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THE GEOLOGY OF THE MOUNT BROSS-BUCKSKIN CREEK AREA
PARK COUNTY, COLORADO

By

Russell M. Corn
A thesis submitted to the Faculty and the
Board of Trustees of the Colorado School of Mines
in partial fulfillment of the requirements for the
Degree of Master of Science.

Signed: ________________________
Russell M. Corn

Golden, Colorado
Date: ________________________

Approved: ________________________
Head, Dept. of Geology

Approved: ________________________
Advisor
THE GEOLOGY OF THE MOUNT BROSS-BUCKSKIN CREEK AREA
PARK COUNTY, COLORADO
BY
RUSSELL M. CORN

ABSTRACT

The Mount Bross-Buckskin Creek area is located in northwestern Park County, Colorado, northwest of Alma on the east slope of the Mosquito Range. Although there has been a relatively small production from the area, indications of mineralization are numerous, and extensive alteration is present.

Paleozoic sedimentary rocks, which overlie Precambrian schist and granite gneiss, are eroded from the crest of the Mosquito Range and dip eastward along the east face of Mount Bross. Mesozoic sedimentary rocks are not present, and Cenozoic deposits consist of talus, alluvium, and glacial drift.
Cenozoic intrusives in the area vary widely in composition. These are generally found as sills in the sedimentary rocks and as dikes and irregular bodies in the Precambrian rocks. An intrusive center is present in upper Buckskin Creek, where numerous types of intrusives are localized within the Precambrian rocks. Lincoln porphyry is present as large laccolithic sills in the lower part of the Minturn formation, and is exposed near the summit of Mount Bross and on the lower east slope of the mountain.

Mineralization in the area is controlled by numerous minor, northeast-trending faults, which may be related to the major northeast-trending Mineral Belt of Colorado. Ores in the area include lead-zinc replacements in the Leadville, Dyer, and Manitou dolomites on the east slope of Mount Bross, and gold-bearing lead-zinc ores in the Precambrian rocks, Sawatch quartzite and Peerless shale. Small molybdenite-bearing quartz veins are exposed in upper Buckskin Gulch and fluorite-rhodochrosite veins carrying a number of copper minerals are exposed in or near an altered zone near Red Amphitheatre.

Extensive sericitization and pyritization occurs in granite gneiss in an elongate, northwest-trending zone centered near Red Amphitheatre. Serpentinization of the Manitou dolomite, of Peerless shale, and of a hornblende
schist is associated with the pyritic and sericitic alteration. Fluorite-rhodochrosite veins occurring within the zone of sericitic alteration are characterized by argillization of the wall rock, which grades out into the widespread sericitic alteration. Along lower Buckskin Creek and on the east slope of Mount Bross, there has been chloritic and carbonatitic alteration near lead-zinc ores in Precambrian schist and in the carbonate sediments.

Molybdenite mineralization in upper Buckskin Creek is correlated with that at Climax only four to five miles to the northwest. The molybdenite may be related to the sericitic-pyritic alteration, which, with the fluorite-rhodochrosite mineralization, is correlatable with similar alteration and mineralization at Climax.

Paragenetic relations within the fluorite-rhodochrosite veins indicate that the copper minerals, bornite and chalcopyrite, are the latest in the depositional sequence. These minerals were found near creek level but not at higher elevations, suggesting that more copper-rich, higher-temperature ores are to be expected at depth. Molybdenite, in the veins near the forks of Buckskin Creek, replaced pyrite and base-metal sulphides, suggesting here that more molybdenite might be expected at depth.
Ores of the area are complex and carry a large amount of zinc. There are no custom mills in the Alma area and the ores are shipped to Leadville to mills or to the lead smelter, which penalizes for zinc. In general, mining in the area will not be profitable until modern milling facilities are established nearby, and payment for zinc content of the ore is obtained.
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PLATE

I. Geology of the Mount Bross-Buckskin Creek Area ........................................ (in pocket)

II. Cross sections of the Mount Bross-Buckskin Creek Area ............................. (in pocket)

III. Outcrop section of Paleozoic sediments .................................................... (in pocket)

IV. Generalized distribution of Alteration and Mineralization .......................... (in pocket)

V. Geologic map of lower adit, Home Sweet Home Mine ................................ (in pocket)

VI. Patented mining claims in the Mount Bross-Buckskin Creek Area ............... (in pocket)
The purpose of this investigation is to supplement existing geologic information on the Alma Mining District with more detailed work in the Mount Bross-Buckskin Creek area. Emphasis is placed on mineralization and hydrothermal alteration in the area. The field work was carried out during the summer of 1956, and laboratory work, consisting of microscopic examination of thin and polished sections, was completed in the fall and winter of 1956-1957.

Location and Accessibility

Mount Bross, the southern part of a mountain massif east of the crest of the Mosquito Range, is located above
and northwest of Alma, a small mining camp in the northwest corner of Park County, Colorado. The area investigated is located in Sections 27, 28, 33, 34, and 35, Township 8 South, Range 78 West and Sections 2, 3, and 4, Township 9 South, Range 78 West. The area includes parts of the south and east slopes of Mount Bross from Buckskin Creek on the south and west, to Dolly Varden Creek on the north. The Mount Bross-Buckskin Creek area is approximately ten miles north-east of Leadville and only four to five miles southeast of Climax. The location of the area and routes of access are shown on Figure 1.

Alma is six miles north of Fairplay, the county seat of Park County, and can be reached by traveling north on Highway 9 from its junction at Fairplay with U. S. Highway 285. As shown on Plate I, the immediate area of Buckskin Creek and Mount Bross can be reached by the Buckskin Creek road that joins Highway 9 at Alma. The location of individual mines or prospects in the area is shown on Plate VI.

Mount Bross is above 14,000 feet in elevation, but the general topographic relief in the area is no greater than 3,000 feet. Although the east slope of the mountain is relatively gentle, walls of the glaciated valleys and cirques slope at angles of 40° or more. The climate is moist and cold, and snowbanks remain until late in the summer.
Figure 2. Photograph of Mount Bross, taken 2 miles south of Alma, looking northwest and showing Mount Bross (1), and Buckskin Creek (2).

Figure 3. An ancient arrastre in the bed of Buckskin Creek gives mute testimony to early mining in the area.
History

Gold was discovered in the gravels of Buckskin Creek in 1860 or 1861. The close association of placer gold with exposed veins along the valley soon led to lode mining, the first attempted in this part of Colorado. In 1861 the town of Buckskin Joe was laid out in lower Buckskin Gulch, and nearby mines worked for the gold content of their oxidized ores included the Phillips, Excelsior, and Paris. Silver ores were worked between 1871 and 1893, and considerable prospecting and mining activity occurred in the Mount Bross-Buckskin Creek area during this period (Patton, Hoskins, and Butler, 1912, p. 146-155).

Only dosultory mining activity followed the silver price drop of 1893, with intermittent periods of activity in the early 1900's and again during the depression years. There has been very little active mining and prospecting in the years during and since World War II.

The first geologic work done on the Alma district was Eamon's comprehensive report in 1886. Patton, Hoskins, and Butler, of the Colorado State Geological Survey mapped the area in 1912. Later work by the United States Geological Survey has included fairly detailed reports on the Alma district, and geologic mapping of the district by Butler and Sengewald in the 1930's. Bulletin 911, the U. S.
Geological Survey publication based on this field work, places major emphasis on the London Mountain area.

**Acknowledgments**

The writer would like to acknowledge the assistance and cooperation received from the mining men and townsfolk of Alma during his field work in the area, and the encouragement and assistance received from the geology staff and graduate students of the Colorado School of Mines during preparation of this report. The writer is especially indebted to Drs. R. H. Carpenter, J. D. Haun, J. R. Hayes, R. M. Hutchinson, and L. W. LeRoy of the Department of Geology at the Colorado School of Mines for their assistance and helpful suggestions and criticisms during the preparation of this report.
Detailed descriptions of the Paleozoic sedimentary rocks and Precambrian igneous and metamorphic rocks have been published elsewhere (Emmons, 1886; Patton, Hoskins and Butler, 1941; Butler and Vanderwilt, 1930; Johnson, 1934; Singewald and Butler, 1941, and Behre, 1953). With the exception of unconsolidated Quaternary material, the sedimentary rocks range in age from Cambrian to Pennsylvanian. The thickness of the pre-Pennsylvanian sedimentary rocks ranges from 300 to 500 feet. Only the basal portion of the thick Pennsylvanian section has escaped erosion within the area. Along the cliffs facing Buckskin Creek and in the valley, considerable areas of Precambrian metamorphic rocks are exposed.
Precambrian Rocks

The Precambrian rocks can be divided into two general groups, (1) those rocks that are considerably metamorphosed and (2) later intrusives that are relatively unmetamorphosed. The metamorphics are biotite-sillimanite schist, hornblende schist, quartzite schist, and granite gneiss. The granite gneiss apparently represents a metamorphosed intrusive, and the schists probably represent rocks that were originally sedimentary.

Biotite-Sillimanite Schist

The biotite-sillimanite schist is a medium-grained, gray-to-brown schist, containing quartz, biotite, plagioclase, and irregularly distributed sillimanite. The schist is exposed along Buckskin Creek Valley below the Home Sweet Home Mine and in the head of Dolly Varden Creek. Pegmatites are localized preferentially in the schist rather than in other Precambrian rocks. Locally pegmatitic quartz-zose veinlets and quartz segregations are so abundant that the rock resembles an injection gneiss.

Hornblende Schist

Dark green-black, highly altered schist, containing principally the minerals biotite and hornblende, is present in a small outcrop area, covered and obscured by talus,
slightly east of the Home Sweet Home Mine in Buckskin Gulch. The rock is somewhat altered to serpentine and its origin is indeterminate.

**Quartzite Schist**

The major exposure of quartzite schist is slightly east of the Home Sweet Home Mine with a lesser amount present along the eastern edge of the granodiorite occurrence in the upper part of Buckskin Gulch. The rock is fine-grained, gray, banded, and composed essentially of quartz and variable amounts of biotite. Thin bands, probably representing bedding, of relatively pure quartzite, alternate with more biotitic schistose material. The contact of this rock with biotite-sillimanite schist is very gradational, with quartz becoming more prominent and the micas becoming less. This rock probably correlates with the quartz-biotite gneiss in the Leadville area, where it occurs as highly metamorphosed roof pendants (Behre, 1953, p. 19).

**Granite Gneiss**

The granite gneiss is fine- to medium-grained, light-pink, dense, and quartzitic. It is very similar in appearance and composition to a granite. Although metamorphic structures are not prominent, biotite is irregularly
distributed through the rock, and there is a slight parallelism of constituents.

Former authors have described the rock and used the above nomenclature (Patton, Hoskins, and Butler, 1912, p. 37; Singewald and Butler, 1941, p. 7). Granite gneiss is exposed along Buckskin Creek from the Home Sweet Home Mine to the head of the creek. The rock is brittle and breaks up easily, and because of this physical characteristic the granite gneiss is important in the localization of mineralization and alteration.

Silver Plume Granite

A very small outcrop of light-gray, medium-grained granite that has been correlated with the Silver Plume granite occurs near the forks of Buckskin Creek (Butler and Vanderwilt, 1931, p. 327; Singewald and Butler, 1941, p. 7). The outcrop is obscured by large amounts of glacial drift. It seems probable, however, that the granite is contiguous with a larger body to the west.

Pegmatites

Precambrian pegmatite dikes are very much in evidence along the lower portion of Buckskin Gulch. Larger pegmatite dikes are 200 to 300 feet wide and are localized in the more schistose area of Precambrian exposures. The pegmatites are very coarse-grained and generally consist of
quartz, microcline and muscovite. Individual crystals seldom attain a size of several inches. Minerals containing the rarer elements, fluorine, boron, lithium, and beryllium, are completely absent. A few very narrow veins and veinlets of aplitite are associated with the pegmatites.

**Paleozoic Sedimentary Rocks**

The generalized stratigraphy of the Alma region is as follows:

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<td>Unconformity</td>
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<tr>
<td>Ordovician</td>
<td>Manitou dolomite</td>
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<td>0 - 130</td>
<td>Dolomite</td>
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<tr>
<td>Cambrian</td>
<td>Peerless shale</td>
<td></td>
<td>35 - 100</td>
<td>Shales &amp; Dolomite</td>
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<tr>
<td></td>
<td>Sawatch quartzite</td>
<td></td>
<td>65 - 130</td>
<td>Quartzite</td>
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(Modified from Singewald and Butler, 1941, p. 8-9.)

Detailed relationships of the pre-Pennsylvanian sedimentary rocks are graphically portrayed in Plate III, which is an exposed section measured along the cliffs north of Buckskin Creek and due east of the lower adit of the Home Sweet Home Mine. (See Figure 37 for the exact location of the section.) Pennsylvanian rocks were not measured because of poor exposures and rapid facies changes.

The sedimentary rocks have been completely eroded along the crest of the Mosquito Range. The east face of Mount Bross and other mountains west of the South Platte River are generally dip slopes on the base of the Pennsylvanian or on pre-Pennsylvanian sedimentary rocks.

