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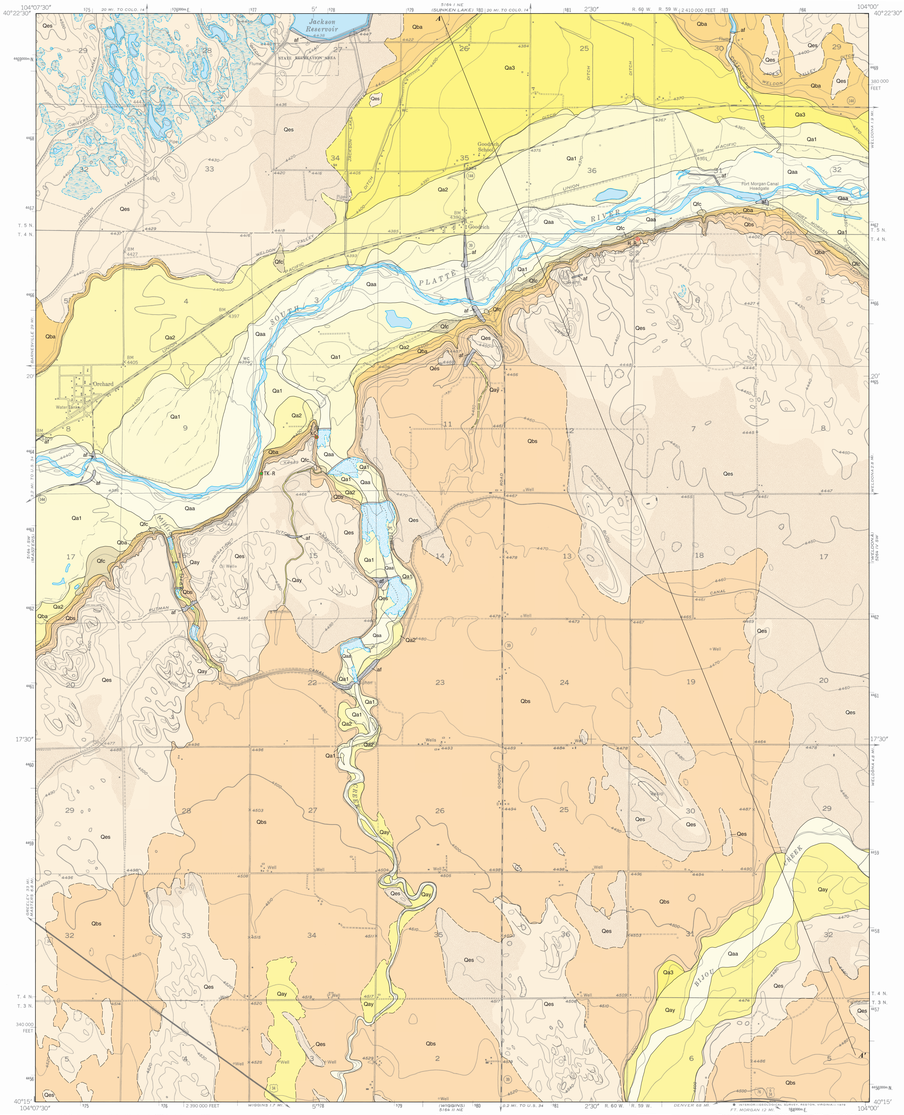
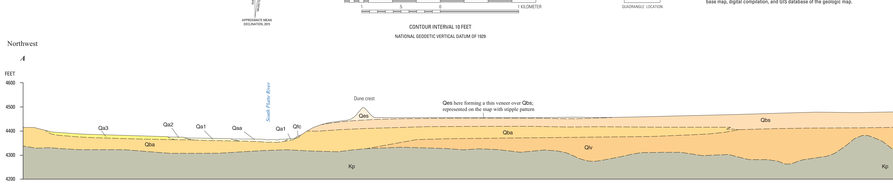


Base from U.S. Geological Survey Orchard Quadrangle, 1971; Limited revision 1971.
Polyconic projection. 1927 North American datum
10,000-foot grid based on Colorado coordinate system, north zone
1000-meter Universal Transverse Mercator grid ticks, zone 13.



