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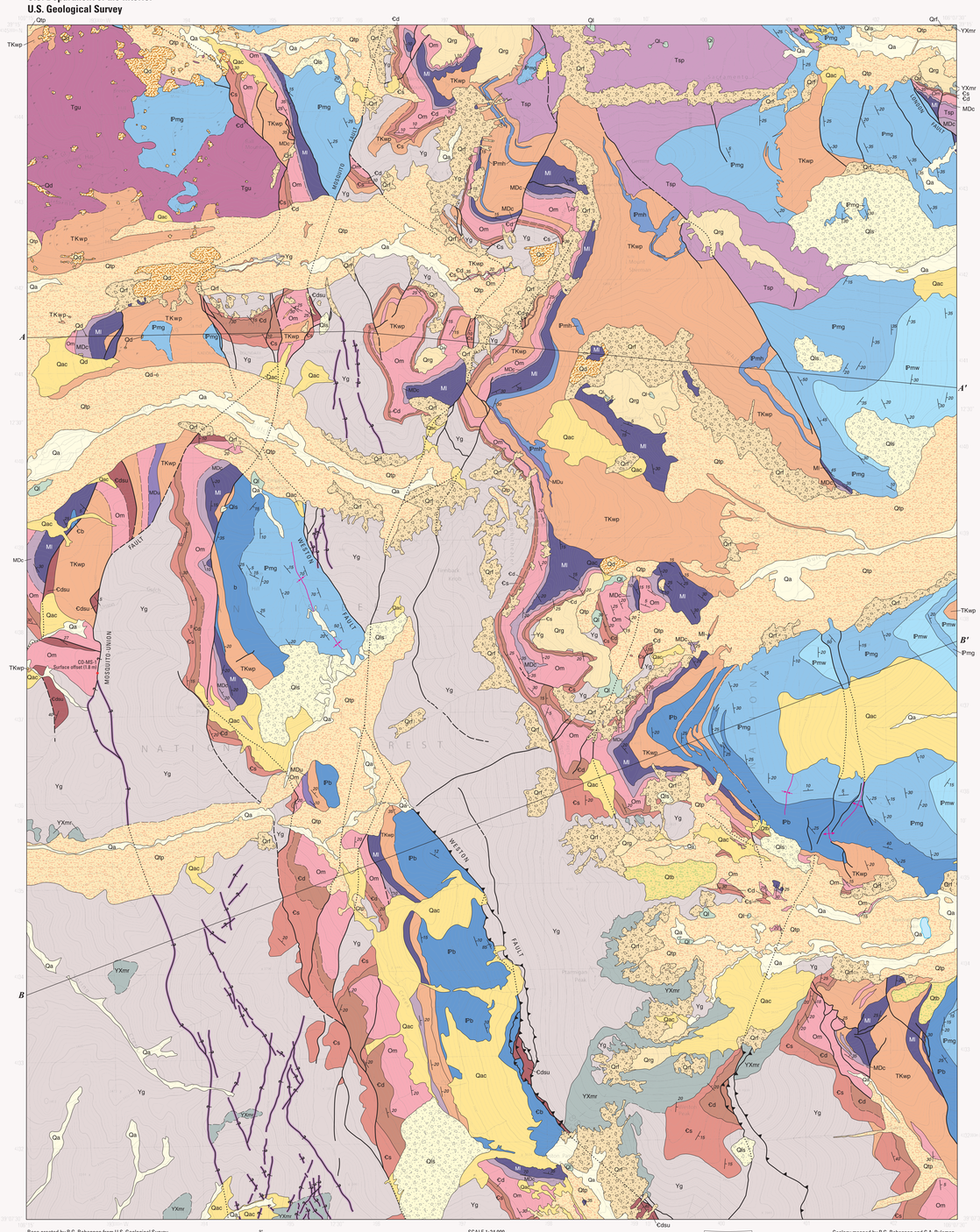
U.S. Department of the Interior
U.S. Geological Survey

Scientific Investigations Map 3271



Base created by R.G. Bohannon from U.S. Geological Survey National Elevation Dataset, 2012 (NED, http://nationalmap.gov/elevation.html)
Projection: Universal Transverse Mercator, zone 15
North American Datum of 1927 (NAD 27)

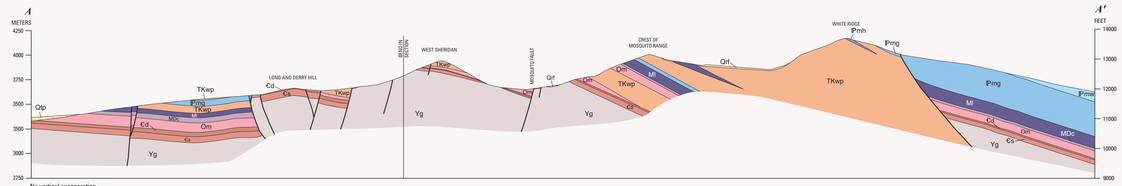
APPROXIMATE MEAN DECLINATION, 2012

SCALE 1:24 000

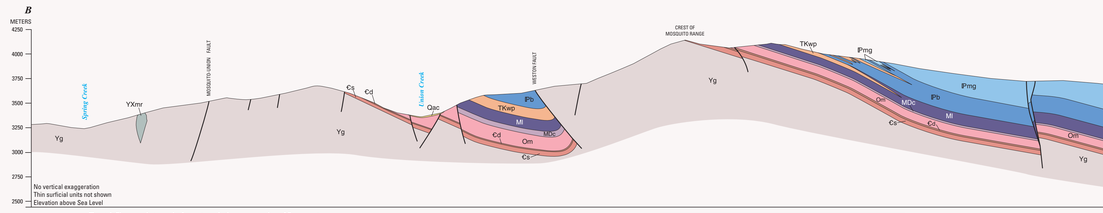
CONTOUR INTERVAL 10 METERS
NATIONAL GEODETIC VERTICAL DATUM OF 1929
To convert meters to feet multiply by 3.2808
To convert feet to meters multiply by .3048

