Eastonville Quadrangle Geologic Map, El Paso County, Colorado

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This publication is dedicated to the pioneering palynologic work of Doug Nichols (1942-2010) in the Cretaceous and Tertiary synorogenic deposits of the Denver Basin.

Authors' Notes

Eastonville Quadrangle Geologic Map, El Paso County, Colorado

Description of Map Units, Structural Geology, Geologic Hazards, Mineral Resources, and Ground-Water Resources

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Photograph taken from a high butte located in the north part of the Eastonville quadrangle looking east towards Pikes Peak. The craggy outcrops in the foreground are rocks of the upper part of the Dawson Formation, an arkosic sandstone unit that forms the main aquifer for many of the residents along the Front Range area.

This mapping project was funded jointly by the Colorado Geological Survey and the U.S. Geological Survey through the National Geologic Mapping Program under STATEMAP Agreement No. G10AC00410.

FOREWORD

The purpose of the *Eastonville Quadrangle Geologic Map, El Paso County, Colorado* is to map and describe the geologic setting, structure, geologic hazards, and mineral and ground-water resources of this 7.5-minute quadrangle located northeast of the Colorado Springs metro area in east-central Colorado. CGS geologists Matthew L. Morgan and Peter E. Barkmann completed the field work on this project during the spring and summer of 2009. Some unit descriptions were coordinated between this area and the neighboring Black Forest (Thorson, 2004b) and Elizabeth (Morgan, 2009) quadrangles.

This mapping project was funded jointly by the U.S. Geological Survey (USGS) and CGS. USGS funding comes from the STATEMAP component of the National Cooperative Geologic Mapping Program, award number G10AC00410, authorized by the National Geologic Mapping Act of 1997, reauthorized in 2009. CGS matching funding comes from the Colorado Department of Natural Resources Severance Tax Operational Funds, from severance taxes paid on the production of natural gas, oil, coal, and metals in Colorado.

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INTRODUCTION

The Eastonville 7.5-minute quadrangle is located northeast of Falcon, Colorado, in the southern part of the Colorado Piedmont section of the Great Plains. The quadrangle is situated in the Kiowa Creek and Black Squirrel Creek drainage basins, which are tributary to the South Platte River and Arkansas River, respectively (**Figure 1**). Geologic mapping of the Eastonville quadrangle was undertaken by the Colorado Geological Survey (CGS) as part of the STATEMAP component of the National Cooperative Geologic Mapping Program. Geologic maps produced by the CGS through the STATEMAP program are intended as multi-purpose maps useful for land-use planning, geotechnical engineering, geologic hazards assessment, mineral resource development, and ground-water evaluation. **Figure 2** shows the location of the Eastonville quadrangle and the status of geologic mapping of 7.5-minute quadrangles in the Colorado Springs area.

The geologic interpretations shown on the Eastonville quadrangle are based on (1) CGS field investigations in April through August of 2009; (2) prior published and unpublished geologic maps and reports; (3) interpretation of black and white 1:40,000-scale (re-sampled to 1:24,000 scale) National Aerial Photography Program (NAPP) aerial photos flown in 1988; (4) a 10-meter digital elevation model (DEM); and (5) a 1-meter resolution National Agricultural Imagery Program (NAIP) digital orthophotograph taken in 2005.

Bedrock geology and surficial deposits were mapped in the field on aerial photographs. The photographs were scanned, georeferenced, and imported into Leica Photogrammetry Suite, where they were photogrammetrically corrected and rendered in 3D. Line work was traced directly from the scanned field photos using ERDAS Imagine Stereo Analyst for ArcView and exported as ESRI shapefiles. Universal Transverse Mercator (UTM; North American Datum 1983, Zone 13 North, meters) coordinates are provided for key geologic areas and photographs. The USGS topographic base map for the Eastonville quadrangle was published in 1954 and photorevised in 1975. Consequently, some of the more recently constructed roads, buildings, and other human-made modifications of the landscape are not shown on the base map.

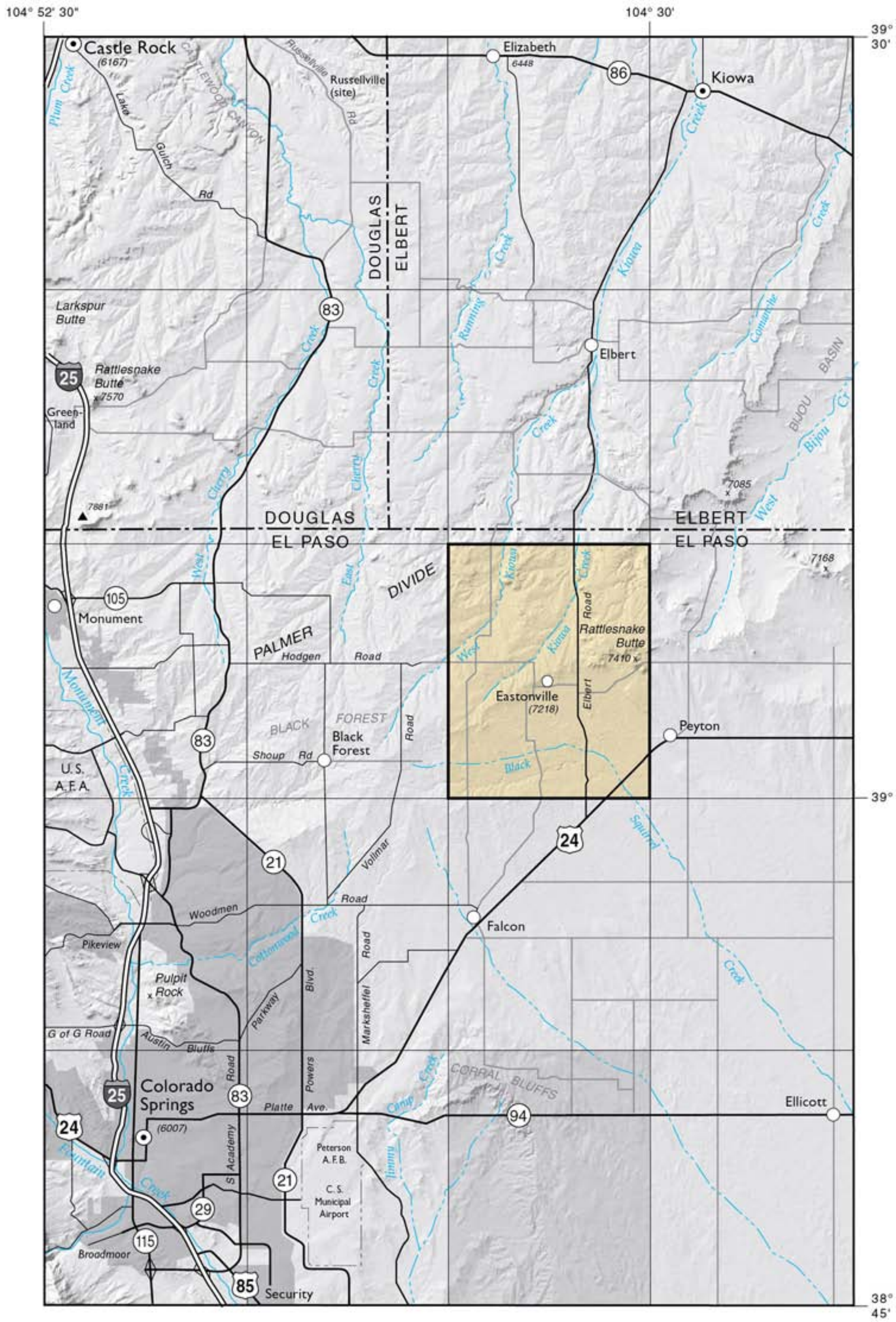
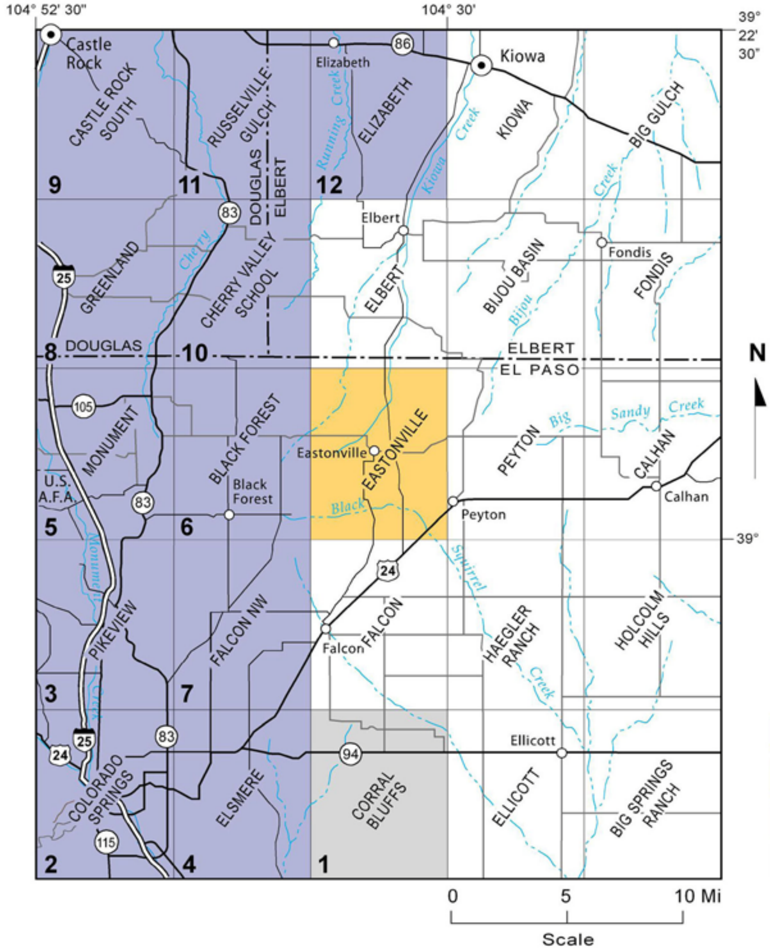


Figure 1. Location of the Eastonville quadrangle (bold black outline) in relation to major geographic features.



Completed 1:24,000-scale geologic maps:

Index Map No.	Publication No.	Date
1	USGS GQ 783 Soister	1968
2	CGS OF 00-03 Carroll and Crawford	2000
3	CGS OF 01-03 Thorson, Carroll and Morgan	2001
4	CGS OF 02-02 Madole and Thorson	2002
5	CGS OF 02-04 Thorson and Madole	2002
6	CGS OF 03-06 Thorson	2003(a)
7	CGS OF 03-08 Madole	2003
8	CGS OF 03-09 Thorson	2003(b)
9	CGS OF 04-05 Thorson	2004(a)
10	CGS OF 04-06 Thorson	2004(b)
11	CGS OF 06-08 Thorson	2006
12	CGS OF 09-03 Morgan	2009

Explanation

This report

Mapped concurrent with this report

CGS completed geologic maps

USGS completed geologic maps

Figure 2. Index map showing the location of the Eastonville quadrangle and adjacent 1:24,000-scale mapping by the USGS and CGS.

Previous geological mapping in the Eastonville area includes the work of Richardson (1915) at 1:125,000 scale and Bryant and others (1981) at 1:250,000 scale. The Colorado Geological Survey has published open-file maps of quadrangles adjacent to the Eastonville quadrangle: Black Forest (Thorson, 2003a), Falcon NW (Madole, 2003) and Cherry Valley School (Thorson, 2004b).

The geological unit names and symbols used for geological units in the Eastonville quadrangle conform as much as possible to those used previously on geologic maps of nearby areas prepared by CGS. The names and symbols for many of the surficial and bedrock units used by Maberry and Lindvall (1972, 1977) do not conform to the geologic formations currently used by CGS. The approximate correlations with earlier geological terminology are described in the "Description of Map Units" section of this text.

The scale of the base map and aerial photographs governed the minimum size of the deposits shown. With few exceptions, deposits that have minimum dimensions of less than 150 feet were not mapped. Deposits that are less than 5 feet thick were not mapped unless they are coincident with landforms that can be delineated on aerial photography or are geologically significant. Some of the surficial deposits of the Eastonville quadrangle are not well exposed. Consequently, the thickness of most units is estimated and descriptions of physical characteristics such as texture, stratification, and composition are based on observations at a limited number of localities.

GEOLOGICAL SETTING

The Eastonville quadrangle is located near the center of the Denver Basin, an asymmetrical, oval-shaped, geological structural depression (Emmons and others, 1896). This structural basin lies directly east of the Front Range and covers a large 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 m.y. ago (Hoyt, 1962). 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.

Much of the exposed bedrock in the Eastonville quadrangle is the upper part of the Dawson Formation. At the time of deposition of this unit, during the Paleocene and Eocene Epochs (about 65 to 50 m.y. ago, **Appendix 1**), the uplift of the Front Range was well underway. Braided streams delivered to the basin a mixture of gravel, sand, silt and clay derived from weathering and erosion of that uplifted area. The source of those granitic arkosic materials was mostly the Precambrian Pikes Peak Granite, located directly west of the Rampart Range mountain-front fault system. The Rampart Range fault is about 25 miles west of the mapped area.

Stream flow was generally toward the east (Morse, 1979; Crifasi, 1992). The pebble conglomerate and arkosic sand beds of the Dawson Formation are cross bedded and fill broad channels generally cut into finer-grained deposits of clayey sandstones and sandy claystones. Interbedded between the coarse-grained beds are finer-grained and thinner-bedded strata of light-gray to gray-green clayey sandstone and brown or brownish-gray sandy claystone occasionally containing fragments of organic material and plant fossils. The fine-grained parts of the upper Dawson Formation were deposited by gentler currents in areas between the braided stream channels and probably were covered with vegetation.

Following the erosion of some of the upper part of the Dawson Formation, probably during the middle of the Eocene Epoch, the conglomerate of Larkspur Butte (Thorson, 2003b) was deposited in a series of channels and broad valleys occupied by streams that drained the newly rejuvenated mountains. In the western part of the Greenland quadrangle (Thorson, 2003b), the conglomerate of Larkspur Butte was deposited in narrowly confined, steep-walled stream valleys. These valleys became broader towards the east as in the Cherry Valley School and Castle Rock South quadrangles (Thorson, 2004a, 2004b). The same eastward widening is apparent in the Castle Rock North (Thorson, 2005b), Russellville Gulch (Thorson, 2006) and Ponderosa Park (Thorson, 2007) quadrangles. However, remnants of the conglomerate of Larkspur Butte are not preserved in the Eastonville quadrangle.

