 50, 100, 200, 300, 360, 500, 530, 600, 670, 740, 800, and 860 feet below the collar (pls. 37, 38, 39, 40, and fig. 182). Shafts 100 feet apart along the vein, 1 east of the main shaft and 5 to the west are now covered by the main dump.

The Caribou vein strikes approximately west and has an average dip of 75° to the north. The vein is nearly 300 feet long on the 300 level (pl. 39) but shortens at depth and feathers out 860 feet below the collar (pl. 36). The width of the vein averages about 2 feet, increasing to a maximum of 10 feet on the less steeply dipping parts (flats) of the vein. The silver ore is localized in well-defined shoots, mostly in the eastern part of the vein near its junction with the No Name vein (fig. 182). The ore is highly siliceous and shows no evidence of postmineral crushing. Carbonate minerals are sparse in the Caribou vein, probably owing to nearly complete filling of openings by earlier vein material.

Ore minerals are galena, sphalerite, argentite, pyrargyrite, and native silver. Finely disseminated pyrite replaces the wall rock near the vein, but only a small amount of pyrite is present in the ore. Some of the ore contains a minor amount of chalcopyrite.

The main Caribou vein has been stoped to a depth of nearly 800 feet and westward from its junction with the No Name vein for distances ranging from 300 feet on the 300-level to 150 feet on the 740-level. Because the main Caribou vein feathers out a short distance below and to the west of the stoped areas and because no ore-bearing extension of the Caribou vein has been found east of the No Name vein, it is doubtful that the vein still contains workable ore.

NO NAME MINE

The No Name vein is the most persistent vein in the Caribou area, having been worked for more than 1,000 feet both horizontally and vertically. According to Raymond (1875, p. 370), the total value of ore produced before 1875 was estimated by the owner to be $400,000. Total production from the vein to date is believed to be about $1,000,000.

The No Name vein is developed by a shaft more than 500 feet deep; the levels correspond to those of the Caribou mine to a depth of 860 feet. In addition there are three deeper levels at 920-, 1040-, and 1140 feet (pl. 37). The vein was not being worked in 1951.

The No Name vein is not a single fissure filling like the Caribou vein but rather a mineralized shear zone, as much as 7 feet wide, that

