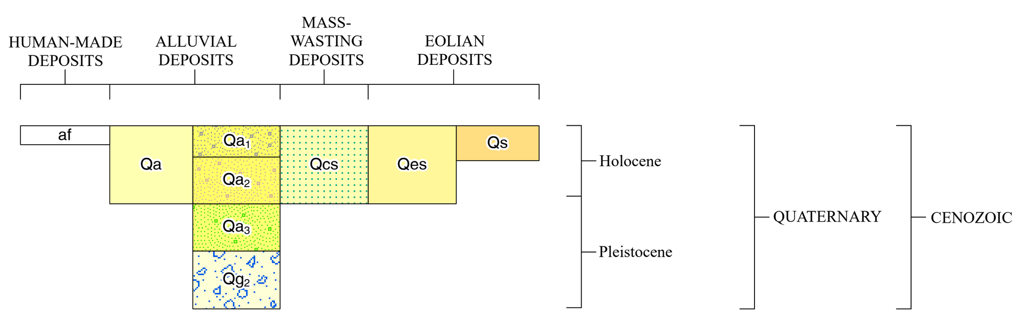
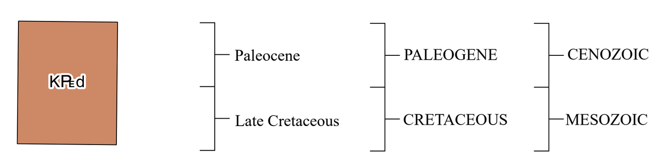
**DOI:** https://doi.org/10.58783/cgs.of2202.dnna2821

