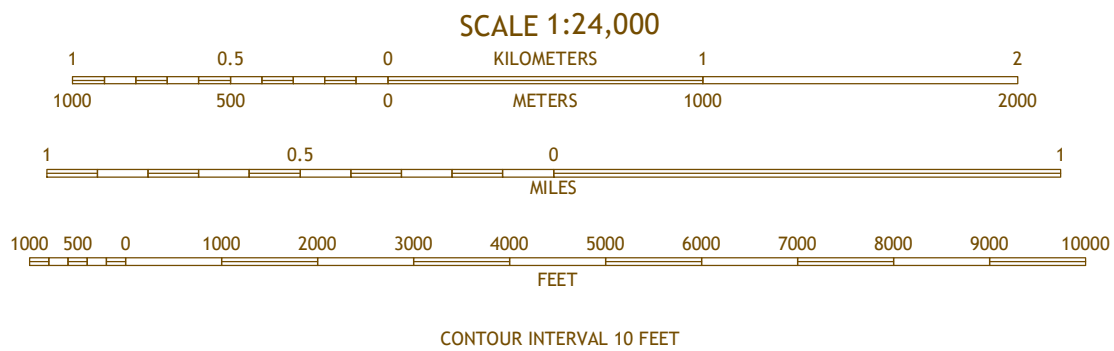
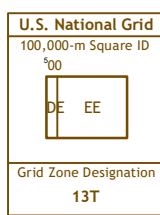


Coordinate System: NAD 1983 UTM Zone 13N shown as 1000 meter grid ticks along map edges
Projection: Transverse Mercator
Datum: North American 1983

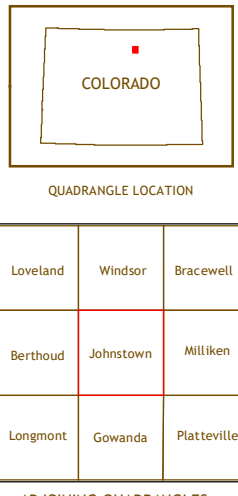
This map is not a legal document. Boundaries may be generalized for this map scale. Private lands within government reservations may not be shown. Obtain permission before entering private lands.

Initial styling of this Map Document was provided by the US Geological Survey. The edited content in this document are neither done by nor endorsed by the USGS.

Roads.....US Census Bureau, 2015-2016
Contours.....National Elevation Dataset, 1998
Names.....GNIS, 2016
Hydrography.....National Hydrography Dataset, 2013
Boundaries.....Multiple sources; see metadata file, 1972-2016
Public Land Survey.....BLM, 2011
Wetlands.....FWS National Wetlands Inventory, 1977-2014



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Geology mapped in 2016
GIS and cartography by Pangaea Geospatial

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

HUMAN-MADE DEPOSITS

af Artificial fill (uppermost 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.

dg Disturbed ground (uppermost Holocene) — Areas where mining operations have removed much of the original deposits and reclamation of the landscape has not occurred.

ALLUVIAL DEPOSITS

Qa₁ Alluvium one (upper Holocene) — Reddish-brown to dark-brown, poorly sorted, loosely consolidated clayey sand, with lesser amounts of gravel deposited during high-energy events. Gravel-sized material consists of granitic fragments and quartzite derived upstream from the Precambrian igneous and metamorphic rocks exposed in the Front Range. The unit underlies the Little Thompson River, Big Thompson River, and St. Vrain Creek, and occupies low-lying terraces 2-5 ft (0.6-1.5 m) above these streams. On the adjacent Berthoud quadrangle (Keller and others, 2017), a bulk carbon sample taken from bedrock of 3 ft (1 m) below a ~5 ft (~1.5 m) terrace of the Little Thompson River yielded a radiocarbon age of 910 ± 30 14C yr BP (Beta Analytic Sample #444186) indicating the unit is late Holocene in age. Unit Qa₁ is generally correlative, by virtue of height above stream level, soil characteristics, and radiometric dates with the post-Piney Creek Alluvium (Colton, 1976). This unit is prone to occasional flooding and a low water table due to its proximity to modern streams. Unit Qa₁ is typically 2-5 ft (0.6-1.5 m) thick.

