



## DESCRIPTION OF MAP UNITS

### SURFICIAL DEPOSITS

#### HUMAN-MADE DEPOSITS

**af** Artificial fill (Upper Holocene) — Riprap, fill, and refuse placed during construction of roads, railroads, buildings, dams and landfills. Generally consists of unsorted clay, silt, sand, and rock fragments. The average thickness of the unit is less than 20 ft (6 m). Artificial fill may be subject to settlement, slumping, and erosion if not adequately compacted. Extensive areas of artificial fill may exist in residential and commercial developments in the La Salle, Evans, and Greeley areas; however, fill areas are usually less than 5 ft (1.5 m) thick and difficult to delineate.

#### ALLUVIAL DEPOSITS

**Qa1** Alluvium one (Upper Holocene) — Medium-brown (10YR 6/3), poorly sorted, loosely consolidated micaceous quartz sand with gravel. Fine-grained fractions of unit Qa1 are primarily confined to the channel bottom, while the coarser-grained components of unit Qa1 are found in the point bars and adjacent floodplain deposits. Gravel-sized material ranges from subangular to well rounded and dominantly consists of quartzite, vein quartz and granitic fragments. Gravel in Qa1 is either derived upstream from the Precambrian igneous and metamorphic rocks exposed in the Front Range, or reworked from older alluvial units. Unit Qa1 occupies active channels of the South Platte River and low-lying terraces 0 to 5 ft (0.6 to 1.5 m) thick adjacent to the river. Unit Qa1 is confined by unit Qa2 everywhere in the La Salle Quadrangle. Low-lying terraces of Qa1 and adjacent floodplains are often heavily vegetated. A sieve sample of unit Qa1 along the South Platte River from SW¼ NE¼ sec. 35, T. 5 N., R. 66 W. contained 30.2% gravel, 66.1% sand, 2.7% silt, and 1.2% clay (USCS Classification = well-sorted sand with gravel (SW), AASHTO Classification = A-1-a). Channel-bar deposits exist adjacent to the South Platte River, and are composed of poorly sorted, light-brown (10YR 8/3) gravelly sand, with lenses of fine-grained sediment. Gravel-sized material in the channel bar deposits consists of granitoids, quartzite, and vein quartz. On the nearby Berthoud quadrangle (Keller and others, 2017), a bulk 14C sample taken from a depth of 3 ft (1 m) below a 5-ft-high (1.5 m) terrace of the Little Thompson River (a tributary of the South Platte River) yielded a 14C age of 905 to 855 cal BP (910 ± 30 14C yr BP), indicating the unit is late Holocene in age. Unit Qa1 is generally correlative, by virtue of height above stream level and radiometric dates on nearby quadrangles, with the post-Piney Creek Alluvium (Colton, 1978). In places, this unit was cut and/or graded, and may contain artificial fill in the upper 5 ft (1.5 m). The unit lies within the FEMA Regulatory Floodway for the South Platte River, is prone to flooding, and may have a high water table due to its proximity to adjacent streams.

**Qa2** Alluvium two (Holocene to Upper Pleistocene) — Unit Qa2 occupies stream terrace deposits that are approximately 5 to 15 ft (1.5 to 4.6 m) above the modern floodplain. Unit Qa2 is pale-brown or beige (10YR 8/2), poorly to moderately sorted, weakly stratified, silty to clayey sand with thin beds and lenses of sandy pebble gravel. Unit Qa2 is bounded entirely by Qa3 on the south side of the South Platte River, while it is bounded by Qa1, Eolian Loess (Qel), Eolian Sand (Qes), and a small outcrop of the Laramie Formation (Kl) on the north side of the South Platte River. Clasts are subrounded to well rounded pebbles of quartzite, vein quartz and granitic fragments derived from the Front Range. Humic material is found in the upper 1 to 2 ft (0.3 to 0.6 m) of the unit and stringers of calcium carbonate (Stage I of Machette, 1985) are common lower in the unit. Maximum exposed thickness of the unit locally exceeds 10 ft (3 m). Two optically stimulated luminescence (OSL) analyses were performed on a section of unit Qa2 from NW ¼ sec. 35, T. 5 N., R. 66 W. (Plate 2, Table 2); sample LS108a, taken at a depth of 8 ft (2.4 m) below ground surface, yielded an OSL age estimate of 3,040 ± 260 years. Sample LS108b, taken at a depth of 12.5 ft (3.8 m) below ground surface, yielded an OSL age estimate of 3,020 ± 200 years. In the nearby Berthoud quadrangle, Keller and others (2017) reported two 14C ages from unit Qa2 that range from 1,350 to 2,490 cal yrs BP (1,530 ± 30 to 2,390 ± 30 14C yr BP). Unit Qa2 is generally correlative, by virtue of height above stream level and radiometric dates, with the upper part of the Piney Creek Alluvium described by Hunt (1954) in the Denver area. In places, this unit was cut and/or graded, and may contain artificial fill in the upper 5 ft (1.5 m). Unit Qa2 lies within the 1% Annual Chance Flood Hazard Zone (zone AE), and portions of the unit closest to the South Platte River may lie within the FEMA Regulatory Floodway for the South Platte. The unit is a potential source of commercial sand and is actively being mined on the adjacent Milliken quadrangle (Palkovic and others, 2018).

