OPEN-FILE REPORT 01-3

Geologic Map of the Pikeview Quadrangle, El Paso County, Colorado

By Jon P. Thorson, Christopher J. Carroll, and Matthew L. Morgan

Colorado Geological Survey
Division of Minerals and Geology
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Description of Map Units, Mineral Resources, and References

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This mapping project was funded jointly by the Colorado Geological Survey and the U.S. Geological Survey STATEMAP component of the National Cooperative Geologic Mapping Program, Agreement No. 00HQAG0119.

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FOREWORD

The purpose of Colorado Geological Survey Open File Report 01-3, *Geologic Map of the Pikeview Quadrangle, El Paso County, Colorado* is to describe the geologic setting and mineral resource potential of this 7.5-minute quadrangle located in northern part of Colorado Springs along the I-25 corridor. Jon P. Thorson, consultant, Christopher J. Carroll and Matthew L. Morgan, staff geologists at the Colorado Geological Survey, completed the field work on this project in the summer of 2000.

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, Agreement No. 00HQAG0119, 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.

Vince Matthews
Senior Science Advisor

Vicki Cowart
State Geologist and Director

ACKNOWLEDGMENTS

This mapping project was funded jointly by the Colorado Geological Survey and the U.S. Geological Survey through the National Cooperative Geologic Mapping Program. Many people have earned our thanks. Robert M. Kirkham, John Keller, and Vincent Matthews of the Colorado Geological Survey; Kirk Johnson of the Denver Museum of Nature and Science; Robert G. Raynolds of the Denver Basin Project; and John W. Himmelreich, Jr. of John Himmelreich and Associates, Inc. reviewed all or parts of the map and text. Jane Ciener served as technical editor. James Messerich set photogrammetric models on Kern PG-2 plotters. This project benefited from discussions with Glenn Scott, Jon White, Jon Lovekin, David Noe, and George Vanslyke. Despite the best intentions of all of the above people, any remaining shortcomings of this work remain ours.

Special thanks go to the landowners and developers who granted permission to enter their property. The Colorado Springs City and El Paso County Planning Departments provided helpful assistance and information on the geology of the area.

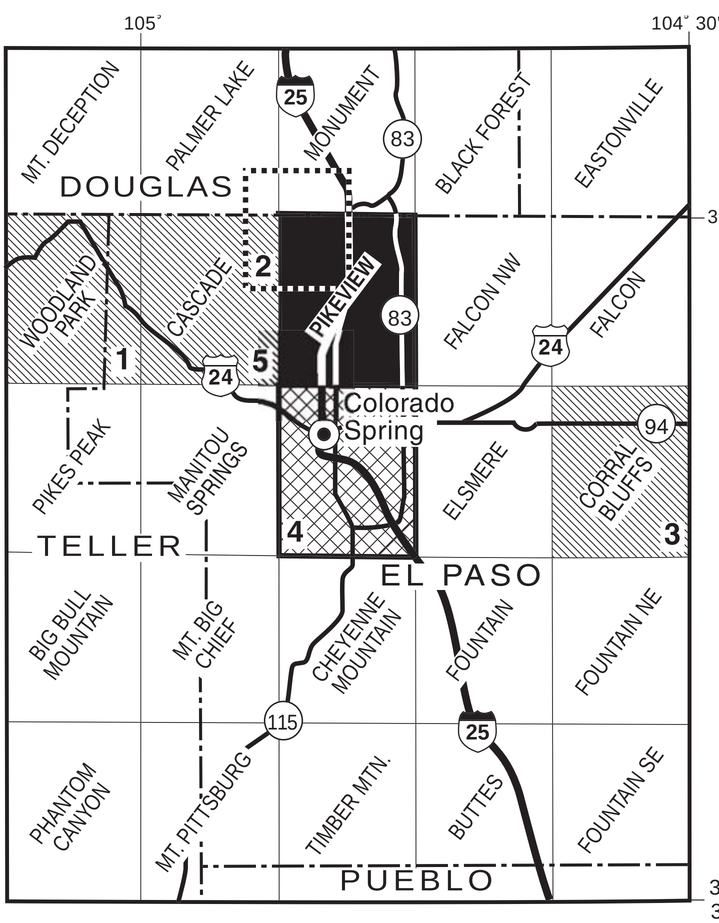
INTRODUCTION

Geologic mapping of the Pikeview 7.5-minute 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 exploration.

Figure 1 shows the status of geologic mapping of 7.5-minute quadrangles in the Colorado Springs area. This is the second quadrangle in the area to be mapped by the CGS. The Colorado Springs 7.5-minute quadrangle was mapped in 1999 by Carroll and Crawford (2000) and is available from CGS as Open-File Report 00-3. The CGS plans to map additional quadrangles in the Colorado Springs area in the future.

This map was based on (1) prior published and unpublished geologic maps and reports, (2) interpretation of black and white, 1:24,000-scale aerial photography flown in flown in 1947 and 1991, and (3) field investigations in 2000. Mapping of some of the more heavily urbanized parts of the quadrangle was extrapolated from reconnaissance mapping by Scott and Wobus (1973) and Trimble and Machette (1979).

Previous geological mapping in the Colorado Springs area includes the work of Emmons, Cross, and Eldridge (1896) and Finlay (1916). Varnes and Scott (1967) mapped the area which is



Index Map No.	Publication No.	Date	Scale
1	USGS MF-842 Wobus and Scott, 1977a	1977	1:24,000
2	USGS PP 551 Varnes and Scott, 1967 (Covers parts of four quads)	1967	1:12,000
3	USGS GO-783 Soister, 1968	1968	1:24,000
4	CGS OF 00-3 Carroll and Crawford, 2000	2000	1:24,000
5	USGS OF 77-138 Wobus and Scott, 1977b	1977	1:24,000

Figure 1. Index map showing the location of the Pikeview quadrangle and other geological maps in the area published at a scale of 1:24,000 and 1:12,000.

now the United States Air Force Academy at a scale of 1:12000. Some of their work has been modified as part of this Pikeview quadrangle map. Scott and Wobus (1973) mapped the entire Colorado Springs and vicinity in reconnaissance fashion and published a geologic map at a scale of 1:62,500. That map was generalized as part of the geologic map of the Front Range urban corridor (Trimble and Machette, 1979). To all of those geologists “on whose shoulders we stand”, and to the many others on whose work we have drawn, we owe a debt of gratitude.

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

Surficial deposits shown on the map are generally more than 5 ft thick but may be thinner locally. Residuum, artificial fills of limited extent, and concrete/asphalt cover were not mapped. Contacts between surficial units may be gradational, and mapped units locally may include interfingering deposits of another type. Divisions of the Pleistocene used herein correspond to those of Richmond and Fullerton (1986). 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 weathering, and soil development. Many of the surficial deposits are calcareous and contain varying amounts of both primary and secondary calcium carbonate. The Front Range piedmont stratigraphic nomenclature of Quaternary alluvial deposits was established by Scott (1960; 1963a). Varnes and Scott (1967), Scott and Wobus (1973), and Trimble and Machette (1979) applied this nomenclature to Quaternary deposits in the Pikeview quadrangle (Figure 2).

Age	Finlay (1916)	Varnes and Scott (1967)	Scott and Wobus (1973); Trimble and Machette (1979)	Carroll and Crawford (2000)	This map
Late Holocene	Terraced stream gravels	Floodplain and tributary drainage deposits	Post-Piney Creek and Piney Creek Alluvium	Terrace alluvium one Qt_1	Alluvium and colluvium Qac
Holocene		Husted Alluvium			Terrace alluium one Qt_1
Late Pleistocene		Monument Creek Alluvium	Broadway Alluvium	Terrace alluvium Two Qt_2	Terrace Alluvium Two Qt_2
		Kettle Creek Alluvium	Louviers Alluvium	Terrace alluvium three Qt_3	Terrace Alluvium three Qt_3
Pleistocene		Pine Valley Gravel	Slocum Alluvium	Pediment gravel one Qg_1	Older gravel one Qg_1
Pleistocene	Mesa gravels	Douglass Mesa Gravel	Verdos Alluvium	Pediment gravel two Qg_2	Older gravel two Qg_2
		Lehman Ridge Gravel	Rocky Flats Alluvium	Pediment gravel three Qg_3	Older gravel three Qg_3

Figure 2. Correlation chart of nomenclature used for Quaternary alluvial deposits in the Pikeview quadrangle area.

HUMAN-MADE DEPOSITS—

af

Artificial fill (latest Holocene)— Artificial fill consists of waste rock, engineered fill, and refuse placed during construction of roads, railroads, buildings, dams, and landfills and is composed mostly of unsorted silt, sand, clay, rock fragments, and construction materials. The maximum unit thickness is about 30 ft for engineered fill and bridge abutments along I-25 and railroad embankments. Many artificial fills are dams for small reservoirs. Artificial fill may be subject to settlement when loaded if not adequately compacted.

ALLUVIAL DEPOSITS—These map units are silt, sand, and gravel deposited in stream channels, on flood plains, on pediments, and as sheetwash along Monument Creek and its tributary drainages. Terrace alluvium along this mainstem creek was deposited mostly during late-glacial and early-interglacial stages. The approximate terrace heights reported for each unit are the elevation differences measured between the creek bed and the top of the original or remnant alluvial (tread) surface near the creek edge of the terraces. Thickness is measured on the riser or is the maximum exposed thickness of the unit.

Qsw **Sheetwash deposits (Holocene and late Pleistocene)—** These deposits were transported by sheetflow and deposited in valley sides of ephemeral and intermittent streams, on gentle hillslopes below terraces, landslides, alluvial fans, and in basinal areas. Sheetwash deposits may include weathered shale pieces, clay, silty sand, clayey silt, and sand, and are mostly derived from weathered Dawson Formation and Pierre Shale. Locally this unit grades into and interfingers with colluvium on steeper hillslopes and with slackwater deposits in closed depressions. Sheetwash deposits below landslides are chiefly composed of clay and silt eroded from the landslide deposits. The maximum thickness of this deposit type in the Pikeview quadrangle is about 20 ft. Sheetwash deposits may be prone to hydrocompaction, settlement, and piping where low in density.

Qt_1 **Terrace alluvium one (Holocene and late Pliestocene)—** Light- to dark-brown clay, silt, sand, gravel and scattered boulders deposited as clast-supported, low-terrace alluvium up to 12 ft above the modern creek bed. Clayey humic layers are infrequently scattered along Monument Creek. This unit is poorly to moderately sorted, and consists of unconsolidated material capped with a 1–2 ft thick humic soil. Clasts are well-rounded to subangular gravel locally derived from Cretaceous shales and sandstones with lesser amounts of granitic material. Lithology becomes increasingly sandier to the north, where the Dawson Formation parent material underlies the unit locally.

Terrace alluvium one was deposited in valley bottoms and preserved as low-relief strath terraces in the modern creek beds. Much of Monument Creek is scoured to bedrock with only remnants of terraces remaining as terrace alluvium one. This unit correlates with the Husted Alluvium of Varnes and Scott (1967) which is 9–12 ft above Monument Creek on the U.S. Air Force Academy. Terrace alluvium one and Husted Alluvium may correlate with Piney Creek Alluvium in Denver (Hunt, 1954) and the Front Range (Trimble and Machette, 1979) as the lowest distinctive terraces above stream level with a distinct lack of soil development and light weathering of clasts. The maximum thickness of terrace alluvium one along Monument Creek is 12 ft. Low-lying areas are subject to flooding.

Qt_2 **Terrace alluvium two (late Pleistocene)—** Terrace alluvium two is chiefly stream alluvium that underlies terraces about 12 to 22 ft above modern stream level. The unit is poorly sorted, pebble and cobble gravel in a sandy or silty matrix. Clasts in deposits along Monument Creek are mainly subrounded to round and are composed of varied lithologies that reflect the rock types exposed in the drainage basin. In the north half of the quadrangle clasts along Monument Creek are mostly derived from the Dawson Formation. Clasts in the southern part are derived from local bedrock exposures of Pierre Shale, Fox Hills Sandstone, Laramie Formation, and Dawson Formation, and are generally more rounded and weathered than in the north. The surface of terrace alluvium two is generally very flat but may slope gently toward Monument Creek.

Terrace alluvium two is correlated with Monument Creek Alluvium of Varnes and Scott (1967) on the U.S. Air Force Academy and is considered to be late Wisconsin in age by stratigraphic superposition and diagnostic vertebrate fossils (Scott, 1963a). It is similar in lithology, geomorphic appearance, and height above stream level to the Broadway Alluvium in the Denver area (Hunt, 1954). In the southern part of the quadrangle along Monument Creek, terrace alluvium two underlies a level surface used for parks and ball fields in sec. 30 and 31, T 13 S, R. 66 W. This unit is a source of sand and gravel. Maximum thickness of terrace alluvium two is 22 ft.

Qt_3 **Terrace alluvium three (late-middle Pleistocene)—**Terrace alluvium three is composed of poorly sorted, pebble and cobble gravel with occasional small boulders in a sandy, silty matrix. The unit is similar in texture and lithology to terrace alluvium two (Qt_2) but is much more weathered. In the southern part of the quadrangle terrace alluvium three is subdivided and mapped as two distinct benches 25 and 45 ft above Monument Creek where unit Qt_{3u} is older and higher than unit Qt_{3l}. The surface of terrace alluvium three slopes gently toward Monument Creek.

