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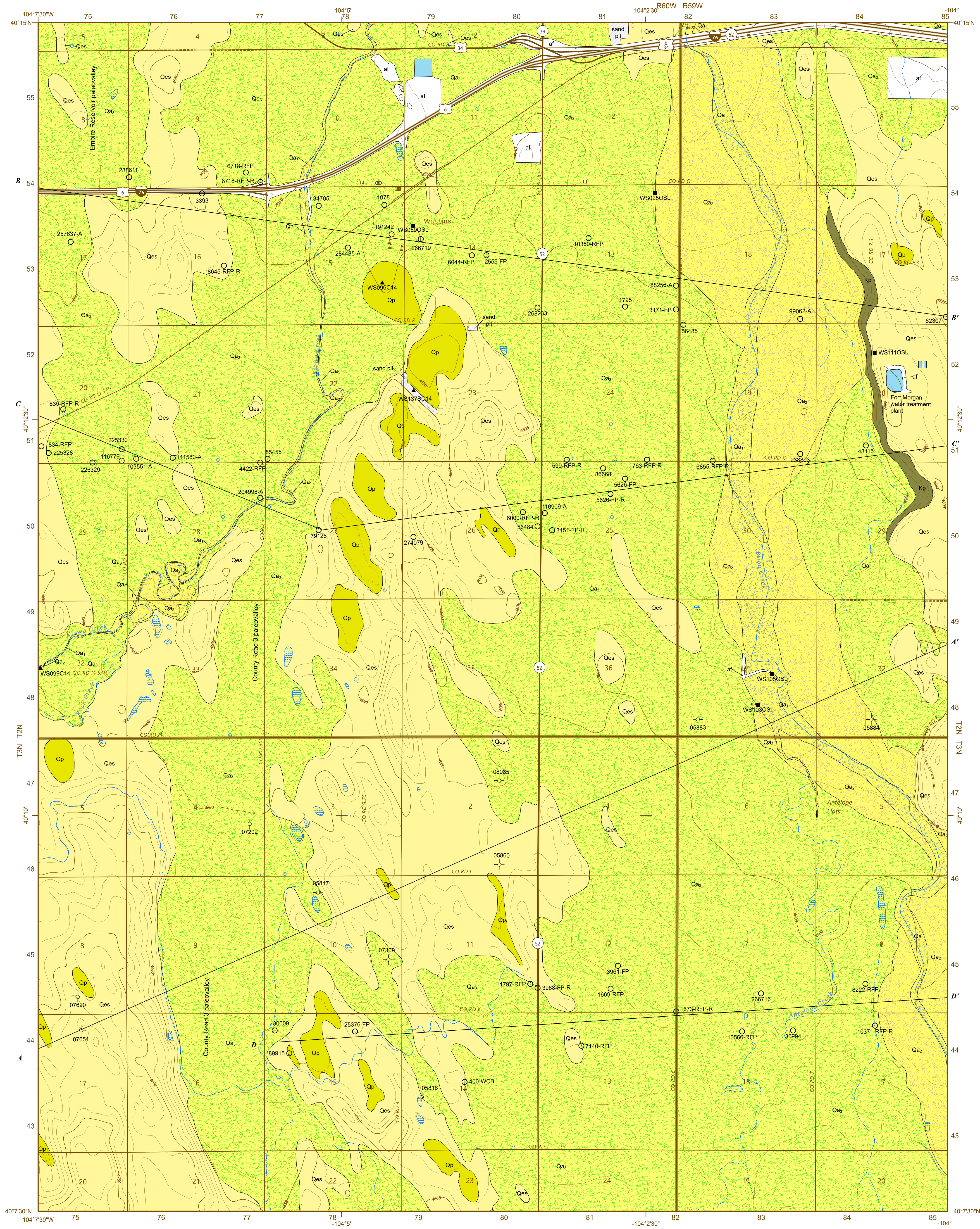

Coordinate System: NAD 1983 UTM Zone 13N
Projection: Transverse Mercator
Datum: North American 1983

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Roads....................U.S.Census Bureau, 2016
Hydrography....................National Hydrography Dataset, 2002-2019
Contours....................National Elevation Dataset, 2007
Boundaries............Multiple sources; see metadata file, 2019-2021
Public Land Survey System....................BLM, 2021

SCALE 1:24,000

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1 0.5 0 MILES 1
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CONTOUR INTERVAL 10 FEET

