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

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Trace Elements Investigations Report 228

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Geology and Mineralogy

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*This report concerns work done on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

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INTRODUCTION

Pitchblende was discovered in the Caribou mine, Boulder County, Colo., in 1948 by Consolidated Caribou Silver Mines, Incorporated, during the reopening of the 1040-level. Since 1948, a small quantity of pitchblende has been produced from the Radium vein during exploratory work that was done under contract with the Atomic Energy Commission. The Caribou mine, primarily a silver mine, develops five veins (Caribou, No Name, Poorman, Sherman and Silver Dollar) that were formerly worked as separate mines. Three other veins, the Radium, Elmer, and Nelson, are exposed in the Caribou mine only at and below the 920-level.

The general geology of the Caribou area, known since 1869 as a silver district, has been discussed by Bastin and Hill (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 (1950) of the U. S. Geological Survey examined the Caribou mine to evaluate the uranium deposit. In 1950, D. M. Sheridan and E. N. Hinrichs of the U. S. Geological Survey made a radioactivity reconnaissance of the mine dumps at Caribou and vicinity. This reconnaissance included examination of most of the accessible workings of the Caribou mine. Other reports on the area are listed in the bibliography.

As a result of King's preliminary examination and the later exploration for uranium on the property, the U. S. Geological Survey in 1951 began a detailed investigation of the Caribou area on behalf of the Division of Raw Materials of the 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. Upon the assignment of Kaiser to another project in August 1951, the investigation was continued until November 1951, by F. B. Moore and W. S. Cavender. During the study of the district the writers prepared a geologic map at a scale of 1 inch to 100 feet of an area of 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 inch to 40 feet.

The writers wish to acknowledge the cooperation of the staff of the Consolidated Caribou Silver Mines, Incorporated, 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 containing information on the Caribou mine. T. S. Lovering of the U. S. Geological Survey made many valuable suggestions on the identification of alteration products in thin section.

LOCATION AND GENERAL FEATURES

The Caribou area is in sec. 8, T. 1 S., R. 73 W., in the Grand Island mining district, in the southwest part of Boulder County, Colo. (fig. 1). The town of Caribou, now largely abandoned, 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 silver mines are at an altitude of about 10,200 feet on the northeast side of Caribou Hill which, with Klondike Mountain on the west and Boulder County Hill on the east, forms a divide between Caribou Creek and Coon Trail Creek, both tributaries of Boulder Creek (fig. 2). Although the relief in the area mapped is nearly 1,000 feet, both Caribou and Boulder County Hills are well rounded with moderate slopes. Broad, flat mountain meadows occupy the areas adjacent to Caribou Hill on the north and south.

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. 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).

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The ore in the upper levels of many of the mines on Caribou Hill was exceedingly rich as shown by reports in the "Rocky Mountain News" (1871-1874) and the "Mining Review" (1873-1874). Assay values 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, over $300 per ton; second class ore, $100 to $300 per ton; third class ore, $50 to $100 per ton; and fourth class ore, less than $50 per ton. Fourth class ore was either discarded or stock-piled to await construction of a mill.

The high value of much of the near surface ore apparently resulted from secondary enrichment. Native and horn silver, both secondary minerals, are frequently mentioned in early newspaper reports. Gold values were low in the lead-silver veins and Henderson (1926) records no lead production for Boulder County until 1887 when 593 pounds were produced. In 1874, Raymond (1875) noted a decrease in the grade of the ore from the Caribou mine at a depth of 430 feet. Ore production from the mine that year totaled $130,000 and had an average value of $72 a ton. Strangely enough, many of the mines from which $300 to $1,000 ore was reported early in the camp's history, failed to yield a large production. This 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 from such sources as the "Mining Review" (1873, 1874), "Rocky Mountain News" (1871-1874), Corbett (1879), Fossett (1876), Burchard (1882), and Raymond (1872-75) when integrated show a definite, gradual decline of ore values as the mines became deeper. This is best illustrated by the records, given below, from the Caribou mine--the richest and best known mine in the area.

Year	Depth of mine (feet)	Production	Value of ore (per ton)
1870	180	$ 15,000	$300
1871	212	76,576	176 to $1,000
1872	329	-	
1873	-	-	160 to 200
1874	420	130,000	72
1875	500	204,703	69

Ore was produced from the Caribou area until 1893 when the drop in the price of silver forced most of the mines to close. Some of the richer gold mines, whose initial production had been completely overshadowed by the early silver boom, resumed production in 1898. 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, following the discovery of uranium on the dump, the Caribou mine was reopened by the Consolidated Caribou Silver Mines, Incorporated, with offices in Boulder, Colo., and New York City. This mine, which has workings intersecting the No Name, Poorman, Sherman, and Silver Dollar veins, was the only one operating in the Caribou Hill area in 1951.

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

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 igneous and metamorphic rocks of pre-Cambrian age and, with the exception of unconsolidated Quaternary glacial and stream deposits, is devoid of sedimentary rocks. The pre-Cambrian 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 II). 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 shears several of which were quite productive of lead and silver. The lead-silver mineralization at Caribou is, with the exception of one mineral, 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 this deposit from all but a few in the Front Range.

Rock units

The three principal rock formations in the Caribou area are the Idaho Springs formation and the Boulder Creek granite of pre-Cambrian age, and the monzonite of the Caribou stock (fig. 2), Tertiary in age. The Caribou stock also contains small bodies of diorite, diabase, gabbro, and ultra-basic rocks.

Minor units include pre-Cambrian quartz monzonite gneiss and pegmatite (fig. 2). All the pre-Cambrian rocks are cut by Eocene(?) diorite and andesite dikes in the area southeast of Caribou. Because none of the minor rock units occur in the area mapped (fig. 3), they are not described below. Most of the lead-silver veins of the area are in the monzonite of the Caribou stock and all the pyritic gold veins are in pre-Cambrian 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 rocks of the Idaho Springs formation constitute a narrow belt, about half a mile wide, along the eastern edge of the area mapped (fig. 2); they are bordered by monzonite on the west and granite on the east. Within this belt, the Idaho Springs formation consists mostly of quartz-biotite schist and injection gneiss and, near the contact with monzonite on Idaho Hill, contains 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 pre-Cambrian 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 on the north and east sides (fig. 2). 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 few mineralized veins.

Caribou monzonite

The Caribou stock is about one square mile in extent and underlies most of the area mapped. It varies considerably in composition and is described by Smith (1938) 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 quartz monzonite, gabbro, and ultramafic rocks within, and as part of, this stock (figs. 2 and 3).

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; local 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 sparse 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 numerous places in the stock, but Smith (1938, p. 171) points out that "the distribution of the ultramafic and gabboric bodies is highly irregular and apparently unsystematic." The ultramafic bodies are composed chiefly of 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 (fig. 3).

Structure

The dominant structure of the Caribou region is a large north-northeast-trending anticline of pre-Cambrian age which appears to have controlled the intrusion of the Caribou and nearby stocks. As described by Lovering and Goddard (1950, p. 54), this anticline extends 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. On the east side of the Caribou stock, in the area mapped (fig. 3), the strike of the gneissic structure in the Idaho Springs formation is nearly concordant with the contact of the monzonite. Although local discordant contacts between the monzonite

and the Idaho Springs formation are present, the preponderance of concordant over discordant contacts and the general distribution of the monzonite bodies in the area indicate that pre-existing structures in the pre-Cambrian rocks controlled the localization of the Caribou stock.

Although the monzonite is generally massive, planar structures are visible locally. Near the eastern margin a faint banding, varying in strike from N. 25° to 55° E. and in dip from 55° to 82° NW., was observed at two places. As the monzonite is not deformed, the planar structures are interpreted to be the result of primary flow.

Jointing in the monzonite is not uncommon but is not conspicuous. The most prominent set of joints has a range in strike from N. 40° to 60° NE. 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, plate 2), and in the northern parts of Clear Creek and Gilpin Counties to the south are several large northeast-trending faults. Although these structures are not apparent in the Caribou area, they can be traced to within a few miles of Caribou and, if extended along the strike, would intersect in the Caribou district. Such faults may have served as channelways for the ore solutions in depth even though no surface indication of the faults exist. Lovering (1932) believes that the northwest-trending faults of Boulder County served as localizing agents for 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 to the north at angles of 70° or more. The northeast- and east-trending veins on Caribou Hill form an interconnecting vein system (figs. 4, 5, and 6); 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 predominantly contain pyrite-gold-quartz, form a separate system. Apparently these veins were formed earlier than the Caribou stock because veins of this type are not known in the monzonite.

The northeast-trending veins on Caribou Hill are interpretated to occupy shear zones and the veins trending east and west from the No Name vein, tension fractures branching from the shears. Although data, such as offset geologic contacts, are not available to furnish conclusive proof, this interpretation is compatible with most of the geologic data. A northeast-trending shear (the No Name) could be produced either by a compressional force acting nearly in an east-west direction or by a northeast-southwest shearing couple. The regional forces producing fracturing in the Front Range Mineral Belt of Colorado are interpreted by Lovering and Goddard (1950, p. 81) to have acted in a northeast-southwest direction. If the left side of such a shearing couple moved forward (fig. 4) any tension fractures produced should trend about east as do the Caribou, Poorman, and Radium veins.

The direction of relative movement of the vein walls is difficult to determine by underground examination. Slickensides are nearly horizontal in the mine workings, but the evidence presented by chatter marks is inconclusive. The amount of horizontal movement along the veins is 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. What appears to be a displacement of the Radium-Elmer vein (fig.4) 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 the case 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 in amount, the brecciation and fracturing of the vein walls and 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 4, 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, only the levels below the 860 can be considered. On the 920-level, and less obviously,

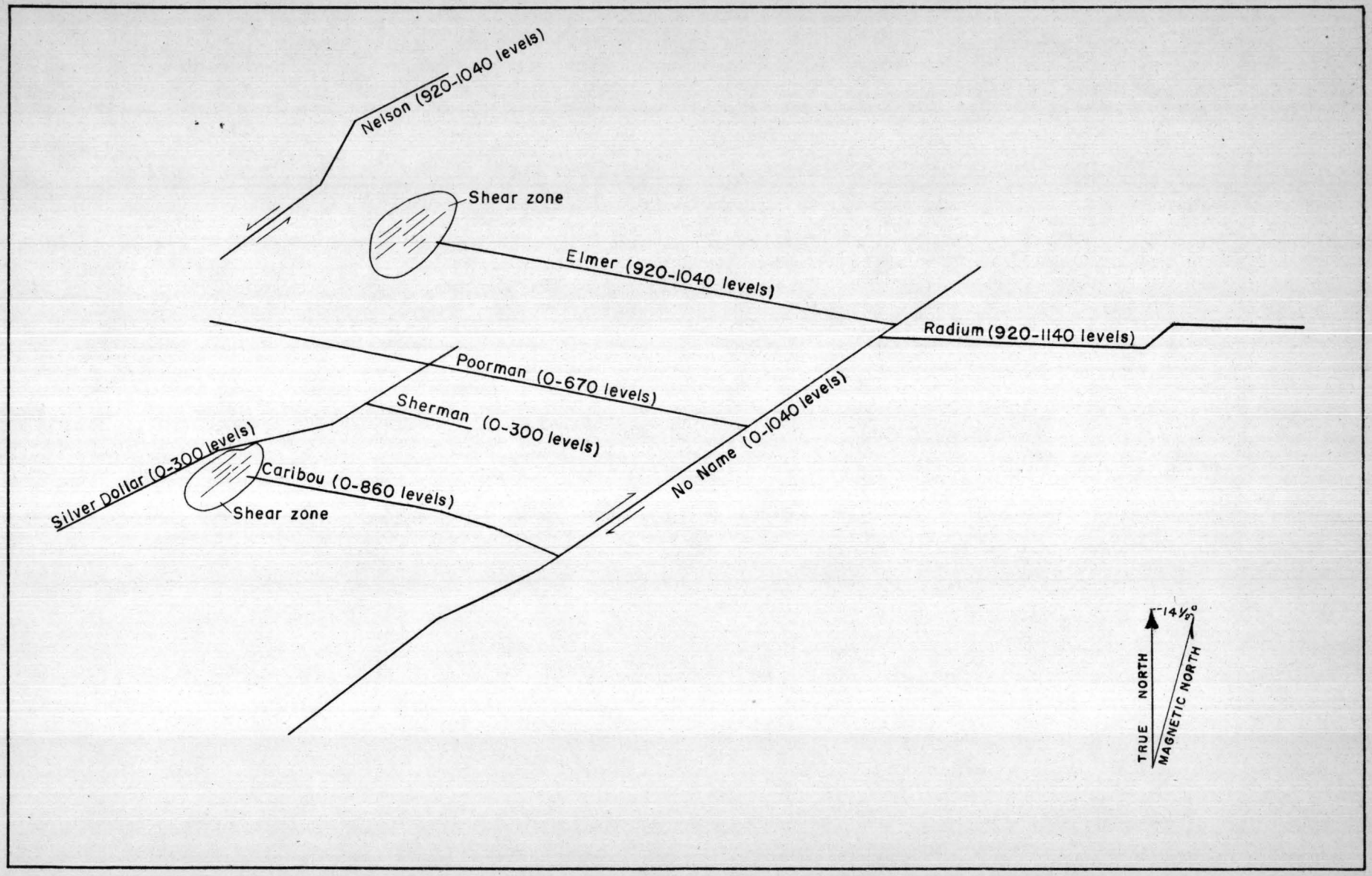


FIGURE 4.—GENERALIZED STRUCTURE OF THE CARIBOU GROUP VEIN SYSTEM, BOULDER COUNTY, COLORADO.

