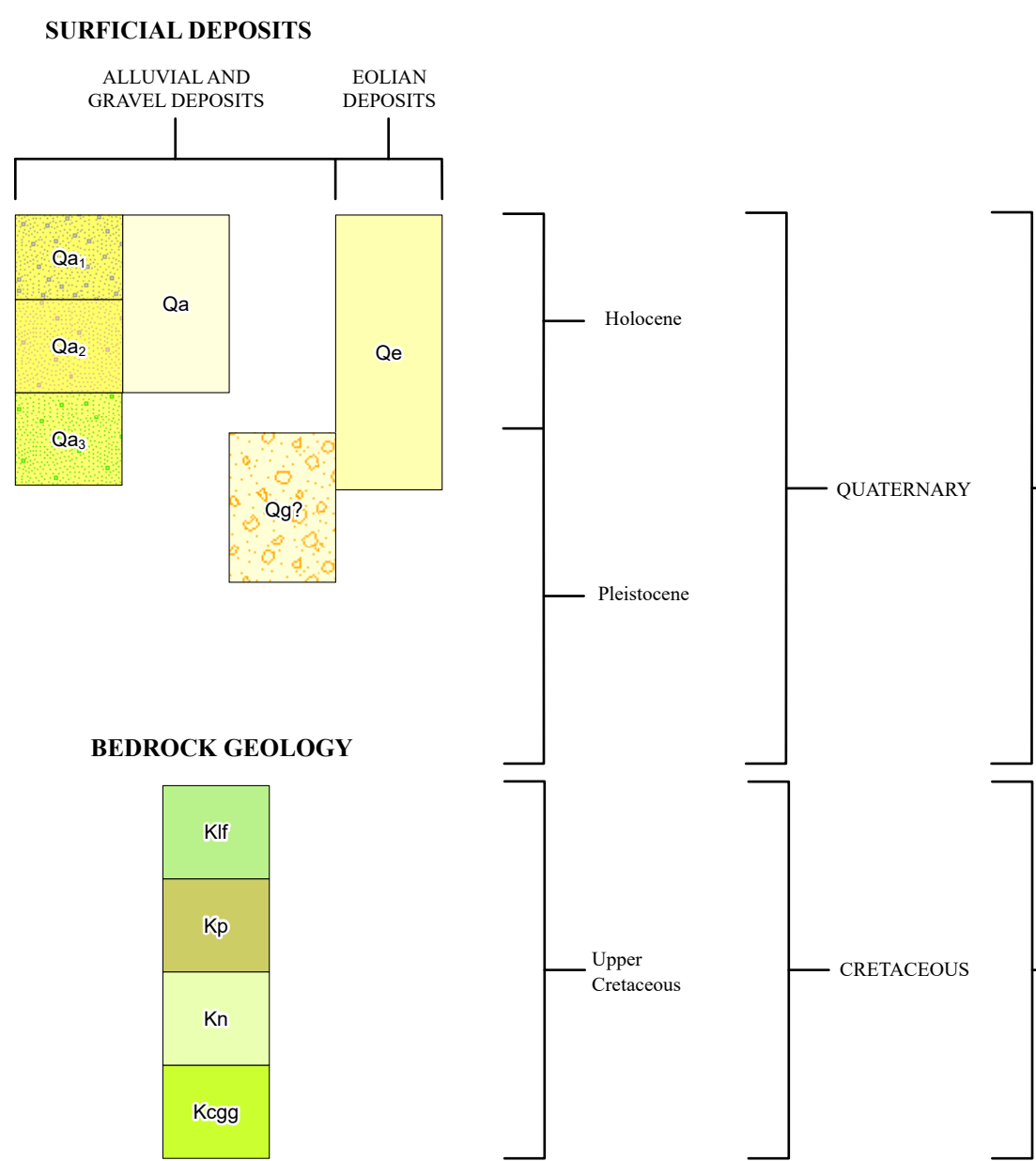
