OPEN-FILE REPORT 07-04

Geologic Map of the Ponderosa Park Quadrangle, Douglas and Elbert Counties, Colorado

Bill Ritter Jr., Governor
State of Colorado

COLORADO
DEPARTMENT OF
NATURAL
RESOURCES

Harris D. Sherman, Executive Director
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by
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Colorado Geological Survey
Department of Natural Resources
Denver, Colorado
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Description of Map Units, Structural Geology, Geologic Hazards,
Mineral Resources, and Ground-Water Resources

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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. 06HQAG0045.

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FOREWORD

The purpose of Colorado Geological Survey Open File Report 07-04, *Geologic Map of the Ponderosa Park Quadrangle, Douglas and Elbert Counties, Colorado* is to describe the geologic setting, mineral and water resources, and geologic hazards of this 7.5-minute quadrangle located southeast of Denver in central Colorado. Consulting geologist Jon P. Thorson completed the field work on this project during the summer of 2006.

This mapping project was funded jointly by the U.S. Geological Survey through the STATEMAP component of the National Cooperative Geologic Mapping Program, which is authorized by the National Geologic Mapping Act of 1997, award number 06HQAG0045, and the Colorado Geological Survey using the Colorado Department of Natural Resources Severance Tax Operational Funds. The CGS matching funds come from the Severance Tax paid on the production of natural gas, oil, coal, and metals.

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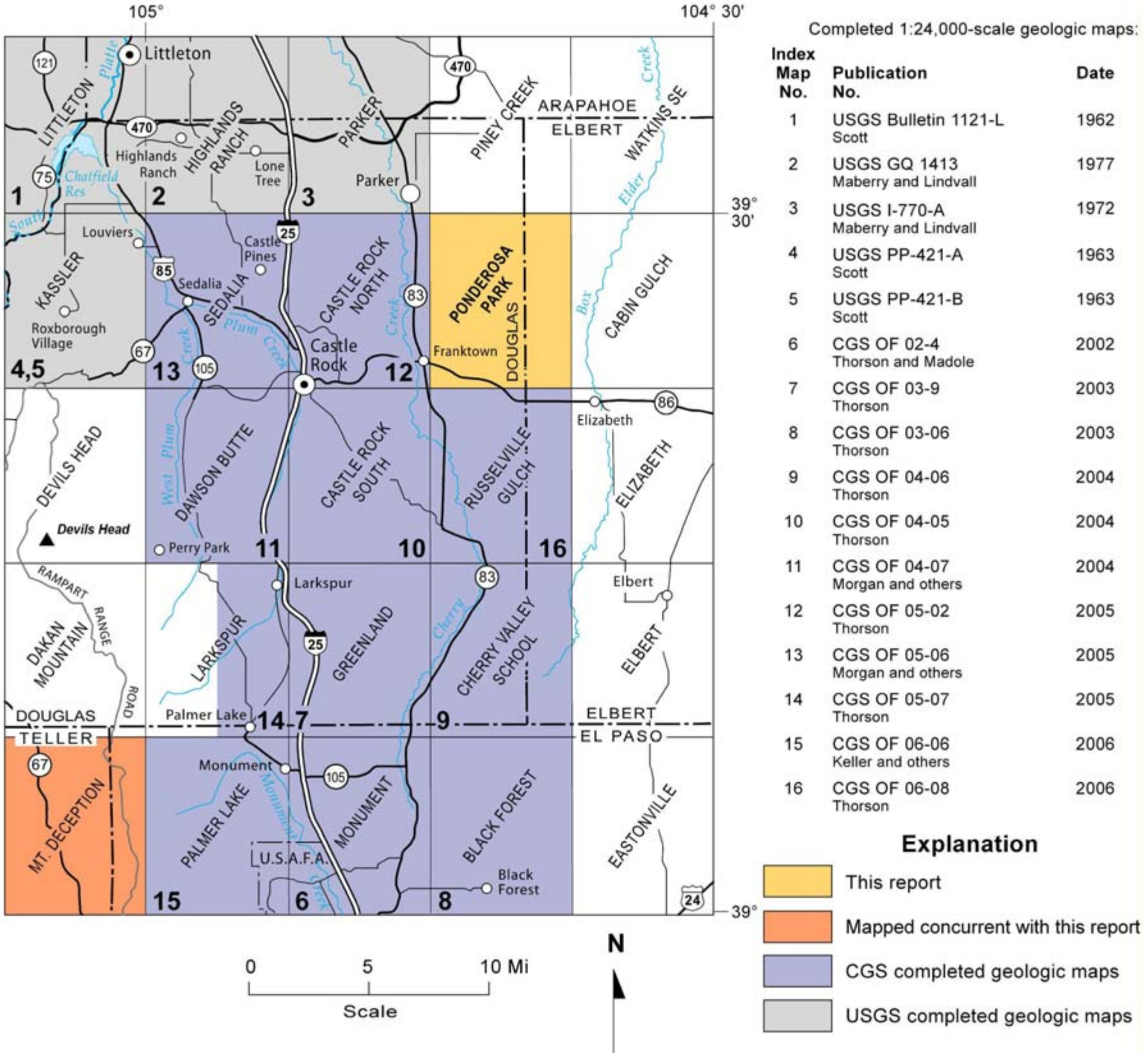
INTRODUCTION