100 0 100 200 Feet

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 pyritic 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 half a square mile on Caribou Hill (fig. 3); a few are on Boulder County and Idaho Hills, half a mile to the east. The majority of the lead-silver veins are in the Tertiary monzonite, but a few also occur in the pre-Cambrian rocks. The pyritic gold veins occur only in pre-Cambrian rocks, predominantly in gneisses of the Idaho Springs formation. The absence of pyritic gold veins in the monzonite suggests that these veins were formed before the fracturing or even emplacement of the Caribou monzonite stock 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 pyritic gold mineralization was earlier than the lead-silver mineralization.

Pyritic gold veins

The pyritic gold veins of the Caribou area are relatively unimportant, both quantitatively and economically. A few pyritic gold veins were worked in the 1890's (Mining Reporter, Aug. 11, 1898, p. 18), after the silver mines were closed, but the total production from these is believed to be small. A small group of veins, including the Silver Point, Idaho, Elephant, and Windy Point (fig. 3), which contained both gold and silver minerals (Lovering and Goddard, 1950, p. 202), are included in this report with the pyritic gold veins, but perhaps these should be classed as composite veins. None of the pyritic gold mines was accessible at the time of this survey.

The pyritic gold veins are on the west side of Idaho Hill, less than half a mile east of the Caribou mine (fig. 3). 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. For this reason, it is believed that these veins do not extend into the monzonite. The country rock cut by the pyritic gold veins is mostly schist and gneiss; however, near the contact with the monzonite, large amounts of pegmatitic rock are present.

Although none of the pyritic 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, states: "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

All the veins in the Caribou monzonite stock contain silver as the most valuable and lead as the most abundant metal. The Radium vein, in addition to lead-silver minerals, contains pitchblende, and because of this it is discussed separately. A small quantity of radioactive material 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 one-half mile square, on the east and northeast slope of Caribou Hill (fig. 3); a few veins are found about one mile away to the east, north, and northwest of Caribou Hill. Of these nearby but outlying veins, only the Boulder County vein to the east is believed to have had more than small production. None of these outlying veins is included in the area mapped.

The mineralogy and paragenesis of the Caribou lead-silver ores is bases 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 order of deposition, the primary minerals in the lead-silver ores are quartz, pyrite, sphalerite, galena, chalcopyrite, pitchblende, 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.

All of the lead-silver ores of Caribou Hill are similar and the minerals listed above, with the exception of pitchblende, are believed typical. 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 mineralizing period. The early quartz is massive white "vein quartz" usually 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 a dark sphalerite, "black jack", and a yellowish-green sphalerite, "rosin jack", are present in the Caribou mine. Except for one place along the Radium vein at the 1040-ft 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-ft 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 over a foot in width occurs along the No Name vein on the 500-ft 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-ft level. The workings are inaccessible, but Endlich (1874) reports cerussite, malachite, and native silver from the 210-ft level and Raymond (1875) reports "horn silver" from the 200-ft level. The writers found abundant native silver in a veinlet on the 300-ft level and saw small amounts on the 360-ft level. The operators of the mine report that some native silver was found in a stope on the 920-ft 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" only in 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 ore values 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 increased 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 ore values by as much as 50 percent. The base of the zone of secondary sulfides is believed to be at about 740 ft where there there is a noticeable decrease in iron oxide.

The lower limits of the oxidized and the secondary sulfide zones are related to the water table which is controlled primarily by the topography (fig. 7). The water table is normally somewhat higher than indicated in figure 7 and would be at the level shown only during excessively dry periods. The lower limit 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 have relatively rapid downward movement, but in the secondary

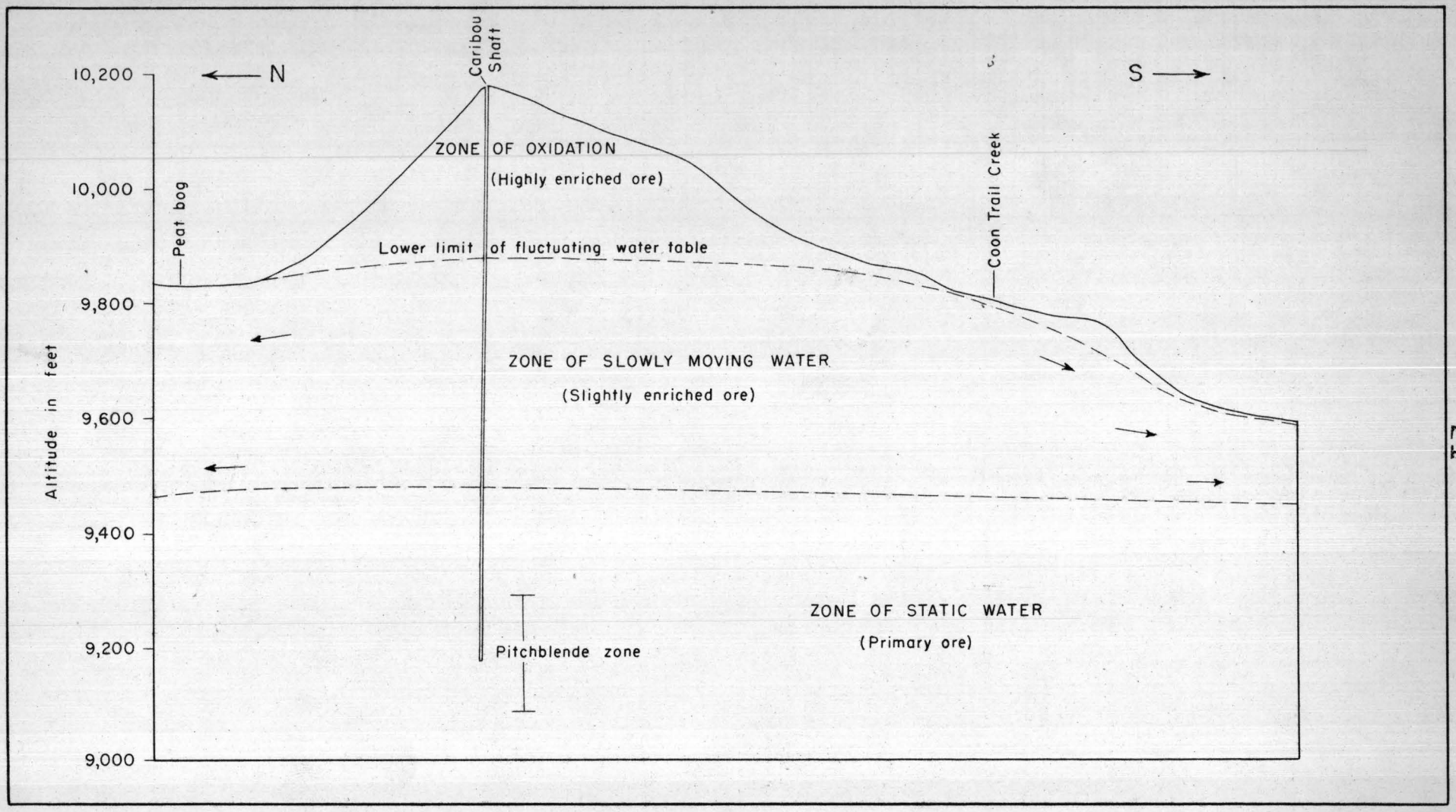


FIGURE 7.—GENERALIZED SECTION OF CARIBOU HILL, BOULDER COUNTY, COLORADO, SHOWING RELATIONSHIP OF ORE ENRICHMENT TO GROUND WATER MOVEMENT.

Horizontal Scale
600 0 1200 Feet

Datum is mean sea level

sulfide zone the ground water would move much more slowly, because the gradient would be controlled by Coon Trail Creek at the same elevation 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 are gradational. The absence or scarcity of the very active precipitants of silver (pyrrhotite, chalcocite, etc.) in the mine makes possible the easy movement of the silver by the ground water.

The effects of enrichment on ore minerals other than silver are not well known 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, it presumably was leached from the near surface parts of the veins. The Mining Review (v. 1, no. 6, p. 11, 1873) 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, which occurs almost entirely below the oxidized zone, probably was not affected by secondary processes. If it were present in the oxidized part of the vein, it probably was removed for it is readily soluble in acid solutions.

The wall rock of the Caribou lead-silver veins is mostly a 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 the more mafic rocks was made.

The wall rocks of the lead-silver veins of the Caribou area have been silicified, argillized, and chloritized progressively outward from the vein as much as three feet. Silica and chlorite occur along all the veins. The products of argillization, possibly extensive at one time, have been partly obliterated by later alteration; they form a distinct zone only at a few places. The monzonite adjacent to the veins is intensely altered to a hard, bleached, silicified rock in which the texture has been destroyed. This silicified zone, ranging from a few inches to 2 feet in thickness, is characterized by disseminated

cryptocrystalline quartz, sericite, and carbonates as well as by numerous veinlets of fine-grained quartz and carbonates. In most places, this intensely altered zone, grades into slightly altered rock characterized by chlorite. The chloritic zone grades outward into fresh rock. An argillized zone occurs in a few places between the chloritic and silicified zones (fig. 8). Composed of a green-gray, friable rock, the argillized zone contains abundant minerals of the montmorillonite group. This montmorillonite zone is only 6 to 12 inches thick along the Radium vein, but is several feet thick along the No Name vein on the 500-ft level. The contacts of the montmorillonite and adjacent zones are sharp.

Assignment of alteration minerals to definite zones is not meant to imply that these minerals are limited to a particular zone or that other alteration minerals are absent from this zone. The zones are names for the most abundant or characteristic minerals. In addition to sericite, silica, calcite, montmorillonite, and chlorite, the following minerals have been tentatively identified microscopically: (1) kaolinite--common but not abundant, in the two inner zones, (2) beidellite in the montmorillonite zone and (3) hydromuscovite, chiefly in the montmorillonite zone.

Wright (1950) in studying the pitchblende ore shoot in the Radium vein, recognized four zones of alteration which he numbered outward from the vein; (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, containing abundant sericite and small amounts of kaolinite and montmorillonite, and marking 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, they form a single, gradational zone.

The most persistent vein in the Caribou area--the No Name vein (figs. 3 and 4)--strikes northeast and has been worked over 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 (fig. 3). Most of the other veins are short--300 to 400 feet in length--and few have been worked to depths of more than 300 feet. The