Contact between bedrock (Kp) and overlying Quaternary deposits based on drill data given in Bjorklund and Brown (1957) and downloaded from the Colorado Division of Water Resources (2013)

Geologic Map of the Orchard 7.5′ Quadrangle, Morgan County, Colorado

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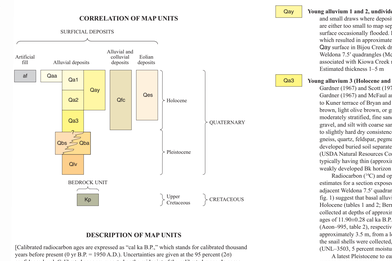
CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

[Calibrated radiocarbon ages are expressed as "cal ka B.P." which stands for calibrated thousand years before present (0 B.P. = 1950 A.D.). Uncertainties are given at the 95 percent (2σ) confidence level. Calibrated ages are reported as the midpoint of the calibrated range. In cases where calibration produced more than one age range with a probability of 5 percent or more, ages are based on the mean of the ranges weighted by their probabilities. See table 2 for more information on uncertainties.

The soil-horizon terminology used in this report is that of the Soil Survey Staff (1993), except for Bk horizon stages of carbonate morphology, which are described in Birkeland (1999). The term "consistence" is the resistance to crushing of soil or surficial material in the hand, as described by Soil Survey Staff (1993). Most colors are field dry colors that were described with the aid of Munsell soil color charts (Munsell Color, 1975)]

SURFICIAL DEPOSITS

Artificial fill

Artificial fill (latest Holocene)—Includes abutments where roadways cross South Platte River and small dams across ephemeral streams and gullies, some artificial levees and banks, and dam embankment at Jackson Reservoir. Artificial fill is present along most canals and ditches but only mapped locally. Chiefly consists of gravel, sand, silt, and rock and concrete fragments

Alluvial deposits

Active channel and floodplain alluvium (late Holocene)—Equivalent to part of post-Piney Creek alluvium of Scott (1963). Very pale brown, light brownish gray, light yellowish brown, or light pinkish brown (5yr 7/1 through 10yr 6/2) fine to coarse sand, pebbly sand, silty sand, and sandy pebble gravel, interstratified with thin (<1–5 cm) layers or lenses of very pale brown silt and dark grayish brown, organic-rich clayey silt and clay. Poorly to well-sorted, weakly to moderately stratified. Sand beds commonly cross-stratified. Fills buried channels of South Platte River and small eroded gullies; also forms low terrace. Consists mainly of clasts of granite, gneiss, potassium feldspar, and quartz. Locally, grains stained with reddish yellow iron oxide and black manganese oxide. Upper 25–50 cm of sediment on floodplain typically light grayish brown, crudely stratified, poorly sorted sandy silt, silty sand, and granule- to fine-pebbly sand. Less active parts of floodplain have weakly developed surface soil (A/C or A/C/C profile). Along tributaries, alluvium mostly thinly stratified sand, sandy silt, and silty clay. Unit contains lignite fragments thought to be eroded from Upper Cretaceous Laramie Formation. Surface soil typically weakly developed A/C or A/C/C profile. Estimated thickness 3–5 m