The Ponderosa Park 7.5-minute quadrangle is located east of Castle Rock, Colorado, in the southern part of the Colorado Piedmont section of the Great Plains. The quadrangle is located in the Cherry Creek and Coal Creek drainage basins, which are tributary to the South Platte River. Geologic mapping of the Ponderosa Park 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 1 shows the location of the Ponderosa Park quadrangle and the status of geologic mapping of 7.5-minute quadrangles in the Castle Rock area.

This map is based on interpretation of aerial photography and field mapping in 2006 and prior published and unpublished geologic maps and reports. The aerial photographs used are approximately 1:26,600 scale black and white photographs flown in 1971 for the U.S. Geological Survey (USGS). The USGS topographic base map for the Ponderosa Park quadrangle was published in 1966 and revised by photo inspection in 1994. Consequently, some of the more recently constructed roads, buildings, and other human-made modifications of the landscape are not shown on the base map.

Previous geological mapping in the Ponderosa Park area includes the work of Emmons and others (1896) and Richardson (1915). Trimble and Machette (1979a, 1979b) published 1:100,000 scale regional geologic maps of the Front Range urban corridor, one of which includes the Ponderosa Park quadrangle. Bryant and others (1981) compiled a 1:250,000 scale map that includes the Ponderosa Park quadrangle. Maberry and Lindvall (1972, 1977) mapped the Parker and Highlands Ranch quadrangles, located north and northwest, respectively, of the Ponderosa Park quadrangle. The Colorado Geological Survey has published open-file maps of quadrangles adjacent to the Ponderosa Park quadrangle: Castle Rock North (Thorson, 2005b), Castle Rock South (Thorson, 2004a), and Russellville Gulch (Thorson, 2006). See figure 1 for locations of these and other quadrangles from this area that have been mapped and published by the CGS and USGS.



Completed 1:24,000-scale geologic maps:

Index Map No.	Publication No.	Date
1	USGS Bulletin 1121-L Scott	1962
2	USGS GQ 1413 Maberry and Lindvall	1977
3	USGS I-770-A Maberry and Lindvall	1972
4	USGS PP-421-A Scott	1963
5	USGS PP-421-B Scott	1963
6	CGS OF 02-4 Thorson and Madole	2002
7	CGS OF 03-9 Thorson	2003
8	CGS OF 03-06 Thorson	2003
9	CGS OF 04-06 Thorson	2004
10	CGS OF 04-05 Thorson	2004
11	CGS OF 04-07 Morgan and others	2004
12	CGS OF 05-02 Thorson	2005
13	CGS OF 05-06 Morgan and others	2005
14	CGS OF 05-07 Thorson	2005
15	CGS OF 06-06 Keller and others	2006
16	CGS OF 06-08 Thorson	2006

