



Coordinate System: NAD 1983 UTM Zone 13N
Projection: Transverse Mercator
Datum: North American 1983

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Unit	Color	Symbol	Notes
Qa1	Light yellow	Circle	Artificial fill (uppermost Holocene)
Qa2	Light brown	Square	Alluvium one (Upper Holocene)
Qa3	Light green	Triangle	Alluvium two (Middle to Lower Holocene)
Qa4	Light blue	Diamond	Alluvium three (Lower Holocene to Upper Pleistocene)
Qa5	Light purple	Star	Sheetwash alluvium (Holocene and Upper Pleistocene)
Qa6	Light orange	Cross	Gravel one (Upper Middle Pleistocene)
Qa7	Light pink	Circle with cross	Gravel, undivided (Pleistocene?)
Qa8	Light red	Square with cross	Mass-wasting deposits
Qa9	Light green	Circle with cross	Eolian deposits (Holocene to Upper Pleistocene?)

ADJOINING QUADRANGLES

U.S. Census Bureau, 2016-2016
Names, 2016-2016
Hydrography, 2016-2016
Boundaries, 2016-2016
Public Land Survey System, 2016-2016

Geology mapped in 2022
GIS and cartography by Pangaea Geospatial

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DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

Descriptions of soil-carbonate morphology are after Machette (1985) and Birkeland (1999). Water-well data is compiled from Colorado Division of Water Resources (DWR), 2023. Oil- and gas-well data is compiled from Colorado Energy and Carbon Management Commission (ECMC), 2023.

HUMAN-MADE DEPOSITS

af Artificial fill (uppermost Holocene) — Artificial fill includes riprap and fill material placed during the construction of roads, railroads, buildings, dams, reclamation of quarry areas, and disturbed areas like active quarries. The unit is poorly sorted clay, silt, sand, and gravel fragments. Artificial fill may be locally present in residential or commercial areas but may not be thick enough to map. Fill materials can vary in particle size and may locally include refuse of many types like household and industrial waste. Artificial fill may be subject to settlement, slumping, and erosion if not adequately compacted and (or) if it is placed on unstable slopes. The unit is as much as 7 m thick.

ALLUVIAL DEPOSITS

Qa1 Alluvium one (Upper Holocene) — The unit is mostly moderately to well-sorted silt to medium sand that is generally brown to very dark brown. Alluvium one underlies modern stream channels and low-lying terraces up to 1.5 m high above adjacent streams. An exposure along the Big Thompson River at NW ¼, sec. 21, T. 5 N., R. 68 W. has approximately 1.7 m of unit Qa1 underlain by clast-supported gravel that is presumed to be unit Qa1. The gravel clasts are round to subround and as much as 13 cm in diameter. There are no carbonate rinds on the clasts. The gravels are weakly imbricated. Secondary carbonate is present near the contact of the overlying finer-grained alluvium with the underlying gravelly alluvium. The carbonate is likely deposited, in-part, by groundwater. Sample LV-WOS-01 was collected at this location approximately 0.6 m below ground surface (bgs) and was analyzed by optically stimulated luminescence (OSL) techniques. The sample yielded an age estimate of 340 ± 15 yrs BP. A radiocarbon sample collected from Qa1 along the Little Thompson River in the Berthoud quadrangle yielded an age estimate of $1,530 \pm 30$ yr BP (Keller and others, 2017). The unit is a potential source of sand and gravel. Areas underlain by the unit have a 1% annual chance of flooding (Zone A and Zone AE) as mapped by the Federal Emergency Management Agency (FEMA, URL link in references). Unit Qa1 may be interbedded with units Qaf and Qsw locally. The unit may be as much as 4 m thick.

Qa2 Alluvium two (Middle to Lower Holocene) — The unit is chiefly poorly sorted, massive clay, silt, and sand. Unit Qa2 is brown to yellowish-brown. Discontinuous gravel beds as much as 7.5 cm thick are present locally. Unit Qa2 is also exposed in a quarry in SE ¼, sec. 16, T. 5 N., R. 69 W. Here, the unit is underlain by clast-supported gravel (unit Qa1). At this site, a soil with a moderately developed Bt horizon and Stage 1+ to II B horizon is exposed. The unit is correlative with unit Qa1 of nearby quadrangles mapped by the Colorado Geological Survey (CGS). Areas underlain by the unit have a 1% annual chance of flooding (Zone AE) and 0.2% annual chance flood hazard or areas of 1% annual chance flood with an average depth less than one foot or with drainage areas of less than one square mile (Zone X), as mapped by the Federal Emergency Management Agency (FEMA, URL link in references). The unit is as much as 1.8 m thick.

