OPEN-FILE REPORT 08-12

Geologic Map of the Cameron Mountain, Quadrangle, Chaffee, Park, and Fremont Counties, Colorado

Explanatory text and expanded Description of Map Units

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Denver, Colorado
2008

INTRODUCTION

The Cameron Mountain quadrangle is located in southeastern Chaffee County, southern Park County, and western Fremont County in the southern part of the Mosquito Range about 10 km north of Salida, Colorado. The map area includes rugged terrane along the western border, and high rolling hills and a high plateau in the central and eastern parts of the quadrangle. Elevations range from about 8,500 to 11,000 ft.

The oldest rocks in the quadrangle are Proterozoic metamorphic and igneous rocks that are overlain unconformably by Paleozoic sedimentary rocks, Tertiary volcanic rocks, and Quaternary glaciofluvial, slope-wash, and stream deposits. The Late Cretaceous Whitehorn Granodiorite intruded Paleozoic sedimentary units. Steep faults offset Proterozoic and Paleozoic rocks. Late Cretaceous plutonic rocks are not offset by most faults and most faults a pre-Late Cretaceous in age. Tertiary volcanic rocks are composed mainly of silicic welded tuff and air-fall tuff, and Tertiary sedimentary rocks are composed of silt, sand, and gravel.

PREVIOUS STUDIES

Numerous geologic studies, most of which date from 1960 to 1980, established the regional geologic framework in the southern Mosquito Range. Reports on regional stratigraphic studies of lower and middle Paleozoic rocks by Campbell (1972), Conley (1972), Gerhard (1972), Nadeau (1972), and Ross and Tweto (1980) established the regional stratigraphic sequence and lithofacies relations. Peel (1971), Pierce (1969, 1972), De Voto (1972, 1980a, 1980b), and De Voto and Peel (1972) studied upper Paleozoic rocks south and southeast of the Cameron Mountain quadrangle, and the reports and maps that resulted from this work determined the stratigraphic sequence south of the map area. Wrucke (1974) described the Late Cretaceous Whitehorn Granodiorite, the main plutonic body in the map area, and determined that the pluton was a laccolith. Chapin and Lowell (1979) described the Wall Mountain Tuff as a valley-fill deposit. A series of 15-minute geologic maps by the U.S. Geological Survey described relations among Proterozoic and Paleozoic successions, Cretaceous plutonic rocks, Tertiary intermediate and silicic volcanic rocks and poorly consolidated sedimentary rocks and Quaternary deposits in the southern Mosquito Range. The original Cameron Mountain 15-minute quadrangle was subdivided into four 7.5 minute quadrangles that were named the Salida East, Cameron Mountain, Gribbles Park, and Jack Hall Mountain quadrangles; the same name given to quadrangles of different vintage and scale is the source of some confusion. Wrucke and Dings (1979) published an open-file map of the Cameron Mountain 15-minute quadrangle (scale 1:62,500), which includes the Cameron Mountain 7.5 minute quadrangle (scale 1:24,000) of this report. The Black Mountain 15-minute quadrangle (scale 1:62,500) of Epis and others (1979a) adjoins the Cameron Mountain 15-minute quadrangle of Wrucke and Dings (scale 1:62,500) on the east, and the Guffey 15-minute quadrangle (Epis and others, 1979b) borders the Cameron Mountain 15-minute quadrangle of Wrucke and Dings (1:62,500) to the northeast. The Salida East 7.5-minute quadrangle, which adjoins the Cameron Mountain 7.5-minute quadrangle of this report on the south, was mapped by Wallace and others (1997) at a scale of 1:24,000. The geology of the Cameron Mountain quadrangle is shown in a generalized form in the western part of the Pueblo 1° X 2° quadrangle (Scott and others, 1978).

PRESENT STUDY

The present study focuses on geologic mapping of the Cameron Mountain 7.5-minute quadrangle at a scale 1:24,000. Most geologic mapping was completed in June and July 1997. C.A. Wallace and Allison D. Lawson mapped and compiled the Phanerozoic terrane, and prepared the cross sections. Wallace wrote the explanatory text. Wallace revised Proterozoic geology mapped by Wrucke and Dings (1979). Rock names in this report are field terms: sedimentary rocks are named according to the scheme proposed by Pettijohn (1957), metamorphic rocks names follow the system proposed by Best (1982), and volcanic and igneous

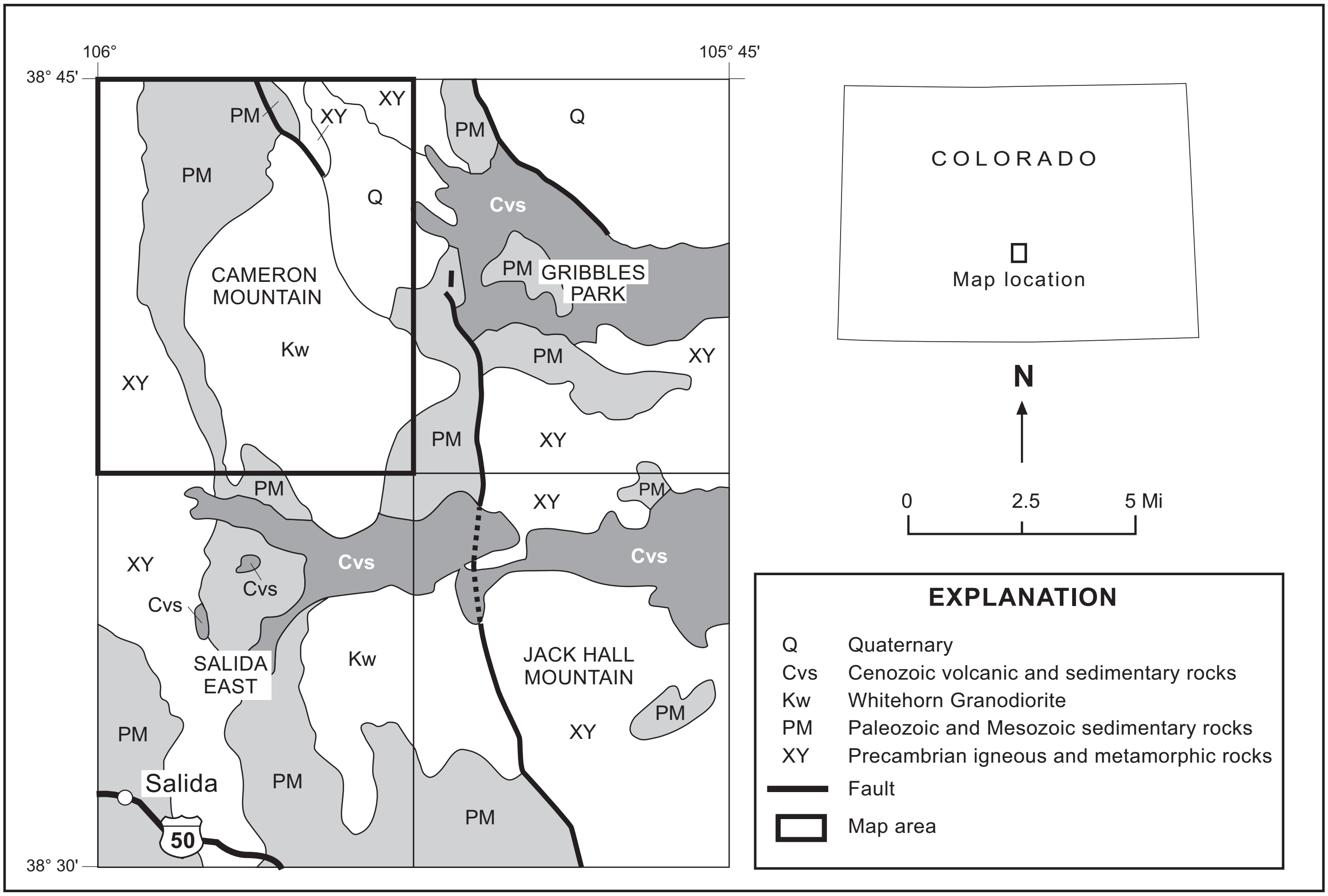

Figure 1. Location of Cameron Mountain quadrangle.

rocks were named according to the I.U.G.S. classifications proposed by Streckeisen (1973, 1978).

