The geology was mapped by M.E. Berry from 2011 to 2016. E.M. Taylor Base from U.S. Geological Survey Weldona Quadrangle, 1971; photorevised 1984. d J.L. Slate assisted with geochronology sample collection and Polyconic projection, 1927 North American Datum (NAD 27) stratigraphic interpretation, J.B. Paces processed and analyzed 10.000-foot grid based on Colorado coordinate system, north zone samples for U-series dating and interpreted results. P.R. Hanson 1,000-meter Universal Transverse Mercator grid ticks, zone 13 rocessed and analyzed samples for OSL dating and interpreted results. T.R. Brandt prepared the digital topographic base, digital compilation, and GIS database of the geologic map. **CONTOUR INTERVAL 10 FEET** NATIONAL GEODETIC VERTICAL DATUM OF 1929 SUNKEN LAKE JUDSÔN HILLS PEACE VALLEY ROGGEN Figure 1. Index map showing map area (in yellow) and nearby 7.5' quadrangles. Geologic **EXPLANATION** Figure 2. Shaded relief was derived from U.S. Geological Survey National Elevation Dataset (NED) with 10-meter resolution elevation data maps of Orchard and Masters quadrangles published as Scientific Investigations Map 3331 EIC 230 Th/U sample site and identifier

(accessed June 17, 2014, at http://ned.usgs.gov/).

Sidestream deposits of Broadway Alluvium (late Pleistocene)—Mapped as informal Bijou Flats tongue of Broadway Alluvium by Gardner (1967) and upper member of Broadway Alluvium by Scott (1978). Overlies and inferred to interfinger with mainstream deposits of Broadway Alluvium (Qba) south of South Platte River. Consists mainly of sheetflood deposits interpreted to have been deposited primarily by large-magnitude floods along Bijou and Kiowa Creeks (fig. 1; Gardner, 1967; Scott, 1978, 1982; Berry and others, 2015a, b). Deposits form a low-gradient fan that slopes roughly 3 m/km toward the South Platte River. Distribution of deposits suggests that influx of large amounts of sidestream alluvium during flood events deflected the South Platte River to the north side of its valley and may have episodically dammed the river for short periods of time (Scott, 1982). Accumulation of the sidestream alluvium built up surface to a level that now stands approximately 21 m above the active floodplain in Masters 7.5' quadrangle (Berry and others, 2015b), 21–24 m above the active floodplain in Orchard 7.5' quadrangle (Berry and others, 2015a), and

reaches a maximum height of approximately 27 m above the active floodplair

here in Weldona 7.5' quadrangle, near the Bijou Creek confluence. Height of surface decreases progressively downstream from Bijou Creek confluence to approximately 15 m above the active floodplain at eastern edge of Fort Morgan 7.5' quadrangle. Deposits have been identified as far downstream as Prewitt Reservoir (roughly 45 km east) and Atwood, Colo. (roughly 60 km east) by Gardner (1967) and Scott (1978), respectively. Alluvium light yellowish brown, light olive brown, pale yellow, or light gray, poorly to well sorted, moderately stratified, coarse to very fine sand and silty sand in beds generally 20–60 cm thick. Sand beds commonly separated by thin (1–5 millimeters [mm]) mats of organic debris and clay or packets (5–10 cm thick) of thinly laminated dark-grayish brown or black organic-rich clay interbedded with layers of pale yellow or light gray silt and fine sand. Contains abundant detrital lignite that Gardner (1967) and Scott (1978) attributed to Upper Cretaceous Laramie Formation (see text below). Graded beds that fine upward from poorly sorted coarse sand and granules to mostly fine sand are common, as well as sand beds that are cross-stratified, finely laminated, crudely stratified, or massive. Sand grains and granules mostly subangular to subrounded, and are mostly composed of quartz and feldspar. Few scattered small pebbles of tuff, shale, and granitic rocks. Soft to hard dry consistence. Iron oxide nodules, masses, or pore linings present locally, particularly in sandy clay layers. Typically forms vertical exposures, especially along South Platte River bluff (Berry and others, 2015a) and Bijou Creek drainage. Contact with mainstream alluvium typically sharp, most notably marked by difference in color and dry consistence attributable to differences in provenance. Soil profile characterized by thin argillic B horizon with moderate prismatic structure and Bk horizon with stage II filamentous carbonate morphology. Soil profile buried by younger eolian

CORRELATION OF MAP UNITS

[The Louviers Alluvium (Qlv) does not crop out in the study area but is present in the subsurface;

for this reason, the unit is blank and not described but maintained for correlation purposes]

SURFICIAL DEPOSITS

BEDROCK UNIT

types that are felsic to intermediate in composition]

DESCRIPTION OF MAP UNITS

[Calibrated radiocarbon ages are expressed as "cal ka B.P.," which stands for calibrated thousand

confidence level. Calibrated ages are reported as the midpoint of the calibrated range. In cases

are based on the mean of the ranges weighted by their probabilities and are presented without

Soil-horizon designations and other descriptive soil terminology used in this report follow

criteria outlined in Soil Survey Division Staff (1993), Birkeland (1999), and Schoeneberger and

others (2012). Most colors are field dry colors and based on Munsell soil color charts (Munsell

Color, 1975). The term "consistence" is the resistance to crushing of soil or surficial material in

the hand, as described by Soil Survey Division Staff (1993). Textures are field estimates. In

descriptions of clast lithology, the term "granite" refers to phaneritic igneous or meta-igneous rock

SURFICIAL DEPOSITS

Artificial fill (latest Holocene)—Includes abutments where roadways cross South

Chiefly consists of gravel, sand, silt, and rock and concrete fragments

Shoreline deposits (latest Holocene)—Mostly pale brown, brown, or yellowish

sand deposits by shoreline processes at Bijou No. 2 Reservoir. Deposits

Active channel and floodplain alluvium (late Holocene)—Equivalent in part to

post-Piney Creek alluvium of Scott (1963). Very pale brown, pale yellow, light

coarse sand, pebbly sand, silty sand, and sandy pebble and minor small cobble

gravel, interstratified with thin (<1-5 centimeters [cm]) layers or lenses of very

to well sorted, and weakly to moderately stratified. Sand beds commonly

reddish yellow iron oxide and black manganese oxide at stream level.

cross-stratified. Clasts mostly granite, gneiss, pegmatite, quartz, feldspar, and

sandstone; most clasts subrounded to rounded. Locally, grains stained with

Uppermost 25–80 cm of sediment on floodplain typically light grayish brown,

developed surface soil (A/C or A/AC/C profile). Krotovinas are common locally.

Along Bijou Creek, alluvium mostly stratified sand, silty sand, and clayey silt.

Unit contains minor amounts of detrital lignite eroded from bedrock (possibly

Upper Cretaceous Laramie Formation; Gardner, 1967) exposed along tributaries

of Scott (1963). Forms low terrace approximately 1.5 m above active floodplain

Surface occasionally flooded. Alluvium very pale brown, light brownish gray,

light yellowish brown, or light pinkish brown, fine to coarse sand, pebbly sand,

organic-rich clayey silt and clay. Poorly to well sorted and 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

deformation. Clasts mostly granite, gneiss, quartz, feldspar, pegmatite, chert,

in alluvial sequence typically light gravish brown or pale brown, crudely

and sandstone; most clasts subrounded to rounded. Uppermost sediment packet

stratified, poorly sorted sandy silt, silty sand, and granule- to fine-pebbly sand

typically poorly drained A/C or A/AC/C profile. Krotovinas are common locally.

Along Bijou Creek, alluvium mostly stratified sand, silty sand, and clayey silt.

