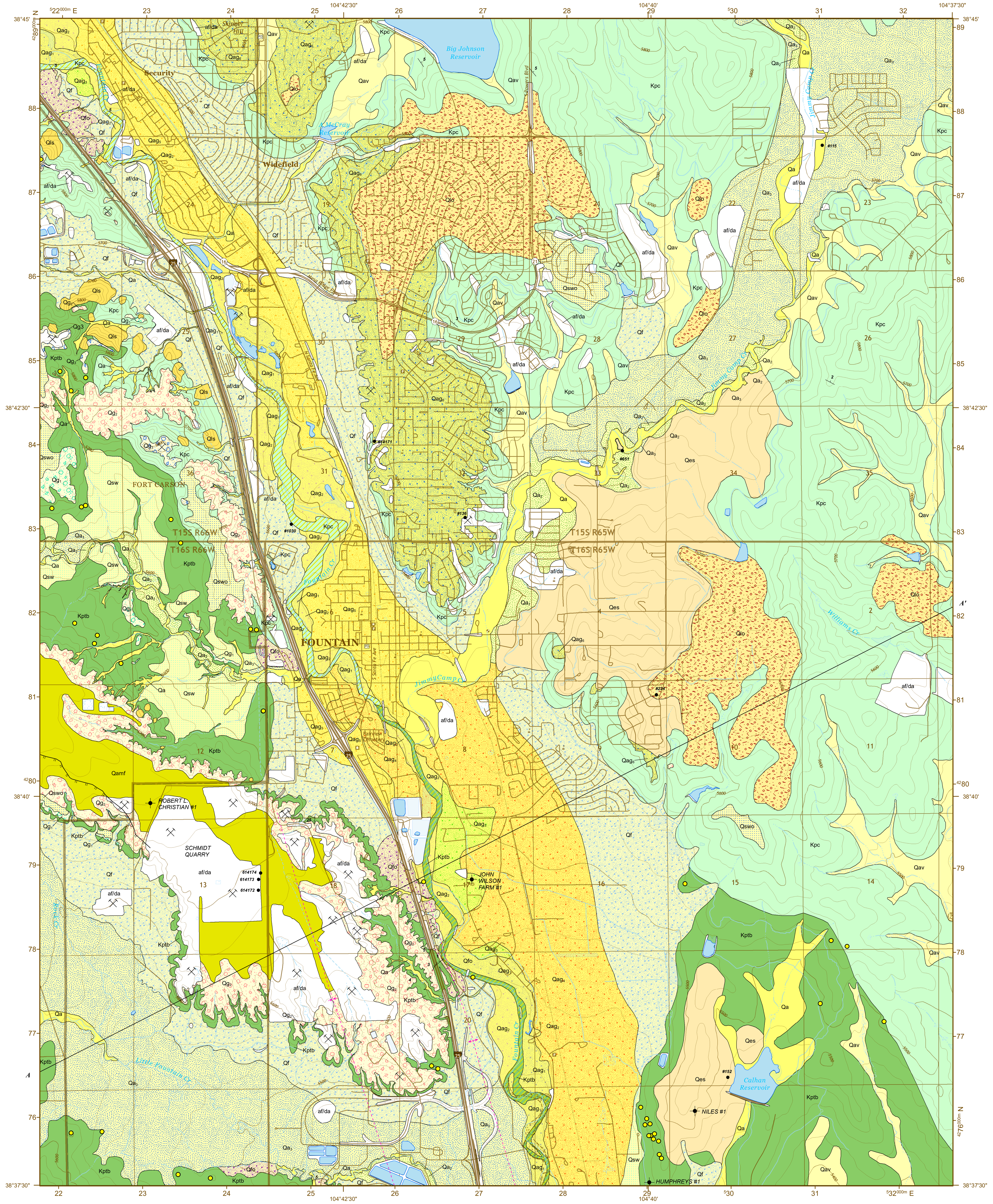

Coordinate System: NAD 1983 UTM Zone 13N
Projection: Transverse Mercator
Datum: North American 1983