**Qa3** Alluvium three (Upper Pleistocene) — Orange-brown (2.5Y 7/6), poorly sorted, fine to coarse sand with lenses of pebble gravel and lenses of silt to very fine-grained sand. Unit Qa3 underlies terraces approximately 35 to 70 ft (11 to 21 m) above adjacent streams, and occupies terraces along the north and south sides of the South Platte River. Clasts in unit Qa3 are subrounded to well rounded and dominantly consist of quartzite, schist, gneiss, vein quartz and granitoids. The matrix material predominantly consists of sand. Unit Qa3 is generally correlative, by virtue of height above stream level with the Broadway Alluvium (Colton, 1978) and units T3 and T4 of Schwochow (1974). Water-well borholes registered with the Colorado Division of Water Resources (Permit No's 236302—A, 251422—A and 247906—A) in unit Qa3, encountered bedrock between 54 to 62 ft (16 to 19 m) below ground surface, indicating the unit may be at least 62 ft (19 m) thick in the quadrangle. In places, this unit was cut and/or graded, and may contain artificial fill in the upper 5 ft (1.5 m), especially in residential areas. The unit is a potential source of sand and gravel.

**Qa** Alluvium, undivided (Holocene to Upper Pleistocene) — Pale-brown or beige, weakly stratified, moderately to loosely consolidated, silty to clayey sand with thin beds and lenses of sandy pebble gravel. Unit Qa is deposited in valley heads and swales in the upper parts of tributary drainages where differentiation of specific alluvial units was not possible due to poor exposure or lack of access. The exposed thickness of the unit locally exceeds 5 ft (1.5 m). Within Beebe Draw, unit Qa may represent a paleochannel of the South Platte River (Scott, 1982). The unit may be prone to seasonal flooding.

**Qg1** Gravel deposit one (Upper to Middle Pleistocene (?) — Pale-grey to golden-brown (7.5YR 8/3), poorly sorted, poorly consolidated, matrix-supported gravel with a sandy matrix that underlies an abandoned alluvial terrace on the west side of Beebe Draw, and is overlain by Qes. Unit Qg1 is typically found on abandoned alluvial terraces 10 to 90 ft (3 to 27 m) above adjacent streams. Estimated thickness is 10 to 90 ft (3 to 27 m) (Madole, 1991). Clasts are subrounded to rounded, and dominantly composed of quartzite, granitoids, vein quartz and schist. The absence of gneiss and the relatively low abundance of schist, two of the more common metamorphic rocks in the Front Range mountains, is notable. Discontinuous carbonate rinds cover approximately one-third of examined clasts. In the nearby Giovanni quadrangle (Keller and others, 2019), unit Qg1 consists of stratified sand, gravel, and clay, while in the adjacent Milliken quadrangle (Palkovic and others, 2018), Qg1 is described as a gray to light-brown, poorly sorted, matrix-supported gravel. The unit is overlain by and occasionally reworked with unit Qes along hillslopes. Unit Qg1 may represent a paleochannel of the South Platte River during its course through Beebe Draw (Scott, 1982). Unit Qg1 is generally correlative, by virtue of height above stream level, with the Slocum Alluvium (Colton, 1978). This unit was quarried for aggregate on the quadrangle and is considered a source of sand and gravel.