Terrace alluvium three is correlated with Kettle Creek Alluvium of Varnes and Scott (1967) at the U.S. Air Force Academy. It is generally similar to Louviers Alluvium in the Denver region (Hunt, 1954). Terrace alluvium three is considered Illinoian in age based on diagnostic vertebrates and invertebrate fossils (Scott, 1960). In the southern part of the quadrangle, the upper unit (Qt_{3u}) grades into a broad level surface east of Monument Creek underlying Nevada Avenue. It also underlies the gently sloping surface and valley floor incised by Douglas Creek in the vicinity of Andrew Jackson School (NE¼ sec. 25, T. 13 S., R. 67 W.). Maximum thickness of terrace alluvium three in the Pikeview quadrangle is about 25 ft. This unit is a potential source of sand and gravel.

Older alluvial gravels (Pleistocene)— Partially dissected remnants of deposits of three older gravel deposits are preserved along Monument Creek and the piedmont of the mountain front. Finlay (1916) recognized the highest elevation deposits (Qg_2 and Qg_3, this report) and called them "mesa gravels" after their distinctive topographic form. Finlay clearly recognized that these gravels were deposited by streams. Varnes and Scott (1967) recognized Finlay's higher gravels and identified a third partially dissected gravel deposit at a lower elevation. Varnes and Scott gave these three gravel deposits local names that, from youngest to oldest, are the Lehman Ridge Gravel, Douglass Mesa Gravel, and Pine Valley Gravel (Figure 2). They called these deposits simply "Gravels," classed them "pediment gravels" and described them as "stream alluvium laid down on ancient pediments." Scott and Wobus (1973) referred to all three deposits as "alluvial terrace or pediment gravel" and correlated them with similar deposits in the Denver area that were named the Rocky Flats Alluvium, Verdos Alluvium, and Slocum Alluvium by Scott (1960, 1963a). Trimble and Machette (1979) called these deposits gravel or alluvium, and made no mention of pediments in their unit descriptions. Carroll and Crawford (2000) resurrected the designation of these deposits as pediment gravels.

The older alluvial gravels were deposited on erosional surfaces cut across bedrock units, but it is not clear that these surfaces should be called pediments, as the configuration of the of the eroded bedrock surface is poorly understood at this time.

In this report these deposits are informally called older gravels and included as alluvial deposits (Figure 2). The map designations (Qg_1, Qg_2, Qg_3) remain the same as those used by Carroll and Crawford (2000) in the Colorado Springs quadrangle.

Qg_1

Older gravel one (middle Pleistocene)— This map unit is composed of gravel deposits that underlie a gently sloping topographic surface from 35 to 100 ft above Monument Creek. West of Monument Creek older gravel unit Qg_1 consists of light-reddish-brown, poorly sorted, moderately to poorly stratified pebble and cobble gravel derived primarily from Pikes Peak Granite. In this area the clasts are moderately to highly weathered and have thin carbonate coatings. East of Monument Creek, unit Qg_1 is finer grained and has clasts derived from Dawson Formation parent material. Locally, this map unit also includes thin overlying sheetwash deposits, colluvium, and eolian sand. The unit is considered pre-Illinoian in age from stratigraphic position, mollusks, and soil development (Scott, 1960). It correlates with the Pine Valley Gravel at the U.S. Air Force Academy (Varnes and Scott, 1967) and was correlated with Slocum Alluvium by Scott and Wobus (1973). Maximum thickness of older gravel one is 35 ft in Douglas Creek Valley on the U.S. Air Force Academy. This unit is a potential source of sand and gravel.

Qg_2

Older gravel two (middle Pleistocene)— These deposits are composed of medium-reddish-brown to brown, poorly sorted, well-stratified bouldery cobble gravel and sand that underlie gently sloping topographic surfaces 125 to 175 ft above Monument Creek. The unit consists of rounded to subrounded clasts derived from the Pikes Peak Granite with relatively much fewer clasts of sedimentary rock. Clasts range in size from 2 in. to 3 ft in diameter and are strongly weathered. This unit coarsens upward and fines eastward away from the mountain front. The basal part of older gravel two contains silt and clay layers interbedded with coarse-grained sand and cobble gravels.

Unit Qg_2 is primarily found west of Monument Creek. The area in the southwest corner of Pikeview quadrangle named "The Mesa" is capped by older gravel two. Most of the prominent, dissected, gently east-sloping, upland surfaces in the northwest quarter of the Pikeview quadrangle are remnants of once much more extensive deposits of Qg_2 gravel. A well-developed pedogenic soil with a thick K-horizon is locally preserved. Much of the unit is cemented with calcium carbonate and moderately well lithified.

Older gravel two correlates with the Douglas Mesa Gravel of Varnes and Scott (1967) which is considered pre-Illinoian in age based on the Lava Creek B ash by Scott (1960). Scott and Wobus (1973) and Trimble and Machette (1979) correlated the unit with the Verdos Alluvium, in the Denver area, which is interbedded with the Lava Creek B volcanic ash in the Littleton and Fort Logan quadrangles. The Lava Creek Tuff in the Yellowstone area, which is near-source equivalent of the Lava Creek B ash, was recently redated with an age of 0.64 ± 0.02 m.y. (M. Lanphere, 2001, written communication). Thickness of Qg_2 averages about 25 ft but maximum thickness may locally exceed 90 ft.

This unit is a source of sand and gravel in the Colorado Springs area. The edge of "The Mesa" at the NW¼ sec. 36, T.13 S., R.67 W. has been extensively mined for gravel. A previously mined deposit of Qg_2 in SE¼, sec. 15, T. 13 S., R. 67. W. was reclaimed and developed for residential uses.

Qg_3

Older gravel three (middle to early Pleistocene)— These deposits are composed of dark-reddish-brown to brown, poorly sorted, stratified boulder gravel that overlies remnants of an erosion surface on the western part of the U.S. Air Force Academy about 200 to 300 ft above Monument Creek. The unit is similar to Qg_2 but generally contains a higher percentage of cobbles and boulders. Clasts are composed entirely of very weathered Pikes Peak Granite and are coated with carbonate rinds. A thin carbonate soil is present. The unit is correlative with the Lehman Ridge Gravel at the U.S. Air Force Academy (Varnes and Scott, 1967) which Scott (1960) considered pre-Illinoian in age based on stratigraphic relationships with the Verdos Alluvium. Older gravel three is similar in characteristics to the Rocky Flats Alluvium in the Denver area (Scott and Wobus, 1973; Trimble and Machette, 1979). Maximum thickness of older gravel three is about 80 ft.

COLLUVIAL DEPOSITS—Sediments that were mobilized, transported, and deposited primarily by gravity on valley sides, valley floors, and hillslopes.

Qlsr

Recent landslide deposits (Holocene)— Includes recently active landslides with fresh morphological features such as lateral shear zones, hummocky terrain, headscarps and toes. Texturally, recent landslide deposits are heterogeneous mixtures of unsorted, unstratified, clay, silt, and sand with occasional cobbles and boulders. Most recent landslide deposits are usually gray matrix material with reddish-brown to brown clasts, but occasional olive-green claystone can be found. This latter material may be re-healed shear zones of older landslide material incorporated within recent landslide deposits. Large, relatively intact and deformed blocks of shale and claystone bedrock may be included in the deposit.

Recent landslides in the Pikeview quadrangle are most numerous in the southwestern part of the map area along the flanks of "The Mesa." Here, recent landslide deposits involve failure planes in Pierre Shale on moderate to steep hillslopes adjacent to gravel-capped Qg_2 surfaces. Large, reactivated landslides on slopes steeper than 10 percent (5°–6°) are common.

Recent landslides within larger, older landslide complexes may occur on slopes with any aspect (Carroll and Crawford, 2000). They may also occur on highly fractured, weathered, steeply dipping shale and claystone bedrock (J. Himmelreich, 2001, written communication). Thin-skinned rotational slumps too small to map also occur in the Pikeview quadrangle. Most of these are derived from Cretaceous sandstone and shale units in the lower part of the Dawson Formation and the upper member of the Laramie Formation. Many of these slumps are not easily recognizable due to subsequent colluvial cover (Noe, 1996).

A large (8-acre) recent landslide in SE¼SW¼, sec. 25, T. 13 S., R. 67 W. (Holland Park subdivision) occurred as a result of heavy rainfall events in 1999. Rotation and lateral movement of the landslide toe severly damaged several homes along Hofstead Court and Hofstead Terrace. Local geomorphology strongly suggests this to be a reactivated, older landslide. A recent landslide in the west side of the quadrangle in sec. 22, T. 13 S., R. 67 W. (Mountain Shadows subdivision) moves as slow creep along the toe front. This landslide has damaged foundations and several residential structures in the last 12 years. A study by the Colorado Geological Survey in 1993 indicates this landslide activity resulted from failure of the Niobrara Formation or colluvium derived from it (Colorado Geological Survey, 2001).

Recent landslide deposits are prone to renewed or continued landsliding, and may be associated with expansive soils or susceptible to settlement when loaded. Springs, seeps, and shallow groundwater are commonly associated with recent landslide deposits and potentially increase their susceptibility to movement. Maximum thickness of recent landslides in this quadrangle is about 40 ft (J. Himmelreich, 2001, written communication).

Qls

Landslide deposits (Pleistocene)— Highly variable deposits consisting of unsorted, unstratified clay, silt, sand, gravel, and rock debris interpreted to be older landslides. This unit includes translational landslides, rotational landslides, earthflows, and extensive slope-failure complexes with moderately well preserved geomorphic characteristics. Landslide deposits in the quadrangle are mostly heterogeneous clayey mixtures of reworked Pierre Shale and very coarse-grained sand and pebble gravel derived from Qg_2 gravels. The deposits range from slowly creeping landslides to long-inactive, middle or perhaps even early Pleistocene landslides. Landslides in the Colorado Springs region that affect the margins of surfaces capped by Qg_2 gravel have a maximum age of at least 640,000 years for the oldest preserved landslide deposits.

Areas of moderate to steep slopes in Pierre Shale have a higher susceptibility to failure. Several landslide deposits mapped along the north edge of "The Mesa" are interpreted from 1947 aerial photography; this area is now urbanized and evidence of slope failure has been removed or regraded.

Landslide deposits may be subject to future movement, but deeply dissected deposits may indicate a longer period of dormancy. Excavations within landslide deposits should be individually evaluated for stability. Deposits may be prone to settlement when loaded and may have inherently low internal structural stability. Landslide deposits may contain expansive soils. Shallow groundwater seeps or springs may occur within landslide deposits. Maximum thickness of Qls landslide deposits in the quadrangle may exceed 60 ft.

Qc

Colluvium (Holocene and late Pleistocene)— Colluvium deposits are widely variable, from dark-gray and brownish-gray, matrix-supported sandy silt and clayey sand to clast-supported pebble or cobble gravel with occasional boulders in a sandy matrix. These deposits are derived from weathered bedrock and surficial deposits and are transported downslope primarily by gravity but sometimes partly by sheetwash. This map unit grades to sheetwash deposits or undifferentiated deposits of mixed alluvium and colluvium (Qac) on lower slopes. Colluvial deposits are unsorted or poorly sorted with weak or no stratification and are usually coarser grained in steeper areas and finer grained on lower slopes. The map unit may include some landslide deposits, sheetwash deposits, or debris-flow deposits that are too small or too indistinct on aerial photographs to be mapped separately. Colluvium interfingers with older fan deposits (Qfo) in Pulpit Rock Park (SW¼, sec. 17, T. 13 S., R. 66 W.) but the deposits are too small to be mapped at 1:24,000 scale.

Areas mapped as colluvium are susceptible to future colluvial deposition and may be locally subject to sheetwash, rockfall, small debris flows, mudflows, and landslides. Several landslides are the result of failure in colluvial slopes in the Pinecliff subdivision area near "The Mesa" and Centennial Blvd. (J. Himmelreich, 2001, written communication). Fine-grained, low-density colluvium may be prone to collapse. Maximum thickness of the colluvium deposits in the Pikeview quadrangle is probably about 70 ft.

ALLUVIAL AND COLLUVIAL DEPOSITS— Sediments in debris fans, floodplains, tributary stream channels, and adjacent hillslopes. Depositional processes in stream channels are primarily alluvial and may include hyperconcentrated debris flows. Colluvial processes prevail where sheetwash and colluvium are washed or rolled into alluvial fans, hillslopes, and along the hillslope-valley floor boundary.

Qfy

Younger fan deposits (Holocene)— Generally consist of poorly stratified deposits that range from poorly sorted, clast-supported pebble, cobble, and boulder gravel in a sandy matrix to matrix-supported, clayey, sandy gravel. This unit may include alluvial and sheetwash deposits in low-angle fans and tributary drainages and small landslide deposits. Younger fan deposits are coarser grained near the heads of fans. Deposits tend to be finer grained in the distal ends of fans where sheetwash and mudflow processes are common. Maximum thickness on the quadrangle is about 30 ft. Younger fan deposits are subject to flooding and future debris-flow, hyperconcentrated-flow, and sheetwash deposition. Several younger fan deposits on the west side of the quadrangle are composed of fine rock debris of Cretaceous units. In particular, the Niobrara Formation erodes to form fine-grained, low-density younger fan deposits that may be prone to settlement, hydrocompaction, piping, and landsliding.