GEOLOGIC SETTING

Proterozoic rocks consist mainly of igneous rocks and a lesser amount of metamorphic rocks. They are divided into main two groups: gneiss and granodiorite (Boardman, 1971; Wrucke and Dings, 1979). The gneiss consists primarily of well-foliated biotite gneiss and amphibolite. The gneiss resembles other mafic and felsic gneisses in Colorado that have a metamorphic age of about 1.7 Ga. The granodiorite is a coarse-grained, porphyritic, biotite-rich quartz and feldspar gneiss. The granodiorite may be of Boulder Creek age. Locally, foliated amphibolite occurs interlayered with the granodiorite. Both units contain pegmatitic and aplitic intrusive bodies. The contacts between the gneiss and amphibolite are gradational and occur over distances of 20 to 100 meters. The granodiorite extends from the southern edge of the quadrangle to the northern border.

The Paleozoic sequence is a maximum of about 3,185 m thick in the map area. At the base is the Sawatch Quartzite (Upper Cambrian), which, in ascending order, is overlain by the Manitou Limestone (Lower Ordovician), Harding Quartzite (Middle Ordovician), Fremont Dolomite (Upper and Middle Ordovician), Chaffee Formation (Upper Devonian), Leadville Limestone (Lower Mississippian), Kerber Formation (Lower Pennsylvanian), Sharpsdale Formation (Middle Pennsylvanian), Belden Shale (Middle Pennsylvanian), Minturn Formation (Middle Pennsylvanian), and the lower part of the Sangre de Cristo Formation (Upper Pennsylvanian). Most of the lower Paleozoic units are separated by disconformities that represent long periods of nondeposition or cycles of deposition and erosion. Lower Paleozoic rocks were deposited in shallow marine environments.

Regionally, sedimentary rocks deposited above the Leadville Limestone consist of clastic and carbonate rocks that are cyclic repetitions of marine and continental deposits in the southern and central part of a north-northwest-trending, fault-bounded arm of the Pennsylvanian-Permian interior seaway, known as the Central Colorado Trough (De Voto, 1972). Most of the upper Paleozoic units are conformable or have gradational contacts that intertongue. In the southern part of the Cameron Mountain quadrangle the base of the first depositional cycle is represented by the Kerber Formation, which is a predominantly marine and deltaic unit. The Kerber Formation is overlain by the Sharpsdale Formation, which is mainly a continental deposit. The second depositional cycle in this part of the Central Colorado trough is represented by the predominantly marine Minturn Formation and the overlying member one of the Sangre de Cristo Formation, a continental deposit. The base of the third cycle in the Central Colorado Trough is represented by member two of the Sangre de Cristo Formation, a marine deposit, and by member three, a continental deposit at the top of the cycle. In the southern part of the Cameron Mountain quadrangle the cyclic repetition of marine to continental deposits typifies Pennsylvanian and Permian rock units, but in the northern part of this quadrangle, the rock units are a deltaic and marine succession of Kerber, Belden, and Minturn Formations, which is characteristic of the middle part of the Central Colorado Trough. The cyclic repetition of marine and nonmarine strata was controlled by syndepositional tectonics of bounding faults located east and west of the map area (De Voto, 1972; De Voto and Peel, 1972).

In the Cameron Mountain quadrangle the Whitehorn Granodiorite (Upper Cretaceous), which is a laccolith, intruded Paleozoic rocks. The border zones of the pluton are fine-grained porphyries, whereas interior parts of the pluton are uniformly fine- and medium-grained and equigranular.

Tertiary units are mainly volcanic rocks of silicic composition and sedimentary deposits. Quaternary units include pediment, alluvial, colluvial, and eolian deposits. The oldest Quaternary units occur as prominent pediment deposits in the northeastern part of the quadrangle. Eolian deposits are common in drainages, and deposits of colluvium and alluvium formed in modern drainages during Holocene time. Quaternary deposits consist of gravel, sand, silt, and clay deposited in glacial, fluvial, colluvial, and eolian environments during Pleistocene and Holocene time. Wrucke and Dings (1979) identified several deposits that they related to glacial periods, and they used the elevation above modern streams to establish an age sequence. The terrace levels used by Wrucke and Dings (1979) to form the basis of their Quaternary stratigraphic succession occur along the Arkansas River Valley near Salida. Our nomenclature for Quaternary deposits in the Cameron Mountain quadrangle uses a relative time scale suggested by R. Kirkham (Colorado Geological Survey, written communication, 1997) that was used for the Salida East quadrangle (Wallace and others, 1997). According to Kirkham, the scheme used by Wrucke and Dings (1979) that related continental glacial events to alpine deposits is not clearly established, so a purely relative scale is best applied to pediment deposits in the map area.

STRUCTURE

The principal structures in the map area are steeply dipping normal and reverse faults that trend east-west in the western part of the quadrangle and a northwest-trending fault in the northeastern part of the quadrangle. Most faults are steep east-west striking normal faults of small separation that offset Proterozoic and Paleozoic rocks. Cambrian to Mississippian sedimentary rocks are more intensely faulted than overlying Pennsylvanian and Permian sedimentary rocks, but all Paleozoic rocks are folded locally. A series of northeast-trending anticlines and synclines occurs in the west-central part of the map area where rocks of Cambrian through Mississippian age are deformed; Pennsylvanian and Permian units in the western part of the map area are also folded.

The Cameron Mountain quadrangle is located in the southern part of the Late Paleozoic Central Colorado Trough of De Voto (1972) and the southern part of the early Paleozoic “Colorado Sag” as described by Ross and Tweto (1980). North-northwest trending faults parallel the trend of the central and southern part of the “Colorado Sag”.

The north-northwest orientation of the principal fault in the northeastern part of the map area parallels that of principal faults in nearby Proterozoic terranes (Tweto, 1980), and it may be an extension of the Weston-Pleasant Valley fault that has been mapped southeast of the map area by Wrucke and Dings (1979). The north-northwest orientation of the fault may have been controlled by rejuvenated slip on older Early and Middle Proterozoic faults (Tweto, 1980; Ross and Tweto, 1980). Many of these faults produced highlands adjacent to shallow basins (Tweto, 1980) and controlled erosion and sedimentation since Proterozoic time (Tweto, 1980; Ross and Tweto, 1980).

The main regional tectonic elements that influenced sedimentation during Paleozoic time are: (1) the Sawatch anticline of De Voto (1972) located west of the map area; (2) the ancestral Front Range and the Apishapa highlands to the east (Ross and Tweto, 1980), which are equivalent to the Front Range and Wet Mountains anticlines of De Voto (1972); (3) the ancestral Uncompaghre and San Luis highlands to the southwest (De Voto, 1972; Ross and Tweto, 1980); and (4) the Central Colorado Trough, which extended northwest between the ancestral Uncompaghre-San Luis uplift to the southwest and the ancestral Front Range-Apishapa uplift to the northeast (De Voto, 1972).

North-northwest-trending faults in the region of the Cameron Mountain quadrangle were active during Pennsylvanian time (De Voto, 1972). In this region most separation on north-northwest-striking faults in the map area postdates lithification and subsequent exposure of the Leadville Limestone at the surface (Wallace and others, 1997). Some north-northwest-trending faults may have been reactivated after Paleozoic time, but these faults had no slip after about 70 Ma when the Whitehorn Granodiorite was intruded because the laccolith truncates most faults that cut Paleozoic rocks and the laccolith has not been faulted by most faults that cut Paleozoic rocks.

A prominent set of east-west-striking faults was mapped in Proterozoic rocks, and many of these faults extend into lower and upper Paleozoic rocks in the western part of the map area. Small-separation faults in Cambrian to Devonian rocks do not appear to offset Pennsylvanian and Permian rocks, but detailed stratigraphic data for Pennsylvanian and Permian rocks is not available to locate faults of small separation.

In the northeastern part of the map area a northwest-trending fault juxtaposes lower Paleozoic rocks against Pennsylvanian rocks and Pennsylvanian strata against Middle Proterozoic igneous rocks. This fault appears to be the northern extension of the Weston-Pleasant Valley fault mapped by Wrucke and Dings (1979), a range-bounding fault that controlled erosion and deposition in the Central Colorado Trough (De Voto, 1972). The strike of the Weston-Pleasant Valley fault is similar to the trend of faults that bound the Rio Grande rift. Faults and folds in the Cameron Mountain quadrangle do not record the extensional event that characterized formation of the Rio Grande rift during late Cenozoic time.

Folds in the map area are medium-scale structures in Paleozoic rocks. Several tight and open anticlines and synclines occur in Ordovician, Devonian, Mississippian, and Pennsylvanian rocks near the Whitehorn Granodiorite. In the west-central part of the map area tightly folded rocks occur on fault-bounded blocks. Generally folds trend northeast and northwest, although east-west trending folds were mapped in the central part of the quadrangle.