Qa Alluvium, undivided (Holocene) — The unit is chiefly comprised of moderately sorted silt to medium sand and is brown to yellowish-brown. Deposits are typically homogeneous, but discontinuous pebble-gravel lenses may be present locally. Carbonate development up to Stage II may be present locally. The unit underlies ephemeral drainages in the northwest part of the mapped area and Fossil Creek. Samples LV-CW-01, collected from an exposed terrace deposit in Fossil Creek (NW ¼, sec. 18, T. 6 N., R. 68 W.) and LV-RENA-01, collected in an exposed terrace deposit in SW ¼, sec. 23, T. 5 N., R. 69 W., were analyzed by OSL techniques. Sample LV-FWC-01 was collected approximately 2 m bgs and yielded an age estimate of $2,940 \pm 270$ yrs BP. Sample LV-RENA-01 was collected approximately 1.1 m bgs and yielded an age estimate of $1,500 \pm 70$ yrs BP. The area is not mapped by FEMA, but areas underlain by the unit may be prone to stream flooding. The unit is likely as much as 1.5 m thick.

Qa3 Alluvium three (Lower Holocene to Upper Pleistocene) — The unit is light brown, light brownish-gray, pale brown, brown, and yellowish-brown. Unit Qa3 consists of clast-supported, pebbles to cobble-gravel and moderately sorted silt to sand. Sandy facies are planar- or cross-bedded. Sand lenses are discontinuous and as much as 0.5 m thick. Channel cut-and-fill structures are present in the unit. Gravel beds and lenses are discontinuous and as much as 2.5 m thick. Clasts are subround to round, as much as 13 cm in diameter, and imbricated locally. No carbonate rinds or secondary carbonate have formed on gravel clasts or within the matrix. Clasts are predominantly white granitic rocks with lesser amounts of metamorphic gneiss and quartzites derived from Precambrian bedrock west of the mapped area. Other clasts consist of sedimentary rocks, mostly sandstone, derived from nearby sedimentary bedrock. The unit is a source of sand and gravel.

A gravel quarry in SE ¼, sec. 16, T. 5 N., R. 69 W. exposes the unit. Here, two samples, LV-LRM-01 and LV-LRM-03, were collected from sandy facies and analyzed by OSL techniques. Sample LV-LRM-01 was collected approximately 4 m bgs and yielded an age estimate of $15,625 \pm 900$ yrs BP. Sample LV-LRM-03 was collected approximately 2.7 m bgs and yielded an age estimate of $12,780 \pm 1,025$ yrs BP. The unit is correlative with unit Qa3 of other nearby CGS maps and Broadway Alluvium of nearby USGS geologic maps; unit Qa3 was mapped as Broadway Alluvium by Cole and Braddock (2009). Units of this age are correlative with the Pinedale glaciation, which began around 30 ka (Kellogg and others, 2008), potentially earlier (Madole and others, 2010), and culminated by 12 ka (Kellogg and others, 2008). The unit is as much as 6 m thick.

Qsw Sheetwash alluvium (Holocene and Upper Pleistocene) — The unit is mapped in one location in the northwest part of the quadrangle. It is comprised chiefly of sediment derived from the Pierre Shale and is yellowish-brown, olive-brown, or grayish in color. Sheetwash alluvium is deposited by overland flow during periods of higher-than-normal precipitation and is chiefly mud, clay, and fine sand. There are likely other areas in the quadrangle that are mantled by sheetwash alluvium, but the unit is not thick enough to map. The unit is not a potential source of sand or gravel. Areas underlain by the unit may be prone to hazards related to flooding, expansive soils, and collapsible soils. Unit Qsw is as much as 1.5 m thick.

Qg1 Gravel one (upper Middle Pleistocene) — The unit is poorly exposed in the mapped area and almost completely mantled by eolian sediment (unit Qe). In nearby quadrangles, the unit is chiefly clast supported, pebble- and cobble-gravel and silty sand and varies widely in color; dark brown, very dark-brown, yellowish-brown, dark yellowish-brown, and pinkish gray. The unit underlies surfaces at two elevations, 14 m and 17 m above the modern stream channel. Cole and Braddock (2009) mapped the unit as Slocum Alluvium. The unit is correlative with other Qg1 deposits mapped along the Front Range by CGS. Unit Qg1 may be a local source of sand and gravel and is as much as 9 m thick, but usually less.

Qg2 Gravel, undivided (Pleistocene?) — Shown in cross-section only. The unit consists of unit Qg1 and old gravelly alluvium identified in geotechnical boreholes and DWR well-logs.