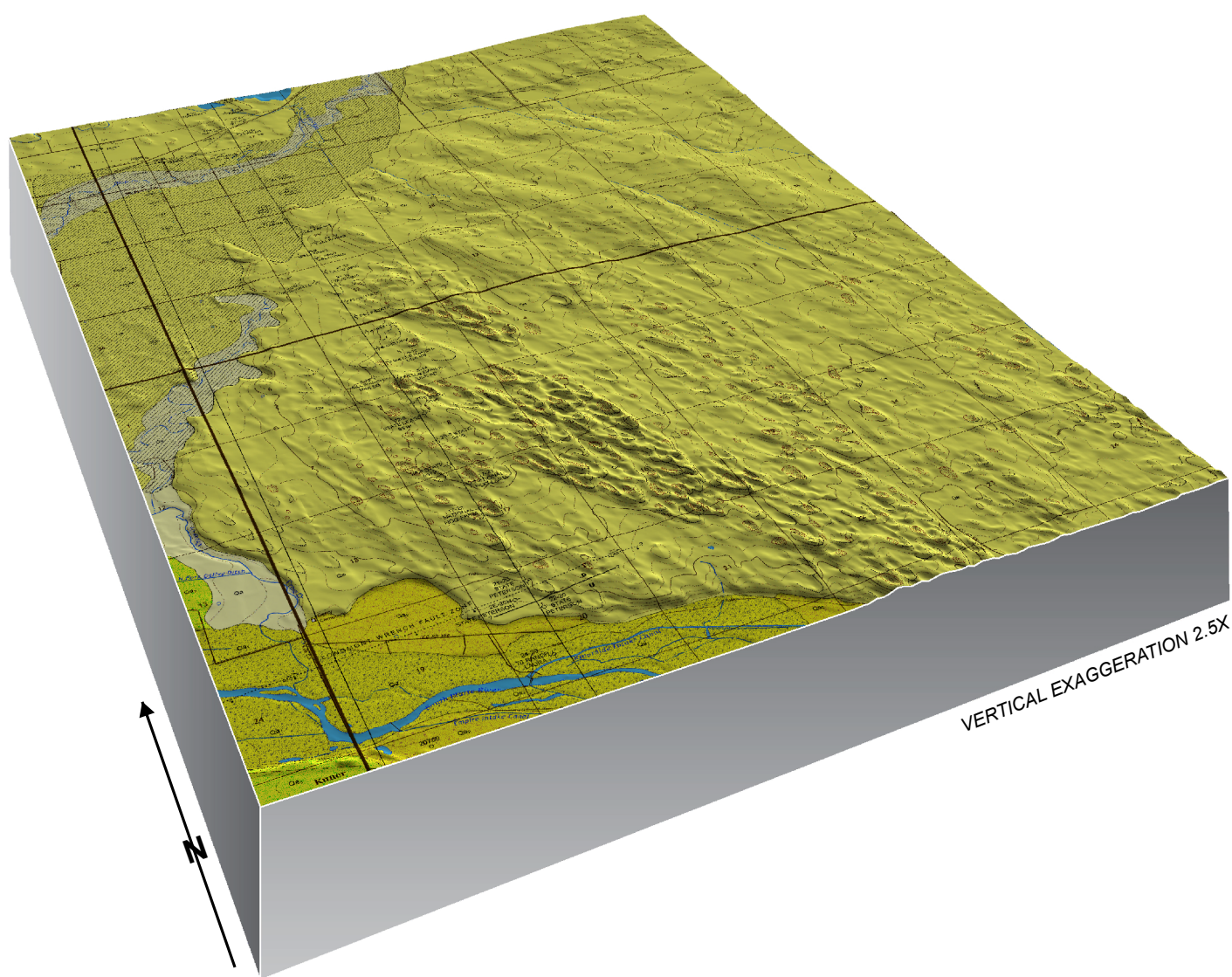