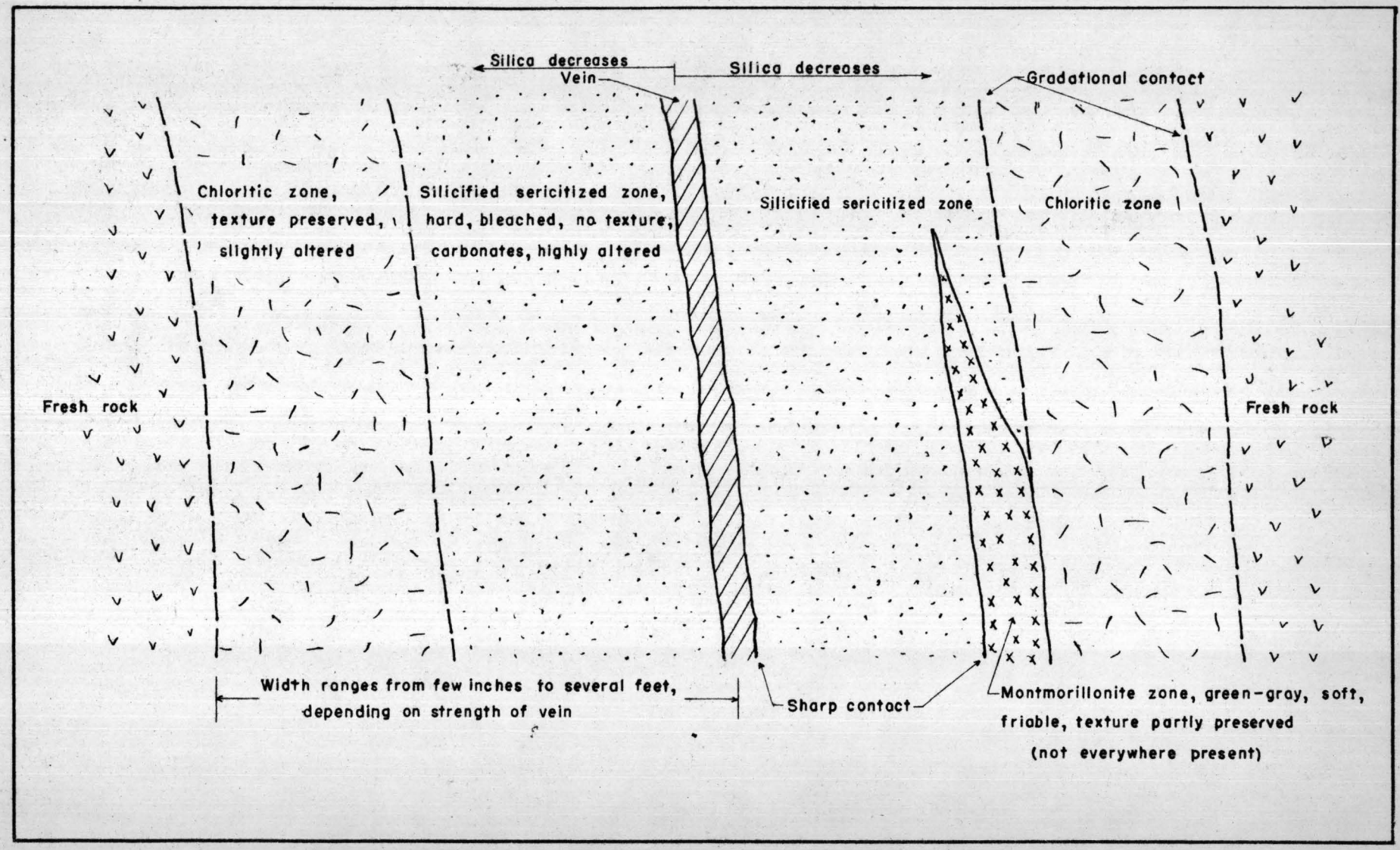


FIGURE 8.—DIAGRAMMATIC CROSS SECTION OF VEIN, SHOWING ALTERATION, CARIBOU MINE, BOULDER COUNTY, COLORADO

Caribou vein, which can be traced for 300 feet on the 300-ft level of the Caribou mine, appears to become shorter as the depth increases (fig. 5). Below the 860-ft level, it cannot be recognized. Several veins which are known on the deeper levels--the Elmer, Radium, and Nelson--may be deeper parts of surface veins that were worked to shallow depths under other names.

The lead-silver ore bodies of the Caribou mine form vertical or steeply plunging ore shoots. The larger shoots extend for over 200 feet along the vein and have been followed to depths of more than 700 feet. The veins are as much as 7 ft 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 and the other wall 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 latter type of rock.

The ore shoots in the veins on Caribou Hill are localized by changes in dip or strike of the vein and by vein intersections. A series of tension fractures that trend west from the No Name vein contain ore shoots near their intersection with the No Name vein, a northeast-trending shear 4 to 6 feet wide. The concentration of ore minerals in the tension fractures (i.e. the Caribou vein) was in many places greater than in the stronger shear fractures. Highly fractured rock partly filled the openings along the No Name vein prior to mineralization and, in places, was cemented by the minerals. Such brecciation is absent along the subsidiary west-trending tension fractures. Post mineral movement, indicated by crushed vein minerals except the last deposited carbonates, is apparent along the northeast-trending shear fractures. No post-mineral movement is apparent in the west-trending veins.

The ore bodies in the Caribou vein are thicker in the flat parts of the vein. This is especially evident on the 360-level where the vein flattens from about 80° to 50° and increases to 10 feet in thickness (fig. 9). The Caribou vein steepens at the 800-ft level and is too thin to furnish minable ore; it was not explored below the 860-ft level. Although the other veins in the Caribou group are not sufficiently well exposed to determine the structure of the ore shoots, it is believed that a similar structural relationship may also control, in part, the localization of ore in other shoots.

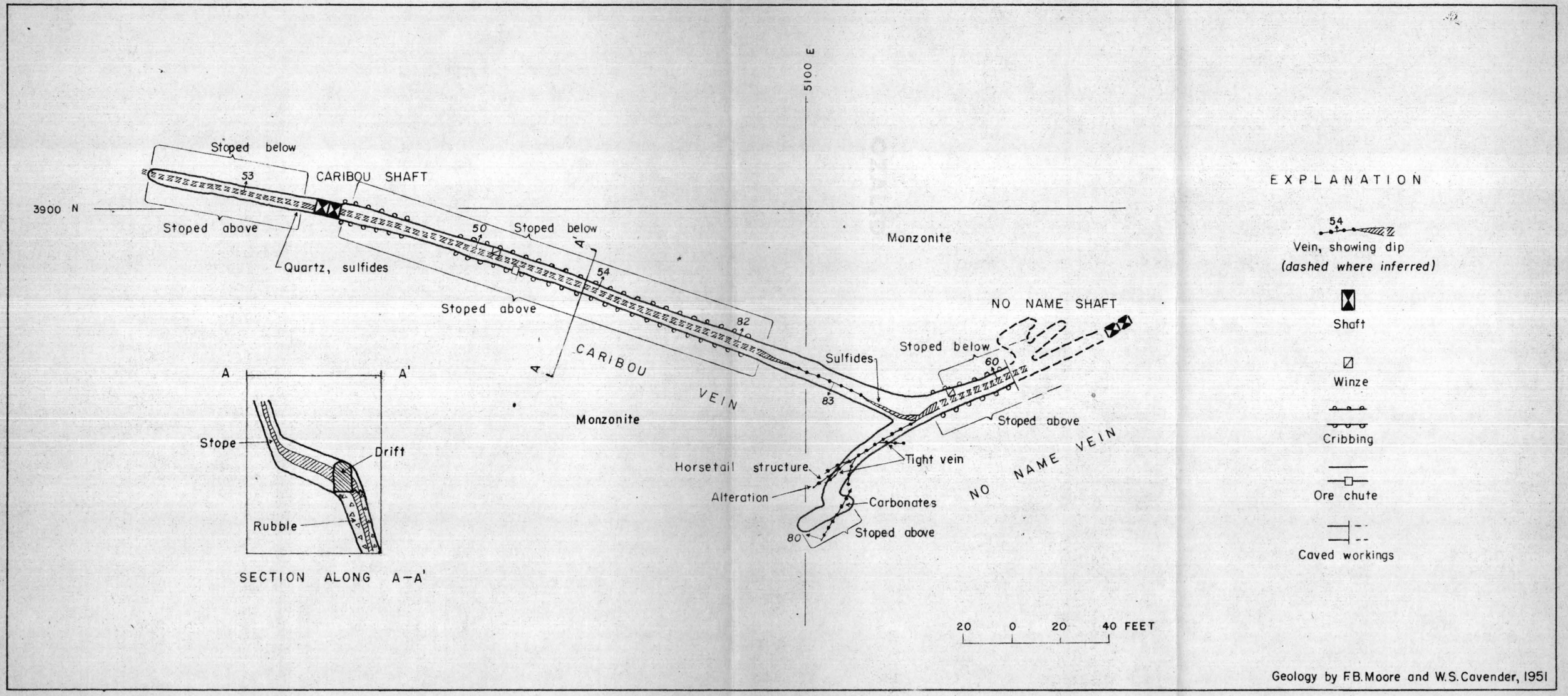


FIGURE 9. — GEOLOGIC MAP OF THE 360-FOOT LEVEL, CARIBOU MINE, BOULDER COUNTY, COLORADO

Changes in strike, especially along the northeasterly striking 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 intersection of that vein with the Caribou vein is the dominant influence in ore localization but on the 1040- and 920-levels (figs. 10 and 11), where no Caribou vein is present, slight changes in strike to a more easterly direction coincide with the stoped areas. In general, the westerly trending tension veins are straight because of the homogeneity of the wall rock and the horizontal movement, relative to that of the shear zones, is small. Accordingly, changes in strike were not important factors in the control of the ore deposition in the tension veins. The ore shoot localized by a change in strike along the Radium vein (tension), is small.

Silver is by far much more important economically than lead in the ores of Caribou Hill area. Gold rarely exceeds one or two-tenths ounce per ton and no gold values are reported for the lead-silver veins by early newspaper accounts or by Fossett (1879) or Raymond (1872-1875). 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 ores, especially in the oxidized zone, were exceedingly rich; assay values of 200 to 300 ounces of silver per ton were not uncommon. However, the bulk of the production came from ores of much lower grade. The Caribou vein, both 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/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. Figures released by the Consolidated Caribou Silver Mines, Inc. show the following receipts from the smelter at Leadville: 1947, $8,718.84; 1948, $15,788.74; 1949, $53,359.17; 1950, $56,997.46; 1951, $127,658.24; 1952 to November, $257,124.74. Most of the ore came from the 920 and 1040-ft levels but a small amount came from the 500-ft 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 much less abundant than lead. Analyses of 17 samples taken from the uranium-bearing areas of the Radium vein are shown in table 1.

Table 1. --Analyses of samples from the Radium vein.
(See figure 4)

Sample number	Level	Location: Distance from No Name vein (feet)	Length of sample (inches)	U (percent)	Pb (percent)	Zn (percent)	Cu (percent)	Ag (oz./ton)	Au (oz./ton)
CCA-1	920	75	8	0.08	5.85	3.94	0.02	72.07	0.03
CCA-2	920	80	8	.22	2.29	3.78	.04	10.14	.03
CCA-5	920	111	9	.79	4.28	5.27	.02	15.12	.04
CCA-6	920	116	2 1/2	.18	8.29	4.07	.11	76.77	.10
CCA-8	920	121	9	.23	3.01	3.07	.36	75.84	Tr.
CCA-9	920	126	10	1.85	5.20	2.77	.39	217.64	.14
CCA-10	920	131	9	.11	3.96	2.82	.24	38.28	.08
CCA-3	1040	51	3	.36	22.99	16.73	.01	3.20	Tr.
FM-5-48	1040	271 1/2	6	.49	3.73	5.33	.04	22.31	.05
-49	1040	276	7	.04	1.96	1.46	.02	2.76	None
-50	1040	280 1/2	12	.36	10.13	4.80	.01	8.87	.03
-51	1040	285	13	.08	15.82	7.68	.02	1.64	None
-52	1040	285	12	.01	11.84	17.06	.03	4.30	.04
-53	1040	293 1/2	13	.15	7.74	3.98	.05	14.05	.02
-54	1040	302	12	.19	12.23	2.78	.16	108.40	.07
-55	1040	309 1/2	8	.28	6.16	6.61	.02	7.84	.02
-56	1040	315	8	.02	.46	.22	<.01	.72	None

Uranium-bearing lead-silver veins

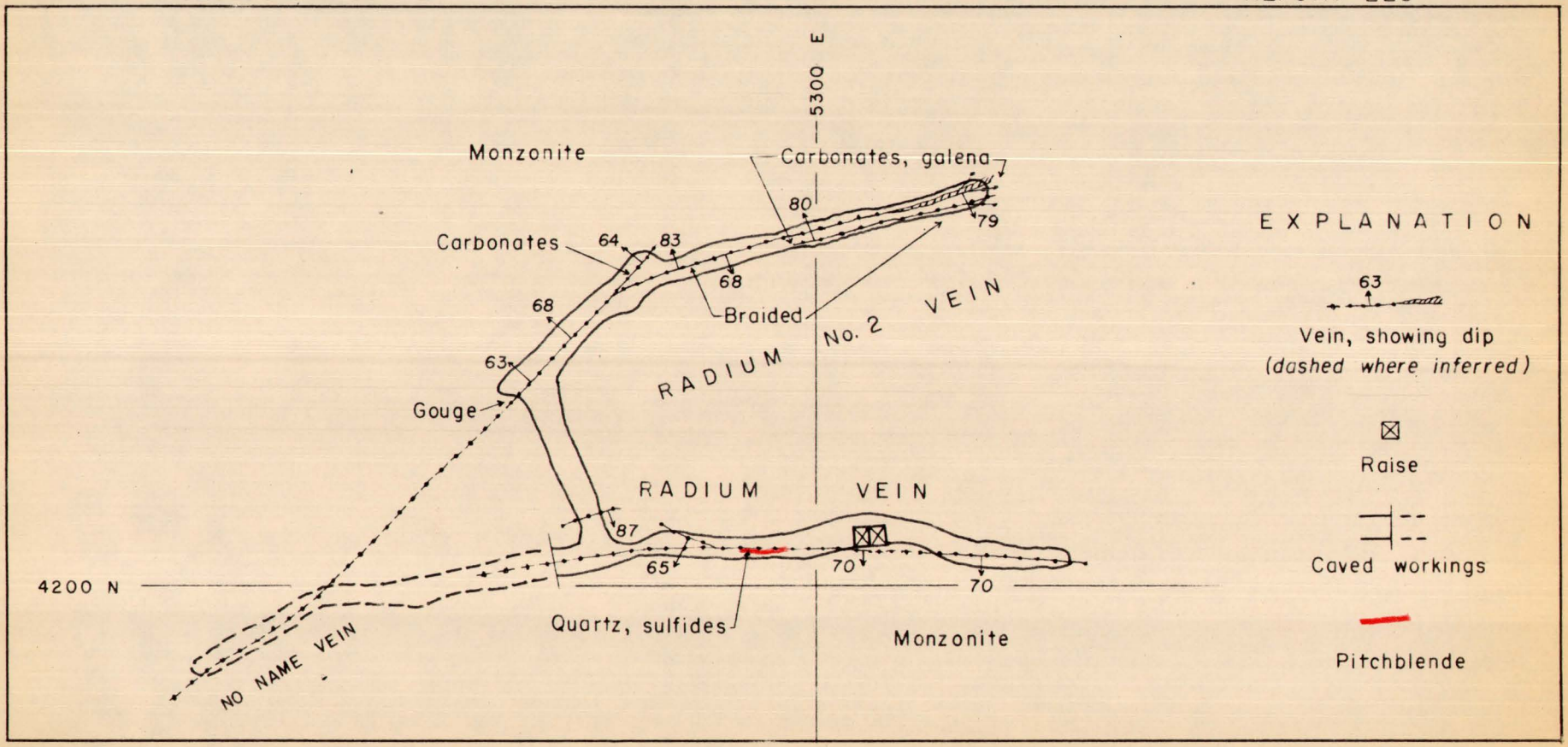
Aside from the presence of pitchblende, the uranium-bearing veins in the Caribou area are similar mineralogically to the lead-silver veins; also the two types of veins form one interconnecting vein system. However, the uranium-bearing veins are discussed separately in this section, not because they are considered a separate type of vein, but because they were given special attention in view of the strategic importance of uranium.

