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COLORADO SCHOOL OF MINES
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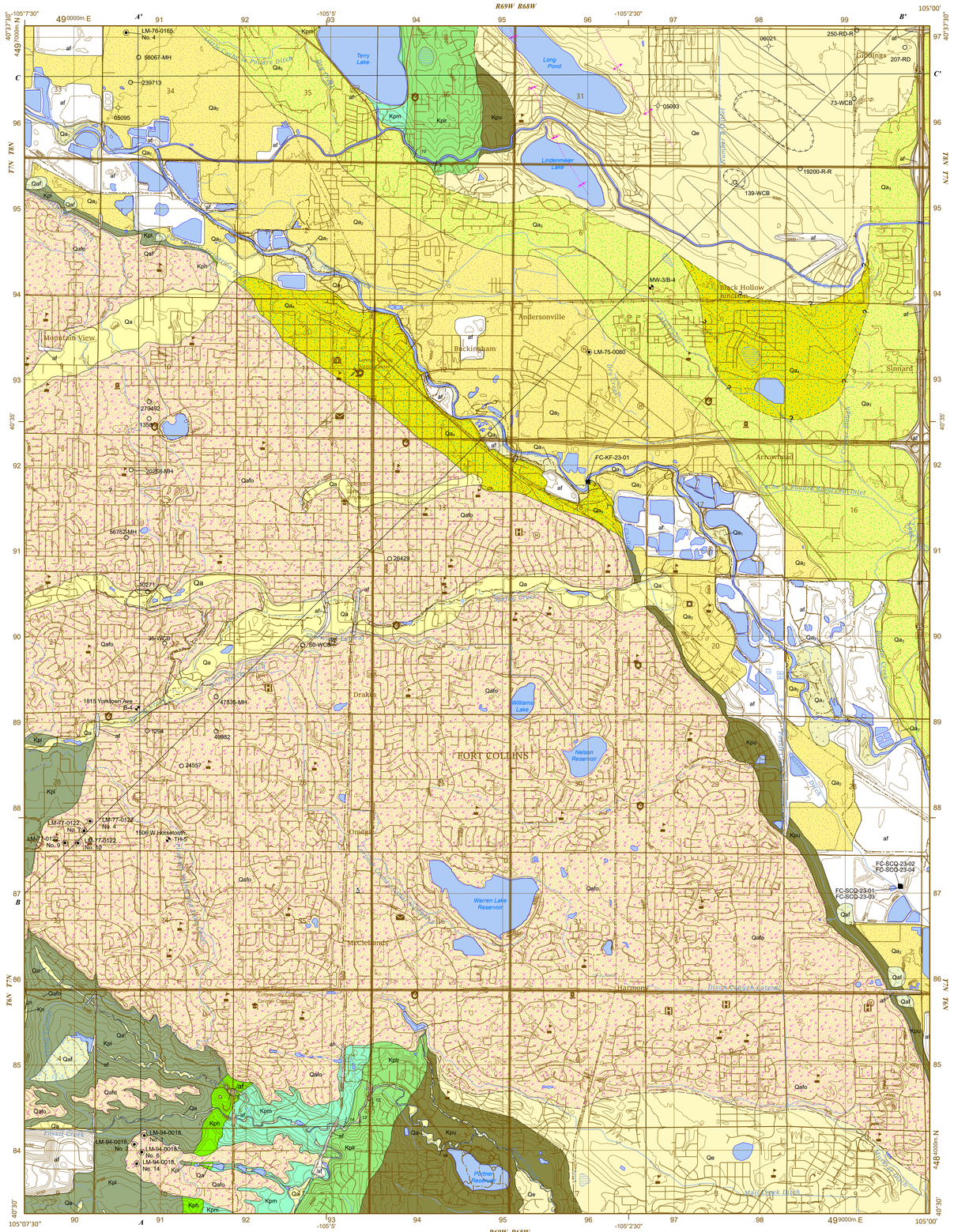

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MILES
1000 500 0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000
FEET
CONTOUR INTERVAL 10 FEET

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

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Roads.....US Census Bureau, 2016-2016
Names.....GNIS, 1978-2021
Hydrography.....National Hydrography Dataset, 2004-2021
Contours.....National Elevation Dataset, 2015
Boundaries.....Multiple sources, see metadata file, 2019-2021
Public Land Survey System.....BLM, 2021

Geology mapped in 2023
Cartography and GIS by Pangaea Geospatial

ADJOINING QUADRANGLES

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GEOLOGIC MAP OF THE FORT COLLINS QUADRANGLE, LARIMER COUNTY, COLORADO

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2025

DESCRIPTION OF MAP UNITS

Notes on frequently used references and terminology: All reported optically stimulated luminescence (OSL) analysis data are in Table 1 on Plate 2. All colors are from hand samples unless otherwise stated. Website links for the Federal Emergency Management Agency (FEMA) flood mapping, Colorado Division of Water Resources (DWR), and Colorado Energy and Carbon Management Commission (ECMC) are in the reference section. The Cache la Poudre River is referred to as the Poudre River hereafter.