CORRELATION OF MAP UNITS



3-D OBLIQUE



GEOLOGIC HISTORY, GEOLOGIC HAZARDS,
GROUNDWATER RESOURCES, AND MINERAL
RESOURCES

The Southern Rocky Mountains bounds the western margin of the Denver Basin; the latter underlies much of the Great Plains physiographic province in north-eastern Colorado. The Barnesville quadrangle is situated within the Colorado Piedmont section of the Great Plains, approximately 80 km northeast of Denver and 50 km east of Fort Collins, Colorado. The Western Interior Seaway (WIS) occupied most of Colorado during the Late Cretaceous, depositing transgressive and regressive sedimentary rock sequences that underlie most of the map area. The early phase of the Laramide orogeny (~70 Ma) is correlative with the final stages of the WIS in the region (Weimer, 1996). The Carlile Shale, Greenhorn Limestone, and Codell Sandstone (collectively known as the Colorado Group, map unit Kgg), Niobrara Formation (Kn), and the Pierre Shale (Kp) record the final WIS transgressive and regressive marine sequences.

The Johnstown (JWFZ) and Longmont (LWFZ) wrench fault zones formed during Colorado's complex tectonic history. The different faults are normal oblique left-lateral systems and have an intricate network of relatively smaller faults with different orientations; major faults are likely either listric or nearly vertical (Weimer, 1996). The JWFZ and LWFZ locally have trapped hydrocarbons produced by the Cretaceous bedrock in Colorado (Higley and Cox, 2007; Weimer, 1996). As a result, the Cretaceous units are valuable reservoirs for oil and gas within the Denver Basin. The oil and gas industry developed the petroleum resources in the Denver-Julesburg basin and subsequently those of the Wattenberg Field in northeastern Colorado. The Wattenberg Field is a world-class oil and gas producing area, with over 4 trillion cubic feet of gas and 210 million barrels of oil. The Barnesville quadrangle lies on the eastern edge of the Wattenberg Field (Weimer, 1996). Detailed mapping of JWFZ and LWFZ from Weimer (1996) does not include the map area and regions east of the Wattenberg Field. Approximately 152 m of offset, possibly associated with the LWFZ, was identified between wells 21-20 State Peterson and 22-20 State Peterson (see Section C-C'). Additional offset of approximately 46 m along the northern unnamed fault is evident between wells 17-52 Cache and 17-22 Peppier (Section C-C'). The mapped area lies on the northern boundary of an important groundwater resource in the Upper Cretaceous Fox Hills Sandstone and Laramie Formation (unit Kf). Quaternary sediments completely mantle bedrock units in the map area.

Ancestral rivers eroded sediment and bedrock, deposited sandy and gravelly alluvium, and abandoned older terraces higher in the landscape. Terraces can be locally correlated based on their heights above the modern stream channel. Within the Barnesville quadrangle, Colorado Department of Water Resource (DWR) wells 189278, 3738, 3783, and 23003 penetrate gravels that are roughly correlative with alluvium historically mapped as "Siccum Alluvium" (Berry and others, 2019). Additionally, Pleistocene alluvium sourced from and inset into Oligocene- and Miocene-age bedrock units is mapped along Crow Creek near its headwaters in Wyoming (Ver Ploeg, 1995). This suggests ancestral drainages were active as early as Middle Pleistocene in the map area.

The Bull Lake and Pinedale glaciations contributed significant volumes of meltwater to maintain highly energetic fluvial during parts of the late Middle and Late Pleistocene. A gravel deposit penetrated by DWR well 63852 is correlative, by virtue of height above stream channel, with alluvium historically mapped as "Louviers Alluvium", which was deposited near the end of the Bull Lake Glaciation (190 to 130 Ka) (Madole, 1991; Schilgen, 2002). Radiometric ages from gravel deposits in the nearby Gowanda and Kersey quadrangles indicate that the ancestral South Platte River and its tributaries periodically aggraded during the Middle and Late Pleistocene, without significant channel incision (Keller and others, 2019; Lindsey and Palkovic, 2020). Aggradation culminated around the end of the Pinedale Glaciation (~31 to 13 Ka; Table 1) (summarized in Berry and others, 2019). Unit Qa₁ (historically mapped as "Broadway Alluvium") is commonly identified in the upper portion of the aggradation sequence and is mapped in the southwest corner of the Barnesville quadrangle as unit Qa₁. Water-well log data indicates eolian sediment mantles unit Qa₁ on the north side of the modern channel. By 11 ka the ancestral South Platte River altogether abandoned the terrace underlain by unit Qa₁ (Haynes and others, 1998) and thus the unit is not hydraulically connected to the South Platte River. However, groundwater may be perched locally within the unit. Unit Qa₁ is a source of sand and gravel and correlative with unit T3 (stream-terrace, fine aggregate) of Schwachow and others (1974). The unit is actively quarried for sand and gravel in nearby quadrangles.

