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Geology mapped by W.A. Braddock, 1981–1982, and J.B. Workman, 2007–2009

Digital map database prepared by Jeremiah B. Workman

Editing and digital cartography by Gayle M. Dumonceaux
Denver Publishing Service Center

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## CORRELATION OF MAP UNITS

## INTRODUCTION

New geologic mapping within the Sand Creek Pass 7 ½' quadrangle defines geologic relationships within the northern Front Range of Colorado along the Wyoming border approximately 35 km south of Laramie, Wyo. Previous mapping within the quadrangle was limited to regional reconnaissance mapping (Tweto, 1979; Camp, 1979; Braddock, 1983). Workman (2008) mapped the Eaton Reservoir 7 ½' quadrangle to the east, Burch (1983) mapped portions of the Rawah batholith to the south, Camp (1979) mapped the Laramie River valley to the west, and Ver Ploeg and Boyd (2007) mapped the Laramie 30' x 60' quadrangle to the north. Field work was completed during 1981 and 1982 by W.A. Braddock, during 2007 and 2008 by J.B. Workman, and the mapping was compiled at 1:24,000-scale by J.B. Workman. Minimal petrographic work was done and no isotope work was done in the quadrangle area, but detailed petrographic and isotope studies were performed on cormeliatse map units in surrounding areas as part of a related regional study of the northern Front Range. Stratigraphy of Proterozoic rocks is primarily based upon field observation of bulk mineral composition, macroscopic textural features, and field relationships that allow for correlation with rocks studied in greater detail outside of the map area. Stratigraphy of Phanerozoic rocks is primarily based upon correlation with similar rocks to the north in the Laramie Basin of Wyoming and to the east in the Front Range of Colorado.

## DESCRIPTION OF MAP UNITS

[Thin, discontinuous surficial deposits were not mapped. Unit symbols for Proterozoic igneous rocks in some cases utilize nonstandard symbols (such as **YgSH**) which are intended to emphasize composition while differentiating broadly accepted lithodemic unit names. Lower case letters after the age designation indicate rock composition and textural features whereas upper case letters indicate major named intrusive body or rock suite.]

Qa **Alluvium (Holocene)**—Poorly sorted coarse sand and pebbles to boulders in stream channels, flood plains, and low terraces. Flood-plain and terrace deposits are generally less than 5 m above present stream level. Unit may locally include colluvium not mapped separately. Composition reflects bedrock exposed upstream

Qac **Alluvium and colluvium, undivided (Holocene to middle? Pleistocene)**—Mapped along and near Dry Creek, the northeastern foot of Bull Mountain, and the southeastern part of the map area where alluvial deposits (Qa) higher on the slopes grades into alluvium (Qa) downslope and the contact between the two deposits has not been identified. Unit may include pediment deposits east of Dry Creek

Qc **Colluvium (Holocene to middle? Pleistocene)**—Non-sorted clay, silt, sand, and angular to subrounded clasts ranging in size from granules to large boulders. Includes deposits transported downslope from various material chiefly by sheetwash, landslides, debris flow, hyperconcentrated flow, rock fall, and possibly periglacial processes

Qls **Landslide deposits (Holocene to middle? Pleistocene)**—Non-sorted clay, silt, sand, and angular to subrounded debris on slopes and at base of slopes characterized by hummocky topography. Upslope regions characterized by headwall scarps and closed depressions and downslope areas by lobate toes. Formed along edges of Bull Mountain where Pierre Shale and underlain largely by shales, siltstones, and claystones that are overlain by sandstones and conglomerates of the Dakota Group (Kd)