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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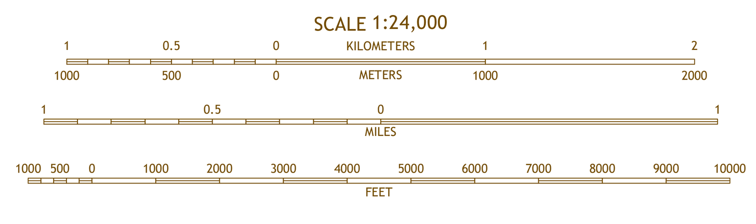
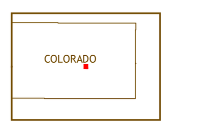
Contours............................National Elevation Dataset, 2003
Roads...............................U.S. Census Bureau, 2015-2016
Names...............................GNIS, 2016
Hydrography.......................National Hydrography Dataset, 2013
Boundaries.........................multiple sources; see metadata file, 1972-2016
Public Land Survey System......BLM, 2011

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 G16AC00189.



QUADRANGLE LOCATION

Geology mapped in 2016
GIS and cartography by Pangaea Geospatial

Colorado Springs	Elsmere	Corral Bluffs
Cheyenne Mountain	Fountain	Fountain NE
Timber Mountain	Buttes	Fountain SE

ADJOINING QUADRANGLES

GEOLOGIC MAP OF THE FOUNTAIN QUADRANGLE, EL PASO COUNTY, COLORADO

By Jonathan L. White, Kassandra O. Lindsey, Matthew L. Morgan, and Shannon A. Mahan
2017

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

HUMAN-MADE DEPOSITS AND SURFACE-DISTURBED AREAS

af/da

Artificial fill and disturbed areas (uppermost Holocene) — Gravel, sand, silt, clay, dimension rock, and other human-made materials emplaced, disturbed, or removed by human activities. Artificial fills may be engineered as roadway embankments and development overlot grading, or uncontrolled and unsorted storage piles of varying compositions and properties. Unit also includes landfills, human-made river embankments, and surface mine areas, overburden spoils and reclaimed areas. Gravel pit operations are marked with mine symbols.

ALLUVIAL DEPOSITS

Qa

Alluvium, undivided (upper Holocene) — Tan to tan-gray sand and clayey to silty sand. Stratified with occasional thin gravelly lenses. Forms lowest terrace deposit that includes active stream channels that may be further incised 2 to 4 ft (0.6 - 1.2 m) into the deposit. Unit is most prominent along floor of Jimmy Camp Creek where it is predominantly sand. Optically stimulated luminescence (OSL) of a sand sample (#115) of this unit at a depth of 7 ft (2.1 m) in the Jimmy Camp Creek basin yielded an age of 400 ± 40 yrs BP. Thicknesses is unknown since the Qa deposit has incised into the thicker Qa_3 fill terrace. Deposits associated with smaller drainages within steeper, narrow drainage channels west of I-25 and within Fort Carson (where access was limited) are very thin (≤5 ft, (≤1.5 m)), darker gray, and contain higher contents of clay from erosion of the Pierre Shale and dispersed crystalline gravel reworked from erosion of the Pleistocene gravel units that cap the mesas. Parts of this unit may be equivalent to unit Qay_1 of Madole and Thorson (2003). This unit is prone to flooding and high ground water levels. Sediments may also be soft, very moist, potentially compressive, and contain swelling clay minerals.

Qa_2

Alluvium two (middle Holocene) — Tan-gray to brownish-gray, clayey to silty sand and sandy clay, weakly stratified, with occasional dispersed gravel-bearing lenses. Unit was deposited as muddy sediments in a fluvial setting. Poorly to moderately sorted sand is predominantly fine- to very fine-grained but can have layers that are coarse to very coarse; these were deposited in higher energy fluvial settings where small pebble- to granule-sized gravel clasts are dispersed in a clayey sand matrix. Soil profile on deposits consists of immature A/C horizons. Gravel clasts are generally crystalline rocks reworked from other surficial units but also include angular concretion fragments from the Pierre Shale. Unit underlies a secondary terrace cut into the Qa_3 unit, and also forms a bluff 5 to 10 ft (1.5 – 3 m) high where incised by the lower Qa surface. Dating of this unit at a sample depth of 7 ft (2.1 m) in the Jimmy Camp Creek basin (#651) yielded a conventional radiocarbon age of 5,040 ± 30 yrs BP. This unit may be equivalent to unit Qay_2 of Madole and Thorson (2003). Sediment contains visible "pinhole" porosity and may be prone to hydrocompaction. Seasonal high ground water levels may also be a concern. Clay content is derived from the expansive Pierre Shale and unit may also be prone to swelling.

