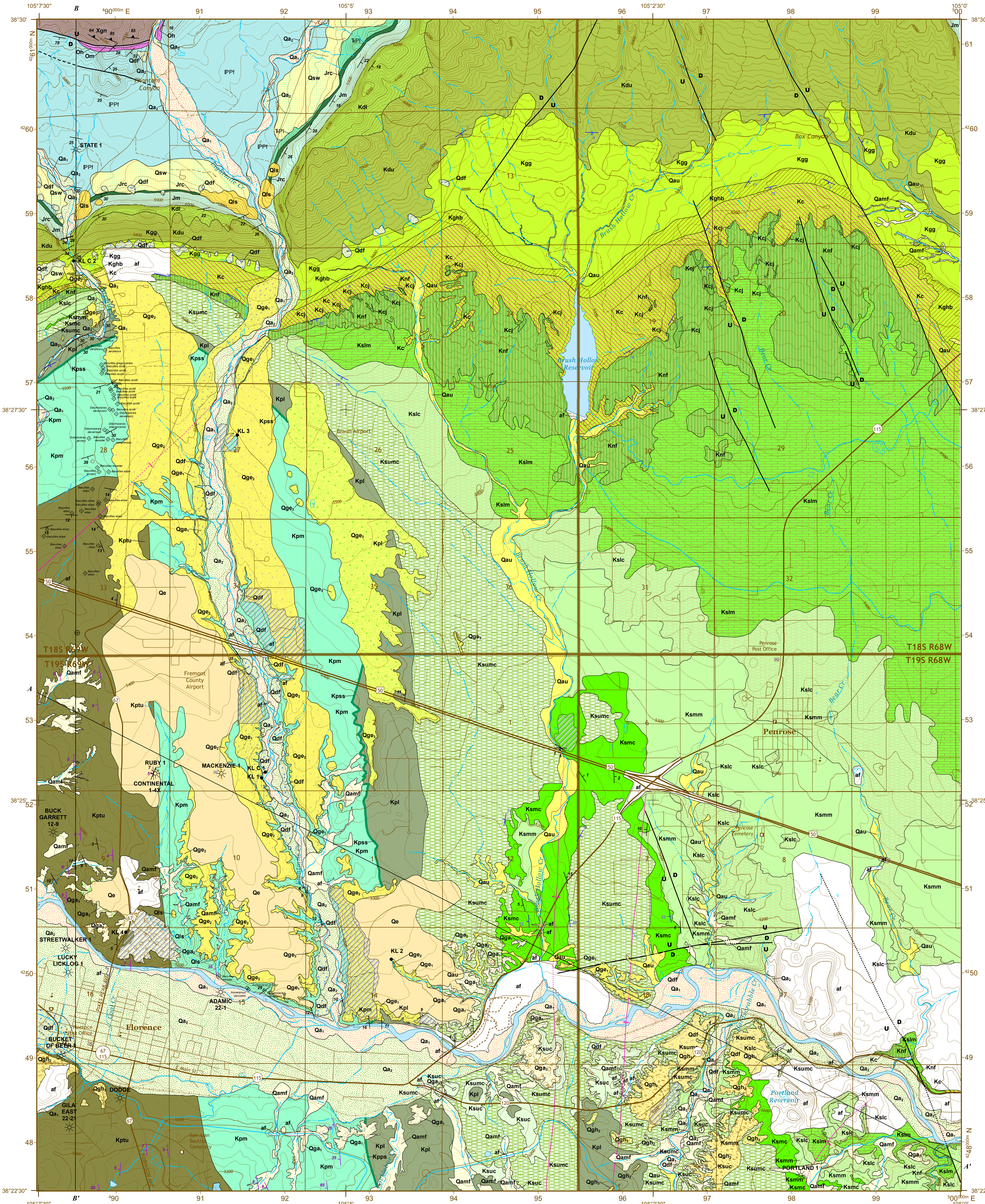

Coordinate System: NAD 1983 UTM Zone 13 North
Projection: Transverse Mercator
Datum: North American 1983

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.

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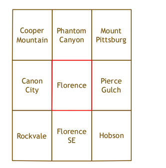
Roads....U.S. Census Bureau, 2015-2016
Names....GNIS, 2016
Hydrography....National Hydrography Dataset, 2013
Contours....National Elevation Dataset, 2007
Boundaries....Multiple Sources; see metadata file, 1972-2016
Public Land Survey System....BLM, 2011
Wetlands....FWS National Wetlands Inventory, 1977-2014

SCALE 1:24,000

CONTOUR INTERVAL 20 FEET

This mapping project was funded jointly by the Colorado Geological Survey and the U.S. Geological Survey through the National Cooperative Geologic Mapping Program under STATEMAP agreement G17AC00259.

QUADRANGLE LOCATION



ADJOINING QUADRANGLES

Geology mapped in 2017
GIS and cartography by Pangaea Geospatial

GEOLOGIC MAP OF THE FLORENCE QUADRANGLE, FREMONT COUNTY, COLORADO

By Kassandra O. Lindsey, David Sawyer, and Jay Temple
2018

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

HUMAN-MADE DEPOSITS

af — **Artificial fill (uppermost Holocene)** — Artificial fill includes riprap, fill, and refuse placed during construction of roads, railroads, buildings, dams, and landfills. The unit generally consists of clay, silt, sand, and rock fragments. The average thickness of the unit is less than 10 ft (3 m). Artificial fill may be subject to settlement, slumping, and erosion if not adequately compacted or emplaced on steep slopes. Extensive areas of artificial fill may exist in residential and commercial developments in the map area; however, fill deposits are usually less than 5 ft (1.5 m) thick and difficult to delineate, thus the underlying geology was not mapped in developed areas. Fill materials can vary in particle size from sand, silt, and clay to boulders and may locally include refuse of many types including household and industrial waste.

ALLUVIAL DEPOSITS

Qau — **Alluvium, undivided (Upper Holocene)** — Greenish-brown, brown, and tan, clay, silt, and sand, ranging from 3 ft to 20 ft (1 m to 6 m) thick. Gravels may occur locally within the upper reaches of Brush Hollow Creek. This unit occurs in minor, intermittent drainages in the mapped area. Along Brush Hollow Creek, the unit is mapped at 5 ft (1.5 m) above the active channel near the confluence with the Arkansas River. Closer to Brush Hollow Reservoir the top of the unit is as much as 20 ft (6 m) above the active channel. The unit generally consists of eroded materials from bedrock in the upper reaches of the drainages and is typically composed of silty and clayey sand. The unit may be subject to flooding and is not a potential source of sand and gravel.

Qa_1 — **Alluvium one (Upper Holocene)** — Tan to light-brown and reddish-brown, clayey to silty sand and gravel. Gravels tend to be subangular to subrounded. Sands are usually fine to medium grained, with minor coarse grains and are poorly to moderately sorted. The unit is approximately 3 ft (1 m) thick and underlies active stream channels. Within the Sixmile Creek drainage, terraces are approximately 5 ft (1.5 m) above the active stream channel. Deposits in the drainage consist of sand and silt and minor amounts of pebbles. The unit mapped within Eightmile Creek drainage tends to have higher amounts of gravel. Here clasts can be as much as 1 ft (0.3 m) in diameter. As much as 10% of clasts are sedimentary rocks, mostly red sandstones. Within the Arkansas River drainage, deposits range from silty sand to poorly sorted sandy gravel. The unit is subject to flooding and is not a potential source of sand and gravel.