QUADRANGLE LOCATION

Geology mapped by R.G. Bohannon and C.A. Ruleman during 2010–2012.
D. Paco Van Sistine prepared the digital compilation of the geologic map and the GIS database
Edit and cartographic layout by L.J. Binder
Denver Publishing Service Center



No vertical exaggeration
Thin surficial units not shown
Elevation above Sea Level



No vertical exaggeration
Thin surficial units not shown
Elevation above Sea Level

Figure 1. Close-up photograph of an outcrop in the upper reaches of Sacramento Creek showing the typical textural elements found in the Sacramento Porphyry (Tsp) of the Gray Porphyry group.

Figure 2. Photograph of vertical dikes in the Sacramento Porphyry (Tsp). These dikes are well exposed in the upper reaches of Little Sacramento Creek.

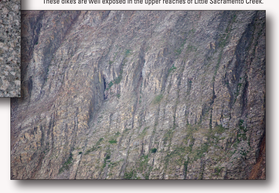
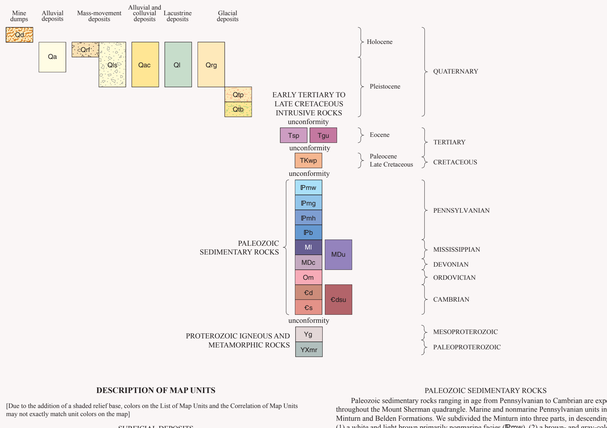


Figure 3. View to the east of large stock of the White porphyry group (TKwp) exposed on the steep west face of White Ridge. Several thick sills and laccoliths compose the stock in this area. Pinedale Till (Qtp) can be seen low in the photo in the upper reaches of Fourmile Canyon.

Suggested citation:
Bohannon, R.G., and Ruleman, C.A., 2013, Geologic map of the Mount Sherman 7.5′ quadrangle, Lake and Park Counties, Colorado: U.S. Geological Survey Scientific Investigations Map 3271, scale 1:24,000, http://pubs.usgs.gov/sim/3271/.

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

[Due to the addition of a shaded relief base, colors on the List of Map Units and the Correlation of Map Units may not exactly match unit colors on the map]

SURFICIAL DEPOSITS

Mine waste

Qd **Mine dumps and waste (Holocene)**—Unconsolidated material deposited by mining and milling processes. Prospect-pit tailings are also included in this unit. Deposit ranges from silt and sand to subangular to subrounded boulders. Unit locally contains clasts from units Qtb and Qtp. In the Breece Hill–Ball Mountain–Iowa Gulch region, unit is possibly more extensive than mapped. Only deposits greater than 20 m² are shown. Thickness is 1 to 10 m

Alluvial deposits

Qa **Stream alluvium (Holocene and latest Pleistocene)**—Pebble- to boulder-sized clasts in a silty sand or sandy silt matrix. Pebbles are generally rounded, where boulders tend to be subangular. Deposit commonly is overlain with organic-rich clayey silt and includes floodplain and overbank deposits. Locally includes sheetwash deposits. In several places peat deposits are included where perennial runoff has ponded in a closed depression. In Fourmile Creek, Twelvemile Creek, Big Union Creek, and Empire Gulch, locally contains Pinedale Till (Qtp). Thickness 2 to 5 m

Mass-movement deposits

Qrf **Rockfall deposits (Holocene)**—Coarse, angular clasts that are primarily clast supported with little to no matrix. Largest clasts are generally at the toes of deposits. In some places, the deposit mantles relict rock glaciers and appears to have flow features, being lobate in form. Chiefly forms at the base of cliffs deposited by gravitational collapse. Deposit occurs as various landforms such as talus cones, rock fans, and block fields. Deposits usually have little to no soil development. Thickness ranges from less than 1 to 20 m

Qls **Landslide deposits (Holocene and late Pleistocene)**—Poorly sorted, fine- to coarse-grained deposit typically characterized by hummocky topography that forms lobes. Deposits mainly lack sorting or stratification. Processes of deposition involved downslope movement of unconsolidated material. Includes previously deposited till that has been remobilized by gravitational creep. Dormant landslides may become reactivated periodically. Most of the landslides post-date the last glaciation (Pinedale) (< 18–20 ka). Thickness varies from 1 to 20 m