Qa_3

Alluvium three (lower to middle? Holocene) — Dark-brownish gray to tan-gray, occasionally mottled, stratified, poorly to occasionally well-sorted sand and clayey to silty sand. Unit can contain clean, medium-grained, well-sorted sand layers and sporadic gravel lenses with clasts sizes up to small cobbles. Gravel provenance is crystalline rocks reworked from either conglomerates in the Dawson Formation up-valley along Jimmy Camp Creek or reworked from Pleistocene gravel-capped mesas; contains angular concretion fragments derived from the Pierre Shale. Soils contain calcic stringers and dispersed $CaCO_3$ particles; multiple, weakly developed buried Bt horizons are present. This unit forms broad terraces along Jimmy Camp and Little Fountain creeks. Bluffs occur where it has been downcut and later Qa_2 and Qa units were deposited. This terrace occurs about 15-20 ft (4.6 – 6 m) above the stream base level. This unit is equivalent to unit Qam of Madole and Thorson (2003) and unit Qt_1 in Rowley and others (2004). The soils in this unit contain macroscopic porosity and may be prone to settlement or swelling. Geotechnical borings indicate this unit is up to 50 ft (15 m) thick with increased gravel content in the lower 15 ft (4.6 m).

Qav

Valley-fill alluvium (Holocene) — Gray to light-tan to brownish-gray, unsorted to poorly sorted, weakly stratified, sandy to silty clay deposited as valley fill in broad drainage swales on low hillsides of the central and eastern parts of the quadrangle where underlain by Pierre Shale. Unit typically contains dispersed small gravel clasts composed of crystalline fine to medium pebble-gravel and Pierre Shale concretion fragments are common. This unit may include sheetwash (Qsw) sediments. An immature A/C soil profile is present where exposed in gullies. Unit thickness is about 5 ft (1.5 m) in narrower drainageways and up to 20 ft (6 m) in the wider swales. Unit contains expansive clays and and may be prone to swelling.

ALLUVIAL-GRAVEL DEPOSITS

Alluvial gravel (Holocene to lower Middle Pleistocene) — Glaciofluvial gravel that episodically aggraded the Fountain Creek valley. Episodic aggradation and downcutting, probably during interglacial periods, resulted in five strath-terrace levels recognized in the map area. The gravel is typically reddish, composed of well-rounded ovoid pebbles and cobbles in a clean, very coarse sand to fine pebble matrix. Small boulders (≤3 ft (≤0.9 m)) are present locally. The deposit includes clean lenses of well-sorted, medium- to coarse-grained arkosic sand. Unit is crossbedded and contains cut-and-fill channels. Clasts are river packed and imbricated by flow direction. In some locations, the deposit is streaked with orange-brown to dark blue-gray staining. Clast provenance is predominantly the reddish Proterozoic Pikes Peak Granite from the upper Fountain Creek basin in the Front Range. Rarer constituents include Paleozoic quartzites, carbonates, and red sandstones. In many areas, later alluvial-fan sediments (Qf and Qfo) from ephemeral hillside draingeways buried the terrace surface. Pierre Shale is exposed on the floor of Fountain Creek and older strath terrace river-cut cliffs. The river is actively incising within the map area and prone to lateral migration where the river banks of exposed alluvial gravel are being actively scoured. The present river course has moved laterally in many areas and does not match the river course as shown on the current topographic basemap.

Qag_1

Alluvial gravel one (upper to middle Holocene) — Lowest unit underlies terrace remnants 4 to 6 ft (1.2 – 1.8 m) above the scoured river floor. This unit has increased sand content near the top. Unit is 3 to 6 ft (0.9 – 1.8 m) thick and prone to seasonal flooding and threat of erosion/scour by lateral creek migration. This unit is equivalent to a lower surface of unit Qt_1 of Carroll and Crawford (2000) and Rowley and others (2004).