Qac

Alluvial and colluvial, undivided (Holocene) — Chiefly stream-channel alluvium deposited as mainstem floodplain deposits and in tributary drainages and valley floors. The alluvial part consists of poorly to well sorted, stratified sand, pebbles, and sandy gravel clasts of mostly Cretaceous parent material. The colluvial part consists of poorly sorted, unstratified or poorly stratified, clay, silty sand, sandy silt, pebble to boulder gravel of mostly Cretaceous bedrock exposed on the Pikeview quadrangle. The variety of clasts are restricted to mostly sandstone, siltstone, shale, conglomerate, and coal. This unit increases in sand content in the north part of the map area where it is locally derived from the Dawson Formation. This deposit differs from terrace alluvium one (Qt_1) in that it is an active Holocene flood-plain deposit. Thickness commonly is 5 to 20 ft, with maximum thickness estimated at about 40 ft. Low-lying areas are subject to flooding. Valley sides are prone to sheetwash, rockfall, and small debris flows. Unit may be hydrocompactive and piping and settlement may occur where the deposit is fine-grained and low in density.

Qfo

Older fan deposits (late and middle? Pleistocene)— Unit is poorly sorted, clast-supported, boulder, cobble, and pebble gravel in a sand or silty sand matrix. Clasts are generally subangular to subrounded. Unit is deeply dissected and debris and hyperconcentrated flows may run in the incised channels. Older fan deposits are prevalent in Pulpit Rock Park area (SW¼ sec. 17, T. 13 S., R. 66 W.) and near the Four Diamond Sports Complex (sec 20. T. 13 S., R. 66 W.). These fans are derived from Dawson Formation parent material exposed in cliffs at the heads of the fans. The unit has a thin, moderately well-developed pedogenic soil. Older fan deposits may be a source of sand and gravel.

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

Qes

Eolian sand (Holocene to late Pleistocene)— These deposits are fine- to coarse-grained, light-brown to orange frosted sand and silt deposited by wind and preserved on level to gently sloping surfaces downwind (east) of Monument Creek. Typically this unit is faintly stratified and non-cohesive. Eolian sand blankets much of the east side of Pikeview quadrangle but the mapped distribution of eolian sand is approximate due to its poor exposure in urbanized areas. Eolian sand is moderately compacted, easily excavated, and drains well. It has a maximum thickness of 60 ft.

UNDIFFERENTIATED SURFICIAL DEPOSITS

Q

Surficial deposits, undifferentiated (Quaternary)— Undifferentiated surficial deposits are shown only on the cross sections and may include any of the above surficial deposits.

BEDROCK

Dawson Formation (Upper Cretaceous and Paleocene)— The sedimentary rocks lying above the Laramie Formation were first called Dawson arkose (with a lower case "a") by Richardson (1912, 1915) from a type locality on Dawson Butte, about 20 mi. north of the Pikeview quadrangle. Richardson shows Dawson arkose interfingering with the Arapahoe and Denver Formations of the Denver area, with the upper part of the Dawson arkose lying above the Denver Formation. Finlay (1916) recognized that the Dawson arkose extended into the area of the Pikeview quadrangle and contained an andesitic sandstone member at the base. Varnes and Scott (1967) used the name Dawson Arkose (upper case "A") and recognized that there are two "beds of andesitic material" in the area south and east of the U.S. Air Force Academy. Scott and Wobus (1973) changed the name to Dawson Formation, apparently in recognition that the unit was not entirely composed of arkose; they mapped a lower part (andesitic) and upper part of the Dawson Formation. This work (OF 01-03) recognizes three additional mappable informal members of the Dawson Formation (Figure 3) which Scott and Wobus described in the upper part of the Dawson Formation but did not map separately. The nomenclature used in this description for the Dawson Formation follows that of Scott and Wobus (1973) and Trimble and Machette (1979) in referring to Dawson Formation rather than Dawson Arkose. The use of the symbol "TKda" for the upper part of the Dawson Formation follows the usage of Trimble and Machette.

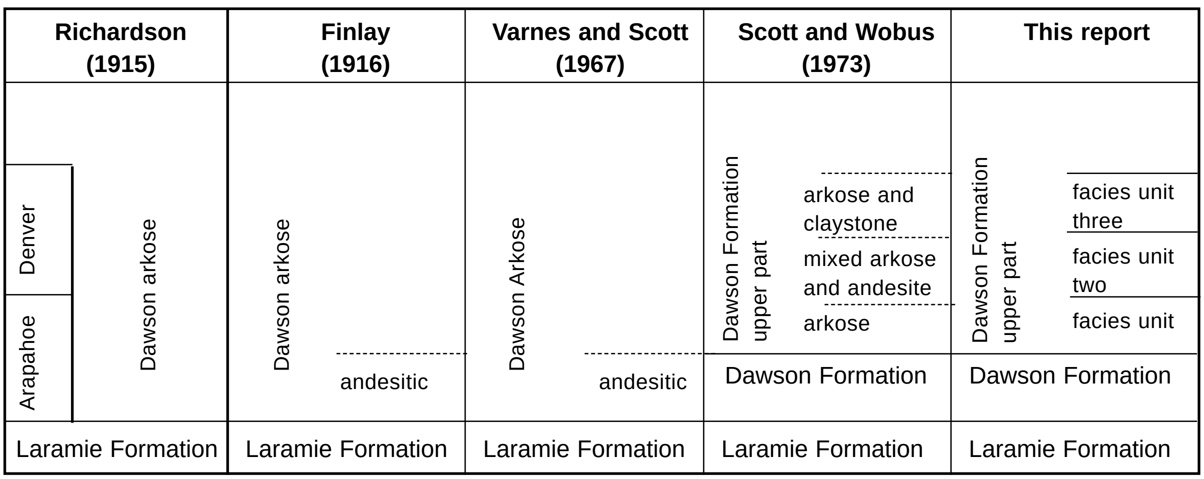


Figure 3. Correlation diagram for subdivisions of the Dawson Formation as used in various publications.

Upper part of the Dawson Formation (Upper Cretaceous and Paleocene)— The upper part of the Dawson Formation is divided into facies unit one (TKda$_1$), facies unit two (TKda$_2$), and facies unit three (TKda$_3$). Facies unit one occurs as a very thick "basin edge" deposit close to the mountain front on the U.S. Air Force Academy and in the Woodmen Valley area, and as a basal unit beneath the finer-grained facies in the upper part of the Dawson Formation in the eastern part of the quadrangle. The finer grained basinal facies, facies unit two and facies unit three, may interfinger with the coarser mountain front facies. Contacts between facies units within the basin are probably both gradational and

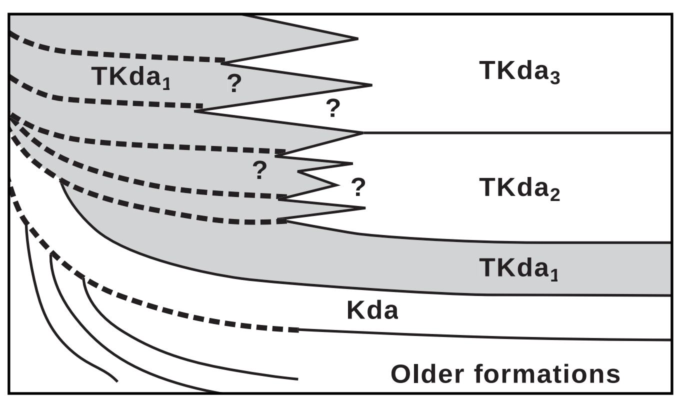


Figure 4. Diagram showing the relationship between the subdivisions of the Dawson Formation in the Pikeview quadrangle. The heavy dashed lines are erosional unconformities, other lines are normal sedimentary contacts.

interfingering. Figure 4 illustrates the facies relationship between these units.

The upper part of the Dawson Formation spans the Cretaceous–Tertiary boundary, but the exact location of the time boundary has not been confirmed. Kluth and Nelson (1988) recently reconfirmed the Late Cretaceous (late Maastrichian) age for the upper part of the Dawson Formation on the U.S. Air Force Academy. All of the upper part of the Dawson Formation mapped in the Pikeview quadrangle appears to be included within the D_1 member of the Dawson Arkose in the Denver Basin (Raynolds, 1997) and therefore must be no younger than early Paleocene, (R. Raynolds, 2001, oral communication).

$TKda_1$

Facies unit one— This facies is composed of white to light-gray, crossbedded or massive, very coarse arkosic sandstone, pebbly arkose, or arkosic pebble conglomerate; the unit contains occasional interbeds of thin- to very thin-bedded gray claystone and sandy claystone, or dark-brown to brownish-gray, organic-rich siltstone to coarse sandstone containing abundant plant fragments. Facies unit one comprises the lower strata in upper part of the Dawson Formation in the eastern, basinward, part of the quadrangle, whereas it constitutes the entire upper part of the Dawson Formation in the western part of the map area, proximal to the mountain front. It varies in thickness from about 400 ft. in the southeastern part of the quadrangle to about 1,200 ft. in the western part.

Excellent bold exposures of facies unit one occur as cliffs in an arcuate trend across the Pikeview quadrangle from the U.S. Air Force Academy and Woodmen Valley area through Pulpit Rock, Austin Bluffs, and Palmer Park. Six different lithofacies are present in facies unit one. These lithologies are:

1. Beds of white to light-gray very coarse arkosic sandstone, pebbly sandstone, or arkosic pebble conglomerate dominate the unit. Many outcrops have only beds of this character. These beds are generally very thick, often 8 or 10 feet in thickness, and commonly have steeply inclined crossbedding and scoured bases. The sand- and gravel-size material in facies unit one is subangular to subround and poorly sorted. The coarse beds have irregularly distributed areas of finer grained and better sorted, more quartz-rich sandstone that is composed mostly of gray and clear fine- to medium-grained quartz grains. Clasts of this finer, more quartzose but still arkosic sandstone occur as ripped-up and included sandstone clasts in the pebble conglomerate beds. The character of the sediments and sedimentary structures of the upper Dawson Formation conglomerate beds suggest deposition in energetic fluvial environments, probably braided streams. The pebbles in these coarse-grained beds are dominated by subround fragments of quartz up to 3 in. in diameter. Also common as clasts are pieces of recognizable white or light-gray granite and fragments of white feldspar, up to 1.5 in. in size. The granite and feldspar clasts commonly have perthitic and "graphic granite" textures. Minor amounts of pebbles of chert, smoky quartz, or granitic metamorphic rocks occur locally. Pebbles of volcanic origin are extremely rare; their scarcity is all the more significant considering the dominance of andesitic volcanic material in the underlying lower part of the Dawson Formation.

2. Beds of white to light-tan, fine- to medium-grained feldspathic sandstone with lower angle crossbeds are often interbedded with the gravel beds, but being more friable, make up more recessive parts of the outcrops. These sandstones are poorly sorted, have high clay contents, and are often thin or medium bedded. Wavy bedding and ripple cross-laminations are common. Carbonized plant fragments are common as both disseminations and as laminae of organic material. These beds appear to be the deposits of less energetic streams or backwater areas between braided streams. Clasts of sandstone of this character occur in the conglomerate beds.

3. Massive, light-gray to light-brownish-gray, very thick, homogeneous beds with little internal structure are interbedded with the conglomerate beds in some areas. Close examination of these beds reveals local poorly developed crude grading of the coarser fragments, disseminated small dark flakes of carbonaceous organic

material, and a few wispy dark laminae. The matrix of these beds is a very clay-rich, fine- to coarse-grained sandstone containing matrix-supported, angular to subround grains ranging in size from very coarse sand to pebbles. These generally structureless, massive beds appear to have originated as mudflows.

4. Interbedded with the gravel beds and mudflow beds at Pulpit Rock are dark-brown to brownish-gray organic-rich beds of siltstone to coarse sandstone with abundant plant fragments. These beds are usually structureless and commonly darkest colored at their tops. They may grade downward into gravel or mudflow beds, but the tops are generally sharp and may have load deformation structures where overlain by thick arkosic gravel or mudflow beds. These dark beds, or dark zones at the tops of thick beds of other characteristics, are interpreted as the deposits of ephemeral swamps and swampy soil areas buried in a rapidly subsiding area at the margin of the basin.

Examples of each of the first four types of beds can be seen in a small area of excellent exposures at Pulpit Rock and the ridge which extends east-southeast from Pulpit Rock (SW¼ SW¼ sec. 17, T. 13 S., R. 66 W.).

5. In many outcrops of facies unit one occasional beds of thin- to very thin-bedded, light- to dark-gray claystone and sandy claystone are interbedded between thicker beds of arkosic gravel.