Qp **Pediment deposits (middle Pleistocene)**—Poorly stratified and non-sorted to poorly sorted, clast- and locally matrix-supported gravelly and sandy alluvial sediments that create gently sloping surfaces at and Red Peak and upper part of Goose Egg Formations (**\$Pnpu**) at the northeast corner of quadrangle. Composition of clasts generally reflect upslope bedrock with sandstone-rich gravel and non-pebbly to pebbly silty sand derived from Mesozoic rocks to south on Bull Mountain. Unit may include minor unmapped sheetwash deposits, colluvium, and probable hyperconcentrated flow deposits. Lower limit of pediment surface is about 18 m above East Shell Creek to the north of the quadrangle boundary. Pediment surface is about 60 m above Sand Creek in northeast corner of quadrangle. Estimated thickness is 1–5 m

Kb **Benton Group (Upper and Lower Cretaceous)**—Black siliceous and non-siliceous marine shales interbedded with thin, discontinuous bentonite and fine-grained sandstone beds. Includes all dark shales conformably deposited above upper sandstone of the Dakota Group (Kd) and below Niobrara Formation (latter unit exposed to west of the map area). Unit is poorly exposed and includes Frontier Formation and Mowry Shale (Reiser, 1957). Upper part of unit not exposed in map area. Frontier Formation is equivalent, in descending order, to Carlile Shale, Greenhorn Limestone, and Graneros Shale of eastern Front Range (Berman and others, 1980; W.A. Cobban, oral commun., 1998). Lower 30 m of unit consists of rusty dark-brown to black, wavy bedded, siliceous, fissile shale containing fish scales intercalated with thin beds of bentonite, equivalent to Lower Cretaceous Mowry Shale of eastern Front Range (Cole and Braddock, 2009). Estimated total thickness is 168 m from well logs in the Laramie River valley (Camp, 1979)

Kd **Dakota Group (Lower Cretaceous)**—Light-gray to brown, fine-grained, ripple-marked, cross-stratified quartz sandstone deposited along alluvial plain interbedded with black to dark-gray, laminated, carbonaceous, shallow marine shale and siltstone and gray to brown, planar to trough crossbedded chert-pebble conglomerates at base. Unit unconformably overlies less resistant clays of the Morrison Formation (Jm). Includes, in descending order, Muddy Sandstone, Thermopolis Shale, and Cloverly Formation as mapped by Ver Ploeg and Boyd (2007). Muddy Sandstone consists of approximately 20 m of white to brown, fine- to very fine grained quartz sandstone with minor interbedded sandy, carbonaceous shales. Thermopolis Shale consists of approximately 20 m of dark-gray shale which grades upward to siltstone and very fine grained quartz sandstone of overlying Muddy Sandstone. Cloverly Formation consists of 12 m of light-gray, fine- to medium-grained quartz sandstone at top which grades into 10 m thick section of dark-gray laminated shale overlying approximately 20 m of gray to brown, trough-crossbedded quartz- and chert-pebble conglomerates at the base, filling channels in underlying Upper Jurassic rocks. Total thickness in map area estimated to be 83 m, but slumping and colluvial cover make thickness difficult to measure. Camp (1979) estimated total thickness of 91 m based on well data from Laramie River valley to west of map area

Jm **Morrison Formation (Upper Jurassic)**—Greenish-gray, gray, and maroon siliceous claystone interbedded with gray thin-bedded, fine-grained, crossbedded sandstone and discontinuous beds of gray, micritic limestone deposited in fresh-water rivers, lakes and swamps. Sandstone and limestone beds increase up section. Upper contact with overlying Dakota Group (Kd) marked by channel-cutting erosional unconformity. Lower contact is marked by one or more cherty shale beds which may represent a minor erosional unconformity or may be gradational with the upper sandstones of the Sundance Formation (Curtis, 1963). Forms recessive slope below more resistant sandstones and conglomerates of Dakota Group. Total thickness estimated to be 78 m on eastern slope of Bull Mountain