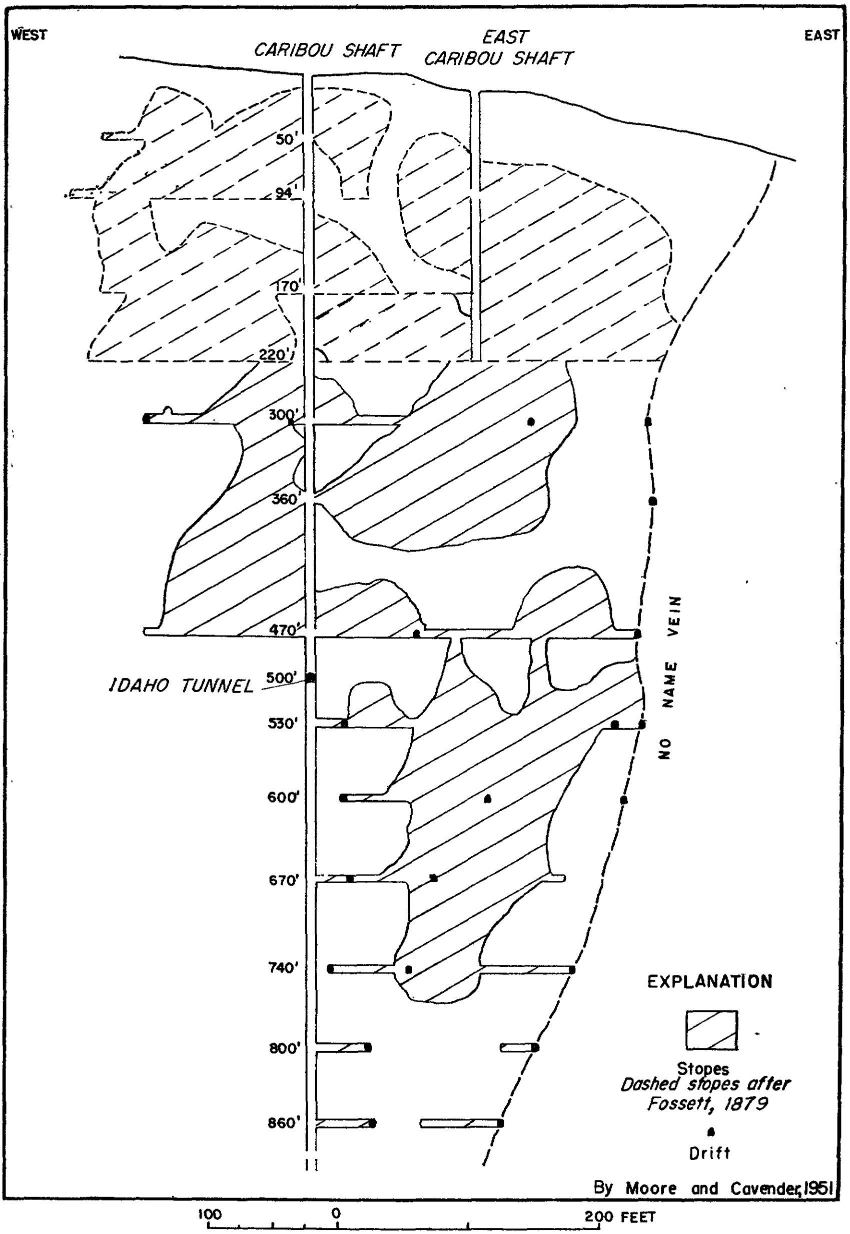

FIGURE 182.—Vertical longitudinal projection of Caribou vein, Caribou mine, Boulder County, Colo

strikes N. 55° E. and dips an average of 70° NW. (pl. 37). The ore is disseminated in stringers through the shear zone, cutting and surrounding brecciated fragments of country rock. The ore minerals are similar to those of the Caribou vein: galena, sphalerite, argentite, pyrargyrite, and native silver. Postmineral movement fractured the early vein minerals and formed openings in which late carbonates were deposited. The carbonate minerals, mostly dolomite and calcite, occur as veinlets and as tabular masses as much as one foot thick along the vein.

The shape and distribution of ore shoots along the No Name vein cannot be accurately determined because large parts of the No Name workings are inaccessible. One ore shoot extends from the 600 to the 920 level at and near the junction of the No Name and Caribou veins and plunges steeply to the northeast. The lateral and upward limits of this shoot are not known, but it is believed to be a downward continuation of the main No Name ore shoot. A large stope to the southwest on the 600 level (pl. 40) indicates the presence of a second ore shoot in that direction.

Reserves of lead-silver ore in the No Name vein are believed to be small.

POORMAN MINE

The Poorman shaft is 190 feet north-northeast of the main Caribou shaft (pl. 35). The mine worked the Poorman and probably the Silver Dollar veins, both of which were owned by the Poorman Mining Company. Although the Poorman vein was one of the first to be discovered in the area (1869), the mine was not one of the early producers. In 1879, when the shaft was 220 feet deep, the production to that time was estimated to be only $35,000 (Corbett, 1879). A prospectus written by the Poorman Mining Company about 1885 states that mill certificates show a total production (Poorman and Silver Dollar veins) of nearly $200,000. The mine was operated until 1893, and consists of the Poorman shaft, 600 feet deep, with acccessible levels corresponding to the 300, 500, and 670 levels of the Caribou mine.

The Poorman vein strikes N. 78° W. and dips steeply to the north. On the 500 level, stope outlines indicate that the ore bodies were localized along the Poorman vein near its junctions with the No Name vein on the east and with an unnamed vein (possibly the Nelson) on the west (pl. 38). The eastern ore body extends for more than 120 feet along the vein. The vertical dimensions of the ore bodies are not known.