6. There are also numerous interbeds of 1- to 6-foot-thick, light- to dark-red paleosols in the upper part of facies unit one in the northwestern part of the quadrangle. The thickest and best developed of these paleosol interbeds is exposed in the west bank of Monument Creek about 700 feet south of the sewage disposal plant on the U.S. Air Force Academy (NW¼ NW¼ sec. 30, T. 12 S., R. 66 W.). Here greenish-gray gritty claystones interbedded with thin lenses of coarse arkosic sandstone are oxidized to red and yellow-brown colors. The oxidized claystones contain small chips of dark-brown plant remains and root casts. The paleosols in facies unit one in the quadrangle have been found only on the U.S. Air Force Academy, along Monument Creek, and in outcrops north of West Monument Creek; including an outcrop in SW¼ SE¼ sec. 25, T. 12 S., R. 67 W.; a road cut about 400 ft west of the fire station in sec. 27, T. 12 S., R. 67 W. on the west edge of the quadrangle; and in many outcrops along Monument Creek north of the sewage treatment plant. Particularly good exposures occur in high creekside bluffs in NW¼ NW¼ sec. 19 T. 12 S., R. 66 W. near the north edge of the quadrangle, where 5 or 6 individual red paleosol zones can be seen in 20 to 30 ft of light-colored arkosic sandstone beds.

At many exposures of the lower Dawson- upper Dawson contact, the basal 20 to 30 ft of strata consist of brown coaly siltstone and brown, fine- and very fine-grained quartzose sandstone with abundant plant fragments and thin laminations of organic material. Interbedded with these organic-rich beds are occasional thick beds of light-gray, coarse to very coarse or pebbly, arkosic sand similar to the arkosic beds that are characteristic of facies unit one of the upper Dawson. These beds are overlain by very thick bedded, massive and crossbedded, very coarse arkosic sandstone beds on a very sharp contact. In a few places the brown quartzose sandstone beds are missing, and thick, coarse arkosic sandstone beds of facies unit one rest directly on the olive to yellowish-green, clay-rich sandstones of the uppermost lower Dawson. The contact between the lower part of the Dawson Formation and facies unit one is placed at the change from clayey, yellowish-green, andesitic sandstone below, to more quartzose and arkosic lithologies above.

Evidence for the origin of the brown, orange, and red iron-oxide-cemented layers which are so common in the white arkosic beds of the upper Dawson is found in the Pikeview quadrangle. Along Cottonwood Creek, and in other occasional creekside outcrops where down cutting has been rapid enough to expose unoxidized rocks, there is abundant iron sulfide, probably pyrite, in these rocks. Particularly good examples of these occurrences can be seen in nearly every outcrop along Cottonwood Creek from the upper part of the lower Dawson

Formation (Kda), through facies units one and two of the upper Dawson Formation. Pyrite occurs as disseminations in the sandstones and as spherical concretions as large as 2 to 3 in. in diameter. The concretions essentially consist of pyrite-cemented quartz sand grains that weather out of the strata intact. Pyrite fills pore space in the sandstone, probably replacing the sandstone cement, and possibly partially replacing chemically reactive sand grains.

In upper Dawson sandstone beds with high carbon contents, abundant woody fragments, and high permeability, iron sulfide has grown into flat clusters of intergrown spherical pyrite concretions and layers of pyrite-cemented sand. These sulfide layers erode out of the soft, friable sands and litter the banks and bed of Cottonwood Creek as flat clusters of sulfide spheres which look like clusters of large grapes, or small oranges, a form commonly known as mammilary.

Sulfide balls and irregular masses in sandstones are common in many sedimentary basins in which sandstones have been subjected to reducing conditions. In the upper Dawson Formation sandstone beds with remaining carbonized organic matter, usually wood fragments, it is common to find that the wood has been partially replaced by pyrite. These occurrences illustrate the effect of the strong chemical affinity of carbon for oxygen (Krauskopf, 1967). Carbonized wood is oxidized into carbon dioxide, which removes oxygen from reactive mineral grains and ground water, and results in chemically reducing (oxygen-depleted) conditions during diagenesis. In the case of sulfate-bearing ground water, the reduction of sulfate produces sulfide ions, which react with iron to produce iron sulfides. This reaction goes on as long as there is carbon remaining in the sediments. In the Dawson Formation sandstone beds, iron sulfide appears to have nucleated on carbonaceous organic grains and grown outward into the sandstone pore space.

The diagenetic effects of carbon oxidation results in the concentration of iron, as sulfide, in certain sandstone beds, and as discrete iron-enriched layers within sandstone beds. As the iron-rich sandstone beds begin to oxidize, the unstable iron sulfide is converted into bright yellow- and orange-colored iron sulfate which can be seen as an efflorescent crust on many outcrops along Cottonwood Creek. Further oxidation converts iron sulfate to iron oxide which is very stable in the weathering environment. The final result is the strong concentration and dense cementation of sandstone layers in the Dawson Formation by iron oxides. These iron-oxide-cemented sandstone layers are more resistant to weathering and protect columns of more friable sandstone as pedestals and monument-like forms with flat, hat-like or mushroom-shaped tops (hoodoos) that are characteristic of weathered upper Dawson outcrops.

Facies unit one is generally permeable, well drained, and has good foundation characteristics. Excavation may be difficult, even though the arkoses are friable and easily eroded. The finer grained interbeds may be less stable and may have greater shrink-swell properties. The block-failure of cliffs in facies unit one pose a significant slope stability hazard in some residential areas. Facies unit one may be equivalent to the upper part of Arapahoe Formation and/or Arapahoe aquifer in the Denver area (J. Himmelreich, 2001, oral communication).

$TKda_2$ **Facies unit two—** Facies unit two is composed of light-gray to greenish-gray arkosic sandstone and olive-green to brownish-gray, pebbly, andesitic sandstone interbedded with dark-gray to grayish-green, fine-grained micaceous sandstone and sandy claystone. Facies unit two is 400 to 500 ft thick and occurs in the middle part of the upper Dawson Formation in the basinward part of the quadrangle.

The lower strata in facies unit two is well exposed in the bed of Cottonwood Creek in sec. 9 and 10, T. 13 S., R. 66 W. where light-gray to greenish-gray arkosic sandstone beds up to 5 ft thick are interbedded with thin beds of dark-gray to grayish-green sandy claystone. The arkosic sandstone resembles those in facies unit one but is finer grained, much less pebbly, and greenish colored rather than white or light gray. Sand grain size is fine to very coarse. The sandstone beds commonly have pyrite concretions, and the effloresence of iron sulfate indicates the oxidation of pyrite is in progress. In the lower part of the facies unit two, the finer grained beds are mostly dark-gray to grayish-green fine sandstone and sandy claystone. Several beds have excellently preserved leaf fossils and impressions, including palm fronds.

The upper part of facies unit two is well exposed in the Sunset Mesa area (E½ sec. 15, and W½ sec. 14, T. 13 S., R. 66 W.), in Rampart Park (NE¼ sec. 4, T. 13 S., R. 66 W.) and in Kettle Creek between the bridges on Highway 83 and Old Ranch Road (NW¼ sec. 28, T. 12 S., R. 66 W.). In these locations this unit is characterized by greenish-gray and brown sandy claystone, gray fine-grained sandstone, and olive pebbly sandstone containing small rounded andesite pebbles. The olive pebbly sandstone contains a mixed population of clasts, which vary widely from bed to bed. In this unit fragments of pink Pikes Peak Granite are mixed with small rounded andesite pebbles up to about 0.75 in. in diameter. Large clusters of carbonized and partially petrified logs were found in two places in the upper part of facies unit two. One of these localities is in Rampart Park where a log up to 1.5 ft in diameter and 35 ft long occurs and over 30 logs have been mapped (K. Johnson, 2001, written communication). The other locality is on Point of the Rocks Drive (NE¼ NE¼ sec. 15, T. 13 S., R. 66 W.) where a log about 2.5 ft in diameter is exposed.

The upper and lower parts of facies unit two were mapped together since they represent a reintroduction of andesitic material into the basin. Varnes and Scott (1967) recognized the facies relationship of the facies unit two to the rest of the Dawson Formation, although only one very small outcrop of this lithology is shown on their map. Varnes and Scott (1967, p. 16–17) also recognized that the clays of the andesitic facies unit two were different from those of the arkosic facies unit one. The white and light-gray arkosic beds are characterized by kaolinite while the greenish andesitic beds are dominated by montmorillonite. The lower part of facies unit two unit appears to be transitional between facies units one and two, but the dark-gray to grayish-green sandy claystones represent the reintroduction of andesitic material (green montmorillonite) into the basin. The reintroduction of andesite is confirmed by the deposition of pebbly sandstones containing andesite pebbles in the upper part of facies unit two.

Clastic dikes were found in outcrops of facies unit two in the bed of Cottonwood Creek. In low outcrops along the north side of the stream about 500 ft downstream from the north end of Gambol Quail Drive (NE¼ SW¼ sec. 9, T. 13 S., R. 66 W.) a swarm of northwest-trending, light-gray sandstone clastic dikes, 3 to 6 in. thick, cut dark-green sandy claystones. A coalified tree stump was found nearby, buried upright in growth position. The second swarm of clastic dikes are located about 200 ft upstream from a washed-out concrete, erosion-control dam in NW¼ SE¼ sec. 9, T. 13 S., R. 66 W. Several clastic dikes originated in a gray coarse sandstone bed, penetrate upwards through a dark-grayish-brown sandy claystone bed about 4 ft thick, and connect with an overlying lenticular bed of gray sandstone. The upper sandstone bed may be a "sand volcano" or "sand blow." The sand deposited as the upper sandstone bed appears to have originated from the lower sandstone bed and may have been transported upward to the surface as a fluidized slurry.

The orientation of the clastic dikes varies from N.20°W. to N.55°W., and they dip steeply towards the southwest. The gray clastic dikes are contorted by the compaction of the dark-grayish-brown sandy claystone bed, indicating that the sandy claystone was uncompacted and plastic during the emplacement of the clastic dikes. Dewatering and compaction of the sandy claystone distorted the gray sands of the clastic dikes, which contained less water and were less compactible. The dip of the clastic dikes may have been caused by creep of unconsolidated sediments basinward, towards the northeast, rotating the sand dikes into the steep southwest dip.

One paleosol bed was found in an outcrop of facies unit two along Pine Creek, just east of Highway 83 in SE¼ NE¼, sec. 32, T. 12 S., R. 66 W. This paleosol, in the westernmost part of facies unit two, and the numerous paleosols in the upper part of facies unit one on the U.S. Air Force Academy, suggest an explanation for the transport of andesitic material into the basin during the deposition of facies unit two. The lower part of the

Dawson Formation (Kda) is dominated by andesitic material, but facies unit one of the upper Dawson is essentially andesite-free. The paleosol beds in the facies units one and two were formed during small periods of uplift and erosion along the mountain front. Numerous paleosol beds in upper part of facies unit one indicate that uplift and erosion closer to the mountain front was episodic and repeated. This uplift and erosion suggests that reintroduction of andesite debris into the basin in facies unit two, mixed with arkosic material, may have been the result of erosion of the lower part of the Dawson Formation. Much as the Pierre Shale and Fox Hills Sandstone were being eroded and truncated during the deposition of the lower part of the Dawson Formation, some of the lower part of the Dawson Formation may have been eroded and truncated during the deposition of facies unit two.

The sandstones and arkoses of facies unit two are generally stable and have good foundation characteristics. The finer grained, more clay-rich lithologies are less stable and have high shrink-swell properties. Facies unit two may be equivalent to the Denver Formation and/or Denver aquifer in the Denver area (J. Himmelreich, 2001, oral communication).

TKda$_3$

Facies unit three— This lithofacies unit consists of sub-equal amounts of three lithologies: (1) very thick-bedded, massive and crossbedded, white, tan, and light-gray arkose; (2) thin to thick beds of light-green to olive-gray clay-rich, fine- to medium-grained micaceous and feldspathic sandstone; and (3) thin to thick beds of dark-gray to greenish-gray sandy claystone. The entire thickness of facies unit three is not present in the Pikeview quadrangle. The preserved part of the unit is as much as about 500 ft thick.

The very thick-bedded, massive or crossbedded, light-colored arkose beds resemble those in facies unit one but are finer grained and generally thinner. Most of the grains in these arkoses are less than 0.5 in. in diameter; a few pebbles are up to 1.5 in. The lithologies of the coarse grains are much more varied than those in the arkoses of facies unit one, with grains of quartz, white feldspar, pink feldspar, white granite, pink granite, and small amounts of tan vuggy dolomite and red, black, or orange-brown chert. A few subround to round pebbles of altered volcanic rocks were found, but these are the least common of all the clast lithologies.

The light-green to olive-gray, clay-rich, fine- to medium-grained micaceous and feldspathic sandstone and the dark-gray to greenish-gray sandy claystone resembles similar lithologies in the lower part of facies unit two. The finer grained lithologies in this map unit are characterized by greenish colors, which are suggestive that the unit contains considerable montmorillonite clay.

The sandstones and arkoses of facies unit three are generally stable and have good foundation characteristics. The finer grained, more clay-rich, lithologies should be expected to be less stable and may have high shrink-swell potential. Facies unit three may be equivalent to the Dawson Arkose and/or Dawson aquifer as used in the Denver area (J. Himmelreich, 2001, oral communication).

Kda

Lower part of the Dawson Formation (Upper Cretaceous)— This lowest informal member of the Dawson Formation is mostly greenish-gray to olive-brown pebbly sandstone almost exclusively composed of andesitic material, interbedded with grayish-green to dark-green and brown to brownish-gray siltstone and sandy claystone. Locally at the base of the member there are lenticular beds of light-gray, medium- to coarse-grained, quartzose pebbly sandstone or yellowish-gray to orange chert-pebble conglomerate.