Qa₂ Alluvium two (Holocene to Upper Pleistocene) — Pale-grey to golden-brown to dark-brown, poorly to moderately sorted, weakly stratified, silty to clayey sand with thin beds and lenses of sandy pebble gravel. Clasts are subrounded to well rounded pebbles of granite and quartzite derived from the Front Range. Sieve Analysis (Sample #1 on map) of Unit Qa₂ yielded 1% gravel, 20% sand, and 79% fines (material passing a #200 sieve). Unit Qa₂ underlies stream terrace deposits that are approximately 5-15 ft (1.5-4.6 m) above the modern floodplain. Humic material is found in the upper 1-2 ft (0.3-0.6 m) of the unit and strings of calcium carbonate (Stage I) are common lower in the unit. In the adjacent Berthoud quadrangle, Keller and Lindsey (2017) reported two radiocarbon ages from unit Qa₂ that range from 1,530 to 2,390 ± 30 14C yr BP (Beta Analytic). Hunt (1954) reported a radiocarbon age of 1,150 ± 150 14C yr BP (800 AD) of charcoal from 18 in (0.45 m) below the surface of a terrace underlain by Piney Creek Alluvium in the Commerce City quadrangle; Madole and others (2005) obtained an age of 1,110 ± 70 14C yr BP (Beta Analytic) from organic-rich sediment near the top of the Piney Creek Alluvium type locality of Hunt (1954); Berry and others (2015) reported 14C ages of 11,900 ± 0.28 cal ka BP and 11,950 ± 0.24 cal ka BP taken near the base of the alluvium in the Masters quadrangle near Fort Morgan, CO (Note: according to Madole (personal commun., 2016) Hunt's age assignment to its type locality along Piney Creek was based on archaeological data (the presence of Plains Woodland artifacts) and the site he radiometrically dated and ultimately assigned an age to the Piney Creek Alluvium was based on the 14C age of charcoal at a Plains Woodland site ~20 mi (32 km) to the north-northwest from the type locality). These ages only indicate that Piney Creek Alluvium was deposited prior to the time that Plains Woodland people camped at these two localities. Unit Qa₂ is generally correlative, by virtue of height above stream level, soil characteristics, and radiometric dates with the upper part of the Piney Creek Alluvium described by Hunt (1954) in the Denver area. The unit is subject to occasional flooding. Unit Qa₂ is a potential source of commercial sand. Due to its high content of fine grained material, this unit may be subject to swelling or post construction settlement if not adequately compacted. Maximum exposed thickness of the unit locally exceeds 10 ft (3 m).

Qa₃ Alluvium three (Upper Pleistocene) — Dark-grey to pale-brown, poorly sorted, poorly consolidated, matrix supported gravel that underlies terraces approximately 35 to 70 ft (11 to 21 m) above modern streams. Clasts in unit Qa₃ are subangular to well rounded and consist predominantly of quartzite fragments and phaneritic, felsic igneous rocks. The matrix consists predominantly of silt and clay. A sample of Qa₃ from the northern part of the quadrangle (Sample #2 on map), contained 39% gravel, 22% sand, and 39% fines (material passing a #200 sieve). Minimal organics (mainly tree roots and wood fragments) are found in the uppermost 1 ft (0.3 m) of the unit. The Qa₃ terrace along the Big Thompson River is identifiable on Lidar imagery and as a gentle rise in the field; however, a distinct terrace surface is not obvious along the Little Thompson River and is mapped on the basis of its elevation above the active floodplain. Unit Qa₃ is generally correlative, by virtue of height above stream level and soil characteristics with the Broadway Alluvium (Colton, 1976). The unit is a potential source of sand and gravel. The unit is approximately 8-15 ft (2.4-4.6 m) thick based on the thickness in the adjacent Longmont quadrangle (Madole, 2016).

Qa Alluvium, undivided (Holocene to Upper Pleistocene) — 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. Deposit is generally gray to brown, weakly stratified, moderately consolidated, silty to clayey sand with thin beds and lenses of sandy pebble gravel. The exposed thickness of the unit locally exceeds 5 ft (1.5 m). Unit is subject to occasional flooding.

