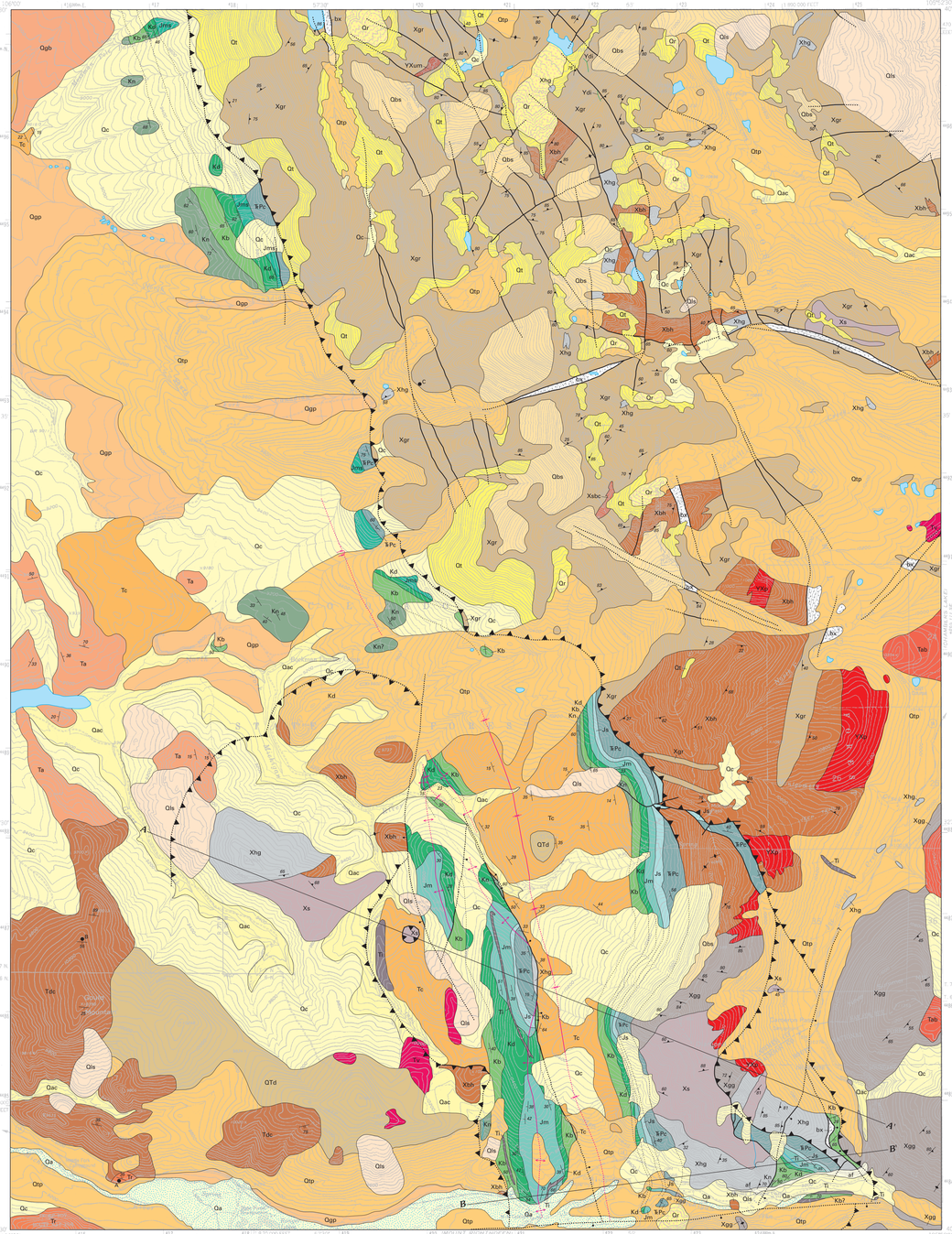
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY



Base from U.S. Geological Survey, 1977; revision by USDA Forest Service, 2000
Universal Transverse Mercator projection
10,000-foot grid ticks based on Colorado coordinate system, north zone
1,000-meter Universal Transverse Mercator grid ticks, zone 13
1927 North American Datum

APPROXIMATE MEAN DECLINATION, 2004

SCALE 1:24 000

CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

QUADRANGLE LOCATION

Geology mapped by K.S. Kellogg and C.A. Ruleman in 2005–2006, and R.R. Shroba in 2007