The lenses of quartzose pebbly sandstone or conglomerate in the base of the lower part of the Dawson Formation are exposed in three places in the Pikeview quadrangle. On a small hill near the west entrance to the UCCS campus from Austin Bluffs Parkway (NE¼ NW¼ sec. 29, T. 13 S., R. 66 W.) about 8 feet of yellowish-gray to orange chert-pebble conglomerate is poorly exposed. The red, yellow, and black chert fragments in the conglomerate are subangular to subround and up to 1.5 in. in diameter. This conglomerate is overlain by 8 to 10 ft of light-brown to tan, fine- to medium-grained sandstone with partings of brown organic material and 6 to 8 ft of organic-rich brown clay shale which resemble the upper member of the Laramie Formation lithologies. Above these beds are about 15 ft of olive to light-green, clay-rich, fine- to medium-grained sandstone with abundant rock fragment and feldspar grains, and then massive, light-green to olive, sandstone with abundant rounded and subrounded pebbles of andesite, characteristic of the lower part of the Dawson Formation.

Also exposed on the UCCS campus, in bold outcrops below Columbine Hall, is a pebbly sandstone which appears to be at the base of the lower part of the Dawson Formation. This sandstone body is at least 20 to 30 ft thick and is composed of a stacked series of sand-filled channels. The channels were filled with complexly crossbedded medium- to very coarse-grained, light-gray to buff sandstone in thick to very thick beds. The sand grains are subangular to subround, and mostly quartz with about 5 - 7 percent sand-size chert grains. The basal parts of the crossbedded units are often pebbly sandstones with subangular to subround red, yellow, or black chert pebbles up to 1.5 in. in diameter. White silicified wood fragments are also found in a few places in this outcrop as well as the mold impression of a small log about 5 in. in diameter and 6 ft long.

An exposure of similar white to light-gray crossbedded pebbly sandstone with chert pebbles and petrified wood fragments occurs at the base of the lower part of the Dawson Formation in Pulpit Rock Park NW¼ SW¼ sec. 17, T. 13 S., R. 66 W.

The sandstone in most of the lower part of the Dawson formation is thick to very thick bedded, massive or crossbedded, and appears to be amalgamated bodies of braided-stream fluvial channels. The sandstone characteristically contains subround to round pebbles up to 3 in. in diameter in a poorly sorted matrix of medium- to very coarse-grained sand. Pebble lithology is predominantly andesite with only rare fragments of quartz, chert, or pink granite. Non-andesite pebbles probably account for less than 1 percent of the clasts and are usually only found in the coarser deposits. Carbonized wood fragments, as large as logs up to 12 in. in diameter and 8 ft long, are common in the sandstone channels. The sandstone often contains rip-up clasts of finer lithologies, occasionally as large as 3 ft in diameter in thick channels with coarse pebbles. In a very well-exposed section along the south bank of Cottonwood Creek, about 300 ft upstream from the Vincent Drive bridge (SW¼ SW¼ sec. 8, T. 13 S., R. 66 W.) very thick, crossbedded or massive, coarse pebbly sandstone beds contain large rounded clasts of olive-brown siltstone and sandy claystone which appear to be eroded fragments of the upper transition member of the Pierre Shale or some of the finer beds in the Fox Hills Sandstone. Two of these clasts contain small, highly polished, phosphate pebbles or nodules, which are characteristic of the upper Pierre Shale and Fox Hills Sandstone. Selected samples of the phosphate nodules were collected from each of the clasts (PV-97, PV-98) and submitted to ALS Chemex for phosphate analysis. The results of these analyses are 18.8 percent and 23.2 percent P_2O_5, respectively (ALS Chemex, Certificate of Analysis A0034846). One of the thick sandstone beds in this section also contains the ripped up stump of a palm tree which can be identified by its characteristic root structure.

The finer grained units are very thin to medium bedded and are finely laminated to massive. Occasional ripple laminations are seen. The beds of grayish-green to dark-green clayey siltstone and sandy claystone very commonly have brown plant fragments on bedding planes. Well preserved fossil leaves of several species were found along the north bank of Cottonwood Creek in SW¼ SW¼ sec. 8, T. 13 S., R. 66 W., about 300 ft west of the Vincent Drive bridge. Beds of brownish-gray siltstone and brown to black, organic-rich sandy claystone are common near the top of the lower part of the Dawson Formation, especially in the transition with the overlying facies unit one of the upper part of the Dawson Formation.

The thickness of the lower part of the Dawson Formation varies from 0 to perhaps as much as 240 ft. A nearly complete section of about 210 ft of the Lower Dawson is exposed on the western end of the UCCS campus (NE¼ NW¼, sec. 29, T. 13 S., R. 66 W.). In the vicinity of Pulpit Rock Park (SW¼ sec. 17, T. 13 S., R. 66 W.) the lower part of the Dawson Formation is about 200 ft thick. The lower part of the Dawson Formation thins to the southeast along its outcrop trend in the Pikeview quadrangle as the formation is only about 120 ft thick in Palmer Park (NE¼ NW¼ sec. 33, T. 13 S., R. 66 W.). To the northwest this unit also thins rapidly because it is unconformably missing in the steeply dipping section at the head of Woodmen Valley (SE¼ sec. 3, T. 13 S., R. 67 W.), where the $TKda_1$ unit of the upper part of the Dawson Formation was deposited directly over an unconformity cut on the eroded edge of the upper member of the Laramie Formation.

The top of the lower part of the Dawson Formation is well exposed in the Pikeview quadrangle. Good examples of this contact are at in gullies at the base of the upper Dawson Formation $TKda_1$ cliff in SE¼ sec. 11, T. 13 S., R. 67 W.; in Pulpit Rock Park on the north side of an unnamed east-flowing tributary to Monument Creek (N½ SW ¼ sec. 17, T. 13 S., R. 66 W.); on the west face of Pulpit Rock and continuing to the southeast along the base of the cliffs formed by the upper part of the Dawson Formation; on the UCCS campus, particularly in gullies behind (above) the buildings named “The Lodge” and “Breckenridge House”; and in Palmer Park in NE¼ NW¼, sec. 33, T. 13 S., R. 66 W. In these exposures the uppermost beds of the lower part of the Dawson Formation are thick to very thick beds of massive, olive to yellowish-green, clay-rich sandstone containing common plant fragments. These sandstone beds contain sticky, greenish, montmorillonitic clays derived from weathering or alteration of the andesitic debris and are typical of the lower part of Dawson Formation. A few thinner beds of dark-brown coaly shale are interbedded with the yellowish-green and olive-colored uppermost beds of the lower part of the Dawson Formation. Above the yellowish-green clayey beds there is commonly 20 to 30 ft of thin beds of brown organic-rich siltstone and brown fine- and very fine-grained quartzose sandstone with a few interbedded, light-gray, coarse arkosic beds. This change in lithology from clayey andesitic rocks to quartzose and arkosic rocks is the contact between the lower part of the Dawson Formation and the $TKda_1$ unit of the upper part of the Dawson Formation.

The age of the lower part of the Dawson Formation is considered by Varnes and Scott (1967) and Scott and Wobus (1973) to be late Cretaceous. That age assignment was confirmed by Kluth and Nelson (1988) who found late Maastrichtian (latest Upper Cretaceous) pollen in arkoses of the upper part of the Dawson Formation.

The depositional environment indicated by the sandstone beds in the lower part of the Dawson Formation is a very energetic fluvial system capable of moving large volumes of andesitic pebbles, logs, and boulders up to 3 ft in diameter. Sedimentary structures in the sandstone beds indicate that this system was dominated by braided streams. The coarse debris, braided streams, and erosional power indicated by clasts of Pierre Shale or Fox Hills Sandstone suggest deposition close to the rapidly rising mountain front. In the Pikeview quadrangle the finer deposits of siltstone and sandy claystone with leaf fossils, interbedded in the braided stream deposits, suggest that the depositional location was probably a forested, relatively low-slope complex of coalescing alluvial fans. A greater proportion of finer deposits characteristic of flood plains and swamps should be expected farther eastward, into the Denver Basin, while coarser deposits could be expected closer to the mountain front, if they had not been removed by erosion.

On the west side of the Pikeview quadrangle (sec. 3 and 11, T. 13 S., R. 67 W.) a profound local unconformity exists between the upper member of the Laramie Formation and upper part of the Dawson Formation. The entire lower part of the Dawson Formation and much of the upper member of the Laramie Formation were removed as the unconformity was cut. Clasts of upper Pierre Shale and Fox Hills Sandstone that are present in the lower part of the Dawson Formation in the Cottonwood Creek locality indicate that Fox Hills and Pierre strata were exposed as the lower part of the Dawson Formation was being deposited. On the basis of the rarity of granitic fragments in the lower part of the Dawson Formation, erosion had not yet exhumed basement rocks from beneath a carapace of Late Cretaceous andesite volcanics. This unconformity has been mapped farther to the northwest by Varnes and Scott (1967), in the southwest corner of the U.S. Air Force Academy, where the Dawson Arkose (upper part of the Dawson Formation) rests unconformably on Fox Hills Sandstone. Kluth and Nelson (1988) remapped the area of Varnes and Scott’s unconformity and demonstrated that unit $TKda_1$ of the upper part of the Dawson Formation rests unconformably on the Pierre Shale as well.

Two swarms of small clastic dikes were found in the lower part of the Dawson Formation in scoured outcrops along Cottonwood Creek. One swarm is located about 200 ft downstream from the Vincent Drive bridge (SW¼ SW¼ sec. 8, T. 13 S., R. 66 W.), where outcrops of dark green sandy claystone in the creek bottom are usually covered with water. These dark beds are cut by a N45°E-trending swarm of small dikes, up to 0.75 in. thick, which are filled with light-gray silt and clay. Another swarm of thicker and coarser sand dikes were found upstream on Cottonwood Creek (about 1500 feet east-southeast of the Vincent Drive bridge, SE¼ SW¼ sec. 8, T. 13 S., R. 66 W.) near the top of the lower part of the Dawson Formation. At this locality 4- to 6-in.-wide dikes of light-gray, coarse to very coarse sandstone intrude outcrops of green sandy claystone in the bottom of the creek. Most of the dikes in this swarm strike between N45°E and N55°E, but one of the dikes bifurcates with one branch that strikes approximately E-W. Clastic dikes are generally created by either rapid loading of soft sediments or as sand “blows” associated with earthquakes.

The sandstones in the lower part of the Dawson Formation may be difficult to excavate but will probably have good foundation stability. The finer grained units are clearly the opposite, having achieved a local reputation as “green slime” for their considerable instability (D. Noe, 2000, oral communication). The lower part of the Dawson Formation, as used on this map and as used by Scott and Wobus (1973), may be equivalent to the lower part of Arapahoe Formation and/or Arapahoe aquifer in the Denver area (J. Himmelreich, 2001, oral communication).

Kl

Laramie Formation (Upper Cretaceous)— The Laramie Formation has been subdivided and mapped as three informal members; lower (Kll), middle sandstone (Kls), and upper (Klu) in the Pikeview quadrangle. An undivided Laramie Formation (Kl) is shown on the cross sections. The formation is also not divided in the southern part of the map area in sec. 29, 32, and 33, T. 13 S., R. 67 W. where recent urbanization conceals the bedrock geology. Here the formation is querried (Kl?). The Laramie Formation was mapped in this area by Finlay (1916) and Scott and Wobus (1973). Possible bedrock outcrops can be seen on 1947 aerial photography but are now obscured by the recent urbanization.

Klu

Upper member of the Laramie Formation— The upper member of the Laramie Formation is composed of brownish-gray sandy shale and very fine-grained shaley sandstone, thin coal beds, and channel-fillings of fine- to medium-grained, white, light-gray, or light-orange sandstone.

The upper Laramie is a soft and recessive unit composed mostly of of brownish-gray sandy shale which makes poor natural outcrops. At least 175 ft of the lower part of this member is well exposed in a road cut along Allegheny Drive just east of Centennial Boulevard (SW¼ sec. 11, T. 13 S., R. 67 W.). Here, thin to thick beds of brownish-gray and gray sandy shales with subordinate dark-brown coaly shale and gray, shaly very fine-grained sandstones are interbedded with several lenticular bodies of light-colored, fine- to coarse-grained sandstone similar to that in the middle member of the Laramie Formation. These sandstones have crossbedding, contorted bedding, and cut-and-fill structures which indicate that they are channel-fill deposits. The sandstones in these filled channels are locally strongly stained orange, brown, and maroon with iron oxides. The sand grains are dominated by quartz with small amounts of sand-size black chert grains. The shaly beds, particularly the brown and brownish-gray beds, contain abundant brown plant fragments. Projections from a partial section of the upper member in the Bluffside Terrace neighborhood, about 0.25 mi. northwest of the Allegheny Drive section, indicate that the upper member is about 400 ft thick. In the banks of an unnamed drainage, tributary to Monument Creek, between Rockrimmon Boulevard and Delmonico Drive (NE¼ sec. 13, T. 13 S., R. 66 W.), thin coal beds up to 2 ft thick, are present in the upper Laramie Formation.

The uppermost part of the upper member of the Laramie Formation is poorly exposed on a small hill near the west entrance to the UCCS campus from Austin

Bluffs Parkway (NE¼ NW¼ sec. 29, T. 13 S., R. 66 W.). Another exposure of the uppermost part of the upper member is located in Pulpit Rock Park in NW¼ SW¼ sec. 17, T. 13 S., R. 66 W.