J\$kq **Sundance Formation (Upper and Middle Jurassic) and Jelm Formation of Chugwater Group (Upper Triassic), undivided**—Sundance Formation consists of calcareous nearshore marine sandstone and laminated siltstone. Pipiringos (1957, 1968) and Pipiringos and O'Sullivan (1976) define three members on west side of Bull Mountain (just west of map area). These are, in descending order, Windy Hill Sandstone Member, Pine Butte Member, and Canyon Springs Sandstone Member. Windy Hill Sandstone Member consists of gray-white, buff-weathering, thin-bedded to crossbedded, calcareous sandstone. Unconformity separates the Windy Hill from underlying Pine Butte Member. Pine Butte Member consists of white to greenish-white and yellow, crossbedded sandstone overlain by blue-green to gray calcareous shale interbedded with lenses of calcareous sandstone and sandy oolitic limestone. Canyon Springs Sandstone Member is white, yellow-weathering, fine- to very fine grained, thin-bedded to crossbedded, well-sorted calcareous and glauconitic sandstone and laminated siltstone equivalent to Entrada Sandstone of eastern Front Range (Pipiringos and others, 1969). Canyon Springs Sandstone Member regionally becomes younger to south and overlies a regional unconformity marked by a thin horizon of chert pebbles within map area (Pipiringos, 1968).

The Chugwater Formation of Darton (1908) has been modified significantly by many authors. High and Picard (1967) proposed raising the Chugwater to group status and its members to formational status as used here. Pipiringos (1968) described Jelm Formation as grading laterally into upper part of Crow Mountain Member of the Chugwater of Love (1939) in south-central Wyoming and therefore includes Jelm Formation as part of the Chugwater Group as used here. Jelm Formation of Knight (1917) and Red Peak Formation of Lowe (1939) are recognized in map area. Jelm Formation is mapped here with the Sundance Formation and the Red Peak Formation is mapped here with the upper part of the Goose Egg Formation.

Upper part of Chugwater Group (Gypsum Spring and Popo Agie Members of Love, 1939) was removed by regional unconformity at base of Sundance Formation within map area. The regionally extensive Alcova Limestone of Lee (1927), which sits at or near base of Jelm Formation equivalent in central Wyoming, pinches out in Laramie Basin and is not present in map area

Jelm Formation of the Chugwater Group consists of non-marine sandstone with minor shale, silt, and limestone-pebble conglomerate divided into two members, as defined by Pipiringos (1968), within map area. These are, in descending order, Sips Creek and Red Draw Members. Sips Creek Member consists of greenish-white, orange-weathering, fine- to medium-grained, trough crossbedded fluvial sandstone overlying a basal greenish-gray shale and limestone-pebble conglomerate. Red Draw Member consists of reddish-brown to reddish-pink, orange-weathering, very fine to fine-grained, crossbedded calcareous sandstone (possibly eolian) interbedded near top with dark reddish-brown, laminated siltstones and shales. Siltstone and shale beds thicken to north into Wyoming (Pipiringos, 1957). Base of unit contains rounded siltstone pebbles and boulders. Pipiringos (1957) described an erosional disconformity between Jelm and underlying Red Peak Formations within Chugwater Group which correlates with a regional unconformity above Lykins Formation on east side of Front Range (Pipiringos and O'Sullivan, 1976), but Camp (1979) described this contact in Laramie River valley as conformable and irregular due to slumping under differential compaction. Jelm Formation thins significantly to south and may pinch out in vicinity of Cameron Pass (Kellogg and others, 2008).

Pipiringos (1957) measured total thickness between base of Morrison Formation (Jm) and top of Red Peak Formation on west side of Bull Mountain at 74 m. Camp (1979) estimated 79 m of Jelm Formation and 9 m of Sundance Formation in Laramie River valley. On eastern slope of Bull Mountain in map area, exposure is extremely poor due to pervasive, unmapped thin colluvial cover derived from upslope slumping of Dakota Group (Kd) sandstones and conglomerates. Unconformity separating units is not exposed and therefore is not mappable. Total thickness of undivided map unit estimated to be 100 m in map area

\$Pnpu **Red Peak Formation of Chugwater Group (Lower Triassic) and upper part of Goose Egg Formation (Lower Triassic and Upper Permian), undivided**—Combined unit characterized by red to red-brown, planar-laminated to ripple crossbedded siltstone, planar-bedded, fine-grained sandstone, and micaceous shale interbedded with gypsum beds near base.