Cambrian

Cambrian sedimentary rocks are represented by a thick sequence of quartzite and shale. The rocks have been divided into the Sawatch quartzite and the Peerless shale.

Sawatch Quartzite

The Sawatch quartzite was deposited on an eroded Pre-cambrian surface of extremely low relief (Emmons, Irving, and Loughlin, 1927, p. 25). Throughout the area the base of the Sawatch quartzite is an almost smooth surface, and is marked by a thin bed of conglomeratic quartzite. The general lithologic character of the formation is light-colored,
quartzite, with thin beds of calcareous sandstone prominent near the top. The color is usually white, but individual beds are tinted light-purple or light-green. The thickness of the quartzite varies from 100 to 125 feet, and is fairly uniform throughout the Mosquito Range (Butler and Singewald, 1941, p. 3).

The Sawatch quartzite is a prominent cliff former and, where exposed along the lower reaches of Buckskin Creek, forms an almost continuous cliff (Figure 15). Nowhere in the area was the rock crumpled or sharply folded, and it is the most competent of all the sediments.

The lower contact is well marked, but the upper contact is gradational from quartzite to shales and non-clastics. The contact was chosen by the writer at the top of a dense, dark-green quartzite bed directly above cross-bedded, light-purple sandstone, and below sandy shales. This position correlates well with the top of the Sawatch as defined by Johnson (1934, p. 20) and Behre (1953, p. 25).

The name Sawatch quartzite was used by Emmons, Irving and Loughlin, while working in the Leadville area in preference to the local term "Lower Quartzite", which had formerly been used (Emmons, Irving and Loughlin, 1927, p. 25). The age of this formation has been determined as Late Cambrian (Johnson, 1934, p. 20; Behre, 1953, p. 25).
Peerless Formation

The Peerless formation or Peerless shale is gradational with sandy shales at the base grading to dolomitic shales and finally to dolomites at the top. The sandy shales and dolomitic shales of the lower part of the formation are generally green and the dolomite in the upper part of the formation is light-brown to red. Dolomites at the top of the Peerless shale are distinguished by beds exhibiting irregular fucoidal red markings set in a light-gray dolomite. These beds have been termed "red cast" beds and have served to mark the top of the Peerless shale (Johnson, 1934, p. 20). The "red cast" beds have been found throughout 30 feet of strata, and their use as a marker may not be valid (Behre, 1953, p. 27). In the Mount Bross-Buckskin Creek area, the beds were present only in a few feet of strata, and the top of these beds was chosen as the contact between the Peerless shale and the overlying Manitou dolomite. Although a few shales are present above this interval, the general character of the rock has changed to carbonates. This position correlates well with the placement of the contact given by Johnson (1934, p. 20) and Behre (1953, p. 27).

The Peerless shale is eroded easily, and its position is marked by a gentler slope than that on the other sedimentary rocks. Within the immediate area of Mount Bross and Buckskin Creek the thickness varies from 40 to 45 feet.
The nomenclature of the formation is from Behre (1953, p. 27). In earlier publications this formation was designated as a member of the Sawatch, and prior to 1932, it was termed the "Transition shales." On fossil evidence the Peerless shale is generally referred to as Late Cambrian (Johnson, 1934, p. 20). However, Behre feels that there is a possibility that the age may be Early Ordovician (Behre, 1953, p. 27).

Ordovician

The Manitou dolomite represents Ordovician sedimentary rocks in the area.

Manitou Dolomite

The Manitou dolomite consists of thin-bedded, light-gray dolomite with thin beds of green shale and some white, recrystallized calcareous dolomite. The recrystallized, bleached and limy character of the rock may have been caused by hydrothermal alteration. The thin beds of dolomite, shale, and bleached dolomite grade upward to more massive beds of dolomite with slight amounts of chert which causes siliceous "ribbing" to stand out on weathered surfaces in small bands or ridges. Megascopie lentils of chert, common in other areas, were not observed.

The thickness of the formation varies from approximately 50 feet to 100 feet, with the average thickness
closer to the larger figure. The contact with the overlying Chaffee formation is sharply marked by the change from dolomite to sandstone and quartzite, and is thought to be unconformable, with the variation in thickness of the Manitou caused by erosion previous to deposition of the overlying sediments (Behre, 1932, p. 59).

The name Manitou is applied to rocks that were termed by Sanborn (1888) and Patton, Hoskins, and Butler (1912), the White limestone. After correlation with the Manitou on the eastern slope of the Front Range in Colorado, the formation in the Leadville area was also termed Manitou (Behre, 1933, p. 29). The Manitou dolomite, from fossil evidence, is dated as Early Ordovician (Johnson, 1934, p. 22; Behre, 1953, p. 29).

Devonian

The Devonian sedimentary rocks in the area are grouped under the Chaffee formation. These rocks are quartzites and dolomites and are separated from the Ordovician by an unconformity.

Chaffee Formation

The Chaffee formation includes those sedimentary rocks dated as Devonian in the area. It is divided into two members, the Parting quartzite below and the Dyer dolomite above.
The Parting quartzite is generally a light-colored quartzite with interbedded dolomitic sandstone. Considerable variation in thickness and lithology occurs within the Mount Bross-Buckskin Creek area, with red shales present at the base of the quartzite along the lower reaches of Buckskin Creek. The quartzite is approximately 50 feet thick in this part of the area, grades to thin beds to the north and west, and is completely absent in the summit area of Mount Bross. Contacts with the other sedimentary rocks were placed at the change from dolomite to quartzite or sandstone.

Emmons used the term Parting quartzite to indicate the position of the quartzite between the two massive series of dolomites (Emmons, 1866, p. 36). This name was retained and used by later authors. The Parting quartzite has been stated to be Late Devonian on faunal evidence and lithologic correlation with known Devonian formations (Johnson, 1934, p. 24; Sahne, 1953, p. 32).

Overlying the Parting quartzite is dense, gray and blue-gray dolomite. Near the base, the dolomite is thin-beded, but the upper beds are massive. The upper beds weather to light-brown and the fresh dolomite throughout is generally a lighter color than the overlying Leadville dolomite.
The lower contact with the Parting quartzite is marked by an abrupt change in lithology. The Dyer dolomite is similar to the overlying Leadville dolomite, and the contact is placed at the base of a dolomite pebble conglomerate which indicates erosion and reworking of sedimentary material. The conglomerate lies directly above light-brown weathering dolomite, and the contact can be recognized easily where exposed.

The thickness of the Dyer dolomite varies from 40 to 80 feet. Because of the unconformity that separates it from the Leadville dolomite, the Dyer dolomite thins considerably in some parts of the Mosquito Range (Singewald, and Butler, 1941, p. 10; Behre, 1953, p. 34).

The Dyer dolomite was formerly known as the lower part of the "Blue limestone", but after the recognition that the beds were Devonian, the nomenclature was changed (Behre, 1932, p. 59-60). From fossil evidence and lithologic correlations, the Dyer dolomite is dated as Devonian (Johnson, 1934, p. 25; Behre, 1953, p. 34).

**Mississippian**

The Leadville dolomite includes those rocks dated as Mississippian in the area.
Figure 4. Fucoidal markings in the "red cast" beds at the top of the Peerless shale, exposed on the cliffs north of Buckskin Creek.

Figure 5. Dolomite conglomerate at the base of the Leadville dolomite, exposed on the cliffs north of Buckskin Creek.
Figure 6. Leadville dolomite on cliffs north of Buckskin Creek, looking northwest; Minturn formation (Pm); Leadville dolomite (Ml); Dyer dolomite (Dd).

Figure 7. Chaffee formation along cliffs north of Buckskin Creek, looking northwest; Leadville dolomite (Ml); Dyer dolomite (Dd); Parling quartzite (Dpq); Manitou dolomite (Om).
Leadville Dolomite

Mississippian sedimentation began in the Alma area with deposition of calcareous and dolomitic sands and dolomite conglomerate composed of slightly rounded dolomite fragments, mostly of the underlying Dyer, in a matrix of sandy dolomite. Around Mount Bross conglomerate is present but the sandstones are absent. The major part of the formation is composed of dense, massive, dark-gray or blue-gray dolomite. Near the center of the formation and between beds of massive, dense, blue-gray dolomite are thin sandy beds, one with a few black chert pebbles. The top 25 to 30 feet of the Leadville show characteristics that appear to be caused by pre-Pennsylvanian erosion and have been intensified by hydrothermal alteration. Solution resulted in rocks characterized by sandy dolomite, which is porous, brecciated, and cavernous, and contains angular dolomite fragments, considerable chert, and some fine-grained quartzite, very irregularly distributed in the sandy dolomite matrix.

The Leadville dolomite may be easily differentiated from other dolomites because of its dark color on both fresh and weathered surfaces. The contact with the Dyer dolomite was placed, as previously described, at the base of the dolomite conglomerate. The upper contact is at the base of shaly sandstone overlying the sandy brecciated dolomite. The thickness of the Leadville varies in the
Mount Bross-Buckskin Creek area from 50 feet to 165 feet, and the variation was caused by erosion preceding the deposition of the Pennsylvanian sediments (Singewald and Butler, 1941, p. 10).

The Leadville dolomite was previously termed the "Leadville limestone" and together with the Dyer dolomite was called the "Blue limestone" (Behre, 1953, p. 33). Since the recognition that the Dyer dolomite was Devonian, the upper part of the dolomite sequence has been termed the Leadville dolomite (Behre, 1953, p. 34).

Fossil evidence, gathered during early investigations of central Colorado, has led authors to conclude that the Leadville is Mississippian. Correlation studies have shown that the formation is probably equivalent to the widespread Madison limestone (Behre, 1953, p. 34).

Pennsylvanian

The thick series of Pennsylvanian coarse clastics, the Minturn formation, was deposited unconformably on the Leadville dolomite. Only the lower part of the formation is found in the vicinity of Mount Bross and Buckskin Creek.

Minturn Formation

Overlying the Leadville dolomite is the Minturn formation, an assortment of sandstones, sandy shales and conglomerates. Erosion has stripped away the greater part of
the formation in the Mount Eross area. In general, the first hundred feet directly overlying the Leadville dolomite are sandy shales, quartzites, and slightly shaly sandstones with a few thin beds of black limestone. Above the basal portion of the formation is a micaceous, arkosic sandstone and conglomerate. In places the numerous feldspar and quartz fragments make the rock almost indistinguishable from altered and weathered intrusive porphyries.

A thin-bedded black shale is found only along a cut on the Buckskin Creek road near Alma. The exposed shale appeared to be overlain and underlain by conglomerates and sandy conglomerates of the Minturn formation, and the relationship to the Leadville dolomite could not be determined. Shale of this type generally underlies the Minturn formation on the west side of the Mosquito Range (Johnson, 1934, p. 28-43; Behre, 1953, p. 40). Elsewhere in the Mosquito Range black shale of this type has been correlated with the Belden shale (Brill, 1953, p. 814; Jonson, 1955, p. 35-37). This shale may have been deposited in a deltaic environment and, as such, may be restricted and spotty in areas near the former Front Range highland. Another possibility is that local erosion, previous to the deposition of the Minturn, may have stripped the shale, especially near the highland area.
Although only the lower few hundred feet of the Minturn formation are present in the Mount Bross area the full thickness of the formation in adjacent areas has been estimated as 2,000 feet or greater (Johnson, 1934, p. 43). The name Minturn has only recently been applied to this formation. Before 1952 it had been termed the Weber? grits (Brill, 1952, p. 810-812; Jonson, 1955, p. 38). Abundant fossil evidence indicates this formation should be assigned to the Pennsylvanian period (Johnson, 1934, p. 42).

Quaternary Unconsolidated Materials

Unconsolidated material resulting from glacial and post-glacial erosion and deposition is prominent in the area and covers a large part of the surface. This material can be grouped in these genetic divisions: talus, alluvium, and glacial drift. An understanding of the distribution and derivation of these unconsolidated materials requires an understanding of the geomorphic environment of the area.

Climatically the area is alpine-humid, with considerable snowfall in winter and rainfall in summer. Above 13,000 feet the annual mean temperature is below freezing. With such a climate it is to be expected that strong glacial activity was present during Pleistocene and that glacial erosion was preceded and succeeded by strong stream activ-
ity. Periglacial processes have been active on high
mountain areas above timberline and have resulted in
stone striping, and other solifluction effects and the
formation of large amounts of talus.

Glacial Drift

The valleys of Buckskin Creek and the South Platte
River, major drainages in the area, have been glaciated by
valley glaciers, and as a result are characterized by U-
shaped valleys, cirques, and other glacial features. Glac-
ciers occupying the valleys were probably proportional to
drainage area, and glacial deposits were derived from their
respective drainage areas.

Glacial deposits between Alma and Fairplay reflect
two or more stages of glaciation, but features and deposits
observed in the Mount Bross-Buckskin Creek area were caused
by Wisconsin glaciation. The South Platte Glacier exten-
ded downstream several miles below Alma, and its lateral
moraine effectively dammed the small side streams on the
east slope of Mount Bross, Sawmill Creek, and Dolly Varden
Creek. Figure 9 is a photograph of one of these morainal
dams.