During the period 70 to 36 Ma (Maastrichtian to Rupelian age) sedimentary, metamorphic, and plutonic rocks in the map area were uplifted and the southern part of the Central Colorado Trough, which received a large volume of sediment during Paleozoic time, became a source area for sediment during early Tertiary time. An erosional event occurred after emplacement and crystallization of the Whitehorn Granodiorite. The Gribbles Run paleovalley of Chapin and Lowell (1979), drained from west to east south of the map area before the Wall Mountain Tuff was erupted (Early Oligocene). This paleovalley was part of a larger drainage system that trended southeast according to Chapin and Lowell (1979).

METAMORPHISM

Paleozoic sedimentary rocks were metamorphosed by the Whitehorn Granodiorite, and the metamorphic effects are most prominent along the western edge of the laccolith where Paleozoic clastic and carbonate rocks were subjected to contact metamorphic conditions. The most prominent metamorphism occurred in the vicinity of Marble Quarry Gulch in the western part of the map area where upper Paleozoic rocks are underlain by a granodiorite porphyry sill and overlain by the basal part of the granodiorite laccolith. The metamorphism formed a skarn in Mississippian and lower Pennsylvanian rocks east of Marble Quarry Gulch between the sill and the laccolith. The Manitou Limestone was metamorphosed to a fine- to coarse-grained, dolomite marble that contains rare interbeds of calcite marble. The Harding Quartzite was metamorphosed to a siliceous, dense quartzite. The Fremont Dolomite was metamophosed to a fine- to coarse-grained dolomite marble. At some places near the intrusions the Fremont Dolomite contains blades of tremolite, pyroxene, and biotite in addition to recrystallized dolomite. Metamorphism of the Parting Member of the Chaffee Formation formed a flinty calc-silicate hornfels and biotite-chlorite-quartz hornfels. The Dyer Member of the Chaffee Formation was metamorphosed to dolomite marble and calc-silicate hornfels. The Leadville Limestone was metamorphosed to a fine- to coarse-grained dolomite and calcite marble. The basal sandstone beds of the Leadville Limestone were recrystallized to dense quartzite, and argillaceous beds were recrystallized to tremolite-, pyroxene-, and mica-bearing calc-silicate hornfels. Basal beds of the Kerber Formation were metamorphosed to quartzite, non-calcareous hornfels, and calc-silicate hornfels. The skarn that formed east of Marble Quarry Gulch where the Calumet Mine is located occurs at the uppermost part of the Leadville Limestone and at the base of the Kerber Formation. The limestone was replaced by massive tremolite, actinolite, epidote, calcite, dolomite, garnet, pyrite, chalcopyrite, and oxidized iron minerals. Minerals of economic interest that occur in the skarn are scheelite, corundum, and beryl.

ACKNOWLEDGEMENTS

We are indebted to the many folks in the Salida area who helped us with access to private land and with advice and counsel as we mapped the Cameron Mountain quadrangle. Glenn and Jeannie Everett permitted access across land of the Everett Land and Cattle Company, and Roy Smith gave permission to access his property. Charles Medina and his staff at the Salida Ranger District, U.S. Forest Service, provided information on land access and access to Forest Service land. We thank the people of the Salida area for the many courtesies rendered during this mapping project. Beth Widmann provided able assistance in the field. Helpful technical reviews by James A. Cappa and Robert W. Kirkham (Colorado Geological Survey) improved and sharpened the map and text. The text and geologic map were significantly improved by Jane Ciener’s editing.

EXPANDED DESCRIPTION OF MAP UNITS

QUATERNARY SURFICIAL DEPOSITS

af

Artificial fill (latest Holocene)— Fill and waste rock deposited during construction and mining operations. Artificial fill is composed mostly of unsorted silt, sand, and large rock fragments.

Qac

Alluvium and colluvium (Holocene and Pleistocene?)— Alluvial and colluvial deposits are mapped in many drainages where Wrucke and Dings (1979) showed alluvial deposits. The deposits that we show as alluvium and colluvium are crudely stratified and are tan and grayish-yellow-brown, fine-grained, nonconsolidated sediment composed of clayey silt, silty sand, sand, pebbly and cobbly silt and sand and interbedded lenses of matrix-supported, angular cobbles and pebbles in a clayey to sandy matrix. Lenses of alluvium are composed of framework-supported angular to subrounded clasts surrounded by clayey and sandy matrix. Lenses of coarse debris preserve flat bedding. Deposition of alluvium and colluvium predates modern alluvium because modern stream deposits have incised colluvial deposits in many drainages. Alluvium and colluvium form broad extensive benches that can be 5 to 15 m or more above active stream channels. Alluvium and colluvium in the central part of the map area have not been incised.

Qes

Eolian sand and silt deposits (Holocene and Pleistocene?)—Eolian deposits occur only in the southwestern part of the quadrangle. These light-tan, tan, and grayish-light-brown deposits are composed of a mixture of silt and very fine- to fine-grained sand. Rare angular pebbles occur as isolated clasts; most likely these pebbles were emplaced as sheet wash. A thin layer of eolian silt and sand overlies alluvium and colluvium at many places, but these thin alluvium and colluvium deposits are too thin and laterally discontinuous to show on the map. Eolian deposits clearly postdate formation of alluvial and colluvial deposits.

Qao

Older Alluvium (Pleistocene)—Older alluvial deposits occur in an alluvial fan in the southwestern part of the quadrangle. Nonconsolidated silty clay, clayey silt, silt, silty sand, sand, and pebble, cobble, and boulder gravel form a prominent fan-shaped deposit in Marble Quarry Gulch. Boulders are angular and sub-angular in a matrix of fine-grained sand and silt. Older alluvial deposits predate alluvium and colluvium.

Pediment deposits (Pleistocene)—Poorly stratified sand and silt that contains dispersed boulders, cobbles, and pebbles. Pediment surfaces and terrace remnants reach elevations of about 9,600 ft in the northeastern part of the map area. Clasts are composed of Harding Quartzite, cherty dolomite of the Manitou Formation, olive drab sandstone, siltstone, and shale of the Kerber Formation, Proterozoic granodiorite, Wall Mountain Tuff, vein quartz, and calc-silicate hornfels. Gravel and boulder composition reflects a strong local provenance. Because these pediment deposits are not continuous with those mapped in the Salida East quadrangle (Wallace and others, 1997) the terminology used in the Cameron Mountain quadrangle differs from that used in the Salida East quadrangle. In the Salida East quadrangle unit T3 (equivalent to Wrucke and Dings, 1979 unit Qsp) was mapped as one unit, but in the Cameron Mountain quadrangle two levels of pediment deposits were mapped as Qp_2 and Qp_3. Qp_2 is the older and higher level pediment deposit, and Qp_3 is the younger and lower level pediment deposit. These pediment deposits are alluvial in origin, and Wrucke and Dings (1979) thought these deposits formed during the Sangamon interglacial stage or the Illinoisan glaciation.

Qp_3

Pediment deposit three (Pleistocene)— Poorly stratified sand and silt that contains boulders, cobbles, and pebbles. Alluvial origin. Boulders are subangular to angular and as large as 0.4 m in diameter. Upper surface is about 3 to 9 m above adjacent streams in Herring Park. Mapped as T3 in Salida East quadrangle by Wallace and others (1997), and mapped as Qsp_2 by Wrucke and Dings (1979) in the Herring Park area.

Qp_2

Pediment deposit two (Pleistocene)— Poorly stratified sand and silt that contains boulders, cobbles, and pebbles.

Boulders are subangular to angular and as large as 0.4 m in diameter. Upper surface is about 12 m above adjacent streams in Herring Park. In Salida East quadrangle this unit was grouped with T3 by Wallace and others (1997), and mapped as Qsp_1 by Wrucke and Dings (1979) in the Herring Park area.

Qp_1 **Pediment deposit 1 (Pleistocene)—** Poorly stratified gravel of pebbles, cobbles, and boulders in a silty and sandy matrix. Strongly developed grayish-red, grayish-brown, and red-brown soil marks the upper surface of the terrace. Remnants of this pediment surface reach an elevation of about 9,600 ft in the Herring Park area. Wrucke and Dings (1979) suggested these deposits formed during the Yarmouth interglacial stage or the Kansan glaciation. They related these deposits to the Verdos Alluvium of the Colorado pediment and showed these deposits as Qv on their map. This unit is equivalent to unit T2 in the Salida East quadrangle (Wallace and others, 1997).

TERTIARY ROCKS AND DEPOSITS

Tw **Wagon Tongue Formation (Miocene)—** Moderate-gray, light-gray, grayish-white, and light-yellowish-gray, poorly consolidated and nonconsolidated, poorly to moderately sorted, interbedded siltstone, sandstone, granular and pebbly sandstone, and fine gravel. Gravel and sand beds have shallow channels at basal contacts and contain low-angle planar crossbeds. Beds of air-fall tuff are well indurated and contain quartz, feldspar, and biotite in a lithified matrix of ash. Subangular and angular pebbles, cobbles, and boulders commonly occur in the Wagon Tongue Formation, and these clasts commonly were incorporated in younger pediments that formed on the surface of the Wagon Tongue Formation. Generally poorly exposed; thickness estimated at about 120 m.