Alluvial and colluvial deposits

Qac **Alluvium and colluvium, undivided (Holocene and late Pleistocene)**—Poorly to moderately sorted, pebble- to cobble-sized, subangular to subrounded clasts within a fine- to coarse-grained silt and sand matrix. Forms gently to moderately sloping surfaces. Some channelized pebble-sand alluvium is included in this unit. Locally includes sheetwash deposits. Outwash and till of Bull Lake (late middle Pleistocene) and Pinedale (late Pleistocene) glaciations are locally within unit. Contains fine-grained silty sand deposits proximal to springs. Thickness ranges from 1 to 5 m

Lacustrine deposits

Ql **Lake deposits (Holocene and latest Pleistocene)**—Consists chiefly of silts and clays deposited by settling out of suspension. These fine-grained sediments most likely have an eolian origin. Contains organic-rich paludal deposits. Coarser clastic sands and gravels occur proximal to the inlets of these lacustrine environments. Deposits primarily occur in either glacially scoured bedrock depressions or undrained kettles in late Pleistocene till. All deposits post-date the last glacial period. Thickness 1 to 57 m

Glacial deposits

Qrg **Rock glacier deposits (Holocene and latest Pleistocene)**—Clast-supported, angular to subangular boulders, cobbles, pebbles, sand, and silt. Unit has little to no sorting and is nonstratified, except at the toes of side slopes where slope processes have sorted finer-grained sediment. Deposits generally are lobate and hummocky in form due to downslope movement of remnant interstitial ice from Pinedale glaciation. The downslope toes of deposits are generally very steep (angle of repose) due to Holocene reactivated creep, showing relatively fresh displacement. Forms primarily in the cirque headwall of glaciated drainages. Commonly contains rockfall deposits. Thickness 5 to 20 m

Qtp **Pinedale Till (late Pleistocene)**—Unconsolidated subangular to rounded cobbles and boulders in a clay, silt, sand, and gravel matrix. Sediment was deposited directly by ice with little to no reworking by glacial meltwater. Forms terminal, lateral, recessional, and ground moraines in predominantly east-west drainages flowing off the crest of the Mosquito Range. Surface topography is characterized as hummocky with undrained closed depressions. Sorting or stratification is commonly absent except where lenses of silty sand were deposited by subglacial streams. Clasts are polymictic consisting of all lithologies within the map area and generally show very little weathering. Pedogenic soils in deposit are commonly weakly to moderately developed Bw horizons, but locally may also have weak Bt horizons. Most sediment was likely deposited within oxygen isotope stage 2 (~12–20 ka) (Briner, 2009; Young and others, 2011; Mason and Ruleman, 2011), but locally contains clasts from late middle Pleistocene unit Qtb. Thickness 5 to 60 m

Qtb **Bull Lake Till (late middle Pleistocene)**—Subangular to subrounded cobbles and boulders in a clay, sand, silt, and gravel matrix deposited directly by glacial ice. Identified and mapped only on the south side of Twelvemile Creek. Clasts consist predominantly of Proterozoic igneous and metamorphic lithologies derived from the crest of the Mosquito Range. Surface boulders are generally partly buried, and the surface morphology is smoothed from the original depositional form. Soils generally have moderately formed argillic horizons and slightly red chroma. Granitic clasts show moderate weathering, tend to be friable and easy crushed with a hammer. Thickness unknown

EARLY TERTIARY TO LATE CRETACEOUS INTRUSIVE ROCKS

Gray porphyry group—Sills in the Mount Sherman quadrangle fall into one of two broad groupings of intrusive rock units. The younger group of sills is the Gray porphyry group, which includes the Lincoln, Sacramento, Evans, and Johnson Gulches, Mount Zion, and Iowa Gulch Porphyries according to Behre (1953) and Pearson and others (1962). Behre (1953) identified the Sacramento, Johnson, and Evans Gulches units in the quadrangle and the others are exposed to the north. The age of the Gray porphyry group is only generally known. No ages have been determined from rocks within the quadrangle, but a nearby fission-track age suggests that the Sacramento Porphyry is 43.9 Ma (Thompson, 1990). Other units in the Gray porphyry group are undated locally. Similar megacrystic porphyritic sills to the north and east of the Leadville mining district have been dated, and all ages are within the Eocene. Mach (1992) dated a porphyritic monzogranite sill from the Gray porphyry group near Copper Mountain, 19 km to the north, at 36.7 Ma (fission track on apatite) to 48.6 Ma (fission-track on zircon). Marvin and others (1989) determined that another megacrystic porphyry near the town of Frisco is 44.1 Ma, based on K/Ar. Bryant and others (1981) dated several related sills near Keystone and Boreas Pass at 43.1 to 50.6 Ma