The Buckskin Glacier may have joined the South Platte,
but its terminus stood temporarily in lower Buckskin Gulch,
where a terminal moraine is exposed in the creek valley
Figure 8. View of the glaciated U-shaped valley of Buckskin Creek, taken from near the Paris Mill, and looking upstream towards the cirque scalloped face of Mount Democrat. Mount Bross is on the right.

Figure 9. Dam formed by the lateral moraine of the South Platte Glacier across Dolly Varden Creek. (Looking southeast across the alluvial flat behind the morainal dam.)
slightly below the Paris Mill. Many of the glacial deposits along Buckskin Creek have been removed by stream action or covered by alluvium and talus.

The glaciers were probably developed on mature topography with drainage similar to that of the present. Since glacial erosion cut through the oxidized zone of the ore-bodies, oxidation or supergene enrichment is to be expected only in unglaciated areas. Native gold was concentrated into valuable placers in the glacial moraines and outwash below Alma.

Talus

There are large areas of talus accumulation along the cliffs north and east of Buckskin Creek and on the higher elevations of Mount Bross. Talus in Red Amphitheatre is more than 50 feet deep and somewhat resembles a rock glacier. Talus is probably of both glacial and post-glacial origin. Large talus areas on fairly steep slopes near the summit of Mount Bross are probably bonded by ice, since mine adits in the area were ice-filled very near the surface, at elevations above 13,000 feet. The presence of such a thin, non-melting ice bond near the surface would slow down the rate of talus creep and hasten the breakdown of bedrock. Irregular blocks of Lincoln porphyry form a large part of the talus on the higher elevations of Mount Bross, while
very few fragments of the underlying sedimentary rocks are found. This condition is probably caused by greater erosion of the outcropping Lincoln porphyry and less erosion of the talus-protected sedimentary rocks. Within these large talus areas, there are probably a number of veins that are covered and, therefore, have not been explored.

Alluvium

The stream alluvium in the area consists of reworked glacial material and talus. Although the low-lying glacial deposits have been eroded and reworked, only minor stream erosion in bedrock has occurred since glaciation. The major development of stream alluvium is in outwash areas and behind morainal dams. Placer gold is present in the reworked morainal material in lower Buckskin Creek, but deposits are not very rich, and at present these placers are uneconomical.
The intrusive igneous rocks here described are probably Tertiary, but may be in part Late Cretaceous (Behre, 1953, p. 42). These intrusives, generally found as dikes and sills, are related to similar rocks in nearby districts and are part of the porphyries in the Colorado Mineral Belt. The localization of these rocks has been effected by Laramide crustal movement, probably deep-seated movement, and association of porphyries and ore is structurally influenced.

The intrusives of the Mount Bross-Buckskin Creek area are present predominantly as sills in the sedimentary rocks and as dikes or irregular bodies in the Precambrian rocks. Although intrusives are found throughout the area studied, they are concentrated near the head of Buckskin Creek.

The intrusives of the area were first classified by Emmons (1886, p. 75-89). Some of the intrusive porphyries have distinctive features and are easily recognized in the field. Since names proposed by Emmons for these porphyries
are still in general use, these names will be used in the following discussion. The non-distinctive rocks are given compositional names in agreement with other workers.

The petrographic character of these intrusives has been discussed previously by Emmons (1886), Patton, Hoskins, and Butler (1912), Emmons, Irving, and Loughlin (1927), Butler and Singewald (1931), Singewald (1932), and Behre (1953). The writer limited his investigations of the intrusive rocks to field and thin-section examination. For more details on the petrography of these rocks the reader should refer to the authors mentioned above.

**Spotted Diorite Porphyry**

The spotted diorite porphyry is darkest of all the intrusives and contains approximately 40 percent ferro-magnesian minerals, (hornblende and biotite) in elongate oval aggregates three to five mm. in length showing parallelism with the intrusive walls. The rock appears in hand specimen to be entirely crystalline and somewhat schistose, with plagioclase the only mineral evident, other than the hornblende and biotite aggregates. Microscopic examination shows that the oval ferro-magnesian aggregates are nests of biotite and hornblende, and that the intervening area is filled with andesine phenocrysts somewhat
altered to sericite. There is also a slight groundmass of oligoclase (?), orthoclase, and quartz.

**Distinctive Features and Distribution**

Although the spotted diorite porphyry is dense and tough, it has slight resistance to weathering, which is reflected by a negative topographic relief. The rock is present only in a few narrow dikes near the base of the cliffs north of Buckskin Creek, from the Criterion Mine westward for one and one half miles. The spotted diorite dikes cut Precambrian biotite-sillimanite schist and pegmatites but were not observed in contact with any sedimentary rocks. The writer was unable to determine the age relationship with the known Tertiary intrusives, and published descriptions do not mention any rock which is similar to the spotted diorite porphyry.

**Relative Age**

The apparent schistosity of the rock is caused by alignment of the original minerals parallel to the walls of the intrusive during intrusion. Veins are found in the spotted diorite porphyry, which is pre-mineral, similar to all the porphyries except perhaps the later white porphyry. Because the rock does cut the Precambrian pegmatites and the dikes seem to have a northeast trend similar to the known Tertiary structures and intrusives, the writer
tentatively classifies the rock as a Tertiary intrusive.

Granodiorite

The granodiorite is a holocrystalline, medium-grained, gray- to light-brown, non-porphyritic rock, that ranges from quartz monzonite to granodiorite in composition. Primary minerals in their order of abundance are plagioclase, (oligoclase-andesine) showing prominent progressive zoning, orthoclase, quartz, biotite, and hornblende. There appears to be quite a variation in the mineral percentages as determined microscopically, although the megascopic appearance of various specimens is similar. Singewald (1932, p. 57-60) gives a very detailed petrographic description of this rock. Other descriptions include those of Emmons (1886, p. 333-334), and Patton, Hoskins, and Butler (1912, p. 66-67).

Distinctive Features and Distribution

The granodiorite is exposed in Section 28, south and east of the forks of Buckskin Creek, between the forks and Red Amphitheatre. The outcrop area is obscured and covered by talus and glacial drift. The well-exposed areas are along the cliff faces and the irregular relationship of the contact leads the writer to doubt that this rock type is as extensive as has formerly been supposed (Singewald, 1932, p. 60). Singewald termed this body and an adjoining diorite
the "Buckskin Gulch Stock." The granodiorite has a medium resistance to erosion, is generally well-jointed and broken, and most of the rock has a somewhat altered appearance.

Relative Age

The granodiorite does not, insofar as the writer could determine, intrude sedimentary rocks. It is cut by later white porphyry, monzonitic diorite porphyry, Lincoln porphyry, and quartz monzonite porphyry. Pegmatite dikes cut the granodiorite, and in some areas, abundant, narrow, aplite dikes are also found in the granodiorite (Singewald, 1932, p. 56). Granodiorite is the only rock of those classed as Tertiary that exhibits this relationship. The rock has been classified as Tertiary by Patton, Hockins, and Butler (1912), and Singewald (1932), but the writer could find no proof that the granodiorite was definitely Tertiary. The granodiorite is later than the known Precambrian rocks and may be one of the earliest Tertiary intrusives in the area.

Diorite

Designated by Singewald (1932) as a facies of the "Buckskin Gulch Stock," the diorite is granular, fine- to medium-grained, generally dark green-gray, and varies between a diorite and quartz monzonite. Specimens from
the upper part of the intrusive are distinctly porphyritic
and show in thin section as much as 40 percent quartz and
orthoclase as a groundmass.

Microscopic investigation reveals andesine zoned to
oligoclase, hornblende, orthoclase, quartz, biotite, and
augite, in that general order of decreasing abundance. The
ferro-magnesian minerals make up approximately 30 to 40 per-
cent of the rock with augite replaced by hornblende and
biotite, and all of the ferro-magnesian minerals somewhat
altered to chlorite. Detailed petrographic descriptions
to which the reader can refer are Emmons (1936, p. 334),
Patton, Hoskins, and Butler (1912, p. 68-69) and Singewald
(1932, p. 60-61).

Distinctive Features and Distribution

The diorite is one of the darker colored rocks of the
area. The color, in addition to the fine-grained, holo-
crystalline texture, serves to distinguish the rock from
other types. It is tough, dense, and resistant to weather-
ing. Although the diorite is found in an area of major
alteration, Red Amphitheatre, it almost always appears very
fresh and unaltered in contrast to adjoining rocks. The
lack of general alteration apparently results from the tough-
ness and resistance to fracturing of the diorite. Chloritic
alteration of the ferro-magnesian minerals is the only wide-
spread alteration of the diorite.

The diorite forms the southeastern edge of the "Buck-skin Gulch Stock" described by Singewald (1932, p. 60-61). The only outcrop is a large dike-like mass on the east side of Red Amphitheatre extending from the head of the amphitheatre southwest across Buckskin Creek. The borders of this body are obscured by talus and glacial drift, and its relationship to the granodiorite could not be determined.

**Relative Age**

The diorite is definitely post-Paleozoic, because it cuts the sedimentary rocks at the head of Red Amphitheatre. Figure 11 shows the dike-like extension of the diorite cutting the Sawatch quartzite and terminating two extremely altered quartz-rich, monzonitic diorite sills. From field examination it appears that the diorite was later than the sills, but this was not definitely established, since talus covered the projected sills north of the dike. No other intrusives were observed in contact with the diorite.

In its mineralogy and in its characteristic freshness, the rock is very similar to the monzonitic diorite porphyries and especially similar to a dike, perhaps of this general type, that cuts the Minturn formation directly above the extension of diorite at the head of Red Amphitheatre. This dike is adjacent to a dike of quartz monzonite porphyry,
Figure 10. Quartzite schist near the forks of Buckskin Creek showing banding developed from layered quartz and biotite.

Figure 11. View, looking east, of the east wall of Red Amphitheatre showing the dike-like extension of diorite intruding Sawatch quartzite. Diorite (Td); granite gneiss (grg); Sawatch quartzite (Cs); Peerless shale (Cp); Manitou dolomite (Om); Dyer dolomite (Dd); Leadville dolomite (Ml); Monzonitic diorite porphyry sills (Tmd).
and although the contact has been faulted, a minor chilled margin and relative freshness contrasted to extreme alteration in the quartz monzonite porphyry dike, indicate that the dioritic dike is later in age. Although the dioritic dike was somewhat altered, (the ferro-magnesian minerals altered to chlorite, plagioclase and the groundmass altered slightly to carbonate and sericite), a generally fine-grained, non-porphyritic texture was observed, and the dike was very similar both in hand specimen and in thin section to the underlying diorite. Extensions of the dike are covered by talus and a definite relationship with other intrusives could not be determined.

Singewald suggests that the diorite predates the granodiorite (1932, p. 34). Apparently this suggestion was based partly on an earlier statement that fragments of dark-green diorite appear in a breciated zone enclosed in a lighter matrix (Patton, Hocking, and Butler, 1912, p. 69). This rock was apparently well altered, since Patton was unable to determine whether or not orthoclase occurred in the rock.

In the writer's opinion the diorite is sufficiently different from the granodiorite to be treated as a separate intrusive. Although the diorite is similar mineralogically to granodiorite, the lack of alteration and the mineralogic similarity to the nonmonzonitic diorite porphyry suggest that the age of the diorite should be the same as these similar
porphyry intrusives.

Lincoln Porphry

The Lincoln porphyry was first described by Emmons and named for its occurrence on Mount Lincoln (Emmons, 1886, p. 111). The rock is characterized by large (1 to 4 in.) pink, orthoclase phenocrysts and medium-sized quartz, plagioclase, and biotite phenocrysts, set in a light-green, gray, or pink groundmass. In general, the groundmass of the porphyry is aphanitic, but a gradational facies with a holocrystalline groundmass exists near the head of Buck-skin Creek.

Quartz is found as rounded grains, slightly embayed by the groundmass, and also as euhedral, dipyramidal crystals. In the holocrystalline facies, quartz was interstitial and definitely not rounded. The plagioclase is andesine, and the ferro-magnesian minerals are biotite and minor amounts of hornblende. In the holocrystalline facies the ferro-magnesian content was slightly greater than normal and a small amount of augite was present. The writer classified the rock as a quartz monzonite porphyry, gradational to a granodiorite. This is similar to the classification proposed for the Lincoln porphyry on the western slope of the Mosquito Range (Behre, 1952, p. 49). Authors who
have published detailed petrographic studies on the Lincoln porphyry include Emmons (1886, p. 323-330), Patton, Hoskins, and Butler (1912, p. 83-85), and Emmons, Irving, and Loughlin (1927, p. 47-48).

**Distinctive Features and Distribution**

The major distinctive features serving to distinguish the Lincoln porphyry from other quartz monzonite intrusives are the generally overall pink or pinkish-gray color, the large crystals of orthoclase, and the well-developed quartz phenocrysts that are generally present.

The Lincoln porphyry has the largest outcrop area of any of the intrusives and is generally found as thick, laccolithic sills in the Minturn formation, especially localized near the base of the formation. These sills form the large outcrop areas on the summit of Mount Bross and the lower shoulders of the mountain. Lincoln porphyry dikes cut the sedimentary rocks near Red Amphitheatre, and a dike is present on the west side of Dolly Varden Creek.