MASS-WASTING DEPOSITS

Qaf Alluvial-fan, debris-flow, and stream-alluvium deposits, undivided (Holocene) — The unit is brown, yellowish-brown, or olive-brown, poorly sorted silt, sand, and matrix-supported pebble gravel. The unit is poorly exposed in the mapped area. Sediments comprising the unit are deposited in fan-shaped lobes at the base of relatively steep, relatively short drainages. Clasts and sand grains are locally derived, primarily from the Pierre Shale but may locally include gravel clasts where gravelly alluvium is present in the source areas. Areas underlain by unit Qaf may experience debris flows or sediment-laden stream and overland-flow floods in the future. The unit is not a potential source of sand or gravel and is as much as 2 m thick.

Qaf2 Old alluvial-fan, debris-flow, and alluvium deposits (Upper Pleistocene?) to upper Middle Pleistocene) — The unit is chiefly brown to yellowish-brown, poorly sorted silt, sand, and matrix-supported, pebble gravel. Gravel clasts are predominantly angular to subangular and derived from local sandstone bedrock units. Pebble gravel lenses as much as 3 cm thick are typically discontinuous. Less than 5% of clasts are derived from igneous and metamorphic Precambrian bedrock sourced west of the quadrangle. The unit underlies surfaces at roughly three elevations, indicating there was episodic deposition and stream downcutting during the Pleistocene. Less than 1 km northwest of the mapped area, the unit is exposed in a trench. Here, the unit is comprised of poorly sorted, matrix-supported, pebble- to cobble-gravel with clasts as much as 20 cm in diameter.

The unit was mapped as Slocum Alluvium by Cole and Braddock (2009). Although there may be alluvium facies within the units, locally, it is primarily fan alluvium and underlies surfaces with fan, apex, and lobate geomorphology; therefore, the deposits are mapped as unit Qaf2. Two samples, LV-LCL-01 and LV-LCL-02, were collected for age dating near the northwest corner of the mapped area. They were both analyzed by infrared stimulated luminescence techniques. Sample LV-LCL-01 was collected approximately 0.7 m bgs and yielded an age estimate of 17.8 ± 1.86 ka. The former age is much too young for the deposit. Owing to it being within 1 m of the ground surface, potential contamination from younger wind-blown sediment or reworking, pedogenic processes, or biotic processes could result in a younger age. The latter age falls within current age estimates of the Slocum Alluvium or Louviers Alluvium (Bull Lake glaciation). Uranium-series dating of a fossil horn core collected from a deposit mapped as Slocum Alluvium near Canon City, CO, yielded an age estimate of $160,000 \pm 60,000$ yr (Szabo, 1980). The IRSL age estimate falls in the age range reported by Szabo (1980) and is roughly correlative with previous age estimates of the Slocum Alluvium at the same site as the fossil horn core was collected (Scott and Lindvall, 1970; Lewis, 1970). Conversely, the sample may be correlative with the Bull Lake glaciation (170 to 120 ka) and the Louviers Alluvium mapped in the area (Kellogg and others, 2008). The unit may be a local source of sand or gravel and is as much as 3.7 m thick.

EOLIAN DEPOSITS

Qe Eolian deposits (Holocene to Upper Pleistocene?) — The unit is chiefly comprised of moderately to poorly sorted, silt to medium sand. Unit Qe varies in color; yellowish-brown, light yellowish-brown, brown, light-brown, tan, and reddish-brown. The unit is poorly exposed in and mantles much of the southern and eastern portions of the mapped area; however, it is well-exposed in the DWR well logs (URL in references), geotechnical boreholes, and in nearby quadrangles mapped by CGS. Secondary carbonate is present in unit Qe in nearby quadrangles and the unit likely contains varying degrees of soil development within the Loveland quadrangle. Eolian sediment (unit Qe) is not a potential source of sand in the mapped area. Areas underlain by the unit may be prone to hazards associated with collapsible soils. As much as 6 m of eolian sediment mantles the other surficial and bedrock units in the quadrangle.

BEDROCK GEOLOGY

Pierre Shale (Upper Cretaceous)

Qps Upper member (Upper Cretaceous) — The unit consists of valley-forming, gray silty shale and friable, yellow to yellowish-brown sandstone. Concretions are present in the unit. The sandstone within the unit may be correlative with unit Kpus in the Berthoud quadrangle (Keller and others, 2017). Eolian sediment (unit Qe) mantles most of the upper member of the Pierre Shale. Soils derived from unit Kpu are typically grayish-green, gray, or light olive-brown in color. The unit contains index fossil ammonites *Baculites cinnabarinus*, *Baculites grandis*, *Baculites baculus*, *Baculites eliasi*, and *Baculites jenseni* (Scott and Cobban, 1965). Areas underlain by the Pierre Shale are prone to hazards related to expansive soils. The upper member of the Pierre Shale is as much as 853 m thick.