Qa_2 — **Alluvium two (Holocene)** — Unit underlies terraces within the Sixmile and Eightmile creek drainages. Within Eightmile Creek the unit is tan to reddish-brown and light-brown to reddish-brown. The unit is silty to clayey medium sand that contains scattered clasts as much as 3 inches (8 cm) in diameter. Terraces are approximately 5 ft (1.5 m) above the active channel. A sample collected at location KL C 1 (Beta Analytic Sample #474336) in silty sand at the base of the roughly 5 ft (1.5 m) thick exposure yielded radiocarbon ages of 960 ± 30 14C yr BP. Within Sixmile Creek the unit is light tan. The unit consists of poorly sorted, silty, fine to coarse sand and secondary carbonate is present in the matrix. Terraces along Sixmile Creek are as much as 20 ft (6 m) above the active channel. A sample collected at location KL C 2 (Beta Analytic Sample #492439) in sand at the base of the roughly 20 ft (6 m) thick exposure yielded a radiocarbon age of 8,260 ± 30 14C yr BP.

Morgan and others (2006) reported an age of 1,170 ± 40 14C yr BP and Madole (1989) reported an age of 1,150 ± 60 14C yr BP for units Qa_1 and Qa_2, respectively, in the Mount Pittsburg quadrangle (adjacent quadrangle to the NE). Older ages reported by Berry and others (2015) include 11.90 ± 0.28 cal ka BP and 11.95 ± 0.24 cal ka BP, which were collected near the base of alluvium in the Masters quadrangle, northeast of Denver. The unit is likely correlative with, by virtue of height and radiometric age, the Piney Creek Alluvium (Hunt, 1954; Madole and others, 2005; Berry and others, 2015; Keller and others, 2017). The unit is subject to flooding and is a potential source of sand and gravel.

Gravels of Eightmile and Sixmile creeks — Poorly sorted, clast supported gravel deposited by tributary streams of the Arkansas River. Deposits along Eightmile Creek and Sixmile Creek are red in color, compared to other gravel deposits in the mapped area. The red color of the unit is likely due to red sandstone beds found a few miles upstream in the northernmost part of the map area. Clasts are more angular than gravel in other deposits on the map. Clast lithologies consist of approximately 10% vein quartz, 30% sandstones, 30% granitic clasts, and 30% metamorphic rocks. Clasts range in size from less than 6 in (15 cm) to approximately 2 ft (0.6 m) in diameter. Localized landslides of limited extent may occur at the contact between the gravel and the underlying Pierre Shale.

Qge_1 — **Eightmile and Sixmile creeks gravel one (Upper Pleistocene(?))** — Reddish-brown, clast supported sandy gravel. Discontinuous rinds composed of secondary carbonate coat many of the clasts. Commonly, rinds are less than 0.04 in (1 mm) thick. Along Eightmile Creek, the surface of the unit is approximately 90 ft (27 m) above active channels at their confluence with the Arkansas River and decreases upstream to roughly 30 ft (9 m) above the active channel. The unit is as much as 30 ft (9 m) thick near the Arkansas River and decreases in thickness upstream to roughly 10 ft (3 m) thick. Sample KL 1, which was taken near the base of the unit in gravel, yielded an OSL age of 3,460 ± 590 BP (central age) or 1,200 ± 200 BP (minimum age). However, this age is inconsistent with other ages of similar deposits nearby. An age collected from Qa_2 from Sixmile Creek yielded an age of 8260 ± 30 14C yr BP. The soil profile is less developed compared to unit Qge_1. Additionally, the carbonate rinds on the clasts in unit Qge_1 are consistent with an older age than the OSL age from sample KL 1. The unit is mapped as Louviers Alluvium (Upper Pleistocene) by Scott (1985). Szabo (1970) collected bone fragments from the Parker area and Chatfield Dam site. Uranium-series ages range from 86,000 ± 6,000 to 129,000 ± 10,000. This unit is a source of sand and gravel.

Qge_2 — **Eightmile and Sixmile creeks gravel two (Upper Pleistocene (?) to upper Middle Pleistocene)** — Deposits along Eightmile Creek consist of alternating layers of very coarse sand and silt, and poorly sorted gravel. Carbonate rinds on clasts are about 0.04 in (1 mm) thick and are more continuous than those on clasts in unit Qge_1. Clasts break apart more easily when struck with a rock hammer compared to those in Qge_1. Rip-up clasts of Pierre Shale are found within the basal part of the deposit. Imbricated clasts, near the confluence with the Arkansas River indicate transport from north to south toward the Arkansas River. The unit is roughly 40 ft (12 m) thick along Eightmile Creek and thins to less than 3 ft (1 m) thick along the western edge of the unit. The upper part of the unit is approximately 95 ft (29 m) above the active channel near the confluence with the Arkansas River. The basal 4 to 6 ft (1.2 to 1.8 m) is strongly cemented by secondary calcium carbonate in the part of the unit mapped in the W. ½, sec. 21, T. 18 S., R. 69 W. The secondary carbonate is likely precipitated by groundwater. Sample KL 6 analysis of detrital zircon indicates the zircons are of Cretaceous age. This suggests a provenance (sediment source) 1 to 2 miles north of the sample location. Sample KL 3, taken near the base of the unit in a coarse sand bed, yielded an OSL age of 18,950 ± 1310 BP (central age). The unit is mapped as Slocum Alluvium (lower Upper Pleistocene) by Scott (1985). This unit is a source of sand and gravel.

Qge_3 — **Eightmile and Sixmile creeks gravel three (lower Middle Pleistocene)** — Reddish-brown, clast supported sandy gravel. The clasts break apart easily when struck with a rock hammer and carbonate rinds are 0.07 to 0.11 in (2 to 3 mm) thick. There are two depositional episodes mapped by Scott (1985) for this unit that are not mapped separately here. The surface of the upper deposits is 130 to 140 ft (40 to 43 m) above the active channel and is underlain by less than 4 ft (1.2 m) of gravel. The surface of the lower deposits is approximately 90 to 130 ft (30 to 40 m) above the active stream channel and is 30 to 40 ft (9 to 12 m) below the surface of the upper gravel. Thickness of the lower terrace gravel is 5 to 15 ft (1.5 to 4.5 m). The lower gravel-capped surface is more widespread than the upper gravel-capped surface. Normally, terraces would be deposited such that the oldest terrace is located the furthest from the modern drainage and the stream would incise into the older terraces (younger terraces would be inset into older terraces). In the case of Eightmile Creek, the lower gravel surface (younger) is mapped on the east side of the upper surface (older), while the active channel (youngest) currently occupies a valley to the west of the upper surface (older). In other words, the younger terrace is not inset into the older terrace on the same side as the modern channel. This suggests that Eightmile Creek may have avulsed or shifted to its current location sometime between the deposition of Qge_3 and Qge_2. The unit is mapped as Verdos Alluvium (lower Middle Pleistocene) by Scott (1985). This unit is a source of sand and gravel.

Arkansas River Gravel — Poorly sorted, clast supported gravel deposited by the Arkansas River. Deposits are typically light tan-gray in color. Clasts consist of 30% gneiss and quartzite, 30% granite, and 5% sandstone and other sedimentary rocks. Remaining clast types are predominantly porphyritic and pegmatitic igneous rocks. Clasts are subrounded to round. Clasts range in size from 3 to 12 inches (8 to 31 cm) in exposed diameter. Clasts locally may exceed 12 inches (31 cm). Localized landslides of limited extent occur at the contact between the gravel and the underlying Pierre Shale.