SURFICIAL UNITS

HUMAN-MADE DEPOSITS

af

Artificial fill (uppermost Holocene) — The unit consists of clay, silt, sand, gravel, and cobbles deposited as fill or rip-rap. Fill and rip-rap are placed to support roadways and highways, mitigate damage to buildings from natural geologic hazards like expansive soils, construct earthen dams, and during land reclamation practices after the completion of quarrying operations. Much of the area underlain by unit af in the quadrangle is disturbed and reworked areas from active or reclaimed gravel quarries. Artificial fill likely exists below and around human-made structures, even though it may not be mapped in the quadrangle. A good example of this is the eastern edge of Warren Lake Reservoir; houses are constructed on damming material up to the eastern edge of the reservoir, but because there are structures built here, unit af is not mapped. If not placed and compacted properly, areas underlain by unit af may experience hazards related to expansive soils, soil collapse, erosion, and (or) slope failure, especially in areas where the Pierre Shale members are near the surface. Thickness varies but is likely at least 2 m thick below buildings and local roadways and may be as much as 6 m below highways.

ALLUVIAL DEPOSITS

Qa1

Alluvium one (Upper Holocene) — The unit is comprised of poorly to moderately sorted, massive, clay, silt, and sand, and clast-supported gravel deposited by the Poudre River. Exposures are poor in the mapped area; in general, deposits are typically light brown to dark brown in color. The unit is most commonly exposed in gravelly and sandy bars present along reaches of the Poudre River that are not modified by quarrying operations. Deposits underlie the modern river and low-lying terraces that are 2 m (or less) above the modern channel. Post-Piney Creek Alluvium was previously mapped underlying the whole modern Poudre River channel (Colton, 1978; Kellogg and others, 2008; Cole and Braddock, 2009; Workman and others, 2018). Most areas underlain by the unit have a 1% annual chance of flooding (Zone AE), and some have a 0.2% annual chance as mapped by FEMA; therefore, these areas may be prone to flooding, erosion, and (or) sediment inundation. The unit is not a likely source of sand or gravel. The unit may be as much as 2 m thick.

Qa2

Alluvium two (Middle to Lower (?) Holocene) — The unit is chiefly comprised of poorly to moderately sorted, massive clay, silt, sand, and clast-supported gravel. Sandy deposits are mostly homogeneous and massive. Discontinuous pebble lenses that are as much as 2.5 cm thick are present locally. Clasts in gravelly deposits are 3 to 5 cm in diameter, in a sandy matrix. The unit is light brown, reddish-brown, or dark brown in color. Many areas underlain by unit Qa_2 have been heavily modified by quarrying activities to access the underlying gravel deposits of unit Qa_3. Unit Qa_2 underlies low-lying terraces as high as 3 m above the Poudre River.

A quarry in NW ¼, sec. 33, T. 7 N., R. 68 W. exposes units Qa_2 and Qa_3. The area is mapped as af because its surface has been heavily reworked, deposits are in the process of being removed, and the area will continue to be modified until it has been reclaimed. In 2023, four OSL samples were collected from in-situ deposits exposed in active quarry walls. Two samples are discussed here, and the others are discussed with unit Qa_3 below. Sample FC-SCQ-23-02 was collected from a silty sand Qa_2 deposit, approximately 0.6 m below ground surface (bgs). The sample yielded a SAR-OSL age estimate of 6,100 ± 210 yrs. Sample FC-SCQ-23-03 was collected from a sandy lens in a clast-supported gravel deposit, approximately 1.9 m bgs. This sample yielded a SAR-OSL age estimate of 5,085 ± 325 yrs. See the Geologic History on Plate 2 for more discussion. The unit may be a potential source of sand or gravel, though it is typically removed to access the underlying gravelly deposits of unit Qa_3. Areas underlain by unit Qa_2 may be prone to flooding, erosion, and (or) sediment inundation, especially areas directly adjacent to the Poudre River. Deposits are typically around 2 m thick but may be as much as 4 m thick locally.