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

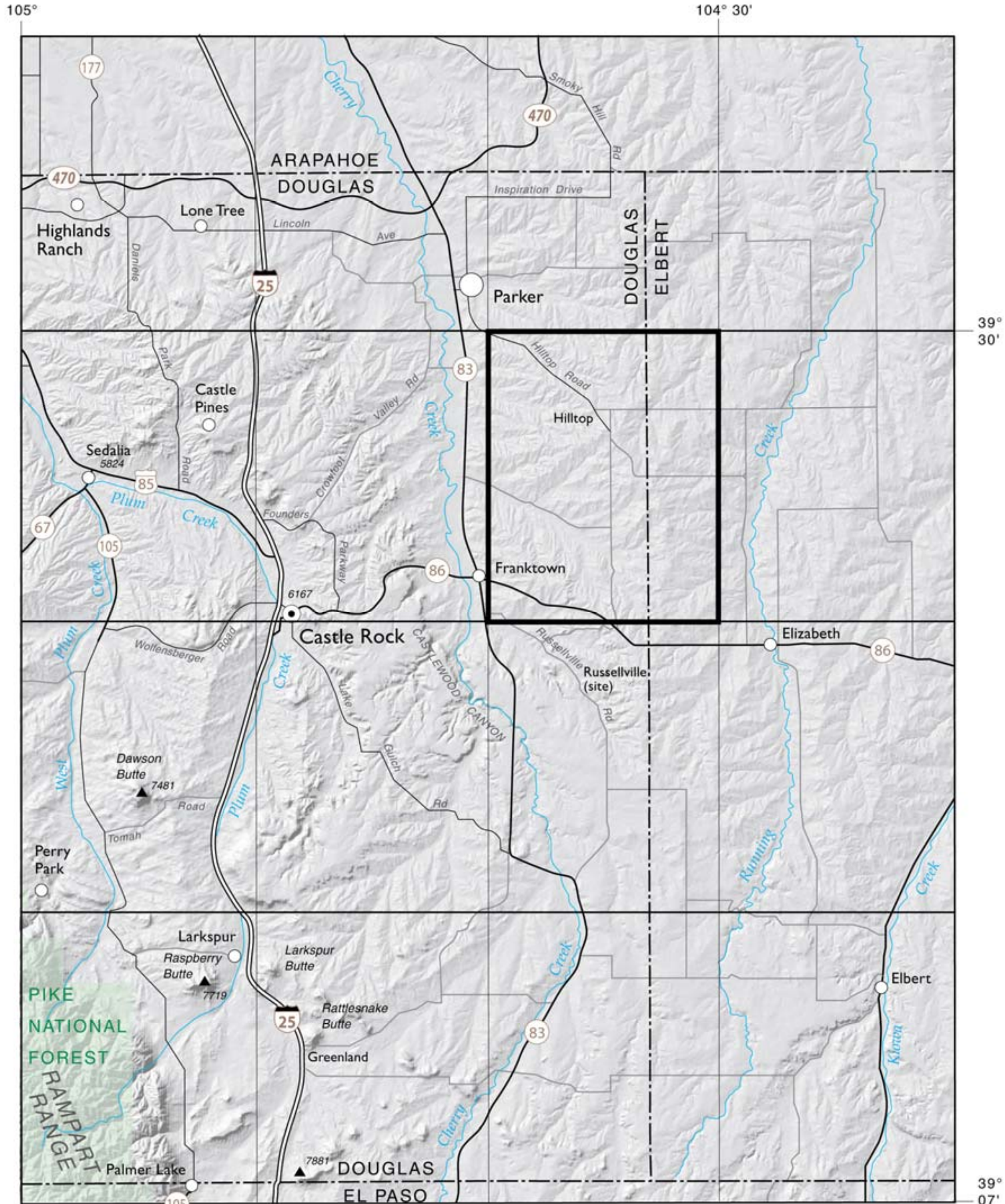


Figure 2. Physiographic map for the Ponderosa Park quadrangle; shown with the bold outline.

The geological unit names and symbols used for geological units in the Ponderosa Park 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. Also, deposits that are less than 5 feet thick were not mapped unless they are coincident with landforms that can be delineated on aerial photography. Some of the surficial deposits of the Ponderosa Park 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.