Qag_2

Alluvial gravel two (early Holocene to Upper Pleistocene) — This gravel underlies terrace remnants 8 to 12 ft (2.4 – 3.7 m) above the scoured river floor. Historically, this unit has been mined for aggregate and many of the gravel pits have flooded and are now ponds within the Fountain Creek Regional Park. The creekside bluff of this unit is at risk of lateral scour by the creek. Deposit thickness is 6 to 12 ft (1.8 – 3.7 m). This unit is equivalent to unit Qay_2 of Madole and Thorson (2002) and the upper surface of unit Qt_1 of Carroll and Crawford (2000) and Rowley and others (2004).

Qag_3

Alluvial gravel three (Upper Pleistocene) — This gravel unit underlies terrace remnants 18 to 20 ft (5.5 – 6.1 m) above the scoured river floor. This unit is typically buried by later Qf deposits that fanned out onto the Fountain Creek valley from side drainageways. Along river terrace escarpments, the unit was measured from 6 to 15 ft (1.8 – 4.6 m) thick. Creekside bluffs of this unit are at risk of lateral scour. Optically stimulated luminescence of a sample (#1030) collected 17 ft (0.9 m) below the ground surface along a recently scoured cut bank yielded an age of 19,920 ± 2,460 yrs BP. This unit is equivalent to unit Qt_2 of Carroll and Crawford (2000).

Qag_4

Alluvial gravel four (middle to lower Upper Pleistocene) — This gravel deposit underlies terraces in the Fountain Creek valley 25 to 35 ft (7.6 – 10.7 m) above the river floor. The most extensive deposit is on the east side of the river in the southern portion of the map area. This unit is mantled by variable thicknesses of unmapped eolian and sheetwash sediments, and is buried on the east margin of the river valley by low-gradient coalesced alluvial fans that flowed westward from low Pierre Shale hills and from the confluence of Jimmy Camp Creek. Below the overburden, the gravel may be an aggregate resource. Creekside bluffs at outside curves of the creek are at risk of lateral scour. This unit is equivalent to unit Qt_3 of Carroll and Crawford (2000).

Qag_5

Alluvial gravel five (lower Upper Pleistocene) — This gravel deposit underlies the highest terrace, 40 to 50 ft (12.1 – 15.2 m) above the Fountain Creek floor. This unit is mantled by variable thicknesses of unmapped, fine-grained eolian sediments, sheetwash sediments, and low-gradient alluvial-fan deposits sourced from drainages that cut into Fountain Mesa. Below this overburden, the gravel may be an aggregate resource. Exposed river-cut escarpments indicate this unit is 10 to 15 ft (3 – 4.6 m) thick above a 30 to 40 ft-high (9.1 – 12.2 m) strath exposure of shale bedrock. Creekside bluffs at outside curves of the creek are at risk of lateral scour.

Qag_6

Alluvial gravel six (lower Upper Pleistocene to upper Middle Pleistocene) — Red to light-grayish red pebble-gravel sand and well sorted, crossbedded, coarse to very coarse sand. Locally, contains lenses of cobbles and small boulders in a coarse sand matrix. Coarser parts of the unit may be streaked with iron-oxide staining. This unit roughly parallels the east side of Fountain Creek and underlies Fountain Mesa. This deposit was mapped as Verdos Alluvium by Scott and Wobus (1973) and Timble and Machette (1979) and is at similar elevation above stream level to unit Qg_2. This unit is equivalent to an older alluvium - unit Qao_1 of Madole and Thorsen (2003). Two samples were collected on Fountain Mesa for OSL dating. One sample (#136) near the center of the unit, 17 ft (5.2 m) below the ground surface (sample elev. 5,668 ft (1,728 m)) yielded an age of 35,400 ± 5,270 yrs BP. The second location (#614171), 18 ft (5.5 m) higher in elevation near the west bluff of the mesa at 11 ft (3.4 m) below ground level (sample elev. 5,686 ft (1,733 m)), yielded a significantly older age of 141,790 ± 7,300 yrs BP. These age dates suggest the unit underwent multiple periods of channelized scour, abandonment, and aggradation. This unit was mined for sand and gravel.