## CORRELATION OF MAP UNITS

### SURFICIAL DEPOSITS




### BEDROCK GEOLOGY




## 3-D OBLIQUE

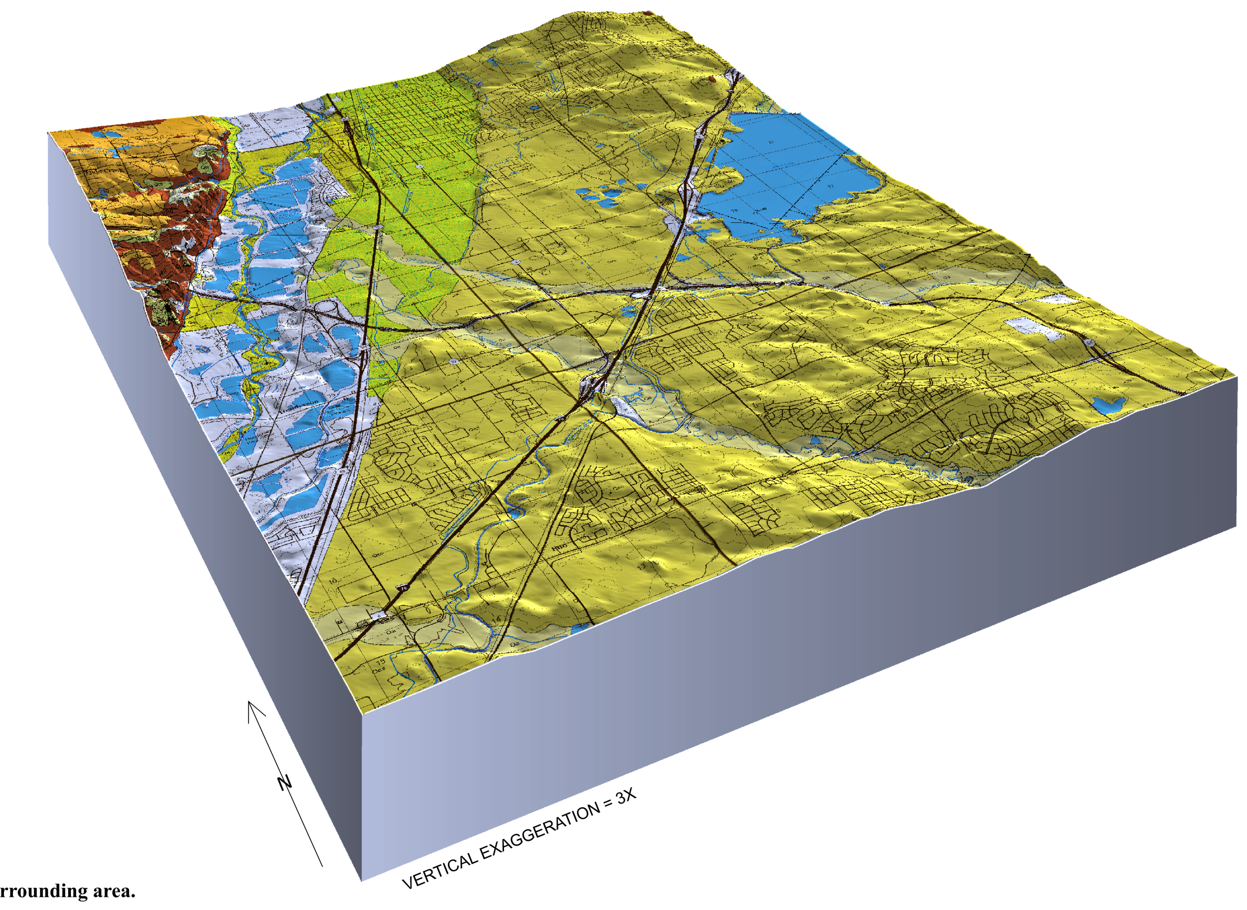



**Table 1. Optically Stimulated Luminescence and Thermal Transfer (TT-OSL) results for select Quaternary deposits in the Brighton quadrangle and surrounding area.**

| Field Number | Laboratory Number | Quadrangle Name | Map Unit | Material | Latitude | Longitude | Depth Below Ground Surface (m) | Aliquots[a] | Equivalent Dose (De) (Gy)[b] | Over dispersion (%)[c] | U (ppm)[d] | Th (ppm)[d] | $K_2O$ (%)[d] | $H_20$ (%) | Cosmic dose rate (mGray/yr)[e] | Dose Rate (mGray/yr) | SAR-OSL age (yr)[f] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BR_OSL-1 | 5210 | Commerce City | Qa3 | Alluvium | 39.8598 | -104.9146 | 14.3 | 5/5 | >650 | NA | 1.49 ± 0.01 | 5.58 ± 0.01 | 4.66 ± 0.01 | 20 ± 5 | 0.075 ±0.007 | 3.63 ± 0.18 | >179,000 |
| BR_OSL-2 | 5211 | Commerce City | Qa3 | Alluvium | 39.8609 | -104.9129 | 4.3 | 40/41 | 197.67 ± 7.05 | 18 ± 2 | 3.66 ± 0.01 | 19.55 ± 0.01 | 4.34 ± 0.01 | 15 ± 3 | 0.177 ± 0.018 | 5.08 ± 0.15 | 39,170 ± 1825 |
| BR_OSL-3 | 5212 | Commerce City | Qa3 | Alluvium | 39.8613 | -104.9129 | 3.4 | 40/41 | 58.92 ± 2.06 | 18 ± 2 | 1.28 ± 0.01 | 6.39 ± 0.01 | 4.29 ± 0.01 | 15 ± 3 | 0.194 ± 0.019 | 3.80 ± 0.12 | 15,490 ± 720 |
| BR_OSL-4 | 5213 | Commerce City | Qa3 | Alluvium | 39.8613 | -104.9127 | 2.7 | 36/36 | 79.13 ± 2.22 | 11 ± 1 | 4.26 ± 0.01 | 20.10 ± 0.01 | 4.93 ± 0.01 | 15 ± 3 | 0.208 ± 0.021 | 5.87 ± 0.18 | 13,465 ± 550 |
| BR_OSL-6 | 5214 | Ft. Lupton | Qa3 | Alluvium | 40.0416 | -104.813 | 10.4 | 39/45 | 64.31 ± 3.04 | 24 ± 3 | 1.41 ± 0.01 | 7.56 ± 0.01 | 4.31 ± 0.01 | 25 ± 5 | 0.100 ± 0.010 | 3.46 ± 0.16 | 18,555 ± 1225 |
| BR_OSL-7 | 5216 | Brighton | Qes | Eolian Sand | 39.9537 | -104.7693 | 1.8 | 10/10 | 150-250 | NA | 2.25 ± 0.01 | 9.46 ± 0.01 | 2.05 ± 0.01 | 15 ± 3 | 0.230 ± 0.023 | 2.58 ± 0.07 | >76,400 |
| BR_OSL-8 | 5217 | Brighton | Qg2 | Alluvium | 39.9448 | -104.8715 | 0.9 | 10/10 | 355-500 | NA | 2.38 ± 0.01 | 15.75 ± 0.01 | 2.83 ± 0.01 | 15 ± 3 | 0.250 ± 0.025 | 3.41 ± 0.10 | >96,700 |