The Poorman vein contains highly siliceous ore resembling the ore in the Caribou vein, although not as rich. A sample from the 670 level contains sphalerite, galena, pyrite, and chalcopyrite in silicified monzonite. The sulfides occur in interwoven veinlets and disseminations with sphalerite the most abundant. No silver minerals are visible.

The nearly vertical Silver Dollar vein strikes northeast and crosses the Poorman vein without displacement (pl. 39). Where exposed on the 300 level of the Caribou mine, it is a 1-foot-wide brecciated, iron-stained shear fracture with no visible sulfides. The absence of stopes on this vein indicates that the production was probably small.

SHERMAN MINE

The Sherman mine, about 100 feet north of the Caribou mine, is developed by a shaft 265 feet deep. The workings are cut by the Caribou tunnel at a depth of 210 feet (pl. 39). The mine is on the Sherman vein which strikes east and dips 85° to the north. Where cut by the Caribou tunnel the vein is timbered and could not be examined. The ore apparently did not extend to depth and no evidence of the vein can be found on the 500 level of the Caribou mine.

According to Raymond (1875), $40,000 worth of silver was produced in 1874 from ore valued at $180 per ton. Fossett (1879) states that 300 tons of ore produced in 1896 had an average value of $270 per ton.

COLUMBIA, SPENCER, AND SOCORRO MINES

The Columbia, Spencer, and Socorro mines are on veins closely related to the Caribou–No Name vein system. About 1881, the Columbia and Spencer mines were incorporated with the Caribou and No Name mines, largely in order to avoid litigation. The Columbia is apparently on a southwestern extension of the No Name vein. The Columbia workings are undercut by the No Name workings. The mine produced little ore. The Spencer vein is adjacent and parallel to the No Name vein on the southeast. Developed by a shaft 420 feet deep, it is credited with a total production of $10,000 before 1879 (Corbett, 1879). The Socorro claim adjoins the Caribou claim on the south. No evidence remains of the Socorro mine but its reported location suggests that it probably was on the South Caribou vein which is exposed in the Caribou mine workings. No production is recorded from the Socorro mine.

RADIUM, ELMER, AND NELSON VEINS

The Radium, Elmer, and Nelson veins are exposed on the 920 and 1040 levels of the Caribou mine (pl. 37), but have not been correlated with veins visible at the surface. The Radium vein branches to the east from the No Name vein near the point where the Elmer vein joins the No Name from the west. The Radium vein strikes east and the Elmer vein slightly north of west; both dip about 85° north on the 1040 level but the dip of the Elmer vein decreases to about 60° above the 920 level. The Nelson vein strikes northeast and is nearly vertical.

Lead-silver ore averaging at least $40 a ton has been produced recently from both the Elmer and the Nelson veins. The Radium vein also contains pitchblende, and mining of the vein has been confined to the uranium-bearing ore shoots. Except for pitchblende, the mineral suites of the Radium, Elmer, and Nelson veins generally are similar. Galena, sphalerite, argentite, and ruby silver are the ore minerals, with galena as the most abundant. Sphalerite, both dark and rosin colored, is intermixed with the galena. The gangue consists of quartz, carbonates, chalcopyrite and pyrite, with quartz as the chief gangue mineral, although, locally, carbonates and chalcopyrite are abundant. On the 1040 level, near the northeast face of the Nelson vein, more than half the vein filling is carbonate (calcite and dolomite). Chalcopyrite is the most abundant sulfide at a point 30 feet east of the winze along the Radium vein on the 1040 level. In general, however, carbonates, chalcopyrite, and pyrite are present in only minor amounts. Pitchblende occurs with the lead-silver ore on the 920 and the 1040 levels of the Radium vein (pl. 37). The pitchblende forms a streak ½–6 inches wide on the footwall side of the vein and is not intermixed with the sulfides.

The Radium and Elmer veins occupy tension fractures produced by the No Name shear fracture (pl. 37). Ore bodies occur along both the Radium and Elmer veins near their intersections with the No Name vein (pl. 37). The eastern ore body of the Radium vein and the ore body in the Nelson vein were localized apparently by changes in strike. The ore body west of the crosscut to the Elmer vein at and above the 920 level was controlled by a decrease in dip.