ACKNOWLEDGMENTS

This mapping project was funded jointly by the Colorado Geological Survey and the U.S. Geological Survey through the National Geological Mapping Program. Many people have earned my thanks: Matt Morgan and Vincent Matthews reviewed the map and text. Matt Morgan and Karen Morgan of the Colorado Geological Survey provided valuable help in converting notes and field mapping on aerial photographs into the geological map. Karen Morgan assembled the final cartography and booklet. Jane Ciener was technical editor. Special thanks go to the landowners and developers who granted permission to enter their property.

GEOLOGICAL SETTING

The Ponderosa Park 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.

Much of the exposed bedrock in the Ponderosa Park quadrangle is the assemblage of lithologies shown on the geologic map as the upper part of the Dawson Formation (TKda). At the time of deposition of this unit, during the Paleocene and Eocene Epochs (about 65 to 50 million years ago, fig. 3), 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 12 miles west of the quadrangle. Stream flow was generally towards 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 Fm. 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) and Russellville Gulch (Thorson, 2006) quadrangles. Small remnants of the conglomerate of Larkspur Butte cap high ridges in a small area along the southern margin of the Ponderosa Park quadrangle.

The Wall Mountain Tuff, an ignimbrite, or glowing hot volcanic ash flow, was erupted 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. Erosional remnants of the Wall Mountain Tuff overlie the Dawson Formation or conglomerate of Larkspur Butte a few miles south of the Ponderosa Park quadrangle.

The Castle Rock Conglomerate was deposited near the end of the Eocene as a broad sheet following a northwest-trending paleo-valley that was eroded across the upper Dawson Formation, conglomerate of Larkspur Butte, and Wall Mountain Tuff. Small erosional remnants of the Castle Rock Conglomerate were found near the southern margin 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 probably once covered the quadrangle but has since been removed by erosion. During the Quaternary, deposits of unconsolidated sands and gravels were left in paleochannels, flood plains along stream courses, and on various upland erosion surfaces as streams eroded the landscape.