Unit contains minor amounts of lignite fragments. Estimated thickness 3–6 m

Young sidestream alluvium, undivided (Holocene)—Mapped in tributary drainages

light brownish gray sandy silt or silty sand with scattered granitic granules,

moderately stratified. Loose to slightly hard dry consistence. Estimated

Qa2 Young alluvium 2 (late Holocene)—Equivalent in part to post-Piney Creek alluvium

and small draws north of the South Platte River; includes alluvium in channels,

on floodplains, and forming low terraces 1–3 m above valley bottoms. Alluvium

commonly consists of pale yellow, pale brown, brown, light yellowish brown, or

pebbles, and lenses and stringers of poorly sorted pebbly silty sand. Weakly to

of Scott (1963). Forms low terrace approximately 3 m above active floodplain.

Surface occasionally flooded in places and rarely flooded in others. Alluvium

very pale brown, light brownish gray, light yellowish brown, or light pinkish

brown, fine to coarse sand, pebbly sand, and sandy pebble and minor small

well sorted and weakly to moderately stratified. Sand beds commonly

cobble 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

cross-stratified. Loose to slightly hard dry consistence. Locally, grains stained

pegmatite, chert, and sandstone; most clasts subrounded to rounded. Uppermost

fine-pebbly sand with lenses of silt and dark grayish brown clayey silt and clay.

Surface soil variable, ranging from poorly drained A/C profiles to profiles with

weakly developed textural B horizons (U.S. Department of Agriculture [USDA]

Natural Resources Conservation Service, 2009). Krotovinas are common locally

Along Bijou Creek, alluvium mostly stratified sand, silty sand, and clayey silt.

Unit contains minor amounts of lignite fragments. Estimated thickness 3–6 m

Gardner (1967) and Scott (1978). Forms terrace and low-gradient fans 6–11 m

whose type locality is about 45 kilometers (km) west of Weldona, Colo. Includes

above active floodplain; Gardner (1967) and McFaul and others (1994)

considered this terrace correlative to Kuner terrace of Bryan and Ray (1940).

sheetwash alluvium and colluvium interbedded with river alluvium, most

Shale bedrock. Based on where terrace surface is well defined, gradient of

terrace surface is less than gradient of floodplain such that relative height of

terrace is higher downstream from the Narrows (fig. 1) than it is upstream in

brown. Poorly to well sorted, weakly to moderately stratified, fine sand, silt,

sand lenses and granule- to fine-pebble stringers. Soft to slightly hard dry

clayey silt, pebbly sand, sandy pebble gravel, cobble gravel, and silt with coarse

consistence. Clasts mostly granite, gneiss, pegmatite, quartzite, quartz, feldspar,

125 km southwest of the map area. Most clasts subrounded to rounded. Locally,

weakly developed buried soil separates deposits within alluvial sequence. Soil

survey (USDA Natural Resources Conservation Service, 2009) shows surface

Radiocarbon (¹⁴C) and optically stimulated luminescence (OSL) age

tributary near the Narrows (site AK, near section AK of Gardner, 1967; fig. 1)

Holocene (tables 1 and 2; Berry and others, 2013, 2015a). Probable Succinea

snail shells collected at depths of approximately 4.7 m and approximately 3.6 m

vielded ¹⁴C ages of 11.90±0.28 cal ka B.P. (Aeon–994, table 2) and 11.95±0.24

cal ka B.P. (Aeon–995, table 2), respectively. Sediment collected at a depth of

approximately 3.5 m, from a site about 10 m upstream from where the snail

shells were collected, gave an OSL age estimate of 9.1±0.9 ka (UNL-3503,

5 percent moisture, table 1). A latest Pleistocene to early Holocene age for basal

alluvium is also supported by an age of 11.68±0.36 cal ka B.P. (AA–11084A,

(1998) for humic acids in charcoal from Kuner terrace alluvium (of Bryan and

Timing of uppermost alluvium deposition and surface stabilization is

constrained by a date from McFaul and others (1994) of 5.84±0.18 cal ka B.P.

(Beta-42564, 5.12±0.08 ¹⁴C ka B.P.) for soil humate from a buried A horizon

developed in Qa3 terrace alluvium at a site in the Masters 7.5' quadrangle.

have been stabilized for a few thousand years prior to its burial at that site by

Degree of development of the buried soil indicates that the Qa3 surface may

eolian sediment about 5.8 cal ka (McFaul and others, 1994). Stabilization of the

Qa3 surface by middle Holocene time is supported by degree of development of

soils mapped on the terrace surface by USDA Natural Resources Conservation

Service (2009), and by a 14 C age of 4.92±0.07 cal ka B.P. (Aeon–2101; table 2)

for a buried A horizon developed in Qa3 terrace alluvium of Wildcat Creek in

adjacent Fort Morgan 7.5' quadrangle (site FMR; fig. 1). Degree of development

35 cm thick and filamentous stage I carbonate accumulation, is consistent with

several thousand years of soil development on the terrace surface prior to its

burial at that site by sheetwash alluvium about 4.9 cal ka. Estimated thickness

of the buried soil profile, which has a weakly developed Bt horizon roughly

uncalibrated age of 10.11±0.09 ¹⁴C ka B.P.) obtained by Haynes and others

Ray, 1940) at the Bernhardt site, roughly 80 km west of site AK.

estimates from a section exposed in a stream cut along a small unnamed

indicate that basal alluvium was deposited in latest Pleistocene or early

soil as typically having thin argillic B horizon and weakly developed Bk horizon

chert, and sandstone; includes bluish gray quartzite that probably originated

from outcrops in Coal Creek Canyon (Lindsey and others, 2005), roughly

Alluvium pale yellow, light yellowish brown, light olive brown, or grayish

Orchard and Masters quadrangles (Berry and others, 2015a, b).

with stage I–II carbonate morphology

notably on north side of South Platte River where valley wall is cut into Pierre

Qa3 Young alluvium 3 (Holocene and latest Pleistocene?)—Piney Creek Alluvium of

with reddish yellow iron oxide and black manganese oxide. Some beds show

soft sediment deformation. Clasts mostly granite, gneiss, quartz, feldspar,

sediment packet in alluvial sequence typically light grayish brown or pale

brown, crudely stratified, poorly sorted sandy silt, silty sand, and granule-to

with lenses of silt and dark gravish brown clavev silt and clay. Surface soil

manganese oxide. Some of the finer grained beds show soft sediment

and sandy pebble and minor small-cobble gravel. Interstratified with thin (<1-

5 cm) layers or lenses of very pale brown silt and dark grayish brown,

south and southwest of map area (Braddock and Cole, 1978; Sharps, 1980).

Young alluvium 1 (late Holocene)—Equivalent in part to post-Piney Creek alluvium

Estimated thickness 3–5 m

thickness 1–5 m

crudely stratified, poorly to moderately sorted sandy silt, silty clay, silty sand,

and granule to fine pebbly sand. Less active parts of floodplain have weakly

pale brown silt and dark grayish brown, organic-rich clayey silt and clay. Poorly

brownish gray, light yellowish brown, or light pinkish brown. Mostly fine to

reservoir is high. Estimated thickness less than 2 meters (m)

Alluvial deposits

post-date reservoir construction. Periodically inundated when water level in

brown, moderately to well sorted, fine to medium sand, reworked from eolian

Platte River, raised track of railroad, artificial levees and banks, small earthen

dams forming holding ponds, and dam embankments at Bijou No. 2 Reservoir.

Artificial fill is present along most canals and ditches but only mapped locally.