Tb **Basalt (Miocene)—**Dense and vesicular, basalt flows that contain olivine and plagioclase phenocrysts in an aphanitic and felted matrix of plagioclase laths. Occurs in Herring Park in the northeastern part of the quadrangle. Thickness about 85 m.

Twm **Wall Mountain Tuff (Oligocene)—**The oldest Tertiary volcanic unit exposed in the Cameron Mountain quadrangle is the Oligocene Wall Mountain Tuff (Wrucke and Dings, 1979), a welded rhyolite ash-flow tuff exposed only in the northern parts of the quadrangle. The tuff is mainly eutaxitic in texture and is moderately to densely welded, although no pattern in the distribution of different degrees of welding was determined from our mapping. The welded tuff is mostly light-gray, moderate-gray, light-brownish-gray, and grayish-red rhyolite that contains prominent sanidine and plagioclase phenocrysts (Wrucke and Dings, 1979). Epis and Chapin (1974) reported that J.D Obradovich (U.S. Geological Survey, communication to Epis and Chapin, 1973) determined potassium-argon isotopic ages of 34.7±0.7 Ma and 36.2±0.8 Ma from sanidine, and 35.7±0.8 Ma from biotite; they regarded the age of about 36 Ma to be a reliable estimate of the eruption time for the Wall Mountain Tuff. Flow foliation in glassy welded tuff is prominent. Chapin and Lowell (1979) described primary and secondary deformation structures from the Wall Mountain Tuff in the Gribbles Run paleovalley where this glassy tuff formed a single cooling unit that slid and folded into the paleovalley as the plastic and mobile tuff degassed and compacted. The scattered remnants of the Wall Mountain Tuff in the northwestern and northeastern part of the Cameron Mountain quadrangle do not permit reconstruction of pre-eruption topography.

Tad **Andesite (Tertiary)—**Dark-greenish-gray and greenish-dark gray, equigranular dikes composed of fine- to medium-grained, subhedral to euhedral plagioclase in a chloritic matrix. Some dikes contain quartz phenocrysts. Dikes range in composition from andesite, to quartz andesite, and dacite. They commonly intrude Middle Proterozoic granodiorite in the western part of the map area. Dikes are usually 1 to 2 m thick and commonly extend 1 to 2 km along strike. A "Laramide" age was assigned to these dikes by Boardman (1971) and Tertiary age was assigned by Wrucke and Dings (1979)

Trp **Rhyodacite porphyry (Tertiary)—**Pinkish-gray to greenish-gray porphyritic dikes. Quartz, plagioclase, biotite, and hornblende phenocrysts occur in a fine-grained matrix of the same minerals or these phenocrysts occur in an aphanitic matrix. Chlorite, epidote, biotite, and calcite occur as secondary minerals. Dikes range in composition from rhyodacite to dacite. Dikes occur in the western part of the quadrangle where they intrude Middle Proterozic granodiorite. A Tertiary age was assigned to these dikes by Wrucke and Dings (1979).

MESOZOIC ROCKS

Kw

Whitehorn Granodiorite (Late Cretaceous)— The only Mesozoic rock unit in the Cameron Mountain quadrangle is the Late Cretaceous Whitehorn Granodiorite, which was originally described by Wrucke (1974). The Whitehorn Granodiorite forms a large laccolith in the central and southern parts of the quadrangle and intrudes lower Paleozoic shallow-marine deposits and Pennsylvanian and Permian marine and continental rock units (Wrucke and Dings, 1979). The basal contact of the laccolith is best exposed in westernmost exposures of the main body in the adjacent Salida East quadrangle where the contact dips gently eastward at about 35° (Wallace and others, 1997). Most of the Whitehorn Granodiorite is a fine- and medium -grained, equigranular and hypidiomorphic-seriate biotite granodiorite that contains varietal hornblende and pyroxene. Biotite- and plagioclase-rich xenoliths are locally common along borders in some places; the xenoliths probably were derived from wall rocks. The basal and upper contacts of the laccolith generally have a prominent porphyritic texture and contain plagioclase crystals, 1 to 5 mm long, in a fine-grained equigranular or aphanitic matrix. The granodiorite is foliated parallel to adjacent sedimentary rock units near contacts in the Cameron Mountain quadrangle, but foliation is rare in the Salida East quadrangle to the south (Wallace and others, 1979). Country rocks at the basal contact on the western border of the laccolith are metamorphosed to marble, quartzite, hornfels, and calc-silicate hornfels. Skarns formed locally along the basal and western contact of the laccolith. Wrucke (1974) reported a potassium-argon age of 70.0 ± 2.6 Ma from biotite for the Whitehorn Granodiorite. McDowell (1971) reported concordant potassium-argon ages of 70.4 ± 2.1 Ma from biotite and 69.4 ± 2.1 Ma from hornblende for the age of intrusion.

PALEOZOIC ROCKS

Sangre de Cristo Formation (Lower Permian and Upper Pennsylvanian)— Overlies the Minturn Formation on a gradational contact. Pierce (1969) and De Voto and Peel (1972) subdivided the Sangre de Cristo Formation into four informal members in the northern Sangre de Cristo Range and the southern Mosquito Range. De Voto and Peel (1972) estimated that thickness of the Sangre de Cristo Formation is about 4,570 m. Only the lower unit (member one below) of the four regionally recognized members is present in the Cameron Mountain quadrangle.

IPsc$_1$

Member one (Upper Pennsylvanian)— Member one overlies the Minturn Formation on a gradational contact where red, coarse-grained beds of the basal Sangre de Cristo Formation intertongue with black and olive-drab shale, siltstone, and fine-grained sandstone of the Minturn Formation. This member of the Sangre de Cristo Formation is composed mainly of grayish-red, coarse-grained, pebbly, and granular arkose, subarkose, and orthoquartzite interbedded with grayish-red and reddish-gray, medium- and fine-grained feldspathic sandstone and lesser amounts of dark-grayish-red and purplish-red, micaceous siltstone, and dark-red, silty, micaceous shale. Member one is equivalent to unit 4 of Pierce (1969), which forms the lower part of his lower member of the Sangre de Cristo Formation. In member one, coarse-grained arkose, pebbly arkosic conglomerate, coarse-grained arkose, and medium- and fine-grained arkose form composite bedding units that generally range between 60 cm and 15 m thick. Polymict conglomerate beds are generally matrix-supported and composed of subangular to subrounded, granitic, metamorphic, and sedimentary clasts. Channeled bases of these composite bedding units commonly overlie the fine-grained upper parts of fining-upward sequences. Within coarse-grained zones, channeled contacts are common among multiple co-sets of crossbeds. An ideal fining-upward sequence is composed of coarse-grained, pebbly and granular arkose overlain by grayish-red beds of medium- and fine-grained arkose, siltstone, and less common red silty shale at the top. Many fining-upward sequences in member one are incomplete, and coarse-grained basal parts of fining-upward sequences occur on medium-grained sequences where the siltstone and shale tops of the sequences are not preserved. Primary sedimentary structures in the coarse-grained rocks are large- and medium-scale trough and planar crossbeds that form multiple co-sets, channels, shale-chip conglomerates, and dispersed pebble conglomerate. In medium- and fine-grained arkose and subarkose, primary structures are predominantly small-scale trough and planar crossbeds, shallow channels, ripple cross-lamination, climbing ripples, cuspate and linguoid ripples, rib-and-furrow structures, parting lineation, and planar lamination. Siltstone and silty shale beds at the tops of fining-upward sequences contain ripple cross-lamination, planar lamination, flasers, and microlamination. Rare secondary sedimentary structures in the sandstone beds are deformed and overturned crossbeds and load casts. Some fine-grained intervals in member one of the Sangre de Cristo Formation are olive-drab, grayish-green, dark-gray, and moderate-gray fine-grained sandstone, siltstone, and shale; these fine-grained intervals are generally less than 1 m thick. Sandstone beds within these dark-colored, fine-grained intervals commonly have channeled basal contacts, and sandstone beds contain common medium- and small-scale ripple cross-lamination. Member one is exposed only in the southeastern corner of the map area and neither the top nor the bottom of this member is exposed; an estimated 550 m of this lower member occurs in the map area.