Qa

Alluvium (Upper to Lower (?) Holocene) — The unit is comprised chiefly of light brown to brown clay, silt, and sand. Discontinuous gravel lenses may be present locally. The unit is mapped in the valleys of ephemeral drainages, which have incised into unit Qafo. Deposits of Qa are of similar age to units Qa_1 and Qa_2, but are not geomorphologically differentiable, such as units Qa_3 and Qa_5. Post-Piney Creek Alluvium has previously been mapped underlying many of these ephemeral drainages (Colton, 1978; Kellogg and others, 2008; Cole and Braddock, 2009; Workman and others, 2018). Areas underlain by the unit may be prone to flooding, sediment inundation, and (or) erosion. Deposits of Qa are not likely sources of sand or gravel. The unit is typically around 2 m thick but may be as much as 5 m thick locally.

Qa3

Alluvium three (Lower Holocene to Upper Pleistocene) — Unit Qa_3 deposits underlie unit Qa_2 along much of the modern Poudre River. Where exposed at the ground surface, unit Qa_3 underlies terraces 3 to 8 m above the modern river channel. Unit Qa_3 is well exposed in a quarry in NW ¼, sec. 33, T. 7 N., R. 68 W. The area is mapped as unit af because its surface has been heavily reworked, deposits are in the process of being removed, and the area will continue to be modified until it has been reclaimed. Here, the unit is tan, gray, and brown in color. Clast-supported cobble-gravel comprises most of the unit and is interlayered with matrix-supported gravel, sand beds, and pebble-gravel beds. Coarser gravelly alluvium is poorly sorted. Clasts are typically as much as 20 cm in diameter, but may be larger locally, and are subround to round. Clasts are derived from Precambrian bedrock west of the mapped area, with minor sedimentary clasts sourced closer to the mapped area. Pebble-gravel and sand beds are typically as much as 8 cm thick and laterally continuous over several meters. Pebble-gravel beds are moderately to poorly sorted, comprised chiefly of medium to coarse sand and pebbles, and are massive. Sand beds are moderately sorted, contain fine- to coarse-grained sand, generally lack pebbles, and are either planar- or cross-bedded. Iron-oxide and manganese staining are prevalent throughout the deposit.

Two samples were collected from the exposure at the quarry located in the NW ¼, sec. 33, T. 7 N., R. 68 W., and analyzed using OSL techniques. In 2023, samples FC-SCQ-23-01 (0.8 m bgs) and FC-SCQ-23-04 (4.3 m bgs) were collected from in-situ alluvium exposed in quarry walls. These samples yielded SAR-OSL age estimates of 9,665 ± 415 yrs and 16,025 ± 975 yrs, respectively. These samples and deposits are discussed in more detail in the Geologic History on Plate 2. Unit Qa_3 has previously been mapped as Broadway Alluvium, which is roughly correlative with the later part of the Pinedale glaciation (Colton, 1978; Kellogg and others, 2008; Cole and Braddock, 2009; Workman and others, 2018). The Pinedale glaciation ended by 12 ka while outwash continued until around 10 ka (Holliday, 1987). The unit is a source of gravel. Perched groundwater may be present at the base of the unit where it overlies clayey and shaley members of the Pierre Shale (unit Kp). Where unit Qe overlies unit Qa_3 deposits, soils may be prone to collapse. The unit may be as much as 10 m thick locally.

Qa4

Alluvium four (Upper Pleistocene to upper Middle (?) Pleistocene) — A cutbank in NW ¼, sec. 18, T. 7 N., R. 68 W. exposes 1 m of clast-supported gravel underlying 2 m of sandy alluvium. The deposit is reddish-brown in color. The upper sandy alluvium is comprised chiefly of silt to coarse sand and is massive. Secondary carbonate to a maximum of Stage II is present, indicating the unit is at least late Middle to early Late Pleistocene in age (Machette, 1985; Birkeland, 1999). Gravel clasts in a silt- to sand-matrix comprise the lower part of the deposit and lie beneath the developed soil. Clasts lack carbonate rinds at this location. Clasts are generally up to 15 cm in diameter, but are larger locally, and are typically subround. A weak fining-upward sequence may be present at the contact between the upper sandy alluvium and the underlying gravel; pea-sized gravel and coarse sand are abundant at the contact. The 3 m of alluvium overlies the Pierre Shale (unit Kp), which is exposed at this site. This Qa_4 deposit underlies an exposed terrace approximately 9 to 11 m above the modern Poudre River. In other locations, this unit likely underlies higher terraces that are completely mantled by unit Qe.