Artificial fill

where calibration produced more than one age range with a probability of 5 percent or more, ages

years before present (0 yr B.P. = 1950 A.D.). Uncertainties are given at the 95 percent (2 σ)

fill deposits

Alluvial and colluvial

alluvium that grade to mainstream terrace alluvium (Qba) along the river. Granules and pebbles in the sidestream deposits are composed mostly of rock types associated with the South Platte River drainage, indicating that the clasts were likely reworked from older South Platte River deposits. OSL and ¹⁴C age estimates indicate a late Pleistocene age for Qbs (Berry and others, 2015a). A dated section at the mouth of Kiowa Creek (site KC, in Orchard 7.5' quadrangle; fig. 1) yielded OSL age estimates (5 percent moisture) of 12.0±1.1 ka (UNL–3462) at approximately 1.7 m depth, 16.8±1.7 ka (UNL-3466) at approximately 2.6 m depth, and 15.2±1.5 kg (UNL-3463) at approximately 3.6 m depth (table 1). These age estimates are in good agreement with a ¹⁴C age of 14.53±0.56 cal ka B.P. (Aeon–1064, table 2) obtained for probable Succinea snail shells collected at a depth of approximately 3.7 m from a section of Qbs exposed in the South Platte River bluff about 4.8 km downstream from Kiowa Creek (site H–R, in Orchard 7.5' quadrangle, at section H of Gardner, 1967; fig. 1). The ages also are in good agreement with OSL age estimates (5 percent moisture) for a section exposed in the north cutbank of Bijou Creek (site BC, this quadrangle, about 13.5 km upstream from the river confluence; fig. 1): 12.4±1.1 ka (UNL–3498) sampled at approximately 1.1 m depth and 14.6±1.2 ka (UNL-3499) sampled at approximately 1.9 m depth

North of river, Qbs also includes a few remnants of sidestream terrace

sand in many places.

Organic material collected from a thin (2–5 mm) interbed of organic debris and clay at approximately 2.5 m depth, just above OSL sediment sample UNL-3466 (site KC), yielded a ¹⁴C age estimate of 43.90±5.69 cal ka B.P. (Aeon–950, table 2). This is likely an infinite age, meaning the sample is probably too old to date by the ¹⁴C method; the age is at the practical upper limit of the method, where trace amounts of contamination by young carbon have a large effect. Gardner (1967) also dated organic material from Qbs that yielded an anomalously old date. Pollen analysis of his dated sample indicated a plant assemblage of Late Cretaceous age, leading Gardner (1967) to interpret the sample as lignite from the Laramie Formation, which crops out in Kiowa and Bijou Creek drainage basins (Braddock and Cole, 1978; Sharps, 1980). The dated sample (Aeon-950) also is suspected to contain lignite. Probable lignite debris is common to abundant in other exposures of Qbs along Bijou Creek and the South Platte River bluff, as also noted by Scott (1978). Estimated thickness 18–24 m near the confluence of Bijou Creek and the South Platte River Mainstream deposits of Broadway Alluvium (late Pleistocene)—Mapped

Alluvium by Scott (1978). Underlies and inferred to interfinger with sidestream Broadway Alluvium (Qbs) from Kiowa and Bijou Creeks (fig. 1) south of South Platte River. North of river, mostly covered by eolian sand (northwest edge of quadrangle) or exposed downstream from the Narrows in isolated terrace remnants roughly 15–18 m above active floodplain; also locally exposed beneath Qa3 alluvium at site AK (fig. 1). Unit poorly exposed due to cohesionless nature of the sediment when dry. High potassium feldspar content gives unit a distinctive pinkish hue Alluvium is 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, quartzite (including bluish gray quartzite), and sandstone. Largest clasts commonly 3–5 cm diameter, but cobbles and small boulders (up to 32 cm in diameter) present locally. Terrace remnants north of river also include subangular sandstone boulders of upper transition member Pierre Shale (Kp). Reddish yellow to yellowish red iron oxide and black manganese oxide common as grain coatings, masses in matrix, and accumulations along bedding planes. Surface soil profile typically has thin

Broadway Alluvium by Gardner (1967) and lower member of Broadway

argillic B horizon with weak to moderate prismatic structure, and a thin Bk horizon with stage II carbonate morphology At a site in Masters 7.5' quadrangle (Berry and others, 2015b), unit includes 70 cm of crumbly clay, pinkish silt, platy silty fine sand, and burrowed sandy silt with gray and yellowish green color banding above white silt with common shell fragments and small, articulated clam shells. Hard dry consistence. Interpreted as quiet water deposits that may have been deposited at a time when the river was temporarily dammed by sidestream flood deposits (Qbs). Underlying sands brightly stained reddish yellow, yellowish red, or dark red due to iron-oxide An OSL age estimate for mainstream Broadway Alluvium (8.0±0.7 ka,

UNL–3502, 5 percent moisture, table 1; Berry and others, 2015a) was obtained for sediment collected at site AK (fig. 1, this quadrangle; near section AK of Gardner, 1967) at a depth of approximately 5.1 m, just below its contact with young alluvium 3 (Qa3). This age estimate is anomalously younger than and stratigraphically inconsistent with basal ages obtained for the overlying Qa3 deposit (see discussion above), and therefore not considered a realistic estimate for age of the sediment. Another OSL age estimate of 9.4±1.0 ka (UNL-3504, 5 percent moisture, table 1; Berry and others, 2015a) was obtained for mainstream Broadway Alluvium where it underlies approximately 7 m of Qbs at a locality about 0.8 km upstream from Kiowa Creek confluence (site TK-R, fig. 1, Orchard 7.5' quadrangle). This age estimate is anomalously younger than and stratigraphically inconsistent with ages obtained from samples analyzed for overlying Qbs (see discussion above), and therefore also not considered a realistic estimate for age of the sediment. Reasons for the anomalously young OSL age estimates are unknown, but could be due to a number of factors associated with sampling and dating or exposure of sediment to sunlight by burrowing animals. Results of a dose recovery test performed on UNL-3504, however, rule out most systematic problems with luminescence behavior of these dated sediments.

Uranium-series age analysis of a bone fragment (possibly bison horn-core) encased in fine-grained sediment from the uppermost meter of mainstream Broadway Alluvium at site EF (fig. 1, Masters 7.5' quadrangle) indicates that burial of the bone occurred sometime between 15 and 11 ka (table 3; Berry and others, 2015b). The oldest ages are for two interior-most subsamples that produced apparent closed-system ²³⁰Th/U ages within analytical uncertainty of one another (Wp67–5 and Wp67–7, table 3; fig. 1–1 in Paces, 2015). The error-weighted average value of these two oldest ages, 15.24±0.06 ka, may most closely estimate the minimum age of the deposit that contained the bone. However, because data for the specimen indicate a complex history of uranium uptake and subsequent leaching (see discussion in Paces, 2015), data for additional specimens are needed to better constrain the minimum age of the Broadway Alluvium is considered coeval with the Pinedale glaciation