Digital database prepared by D. Paco Van Sistine

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

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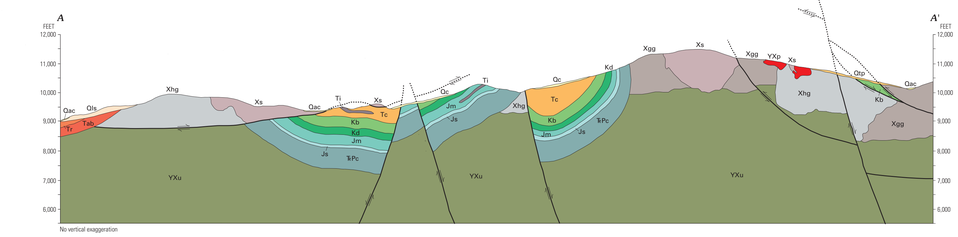
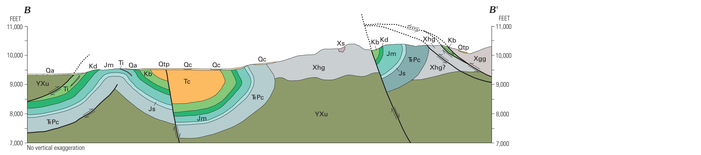
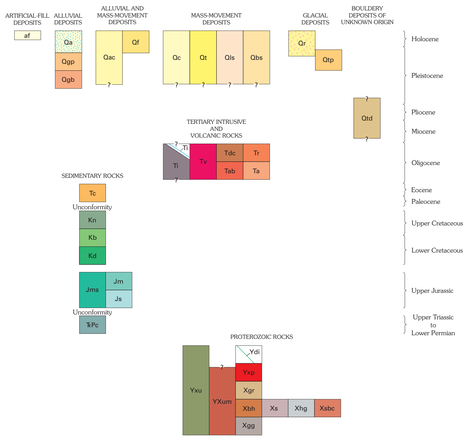


No vertical exaggeration



No vertical exaggeration

CORRELATION OF MAP UNITS



DIVISIONS OF QUARTERNARY AND NEOGENE TIME USED IN THIS REPORT

Period or Subperiod	Epoch		Age
Quaternary	Holocene		0–10 ka
	Pleistocene	late	11–32 ka
		middle	133–788 ka
		early	789 ka–1.81 Ma
Neogene	Pliocene		1.82–5.32 Ma
	Miocene		5.33–23.8 Ma

After Hansen (1991) with these exceptions: 133 ka (late–middle Pleistocene boundary) and 789 ka (middle–early Pleistocene boundary) from Richmond and Fullerton (1986); 1.82 Ma (Pleistocene–Pliocene boundary) from Lourens and others (1996); 5.33 Ma (Pliocene–Miocene boundary) and 23.8 (Miocene–Oligocene boundary) are from Berggren and others (1995). Ages are expressed in ka for kilo-annum (thousand years) and Ma for mega-annum (million years).

DESCRIPTION OF MAP UNITS

ARTIFICIAL-FILL DEPOSITS

af **Artificial fill (latest Holocene)**—Compacted material composed mainly of rock fragment and sand mapped only along and beneath Highway 14 near southeast corner of quadrangle. Estimated thickness greater than 1 m

ALLUVIAL DEPOSITS

Qa **Alluvium (Holocene and late Pleistocene)**—Mostly poorly sorted coarse sand and pebbly to boulders-cobble gravel in stream channels, flood plains, and low terraces. Flood plain and terrace deposits of Holocene age are commonly about 1 m or less above present stream. Unit may locally include a minor amount of colluvium (Qc), landslide deposits (Qls), glacial outwash (Qg), fan deposits (Qf), till of Pinedale age (Qtp), and organic-rich sediments in bogs and marshes. Low-lying areas are prone to periodic flooding. Mapped only along Michigan River near southern boundary of quadrangle. Estimated thickness 5–10 m

Qgp **Outwash gravel of Pinedale glaciation (late Pleistocene)**—Clast-supported alluvial deposits consisting chiefly of bouldery-cobble gravel derived almost entirely from Proterozoic basement. Forms gently sloping surface just north of Mosman Pole Patch Creek. Well-developed soil mantles deposit in most places. Grades to till of Bull Lake glaciation in Rawah Lakes quadrangle to the north. ^{10}Be and ^{26}Al analyses of surface boulders on moraines composed of till of Bull Lake age near Nederland, about 60 km south of quadrangle, yielded minimum age estimates of 101±21 and 122±26 ka (Schildgen and others, 2002). These age estimates are in accord with a uranium-trend age estimate of 130±40 ka for till of Bull Lake age (Shroba and others, 1983) near Allens Park, Colo., about 35 km southeast of quadrangle. Estimated thickness 10–15 m