[a] Aliquots measured and used to define De population by Central Age or Minimum Age Model (Galbraith and Roberts, 2012)

[b] Equivalent dose calculated on a pure quartz fraction with ultra-small aliquots with 20-80 grains/aliquot and analyzed under blue-light excitation (470 ± 20 nm) by Single Aliquot Regeneration protocols (SAR; Murray and Wintle, 2003; Wintle and Murray, 2006). Equivalent dose (De) was calculated by the Central Age assuming a normal data distribution (Galbraith and Roberts, 2012; Liang and Forman, 2019). Prefix "TT-" means the use of Thermal Transfer approaches as outlined in Forman et al. (2022).

[c] Overdispersion values reflects precision beyond instrumental errors; values of ≤ 20% (at 1 sigma limit) indicate low dispersion in equivalent dose values and defines a unimodal distribution. Values > 20% are associated with mixed equivalent dose signature reflecting multiple grain populations or partial solar resetting.

[d] U, Th, Rb and K content analyzed by inductively coupled plasma-mass spectrometry by ALS Laboratories, Reno, NV.

[e] Includes a cosmic dose rate calculated from parameters in Prescott and Hutton (1994) and includes soft components (Liang and Forman, 2019). Luminescence Dating and Age Calculator (LDAC) at https://www.baylor.edu/geosciences/index.php?id=962356 (Liang and Forman, 2019) Datum year is AD 2010.

[f] Systematic and random errors calculated in a quadrature at one standard deviation by the OSL ages determined at Geoluminescence Dating Research Laboratory, Dept. of Geosciences, Baylor University, Waco, TX, USA

**Table 2. Detrital zircon results for select bedrock units in the Brighton quadrangle and surrounding area.**

| | | | | | MDA Candidates[1,2] | | Modes | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Field Number | Latitude | Longitude | N | n | youngest date | youngest population | Principal | 2 | 3 | 4 |
| BRDZ1 | 39.8598 | -104.9147 | 139 | 125 | 60.2 ± 4.1Ma | 67.1 ± 1.4 Ma (n=31; MSWD=0.91) | 66.7 Ma | 75 Ma | 101.2 Ma | 87.9 Ma |
| BRDZ3 | 39.9493 | -104.8724 | 139 | 129 | 72.8 ± 2.7 Ma | 76.4 ± 1.7 Ma (n=9; MSWD=0.75) | 93.8 Ma | 1720.6 Ma | 1621.7 Ma | 585.2 Ma |

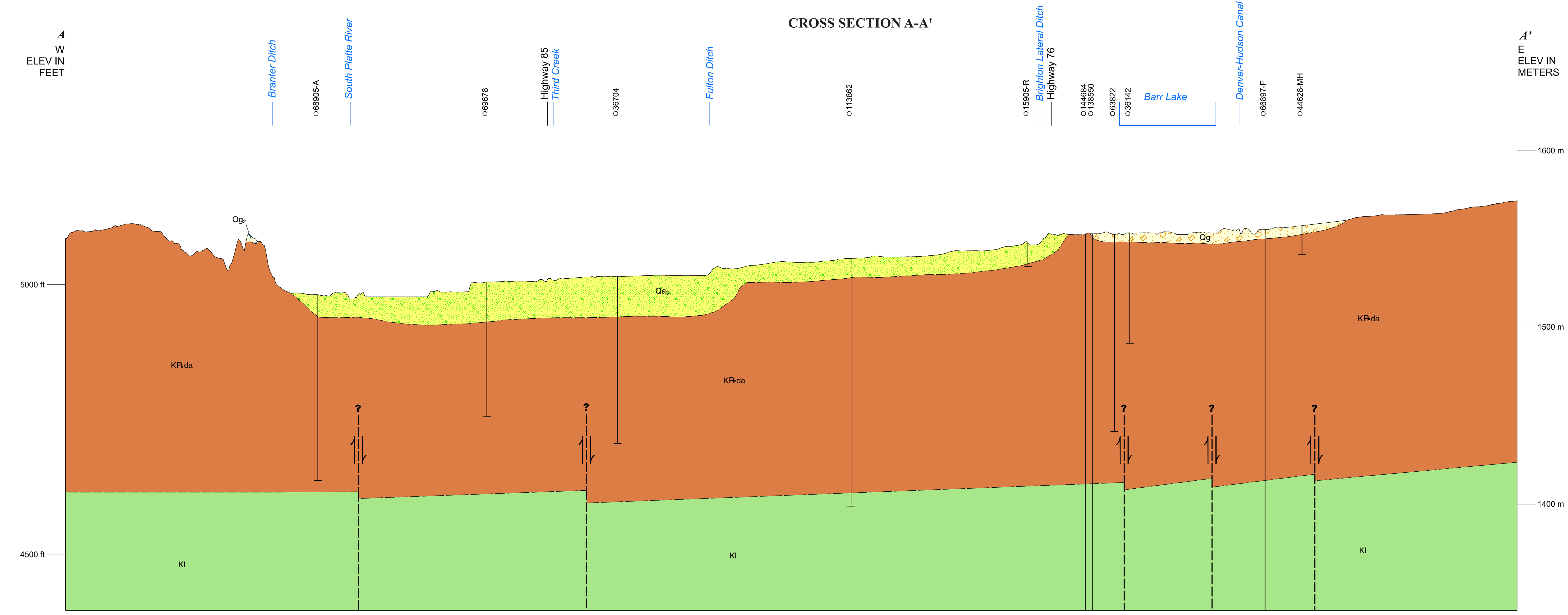
[1] MDA = maximum depositional age; [2] uncertainties reported at 95% confidence; N = total number of analyses; n = number of concordant analyses;