(Bryan and Ray, 1940; Hunt, 1954; Scott, 1960, 1975; Madole, 1991), which spanned from >31 ka to about 15–13 ka (Nelson and others, 1979; Madole, 1986; Schildgen and others, 2002; Benson and others, 2004, 2007; Licciardi and Pierce, 2008; Madole and others, 2010; Young and others, 2011; Schweinsberg and others, 2016). Fluvial sediment load may have been greatest during and shortly after deglaciation (Church and Ryder, 1972; Madole, 1991; Schildgen and others, 2002; Lindsey and others, 2005), a process that started either about 17 ka (Licciardi and others, 2004; Benson and others, 2005; Schaefer and others, 2006) or about 16–15 ka (Young and others, 2011) and largely was completed between about 15 and 13 ka (Benson and others, 2007; Young and others, 2011; and references therein). Correspondingly, Clovis artifacts present in upper part of terrace alluvium near Kersey, Colo. (roughly 50 km west of Weldona, Colo.), combined with other archaeological data, indicate that aggradation of Broadway Alluvium was still in progress between about 13.3 and 12.9 cal ka (11.5–11 ¹⁴C ka) but completed and the surface stabilized by about 11.5 cal ka (10 ¹⁴C ka) at the latest (Holliday, 1987). A ²³⁰Th/U age of 11.0±1.1 ka (Wp67–1, table 3; Berry and others, 2015b) for pedogenic carbonate coating the outer edge of bone 7.5' quadrangle) further supports surface stabilization and the onset of soil formation sometime prior to 11 ka. Estimated thickness 12 m to as much as 30 m; thins to 1–1.5 m north of South Platte River downstream from the Narrows

Intermediate alluvium (middle Pleistocene)—In area covered by Weldona 7.5′ quadrangle deposits either previously unmapped (here mapped as Qai1) or mapped by Gardner (1967) and Scott (1978) as Verdos Alluvium (here mapped as Qai2). Thought to be younger than Verdos Alluvium based on height above river relative to other deposits of probable Verdos Alluvium in adjacent Fort Morgan 7.5' quadrangle (Gardner, 1967; Scott, 1978, 1982). Deposits are made up of pebble and cobble gravel, pebbly sand, and silty sand in terrace remnants and pebble- and cobble-gravel lags. Alluvium light gray, very pale brown, light vellowish brown, or light reddish brown, locally cemented, and poorly to moderately sorted. Sand beds commonly cross-stratified. Pebbles and cobbles mostly quartzite (including bluish gray quartzite), gneiss, granite, pegmatite. sandstone, and chert; subrounded to well rounded; diameter of largest clasts commonly 13–16 cm but ranging up to 26 cm. Some granitic clasts are weathered (beginning to disaggregate). Also includes subangular to subrounded, sandstone and bioturbated claystone boulders up to 1 m in diameter of upper transition member Pierre Shale (Kp), probably derived locally. Thin coats (rinds) of calcium carbonate on clasts common. Where soil profile preserved, includes carbonate horizons with stage III morphology. Probably correlative at least in part to intermediate alluvium (Qai) in Masters 7.5' quadrangle, which has been dated using the uranium-series method (Paces, 2015). Uranium-series age analysis of innermost calcium carbonate rinds, subsampled from multiple clasts collected at site EIC (fig. 1, Masters 7.5) quadrangle), produced reliable results and oldest ²³⁰Th/U ages that primarily cluster in two groups, one (table 3, Wp95–A1–2, Wp95–A2–1, Wp95–B1, and Wp95-B2) with an error-weighted-mean age of 334±9 ka and the other (table 3 Wp95–B3 and Wp95–E1) with an error-weighted-mean age of 382±16 ka (fig. 1– 7 in Paces, 2015). These data indicate with a high degree of confidence that the alluvial clasts at EIC were deposited prior to 334 ka; based on the two oldest ages, the best estimate for the minimum age of the deposit is somewhat older than 382 ka. These results support correlating Qai at site EIC with older deposits of Slocum Alluvium, which have a proposed age range of 390–320 ka (Kellogg and others, 2008) Intermediate alluvium 1 (middle Pleistocene)—Remnant terrace gravels capping

low ridges or forming thin lags 21-25 m above active floodplain. Only identified downstream from the Narrows. Estimated thickness generally 1.5 m or less Intermediate alluvium 2 (middle Pleistocene)—Forms broad terrace generally 34–40 m above active floodplain; locally preserved only as thin gravel lag. Mostly covered by eolian sand (Qes) or mixed eolian and alluvial deposits (Qea). More extensively preserved than Qai1. Estimated thickness 3–8 m in terrace deposits to less than 1 m in gravel lags

Verdos Alluvium (middle Pleistocene)—Made up of poorly sorted pebble and

cobble gravel in inferred terrace remnants mostly 49–55 m above active

floodplain. In places, preserved only as thin pebble- and cobble-gravel lag. Mostly covered by eolian sand (Qes) or mixed eolian and alluvial deposits (Qea). Two small remnants preserved at 44–45 m above the active floodplain may represent a lower (younger) terrace of Qv; two levels of Verdos Alluvium have been reported at sites near the mountain front (Scott, 1972; Kellogg and others, 2008). However, deposits in Weldona quadrangle are too poorly exposed to allow confirmation of two distinct levels. QV deposits were previously mapped as Rocky Flats Alluvium by Gardner (1967) and Scott (1978), but are reinterpreted here as Verdos Alluvium based on height above river and correlation to deposits mapped as Verdos Alluvium by Gardner (1967) and Scott (1978) in adjacent Fort Morgan 7.5' quadrangle. Alluvium very pale brown, vellowish brown, light reddish brown, or pinkish gray. Pebbles and cobbles mostly quartzite (including bluish gray quartzite), gneiss, granite, pegmatite, volcanic clasts, chert, sandstone, and petrified wood; subrounded to well rounded; diameter of largest clasts up to 24 cm. Also includes subangular to subrounded, sandstone and bioturbated claystone boulders 0.5–1 m in diameter of upper transition member Pierre Shale (Kp), probably derived locally. Soil profile poorly exposed in Weldona quadrangle but includes variably cemented K horizon with thin to thick coats (rinds) of calcium carbonate on clasts. In adjacent Fort Morgan quadrangle where soil is better exposed, eroded profile includes a 1-m-thick K horizon with

stage III–IV carbonate morphology and carbonate coats on clasts up to 1 cm thick.

Age of Verdos Alluvium is constrained by its association with the Lava Creek B ash (Scott, 1960; Madole, 1991; Kellogg and others, 2008; and references therein), which erupted from the Yellowstone Plateau volcanic field about 640 ka (Lanphere and others, 2002). Beds of Lava Creek B ash in Verdos Alluvium have been documented at several sites along the South Platte River corridor northeast of Weldona 7.5' quadrangle (Scott, 1978, 1982; Izett and Wilcox, 1982), although no ash deposits have been identified within the quadrangle. Thickness of the alluvium is poorly constrained in Weldona 7.5' quadrangle but could be as much as 6–8 m based on exposures in adjacent Fort

Alluvial and colluvial deposits Fan alluvium and hillslope colluvium (Holocene)—Mapped along south side of South Platte River, where hillslope processes are actively degrading river bluff made up of mainstream and sidestream Broadway Alluvium (Qba and Qbs). Locally includes individual and coalescing alluvial-fan deposits at mouths of headward-eroding gullies, colluvium mantles on slopes, and sheetwash alluvium at toes of slopes. Very pale brown, crudely stratified, poorly sorted pebbly sand and moderately sorted sand with silt lenses and medium to coarse sand stringers. Most clasts <3 cm diameter and subangular to subrounded. Many clasts composed of potassium feldspar. Surface soil weakly developed A/C profile. Estimated thickness up to about 3 m