Qg₁ Gravel deposit two (Middle Pleistocene) — Pale- to golden-brown, poorly sorted, clast supported gravel with a sandy-silty matrix that is found 100 to 250 ft (30-76 m) above modern streams. Two NW-SE trending bands of this alluvium exist in the quadrangle, which may be inverted paleochannels of the Big Thompson River. Unit Qg₂ is generally correlative, by virtue of height above stream level and soil characteristics with the Verdos Alluvium (Colton, 1976). This unit is a potential source of sand and gravel. The thickness of unit Qg₂ typically ranges from 10-40 ft (3-12 m).

Qf Alluvial-fan deposits (Holocene to Upper Pleistocene) — Tan to yellowish-brown, poorly sorted, unconsolidated, clayey to silty sand and gravel, deposited as individual or coalesced alluvial fans at the mouths of hillside swales and ephemeral streams. They have a fan-like shape and may contain reworked well-rounded pebbles derived from local surficial and bedrock deposits. The unit may be prone to flooding and sediment-laden mud floods. The unit is a potential source of sand and gravel. Deposits locally exceeds 8 ft (~2 m) in thickness.

Qcs Colluvium and sheetwash deposits, undivided (Holocene to Upper Pleistocene) — Colluvium consists of fragments of high-level gravels and bedrock that have been transported downslope primarily by gravity. The deposits are gray to tan to yellowish-brown, poorly sorted, clast supported, pebble to boulder gravel in a sandy matrix, to matrix supported, gravelly, clayey, sandy silt. Colluvium contains rounded to subrounded clasts and is weakly stratified. Sheetwash deposits are gray-brown to gray-tan, stiff to hard, roughly stratified, poorly sorted, silty to sandy clay with scattered granule to gravel rock fragments and pebbles. Unit thinly mantles low-relief moderate slopes where bedrock is shallow and consists chiefly of local materials transported by sheet flow. Unit may include eroded sediments from rills and minor gullies, and reworked sandy loess and bedrock residuum. Unit is generally 5-10 ft (1.5-3 m) thick but may include zones of bedrock residuum near surface. Colluvium and sheetwash deposits may grade into, and interfinger with, alluviums one, two, and three (Qa₁, Qa₂, and Qa₃) and eolian deposits (Qe). Sample #3 has an optically stimulated luminescence (OSL) age estimate of 11,080 ± 840 yrs taken from alluvium 7 ft (2.1 m) below the terrace surface (S. Mahan, personal commun., 2017) (Table 1). Areas mapped as colluvium and sheetwash are susceptible to future colluvial and sheetwash deposition and locally are subject to small debris flows. These deposits may be sources of aggregate. Maximum thickness of this unit is approximately 15 ft (4.5 m).

EOLIAN DEPOSITS

Qe Eolian sediment (middle Holocene and Upper Pleistocene) — Pale golden-brown to yellowish-brown, windblown, micaceous clayey silt with minimal sand (commonly referred to as "loess"). Sieve analysis of a sample from the northeast portion of the quadrangle (Sample #4 on map) contains 0% gravel, 14% sand, and 86% fines (material passing a #200 sieve). Aterberg Limit determinations revealed 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). Note that a sieve analysis does not discern silt from clay; rather, the material is classified as silt due to its plasticity index. Loess commonly lacks topographic relief and is not associated with any landform (Madole, 2016); however, contacts were discernable on Lidar imagery due to the landforms associated with adjacent alluvial deposits. Late Pleistocene and Holocene alluvial units may contain reworked Qe. Sample #5 was collected from eolian sand at a depth of 5 ft (1.5 m) below the surface and has an OSL age estimate of 22,150 ± 2720 yrs (S. Mahan, personal commun., 2017). Carbon recovered at the location of Sample #4 at a depth of 3 ft (1 m) yielded a 14C age of 9255 to 9025 cal BP (8180 +/- 30 C14 yr BP) (Table 1). On the basis of these ages, windblown sediment in the quadrangle is generally correlative with loess near Beecher Island, CO (Sample #4) (Muls and others, 1999) and Late Pleistocene dune sand of eastern Colorado (Sample #5) (Muls and others, 1996). These units were not mapped separately due to poor exposures and limited access.