The shales and poorly cemented, very fine-grained, shaly sandstones of the upper member of the Laramie Formation can be excavated easily but may be expected to have poor stability. Several small landslides have occurred in NE¼ sec. 13, T. 13 S., R. 66 W in this unit where it is being undercut by the unnamed drainage that is tributary to Monument Creek. The more massive and well-cemented sand-filled channels may have excellent foundation characteristics although they can be expected to be difficult to excavate.

Kls

Middle sandstone member of the Laramie Formation— The middle member of the Laramie Formation is composed of thick- to very thick-bedded, white, light-gray, or light-orange, crossbedded sandstone with small amounts of gray and brown sandy shale and fine-grained sandstone interbeds, and thin coal beds. The most accessible and best exposed section of the middle Laramie Formation sandstones are exposed in artificial cuts along Centennial Boulevard north of Allegheny Drive (W½ sec. 11, T. 13S, R. 67 W.). Here, this informal member is about 200 feet thick and is dominated by thick- to very thick-bedded, light-colored sandstones in packages about 50 feet thick. The sandstones are white, but often stained yellow, orange, or pink by iron oxides, and commonly contain common dark-brown ironstone lenses and masses of sand grains cemented with goethitic iron oxides. Middle Laramie Formation sandstones are fine- to medium-grained and subangular to subround throughout most of the member but some of the uppermost beds are coarse-grained. Small amounts mica and dark grains of sand-size chert are characteristic.

Crossbedding and channels are observed throughout the middle member. The lower part of the member has thin laminae of dark minerals in the light-colored sandstones and lag deposits of chert pebbles and shale clasts. The fragments in these deposits may be up to 3 inches in diameter. Much of the porosity in the middle member sandstones can be seen to be partially or fully plugged with white clay. Interbedded with the white sands of the middle member are subordinate softer beds of brownish-gray sandy shale and layers of organic-rich, dark-brown coaly shale. An outcrop of the middle member easily seen from the I-25 freeway, but more safely examined from Rusina Road (SW¼ NW¼, and NW¼ SW¼ sec. 19, T. 13 S., R. 66 W.), contains thin coal beds. The sandstones of the middle member of the Laramie Formation were deposited by a river system probably near the place where it emptied into the lagoons. The gray and brown sandy shale, fine-grained sandstone, and thin coal beds were deposited between the river channels.

The sandstones of the middle member of the Laramie Formation make bold outcrops that trend diagonally across the southwestern part of the quadrangle. These outcrops extend from Centennial Boulevard and Ute Valley Park, where they are turned up and dip steeply to the east, to Popes Bluffs, Monument Creek, and unnamed gullies just east of Nevada Avenue in SE¼ SE¼ sec. 19, T. 13 S., R. 66 W. where the dips are very gently to the northeast. Farther east, under the University of Colorado at Colorado Springs (UCCS) campus, Portal Park, and near the Colorado Springs Country Club, the middle and lower members are completely concealed by surficial deposits or the effects of urbanization.

Another outcrop of interest, for its spectacular display of complex sets of cross-cutting deformation bands, is in Ute Valley Park on the west side of the ridge underlain by the middle member, in the center of sec. 14, T. 13 S., R. 67 W. These outcrops, with both steeply east-dipping sets of deformation bands and nearly flat zones of deformation bands, may have much to tell about the strain history of steeply east-dipping middle Laramie sandstones.

The sandstones of the middle member have excellent foundation characteristics, as can be seen from the cliffside residences at the edges of Popes Bluffs. The sandstones may be difficult to excavate, however. In this unit there may be some risk of large blocks of coherent hard sandstone sliding on softer interbeds of sandy or coaly shales. There is also some risk of rock-fall damage to structures built below sandstone cliffs of the middle member.

Kll

Lower member of the Laramie Formation— The lower member of the Laramie Formation is composed of light-gray to light-brownish-gray, very fine-grained sandstone interbedded with gray sandy shale, brown organic-rich shale, and coal beds up to 10 ft thick.

The lower member of the Laramie Formation is not well exposed in the Pikeview quadrangle. A partial section of the lower member is moderately well exposed in a road cut on Centennial Boulevard near the head of the Douglas Creek drainage (NE¼ NE¼ sec. 10, T. 13 S., R. 67 W.) and overlies the exposure of the Fox Hills Sandstone and upper transition member of the Pierre Shale. Here, the lower member of the Laramie Formation is light-gray to light-brownish-gray, very fine-grained sandstone interbedded with gray sandy shale and minor brown organic-rich shale. The sandstones are thin bedded to massive and the shales are very thin to thin bedded. Thinner bedded units have thin and very thin internal laminations, cut and fill structures, low-angle cross laminations, or low-angle cross-bedding. Ironstone ledges of limonite-cemented sandstone are common. The brown shales are moderately organic-rich and have small chips of coaly plant material. The historically mined coal beds of the Colorado Springs area occur in the lower part of the Laramie Formation. The lower member of the Laramie Formation is about 115 ft thick.

The conformable lower contact of the Laramie Formation with the top of the Fox Hills Sandstone is somewhat arbitrary, but has been placed at the bottom of the light-gray, very fine-grained sandstone interbedded with brown organic-rich shale. Below this contact, in the top of the Fox Hills Sandstone, the sandstone is light-olive-gray and orange-gray, lacks the organic-rich beds, and has few ironstone ledges. This contact is rather poorly exposed in the Centennial Boulevard section, although the color change in the sandstone is distinct.

The Laramie-Fox Hills contact is well exposed in an artificial cut exposure along the channelized drainage of Douglas Creek at the foot of Popes Bluffs (NE¼ SE¼ sec. 23, T. 13 S., R. 67 W.). The top of this cut has about 40 feet of very thin- to very thick-bedded, light-gray, fine- and very fine-grained sandstone with partings of brown, organic-rich, sandy shale and shaly sandstone. Low-angle cross laminations and small channels are common. These light-gray sandstones contain common ledges of limonite-cemented ironstone and are stained orange from the iron oxides. Below the Kll-Kf contact, the Fox Hills part of this section is about 70 feet of light-olive-brown, light-brown, or orange-gray, very fine-grained sandstone in very thin to very thick beds with partings of brownish-gray sandy shale. The thicker sand beds were deposited in channels up to 5 ft deep. Small concretions up to 1.5 in. in diameter are common in the thicker sand beds. The Fox Hills part of the contact zone has much fewer ironstone layers and much less orange iron-oxide stain than the overlying lower member of the Laramie Formation.

The coals of the lower member of the Laramie Formation are not exposed in these sections, but a small coal mine dump is located along the foot of Popes Bluffs, about 1,000 feet south of the gap where Vindicator Drive crosses the Laramie Formation outcrop (SW¼ sec. 11, T. 13 S., R. 67 W.), indicating their presence near by. Numerous coal mines and collapsed coal mine workings can be seen on 1947 aerial photography along the projected lower contact of the Laramie Formation in sec. 29, 32, and 33, T. 13 S., R. 66 W. Considerable tonnage of coal was mined from the Laramie Formation, apparently mostly from the lower member. The economic geology section of this report elaborates on coal production from the Pikeview quadrangle.

The coal beds and brown organic-rich shales of the lower member of the Laramie Formation were deposited in swampy areas with heavy vegetation growth. The fine-grained sandstones and sandy shales were deposited in a low-energy environment as a transition from the shoreline environments of the Fox Hills Sandstone, below, to coal swamps. A likely environment of deposition is a series of protected lagoons between shoreline beaches and barrier islands on one side and swampy marshes and forests on the other.

The lower member of the Laramie Formation is relatively soft and easily excavated and has relatively stable foundation characteristics. The main hazard to structures and humans related to the lower member of the Laramie Formation is subsidence over abandoned coal mine workings. The subsidence risks over the mined-out areas of the Pikeview quadrangle have been assessed for the Colorado Department of Natural Resources (Dames and Moore, 1985). Maps portraying the subsidence risks can be examined at the offices of the Colorado Geological Survey. Detailed investigations are needed to accurately characterize mine-related hazards for specific sites.

Kf

Fox Hills Sandstone (Upper Cretaceous)— The Fox Hills Sandstone is composed of light-olive-gray fine- and very fine-grained sandstone in the upper part and thin to very thick massive beds of greenish-gray to orange-brown, micaceous, poorly sorted, fine-grained to medium-grained sandstone in the lower part. The Fox Hills Sandstone is reasonably well exposed in only one place in the Pikeview quadrangle: in road cuts along an abandoned road grade on the north side of Centennial Boulevard near the head of the Douglas Creek drainage in the NE¼ sec. 10, T. 13 S., R. 67 W. Here, the upper part of the Fox Hills Sandstone is about 140 ft thick and is light-brownish-gray, olive-gray, and orange-gray, very fine-grained and fine-grained, micaceous sandstone and sandy shale. The lower part of the Fox Hills is about 150 ft of fine- to medium-grained sandstone in thin to very thick massive beds of greenish-gray and orange-brown, micaceous, poorly sorted sandstone. The sandstones in this part of the section have abundant dark chert grains (5 to 7 percent), and common large oval sandstone concretions up to 12 x 18 in. in size.

Also distinctive of the lower part of the Fox Hills Sandstone are abundant pebbles or nodules of phosphate. The phosphate pebbles are usually light to dark brown, but sometimes have a lighter buff-colored rind and a darker center. Their size ranges from coarse sand size to about 1.5 in. and their surface has a high polish as if they have been tumbled in their depositional environment. Shapes vary from very well rounded through very angular, and some of the these phosphate nodules are very irregular shaped. It is common to find pebbles that have a well rounded shape on part of the pebble and an angular or subangular shape on the rest of the pebble. The variations in their shapes and degree of rounding suggests that they were being rounded and polished, broken, and repolished in their depositional environment. Two selected samples (PV-83 and PV-84) of these polished phosphate nodules were collected from the Fox Hills Sandstone exposures along Centennial Boulevard and submitted to ALS Chemex Labs for P_2O_5 analysis. The analyses of 21.8 per cent and 21.0 percent P_2O_5, respectively, confirm the identification of these polished nodules as phosphate (ALS Chemex, Certificate of Analysis A0034846).

Smaller areas of partial exposure of the Fox Hills Sandstone occur at the foot of Popes Bluffs (NE¼ SE¼ sec. 23, T. 13 S., R. 67 W.) where the contact between the upper Fox Hills Sandstone and lower Laramie Formation is exposed (see the section of this report on the lower Laramie Formation for a description). An additional exposure is along Monument Creek just south of Garden of the Gods Road. Areas of probable Fox Hills Sandstone are shown as Kf? on the geologic map in sec. 29, 32 and 33, T. 13 S., R. 66 W., an area now covered by urbanization, because the Fox Hills Sandstone was mapped through this area by Finlay (1916) and Scott and Wobus (1973). Exposures of probable Fox Hills Sandstone can be seen on 1947 aerial photography but can not be confirmed because of the more recent urbanization.

The Fox Hills Sandstone was deposited during the transition from marine conditions represented by the Pierre Shale to fluvial, lagoonal, and coal swamp environments of the Laramie Formation. The coarser sandstones of the lower part of the Fox Hills Sandstone are apparently either off-shore sand bars or beaches. The finer grained deposits of the upper part of the Fox Hills Sandstone appear to be wash-over fans and lagoonal back-beach sand deposits.

Kp

Pierre Shale (Upper Cretaceous)— The Pierre Shale is composed mostly of gray to dark-gray shale that weathers to brown and olive-green clay. The formation contains occasional interbeds of bentonite that are typically 1 to 3 in. and as much as 8 in. thick and frequently contains curvilinear fractures that are filled with sulfate salts. The age of the Pierre Shale near Colorado Springs is late early Campanian to early Maastrichtian, on the basis of mapping of ammonite faunal zones by Scott and Cobban (1986). The formation was deposited as marine clay in a shallow epieric seaway. Thickness in the quadrangle is about 4,500 ft. Contact with the underlying Smoky Hill Shale Member of the Niobrara Formation is gradational and conformable.

The upper part of the Pierre Shale is composed of sandy shale and very fine-grained sandstone which were previously included in the Fox Hills Sandstone by Finlay (1916). On the recognition of the Baculities clinolobatus fossil ammonite zone, Scott and Cobban (1986) included about 400 feet of strata mapped as Fox Hills Sandstone in the upper transition member of the Pierre Shale. This transitional zone at the top of the Pierre Shale can be further subdivided into an upper sandy shale or siltstone and lower sandstone sub-members. The Pikeview map follows the convention of Scott and Cobban, with the caveat that the contact between the upper transition member of the Pierre Shale and Fox Hills Sandstone is gradational and difficult to place.

This gradational contact between the upper sandy shale or siltstone sub-member of the Pierre Shale and the lower part of the Fox Hills Sandstone is moderately well exposed in the Pikeview quadrangle along an abandoned road above Centennial Boulevard in NE¼ sec. 10, T. 13 S., R. 67 W. Here Finlay (1916) shows a section of about 600 feet of Fox Hills Sandstone and apparently included about 400 feet of fine sandstone beds with interbedded thin beds of olive-gray sandy shale in the Fox Hills Sandstone. Scott and Wobus (1973) mapped the same exposures and recognized a much thinner section of Fox Hills Sandstone, about 290 feet. They apparently included the fine sandstone beds in the Pierre Shale although they did not map the upper transition member separately at this time. Scott and Cobban (1986) recognized the Baculites clinolobatus fossil ammonite zone, which is diagnostic of the upper transition member of the Pierre Shale in the Colorado Springs area, in these Centennial Boulevard exposures.