IPm

Minturn Formation (Middle Pennsylvanian)—Overlies the Sharpsdale Formation. Generally poorly exposed; thickness estimated at about 120 m on a gradational and conformable contact in the southern part of the quadrangle and conformably overlies the Belden Shale in the northern part of the quadrangle. The Minturn Formation is composed mainly of dark-gray, gray, olive-drab, grayish-green, greenish-gray, and black, fine-, medium-, and coarse-grained feldspathic sandstone, argillaceous and micaceous siltstone, silty micaceous shale, and rare black fetid limestone and dolomite. Some dark-reddish-gray clastic beds occur in the Minturn. Accurate estimates of the thickness of the Minturn elsewhere are not possible because the upper contact is missing in the map area and because this unit is folded where it is the thickest in the northwestern part of the map area; cross section B—B' shows about 500 m of the Minturn Formation. Flaggy weathering, gray, grayish-green, and olive-drab sandstone beds are fine-, and medium-grained and contain planar lamination, ripple cross-lamination, rib-and-furrow structures, low-amplitude hummocky crossbeds, and shallow channels. Coarse-grained, olive-drab and grayish-green arkose beds contain planar and trough crossbeds. Dark-gray and olive-drab siltstone and shale are planar laminated and microlaminated and contain ripple cross-lamination; sandstone and sandy siltstone are more common in the lower part of the unit, and siltstone and shale are more common in the upper part of the unit. Convolute lamination and ball-and-pillow structures are common soft-sediment deformation features near Little Bull Gulch where a probable growth fault cuts the Minturn Formation and the Belden Shale. Sedimentation units are fining-upward sequences that are capped by dark-colored shale. Limestone beds are thin, laminated and microlaminated, black and dark-gray, fetid micrite. Commonly limestone beds are 1 to 15 cm thick and are interbedded with black and dark-gray, silty shale; zones of interbedded limestone and shale form bedding units that are 1 to 3 m thick, but some individual limestone beds are as thick as 1 m. Limestone beds are more common in the upper part of the Minturn Formation.

IPb

Belden Shale (Middle Pennsylvanian)—Black, laminated and nonlaminated shale, and black and dark-gray, argillaceous siltstone interbedded with moderate-gray, rusty-weathering siltstone and rare gray, fine-grained sandstone. Black shale is the dominant lithology in this unit. A fetid, black limestone occurs at the top. The Belden Shale occurs only in the northwestern part of the quadrangle where black shale overlies an upper olive-drab and grayish-green, coarse-grained, pebbly arkose of the Kerber Formation. The Belden Shale is overlain by the Minturn Formation in the northern part of the map area where the top of the Belden Shale is marked by a limestone bed 2 to 3 m thick. The Belden Shale is about 190 m thick in cross section B—B'. The Belden Shale changes thickness abruptly in Little Bull Gulch; the Belden is about 300 m thick at the north border of the map area and only about 30 m thick directly south of a fault in Little Bull Gulch. This abrupt thickness change may result from slip on the growth fault in Little Bull Gulch during de-position of the Belden Shale or from erosion before deposition of the overlying Minturn Formation. The Belden Shale pinches out 2.4 km south of Little Bull Gulch.

IPs

Sharpsdale Formation (Middle Pennsylvanian)—Occurs only in the south-central part of the Cameron Mountain quad-rangle where this unit overlies the Kerber Formation on a contact that appears grada-tional and conformable; the upper contact is absent. About 550 m of the Sharpsdale Formation is exposed west of Cameron Mountain near the southern border of the map area. The Sharpsdale Formation is com-posed mainly of grayish-red and reddish-gray, coarse-grained arkose and pebbly and granular arkose, subarkose, and ortho-quartzite interbedded with grayish-red and reddish-gray, medium- and fine-grained feldspathic sandstone and lesser amounts of dark-red, micaceous siltstone and purplish-red, silty, micaceous and shale. Grayish-red, purplish-red, and bright-grayish-red, coarse-grained arkose, pebbly arkose, and medium- and fine-grained arkose of the Sharpsdale Formation form composite bedding units that generally range between 60 cm to 15 m thick. Channeled bases of these composite bedding units commonly overlie the fine-grained upper parts of fining-upward sequences. Within coarse-grained zones, channeled contacts commonly separate mul-tiple co-sets of crossbeds. In the Salida East quadrangle south of the map area, an ideal fining-upward sequence is composed of coarse-grained, pebbly and granular arkose overlain by grayish-red beds of medium- and fine-grained arkose, siltstone, and less common red silty shale at the top. South of the map area in the Salida East quadrangle, the upper part of the Sharpsdale contains complete fining-upward sequences, but in the map area metamorphism has obscured much of the original stratigraphic and sedi-mentologic features of the Sharpsdale Formation. Primary sedimentary structures in the coarse-grained rocks are large- and medium-scale trough and planar crossbeds that form multiple co-sets, channels, shale-chip conglomerates, and dispersed pebble conglomerate. In medium- and fine-grained arkose and subarkose, primary structures are predominantly small-scale trough and planar crossbeds, shallow channels, ripple cross lamination, climbing ripples, cuspate and linguoid ripples, rib-and-furrow struc-tures, and planar lamination. Siltstone and silty shale beds at the tops of fining-upward sequences are dominated by ripple cross-lamination, planar lamination, flasers, and microlamination. Rare secondary sedimentary structures in the sandstone beds are deformed and overturned crossbeds and load casts; secondary structures in the silt-stone and shale are convolute lamination and small-scale load casts. At some places, the base of the Sharpsdale Formation con-tains rare interbeds of grayish-green and gray limestone; these interbeds disappear within about 45 m of the basal contact. Rare fine-grained intervals in the Sharpsdale Formation are olive-drab, dark-grayish-green, dark-gray, and moderate-gray, fine-grained sandstone, siltstone, and shale; these fine-grained intervals are generally less than 1 m thick. Sandstone beds within these dark-col-ored, fine-grained intervals commonly have channeled basal contacts and contain com-mon medium- and small-scale ripple cross-lamination.

IPk

Kerber Formation (Lower Pennsylvanian)—Disconformably overlies the Leadville Limestone in the western part of the quad-rangle. The Kerber Formation is about 120 m thick in the southwestern map area, and it thickens to about 320 m at the north border of the quadrangle. This formation is com-posed mostly of grayish-green, olive-drab, olive-gray, moderate-gray, and dark greenish-gray, coarse-grained arkose and conglomer-atic arkose and subarkose interbedded with medium- and fine-grained sandstone, medi-um- and fine-grained quartzarenite, silt-stone, and shale. Black, silty micaceous shale, black siltstone, moderate-gray biomi-critic limestone, and rare dolomite occur as interbeds in the olive-drab and grayish-green rocks in the lower and upper parts of the unit.

Burbank (1932, p. 13) used the name "Kerber" for a sequence of carbonaceous black shale, siltstone, and brown sandstone that separate red coarse-grained rocks (Sharpsdale Formation) from limestone of the Leadville Limestone at Kerber Creek, southwest of Salida, Colorado. De Voto and Peel (1972) described detailed lithofacies variations in the Kerber from the Arkansas River Valley, described lateral stratigraphic relations with the Belden Formation, and discussed vertical stratigraphic relations with the Sharpsdale Formation. Wrucke and Dings (1979) and Taylor and others (1975) applied the name "Belden Formation" to this stratigraphic interval, but, as pointed out by De Voto and Peel (1972), the Belden Shale is primarily a fine-grained carbonaceous shale and siltstone, whereas the Kerber Formation is a coarse-grained arkose, conglomerate, and sandstone, and olive-drab shale and siltstone that contains rare black shale and siltstone, so the term "Belden" is not properly applied to the latter rocks. De Voto (1971) mapped about 22 m of Kerber Formation on Kauffman Ridge in the southern part of the Antero Reservoir quadrangle that borders this map area on the north, and directly north of the area where we mapped a sequence of Kerber Formation and Belden Shale. We show about 290 m of Kerber Formation below the Belden Shale directly south of the area where De Voto (1971) showed only Belden Shale. Coarse-grained, olive-drab arkose, interbedded with olive-drab fine-grained quartz sandstone, and lesser amounts of siltstone, shale, and limestone that De Voto included in the basal Belden Shale we separate as Kerber Formation. De Voto restricted the Kerber Formation in the Antero Reservoir quadrangle to fine-grained, light-gray, quartz sandstone that contained no shale, but we included olive-drab, gray, and dark-olive-gray siltstone, shale, and thin beds of gray limestone in the Kerber Formation below the black shale and siltstone of the Belden Shale in the northwestern part of the map area; the fine-grained sandstone defined as Kerber Formation by De Voto north of our map area is included at the base of the Kerber as we define it in our map area. The coarse-grained arkose and dark-colored shale included in the base of the Belden by De Voto (1971) was shifted to the upper Kerber Formation to maintain lithologic continuity with the Kerber Formation as mapped south and southeast of the Cameron Mountain Quadrangle (Pierce, 1969; Peel, 1971), and as described by De Voto (1980b) and by Wallace and others (1997). The effect of this change from De Voto's (1971) use of "Kerber" is to put fine-grained dark-colored siltstone and shale directly above the Leadville Limestone in the Belden Formation, and to place rocks dominated by coarse-grained arkose above the Leadville Limestone in the Kerber Formation.