In the upper valley of Buckskin Creek normal Lincoln porphyry dikes gradually change to a rock with a fine-grained crystalline, and then medium-grained crystalline groundmass showing a continuation of the large orthoclase phenocrysts. This rock was formerly described as a facies of the "Buckskin Gulch Stock" (Singewald, 1932, p. 61).
The granite gneiss and granodiorite adjoining this facies of the Lincoln porphyry grade into the porphyry, with the gradation marked by the growth of large rounded grains of quartz in these rocks. Under the microscope, the large grains of quartz appear to be aggregates of smaller grains. In the writer’s opinion this occurrence represents migration, rearrangement, and recrystallization of quartz in the silicic wall rocks caused by the heat and volatiles supplied by the intrusive porphyry.

Relative Age

The Lincoln porphyry cuts sedimentary rocks, known Precambrian rocks and granodiorite, but evidently does not cut any of the other Tertiary intrusives. A narrow dike of later white porphyry cuts the crystalline facies of the Lincoln porphyry in the basin at the head of Buckskin Creek near the small stream that heads towards the summit of Mount Bross. Slightly east of the stream a dike of the quartz monzonite porphyry group appears to cut the Lincoln porphyry, but because glacial drift and talus obscure the outcrop, this relationship can not be definitely stated.

Emmons reports that on the eastern spur of Mount Lincoln, north of Mount Bross, the Lincoln porphyry is apparently cut by "porphyrite", although the character of the outcrop was such that the relation could be doubtful (Emmons, 1886, p.
Emmons' term "porphyrite" corresponds to the term monzonitic diorite porphyry used in this report. The relative age of the Lincoln porphyry has been previously defined as more recent than the quartz monzonite porphyry and monzonitic diorite porphyry (Singewald and Butler, 1941, p. 20). Emmons (1886, p. 294) felt that the more basic rocks were later than the Lincoln porphyry, and Behre (1953, p. 56) places the Lincoln porphyry among the earlier monzonitic porphyries. The writer's opinion is that the Lincoln porphyry predates the monzonitic diorite porphyries and is partly equivalent to or older than the quartz monzonite porphyries.

Quartz Monzonite Porphyry

The quartz monzonite porphyries include all porphyries that do not fall into a classification based on characteristic appearance or mineralogy. All of the rocks so listed by the author are quartz latite porphyries and fit in this general classification, which has been previously used by Patton, Hoskins, and Butler (1912, p. 75-80), and Singewald and Butler (1941, p. 16, 19-20). Detailed petrographic studies of this type of rock were made by the above authors. These rocks are all of a very light color, are well altered, and are marked by phenocrysts of quartz, plagio-
class, and sometimes orthoclase, set in an aphanitic, dense, stony groundmass. The rocks generally contain less than 10 percent ferro-magnesian minerals. Microscope examination reveals some relatively subhedral quartz phenocrysts, but the majority are rounded. Orthoclase is quite rare as phenocrysts but forms a major part of the groundmass. Plagioclase varies from albite to andesine, but is generally andesine with albite perhaps caused in part by alteration (Simgewald and Butler, 1941, p. 20). Sericite, chlorite, and carbonate are the predominant alteration minerals, and they selectively replace the feldspar and ferro-magnesian phenocrysts.

**Distinctive Features and Distribution**

Distinctive features of the rock are the relatively small size of phenocrysts, compared to the Lincoln porphyry, the light-gray, green-gray, or light-pink color, and the dense, stony groundmass. This rock type is well distributed throughout the area and occurs as sills in the Minturn formation near the summit of Mount Bross, and as numerous dikes within the Precambrian rocks and the Paleozoic sedimentary rocks.

**Relative Age**

Dikes of quartz monzonite porphyry cut sedimentary rocks and Precambrian rocks. They also cut granodiorite
near the head of Buckskin Creek and a dike appears to cut Lincoln porphyry in the same general area. At the base of the sedimentary rocks below the Paris mine a dike of quartz monzonite porphyry is cut by a sill of monzonitic diorite porphyry, which indicates that the quartz monzonite porphyry predates the monzonitic diorite porphyry. The above relationship is shown in Figure 16.

**Monzonitic Diorite Porphyry**

The monzonitic diorite porphyries range from quartz-rich quartz monzonite to quartz-poor monzonite and diorite. These porphyries have been divided by the author into the normal monzonitic facies and the quartz-rich facies that are mineralogically similar except for the presence of quartz phenocrysts. The rocks have a very fresh appearance and are the least altered of all the porphyries. They range from dark-green to dark-gray, and all have an appreciable content of ferro-magnesian minerals.

Microscope work showed that orthoclase is confined to the groundmass and is associated with slight amounts of quartz, that the plagioclase is andesine, from two to five mm. in length, and that in a few specimens a small amount of augite is present in addition to hornblende and biotite. The writer classified these rocks as ranging from quartz
latite to latite-andesite.

Within an individual dike in the quartz-rich facies of this rock, the amount of the quartz phenocrysts varies considerably. Under the microscope these phenocrysts are invariably rounded and embayed by the groundmass while adjacent plagioclase crystals remain sharp. Relations of quartz phenocrysts are shown in Figures 12, 13, and 14. The quartz phenocrysts are often an aggregate of several different grains and in many instances the grains are rounded similar to sedimentary grains. The appearance of the quartz suggests that it had been picked up by the intrusive magma from the Sawatch or Parting quartzites, or the quartz-rich Precambrian rocks below. This suggestion is born out by megascopic inclusions found within the dikes (Singewald and Butler, 1941, p. 19). Detailed petrographic descriptions are given by Emmons (1886, p. 334-340), Patton, Hoskins, and Butler (1912, p. 86-91), and Singewald and Butler (1941, p. 19).

The term monzonitic diorite porphyry was first applied to these rocks in 1932, and previously the rocks had been termed by Patton, Hoskins, and Butler (1912), and Emmons (1886), as "porphyrite" (Singewald and Butler, 1932, p. 94). In the writer's opinion the name monzonitic diorite porphyry is valid as long as classification is not influenced by the percentage of quartz phenocrysts.
Figure 12. Photomicrograph of quartz-rich monzonitic diorite porphyry. Large quartz phenocryst (q) is rounded and embayed by groundmass. Crossed nicols. 25X Sample I-33

Figure 13. Photomicrograph of quartz-rich monzonitic diorite porphyry. Small round grain of quartz (q) is near relatively sharp plagioclase phenocryst (p). Crossed nicols. 25X Sample I-32

Figure 14. Photomicrograph of quartz-rich monzonitic diorite porphyry. A large irregular grain of quartz (q) enclosing chlorite, and made up of a number of small grains of quartz, is embayed by the groundmass. Crossed nicols. 25X Sample I-36
Figure 15. View of cliffs near the Criterion mine, looking north from Buckskin Valley, and showing a sill of monzonitic diorite porphyry near the base of the Sawatch quartzite. Sawatch quartzite (Cs); monzonitic diorite porphyry (Tmd); pegmatite dikes (pt).

Figure 16. Sill-like monzonitic diorite porphyry near the Paris mine cutting across a dike of quartz monzonite porphyry. Monzonitic diorite porphyry (Tmd); quartz monzonite porphyry (Tqm); Sawatch quartzite (Cs); schist (sch).
Distinctive Features and Distribution

The monzonitic diorite porphyry is distinguished from other porphyries by its dark color, relative freshness, and the microcrystalline groundmass. This porphyry, when free of quartz phenocrysts, is very easy to distinguish but the quartz-rich facies, when altered, is difficult to determine, and resembles quartz monzonite porphyry.

The major outcrop of the monzonitic diorite porphyry is a thin sill near the base of the Sawatch quartzite extending along the cliffs north and east of Buckskin Creek from the Criterion mine area to the area of the Paris mine. Most other outcrops of the rock are along the cliffs above Buckskin Creek, and the dikes are generally of the quartz-rich variety.

Relative Age

This porphyry definitely cuts quartz monzonite porphyry and granodiorite. Emmons thought an equivalent rock cut the Lincoln porphyry on the east spur of Mount Lincoln (Emmons, 1886, p. 294). Singewald and Butler considered the monzonitic diorite porphyry to predate the Lincoln and quartz monzonite porphyries (Singewald and Butler, 1932, p. 94). In the writer's opinion, however, the monzonitic diorite porphyry postdates the Lincoln and quartz monzonite porphyries.
White Porphyrnes

The white porphyrnes will be discussed together notwithstanding their great disparity in relative age. As used by Behre (1953), the term White porphyry refers to early White porphyry and later white porphyry designates the more recent rock. Both intrusives are gray-white to snowy-white porphyry showing only a few phenocrysts of quartz and plagioclase in a dense, stony, groundmass, and are very similar megascopically.

Microscopically the early White porphyry shows a slight amount of biotite, from one to two percent of the rock. Most features have been destroyed by alteration but chemical analysis and petrographic studies have led to the classification of this rock as a leucocratic granodiorite porphyry (Emmons, Irving, and Loughlin, 1927, p. 45; Behre, 1953, p. 43).

The later white porphyry seems to have fewer quartz phenocrysts than the early White porphyry, very little biotite, and the groundmass contains orthoclase, plagioclase, and abundant quartz. This rock is classified as a rhyolite porphyry (Behre, 1953, p. 46). Other detailed petrographic studies on both porphyries are Emmons (1886, p. 334-337), Patton, Hoskins, and Butler (1912, p. 72-74), Emmons, Irving, and Loughlin (1927, p. 46).
Distinctive Features and Distribution

The white porphyries are almost impossible to distinguish from each other in hand specimen. From the other intrusives they are easily distinguished by their color, lack of phenocrysts, and generally stony texture. Two small narrow dikes of later white porphyry are present near the forks of Buckskin Creek. A small outcrop on the east side of Red Amphitheatre is thought by the writer to be early White porphyry because of the substantial amount of biotite phenocrysts present. Because of alteration, however, the identification is not definite.

Relative Age

The early White porphyry was thought by Emmons, Irving, and Loughlin to be earlier than all other porphyries at Leadville (1927, p. 52). Singewald and Butler in the Alma district consider the early White porphyry to predate the other intrusives (1931, p. 304).

The later white porphyry was observed cutting granodiorite, Lincoln porphyry and quartz monzonite porphyry. Later white porphyry was not observed in contact with the monzonitic diorite porphyry or the diorite in Red Amphitheatre. Singewald and Butler state that this porphyry postdates all other porphyries in the Alma region (1941, p. 16). Behre states that this rock at Leadville was later
Figure 17. Later white porphyry dike in granodiorite, looking northwest at the head of Buckskin Creek.
than the gray porphyry group which probably correlate with
the porphyries of quartz monzonite composition near Alma,
and it is thought that the rock may be later than mineral-
ization (Behre, 1953, p. 46).

**Alteration of the Intrusives**

More striking than the individual characteristics of
the various porphyries is the intense alteration that many
have undergone and the relative similarity of that alter-
ation. Intensity of alteration of the porphyries varies
with location within the area, and generally sills are more
highly altered than dikes. Thin-section examination reveals
that some of the porphyries are well altered in all occur-
cences while others are comparatively fresh. Intrusives
arranged in general sequence of alteration intensity from
the most intense to the least intense are:

Higher alteration intensity

- Quartz monzonite porphyry
- Early White porphyry
- Spotted diorite porphyry
- Granodiorite
- Lincoln porphyry
- Diorite
- Monzonitic diorite porphyry

Lower alteration intensity

Reasons for this relative alteration are obscure,
especially when the minerals that are most susceptible to
alteration, plagioclase, and the ferro-magnesian minerals, 
are present in greatest quantity in the least-altered intru-
sives. The alteration sequence above is somewhat similar 
to the writer's concept of the general age relations, and 
relative age may be a factor in the alteration.

Major alteration minerals are sericite, chlorite, car-
bonate, and quartz. The alteration has been studied, and 
was thought to be the result of "end-phase" alteration, or 
alteration which was the final phase of intrusive activity 
and which was caused by solutions rising from the magma 
source through still molten dikes to effect the intensive 
alteration in the sills (Singewald, 1932, p. 16-30). Behre 
differed with the earlier interpretation because sills were 
invariably more highly altered than dikes (Behre, 1953, p. 
57). The alteration probably can be ascribed to deuteric 
effects within the porphyries as they were intruded, to 
interaction between the magmas and the host rocks, especially 
the carbonates in the sedimentary section, and to post-intru-
sive intense and widespread hydrothermal alteration. Concen-
tration of the intensely altered porphyries near Red Amphithec-
tre, a center of hydrothermal activity, accentuates the 
role of hydrothermal alteration.
Summary of Relative Age of Intrusives

Positive determination of the relative age of some of the intrusives has been impossible because of poor exposures and a lack of intrusive relations between the various intrusives. The interpretation of the sequence of intrusives is based partly on direct field evidence and partly on correlation with similar rocks from nearby areas. The various intrusives listed below are placed in what seems to be the correct order of relative age on the basis of available data. A question mark after the rock type indicates that the evidence for the position of that type is slight.