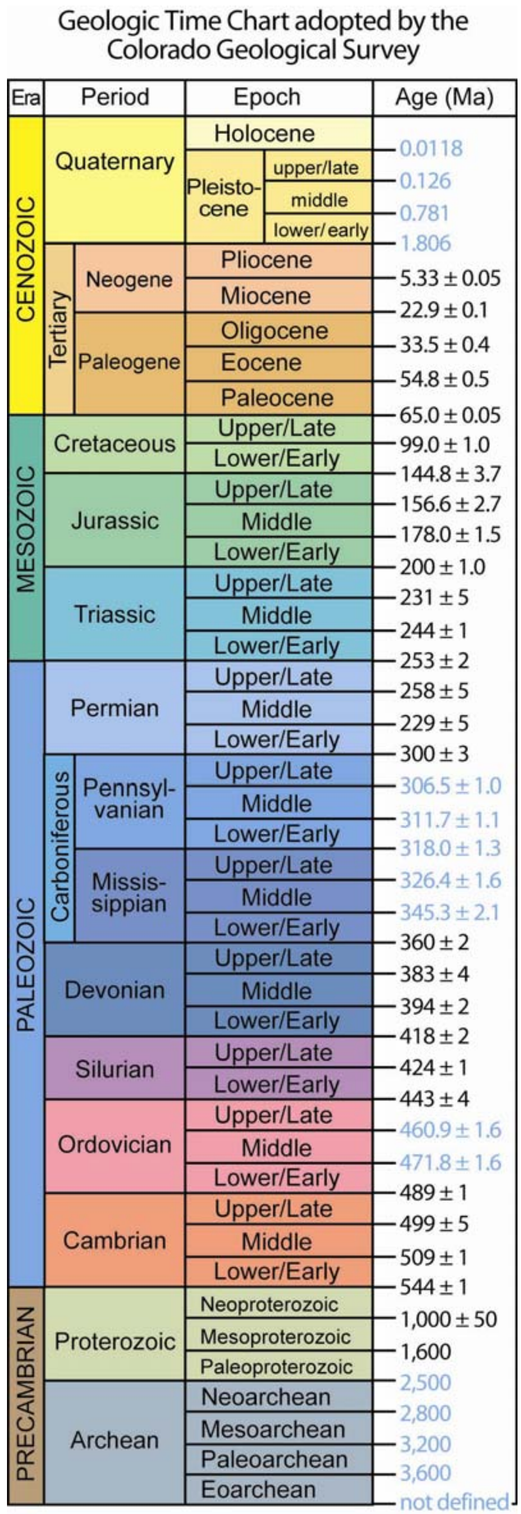


Figure 3. Geologic time chart adopted by the Colorado Geological Survey and used for this report. Numerical ages shown in black are from the Geological Survey of Canada (Okulitch, 2002); ages shown in blue are from the International Commission on Stratigraphy (2005).

AGE OF FORMATIONS

Dawson Formation. The lower part of the upper Dawson Formation spans the Cretaceous-Paleogene (K-P) 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-P 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 (million years before present), 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-P boundary on the basis of correlations with the Castle Pines cored well located in the adjacent 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. 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 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 TKda5 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 area confirm that the Dawson unit mapped in the Ponderosa Park quadrangle lies above the Paleocene rain-forest strata and is accepted to be Eocene in age.

Conglomerate of Larkspur Butte. The conglomerate of Larkspur Butte (Tlc) is a newly recognized unit that underlies the late Eocene Wall Mountain Tuff on Larkspur Butte and on many of the high buttes in the Greenland (Thorson, 2004b), Black Forest (Thorson, 2003a), Cherry Valley School (Thorson, 2004b), Castle Rock South (Thorson, 2004a), Castle Rock North (Thorson, 2005b), Sedalia, (Morgan and others, 2005, and Russellville

Gulch (Thorson, 2006) quadrangles. This conglomerate is clearly of Eocene age; it lies between Eocene upper Dawson Formation and late Eocene Wall Mountain Tuff. It is of probable late Eocene age because a significant part of the Eocene epoch probably passed during the deposition, alteration, and erosion of the upper Dawson Formation. A late Eocene age is indicated because the conglomerate of Larkspur Butte fills, or partially fills, paleovalleys that were present in the late Eocene. The paleovalleys contained the thickest deposits of the Wall Mountain Tuff. These thicker channel-filling deposits of welded tuff are often the only remnant left capping higher buttes in the Castle Rock area.

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 33.5 mybp (fig. 2), so the Wall Mountain Tuff should now be considered to be late Eocene.

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 33.5 mybp.

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

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

af **Artificial fill (latest Holocene) —** Gravel, sand, silt, clay, and rock or concrete debris emplaced for constructing railroads, highways and dams. Thickness generally is between 5 and 50 feet.

ALLUVIAL DEPOSITS — Sand, silt, gravel, and clay transported and deposited by flowing water in channels or as unconfined runoff. The alluvial deposits in the Ponderosa Park 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 and Qau) and terrace (Qt1, Qt2, Qt3) deposits are subround coarse pebbles (less than 1.25 inches) or smaller grains. Occasional larger pebbles and small cobbles (up to about 4 inches) of well rounded light-colored and rare larger round to subround cobbles of granite, 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, the conglomerate of Larkspur Butte, or from the Castle Rock Conglomerate. Large cobbles of Dawson Formation arkose in the alluvial deposits were derived from local sources.

Part of the Ponderosa Park quadrangle is mantled by older alluvial deposits of probable Pleistocene age (Qp). The relative age of these deposits has been interpreted from their slope, base level, and position in the landscape. These deposits have been named "older alluvium" because they represent deposition at higher elevations compared to the present drainage system.

Qa **Channel and flood-plain alluvium (late Holocene) -** Pale-brown to brown sand, gravel, silt, and minor clay underlying narrow flood plains, stream channels, and, locally, low terraces flanking flood plains. Unit is generally coarser, lighter in color, and more poorly sorted than unit Qt1. In many places, the unit is so young that plant roots have scarcely disturbed or destroyed stratification that extends nearly to the ground surface. Typically, soil horizons have not developed. Unit is subject to frequent flooding. Estimated thickness is 3-7 feet.