Geology mapped in 2022
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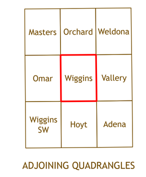
QUADRANGLE LOCATION



ADJOINING QUADRANGLES

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GEOLOGIC MAP OF THE WIGGINS QUADRANGLE MORGAN COUNTY, COLORADO

By Stephen M. Keller and Emily A. Perman

2024

DESCRIPTION OF MAP UNITS

SURFICIAL UNITS

For more detail on grain size distribution, bedding, sorting, color, secondary carbonate, and other characteristics of surficial map units see Table 1a (for units Qa_1, Qa_2, Qes, and Qp) and Table 1b (for unit Qa_3); general characteristics are presented below in the text describing the map units. For radiocarbon and optically stimulated luminescence (OSL) ages of select map units see Table 2. Subdivision of the Quaternary follows the International Chronostratigraphic Chart, v 2023/09 (International Commission on Stratigraphy, International Union of Geological Sciences, 2023). Particle size designation is according to the Udden-Wentworth grain size scale (see Nichols, 2009), but in Tables 1a and 1b on Plate 2 the designation is modified such that sand-size categories are divided into coarser (U) and finer (L) sub-categories with the aid of a sand grain-size card (US GeoSupply, Incorporated, 2020). For example, very coarse (vc) sand is divided into the categories vcU (very coarse upper – coarser) and vcL (very coarse lower – finer). In this report the term “fines” refers to silt- and clay-sized particles. The term “clay” refers to clay-rich sediments.

In Tables 1a and 1b the colors are designated with the aid of color charts of Munsell Color (1991) and Visual Color Systems (no publication date). Description of soil calcium carbonate ($CaCO_3$) morphology is after Machette (1985), and the type of effervescence in sediment or soil observed when treated with dilute hydrochloric acid is according to U.S. Department of Agriculture (2018).

HUMAN-MADE DEPOSITS

af — **Artificial fill (Upper Holocene) —** Mostly riprap, fill material, and material placed during construction of roads, railroads, buildings, stockyards, dams, storage ponds, and landfills. The fill deposits generally consist of unsorted clay, silt, sand, and rock fragments. Typically, the unit is less than 6 m thick. Some deposits of artificial fill (e.g., state highways and county roads) are not mapped because they are too narrow for presentation at map scale. Artificial fill may be subject to settlement, slumping, and erosion if not adequately compacted and(or) if placed on unstable slopes.

ALLUVIAL DEPOSITS

Qa_1 — **Alluvium one (Upper Holocene) —** Unit Qa_1, also known as post-Piney Creek Alluvium, occupies active and historically active channels of Bijou Creek, Antelope Creek, and Kiowa Creek. According to local landowners contacted during the summer 2022 field work for this map, Kiowa Creek flooded during 2013 and Antelope Creek last flowed during 2015. All three creeks were dry when observed during field work in 2022. Reports from locals and new sand deposits observed in 2023 indicate that the main channel of Bijou Creek was active during the summer of 2023. The Bijou Creek unit Qa_1 channel is much wider than its tributary, the Antelope Creek unit Qa_1 channel, and much wider than the Kiowa Creek unit Qa_1 channel. Lidar imagery of unit Qa_1 in the Bijou Creek valley shows a network of braided historical channels and channel bars, including the present active channel. The full thickness of unit Qa_1 was not exposed but may be 2 m or less. Most of unit Qa_1 is weakly cohesive to loose, pinkish-white and light-gray sand. The sand is fine to coarse or is medium to coarse with rare very coarse grains. Rare gravel content ranges in size from granules to pebbles as large as 10 mm. Locally, coarse sand interbeds 6–10 cm thick are present in the unit. Sand composition is estimated as 85–90% quartz, 5–14% feldspar, and from <1 to 5% opaques, with trace mica. Gravel content is granitic. In Antelope Creek there are some muddy reaches ~2–3 meters long that have prominent desiccation cracks; these possibly are overbank deposits. No secondary carbonate was observed in this unit.