Red Peak Formation of Chugwater Group consists of four gradational facies subdivisions, as defined by Picard (1967). All facies are recognized in map area and described in descending order. Upper platy facies is characterized by slope-forming horizontally bedded siltstone interbedded with lesser silty claystone and discontinuous lenses of mud-pebble conglomerate deposited in a tidal-flat environment. Alternating facies is characterized by resistant massive beds of moderate to well-sorted nearshore marine siltstone alternating with thin, fissile beds of poorly sorted siltstone, silty claystone, and very fine grained sandstone deposited in tidal-flat environments. Lower platy facies is similar to upper platy facies and is characterized by slope-forming, cyclic-bedded siltstone interbedded with lesser mud-pebble conglomerate and silty claystone with minor, very fine grained sandstone. Basal silty claystone facies is characterized by poorly exposed valley-forming silty claystone interbedded with minor ledges of thin-bedded siltstone and sandstone with abundant ripple cross-bedding deposited in a transitional environment. Red Peak Formation conformably overlies upper part of the Goose Egg Formation.

Underlying upper part of the Goose Egg Formation is here informally defined as all rocks above the Forelle Limestone Member of Goose Egg Formation (**Pgf**) and below Red Peak Formation. Burk and Thomas (1956) originally reassigned this interval to upper part of Goose Egg Formation and Maughan (1964) defined four members at Red Mountain (northeast of map area) within upper part of the formation deposited in tidal-flat or lagoonal environments adjacent to the Phosphoria sea. They are, in descending order, Lower Triassic Little Medicine and Freezeout Shale Members, and Upper Permian Envy and Difficulty Shale Members. Maughan (1964) describes a local unconformity above the Envy Member related to late movements of the ancestral Front Range highlands in the southern Laramie Basin. This valley-forming sequence is very poorly exposed within map area, and therefore contacts between individual members and contact with overlying Red Peak Formation are not mapped. The top of the Little Medicine Member is recognized, where exposed, as the top of thin carbonate bed approximately 22 m above the top of the Forelle Limestone Member (**Pgf**) or as the top of the highest gypsum bed in section.

Total thickness of combined unit estimated to be 209 m on eastern slope of Bull Mountain within map area. Camp (1979) estimated total thickness to be 177 m in Laramie River valley

**Lower part of Goose Egg Formation (Permian)**—The Goose Egg Formation was defined by Burk and Thomas (1956) for exposures in central Wyoming. Maughan (1964) describes eight members, reducing some units from formational rank and reassigning some units previously included in overlying Chugwater Formation of Darton (1908). Upper part of formation (Little Medicine, Freezeout Shale, Envy, and Difficulty Shale Members), described above as lower part of unit (**\$Pnpu**), cannot be differentiated from overlying rocks of Chugwater Group in map area. Members of lower part of the Goose Egg Formation, described in detail below, include the Forelle Limestone and Satanka Shale Members

Pgf **Forelle Limestone Member (Upper Permian)**—Gray, microcrystalline, algal, wavy-laminated dolomite interbedded with purple and tan, laminated shaly dolomite deposited in hypersaline nearshore environment. Camp (1979) described three subunits in the Laramie River valley which are also present in map area. These divisions are, in descending order, gray dolomite interbedded with purple shaly dolomite, purple and tan shaly dolomite, and gray dolomite at base. Estimated thickness is 8 m