ALLUVIAL AND MASS-MOVEMENT DEPOSITS

Qac **Alluvium and colluvium, undivided (Holocene to middle? Pleistocene)**—Chiefly undifferentiated alluvium (Qa), fan deposits (Qf), colluvium (Qc), and other mass-movement deposits along minor streams and on adjacent lower slopes. Low-lying areas of unit adjacent to stream channels may be subject to periodic stream flooding and debris-flow deposition. Commonly associated with dense grassy vegetation in meadows underlain by soils with thick, organic-rich surface horizons. Estimated thickness 3–15 m

Qf **Fan deposit (Holocene and late Pleistocene)**—Mostly poorly sorted, slightly bouldery-pebble and cobble gravel and probably lenses of pebbly and cobbly sand. Deposited chiefly by stream and debris flow and forms a small fan-shaped landform near northeast corner of quadrangle. Unit may include sheetwash deposits and hyperconcentrated-flow deposits. Thickness about 3–15 m

MASS-MOVEMENT DEPOSITS

Qc **Colluvium (Holocene to middle? Pleistocene)**—Non-sorted deposits that consist of clay, silt, sand, and angular to subrounded clasts that range in size from granules to large boulders. The composition of the deposits reflect that of either underlying or upslope bedrock or sediment from which the colluvium was derived. Deposits derived from shale, siltstone, and claystone contain more clay and silt than those derived from Proterozoic igneous and metamorphic rocks and may contain expansive clays and expand when wet and shrink when dry. Unit includes material transported by sheetwash, landslide, debris flow, hyperconcentrated flow, and possibly rock fall. Estimated thickness 3–50 m

Qt **Talus deposit (Holocene to middle? Pleistocene)**—Angular pebbles to large boulders deposited chiefly by rock fall, rock and snow avalanche, rock slide, debris flow, and snow-melt runoff. Deposits accumulate at base of cliffs and steep slopes where debris forms aprons, fan-shaped deposits, and cones. Locally includes debris-flow deposits, small protalus-rampart deposits, and tills of latest Pleistocene (Benedict, 1985; Davis, 1988) and Holocene age near cirque headwalls. Much of talus deposits in glaciated valleys and cirques postdates the retreat of Pinedale ice. Estimated thickness 3–15 m

Qls **Landslide deposit (Holocene to middle? Pleistocene)**—Deposits of unsorted and unstratified debris, on slopes or at base of slopes that are commonly characterized by hummocky topography. Younger deposits are commonly bounded upslope by crescent-shaped headwall scarps and downslope by lobate toes. Unit locally includes material displaced chiefly by rotational rock slides, rotational earth slides, debris slides, and earth flows as defined by Varnes and Cruden (1996). Landslide deposits are prone to continued movement or reactivation due to natural, as well as human-induced, processes. Deposits derived from clayey sedimentary rocks may contain expansive clays that expand when wet and shrink when dry. Locally includes minor rock-fall deposits. Estimated thickness 5–50 m

Qbs **Block-slope deposit (Holocene to middle? Pleistocene)**—Deposits on steep slopes (commonly greater than 10°) in north-central part of quadrangle composed chiefly of angular blocks of Early Proterozoic gneiss or granitic rock commonly as long as about 3 m but typically 0.5–1 m long. Block size probably decreases with increasing depth (White, 1981). Formed chiefly by freeze-thaw, frost creep, and other periglacial processes in non-glaciated alpine areas above an elevation of about 3,300 m. Most of deposits are relict features that probably formed chiefly under glacial and periglacial climatic conditions during the Pleistocene. Blocks at surface are interlocked and have voids between them that are open or contain a dark-brown stony material that is derived from freeze-thaw weathering of rock and deposition of eolian silt (loess). Composition of blocks and smaller rock fragments are the same as underlying bedrock. Small, unmapped deposits are common along some high ridges. Locally may include block-field deposits (on slopes of less than 10°), block-stream deposits ("rock stripes"), and talus deposits (Qt). Rates of movement of active block-field deposits on steeper slopes in the Front Range of Colorado are approximately 1–2 cm/yr (White, 1981). Estimated thickness less than 5 m