Qt1 **Terrace alluvium one (Holocene) —** Pale-brown and brown to grayish-brown beds of sand, silty fine sand, sandy silt, clayey silt, and gravel. Generally, stratification is weakly expressed, and texture and composition vary along the valley axis. The upper surface of the unit is 3-10 feet higher than some of the larger streams but is only about 2-5 feet higher than the smaller streams of the area. Infrequent large floods may inundate Qt1 in places. By comparison with the adjacent Parker quadrangle, the unit correlates with the Post-Piney Creek Alluvium of Maberry and Lindvall (1972). Thickness is estimated to be 5-15 feet.

Qt2 **Terrace alluvium two (early Holocene to late Pleistocene) —** Very pale-brown to dark-grayish-brown, very poorly sorted sand and subordinate amounts of gravel. The unit correlates with the Piney Creek Alluvium of Maberry and Lindvall (1972) by virtue of height above stream level and soil characteristics. The upper surface of the unit is typically 5-15 feet higher than the larger streams. Thickness is 5-20 feet.

Qt3 **Terrace alluvium three (early Holocene to late Pleistocene) —** Chiefly pale-brown to light-grayish-brown, extremely poorly sorted sand, gravel, and cobbly gravel that underlies terrace remnants along the larger streams of the area. The upper surface of the unit is 10 to 30 feet higher than the drainages. The unit may correspond to Broadway Alluvium of Maberry and Lindvall (1972). Estimated thickness is 5-30 feet.

Qsw **Sheetwash (Holocene and late Pleistocene) —** Typically, light-grayish-brown, pale-brown, to brown, extremely 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 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 alluvial deposits. Estimated thickness is 3-20 feet.

Qp **Older alluvium one (late middle Pleistocene) —** Chiefly light-brown to light-reddish-brown, extremely poorly sorted silt, sand and gravel, which, in places, includes small cobbles. The unit may have pebbly layers and subrounded clasts of Dawson Formation arkose. At lower elevations this unit appears to correlate with the Slocum Alluvium of Maberry and Lindvall (1972) but may include some material that they would have mapped as Louviers Alluvium at lower elevations. At higher elevations in the northern and northeastern parts of the quadrangle this unit mantles upland surfaces and includes some material that may be wind-blown silt and fine sand. In places these wind-blown deposits make distinct land forms visible on aerial photographs, but the deposits are not distinct on the ground. In places these possible wind deposited materials contain layers and laminae of coarse sand and small pebbles that are too coarse to have been transported by wind. Consequently attempts to map a wind-blown facies of this unit as an eolian deposit proved inconsistent. Unit Qp has an estimated thickness as great as 60 feet.

Qau **Alluvium, undivided (Holocene and late Pleistocene) —** Chiefly pale-brown to brown, poorly sorted sand and fine gravel in valley heads in the upper parts of drainages. 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, Qt1, Qt2, and possible Qt3. Estimated thickness is 3-10 feet.

BEDROCK DEPOSITS

Tcr **Castle Rock Conglomerate (late 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 and quartz 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. 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. The Castle Rock Conglomerate is younger than the Wall Mountain Tuff, which has been dated at about 36.7 my (McIntosh and others, 1992; McIntosh and Chapin, 1994, 2004). It must be older than the end of the Eocene (33.5 my; figure 2) 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 50 feet in the larger of the two erosional remnants preserved near the southern edge of the quadrangle.

The Castle Rock Conglomerate was deposited as a large sheet that filled a paleovalley on an erosion surface cut across the top of the upper Dawson Formation, conglomerate of

Larkspur Butte, and Wall Mountain Tuff. This surface slopes gently to the north and northwest from elevations between 6800 and 6850 feet in the southern part of the Russellvile Gulch quadrangle to about 6540 feet in the Ponderosa Park quadrangle.

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 plateaus 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.