Qa_2 — **Alluvium two (Upper to Middle Holocene) —** Unit Qa_2, also known as Piney Creek Alluvium (Scott, 1960), occupies a large portion of the Bijou Creek valley, occurring 1 to 2 m above both sides of unit Qa_1 (the area of active and historic channels) and forming the lowest terrace of the valley. In the Bijou Creek valley the unit Qa_2 fill terrace is ~3 to 6 m below the fill-cut terraces of unit Qa_3 that bound unit Qa_2 on both sides. In the Kiowa Creek valley unit Qa_2 forms two small fill terraces, ~ 1 to 2 m lower than the Qa_3 fill terrace of that valley (the valley has no fill-cut terraces in unit Qa_3). Lidar imagery of the Bijou Creek valley shows that braided channels of unit Qa_2 are approximately twice as wide as those of the unit Qa_1 channels, and that the unit Qa_2 channel bars are more numerous and much larger than those of unit Qa_1. The different surface characteristics of the two units, although observable in the field, are more prominent in lidar imagery and allow the units to be readily distinguished for mapping purposes. Also, in lidar imagery of the Bijou Creek valley, the relatively rough surface morphology of unit Qa_2 with its many braided channels and bars contrasts markedly with the higher, relatively smoother surface of the bounding unit Qa_3 terraces (although the latter have a few prominent channel bars). Unit Qa_2 is incised into unit Qa_3 and neither the base nor the total thickness of unit Qa_2 is exposed. Thickness is estimated to be 7–8 m based upon the limited water well data for unit Qa_2 in the Wiggins quadrangle.

At most locations unit Qa_2 consists of light-gray to light-brown sand with fines (particles < 2 mm in diameter) being absent or minor. The sediment is very fine to fine sand with rare medium sand; and fine to medium or coarse sand with minor very fine sand, and some rare coarse or very coarse sand, and granules up to 3 mm. At one location (along Kiowa Creek) unit Qa_2 is a very well-sorted, very fine sand with trace fine mica, interbedded with dark-gray clay layers 6–7 cm thick and lighter-colored silty layers 2–3 cm thick. At a few locations in the Bijou Creek valley unit Qa_2 consists of light to dark grayish-brown sandy clayey silt or sandy silty clay, with 30–50% sand content consisting of very fine sand, or of very fine to coarse sand with rare very coarse sand. At most locations unit Qa_2 contains no secondary carbonate. At one location (in Kiowa Creek), the sandy clayey silt or sandy silty clay contains a few very small carbonate nodules having violent effervescence. At a few locations the matrix has strong effervescence, but nodules are not present. The coarser sand beds of unit Qa_2 have no secondary carbonate.

Radiocarbon sample WS099C14, from unit Qa_2 clay exposed along Kiowa Creek (location labeled on geologic map), yielded a conventional radiocarbon age of 4,420±30 yr (Middle Holocene) (Table 2). OSL sample WS105OSL, from unit Qa_2 sand exposed along Bijou Creek, yielded an age of 1,095±135 yr (Late Holocene) (Table 2). Post-Piney Creek alluvium (unit Qa_2) is estimated by Kellogg and others (2008) to be as old as ~4 ky. Colorado Geological Survey (CGS) radiocarbon ages for unit Qa_2 and unit Qa (Quaternary alluvium, undivided; time-equivalent to unit Qa_2) in other quadrangles in the northern Colorado Piedmont are approximately 1.3–4.6 ky (Madole, 2016; Keller and Morgan, 2018; Palkovic and others, 2018; Keller and others, 2019; Palkovic and others, 2019; Keller and Morgan, 2020; Lindsey and Palkovic, 2020; Palkovic and Morgan, 2021; Keller and Marr, 2023a; Keller and Marr, 2023b). Unit Qa_2 in the Wiggins quadrangle is unlikely to be a potential source of aggregate because the deposit contains very little gravel and has a large fines fraction. Areas mapped as Qa_2 are prone to periodic flooding.