The Wall Mountain Tuff, an ignimbrite, or glowing hot volcanic ash flow, was erupted from an unidentified area in the Sawatch Range (McIntosh and Chapin, 2004) in the late Eocene and poured across the landscape. This ash flow blanketed the eroded surface of the Dawson Formation and valleys that contained the conglomerate of Larkspur Butte. Because of its great heat, the ash compacted into a viscous plastic that flowed for short distances before it cooled into welded tuff. A small erosional remnant of the Wall Mountain Tuff overlies the Dawson Formation on the southern part of Rattlesnake Butte.

The Castle Rock Conglomerate was deposited near the end of the Eocene within a series of paleo-vallies that consisted of a southeast-trending "main channel" and at least two tributaries that flowed into the main channel from the west-southwest (M. Morgan and S. Keller, personal commun, 2011). The Castle Rock Conglomerate was eroded across the upper Dawson Formation, conglomerate of Larkspur Butte, and Wall Mountain Tuff. Large erosional remnants of the Castle Rock Conglomerate are located in the northwestern corner of the mapped area.

Since the deposition of the late Eocene rocks, the area experienced continued periods of erosion and deposition. During the Miocene, the Ogallala Formation was deposited across much of eastern Colorado and may have once covered the quadrangle but has since been removed by erosion. During the Quaternary, or maybe as early as the Pliocene, deposits of unconsolidated sands and gravels were deposited in paleochannels, flood plains along stream courses, and on various upland erosion surfaces as streams eroded the landscape.

AGE OF FORMATIONS

Castle Rock Conglomerate. The Castle Rock Conglomerate post-dates the Wall Mountain Tuff because the conglomerate contains clasts of the tuff. The Castle Rock Conglomerate also contains bones of Chadronian (late Eocene) titanotheres (K.R. Johnson, Denver Museum of Nature and Science, written commun., 2002) and so must be late Eocene in age, between 36.7 and 33.9 mybp (million years before present).

Wall Mountain Tuff. The ignimbrite eruption that deposited the Wall Mountain Tuff has been considered in the past to be an Oligocene event (for example, see Trimble and Machette, 1979a). Recent radiometric dates on its eruption are about 36.7 mybp (McIntosh and others, 1992; McIntosh and Chapin, 1994, 2004). However, the age for the end of the Eocene is now recognized to be 33.9 mybp (Appendix 1), so the Wall Mountain Tuff is now be considered to be late Eocene.

Dawson Formation. The lower part of the upper Dawson Formation spans the Cretaceous-Tertiary (K-T) boundary, but the exact location of the time boundary in much of the basin has not been identified. Kluth and Nelson (1988) reconfirmed the Late Cretaceous (late Maastrichtian) age for part of the Dawson Formation on the U.S. Air Force Academy. In the Elsmere quadrangle, the K-T boundary has been approximately located about 370 feet above the base of the upper part of the Dawson Formation (Benson, 1998; Benson and Johnson, 1998; Johnson and Raynolds, 2001; Madole and Thorson, 2002; Johnson and others, 2003). Fossil leaf localities in the Monument quadrangle are Paleocene in age: Scotty's Palm, Denver Museum of Nature & Science, DMNH-1204, NE 1/4 SW 1/4 sec. 12, T. 12 S., R. 67 W. (Johnson, 2001, Johnson and others, 2003); and Baptist Road, Denver Museum of Nature & Science, DMNH-2177, NW 1/4 sec. 35. T. 11 S., R. 67 W. (Johnson and Raynolds, 1998; Johnson and others, 2003). An important early Paleocene rain-forest fossil-leaf locality, estimated to be 63.8 ± 0.3 mybp, is located in the NE 1/4, SW 1/4, sec. 2, T. 8 S., R. 67 W. of the Castle Rock North quadrangle (Johnson and Ellis, 2002; Ellis and others, 2003; Johnson and others, 2003). This site is estimated to be 284 m (930 ft) above the K-T boundary on the basis of correlations with the Castle Pines cored well located in the Sedalia quadrangle (Ellis and others, 2003, **Figure 3**).

The rain-forest fossil locality is estimated to lie just below the Denver Basin paleosol, a regional paleosol traced around the basin by Soister and Tschudy (1978) and proposed to mark the Paleocene-Eocene boundary. Recent work on this paleosol has recognized that it separates early Paleocene pollen zone P3 from late Paleocene pollen zone P6 (Nichols and Fleming, 2002) and lies just below the Paleocene-Eocene boundary. Subsurface correlations of high-resistivity intervals interpreted to be arkosic layers on geophysical logs from water wells, oil and gas wildcat wells, and mineral exploration boreholes in the area indicate that this paleosol interval passes beneath the Eastonville quadrangle anywhere from 200 to 1,000 feet below the surface, depending on location (Dechesne and others, 2011). This would indicate that Dawson Formation sediments in the Eastonville quadrangle are of late Paleocene or early Eocene age.

A prominent paleosol thought to be the Denver Basin paleosol was used as the boundary between Dawson facies units four and five in the Monument quadrangle (Thorson and Madole, 2002). Mapping of the Castle Rock South (Thorson, 2004a) and Castle Rock North (Thorson, 2005b) quadrangles has shown that most of the local Dawson Formation lies above a well developed paleosol thought to be the Denver Basin paleosol and is therefore correlated with the Eocene $TKda_5$ facies unit of the Monument quadrangle. However, Morgan and others (2004) have confirmed the observation that there are multiple paleosols developed in the Dawson Formation along the western edge of the Denver Basin (Thorson and Madole, 2002; Thorson, 2003a), so appropriate caution is advised in using the relation of a stratigraphic unit to any particular paleosol as an indication of age. Nonetheless, the topography and generally low dips of the upper part of the Dawson Formation in the Castle Rock-Falcon area confirm that the Dawson unit mapped in the Eastonville quadrangle lies above the Paleocene rain-forest strata and is accepted to be Eocene in age.

Recently collected palynological samples identified by D.J. Nichols (Denver Museum of Nature & Science, written commun, 2007) indicate that there are rocks of middle to late Paleocene (P4 and P5 pollen zones) preserved in parts of the Denver Basin (J.P. Thorson, written commun., 2009). This new palynological data, collected from outcrops in the Castle Rock North, Greenland, and Monument quadrangles, establishes that the hiatus described above between Paleocene pollen zones P3 and P6, and represented in parts of the basin by a major paleosol, is not universally present throughout the Denver Basin. Thorson (2011), has proposed that parts of the basin continued to subside, receiving Paleocene P4 and P5 strata, while other parts, particularly on the northern and eastern periphery, underwent erosion and paleosol development. As a result of these discoveries, the palynology of the Denver Basin, once thought to be relatively simple (Nichols, 2003), is being re-evaluated.

Five samples of fine-grained overbank deposits were collected from the Dawson Formation for palynologic dating as part of this mapping effort. Of these, only one was found to have sufficient pollen present to adequately characterize the pollen zonation. This sample, EVP-6 collected from a lignitic mudstone layer near the base of the cut bank on the south side of Black Squirrel Creek west of Elbert Road (SE SE sec 10, T. 12 S, R. 64 W; UTM 540,217N: 4,318,597E), yielded an Early Eocene date (D.J. Nichols, written commun., 2009). This date is consistent with interpretations from the geophysical log correlations and topographic projections described above.

DESCRIPTION OF MAP UNITS

Geologic time divisions used in this report are shown in **Appendix 1**. The following conventions are used for describing the surficial deposits and bedrock outcrops. Clast sizes were based on the Wentworth grain-size scale (Wentworth, 1922), using a chart from the American Geological Institute (Ingram, 1989). Colors of materials were determined by comparison to Munsell rock and soil color charts (Geological Society of America, 2000; GretagMacbeth, 2000). The stages of calcic soil development are based on the classification of Machette (1985).

SURFICIAL DEPOSITS

Surficial deposits shown on the map are generally more than 5 feet thick but may be thinner locally. Residuum, sheetwash, colluvium, and artificial fills of limited extent were not mapped. Contacts between surficial units may be gradational, and mapped units locally may include deposits of other types. Age divisions for the Holocene used in the Eastonville quadrangle are arbitrary and informal. They are based chiefly on paleontological data compiled for the southwestern United States. Relative age assignments for surficial deposits are based primarily on the degree of erosional modification of original surface morphology, height above modern stream levels, degree of dissection and slope degradation, and soil development.

HUMAN-MADE DEPOSITS — Earth materials emplaced or modified by human beings or deposited as a consequence of human activities.

af **Artificial fill (uppermost Holocene)** — Riprap, engineered fill, and refuse placed during construction of roads, railroads, buildings, dams, and landfills. Generally consists of unsorted silt, sand, clay, and rock fragments. The average thickness of the unit is less than 20 feet. Artificial fill may be subject to settlement, slumping, and erosion if not adequately compacted.

ALLUVIAL DEPOSITS — Sand, silt, gravel, and clay transported and deposited by flowing water in channels or as unconfined runoff. The alluvial deposits in the Eastonville quadrangle are predominantly composed of quartz and feldspar fragments derived mostly from arkosic source materials in the Dawson Formation. Most of the fragments in the channel and flood-plain (Qa_1) and terrace (Qa_2, Qa_3, Qa_4) deposits are subrounded coarse pebbles (less than 1.25 inches) or smaller grains. Occasional larger pebbles and medium-sized cobbles (up to about 6 inches) of well-rounded, light-colored and rare larger round to subrounded cobbles of granite and Wall

Mountain Tuff, found in the channel, flood-plain, and terrace deposits, cannot have been derived from the Dawson. These clasts appear to be recycled from either older surficial deposits or from the Castle Rock Conglomerate. Large cobbles of Dawson Formation arkose in the alluvial deposits were derived from local sources. The thickness of the alluvial deposits vary by location; however, samples taken from local water well drill holes indicate approximately 50 feet of total alluvial thickness above the Dawson bedrock.

Qa_1 **Alluvium one (late Holocene)** — Tan to pale-brown, poorly to moderately sorted, poorly consolidated, sand, gravel, silt, and minor clay and occasional boulders in the currently active stream channels or in low stream-terrace deposits above the current stream channel but within the modern flood plain (**Figure 3**). Clasts are subrounded to well rounded and the dominant sediment is sandy gravel with a sandy silt matrix. Some boulders reach 1.5 feet in diameter. The unit forms terraces that are less than 3 feet above current stream level and is generally coarser grained and lighter in color than unit Qa_2. In many places, the unit is so young that plant roots have scarcely disturbed or destroyed stratification that extends nearly to the ground surface. Soil development is absent in the main thalweg; however a juvenile A horizon is present on some of the small terraces. The unit correlates with the Post-Piney Creek Alluvium described by Hunt (1954) in the Denver area and of Maberry and Lindvall (1972). The unit is subject to frequent flooding and is a source of sand and gravel. Maximum exposed thickness of the unit locally exceeds 5 feet.

Qa_2 **Alluvium two (early Holocene)** — Dark gray to brown, poorly to well sorted, moderately consolidated, silt, sand, gravel, and minor clay and occasional boulders in stream terrace deposits above the modern flood plain or as non-terrace forming alluvium in valley headwaters that may or may not underlie Qa_1. Clasts are subrounded to well rounded and the dominant sediment is sandy gravel with a silty sand matrix. Some boulders reach 2 feet in diameter. The unit forms terraces that reach a maximum height of 12 feet above current stream level. The unit correlates with the Piney Creek Alluvium described by Hunt (1954) in the Denver area and of Maberry and Lindvall (1972) by virtue of height above stream level and soil characteristics (horizons: A/Bk/C) (**Figure 4**). The unit is subject to occasional flooding and is a potential source of sand and gravel. Maximum exposed thickness of the unit locally exceeds 25 feet.

Figure 3. Alluvium deposit Qa_1 within the active channel of Black Squirrel Creek. The unit may also form low-level terraces that (visible just above the water on the left side of the image) are commonly covered with grassy vegetation. UTMX: 542,116.3 UTMY:4317310.2.

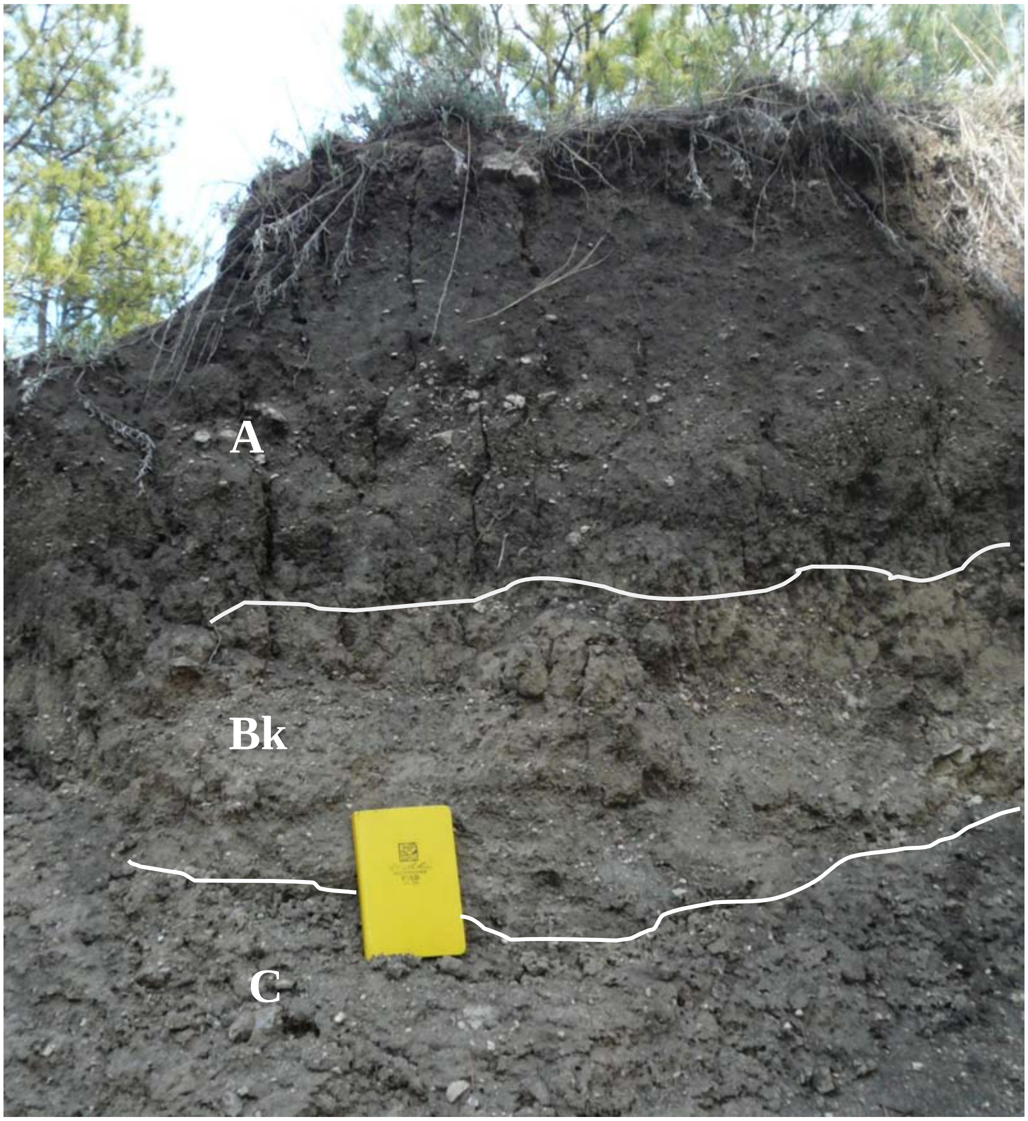


Figure 4. The soil profile developed on unit Qa_2 along a tributary to Kiowa Creek. The soil horizons are outlined by white lines and indicated by the letters. Unit Qa_2 likely correlates with the extensive Piney Creek Alluvium in the Denver Area (Hunt,1954). UTMX: 540032.5, UTMY: 4325,071.3.