ALLUVIAL PEDIMENT-FAN DEPOSITS

Pediment-fan gravel (Middle to lower Pleistocene) — Pebble to boulder gravel, sand, and sandy clay that were deposited eastward from the Front Range as alluvial fans. These deposits are not related to the Fountain Creek river gravel, although they have a similar reddish color, lithology, and provenance. These earlier glaciofluvial outwash deposits of subangular to rounded gravel, eroded from Pikes Peak and Cheyenne Mountain crystalline basement rocks, were deposited in mountain-front aprons of coalesced alluvial fans. Laterally migrating, braided stream, and cut-and-fill riverine depositional systems aggraded coarse deposits upon the Colorado Piedmont on a generally west-to-east slope gradient. Conversely, the more rounded terrace gravels of Fountain Creek were deposited along the south-trending profile of the river valley. Dissected remnants of the pediment fan gravels now cap mesas and small buttes west of I-25 within Fort Carson Military Reservation and north of the Colorado Springs Utilities Nixon Power Station.

Qg_1

Pediment gravel one (Middle Pleistocene) — Reddish-tan, poorly sorted gravel. Clasts are typically subangular to subrounded pebbles, cobbles, and small boulders (≤2 ft (≤0.6 m)), derived from granodiorite rocks of Cheyenne Mountain and lesser amounts of hard sedimentary rocks exposed along the mountain front. This unit is lower than unit Qg_2 and marks a time of base-level incision below the Qg_2 surface elevation and west-to-east deposition of gravels from the mountain front. The deposit is discontinuous and thin (≤5 ft (≤1.5 m)), but holds a slope because the clasts resist weathering. Some isolated mapped remnants of this unit lie in restricted areas of Fort Carson and could not be field verified. This unit was previously mapped as the Slocum Alluvium by Scott and Wobus (1973) and Trimble and Machette (1979).

Qg_2

Pediment gravel two (Middle Pleistocene) — Interlayered sand, gravel, and silty to sandy clay. The major sediment types are 1) stratified and occasionally imbricated, crossbedded, and channelized pebble to cobble gravelly sand with scattered small boulders (<2 ft (<0.6 m)), and 2) fine-grained beds and channel fills of reddish-gray to light-gray fine-grained sand, silt, and clay. Light-gray silty clay channel fills commonly contain calcic nodules. Gravel is typically unconsolidated; however, it may be cemented and form ledges within a one-ft-thick basal zone at the Pierre Shale contact. A well-developed 4-ft-thick (1.2 m) Bk horizon is present at the top of the gravelly sand. This unit is mantled by a late Pleistocene mud-flow deposit - Qamf. Optically stimulated luminescence of samples taken from the wall of the Schmidt gravel pit at 15-ft (4.6 m) (#614173) and 30-ft (9.1 m) (#614172) depths yielded minimum ages of >210ka yrs (BP) and >250ka yrs BP, respectively. Along the south edge of the Qg_2 mesa north of Little Fountain Creek, and above the major quarry sites, there is an elevation break and subtle 15 ft (4.6 m) lowering in the pediment level (shown as a pediment terrace break on the map.) Unit Qg_2 is mapped as the Verdos Alluvium by Scott and Wobus (1973) and Trimble and Machette (1979). Measured unit thickness at the Schmidt quarry is 35 ft (10.7 m). The surface of this unit lies 150 to 200 ft (46 – 61 m) above the Fountain Creek floor. The unit is a source of aggregate and contains several active and abandoned gravel and sand pits west of I-25. The fine-grained clayey sand beds and channel fills makes quarrying problematic because the high fines content is out of specifications for good aggregate.

Qg_3

Pediment gravel three (Middle? to lower Pleistocene) — This unit is only present as erosional remnants that cap the highest mesas in the quadrangle; the remnant gravel-capped buttes were mined and only disturbed areas remain. Deposit remnants are only found within Fort Carson. This unit was mapped as the Rocky Flats Alluvium by Scott and Wobus (1973) and Trimble and Machette (1979). The surface of this unit lies 280 to 300 ft (85 – 91 m) above the Fountain Creek floor. This unit is considered to be Middle? to lower Pleistocene on the basis of height above stream level.