BELCHER MINE

The Belcher mine, 350 feet west of the Poorman mine, is on a northeast-striking vein. Corbett (1879) reports that the vein is 4 feet thick with a 6- to 18-inch "pay vein" that averages 50 ounces of silver per ton. The shaft was 110 feet deep in 1879 and 120 feet deep in 1883. Most of the ore from this mine is believed to have been produced in the late 1890's, when most of the camp was closed. Seeley (1906) reports that the shaft was 300 feet deep and the total production was $75,000.

COMSTOCK MINE

The Comstock mine (pl. 37) is the only mine, other than the Caribou Group, that was accessible in 1951. Although not in operation, the mine is being maintained in a working condition. The workings consist of a shaft 450 feet deep, accessible levels at 200 and 450 feet, and an inaccessible level at 45 feet.

The Comstock vein strikes nearly east and dips 88° to the north. The vein cuts gabbroic rocks about 50 feet east of the shaft but contains few ore minerals. On the 200 level west of the shaft, the vein consists of heavily iron-stained quartz and carbonate. One hundred and fifty feet west of the shaft on the 450 level, the vein splits; the south branch strikes S. 67° W., and is almost certainly the No Name vein. The Comstock workings on this level apparently joined with the 600 level of the No Name mine; but the workings are caved about 35 feet, horizontally and vertically, from the presumed junction. The ore along the south (No Name) branch of the Comstock vein is similar to the ore in the No Name mine. Galena, sphalerite, quartz, and massive carbonates are abundant as in the No Name vein. Bastin and Hill (1917) report that the owners of the Comstock mine recognized the No Name vein on the 45 level, 80 feet west of the shaft.

NATIVE SILVER MINE

The Native Silver mine is 700 feet west of the Caribou shaft and nearly on strike with the Caribou vein. Although the Rocky Mountain News for July 21, 1877, states that the Native Silver vein is really a western extension of the Caribou lode, recent workings on the 500 level in the Caribou mine indicate that the two veins are not continuous.

The Native Silver vein strikes nearly east and dips steeply to the north. Minerals reported (Corregan and Lingane, 1883) as present in the mine are galena, gray copper (tetrahedrite?), yellow copper sulphurets (chalcopyrite?), and quartz.

The vein reportedly averages 5½ feet in width, with a pay streak as much as 4 feet wide (Corbett, 1879). Workings consist of a shaft, at least 580 feet deep, and levels aggregating 1,700 feet in length. The total production from the mine to 1883, the last year for which figures are available, is estimated to be $1,000,000 (Corregan and Lingane, 1883).

SEVEN-THIRTY MINE

The Seven-Thirty mine is 100 feet north of the Native Silver mine and—like the latter—was considered a westward extension of the Caribou lode. However, there is no evidence in the present Caribou mine workings to indicate a westward extension of the Caribou vein.

The Seven-Thirty vein strikes nearly east and dips about 80° to the north. Corbett (1879) reports a "pay vein" as much as 22 inches wide with ore averaging $143 per ton in silver. Unlike most of the mines on Caribou Hill, the near-surface ore was very low grade. The Rocky Mountain News (October 19, 1880) reports that the mine "having passed through 200 feet of 'Cap' it opens up with a rich pay streak." The main shaft was 185 feet deep in 1879, but the size of the dump indicates further development. Production of the mine before 1879 was $25,000 (Corbett, 1879).

Samples of vein material found on the dump contain quartz, galena, sphalerite, chalcopyrite, and carbonate. In one sample from the dump only pyrite and quartz are visible; this sample bears much more resemblance to the ore from the gold mines than to the typical lead-silver ore of the Caribou Hill mines.

ISABEL MINE

The Isabel mine is 400 feet southeast of the Native Silver shaft. Corbett (1879) stated that the main shaft was 60 feet deep and production from the mine totalled $10,000. The size of the dump indicates that the mine is considerably deeper than 60 feet.