Qa_3 **Alluvium three (late Pleistocene)** — Tan to reddish brown to grayish brown, poorly sorted, moderately consolidated, silt, sand, gravel, and cobbly gravel and occasional boulders in stream terrace deposits above the modern flood plain or as non-terrace forming alluvium in valley headwaters that underlies the younger alluviums. Clasts are subrounded to well rounded and the dominant sediment is sandy gravel with a sandy matrix. Some boulders reach 2 feet in diameter. The unit forms terraces that reach a maximum height of 30 feet above current stream level. The unit correlates with the Broadway Alluvium described by Hunt (1954) in the Denver area and of Maberry and Lindvall (1972) by virtue of height above stream level and soil characteristics (horizons:

A//Bt/Bk/C) (**Figure 5**). Holliday (1987) determined that deposition of the Broadway Alluvium ceased by 11 to 10 ka on the basis of geoarchaeological evidence (Clovis people artifacts) found in the alluvium in the Greeley area. Soil profile of the unit is characteristic of deposits associated with the Pinedale glaciation, which began approximately 30 ka and ended prior to 10 ka (Benedict, 1979; Madole, 1986). The unit probably correlates with the latest stade of the Pinedale glaciation that began at about 15,000 yr BP. and lasted until 10,000 yr BP. (Benedict, 1979). The unit is a potential source of sand and gravel. Maximum exposed thickness of the unit locally exceeds 20 feet.

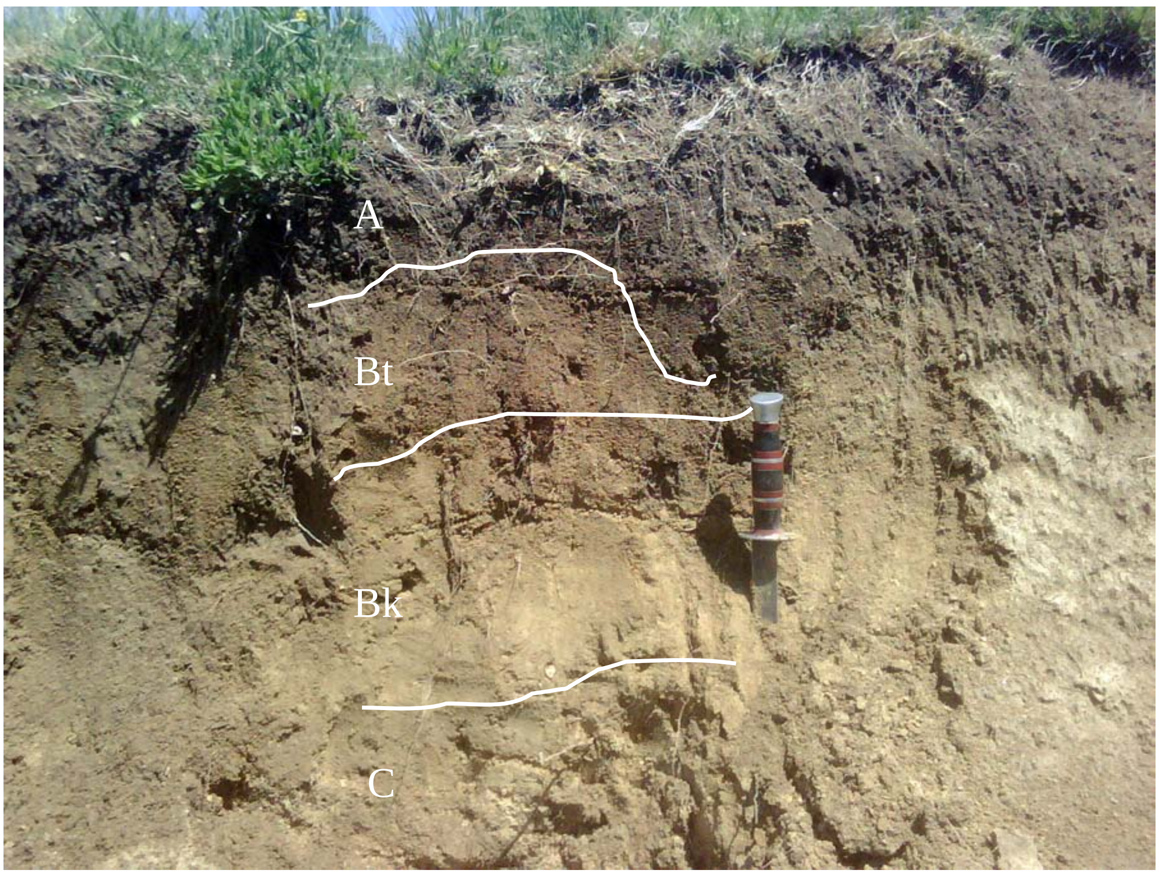


Figure 5. Soil profile developed on unit Qa_3 along West Kiowa Creek with horizons indicated by white letters. The unit likely correlates with the Broadway Alluvium in the Denver Area (Hunt,1954). UTMX: 541502.3, UTMY: 4345835.6.

Qa_4 **Alluvium four (late middle Pleistocene)** — Dark grayish-brown to yellow-reddish-brown, poorly sorted, moderately consolidated, silt, sand, gravel, and cobbly gravel and occasional boulders in stream terrace deposits above the modern flood plain or as non-terrace forming alluvium in valley headwaters that underlies the younger alluviums.

Clasts are subrounded to well rounded and have varied lithology. Terrace heights reach as much as 40 feet above current stream level. Maximum exposed thickness of unit locally exceeds 60 feet. The unit is correlative, by virtue of height and soil characteristics, with the Louviers Alluvium of the Denver area (Scott and Wobus, 1973). The soil development on unit Qa_4 is greater than the soil developed on unit Qa_3, leading previous workers (Madole, 1969; Shroba, 1977; Madole and Shroba, 1979) to correlate the deposition of the Louviers Alluvium (Qa_4) with the Bull Lake glaciation. This correlation, however, is problematic since two uranium-series age dates of the Louviers Alluvium near Denver provided values of 129 $\pm$ 10 ka and 86 $\pm$ 6 ka (Szabo, 1980). The Bull Lake glaciation ended at approximately 130 ka and thus, only part of the Louviers Alluvium (Qa_4) may be correlative. The unit is a potential source of commercial sand and gravel.

Qa **Alluvium, undivided (Holocene to late Pleistocene)** — Reddish brown to tan brown, poorly sorted sand and fine gravel in valley heads in the upper parts of drainages and in main trunk streams where differentiation of specific alluvial units was not possible. The unit includes sheetwash and stream-deposited alluvium that are undivided. These alluvium-filled valley heads are not exhumed or deeply incised. The unit may include sediment that is correlative with units Qa_1, Qa_2, and Qa_3. Maximum exposed thickness of the unit locally exceeds 20 feet.

Qg_1 **Gravel deposit one (middle Pleistocene)** — Brownish-red to reddish-tan, poorly sorted, moderately to poorly stratified pebble and cobble gravel derived from the Dawson Formation, the Castle Rock Conglomerate or Wall Mountain Tuff, and older gravel deposits. Clasts are subrounded to rounded and are moderately weathered. Matrix typically consists of feldspar and quartz sand derived from weathered Dawson Formation arkose. Top of the unit is 50 to 65 feet above adjacent modern streams and the unit locally exceeds 30 feet in thickness; however, the unit is poorly exposed and commonly forms a mantle of gravel on eroded Dawson Formation bedrock. Unit correlates with the Slocum Alluvium (Scott and Wobus, 1973) by virtue of height above stream level and is considered to be middle Pleistocene in age on the basis of local stratigraphic and physiographic position. Scott and Lindvall (1970) collected a bison horn core from the lower part of the Slocum Alluvium near the Arkansas River that yielded calibrated uranium-series age of 190 $\pm$ 50 ka (Szabo, 1980). The deposit forms a stable building surface, but excavations may be prone to slumping. The unit is a potential source of sand and gravel.

Qg_2 **Gravel deposit two (middle Pleistocene)** — Medium-red to brown, poorly sorted, moderately to poorly stratified pebble, cobble, and boulder gravel derived from the

Dawson Formation, the Castle Rock Conglomerate or Wall Mountain Tuff, and older gravel deposits. Clasts are subrounded to rounded and are moderately weathered (**Figure 6**). Matrix typically consists of feldspar and quartz sand derived from weathered Dawson Formation arkose. Top of the unit is 70 to 100 feet above adjacent modern streams and the unit locally exceeds 40 feet in thickness; however, the unit is poorly exposed and commonly forms a mantle of gravel on eroded Dawson Formation bedrock. Unit correlates with the Verdos Alluvium of the Denver area (Scott and Wobus, 1973) by virtue of height above stream level and is considered to be middle Pleistocene on the basis of local stratigraphic and physiographic position. In the Denver area, the upper part of the Verdos Alluvium contains Lava Creek B ash (Scott, 1963a), which was dated at 640,000 YBP (Lanphere and others, 2002). This unit forms a stable building surface, but excavations may be prone to slumping. The unit is a potential source of sand and gravel.

Qg Gravel deposit, undivided (Pleistocene)

Light-brown to reddish-brown, poorly sorted, poorly stratified pebble, cobble, and boulder gravel derived from the Castle Rock Conglomerate and Dawson Formation. Clasts types are predominantly Wall Mountain Tuff and milky quartz, and lesser amounts of chert and granite. The clasts are well rounded and are moderately weathered. Matrix typically consists of feldspar and quartz sand derived from weathered Castle Rock Conglomerate and Dawson Formation arkose. Top of the unit is approximately 100 feet above adjacent modern streams and the unit locally exceeds 10 feet in thickness; however, the unit is poorly exposed and commonly forms a mantle of gravel on eroded Dawson Formation bedrock. This gravel deposit lies on the interfluve between West Kiowa and Kiowa Creeks and emanates from a small butte that is capped by the Castle Rock Conglomerate. The approximate age of this deposit is speculative; it could be as old as middle Pleistocene on the basis of height above stream level or as young as the last glacial maximum (~21,000 ybp) based on radiometrically dated deposits of similar origin and appearance near Larkspur, Colorado (Morgan and others, 2008). This unit forms a stable building surface, but excavations may be prone to slumping. The unit is a potential source of sand and gravel.

Figure 6. A variety of clast types are visible on the surface of a typical exposure of a Qg_2 gravel deposit, these include Wall Mountain Tuff (red arrows), pink granite (purple arrow), and arkosic Dawson Formation (blue arrow). Red pencil is 4.5” in length. UTMX: 542252.3 UTMY: 4323671.6.

QPg **Gravel of Palmer Divide (early Pleistocene? or late Pliocene?)** — Exposures of this unit vary in quality, but it is generally composed of light brown, pinkish brown to reddish brown, fine to coarse sand interbedded with pinkish brown to brownish gray pebble and cobble gravel (**Figure 7**). The sand is poorly sorted, thinly bedded, weakly stratified and composed of chiefly of quartz and feldspar grains. Clast types within the gravel are predominantly milky white quartz and pink granite, with decreasing amounts of white quartzite, red sandstone, tan arkosic sandstone, ironstone, petrified wood, and porphyritic and tuffaceous volcanic clasts (some may be weathered fragments of the 36.7 Ma Wall Mountain Tuff). Many of the porphyritic volcanic and granitic clasts range from moderately to highly decomposed, with weathering rinds up to 1.25 in (3.2 cm) thick.

The gravel occurs in weakly stratified to massive beds or as lenses within fluvial sand. Where well-exposed, the unit is channelized into the underlying Dawson Formation and is stained with iron oxides. In areas where a soil profile is preserved, the development of a strong Bt horizon suggests a minimum age of at least early Quaternary. Absent from the deposits are the presence of a Bk or K horizon that is present in both the early Pleistocene-Pliocene Nussbaum alluvium (Scott, 1963b, 1982; Madole and others, 1991) and the Miocene Ogallala Formation. Thorson and Madole (2003) mapped a similar deposit in the Monument quadrangle and suggested its age could be as young as early Pleistocene or as old as Pliocene. Soister (1967) briefly mentions this deposit and suggested it may be correlative with the Nussbaum alluvium. The thickness of the gravel of Palmer Divide is approximately 40 feet.

Projections using GIS software along the base of the deposit to the east onto the High Plains escarpment north of Limon near Cedar Point indicate that by height, this unit post-dates the Miocene Ogallala Formation. The base is approximately 150 feet above the top of Ogallala Formation. Similar projections from the base of the Nussbaum Alluvium mapped by Soister (1967) in the Corral Bluffs quadrangle, place this deposit approximately 200 feet below the Nussbaum projection line. The slope of the crest of the gravel of Palmer Divide is to the east and the crest of the mapped Nussbaum deposit slopes south-southeast, toward the Arkansas River. Conversely, the northern flanks of the gravel of Palmer Divide slope to the north-northeast along with the mainstem creeks that are tributary to the Platte River. The original gradient of this deposit was likely eastward (as determined by GIS trend-surface maps of the crest) and was subsequently re-graded to the northeast when the Platte River tributaries (Kiowa Creek and West Bijou Creek in the mapped area) eroded headward north toward the Palmer Divide. It is possible that the Nussbaum alluvium in the Corral Bluffs quadrangle may be derived from the gravel of Palmer Divide and the lowering of the crest of the deposit is due to erosion of the original gravel deposit.