Qga_1 — **Arkansas River gravel one (Upper Pleistocene(?))** — Near the confluence of Eightmile Creek and the Arkansas River, gravel deposits have a coarse sand matrix and are redder compared to the usual tan, light brown, and gray color of the deposit elsewhere along the river. This is due to the contribution of red clasts and sediments from Eightmile Creek. The unit is as much as 30 ft (9 m) thick near the confluence of the Arkansas River and Eightmile Creek. Near Highway 115, the unit is 10 to 15 ft (3 to 4.5 m) thick. The surface of the unit is 85 to 100 ft (26 to 30 m) above the active channel of the Arkansas River. Deposits are more prevalent on the north side of the drainage. The unit is mapped as Louviers Alluvium (Upper Pleistocene) by Scott (1985). Szabo (1970) collected bone fragments and reports Uranium-series ages ranging from 86,000 ± 6,000 to 129,000 ± 10,000. The unit is a source of sand and gravel.

Qga_2 — **Arkansas River gravel two (Upper Pleistocene (?) to upper Middle Pleistocene)** — Tan to gray gravel composed of alternating layers of clast-supported gravel and sandy silt. Continuous carbonate rinds are present on the bottom of many of the gravel clasts; carbonate is present in the matrix, but only weakly binds the matrix. Deposits are more widespread on the north side of the drainage. Much of the unit has been reworked or removed through quarrying. Unit thickness could be as much as 30 ft (9 m) but the unit is approximately 10 ft (3 m) thick in most places. The terrace surface is approximately 130 to 150 ft (40 to 46 m) above the active stream channel. Sample KL 4, collected in gravelly sediments near the base of the unit just above the contact with bedrock, yielded an OSL age of 17,450 ± 1640 BP (central age). The unit is mapped as Slocum Alluvium (lower Upper Pleistocene) by Scott (1985). Numerous ages have been recorded for this unit. In the adjacent Canon City quadrangle (west of this map), Szabo (1980) reports a Uranium-series age of 190,000 ± 50,000 years from a *Bison (Gigantobison) latifrons* (Harlan) horncore. Scott and Lindvall (1970) report a Sangamon age (what is now considered Late Pleistocene) for the deposit based on geomorphic evidence. Schultz and Frankforter (1946) assigned it an age of Kansan or older, Miller (1968) assigned it late Wisconsin (which is approximately correlative to the age dates from this study), and Skinner and Kaisen (1947) identified it as Middle Pleistocene. This unit is a source of sand and gravel.

Qga_3 — **Arkansas River gravel three (lower Middle Pleistocene)** — Gray-brown to tan, clast supported sandy gravel. The only deposit of the unit in the mapped area is in S. ½, sec. 9, T. 19 S., R. 69 W., near the western boundary of the quadrangle. The unit is as much as 15 ft (4.5 m) thick. The surface of the unit is approximately 180 ft (55 m) above the active channel. The base of the northern part of the unit is cemented by secondary calcium carbonate, potentially from groundwater. No cementation was observed in the southern part of the same unit. Clasts have carbonate rinds a few mm thick and break apart easily when hit with a rock hammer. The unit is mapped as Verdos Alluvium (lower Middle Pleistocene) by Scott (1985). The unit is a source of sand and gravel for concrete aggregate, but could be used for fill material.

Gravel of Hardscrabble Creek — Poorly sorted, clast-supported gravel deposited by streams. Deposits are light tan-grey and consist of poorly sorted gravel with a silty sand matrix. Clast composition consists of: 40% granitic rocks, 15% tan and red sandstone, 25% mafic intrusive and porphyritic, intrusive igneous rocks, and 20% vein quartz and metamorphic rocks, likely derived from the Wet Mountains located south of the quadrangle. Clasts are subrounded to round and range in size from 3 to 12 inches (8 cm to 31 cm) in exposed diameter. Clasts locally exceed 12 in (31 cm). Exposures of Hardscrabble Creek gravel deposits are sparse in the mapped area. Landslides of limited extent occur locally at the contact between the gravel and the underlying Pierre Shale.

Qgh_1 — **Hardscrabble Creek gravel one (Upper Pleistocene(?))** — Deposits are mixed with Arkansas River gravel near the confluence of the two drainages mapped. Deposits are 5 to 8 ft thick (1.5 to 2.5 m). Much of the unit has been removed due to quarrying. The terrace surface occurs approximately 90 ft (27 m) above the active Hardscrabble Creek. The unit is mapped as Louviers Alluvium (Upper Pleistocene) by Scott (1985). Szabo (1970) collected bone fragments and reports Uranium-series ages ranging from 86,000 ± 6,000 to 129,000 ± 10,000. The unit is a source of sand and gravel.

Qgh_2 — **Hardscrabble Creek gravel two (Upper Pleistocene (?) to upper Middle Pleistocene)** — Deposits are mixed with Arkansas River gravel near the confluence of the two drainages. Clasts can be up to and locally exceed 1 ft (0.3 m) in diameter. The unit commonly caps isolated hills along Hardscrabble Creek. Here the unit is underlain by the erodible Pierre Shale (Kp) and acts as a shield to weathering, creating inverted topography. Along Hardscrabble Creek, the unit is approximately 6.5 ft (2 m) thick and the terrace surface occurs 120 to 130 ft (37 to 40 m) above the active stream channel. Some parts of the unit have been removed due to quarrying. Unit Qgh_2 also includes gravels from Coal Creek. Along Coal Creek, the unit is a poorly sorted, clast-supported gravel. Clasts range in size from 3 to 18 in (8 to 46 cm) and locally exceed 18 in (46 cm) in exposed diameter. The deposit is as much as 12 ft (3.7 m) thick. The surface of the unit along Coal Creek is approximately 60 to 70 ft (18 to 21 m) above the active stream channel. The unit is mapped as Slocum Alluvium (lower Upper Pleistocene) by Scott (1985). This unit is a source of sand and gravel.

Qgh_3 — **Hardscrabble Creek gravel three (lower Middle Pleistocene)** — The unit caps isolated hills of Pierre Shale. The basal 4 ft (1.2 m) of the deposit exposed in sec. 19, T. 19 S., R. 68 W. and sec. 24, T. 19 S., R. 69 W. is cemented by calcium carbonate. Much of the unit has been removed due to quarrying. The unit is as much as 12 ft (3.7 m) thick. The surface of the unit occurs about 160 ft (49 m) above active stream channel. The unit is mapped as Verdos Alluvium (lower Middle Pleistocene) by Scott (1985). The unit is a source of sand and gravel.

EOLIAN DEPOSITS

Qe — **Eolian sand (Holocene)** — Light-tan, silt and very fine to medium sand deposited predominantly by wind. Dispersed pebbles locally mantle the surface of the deposit. Some exposures contain secondary calcium carbonate accumulation within 5 ft (1.5 m) of the surface. Eolian deposits predominantly blanket the gravel deposits of Eightmile Creek and nearby surrounding areas. They can be as thick as 8 ft (2.4 m). Scott (1985) mapped an area of the quadrangle as eolian sand and assigned it an age of Late Pleistocene to Early Holocene on the basis of calcium carbonate accumulation. Sample KL 2 (Beta Analytic Sample #477468) taken from a natural exposure at a depth of 5 ft (1.5 m) below ground surface yielded an age of 2080 ± 30 14C yr BP. This unit may be a potential source of industrial sand.

MASS-WASTING AND ALLUVIAL FAN DEPOSTIS

Qsw — **Sheetwash deposits (Holocene (?))** — Tan to brown, fine-grained silty sand with dispersed coarse sand to pebble-sized rock fragments. Most deposits are mapped along the north side of the hogbacks in the northeast part of the quadrangle. Deposits are formed by sheet flow, when sediment is mobilized and reworked downhill during heavy precipitation events. In general, the unit is poorly exposed. Unit locally exceeds 3 ft (1 m) in thickness.