Qa_3 — **Alluvium three (Middle Holocene to Upper Pleistocene) —** Unit Qa_3 is also known as Broadway Alluvium (Scott, 1960) and has been mapped in nearby areas by Lindsay and others (2005) and by Berry and others (2019). In the Orchard quadrangle, adjoining the Wiggins quadrangle on the north, unit Qa_3 is mapped as sidestream deposits (Qbs) of Broadway Alluvium (Berry and others, 2015a, 2019). This is a subdivision of Broadway Alluvium including Late Pleistocene deposits of major north-flowing tributaries to the South Platte River (Berry and others, 2015a). CGS unit Qa_3 in the Wiggins quadrangle is continuous with and equivalent to unit Qbs in the Orchard quadrangle. According to Madole (1991), Broadway Alluvium near the Front Range consists of vertical sequences of superposed, longitudinal bars of sand and gravel deposited by braided streams flowing eastward from the Front Range. These sequences locally contain finer-grained layers that probably are overbank deposits. Unit Qa_3 covers more than half of the Wiggins quadrangle, including the valleys of Bijou Creek, Antelope Creek, and Kiowa Creek, and the paleovalleys of the (informally named) County Road 3 and Empire Reservoir paleovalleys (see geologic map). The deposit overlies Pierre Shale, underlies valley alluvium of units Qa_2 and Qa_1, and underlies eolian sand (unit Qes) of a dune field between the Kiowa Creek and Bijou Creek valleys. Unit Qa_3 is syndepositional with the eolian deposits and overlaps the dune field. Eolian deposition began in Late Pleistocene time on a lower-elevation aggradation surface of unit Qa_3 in both valleys, and as the alluvium aggraded it partially buried the dune field. This is indicated by interpretation of lidar imagery and by the optically stimulated luminescence (OSL) age of ~13 ky (Late Pleistocene) for the dune field covering the upland east of the Bijou Creek valley (location WS111OSL, geologic map). This upland is at about the same elevation as the dune field between the two creeks, suggesting that the two dune fields are about the same age. Ages of unit Qa_3 in the Kiowa Creek and Bijou Creek valleys are ~10 ky (WS059OSL) and ~6 ky (WS025OSL) (see geologic map for locations), younger than the age of the dune field between them (providing that the dune field is about the same age as unit Qes in the upland east of Bijou Creek). Detailed plotting of sediments from water well logs in Wiggins quadrangle (Colorado Division of Water Resources, 2022) was the basis for the Plate 2 cross sections. The data analyses indicate that unit Qa_3 is generally dominated by sand, with subordinate clay layers, in its upper ~20 m; and dominated by gravel and sand layers, with subordinate clay layers, from a depth of ~20 m down to bedrock. Unit Qa_3 underlies the dune field between the two creeks, and this supports the hypothesis that the lower portion of the dune field was deposited on the unit Qa_3 valley floor during the Late Pleistocene. Sand content of unit Qa_3 is generally 85–90% quartz, 10–14% feldspar, <1% opaques, with trace mica. Unit Qa_3 thickness ranges approximately from 17–67 m, with the greatest thickness being in the Bijou Creek valley (cross sections B-B’, C-C’, and D-D’, Plate 2). Unit Qa_3 has a variable thickness because of the topography of the Pierre Shale surface beneath it. Descriptions of unit Qa_3 in each of the above five drainages follow.

Unit Qa_3 in the *Bijou Creek valley* consists of three different types of sand. 1) The first type is a medium to coarse sand occurring on the east valley terrace, 2 km south of City of Fort Morgan water treatment plant (near sample location WS111OSL shown on the geologic map); in the northeast quadrant of the quadrangle; and on the valley’s west terraces between County Roads O and Q. It contains a small fraction of very fine to fine sand, rare granules and small pebbles, and 0–25% fines. The sediment has layers of gravelly (granules and small pebbles) sand; fine to medium sand containing some coarse to very coarse sand; medium sand to granules and pebbles; and sandy clayey silt. 2) The second type, a very fine to medium sand, occurs on the valley’s east terraces, 2 km south of the water treatment plant, and occurs in uplands between Bijou Creek and Antelope Creek near the quadrangle south boundary. 3) The third type, a clayey silty sand, covers the valley’s west terraces between County Roads L and Q. Generally, the sand fraction of unit Qa_3 is mostly fine to coarse sand with minor very fine and very coarse sand and minor granules and pebbles; the fines content is 15–40%. Unit Qa_3 colors in the Bijou Creek valley are light yellowish brown, dark brown, dark grayish brown, and light olive brown. Sand content is 85–90% quartz, 10–14% feldspar, <1% opaques, with trace mica. Generally, unit Qa_3 becomes finer grained in the downstream direction (northward) in the Bijou Creek valley. OSL sample WS059OSL was collected from the unit Qa_3 fill terrace in the Kiowa Creek valley (see geologic map for locations) and yielded an age of 9,810±440 yr (Early Holocene). OSL sample WS025OSL was collected from a unit Qa_3 fill-cut terrace ~3 km east of the town of Wiggins and yielded an age of 6,125±255 yr (Middle Holocene). OSL sample WS103OSL was collected from unit Qa_3 in a fill-cut terrace on the west side of Bijou Creek and yielded an age of 910±30 yr. Because this sample was taken from unit Qa_3, much of which is known to be of Late Pleistocene age, this laboratory age is in error possibly due to sample contamination or exposure to light. (For complete laboratory age results see Table 2, Plate 2.)