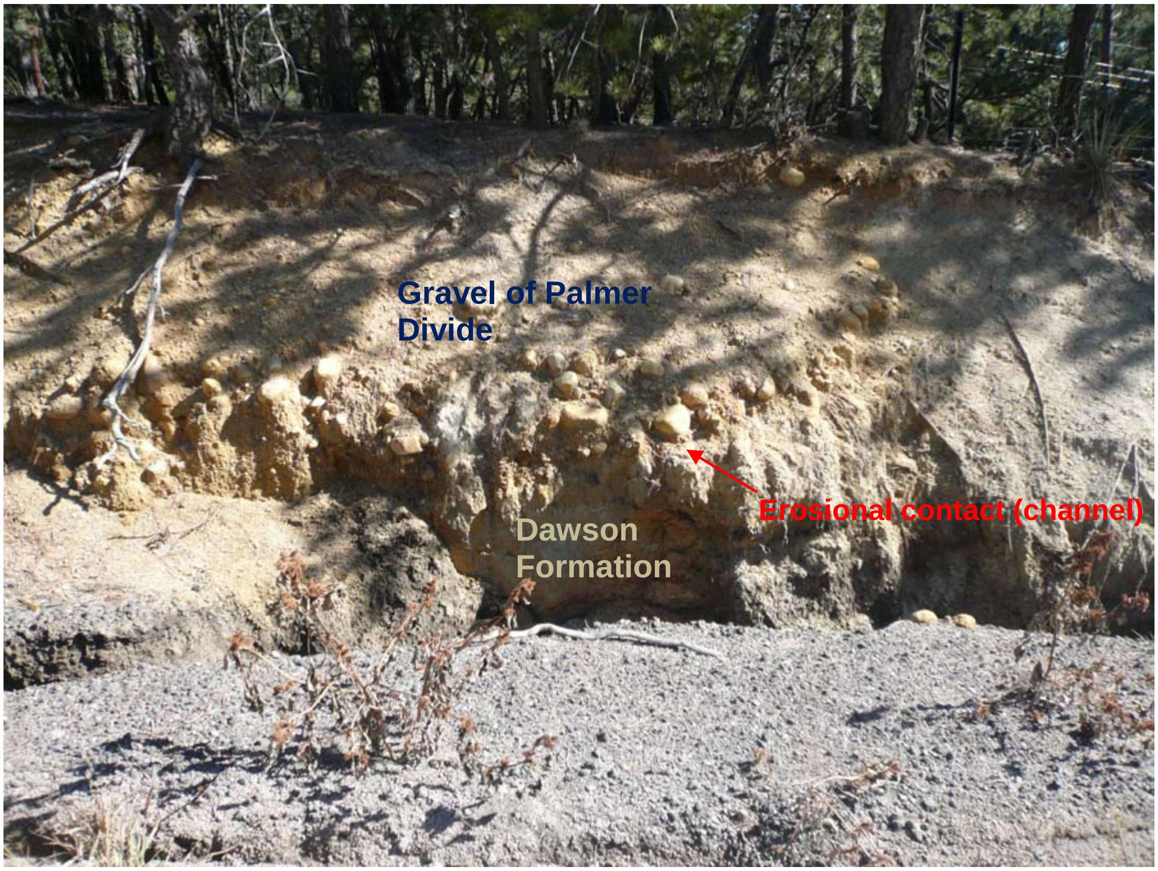


Figure 7. An exposure of the base of the gravel of Palmer Divide and its erosional contact with the underlying Dawson Formation (indicated by arrow). The unit is stained orange by iron oxides from surface waters seeping into the deposit. UTMX: 542252.3 UTMY: 4323671.6.

Qf_1 **Alluvial-fan deposit one (late Holocene)** — Tan to pale-brown, poorly to moderately sorted, poorly consolidated clay, silt, sand, gravel, and boulders deposited as alluvial fans at the mouths of perennial streams. These deposits are similar to and depositionally related to unit Qa_1. They have a fan-like shape and consist of subangular to well-rounded clasts of varied lithology that are derived from local surficial deposits; however, sand and gravel derived from the Dawson Formation is a major constituent. Sediments are deposited primarily by streams with significant input from sheetwash, debris flows, and hyperconcentrated flows. Several fans were deposited by large debris flow events in 1935, 1965 and 1973. Fans deposited by the 1965 and 1973 events host little vegetation and often divert the active stream channels into which they were deposited. Deposits locally exceed 10 feet in thickness. Areas mapped as alluvial fans are subject to future flash floods and debris flow events. Deposits may be prone to collapse, hydrocompaction, or slope failure when wetted or loaded. Deposit is a potential source of sand and gravel.

Qf_2 **Alluvial-fan deposit two (early Holocene)** — Dark gray to brown, poorly to moderately sorted, poorly consolidated clay, silt, sand, gravel, and boulders deposited as alluvial fans at the mouths of perennial streams. Clasts are subangular to well rounded and have varied lithology that are derived from local surficial deposits and the Dawson Formation. These deposits are similar to and depositionally related to unit Qa_2. They have a fan-like shape, but are more dissected than younger Qf_1 deposits. Sediments are deposited primarily by streams with significant input from sheetwash, debris flows, and hyperconcentrated flows. The apex of the fan is as much as 15 feet above modern streams. Deposit locally exceeds 15 feet in thickness. Areas mapped as alluvial fans are subject to future flash floods and debris flow events. Deposits may be prone to collapse, hydrocompaction, or slope failure when wetted or loaded. Deposit is a potential source of sand and gravel.

Qac **Alluvium and colluvium, undivided (Pleistocene)** — Tan to reddish-brown, unsorted to poorly sorted, moderately to poorly stratified, pebble, cobble, and boulder gravel derived from the erosion of a partially deteriorated butte in sec. 17, T. 11 S., R. 64 W. Clasts are subangular to subrounded and slightly weathered. Clast lithology consists of buff-colored Wall Mountain Tuff, white to tan arkosic sandstone, and minor amounts of milky quartzite, blue quartzite, and granite presumably derived from previously existing outcrops of Castle Rock Conglomerate and Dawson Formation. Matrix typically consists of quartz and feldspar sand from disaggregation of the these units. Alluvium is typically composed of poorly to well sorted, stratified, interbedded, pebbly sand, sandy silt, and sandy gravel. Colluvium may range from unsorted, clast-supported, pebble to boulder gravel in a sandy silt matrix to matrix-supported, gravelly, clayey, sandy silt. Maximum thickness of the unit is approximately 20 feet.

Qae **Alluvial and eolian deposits, undivided (Holocene to late Pleistocene)** — Light-brown to reddish-brown, very poorly sorted silt, sand, and rare gravel that locally, includes small pebbles. The unit contains channelized sand and pebbly gravel interbedded with windblown sediments, typically deposited as sheet sands. Consequently, attempts to map a wind-blown facies of this unit as an eolian deposit proved inconsistent. Maximum exposed thickness of the unit locally exceeds 15 feet.

Qsw **Sheetwash deposits (Holocene to late Pleistocene)** — Light-grayish-brown, pale-brown, to brown, poorly sorted sand, silty and clayey sand, and minor amounts of gravel including some cobbles and small boulders. Unit consists chiefly of material transported on moderate slopes (~10 percent grade) by sheet flow but also includes some sediment delivered by runoff in rills and minor gullies. The abundance of sand-size grains and pebbles in this unit make it a grüs-like deposit. The unit has been largely derived from disintegration of the Dawson Formation, but a smaller amount may have been derived from the older Quaternary alluvial deposits. Maximum exposed thickness is 20 feet.

EOLIAN DEPOSITS — Silt, sand, and clay deposited by wind on level to gently sloping surfaces.

Qes **Eolian sand (Holocene to late Pleistocene)** — Yellowish-brown to tan, fine- to coarse-grained, frosted sand and silt deposited by wind and preserved on a level to gently northeast sloping surface north of Kiowa Creek and in a depression approximately ½ mile south of Rattlesnake Butte. Typically this unit is faintly stratified and non-cohesive; dune forms are not present. The unit is likely deposited as a sandsheet by winds capable of moving pebble-sized clasts (**Figure 8**). Eolian sand is moderately compacted, easily excavated, and drains well. Unit locally exceeds 15 feet in thickness.

Qlo **Loess (late Pleistocene)** — Brown to light-brown sandy silt and silty, very fine sand deposited by wind. Degree of soil development suggests a late Pleistocene age. The unit occurs in small isolated locations along the ridge between the upper Kiowa Creek watershed and the upper Black Squirrel watershed and lacks topographic expression. Contains minor coarse granules of quartz and clay particles. Thickness ranges from 1 to 5 feet. Unit may be subject to hydrocompaction where bulk density is low.

Figure 8. Eolian sand deposit about ½ mile south of Rattlesnake Butte. The sand at this location is deposited as a sheet by high winds that can move pebble-sized clasts across the ground surface. UTMX: 542204.9 UTMY: 4323292.1.

MASS-WASTING DEPOSITS — Earth materials that were transported downslope primarily by gravity and not within or under another medium, such as water or ice. Some of these deposits have moved by creep, which is a slow, gradual, progressive downslope movement of earth materials.

Qc **Colluvial deposits, undivided (Holocene to late Pleistocene)** — Fragments of bedrock that have been transported downslope primarily by gravity. Colluvium consists of gray to tan to yellowish-brown, poorly sorted, clast-supported, pebble to boulder gravel in a sandy matrix to matrix-supported, gravelly, clayey, sandy silt. Unit contains angular to subangular clasts, and is weakly stratified.

Colluvium of large cobble- and boulder-sized rock fragments may include rockfall debris. Deposits locally exceed 25 feet in thickness. Areas mapped as colluvium are susceptible to future rockfall events

Qcwm Colluvium of Wall Mountain Tuff (Holocene to late Pleistocene) — Two small knobs southeast of the intersection of Meridian and Murphy Roads, sec. 6, T. 12 S., R. 64 W., have an abundance of Wall Mountain Tuff cobbles and small boulders littering the slope that are mostly angular, suggesting very close proximity to a source. Undisturbed outcrops of Wall Mountain Tuff (Twm) or Castle Rock Conglomerate (Tcr) that could be a source of the fragments, could not be located nearby.

Qls Landslide deposits (late Holocene) — Heterogeneous deposits consisting of unsorted and unstratified clay, silt, sand, and angular, cobble- to boulder-sized rock fragments. Unit includes rotational slides that are the result of the undermining of slopes by active stream channels. There are very few landslide deposits mapped in the area; however, along the active steam channels are many cut banks that appear to be landslide head scarps. Because the banks are typically Dawson Formation arkose, the resulting landslide deposit becomes disaggregated once it is mobilized by water. Landsliding is likely more prevalent than the limited mapped deposits would suggest.

Landslide areas are subject to future movement during episodes of heavy rain or snowfall or may be reactivated by human-made disturbances such as cutting of slopes for roads, housing developments, irrigation systems, and septic systems. Landslide deposits are prone to settlement when loaded or wetted. Maximum thickness of landslide deposits in the quadrangle locally exceeds 20 feet.

BEDROCK DEPOSITS

Tcr Castle Rock Conglomerate (upper Eocene) — The Castle Rock Conglomerate is a pebble, cobble, and boulder arkosic conglomerate composed predominantly of subround to round fragments of pink and gray granite, quartz, and feldspar with subordinate amounts of gneissic metamorphic rocks, quartzite, red sandstone, welded tuff, and chert in a coarse to very coarse sand matrix of quartz and feldspar grains (**Figure 9**).
The distinguishing characteristic of this unit is the presence of angular to subangular cobble- to boulder-size blocks of gray, brownish-gray, maroon, or lavender-gray welded tuff that have been eroded from deposits of the Wall Mountain Tuff (**Figure 10**). The Castle Rock Conglomerate is younger than the Wall Mountain Tuff, which has been dated at about 36.7 mybp (McIntosh and others, 1992; McIntosh and Chapin, 1994, 2004). It must be older than the end of the Eocene (33.5 mybp; **Appendix 1**) since it contains bones of titanotheres (late Eocene, K.R. Johnson, Denver Museum of Nature and Science, written commun. 2002). The Castle Rock Conglomerate reaches a thickness of up to 60 feet in the northwestern part of the mapped area.