Mixed eolian and alluvial deposits (Holocene and late Pleistocene)—Mostly

mixed with lesser amounts of terrace gravel; typically overlies middle

sheetwash deposits mapped north of the river, consisting of reworked eolian sand

Pleistocene terrace alluvium (Qai1, Qai2, and Qv); locally includes small areas

of eolian sand and terrace alluvium that have not been reworked. Pale brown,

Morgan 7.5' quadrangle

and scattered rounded pebbles and small cobbles. Clasts mostly granite, gneiss, quartz, feldspar, pegmatite, chert, and sandstone. Estimated thickness 3–6 m Alluvial and colluvial deposits (Holocene to middle? Pleistocene)—Mapped north of river mostly in areas where alluvial and colluvial deposits mantle hillslopes underlain by Pierre Shale (Kp). Largely deposited by overland flow and soil creep processes. Made up of residuum from weathered bedrock mixed with sediments derived from river and eolian deposits higher on hillslopes. Locally includes outcrops of Pierre Shale too small to map separately. Very pale brown, light vellowish brown, or light olive brown. Crudely stratified and poorly sorted. Mostly clayey silty sand or sandy clayey silt, with scattered, subrounded to rounded pebbles and cobbles of river alluvium and angular to subangular fragments of sandstone from the Pierre Shale. Deposits typically calcareous. Estimated thickness up to 3 m

Qes Eolian sand (Holocene and late Pleistocene)—Forms simple and compound parabolic dunes and low-relief sand sheets. Blowouts common within dune fields. Pale brown, brown, or yellowish brown, moderately to well sorted, mostly fine to medium sand. Locally contains minor amounts of coarse to very coarse sand and a few scattered, subangular to rounded granules and small pebbles composed mostly of granitic and gneissic rock types. Loose to slightly hard dry consistence. Sand deposits of more than one age commonly separated by buried soils. Locally includes sheetwash deposits of reworked eolian sand and marsh or pond deposits in interdune and other low-lying wetland areas. Deposits of Qes may be more extensive than mapped due to the difficulty in distinguishing thin eolian sand cover from sandy terrace alluvium in a region that has been farmed and cultivated for more than a century. Unstippled parts of Qes are shown in county soil survey as having mostly Valent, Valentine-Dwyer, and Dwyer soils characterized by weakly developed A/C or A/AC/C soil profiles (USDA Natural Resources Conservation Service, 2009), typical of relatively young (late and middle Holocene) eolian sand deposits (Madole, 1995; Muhs and others, 1996; Madole and others, 2005). In northeastern part of quadrangle, unstippled parts also include Valent-Vona soils

ka B.P. (Beta-70543, 1.23±0.08 ¹⁴C ka B.P.) at Milliron Draw in adjacent

cal ka B.P. (Beta–62192, 0.89±0.10 ¹⁴C ka B.P.) in Greasewood Lake 7.5'

quadrangle. Radiocarbon ages for soil carbonate rhizoliths collected from a

quarry exposure north of Orchard, Colo., are in good agreement indicating a

(CAMS-8234, 1.56±0.07 ¹⁴C ka B.P., Muhs and others, 1996). Ages from

the late Holocene (Clarke and Rendell, 2003, and references therein).

Orchard 7.5' quadrangle; 0.88±0.21 cal ka B.P. (Beta–84821, 0.96±0.11 ¹⁴C ka

B.P.) at south edge of Orchard 7.5' quadrangle near Bijou Creek; and 0.82±0.16

maximum-limiting age for uppermost eolian sand of about 1.44±0.13 cal ka B.P.

elsewhere in the region also support widespread deposition of eolian sand during

mostly underlying late Holocene sand deposits. At a site near Empire Reservoir

(site ER, Masters 7.5' quadrangle, fig. 1), approximately 1 m below the surface,

a middle Holocene sand deposit covered by a thin veneer of late Holocene sand

has an OSL age estimate of 7.7±0.8 ka (UNL-3468, 5 percent moisture, table 1;

quadrangle, the age of a buried sand deposit is constrained by ages on buried

(Beta-72203, 5.51±0.09 ¹⁴C ka B.P.) and a minimum-limiting age of about

1.14±0.16 cal ka B.P. (Beta-70543, 1.23±0.08 ¹⁴C ka B.P.) for the deposit

(Madole, 1995; Madole and others, 2005). Radiocarbon ages for soil carbonate

rhizoliths collected from a quarry exposure north of Orchard, Colo., suggest a

minimum-limiting age for buried eolian sand of about 3.90±0.20 cal ka B.P.

(CAMS-6378, 3.60±0.07 ¹⁴C ka B.P., Muhs and others, 1996) at that site.

Episodes of eolian sand deposition during the middle Holocene are also

references therein).

documented at other sites within the region (Clarke and Rendell, 2003, and

extensive in northern part of Weldona 7.5' quadrangle as well as regionally

Sand deposits of probable late Pleistocene age (marked by dark stipple) are

(Muhs and others, 1996; Madole and others, 2005). In Masters 7.5' quadrangle at

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, 5 percent moisture, table 1; Berry and

others, 2015a, b). This age is in good agreement with radiocarbon ages Muhs and

others (1996) obtained for soil carbonate nodules from an underlying buried soil

at a site about 2 km north of site ER that provide maximum-limiting ages for the

overlying sand of 31.21±0.23 cal ka B.P. (CAMS–11339, 27.30±0.17 ¹⁴C ka

B.P.), 31.36 ± 0.48 cal ka B.P. (CAMS–16612, 27.42 ± 0.30^{-14} C ka B.P.), and

30.58±0.51 cal ka B.P. (CAMS–16604, 26.41±0.24 ¹⁴C ka B.P.). Eolian sand

deposition during the late Pleistocene likely was intermittent, and may have

be as young as 12 or 13 ka (Madole and others, 2005).

river, but thins to less than half a meter locally

resulted in late Pleistocene deposits of various ages within the region; some may

Eolian sands in the Weldona quadrangle south of the South Platte River are

part of a series of dune fields that make up the Fort Morgan dune field (fig. 2).

Main sources of sand in the Fort Morgan dune field could include the South

Platte River sediments (Muhs and others, 1996; Aleinikoff and Muhs, 2010;

Muhs, 2017) and the Tertiary Ogallala Formation (Muhs, 2017). North of the

river, eolian sands are considered part of the Sterling dune field (Muhs and

others, 1996). Sand source for the Sterling dune field has not been studied but

could be similar to that for the adjacent Greeley dune field (fig. 2); likely sand

sources for the latter are the Laramie Formation (Muhs and others, 1996;

Aleinikoff and Muhs, 2010; Muhs, 2017) and the Ogallala Formation (Muhs,

2017). Dune orientation in Weldona quadrangle is generally consistent with

indicates sand-transporting winds that formed the dunes primarily came from the

northwest (Muhs and others, 1996; Madole and others, 2005). Currently, dunes

are mostly stabilized by sandsage and short grass prairie vegetation (Chapman

and others, 2006). Thickness up to 10 m in compound parabolic dunes south of

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composed chiefly of marine calcareous silty shale or claystone, shaly sandstone,

weathered residuum; locally includes colluvium and other surficial deposits not

silty shale weathering to olive gray. Selenite (gypsum) crystals are common. Also

diagnostic ammonites Sphenodiscus (Coahuilites) sp. and Baculites clinolobatus

(Scott, 1978). Thickness of Pierre Shale about 1,800 m in map area (Gardner,

and sandy shale (Gardner, 1967; Scott, 1978). Mostly covered by unmapped

mapped separately. Outcrops are light gray, fine-grained sandstone and shaly

contains concretionary limestone layers up to 1 m thick. In northeastern

Colorado, upper transition member of Pierre Shale is reported to contain

sandstone weathering to yellowish brown or light olive brown, and dark gray

Pierre Shale (Upper Cretaceous)—Upper transition member of Pierre Shale

regional trends reported by Muhs (1985) and Muhs and others (1996) and

soils that provide a maximum-limiting age of about 6.33±0.16 cal ka B.P.