Sample FC-KF-23-01 was collected 2 m bgs, near the contact of the upper fines and lower gravel, and was analyzed using TT-OSL (Thermally Transferred Optically Stimulated Luminescence) techniques. It yielded a SAR-OSL age estimate of 76,820 ± 5,210 yrs and is correlative with marine isotope stage (MIS) 4-5 (Lisiecki and Raymo, 2005). This sample predates the Pinedale glaciation (ended by 12 ka; Madole and Shroba, 1979) and post-dates the Bull Lake glaciation (ended by 120 ka; Madole, 1991). Unit Qa_4 is correlative with the Louviers Alluvium of Colton (1978), Kellogg and others (2008), Cole and Braddock (2009), and Workman and others (2018). Kellogg and others (2008) included MIS 5-aged deposits (70-130 ka; Lisiecki and Raymo, 2005) and MIS 6-aged deposits (130-190 ka; Lisiecki and Raymo, 2005) as Louviers Alluvium. The deposit at and near this site has previously been mapped as the Broadway Alluvium (Colton, 1978; Kellogg and others, 2008; Cole and Braddock, 2009; Workman and others, 2018). See the Geologic History on Plate 2 for more discussion. The unit may be a source of sand and (or) gravel. Though none are mapped, localized slope failures may initiate at or near the contact of the unit with the underlying bedrock, especially where the underlying bedrock is relatively weak, like unit Kp. Perched groundwater may be present at the base of the unit where it overlies clayey and shaley members of the Pierre Shale (unit Kp). The unit is as much as 6 m thick, according to DWR well logs.

ALLUVIUM AND MASS-WASTING DEPOSITS

Qaf

Debris-flow and alluvial-fan deposits (Holocene) — There are no outcrops of the unit in the mapped area; however, distinct, fan-shaped landforms are mapped as unit Qaf on the south side of the Poudre River escarpment. As the river incised, it exposed unit Qafo and the underlying members of the Pierre Shale. Subsequently formed ephemeral drainages have incised into unit Qafo during episodic above-average precipitation and runoff, and deposited alluvial-fan and debris-flow deposits at their outlets in the modern Poudre River valley. Colluvium may also be present locally. Debris-flow deposits are typically poorly sorted, matrix-supported gravel or poorly sorted mud, sand, and clay. Alluvial-fan deposits are typically poorly sorted and may contain clay to gravel. Alluvium is typically moderately to well sorted and may be stratified or massive. Colluvium is typically poorly sorted and may be difficult to distinguish between debris flow and alluvial-fan deposits. Areas underlain by the unit may be subject to future debris flow or alluvial-fan processes and (or) flooding. The unit is not a likely source of sand or gravel. Deposits may be as much as 3 m thick, but may be thicker locally.

Qafo

Old debris-flow and alluvial-fan deposits (Middle Pleistocene) — The unit is not well exposed in the quadrangle, but many DWR logs and geotechnical borings record and describe the deposits. The unit is typically light brown, brown, reddish-brown, or olive-brown in color and is calcareous locally. Deposits are typically either silty clay and clayey silt or consist of sand and gravel. Much of unit Qafo deposits are mantled by unit Qe; however, given the limited exposure and lack of distinguishing morphology in well and geotechnical logs, Qe is mapped with unit Qafo in most of the quadrangle. The unit underlies surfaces at several distinct levels, indicating episodic deposition punctuated by periods of incision, especially by the ancestral Fossil Creek in the southern part of the mapped area, during the Middle Pleistocene (Section A-A' and Section B-B', Plate 2).

The unit has previously been mapped as Slocum Alluvium (Colton, 1978; Kellogg and others, 2008; Cole and Braddock, 2009; Workman and others, 2018). Deposits underlying the fan-shaped surface in the southwest corner of the quadrangle are either thin (less than 1 m) or have been completely eroded near the apex of the landform. Similar deposits were evaluated in trenches on the Larimer County Landfill property in the Loveland Quadrangle (Lindsey, 2024). Here, no true fluvial gravel deposits were identified. Instead, the deposits were poorly sorted, calcareous, and comprised of clay, sand, and pebble-gravel, interpreted as alluvial fans. Two samples were collected from two trench sites and analyzed using infrared stimulated luminescence techniques. They yielded age estimates of 17.08 ± 1.86 ka and 166.2 ± 21.8 ka (Lindsey, 2024). The latter date correlates with the earlier part of the Bull Lake glaciation (Madole, 1991; Kellogg and others, 2008). Areas, where the unit is mantled by eolian sediment (unit Qe), may experience hazards related to soil collapse. The unit is not a likely source of sand or gravel. Water well and geotechnical logs indicate the unit may be as much as 9 m thick, but is typically 6 m thick or less.