Coarse- and medium-grained conglomeratic arkose is a dominant rock type in the Kerber Formation, and it occurs in composite beds that are as thick as 15 m. Coarse-grained zones are separated by zones of medium- and fine-grained arkose, siltstone, or shale that commonly are 3 to 10 m thick. Coarse-grained rocks are most abundant near the base of the Kerber Formation, and finer grained rocks, mostly olive-drab shale and siltstone and black shale, become more common upward in the sequence. Moderate-gray limestone interbeds occur near the top of the Kerber Formation. Thin limestone beds are 1 to 2 m thick and contain fossil fragments. Thin mottled limestone beds near the top of the Kerber Formation are a distinctive bright grayish-green color that forms a regional marker zone. In the map area a prominent carbon-rich zone occurs at the base of the Kerber Formation, and where this zone is metamorphosed, the basal part of the Kerber Formation is marked by a graphitic zone.

Primary sedimentary structures in the coarse-grained rocks are predominantly large-scale and medium-scale planar and trough crossbeds, channels, ripple cross-lamination, rib-and-furrow structures, cuspate and linguoid ripple marks, climbing ripples, and planar lamination that forms parting lineation. Shallow channels occur at the base of coarse-grained, conglomeratic sandstone beds. Primary sedimentary structures in the fine-grained rocks are ripple-cross-lamination, rib-and-furrow structures, climbing ripples, ripple marks, planar lamination, microlamination, and water-expulsion structures. Locally, black shale and olive-drab siltstone near the top of this unit contain salt-crystal casts. Conglomeratic and sandy units have coarse-grained rocks at the base and become finer grained upward. Dark-gray and black limestone beds that occur in the upper and lower parts of the Kerber Formation are fine-grained, argillaceous, mottled or laminated, fetid micrite that are generally 12 cm to 3 m thick. Several limestone beds contain brachiopods and trilobite fragments, and some rare thin limestone beds near the top are brachiopod coquina.

Contacts between the upper part of a fine-grained sequence and the lower part of a coarse-grained sequence are generally channeled contacts. The upper contact of the Kerber Formation appears to be gradational with the overlying Sharpsdale Formation in the southern part of the map area because grayish-green, coarse-grained conglomeratic arkose, olive-drab siltstone, and green and gray limestone beds of the Kerber Formation are interbedded with coarse-grained, gray-ish- red arkose of the Sharpsdale Formation. In the northern part of the map area the Kerber Formation is gradational with the overlying Belden Shale.

Ml

Leadville Limestone (Lower Mississippian)—Moderate-gray and dark-gray, massive-weathering, thinly bedded micritic limestone and finely crystalline dolomite. Beds range in thickness from 7 cm to 2 m. Grayish-pink and grayish-red beds occur in zones in the lower and upper parts of the Leadville Limestone; these zones are thinly bedded and flaggy, laminated and microlaminated, micritic limestone. Black laminated chert nodules and lenticular chert beds occur at some stratigraphic levels. Overlies the Dyer Dolomite Member of the Chaffee Formation on a disconformable contact. The Leadville Limestone is about 60 m thick in the southern part of the quadrangle and about 180 m thick in the northern part of the map area. The thickness variation may result from post-lithification solution of limestone and from volume reduction that resulted from solution and silicification of limestone. The base of the Leadville Limestone is channeled into the underlying Dyer Dolomite Member, and the shallow channels are filled with medium-grained orthoquartzite cemented by calcite and silica. Where the Leadville Limestone is contact metamorphosed, the basal sandstone forms a prominent quartzite. Sandy limestone, flat-pebble conglomerate, and limestone breccia occur in the shallow channels at the base of unit. Clasts of grayish-yellow, laminated and microlaminated dolomite, presumably derived from the Dyer Dolomite Member, occur in the basal sandstone beds of the Leadville Limestone at some places. Above the basal sandstone several beds of calcareous sandstone are interbedded with moderate- and dark-gray micrite. These sandstone beds above the basal unit are 2.5 to 30 cm thick, and they decrease in thickness upward; about 3 m above the base the sandstone beds are absent. Most of the Leadville Limestone is composed of interbedded zones of finely crystalline dolomite and micrite, with lenticular interbeds of biomi-crite and oolitic limestone that occur sporad-ically through the sequence. Some limestone and dolomite beds are mottled light gray and moderate gray. Two distinctive zones of flaggy-weathering, thinly bedded, laminated, grayish-pink and grayish-red micritic lime-stone and edgewise conglomerate occur in the lower third of the Leadville Limestone in the Salida East quadrangle (Wallace and oth-ers, 1997), but these zones do not appear to be present in the Cameron Mountain quad-rangle.

Alteration of the Leadville Limestone consists of an early diagenetic event of dolomitization, and post-lithification events of solution and silicification; events that may have been sequential. Dolomite replaced zones of micrite; the result is interbeds of dolomite and limestone that are 60 cm to 3 m thick, but dolomitization was uneven laterally and vertically so that much of the Leadville Limestone is mostly micrite at some places or thick zones of dolomicrite at other places. A solution event after lithifica-tion of the Leadville formed prominent caves and solution breccias in the upper part of this unit. This post-Mississippian solution event affected Mississippian limestones throughout much of the Cordillera and may have been related to a widespread event of silicification in the Leadville limestone. The prominent zone of chert that was mapped in the Salida East quadrangle to the south was not mapped separately in the Cameron Mountain quadrangle because the chert was too thin and laterally discontinuous. In the southwestern part of the map area the Lead-ville Limestone is locally metamorphosed to a fine-, medium-, and coarse-grained, light-tan, light-gray, and light-grayish-yellow, mottled and streaked marble. Some marble is foliated, and foliation appears to be paral-lel to bedding. The skarn that occurs at the Calumet Mine in the southwestern part of the quadrangle occurs in the upper part of the Leadville Limestone.

Chaffee Formation (Upper Devonian)—Rests disconformably on the Fremont

Dolomite. The Chaffee Formation is divided into the Parting Quartzite Member at the base and the Dyer Dolomite Member at the top (Wrucke and Dings, 1979). Campbell (1972) applied group rank to the Chaffee and applied formation rank to the Parting Quartzite and Dyer Dolomite, and he subdivided the Parting Quartzite and Dyer Dolomite into several members on the basis of measured sections. Members could not be mapped separately at a map scale of 1:24,000, so we retain the nomenclature hierarchy of Wrucke and Dings (1979). The Chaffee Formation is resistant to weathering, but the units are thinly bedded; therefore, they are less resistant to weathering than the massive-weathering Fremont Dolomite below and the massive-weathering Leadville Limestone above, so, where this unit is not metamorphosed, the Chaffee Formation forms slopes between the two carbonate units.

Dcd

Dyer Dolomite Member—Yellowish-gray, light-gray, tan, and pale-yellowish-gray, prominently laminated and microlaminated, finely crystalline and microcrystalline dolomite that contains some lenticular interbeds of light-grayish-green and light-greenish-gray shale and laminated yellowish-gray chert. The dolomite is bioturbated and flaggy or massive-weathering. Rare chert layers are interbedded with dolomite and range from 1 to 5 cm thick. The Dyer Dolomite Member is about 30 m thick in the southern part of the map area, and it thickens to about 75 m in cross section B—B'. In the southwestern part of the map area the Dyer Dolomite is locally metamorphosed to a fine-and medium-grained, foliated, light-tan dolomite marble. Foliation appears to parallel previous bedding planes. Prominent lamination of non-metamorphosed dolomite commonly is preserved in marble.