Tsp **Sacramento Porphyry (Eocene)**—The Sacramento Porphyry (Emmons, 1886; Behre, 1953) is porphyritic monzogranite; gray green when fresh; weathers to gray brown or yellow gray. Subhedral-to-euhedral phenocrysts are composed of plagioclase (as large as 1.5 cm), biotite (as large as 0.75 cm), and hornblende (0.75 cm). Subhedral to anhedral quartz is also present (as large as 2.5 cm). Phenocrysts are supported in a fine-grained, quartz-rich matrix that is pale green in color (fig. 1). Primarily exposed on the east flank of the Mosquito Range in the northeast corner of the quadrangle, where it forms a large stock-like body with a roof that is subparallel to bedding in the overlying Pennsylvanian sedimentary rocks. Interior of stock, which is well exposed in the high reaches of Little Sacramento Gulch, is composed of near-vertical dikes, each 0.5 meter to several meters in width (fig. 2). Considered by Thompson (1990) to be the same age as the Evans Gulch Porphyry and older than the Johnson Gulch Porphyry

Tgu **Gray porphyry group, undifferentiated (Eocene)**—Includes the Evans Gulch and Johnson Gulch Porphyries, both of which are exposed in the northwest corner of the quadrangle around Breece Hill and Ball Mountain (Behre, 1953). These two porphyries are similar in composition, but represent different plutons. Each of these porphyries can be separately identified, but poor exposures and widespread cover by mine waste inhibited detailed mapping in this area, so they are undifferentiated in this report. Evans Gulch Porphyry is light gray-green to light green and is fine grained with crystals smaller than 2 mm. Larger crystals are oligoclase and andesine (25 percent), quartz (5 percent), and biotite and hornblende are also common. Less common are apatite, rutile, and zircon, and all are set in a very fine-grained groundmass. Johnson Gulch Porphyry is chiefly gray and is characterized by quartz crystals as large as 5 mm and smaller, but more common plagioclase crystals; rare orthoclase occurs as do biotite and hornblende

TKwp **White porphyry group, undifferentiated (early Paleocene and Late Cretaceous)**—Probably includes rocks equivalent to the Pando Porphyry of Tweto (1951). Mostly occurs as light-white or light-yellowish-brown sills that are present throughout the quadrangle and as a thick stock or laccolith in the Mount Sherman and upper Fourmile Creek drainage areas. Forms numerous sills that intrude subparallel to bedding in all of the units of the Pennsylvanian sedimentary section and at many locations between the Upper Cambrian Sawatch Quartzite (Cs) and the Proterozoic crystalline basement. Several thick sills, distinguished by slight color variations, grain size and weathering/erosional character, comprise the stock or laccolith in upper Fourmile Creek (fig. 3). Fine grained to cryptocrystalline with a sugar texture in hand specimens. Composed of quartz, plagioclase, and biotite, with quartz being the largest grains at 2 mm or smaller. Liesegang bands common. Considered to be earliest Paleocene to Late Cretaceous in age because northwest of the quadrangle, the Pando Porphyry has been dated to 70 Ma by K/Ar (Pearson and others, 1962) and at 64.1 ± 0.9 Ma by a $^{238}U/^{206}Pb$ SHRIMP age on zircon (Wayne Premo, USGS, written commun., 2012)

PALEOZOIC SEDIMENTARY ROCKS

Paleozoic sedimentary rocks ranging in age from Pennsylvanian to Cambrian are exposed throughout the Mount Sherman quadrangle. Marine and nonmarine Pennsylvanian units include the Minturn and Belden Formations. We subdivided the Minturn into three parts, in descending order: (1) a white and light brown primarily nonmarine facies (Pmw), (2) a brown- and gray-colored cheefly transitional marine facies (Pmg), and (3) a dark-colored and dense hornfels facies (Pmh). The Belden Formation (Pb) is a carbonate-rich black shale that is predominately marine. Other Pennsylvanian rock units have been identified in the nearby region such as the Coffman Formation, a black shale that interfingers with the Minturn. Variously named marine limestone members within the Minturn were not differentiated in the quadrangle, although those lithologies are present in places. Locally, the dark-gray marine Leadville Limestone (Mi) makes up most of the Mississippian System. The local units that compose the Mississippian and Devonian are the Dyer Dolomite and Parting Formation of the Chaffee Group (MDc). These formations are not differentiated in this report. The Manitou Dolomite (OCm) makes up the Lower Ordovician. According to Myrow and others (1995, 1999, 2003) a thin unit of red-colored beds at the base of the Manitou they called the Ey Fox Pass Member is Cambrian in age. The red-colored beds are present in most places, but are not differentiated on our map. Two Cambrian quartzite units, the Dotsero Formation (Cd) and Sawatch Quartzite (Cs), are differentiated on the map, except in places where exposures are poor, or in regions of steep terrain that rendered it hard to display both units

Pmw **Minturn Formation (Desmoinesian and Atokan)**

White facies—White to light gray coarse-grained arkosic sandstone and pebble-to-cobble conglomerate (fig. 4). Exposed near the central and eastern map border at highest stratigraphic levels of Minturn in the quadrangle. Resistant and well indurated in most places. Quartz, feldspar, quartzite, and granite clasts are scattered throughout and make up about 15 percent of the generally sandier rock body. Low-angle cross stratification that is defined by clast alignments and parting along bedding surfaces is ubiquitous at scales of centimeters to tens of centimeters. On a larger scale of several meters, bedding is subparallel and more massive. Nonmarine; probably deposited on an alluvial fan of low relief by braided streams. Total thickness is unknown. About 800 m is exposed in quadrangle