Kpsu Larimer, Richard, and Rocky Ridge members and intervening shales (Upper Cretaceous) — The unit is comprised of yellow to tan, moderately indurated sandstone. Sandstones are interbedded with friable shales. Interbedded shales weather to a grayish-green, gray, or light olive-brown color. Sandstones are well-exposed in sec. 14 and sec. 23, T. 6 N., R. 69 W. Here, brownish concretions, some containing a shell, are present and abundant. Also present in these outcrops are ophiomorphia burrows and other trace fossils. The unit contains index fossil ammonite *Baculites resisteri* (Scott and Cobban, 1965). Soils derived from the shales in this unit may be prone to hazards associated with expansive soils. The three members and interbedded shales are approximately 79 m thick.

Kgm Middle shale member (Upper Cretaceous) — The unit is comprised of erodible, valley-forming, greenish-gray claystone and sandy siltstone that does not crop out well in the mapped area. Bentonite beds are present locally. Index fossil ammonites *Baculites curvatus*, *Baculites compressus*, *Dalmanites cheyennense*, *Ectoceras jennys*, *Dalmanites stewarti*, and *Dalmanites adrianae* are present in this member (Scott and Cobban, 1965). Soils derived from the member may be prone to hazards related to expansive soils. The unit is as much as 218 m thick.

Kpmu Middle, Larimer, Richard, Rocky Ridge, and Upper members, undivided (Upper Cretaceous) — Shown in cross section only.

Kgm Hygiene Sandstone member (Upper Cretaceous) — The upper part of the member is well-indurated, light-gray, sandstone. The middle part of the unit is friable, gray siltstone. The lower part of the unit is weakly indurated gray sandstone that contains concretions. Much of the unit is mantled by alluvium, old fan alluvium, and eolian deposits. The sandstone facies of the member does not crop out well in the mapped area. Index fossil ammonites *Baculites scotti* and *Baculites gregoryensis* are present in the member (Scott and Cobban, 1965). The unit is estimated to be approximately 213 m thick but can range from 183 to 244 m thick.

Kpsl Lower member (Upper Cretaceous) — The unit is comprised of dark olive-brown, valley-forming shale and sandy shale. Concretions are present locally. Bentonite beds are present in the lower portion of the member. The unit is not well-exposed in the mapped area because it is easily eroded. Index fossils *Baculites perplexus*, *Baculites asperifrons*, *Baculites melarni*, and *Baculites obesus* are present in the unit (Scott and Cobban, 1965). Soils derived from the unit may be prone to hazards related to expansive soils. Regionally the member is as much as 579 m thick. However, the ECMC well logs indicated the unit is 862 to 903 m thick, thinning to the east.

Kn Niobrara Formation (Upper Cretaceous) — In the region, two members make up most of the unit: the Fort Hays Limestone member at the bottom and the Smoky Hill Shale member above. The lower member is not present in the mapped area but is mapped just west of the quadrangle boundary in the Masonville quadrangle (Braddock and others, 1970). In the quadrangle, the unit crops out as moderately indurated, yellowish-brown, sandy limestone in location on the western part of the mapped area. The member forms prominent hogbacks along the Front Range. Oil and gas well logs indicate the unit is approximately 100 m thick.

Kcpo Colorado Group (Upper Cretaceous) — Includes the Carlile Shale (shale and sandstone), Graneros Shale (shale interbedded with sandstone), and Greenhorn Limestone (shale, chalky-shale, and limestone). Approximately 120 to 140 m thick.

MPu Mesozoic and Paleozoic formations, undivided (Mesozoic to Paleozoic) — Lower Cretaceous to Paleozoic ages formations, undivided. Colorado Energy and Carbon Management Commission (ECMC, link in references) well logs do not record tops.

MAP SYMBOLS

— Contact — Identity and existence certain, location accurate; dashed where approximately located

— Fault — Existence certain, location approximate

Land Use Review soil boring

City of Loveland soil boring

Water well — Well number and drill-log data from Colorado Department of Water Resources well permit map viewer (CO DWR, link in references).

Oil and Gas Well — Label is the American Petroleum Institute (API) Unique Well Identifier. Label does not include preceding State Code (05) and County Code (069 for Larimer County) (CO ECMC, link in references).

Strike and dip of inclined bedding — Showing direction and angle of dip

Strike and dip of inclined bedding determined from imagery — Showing direction and angle of dip

Optically stimulated luminescence (OSL) sample site

Alignment of cross section

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