Unit Qa_3 alluvium of the *Antelope Creek valley* consists of three types of sediment. 1) The first type is very fine to medium sand, with rare coarse to very coarse sand and rare granules and pebbles. Fines usually are absent, but one location has a 10% fines fraction. 2) The second type is dominated by clayey silty sand, with the sand fraction mostly fine to coarse with minor very fine sand; there is subordinate coarse to very coarse sand with rare granules and pebbles; and minor very fine to medium sand with minor coarse to very coarse sand having rare granules and pebbles, and a fines fraction of 10–25%. 3) The third type is sandy silty clay (60-80% fines) with the sand fraction varying from very fine to fine, to very fine to medium with rare coarse sand and granules. Unit Qa_3 colors in the Antelope Creek valley are brown, dark grayish brown, light olive brown, and yellowish brown. Unit Qa_3 sediment in the Antelope Creek valley is generally finer than that of the Bijou Creek valley, to which Antelope Creek valley is a tributary.

Unit Qa_3 alluvium of the *Kiowa Creek valley* consists of three types of sediment. 1) The first type is fine to medium sand occurring downstream (northward) from Wiggins. It contains rare coarse sand to granules, fine to coarse sand with minor very fine sand and minor fines, and rare very coarse sand and granitic granules and pebbles. 2) The second type is clayey silty sand, in the part of the valley from the Omar quadrangle (adjacent to the west of the Wiggins quadrangle) downstream approximately to Wiggins. The sand fraction is locally a medium to coarse sand with subordinate very fine to fine sand and rare very coarse sand and granules; and locally a very fine to medium sand with rare coarse to very coarse sand. The fines fraction of the second type is 10–30%. 3) The third type is silty clay and sandy clayey silt, occurring in the part of the valley between Wiggins and the west quadrangle boundary. The sand is very fine to medium with rare coarse sand and granules, and the fines fraction is 15–40%. Unit Qa_3 colors in the Kiowa Creek valley are pale brown, brown, grayish brown, light gray, and dark gray.

Unit Qa_3 alluvium of the *County Road 3 drainage* consists of two types of sediment. 1) The first type is clayey silty sand. The sand fraction is very fine to medium sand with rare coarse to very coarse sand, and the fines content is 10–20%. 2) The second type is sandy clayey silt, with the sand fraction being fine to medium sand, with minor very fine sand and rare coarse sand to small pebbles. The fines fraction of the second type is 50–80%. Overall, colors are grayish brown, dark grayish brown, and light olive brown. Unit Qa_3 sediment in the County Road 3 drainage is generally finer than that of the Kiowa Creek valley, to which the County Road 3 paleovalley was a tributary.

Unit Qa_3 alluvium of the *Empire Reservoir drainage* consists of clayey silty sand. The sand fraction is fine to very coarse sand with rare very coarse sand to pebbles, and the fines content is 40–70%. Colors are brown and dark grayish brown.

In unit Qa_3, portions of the lower terraces of the Bijou Creek valley and portions of the Kiowa Creek valley may be prone to flooding. Because of a significant fines fraction at many locations, the near-surface portions of unit Qa_3 probably are not potential sources for clean sand or aggregate.

EOLIAN, POND, AND SHEETWASH DEPOSITS

Qes — **Eolian sand (Upper Pleistocene) —** Unit Qes covers approximately one-quarter of the Wiggins quadrangle, including the extensive body of eolian sand occupying the upland between the Kiowa Creek and Bijou Creek valleys and extending south between the Bijou Creek valley and the County Road 3 drainage; the uplands in the northwest and southwest corners of the quadrangle; and the upland on the east side of the quadrangle. Eolian sand in the quadrangle is part of the eastern South Platte sand area, as mapped by Madole and others (2005). This sand body is one of several extensive, eastern Colorado eolian sand deposits mapped and described in that publication. Eastern Colorado dunes range in form from sand sheets to parabolic dunes, the latter being the dominant form in northeastern and central Colorado (Madole and others, 2005). In the Wiggins quadrangle, areas covered by unit Qes consist of mostly stable, vegetated, parabolic sand dunes paired with abundant blowouts. The many superposed dune crests combined with the bowl-shaped blowouts (zones of sand deflation) create the dune form known as compound parabolic dunes (Madole and others, 2005). These dunes are typical of unidirectional paleowind direction (generally from the northwest in the Wiggins quadrangle). Lidar imagery of the Wiggins quadrangle shows eolian sand terrain as distinctly characterized by dunes trending north-northwest to south-southeast, by blowouts whose long directions are parallel to the dunes, and by flat, elongate interdunal areas containing pond and sheetwash sediments of unit Qp (discussed further on in this section). Cross sections B-B’, C-C’, and D-D’ (Plate 2) are based on water well data and lidar imagery and show unit Qes to overlie and be partially overlain by alluvium of unit Qa_3. Unit Qes thickness varies between 3 and 20 m.