Berry and others, 2015a, b). At Milliron Draw, in adjacent Orchard 7.5'

Eolian sand deposits of probable middle Holocene age are locally exposed,

that probably reflect both Holocene and late Pleistocene sand deposits in a distribution pattern too complex to map separately. Light stippled parts of Qes are mainly mapped south of South Platte River where eolian sand covers late Pleistocene sidestream deposits of Broadway Alluvium (Qbs). County soil survey shows mostly Bijou, Bresser, and Truckton soils, characterized by argillic (Bt) horizon development in sandy, mostly alluvial soil parent material (USDA Natural Resources Conservation Service, 2009). Field investigation revealed argillic horizon to be part of a buried soil developed in the underlying stream and sheetflood alluvium and later covered by a veneer of younger eolian sand. Therefore, as in unstippled areas, eolian sand deposits in light stippled areas probably are Holocene in age, but generally thin (<1 m), such that underlying buried soil controls soil classification and series designation. Dark stippled parts of Qes, located north of the South Platte River, are shown in county soil survey as having mostly Vona and Ascalon soils, artificial levees, and floodwater inundation zones. characterized by A/Bt/Bk (stage I–II carbonate morphology) soil profiles developed in eolian sand (USDA Natural Resources Conservation Service, 2009). These soil profiles are typical of late Pleistocene eolian sand deposits (Madole, 1995; Muhs and others, 1996; Madole and others, 2005). Locally includes sand deposits of Holocene age that are too small to map separately. Widespread deposition of eolian sand during the late Holocene is indicated by radiocarbon ages reported by Madole (1994, 1995) and Madole and others (2005) for buried soils that provide maximum-limiting ages for uppermost sand deposits in and near Weldona 7.5' quadrangle: 0.64±0.11 cal ka B.P. (Beta-70542, 0.68±0.08 ¹⁴C ka B.P.) near Bijou No. 2 Reservoir: 1.14±0.16 cal

and values were calculated using the Central Age Model (CAM) 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 (table 1; Berry and others, 2015a). Moisture content of some of the samples (collected in November 2011) was very low and unlikely to approximate an average condition; the fixed estimate of 5 percent (an intermediate value within the range of values for samples collected in November 2011 and April-May 2012) may better represent moisture history of the samples for the purpose of calculating estimated ages from the dose rates. Radiocarbon ages, including those obtained in our study (table 2; modified from Berry and others, 2015a) 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) for better comparison to ages generated by other dating methods. Uranium-series age analyses were done at the U.S. Geological Survey Denver radiogenic isotope laboratory using procedures outlined in "USGS–DRIL–01, R0 Uranium-Thorium Disequilibrium Studies" (accessible at http://esp.cr.usgs.gov/projects/uth/USGS DRIL 01cR0 U series.pdf). Details about the samples analyzed and results obtained are provided in Paces (2015). The ²³⁰Th/U analyses provide constraints on the minimum ages of deposits from which samples were collected (table 3; Berry and others, 2015b); the oldest ²³⁰Th/U ages are interpreted as being closest temporally to the minimum age of the depositional event.

Louviers Alluvium (Qlv)

The Louviers Alluvium is considered coeval with the Bull Lake glaciation (Scott, 1975; could be up to 30–45 m thick in Weldona quadrangle.

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1967; Scott, 1978)

Table 1. Optically stimulated luminescence (OSL) age estimates with equivalent dose (D) and dose rate data (modified from Berry and others, 2015a).

gives pebbly sands a distinctive pinkish hue. Grayish brown overbank sediment overlies the pebbly sands. Shovel is 68 cm long. Photographs by M.E. Berry, August 2015.

Composite view to the southeast (3 photos) of active channel and floodplain alluvium (Qaa) exposed in north cut bank of the South Platte River downstream of the Narrows. High potassium feldspar content

[UNL Lab, University of Nebraska–Lincoln Luminescence Geochronology Laboratory; quad, quadrangle; UTM, Universal Transverse Mercator; Approx., approximate; m, meter; U, uranium; ppm, parts per million;

					Approx.				CAM D		In situ	Dose	OSL	In situ	Dose	OSL
Field number	UNL lab number	7.5′ quad	UTM Easting ²	UTM Northing ²	depth (m)	U (ppm)	Th (ppm)	K ₂ O (wt.%)	(Gy) ±1 Std. err. ³	Aliquots (n) ⁴	H ₂ O field (%) ⁵	rate (Gy/ka) ⁶	age ka±1σ ⁶	H ₂ 0 est. (%) ⁵	rate (Gy/ka) ⁷	age ka±1σ ⁷
												In situ ⁸			In situ ⁸	
OSL-1-KC	UNL-3462	Orchard	577915	4464174	1.7	5.3	20.0	3.8	67.6 ± 3.3	22/30	2.9	5.77 ± 0.32	11.7±1.0	5.0	5.64 ± 0.35	12.0±1.1
OSL-4-KC	UNL-3466	Orchard	577915	4464174	2.6	3.3	16.3	4.3	87.8 ± 5.4	24/37	2.1	5.41 ± 0.30	16.2±1.5	5.0	5.23 ± 0.34	16.8±1.7
OSL-5-KC	UNL-3463	Orchard	577915	4464174	3.6	3.7	15.8	4.3	80.6 ± 4.8	22/32	2.4	5.45 ± 0.31	14.8 ± 1.4	5.0	5.29 ± 0.35	15.2±1.5
OSL-6-ER	UNL-3467	Masters	568185	4455813	0.7	2.9	11.4	3.4	109.7 ± 5.6	20/37	5.0	4.15 ± 0.27	26.4 ± 2.5	5.0	4.15±0.27	26.4±2.5
OSL-7-ER	UNL-3468	Masters	568198	4455836	1.0	2.4	8.1	3.7	31.4±2.2	29/37	1.9	4.22 ± 0.25	7.4 ± 0.7	5.0	4.07±0.28	7.7 ± 0.8
OSL-BC-14	UNL-3498	Weldona	585123	4459026	1.1	4.8	19.5	3.7	67.0 ± 2.8	31/48	7.7	5.23 ± 0.39	12.8±1.2	5.0	5.39 ± 0.34	12.4±1.1
OSL-BC-13	UNL-3499	Weldona	585123	4459026	1.9	4.3	17.6	4.1	79.1±2.9	36/54	6.7	5.33 ± 0.38	14.8±1.3	5.0	5.43±0.35	14.6±1.2
												UNL lab9			UNL lab9	
OSL-AK-10	UNL-3502	Weldona	592468	4463758	5.1	5.7	23.3	2.7	40.2±1.4	43/54	7.0	4.92±0.35	8.2 ± 0.7	5.0	5.03 ± 0.31	8.0 ± 0.7
OSL-AK-11	UNL-3503	Weldona	592478	4463772	3.5	3.5	9.9	2.6	32.5±1.8	27/35	5.9	3.52±0.24	9.2 ± 0.9	5.0	3.56±0.23	9.1±0.9
SL-TK-R-12	UNL-3504	Orchard	577216	4463702	8.0	1.5	6.7	3.9	35.8±2.0	48/54	3.3	3.88±0.26	9.2±0.9	5.0	3.81±0.28	9.4±1.0
											I					

Gray is an SI unit of absorbed dose of ionizing radiation (Taylor and Thompson, 2008). 927 North American Datum (NAD 27), zone Determined using the Central Age Model (CAM) of Galbraith and others (1999).