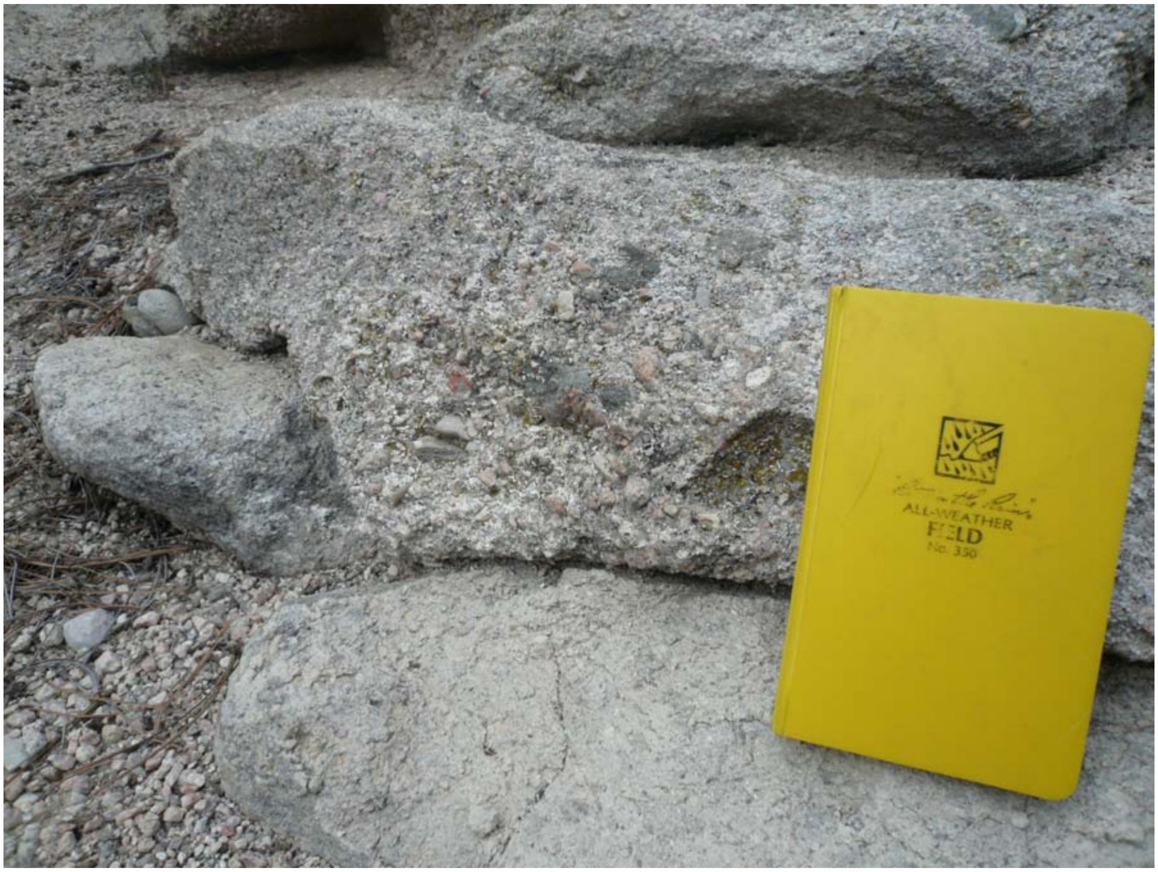


Figure 9. Photograph showing the distinct erosional contact between the Castle Rock Conglomerate and the underlying Dawson Formation. Both units are arkosic; however, the Castle Rock Conglomerate is coarser-grained and contains clasts of the 36.7 m.y. old Wall Mountain Tuff (**Figure 10**). This location is one of the best-preserved locations on the Colorado Piedmont where the contact between the two units is visible. UTMX: 536035.0 UTMY: 4327336.0.

Figure 10. Two gray, cobble-sized fragments of Wall Mountain Tuff within the Castle Rock Conglomerate. UTMX: 536044.5 UTMY: 4327302.5.

The Castle Rock Conglomerate was deposited within a paleovalley or series of paleovalleys on an erosion surface cut into the upper Dawson Formation, conglomerate of Larkspur Butte, and Wall Mountain Tuff. Determining the overall dip of the Castle Rock surface is difficult due to the multiple depositional and erosional levels that comprise the unit. In general, within the mapped area, the surface slopes gently to the north from elevations of 7,420 to 7,360 feet. However, overall, the paleocurrent directions measured from channels within the unit predominantly trend to the south-southeast in the small area of exposures in the mapped area (**Figure 11**). Morse (1985) also noticed the northerly dip of the Castle Rock Conglomerate and suggested that the slight tilt was the result of post-depositional uplift of the southern part of the Denver Basin.

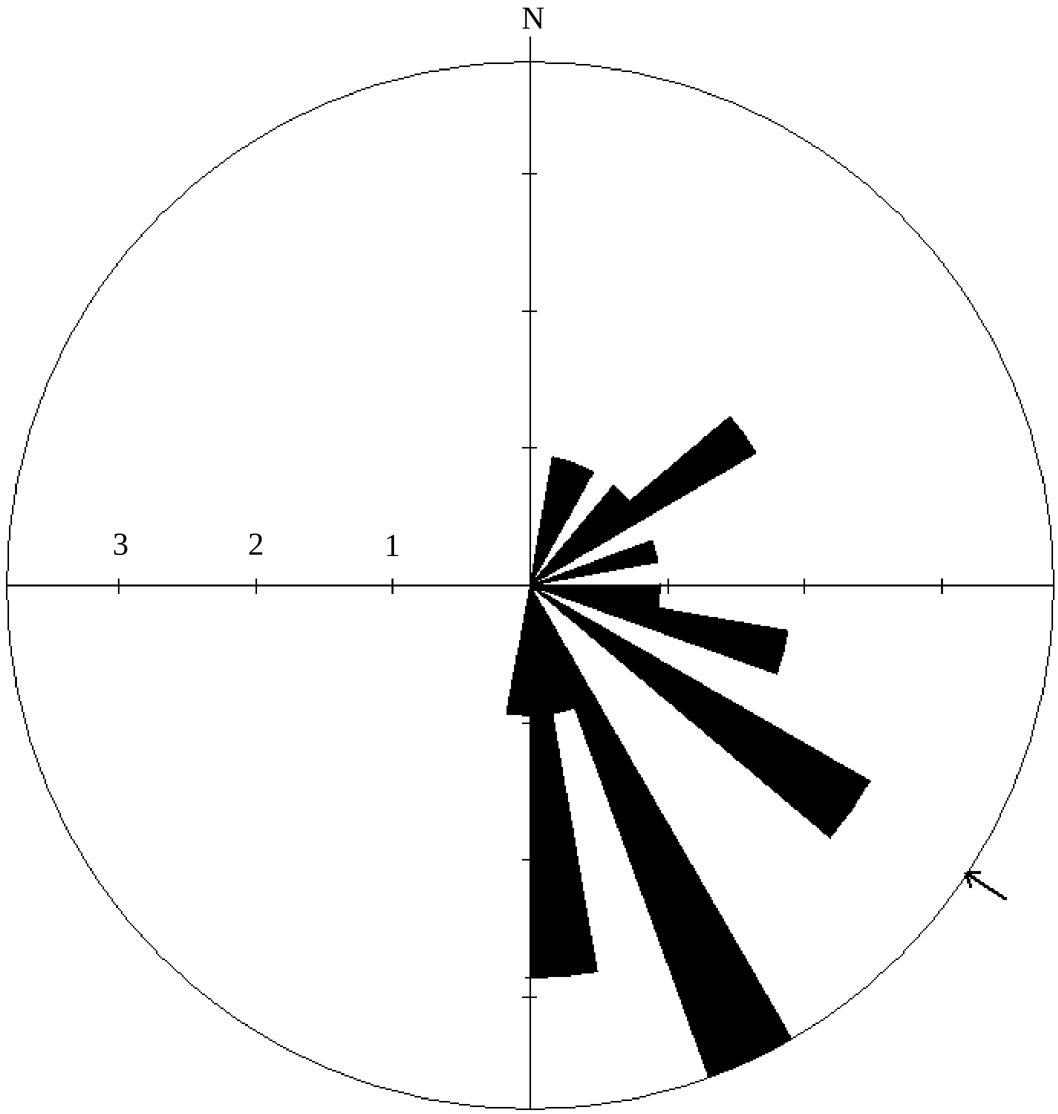


Figure 11. Rose diagram plot of paleocurrent directions within the Castle Rock Conglomerate from the outcrops in secs. 1 and 12, T. 11S, R. 65 W. The dominant direction within the Eastonville quadrangle is south-southeast, the average direction is southeast (black arrow) with a lesser population of measurements trending northeast. 21 total measurements.

The Castle Rock Conglomerate is variably permeable, in some places well drained and in others supporting local ephemeral ponds. It has good foundation characteristics. Excavation may be difficult, even though the unit is friable and easily eroded on weathered outcrops. Rock fall from cliffs at the edges of buttes of this unit poses a possible slope-stability hazard in some areas, especially where the unit rests on easily erodable sandstone or sandy mudstone beds in the Dawson Formation.

Twm **Wall Mountain Tuff (upper Eocene)** — The Wall Mountain Tuff is a moderately to densely welded tuff of rhyolitic composition (Izett and others, 1969; Epis and Chapin, 1974). It is generally light to medium-brown when fresh but is locally medium gray in a few of the more densely welded outcrops. On weathering, the tuff may be light brown, lavender, pink, reddish brown, or maroon. The fine-grained groundmass usually contains small phenocrysts of biotite and sanidine, and occasionally near the base may contain quartz grains and small arkose fragments ripped up from the underlying strata. The Wall Mountain Tuff was emplaced in this area as an ash-flow that was hot enough that the ash compacted and welded into a viscous plastic-like consistency after emplacement. In places on the Colorado Piedmont, the welded ash flowed and developed flow banding before cooling and solidifying. The Wall Mountain Tuff has been dated to about 36.7 mybp by McIntosh and others (1992) and McIntosh and Chapin (1994, 2004). The Wall Mountain ash flow was erupted from an unidentified location west of the upper Arkansas River valley between Salida and Buena Vista, in the Sawatch Range (Epis and Chapin, 1974; McIntosh and Chapin, 2004).

The Wall Mountain Tuff is about 3-6 feet thick in the small erosional remnant at the south end of Rattlesnake Butte, sec. 25, T. 11 S., R. 64 W., where it rests on the Dawson Formation at about 7,390 feet in elevation. The Wall Mountain Tuff breaks into angular blocks and slabs as it weathers, and makes poor outcrops. Below the weathered zone, however, the unit should be expected to be fractured into larger blocks, generally 3 to 4 feet in size, and may be difficult to excavate.

Dawson Formation (Eocene to Upper Cretaceous) — Previously, the Dawson Formation has been divided into upper and lower parts in the Colorado Springs area (Thorson and others, 2001; Thorson and Madole, 2002) with the lower part being entirely Upper Cretaceous in age and composed almost exclusively of andesitic debris and the upper part being a mixture of andesitic and arkosic material deposited during the Late Cretaceous and early Tertiary. The upper part of the Dawson Formation is divided into facies unit one ($TKda_1$), facies unit two ($TKda_2$), facies unit three ($TKda_3$), facies unit four ($TKda_4$), and facies unit five ($TKda_5$). A sixth facies unit has been recognized locally in the Cherry Valley School (Thorson, 2004b) and Larkspur quadrangles (Thorson, 2005a). These facies units are differentiated on the relative proportions of andesitic and arkosic material, on the thickness and style of coarse-grained bedding units, and on the relative proportion of fine-grained claystone and siltstone versus coarser-grained beds of sandstone, arkose, pebbly arkose, and pebble conglomerate.

Thorson (2011) renamed these units in a manner reflecting earlier mapping in the basin. He renamed the entire Dawson Formation, as used in previous 1:24,000-scale maps, the Dawson Group which is subdivided into different members or formations as shown in **Figure 12**. He named the lower andesitic unit (Kda) the Pikeview Formation and the lower arkosic facies unit found near the mountain front (TKda$_1$) as the Pulpit Rock Formation (TKpr). A second andesitic facies unit sourced from the south that has been mapped as TKda$_2$ would now be called the Jimmy Camp Formation (TKjc) while the facies unit mapped as TKda$_3$ containing mixed lithologies would mapped as the Black Squirrel Formation (Tbs). Arkosic facies units TKda$_4$ and TKda$_5$ are combined as the Dawson Arkose (Tda).

For consistency with other CGS 1:24,000-scale maps, this map retains the former facies designations for mappable sub-units of the Dawson Formation. Only facies unit TKda$_{5,}$ or the Dawson Arkose, is present at the surface in the Eastonville quadrangle.

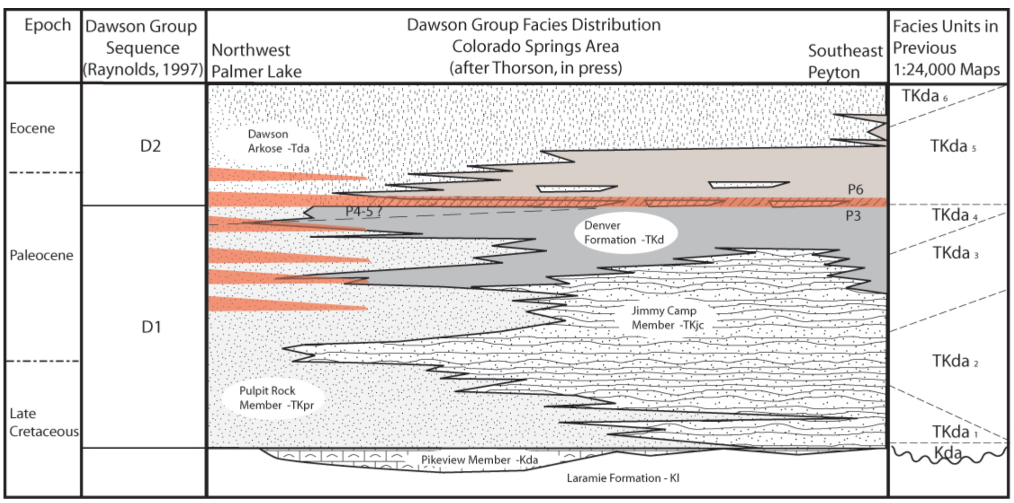


Figure 12. Stratigraphic cross-section showing the relationships of facies and nomenclature used in previous CGS 1:24,000-scale maps with the new nomenclature proposed by Thorson in his compilation of CGS mapping in the southwestern Denver Basin (2010, in preparation), and Denver Basin sequences proposed by Raynolds (2002). Light stipple pattern indicates arkosic coarser-grained sediments and wavy stippled pattern indicates andesitic material. Shading indicates a decrease in overall grain size and orange shading denotes red-colored paleosols.

In the Denver area, the nomenclature for the comparable Upper Cretaceous to Eocene strata mapped as Dawson Formation in the Colorado Springs area is quite variable. Maberry and Lindvall (1972, 1977) used Dawson Arkose and Denver Formation, with the Dawson Arkose younger than, and stratigraphically above, the Denver Formation. Trimble and Machette (1979b) changed terminology and used “Dawson and Arapahoe Formations” and “Denver Formation” of comparable Paleocene to Upper Cretaceous age. Bryant and others (1981) used Arapahoe Formation and restricted this unit to Upper Cretaceous age, while Dawson Arkose and Denver

Formation were retained. On the map of Bryant and others (1981), the Dawson Arkose is designated as Eocene, Paleocene, and Upper Cretaceous, the Denver Formation is described as Paleocene and Upper Cretaceous, and the formations are shown as interfingering lateral equivalents of each other.

In an attempt to simplify the nomenclature confusion, Raynolds (2002) defined two unconformity-bounded sequences, D1 and D2. The D2 sequence contains Maberry and Lindvall's (1972, 1977) Dawson Arkose, above the regional Denver Basin paleosol, but only part of Bryant and others' (1981) Dawson Arkose. All the rest of the Upper Cretaceous through Paleocene strata of the Denver Basin are included within the D1 sequence. The recognition of the D1 and D2 sequences is a very useful addition to the understanding of the depositional sequence of Upper Cretaceous through Eocene strata in the Denver Basin. This nomenclature has been widely adopted (Raynolds and Johnson, 2002; Nichols and Fleming, 2002; Obradovich, 2002; Wilson, 2002; Kelley, 2002; Farnham and Kraus, 2002; Kelley and Blackwell, 2002; Woodward and others, 2002; Carpenter and Young, 2002; Hicks and others, 2003; Wheeler and Michalski, 2003; Barclay and others, 2003; Ellis and others 2003; Johnson and others, 2003; Hutchinson and Holroyd, 2003; Eberle, 2003; Raynolds and Johnson, 2003).