Qdf — **Fan deposits (Holocene (?))** — Light-tan to dark-brown, poorly sorted fan-shaped deposits composed chiefly of sand and gravel deposited at the base of steep stream channels. The unit is poorly exposed. Much of the unit is deposited at and near the base of the hogbacks in the northern part of the mapped area and along Eightmile Creek. Deposits along the hogbacks are generally finer grained and smaller in areal extent than those mapped along Eightmile Creek. Deposits on the north side of the hogbacks can be up to 10 ft (3 m) thick whereas debris fans on the south side can be up to 20 ft (6 m) thick. Along Eightmile Creek deposits consist of mud derived from the Pierre Shale and alluvial gravel from adjacent gravel deposits. Deposits along Eightmile Creek range from 5 to 10 ft (1.5 to 3 m) thick, but can be as much as 20 ft (6 m) thick. Typically they are poorly sorted and poorly stratified. Locally, deposits consist of well stratified layers of sand and gravel. Fan deposits may be locally prone to debris flows or sediment-laden floods. This unit is not a source of sand or gravel.

Qls — **Landslide deposits (Holocene to Pleistocene)** — Unsorted, mass-wasting deposits that contain angular to subrounded clasts derived from local bedrock and surficial units. Landslides in the mapped area are predominantly rotational failures. Headscarps are not well defined in the northern part of the mapped area and deposits can locally exceed 50 ft (15 m) thick. Landslide deposits along the Arkansas River form near the contact between the alluvial gravel and Pierre Shale. Landslide deposits at these locations are about 20 to 30 ft (6 to 9 m) thick. Materials in these landslide deposits consist chiefly of Pierre Shale fragments and gravel clasts. Headscarps are easy to identify using 1-m resolution lidar imagery. Mapped landslide deposits may be subject to reactivation if disturbed by stream avulsion or human activity.

Qamf — **Alluvial mudflow-and-fan valley-fill deposits (Holocene (?))** — Gray-green, clayey deposits, commonly sourced from Pierre Shale. The unit is composed of light-tan, silty clay deposits where sourced from the Niobrara Formation. Exposures are sparse, deposits are typically homogeneous, possibly due to lack of coarse sediment grains in the Pierre Shale. Gravel clasts are locally present when sourced from alluvial gravel deposits. Valley-fill and fan deposits are typically sourced from arroyos where high-discharge flood events mobilize unconsolidated materials and sediment. Sediment accumulates at the mouths of arroyos. Deposits range in thickness from 5 to 10 ft (1.5 to 3 m). Unit may be prone to hydrocompaction and may contain swelling clay minerals.

BEDROCK GEOLOGY

Pierre Shale (Upper Cretaceous) — The Pierre Shale on the Florence quadrangle is about 4000 ft (1219 m) thick; it is 3919 ft (1195 m) in Scott and Cobban (1975, Figure 1). This value is less than the 5200 ft (1585 m) thickness reported in the Pueblo and Colorado Springs area (Scott and Cobban, 1986). The Pierre Shale was deposited in the axis of the Western Interior Seaway foreland basin during the Late Cretaceous from about 83 Ma to 69 Ma. The individual subunits of the Pierre Shale in the Florence Basin vary in thickness by biostratigraphic zones when compared to Pierre Shale in the Pueblo-Colorado Springs area. However, most of the Pierre Shale biostratigraphic and lithostratigraphic units from Pueblo-Colorado Springs area can be correlated into the Florence Basin. The principal stratigraphic difference is in the timing of depositional environments, leading up to the Fox Hills Sandstone as the final regressional shoreface sand deposits in the Pueblo-Colorado Springs area. In the Florence Basin, the end Cretaceous regressional sandstone is correlated with the Trinidad Sandstone to the south.

The subunits of the Pierre Shale are mapped as four distinct map units, which is less than those of Scott and Cobban (1975, Figure 1). The uppermost part of the upper transition member and its contact with the overlying Trinidad Sandstone is not exposed within the quadrangle. The unit thickness was measured 1 to 2 miles to the west, along the road leading into the East Canon City Correctional Complex in sec. 31, T. 18 S., R. 69 W. by Scott and Cobban (1975). They mapped the following subunits of the Pierre Shale, from basal contact of the Pierre Shale with the underlying Upper Chalk unit of the Smoky Hill Shale Member of the Niobrara Formation in ascending order: lower transition member, Apache Creek Sandstone Member, Sharon Springs Member, Rusty zone of Gilbert (1897), Tepee Butte zone of Gilbert (1897), cone-in-cone zone of Lavington (1933), and the upper transition member (the thickest uppermost Pierre Shale unit). These units are correlated to the interpreted high-resolution borehole geophysical log 4.25 miles southwest of the mapped area (Figure 1). Lithologic and biostratigraphic characteristics of the four map units of the Pierre are described below. Areas underlain by the Pierre Shale may be subject to hazards associated with expansive soils.

Kptu — **Upper transition member** — The upper transition member is about 1101 to 1128 ft (336 to 344 m) thick, and is entirely *Baculites eliasi* in age (72.5 ± 0.3 Ma). The estimated age of the overlying *B. baculus* ammonite zone (71.8 Ma) and underlying *B. jenseni* zone (72.9 Ma) indicate the upper transition zones was deposited in about 550 ka. Local estimated rates of accommodation (2,000 ft/My) are due to rapid, localized subsidence in the Florence Basin. The overlying subunits of the Pierre Shale in the Denver Basin and southward in the Colorado Springs-Pueblo area are not recorded in the Florence Basin. Instead they are represented by the Cretaceous beach shoreface Trinidad Sandstone and overlying nonmarine fluvial sediments and coal beds in the Vermejo Formation (not in the mapped area). The sedimentary facies of the upper transition member of the Pierre Shale consists entirely of distal sandy shale. The unit grades upward into shaly sand that is overlain by nearshore sand beds of the Trinidad Sandstone (not in the mapped area).

Kpm — **Middle unit, undivided** — Marine shale consisting of the cone-in-cone zone of Lavington (1933), the Tepee Butte zone of Gilbert (1897) and the Rusty zone of Gilbert (1897) as illustrated in the measured section (Figure 1). Unit thickness is about 2,460 ft (750 m) thick in the Florence Basin.

The cone-in-cone zone of Lavington (1933) is a noncalcareous marine dark-gray clay-rich to silty shale, about 600 ft (183 m) thick with a few prominent zones of cone-in-cone concretions (Figure 1, Plate 2), iron-rich concretions, and iron-stained limestone concretions. The cone-in-cone zone contains the Western Interior Seaway ammonite zones ranging from the middle of the *Didymoceras cheyennense* zone, all of the *B. compressus, B. reesidei, B. jenseni* zones, and the lowest part of the *B. eliasi* zone. The zones range in age from about 74 to 73 Ma and record the peak of the Bearpaw Transgression. Bentonites (at least 14) are common in the lower to middle part of the cone-in-cone zone.