The approximately 400 feet of sandy beds exposed in the lower part of the Centennial Boulevard section, and here included as the top of the Pierre Shale, are light-gray, brownish-gray, orangish-gray, or orange-brown, very fine- to medium-grained shaly sandstone in thin to very thin beds. Gray micaceous shale partings and pelecypod fossils are common. Phosphate nodules are reported to be common throughout the upper transition member although they are less abundant in this unit than in the Fox Hills Sandstone at the Centennial Boulevard section.

The Pierre Shale is easily excavated, but foundation stability is poor. The formation has a high potential for shrink-swell and heaving bedrock problems due to the presence of smectitic claystone and bentonite beds. The Pierre Shale is also prone to slope instability. Examples of this instability are the numerous landslides on the northern and western slopes of The Mesa in the the southwestern part of the quadrangle. Fill material derived from Pierre Shale is not acceptable for use as structural foundation material without special soil treatments (J. White, 2000, oral communication).

Kn

Niobrara Formation (Upper Cretaceous)— The Niobrara Formation is composed of two members, the Fort Hayes Limestone Member and the overlying Smoky Hill Shale Member. The Fort Hayes Limestone Member is comprised of thin-bedded gray limestone and lesser amounts of chalky limestone and shale. The Smoky Hill Shale Member consists of yellowish-orange to brown shale, interbedded with thin gray and white chalk beds, and rare thin limestone beds. The Smoky Hill Shale Member is predominantly thinly bedded and planar with thin partings, but contains basal limestones which are more massive. Rare, thin, siliceous sandstone beds are interbedded in the middle of the Smoky Hill Shale Member. Inoceramus sp. shells, shark teeth, and segmented plant-stem fossils can be found in the Niobrara Formation. The Niobrara Formation was deposited in a quiet marine environment and is Coniacian and Santonian in age.

The Fort Hayes Limestone Member of the Niobrara Formation crops out as a prominent hogback in the southwest corner of the quadrangle near the entrance to Garden of the Gods Park. Other small outcrops of the Niobrara Formation occur along the west edge of the quadrangle in sec. 22 and 27, T. 13 S., R. 67 W. Total thickness of the Niobrara Formation is reported to be about 450 ft (Carroll and Crawford, 2000) in the adjacent Colorado Springs quadrangle, with about 50 ft of Fort Hayes Limestone. The Niobrara Formation has been used as a source of cement additives and smelter limestone.

Kcgg

Graneros Shale, Greenhorn Limestone and Carlile Shale, undifferentiated (Upper Cretaceous)— The oldest bedrock units in the Pikeview quadrangle outcrop in the extreme southwest corner of the map area. These strata are part of the the Colorado Group which includes, in ascending order, the Graneros Shale, Greenhorn Limestone, and Carlile Shale. Total thickness of the Colorado Group section is reported to be about 350 ft (Carroll and Crawford, 2000), but it is unlikely that the entire unit is present in the Pikeview quadrangle. The Colorado Group is poorly exposed in the map area, except for the Codell Sandstone Member at the top of the Carlisle Shale. The Graneros Shale represents Albian and Cenomanian age Cretaceous stratigraphy; the Greenhorn Limestone is Cenomanian and Turonian; and the Carlile Shale is Turonian in age (Berman and others, 1980).

The Graneros Shale is a black marine shale with abundant marine fossils and thin interbedded bentonite. The Greenhorn Limestone consists of dark- to light-gray limestone with lesser shale and siltstone interbeds. The Graneros Shale and Greenhorn Limestone do not outcrop in the Pikeview quadrangle, although they may project into the quadrangle.

The Carlile Shale consists of dark-gray shale interbedded with thin beds of dark-brown sandstone, yellowish-brown siltstone, and gray limestone. The sandstone beds are very fine grained, calcareous, and planar. The limestone beds are thin, chalky, and planar as well. The Codell Sandstone Member, uppermost member of the Carlile Shale, is composed of thick light-brown to white sandstone beds that outcrop on the west side of the hogback ridge held up by the Niobrara Formation.

Bentonite beds in the Colorado Group have a high shrink-swell potential. The shale and siltstone beds are easily excavated, but the Codell Sandstone Member may be difficult to excavate. The Codell Sandstone is a target for oil and gas exploration in the deeper parts of Denver Basin.

MINERAL RESOURCES

Coal and sand and gravel are the most significant mineral resources in the Pikeview quadrangle. Coal mining, though once significant, has ceased on the quadrangle even though coal resources may still exist in the Laramie Formation. The only active mining is a small sand and gravel operation. Resources of sand and gravel still exist in eolian sands, floodplain deposits, and Quaternary gravels. The only metallic mineral resource identified is a small, uneconomic uranium occurrence in the northeast part of the quadrangle. Test wells for oil and gas reported no shows and were abandoned.

COAL— In the early 1900s, coal mining from seams in the Laramie Formation was a major industry in Colorado Springs. More than 16.5 million tons of coal were produced from underground mines in the quadrangle between 1896 and 1957. Historical production data for coal mines in the Pikeview quadrangle are listed in Tables 1 and 2. Surface indications of this once thriving industry, visible on 1947 aerial photography, have been largely erased by urbanization. Only one caved mine adit and dump was found during mapping, in Ute Valley Park about 1,000 ft south of the gap where Vindicator Drive crosses the Laramie Formation (SW¼, sec. 11, T. 13 S., R. 67 W). Figure 5 shows the general location of some of the now recontoured historical coal mine openings, but other locations have been lost. Subsidence risks over the mined-out areas of the Pikeview quadrangle have been assessed for the Colorado Department of Natural Resources (Dames and Moore, 1985). Maps portraying some of the subsidence risks can be examined at the offices of the Colorado Geological Survey.

Two coal-producing areas are located in the quadrangle, the Rockrimmon (Figure 5 and Table 2) and Cragmoor (Figure 5 and Table 1) areas. The Pikeview mine was the most productive mine in the Rockrimmon area with 8.9 million tons produced (Turney and Murray-Williams, 1983). It was the longest-lived and also the last operating coal mine in the quadrangle, closing in 1957 after a mine fire. The Curtis Mine was the most productive coal mine in the Cragmoor area with 1.8 million tons produced from 1898-1913.

The three main coal seams, beds A, B, and C (Eakins, 1986), are 5 to 10 ft thick and generally lenticular. The A bed was the primary bed mined in the coal field and is located in the basal 30 ft of the Laramie Formation. The B coal bed is the thickest coal and is located 10 to 45 ft above the A coal bed. The C bed is the stratigraphically highest and thinnest coal bed and is not generally a significant resource (Eakins, 1986).

Sulfur content generally ranges from about 0.3 to 0.7 percent; ash varies from 5.4 to 20.8 percent; and volatile matter ranges from 30.2 to 45.1 percent. Laramie Formation coal has a free swelling index of 0 and generally ranks as subbituminous B to subbituminous C. On the basis of laboratory data for 14 samples collected at the Carlton, City Mine No. 1, 2, and 3, Curtis, Danville, Keystone, Monument Valley, Neer, Pikeview, and Rapson (Kirkham, 1978; U.S. Bureau of Mines, 1973), “as-received” heat values vary from 8,000 to 9,310 Btu/pound, sulfur varies from 0.2 to 0.5 percent, ash varies from 3.9 to 13.9 percent, volatile matter varies from 29.7 to 43.3 percent, and moisture varies from 18.2 to 26.9 percent.

SAND AND GRAVEL—Several sand and gravel operations were once active in the Pikeview quadrangle (see Table 3 and Figure 6). Currently, the only active permitted sand and gravel operation is the Phyllis E Mine located in SE¼ NE¼, sec. 27, T. 12 S., R. 66 W. The sand and gravel is primarily used for construction material. Colorado Silica Sand, Inc. produced specialty sand from the Chapel Hills Pit (sec. 33, T. 12 S., R. 66 W.) that was used for hydraulic fracturing of oil and gas wells, filtration media for water purification, and gravel packs for domestic and environmental water wells (Cappa and others, 2000). This high quality sand originated from the Quaternary eolian sands south of Kettle Creek.

URANIUM—The Burgess claim is a small uranium prospect located in NE¼ sec. 22, T. 12 S., R. 66 W (Figure 6). Concentrations of 0.52 per cent U_3O_8 were reported but this prospect was not commercially viable. The uranium on the Burgess claim occurs as uraniferous limonite in the $TKda_3$ lithofacies of the Dawson Formation. No production of uranium is reported from the Dawson Formation (Nelson-Moore and others, 1978).

Table 1. Reported production data for coal mines within the Cragmoor mining area in the Pikeview quadrangle (from Kirkham, 1978; Boreck and Murray, 1979; Turney and Murray-Williams, 1983). Refer to Figure 5 for mine locations.

MINE NAME	LOCATION	COAL BED NAME and THICKNESS (ft)	REPORTED DATES OF OPERATION	TOTAL KNOWN PRODUCTION (tons)
Bennett	SW¼ NW¼ sec. 29, T.13 S., R.66 W.		unknown	Not reported
City No. 1	SW¼ NE¼ sec. 29, T.13 S., R.66 W.	'A' bed; 6.0–20.0 modified panel mining	1918–1945	1,220,824
City No. 2	SW¼ SW¼ sec. 29, T.13 S., R.66 W.	'A' bed; 14.0	1918–1921	27,074
City No. 3	SW¼ NW¼ sec. 33, T.13 S., R.66 W.	'A' bed; 4.5	1934–1945	481,344
Climax No. 1	NE¼ SW¼ sec. 29, T.13 S., R.66 W.	'A' bed; 8.0–10.0	1928–1940	27,765
Climax No. 2	SE¼ SW¼ sec. 29, T.13 S., R.66 W.	'A' bed; 8.0–10.0	1941–1942	1,882
Corley	NW¼ NW¼ sec. 33, T.13 S., R.66 W.	'A' bed; 8.0	1924–1934	270,292
Curtis	NW¼ SE¼ sec. 29, T.13 S., R.66 W.	'A' bed; 9.0–20.0	1898–1913	1,876,258
Danville	SE¼ NW¼ sec. 29, T.13 S., R.66 W.	'A' bed; 11.0	1898–1926	595,011
Keystone	SW¼ NE¼ sec. 33, T.13 S., R.66 W. (also partly on Colorado Springs quadrangle)	'A' bed; 7.5–8.3 (coal bed dips 13º)	1917–1925	533,756 (T.13 S., R.66 W only)
New Altitude No. 1 and No. 3	NW¼ NW¼ sec. 29, T.13 S., R.66 W.	'A' bed; 2.3-13.0 (overburden 100–140, coal bed dips 3º)	1938–1941	7,611
Patterson (Busy Bee)	NE¼ NE¼ sec. 32, T.13 S., R.66 W.	'A', and 'B' beds, 4.0–14.0	Patterson 1905–1924 Busy Bee 1933–1948	'A' bed 265,762 'B' bed 57,613
Pine Grove	NW¼ SE¼ sec. 19, T.13 S., R.66 W.	3; uncorrelated	1896–1897	7,784
Rapson	SE¼ NW¼ sec. 33, T.13 S., R.66 W. (also partly on Colorado Springs quadrangle	'A' bed; 5.0–8.0	1901–1916	598,791 (partly from Springs quad
Unknown No. 1, 2, 3	NE¼ SW¼ sec. 29, T.13 S., R.66 W.	'A' and 'B' beds; uncorrelated	unknown	none reported
Williamsville and Altitude	C NW¼ sec. 29, T.13 S., R.66 W.	'B' bed; 2.3–13.0	Williamsville No.1 and 2:1898–1920; Altitude:1921–1929, and 1932–1937	248,409
Total known production in Cragmoor area				**7,398,893**

Table 2. Reported production data for coal mines within the Rockrimmon mining area in the Pikeview quadrangle (from Kirkham, 1978; Boreck and Murray, 1979; Turney and Murray-Williams, 1983). Refer to Figure 5 for mine locations.