The only known pitchblende deposits in the Caribou area are in the Caribou and the Great Northern mines. In the Caribou mine, pitchblende occurs along the Radium vein at depths between 900 and 1140 feet (figs. 10, 11, 12, and 13) and along the Nelson (?) vein on the 500-ft level (fig. 14). Pitchblende was found on the dump of the Great Northern mine, but because the mine has been inaccessible for many years 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 forms a streak generally less than an inch thick between sulfides and gouge along the footwall of the vein. The streak in a few places is as much as six inches thick; in places it 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 minor pyrite were the earliest minerals. The quartz is mostly white and massive; however, some of it 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, appears at places to corrode and embay these minerals and probably is younger in part. A younger age for part of the chalcopyrite is indicated by its occurrence along cleavages in galena, as crystals growing along a sphalerite-galena contact, and as convex projections into galena.

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 the samples that were collected failed to show definite age relationships with other minerals. It is believed, however, that the



Geology by F.B. Moore and W.S. Cavender, 1951

FIGURE 12.—GEOLOGIC MAP OF THE 1140-FOOT LEVEL, CARIBOU MINE, BOULDER COUNTY, COLORADO.

20 0 20 40 Feet

hard pitchblende is slightly younger than the galena and sphalerite. One specimen contains an irregular veinlet of hard pitchblende that cuts pyrite. If the pitchblende were earlier than the galena, it is believed that evidence of galena cutting pitchblende would be available due to the relative abundance of galena in the pitchblende zone. If the pitchblende were contemporaneous with the galena and sphalerite, small amounts 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, Appendix, p. 1) in discussing the mineralogy of the Radium vein states: "The ore minerals recognized in the polished surface are uraninite, 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. The deposition of sooty pitchblende in vugs, following deposition of colloform quartz and fine oolitic pyrite, 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 (1952) give an age of 23 ± 10 million years for the pitchblende at the Caribou mine. The above age determination, which was probably made on pitchblende of the hard variety, was not corrected for common lead. George 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 and Hill (1917, p. 124) believed was contemporaneous with the pyritic 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 that: "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 (1951, p. 92) 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 seems unlikely because, were this the case, it would be possible to find places where only hard pitchblende occurred and places occupied only by soft pitchblende. The two varieties appear to be coextensive.

Most of the pitchblende in the Caribou mine is in the Radium vein; a small amount occurs along an unnamed vein (possibly the Nelson) on the 500-ft level. Pitchblende has been exposed along the Radium vein on the 920-, 1040-, and 1140-levels, the only levels that have explored the Radium vein (figs. 10, 11, 12). 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 has a horizontal length of over 70 feet (fig. 13). The smaller ore shoot extends for 40 feet along the drift and upward 75 feet in a raise from the 1040-level. The larger pitchblende ore shoot plunges steeply to the west and the smaller one appears to be vertical but also may plunge steeply to the west.

Within the ore shoots the pitchblende is erratically distributed. Assay values vary by as much as 100 to 1 in a distance of 2 1/2 feet. At places where pitchblende occurs, the minerals typical of the lead-silver veins are always present, usually in considerable abundance. Some of the ore in the pitchblende-bearing areas is minable for the lead-silver content. The uranium ore, some containing as much as 7 percent uranium, has been separated from the lead-silver ore and from the gangue by hand sorting. With the exception of a small shipment for metallurgical purposes, all the uranium ore produced from the Caribou mine has been stockpiled by the company.

MINE DESCRIPTIONS

There are 100 patented claims in the area mapped (fig. 3). Forty-six of these claims have been identified with surface workings and names also have been assigned to an additional 38 unpatented properties. The mine and vein names on figure 3 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 names of the smaller mines or prospects could not be determined. About 30 mines are 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 of the mines described, the Great Northern, is a few hundred feet outside the area mapped and its location is shown on figure 2. The Caribou and the Comstock mines were the only ones accessible in 1951.

Silver mines

Caribou group

The Caribou group (fig. 3) 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 300-ft 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-ft 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 a 3700-ft adit (fig. 15) that intersects the Caribou shaft at a depth of 500 ft. In 1951 the ore was being exploited from the No Name, Nelson, Elmer, and Radium veins on the 920- and 1040-ft 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 prior to 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, and the total value of ore produced from the mine is estimated as $2,500,000.

Some of the ore was very rich; assay values of $300 to $500 a ton were not uncommon.

The mine is developed by a shaft 1,040 feet deep with levels at 50, 100, 200, 300, 360, 380, 470, 500, 530, 600, 670, 740, 800, and 860 ft below the collar (figs. 9, 14, 16, 17, 18, 19, 20, 21, 22, 23, 24, and 25). Shafts 100 feet apart along the vein, one to the east and 5 to the west of the main shaft, are now covered by the main dump.

The Caribou vein strikes approximately east and has an average dip of 75° to the north. The vein is nearly 300 ft. long on the 300-ft level (fig. 16) but shortens at depth and feathers out 860 feet below the collar (fig. 6). The width of the vein averages about 2 feet, increasing to a maximum of 10 feet on the more gently dipping parts of the vein (flats). The silver ore is localized in well defined shoots mostly in the eastern part of the vein near its intersection with the No Name vein (fig. 17). The ore is highly siliceous and shows no evidence of post-mineral crushing. Carbonates are sparse in the Caribou vein probably due 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 minor chalcopyrite.

The main Caribou vein has been stoped to a depth of nearly 800 ft and westward from the No Name vein for distances varying from 300 ft on the 300-level to 150 ft on the 740-level. As the main Caribou vein feathers out a short distance below and to the west of the stoped areas and as no ore-bearing extension of the vein has been found east of the No Name vein, it is doubtful if the vein still contains workable ore.

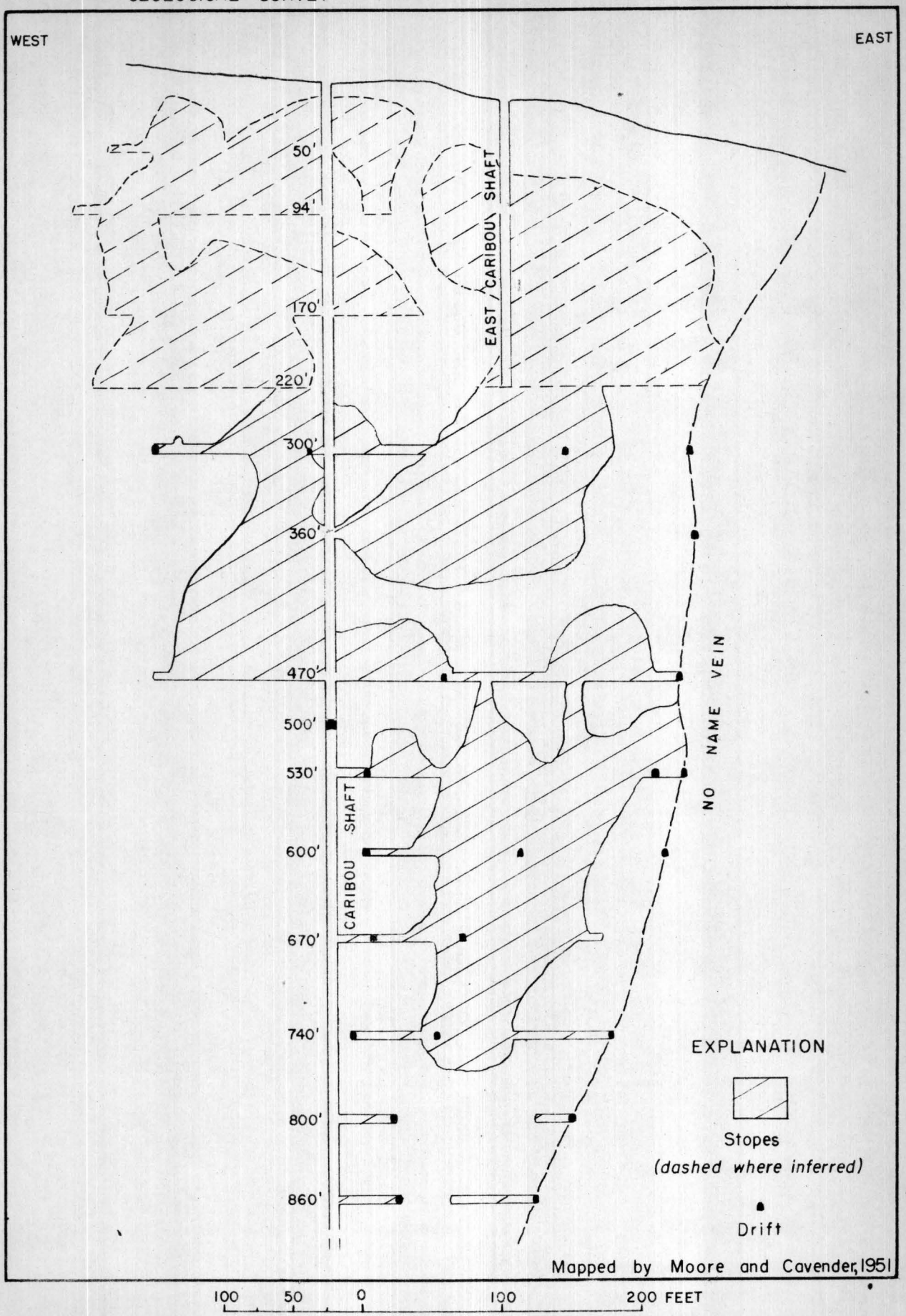
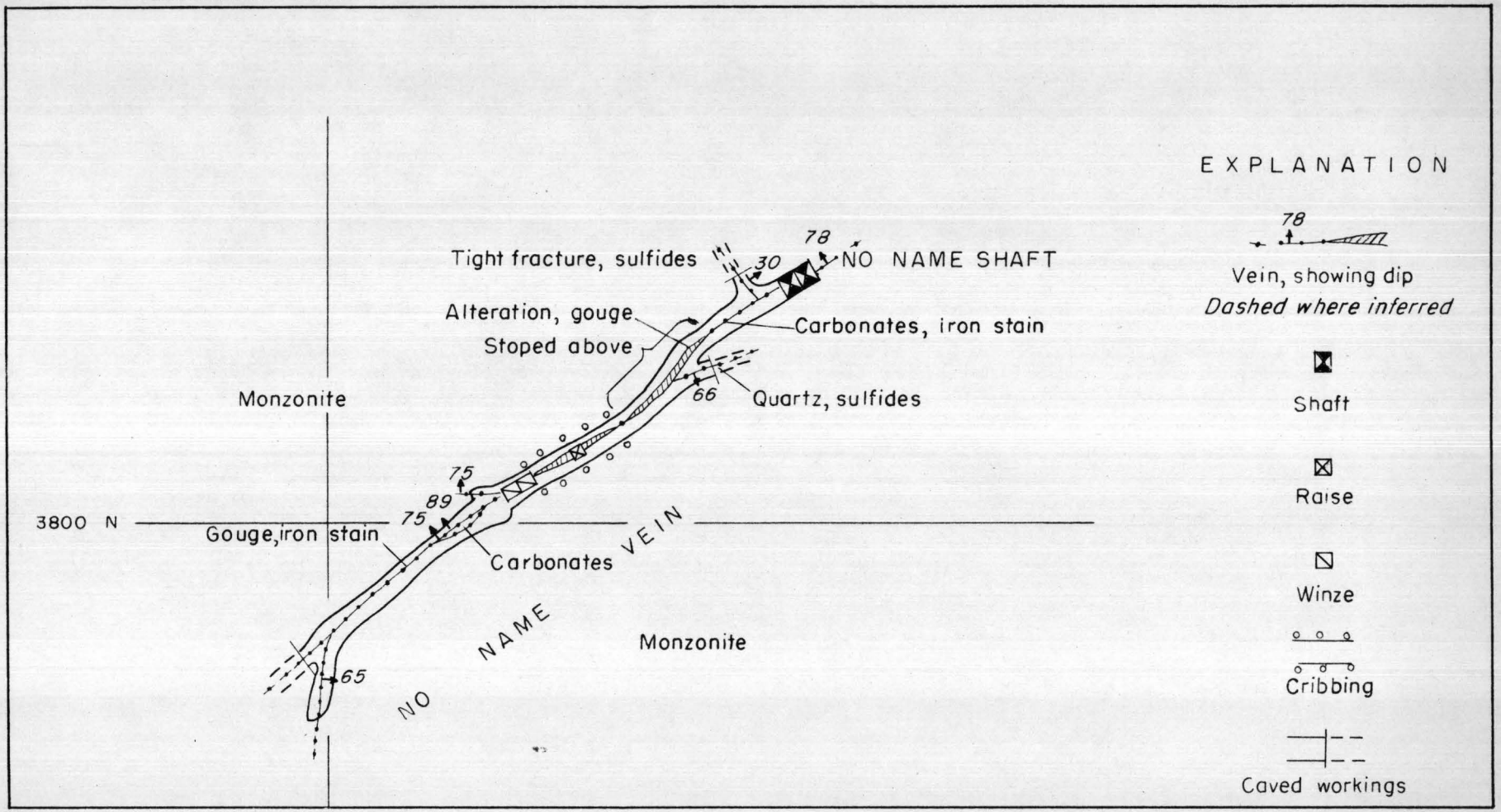