Modes = value that has a higher frequency in a given set of values

LA-ICPMS was used for U-Pb analysis

Analysis was completed by the Isotope Geology Laboratory at Boise State University

## CROSS SECTION A-A'




## MINERAL RESOURCES, GROUNDWATER, AND GEOLOGIC HAZARDS

### MINERAL RESOURCES

The Brighton quadrangle is located along the northern boundary of Adams County within the western portion of the Denver-Julesburg Basin (DJ). Mineral resources in the quadrangle include sand, gravel, oil, and natural gas. Other resources may include coal and coalbed methane. The DJ Basin contains many oil and gas fields and several active oil and gas wells are located within the quadrangle. The quadrangle is located on the southern edge of the Wattenberg oil and gas field, located mostly in Weld County to the north, which is one of the most active and productive fields in Colorado. Most of the Denver Basin's oil and gas production is derived from the Cretaceous-aged rocks underlying the area. In Adams County, both conventional and unconventional oil and gas plays include the Dakota Group (combined Lower Cretaceous J Sandstone of the Muddy Sandstone and Upper Cretaceous D Sandstone), Codell Sandstone, Niobrara Formation (mixed shale and chalk unconventional play), and the Pierre Shale (shale and sandstone play) (CGS, 2003). In 2019 and 2020, Adams County ranked second and seventh for total oil and natural gas production in the state, respectively (COGCC, 2021).

The Brighton quadrangle is in the Denver Coal Region. Coal- and lignite-bearing strata underlie a portion of the Denver Coal Region and are associated with the Upper Cretaceous Laramie Formation. Some lignite was mined in the Denver Formation within the Denver Coal Region. Although the Denver and Laramie formations underlie the Brighton quadrangle and likely contain coal-bearing beds, the nearest known historic coal mine is in the Boulder-Weld coal field ~4 km northwest of the northwest edge of the Brighton quadrangle (Carroll, 2004; Carroll and others, 2002).

Coalbed methane potential of the Late Cretaceous to early Paleogene coals and lignite in the DJ Basin is summarized by Wray and Koenig (2001). Although a potential resource likely exists in either the Denver or Laramie formation coals based on measured gas contents, the extent and economic feasibility of this resource has not been evaluated. Furthermore, potential roadblocks associated with the extraction of coalbed methane include water quality and water rights, protection of groundwater resources, and resource economics (Wray and Koenig, 2001). Generally, coalbed methane production in Colorado has been in decline since 2008 largely due to the increase of natural gas production from unconventional reservoirs using horizontal drilling and hydraulic fracturing techniques (O'Keeffe and Berry, 2021).

Sand and gravel associated with unit $Qa_3$ has been mined extensively and is an excellent source of sand and gravel. However, much of this material has been mined within the South Platte River valley. Some of this material may exist in the subsurface to the east of the main river valley within the quadrangle. Units Qes, Qs, Qa, $Qa_1$, and $Qg_2$ may be a local source of borrow material.