GLACIAL DEPOSITS

Qr **Rock-glacier deposit (Holocene and late Pleistocene)**—Bouldery, tongue-shaped masses of rock debris on valley floors and lobate masses along valley walls that commonly have steep fronts and flanks. Deposits consist of a veneer of angular boulders that overlies a thick mass of rock rubble that contains finer interstitial rock fragments. Deposits probably contain interstitial ice, ice lens, or ice core. Rock fragments on and within rock-glacier deposits are derived from steep slopes above rock glaciers, chiefly by rockfall and locally by rock slide and avalanche. Rock-glacier deposits locally include small protalus-rampart deposits, talus deposits (Qt) displaced by post-depositional flowage, colluvium (Qc), and other mass-movement deposits. Unit also may locally include till of Pinedale age (Qtp) and younger tills near cirque headwalls. Many rock-glacier deposits in Colorado are of latest Pleistocene or early Holocene age (Meierding and Birkeland, 1980). Rates of movement of active rock glaciers in the Front Range of Colorado are approximately 1–10 cm/yr (White, 1976; 1981). Estimated thickness at front of deposit 10–50 m

Qtp **Till of Pinedale age (late Pleistocene)**—Mostly non-sorted and non-stratified subangular to subrounded boulders to granules in a silty sand matrix. Material less than 2 mm in diameter is estimated to be 20–40 percent of unit. Unit locally forms large prominent, sharp-crested lateral and end moraines that are very bouldery and have distinct constructional morphology. Most of biotite-rich granitic and gneissic clasts within till are unweathered and granitic clasts are rare. Unit locally includes deposits of stratified drift and minor amounts of mass-movement deposits, younger tills of latest Pleistocene age (Benedict, 1985; Davis, 1988) near cirque headwalls, colluvium (Qc) and other mass-movement deposits, and alluvium (Qa). Locally may include till of Bull Lake age (late to middle Pleistocene) or older near lower limit of glaciation. Radiocarbon (^{14}C) and cosmogenic-exposure ages indicate that till of Pinedale age is about 12–30 ka (Nelson and others, 1979; Madole, 1986; Benson and others, 2005). Estimated thickness as much as 30 m

BOULDERY DEPOSITS OF UNKNOWN ORIGIN

QTd **Diamicton (early? Pleistocene to Miocene?)**—Unit consists of bouldery deposits that cap ridge and small hill above limit of Pinedale ice in southern part of quadrangle. Deposits are unsorted, unstratified, and rich in granitic and gneissic clasts as large as 3 m in diameter. Matrix is sandy and rich in feldspar and quartz. Pebbles and cobbles on deposits commonly are subrounded, and boulders have rounded edges. Unit may have been deposited by mass-movement (debris-flow), fluvial, or possibly glacial processes. Although unit now caps topographic highs, it is inferred to have accumulated in paleovalleys, resulting in inverted topography (valley-fill deposits are preserved on topographic highs and adjacent bedrock is deeply eroded and now forms topographic lows). Map unit along north side of Michigan River Valley locally includes small deposits of colluvium (Qc). Lower limit of unit is about 180–195 m above Michigan River. Estimated thickness of deposits is as much as about 150 m

TERTIARY INTRUSIVE AND VOLCANIC ROCKS

Ti **Intrusive porphyry (Oligocene?)**—Several small plugs, dikes, and sills composed of andesite porphyry, latite porphyry, quartz latite porphyry, dacite porphyry, and rhyolite porphyry (Braddock and Cole, 1990). Exposures poor; most occurrences mapped from colluvium derived from porphyry ("float"). Oligocene age inferred from dated Oligocene igneous rocks in area

Tv **Volcanic rocks, undivided (Oligocene)**—Mostly rhyolite and dacite; mapped where type of volcanic rock uncertain

Tdc **Dacite (Oligocene)**—Very light gray to pinkish-brown-gray, massive to weakly flow-foliated dacite porphyry flow. Phenocrysts include 1–3 percent euhedral sanidine, 10 percent plagioclase, 3–4 percent biotite, 1 percent hornblende, 0–1 percent clinopyroxene, 1–2 percent opaque minerals, and 1–2 percent secondary epidote. Matrix devitrified. Locally vesicular, with vesicles filled with white, chalky, fine-grained vapor-phase crystals. $40Ar/^{39}Ar$ age on sanidine from location B is 28.52±0.02 Ma (Knox, 2006)