Assumes 100% error in estimated moisture content. Field, moisture content of sample, measured at UNL lab; Est., estimate of moisture content, which may better represent moisture history of sample. Calculated using field moisture content of sample. Calculated using 5% as estimated moisture content. Measured in field with a portable gamma spectromete Measured at UNL Lab using high-resolution gamma spectrometry (updated from Berry and others, 2015a, b)

EXPLANATION OF MAP SYMBOLS

Blowout rim within dune field

——— Contact—Dashed where approximately located

Qes Light stipple—Areas where eolian sand (Qes) is likely Holocene in age (as in unstippled areas) but where sand deposits could be thin Qes Dark stipple—Areas where eolian sand (Qes) may be late Pleistocene in age Intermittent wetlands and ponds—Low-lying areas prone to wetness and ponding

within eolian sand deposits (Qes) Water—Includes water in natural and artificial ponds, Bijou No. 2 Reservoir, and channels of South Platte River wide enough to be mapped at 1:24,000 scale. Based on 2015 NAIP orthoimagery

Optically stimulated luminescence (OSL) sample location—With site name that links to sample field number (table 1) Radiocarbon (14C) and OSL sample location—With site name that links to sample

field number (tables 1 and 2) INTRODUCTION

brown, or light yellowish brown, poorly sorted silty sand, sandy silt, granules, The Weldona 7.5' quadrangle is located on the semiarid plains of northeastern Colorado, along the South Platte River corridor where the river has incised into Upper Cretaceous Pierre Shale. The Pierre Shale is largely covered by surficial deposits that formed from alluvial, eolian, and hillslope rocesses operating in concert with environmental changes from the Pleistocene to the present. The South Platte River, originating high in the Colorado Rocky Mountains, has played a major role in shaping surficial geology in the map area, which is several tens of kilometers downstream from where headwater tributaries join the river. Recurrent glaciation (and deglaciation) of basin headwaters has affected river discharge and sediment supply far downstream, influencing deposition of alluvium and river incision in the Weldona quadrangle. During the Pleistocene, the course of the river within the map area shifted progressively southward as it incised, and by late middle Pleistocene the river was south of its present position, cutting and filling deep paleochannels (Bjorklund and Brown, 1957) now covered by younger alluvium. The river shifted back to the north during the late Pleistocene. Kiowa and Bijou Creeks (fig. 1) are unglaciated tributaries originating in the Colorado Piedmont east of the Front Range that also have played a major role in shaping surficial geology of the map area. Periodically during the late Pleistocene, major flood events on these tributaries deposited large volumes of sediment at their confluences, forming a broad, low-gradient fan of sidestream alluvium that could have occasionally dammed the river for short periods of time (Scott, 1982). Eolian sand deposits of the Sterling (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 prolonged drought (fig. 2; Muhs and others, 1996). With the onset of irrigation and damming during historical times, the South Platte River has changed from a

(Nadler and Schumm, 1981; Harvey and others, 1985).

narrower, deeper river with braided-meandering transition morphology and more uniform discharge

broad, shallow, and sandy braided river with highly variable seasonal discharge to a much

The geology of the Weldona 7.5' quadrangle was previously mapped by M.E. Gardner during the 1960s (Gardner, 1967). Gardner's map (1967) provided the foundation for the digital geologic map presented here. This new geologic map was completed using a combination of methods, including field investigation, geochronologic research, and interpretation of the following: National Agriculture Imagery Program (NAIP) orthoimagery (USDA Farm Service Agency Aerial Photography Field Office, 2009, 2011, 2013, 2015); Quality-level 2 lidar data (1-m resolution) from the 2013 South Platte River Flood Area 1 Lidar data set (U.S. Geological Survey, 2015); 7.5' topographic and 1/3 arc-second (10-m resolution) digital elevation data; digital soil survey data (USDA Natural Resources Conservation Service, 2009); satellite imagery viewed with Google stereoscopic pairs of National Aerial Photography Program (NAPP) color-infrared (1988, 1:40,000 scale) and historical black and white (1948, 1:39,230 scale; 1949, 1:16,620 scale) aerial photographs: and subsurface lithologic data from test holes and water wells (Bjorklund and Brown, 1957; Colorado Division of Water Resources, 2013). Field mapping and research were carried out between 2011 and 2015. Digital mapping, completed in 2016 using ArcMap software, was done on 2015 NAIP orthoimagery; location and dimensions of the South Platte River and other water bodies shown on this map are based on the 2015 imagery. Much of the area has been extensively farmed and cultivated for more than a century, and in many places geomorphologic features are difficult to distinguish in orthoimagery or aerial photographs. However, they are commonly evident in the lidar images even within areas traversed by central pivot irrigation. The 1-m resolution lidar data. available for roughly 95 percent of the quadrangle, were used to enhance recognition and facilitate mapping of valley margins, river and stream terraces, sand dune crests and blowouts, natural and

Geologic mapping was aided by optically stimulated luminescence (OSL), radiocarbon (¹⁴C), and uranium-series (²³⁰Th/U) age determinations (tables 1–3; Berry and others, 2015a, b). Sediment samples for OSL dating were processed and analyzed at the University of Nebraska-Lincoln Luminescence Geochronology Laboratory using the single aliquot regenerative (SAR) method (Murray and Wintle, 2000). Equivalent dose (D_a) was measured on a Risø DA–20 TL/OSL reader

SUBSURFACE ALLUVIAL DEPOSITS

This middle Pleistocene unit is within the subsurface of the study area and not shown on map. Pebble to cobble gravel, sand, and finer grained alluvium filling paleovalley located south of the modern South Platte River; buried by younger alluvium but inferred from subsurface lithologic data from test holes and water wells in Weldona and adjacent quadrangles (Bjorklund and Brown, 1957; Colorado Division of Water Resources, 2013). Inferred to be Louviers Alluvium by Gardner (1967) and Scott (1978). Some of the deeper paleochannels locally may contain deposits of older alluvium. Surface exposures previously mapped as Louviers Alluvium by Gardner (1967) are reinterpreted here, mostly as mainstream deposits of Broadway Alluvium (Qba). Gardner (1967) similarly recognized these deposits as late Pleistocene in age, but mapped them as Louviers Alluvium because he inferred the age of Louviers Alluvium to be only about 50–10.5 ka. Madole, 1991). Timing of Bull Lake glaciation is less well constrained than that of Pinedale, but ages that have been obtained for Bull Lake deposits suggest the glaciation spanned from about 190 to ≤130 ka (see discussions in Madole, 1991; Schildgen and others, 2002; Pierce, 2003; Sharp and others, 2003; Kellogg and others, 2008; Licciardi and Pierce, 2008; Schweinsberg and others, 2016). Fluvial sediment load may have been greatest during and shortly after deglaciation (Church and Ryder, 1972; Madole, 1991; Schildgen and others, 2002; Lindsey and others, 2005); therefore, some of the youngest alluvium may post-date the Bull Lake glaciation by a few thousand years. Thickness is uncertain because unit is mostly buried by younger deposits along the South Platte River corridor between Greeley and the Colorado-Nebraska State Line (for example, Colton, 1978; Scott, 1978), but subsurface lithologic data from test holes and water wells (Bjorklund and Brown, 1957; Colorado Division of Water Resources, 2013) indicate that in buried paleochannels, unit

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climatic and nonclimatic forcing of Pinedale glaciation and deglaciation in the western United

DIVISION OF QUATERNARY TIME USED IN THIS REPORT

ages for time divisions are from Walker, J.D. and others (2012), Walker, M.J.C and others (2012), and

0.6214

Exposure of weathered upper transition membe

southeast of the Narrows. Shovel is 68 cm long

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Pierre Shale (Kp) capped by thin veneer of

young alluvium 3 (Qa3) terrace gravels

Photograph by M.E. Berry, June 2015.