Pgsu **Upper part of Satanka Shale Member (Upper and Lower Permian)**—Reddish-brown to reddish-orange, massive, horizontally bedded sandy shale and siltstone interbedded with lesser amounts of reddish-brown to pale-orange, fine-grained, laminated sandstone and thin blocky gypsum and thin, purplish-gray, wavy-laminated dolomitic limestone near base of unit. Deposited in tidal flat or lagoonal environment. Unit is equivalent, in descending order, to Glendo Shale and Minnekahta Limestone Members of the Goose Egg Formation, as defined by Burk and Thomas (1956). Pearson (1972) described a thin gypsum bed within his Satanka Shale in the southern Laramie basin which he correlated to Minnekahta Limestone. We loosely correlate the dolomite and gypsum beds at base of map unit to Minnekahta Limestone Member, but Satanka terminology, as defined by Pearson (1972), is preferred due to uncertainty of correlation. Campbell (1963) correlated Minnekahta Limestone Member to Falcon Limestone Member of Lykins Formation on east side of Front Range. Base of unit is defined by a thin gray dolomitic limestone with white to gray chert nodules. Camp (1979) estimated thickness to be 43 m in Laramie River valley. Estimated thickness on eastern side of Bull Mountain is 52 m

Pgsl **Lower part of Satanka Shale Member (Lower Permian)**—Reddish-orange to dark maroon, thin laminated, sandstone and siltstone with increasing interbedded dolomitic sandstone and gypsum near top of section. Percentage of sandstone in lower part of unit increases to south across map area. Deposited in tidal flat or lagoonal environment. Unit is loosely correlated with Opeche Shale Member, as defined by Burk and Thomas (1956). Maughan and Wilson (1963) correlate the lower part of the map unit at Chimney Rock with the Owl Canyon Formation of Condra and others (1940). The regional unconformity above the Owl Canyon Formation on the eastern side of the Front Range (Cole and Braddock, 2009) is inferred to exist in the lower part of the Satanka Shale Member in map area, but has not been identified due to poor exposure. Satanka terminology, as defined by Pearson (1972), is preferred due to uncertainty of correlations. Estimated thickness at Sand Creek Pass is 35 m

PPIc **Casper Formation (Lower Permian to Middle Pennsylvanian)**—White to buff, yellow-weathering, fine- to medium-grained, well-sorted quartz-rich, carbonate-cemented eolian sandstone interbedded with discontinuous, thin lenses of freshwater limestone. Unit displays prominent ripple and large-scale trough (festoon) cross-laminations with significant soft-sediment deformation at several levels. Darton (1908) originally defined Casper Formation to include all rocks below Satanka Shale and above Precambrian rocks, but Knight (1929) restricted name to exclude arkosic rocks assigned to Fountain Formation (**IPf**), as used here. Equivalent to Ingleside Formation of Butters (1913) on east side of Front Range. Contact with overlying Satanka Shale Member is sharp and conformable. Contact with underlying Fountain Formation (**IPf**) is generally sharp, although gradational in some exposures. Maughan and Wilson (1963) described a local unconformity at base of Casper Formation in area related to onlapping and beveling of basin fill along flanks of Ancestral Front Range uplift. In northern parts of map area near Chimney Rock, Casper Formation appears to be in conformable contact with underlying Fountain Formation (**IPf**), but to south, where exposures are poor, upper unit of Fountain Formation thins, which could be a result of non-deposition- or of erosion, but no angular discordance is noted across this contact. Within map area, unit thins significantly to south and pinches out north of Sand Creek Pass. At Chimney Rock location, thickness estimated to be 29 m