EOLIAN DEPOSITS

Qes

Eolian sand (Holocene) — Tan to brown, well to moderately sorted, sand and minor silt deposited primarily by wind. Weathered deposits are yellow-brown in color. Sand deposits may contain a weakly developed Bk horizon. Eolian sand mantles low hills in the central and eastern portions of the quadrangle. Unit may contain variable amounts of silt and clay and may contain unmapped patches of loess. Unit may have thin intervals where sediment may have been reworked as slope wash; traces of shale concretion fragments and crystalline very fine to medium pebble-gravel were seen in reworked areas and where unit thins. Optically stimulated luminescence of a sand sample (#152) of this unit at a depth of 10 ft (3 m) east of Calhan Reservoir yielded an age of 5,500 ± 430 yrs BP. Thickest measurement of unit was 20 ft (6.1 m) at a bluff scoured by Jimmy Camp Creek where a buried Bt horizon indicated a hiatus in deposition. Windblown sediments are generally dry, of low density, high porosity, and can have a meta-stable grain-to-grain structure; soils with such properties may be prone to collapse and settlement upon wetting.

Qlo

Eolian loess (lower Holocene to Upper Pleistocene) — Tan to light-brown loamy silt, clay, and very fine-grained sand deposited by wind. Better consolidated than Qes, in some areas the soil has a reddish hue and weak calcic soil development. Optically stimulated luminescence of a sample (#224) collected 3 ft (0.9 m) below the ground surface yielded an age of 19,920 ± 2,460 yrs BP. Some mapped areas may be reworked or grade into residuum; also present are zones of rare, very fine to medium pebble-gravel and Pierre Shale fragments. Maximum thickness of the unit is 20 ft (6.1 m) on Fountain Mesa. Loess contains visible "pinhole" porosity and may be prone to collapse and settlement upon wetting.

ALLUVIAL-FAN, MUD-FLOW, SHEETWASH, AND LANDSLIDE DEPOSITS

Qf

Young alluvial-fan deposits (late to middle Holocene) — Dark-gray to gray clay, gravel, and sand. Unsorted to poorly sorted and weakly stratified with gravel and sand dispersed within a clay matrix; this sediment was deposited as episodic mudflows from tributary channels onto low-gradient river terraces and floodplains. Deposits are typically coalesced aprons that mantle the transition from shale bedrock hills to floodplains or terraces, and generally slope upwards toward the mouths of drainage and swales. Alluvial fans sited below drainage channels incised into the mesas on the west side of the map area have higher gravel contents and are reworked from the mantling Qg units. Unit contains clay derived from nearby hills of Pierre Shale and may be expansive. The rapid and unsorted nature of alluvial-fan deposition make them prone to soil collapse and settlement. Slope gradients suggest the thickness ranges from 30 to <5 ft (9.1 to <1.5 m) at the distal fan edge.

Qamf

Alluvial mud-flow deposits (Upper Pleistocene) — Olive-gray to reddish-gray sandy to silty clay with dispersed very fine to medium pebbles. The mud-flow deposit is usually poorly- to un-sorted, but is poorly stratified where pebbles are segregated into thin lenses of gravelly clay. The lack of larger clasts would indicate that the mud was likely deposited as a high-water-content, low-viscosity slurry. Pebble-sized clasts are angular to subangular crystalline rocks. This unit disconformably mantles the older Qg_2 unit. The unit has a poorly developed Bk horizon. Optically stimulated luminescence of of sample #614174 collected 6 ft (1.8 m) below the ground surface yielded an age of 19,420 ± 800 yrs BP. Unit thickness was measured at 10 ft (3.1 m) from exposures within the Schmidt quarry. This unit was mapped as eolian (Qes) sediments by Rowley and others (2004). Clay constituents of the deposit may be partially derived from the expansive Pierre Shale resulting in soils that have swell potential. Unit is considered overburden with aggregate quarry operators and stripped away when mining sand and gravel from the underlying Qg_2 unit.

Qfo

Old alluvial-fan deposits (middle Holocene to Upper Pleistocene) — Old alluvial-fan deposits that may contain multiple Bt horizons and calcic soil development. The base of this unit can be cemented at the contact with Pierre Shale. The old deposits are generally incised by the more recent Qf deposits. Thickness may range from 20 to <5 ft (6.1 to <1.5 m).

Qsw

Young sheetwash deposits (Holocene) — Tan-gray to light-gray, sandy to silty clay with dispersed pebble to granule gravel deposited along bases of hillsides by limited downslope transport by slope wash processes during heavy precipitation events; may include unmapped Qf deposits of limited extent. Deposit may also include fine-grained sediment from reworked loess. Deposits are typically thin (≤5ft (≤1.5 m)) and may include patches of bedrock residuum where underlying Pierre Shale is near, or at surface. Deposits are cut by recent gullying and stream incision. These dry, shallow hillside deposits are principally derived from expansive Pierre Shale and swelling soils may be a potential hazard.