However, paleontological or other age control is necessary for the recognition and application of the D1-D2 nomenclature. Recent mapping along the west side of the Denver Basin (Thorson and Madole, 2002; Thorson, 2003a, 2005a; Morgan and others, 2004, 2005) has shown that there are multiple paleosol horizons in the Dawson Formation (**Figure 12**) and that no single paleosol exposure clearly defines the D1-D2 boundary without age confirmation. Nonetheless, facies unit $TKda_5$, or the Dawson Arkose, of this report appears to be consistently equivalent to Raynolds' D2 sequence.

Geophysical logs of the Denver Basin Group in the abandoned petroleum test well just outside the northeast corner of the quadrangle (SE SE sec. 36 T. 10S R. 65W; Norsk Hydro, Zion State #1.), indicate that the Denver Basin Group is as much as 2,350 feet thick in this area. Cross-sections prepared using correlations of geophysical logs from water wells, oil and gas wildcat wells, and mineral exploration boreholes in the area indicate that thins to about 1,600 feet in a southeast direction due to erosion and stratigraphic thinning away from the mountain source.

$TKda_5$-Facies unit five (middle? to early Eocene) — Facies Unit $TKda_5$, or the Dawson Arkose, contains many lithofacies with three dominating in the Eastonville quadrangle: 1) thick light-colored cross-bedded arkosic sand; 2) beds of gray to olive-green and brown sandy mudstone; and 3) beds of nearly white massive and unstructured sand mixed with silt and clay. Other less common lithofacies to note include friable well-sorted medium to fine grained quartzose sand and dark lignitic mudstone. The unit was deposited in an environment characterized by braided streams emerging into the basin from the active Laramide range front to the west and is at least 900 feet thick in the quadrangle. Erosion has removed its top and approximately 700 feet of its stratigraphic thickness are exposed in the quadrangle between an elevation of 6,800 ft MSL at the southeast corner where Black Squirrel Creek exits the quadrangle at Highway 24 and 7,500 feet at near its headwaters to the west. The unit appears to correlate with Raynolds' (2002) D2 sequence and with the Dawson Arkose of Mayberry and Lindvall (1972, 1977), but the unit does not correlate specifically with any of the units used by Bryant and others (1981).

Thick-bedded to massive, cross-bedded, light-colored arkose and pebbly arkose predominates, but the unit also contains common beds of white to light-tan, fine- to medium-grained feldspathic, cross-bedded friable sandstone (**Figure 13**). These sandstones tend to be poorly sorted, have high clay contents, and are often thin or medium bedded; wavy bedding and ripple cross-laminations are common in the finer-grained parts. Individual sandstone bodies often display distinctive lenticular channel morphologies incised into older layers of sandstone or mudstone (**Figure 14**). Channels trend predominantly to the northeast in this part of the basin (**Figure 15**).

Figure 13. Cross-bedded TKda$_5$ arkose in a cut-bank of Black Squirrel Creek. UTMX: 540489.5 UTMY: 4319482.1.

Figure 14. TKda$_5$ channel sands incised into older mudstone layers in a cut-bank of Black Squirrel Creek. Sand grades up into sandy mudstone that contains pedogenic structures. A thin deposit Qa$_3$ alluvium is shown on top. UTMX: 533734.0 UTMY: 4318095.7.

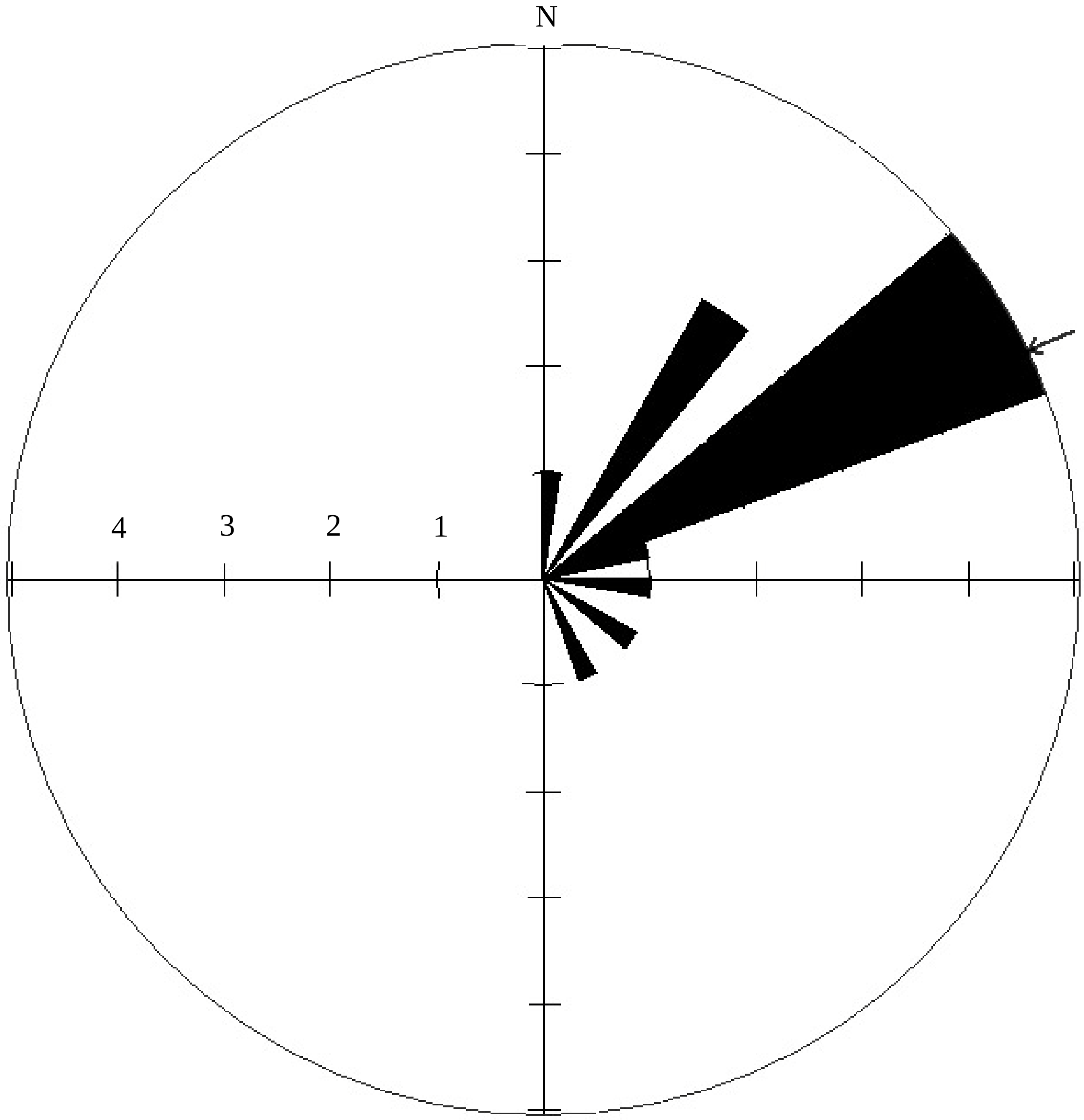


Figure 15. Rose diagram plot of paleocurrent directions within unit $TKda_5$ using paleochannel orientations. Predominant direction is to the northeast away from the modern-day Pikes Peak highlands. The dominant direction and average direction within the Eastonville quadrangle is east-northeast (black arrow) with a lesser population of measurements trending north and southeast. 18 total measurements.

Clast composition in the arkose reflects a source in the Pikes Peak highlands to the west. Grains are made up almost entirely of quartz, tan to pink perthitic feldspar, sodium feldspar that is altered to white clay to varying degrees, and fragments of granite. **Figure 16** is a plot that shows that there is little variation in composition of the arkose with elevation in a profile along Black Squirrel Creek. Grain size distribution within the arkose channel deposits are similar throughout the same section; although a slight increase in the percentage in coarse sand higher in the section is evident. **Figure 17** is a cross-section through water wells along the southern edge of the quadrangle roughly parallel to Black Squirrel Creek constructed using resistivity logs that shows the predominance of high-resistivity layers of arkose throughout the section. For this reason the entire stratigraphic thickness exposed at the surface in the quadrangle is assigned to $TKda_{5,}$ or the Dawson Arkose.

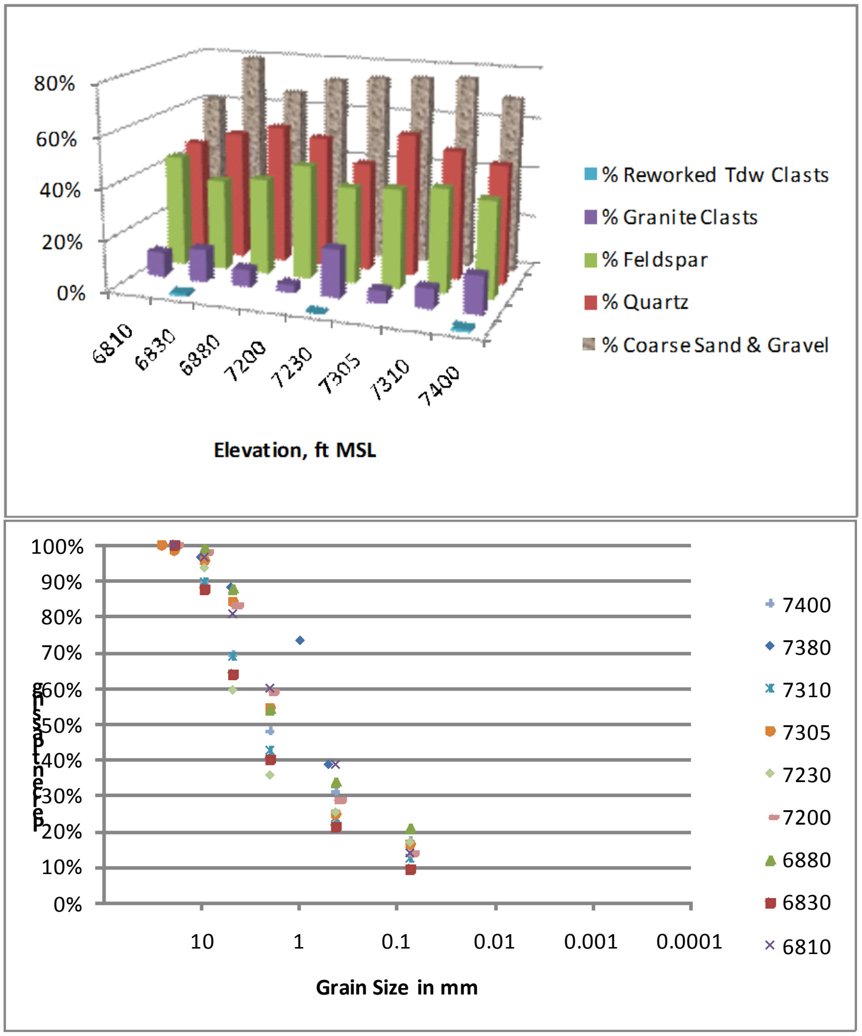


Figure 16. Top graph shows relative composition of clasts within the coarse-grained fluvial deposits of unit $TKda_5$ (Dawson Arkose) by elevation from a profile along Black Squirrel Creek. Similar composition throughout reflects a common source from the Pikes Peak granitic highlands to the west. Lower graph shows grain-size distribution plots along the same profile illustrating similar size distributions throughout the section.

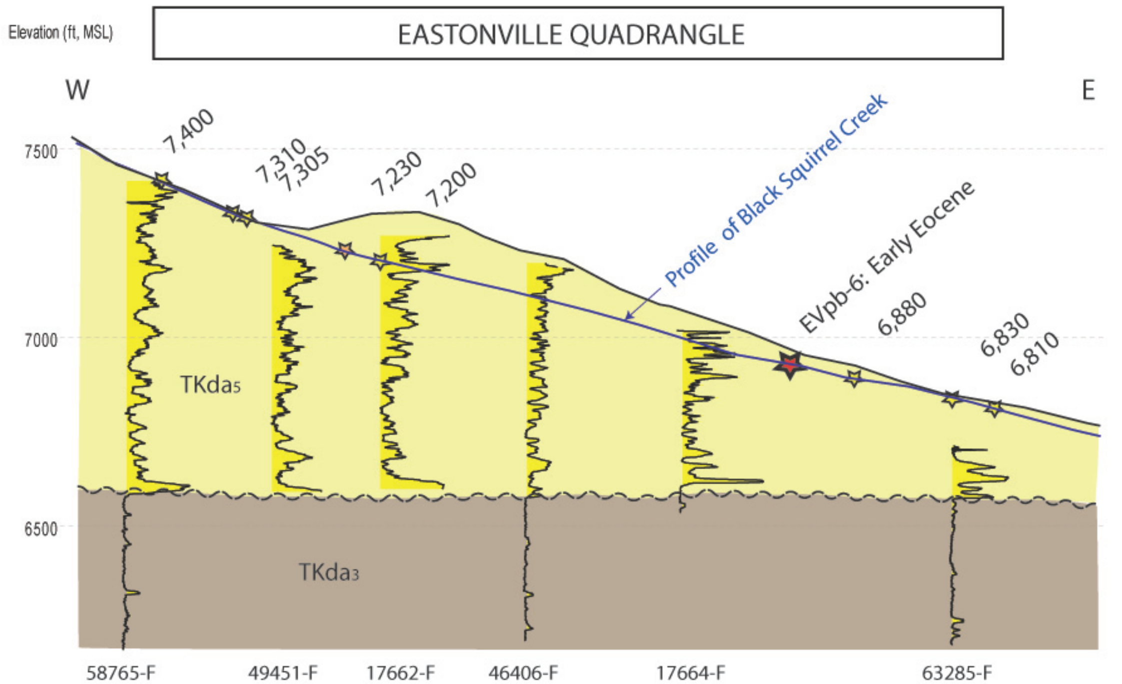


Figure 17. Cross-section constructed using resistivity logs from water wells along the southern edge of the quadrangle parallel to Black Squirrel Creek. Curve deflections on the logs to the right shaded yellow indicate higher resistivity due to coarser grain size and lack of clay in the matrix. Logs indicate the predominance of arkose throughout the section of $TKda_5$ exposed at the surface within the Eastonville quadrangle. Locations of arkose samples used in **Figure 14** are indicated by yellow stars along with lignitic mudstone sample EVpb-6, red star, that yielded an Early Eocene pollen date. The base of $TKda_5$ is indicated by the wavy line and is at least 200 feet below the surface at the lowest elevation of the quadrangle. Resistivity values below this contact are considerably lower reflecting higher clay content of unit $TKda_3$.