EOLIAN DEPOSITS

Qe

Eolian deposits (Holocene and Upper Pleistocene (?)) — The unit is not well exposed in the mapped area, but numerous DWR well logs and geotechnical borings record descriptions of the unit. It is comprised predominantly of silt and sand. Deposits are tan, light-yellowish brown, yellowish-brown, and olive-brown in color, massive, and homogenous. Secondary carbonate is present in older deposits. Deposits are more widespread than what is mapped, but unit Qe is locally discontinuous and contacts between Qe and other surficial deposits are difficult to identify, so they are mapped together in many places (such as unit Qafo). Colton (1978) mapped deflation basins in the northeast portion of the quadrangle that may have been eroded, in part, by wind. Northwest-southeast trending dune crests are also mapped by Colton (1978) in this area. Lidar was used to map deflation basins and dune crests in the mapped area, but topography is muted, so locations are approximate. The presence of dunes indicates a higher concentration of sand in the eolian deposits in this part of the mapped area. Elsewhere, eolian sediment may have a higher concentration of silt. In silt-dominant deposits, lenses of sand and dispersed pebble-gravel are present owing to the periodic reworking of the unit locally. Areas underlain by eolian sediment may be subject to hazards related to soil collapse or expansion, owing to the higher concentrations of clay derived from the Pierra Shale. The unit is not a likely source of sand. DWR wells and geotechnical borings record sandy silt and clay as much as 11 m thick in places, but unit Qe can be much thinner, locally. It is unclear how much thinner. Colton (1978) reports that deflation basins may be directly underlain by bedrock. Lidar imagery interpretation indicates there may be as much as 12 m of eolian sediment in the northeastern part of the mapped area, assuming bedrock is close to the ground surface underlying deflation basins.

BEDROCK GEOLOGY

Kp

Pierre Shale (Upper Cretaceous) — Only shown on cross-sections A-A' and B-B' (Plate 2). All members in the quadrangle are mostly mantled by surficial deposits. Areas underlain by members of the Pierre Shale, especially those with higher proportions of claystone, siltstone, and shale, may be subject to hazards related to expansive soils, collapsible soils, and are easily eroded. Though no landslides are mapped in the quadrangle, slopes underlain by the unit may be subject to landsliding, especially where slopes are greater than 10 degrees, contain higher concentrations of clay, and are overlain by gravelly deposits. Historically, clayey members of the Pierre Shale have been mined for materials to manufacture brick and tile. Larrabee (compiler, 1947) mapped much of the clay-rich Pierre members in the quadrangle as a resource of brick and tile manufacturing materials.

Kpu

Upper member (Upper Cretaceous) — The unit consists of easily eroded, valley-forming, gray, silty shale interbedded with sandstone. Sandstone interbeds are friable and typically yellow. The unit weathers to grayish green, gray, or light-olive brown soils. Index fossils *Baculites clinolobatus, Baculites grandis, Baculites baculus, Baculites eliasi,* and *Baculites jenseni* have been identified by Scott and Cobban (1965). The unit can be as much as 865 m thick in the region (Colton, 1978).

Kpr

Larimer, Richard, and Rocky Ridge members and intervening shale (Upper Cretaceous) — The unit underlies low-lying ridges in the quadrangle. It is comprised of yellow- to tan-colored sandstone with interbedded friable shales. Shales are grayish-green, gray, or light-olive brown. Sandstones within the unit are moderately indurated to friable, medium- to coarse-grained, and weakly to very weakly bedded. Concretions containing shell hash are abundant, and *Ophiomorpha* burrows and other trace fossils are present. The unit contains index fossil ammonite *Baculites reesidei* (Scott and Cobban, 1965). Clay-rich soils derived from shales in unit Kplr may be prone to hazards related to expansive and collapsible soils. The unit is 71 to 161 m thick (Colton, 1978).