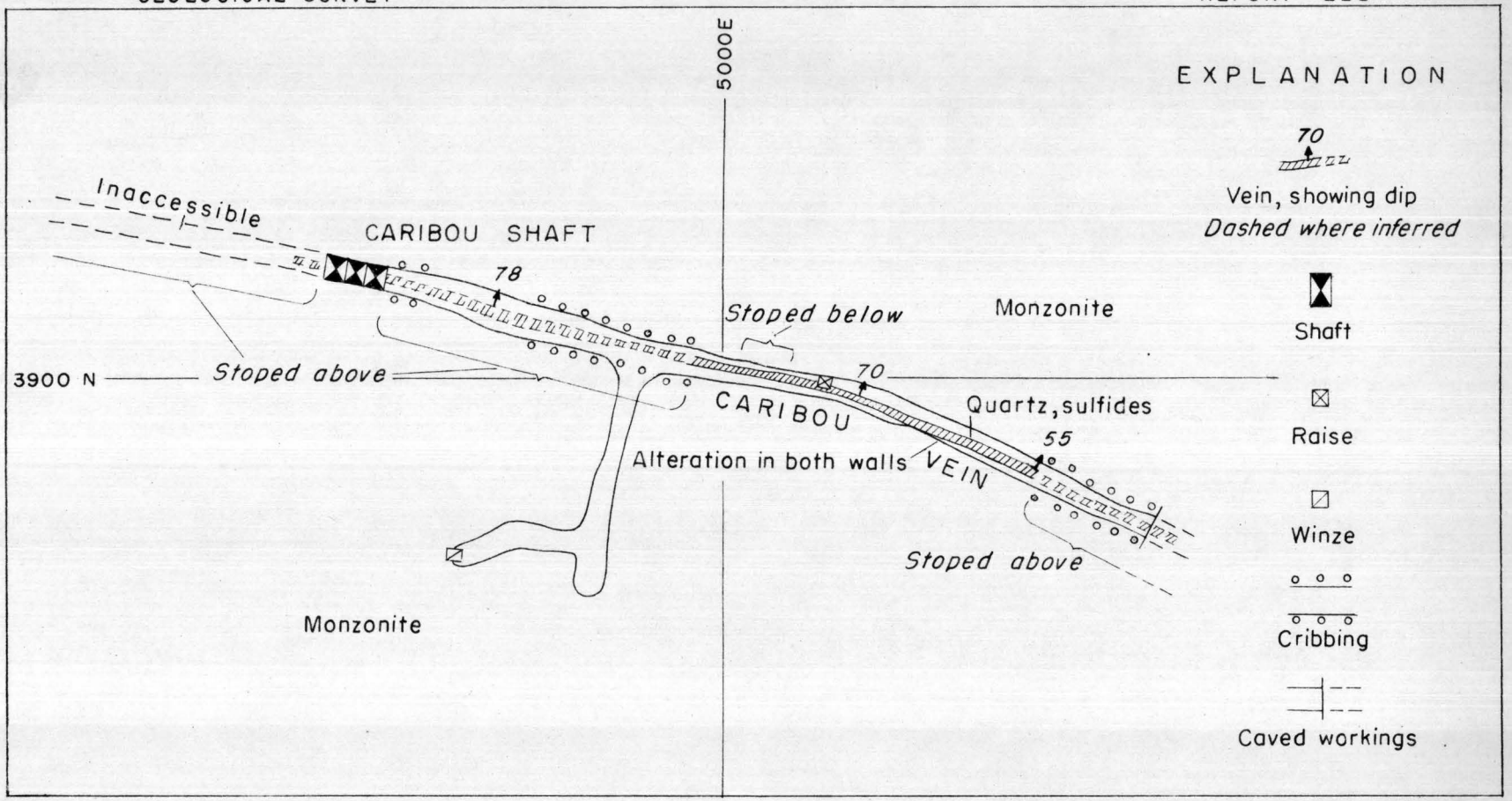
FIGURE 17.—VERTICAL LONGITUDINAL PROJECTION OF CARIBOU VEIN, CARIBOU MINE, BOULDER COUNTY, COLORADO



Geology by F.B. Moore and W.S. Cavender, 1951

FIGURE 18.— GEOLOGIC MAP OF THE 380-FOOT LEVEL, CARIBOU MINE, BOULDER COUNTY, COLORADO.

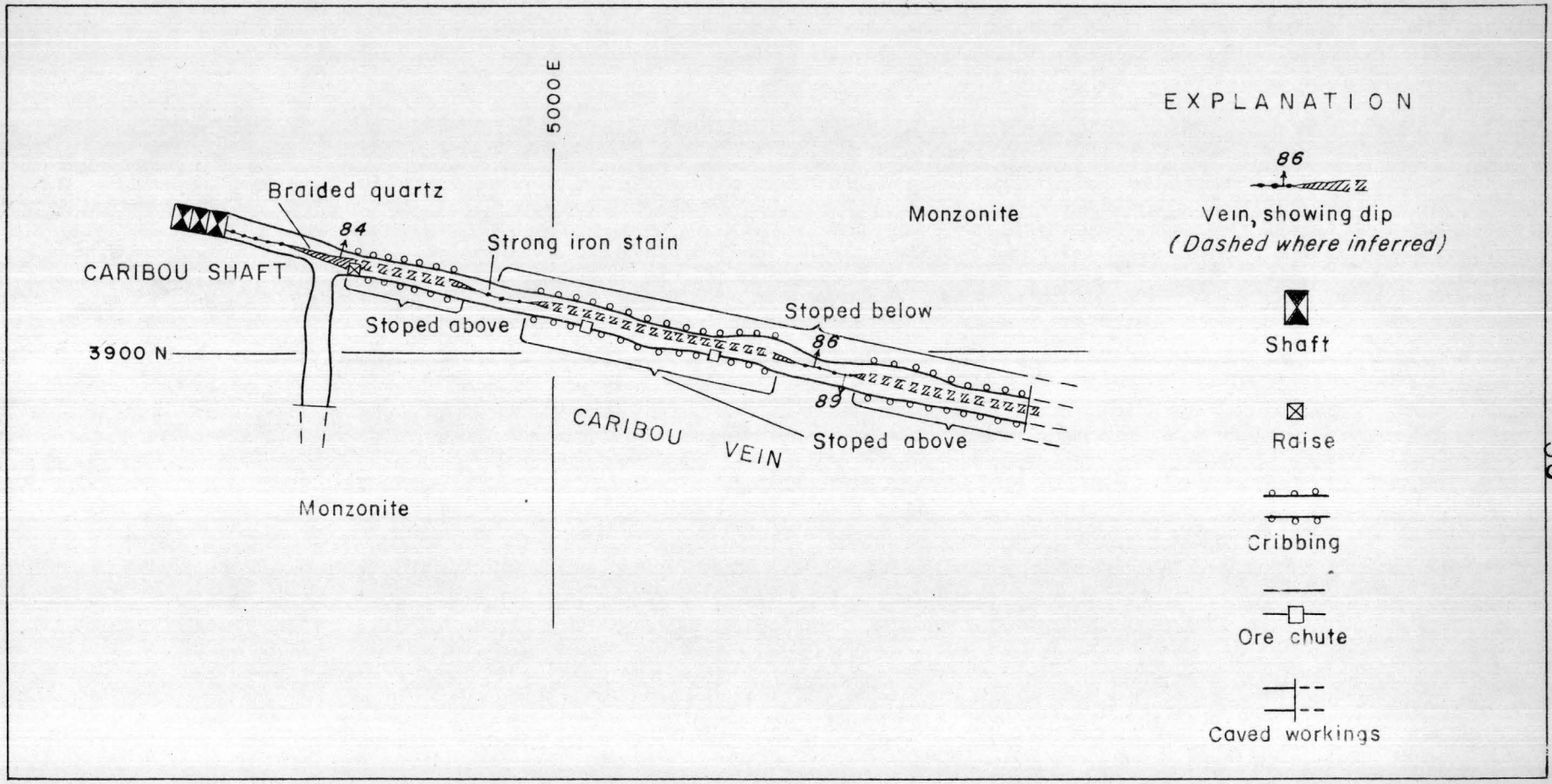
40 0 40 80 Feet



Geology by F. B. Moore and W. S. Cavender, 1951

FIGURE 19.-GEOLOGIC MAP OF THE 470-FOOT LEVEL, CARIBOU MINE, BOULDER COUNTY, COLORADO.

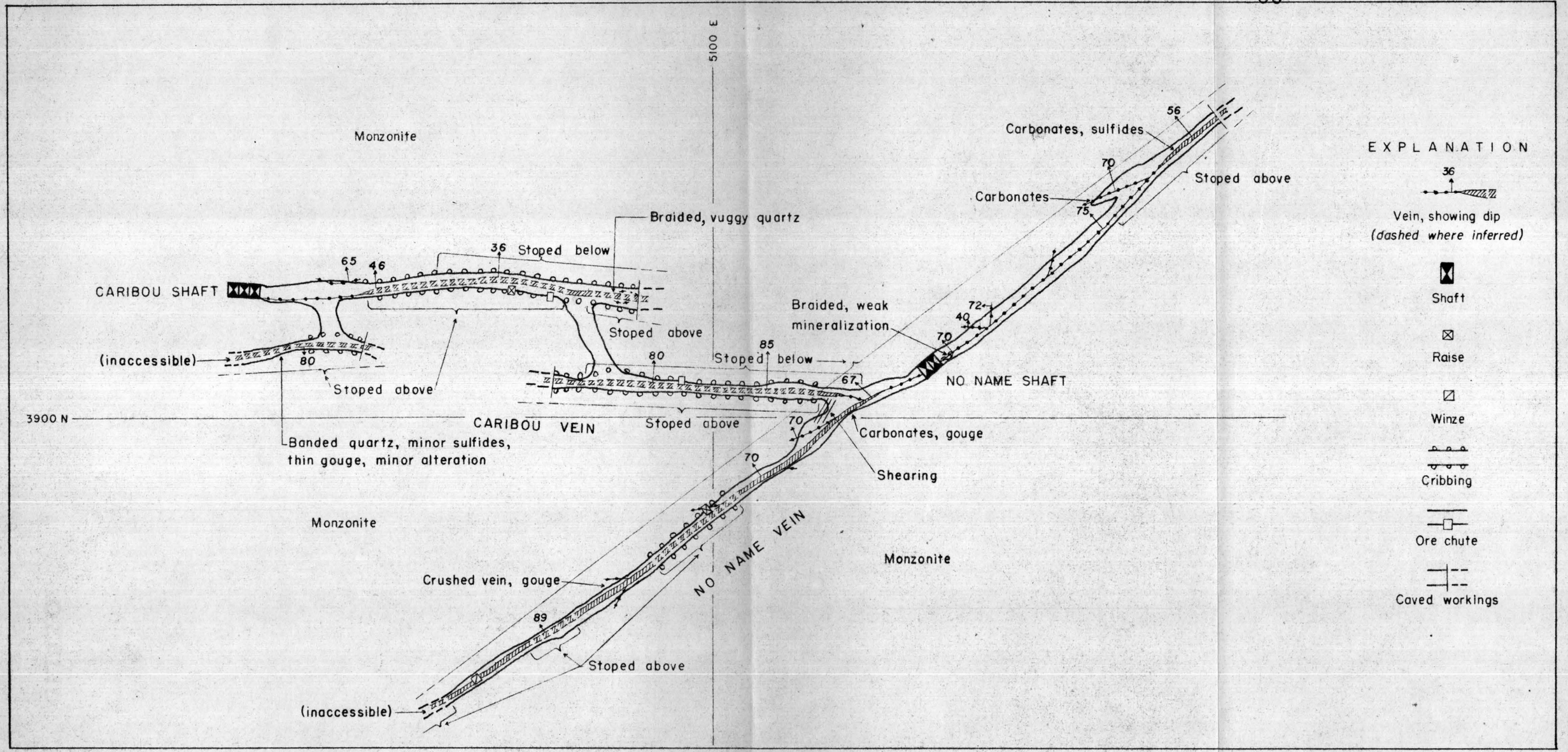
40 0 40 80 Feet



Geology by F.B. Moore and W.S. Cavender, 1951

FIGURE 20.—GEOLOGIC MAP OF THE 530-FOOT LEVEL, CARIBOU MINE, BOULDER COUNTY, COLORADO.