The Tepee Butte zone of Gilbert (1897) is about 1050 ft (320 m) thick in the Florence quadrangle, which is interpreted from well logs to be over 50% thicker than that portrayed by Scott and Cobban (1975). It is renowned for the circular limestone masses that make up the core of the widespread "Tepee Buttes" landforms in the Pierre Shale on the plains east of Colorado Springs and Pueblo. The Tepee Butte zone is a calcareous shale, olive gray to medium gray, distinctly lighter than the adjoining zones. It has regions of higher electrical resistivity that probably correspond to zones of higher calcite contents. The limestone concretions of the Tepee Buttes are considered to have formed as submarine methane seeps. It is unclear why Scott and Cobban (1975) depicted a thicker Rusty zone than Tepee Butte zone in the map area, 1168 ft (356 m) and 777 ft (237 m), respectively. In the adjoining Pueblo-Colorado Springs area, the Rusty zone is approximately one- third of the thickness of the Tepee zone. In both areas, the bases of the subunit start in the *B. scotti* ammonite zone, and limestone concretions extend up to 1050 ft (320 m) below the top of the Tepee zone (Scott and Cobban, 1986). Ammonite biostratigraphy of the Tepee zone begins in the lower *B. scotti* zone, extends upward through the ammonites of the *Didymoceras nebracense, D. stevensoni, Exiteloceras jenneyi* zones, and ends in the middle of the thin (42 ft [13 m]) *D. cheyennense* zone. The zones represent about 1.5 My of time from 76 to 74.5 Ma. Bentonites are especially common in the upper 300 ft (91 m) of the Tepee zone.

The lowest Pierre Shale unit of the middle Pierre is the Rusty zone of Gilbert (1897), a noncalcareous shale about 780 ft (238 m) thick. The Rusty zone is a dark gray fissile shale, generally low in electrical resistivity, with common reddish-brown ironstone concretions, sparse limestone concretions, and relatively few bentonite beds. The zone contains sparse ammonites from the *Baculites perplexus* and *B. gregoryensis* zones, and extends up into the lower *B. scotti* zone, and has sometimes been informally referred to as the "barren zone". Sediments of the Rusty zone were deposited over 3 million-year interval of time, from about 79 to 76 Ma.

Kpss — **Sharon Springs Member** — Relatively thin (60 ft [18m]), organic-rich, distinctive stratigraphic unit of the lower part of the Pierre Shale. The unit consists of dark-gray silty shale, with abundant surface selenite gypsum crystals that reflect its high sulphur content. In the subsurface, it has a characteristic gamma-ray signature reflecting its high uranium content. The member contains phosphate nodules and has a high metal content. The Sharon Springs Member is considered a major source rock for the petroleum produced from fractures in the Pierre Shale in the Florence oil field. This field is Colorado's first oil producer dating back to 1860 (Kupfer, 2000), and the oldest continuously producing operating oil field in the country that has produced over 16 million barrels of oil. The Sharon Springs Member is one of the most distinctive marker units of the Cretaceous Western Interior Seaway, extending from the type area in western Kansas (Gill and others, 1972) through the Dakotas, Montana, Wyoming, to western Colorado. However, the basal package of multiple bentonite layers (the Ardmore "bentonite") is not present in the Florence Basin suggesting it was either not deposited or was removed by erosion. The baculite ammonite zones *Baculites obtusus, B. maclearni, and B. asperiformis*, all occur in this thin unit, which was deposited from about 81.3 to 80 million years ago. The unit is a potential source of Radon (Colorado Geological Survey, 1991).

Kpl — **Lower unit, undivided** — The undivided lower unit consists of the Apache Creek Sandstone Member and the lower transition member. The latter grades into the calcareous marls of the underlying Niobrara Formation. The Apache Creek Sandstone Member (Scott and Cobban, 1963) is a dark gray, thin-bedded unit about 90 ft (27 m) thick in the Florence Basin where it is about as half as thick as in the Pueblo-Trinidad area. It is a quartz-rich sandy shale, with thin sandstone lentils, and is the temporal and lithological equivalent of the Mesaverde Formation at and near its type sections in southwest Colorado, where it is over 800 ft (244 m) thick in the San Juan Basin.

The underlying lower transition member represents a lithologic gradation from the chalks and marls of the subjacent Niobrara Formation to the carbonate-poor clastic sediments of the overlying Pierre Shale. The member is about 225 to 300 ft (69 to 91 m) thick in the Florence Basin. The lowest beds include meter-thick chalk and intertonguing shale beds; Scott and Cobban (1964 and 1975) placed the basal contact of the member at the distinctive, resistant upper chalk bed of the Smoky Hill of the Niobrara Formation. Therefore the entire gradational transition is included in the Pierre Shale. It is slightly fossiliferous, with only scattered specimens of the lowest Baculites sp. (smooth). The lower unit of the Pierre Shale units range in age from about 83 to 81.5 Ma.

Niobrara Formation (Upper Cretaceous) — In the Florence Basin, the Niobrara Formation comprises the only widespread thick calcareous shale and limestone deposits of the Cretaceous Western Interior Seaway. In comparison, the calcareous deposits in the underlying Carlile Shale and Greenhorn Formation are relatively thin (170 ft [52 m]). Despite close proximity to the principal reference section of the Niobrara Formation in Pueblo, Colorado (Scott and Cobban, 1964), the Niobrara in the Florence Basin is significantly thinner, about 500 ft (152 m) thick based upon outcrop and subsurface well log data. The difference in thickness (740 ft [226 m] compared to ≤500 ft [152 m]) is due to thicker deposits of the middle shale and upper chalky shale in the Pueblo area. All of the Niobrara Formation subunits reported by Scott and Cobban (1964) are present in the Florence Basin, but the terminology for the calcareous shales has been revised (Dean and Arthur, 1998) to use the term marl instead of calcareous shale; the Smoky Hill Shale Member (Scott and Cobban, 1964) is therefore herein referred to as the Smoky Hill Marl Member of Niobrara Formation which consists of interbedded marls and chalks (predominantly chalky marls and marly chalks). The Fort Hays Limestone Member is resistant and typically forms hogbacks in the mapped area. All of the Niobrara units are mapped as one unit on cross section B-B'. Some members are a potential source of Radon (Colorado Geological Survey, 1991).

Ksuc — **Smoky Hill Marl Member, upper chalk** — Chalk beds about 7 to 10 ft (2 to 3 m) thick, along the western boundaries of the Denver and Florence Basins as well as throughout the Denver Basin in the subsurface. Weathered outcrops of the upper chalk and some chalk beds in the lower part of the lower transition member of the Pierre Shale typically are a light orange color. The upper chalk is commonly referred to as the "A" chalk in the Denver Basin, and is a major biogenic gas reservoir in Yuma County, Colorado and northwest Kansas. The only age-diagnostic fossil in the Smoky Hill upper chalk is *Haresiceras natronense*, north of Boulder, Colorado. This fossil is early Campanian in age (Scott and Cobban, 1964). The Smoky Hill Marl Member, upper chalk is included in unit Ksmuc on cross section A-A'.

Ksmuc — **Smoky Hill Marl Member, upper marl and chalk** — The upper marl and chalk unit of the Smoky Hill is a revised name for the thick upper chalky shale member of the Scott and Cobban (1964), which varies from 200 to 260 ft (61 to 79 m) thick in the Florence Basin. This unit has multiple alternating chalk-rich zones and marls, the pattern of which has not been consistently correlated, perhaps due to syndepositional tectonism and submarine erosion. Lithologies range from packages of laminated marls to chalk beds, that form local patterns in outcrop section but are difficult to correlate from basin to basin. They include the widespread kerogen-rich (high total organic carbon) source rocks that produce prolific unconventional oil-bearing units in the Denver Basin. The ammonite *Haresiceras placentiforme* is indicative of middle to upper Santonian age for the upper marl and chalk, possibly extending into the lowest Campanian (Scott and Cobban, 1964). The Smoky Hill Marl Member, upper marl and chalk includes unit Ksuc on cross section A-A'.

Ksmc — **Smoky Hill Marl Member, middle chalk** — The middle chalk is a gray, chalk-rich hogback-forming unit about 20 to 50 ft (6 to 15 m) thick, and occurs about 200 ft (61 m) stratigraphically above the top of the Fort Hays Limestone Member. Characteristic fossils include the inoceramid *Cordiceramus bueltenensis* and the ammonite *Clioscaphites choteauensis*, with *Clioscaphites vermiformis* occurring just beneath in the upper part of the middle marl. These fossils are all indicative of a middle Santonian age (Walaszczyk and Cobban, 2007) of about 85 Ma. The Smoky Hill Marl Member, middle chalk includes units Ksmm, Kslc, Kslm, and Knf on cross section A-A'.