Due to its low plasticity index, this unit is not likely to experience post-construction swelling, despite its high content of fine grained material. This unit has little economic value; however it is a highly productive agricultural medium. Unit Qe may be subject to migration in areas that are not sufficiently vegetated. From an excavation located at 12N 506094m E 4456371m N, the unit was observed to be at least 10 ft (3 m) thick. In the adjacent Berthoud quadrangle (Keller and others, 2017), the unit varies between 8 and 15 ft (2.4 to 4.6 m) thick.

BEDROCK GEOLOGY

Kfh Fox Hills Sandstone (Upper Cretaceous) — Whitish-beige, friable, massive sandstone to shaly sandstone. Outcrop exposures are poor within the quadrangle. The contact between the Upper Transition Member of the Pierre Shale (Kpt) and the Fox Hills Sandstone is arbitrarily defined by Lovering and others (1932) as being 250 ft (76 m) below the base of the Maastrichtian Laramie Formation, while Scott and Cobban (1965) note that the contact between the two is unapparent between Denver and Loveland. This unit was differentiated in the field from the Kpt by the presence of ophiomorph trace fossils and fewer shale interbeds. The unit is approximately 300-500 ft (92-152 m) thick.

Kp Pierre Shale (Upper Cretaceous) — The Pierre Shale is a regionally extensive unit of marine strata found over much of eastern Colorado, and is largely considered to be Campanian to Maastrichtian in age (Scott and Cobban, 1965). 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). Weathered Pierre Shale near the surface may be subject to swelling. Total thickness is approximately 6,500 ft (1981 m).

Kpt Upper Transition Member (Upper Cretaceous) — Composed of golden-brown to light-brown, friable sandstone to shaly sandstone that is moderately indurated, and well laminated to bedded. Poor outcrop exposure exists in Johnstown. The contact is conformable and gradational with the underlying Fox Hills. The unit is approximately 20 to 380 ft (6-125 m) thick in the map area.

Kpu Upper Shale (Upper Cretaceous) — Shown in cross section only. Approximately 2,200 ft (671 m) thick.

Kplr Larimer, Richard and Rocky Ridge Sandstone Members and intervening unnamed shale units (Upper Cretaceous) — Shown in cross section only. Commonly referred to as the Parkman Sandstone member in the subsurface. Approximately 300-365 ft (92-111 m) thick.

Kpm Middle Shale Member (Upper Cretaceous) — Shown in cross section only. Contains the Sussex Sandstone member. Approximately 360-430 ft (110-131 m) thick.

Kph Hygiene Sandstone Member (Upper Cretaceous) — Shown in cross section only. Commonly referred to as the Shannon Sandstone Member in the subsurface. Approximately 375-425 ft (114-130 m) thick.

Kpl Lower Shale Member (Upper Cretaceous) — Shown in cross section only. Approximately 2,150-2,275 ft (655-695 m) thick.

Kn Niobrara Formation (Upper Cretaceous) — Shown in cross section only. Approximately 280-540 ft (85-104 m) thick.

Kcgg Carlile Shale, Greenhorn Limestone, and Graneros Shale, undivided (Upper Cretaceous) — Shown in cross section only. Units are correlative with the Colorado Group or Benton Group. Approximately 400-450 ft (122-137 m) thick.

Table 1. Age dates in the Johnstown quadrangle				
Radiocarbon Dating (by Beta Analytic Inc., Miami, Florida, February 2017)				
Map Unit	Map Location	Laboratory number	Material	Calibrated 14C age (yr BP)
Qe	Sample #4	Beta-459484	Silt	9255 to 9025

Optically Stimulated Luminescence (OSL) dating (by U.S. Geological Survey, Lakewood, Colorado, February 2017)				
Map Unit	Map Location	Material	Age (yr BP)	
Qcs	Sample #3	Sand and Gravel	11,080 ± 840	
Qe	Sample #5	Silt and Clay	22,151 ± 2720	

MAP SYMBOLS

- Contact
- Oblique-slip fault — Dashed where approximately located, dotted where concealed; U = upthrown side, D = downthrown side; arrows indicate relative displacement
- Strike and dip of inclined bedding — Showing direction and angle of dip in degrees
- Sample location
- Oil and gas well
- Alignment of cross section