### GROUNDWATER

The basal portion of the Laramie Formation, containing two relatively thick sandstone units, and the underlying Fox Hills Sandstone constitute the Laramie-Fox Hills aquifer. As reported by Keller and Morgan (2018), this aquifer underlies the Denver Basin, including the Brighton quadrangle, and can be up to ~107 m thick, although its water-yielding thickness is seldom greater than ~60 m thick. The aquifer underlies the surficial deposits throughout the quadrangle; is generally under artesian conditions; and is extensively utilized for domestic groundwater use (Topper and others, 2003; Keller and Morgan, 2018). Other principal bedrock aquifers above the Pierre Shale in the area include the Denver Formation; the aquifers within the Denver Formation are generally suitable for domestic use. The alluvial deposits within the South Platte River valley and its tributaries are also a source of domestic groundwater production. Groundwater well locations and driller's well logs were used to construct cross section A-A' on Plate 2. According to maps provided by the Colorado Division of Water Resources (CO DWR, 2022), the greatest concentration of domestic wells lies within the South Platte River valley and its tributaries with the majority producing from unit $Qa_3$ or un-mapped older alluviums below this unit. Well depths over the quadrangle reach a maximum of 420 m and terminate in the Arapahoe Aquifer and have an average production value of ~6 gallons per minute. Additional information regarding groundwater wells within and near the quadrangle can be obtained from the Colorado Division of Water Resources website at https://dwr.colorado.gov/.

### GEOLOGIC HAZARDS

Much of the Brighton quadrangle is underlain by the Denver Formation, which may contain swelling clays that could cause serious adverse impacts to building foundations, structures, and infrastructure. Geotechnical reports may be obtained from the Adams County Planning and Development Department. As reported by Turner (1973), the bluffs to the west of the South Platte River contain failure surfaces within the Denver Formation which could lead to landslides in this area and may negatively impact past and future building and infrastructure development (also see the description for Qcs on Plate 1). As reported by Keller and Morgan (2018) in the nearby Frederick quadrangle, units Qes and Qs "…locally may be, in geotechnical terms, collapsible (hydrocompactive) soils. The finer-sized particles (silt and clay content) in collapsible soils are soil-binding agents giving the soil greater compressive strength under dry conditions. Upon wetting, however, the fines can be packed into a denser configuration such that void space in the soil is reduced. This compaction can cause settlement at the ground surface with resultant damage to structures and infrastructure (White and Greenman, 2008)."

The South Platte River and its tributaries were inundated during the September 2013 flooding that occurred extensively along the Colorado Front Range. Within the Brighton quadrangle, units mapped as $Qa_1$, $Qa_2$, Qa, and parts of $Qa_3$ were overwhelmed by floodwaters of the South Platte River and its major tributaries. In some locations that were not mined for sand and gravel, unit $Qa_3$ helped confine floodwaters to the modern river channels. Units $Qa_1$, $Qa_2$, and Qa are subject to frequent stream flooding events, as recorded and demonstrated in the geologic record. Extreme caution should be taken when developing on these deposits. The Federal Emergency Management Agency (FEMA) floodplain designation of South Platte River valley and its tributaries varies depending upon location, but generally lies within "Special Flood Hazard Areas." More information about this designation and flood hazard zone maps can be obtained from FEMA at https://msc.fema.gov/.

## GEOLOGIC HISTORY

The Brighton quadrangle is located within the Front Range Urban Corridor, about 20 km north of Denver, Colorado. It lies within the northern part of the Colorado Piedmont, a physiographic providence that is bounded by the Rocky Mountains Foothills to the west, and High Plains to the north and east (Fenneman, 1931; Leonard, 2002; and Smith and others, 2016). The Colorado Piedmont is largely devoid of Neogene rocks and sediments due to fluvial downcutting, erosion, and geomorphic evolution of the South Platte and Arkansas rivers drainage basins during the Pliocene (Madole, 1991). These processes resulted in a scoured region that is topographically lower than the other physiographic provinces that bound it. Relief within the quadrangle ranges in elevation from approximately 1,495 m to 1,600 m, and is largely the result of incision by the South Platte River and its tributaries.The river flows from the southwest to north on the western portion of the quadrangle.