Pmg **Gray-brown facies**—Mostly coarse-grained arkose that includes minor amounts of micaceous pebble and cobble conglomerate in lenses; found throughout eastern and northwestern parts of the quadrangle; gray to gray red-brown in color in most of quadrangle, red brown in northeast corner of quadrangle. Clasts are chiefly quartz and chert. Sandstone is moderately resistant in most areas. Layers of dark-gray carbonaceous shale are common, especially lower in the section. Shale layers are fissile and form recesses and swales commonly covered by vegetation (fig. 5). Gray limestone beds are described as commonly occurring in the Minturn Formation in nearby areas (for example, Widmann and others, 2004 and 2006; McCalpin and others, 2012), but are uncommon in Mount Sherman quadrangle. Bedding includes low-angle cross-stratification upon close inspection. Fine-grained sand beds are mostly parallel bedded and coarser grained beds are mostly cross stratified. Beds vary between several cm and 1 m in thickness. Calcareous shale and limestone beds are marine; gray arkose is likely deltaic marginal marine. About 1,000–1,100 m thick

Pmh **Hornfels facies**—Dense dark-gray to black, thermal contact metamorphosed sandstone or shale, the protolith of which is the gray arkose facies of the Minturn Formation. Occurs as irregular blobs, stringers, and lenses preserved between sills of the upper parts of the White porphyry group around Mount Sherman, White Ridge, and Dyer Mountain. Most bodies are only a few meters in thickness

Pb **Belden Formation (Atokan and Morrowan)**—Interbedded black shale, very fine-grained sandstone, and dark-gray limestone at the base of the Mississippian section in the southern half of the quadrangle. Recessive units covered by thin surficial deposits, soils, and vegetation in most areas. Shale outcrops form saddles and topographic lows between the more resistant sandstone and limestone beds, and are locally calcareous and (or) carbonaceous, and may contain plant and marine fossils and silicified wood. Interbeds of fine-grained, micaceous, and arkosic sandstone that are generally olive drab to light gray in color. Limestone beds are dark gray to black, locally contain marine fossils and microlaminations, and are about 2 m thick. At least 500–600 m thick in southern part of quadrangle where unit comprises the footwall of the Weston fault

Mi **Leadville Limestone (Mississippian)**—Bluish-gray to black, thick-bedded, fine-grained dolomite characterized by localized irregular, alternating 1- to 5-mm bands of dark-gray to black dolomite and white, coarse-grained, vuggy dolomite, known as "zebra rock," and well-rounded to fragmented black-chert pebbles and cobbles (fig. 6). Bedding is irregular and wavy. The rock is mottled or brecciated, with the breccia typically occurring within, and not across, beds. Abundant dissolution features characterize the unit prompting interpretations that the unit represents paleokarst (Maslyn, 1977; Beaty and others, 1990). Thin, discontinuous lenticular beds of tan-weathering, medium-grained, white quartz sandstone and orthoquartzite, and localized beds containing abundant subangular rip-up clasts of limestone are found near the base of the formation. Heavily intruded by sills of the White porphyry group (TKwp), especially at the top of unit. Thickness is highly variable due to incomplete preservation except on north flank of Mount Sheridan where a complete section, about 100 m thick, is exposed

MDc **Chaffee Group (Lower Mississippian and Upper Devonian)**—Includes Dyer Dolomite and Parting Formation, but the two units are undifferentiated on this map. Dyer Dolomite is thinly bedded to unbedded, finely crystalline and micocrystalline dolomite. The lower third of the unit is medium gray, whereas the upper part is slightly darker. Weathering and alteration produces an irregular pattern of yellowish to brownish gray outcrop in many places (fig. 7). Thin (~5 cm) lenses of shale and (or) chert occur locally. Parting Formation is predominantly bright-white to subdued-gray, fine- to medium-grained, well-sorted orthoquartzite and moderately well-sorted, quartz-rich sandstone with a few interbeds of light yellowish-brown dolomitic sandstone. Locally, this unit is coarse grained and contains quartz pebbles, particularly near its base. Orthoquartzite beds appear unstratified on a fresh surface, but on weathered surfaces thin lenses of less well-cemented sandstone are revealed. Although similar in character, the Parting Formation generally is not as pure a quartzite or as white as the Sawatch Quartzite (Cs). Finer grained facies weather orange brown, whereas coarse-grained facies tend to be light gray or purple. Irregular thickness, 0–40 m

MDu **Leadville Limestone and Chaffe Group, undivided (Mississippian and Upper Devonian**—Mapped together where exposures are poor

Om **Manitou Dolomite (Lower Ordovician)**—Cliff-forming unit composed of light- to dark-gray, thin- to thick-bedded dolomite with rare interbeds of dark gray limestone (fig. 7). Generally weathers to light yellow-brown color. Characterized in many places by orange-brown laminations that occur as indistinct layers (2 to 30 cm thick) of sandy dolomite and by whitish-gray to black laminated chert nodules, blebs, and stringers (fig. 8). The lowermost 1–3 m of the Manitou Dolomite contains thick beds of whitish dolomite with abundant brick-red ovoid spots. These beds have a red hue from a distance (fig. 7) and have been called the "red-cast beds" (Emmons, 1886). The red-cast beds were formerly considered to be the upper part of the Peerless Formation (Behre, 1953). Myrow and others (2003) placed these beds within the Taylor Pass Member of the Manitou Dolomite. The Manitou is 60 to 70 m thick at Horseshoe Mountain