Dcp

Parting Quartzite Member—Light-gray, pale-brownish-gray, light-grayish-red, and pinkish-gray, fine-grained, silica-cemented, dense, flinty, conchoidal-fracturing orthoquartzite. Rare thin interbeds of dolomite and green shale are 5 to 20 cm thick, and some pebbly and granular quartzite interbeds occur. Some thin beds of dolomite and dolomitic quartzite interbedded with silica-cemented quartzite. Thinly bedded and massive-weathering quartzite beds are generally 5 to 25 cm thick. Planar lamination, ripple-cross-lamination, and rare planar crossbeds are the principal sedimentary structures but are masked by metamorphism near the basal contact with the Whitehorn Granodiorite laccolith. Breccias that were common in the Salida East quadrangle are rare in the Cameron Mountain quadrangle. The thickness of the Parting Quartzite decreases from about 15 m at the south border of the quadrangle to about 1 m in the Aspen Ridge area, but the Parting Member increases in thickness from Aspen Ridge northward, and the Parting Member is about 50 m thick in cross section B—B'. Where the Parting Quartzite is thin near Aspen Ridge, much of the unit is a dolomite-cemented sandstone and sandy dolomite. East of Cable Spring at the eastern boundary of the map area, and in the northeastern part of the map area, where the Parting Quartzite is 3- to 5-m thick, it is a silica-cemented quartzite.

Of

Fremont Dolomite (Upper and Middle Ordovician)—Overlies the Harding Quartzite on a disconformable contact. The Fremont Dolomite is about 60 m thick in the southern part of the quadrangle. Where the Fremont Dolomite is not contact metamorphosed in the northern part of the map area, it is a dark-, moderate-, and light-gray, massive-weathering, crystalline, fetid dolomite that contains echinoid debris and dolomitized coral in a fine-grained dolomite matrix. Trilobite and brachiopod fragments occur on some bedding planes. The dolomite may be mottled light gray and dark gray, or it is laminated and microlaminated. Rare black chert nodules are irregularly distributed through the dolomite. Beds are generally 5 cm to 1 m thick and bedding is poorly preserved. This dolomite resists weathering and has a rough, uneven weathering surface that has sharp ridges. The Fremont Dolomite is metamorphosed near the Whitehorn Granodiorite, and near that contact the dolomite forms a banded, moderate-gray and light-yellowish-gray, fine-, moderate-, and coarse-grained dolomite marble.

Oh

Harding Quartzite (Middle Ordovician)—Overlies the Manitou Limestone on a disconformable contact. The Harding Quartzite is a dark-reddish-gray, dark-grayish-orange, dark-grayish-red, light-gray, moderate-gray, and rusty-orange, fine- to medium-grained, well-sorted, silica-cemented, dense, mottled orthoquartzite. The sandstone is completely cemented by silica, and it has the conchoidal fracture of a quartzite. This indurated, cliff-forming unit is about 30 m thick at most places in the quadrangle, but in the north-western part of the map area this unit is about 46 m thick. Quartzite beds range from 2.5-cm thick to about 20-cm thick. They contain planar lamination and planar crossbeds, which are obscured by pervasive replacement by diagenetic silica. Phosphatic bony plates of primitive fish occur locally. The breccias that were common in the Salida East quadrangle to the south are generally absent in the Cameron Mountain quadrangle. Pebbly sandstone and bioturbated sandstone occur in some beds of quartzite. Some exposures contain conglomeratic sandstone at the base.

Om

Manitou Limestone (Lower Ordovician)— Overlies the Sawatch Quartzite or, where the Sawatch is absent, it overlies Proterozoic rocks. Dark-, moderate-, and light-gray, thin- to thick-bedded dolomite and cherty dolomite and rare beds of dark-gray limestone. The Manitou is about 37 m thick in most of the quadrangle, but in cross-section B—B', the Manitou is about 75 m thick. It contains little limestone and dolomitic limestone in the Cameron Mountain quadrangle. Dolomite and limestone are laminated and mottled, and beds range between 2 cm and 1 m in thickness. A distinctive characteristic of the Manitou Limestone is the occurrence of black and light-grayish-white chert nodules and lenses in the dolomite. The chert is internally laminated and parallel to bedding. Silicified breccia of pebble- and cobble-sized laminated chert in a matrix of silicified dolomite, which was common in the Salida East quadrangle to the south, is absent in the Cameron Mountain quadrangle.

Ꞓs

Sawatch Quartzite (Upper Cambrian)— Overlies Early Proterozoic granodiorite (Xgd) in the western part of the quadrangle. Ranges between 7 cm and 3 m in thickness in the Salida East quadrangle to the south (Wallace and others, 1997). In general, the Sawatch is less than 30-cm thick in the Cameron Mountain quadrangle and it is absent locally; north of Green Gulch the Sawatch thickens abruptly to nearly 8 m thick. The Sawatch Quartzite is a light-gray, moderate-gray, light-grayish-yellow, fine- to medium-grained, well-sorted, massive-weathering, silica-cemented orthoquartzite and pebbly orthoquartzite that contains planar crossbeds, ripple cross-lamination, and planar lamination at places where bedding is preserved. Pebbly quartzite contains subrounded and rounded vein-quartz clasts. Below the Sawatch Quartzite, Proterozoic rocks are severely weathered and leached locally.

PROTEROZOIC ROCKS

Xp

Pegmatite (Early Proterozoic)—Coarsely crystalline albite, microcline, and quartz form dikes and irregularly shaped bodies that intrude Proterozoic gneiss and granodiorite. Pegmatite bodies may be zoned or unzoned, and they range in diameter from 0.1 m to several tens of meters wide and as long as 500 m. Pegmatites are most common in the strongly foliated gneiss. Contains varietal biotite and muscovite in varying proportions. Some pegmatites contain accessory garnet, beryl, magnetite, and columbite-tantalite. Some aplite occurs with pegmatite. Forms dikes and irregular bodies near Turret, and in Marble Quarry Gulch. Dikes and irregular bodies were mined for albite.

Xqm

Quartz Monzonite (Early Proterozoic)— Described by Wrucke and Dings, (1979) as a pale-reddish-orange and dark-reddish-gray, fine- to medium-grained allotriomorphic granular, biotite quartz monzonite. Composed of quartz, microcline, altered plagioclase, and biotite. Commonly non-foliated. Forms irregular bodies and dikes that intrude older granodiorite.

Xqmp

Quartz Monzonite Porphyry (Early Proterozoic)—Described by Wrucke and Dings (1979) as a moderate and light-gray, porphyritic quartz monzonite that contains dark-gray phenocrysts of quartz, perthitic microcline, and altered plagioclase, in a fine- and medium-grained allotriomorphic granular matrix of the same minerals. Phenocrysts are 0.5 to 1 cm in length. Biotite locally forms glomerophenocrysts. Forms irregular bodies that intrude older granodiorite.

Xl **Lamprophyre (Early Proterozoic)—** Described by Wrucke and Dings (1979) as a greenish-black, light-gray-mottled, fine-grained, panidiomorphic dikes composed of plagioclase, green hornblende, biotite, quartz, and accessory sphene. Dikes are about 1-m wide.

Xgd **Granodiorite (Early Proterozoic)—**Gray, speckled, coarse- to very coarse-grained, strongly foliated granodiorite gneiss and coarse-grained granodiorite porphyry. In places contains augen of quartz and microcline up to 6 cm in length and minor amounts of muscovite and biotite. Foliation is well developed near the contact with older gneiss (unit Xgn) and is parallel to foliation in the older gneiss. This coarse-grained granodiorite forms a prominent pluton along the west side of the quadrangle that extends from the southern boundary of the map area to the northern edge of the quadrangle.

Xgn **Gneiss (Early Proterozoic)—**Predominantly dark-gray to black, fine- to medium-grained quartz-biotite-muscovite gneiss that contains lesser amounts of medium-grained amphibolite and fine-grained, light- to medium-gray feldspar-quartz-biotite gneiss. Commonly well foliated; contains local zones of migmatite and pegmatite. The gneiss contains some epidote as stringers and films along foliation planes. Primary minerals of the gneiss units include quartz, microcline, plagioclase, biotite, and muscovite. Common accessory minerals include biotite, magnetite, muscovite, epidote, zircon, sphene, and allanite (Boardman, 1971). Locally, biotite is altered to chlorite. The feldspar-quartz-biotite gneiss contains approximately 60 percent feldspar, mostly microcline, ranging in size from 0.1 to 0.8 mm; 35 percent strained, very fine-grained quartz; and about 5 percent biotite. Interbedded amphibolite layers generally have obscure contact relations with the surrounding gneiss; however, they appear to be sills and dikes that are younger than and intrude the gneiss, and they are conspicuously not foliated. They contain about 60 percent hornblende ranging in size from 0.5 to 1.0 mm and about 40 percent plagioclase ranging between 0.5 to 1.5 mm. According to Boardman (1971) the amphibolites consist primarily of hornblende and plagioclase and lesser amounts of biotite, pyroxene (diopside), and quartz. Actinolite is found in altered zones. Contains some discontinuous zones of garnet-biotite phyllite that are a thick as 8 m and contain copper carbonate and silicate minerals.