Earliest
1. Spotted diorite porphyry ?
2. Early White porphyry ?
3. Granodiorite ?
4. Lincoln porphyry
5. Quartz monzonite porphyry
6. Diorite ?
7. Monzonitic diorite porphyry
8. Later white porphyry

Latest

Field evidence as reported by other authors, as noted, does not agree completely with relations reported here. It has been suggested that time of intrusion of the various rocks overlapped (Singewald, 1935, p. 527). The writer agrees with this suggestion and also thinks it probable that, because of general mineralogic dissimilarity between the various types of intrusives, only the diorite and the monzonitic diorite porphyry may have a close genetic relationship.
STRUCTURE

Structural relationships of the Alma district and the Mosquito Range have been described by Singewald and Butler (1941, and Behre (1953). The structural features of the area were developed during Late Cretaceous or Tertiary. Precambrian structural features and rock types probably influenced the localization of the later structural features, but the extent of their influence has not been determined.

Regional Structural Features

The Alma district lies in a narrow structurally related belt, generally known as the Colorado Mineral Belt, which is well defined where it crosses the Front Range from Boulder to Breckenridge, and is less well defined as it continues southwest, toward the San Juan Mountains. This structural belt is marked by numerous northeast trending dikes and associated sills and stocks, and also by northeast striking
faults and fault zones (Lovering and Goddard, 1950, p. 58). The belt of transverse structural features cuts across the basic north-south fabric of central Colorado, and is marked by a change in some large structural features and the termination of others. In the Alma area, this structural belt is the northern termination of South Park, a large intramontane basin.

The major structural features of central Colorado, faults, folds, etc., are the result of Laramide compressive stresses resulting in uplift of mountain ranges. First folding and then, with added compression, thrusting occurred. Release of the compressive forces or reorientation of these forces gave rise to normal faulting in the large folded and faulted blocks (Jonson, 1955, p. 65-70).

The transverse mineral belt probably represents structural disruption at considerable depth in the earth’s crust. It is superimposed upon the large compressive features and may represent a strike-slip zone caused by areas of differential tension at depth.

**Local Structural Features**

The Alma district and the Mount Bross-Buckskin Creek area are located on the east flank of a faulted anticline which has been dissected into the Mosquito Range. The
FIG. 18 GENERALIZED TECTONIC MAP OF CENTRAL COLORADO

Modified from U.S.G.S. Geologic Map of Colorado, 1935

Outline of Colorado Mineral Belt
Tertiary Intrusives
Precambrian

Fault marker on down-dropped side of high-angle fault
Serrate on upper plate of thrust fault

MT BROSS-BUCKSKIN Ck. AREA, (RUL)
Mosquito Fault, the largest nearby fault, is a high-angle compound fault with normal movement north of Leadville and reverse movement to the south. Relative movement uplifted the east or Alma side several thousand feet relative to the west side (Butler and Vanderwilt, 1931, p. 332). Large faults in the Alma area, perhaps associated with the Mosquito Fault, are the London and the Coopers Gulch faults, found in the Mosquito Creek drainage south of Buckskin Creek. The fault with several hundred feet of throw that drops the Paleozoic sedimentary rocks from cliffs to creek level in lower Buckskin Creek may be an extension or branch of the Coopers Gulch Fault. This fault, exposed north of Buckskin Creek is northeast striking and could not be traced in the Minturn formation and Lincoln porphyry. Mullion structure in the fault zone was exposed along a road-cut facing Buckskin Creek.

No sharp definite folds are present in the Mount Bross-Buckskin Creek area, although there is considerable minor faulting and some warping of the east dipping sedimentary rocks. This warping and minor folding is, in the writer's opinion, caused by rather abrupt thickening or thinning of laccolithic sills which have forced the sedimentary rocks apart. This relationship of laccolithic sills can be seen on Plate II.
The minor faults are mostly aligned northeast with another set north and northwest. The greatest movement observed was 20 feet, while the general movement was less than five feet. These faults are high-angle faults, generally normal, perhaps with some strike slip movement, and are probably related to the large northeast striking Mineral Belt. They have localized most of the dikes and the mineralization within the area. The greater part of the movement along these faults has been pre-mineral, and only slight post-mineral faulting was observed. Several pre-mineral minor faults, parallel with the bedding or nearly so, are present. The general displacement of these faults is less than 10 feet, and they may represent slippage during folding. The writer could not determine the relationship of the minor structural features to the major structural fabric of central Colorado.

Of interest is the predominant north and northeast strike of veins. Vein directions and mineralization trends are less well developed or completely lacking in directions other than north or northeast. The mineralization seems to reflect the trend of the mineral belt but the reason for this behavior is unknown.
HYDROTHERMAL ALTERATION

One of the significant features of the Mount Bross-Buckskin Creek area is the abundance of hydrothermal alteration which can be subdivided into pyritic and sericitic alteration, chloritic alteration, and carbonatitic alteration. Hydrothermal alteration affects all the rocks of the area but shows its greatest development in Precambrian schist and granite gneiss, Tertiary porphyry sills, and the Peerless and Manitou formations. Part of the alteration observed in the porphyries may be caused by mineralogic changes during and soon after intrusion.

Widespread Alteration

Along the cliff exposures from Mount Bross down to Buckskin Creek are large areas of hydrothermally altered rock which are shown on Plate IV. Fluids causing the alteration were probably related in origin to the solutions that deposited the ore minerals, and the alteration shows some re-
lation in distribution to various types of mineralization.

**Sericitization and Pyritization**

Extensive hydrothermal alteration was localized near Red Amphitheatre. Areas on the east and west walls and along the cliffs east of the Amphitheatre are intensely pyritized and sericitized. These mineralogic types of alteration vary slightly in distribution, but in general the area of pyritic alteration, evidenced on weathered surfaces by reds and oranges of iron oxides, covers the associated sericitized rock. The colors found on the weathered surface of the altered zones are quite striking and were responsible for the name Red Amphitheatre. The altered rocks are broken in the process of weathering more readily than are the unaltered, and consequently altered rocks form large areas of talus slopes. This factor made detailed mapping of the alteration difficult and the relations shown on Plate IV are generalized. An idea of the surface effects, coloration, and distribution of this type of alteration can be seen in Figures 19, 20, and 21, views of the Red Amphitheatre area.

The major development of pyritic and sericitic alteration is in Precambrian granite gneiss, which is the predominant rock type near the Red Amphitheatre. Along the west side of the Amphitheatre, where the strong alteration should extend into the sedimentary rocks, relations are obscured by
extensive talus. Along the east wall of the Amphitheatre, the Sawatch quartzite is pyritized and altered along fracture zones. This alteration diminishes upwards and the quartzite is relatively unaltered at the top. In contrast to granite gneiss, the large dike-like body of diorite is relatively unaltered except where it is crossed by major fractures, which have associated alteration similar to that in the granite gneiss. The selectivity of the alteration for granite gneiss was probably caused by the brittle, easily fractured character of this rock in contrast to the tough diorite that would not readily shatter.

Along the east wall of Red Amphitheatre, associated with the pyritic and sericitic alteration, are areas where portions of the Peerless and Manitou formations have been replaced by light yellow-green serpentine and tremolite. In the formations above the Manitou, recrystallization of the carbonates and bleaching has taken place and in spots irregular veinlets of epidote are present. Specimens of hornblende schist, poorly exposed east of the Home Sweet Home Mine and along the eastern edge of the area of pyritic, and sericitic alteration show alteration of hornblende and biotite to serpentine. The serpentinization in the Red Amphitheatre area seems similar to that described by Behre from Manitou dolomite near magnetite-gold veins on the south side of Printer Boy Hill in the Leadville district (Behre,
Figure 19. Pyritic and sericitic alteration zone on the west side of Red Amphitheatre. Taken from the south side of Buckskin Creek looking northwest. (Altered areas show iron oxide coloration of red and red-brown.)

Figure 20. Pyritic and sericitic alteration near the Home Sweet Home Mine east of Red Amphitheatre. Taken from the south side of Buckskin Creek looking north. (Altered areas show iron oxide coloration of red and red-brown.)
Figure 21. Altered areas in Red Amphitheatre. Taken from the south side of Buckskin Creek, looking northeast. (Altered areas show iron oxide coloration of red and red-brown.)
1953, p. 29).

Microscopic examination of thin sections of altered rock revealed that with intense alteration all feldspars have been changed to sericite, and sericite has replaced some of the quartz. There is a slight amount of late euhe- ral quartz in the intensely altered rock, considerable pyrite, and generally a small amount of epidote, apatite, and fluorite, with a small amount of carbonate present in some specimens. Examination of thin sections from slightly altered granite gneiss revealed alteration of biotite to chlorite, slight alteration of plagioclase to sericite, and the addition of small amounts of carbonate. Examination of a more intense phase of alteration showed complete replace- ment of chlorite and plagioclase by sericite and partial replacement of potash feldspar by sericite. Small amounts of carbonate, apatite, and pyrite were generally present, with some minor amounts of fluorite. In the sections ex- amined, the predominant alteration mineral was sericite. Figures 22, 23, and 24 show variations in intensity of seri- citic alteration in granite gneiss from Red Amphitheatre.

Several thin sections exhibited minor veinlets of microscopic irregular grains of quartz and orthoclase along the boundaries of and cutting the large quartz and feldspar grains. Development of these veinlets was not related to the development of sericite, but small euhestral quartz crys-
Figure 22. Photomicrograph of relatively fresh granite gneiss.
Crossed nicols. 25X
Sample I-34

Figure 23. Photomicrograph of moderately sericitized granite gneiss.
Crossed nicols. 25X
Sample A-8

Figure 24. Photomicrograph of intensely sericitized granite gneiss.
Crossed nicols. 25X
Sample A-3
tals were found only with strong sericitization. Clay minerals were observed in several sections, all showing medium sericitization.

Microscopic examination of the serpentinetic alteration of the Manitou dolomite revealed carbonate minerals (apparently recrystallized), tremolite, and serpentine minerals, predominantly antigorite. The major development of both the tremolite and serpentine was in veinlike replacements intermixed with calcite and dolomite. The tremolite appeared to replace the carbonate. Serpentine replaced the carbonates and in some instances appeared to replace the tremolite.

The pyritic and sericitic alteration so well exposed near Red Amphitheatre extends eastward slightly east of the Home Sweet Home Mine. As more schistose Precambrian rocks were reached, the alteration died out. Near the Home Sweet Home Mine, the zone of alteration extended from the base of the sedimentary rocks to creek bottom, a width of several thousand feet, but along the west wall of Red Amphitheatre the zone had narrowed to approximately 1,000 feet. The extension westward across the high ridge west of Red Amphitheatre is covered by talus; but a correlatable pyritized and sericitized zone, approximately 500 feet wide, is exposed on the west side of the small drainage heading opposite Dolly Varden Creek. These relations are portrayed on
Plate IV. As seen along the north wall of the basin at the head of Buckskin Creek, the altered zone again died out in schist. The relations to schist and granite gneiss imply that the development of the alteration was dependent upon the fracturing qualities of the granite gneiss. Fluorite and rhodochrosite, which are rarely found outside the pyritic and sericitic alteration zone, are characteristic minerals of the ores within this zone.

The general outline of the pyritic and sericitic alteration is an elongate zone trending northwest. A continuation of the trend of the zone lies very near Bartlett Mountain and the pyritized and sericitized area near Climax, which has been described by Butler and Vanderwilt (1930) and Sears (1952).

Both areas show association of sericite and disseminated pyrite. Fluorite is present in both areas as disseminated grains in the altered rock and in veins within the alteration zones. The association of fluorite may be somewhat diagnostic, since insofar as the writer could determine, fluorite is not present in any other mineralized areas nearby. Hubnerite and rhodochrosite are two vein minerals that are present in both areas and molybdenite is also present in the Buckskin Creek drainage, though perhaps not intimately associated with the sericitic alteration. In the writer’s opinion, the two areas of sericitic alteration are
probably genetically related.

**Chloritization and Carbonatization**

In areas removed from the pyritic and sericitic alteration, previously described, are chloritized zones in the Precambrian schists, and areas of carbonate deposition and recrystallization in the sedimentary rocks. Although some of this type of alteration is exposed near the sericitic alteration, there may not be any definite relationship between the two types.

The major chloritized areas are developed in biotite-sillimanite schist along lower Buckskin Creek near the areas of the Paris, Excelsior, and Criterion mines. In hand specimens the alteration is marked by the presence of chlorite rather than the biotite of unaltered schist. Large crystals of muscovite from pegmatites in the altered area have been chloritized and are tinted green. The boundaries of the altered rock are gradational and difficult to determine. The generalized extent of this alteration is shown on Plate IV. Weathered surfaces of the chloritized schist are dark, approaching blue-black, apparently caused by manganese dioxide stain.

Microscopic examination reveals that biotite is changed mostly to sericite and lesser amounts are transformed to chlorite. Plagioclase is entirely replaced by the micas,
but considerable remnant orthoclase is present. Clays are developed on the feldspars, and carbonate is present in slight amount.