The only bedrock unit exposed in the quadrangle is the Cretaceous and Paleogene Denver Formation (KPd), a terrestrial fluvial sandstone locally containing conglomeratic lenses rich in andesitic volcanic debris and beds of claystone and mudstone. The dominant surficial deposits within the Brighton quadrangle consist of Quaternary alluvial deposits ($Qa_1$, $Qa_2$, $Qa_3$, Qa) of the South Platte River and its tributaries, and eolian (windblown) deposits (Qs, Qes) derived chiefly from stream-valley alluvium and bedrock exposures of the Denver Formation. Other aerially less common units include Upper and Middle Pleistocene alluvial gravels ($Qg_2$), sheetwash alluvium, and mass-movement deposits such as undivided colluvium and sheetwash alluvium (Qcs).

The Brighton quadrangle lies about halfway along the north-south axis of the Denver Basin (or Denver-Julesburg Basin) at its western edge. This symmetrical, oval-shaped, structural basin lies directly east of the Front Range and covers part of eastern Colorado north of Pueblo, southeastern Wyoming, and southwestern Nebraska. The formation of the Denver Basin began during the Ancestral Rockies uplift, approximately 300 million years ago (Cross, 1896). Additional accommodation space was created during the Laramide orogeny (starting ~ 70 Ma) when sediments were shed from the west off the uplifted highlands, eastward into the structural depression. The Cretaceous-Paleogene Denver Formation is the second youngest bedrock unit in the Denver Basin (after the Dawson Formation/Arkose) and is oldest unit exposed in the Brighton quadrangle. When the Denver Formation was deposited, the Western Interior Seaway (WIS) was regressing to the east and the Rocky Mountains (during Laramide orogeny) were beginning to rise to the west. Rivers eroded the Mesozoic, Paleozoic, and Precambrian rocks from the Rocky Mountains and filled the Denver Basin with sediments that would eventually become the Arapahoe Conglomerate, Denver Formation, and Dawson Formation/Arkose.

During the Paleogene and Neogene, deposits east of the Rocky Mountains were characterized by alluviation from the mountains (Schwochow, 1972). Through incision by major streams, the geomorphic processes changed from aggregational to erosional by the late Pliocene or the beginning of the Quaternary. This erosion resulted in the removal of Paleogene and Neogene rocks from the Colorado Piedmont. Since the Pleistocene, the erosional pattern followed cyclic geomorphic responses to variations in climate including periods of erosional scouring and deposition of coarse-grained sediments related to multiple glaciations (Bryan and Ray, 1940; Hunt, 1954; Scott, 1963; Madole, 1991).

Within the quadrangle, the coarse-grained fluvial deposits of unit $Qg_2$ were deposited in the early Upper and Middle Pleistocene. This unit mantles hills underlain by Denver Formation bedrock in the western South Platte River valley and represents the former courses of high-energy stream(s) perhaps active during interglacial periods. Unit $Qg_2$ (or other Pleistocene gravels labeled as Qg on cross section A-A') may also be present within a buried paleovalley of the South Platte River that trends SW-NE under present-day Barr Lake (see cross section A-A' on Plate 2). Schwochow (1972) along with other authors (Turner, 1973; Trimble and Machette, 1979) mapped the Verdos ($Qg_2$ in this report) and Slocum alluviums surrounding Barr Lake. Exposures of the gravel units associated with the South Platte River paleovalley near Barr Lake were not observed during this study; however, water-well driller's logs indicate gravel to a depth of about 17 m near Barr Lake (see Plate 1 geologic map and cross section A-A' on Plate 2 for well numbers and locations). Due to its coarse-gravel content, unit $Qg_2$ has a higher resistance to erosion than the underlying finer-grained sediments of the Denver Formation. Later incision and lateral cutting of the finer-grained sediments left isolated remnants of the coarser-grained sand and gravel deposits on hilltops. These deposits (unit $Qg_2$) are exposed on the hills west of the South Platte River within the quadrangle and represent Pleistocene stream channels that carried coarse-grained sediments from the mountains to the west.