Ksmm — **Smoky Hill Marl Member, middle marl** — Marl interval about 50 to 100 ft (15 to 30 m) thick, much less than Scott and Cobban (1964) reported (283 ft [86 m]) for the middle shale unit of the Smoky Hill Shale. Laminated, hard platy organic-rich light to medium olive-gray to yellowish-gray marl that locally contains pyrite. The unit lacks thick chalk layers, is bounded below by the distinct lower chalk member, and is overlain by the middle chalk horizon. In the lower part of the middle marl near Pueblo is the lower occurrence of *Cladoceramus undulatoplicatus*, the index species for the base of the Santonian stage (86.3 Ma; Sageman and others, 2014), and slightly higher is the ammonite *Clioscaphites saxitonianus* (Scott and Cobban, 1964; Walaszczyk and Cobban, 2007). The Smoky Hill Marl Member, middle marl is included in unit Ksmc on cross section A-A'.

Kslc — **Smoky Hill Marl Member, lower chalk** — The widespread lower chalk interval of the Smoky Hill corresponds to the Lower Limestone unit of Scott and Cobban (1964). The lower marl unit is a subtle cliff forming unit composed of beds that has a characteristic light and dark banding. At a distance these look like interbedded 0.5 to 1 m thick chalk and marl beds. On closer examination the unit consist of packages of light chalky laminated beds alternating with laminated darker marl beds about 40 to 60 ft (12 to 18 m) thick, but the prominent banded interval is in the lower 30 to 40 ft (9 to 12 m) of the unit. Inoceramid fossils (*Magadiceramus crenulatus*) and sparse ammonites indicate an upper Coniacian age for the lower chalk; elsewhere in the Western Interior Seaway this inoceramid is associated with ammonites of the *Scaphites depressus* zone, about 87 to 86 Ma in age. The Smoky Hill Marl Member, lower chalk is included in unit Ksmc on cross section A-A'.

Kslm — **Smoky Hill Marl Member, lower marl and lower marl and limestone** — The lower marl unit of the Smoky Hill is redefined as a moderately thin but prominent interval just below the lower chalk unit. The unit is a medium yellowish to dark gray, laminated chalky marl and marl that is 8 to 18 ft (2.4 to 5.5 m) thick in the Florence Basin, and possibly as thin as 2 to 5 ft (0.6 to 1.5 m) thick, regionally. The unit is prominent in subsurface logs because of its very high gamma-ray activity, due to its elevated uranium content. The base of this unit is also the base of a kerogen-rich marl that extend upward throughout the upper Smoky Hill marl and into the lower transition member of the Pierre Shale.

Beneath the lower marl is the lower marl and limestone unit. This unit comprises the base of the lower shale unit together with shale and limestone unit of Scott and Cobban (1964). The unit is about 40 to 50 ft (12 to 15 m) thick. Some of the chalk-rich beds are limestone based upon density, and the marls and limestone are distinctly lower in gamma-ray activity (owing to low total organic carbon) than all of the overlying Smoky Hill Marl Members. The lowest 10 ft (3 m) of the lower marl and limestone unit is often mined together with the Fort Hays Limestone Member at the LafargeHolcim quarry in Portland, Colorado to make Portland cement. The inoceramid zones *Volviceramus involutus* overlain by *Magadiceramus subquadratus* indicates that the lower marl and limestone is middle Coniacian to upper Coniacian in age (89 to 88 Ma), though some intervals of time are missing in disconformities. The Smoky Hill Marl Member, lower marl and limestone is included in unit Ksmc on cross section A-A'.

Knf — **Fort Hays Limestone Member** — The Fort Hays Limestone Member is widespread in the mapped area and consists of hard, indurated limestone beds, interspersed with thinner marl beds. It is 36 ft (11 m) thick at the LafargeHolcim quarry where it consists of about 70 beds in total. Twenty of these are gray hard limestone beds from 10 to 30 in (25 to 75 cm) thick, interspersed with thinner (<20 cm) marl and limestone beds (Scott and Cobban, 1964). The mixture of nearly pure limestone beds and interspersed marls provides excellent material for making Portland cement. The LafargeHolcim kiln produces about 3 million tons per year. The Fort Hays is a conspicuous unit atop a hogback-forming ledge, particularly in the northern half of the Florence quadrangle, where it flanks Brush Hollow Reservoir. The unit has prominent regional disconformities within it and at its upper boundary. Beneath the Fort Hays is the Carlile-Niobrara regional unconformity, the largest in the Upper Cretaceous of the Western Interior Basin of North America. The Fort Hays Limestone Member is included in unit Ksmc on cross section A-A'.

Carlile Shale (Upper Cretaceous) — The Carlile Shale in the Florence quadrangle is comprised of four distinct units, from bottom to top (Pratt and others, 1985): the Fairport Chalky Shale Member, the Blue Hill Shale Member, the Codell Sandstone Member, and the overlying Juana Lopez Member (described separately below). Mapped as unit Kc on cross section A-A'.

Kcj — **Juana Lopez Member** — The Juana Lopez Member of the Carlile Shale is typically 24 to 48 in (60 to 120 cm) thick but can be as much as 7 ft (2 m) thick, locally. It is composed of resistant carbonate-rich bioclastic sandstone that supports the hogbacks and mesas that are capped by the Fort Hays Limestone. The member weathers to a distinct maroon to reddish brown color owing to its complex depositional and diagenetic history (Lewis, 2013). It contains abundant molluscan fragments of inoceramid and oysters, and has a biostratigraphic age of late Turonian based on the ammonite *Scaphites whitfieldi* and *Inoceramus perplexus*, which indicates that the member is about 90.5 to 92 Ma (Cobban and others, 2006). The Carlile Shale, Graneros Shale, and Greenhorn Limestone are included in unit Kcgg in cross section B-B'. Areas below slopes underlain by the unit may be subject to rockfall.

Kc — **Carlile Shale, unidivided** — The Carlile Shale is regionally approximately 180 to 190 ft (55 to 58 m) thick, and bounded above by the Carlile-Niobrara unconformity. The Fairport Chalky Shale Member is the basal member of this unit. It is a light-gray to yellowish-orange marl with decreasing calcium carbonate content from the base. The Fairport Chalky Shale Member is about 60 to 100 ft (18 to 30 m) thick. Fossils in the unit are those of the *Collignoniceras woollgari* zone of middle Turonian age (~92 Ma). It is overlain by the noncalcareous Blue Hill Shale Member, which is 50 to 100 ft (15 to 30 m) thick. The contact is sharp, and may be a local disconformity. The lower Blue Hill Shale Member forms steep slopes. The unit grades upward from black clay-rich or blue-gray shale to medium olive-gray silty sandy shale with fine-grained sandstone interbeds. The unit gets sandier as it grades upward into the Codell Sandstone. The lower shale contains subequal amounts of illite and less abundant mixed layers of illite/smectite, up to 30 percent quartz and feldspar, and less than 10% calcite (Scott, 1969). The upper part of the Blue Hill Shale Member contains conspicuous round septarian limestone concretions, 8 in (20 cm) to 4 to 6 ft (1.2 to 1.8 m) in exposed diameter (Pratt and others, 1985). Bentonite beds are more common in the Fairport Member and less common in the Blue Hill Shale Member. Areas underlain by the unit may be subject to hazards associated with expansive soils.