Cd **Dotsero Formation (Upper Cambrian)**—Fine- to medium-grained quartz sandstone overlain by dolomite-cemented sandstone and thin, sandy to silty dolomite beds. Red-brown to purple-brown color in most exposures. The Dotsero is well exposed in cliffs and on the steepest slopes, but is poorly exposed elsewhere. Bedding in the lower and more quartzitic part of the unit is parallel and uniform, about 0.5 m in thickness. The lower part of the unit typically forms a small cliff that looks nearly unbedded from a distance. Beds in the upper calcareous part of the unit are subparallel and wavy, ranging from a few cm to 25 cm in thickness (fig. 9). Thickness is 25–30 m

Cs **Sawatch Quartzite (Upper Cambrian)**—White, thick-bedded, medium-grained, well-cemented orthoquartzite and quartzitic sandstone with moderately well sorted and subrounded grains. Well exposed in cliffs and on steep slopes. In gentle terrain, exposures are limited to piles of white, loosely aggregated boulders. A thin (10–20 cm) bed of quartz-pebble conglomerate with well-rounded clasts, commonly occurs at the base of the unit. Parallel, uniform, and even beds range between a few cm and 1 m in thickness and are defined by parting, slight differences in resistance, and by variations in color from white to light brown (fig. 9). Thickness is 35–45 m

Cdsu **Sawatch Quartzite and Dotsero Formation, undivided (Upper Cambrian)**—Mapped together where exposures are poor

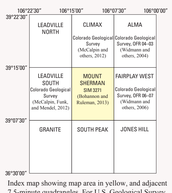
PROTEROZOIC IGNEOUS AND METAMORPHIC ROCKS

Intrusive granitic rocks and high-grade gneiss compose the Proterozoic rocks in the quadrangle. The granitic rocks, which are mostly coarse-grained and only slightly deformed, might correlate with a number of different plutons regionally. Most of the local coarse-grained and slightly deformed Proterozoic intrusive rocks, like those in the Climax quadrangle to the north, belong to the Berthoud Plutonic Suite (1,400 Ma) (McCalpin and others, 2012). Similar rocks occur in the Sawatch Range where they are called the St. Kevin Granite (Tweto, 1974) that has been dated at 1,390 Ma (Pearson and others, 1962) and at 1,444 ± 15 Ma by a concordia $^{238}U/^{206}Pb$ SHRIMP age on zircon (Wayne Premo, USGS, written commun., 2012). Granitic rocks are widespread to the south around the town of Granite, but remain unnamed and undated there. No attempt was made to correlate the granitic rocks in the quadrangle to any specific rock bodies that are outside the quadrangle.

For the most part, the metamorphic rocks in the quadrangle are biotite gneiss and schist. They are metasedimentary and metavolcanic rocks of the Proterozoic gneiss complex of Tweto (1987). These rocks are poorly dated locally, but are thought to have been deposited between 1,770 and 1,700 Ma and metamorphosed between about 1,750 and 1,670 Ma (Wallace, 1995) based upon regional studies

Yg **Granitic rocks (Mesoproterozoic)**—Pink to pinkish-gray, undeformed to moderately foliated, medium- to coarse-grained granitic rock; mostly monzogranite, but ranges from granodiorite to granite in composition; consisting of roughly equal proportions of microcline, quartz, and plagioclase with lesser amounts of biotite and muscovite (fig. 10). The rock has a seriate-to-porphyritic texture defined by alignment of tabular microcline phenocrysts, many of which exhibit Carlsbad twinning. Some euhedral laths of microcline exceed 3 cm in length. Quartz is present as anhedral grains and as aggregates of small, sutured grains. Weathered surfaces have a somewhat rusty coloration

YXmr **Monzogranite, gneiss, and dikes, undivided (Paleoproterozoic)**—Medium- to dark-gray, medium-grained gneiss intruded at all scales by monzogranite and pegmatite dikes (fig. 11). Monzogranite is similar to unit Yg. Gneiss is characterized locally by the layering of schistose, dark-colored laminae containing biotite, hornblende, plagioclase, quartz, and light-gray to pinkish-gray, medium-grained to pegmatitic material composed primarily of quartz, plagioclase, and microcline. Gneiss is well foliated and exhibits numerous prygmatic folds, boudinage, and sigmoidal structures



Index map showing map area in yellow, and adjacent 7.5-minute quadrangles. For U.S. Geological Survey publications the publication number, author(s), and year of publication are shown. For non-USGS publications the State agency, author(s), and publication year are shown.