MINERAL RESOURCES

Mineral resources in the Cameron Mountain quadrangle include metallic vein and replacement deposits in Proterozoic rocks, skarns in middle Paleozoic rocks, stratabound occurrences in upper Paleozoic rocks, and industrial mineral deposits of feldspar, mica, beryl, columbite-tantalite, limestone, dimension stone, and gravel. The economic potential of these mineral occurrences has not been evaluated as part of this project, but mineral occurrences identified in the quadrangle are discussed briefly in the following paragraphs.

VEIN AND REPLACEMENT MINERAL DEPOSITS

Turret District

The Turret district is located about 1.5 km north-northeast of the southwestern corner of the quadrangle. The main part of the Turret district is located in Cat Gulch in sec. 28 and 29, T. 51 N., R. 9 E. Little geological and historical information is available on this district. Gold mineralization in the main part of the Turret district is confined to northeast-trending, steeply dipping quartz veins in Proterozoic granodiorite. The veins contain free gold, quartz, pyrite, chacopyrite, galena, and minor sphalerite, and limonite. The total production is reported to be greater than $100,000 of gold (Bhutta, 1954).

Calumet District

The Calumet Mine is located in the southwestern part of the Cameron Mountain quadrangle in T. 51 N., R. 9 E., at the corners of Sections 26, 27, 34, and 35 Originally discovered by Colorado Fuel and Iron Company in 1880, this mine produced iron ore during the period 1882 to about 1900 (Behre and others, 1936). The extensive underground workings, once accessed by shafts, adits, inclines, and open pits, are caved and covered, and exposed faces at the Calumet Mine are no longer accessible. No new sampling was possible and descriptions of mineral assemblages were taken from earlier reports. The deposit is a skarn and replacement deposit that occurs at the contact between the Leadville Limestone and the Kerber Formation where these units are intruded by the Whitehorn Granodiorite. According to MRDS records (U.S. Geological Survey Mineral Resource Data System) this mine produced iron ore that contained 60 percent iron oxide initially, but the last ore mined contained 43 percent iron oxide with an increased concentration of pyrite. The total production through 1899 was 228,781 long tons of iron ore. Minerals common in ore samples are hematite, magnetite, limonite, pyrite, chalcopyrite, azurite, malachite, scheelite, magnetite, corundum, and vermiculite (Behre and others, 1936). The skarn that was host to replacement ore minerals is composed of abundant diopside, epidote, garnet, green and brown biotite, tremolite, actinolite, calcite, dolomite, and quartz (Behre and others, 1936), and it is a popular place for collecting minerals.

PALEOZOIC STRATABOUND OCCURRENCES

Disseminated stratabound mineral occurrences have been identified in upper Paleozoic rocks in this part of Colorado. These resemble “red-bed” copper-uranium or copper-silver occurrences that are widespread in the western United States in rocks ranging in age from Middle Proterozoic to Cretaceous (Kirkham, 1989; Harrison, 1972; Connor and McNeal, 1988; Lindsey and Clark, 1995; Thorson and Hahn, 1995; Wallace and others, 1997). Highly anomalous concentrations of copper, zinc, lead, barium, chromium, and vanadium, and traces of gold were identified from grab samples from the Sharpsdale, Minturn, and Sangre de Cristo Formations in the Salida East quadrangle (Wallace and others, 1997). Anomalous concentrations of copper, silver, and gold were identified in the Cameron Mountain quadrangle in the uppermost Belden Shale in the Minturn Formation (Table 1).

Lindsey and Clark (1995) described stratabound copper and uranium mineral occurrences in the Minturn and Sangre de Cristo Formations from the northern Sangre de Cristo Range southeast of the Cameron Mountain quadrangle, and Wallace and others (1997) described stratabound copper-silver occurrencs from the adjoining Salida East quadrangle. Although the stratabound mineral occurrences described by Lindsay and Clark (1995) and Wallace and others (1997) are typical of “red-bed” copper-silver and copper-uranium deposits, the depositional setting of the samples collected from the Minturn Formation in the Cameron Mountain quadrangle is a marine and black shale setting. Table 1 shows concentrations in parts per million or percent from four mineralized rock samples in the Cameron Mountain quadrangle. Three samples from the Belden Shale and Minturn Formation show high anomalous concentrations of gold, copper, and silver from chemically reduced zones of fine-grained clastic and carbonate rock. Mineralized zones are commonly 2 to 5 cm thick in dark-gray, moderate-gray, and greenish-gray, calcareous and carbonaceous siltstone and fine-grained sandstone. Stratabound mineral deposits occur mainly in rocks deposited in nearshore marine and deltaic environments near the growth fault in Little Bull Gulch. Rock samples commonly show secondary hydrous copper carbonate minerals on weathered surfaces. Nonweathered rock contains silt-sized grains of pyrite, chalcopyrite, and possible grains of chalcocite and bornite. Sample 97200 is from exploratory pit on Bassam Peak in the northern part of the map area, and samples 97300A and 97300B are from adits and pits in the Futurity district in Futurity Gulch in the northwestern quadrant of the map area. The principal chemical difference between the “red-bed” stratabound association and the marine-black shale setting is the prominent high anomaly of gold in samples from the marine depositional environment.

Table 1. Geochemical analyses of mineral occurrences in the Cameron Mountain quadrangle. Analyses by Cone Geochemical, Inc., Lakewood, Colorado. Gold analyses by fire assay and atomic absorption. All other analyses by partial digestion inductively coupled plasma method.

Sample Number	Ag	As	Bi	Cd	Co	Cu	Hg	Pb	Sb	Sc	Te	Tl	Zn	Mo	Ni	Sn	B
97577	<0.5	31	<50	<5	<10	74	<5	<50	5	<50	<50	<100	46	<1	35	<50	42
	[<0.2]					[62]		[1]					[78]				
97200	17.0	13	<50	<5	<10	53095	<5	<50	6	<50	<50	<100	55	<1	27	<50	10
	[15.3]					[50000]		[18]					[73]				
97300A	2.0	8	<50	<5	13	12612	<5	<50	<5	<50	<50	<100	42	<1	29	<50	<5
	[2.3]					[13200]		[5]					[64]				
97300B	1.8	<5	<50	<5	16	12289	<5	<50	<5	<50	<50	<100	48	7	34	<50	<5
	[2.2]					[12500]		[5]					[72]				

Sample Number	Ba	Be	Li	Mn	P	Sr	Ti	V	W	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	Na_2O	S	Au
97577	4	<1	35	33	180	31	53	29	<20	0.30	0.06	16.61	0.08	0.03	<0.01	0.1	
				[<1]													
97200	244	<1	46	331	1381	22	>1000	94	<20	5.20	0.60	3.44	1.52	2.94	0.04	0.01	
				[<1]													
97300A	75	<1	47	576	1000	15	411	42	<20	3.49	0.62	3.98	0.43	3.65	0.02	<0.01	
				[<1]													
97300B	60	<1	52	310	1046	8	331	51	<20	4.05	0.37	4.46	0.34	4.40	0.02	<0.01	
				[<1]													

All concentrations in parts per million except oxides and sulfur which are in percent.
nd: not determined

INDUSTRIAL MINERAL OCCURRENCES

PEGMATITE MINERALS

There are several large pegmatite bodies within the Early Proterozoic gneiss, some of which are up to 300 m in length and 15 m wide and are shown on the map as discrete units. Small pegmatite bodies also occur in the granodiorite. Many other pegmatite bodies are too small to be shown on the map. Large pegmatite bodies occur in the southwestern part of the map area in Marble Quarry Gulch at the Homestake Mine, which had the largest production of albite in the Turret district (Baillie, 1962). Euhedral, blue-green beryl crystals up to 30 cm in diameter and 2.7 meters in length have been reported from the Rock King prospects (Hanley and others, 1950). Production reported by Boardman (1971) was just over 3,000 pounds during 1943 and 1944.

MARBLE

Marble has been mined in the Marble Quarry Gulch area in the southwestern part of the Cameron Mountain quadrangle. The Leadville Limestone and other lower Paleozoic carbonate rocks have been metamorphosed to tan-weathering, fine- to coarse-grained marble. Metamorphosed dolomite of the Fremont Dolomite commonly forms a gray-and-white streaked coarse-grained dolomite marble. Marble was quarried from several pits and excavations. Production and uses of the marble are not known.

DIMENSION STONE

The Whitehorn Granodiorite was quarried for dimension stone at several localities in the Cameron Mountain quadrangle. The medium-grained texture, salt and pepper color, and relative lack of joints in this granodiorite make it an attractive dimension stone. During 1996 some of the Whitehorn Granodiorite was quarried and used for crushed and decorative stone.

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