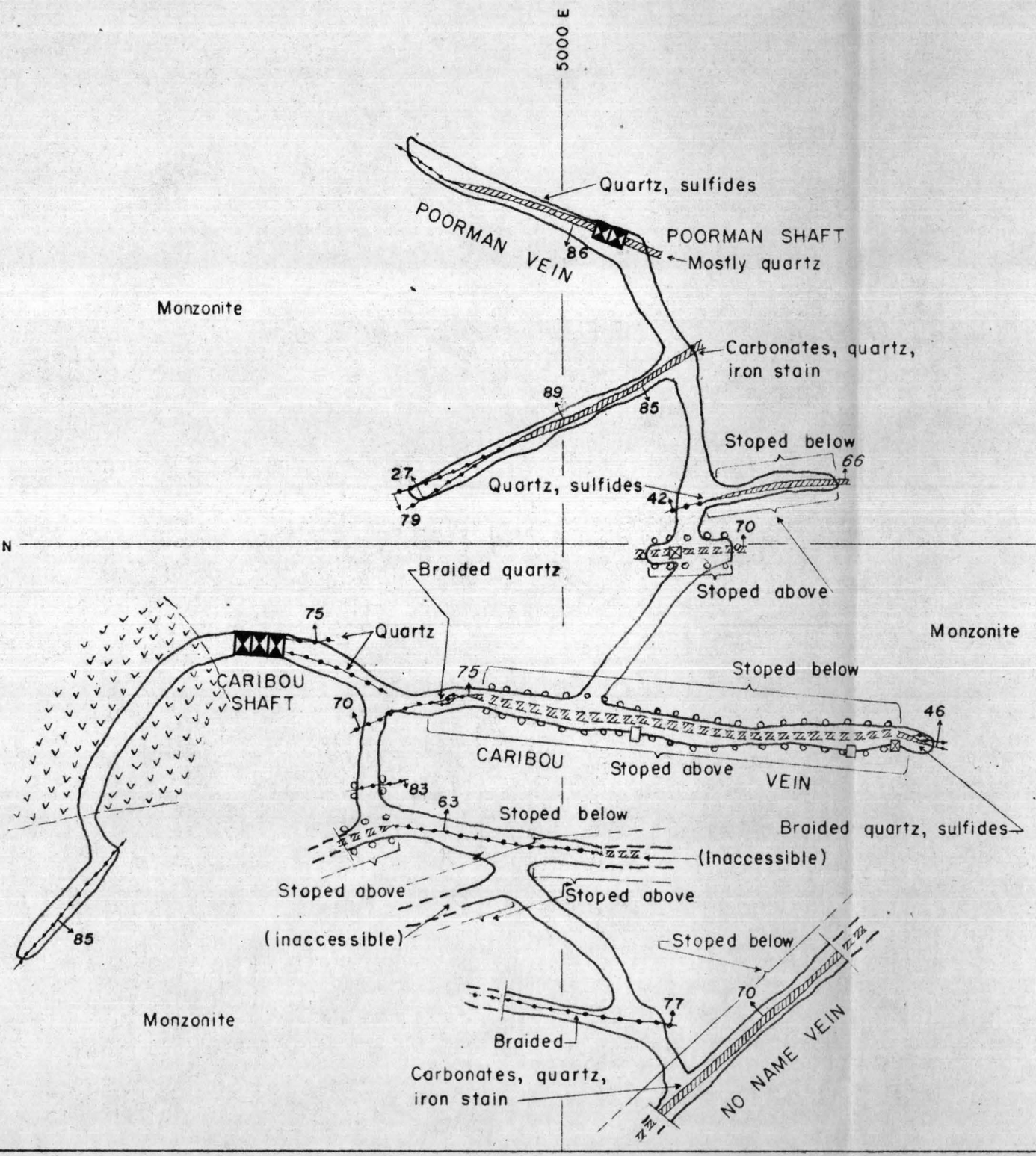
40 0 40 80 FEET



Geology by F.B.Moore and W.S.Cavender, 1951

FIGURE 21.-GEOLOGIC MAP OF THE 600-FOOT LEVEL, CARIBOU MINE, BOULDER COUNTY, COLORADO.

40 0 40 80 Feet



EXPLANATION

Monzonite

Biotitite ?

Gradational contact

42
Vein, showing dip
(dashed where inferred)

Shaft

Raise

Cribbing

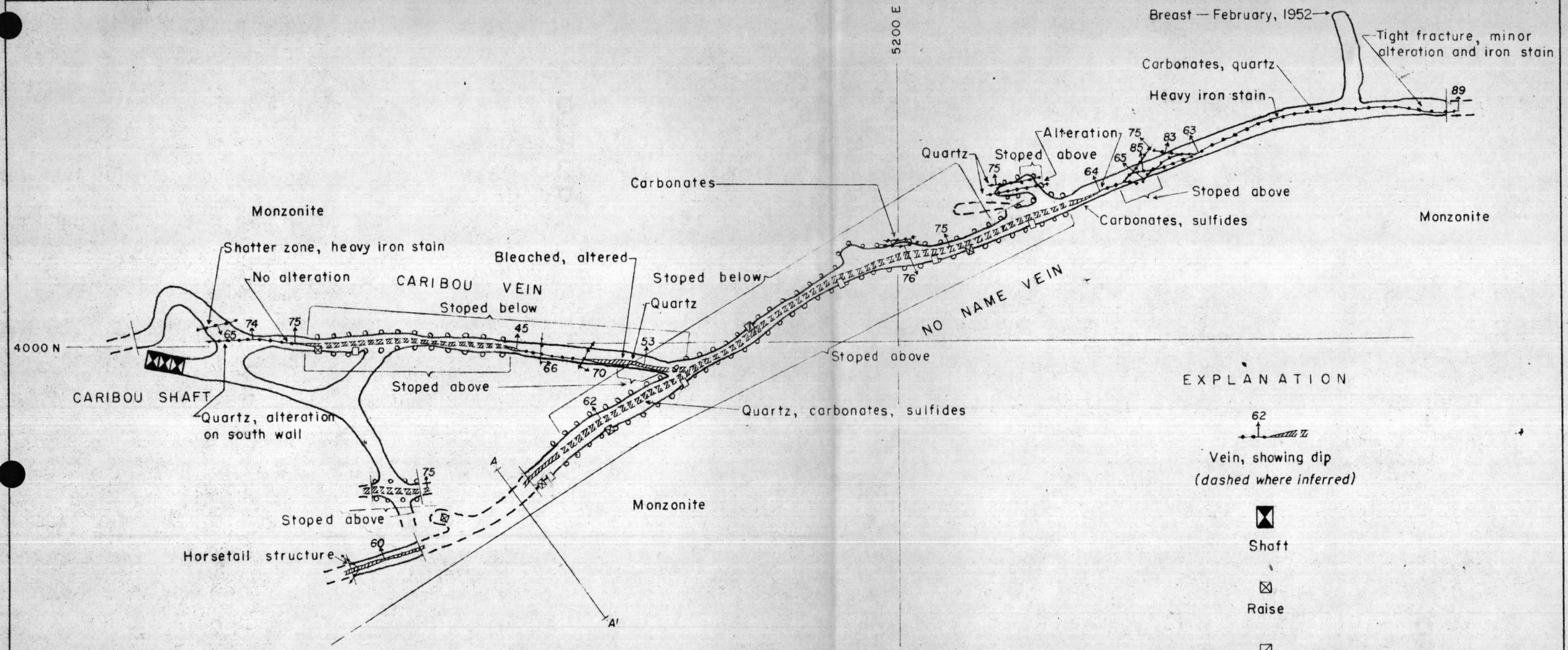
Ore chute

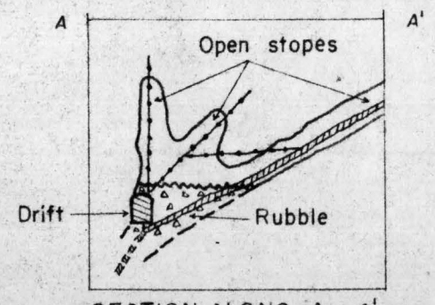
Caved workings

Geology by F.B. Moore and W.S. Cavender, 1951

FIGURE 22.-GEOLOGIC MAP OF THE 670-FOOT LEVEL, CARIBOU MINE, BOULDER COUNTY, COLORADO.

40 0 40 80 Feet





SECTION ALONG A—A'