Young alluvium 1 (late Holocene)—Equivalent to part of post-Piney Creek alluvium of Scott (1963). Forms low terrace approximately 1–5 m above floodplain, and low gradient fans at mouths of Kiowa Creek and Milliron Draw. **Qa1** surface occasionally flooded. Along South Platte River, alluvium very pale brown, light brownish gray, light yellowish brown, or light pinkish brown, fine to coarse sand, pebbly sand, and sandy pebble gravel. Interstratified with thin (<1–5 cm) layers or lenses of very pale brown silt and dark grayish brown, organic-rich clay. Poorly to well-sorted, weakly to moderately stratified. Sand beds commonly cross-stratified. Loose to slightly hard dry consistence. Locally, grains stained with reddish yellow iron oxide and black manganese oxide. Some beds show signs of soft sediment deformation. Filled burrows common. Pebbles and minor small cobbles generally subrounded to rounded clasts of granite, gneiss, quartz, feldspar, pegmatite, chert, and sandstone. Uppermost sediment packet in alluvial sequence typically light grayish brown or pale brown, crudely stratified, poorly sorted sandy silt, silty sand, and granule to fine pebbly sand with lenses of silt and dark grayish brown clay. Mud ball rip-up clasts common locally. In tributaries, alluvium mostly fine grained, thinly stratified sand, sandy silt, and clayey silt. Unit contains lignite fragments thought to be eroded from Upper Cretaceous Laramie Formation. Surface soil typically weakly developed A/C or A/AC/C profile. Estimated thickness 3–5 m

Young alluvium 2 (late Holocene)—Equivalent to part of post-Piney Creek alluvium of Scott (1963). Forms low terrace approximately 3 m above active floodplain. Surface rarely flooded. Along South Platte River, alluvium very pale brown, light brownish gray, light yellowish brown, or light pinkish brown, fine to coarse sand, pebbly sand, and sandy pebble gravel. Interstratified with thin (<1–5 cm) layers or lenses of very pale brown silt and dark grayish brown, organic-rich clay. Poorly to well-sorted, weakly to moderately stratified. Sand beds commonly cross-stratified. Loose to slightly hard dry consistence. Locally, grains stained with reddish yellow iron oxide and black manganese oxide. Some of the finer-grained beds show signs of soft sediment deformation. Filled burrows common. Pebbles and minor small cobbles generally subrounded to rounded clasts of granite, gneiss, quartz, feldspar, pegmatite, chert, and sandstone. Uppermost sediment packet in alluvial sequence typically light grayish brown or pale brown, crudely stratified, poorly sorted sandy silt, silty sand, and granule to fine pebbly sand with lenses of silt and dark grayish brown clay. Mud ball rip-up clasts common locally. Along tributaries, alluvium mostly thinly stratified sand, sandy silt, and silty clay. Unit contains lignite fragments thought to be eroded from Upper Cretaceous Laramie Formation. Surface soil typically weakly developed AC or A/AC profile. Estimated thickness 3–5 m

Mainstream deposits of Broadway Alluvium (late Pleistocene)—Mapped as Broadway Alluvium by Gardner (1967) and lower member of Broadway Alluvium by Scott (1978). Underlies and interpreted to interfinger with sidestream Broadway Alluvium (**Qbs**) from Kiowa and Bijou Creeks south of South Platte River. North of river, forms terrace approximately 12–15 m above active floodplain; terrace largely covered by eolian sand (**Qes**). Unit crops out poorly due to cohesionless nature of the sediment when dry. High potassium feldspar content gives unit a distinctive pinkish hue, particularly in exposures along South Platte River bluff (photo 2).

Alluvium pink, pinkish gray, or light reddish brown, moderately well- to poorly sorted, fine to coarse sand, pebbly sand, silty sand, and sandy granule to pebble gravel. Commonly cross-stratified. Locally has interbeds of pinkish gray to very pale brown silt or laminations of dark grayish brown clay. Sand grains mostly subrounded. Gravel typically rounded to subrounded clasts of granite, gneiss, pegmatite, feldspar, quartz, chert, and sandstone. Largest clasts commonly 3–5 cm diameter, but cobbles and small boulders (up to approximately 32 cm in diameter) present locally. Accumulations of reddish-yellow to yellowish-brown iron oxide and black manganese oxide as coats on grains and masses in matrix common, and in many places accurate bedding. Surface soil profile typically has stage I+ Bt horizon with weak to moderate prismatic structure, and a thin Bk horizon with stage II carbonate morphology.