Present in the sedimentary formations are spotty, discontinuous areas of carbonate alteration, generally marked by bleaching, and recrystallization to a granular rock. The most prominent alteration noticed was in the Manitou and Chaffee formations along cliff exposures east of Red Amphitheatre and also near Dolly Varden Creek. The predominant carbonate alteration mineral is calcite, but dolomite and ankerite are both quite common.

The chloritic alteration exposed along Buckskin Creek is associated with ore-bodies in the overlying Sawatch quartzite and Peerless shale. These ores are essentially replacements of pyrite, galena, and sphalerite along fracture zones, and were mined for their gold content.

The Manitou, Dyer, and Leadville dolomites show bleaching and recrystallization near the replacement deposits of sphalerite and galena. Areas of alteration were observed with no immediate presence of ore and, in general, this alteration was more calcareous than near-ore alteration. In places silicification was associated with the recrystallization of the carbonates, and some sulphide mineralization generally occurred with the silicification.

Somewhat similar bleaching and recrystallization of
the sedimentary carbonates occurs near Red Amphitheatre. The secondary carbonates here have gained greater amounts of iron and weathered surfaces are often rust-colored. Replacement ore was not associated with these secondary carbonates, and in the writer's opinion, the carbonate alteration near Red Amphitheatre was caused by the same solutions that affected the sericitic and pyritic alteration.

**Alteration in the Immediate Vicinity of Ores**

In recent years there has been considerable discussion of hydrothermal alteration. Sales and Nyers (1948), describing wall-rock alteration at Butte, theorized that alteration and ore deposition were caused by the same general solutions. Lovering (1949), on the other hand, postulated different solutions for alteration and for ore deposition in the Tintic district. Relations in the Mount Bross-Duckskin Creek area suggest that both types of alteration may be present. The alteration near lead-zinc veins and replacement bodies is similar to the general alteration nearby, and the alteration near fluorite-rhodochrosite bearing veins is dissimilar to the associated widespread sericitization.
Alteration near Lead-Zinc Ores

Alteration intimately associated with the replacement ore deposits in the sedimentary rocks appears to be similar to widespread carbonate alteration not intimately associated with ore. In general the near-ore alteration is characterized by silicification and recrystallization of carbonates, with the formation of ankerite, calcite, dolomite, and some disseminated sulphides.

Alteration near minor sphalerite-galena veins that are probably related to the replacement deposits, but are localized in porphyry or biotite-sillimanite schist, manifests itself by the presence of carbonate, chlorite, and a slight development of sericite and clays. Sericite, generally disseminated, also occurs with quartz in microscopic veinlets that are cut by veinlets of carbonates. This alteration is similar to the chloritic alteration of the schist and to the widespread alteration of the porphyries throughout the district.

Alteration near Fluorite-Rhodochrosite Veins

The writer studied alteration adjoining the veins of the Home Sweet Home Mine, that is situated in an area of moderate to intense sericitic and pyritic alteration of granite gneiss. The veins contain tetrahedrite, pyrite, sphalerite, quartz, fluorite, and rhodochrosite. Alteration
Figure 25. Photomicrograph of chloritized biotite-sillimanite schist near the Paris Mine.

Crossed nicols. 25X
Sample A-10

Figure 26. Photomicrograph of chloritic and carbonatitic alteration of quartz monzonite porphyry near a lead-zinc vein on the Galveston property.

Crossed nicols. 25X
Sample A-6

Figure 27. Photomicrograph of argillic alteration of granite gneiss near the Home Sweet Home fluorite-rhodochrosite vein. Fine, dark-gray areas are clay, and dark spots and veinlet are fluorite (fl).

Crossed nicols. 25X
Sample A-4
near veins shows no sericite but rather strong development of kaolin-type clays. Also present in the altered rock are considerable amounts of disseminated fluorite and small microveinlets of quartz and fluorite. Away from the veins, the clay and large amounts of fluorite diminish with the appearance of sericite and slight carbonate, until the general relations of the moderately sericitized and pyritized granite gneiss appear. This alteration was definitely caused by solutions different from those which caused the sericitization, although these veins are related, by distribution, to the sericitic alteration.

**Alteration near Molybdenite Veins**

Molybdenite-bearing veins near the forks of Buckskin Creek are not intimately associated with any of the types of widespread alteration mentioned previously, although there is some pyritization of the granite gneiss in the area. There is only slight alteration near the veins and the alteration present appears to consist of silicification near the vein, and then farther from the vein, argillization which in turn grades into relatively unaltered granite gneiss.
Ore deposits and prospects in the Mount Bross-Buckskin Creek area can be divided into three general types.

1. **Lead-zinc ores.** These carry important values in silver and gold and are found as replacement ores in the sedimentary rocks and also as veins in the Precambrian rocks.

2. **Tetrahedrite-bearing, fluorite-rhodochrosite veins.** This type of veins occurs in and near the area of sericitic alteration centered around Red Amphitheatre.

3. **Molybdenite-carrying veins.** These are exposed in Buckskin valley near the forks of Buckskin Creek and are present in scattered outcrops westward toward the crest of the Mosquito Range.

The area described in this report includes part of the Buckskin and Consolidated Montgomery mining districts. Although signs of mineralization are numerous in the area, as shown by numerous mining claims on the claim map, Plate
VI, there has been considerably less production from this area than from the Mosquito and Consolidated Montgomery districts to the south and north, respectively.

The greater part of the production value in the Mount Bross-Buckskin Creek area, which may have amounted to one and one half million dollars, has come from lead-zinc ores carrying gold values that occur as veins and replacement bodies in the sedimentary rocks along the lower part of Buckskin Creek. There has been considerable development of the tetrahedrite-bearing, fluorite-rhodochrosite veins, but these properties have not been major producers. The molybdenite occurrences in upper Buckskin Creek valley have been only slightly prospected, and there has been a small production of placer gold from the gravels of lower Buckskin Creek.

The location of the many mines and prospects in the area is shown on Plate VI, a claim map of the area. The distribution of the various types of mineralization is shown on Plate IV.

Lead-Zinc Replacement Ores

Replacement ores of lead-zinc are the only type of mineralization present on the east slope of Mount Bross between Dolly Varden Creek and Buckskin Creek. Leadville dolomite
is exposed over the greater part of the slope and minor showings of mineralization are present wherever the Leadville or older stratigraphic units are exposed. Major development work on these showings has been below 13,000 feet, in the lower elevations of the exposed Leadville. The great majority of the workings were abandoned in the 1930's and mines are caved, or iced. The following description of mineralization is based on surface showings, dumps, and those underground workings open at the time of the writer's examination.

Mineralogy

The lead-zinc ores are predominantly sphalerite with lesser amounts of pyrite. The pyrite is disseminated through wall-rock and generally is present in greater amounts near the fringe of sphalerite zones. Sphalerite occurs both as light-colored "yellow jack," which is yellow to orange-yellow and has a low iron content, and as a dark-brown sphalerite, which has a higher iron content. Exsolved chalcopyrite is found only in the dark-brown sphalerite.

The two types of sphalerite are found associated in the Harrisburg Mine. "Yellow jack" is present as small ovoid replacements several inches in diameter. These "eggs" of "yellow jack" are completely covered by a layer of dark-brown sphalerite. The change in deposition of sphalerite
seems quite sharp, rather than gradational. Narrow veinlets cutting the replaced dolomite are generally dark-brown sphalerite, but larger ones show a central area of "yellow jack." Several specimens show borders of dark-brown sphalerite on "yellow jack" veinlets and also cross-cutting the "yellow jack" veinlets. These relationships indicate a change in the character of the sphalerite-depositing solutions, probably to solutions of higher temperature and higher iron and copper content, while deposition continued at the replacement front, which was at the outer edges of the already deposited material. These relations suggest that movement of solutions, deposition of minerals, and growth of replacement ore-bodies takes place along the periphery of the replacement sulphides.

The galena content, carrying the recoverable values of the ore, varies considerably within the replacement sulphides. Galena is intimately associated with sphalerite but is later in the paragenetic sequence, and its distribution may have been influenced by later fracturing or perhaps depositional choking of the channelways. Slight amounts of chalcocyprite are present, partly as exsolved spots in the iron-bearing sphalerite, and in some ores minor amounts of tetrahedrite are present. Gangue minerals include carbonates (generally ankerite and dolomite), quartz (both crystalline and as fine-grained, chert-like replacements), and
barite.

**Ore Controls.**

Replacement ore is present in the Leadville, Chaffee, and Manitou formations. In this area all these sediments seem to be equally well replaced, with the exception of the Parting quartzite member of the Chaffee, which is not as amenable to replacement as are the carbonates. Most of the mines and prospects are in the Leadville and Dyer dolomites, probably because of their more extensive outcrop.

Ore depositing solutions rose along fractures, and in general the localization of ores is dependent upon the fracturing. Most prospects show an aggregate northeast trend of mineralization along minor faults. Mineralization was intensified in the more broken or brecciated areas found where changes in rock type (from carbonates to shale, quartzite, or intrusive rocks) caused greater breakage near the fault. Mineralization was also intensified near the intersection of one or more fractures with the minor fault.

**Harrisburgh Adit.**

An example of the replacement type ore is the Harrisburgh property, one of the few workings that is fairly recent and accessible. The Harrisburgh is located along Weber Gulch near Mineral Park. The geology of the mine workings is shown in Figure 28.
**FIGURE 28**

**GEOLOGIC MAP OF THE HARRISBURG MINE**

**PARK COUNTY, COLORADO**

R. CORN  AUGUST 1956
The adit is entirely in altered and recrystallized Manitou dolomite. Ores were primarily sphalerite, and the owner reported that the rock removed in driving the adit averaged 10 percent zinc. The main ore control is a strong northeast fault, and ore was localized where minor fractures, trending nearly east-west intersect the stronger fault, and was also localized along the intersection of stronger fractures with flat, bedding-plane fractures. Ore exposed at the surface in the Parting quartzite is oxidized, and little could be determined about its occurrence in the quartzite.

**Gold-Bearing Lead-Zinc Ores**

Lead-zinc ores worked primarily for their gold content, are exposed in lower Buckskin Creek valley near the site of the old ghost town of Buckskin Joe, and along the cliffs to the north and west. Mines developed on these ores include the Paris, Excelsior, Criterion, Buckskin, and others. The ores occur generally as small and narrow veins in the schist, but at times occur as larger, low-grade replacement zones or fahlbands of the sulphides in schist, and as larger veins and replacement zones in the Sawatch quartzite, Peerless shale, and Manitou dolomite. Early workings were in oxidized material, and the higher gold values were probably caused by concentration during oxidation with grade falling
off in the sulphides. Mineralogically similar ores are found as veins in the Precambrian rocks and large intrusives in upper Buckskin Creek, but little, if any, production has come from these veins.

Mineralogy

Although the gold-bearing ores are very similar to those replacement ores previously described, a few differences are noted. Considerable pyrite is present in these ores, and it is generally more abundant than sphalerite. The sphalerite is entirely iron-bearing and contains plentiful "exsolved" chalcopyrite that grades to replacement chalcopyrite. The chalcopyrite content is greater than that in the dolomite replacements previously described. Gangue minerals are essentially similar to those in the replacement deposits and include quartz, carbonates, and at times barite. Quartz is entirely crystalline, and the veins are not quartz-rich. Galena in variable amounts and minor amounts of tetrahedrite are present.

The great similarity between these ores and the replacements at higher stratigraphic positions suggests that the mineralization is related. The iron-bearing character of the sphalerite signifies a higher temperature of deposition, probably correlating with the later iron-bearing sphalerite deposition in the replacement ore-bodies.
Higher gold values in these lower ores could be explained by the higher temperature of deposition or the chemical changes within the depositing solutions resulting from replacement of silica by carbonate in the schist and quartzite, rather than the replacement of carbonate by silica in the sedimentary carbonates.

**Ore Controls**

The gold-bearing ores, similar to the stratigraphically higher replacements, are localized along the minor northeast-trending faults. Ores widen preferentially where the rock has been broken over a wider area and widespread permeability was established. This effect is present along the intersection of fractures and also, apparently, in the upper parts of the Sawatch quartzite and in crumpling or folding developed in the Peerless shale. Bedding plane faults in these sedimentary rocks also may have effected the localization of ores. Veins commonly widen near porphyry dikes and pegmatites in the schist, because of the change in rock competency. Veins are also wider where they cut across the schistosity rather than where they are parallel or nearly parallel to it.

**Queen Mary and Lower Paris Adits**

Figure 29, a geologic map of a small adit below the main workings of the Paris Mine, shows the relations of a
FIGURE 29

GEOLOGIC MAP
OF
LOWER PARIS ADIT, PARK COUNTY, COLORADO
R. CORN  AUGUST 1966
FIGURE 30
GEOLOGIC MAP
OF
QUEEN MARY MINE, PARK COUNTY, COLORADO
R. CORN AUGUST 1956
vein with a combination of schist and Tertiary dike as wall-rock. The map does not portray the relations of the vein in schist alone. Above the adit, in schist, the vein narrows to only two or three inches in width.