**Qg2** Gravel deposit two (Middle Pleistocene) — Pale-grey to golden-brown (7.5YR 8/3), poorly sorted, poorly consolidated, matrix-supported gravel with a sandy-silt matrix that underlies abandoned alluvial terraces 100 to 250 ft (30 to 76 m) above adjacent streams. The sole exposure of unit Qg2 occurs on a northeast-southwest trending ridgeline that subtly bisects the southern portion of the quadrangle. The exposure is poor, and the only evidence of the deposit is abundant pebbles and cobbles littered among eolian sand. The thickness of unit Qg2 typically ranges from 10 to 40 ft (3 to 12 m). Colton (1978) mapped an occurrence of Rocky Flats Alluvium at the intersection of secs. 29 and 33, T. 4 N., R. 65 W. along the trend of this ridgeline. Clasts are subangular to well rounded, and dominantly composed of granitoids, granitic pegmatite, amphibolite, quartz and schist, with lesser amounts of possible tan Dakota Sandstone, red sandstones of the Fountain Formation, and Lyons Sandstone. Paleodrainages of nearby streams such as St. Vrain Creek, the Big Thompson River, and the Little Thompson River flow across these rocks near the edge of the Front Range foothills, and may have been actively eroding these sedimentary units in the Middle Pleistocene. There is a distinct absence of gneiss and a low abundance of schist in unit Qg2, which are common rock types in the Front Range. Discontinuous carbonate rinds cover approximately one-third of examined clasts. This unit is overlain by and occasionally interfingers with unit Qes. Unit Qg2 is generally correlative, by virtue of height above stream level, with the Vedros Alluvium or the Rocky Flats Alluvium (Colton, 1978). This unit is a potential source of sand and gravel.

#### EOLIAN DEPOSITS

**Qel** Eolian loess (Middle Holocene to Upper Pleistocene) — Medium-brown (10YR 5/6), loosely consolidated, windblown, micaceous clayey silt with minor fine sand, commonly referred to as loess. Distinctly finer grained than eolian sand (Qes). In the nearby Berthoud quadrangle (Keller and others, 2017), the unit varies between 8 and 15 ft (2.4 to 4.6 m) thick. Sieve analysis of a sample from the nearby Johnstown quadrangle (Sample #4; Palkovic and Morgan, 2017) contained 0% gravel, 14% sand, and 86% fines (material passing a #200 sieve). Atterberg Limit tests determined a liquid limit of 27 and a plastic limit of 22 (plasticity index = 5). According to the Unified Soils Classification System, the soil is a "silt with low plasticity (ML)." Loess in the Johnstown quadrangle (Sample #4; Palkovic and Morgan, 2017) is similar in texture and composition to the loess found in the northwest part of the La Salle quadrangle. Mineralogical and geochemical evidence indicates that glaciogenic silt (likely sourced from the Front Range mountains) carried by the South Platte River and its tributaries, the White River Group, and the Pierre Shale may be primary sources of sediment in eolian loess deposits in eastern Colorado (Muls and others 1999). Loess commonly lacks topographic relief and is not associated with any landform (Madole, 2016). Optically stimulated luminescence analysis on eolian loess from the nearby Johnstown quadrangle (Sample #5; Palkovic and Morgan, 2017) yielded an OSL age estimate of 22,150 ± 2,720 years. Bulk carbon recovered from the nearby Johnstown quadrangle (Sample #4; Palkovic and Morgan, 2017) yielded a 14C age of 9,255 to 9,055 cal yrs BP (8,180 ± 30 C14 yr BP). On the basis of these ages, windblown sediment in Johnstown is generally correlative with loess near Beecher Island, CO (Muls and others, 1999) and Late Pleistocene dune sand of eastern Colorado (Sediment in unit Qes is likely derived from South Platte River alluvium, but may also be derived from residuum of Upper Cretaceous rocks (Muls and others, 1999, Madole and others, 2005). Unit Qes may be up to 40 ft (12 m) thick in the map area based on geologic logs from water-well boreholes (Colorado Division of Water Resources). Two bulk 14C samples (LS035a and LS035b) were taken from the same stratigraphic interval in NW¼ SE¼ sec. 33, T. 4 N., R. 66 W. Sample LS035b, taken 8.83 ft (2.69 m) below ground surface yielded a 14C age of 9,523 to 9,431 cal BP (8440 ± 30 14C yr BP; Plate 2, Table 1) and sample LS035a taken 9.0 ft (2.7 m) below ground surface yielded a 14C age of 10,691 to 10,488 cal BP (9,350 ± 40 14C yr BP; Plate 2, Table 1). Many of the dune crests associated with this unit were mapped using Lidar and indicate a prevailing northwesterly wind direction. In places, the unit was cut, filled, and/or graded. Unit Qes may be subject to migration and wind erosion in areas that are not sufficiently vegetated and may be prone to collapse. The unit may be a source of industrial sand.