At a site about 10 km west of Orchard quadrangle (in adjacent Masters 7.5′ quadrangle), unit includes 70 cm thick section of crumbly clay, pinkish silt, platy silty fine sand, burrowed sandy silt with gray and yellowish green color banding, over white silt with common shell fragments and small articulated clam shells. Hard dry consistence. Interpreted as eolian, pond, and lacustrine that may have deposited at a time when the river was temporarily dammed by sidestream flood deposits. Underlying sandy bedload deposit reddish yellow, yellowish red, or dark red due to iron oxide accumulation.

OSL age estimate (5 grains) of 9.4±1.0 ka (UNL–3504, table 1) was obtained for mainstream Broadway Alluvium where it underlies **Qbt** at a locality about 0.8 km south of Kiowa Creek confluence (site TK–R). This age estimate is anomalously young and stratigraphically inconsistent with all ages obtained for overlying **Qbt** (see discussion above), and therefore is not considered a realistic estimate for age of the sediment. Another OSL age estimate (table 1), radiocarbon ages for soil carbonate rhizoliths collected from a quarry exposure north of Orchard suggest a minimum-limiting age for buried eolian sand overlying **Qbt** of about 13 ka B.P. (3.1±0.07 °C ka B.P., CAMS–6378, and 13.0±0.2 ka B.P., CAMS–6374, table 2). Therefore, also not considered a realistic estimate. Reasons for the anomalously young OSL age estimates are unknown but may be due to a number of factors associated with sampling and dating, or exposure of sediment to sunlight by burrowing animals. Results of a dune recovery core in Masters 7.5′ quadrangle, at site near Empire Reservoir (site ER, fig. 1), a deposit of late Pleistocene sand has an OSL age estimate of 26.4±2.5 ka at 0.7 m depth (UNL–3467, see supplemental data, table 1). This age is in good agreement with radiocarbon ages Mahs and others (1996) obtained for soil carbonate nodules from an underlying buried soil at a nearby site (the Empire Reservoir site) for the sand of 31.2±0.25 cal ka B.P. (27.30±0.17 °C ka B.P., CAMS–11339, 31.36±0.48 cal ka B.P. (27.42±0.30 °C ka B.P., CAMS–16612, and 30.58±0.51 cal ka B.P. (26.41±0.24 °C ka B.P., CAMS–16604).

Main source of eolian sand is South Platte River for sands in the Fort Morgan dune field, which covers much of dune fields south of river, and Laramie Formation for sands in the Greeley dune field, located north of river (Muhs and others, 1996). Thickness up to 20 m in parabolic dunes along the south bluff of the South Platte River. Thins to less than half a meter in places

BEDROCK UNIT

Pierre Shale (Upper Cretaceous)—Unit shown in cross section only. Underlies Quaternary deposits in Orchard quadrangle. Mapped as Pierre Shale by Gardner (1967) and Scott (1978). Where crops out in nearby quadrangles composed of gray noncalcareous marine shale; dark-gray calcareous marine silty shale interbedded with light-gray shaly sandstone and sandy shale. Sandstone beds and concretionary limestone layers up to a meter or more thick. Concretions common. Upper Cretaceous marine fossils sparse to abundant. Thickness of formation close to 1,800 m in map area (Gardner, 1967; Scott, 1978)

EXPLANATION OF MAP SYMBOLS

Contact—Dashed where approximately located; dotted where concealed

Dune Crests—Only crests clearly visible on National Agriculture Imagery Program (NAIP) orthoimagery are shown

Areas where eolian sand Qes probably is generally thin

Intermittent wetlands and ponds—Low-lying areas prone to wetness and ponding within eolian sand deposits. Includes areas that in some years have relatively large ponds, but that appear to lack standing water in 2013 NAIP orthoimagery

Intermittent holding pond—Mapped in Kiowa Creek and Milliron Draw, where a series of artificial berms create holding ponds that is intermittently water. Dry in NAIP orthoimagery taken in 2013, but ponds present in imagery taken in both 2009 and 2011