Tr **Rhyolite (Oligocene)**—White, devitrified, massive to weakly flow-foliated rhyolite porphyry flow. Phenocrysts include 5–8 percent euhedral sanidine as long as 5 mm and trace biotite and opaque minerals. Contains numerous cavities as long as 4 mm filled with chalky white, fine-grained, vapor-phase crystals. Notable for absence of quartz phenocrysts. Devitrified matrix in most places is a fine-grained intergrowth of feldspar and quartz with sparse, scattered flecks of hematite. $40Ar/^{39}Ar$ age on sanidine from location A is 28.46±0.08 Ma (Knox, 2006). Sample from location A contains 75.4 percent SiO_2, 13.5 percent Al_2O_3, 0.5 percent total iron as Fe_2O_3, 0.2 percent MgO, 0.4 percent CaO, 3.1 percent Na_2O, 5.1 percent K_2O, 0.14 percent TiO_2, 0.09 percent P_2O_5, and 1.56 percent volatiles. Topography suggests rhyolite flow underlies dacite flow (Tdc)

Tab **Aphanitic alkalic basalt (lower Oligocene)**—Black, sparsely porphyritic, massive, dense, hard trachybasalt flows. Weathered surfaces are dark brown. Tops and bottoms of flows not exposed, and orientation uncertain due to lack of internal flow layering, so thickness unknown. Gorton (1953) describes rock as consisting of "small interlocking labradorite laths, slightly larger sanidine crystals, considerable interstitial augite, and a small amount of glass." Locally contains small phenocrysts of alkali feldspar, hornblende, and augite (Corbett, 1968). Laps onto flanks of Medicine Bow Mountains as high as about 3,400 m. Described as trachyandesite (Pearson and others, 1982; Corbett, 1968), but analysis indicates basaltic composition. Sample collected 1 km east of quadrangle along Highway 14 contains 51.7 percent SiO_2, 16.4 percent Al_2O_3, 9.75 percent total iron as Fe_2O_3, 3.22 percent MgO, 7.24 percent CaO, 3.72 percent Na_2O, 2.48 percent K_2O, 2.15 percent TiO_2, 0.76 percent P_2O_5, 0.13 percent MnO, and 2.06 percent volatile material. $40Ar/^{39}Ar$ whole-rock age is 29.58±0.22 Ma (Knox, 2006)

Ta **Andesite flows (lower Oligocene)**—Dark greenish-gray, devitrified, massive, almost aphyric to porphyritic, non-vesicular to strongly vesicular (near top of flows) andesite, trachyte, and dacite. Dacite contains about one percent quartz and biotite phenocrysts. Trachyte contains about one percent small (less than one mm in diameter) plagioclase phenocrysts in a strongly trachytic matrix (fluidal mass of aligned plagioclase needles). Compositional average of three analyses is 59.2 percent SiO_2, 16.6 percent Al_2O_3, 7.1 percent total Fe as Fe_2O_3, 0.7 percent MgO, 3.7 percent CaO, 3.9 percent Na_2O, 3.9 percent K_2O, 1.3 percent TiO_2, 0.7 percent P_2O_5, and 2.5 percent total volatiles. Consists of at least three flows (probably considerably more); base not exposed. Undated, but underlies rhyolite tuff (Trv) and on basis of dates on similar rock in northern Mummy Range south of the quadrangle (Knox, 2006), is probably about 28–29 Ma. More that 100 m thick

SEDIMENTARY ROCKS

Tc **Coalmont Formation (Eocene and Paleocene)**—Gray, dark-gray, brownish-gray and brown, thin-bedded to thick-bedded shale, arkosic sandstone, and conglomerate. Locally carbonaceous. Sandstone commonly contains abundant, yellow limonitic spots. Conglomerate contains clasts as large as 1.5 m (typically much smaller) of predominately Proterozoic rocks. Some finer-grained conglomerates contain mafic to intermediate volcanic clasts. Beds typically 1–3 m thick. Unconformably overlies Niobrara Formation (Kn) or Benton Shale (Kb). Top not exposed. Poorly exposed in most places and susceptible to landsliding on steeper slopes. About 525 m of lower part of formation preserved in syncline in south part of quadrangle (Braddock and Cole, 1990)