**Qes** Eolian sand (Middle Holocene to Upper Pleistocene (?) — Medium-brown (10YR 6/6), well-sorted quartz sand with trace lithic fragments. A sieve sample from NW¼ SE¼ sec. 33, T. 4 N., R. 65 W. contained 89.7% sand, 4.6% silt, and 5.6% clay. According to the USCS Classification, the unit is a "poorly graded sand with silt" (SP-SM), and an "A-3" soil under the AASHTO Classification system. Atterberg Limit testing determined the sample is nonplastic. A sample from NE¼ SE¼ sec. 8, T. 3 N., R. 65 W. (located approximately 0.6 miles south of the quadrangle boundary) contained 93.2% sand, 1.6% silt, and 5.1% clay (USCS Classification = poorly graded sand with silt (SP-SM), AASHTO Classification = A-3). Both samples are located in the South Platte sand area (Madole, 2005), which covers about half of the quadrangle. Sediment in unit Qes is likely derived from South Platte River alluvium, but may also be derived from residuum of Upper Cretaceous rocks (Muls and others, 1999, Madole and others, 2005). Unit Qes may be up to 40 ft (12 m) thick in the map area based on geologic logs from water-well boreholes (Colorado Division of Water Resources). Two bulk 14C samples (LS035a and LS035b) were taken from the same stratigraphic interval in NW¼ SE¼ sec. 33, T. 4 N., R. 66 W. Sample LS035b, taken 8.83 ft (2.69 m) below ground surface yielded a 14C age of 9,523 to 9,431 cal BP (8440 ± 30 14C yr BP; Plate 2, Table 1) and sample LS035a taken 9.0 ft (2.7 m) below ground surface yielded a 14C age of 10,691 to 10,488 cal BP (9,350 ± 40 14C yr BP; Plate 2, Table 1). Many of the dune crests associated with this unit were mapped using Lidar and indicate a prevailing northwesterly wind direction. In places, the unit was cut, filled, and/or graded. Unit Qes may be subject to migration and wind erosion in areas that are not sufficiently vegetated and may be prone to collapse. The unit may be a source of industrial sand.

## BEDROCK GEOLOGY

**Kl** Laramie Formation (Upper Cretaceous) — Light-grey to yellowish-grey, well-indurated quartz sandstone interbedded with dark-grey, fissile, friable, well-laminated schist and lenticular masses of carbonaceous shale and lignite. The contact with the underlying Fox Hills Sandstone is conformable, and unit Kl may locally interfinger with unit Kh (Dechese and others, 2011).

**Kfh** Fox Hills Sandstone (Upper Cretaceous) — Shown in cross section only. Approximately 500-700 ft (152-213 m) thick. The Fox Hills Sandstone may contain the Upper Transition Member of the Pierre Shale on cross section A-A'.

**Kp** Pierre Shale (Upper Cretaceous) — The Pierre Shale is a regionally extensive unit of marine strata found over much of eastern Colorado. The Pierre Shale is primarily composed of dark-grey shale and siltstone, with as many as six sandstone members that are well-defined on geophysical logs. The Pierre Shale is underlain by the Smoky Hill Shale Member of the calcareous Niobrara Formation and is overlain by the clastic Fox Hills Sandstone (Scott and Cobban, 1965). Total thickness is approximately 6,500 ft (1981 m).

**Kn** Niobrara Formation (Upper Cretaceous) — Shown in cross section only. Approximately 200-340 ft (61-104 m) thick.

**Kcgg** Colorado Group — Carlie Shale, Greenhorn Limestone, Graneros Shale, and Mowry Shale, undivided (Upper Cretaceous) — Shown in cross section only. Approximately 400-450 ft (122-137 m) thick.

## MAP SYMBOLS

**Contact** — Approximately located

**Oil and gas well** (Well name shown on map)

**Water well** (Division of Water Resources permit number shown on map)

**Carbon-14 age date sample**

**Optically stimulated luminescence (OSL) age date sample**

**Alignment of cross section**

**Dune crest** — Only crests visible on Lidar imagery are shown

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## GEOLOGIC MAP OF THE LA SALLE QUADRANGLE, WELD COUNTY, COLORADO

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