IPf **Fountain Formation (Middle to Lower Pennsylvanian)**—Maroon to pink and light-greenish-gray, coarse-grained, trough crossbedded, arkosic, fluvial sandstone and conglomerate interbedded with minor amounts of pink and light-green micaceous siltstone and mudstone. Unit is informally divided into upper and lower members. Sandstones within upper member are finer grained and contain well-rounded clasts of quartz and feldspar, conglomerate beds are thinner and less common, and siltstone is only locally present. Contact between upper and lower members is conformable in vicinity of Chimney Rock and placed below lowest occurrence of sandstone with abundant, well-rounded clasts. Lower member is characterized by more abundant coarse-grained arkosic sandstone and conglomerate interbedded with siltstone and mudstone and minor fine-grained quartzose sandstone. Lower member has very few resistant beds and forms low rolling hills to west of uncomformable contact with underlying Proterozoic Sherman Granite (**YgSH**). Thin, discontinuous limestone bed containing chert nodules is exposed below base of unit just east of map area (Workman, 2008). Ichthyodith fossils indicate a maximum age of Mississippian for limestone but have a long range and could just as well be Pennsylvanian (A. Harris, written commun., 2005). Sando and Sandberg (1987) assigned similar limestones exposed at northern end of Laramie Range in Wyoming to Big Goose Member of Mississippian Madison Limestone of Peale (1893). Very coarse grained arkose conglomerates occur at base of unit. Maughan and Wilson (1963) indicated episodic uplift of Ancestral Front Range during the Permian and Pennsylvanian caused beveling and onlapping relationships towards flanks of uplift (southwest in this area) which caused local erosion both between upper and lower members and at contact with Casper Formation (**PPIc**). Upper member thins to south across map area, but poor exposure prevents confirmation of contact relationships. Estimated thickness of unit is 73 m near Sand Creek Pass. Knight (1929) reported a thickness of 134 m in vicinity of Chimney Rock. On west slope of Bull Mountain, where Fountain is thickest within Laramie River valley, Camp (1979) reported a thickness of 169 m for lower unit of formation and a total thickness of 212 m

Yd **Mafic dikes (Mesoproterozoic)**—Gray to black, fine- to medium-grained, sparsely porphyritic, ophytic to subophytic hornblende-biotite diorite and diabase dikes that form a northwest-trending dike swarm across much of northern Front Range. Composition varies locally and regionally, but generally consists of zoned and altered plagioclase phenocrysts in a matrix of pyroxene, hornblende, biotite, iron oxides, and alteration products. Dikes mostly exposed cutting Sherman Granite (1,412 ± 13 Ma, Aleinikoff, 1983), but cut Paleoproterozoic metamorphic rocks in some locations. Southeast of map area in Livermore Mountain quadrangle, correlative dikes are cut by main phase of granite of Log Cabin batholith (1,390 ± 30 Ma, Braddock and others, 1989) and by pegmatites of similar age (Braddock and Connor, 1988). Extent and orientation of dikes is largely mapped from aerial photographs in conjunction with field observations

YXp **Pegmatite (Mesoproterozoic? and Paleoproterozoic)**—Coarse to very coarse grained, white to pink, inequigranular leucogranitic intrusions forming dikes and small bodies. Contains quartz, plagioclase, microcline, and variable amounts of biotite and (or) muscovite. Graphic granite texture is common, and brecciation is extensive. Unit is poorly exposed and generally mapped based upon abundance in float material. Locally may include aplitic dikes. Age is poorly constrained within map area where unit only intrudes Paleoproterozoic rocks. In surrounding areas, Paleoproterozoic pegmatites related to Rawah batholith, as well as Mesoproterozoic pegmatites related to Log Cabin batholith, have been documented (Peterman and others, 1968; Cole and Braddock, 2009)

YgSH **Sherman Granite (Mesoproterozoic)**—Red to pink, coarse-grained, equigranular to mildly porphyritic hornblende-biotite syenogranite. Composed of quartz, microcline, oligoclase, 5–10 percent sodium-bearing hornblende and biotite, and accessory allanite, zircon, sphene, muscovite, and rutile. Quartz, microcline, and plagioclase form an interlocking matrix of anhedral grains with sparse phenocrysts of subhedral to euhedral microcline and smaller euhedral hornblende and biotite. Microcline contains inclusions of hornblende, rutile, biotite, quartz, and plagioclase. Hornblende contains abundant inclusions of sphene. Subtle alignment of tabular microcline phenocrysts is locally present, but poorly developed and not visible in thin-section (Burch, 1983). Rock is commonly found as weathered to rounded exposures and forms a pink grus of variable thickness composed of angular quartz and feldspar grains. Alteration is common with biotite replaced by magnetite, magnetite altered to hematite, and plagioclase altered to epidote and sericite. Extensive epidote alteration is present in Cow Creek area (southeast corner of quadrangle) extending from contact with older metamorphic rocks north for approximately 2 km. Altered rocks form a prominent topographic high with much less grus development.