Kn **Niobrara Formation (Upper Cretaceous)**—Light- to dark-gray, platy, calcareous, marine shale. Weathered surfaces very light-gray and platy. Contains gray, fine-grained limestone beds near base. Conformable above Benton Shale (Kb). At least 140 m thick

Kb **Benton Shale (Upper and Lower Cretaceous)**—Predominantly black siliceous and non-siliceous marine shale with thin bentonite seams and thin, fine-grained sandstone beds. The Benton Shale (also mapped elsewhere as Benton Group or Benton Formation) encompasses the black-shale dominated sequence below Niobrara Formation (Kn) and above Dakota Sandstone (Kd). In the Laramie River valley and North Park basin, the upper, approximately 75 m is assigned to Frontier Formation (Shaw, 1957; Camp, 1979) and consists of dark-gray calcareous shale capped by about 3 m of tan to buff, fine-grained, bioturbated sandstone, the Wall Creek Sandstone Member of the uppermost Frontier Formation (Shaw, 1957). The Frontier Formation, a term used more commonly in Wyoming, is nearly equivalent to the Carlile Shale, Greenhorn Limestone, and upper part of the Graneros Shale of the Denver area (Merewether and Cobban, 1985). The lower, approximately 45 m consists of dark-brown to black, wavy-bedded, non-calcareous, fissile, rusty shale containing fish scales, equivalent to Upper and Lower Cretaceous Mowry Shale on eastern side of Front Range in Colorado (Braddock and Cole, 1990). Benton Shale is conformable above Dakota Sandstone (Kd). Most Benton Shale rocks are poorly exposed. Total thickness of unit about 120 m

Kd **Dakota Sandstone (Lower Cretaceous)**—Light-gray to light-brown, very fine grained to medium-grained, thin- to very thick bedded, locally ripple-marked, resistant quartz sandstone. Upper sandstone equivalent to Muddy Sandstone, as defined in Laramie Basin of Wyoming (Mallory, 1972). Middle part contains gray, carbonaceous shale beds, equivalent to Thermopolis Shale of Wyoming and North Park (Shaw, 1957; Mallory, 1972) and Skull Creek Member of South Platte Formation of Dakota Group in northeastern Front Range (Mallory, 1972). Lower sandstone, equivalent to Lytle Formation of Dakota Group in northeastern Front Range (Scott, 1972), contains lenticular, chert-pebble conglomerate beds in lower part. Thickness 25–75 m; thinned considerably by faulting along State Highway 14 in southern part of quadrangle. Unconformable above Morrison Formation

Jms **Morrison Formation (Upper Jurassic) and Sundance Formation (Upper Jurassic), undivided**—Mapped in northern part of quadrangle where exposures are poor. Most exposures are of Morrison Formation

Jm **Morrison Formation (Upper Jurassic)**—Greenish-gray, gray, and grayish-red silty claystone, gray, thin-bedded, fine-grained sandstone, and a few gray, discontinuous, dense limestone beds. Conformable above Sundance Formation (Js). Environment of deposition was slow-moving rivers, fresh-water lakes, and swamps. Thickness about 90 m

Js **Sundance Formation (Upper Jurassic)**—Light-tan, fine- to very fine grained, well-sorted sandstone and laminated siltstone. Grains mostly quartz with a few percent white feldspar grains. Equivalent to Canyon Springs Sandstone Member of Sundance Formation in Wyoming (Braddock and Cole, 1990) and along eastern side of northern Front Range (Pipiringos and O'Sullivan, 1976). Weathered surfaces are yellowish-tan. Environment of deposition was near-shore marine (margin of Jurassic "Sundance Sea") (Peterson, 1994). Unconformable above Jdm? Formation. Thickness about 40 m