During the Early Holocene, the South Platte River eroded bedrock and older sediment, and deposited unit Qa₂ during the Middle Holocene. The river further eroded into unit Qa₁, leaving terraces about 2 m high adjacent to the modern channel in the map area. Alluvium deposited during the Late and latest Holocene underlies the active channel and current floodplain of the South Platte River. Crow Creek, a major south-flowing tributary of the South Platte River, also deposited alluvium periodically during the Holocene. Two alluvial units, Qa₁ and Qa₂, are mapped along Crow Creek in the Kersey quadrangle directly to the west (Lindsey and Palkovic, 2020). Extensive cultivation and thick eolian deposits make distinguishing units Qa₁ and Qa₂ challenging in the Barnesville quadrangle; therefore, alluvial units along Crow Creek are mapped as a single, undivided unit, Qa. The modern Crow Creek channel occupies a prominent paleovalley distinguishable in 1-m hillshaded lidar, indicating an ancestral channel may have been much larger and formed a more extensive valley during the Early Holocene. Eolian sediment, at least 1 m thick, mantles most of the Crow Creek paleovalley. Units Qa₁, Qa₂, and Qa₃ are hydraulically connected to the South Platte River and are sources of groundwater and areas underlain by these units have a 1% annual chance of flooding (Zone A or Zone AE floodway) as mapped by the Federal Emergency Management Agency (FEMA, URL link in references). Units Qa₁ and Qa₂ may be potential sources of sand and gravel. These units are roughly correlative with units F3 and T4 (floodplain, fine aggregate and stream-terrace, fine aggregate), respectively, of Schwachow and others (1974). Unit Qa is not a likely source of sand or gravel and is correlative with units F4 and V4 (floodplain, unevaluated aggregate and valley-fill, unevaluated aggregate) of Schwachow and others (1974).

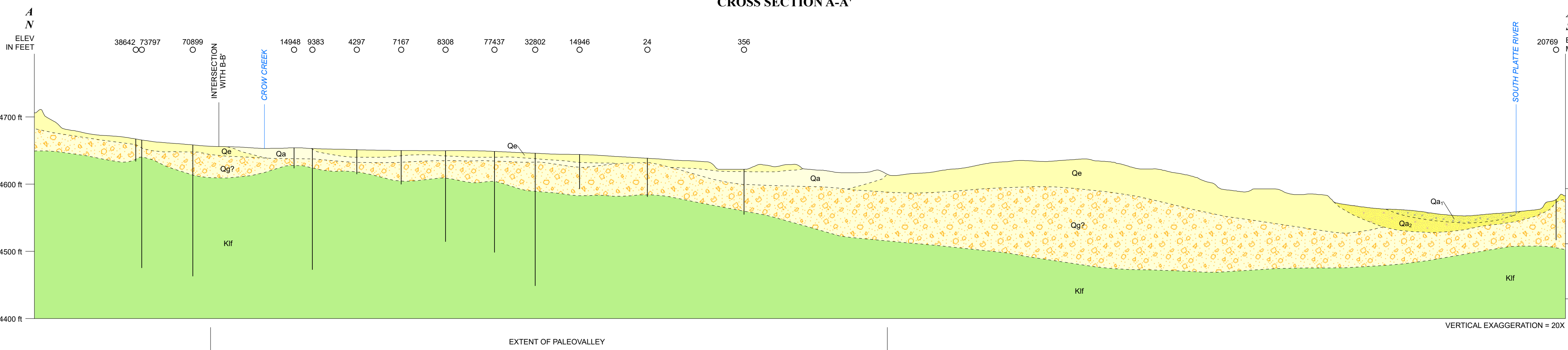
With increased distance east of the Rocky Mountain foothills, wind-blown deposits are generally thicker, more widespread, and coarser in texture. Much of the region's eolian sediment is derived from local alluvium (Madole and others, 2005). Eolian deposits are the most extensive unit mapped in the Barnesville quadrangle. A roadcut on Highway 392 in NW ¼, sec. 17, T. 6 N., R. 63 W., near the northeastern corner of the quadrangle exposes sediments of two depositional episodes. At this location, approximately 1 m of eolian sand mantles a sequence of buried soils. Carbonate development in the buried Bk horizon suggests that eolian sediment was deposited during the Early Holocene, possibly as early as the Late Pleistocene in the Barnesville quadrangle. Soils are not developed in sediment in the upper 1 m of the exposure suggesting that the upper section was deposited during the Late Holocene. Southeasterly winds that were active in the region during most of the Holocene transported sand that formed the dune fields (Madole and others, 2005). Coarser wind-blown sediment underlies dunes mapped on both sides of the South Platte River in the Barnesville quadrangle. Current vegetation and climate conditions have stabilized local dune fields. However, changes in climate and anthropogenic development may easily reactivate them (Madole and others, 2005). Dunes may be subject to reactivation and migration, especially in areas where there is little to no vegetation. Eolian sediment may be prone to collapse when wetted and placed under load. The unit is a potential source of sand and correlative with unit E3 (eolian, fine aggregate) of Schwachow and others (1974).