Unit Qes is readily recognized in road cuts and in sample holes dug deeper than its thin and poorly developed soil A horizon (generally less than 20 cm thick). (For definitions of soil horizons see Birkeland, 1999.) Unit Qes typically is composed of yellowish-brown to olive brown fine to medium sand, with minor very fine sand and rare coarse to very coarse sand. In a few places the sediment is very fine to fine sand with rare medium sand; or medium to coarse sand, having minor very fine to fine sand and rare very coarse sand. Rare gravel content consists of granules up to 3 mm. Sand composition is 80–95% quartz, 4–17% feldspar, and <1–5% opaques, with trace mica up to 2 mm in diameter. At some locations the deposit has planar bedding at a scale of 1–20 cm and the beds are distinguishable by differences in grain size. Unit Qes ranges from loose to moderately cohesive, depending on moisture content and very fine sand content, though it is typically weakly cohesive. Platy partings are present in some of the more consolidated deposits. Scattered carbonate filaments and nodules of secondary carbonate were observed only on the east bluff of the Bijou Creek valley near sample location WS111OSL. Optically stimulated luminescence (OSL) sample WS110OSL, collected from unit Qes exposed on the east bluff of the Bijou Creek valley (geologic map), yielded an age of 12,755±615 yr (Late Pleistocene) (Table 2). Madole and others (2005) collected a radiocarbon sample from a buried soil in the uppermost part of the eolian sand near Wiggins and obtained an age of ~9.5 ky. This suggests a possible Late Pleistocene age for the eolian sand upon which the soil was formed. The above CGS OSL age of ~12.8 ky indicates that the lower part of unit Qes in the Wiggins quadrangle is Late Pleistocene. Late Pleistocene sand is the oldest of three age groups designated for eastern Colorado eolian sand (Madole and others, 2005). There is an abundant, relatively clean sand resource in unit Qes in the Wiggins quadrangle.

Qp — **Pond and sheetwash deposits, undivided (Middle Holocene) —** Unit Qp accumulated in relatively flat, elongate depressions within dune fields of unit Qes, and in parts of the Kiowa Creek valley that formerly may have been temporarily dammed wetlands or may have been partially enclosed by sand dunes. The long axes of the enclosed interdune depressions are generally parallel to the trend of the surrounding linear dunes, and the depressions are lower in elevation than the floors of nearby Kiowa Creek and Bijou Creek valleys. The largest enclosed deposit of unit Qp is ~1,100 m long and ~360 m wide. Unit Qp deposits are indicated by enclosures within topographic contours, are recognizable in the field, and are distinct on lidar imagery. In the Wiggins quadrangle only three water wells are in deposits of unit Qp, and only one penetrates the unit entirely. The geologic log for this well indicates a 6-m-thick layer of clay with some sand content (unit Qp), overlying a layer of gravel, sand, and clay (alluvium of unit Qa_3). In cross sections B-B’, C-C’, and D-D’ (Plate 2) unit Qp is interpreted as ranging between 2 and 6 m in thickness.

At most locations unit Qp is composed of light to dark grayish-brown or light- to medium-brown silty clayey sand or clayey silty sand, with a fines content of 10–40%. The sediment is dominantly very fine to fine or medium sand with rare coarse to very coarse sand. Locally the deposit is a fine to a medium or coarse sand, with minor very fine sand and rare coarse sand having granules up to 3 mm; or a medium to coarse sand with minor very fine to fine sand and rare coarse to very coarse sand. Unit Qp is well exposed only in two places, at ~1.6 km and 3.2 km south of the town of Wiggins. At different levels of these exposures the bedding is on the order of millimeters, 1 to 3 cm, or there is no discernable bedding. At one of the exposures there is marked soft-sediment deformation (described further on in this section). More sandy portions of unit Qp probably are sheetwash deposits originating from the surrounding dunes. The sand fraction of the silty clayey sand or clayey silty sand is 85–90% quartz, 4–14% feldspar, <1–5% opaques, with (at many locations) trace mica. The rare granules are granitic. The dominance of fines in this sediment suggests a minor episode of loess deposition in ephemeral interdunal ponds. Radiocarbon sample WS137BC14, collected from pond sediments in an enclosed depression in the upland south of the town of Wiggins, yielded a conventional age of 6,110±30 yr. (See Table 2 on Plate 2 for details on sample ages.)