Water—Includes water in ponds, Jackson Reservoir, and channels of South Platte River wide enough to be mapped at 1:24,000 scale. Water bodies change in position and size seasonally and annually. Location and dimension of ponds and river channels shown on this map are based on 2013 NAIP orthoimagery

TCR **Optically stimulated luminescence (OSL) sample location**—With site name that links to sample field number (see table 1)

Radiocarbon (°C) sample location—With site name that links to sample field number (see table 2)

INTRODUCTION

The Orchard 7.5′ quadrangle is located along the South Platte River corridor on the semi-arid plains of eastern Colorado, and contains surficial deposits that record alluvial, eolian, and hillslope processes that have operated through environmental changes from the Pleistocene to the present (fig. 1; photo 4). The South Platte River, originating high in the Colorado Front Range, has played a major role in shaping the geology of the quadrangle, which is situated downstream of where the last of the major headwater tributaries (St. Vrain, Big Thompson, and Cache la Poudre) join the river. Recurrent glaciation (and deglaciation) of basin headwaters affected river discharge and sediment supply far downstream, influencing alluvium deposition and terrace formation in the Orchard quadrangle. Kiowa and Bijou Creeks, unglaciated tributaries originating east of the Front Range, also have played a major role by periodically delivering large volumes of sediment to the river during flood events, which may have temporarily dammed the river. Eolian sand deposits of the Greeley (north of river) and Fort Morgan (south of river) dune fields cover much of the quadrangle and record past episodes of sand mobilization during times of drought (Muhs and others, 1996). With the onset of irrigation during historic times, the South Platte River has changed from a broad, shallow, and sandy braided river with highly seasonal discharge to a much narrower, deeper river with braided-meandering transition morphology and more uniform discharge (Nadler and Schumm, 1981; Harvey and others, 1985). Along this reach, the river has incised into Upper Cretaceous Pierre Shale, which, although buried by alluvial deposits in Orchard quadrangle, is locally exposed downstream along the South Platte River bluff near the Bijou Creek confluence, in some of the larger draws, and along Wildcat Creek (Scott, 1978).

METHODS

The geology of the Orchard quadrangle was previously mapped by M. E. Gardner during the 1960s (Gardner, 1967). Gardner's map (1967) provided the foundation for the new, digital geologic mapping presented here, which was completed using a combination of field investigation, geochronologic research, and interpretation of the following: stereoscopic pairs of National Aerial Photography Program (NAPP) color-infrared (1988, 1:40,000 scale) and historical black and white (1948, 1:20,000 scale; 1949, 1:16,620 scale) aerial photographs; National Agriculture Imagery Program (NAIP) orthoimagery (U.S. Department of Agriculture (USDA) Farm Service Agency Aerial Photography Field Office, 2009, 2011, 2013); topographic and digital-elevation (DEM)-data; Web Soil Survey digital soil data (USDA Natural Resources Conservation Service, 2009); satellite imagery viewed with Google Earth; Colorado Emergency Management Agency (1998) flood maps (1:19,200 approximate scale); and subsurface lithologic data from test holes and water wells (Bjorkland and Brown, 1957; Colorado Division of Water Resources, 2013). Field mapping and research was conducted between 2011 and 2013. Digital mapping using ArcMap software was done initially on NAIP orthoimagery taken in 2009 and later refined using imagery taken in 2011 and 2013; location and dimensions of the South Platte River and other water bodies shown on this map are based on the 2013 orthoimagery.

The topographic base is out of date particularly with regard to locations of river bluff; banks of the South Platte River, Bijou Creek, and Kiowa Creek; and roadways across the river, which have changed in places due to flood activity, especially during floods that have occurred since the topographic base was created. Therefore, geologic mapping associated with these features also is based on the NAIP imagery. All field mapping and all imagery used for mapping predate the large-magnitude flood on the South Platte River during mid-September 2013.