Tlc **Conglomerate of Larkspur Butte (late? Eocene) —** The conglomerate of Larkspur Butte is a brown, pinkish-brown, or pink arkosic conglomerate composed predominantly of pebbles and cobbles of gneiss, granite or pink feldspar in a coarse sand-size to small-pebble matrix of quartz and pink feldspar. In the Ponderosa Park quadrangle, clasts of gray or white quartz and a distinctive dark-gray to dark-bluish-gray quartzite are common; less abundant are clasts of red or pink Pikes Peak Granite, brown or yellowish-brown quartzite, red sandstone, and chert; clasts are subround to round. In the quadrangle, this unit does not make good natural outcrops as it is not well cemented, but the resistant rounded cobbles and boulders litter the surface where the unit is present. The conglomerate of Larkspur Butte is up to 30 feet thick in the quadrangle.

The conglomerate of Larkspur Butte is similar in appearance to the Castle Rock Conglomerate although the latter generally lacks pink tones and is light brown or light brownish-gray in color. The principal distinguishing characteristic is fragments of Wall Mountain Tuff in the Castle Rock Conglomerate. In the absence of tuff fragments, the two late-Eocene conglomerates may be very hard to distinguish.

The conglomerate of Larkspur Butte is generally permeable, well drained, and has good foundation characteristics. Excavation may be difficult, even though the some of the conglomerate is friable and easily eroded on weathered outcrops.

Dawson Formation (Upper Cretaceous to Eocene) — The Dawson Formation is divided into upper and lower parts in the Colorado Springs area (Thorson and others, 2001, Thorson and Madole, 2002). The lower part is entirely Upper Cretaceous in age and composed almost exclusively of andesitic debris. The upper part of the Dawson Formation is 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 (TKda1), facies unit two (TKda2), facies unit three (TKda3), facies unit four (TKda4), and facies unit five (TKda5). 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. Only facies unit five (TKda5) is present at the surface in the Ponderosa Park quadrangle.

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; Raynolds, 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 and that no single paleosol exposure clearly defines the D1-D2 boundary without age confirmation. Nonetheless, facies unit TKda5 of this report appears to be consistently equivalent to Raynolds' D2 sequence.

Logs and samples from the Dawson Foramtion in the abandoned petroleum test well in the Greenland quadrangle (sec 17, T. 10 S., R. 66 W.; F.G. Holl et al., #1 Greenland Cattle Co.), plus the thickness of Dawson exposed on the adjacent buttes above the collar of the well, indicate that the Dawson Formation is about 2,750 feet thick. The petroleum test wells shown in table 1, particularly the Trans Texas Energy well (#1) indicate that the Dawson Formation is 2,150 feet thick in the Ponderosa Park quadrangle and was thicker before erosion of the upper part.

TKda5 **Facies unit five (early to middle? Eocene) —** Unit TKda5 is dominated by very thick-bedded to massive, cross-bedded, light-colored arkoses and pebbly arkoses, but the unit also contains common beds of white to light-tan, fine- to medium-grained feldspathic, cross-bedded friable sandstone. These sandstones are 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. Eastward from the mountain front, facies unit five becomes progressively finer grained and loses much of its distinctive thick-bedded character and conglomeratic lithologies. In the Ponderosa Park quadrangle, the unit is predominantly coarse arkosic sandstone and contains common beds of greenish-gray to olive-green sandy claystone.

Unit TKda5 is at least 550 feet thick in the quadrangle but the base is not exposed and the upper part of the unit has been removed by erosion. TKda5 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). In hydrologic studies, facies unit five appears to be equivalent to the Dawson Arkose and/or Dawson aquifer in the Denver area (George VanSlyke, 2001, oral commun.).

TKda5 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 factors. Rock fall from cliffs in facies unit five poses a possible slope-stability hazard in some areas.

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

	1	2	3	4
	Trans Texas Energy	Koch Exploration	Koch Exploration	Koch Exploration
	2-H-B Partnership #1-11	Alma Miller #1	Bentley #1	Albert Pearson #1
	SE 1/4 SE 1/4 Sec. 11	NE 1/4 SE 1/4 Sec. 14	NE 1/4 SW 1/4 Sec. 15	NE 1/4 NE 1/4 Sec. 34
	T. 7 S., R. 65 W.	T. 7 S., R. 65 W.	T. & S., R. 65 W.	T. 6 S., R. 65 W.
Year drilled	1981	1975	1973	1972
Elevation (ft)	6453	6423	6677	6351
Laramie Fm.	2150	2080		
Fox Hills Ss.	2420	2400		
Pierre Sh.	2840	2780		
Niobrara Ls.	8072	8028		8124
Carlile Sh.	8540	8498		8414
Greenhorn Sh.		8570		8600
D sand	8894	8862	9169	
J sand	8933	8894	9204	
Skull Creek Sh.		8958		
Dakota Fm.		9072		
Morrison Fm.		9184		
Total depth (ft)	9046	9207	9291	8997