The Codell Sandstone Member is a regionally extensive sandstone that forms bluff outcrops above the Blue Hill Shale Member. The Codell is typically about 30 ft (9 m) thick, but locally can be as much as 56 ft (17 m) thick. It contains yellow-gray to light-gray to yellowish-brown, cross-stratified to massive, platy to massive, bioturbated sandstone beds (Scott, 1969). The Codell Sandstone and Blue Hill Shale members are in the *Prionocyclus hyatti* ammonite zone, middle Turonian in age. The Fairport and Blue Hill Members are rarely exposed and the Codell Sandstone Member occurs in few discrete locations; therefore they are all mapped as undivided Carlile Shale. The Carlile Shale, Greenhorn Limestone, and Graneros Shale are included in unit Kcgg on cross section B-B'.

Greenhorn Limestone (Upper Cretaceous) — Contains from top to bottom, Bridge Creek Limestone Member, Hartland Shale Member and Lincoln Limestone Member; the Hartland Shale and Lincoln Limestone members are described within the Graneros Shale. Mapped as unit Kg on cross section A-A'.

Kghb — **Bridge Creek Limestone Member** — The Bridge Creek Limestone Member is the most conspicuous component of the Greenhorn Limestone. The unit was deposited at the very highest stage of transgression of the Western Interior Seaway onto the North American continent during the Late Cretaceous. The Bridge Creek Limestone Member is characterized by alternating, 4 to 16 in (10 to 40 cm) thick, hard, dense chalky limestone beds that are rhythmically interbedded with recessive, 4 to 39 in (10 to 100 cm) thick marl beds (Cobban and Scott, 1972; Elder and Kirkland, 1985; Kauffman, 1985). This oscillatory pattern, recognized by Gilbert (1897) during the earliest geologic investigations of the Arkansas River region, may be due to patterns of astronomical forcing. The light colored, weathered, dense micritic limestone layers comprise a package of about 60 layers deposited with alternating softer marls and marly shales in a sequence only 50 ft (15 m) thick. The climatic and paleobiologic record recorded within these layers has been investigated by many researchers, leading to recognition of the global standard Cenomanian-Turonian boundary section in Pueblo (Kennedy and others, 2005). The concept of worldwide Ocean Anoxic Events (OAE), and in particular OAE2 at 94 Ma, have been documented in the Bridge Creek Member. Individual beds of this member have been carefully mapped and correlated over hundreds of miles across Kansas, Colorado, and New Mexico (Hattin, 1975). Multiple isotopically dated bentonites and astronomical tuning of sediment patterns have allowed very precise dating of the Greenhorn Limestone middle Cretaceous sea level high stand (OAE2) and dating of the base of the Turonian stage between 94.3 and 93.7 Ma (Meyers and others, 2012). The Carlile Shale, Greenhorn Limestone, and Graneros Shale are included in unit Kcgg on cross section B-B'.

Kgg — **Graneros Shale and shales in lower Greenhorn Limestone, undivided** — The lower two members of the Greenhorn Limestone, the Hartland Shale Member and the Lincoln Limestone Member, are mapped along with the Graneros Shale, because they are of similar lithology. The Lincoln Limestone Member is a marl unit with distinct calcarenite ledge-forming beds that are 28 to 46 ft (8.5 to 14 m) thick (Bass, 1926). The Hartland Shale Member is dark-colored laminated organic-rich marl that formed mostly in a distal anoxic ocean bottom setting. The shale contains some carbonate-rich intervals (marlstone, biogenic calcarenites, and minor limestone). It is non-fossiliferous, contains a number of bentonites, and is about 40 to 50 ft (12 to 15 m) thick. The entire combined Graneros Shale and lower Greenhorn Limestone map unit is about 180 to 210 ft (55 to 64 m) thick. Areas underlain by the unit may be subject to hazards associated with expansive soils.

The Cenomanian Graneros Shale and the overlying shale-rich members of the Greenhorn Limestone record the initial history of offshore marine sedimentary deposition during the increasingly deeper water transgression leading up to the high stand represented by the Bridge Creek Limestone Member.

The Graneros Shale is a medium to dark gray clay to noncalcareous shale with minor siltstone interbeds, and a single, 6 to 12 in (15-30 cm) thick, widespread carbonate marker bed (Thatcher Limestone Member) that separates the non-fossiliferous lower shale member from the fossiliferous upper shale member of the Graneros Shale (Cobban and Scott, 1972; Kauffman, 1985). The shales in unit range from laminated and organic-rich shale to more bioturbated, oxygenated, low-organic shales (Kauffman, 1985). It contains bentonites that have been isotopically dated at 96.1 to 95.5 Ma (Obradovich, 1993; Cobban and others, 2006). The Graneros Shale, in total, is about 110 to 124 ft (34 to 38 m) thick. Ammonites occurring above the lower barren zone range from *Conlinoceras tarrentense*, the lowest Upper Cretaceous Western Interior ammonite zone, up through *Acanthoceras muldoonense*, to *A. amphibolum*, beneath the capping "X" bentonite. The Carlile Shale, Greenhorn Limestone, and Graneros Shale are included in unit Kcgg on cross section B-B'.

Dakota Group (Upper Cretaceous) — The Dakota Group represents the original marginal marine and shoreface sand-beach deposits that mark the beginning of deposition in the Cretaceous Western Interior Seaway of North America. The group is mainly nonmarine sandstone and shale, including local carbonaceous shale and rare coal. Only the uppermost sandstone is marine, recognized mainly by bedding characteristics and trace fossils; few typical marine fossils have been identified in the sandstone of the Dakota Group. Combined thickness of units of the Dakota Group is variable, and ranges from 180 to 300 ft (55 to 91 m). The members of the Dakota Group are represented in both cross sections as Kd. Areas below slopes underlain by the unit may be subject to rockfall. Some members are a potential source of Radon (Colorado Geological Survey, 1991).

Kdu — **Dakota Group, upper sandstone (Muddy Sandstone-equivalent)** — The upper part of the Dakota Group is the most resistant part of the shale member. It forms a widespread and continuous hogback on the west side of the Denver Basin and on the northern, western, and southern flanks of the Canon City embayment. It also has been the most prolific conventional oil and natural gas reservoir in Cretaceous sequences of the Rocky Mountains and adjoining Great Plains. On the plains adjoining the mountains, it is commonly an important aquifer. The stratigraphic correlation of sandstone and shale sequences of the Dakota Group is obscured by a variety of stratigraphic names and sparse biostratigraphic control. The most definitive work on the sandstone of the Dakota Group in northern Colorado is that of Waagé (1961). The petroleum geology and stratigraphy of the Dakota Group in the Denver Basin is summarized in a comprehensive report by Weimer (1996).

Kdl — **Plainview Sandstone and Lytle Sandstone, undivided** — The lower part of the Dakota Group composed of the Plainview Sandstone and Lytle Sandstone, and is very distinct from the upper part of the Dakota Group (Waagé, 1953). The Plainview is a 15 to 23 ft (4.6 to 7 m) thick, darker brown, resistant fine-grained sandstone locally exposed above the Lytle Sandstone. The Lytle Sandstone is a massive, poorly sorted, white fine- to medium-grained sandstone with discontinuous conglomeratic sandstone lenses. Between Sixmile and Eightmile creeks, the Lytle and Plainview sandstones are thicker than sandstone bodies in the upper part of the Dakota Group. However, well data indicate the Lytle Sandstone is similar in thickness to sandstone in the upper part of the Dakota, where units are 48 to 140 ft (15 to 43 m) thick.