ŦPc **John? Formation (Upper Triassic), Chugwater Formation (Middle and Lower Triassic), Forelle Limestone (Upper Permian), and Satanka Shale (Middle and Lower Permian), undivided**—Reddish-brown to reddish-orange, thin- to medium-bedded, micaceous shale, siltstone, fine- to medium-grained sandstone, and algal limestone. Map unit locally includes several meters of an upper, light-orange, medium-grained, crossbedded sandstone, possibly southern trailing edge of Upper Triassic Jdm Formation. Chugwater Formation contains interbedded reddish sandstone, siltstone, and shale. Lower part of map unit consists of red, sandy shale and siltstone of Satanka Shale, the top of which contains 1- to 2-m-thick, fine-grained, light-gray to white, wavy-laminated algal limestone correlated with Upper Permian Forelle Limestone. Fossils near Laramie, Wyoming indicate that Satanka is Middle to Lower Permian (Chen and Boyd, 1997). This grouped unit is equivalent to Chugwater Formation as mapped by Braddock and Cole (1990). Unit is, in part, equivalent to red beds of the Middle and Lower Triassic Lykins Formation of eastern Front Range (for example, Brain, 1957). Lies unconformably on Proterozoic basement rocks. Environment of deposition was shallow, near-shore marine and marginal mud flats (sabkhas). Thickness about 180–240 m

PROTEROZOIC ROCKS

YXu **Middle and early Proterozoic rocks, undivided**—Shown on cross section only

Ydi **Diabase dike (Middle Proterozoic)**—Dark-gray to black, locally dark-greenish-gray, fine- to medium-grained mafic dikes with a diabasic to subophitic, locally porphyritic texture. Rocks are strongly altered and contain plagioclase (locally as phenocrysts), as much as 39 percent actinolite, 0–10 percent quartz, opaque minerals, and secondary biotite and chlorite (Griswold, 1980). Two northwest-striking dikes are mapped in quadrangle and are parallel to a dominant northwest-trending fault set. Dikes are correlated with a much more extensive northwest-trending diabase-dike swarm to east in northern part of Front Range that are about 1,400 Ma (Kellogg, 1973)

YXum **Metapyroxenite (Middle or Early Proterozoic)**—One small body of black, massive, medium-grained metapyroxenite 1.5 km west of Timber Lake in northern part of quadrangle (Griswold, 1980)

YXp **Pegmatite and aplite (Middle or Early Proterozoic)**—Pegmatite is coarse- to very coarse grained, white to light-pink, inequigranular plagioclase-microcline (or perthite)-quartz-mica rock that forms irregular-shaped, commonly zoned dikes and intrusive bodies that cut Early Proterozoic rocks of Rawah batholith (Xgr). Mica is mostly biotite, but locally includes or is entirely muscovite. Accessory minerals include tourmaline and opaque minerals. Unit consists predominantly of pegmatite, which commonly grades into and is intimately mixed with aplite, which also forms separate dikes and bodies. Aplite is similar in composition to pegmatite but is a pinkish-tan, fine- to medium-grained, leucocratic, equigranular rock. Pegmatite and aplite may be late-stage intrusions associated with rocks of ~1,720 Ma Rawah batholith

Xgr **Granitic rocks of Rawah batholith (Early Proterozoic)**—Gray to pinkish-gray, equigranular to inequigranular, medium- to coarse-grained, biotite-plagioclase, monzogranite or granodiorite, although Griswold (1980) reports early phases of quartz diorite, tonalite, and trondhjemite. Locally serial porphyritic, with microcline phenocrysts as long as two cm. Massive to moderately foliated. Contains numerous inclusions of biotite schist and gneiss (Xs), biotite-hornblende gneiss (Xbh), hornblende gneiss (Xhg), ultramafic rocks (YXum), and sillimanite-biotite-cordierite gneiss (Xsbc). Age from slightly foliated sample at location C is 1,755±23 Ma, interpreted either as an inherited zircon age or age of large granitic gneiss (Xgg) inclusion (W.R. Premo, unpub. data, 2005). Sample from Poudre Canyon, about seven km northeast of quadrangle's northeastern corner is 1,717±8 Ma, and another sample from Rawah Lakes area, about 5 km north of quadrangle, is 1,721±15 Ma, and are considered to represent crystallization age of the Rawah batholith (W.R. Premo, unpub. data, 2005)

Xbh **Biotite-hornblende gneiss (Early Proterozoic)**—Light- to dark-gray and black, medium-grained, layered to uniform textured, weakly to strongly foliated biotite-hornblende-plagioclase gneiss. In most places, consists of finely interlayered biotite gneiss and schist, hornblende gneiss, and amphibolite. Felsic layers locally contain as much as 10 percent microcline. Occurs both as inclusions of variable size in monzogranite of Rawah batholith (Xgr) and as large body in southeastern part of quadrangle. Sample from similar biotite-hornblende gneiss from Ninilchik quadrangle, about 25 km northeast of northeast corner of quadrangle, considered to be part of same unit, is 1,735±14 Ma (W.R. Premo, unpub. data, 2007)