EXPLANATION

62
Vein, showing dip
(dashed where inferred)

Shaft

Raise

Winze

Cribbing

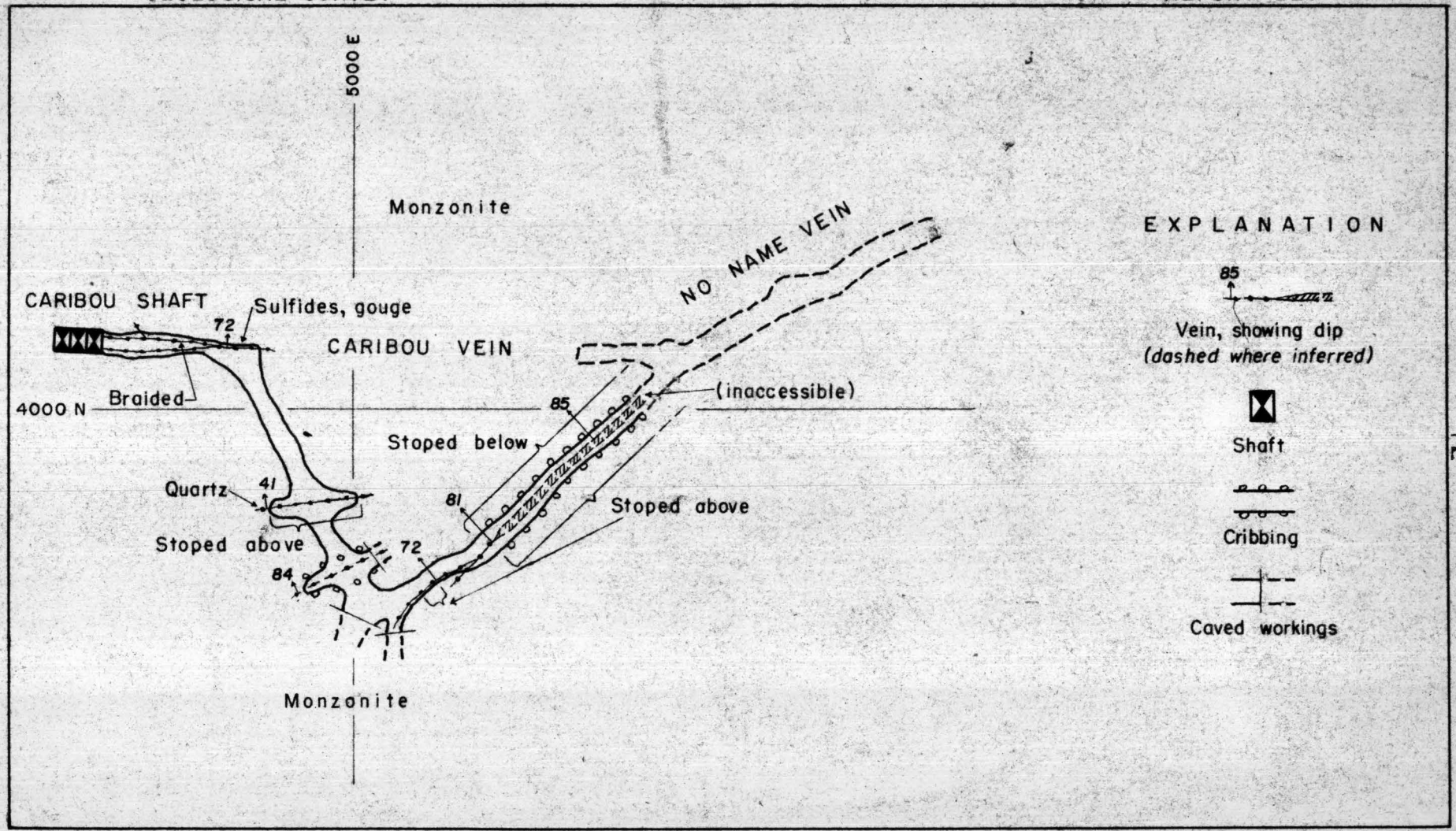
Ore chute

Caved workings

Geology by F.B. Moore and W.S. Cavender, 1951

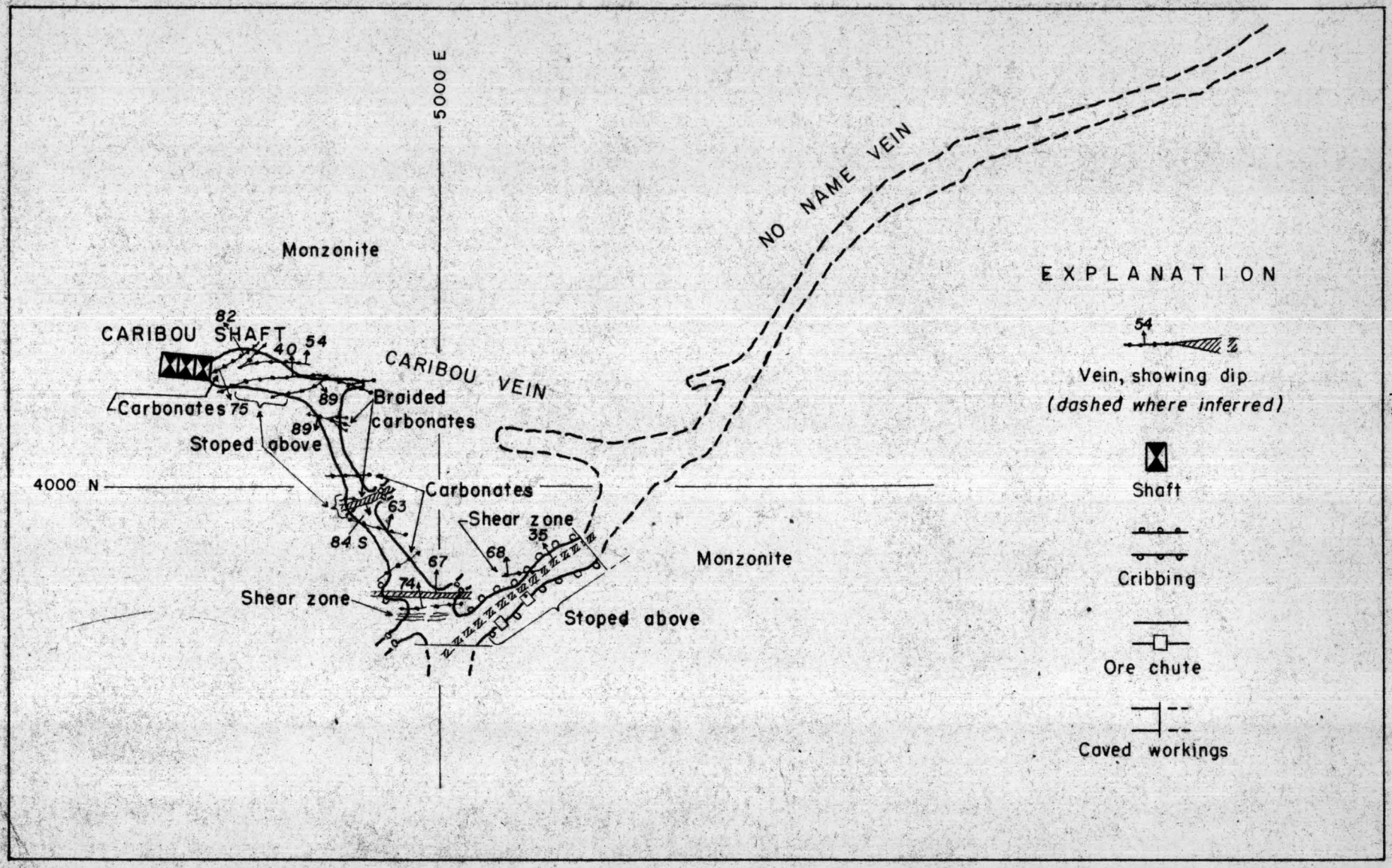
FIGURE 23.—GEOLOGIC MAP OF THE 740-FOOT LEVEL, CARIBOU MINE, BOULDER COUNTY, COLORADO.

40 0 40 80 Feet



Geology by F.B. Moore and W.S. Cavender, 1951

FIGURE 24.— GEOLOGIC MAP OF THE 800-FOOT LEVEL, CARIBOU MINE, BOULDER COUNTY, COLORADO



Geology by F. B. Moore and W. S. Cavender, 1951

FIGURE 25.—GEOLOGIC MAP OF THE 860-FOOT LEVEL, CARIBOU MINE, BOULDER COUNTY, COLORADO

40 0 40 80 FEET

No Name mine.--The No Name vein is the largest vein in the Caribou area, having been worked for over 1,000 feet horizontally and vertically. According to Raymond (1875, p. 370), total value of ore produced before 1875 was estimated by the owner at $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 600 feet deep; the levels match those of the Caribou mine to a depth of 860 ft. In addition there are levels at 920-, 1040-, and 1140-ft (figs. 11, 10, 12). 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 ft wide that strikes N. 70° E. and dips an average of 70° NW. (fig. 16). 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. Post mineral movement fractured the early vein minerals and formed openings in which late carbonates were deposited. The carbonates, 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 of inaccessibility of large parts of the No Name workings. One ore shoot extends from the 600- to the 920-levels at and near the intersection with the Caribou vein. 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. This ore shoot was near the intersection of the No Name with the Caribou vein and plunged steeply to the northeast. A large stope to the southwest on the 600-ft level (fig. 21) 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 ft north northeast of the main Caribou shaft (fig. 3). The mine developed the Poorman and, probably, the Silver Dollar veins, both of which were owned by the Poorman Mining Company. Although the Poorman deposit was one of the first (1869) to be discovered in the area, 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 at 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 600-ft Poorman shaft with accessible 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, stopes indicate that the ore bodies were localized along the Poorman vein near its intersections with the No Name vein on the east and with an unnamed vein (possibly the Nelson) on the west (fig. 14). The eastern ore body extends for over 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 (fig. 16). Where exposed on the 300 level of the Caribou mine, it is a one foot, brecciated, iron-stained shear with no visible sulfides. The absence of stopes on this vein indicates that the production was probably small.

Sherman mine. --The Sherman mine, 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 (fig. 16). 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), in 1874 $40,000 worth of silver was produced from ore valued at $180 per ton. Fossett (1879) states that 300 tons of ore produced in 1876 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. In about 1881, the Columbia and Spencer mines were incorporated with the Caribou and No Name mines largely in order to avoid litigation. The Columbia

from which little ore was produced, is apparently on a southwestern extension of the No Name vein. The Columbia workings are undercut by the No Name workings. 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 prior to 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 that 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 (figs. 11, 10), but have not been correlated with veins on 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 Elmer vein flattens to about 60° above the 920-level. The Nelson vein strikes northeast and is nearly vertical.

Lead-silver ore, averaging $40 a ton or more has been produced recently from both the Elmer and Nelson veins. The Radium vein, in addition to lead-silver minerals, contains pitchblende, and production from the vein has been confined to the uranium-bearing ore shoots. With the exception of pitchblende, the mineral content of the Radium, Elmer, and Nelson veins is generally similar. Galena, sphalerite, argentite and ruby silver are the ore minerals, with galena the most abundant ore mineral. Sphalerite, both dark and rosin, is intermixed with the galena. The gangue consists of quartz, carbonates, chalcopyrite and pyrite. Quartz is 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 (fig. 13). The pitchblende forms a streak 1/2 to 6 inches wide on the footwall side of the vein and is not intermixed with the sulfides.

Field relations and examination of ore from the Radium and Nelson veins indicate the following order of deposition of the vein material; (1) quartz and minor pyrite, (2) sphalerite, galena and chalcopyrite, (3) argentite and pyrargyrite, (4) carbonates. Quartz probably was deposited throughout the period of mineralization as it forms comb structures and bands outside of the sphalerite-galena seams, is mixed with sphalerite and galena, and lines vugs. Chalcopyrite is mostly contemporaneous with sphalerite and galena but some appears to be later. The carbonates are always the last minerals formed.

The Radium and Elmer veins are in tension fractures produced by the No Name shear (fig. 10). Ore bodies occur along both the Radium and Elmer veins near their intersections with the No Name vein (fig. 13). 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 cross cut 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 (fig. 3) is the only mine, other than the Caribou Group, which was accessible in 1951. Although not in commercial production, the mine is being maintained in a working condition. The workings consist of a shaft 450 feet deep with 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-ft level west of the shaft, the vein is heavily iron stained quartz and carbonate. One hundred-fifty feet west of the shaft on the 450-ft 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 this 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-ft 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-ft 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) from the mine are galena, gray copper (tetrahedrite?), yellow copper sulphurets (chalcopyrite ?), and quartz.

The vein reportedly averages 5 1/2 feet in width with a pay streak as much as 4 feet wide (Corbett, 1879). Development consists 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 at $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 in width 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 prior to 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; the sample bearing much more resemblance to the pyritic-gold type of ore than to the lead-silver type 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 be vertical. 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 Caribou Hill and marks the southeastern limit of the mineralization in the Caribou stock (fig. 3). 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.

Gold-Silver mines

A small group of mines on Idaho Hill, 2,500 feet east of the Caribou shaft (fig. 3) were worked for both gold and silver. These mines are in the gneissic and pegmatitic rock east of the contact with the Caribou stock.

Silver Point mine

The Silver Point mine 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 was 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 30-inch iron- and copper-stained shear zone containing no visible sulfides. Corregan and Lingane (1883) report that the vein contained galena and "sulphuret" (sulfide) 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 the vein contained considerably higher gold values than most mines on Caribou Hill.

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 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 these mines were worked for gold and silver during the late 1890's. They are only briefly mentioned by the Rocky Mountain News (1895-1910) and mining journals.

Great Northern mine

The Great Northern mine (fig. 2) 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, judging from the size of the dump, to have been developed to a

depth of at least 200 feet. Bastin and Hill (1917, p. 182), describes 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 Caribou mine, this is the only known occurrence of pitchblende in the Caribou area.

Gold mines

St. Louis mine

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

The vein strikes N. 63° W. and dips 78° NE. Ore found on the dump contained quartz, pyrite, chalcopyrite, minor amounts of sphalerite and galena. Some late carbonates and quartz crystals line vugs. Bastin and Hill (1917) report the shaft to be 335 feet deep.

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CAUTION

Information contained in Part II of this document has been furnished in confidence by Consolidated Caribou Silver Mines, Inc. and shall be handled accordingly within the USGS and AEC. Its classification of "OFFICIAL USE ONLY" shall not be cancelled nor shall the material herein be published without the approval of Consolidated Caribou Silver Mines, Inc. and the U. S. Geological Survey.

ABSTRACT

Indicated reserves of uranium in the form of pitchblende in the Caribou mine, Boulder County, Colo., total 925 tons containing 0.27 percent uranium. An additional 400 tons is inferred. These reserves are in two ore shoots that have an average thickness of one foot and extend between the depths of 900 to 1130 feet in the Radium vein. The pitchblende, for the most part, is soft and sooty. It is difficult to recover by ordinary mining and milling methods.

INTRODUCTION

The Consolidated Caribou Silver Mines are on Caribou Hill, 17 miles west of Boulder, Boulder County, Colo. The Consolidated Caribou Silver Mines Inc., with offices in Boulder and New York City, own some 36 claims or mines on Caribou Hill. Of these, only four mines, the Caribou, No Name, Poorman, and Sherman are accessible. These mines, which form part of the Caribou Group, have interconnecting workings and were formerly worked through the Caribou shaft. Also included in the Caribou group are the Columbia, Spencer, and Socorro mines and the Radium, Elmer, and Nelson veins. The Columbia, Spencer, and Socorro mines were incorporated with the Caribou mine about 1880 and are believed to have interconnecting workings. The Radium, Elmer, and Nelson veins are exposed by workings on the 920 and 1040 levels but have not been correlated with surface veins. Ore mined from the Caribou Group is brought to the surface through a 3,645 foot adit which intersects the main shaft of the Caribou mine on the 500 level (fig. 15). No ore has been produced from above the 500 level since the present company reopened the mines in 1947.

Pitchblende was discovered at the Caribou workings in 1948, having first been found on the Caribou dump in 1945 by G. C. Ridland. In 1949, R. U. King, E. P. Beroni, and H. C. Granger examined the deposit on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission (TEM-13, 1950). Since

1948, C. C. Towle, L. E. Smith, and K. Baker of the Atomic Energy Commission have made periodic examination of the deposit and, since 1950, the Atomic Energy Commission has contracted with the Consolidated Caribou Silver Mines, Inc. for exploration and development in the uranium-bearing section of the mines. D. M. Sheridan and E. N. Hinrichs of the U. S. Geological Survey made a reconnaissance for radioactivity of the Caribou area in 1950. Geologic mapping of a one square mile area surrounding the Caribou Group of mines was started in 1951 and included examination of all accessible mine workings.

Three separate occurrences of pitchblende are known in the Caribou area: (1) along the Radium vein at a depth of 900 to 1,130 feet, (2) in an unnamed veinlet on the 500 level of the Caribou Group workings, and (3) at an unknown depth in the Great Northern mine. A small amount of pitchblende was found on the dump of the Great Northern mine, but because the mine is inaccessible, it is not possible to evaluate this deposit.