The Queen Mary workings are on a fairly large vein and replacement zone in schist on the south side of Buckskin Creek, opposite Red Amphitheatre. Alteration made foliation difficult to determine, but it appears from the general relations of the schist that the vein cuts the foliation at a rather large angle. Figure 30 is a map of the lower adit, opened in 1956. A small rhodochrosite bearing vein cuts the lead-zinc mineralization at almost right angles near the end of the adit.

**Fluorite-Rhodochrosite Veins**

Within and near the pyritic and sericitic alteration zone centered in Red Amphitheatre are many veins characterized by prominent fluorite, rhodochrosite, and tetrahedrite. The great majority of these veins are within the sericitized zone, but several occurrences are in unaltered or slightly altered rock near the zone of intense alteration. Although generally occurring as sharp-walled veins, a pyritic type of this ore was observed slightly east of the Home Sweet Home, replacing quartzite schist outward from a fracture. Plate
IV shows the distribution of the fluorite-rhodochrosite type of mineralization. The greatest development on this type of mineralization has been on veins in the Home Sweet Home Mine, which probably aggregates over 10,000 feet of workings, part of which is shown on Plate V and Figures 31 and 32.

Mineralogy

The three characteristic minerals, as stated above, are tetrahedrite (in varying percentages, but generally a common constituent), fluorite, and rhodochrosite. Galena usually is present as is sphalerite. Pyrite is present at times as a prominent constituent of the ores, but in other veins it is almost completely lacking. The veins are siliceous, occasionally vuggy, and in some instances there is banding.

Bornite, a copper-iron sulphide not usually encountered in the area, is present in three localities along Buckskin Creek, in this type of ore. It is found associated with considerable chalcopyrite and pyrite at a small dump on the Wyandotte property north of Kite Lake, in a narrow sphalerite-galena vein on the main level of the Home Sweet Home, and on a dump one-half mile south and east of the Home Sweet Home Mine building. These occurrences were approximately at creek level and bornite was not found in any of the higher ores. Chalcopyrite was present to a greater extent in
these lower ores, and enargite has been reported from near
creek level at the Home Sweet Home Mine (Patton, Hoskins,
and Butler, 1912, p. 226-227). Other minerals occurring
in this type of ore are hubnerite found with quartz and tetra-
rahedrite at the Home Sweet Home Mine, argentite, and sulfur
and covellite found in the oxidized portion of the veins.

The completely different type of mineralogy and the
cross-cutting relationships of rhodochrosite veins to lead-
zinc mineralization indicates that these ores are of a later
period of mineralization than the lead-zinc veins and re-
placements. The complete lack of the lead-zinc ores within
the pyritic and sericitic alteration zone suggests that the
alteration was also later, and that lead and zinc may have
been carried to higher or more distant areas. The similari-
ity in distribution between the zone of pyritic and serici-
tic alteration and the tetrahedrite, fluorite-rhodochrosite
ores implies a genetic relationship between the altering
fluids and those of ore deposition. Occurrence of bornite,
enargite, and chalcopyrite along creek level, as compared
with their absence or scarcity at higher elevations, sug-
gests a change to more copper-rich, higher temperature ores
with depth.

These ores were primarily valuable for their high
values of silver, which is contained in argentite and tetra-
rahedrite. Samples of tetrahedrite assay several hundred
ounces of silver to the ton (Patton, Hoskins, and Butler, 1912, p. 226-227). There has been a very slight amount of near-surface supergene enrichment of copper in the ores at higher elevations. The oxidation and enrichment is absent on the valley floor because of glacial erosion, and is inhibited along cliff slopes by rapid mass wasting.

**Ore Controls**

The majority of the fluorite-rhodochrosite veins are localized in northeast minor fractures crossing the altered zone, with a few veins trending northwest, parallel to the alteration zone. The writer's impression, gathered from surface expression, from the distribution of mine and prospect dumps, and from underground investigation, was that veins and ore-shoots are somewhat discontinuous and that some disseminated mineralization is present. The numerous, discontinuous veins are probably in part caused by the widespread fracturing of the altered, easily fractured granite gneiss.

The vuggy character of some of the ore implies open space deposition, perhaps in tensional fractures. More open and permeable broken areas formed by fracture intersection and fault curvature also influenced the localization of ore.
Home Sweet Home Mine

The best example of the tetrahedrite-bearing, fluorite-rhodochrosite veins are those of the Home Sweet Home Mine. Figures 31 and 32 and Plate V are geologic maps of parts of three levels of the mine. These three mapped levels are shown in Figure 34 and are at elevations of approximately 11,250, 11,500, and 12,000, respectively. Most of the development work on this mine was carried out in the 1930's, and the writer was hampered in his mapping by bad air and by stoped-out and caved areas.

Plate V, the geologic map of the main adit level, shows extensive areas of alteration and considerable fluorite mineralization. Ground near stopes was caved and the better veins could not be observed.

Mineralization in the uppermost adit is a siliceous, vuggy vein with a minor fault forming one wall. There seems to be curvature of the fault near the mouth of the adit, although this is not definite, and the greater width of the vein at this location may be related to this change in strike. A definite relation of change of fault strike and increase in width of mineralization is shown on Figure 32, a geologic map of the intermediate level. An abrupt change in strike of the fault is related to a more extensive area of brecciation and consequently widening of the ore occurs. The fault zone becomes narrower as it continues along the
Vein contains minor Pyrite, Galena, Sphalerite, & Rodechrosite

STOPED OUT INACCESSIBLE

1' Vuggy Quartz & Tetraedrite

2' Quartz & Tetraedrite

Altered Granite gneiss

Monzonic Granite porphyry

Pegmatite

Granite gneiss

Portal caved

Mineralization

Fault

Contact

FIGURE 31

GEOLOGIC MAP OF
UPPER ADIT, HOME SWEET HOME MINE
PARK COUNTY, COLORADO
R. CORN AUGUST 1956
GEOLOGIC MAP
OF
MIDDLE ADIT, HOME SWEET HOME
PARK COUNTY, COLORADO
R. CORN 
AUGUST 1956
Figure 33. Photograph of the surface at the Harrisburgh property, looking southwest across Weber Gulch.

Figure 34. Photograph of the surface at the Home Sweet Home Mine, showing the location of the upper (1), intermediate (2), and lower (3), adits.

Taken from the south side of Buckskin Creek looking northeast.
same strike and width of ore decreases. Amount and direction of movement on the fault are unknown.

**Molybdenite-Bearing Veins**

Along the creek bottom, near the Forks of Buckskin Creek and westward toward the crest of the Mosquito Range are a number of small molybdenite prospects. Prospecting was done before 1930 and consists of trenches and a few short adits. The veins are small, and the molybdenite content is low.

**Mineralogy**

The molybdenite occurs as minute flakes in milky quartz veins with considerable pyrite. A few occurrences of molybdenite were disseminated in silicified and argillized granite gneiss outside quartz veins. In hand specimen, the association of milky quartz and molybdenite is very similar to molybdenite ore from Climax. The veins contain variable amounts of the base metal sulphides, chalcopyrite, sphalerite, and galena. The sphalerite is light green-brown, and several veins with no molybdenite, but containing sphalerite and milky quartz and pyrite similar to that associated with molybdenite, occur at higher elevations at the head of Buckskin Creek.
Ore Controls

The molybdenite-bearing veins are aligned to the north-east but are not generally formed along definite faults marked by gouge or offset. Veins seem to be discontinuous and short. There are quite a few of these small veins exposed and they are from fifty to several hundred feet distant from each other.

These veins are exposed in granite gneiss and Silver Plume granite. Their alignment suggests that the ores are controlled by the same system of minor fractures that exerts control over other ores in the district. The molybdenite veins are removed from the zone of strong sericitic and pyritic alteration with one exception. Although no molybdenite was observed in place, the writer did find molybdenite-bearing float, similar in character to veins exposed near the forks of Buckskin Creek, in the talus along the west wall of Red Amphitheatre, below intensely altered rock. Although the molybdenite-bearing veins were not intimately associated with the sericitic alteration, it is possible, as suggested by similarity to mineralization at Climax, that the molybdenite mineralization may be related to the sericitic and pyritic alteration.
FIGURE 35

GEOLOGIC MAP
OF
MOLYBDENITE PROSPECT NEAR FORKS OF BUCKSKIN CREEK
PARK COUNTY, COLORADO
R. CORN AUGUST 1956
Figure 36. Molybdenite-bearing quartz vein exposed in a prospect pit near the forks of Buckskin Creek.
FIGURE 37  Index Map showing location of Illustrations

Numbers refer to the number of the illustration in the text.
Figures are numbered only. Plates have prefix PL.

Photographs  Mapped Adit  Outcrop Section
position and direction taken  →  →  0°, S
Molybdenite Prospect near the Forks of Buckskin Creek

The greatest amount of work done on any of the molybdenite prospects was on one near the forks of Buckskin Creek. Figure 35, a geologic map of this prospect, shows a small sphalerite-galena vein at right angles to the quartz vein carrying molybdenite. More development work was done on this small streak than on the larger molybdenite vein. Because of oxidation and pinch-out of the galena-sphalerite vein, the writer could not determine any cross-cutting relations.

Paragenesis

Paragenetic relations were determined by microscopic examination of polished surfaces of the ore minerals. Figures 39 through 47 show features exhibited by these minerals. The complex sequence of deposition is broken down according to the types of ores as previously described. The paragenetic relations of the individual ore types are shown graphically in Figure 38.

Lead-Zinc Ores

Within the lead-zinc group of ores, those with zinc in the form of iron-bearing sphalerite are probably of later age than the "yellow jack"-bearing ores. Although galena is generally later than sphalerite, several specimens showed
indefinite relations, which suggest the opposite deposition-
al sequence. Major deposition of pyrite was prior to the
other sulphides, but slight amounts of pyrite were later.
Chalcopyrite was the latest mineral deposited and had affin-
ity for pyrite, and sphalerite, its growth in sphalerite
marked by enlargement of the dotted "exsolved" chalcopyrite.

**Molybdenite Ores**

The sulphide minerals were deposited along fractures
in the dense, milky vein-quartz. Pyrite was veined and
replaced by chalcopyrite, sphalerite, and molybdenite.
Relations were indeterminate between chalcopyrite, galena,
and sphalerite, but molybdenite definitely replaced all
three, and was the latest mineral to be deposited. The
molybdenite occurs as very thin, narrow veinlets and flakes,
but the other sulfide minerals are in distinct grains.

Paragenetic relations at Climax suggest that the molyb-
denite mineralization probably occurred prior to the deposi-
tion of the tetrahedrite-bearing fluorite-rhodochrosite
veins (Sears, 1952, p. 26). Age relations between the
molybdenite veins and the lead-zinc ores could not be deter-
mined. The observed paragenetic relations showing molyb-
denite replacing other sulphides within the molybdenite-
bearing quartz veins suggest that present exposures are near
the top of the molybdenite mineralization, and that more
molybdenite may be present at depth.

**Fluorite-Rhodochrosite Veins**

The fluorite-rhodochrosite ores commonly show some fracturing during deposition, although the sequence does not appear to be definite, and the fracturing was probably completed prior to deposition of galena and later sulphides. Major deposition of pyrite was prior to the other sulphides, and slight deposition occurred later. Fluorite and rhodochrosite are early, and sphalerite was also deposited at about the same time. Boundaries of the later sulphides, except chalcopyrite, are generally smooth and regular, perhaps indicating simultaneity of deposition. Chalcopyrite sharply replaces these other sulphides with its greatest development in bornite and pyrite.

These ores are definitely later than the lead-zinc ores as shown by cross-cutting relationships and by the lack of lead-zinc ores within the sericitic altered zone. The paragenesis, with chalcopyrite and bornite as the later minerals deposited, supports the suggestion, based on mineral distribution, that the ores are becoming more copper-rich with depth.
FIG. 38  PARAGENESIS OF MINERALIZATION IN THE MOUNT BROSS - BUCKSKIN CREEK AREA  
PARK COUNTY, COLORADO  
Relations Between Lead-Zinc Dikes and Molybdenite Veins are Unknown
Figure 39. Reflection photomicrograph of lead-zinc ore from the Nelson, showing galena (light-gray) replacing sphalerite (dark-gray). 112X
Sample PS-1

Figure 40. Reflection photomicrograph of lead-zinc ore from the Paris Mine, showing chalcopyrite (light-gray) replacing and as excised? dots in sphalerite (dark-gray). 112X
Sample PS-2

Figure 41. Reflection photomicrograph of lead-zinc ore from the Harrisburgh property, showing galena (light-gray) and sphalerite (dark-gray) replacing pyrite (py).
112X
Sample PS-3
Figure 42. Reflection photomicrograph of fluorite-rhodochrosite ore from the Home Sweet Home Mine, showing chalcopyrite (light-gray) replacing bornite (dark-gray). 112X

Sample PS-4

Figure 43. Reflection photomicrograph of fluorite-rhodochrosite ore from the Home Sweet Home Mine, showing chalcopyrite (chpy) replacing pyrite (py). 112X

Sample PS-5

Figure 44. Reflection photomicrograph of quartz (white) replacing fluorite (light-gray) in fluorite-rhodochrosite type ore from the Home Sweet Home Mine. 112X

Sample PS-6
Figure 45. Reflection photomicrograph of molybdenite (dark-gray and black) replacing quartz (light-gray). 60X
Sample PS-7

Figure 46. Reflection photomicrograph of molybdenite (black) replacing quartz (q) (gray) and pyrite (py) (white). 60X
Sample PS-8

Figure 47. Reflection photomicrograph of molybdenite (black) cutting and replacing quartz (q) and sphalerite (sp). 60X
Sample PS-9
CONCLUSIONS

In general, ores of the Mount Bross-Buckskin Creek area will not be profitable until a modern mill is built in the near vicinity and a market for the zinc content of the ore is established. At present, ore from the Alma vicinity is trucked to Leadville for milling or smelting and the nearest point for rail shipment from Alma is Buena Vista.