The degree of cementation is variable and, in places the unit can be quite indurated with silica cement forming prominent cap-rock of buttes and mesas (**Figure 18**). Otherwise, the unit is somewhat friable held together with weak cement and interstitial clay weathering into gently rolling uplands above the Quaternary alluvium and gravel deposits.

Figure 18. Indurated $TKda_5$ forming caprock within Homestead Regional Park. UTMX: 541352.1 UTMY: 4325219.0.

Fine-grained deposits of sandy mudstone comprise the second lithofacies of $TKda_5$ exposed at the surface of the Eastonville quadrangle. Color varies from light gray to olive-green and brown with the lighter shades reflecting a higher silt content. Where clay content is high, desiccation cracks form upon drying. Mudstone often occurs at the top of channel sands with a gradational contact to the coarser-grained fluvial material below. It is usually internally structureless, although, irregular fractures exhibiting pedogenic slickensides are visible. Coarse-sized grains of sand floating in the silt and clay matrix are common in the mudstone. Fractures are commonly stained with iron oxide producing a mottled appearance. Mudstone becomes more prevalent in an eastward direction away from the mountain source as well as deeper in the section.

Organic content is rare in the mudstone deposits; although lignitic mudstone from the south side of Black Squirrel Creek west of Elbert Road (SE SE sec 10, T. 12 S, R. 64 W; 540,217N: 4,318,597E) did yield an Early Eocene pollen age. Large pieces of lignite displaying original wood structure were also found at a slightly lower stratigraphic position than the lignitic mudstone in the channel of Black Squirrel Creek and the tributary entering from the north west of Elbert Road (NE SW sec 11, T. 12 S, R. 64 ; UTMX: 540813, UTMY: 4318854). Nodules of marcasite also occurred in the same interval with the large pieces of lignite.

Beds of nearly white massive and unstructured sand mixed with silt and clay comprise the third notable lithofacies of $TKda_{5.}$ White coloration and better induration often make these beds stand out along stream courses and road cuts (**Figure 19**). White coloration is due to a high content of clay and relative lack of feldspar grains with quartz predominating. Clay may be an alteration product of the original feldspar grains. This unit lacks internal structure and sand grains can be matrix supported. Origin is either from pedogenic processes or deposition by debris flows as evidenced by the material filling desiccation cracks and burrows.

Figure 19. Massive white sand mixed with silt and clay forming a resistant cap of a cut-bank on Black Squirrel Creek south of Latigo Road in sec. 8, T. 12 S, R. 64 W; UTMX: 535621 UTMY: 4318304. Unit is massive with no internal structure and is seen filling possible desiccation cracks and burrows in the underlying mudstone.

$TKda_5$ is generally permeable, well drained, and has good foundation characteristics. Excavation may be difficult even though the arkoses are friable and easily eroded on weathered outcrops. The clay content of the finer-grained parts of the facies unit produces soils that have high swell potential.

TKdu **Dawson Formation, undivided (Upper Cretaceous to Eocene)** — Undivided Dawson Formation possibly including facies units one through facies unit four of the upper Dawson Formation (**Figure 12**); shown on cross section only.

STRUCTURAL GEOLOGY

Between 40 and 80 mybp, the Laramide Orogeny resulted in the formation of basement-cored uplifts throughout Colorado and adjacent states, including the Front Range of central Colorado. As the basement was exposed in fault-bounded, upthrown blocks, synorogenic arkosic sediments of the Dawson Arkose were rapidly deposited from alluvial fans and braided streams along the eastern mountain front. The subsiding Denver Basin to the east of the uplifted range front acted as a trap for this debris (Tweto, 1975; Epis and others, 1980). Portions of these formations became important aquifers in the Denver Basin.

The structural geology of the Eastonville quadrangle largely consists of gentle regional dips of the southern margin of the Denver Basin, primarily within the Dawson Formation, of typically 2 to 4 degrees to the north-northeast. Strike and dip symbols are not abundant on the map because of poor outcrop exposures. Many bedding surfaces, such as cross-beds or channel scour surfaces were inclined at the time of deposition and are unlikely to be representative of true structural attitudes. Strike and dip measurements shown on the map were made on thin-bedded, fine-grained strata that were more likely deposited in a near-horizontal orientation. **Figure 20** is structural contour map of the base of the Dawson Arkose, or $TKda_5$ based on interpretation of resistivity logs from water wells, oil and gas wildcat wells, and mineral exploration boreholes. Contours indicate a curved surface dipping to the north at less than one degree with the basin axis passing under the northeastern corner of the quadrangle.

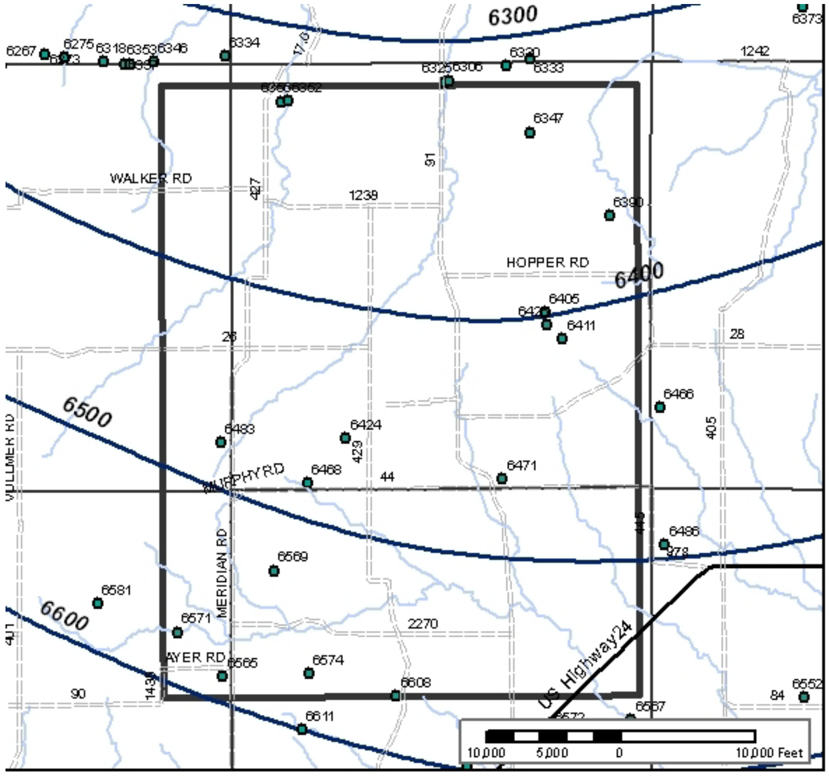


Figure 20. Structural contour map of the base of the Dawson Arkose based on interpretations of resistivity logs from water wells, oil and gas wildcat wells, and mineral exploration wells. Contour interval is one hundred feet and surface dips to the north with the northwest-trending basin axis passing beneath the quadrangle.

MINERAL RESOURCES

One test well for oil and gas was drilled within the quadrangle; however, it was not productive. No radioactive mineral resources have been reported from the quadrangle (Nelson-Moore and others, 1978). Sand and gravel are presently the most significant mineral resources in the Eastonville quadrangle; however, no active or inactive permitted pits are located within the mapped area (U.S. Geological Survey, 2005) although, the potential still exists for the development of new sand and gravel operations in the significant alluvial deposits. **Figure 21** shows the location of the lone oil and gas test well.

OIL AND GAS

The Colorado Oil and Gas Conservation Commission has the completion record for the only petroleum test well in the Eastonville quadrangle. Formation tops from the completion records and well logs are shown in **Table 1**. The nearest oil production is about 25 miles north of the quadrangle, northeast of the town of Kiowa in Elbert County.

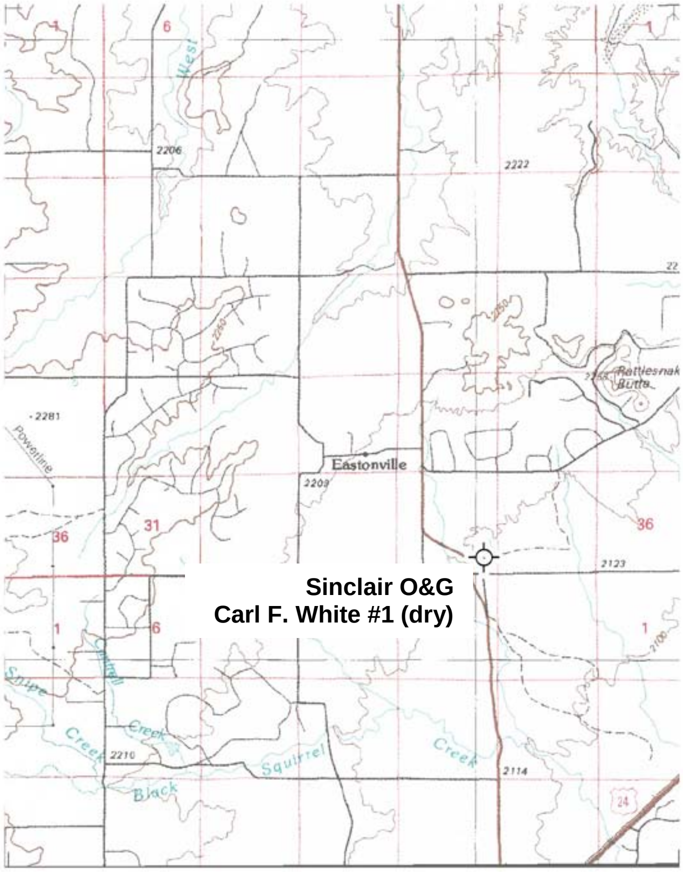


Figure 21. Location of the dry, Carl F. White #1 well within the Eastonville quadrangle.

Table 1. Petroleum test well within the Eastonville quadrangle. Depths for each formation are the depth to the top of the specified unit, in feet.

Well Name	Operator	Date Drilled	Location	Log Top (ft)	Total Depth (ft)	Elevation (ft)
C F White #1	SINCLAIR OIL & GAS CO.	3/23/1955	SE 1/4 SE 1/4 Sec. 34, T. 11 S., R. 64 W	PIERRE 0 NIOBRARA 7474 FORT HAYS 7845 CODELL 7890 CARLILE 7904 GREENHORN 7952 GRANEROS 8168 D SAND 8256 J SAND 8298 SKULL CREEK 8398 DAKOTA 8438 MORRISON 8522	8535	7024

SURFACE AND GROUND-WATER RESOURCES

Surface Water

The Eastonville quadrangle straddles the Palmer Divide, which follows the northeast trending ridgeline just north of the townsite of Eastonville in the center of the map. North of this divide, streams are tributary to the South Platte River and include West Kiowa Creek, the main stem of Kiowa Creek at its headwaters, and West Bijou Creek at its headwaters. South of the divide, streams are tributary to the Arkansas River and include the main stem of Black Squirrel Creek near its headwaters, which is just west of the quadrangle in the Black Forest, and many of its tributaries.

All streams north of the divide are classified as intermittent in the U.S. Geological Survey National Hydrography Dataset (U.S. Geological Survey, 2011) and have dry, sandy streambeds that flow only in direct response to thunderstorms, spring snowmelt, or prolonged periods of rainfall. South of the divide all streams are also classified as intermittent with the exception of the main stem of Black Squirrel Creek, which is classified as perennial. These streams are not reliable and ground water is the dominant water source, although four ditches in the Black Squirrel watershed have adjudicated water rights for irrigation.

Ground water within the Eastonville quadrangle is statutorily classified as “designated ground water” and is administered by the Colorado Ground Water Commission. This distinction means that the ground water is not tributary to a continuously flowing natural stream and is the principal source of water. Designated ground water is administered by watershed basins and the area north of the Palmer Divide falls within the Kiowa-Bijou designated ground-water basin and the area south of the divide falling in the Upper Black Squirrel designated ground-water basin. Each basin has a management district that can adopt specific rules governing ground-water withdrawals and assist in ground water administration within their boundaries.

Ground Water

Ground water provides a primary water source for domestic and agricultural purposes throughout the Eastonville quadrangle and can be found in both the regional semi-consolidated Denver Basin bedrock aquifers and the local Quaternary alluvial aquifers along the streams that run through the quadrangle. The following sections describe each of these hydrogeologic units and provide information about general hydrogeologic characteristics of the units gathered from available literature. The scope of this discussion is limited to providing a general description of the ground-water resources that might be available within the quadrangle; further details, such as specifics about water quality, surface water, and current water level data can be obtained from available literature. Additional information on ground water in Colorado is in the CGS Ground

Water Atlas of Colorado (Topper and others, 2003) and the Citizen's Guide to Denver Basin Groundwater (Topper and Raynolds, 2007).

Denver Basin Bedrock Aquifers

Semi-consolidated sedimentary rocks within the Laramide Denver structural basin comprise the Denver Basin bedrock aquifer system. As defined by the outcrop of the Fox Hills Sandstone, the regional aquifer system covers an area of approximately 6,700 square miles spanning much of the region between Denver and Colorado Springs and supplies ground water for domestic, commercial, municipal, and agricultural purposes throughout much of this urbanized area. It is a layered multi-aquifer system including fluvial sediments of the Dawson Formation that accumulated within the structural basin as it formed, as well as the older Laramie Formation and Fox Hills Sandstone deposited along the coast of the Cretaceous Interior Seaway. Specific hydrogeologic characteristics of the aquifers are summarized in the Ground-Water Atlas of Colorado (Topper and others, 2003). However, the sequence consists of interbedded sandstone, conglomerate, siltstones, and shale with coal present locally throughout the sequence. Ground water is produced from the more porous and permeable sandstone layers of the sequence.