A distinctive, dark-gray clay or clayey silt layer up to 3 m thick (in excavations), underlying <1 m of alluvial sand, was observed south of the town of Wiggins and on the east side of the Kiowa Creek valley, and a similar layer was observed in an excavation in the Omar quadrangle, in the Kiowa Creek valley and ~3 km west of the Wiggins quadrangle west boundary. The conventional radiocarbon age for this clay near Wiggins is 4,090±30 yr (sample WS096C14) and the radiocarbon age in the Omar quadrangle is 3,420±30 yr (sample WS060C142); both ages are Middle Holocene. This clay could have been deposited in flood-plain areas that temporarily were partially dammed by dunes.

Unit Qp can be bedded or massive and at some locations it has platy partings and laminations. Some of the sediment weathers into blocky fragments. Very rarely the sand fraction is found concentrated in small masses up to 10 mm in diameter, and locally there are striations on polished surfaces of the deposit. The striations suggest alternating shrinking and swelling of the material. Unit Qp is most commonly cohesive.

At some locations no secondary calcium carbonate is apparent. At other locations, however, carbonate filaments 1–2 mm thick and up to 10 mm long and(or) nodules up to 15 mm are present. Where present, the filaments range from 3–10% of the mass and nodules can be up to 20–25% of the mass. Filaments and nodules typically effervesce violently, whereas the surrounding mass effervesces weakly to moderately. In locations with significant amounts of calcium carbonate, secondary calcium carbonate may fill fissures in the sediment.

Soft-sediment deformation in unit Qp is well expressed at two exposures where the contacts between pond and sheetwash deposits and the surrounding eolian sand are distinct. At one exposure there are many tube-shaped structures consisting of unit Qes eolian sand extending upward into the overlying Qp unit deposits. The sand structures range from 4–7 cm in diameter and 12–60 cm long, are spaced less than 0.5 m apart, terminate upward in the eolian sand, and have rounded tops. From observing the three-dimensional exposure of the structures, and the casts remaining after erosion of the exposure, the structures are seen to connect only with the underlying eolian sand layer and do not extend to either the top of unit Qp or the ground surface. Thus, the tube-shaped structures apparently are not animal burrows but possibly resulted from liquefaction and injection of eolian sand upward into the overlying pond and sheetwash deposits. At another exposure, a layer of unit Qp apparently was detached and slumped into unit Qes sediments. The layer is ~0.25 m thick and 3 m long, is overlain and underlain by unit Qes sand, and has marked plastic deformation. Below this apparently detached layer is a layer ~1 m thick, which consists of a matrix of eolian sand that contains fragments of unit Qp deposits. A possible explanation for these soft-sediment deformation features is that sediment gravity flow, from the flank of an adjacent sand dune, resulted in rapid sediment loading and associated lateral stresses and elevated pore pressures in saturated or nearly saturated sediments in units Qp and Qes. Unit Qp is not a suitable sand resource because of its high fines content. Unit Qp may exhibit swelling soil characteristics if the fines content contains expansive-clay minerals.

BEDROCK GEOLOGY

Within the Wiggins quadrangle the only bedrock unit mapped at the ground surface is the Pierre Shale, interpreted to be the Upper Transition Member because it underlies the Fox Hills Sandstone (Scott, 1978). The only exposure of this unit is along a bluff on the east side of the Bijou Creek valley, near the City of Fort Morgan water treatment plant in the northeast portion of the quadrangle. In cross section A-A’ the Pierre Shale is undivided. Scott (1978), in his geologic map of the Sterling 1° x 2° quadrangle, does not give a thickness for the Upper Transition Member and the oil and gas well records for the Wiggins quadrangle have no formation picks for Pierre Shale members. The description of the Upper Transition Member is modified from Scott (1978), and for more detail on the Pierre Shale in northeast Colorado see Scott and Cobban (1965) and Braddock and others (1988). The description and regional thickness of the Fox Hills Sandstone are from Scott (1978) and Spencer (1986), and its thickness in cross section A-A’ is interpreted from Dechesne and others (2011). Note that units below the Pierre Shale are shown in cross section only. In cross section A-A’ the descriptions of units below the Pierre Shale are adapted from descriptions in the geologic map of the Carter Lake Reservoir quadrangle, ~90 km to the west of the Wiggins quadrangle, where these older units are described in outcrop (Braddock and others, 1988). Thickness values for the Pierre Shale and older units shown in cross section A-A' were calculated from oil and gas well records from the Colorado Energy and Carbon Management Commission (ECMC) (2023).