Table 1. Summary of ages discussed in the Description of Map Units and Geologic History that were collected from other studies. "Sampled unit" refers to the unit of which the age date was assigned in the cited report. Correlations are continuing to be made between mapped units and ages reported in other studies with the units mapped in Barnesville. The age of "Broadway Alluvium" is considered to be 30 to 12 ka (summarized in Kellogg and others, 2008). The older is correlative with the end of the Bull Lake Glaciation and other alluvium mapped as "Louviers Alluvium" in the region (Schweinsberg and others, 2020).

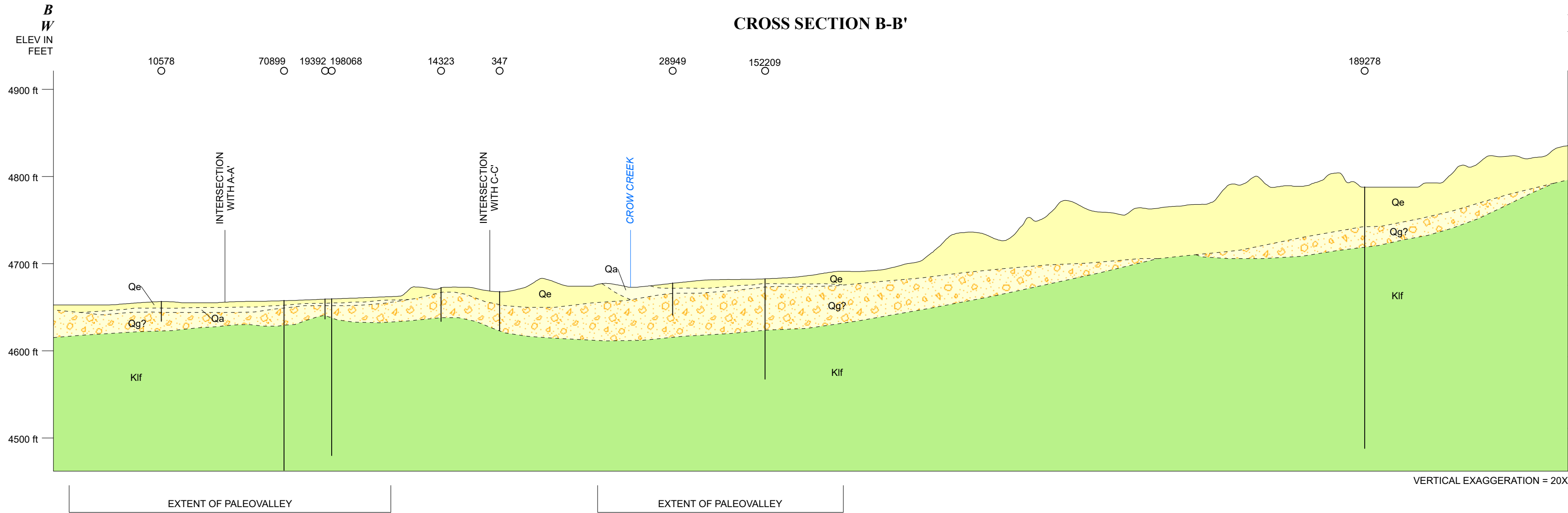
Barnesville mapped unit	Sampled mapped unit	Other correlative alluvium	Analysis Method	Age (years BP)	Citation
Qa1	Qa1	Post-Piney	Carbon-14	1,530 ± 30	Keller and others, 2017
Qa2	Qa2	Piney Creek	Carbon-14	1,714 – 1,565*	Lindsey and Palkovic, 2020
Qa2	Qa2	Piney Creek	Carbon-14	3,929 – 3,817*	Lindsey and Palkovic, 2020
Qa2	Qa2	Post-Piney	Carbon-14	910 ± 30	Keller and others, 2017
Qa2	Qa2	Piney Creek	Carbon-14	2,930 ± 30	Keller and others, 2017
Qa3	underlies Qa3	unknown	OSL	86,980 ± 4090	Lindsey and Palkovic, 2020
Qa3	underlies Qa3	unknown	OSL	75,540 ± 4020	Lindsey and Palkovic, 2020
Qa3	Qa3	Broadway/Pre-Piney Creek	OSL	13,510 ± 1375	Lindsey and Palkovic, 2020
	underlies Qa3	Louviers	OSL	151,360 ± 5,800	Keller and others, 2019
	underlies Qa3	unknown	OSL	>56,305	Keller and others, 2019
	underlies Qa3	unknown	OSL	54,480 ± 5,540	Keller and others, 2019
	underlies Qa3	unknown	OSL	42,285 ± 3,730	Keller and others, 2019
Qa3	Qa3	Broadway/Pre-Piney Creek	OSL	10,940 ± 660	Keller and others, 2017
Qa3	Qa3	Broadway/Pre-Piney Creek	Carbon-14	12,025 ± 45	Madole, 2016
Qa3	Qa3	Broadway/Pre-Piney Creek	Carbon-14	13,460 ± 30	Madole, 2016
	Qa3	Broadway/Pre-Piney Creek	Carbon-14	11,980 ± 155	Madole, 2016
	Qa3	Broadway/Pre-Piney Creek	Carbon-14	12,640 ± 70	Madole, 2016