RESERVES

The indicated reserve of uranium ore in the Caribou Group of mines is 925 tons of 0.27 percent uranium. In addition, about 400 tons of similar grade uranium ore is inferred. The indicated ore is in the Radium vein in two ore shoots which have been exposed and sampled on two sides (fig. 26). The inferred reserves includes ore considered to be present by a reasonable extension of the known ore shoots. Tonnage and grade of both types of reserves is computed for an average vein width of one foot.

In the Radium vein, the two uranium ore shoots are east of the junction of the Radium and No Name veins (fig. 13). The larger shoot extends for 75 feet along the 1040 drift and from the 920- to the 1140-levels. The smaller shoot, 170 feet to the east, has horizontal and vertical dimensions of 35 and 75 feet respectively. Although pitchblende was found in an unnamed veinlet on the 500 level, this occurrence is too small to be considered ore.

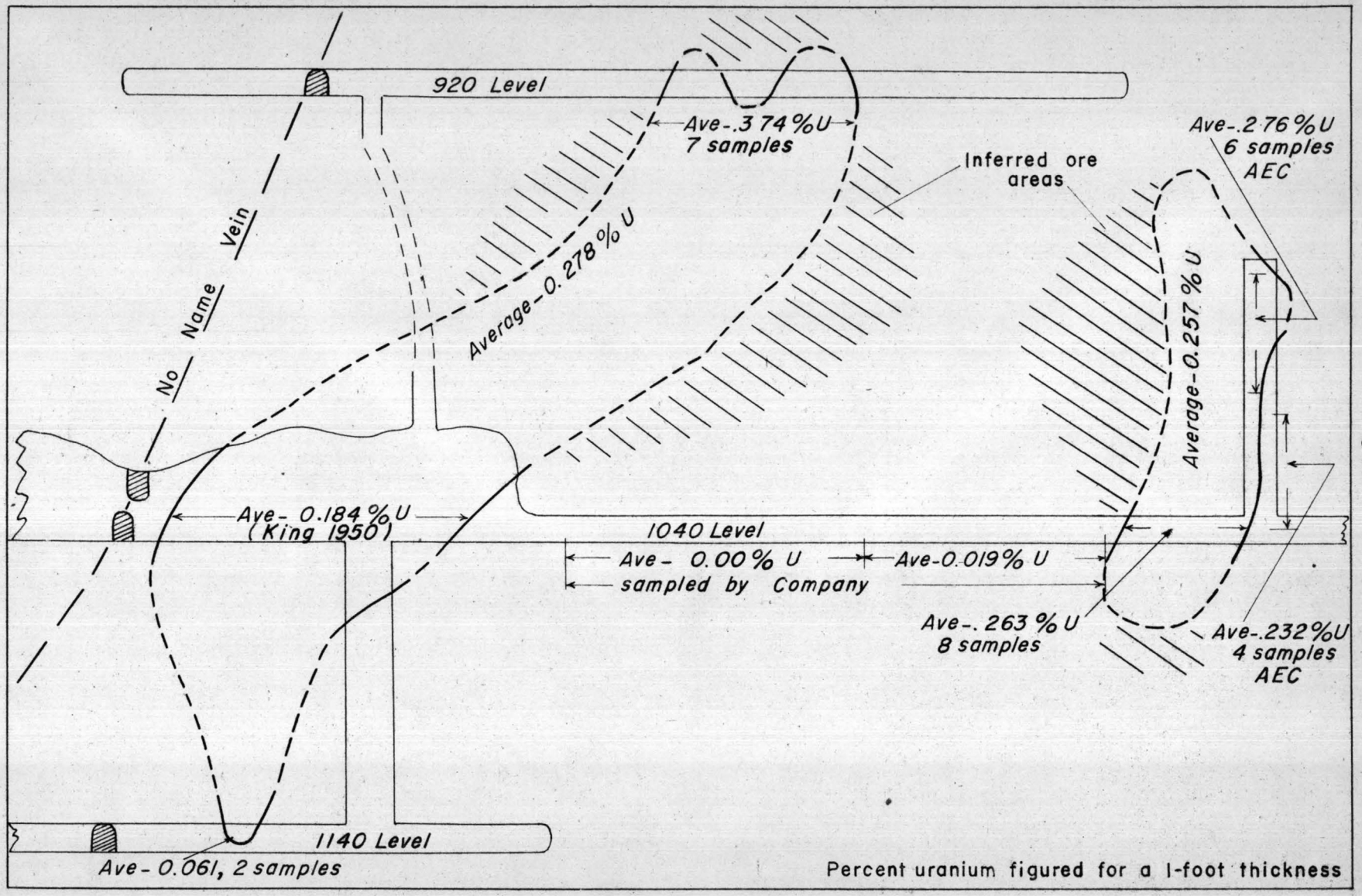

FIGURE 26.- DETAIL FROM FIGURE 13 SHOWING AVERAGE URANIUM VALUES IN THE RADIUM VEIN, BOULDER COUNTY, COLORADO.

40 0 40 80 Feet

The uranium reserves of the Radium vein were compiled from assay data obtained from four sources, the Consolidated Caribou Silver Mines, Inc., the Atomic Energy Commission, TEM-13 (King, 1950) and from samples collected by the writers. The assay data from the collected samples is shown in table 1; the information from other sources is converted, where necessary, from percent U_3O_8 to percent uranium, and the average uranium content and general location of all samples is shown on figure 26. With the exception of the samples taken by King, an average sampling interval of five feet was used. The number of samples on which the averages are based is also shown on figure 26. Of the total of 925 tons of 0.27 percent uranium reserves indicated in the Radium vein, the larger ore shoot contains 638 tons and the smaller shoot 287 tons. The grade of the uranium ore is slightly higher in the larger shoot; 0.28 percent as compared to 0.26 percent.

Reserves of lead, silver, gold, zinc, and copper in the Caribou Group of mines can be divided into two parts: (1) those in the Radium vein which are combined with the uranium ore, and (2) those in the Nelson, Elmer, and No Name veins which can be mined independently. Detailed assay data are available only for the reserves along the Radium vein. The ore shoots along the Radium vein contain an average of 4.3 percent lead, 2.44 percent zinc, and 0.6 percent copper. Average silver content is 50 ounces per ton, and gold content ranges from a trace to 0.1 ounces per ton. Average content of the two ore shoots is shown in table 2.

No attempt has been made by the writers to sample and compute reserves of lead-silver ore in the non-uranium-bearing parts of the Caribou Group of mines. Silver and lead furnish nearly the entire value of the Caribou Group ores. Gold rarely exceeds 0.1 ounces per ton, copper 1 percent, or zinc 2 percent. Estimates of ore reserves, based in part on assay data (fig. 27) furnished by the Consolidated Caribou Silver Mines, Inc. are as follows:

Table 2.--Average content of two ore shoots in Radium vein.

Larger shoot -	638 tons*	Smaller shoot - 287 tons*
Lead -	2.85 percent	7.50 percent
Zinc -	1.26 percent	5.07 percent
Copper -	.78 percent	0.07 percent
Silver -	64.32 ounces/ton	17.47 ounces/ton
Gold -	<0.05 ounces/ton	0.02 ounces/ton
Uranium -	0.278 percent	0.257 percent

*Tonnage and grade is computed for a vein width of 1 foot.

Most of the indicated reserves of lead-silver ore are in the Nelson and Elmer veins. The Nelson vein contains an ore shoot which extends for 300 feet on the 1040 level, at least 100 feet on the 920 level, and averages about 2 feet in thickness. Indicated ore in this shoot is more than 4,000 tons. The general tenor of the ore, computed from the data on figure 27, is 35 ounces of silver per ton and 2 percent lead. A smaller ore shoot in the Elmer vein is exposed for 100 feet on the 920 level, where it ranges from one-half to 3 feet thick. This shoot contains approximately 1,000 tons of indicated ore estimated to be equal in grade to that in the Nelson vein. Reserves of ore for the No Name vein cannot be calculated with the data available, but are believed to be small.

CONCLUSIONS

The possibility for the commercial production of pitchblende from the Caribou group of mines is poor. The Radium vein is the only vein in the Caribou area in which an appreciable quantity of pitchblende is known to occur. Except for possible exploration at greater depth, the unexplored area along the Radium vein is limited. The Radium vein is bounded on the west by the No Name vein, and 300

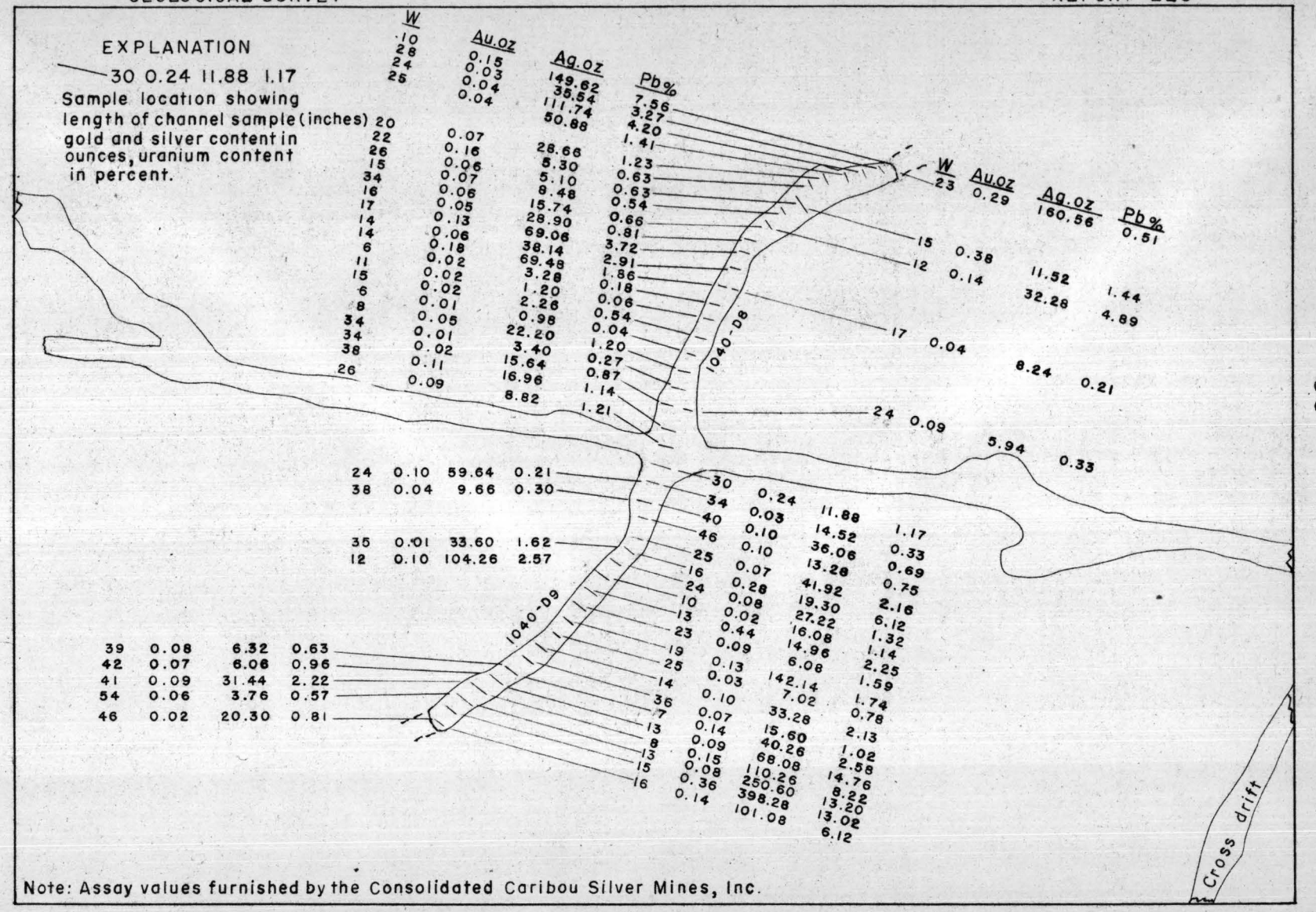

FIGURE 27.—LEAD, SILVER, AND GOLD CONTENT OF THE NELSON VEIN ORE SHOOT, 1040 LEVEL, CARIBOU MINE, BOULDER COUNTY, COLORADO.

40 0 40 80 FEET

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feet east of the No Name vein the Radium vein cuts a large mass of mafic rock believed unfavorable for mineralization. Three hundred feet above the 920-level, workings on the Comstock vein have exposed what may be an upward extension of the Radium. Diamond drill holes, cutting the Radium vein 100 feet below the larger pitchblende ore body, were essentially barren (fig. 13).

The most favorable ground for uranium exploration at Caribou is a 300- by 300-foot block along the Radium vein above the 920-foot level and west of the body of mafic rock. Contracts have been let to the Consolidated Caribou Company by the Atomic Energy Commission for the purpose of exploring the Radium vein by a raise above the 920-foot level and by a cross-cut to it on the 740-foot level.

The pitchblende in the Caribou Group is mostly a soft and sooty variety. The operators of the group have had difficulty in recovering the pitchblende by ordinary mining methods.