EXPLANATION

Contact—Dashed where approximately located

Fault—Dashed where approximately located; dotted where concealed

Probable Quaternary fault—Fault showing displacement during Quaternary time (undifferentiated). Queried where identity or existance is questionable

High-angle reverse fault—Dashed where approximately located; dotted where concealed. Sawteeth on upper (tectonically higher) plate

Anticline

Syncline

Bedding

Vertical bedding—Showing strike

Inclined bedding—Showing strike and dip

Overturned bedding—Showing strike and dip

CO-MS-1 Surface offset (1.8 m) **Location of fault scarp profile**—Surface offset in meters (m) in parenthesis

Water body

CONVERSION FACTORS

Multiply	By	To obtain
millimeters	0.03937	inches (in.)
centimeters (cm)	0.3937	inches (in.)
meters (m)	3.281	feet (ft)
square meters (m²)	10.76	square foot (ft²)
kilometers (km)	0.6214	mile (mi)
square kilometer (km²)	0.3861	square mile (mi²)

REGIONAL GEOLOGY AND STRUCTURE

The Mount Sherman 7.5′ quadrangle is in the central Mosquito Range, a high north-south trending range that separates the relative lowlands of South Park (about 2,800 m elevation) in the east and the Upper Arkansas River valley (about 3,090 m elevation) to the west. Mount Sherman, the highest point in the quadrangle, is 4,278 m in elevation and other peaks along the crest of the range typically exceed 4,100 m in elevation. The crest of the range has been deeply glaciated.

Stratiform rocks in the Mosquito Range, which are Cambrian to Pennsylvanian in age, provide a platform for Late Cretaceous sedimentary rocks and middle Tertiary sills. These Paleozoic and Mesozoic sedimentary rocks dip moderately (20°–30°) to the east. Proterozoic basement rocks are exposed beneath the sedimentary rocks throughout the more highly elevated western parts of the quadrangle. To the east, in central South Park, the Proterozoic basement is buried to depths of 3,000+ m by deformed Phanerozoic sedimentary rocks (Ruleman and others, 2011). To the west, the Upper Arkansas River Basin south of Leadville, is a deep graben in which Upper Tertiary fill of the Dry Union Formation and Quaternary basin fill of indeterminate thickness rests on Proterozoic crystalline rocks (Tweto, 1974; McCalpin and Funk, 2009).

Structural tilting in the Mosquito Range resulted in the complete removal of the platform of stratiform and sedimentary rocks in the Arkansas River Valley (Tweto, 1974; Cappa and Scott, 2007; McCalpin and Funk, 2009), an area that is now a large graben. This Cambrian to Pennsylvanian age platform of stratiform rocks is also absent in the Sawatch Range to the west of the Arkansas River valley (Cappa and Scott, 2007). Tertiary sills in the Mosquito Range are tilted as well, and one of the youngest documented sills, the Chalk Mountain Rhyolite of the Climax area, approximately 18 km north of Mount Sherman, has been dated at 29 Ma (McCalpin and others, 2012) and related dikes in that area are as young as 25.5 Ma (Bookstrom, 1989).

The subparallel dip of sills and the Cambrian to Pennsylvanian age platform of stratiform rocks suggests that the tilting deformation likely postdates intrusion, so regional east dips developed sometime after the late Oligocene. Since the tilting and the erosion of the Paleozoic and Mesozoic rocks in the Arkansas River valley were probably coeval, most of the tilting probably occurred prior to, or in the early stages of graben formation. Regional deformation in this part of Colorado has long been considered to be part of the Laramide orogeny, but this study has revealed that much of the deformation is considerably younger than that. We consider the young regional strattal tilts to be a product of rift-flank uplift occurring in the Oligocene after the youngest igneous rocks (for example, Gray porphyry group ~ 36.7 Ma) were emplaced in the region and unrelated to Laramide compression. This implies that most of the topographic relief in the region is a product of the Rio Grande rift.

Laramide faults are important in the quadrangle, and include the high-angle reverse faults known as the Weston and London faults, which are present in the south-central half and northeast-ern corner of the map, respectively. The Weston fault dips about 40°–50° to the east, is up-to-the-east, and has a vertical separation, measured on the Sawatch Quartzite (Cs), of about 1,250 m. The fault displaces the sills of the White porphyry group so deformation postdates the early Paleocene, but beyond that, the age of the fault is poorly constrained. Little evidence for this fault can be found in the northern half of the quadrangle where all the faults are normal and cut the Weston fault.

The Mosquito fault, the most prominent normal fault in the quadrangle, and the corresponding Mosquito-Union fault, are west-dipping, high-angle faults in the west-central part of the quadrangle that formed during the same extensional tectonism that created the graben of the Arkansas River Valley. The Mosquito fault is up-to-the-east and has an approximate vertical component of offset of about 250 m on the basal Sawatch Quartzite surface in the West Sheridan/Long-and-Derry Hill region. As offsets on related branches of the fault are considered, the basal Cambrian platform strata are about 600 m higher on Mount Sheridan at the crest of the range than they are at the west border of the quadrangle. The difference is accommodated by down-to-the-west displacement of east-tilted blocks in a domino-style of tectonism in the Mount Sherman quadrangle. The total of 600 m of vertical separation is typical of most of the fault along its length, as it has that same approximate displacement in the Climax 7.5′ quadrangle to the north, where the offset is focused on a single fault trace (McCalpin and others, 2012). The age of displacement is not known, but the fault cuts all of the sills and its trace is characterized by west-facing Quaternary scarps in the southern part of the quadrangle. These fault scarps primarily displace colluvium of unknown age and can be mapped as linear features by using the alignment of springs and seeps. One location towards the western boundary of the map yielded a credible fault scarp profile for a single-event fault (location CO–MS–1 on map; fig. 12).