Since the beginning of the Pleistocene, the streams of the Colorado Piedmont underwent cycles of incision and aggregation. After the deposition of $Qg_2$ and during the time of the Bull Lake Glaciation (MIS 6; Schweinsberg, 2020, and references therein), the Louviers Alluvium (unit Qa4 as mapped in other quadrangles by the Colorado Geological Survey) was deposited due to an increase in river discharges and available sediment flowing east from the Rocky Mountains during times of interglacial melting (Madole, 1991). The Louviers Alluvium was either eroded or buried by alluvium deposited during the Pinedale glaciation (MIS 2). The latter consists of sand and gravel of unit $Qa_3$ (Broadway Alluvium equivalent) that filled the South Platte River valley. This alluvium is the most extensive fluvial deposit in the quadrangle and is an important source of aggregate.

During the Holocene, unit $Qa_2$ (Piney Creek alluvium equivalent) was deposited above unit $Qa_3$. Although $Qa_2$ was not mapped separately in the South Platte tributary streams on this quadrangle, others (De Voto, 1968) have mapped these deposits in the First, Second, and Third creek drainages. The active South Platte River channel continues to incise unit $Qa_2$ and deposit additional sediment ($Qa_1$) during flood events.Undivided alluvium (unit Qa) deposits were deposited during the Holocene along tributaries of the South Platte River and Beebe Draw. The latter drains Barr Lake to east.

Eolian sand deposits (Qes) cover over half of the quadrangle east of the South Platte River. These Late Pleistocene to Late Holocene deposits cover broad areas of the Colorado Piedmont, eastern plains, and areas downwind of present-day major streams. Qes mantles areas of $Qa_3$ river terraces (Broadway Alluvium equivalent) on the east side of the South Platte River valley in the quadrangle. Locally, the Qes contains finer silty sand and sandy silt beds likely derived from reworking of the finer-grained fraction of older alluvial deposits and (or) from erosion of the underlying Denver Formation. Qs (eolian sediment) typically contains more silt than Qes deposits. Qs is intermingled with Qes deposits locally and blankets the Denver Formation and alluvial deposits in the western portion of the quadrangle. Late Pleistocene eolian deposits are reportedly more extensive than the Holocene eolian deposits (Madole and others, 2005), possibly due to the stronger prevailing northwesterly winds during the Pinedale glaciation (MIS 2; Madole, 2016).

## NOTES AND ACKNOWLEDGMENTS

The Brighton quadrangle has few natural accessible exposures due to private land ownership and an increase in urban development over the last 20+ years. The geologic descriptions are based on field observations made at natural exposures when accessible during field mapping. Even in areas where test pits were hand excavated to depth of as much as 1 m in exposures along roads, a review of historic aerial photos indicated that many areas within the quadrangle were historically disturbed (chiefly by agriculture, road and building construction and mining operations). In some cases, the descriptions of units were derived from previous authors published work nearby or within the quadrangle before much of the current development occurred and when several aggregate quarries were active along the South Platte River. Sources for this additional information are referenced in the text and chiefly include De Voto (1968), Schwochow (1972), Turner (1973), and Trimble and Machette (1979). The authors appreciate the work and documentation performed by these authors and others (cited in this report) who have worked in the area.

The authors thank the following for their assistance with the Brighton quadrangle mapping project. Jill Carlson (CGS) assisted with obtaining geotechnical investigation documents from the Colorado State Archive. Adams County Open Space provided access to their property along the South Platte River. Ralph Shroba (Scientist Emeritus, U.S. Geological Survey and CGS employee) reviewed the final publication and provided valuable suggestions. Caitlin Bernier (Pangaea Geospatial) produced the final map plates and GIS files. Dr. Steven L. Foreman (Baylor University, Waco, Texas) performed the OSL analyses and Dr. Mark Schmitz (Boise State University, Boise, Idaho) performed the detrital zircon analyses and provided a concordant analysis of the data and the dates presented herein. We are also grateful to several landowners and developers within the quadrangle who allowed us to access their properties and excavations. Thanks to Albert Frei and Sons and Martin Marietta Inc. who allowed us to visit and collect samples in their quarries located to the south and north of the quadrangle, respectively.

GEOLOGIC MAP OF THE BRIGHTON QUADRANGLE, ADAMS COUNTY, COLORADO
CORRELATION OF MAP UNITS, 3-D OBLIQUE, GEOLOGIC HISTORY, CROSS-SECTION, AND GROUNDWATER AND MINERAL RESOURCES
By Matthew L. Morgan, Michael K. O'Keeffe, and Alexander E. Marr
2022

COLORADO GEOLOGICAL SURVEY
COLORADO SCHOOL OF MINES