Geologic mapping was aided by optically stimulated luminescence (OSL) and radiocarbon (°C) age determinations (tables 1 and 2). OSL samples were processed and analyzed at the Nebraska Luminescence Laboratory (Luminescence Geochronology Laboratory using the single aliquot regenerative (SAR) method (Murray and Wintle, 2000). Equivalent dose (D_e) was measured on a Risø DA-20, TL/OSL reader and values were calculated using the central age model of Galbraith and others (1999). Dose rates and age estimates were calculated using both field moisture of the sample, and a fixed estimate of 5 percent moisture, which may better represent annual moisture history of the sample. Radiocarbon ages, including new ages reported here (table 2) and previously published ages cited from the literature, were calibrated using the IntCal13 dataset and CALIB 7.0 (Stuiver and Reimer, 1993; Reimer and others, 2013) to better correspond to ages generated by other dating methods.

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CONVERSION FACTORS

Multiply	By	To obtain
millimeter (mm)	0.03937	inch (in.)
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)

DIVISION OF QUATERNARY TIME USED IN THIS REPORT[1]

Period	Epoch	Age
Quaternary	Holocene	0–11.7 ka
	Pleistocene	late 11.7–126 ka
		early[2] 781 ka–2.58 Ma

[1]Ages for time divisions are from Walker and others (2012) and Cohen and others (2013, updated). Ma, million years; ka, thousand years.
[2]Lalonian and Calabrian Ages.

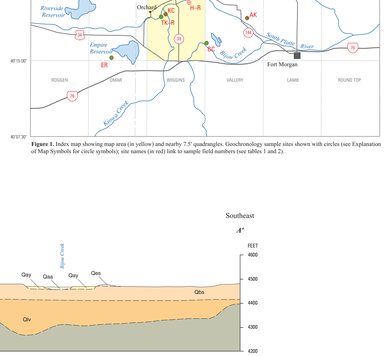

Figure 1. Index map showing map area (in yellow) and nearby 7.5′ quadrangles. Geochronology sample sites shown with circles (see Explanation of Map Symbols for circle symbols); site names (in red) link to sample field numbers (see tables 1 and 2).

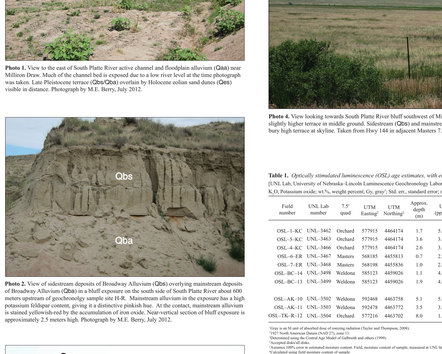

Photo 1. View to the east of South Platte River active channel and floodplain alluvium (**Qaa**) near Milliron Draw. Much of the channel bed is exposed due to a low river level at the time photograph was taken. Late Pleistocene terrace (**Qbs**/**Qba**) overlain by Holocene eolian sand dunes (**Qes**) visible in distance. Photograph by M.E. Berry, July 2012.

Photo 2. View of sidestream deposits of Broadway Alluvium (**Qbs**) overlying mainstream deposits of Broadway Alluvium (**Qba**) in a bluff exposure on the south side of South Platte River about 600 meters upstream of geochronology sample site H-R. Mainstream alluvium in the exposure has a high potassium feldspar content, giving it a distinctive pinkish hue. At the contact, mainstream alluvium is stained yellowish-red by the accumulation of iron oxide. Near-vertical section of bluff exposure is approximately 2.5 meters high. Photograph by M.E. Berry, July 2012.

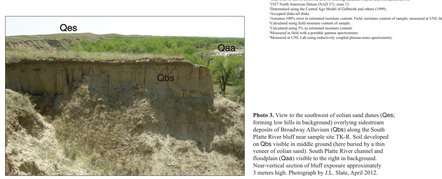

Photo 3. View to the southwest of eolian sand dunes (**Qes**; forming low hills in background) overlying sidestream deposits of Broadway Alluvium (**Qbs**) along the South Platte River bluff near sample site TK-R. Soil developed on **Qbs** visible in middle ground (here buried by a thin veneer of eolian sand). South Platte River channel and floodplain (**Qaa**) visible to the right in background. Near