Qswo

Old sheetwash deposits (Upper to Middle? Pleistocene) — Gray-white, sandy silty clay with dispersed pebble to granule gravel consisting of both shale concretion fragments and reworked crystalline rocks. Well-developed Bk horizons give the unit a chalky appearance in exposures and partially cemented the unit making it less erodible than the underlying Pierre Shale bedrock. Deposits are typically thin (≤5ft (≤1.5 m)) and may include patches of bedrock residuum with calcic soil development where underlying Pierre Shale is near, or at surface. Includes ancient hillslope remnants between Qg_3 and Qg_2 mesas; relative age is estimated by the relationship between gravel-capped mesas (Qg deposits), elevation, and the heavy calcic soil development.

Qls

Landslide deposits (Holocene to Upper Pleistocene) — Unsorted dark-gray deposits of disturbed claystone, clay, and gravel that have sheared and moved downslope under the force of gravity, generally along mesa slopes capped by old gravel deposits. Typical landslide features include headscarps, side shears, slump blocks, pressure ridges and heaved toes, creating an overall hummocky landform. Landslides are of various ages; some old landslides have subdued topography and subtle morphology compared to younger landslide deposits. Many landslides were located within restricted areas of Fort Carson and were mapped using a bare-earth hillshade model created from 1-m resolution LiDAR. Landslides usually occur along northeast- to east-facing hillslopes and drainage slopes that approximates the formational dip of the underlying Pierre Shale. Scarps tend to form near the contact of the overlying gravels and the weathered Pierre Shale. Deposits range from shallow slump failures to larger landslide complexes. Some may be long inactive while others are more recent and may continue to creep. Landslide deposit thicknesses are highly variable. They range from only a few feet in shallow soil slips, to tens of feet in deep-seated rotational failures in bedrock.

BEDROCK GEOLOGY

Pierre Shale (Upper Cretaceous) — The Pierre Shale is the surface bedrock of the Fountain quadrangle. The dark-gray to olive-gray fossiliferous marine shale was deposited during the transgression of the Middle to Late Cretaceous Western Interior Seaway. Thickness of the formation is about 5,000 ft (1,524 m) but neither the upper nor basal contact of the formation occurs in the map area. The Pierre Shale has been subdivided into informal zones following the nomenclature of Scott and Cobban (1986) that was used by Madole and Thorson (2003) in the adjacent Elsmere quadrangle. Contacts of these zones could not be discerned in the field and were approximated based on those shown in Scott and Cobban (1986) that were then corrected to topography and locations of Tepee Buttes and other large limestone concretionary masses. The Pierre Shale is characterized by an abundance of marine invertebrate fossils and expansive clay minerals; swelling soils and bedrock are common hazards for development. Within moderately inclined slopes, such as mesa bluffs and river banks, the Pierre Shale is prone to slope instability. Several landslides are mapped in the northwest corner of the map area. Care is needed for any ground modifications in areas that are underlain by near-surface Pierre Shale.

Kpc

Pierre Shale, cone-in-cone zone of Lavington (1933) — Dark-gray to tan-gray to olive-gray, subblocky to finely fissile non-calcareous shale, silty shale, thin bentonite beds, and orange-tan to buff, very fine-grained sandstone. Orange-brown stained limestone and reddish-brown siderite ironstone concretions are very common and fossiliferous; ammonite and inocerimid fragments are present. Concretions are discoidal, lumpy, and tabular; aligned to bedding, locally abundant, and can be large (≤6 ft (≤1.8 m)). Septarian nodules are also present. Cone-in-cone structures frequently occur in tabular concretionary masses. In the northeastern part of the quadrangle, sandstone beds thicken, are fine to medium grained, and become more common in upper part of zone. Thickness of this zone is approximately 2,290 ft (698 m) (Scott and Cobban, 1986).