Kfh — **Fox Hills Sandstone (Upper Cretaceous) —** Fine- to coarse-grained, yellowish-brown to yellowish-gray to white, quartzose sandstone; cross bedded in the lower part, grading upward to a massive, fine- to medium-grained sandstone. The unit contains some thin beds of olive-gray sandy shale and gray to brown, hard, calcareous sandstone concretions as large as 2.4 m in diameter. Regional thickness ranges from 46 to 91 m. In the southeast corner of the Wiggins quadrangle, the Fox Hills Sandstone overlies the Pierre Shale and is covered by eolian sand of unit Qes. From Colorado Geological Survey archive data used in preparation of Dechesne and others (2011), thickness is interpreted to be ~30 m at the quadrangle’s west boundary; unit pinches out ~1 km east of the boundary (cross section A-A’).

Kp — **Pierre Shale, Upper Transition Member (Cretaceous) —** Marine strata composed of dark-gray shale, siltstone, and fine-grained sandstone. Bentonite beds, rich in weathered volcanic ash, are common in the lower part and calcareous concretions are common throughout. The various members of the Pierre Shale contain index fossil ammonite species (Scott and Cobban, 1965). The Upper Transition Member, the only part of the Pierre Shale exposed in the Wiggins quadrangle, occupies the lower part of the bluff along the east side of the Bijou Creek valley in the northeast corner of the quadrangle. Regionally, the Upper Transition Member is a dark-gray, calcareous silty shale or claystone, shaly sandstone, and sandy shale. It is a marine formation that contains fossil ammonites and baculites (both are cephalopods), calcareous concretions up to 1.8 m in diameter, limestone beds as great as 1 m thick, and thin gypsum layers. The overall regional thickness of the Pierre Shale, including all its members, is ~1,650 m (see cross section A-A', Plate 2). At the Bijou Creek valley bluff, the vertical exposure of the Upper Transition Member is less than 2 m. There, the unit is a yellowish-brown to very pale-brown, moderately sorted, very fine-grained to fine-grained shaly sandstone with a fines content of up to 20%. The sandstone is weakly indurated, breaks along bedding planes, and is bedded at a scale from laminae (<0.5 mm) to ~2 cm. Bedding is indistinct at the weathered exposure but distinct where the exposure is excavated. There are rare black fragments, likely plant remains, that have stemlike forms and are pressed flat along some of the bedding planes; the fragments are ~0.5 mm wide and ~6 mm long. The sandstone has subvertical joints which cause it to break in a blocky manner. The joints have secondary calcium carbonate coatings and filaments, the latter being up to 1 mm thick and several centimeters long.

Kn — **Niobrara Formation, undivided, shown in cross section only (Upper Cretaceous) —** Dark-gray, very fissile, shale containing thin (5 m) micritic limestone layers. Unit is an important oil and gas resource in much of the Denver Basin, but not in the Wiggins quadrangle according to ECMC (2023) data (see section on Mineral Resources, Groundwater Resources, and Geologic Hazards, Plate 2). Thickness is 90–105 m.

Kcgg — **Colorado Group — Carlile Shale, Greenhorn Limestone, Graneros Shale, and Mowry Shale, undivided, shown in cross section only (Upper Cretaceous) —** Olive-gray silty claystone and sandy claystone; dark-gray limestone and olive-gray, calcareous, silty claystone and siltstone; dark-gray to grayish-black siltstone and claystone and siliceous shale. Combined thickness is 115–120 m.

Kd — **Dakota Group — South Platte Formation and Lytle Formation, undivided, shown in cross section only (Lower Cretaceous) —** Unit consists of gray to light-brown, well-sorted, fine- to medium-grained sandstone; dark-gray carbonaceous shale; gray to light-brown, fine-grained sandstone; and gray to light-brown, coarse-grained, conglomeratic sandstone. Combined thickness is 155 m.

MAP SYMBOLS

- **Oil and gas well**
- **Water well**
- **C14 age date sample site**
- **Optically stimulated luminescence (OSL) sample site**
- **Contact —** Approximately located
- A A′ **Alignment of cross section**
- **Sand pit**

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