Evidence of Pleistocene glaciations is recorded in the abundant large drainage basins and cirques within the quadrangle. Although most glacial deposits of Pinedale and Bull Lake ages were deposited outside of the quadrangle, multiple sets of inset glacial trimlines along the walls of the valleys indicate successive glaciations. Absolute ages of glaciations were not acquired within the quadrangle, but studies proximal to the mapped area and within the Rocky Mountains indicate that the penultimate glaciation (Bull Lake) culminated around 122 ka (Schildgen and others, 2002; Pierce, 2004). Deposits mapped as Bull Lake Till occur only within the Twelvemile Creek drainage and are perched above younger glacial deposits and scoured areas of Pinedale age.

The most recent glaciation (Pinedale) has been dated between 20.9 ± 1.0 ka and 14.4 ± 0.8 ka. These deposits are hummocky ground and lateral moraines seen in all of the main drainages within the quadrangle. Mason and Ruleman (2011) studied the recessional moraine complex on the western flank of Mount Massive, right across the Arkansas River valley, and determined that the Pinedale deglaciation occurred between 19.5 ± 1.8 ka and 12.6 ± 1.2 ka to the west. These ages indicate that deglaciation occurred over an approximate 6.5 ky period at a rate of about 1 m/yr.

Within the quadrangle, the post-glacial deposition has been limited to minimal Holocene deposition confined to small floodplains and sheetwash on hill slopes. Within most cirque basins rock glaciers are presently active as evidenced by their fresh hummocky appearance. Rock falls and landslides have occurred, likely as a function of post-glacial gravitational collapse of valley walls.

ECONOMIC GEOLOGY

There are two large carbonate-hosted, sulfide-ore deposits located in the Mount Sherman quadrangle (Emmons, 1882, 1886; Emmons and others, 1927; Behre, 1953). The first, the Leadville deposit, is in the Breece Hill, Ball Mountain, and California Gulch region (northwest part of quadrangle), and is commonly referred to as a Leadville-type deposit (Beaty and others, 1990). The second is the Sherman deposit (called a Sherman-type deposit) and is primarily on the eastern flank of Mount Sherman in the upper reaches of Fourmile Canyon (Beaty and others, 1990). Both deposits occur where sills of either or both of the Gray or White porphyry groups intrude the Mississippian Leadville Limestone. The Leadville-type deposit is primarily associated with the Gray porphyry group. Carbonate stratiform rocks from Devonian to Pennsylvanian age are mineralized. In the Sherman-type deposit, only the Leadville Limestone is mineralized as a result of intrusion by the White porphyry group (Beaty and others, 1990). The Leadville-type deposits formed at moderately high temperatures (300–500°C) (Behre, 1953) in response to migrating mid-Tertiary hydrothermal fluids which derived sulfur and lead from igneous sources (Beaty and others, 1990). Tschauder and others (1990) and Lanis and Tschauder (1990) argued that the Sherman-type mineralization formed during the Late Mississippian as a Mississippi Valley-type deposit in a post-depositional karst system. However, Johansing and Thompson (1990) concluded that those same deposits formed during the Tertiary from basinal brines that moved along thermal gradients controlled by igneous intrusions.

Quartz-gold-pyrite and silver-metal ores emplaced in carbonate rocks in the mid-Tertiary characterize the Leadville-ore body (Tschauder and others, 1990). The Sherman ores are concentrated in white barite and dolostone, and they have a high silver and low gold, pyrite, and chalcopyrite content (Tschauder and others, 1990).

Our mapping does not resolve the disagreement over Sherman-type genesis, but our mapping clearly shows that both major deposit types are associated with large intrusions (80–100 km²). We made an observation that might be of interest: We noted that the preserved volume of Devonian and Mississippian carbonate rock in intruded areas is highly variable, and sills seemed to favor this stratigraphic horizon. We think there has been a process of dissolution of carbonate rock in association with the sill injection. We interpret this dissolution to have facilitated the intrusion of sills as it would have provided space for magma as solid carbonate was dissolved and carried away by hot fluids. This might lend support to the Johansing and Thompson (1990) interpretation, although the sills that intrude Mount Sherman are mostly of the White porphyry group, which the latter authors think are older than the mineralization.

Figure 4. Typical exposure of the sandstone of the white facies of the Minturn Formation (Pmw). Hammer in lower right part of photograph provides scale.

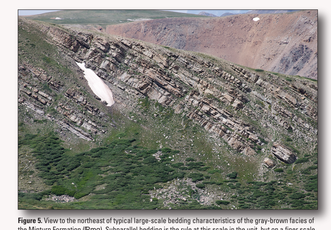
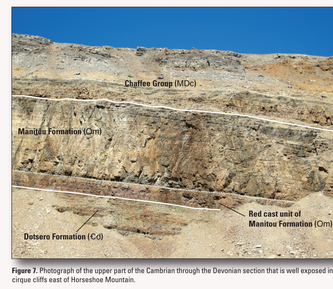


Figure 5. View to the northeast of typical large-scale bedding characteristics of the gray-brown facies of the Minturn Formation (Pmg). Subparallel bedding is the rule at this scale in the unit, but on a finer scale each larger bed is internally cross bedded.

Figure 6. Photograph of the Leadville Limestone (Mi) taken just to the west of Empire Hill in the west half of the quadrangle. Note the irregular, wavy, and poorly defined bedding and uniform gray color of the rock. Fine-grained, brown sandy laminations can also be seen.


Chaffee Group (MDc)
Manitou Formation (Om)