MINE NAME	LOCATION	COAL BED NAME and THICKNESS (ft)	REPORTED DATES OF OPERATION	TOTAL KNOWN PRODUCTION (tons)
Carlton	SE¼ NW¼ sec. 18, T.13 S., R.66 W.	‘A’ bed; 8.8, 0–175 overburden	1897–1899	31,156
Columbine	SE¼ NE¼ sec. 12, T.13 S., R.67 W.	8.0 ft; uncorrelated	1924–1930	270,292
Cottonwood	SW¼ SE¼ SE¼ sec. 13, T.13 S., R.67 W.	‘A’ bed; 3.5	1921–1929	10,624
Gehrung	SW¼ NW¼ sec. 29, T.13 S., R.66 W.	uncorrelated	unknown	none reported
Klondike	SW¼ SW¼ NW¼ sec. 8, T.13 S., R.66 W.	8.9; uncorrelated	1917–1920	74,802
Last Chance	SE¼ SE¼ sec. 13, T.13 S., R.67 W.	‘A’ bed; 4.0	1909	255
Monument Valley (Park or Pitching Vein Mine)	SE¼ SW¼ sec. 11, T.13 S., R.67 W.	‘B’ bed; 4.0	1896–1897	2,050
Mountain View	NW¼ SW¼ sec. 18, T.13 S., R.66 W.	3.0; uncorrelated	1896	360
Neer	C½ SE¼ sec. 13, T.13 S., R.67 W.	‘A’ bed; 4.6	1908–1909	4,387
New Tudor	NW¼ SW¼ sec. 29, T.13 S., R.66 W.	uncorrelated	unknown	none reported
Pikeview	SE¼ SW¼ SW¼ sec. 18, T.13 S., R.66 W.	‘A (Fox Hill)’ bed; 7.0–14.0,	1900–1957 Gas explosion in 1956	8,738,174
Red Ash	SW¼ NE¼ sec. 19, T.13 S., R.66 W.	uncorrelated	unknown	none reported
Rose Hill	SE¼ SW¼ sec. 18, T.13 S., R.66 W.	uncorrelated	unknown	none reported
Total known production in Rockrimmon area				**9,132,100**

OIL AND GAS— The Colorado Oil and Gas Conservation Commission has records for three petroleum test wells drilled in the Pikeview quadrangle (Figure 6). Drilling began in 1953 with the New Seven Falls Co. A. G. Hill No. 1 well (SE¼ SW¼ NW¼, sec. 26, T. 13 S., R. 67 W.) reaching a depth of 3,243 ft. In 1954, the New Seven Falls Co. A. G. Hill No. 1A well (SE¼ SW¼ NW¼, sec. 26, T. 13 S., R. 67 W.) was drilled to a depth of 3,825 ft and encountered the Hygiene sandstone member of the Pierre Shale at a depth of 3,300 ft. In 1959, the Southwestern Development Rusina Ranch No. 1 well (NE¼ NE¼, sec. 24, T. 13 S., R. 67 W.) was drilled to a depth of 485 ft. All three of these holes were wildcats, reported no oil shows, and were subsequently abandoned. No further geologic information is available on these drill holes. No known petroleum production has occurred on the Pikeview quadrangle. The nearest oil production is 30 mi. southwest of Colorado Springs in the Canon City Basin, where oil was produced from a fractured Pierre Shale reservoir in the Florence oil field.

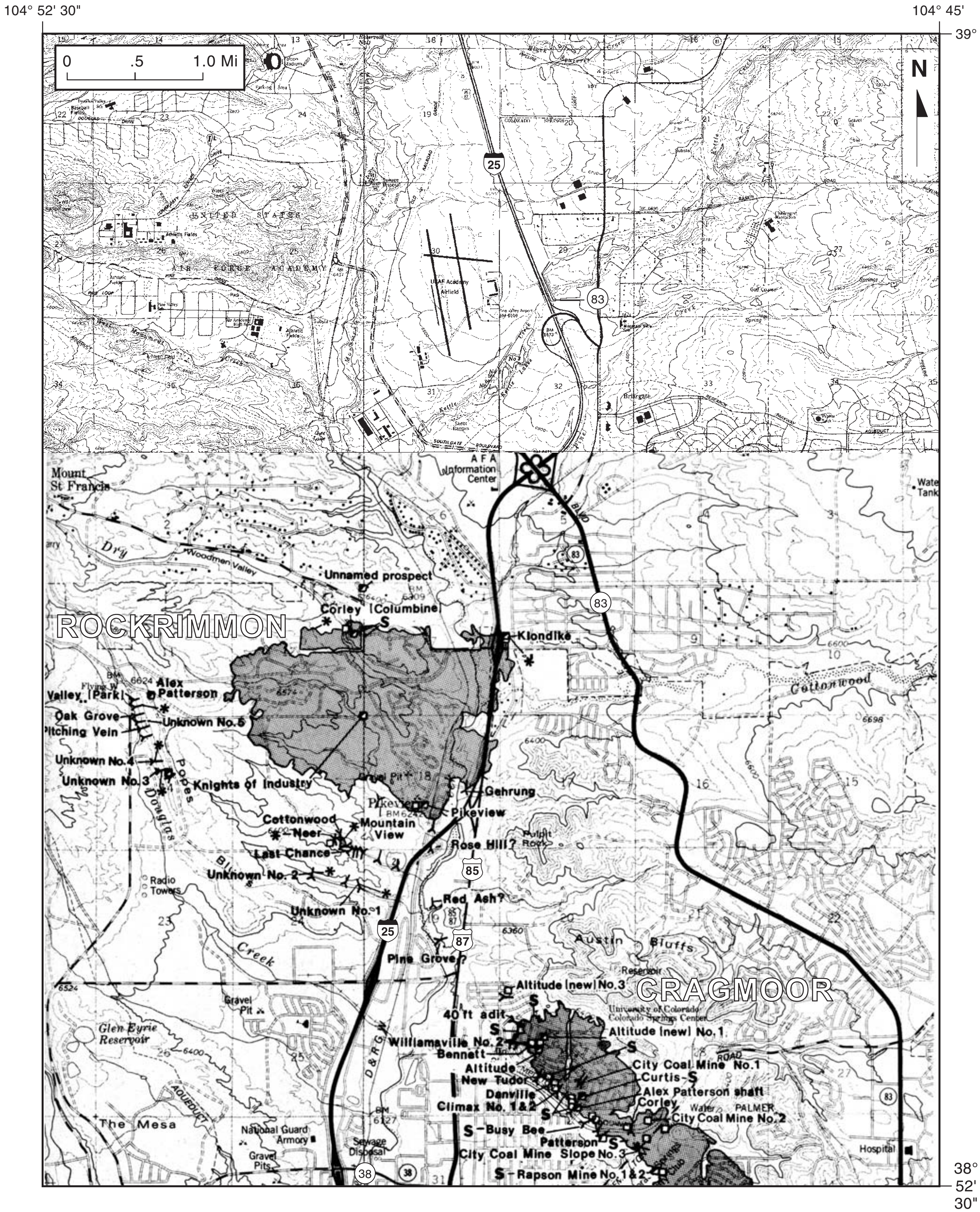


Figure 5. Map of inactive coal mines and areas prone to subsidence in the Pikeview quadrangle (after Turney and Murray-Williams, 1983, plate 6). Gray shading indicates mined areas.

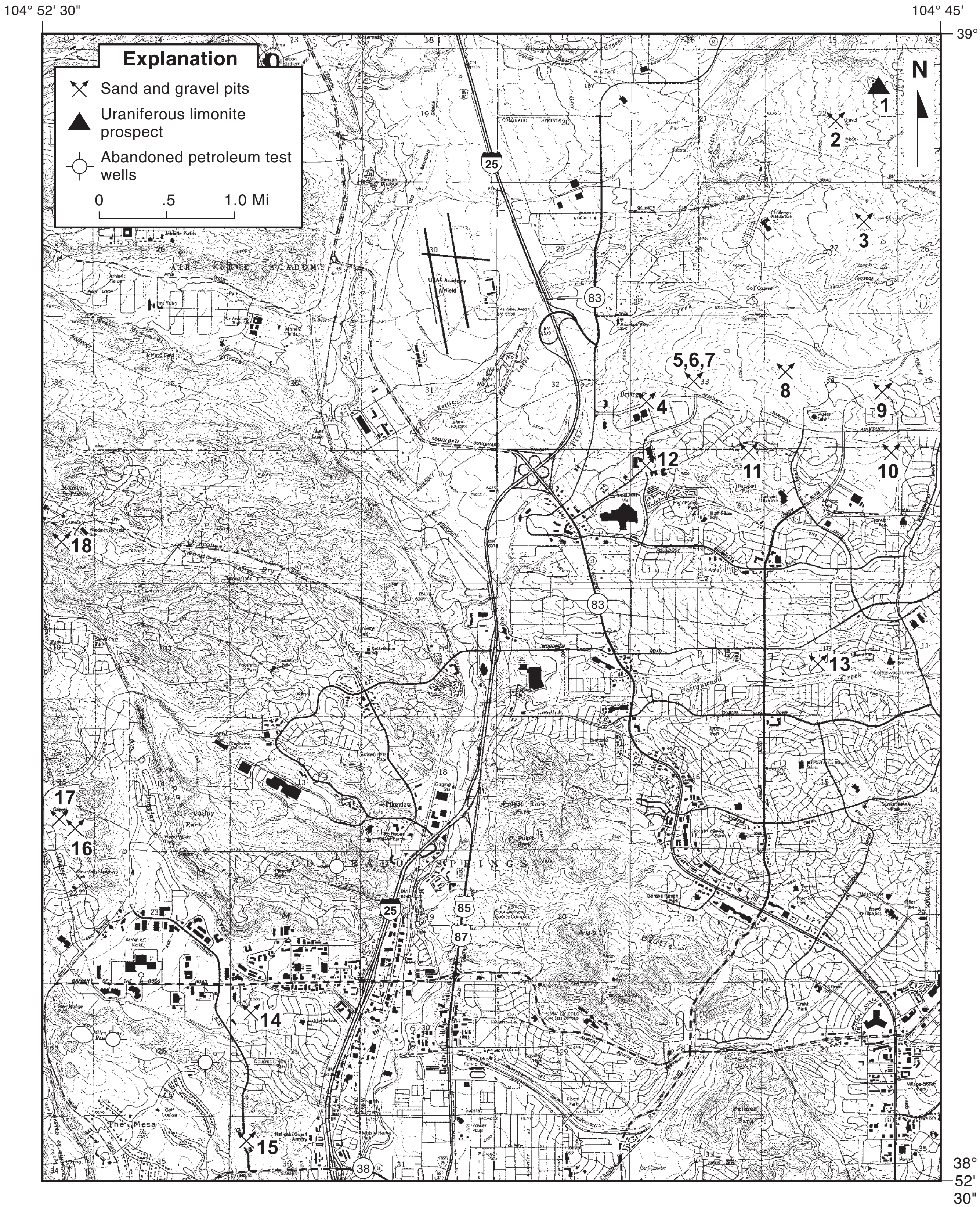


Figure 6. Location map for sand and gravel pits, uraniferous limonite prospect, and abandoned petroleum test wells in the Pikeview quadrangle (from Schwochow and others, 1974; Nelson-Moore and others, 1978; Colorado Division of mInes and Geology, 2000). Numbers correspond to mines listed in Table 3.

Table 3. Active and inactive permitted and non-permitted sand, gravel, and uranium mines within the Pikeview quadrangle (from Schwochow and others, 1974; Nelson-Moore and others, 1978; Colorado Division of Mines and Geology data, 2000). Refer to Figure 6 for mine locations.

MAP NO.	MINE	LOCATION	PRODUCT	OPERATOR	STATUS
1	Burgess Claim	NE¼ sec. 22, T.12 S., R.66 W.	uranium		prospect
2	Chapel Hills Ranch	NW¼ NW¼ SE¼ sec. 22, T.12 S., R.66 W.	shale, sand, gravel	El Paso County	inactive
3	Phyllis "E"	SE¼ NE¼ sec. 27, T.12 S., R.66 W	sand, gravel	Hourglass Inc..	active
4	C & C Pit No. 2	NW¼ SW¼ sec. 33, T.12 S., R.66 W.	sand, gravel	C & C Sand Company	inactive
5	Cimarron Pit	sec. 33, T.12 S., R.66 W.	sand, gravel	Fountain Sand and Gravel Co.	inactive
6	Briargate Pit	sec. 33, T.12 S., R.66 W.	sand, gravel	Hourglass Inc.	inactive
7	Chapel Hills Pit	sec. 33, T.12 S., R.66 W.	sand, gravel	Colorado Silica Sand Inc.	inactive
8	C & C Sand Pit No. 3	SE¼ SW¼ NW¼ sec. 34, T.12 S., R.66 W.	sand, gravel	Hourglass Inc.	inactive
9	North & South Pit	NE¼ SE¼ sec. 34, T.12 S., R.66 W.	sand, gravel	U. S. Silica Corp.	inactive
10	Charleston Place	SE¼ SE¼ sec. 34, T.12 S., R.66 W.	sand, gravel	Elite Properties of America	inactive
11	Unknown	NE¼ sec. 4, T.13 S., R.66 W.	sand, gravel		inactive
12	C & C Pit No. 1	NW¼ NW¼ sec. 4, T.13 S., R.66 W.	sand, gravel	C & C Sand Company	inactive
13	Pring Pit	NE¼ SW¼ sec. 10, T.13 S., R.66 W.	sand, gravel	Colorado Division of Highways	inactive
14	Unknown	NW¼ sec. 25, T.13 S., R.66 W.	sand, gravel		inactive
15	Unknown	NW¼ sec. 36, T.13 S., R.66 W.	sand, gravel		inactive
16	Flying "W" Ranch Pit	NW¼ SE¼ SE¼ sec. 15, T.13 S., R.66 W.	sand, gravel	City of Colorado Springs	inactive
17	Wolf Pit	SE¼ sec. 15, T.13 S., R.67 W.	sand, gravel	Broderick & Gibbons	inactive
18	Moonlight Hills	SE¼ sec. 3, T.13 S., R.67 W.	gravel	HLBE Inc.	inactive

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