Kptb

Pierre Shale, Tepee Zone of Gilbert (1897) — Dark-gray, gray-black to olive-green to gray shale and silty shale; non-calcareous, finely fissile to subblocky with dispersed to locally abundant discoid-shaped concretions and occasional large globular septarian nodules. Light-tan to gray-white bentonite beds are up to 5 in thick (12.7 cm). Unit weathers tan-gray and residuum ground surfaces may contain surface shrink-swell desiccation cracks and popcorn texture. Within this Pierre Shale zone are large irregular mounds of vuggy limestone, coquina, and limestone breccias. Richly fossiliferous, with lucinid bivalves and large inocermid shells being the most abundant. Vugs are primary in nature and cavities are lined with successive rinds of sparry calcite. Some mounds are up to 50 ft (15 m) across and differential erosion of the surrounding soft shale has created cone-shaped hills up to 40 ft (12 m) high called “Tepee Buttes.” The paleofauna, petrology, and geochemical analysis of the limestone mounds have led to the accepted theory that these limestone features were formed in sea floor cold-seep, methane-rich, submarine vents and springs (Kauffman and others, 1996). The individual limestone mounds are mapped as points. Thickness of this zone is about 1,350 ft (410 m) (Scott

Kpl

Lower part of the Pierre Shale, undivided (Upper Cretaceous) — Shown in cross section only

Kn

Niobrara Formation, undivided (Upper Cretaceous) — Shown in cross section only

Kcgg

Carlile Shale, Greenhorn Limestone, and Graneros Shale, undivided (Upper Cretaceous) — Shown in cross section only

Kdp

Dakota and Purgatoire Formations, undivided (Upper to Lower Cretaceous) — Shown in cross section only

MAP SYMBOLS

Contact — Approximately located

Anticline — Identity and existence certain, location approximate

Syncline — Identity and existence certain, location approximate

Pediment terrace break — Hachure marks side where surface elevation lowers

A A'

Alignment of cross section

Alluvial scour zone — River floor scoured into Pierre Shale. Zone may contain very thin gravel bars and scoured alluvium remnants. High flood hazard

2

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

#115

Numerical age date location — Showing sample number, see table below

Gravel pit

Tepee Buttes and other large limestone concretionary masses

Oil and gas well, plugged and abandoned

Table 1. Numerical age dates of surficial deposit map units

Sample Number	Dating Method	Map Unit	Sediment Type	Sample Depth ft (m)	Sample Elevation ft (m)	UTM13 NAD83- X	UTM13 NAD83-Y	Age (yrs) before present (BP)
115	OSL	**Qa**	Alluvial sand of Jimmy Camp Cr.	7 (2.1)	5,702 (1,738)	531042.51	4287592.71	**400 ± 40**
651	C_{14}	**Qa_2**	Older alluvial clayey sand of Jimmy Camp Cr.	7 (2.1)	5,600 (1,706.9)	528677.27	4283950.25	**5,040 ± 30**
152	OSL	**Qes**	Eolian sand	10 (3)	5,472 (1,667.9)	529956.79	4276504.05	**5,500 ± 430**
1030	OSL	**Qg_3**	Alluvial sand and gravel of an intermediate Fountain Cr. terrace	17 (5.2)	5,557 (1,693.8)	524741.49	4283064.41	**19,380 ± 1,240**
614174	OSL	**Qamf**	Mudflow gravelly sandy clay	6 (1.8)	5,683 (1,732.2)	524389.67	4278915.80	**19,420 ± 800**
224	OSL	**Qlo**	Eolian silt (loess)	3.5 (1.1)	5,684 (1,732.5)	529090.28	4281050.99	**19,920 ± 2,460**
136	OSL	**Qag_6**	Alluvial sand and gravel of the highest terrace of Fountain Cr.	17 (15.2)	5,668 (1,727.6)	526808.86	4283148.81	**35,400 ± 5,270**
614171	OSL	**Qag_6**	Alluvial sand and gravel of the highest terrace of Fountain Cr.	11 (3.4)	5,686 (1,733.1)	525726.94	4284052.86	**141,790 ± 7,300**
614173	OSL	**Qg_2**	Pediment alluvial sand and gravel	15 (4.6)	5,674 (1,729.4)	524366.69	4278836.68	**>210,000**
614172	OSL	**Qg_2**	Pediment alluvial sand and gravel	30 (9.1)	5,656 (1,723.9)	524363.64	4278709.98	**>250,000**

COLORADO GEOLOGICAL SURVEY
COLORADO SCHOOL OF MINES