Table 1. Petroleum test wells in the Ponderosa Park quadrangle; numbers match the locations on the geologic map. Elevation is the ground elevation at the well collar from which drill depths are measured; depths for each formation are the depth to the top of the specified unit, in feet. The top of the Laramie Formation is coincident with the base of the undifferentiated Dawson Formation shown on the cross section.

STRUCTURAL GEOLOGY

The structural geology of the Ponderosa Park quadrangle is not complex. The Dawson strata are flat lying or very gently dipping. Few strike and dip symbols are shown on the map. Measurement of strike and dip in the Dawson Formation is difficult and questionable because of the coarse-grained, lenticular and cross-bedded character of most of the beds and because of poor exposures. Bedding surfaces and cross-bed orientation from these beds were inclined at deposition and are unlikely to be representative of the strike and dip of the whole unit. Strike and dip measurements shown on the map were made on thin-bedded, fine-grained strata that were more likely deposited in a horizontal orientation.

MINERAL RESOURCES

Sand and gravel are the most significant potential mineral resources in the Ponderosa Park quadrangle. Four test wells for oil and gas have been drilled. No radioactive mineral resources have been reported from the quadrangle (Nelson-Moore and others, 1978).

SAND AND GRAVEL

Sand and gravel are widely available in the quadrangle from surficial deposits derived mostly from erosion of the Dawson Formation, but there is little indication that these resources are currently being exploited from the quadrangle. An area in SW 1/4 SE 1/4 sec. 11, T. 7 S., R. 65 W. is indicated on the topographic map as a gravel pit. This pit is inactive and revegetated with small pine trees.

OIL AND GAS

The Colorado Oil and Gas Conservation Commission has completion records for four petroleum test wells in the Ponderosa Park quadrangle. Formation tops from the completion records and well logs are shown in figure 3. The nearest oil production is about 15 miles northeast of the quadrangle, northwest of Kiowa in Elbert County.

WATER RESOURCES

Water resources in the Ponderosa Park quadrangle are contained either in shallow groundwater aquifers in surficial alluvial deposits along the major stream drainages, largely the terrace deposits Qt1, Qt2, and Qt3, or in deeper groundwater aquifers of the

Denver Basin (Robson, 1987, 1989). This basin contains four major aquifers: the Dawson, Denver, Arapahoe, and Laramie-Fox Hills, listed from the top down. Drill depths anticipated to completely test the four deep aquifers in the Ponderosa Park quadrangle are approximately 500, 1500, 2000, and 3000 feet, respectively (Robson, 1987). A comprehensive review of the geology and issues associated with ground water supply in the Ponderosa Park quadrangle is beyond the scope of this report. Topper and others (2003) and Raynolds and Reynolds (2004) provide recent reviews of the subject.

GEOLOGIC HAZARDS

Several geologic processes may effect planning and ultimate development within those portions of the Ponderosa Park quadrangle likely to be developed. In some of the steeper slope areas, particularly below the steep slopes composed of Dawson Formation, conglomerate of Larkspur Butte, or Castle Rock Conglomerate, the potential for debris flows and rock falls presents significant threats to developed structures. Rock stability along the upper edges of outcrops of the same units may be tentative as large blocks of well lithified bedrock begin to creep away as they are undermined by erosion of softer underlying strata. Slope instability and swelling soils associated with clay-rich portions of the Dawson Formation are potential problems where this unit is exposed. Over most of the quadrangle flooding probably represents the greatest geological threat, however. Most of the quadrangle contains broad open slopes with thin to moderate density grassland cover that offer little impediment to runoff. This area is subjected to occasional short but intense periods of torrential rain associated with summer thunderstorms. Flooding following these storms can be dramatic and dangerous.

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