* cal yr BP

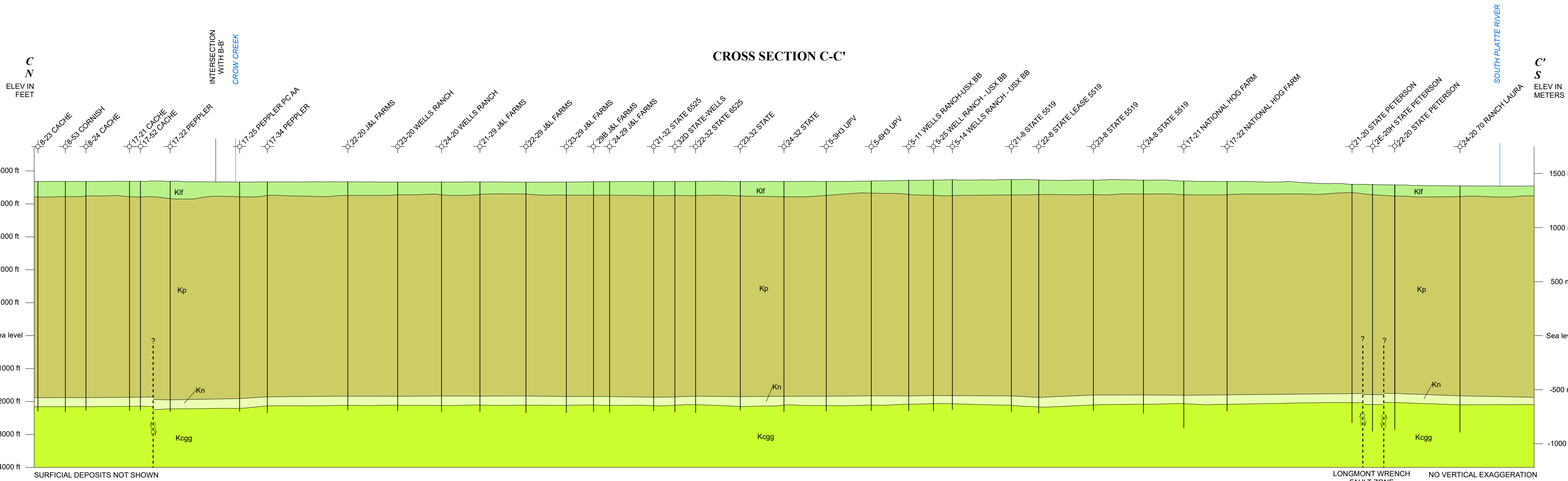
CROSS SECTION A-A'



CROSS SECTION B-B'



CROSS SECTION C-C'



GEOLOGIC MAP OF THE BARNESVILLE QUADRANGLE, WELD COUNTY, COLORADO
CORRELATION OF MAP UNITS, 3-D OBLIQUE, GEOLOGIC HISTORY, GEOLOGIC HAZARDS, GROUNDWATER RESOURCES, MINERAL RESOURCES, AND CROSS SECTIONS

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2021