Jm — **Morrison Formation (Upper Jurassic)** — The Morrison Formation consists of thinly layered claystones, siltstones, fine-grained sandstones, and freshwater limestones. The siltstones are primarily gray to greenish-gray, to maroon, thinly bedded, fissile, and loosely consolidated sediments that form slopes. The sandstones are gray to tan, very fine grained, and cemented with calcium carbonate. The limestones are gray, very fine grained, thinly bedded, and more highly cemented than the clastic rocks. The Morrison Formation clastic sequence was formed in a continental environment dominated by meandering stream channels, overbank areas between stream channels, and mudflats. Limestone accumulated in lacustrine environments. The unit is 300 ft (91 m) thick in the southern part of the nearby Mt. Pittsburg quadrangle (Orr, 1976; Morgan and others, 2006). The Morrison Formation, Ralston Creek Formation, and Lykins Formation are included in unit Jrc on cross section A-A'.

Jrc — **Ralston Creek Formation (Upper Jurassic)** — The Ralston Creek Formation is composed of thinly bedded white gypsiferous siltstone layers with gypsiferous veins and nodules at its base. This contrasts sharply with the orange-red layers of the Lykins Formation below the disconformable contact. The gypsum is locally jointed with silts and muds filling the joints, suggestive of dessication. The Ralston Creek grades upwards to a white to light gray gypsiferous sandstone near its top. The Ralston Creek is approximately 50 to 60 ft (15 to 18 m) thick in the northwest part of the quadrangle and is conformable with the overlying Morrison Formation. Landslides locally initiate from the siltstones and gypsum of the Ralston Creek Formation upon wetting (Morgan and others, 2006). The Morrison Formation, Ralston Creek Formation, and Lykins Formation are included in unit Jrc on cross section A-A'.

TRPl — **Lykins Formation (Lower Triassic to Upper Permian)** — The Lykins Formation is composed of distinct orange-red siltstones, sandstones, and shales, interbedded with thin layers of gray to white, dolomitic limestones and gypsum. Theunit is best exposed at the base of the ridge on the east side of Colorado Road 132 (sec. 11. T. 18 S., R. 69 W.) where it is approximately 120 ft (37 m) thick. The formation thins to the west and is not exposed along Sixmile Creek in sec. 16, T. 18 S., R. 69 W. Recent work suggests that the lower part of the Lykins Formation was deposited during the Early to Middle Permian, and its uppermost strata were likely deposited during the Early to Middle Triassic (Hagadorn and others, 2016). These authors also note the presence of a significant erosional unconformity that has removed the Triassic rocks of the Lykins Formation in central and south-central Colorado. In the Florence quadrangle, the depositional environment is generally interpreted as one of changing conditions between shallow marine, intertidal, supratidal, and terrestrial environments. The Morrison Formation, Ralston Creek Formation, and Lykins Formation are included in unit Jrc on cross section A-A'. Areas below slopes underlain by the unit may be subject to rockfall.

PPf — **Fountain Formation (Lower Permian and Pennsylvanian)** — The Fountain Formation is primarily a dark-red to red to pink, fine- to coarse-grained, arkosic sandstone and pebble conglomerate. Clasts are subangular to rounded and consist of quartz as well as coarse-grained intrusive igneous and metamorphic rocks. Cross bedding and graded bedding are common. Locally, the formation contains beds of dark red to red to reddish-brown, thinly bedded shales and mudstones. The depositional environment for the arkosic sandstones and conglomerates was one of fluvial channels, overbank areas, and alluvial fans, sourced by syntectonic and post-orogenic sediments derived from the Ancestral Rocky Mountain uplift. Thickness is at least 3,450 ft (1,052 m) based on data obtained from the Delhi-Taylor State 1 well log located in sec. 16, T. 18 S., R. 69 W. (Figure 1).

Of — **Fremont Formation (Upper Ordovician)** — The Fremont Formation does not crop out in the map area and is shownonly on the cross section. The formation was identified in cuttings from the Delhi-Taylor State 1 well (Figure 1, Plate 2) in sec. 16, T.18 S., R. 69 W. where it has an estimated thickness of 85 ft (26 m). In outcrops in other areas of the Canon City embayment, the formation consists of a pink to red, fine grained, massive, dense dolomite to dolomitic limestone, which locally contains coarse to medium, well-rounded quartz sand grains. The absence of this formation along the mountain front is probably a result of considerable post-Fremont and pre-Fountain erosion. The resulting disconformity likely accounts for the absence of rocks of Silurian, Devonian, and Mississippian age. The lithology and fauna of the Fremont Formation suggest a high energy environment of deposition in a warm, shallow sea (Sweet, 1954).

Oh — **Harding Formation (Middle Ordovician)** — The Harding Formation is exposed in the same general areas as the underlying Manitou Limestone in the northwest portion of the quadrangle. The formation consists of a well rounded to subrounded, fine- to very fine-grained quartz sandstone. Exposed weathered surfaces are light red to pink and fresh surfaces are white to tan. The Harding is well sorted, moderately cemented, and is about 100 ft (30 m) thick based on the Delhi-Taylor State 1 (sec. 16, T. 18 S., R. 69 W.) well log (Figure 1). The erosional contact with the underlying Manitou Limestone was not observed in outcrops in this quadrangle. The formation is similar in lithology to equivalent rocks observed in other areas near Canon City where it has been interpreted to be the result of deposition in a stable, shallow-shelf, marine environment (Gerhard, 1967). The Harding Sandstone and Manitou Limestone are included in unit Omh on both cross sections (Plate2).

Om — **Manitou Limestone (Lower Ordovician)** — The Manitou Limestone is exposed discontinuously in the northwest part of the mapped area near Colorado Road 67 entering Phantom Canyon. The formation was observed only as rock fragments near the fault in the basement rocks on the west side of the road; however, limited outcrops occur east of the road as blocky, fine-grained, pink to maroon, dolomite to dolomitic limestone. Although not visible in this quadrangle, the unconformable contact with the underlying Proterozoic crystalline rocks is exposed as a planar erosional surface in the Mt. Pittsburg quadrangle to the northeast of the map area (Morgan and others, 2006). Numerous exposures of the basal Manitou Limestone in the Mt. Pittsburg quadrangle contain siltstones and claystones below the main pink carbonates, which suggest low-energy reworking in intertidal and/or supratidal environments during the advance of shallow seas as the unit was deposited. The estimated thickness of the Manitou Limestone in the Florence quadrangle is less than 40 ft (12 m) based on the Delhi-Taylor State 1 well log located in sec. 16, T. 18 S., R. 69 W. (Figure 1). The Harding Sandstone and Manitou Limestone were mapped together on both cross sections (Plate 2).

Xgn — **Migmatitic gneiss (Paleoproterozoic)** — Resistant, foliated, medium to coarse-grained, gray to pink, biotite-potassium feldspar gneiss and migmatite. Gneiss is exposed in a few outcrops in the extreme northwestern part of the quadrangle.

MAP SYMBOLS

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

Strike and dip of inclined bedding — Showing direction and angle of dip in degrees (from Beach, 1983)

Strike and dip of inclined bedding — Showing direction and angle of dip in degrees (from DeFord, 1929)

Strike and dip of inclined bedding — Showing direction and angle of dip in degrees (from Weiner, 1980)

Horizontal bedding

Strike and dip of foliation — Showing direction and angle of dip in degrees

Sample locations

Fossil location (Scott, 1970)

Well locations

Anticline — Identity and existence certain, dashed where approximately located, dotted where concealed

Syncline — Identity and existence certain, dashed where approximately located, dotted where concealed

Fault — Dashed where approximately located; U = upthrown side, D = downthrown side

Alignment of cross section

Disturbed ground

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