Contacts with older intrusive and metamorphic rocks are generally sharp and characterized by a breccia zone up to 200 m wide cut by quartz and epidote veins. Southern boundary of Sherman Granite is defined by Cornelius Creek shear zone that is marked by zones as wide as 1,500 m of cataclastic deformation accompanied by extensive quartz veins and alteration (pattern on map). No mylonite fabric was observed within field area along structure. Brittle nature of this shear zone implies a post-Proterozoic age (Abbott, 1972). No Sherman Granite is exposed to south of shear zone, so main intrusive contact between Sherman Granite and Rawah batholith has been removed by faulting. Small inclusions (less than 1 mi) of older rocks are generally not found more than several meters from main intrusive contact. Due to greater erosional resistance of older granitic and gneissic rocks (**Ygbp** and **Xfl**) intruded by Sherman Granite, contact commonly lies at base of a steep ridge and is conveniently covered by an apron of colluvium derived from older rocks on ridgeline.

Apparent offsets west of map area along Sheep Creek fault zone imply that contact between Sherman Granite and older rocks to south dips to south-southeast below these older rocks and sub-parallel to structural grain in older rocks. Sherman Granite does not show evidence of solid-state foliation, nor does it appear to deform foliation in older metamorphic rocks; it truncates foliation and structural grain at most places along contact. Unit is cut by mafic dikes (**Yd**) within map area and by granite of Log Cabin batholith in southern part of Cherokee Park quadrangle (Eggler and Braddock, 1988) east of map area. U-Pb zircon age is 1,412 ± 13 Ma (Aleinikoff, 1983) and Rb-Sr isochron age is 1,430 ± 20 Ma (Zielinski and others, 1981)

Ygbp **Porphyritic hornblende monzogranite (Mesoproterozoic?)**—Tan to reddish-tan, fine-grained, seriamorphic, porphyritic hornblende monzogranite. Composed of fine-grained matrix of plagioclase, microcline, quartz, and minor amounts of hornblende and biotite with medium- to coarse-grained phenocrysts of predominantly quartz and hornblende and lesser amounts of microcline and plagioclase. Reddish color in some exposures comes from hematite alteration of hornblende and biotite. Unit is cut by Sherman Granite (**YgSH**) and cuts older metamorphic rocks (**Xfl** and **Xh**). Maximum relative age is uncertain, but unit lacks foliation and cuts across structural grain of Paleoproterozoic rocks to east in Diamond Peak quadrangle (Braddock and others, 1989), therefore a Mesoproterozoic age is assumed

XgR **Granite of Rawah batholith (Paleoproterozoic)**—Pink to gray, fine- to medium-grained, xenomorphic, inequigranular to equigranular, biotite granite. Composed of quartz, microcline (locally orthoclase present), plagioclase, biotite, magnetite, ilmenite, and, locally, hornblende. Accessory minerals are sphene, apatite, zircon, allanite, and, less commonly, sillimanite, rutile, and garnet. Secondary epidote or clinozoisite and muscovite are present along with local clay alteration. Biotite percentage varies widely from absent to 7.5 percent and biotite-poor phases are generally not foliated. Unit contains abundant inclusions of older metamorphic rocks. Hornblende grains (Xh) inclusions are commonly rotated with foliations not parallel to regional wall-rock foliation and structural trends. Included bodies range from centimeter- to kilometer-scale in main body of Rawah batholith south of map area (Burch, 1983). Biotite grains inclusions are rarer than hornblende grains inclusions and generally smaller. Inclusions of felsic gneiss may be common, but are difficult to recognize in the field due to similar composition and texture to granite of Rawah batholith. More geochemical work would be needed to clarify these relationships. Burch (1983) described biotite-rich foliated phases of Rawah batholith throughout its exposure in Front Range which have been reinterpreted as older felsic gneisses (Xfl) by Workman (2008) within Eaton Reservoir quadrangle to the east because their foliation parallels structure in older metamorphic rocks, and because these rocks are quite similar to biotite granite phases that are interlayered with hornblende gneiss (Xh).