Xs **Biotite-muscovite schist and gneiss (Early Proterozoic)**—Consists of alternating layers of contrasting composition including black to dark-gray, medium- to coarse-grained layers rich in biotite, muscovite, sillimanite, and magnetite; and gray to white layers consisting of quartz, feldspar, and variable amounts of biotite. Protolith consisted of alternating beds of shale, siltstone, and sandstone (Braddock and Cole, 1990). Layers typically discontinuous and form tight to isoclinal, rootless folds. Forms two large bodies in southern part of quadrangle that may be continuous under Phanerozoic rocks. Undated, but probably approximately coeval with ~1,735 Ma biotite-hornblende gneiss (Xbh)

Xhg **Hornblende-plagioclase gneiss and amphibolite (Early Proterozoic)**—Dark-gray to black, weakly to strongly foliated, layered, mostly medium-grained, hornblende-plagioclase gneiss and amphibolite locally containing variable amounts of biotite, quartz, and augite. Commonly has black-and-white mottled texture due to weathered plagioclase (white) and hornblende (black). Amphibolite contains greater than 50 percent amphibole. Hornblende-plagioclase gneiss contains interlayered amphibolite, and may contain minor calc-silicate gneiss. Commonly intimately interlayered with more felsic gneissic rocks, especially biotite-hornblende gneiss (Xbh), so many occurrences of unit Xhg are included with these units. Undated, but considered coeval with ~1,735 Ma biotite-hornblende gneiss (Xbh)

Xsbc **Sillimanite-biotite-cordierite gneiss (Early Proterozoic)**—One small body of pink to brownish-gray, medium- to coarse-grained sillimanite-biotite-cordierite gneiss mapped in central part of quadrangle (Griswold, 1980). Forms a xenolith within granitic rocks of Rawah batholith (Xgr). Rock is well foliated and typically tightly folded, with light and dark layers depending on biotite content. Undated

Xgg **Granitic gneiss (Early Proterozoic)**—Gray, medium- to coarse-grained, moderately to strongly foliated gneiss of monzogranitic to tonalitic composition. Contains abundant dark-gray to black biotite- and biotite-hornblende-rich, lenticular to diffuse segregations as large as several tens of meters long oriented parallel to foliation. Foliation mostly steep and strikes northeast. Generally more mafic than monzogranite of the Rawah batholith (Xgr), although in some places closely resembles rocks of batholith. Consequently, contact between the two is poorly defined and granitic gneiss may include some intrusive rocks of Rawah batholith. Protolith may be either a felsic volcanic rock or arkosic sedimentary rock in roof pendants or wall rock adjacent to batholith. Sample from Poudre Canyon at Poudre Falls, seven km northeast of quadrangle's northeast corner, is 1,763±6 Ma (W.R. Premo, unpub. data, 2007). Plymate and others (2005) called equivalent rocks "felsic gneiss" in Comanche Peak quadrangle to east and obtained a U-Pb zircon age of 1,764±12 Ma, coeval with other Early Proterozoic metamorphic rocks that represent part of oldest juvenile crust in northern Colorado (Premo and Fanning, 2000)

Contact—Dashed where approximately located; dotted where concealed

Fault types

Fault—Tick shows direction of dip of fault where known; dotted where concealed

Normal—Dotted where concealed

Thrust—Dotted where concealed; sawteeth on hanging wall

Anticline—Dotted where concealed

Syncline—Dotted where concealed

Overturned syncline—Dotted where concealed

Strike and dip of bedding

Inclined bedding

Vertical bedding

Overturned bedding

Inclined foliation in metamorphic bedding

Vertical or near-vertical foliation in metamorphic bedding

Fracture cleavage

Sample location

Breccia zone (bx)

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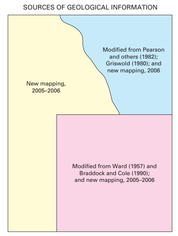
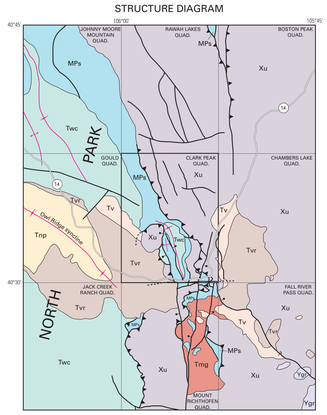
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