The Isabel vein appears to strike S. 78° E. and to have a vertical dip. The relationship of the vein to the southwest extension of the No Name vein is similar to that of the Caribou vein to the central part of the No Name vein.

WIGWAM MINE

The Wigwam mine is on the south side of the Caribou area and marks the southeastern limit of the mineralized area in the Caribou stock (pl. 35). The mine consists of a shaft 215 feet deep and levels at 75, 125, and 200 feet (Bastin and Hill, 1917). Production from the mine in 1874 was valued at $40,000 (Lovering and Goddard, 1950).

The Wigwam vein strikes about N. 75° E. and changes in dip from steeply north at the surface to steeply south at depth. Primary minerals reported by Bastin and Hill (1917) are galena, sphalerite (in part resinous), very minor amounts of chalcopyrite and pyrite, quartz, calcite and barite.

POTOSI AND CROSS MINES

Both the Potosi and Cross are fairly large mines on the south side of Idaho Hill near the contact of the Caribou stock. The material of the dump of the Potosi mine is mostly monzonite and that of the Cross mostly gneiss. Vein material on the dumps is too sparse to determine the average nature of the ore. It is believed that the Cross mine was worked for gold and silver during the late 1890's. [They are only briefly mentioned by the Rocky Mountain News (1895–1900) and the Mining Reporter (1898).] The Engineering and Mining Journal (1877) states that the Potosi vein is similar to the Caribou and is credited with a production of $18,000 to that time.

GREAT NORTHERN MINE

The Great Northern mine (fig. 177) is on the east side of Caribou Park, 3,000 feet northeast of the Caribou mine. Although it is on the contact of the Caribou stock, most of the dump material is monzonite.

The vein is believed to strike east, and on the basis of the size of the dump, to have been developed to a depth of at least 200 feet. Bastin and Hill (1917, p. 182), describe the ore as consisting of quartz, pyrite, and chalcopyrite with subordinate, possibly younger, sphalerite and galena. A small amount of pitchblende, not associated with any sulfide minerals, was found on the dump. Other than the veins in the Caribou mine, this is the only known evidence of pitchblende in the Caribou area.

GOLD-SILVER MINES

A small group of mines on Idaho Hill, 2,500 feet east of the Caribou shaft (pl. 35) was worked for both gold and silver. These mines are in the gneissic and pegmatitic rocks east of the contact with the Caribou stock.

SILVER POINT MINE

The Silver Point mine, about 800 feet east-northeast of Caribou, is on a vein that strikes east and dips about 80° north. Lovering and Goddard (1950) state that the vein has been worked to a depth of 250 feet and that in the oxidized zone the ore averaged about 2 ounces of gold and 100 to 200 ounces of silver per ton. Some of the pegmatitic material on prospect pits just east of the dump is slightly radioactive.

IDAHO MINE

The Idaho mine is 400 feet east-southeast of the Silver Point mine. The Idaho vein strikes N. 75° E. and is vertical. In a crosscut at a depth of about 300 feet in the Idaho Tunnel, it is a 2- to 3-inch iron- and copper-stained shear zone containing no visible sulfides. Corregan and Lingane (1883) report that the vein contained galena and "sulphuret" ore which, when sorted, was valued at from $50 to $500 per ton. The Idaho shaft in 1883 was 180 feet deep and total production was estimated at $7,000. Because this mine was operated in 1898, when most of the silver mines were closed as a result of the low price of silver, it is believed that ore from the vein contained considerably more gold than most mines on Caribou Hill.

GOLD MINE

The St. Louis mine on the west side of Idaho Hill, 1,800 feet east of the Idaho mine (pl. 37), is the only large mine in the area which was worked primarily for gold. Although no figures are available, production apparently was large enough to warrant the erection of a mill and an aerial tram to it. Bastin and Hill (1917) report the shaft to be 335 feet deep.

The vein strikes N. 63° W. and dips 78° NE. Ore found on the dump contained quartz, pyrite, chalcopyrite, and minor amounts of sphalerite and galena. Some crystals of late carbonate minerals and quartz line vugs.

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