Northern boundary of Rawah batholith is defined by Cornelius Creek shear zone, as described above. No granite of Rawah batholith is exposed to north of shear zone; therefore main intrusive contact between Rawah batholith and older metamorphic complex to north has been removed by faulting. McCallum and Hedge (1976) reported a whole-rock Rb/Sr age of 1,710 Ma. Correlative rocks south of map area along Cache la Poudre Canyon have produced a zircon age of 1,717 ± 8 Ma (W. Premo, written commun., 2005)

Xfl **Leucocratic felsic gneiss (Paleoproterozoic)**—Pink to red, fine-grained, leucocratic felsic gneiss. Composed of quartz, plagioclase, and microcline with less than 5 percent biotite and (or) hornblende and magnetite. Composition ranges significantly from aplitic rocks lacking any visible dark minerals to granitic gneiss containing significant hornblende or biotite. Map unit defined by greater than 50 percent leucocratic felsic gneiss where interlayered at centimeter- to meter-scale with unmapped hornblende gneiss and amphibolite (Xh), biotite felsic gneiss, and quartzofeldspathic biotite schist. Foliation defined by fine-scale compositional layering, by alignment of fine-grained biotite or hornblende crystals, and by elongated medium-grained porphyroblastic augen aggregates composed of intergrown fine-grained quartz and feldspar. Foliation is generally poorly defined and absent in more felsic, massive exposures. Strongly layered exposures are interpreted as felsic portion of Paleoproterozoic volcanic sequence that was strongly metamorphosed and foliated prior to intrusion of Rawah batholith (XgR). Zircon ages from SHRIMP analysis of sample collected to east of map area along Cherokee Park road indicate an age of primary volcanism at 1,766.6 ± 8.3 Ma (W. Premo, written commun., 2006). Current usage represents a field term for rocks of similar composition and texture

Xh **Hornblende gneiss and amphibolite (Paleoproterozoic)**—Dark-gray to black, fine- to coarse-grained, interlayered hornblende gneiss, amphibolite, and biotite-hornblende gneiss. Composed predominantly of hornblende with varying quantities of plagioclase and minor quartz and biotite and (or) magnetite, and rarer orthoclase; interpreted as mafic-composition metavolcanic rock. Map unit defined by greater than 50 percent hornblende gneiss or amphibolite where interlayered at centimeter- to meter-scale with unmapped leucocratic felsic gneiss (Xfl), biotite felsic gneiss, and quartzofeldspathic biotite schist. Lenses of calc-silicate gneiss and localized light- to dark-green alteration bands of epidote- or chlorite-bearing rocks are common.

Foliation in unit defined both by compositional layering, and alignment of elongate, prismatic hornblende crystals within a matrix of biotite and to euhedral plagioclase. Poikioblasts of hornblende contain small inclusions of opaque minerals, sphene, biotite, and epidote that parallel foliation. Less commonly, poikioblasts of plagioclase that contain inclusions of zircon, sphene, and hornblende form a spotted texture. Quartz and rare orthoclase occur as minor phases within matrix of rock between larger hornblende and plagioclase crystals. Plagioclase-poor and plagioclase-rich compositional layers 1–10 cm thick are common and define bands that outline tight recumbent folds with centimeter- to meter-scale amplitudes. Rocks of this unit are common as inclusions throughout the younger granite of Rawah batholith (XgR) and as small inclusions along contact zone with younger Sherman Granite (YgSH). Foliation and compositional layering are truncated by younger granite of Rawah batholith. Workman (2008) reported a U/Pb zircon age from SHRIMP analysis of exposures to east of map area along Beaver Creek that indicate an age of primary volcanism at 1,779 ± 5 Ma

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