Many of the lead-zinc ores in the area are now considered sub-marginal because of their high zinc and low silver content, and until such time as milling facilities are erected they will continue to be sub-marginal. There has been very little recent development of this type of ore, and although there are no apparent large tonnages developed, the possible aggregate quantity available from the large number of small properties may be considerable.

The fluorite-rhodochrosite type ores, which have been worked recently in a minor way by lessees, could probably be profitable if payment was received for each of the sev-
eral metals present in the complex ore. Considerable ton-
nages of this type of ore may be present in the Home Sweet
Home Mine and nearby properties along upper Buckskin Creek.

**Exploration Possibilities**

Prospecting in the area would not be worthwhile unless
a mill is put into operation or planned. New lead-zinc ore-
bodies might be found in the Leadville dolomite just below
the Minturn formation on the lower east slopes of Mount
Bross, and good prospecting possibilities are present in the
lower sedimentary rocks, the Manitou, Peerless, and Sawatch
formations, especially where ore was found in the overlying
Leadville or Dyer dolomites. Profitable lead-zinc ores may
be present in Precambrian rocks, but only in granite, gran-
ite gneiss, quartzite schist, or where the foliation of the
schist strikes in a general northwest direction.

Fluorite-rhodochrosite veins have been developed exten-
sively only in the area of the Home Sweet Home Mine. In
this area, there are numerous small, somewhat discontinuous
veins with dissemination of sulphides in intensely altered
areas. The surface of the sericitic-pyritic altered zone,
in which this type of ore is generally found, is obscured
by talus over the greater part of its outcrop area. It is
probable that unprospected fluorite-rhodochrosite veins are
present beneath the talus. The discontinuous, and somewhat disseminated character of the mineralization as well as the indicated change to more copper-rich ores with depth suggests the possibility of low-grade sulphides at depth within the altered zone. This possibility is highly speculative, however.

The molybdenite-bearing veins near the head of Buckskin Creek, are definitely related to the mineralization at Climax. The close spacing of these veins and the observed paragenetic relations of the sulphides suggest the possibility of more molybdenite and perhaps a low grade body at depth. This possibility is again in the realm of rank speculation.

Conclusions Regarding Mineralization and Alteration

From the field and laboratory studies, the writer sums up in sequence the following main features of his interpretation of the alteration and mineralization in the Mount Bross-Buckskin Creek area.

1. The alteration and mineralization postdate almost all structural features and, except perhaps the later white porphyry, all of the Tertiary intrusives.

2. The replacement lead-zinc ore-bodies in the sedimentary rocks, associated with silicification and recrys-
tallization of the carbonates, were probably the earliest mineralization and alteration. A higher temperature phase of the same mineralization probably gave rise to gold-bearing lead-zinc veins and replacements in the lower stratigraphic horizons and Precambrian schist, associated with a carbonate-chlorite type of alteration.

3. Sericitic and pyritic alteration occurred in the Red Amphitheatre area, and the altering fluids caused recrystallization of the carbonate sedimentary rocks and serpentinization of dolomite and hornblende schist. The sericitic and pyritic alteration is probably related to similar alteration developed at Climax.

4. Molybdenite mineralization in the head of Buckskin Creek may be related to the mineralization at Climax and also may be related to the sericitic and pyritic alteration exposed in Red Amphitheatre.

5. Fluorite-rhodochrosite type mineralization is probably related to the sericitic-pyritic alteration, and is best developed within this altered zone. The fluids depositing fluorite, rhodochrosite, and associated minerals are believed to have given rise to argillic alteration within the sericitized zone.

6. Paragenetic relations indicate that the most recent minerals deposited in the fluorite-rhodochrosite type of ore are copper minerals, and field observations of the occur-
rence of these copper minerals suggest that the ore may become more copper-rich with depth.
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APPENDIX A

PATENTED MINING CLAIMS IN THE MOUNT BROSS-BUCKSKIN CREEK AREA, PARK COUNTY, COLORADO

Compiled from claims listed by Patton, Hoskins, and Butler, 1912, and from records of the county treasurer, Park County, Colorado. Claims listed are both lode and placer with placer designated in the claim name. Claims are listed in their order of survey numbers. Claim locations are shown on Plate VI in pocket.

<table>
<thead>
<tr>
<th>Survey Number</th>
<th>Name of Claim</th>
</tr>
</thead>
<tbody>
<tr>
<td>72</td>
<td>Grose &amp; Trewek's Placer</td>
</tr>
<tr>
<td>106</td>
<td>Sweet Home</td>
</tr>
<tr>
<td>107</td>
<td>Pulaski</td>
</tr>
<tr>
<td>143</td>
<td>Phillips</td>
</tr>
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APPENDIX B

DETAILED STRATIGRAPHIC SECTION
OF PRE-PENNNSYLVANIAN SEDIMENTARY ROCKS

This stratigraphic section was measured along the cliffs east of Buckskin Creek in the east one-half of Section 33, Township 8 South, Range 78 West, Park County, Colorado. The section was measured by Russell M. Corn in August 1956. Pre-Pennsylvanian sedimentary rocks include the Leadville dolomite, Chaffee formation, Manitou dolomite, Peerless shale and Sawatch quartzite.

Minturn formation (Pennsylvanian)
Unconformity
Leadville dolomite (Mississippian)

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<th>Unit</th>
<th>Description</th>
<th>Thickness (feet)</th>
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<td>62</td>
<td>Dolomite, gray, cavernous, brecciated, sandy, with chert in lower part.</td>
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<td>61</td>
<td>Dolomite, gray, sandy, porous.</td>
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<td>60</td>
<td>Dolomite, blue-gray, dense.</td>
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<td>59</td>
<td>Sandstone, gray, medium-grained.</td>
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<td>Unit</td>
<td>Description</td>
<td>Thickness (feet)</td>
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<tr>
<td>58</td>
<td>Sandstone, as above, dolomitic, with black chert pebbles.</td>
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<tr>
<td>57</td>
<td>Dolomite and dolomitic sandstone, gray, thin-bedded.</td>
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<tr>
<td>56</td>
<td>Dolomite, gray and buff, sandy.</td>
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<td>55</td>
<td>Dolomite, blue-gray, dense.</td>
<td>27.0</td>
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<td>54</td>
<td>Dolomitic conglomerate, pebbles of gray and blue-gray dolomite.</td>
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<td><strong>Total Leadville dolomite</strong></td>
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--- Unconformity ---
Chaffee formation (Devonian)

Leadville dolomite (Mississippian)
--- Unconformity ---
Chaffee formation (Devonian)

Dyer dolomite member
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<td>53</td>
<td>Dolomite, gray, dense, weathers buff or light-brown.</td>
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<td>52</td>
<td>Dolomite, gray, dense.</td>
<td>43.5</td>
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<td>51</td>
<td>Dolomite, white, recrystallized.</td>
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<tr>
<td>50</td>
<td>Dolomite, white, thin-bedded, recrystallized.</td>
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<td></td>
<td><strong>Total Dyer dolomite</strong></td>
<td>78.0</td>
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</table>
Unit

Parting quartzite member

49  Sandstone, gray, medium-grained, dolomitic.  5.5
48  Dolomite, white, recrystallized.  1.5
47  Sandstone, light-purple, fine-grained.  4.0
46  Sandstone, gray, medium and coarse-grained, dolomitic.  1.0
45  Quartzite, light-purple, medium and fine-grained.  7.0
44  Dolomite, gray, sandy.  2.0
43  Dolomite, gray, with coarse sand grains.  2.5
42  Quartzite, gray, medium and fine-grained.  2.0

Total Parting quartzite 23.5

Total Chaffee formation 101.5

------Unconformity------

Manitou dolomite (Ordovician)

Chaffee formation (Devonian)

------Unconformity------

Manitou dolomite (Ordovician)

41  Dolomite, light-gray, dense, with slight siliceous ribbing.  24.5
40  As above, thin-bedded.  6.0
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<td>Dolomite, light-gray, dense.</td>
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<td>37</td>
<td>Dolomite, light-gray, dense, with a few thin beds of shale.</td>
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<td>36</td>
<td>Dolomite, light-gray, calcareous, bleached and recrystallized.</td>
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<tr>
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<td>Dolomite, as above, with shale.</td>
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<tr>
<td>34</td>
<td>Dolomite, white, sandy.</td>
</tr>
<tr>
<td>33</td>
<td>Dolomite, white, weathers buff.</td>
</tr>
<tr>
<td>32</td>
<td>Shale and shaly dolomite, green, thin-bedded.</td>
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<td>Shale, green, dolomitic.</td>
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<td>Dolomite, light-gray, sandy.</td>
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<td>29</td>
<td>Shale, green, dolomitic.</td>
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<tr>
<td>28</td>
<td>Dolomite, gray, sandy.</td>
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<td>27</td>
<td>Shale, green, dolomitic.</td>
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<tr>
<td>26</td>
<td>Dolomite, light-green, shaly</td>
</tr>
<tr>
<td>25</td>
<td>Shale, green, dolomitic.</td>
</tr>
<tr>
<td>24</td>
<td>Shale, green.</td>
</tr>
</tbody>
</table>

Total Manitou dolomite 96.0

-----Transitional-----
Peerless shale (Cambrian)
<table>
<thead>
<tr>
<th>Unit</th>
<th>Thickness (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manitou dolomite (Ordovician)</td>
<td></td>
</tr>
<tr>
<td>Peerless shale (Cambrian)</td>
<td></td>
</tr>
<tr>
<td>23    Dolomite, mottled gray-green and red,</td>
<td>3.5</td>
</tr>
<tr>
<td>&quot;red cast beds&quot;</td>
<td></td>
</tr>
<tr>
<td>22    Shale and dolomitic shale, green, thin-bedded.</td>
<td>8.0</td>
</tr>
<tr>
<td>21    Shale, green, sandy.</td>
<td>3.0</td>
</tr>
<tr>
<td>20    Shale, green, sandy, calcareous.</td>
<td>15.0</td>
</tr>
<tr>
<td>19    Sandstone, green, medium-grained, shaly, calcareous.</td>
<td>4.5</td>
</tr>
<tr>
<td>18    Sandstone, green, fine-grained, shaly calcareous.</td>
<td>9.0</td>
</tr>
<tr>
<td>Total Peerless shale</td>
<td>43.0</td>
</tr>
<tr>
<td>Sawatch quartzite (Cambrian)</td>
<td></td>
</tr>
<tr>
<td>Peerless shale (Cambrian)</td>
<td></td>
</tr>
<tr>
<td>Sawatch quartzite (Cambrian)</td>
<td></td>
</tr>
<tr>
<td>17    Quartzite, dark-green.</td>
<td>4.0</td>
</tr>
<tr>
<td>16    Sandstone, light-purple, medium-grained, calcareous, cross-bedded.</td>
<td>5.0</td>
</tr>
<tr>
<td>15    Interbedded quartzite, white, and sandstone, white, medium-grained, calcareous.</td>
<td>17.0</td>
</tr>
<tr>
<td>Unit</td>
<td>Description</td>
</tr>
<tr>
<td>-------</td>
<td>-------------------------------------------------</td>
</tr>
<tr>
<td>14</td>
<td>Quartzite, white</td>
</tr>
<tr>
<td>13</td>
<td>Quartzite, light-green</td>
</tr>
<tr>
<td>12</td>
<td>Quartzite, white, and light-green</td>
</tr>
<tr>
<td>11</td>
<td>Quartzite, white</td>
</tr>
<tr>
<td>10</td>
<td>Quartzite, light-green</td>
</tr>
<tr>
<td>9</td>
<td>Quartzite, light-purple</td>
</tr>
<tr>
<td>8</td>
<td>Quartzite, white</td>
</tr>
<tr>
<td>7</td>
<td>Quartzite, light-purple</td>
</tr>
<tr>
<td>6</td>
<td>Sandstone, gray, calcareous</td>
</tr>
<tr>
<td>5</td>
<td>Quartzite, light-purple</td>
</tr>
<tr>
<td>4</td>
<td>Sandstone, gray, calcareous</td>
</tr>
<tr>
<td>3</td>
<td>Quartzite, white</td>
</tr>
<tr>
<td>2</td>
<td>Quartzite, white, with thin beds of sandy shale.</td>
</tr>
<tr>
<td>1</td>
<td>Quartzite, white, slightly conglomeratic</td>
</tr>
</tbody>
</table>

--- Unconformity ---

Biotite-sillimanite schist (Precambrian)