Kpm

Middle member (Upper Cretaceous) — The unit is comprised chiefly of erodible, valley-forming claystone and sandy siltstone. Claystones and siltstones are typically greenish gray in color. Index fossils *Baculites cuneatus, Baculites compressus, Didymoceras cheyennense, Exiteloceras jenneyi, Didymoceras stevensoni,* and *Didymoceras nebrascense* are present in this member (Scott and Cobban, 1965). Bentonite beds are present locally. The unit is as much as 450 m thick in the region (Colton, 1978).

Kpmu

Middle to Upper members, undivided (Upper Cretaceous) — Shown on cross-section C-C' only (Plate 2).

Kpn

Hygiene Sandstone (Upper Cretaceous) — The unit is comprised of yellowish-brown, tan, light-gray, or gray sandstone with varying degrees of induration. In the quadrangle, the Hygiene Sandstone is very weakly bedded and moderately friable. Concretions may be present in the lower part of the unit. Siltstones are interbedded with sandstones in the member. The unit underlies ridges in the southern part of the quadrangle, though the unit does not crop out well. Soils derived from the Hygiene Sandstone are typically sandy and yellowish to tan in color. Index fossil ammonites *Baculites scotti* and *Baculites gregoryensis* are present in the member (Scott and Cobban, 1965). The unit is 185 to 242 m thick (Colton, 1978).

Kpl

Lower member (Upper Cretaceous) — The unit is comprised chiefly of dark-olive brown to black shale and sandy shale. Soils derived from the unit are typically greenish brown to olive. The lower member underlies swales in the western part of the quadrangle and is poorly exposed. Bentonite beds are present in the basal part of the unit. Index fossils *Baculites perplexus, Baculites asperiformis, Baculites mclearni,* and *Baculites obtusus* are present in the unit (Scott and Cobban, 1965). The unit is as much as 500 m thick in the region (Colton, 1978).

Kn

Niobrara Formation (Upper Cretaceous) — The Smoky Hill Member of the Niobrara Formation is exposed only in sec. 4, T. 6 N., R. 69 W. on the western edge of the quadrangle. Here, the upper part of the Niobrara is a thinly bedded, fissile, shaley micritic limestone and limey shale. The color of the unit is gray and it weathers to tan. Fossils are absent from this outcrop. The contact with the Pierre Shale is distinguished by the sharp change from gray limestone to black shale. The unit is approximately 79 m thick in the area.

Kcgg

Carlile Shale, Greenhorn Limestone, and Graneros Shale, undivided (Upper and Lower Cretaceous) — Includes the Codell Sandstone. Only shown on cross-section C-C' (Plate 2). The unit is approximately 165 m thick (Colton, 1978).

Kd

Dakota Group (Lower Cretaceous) — Shown in cross-section C-C' only (Plate 2). The unit is as much as 88 m thick in the Horsetooth Reservoir quadrangle adjacent to the west (Braddock and others, 1989).

JRmj

Morrison Formation, Sundance Formation, and Jelm Formation, undivided (Upper Jurassic and Upper Triassic) — Shown in cross-section C-C' only (Plate 2). The unit is as much as 158 m thick in the Horsetooth Reservoir quadrangle adjacent to the west (Braddock and others, 1989).

TrPy

Lykins Formation and Lyons Sandstone, undivided (Triassic and Permian) — Shown in cross-section C-C' only (Plate 2). Unit is as much as 192 m thick in the Horsetooth Reservoir quadrangle adjacent to the west (Braddock and others, 1989).

PIPsaf

Satanka, Ingleside, and Fountain Formations, undivided (Permian and Pennsylvanian) — Shown in cross-section C-C' only (Plate 2). Unit is as much as 382 m thick in the Horsetooth Reservoir quadrangle adjacent to the west (Braddock and others, 1989).

MAP SYMBOLS

- **Contact —** Identity and existence certain, location accurate
- **Contact —** Identity and existence certain, location approximate
- **Contact —** Identity and existence uncertain, location approximate
- **Anticline —** Existence certain, location approximate (Weimer, 1996)
- **Syncline —** Existence certain, location approximate (Weimer, 1996)
- **Land-use boring—** Colorado Geological Survey Land-use site review boring
- **Geotech well —** City of Fort Collins Geotechnical soil boring
- **Water well —** Well number and drill-log data from Colorado Department of Water Resources well permit map viewer (CO DWR, link in references).
- **Oil and gas well —** Label is the American Petroleum Institute (API) Unique Well Identifier. Label does not include preceding State Code (05) and County Code (069 for Larimer County) (CO ECMN, link in references).
- **Strike and dip of inclined bedding —** Showing direction and angle of dip
- **Luminescence sample site**
- **Alignment of cross section**

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