For purposes of allocating this vital ground-water resource, the Denver Basin bedrock aquifer system has been subdivided by statute into the Dawson, Denver, Arapahoe, and Laramie-Fox Hills aquifers. Separation of the aquifers is based on correlation of laterally extensive shale dominant confining layers identified by the U.S. Geological Survey and the Colorado Division of Water Resources (DWR) on borehole geophysical logs, primarily gamma-ray and resistivity logs (Robson and Banta, 1987). Water rights allocations and well permits are granted based on these designations. DWR has prepared a series of structural contour maps showing the elevation of the top and base of each of the Denver Basin aquifers based on the correlations of the confining layers separating the aquifers. These maps are part of the Denver Basin rules (http://www.water.state.co.us/pubs/rule_reg/denverbasin.pdf) and are used for determining well depths based on location.

Positioned at the structural axis of the basin (**Figure 20**), the entire Eastonville quadrangle is underlain by the Denver Basin bedrock aquifer system and all four aquifers are present and are nearly flat-lying. Only the top-most Dawson aquifer is exposed at the surface and this aquifer is generally unconfined. The other three confined aquifers occur at varying depths depending on location and topographic elevation with the following ranges for the depths estimated from the Denver Basin Rules maps: Denver aquifer top between 200 and 1200 feet, Arapahoe aquifer top between 1100 and 1900 feet, Laramie-Fox Hills aquifer top between 1900 and 2700 feet.

Characteristics of the Dawson, Denver and Arapahoe aquifers vary considerably depending on proximity to the mountain front to the west. These three aquifers originated as alluvial fans deposited by streams originating from the active Laramide uplift. Consequently, coarse-grained sandstone deposits prevail on the west side of the basin and thin to the east where fine-grained mudstone predominates (**Figure 22**). The Eastonville quadrangle lies in the transition from where the finer-grained, mudstone sediment dominates over the coarser-grained, more favorable alluvial fan deposits. In contrast to the highly variable fluvial deposits of the Dawson Group, the fluvial characteristics of the deeper Fox Hills Sandstone are more consistent across the region.

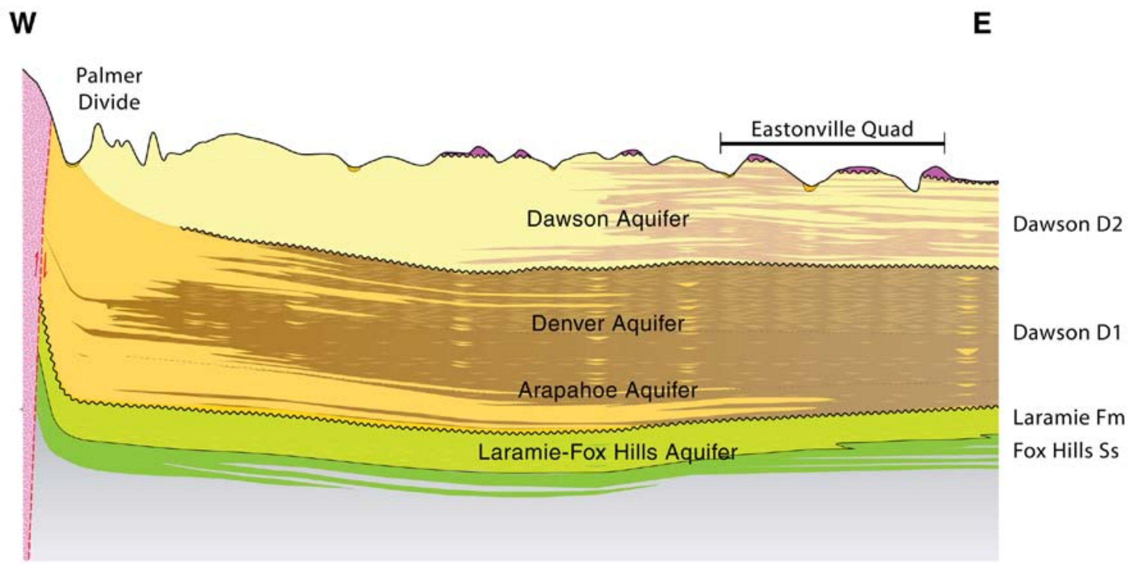


Figure 22. West to east cross-section of the Denver Basin bedrock aquifers at the north end of the Eastonville quadrangle using resistivity logs from water wells, wildcat oil and gas wells, and mineral exploration boreholes. Depositional patterns in the Dawson Group sediments display considerable variation as more permeable coarse-grained sandstone predominates on the west side of the basin, as indicated by higher resistivity and yellow shading, thinning eastward into the basin where finer-grained mudstone prevails, as indicated by darker shading and lower resistivity. The Fox Hills Sandstone at the base is the only aquifer that exhibits consistency across the basin. The Eastonville quadrangle is at the east extent of the prominent alluvial fan deposits found along the west edge of the basin (Dechesne and others, 2011).

Recharge to the upper-most bedrock aquifer comes from infiltration of precipitation in the uplands of the Palmer Divide, primarily the Black Forest region to the west. Other recharge comes from irrigation return flows and individual on-site waste water treatment system leach fields. Springs and small marshy areas, *"jelly wobbles",* along valley slopes near the headwaters of Kiowa Creek are probably local points of discharge where more permeable fluvial channels imbedded in less permeable mudstones in the Dawson aquifer have been truncated by modern erosion.

According to permit data maintained by DWR, nearly all water wells in the Eastonville quadrangle tap both the Dawson and Denver aquifers. As of July 2006 over 2,200 permits were on file at DWR within the quadrangle; many of these permits have never been drilled or never had completion reports filed. Of the total permits, 1,256 have listed completion depths or water levels which indicates that the permits correspond to in-place wells. Colorado Springs is listed as operating a Laramie-Fox Hills aquifer well located in section 17, T. 12 S, R. 64 W. and an Arapahoe aquifer well in section 36 T. 11 S, R. 65 W. Peyton is listed as operating an Arapahoe aquifer well in section 13 T. 12 S, R. 64 W. The remaining wells with listed completion depths or water levels tap the Dawson and Denver aquifers. Most wells in the northern half of the quadrangle where surface elevations are higher tap the Dawson aquifer where its thickness is greatest due to less erosion. In the southeastern corner of the quadrangle where surface elevations are lower and erosion has removed more of the Dawson aquifer most of the wells are completed in the Denver aquifer

Water-level data for the Denver Basin aquifers can be obtained from the Division of Water Resources (DWR) well permit files and their annual ground-water level reports. Well-completion and pump-installation reports for wells often list the water level that existed when the well was completed. These data are one-time measurements and thus, the reported water level is not necessarily representative of current conditions in the area. DWR publishes water levels for a system of observation wells that can be used to assess changes in water levels over time (Colorado Division of Water Resources, 2008). The reader is directed to this publication for more timely water level data in their specific area. Water levels in the Dawson aquifer can be expected to vary considerably depending on location and elevation; values listed in the DWR permit database vary between 0 and 520 feet below the surface. One Dawson aquifer well in sec. 7 T. 11 S, R. 64 W is listed as a flowing artesian well. Well yields from the Dawson aquifer within the quadrangle typically range from 0.5 to 110 gallons per minute (gpm). Water levels in the Denver aquifer range between 10 and 710 feet below the surface and well yields range between 3.5 and 130 gpm. Water levels in the Arapahoe aquifer range between 605 and 1287 feet below the surface and well yields range between 7 and 207 gpm. The one Laramie-Fox Hills aquifer well is listed as having a water level of 1030 feet below the surface and a yield of 40 gpm

Alluvial Aquifers

Additional ground water resources exist in the Quaternary alluvial deposits associated with Kiowa and Black Squirrel Creeks. These alluvial aquifers are also part of the designated basin (Topper and others, 2003). The areal extent of the alluvial aquifer roughly coincides with the areal extent of the alluvium; however, the alluvium is not always saturated with ground water and the presence of alluvium at the surface does not imply the presence of an aquifer at depth.

On the basis of records obtained from the Colorado Department of Water Resources (DWR), approximately 45 wells may tap the alluvium in the quadrangle. The data in the permit files is insufficient to assess typical water levels and well yields.

GEOLOGIC HAZARDS

The most prevalent geologic hazards within the mapped area are flooding events, and rockfall and debris flows that occur below the steep slopes composed of Dawson Formation and/or Castle Rock Conglomerate. Major flooding affected much of the area in 1878, 1935, and 1965 and resulted in severe damage to infrastructure and loss of life (Follansbee and Sawyer, 1948; Gardner, 1967; Matthai, 1969). Other significant and potentially damaging hazards in the mapped area include hydrocompactive, swelling, and erodible soils.

Flooding and Debris Flows (Mudslides)

Debris flows, known popularly as "mudslides", are heterogeneous mixtures of mud, rock fragments, and plant materials that commonly form in the lower parts of tributary streams as they enter a large valley (Rogers and others, 1974). As the debris flow moves down its valley, unconsolidated surficial material is incorporated into the flow until the suspended sediment is no longer confined and is released as a fan-shaped deposit at the mouth of the tributary stream. Debris flows are the result of torrential rainfall or very rapid snowmelt runoff, where sediment supply is abundant and easily mobilized (Selby, 1993). Such conditions may exist in areas mapped as alluvial fans (Qf_1,Qf_2), colluvium (Qc), sheetwash (Qsw), and alluvium (Qa_1, Qa_2, Qa_3, Qa_4, Qa).

Major debris flows and floods associated with large precipitation events have affected the major drainages within the quadrangle. Some of the flooding events were very serious, resulting in loss of human life, livestock, and property. According to regional and local studies, large historic floods in northern El Paso County occurred in the years 1878, 1935, and 1965. The May 30-31, 1935 event killed 9 people, washed out all of the bridges on Kiowa Creek, and destroyed 15 residences in the town of Elbert (Follansbee and Sawyer, 1948). The wall of water was 15 feet high on Kiowa Creek. Evidence of the 1935 flood still exists in the mapped area; fragments of automobiles, concrete, roof shingles, wood, and other debris are found stranded several feet above the current flood plain and tributary streams of Kiowa Creek.

On June 17, 1965 several cloudbursts produced nearly 12 inches of rain along the Palmer Divide, north of the town of Eastonville. Flooding occurred within the Kiowa, Bijou, and Black Squirrel drainage basins and damaged many bridges and flooded farms and ranchlands along these courses. Near the town of Peyton, peak flow within Black Squirrel Creek was estimated between 10,400 and 141,000 CFS (Snipes, 1974), depending on the size of the drainage basin. Peak flow within Black Squirrel Creek is typically less than 500 CFS.

Rockfall

Rockfall deposits are included in the colluvium (Qc) unit in the mapped area. Of particular concern are the extensive colluvium deposits covering the steep slopes surrounding the buttes in northern half of the quadrangle. Blocks of Castle Rock Conglomerate and well-cemented Dawson Formation may reach tens of feet in diameter. Large precipitation events and freeze-thaw processes may trigger rockfall or rock avalanches. The area is susceptible to future rockfall events; developers and homeowners should be extremely cautious when building above or below these unstable cliffs.

Swelling Soils and Heaving Bedrock

Expansive or swelling soils and heaving bedrock are one of the most costly geologic hazards along the Front Range, and account for tens of millions of dollars in damage (Noe, 2007). The swelling in surficial materials is caused by the expansion of clay minerals due to wetting. Differential ground movements as the result of swelling soils, can cause significant damage to houses, roads, sidewalks, and other constructed media (Noe, 2007).

According to the National Resources Conservation Service (NRCS) soil survey data for the Eastonville quadrangle, the mapped area is given a low (0 Linear Extensibility Percentage (LEP)) to moderate (3-6 LEP) swell potential. Particularly susceptible to expansion are areas of exposed Dawson Formation bedrock (3-6 LEP). These categories are derived from the linear extensibility of the soil. Linear extensibility refers to the change in length of an unconfined clod as moisture content is decreased from a moist to a dry state. It is an expression of the volume change between the water content of the clod at 1/3 or 1/10 bar tension (33 kilo Pascals (kPa) or 10kPa tension) and oven dryness. The volume change is reported as percent change for the whole soil (LEP). The amount and type of clay minerals in the soil influence volume change (National Resource Conservation Service, 2010).

Proper investigation and engineering practices, with a focus on expansive clays and heaving bedrock, should be applied during construction in these areas.

Hydrocompactive Soils

Soils that are susceptible to hydrocompaction (settlement or collapse due to the addition of water) may exist in areas mapped as alluvium one, two, three, and four (Qa, Qa_1, Qa_2, Qa_3, Qa_4), alluvial fans (Qf_1, Qf_2), alluvial and eolian deposits (Qae), colluvium (Qc), sheetwash (Qsw), and landslides (Qls) (White and Greenman, 2008). According to the National Resources Conservation Service (NRCS) soil survey data for the Eastonville quadrangle, the highest potential of collapse are the areas mapped as Qlo, Qa_1, Qa_2, Qa_3, Qa_4 and surficial soils derived from the Dawson Formation with 1/3 bar bulk density values between 84.3 lb/ft^3 and 89.3 lb/ft^3 (1.35 and 1.43 g/cm^3) (National Resource Conservation Service, 2010). Bulk density (1/3 bar) refers to the oven dried weight of soil material that is less than 2 mm in size per unit volume at a water tension of 1/3 bar. Typically, a bulk density of greater than 87.4 lb/ft^3 (1.4 g/cm^3) can inhibit storage of water and penetration of plant roots and is considered a stable soil (National Resource Conservation Service, 2010).

Damage such as cracking of foundations and other structural problems can be caused by ground settlement, sinkholes, and subsurface voids, usually as a result of adverse wetting and structural loading. Dry density, moisture content, and swell-consolidation tests are usually performed to determine the degree of potential hydrocompaction. Crumb tests, pinhole tests, double hydrometer tests, and measurement of soluble salts and calculation of the Sodium Absorption Ratio (SAR) are more specialized tests to determine the potential of soil dispersion.

Erodible Soils

Water runoff and wind are the biggest causes of erosion. These are amplified by development and grazing of vegetated lands where the soil is exposed and easily eroded. The National Resource Conservation Service estimates that 134 tons per acre per year of soil erosion is possible from the Qa_2, Qa_3, and Qa_4 alluviums and 86 tons per year from much of the remainder of the mapped area.

Wind erosion may adversely affect the respiratory functions of humans and livestock by reducing air quality by increasing airborne dust. Furthermore, soil erosion increases the risk of pollution to surface and ground waters due to the use of pesticides from agricultural and residential treatment of vegetation.

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Appendix 1. Geologic time chart adopted by the Colorado Geological Survey.