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CONVERSION FACTORS

kilometer (km)

11.7–126 ka

781 ka–2.58 Ma

mile (mi)

Table 2. Radiocarbon sample information. ¹⁴C ages¹, and calibrated ages (modified from Berry and others, 2015a). [UTM, Universal Transverse Mercator; quad, quadrangle; δ^{13} C, delta carbon-13; %, per mil; 14 C ka B.P., carbon-14 thousand years before present; cal ka B.P. calibrated thousand years before present; P, probability; Approx., approximate; m, meter; cm, centimeter; ±1 σ , represents estimates of uncertainty given at the

67 percent confidence interval; $\pm 2\sigma$, represents estimates of uncertainty given at the 95 percent confidence interval.]

3.7 -3.8 12.36 ± 0.15 14.53 ± 0.56 1.00 KC-245 Aeon-950 Orchard 577915 4464174 mostly lignite? 2.5 -23.2 39.80±3.10 43.90±5.69 1.00

²UTM zone 13, 1927 North American Datum (NAD 27). ive difference between \(^{13}\)C/\(^{12}\)C ratio of carbon extracted from subsample and that of Vienna Pee Dee Belemnite (VPDB) international standard. onventional radiocarbon age, normalized to -25%, based on 5,568-year half-life; uncertainty $\pm 1\sigma$. Calibrated age calculated using CALIB 7.0, IntCall3 dataset (Stuiver and Reimer, 1993; Reimer and others, 2013); 0 yr B.P. = 1950 A.D.; uncertainty $\pm 2\sigma$. Calibrated age reported as midpoint of calibrated range. ⁶Probability of calibrated age falling within reported range as calculated by CALIB.

Table 3. *U-Th concentrations, U-series isotope compositions, and calculated* ²³⁰*Th/U ages and initial* ²³⁴*U/*²³⁸*U activity ratios for subsamples of* EF-Wp67 and EIC-Wp95 (taken from Berry and others, 2015b). [Abbreviated version of table 1-1 in Paces (2015). Note that $\pm 2\sigma$ represents estimates of uncertainty given at the 95 percent confidence level; $\mu g/g$, micrograms per gram; σ, sigma; ka, thousand years.]

Field number	Lab sample name	U concentration,	Th concentration,	Measured	Detritus-correcte	ed activity ratios ²	²³⁰ Th/U age	Initial ²³⁴ U/ ²³⁸ U AR±2c	
		in μg/g	in μg/g	²³⁰ Th/ ²³² Th AR ¹	²³⁰ Th/ ²³⁸ U AR±2σ	$^{234}U/^{238}U~AR{\pm}2\sigma$	$\pm 2\sigma(ka)^3$		
	through Wp67–11).	sample Wp67–1) and 67: UTM 564654E., 4	•	mples Wp67–2					
	Wp67-1	22.5	1.64	5.7	0.117±0.011	1.221±0.004	11±1.1	1.228 ± 0.004	
	Wp67-2	83.0	0.325	104	0.1338±0.0012	1.214±0.003	12.70±0.13	1.221±0.003	
	Wp67-3	107	0.044	1150	0.1520±0.0006	1.210±0.003	14.58±0.07	1.219 ± 0.003	
EF-Wp67	Wp67-5	116	0.025	2300	0.1588±0.0007	1.215±0.003	15.21±0.08	1.224±0.003	
-	Wp67-7	115	0.028	2020	0.1600±0.0007	1.221±0.002	15.26±0.08	1.231±0.003	
	Wp67-9	116	0.032	1600	0.1458±0.0006	1.217±0.003	13.87±0.07	1.226±0.003	
	Wp67–11	104	0.124	322	0.1255±0.0006	1.217±0.003	11.82±0.06	1.225±0.003	
-	Innermost carbonate UTM 567342E., 445	rinds on alluvial clas 58109N. ⁴	ts. Location of EIC-	Wp95:					
	Wp95-A1-1	5.92	0.280	66.9	1.040±0.008	1.125±0.007	248±9	1.252±0.010	
	Wp95-A1-2	7.36	0.309	76.7	1.061±0.007	1.084 ± 0.003	337±15	1.217±0.009	
EIC-Wp95	Wp95-A2-1	10.2	0.274	121	1.065±0.009	1.085 ± 0.003	341±20	1.222 ± 0.012	
	Wp95-A3-1	7.12	0.549	41.3	1.048±0.009	1.094 ± 0.004	294±13	1.216 ± 0.008	
	Wp95–B1	7.90	0.901	28.2	1.057±0.01	1.077 ± 0.004	345±24	1.205 ± 0.012	
	Wp95-B2	7.60	0.509	47.6	1.048 ± 0.007	1.079 ± 0.003	324±15	1.197 ± 0.008	
	Wp95–B3	9.58	0.672	46.3	1.069±0.007	1.072 ± 0.003	397±27	1.221 ± 0.014	
	Wp95–E1	9.91	0.461	67.7	1.037±0.006	1.054 ± 0.003	372±21	1.153 ± 0.008	

Measured activity ratio (AR) corrected for mass fractionation, spike contributions, procedural blank and normalized relative to an atomic ratio value for National Institute of Standards and echnology (NIST) Standard Reference Material (SRM) 4321B U-isotope standard of ²³⁴U/²³⁸U=0.0000529 ²Ratios corrected for an assumed Th-bearing detrital component having an atomic Th/U of 4 with the following activity ratios and 2σ errors: ²³²Th/²³⁸U=1.276±0.64; ²³⁴U/²³⁸U=1.0±0.1; and ¹⁰Th/U ages, initial ²³⁴U/²³⁸U activity ratios (ARs), and associated errors are calculated using detritus-corrected activity ratio values.



Shovel is 68 cm long. Photographs by M.E. Berry, September 2015.

seen in middle ground. The South Platte River, visible to the left, has

overflowed its banks and floodwater is covering the active floodplain. Photograph by M.E. Berry, June 2015.

aces J.B. Hanson P.R. and Brandt T.R. 2018. Data release for the geologic man the Weldona 7.5' quadrangle, Morgan County, Colorado: U.S. Geological Survey data release, https://doi.org/10.5066/F7610Z63 ScienceBase citation for geochronology of the river corridor: Berry, M.E., Hanson P.R., Paces, J.B., Taylor, E.M., and Slate, J.L., 2018, Data release of OSL, ¹⁴C, and U-series age data supporting geologic mapping along the South Platte River corridor ortheastern Colorado: U.S. Geological Survey data release, Suggested citation: Berry, M.E., Taylor, E.M., Slate, J.L., Paces, J.B., Hanson, P.R., and Brandt, T.R., 2018, Geologic map of the Weldona 7.5' quadrangle, Morgan County Colorado: U.S. Geological Survey Scientific Investigations Map 3396, 1 sheet, scale 1:24,000, https://doi.org/10.3133/sim3396

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Geologic Map of the Weldona 7.5' Quadrangle, Morgan County, Colorado

and Scientific Investigations Map 3344, respectively (Berry and others, 2015a, b).

Radiocarbon sample site and identifier Platte River valley proposed as a dam site for Narrows Reservoir, which was never built

(Gardner, 1967; Minges, 1983; Rogers, 2009).

Optically stimulated luminescence sample site and identifier

Edit and digital layout by J.A. Herrick

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This report is available at

https://doi.org/10.3133/sim3396

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Geochronology sample sites shown where green and red symbols represent the following:

squares indicate ²³⁰Th/U sample sites, solid circles indicate optically stimulated luminescence

sample sites, and red cross within circles indicate radiocarbon sample sites; site names (in

red) link to sample field numbers (tables 1–3). The Narrows, formerly the site of a railroad

post office (Elliott and Elliott, 1999), is near the start of a natural constriction of the South

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