Open-File Report 03-8

Geologic Map of the Falcon NW Quadrangle, El Paso County, Colorado

By Richard F. Madole

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FOREWORD

The Colorado Department of Natural Resources is pleased to present the Colorado Geological Survey Open-File Report 03-8, *Geologic Map of the Falcon NW Quadrangle, El Paso County, Colorado.* Its purpose is to describe the geologic setting and mineral resource potential of this 7.5-minute quadrangle located along the I-25 corridor about 40 miles south of Denver. Dr. Richard F. Madole, contract geologist for the Colorado Geological Survey, completed the field work on this project in the summer of 2002.

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 Account. The CGS matching funds come from the Severance Tax paid on the production of natural gas, oil, coal, and metals.

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CONTENTS

INTRODUCTION

The Falcon NW 7.5-minute quadrangle is in El Paso County at the northeast edge of the Colorado Springs metropolitan area (Fig. 1). For the past several years, El Paso County has been among the fastest growing counties in the nation. Although the western part of the Falcon NW quadrangle is heavily urbanized, much of the eastern part of the quadrangle is sparsely populated and used for grazing. Because urbanization will continue to expand eastward, the Falcon NW quadrangle was selected for mapping under the STATEMAP component of the National Cooperative Geologic Mapping Act. STATEMAP is intended to produce geologic maps that are useful for a variety of purposes including land-use planning, geotechnical engineering, identifying geologic hazards, and developing or protecting ground water and mineral resources.

Most of this booklet is devoted to describing the units shown on the geologic map and to discussions of related topics. Descriptions of the facies of the Dawson Formation are from the work of Jon Thorson in adjoining quadrangles (Fig. 2). He also provided the contacts for the Dawson Formation facies shown on this map (Thorson, written commun., 2002).

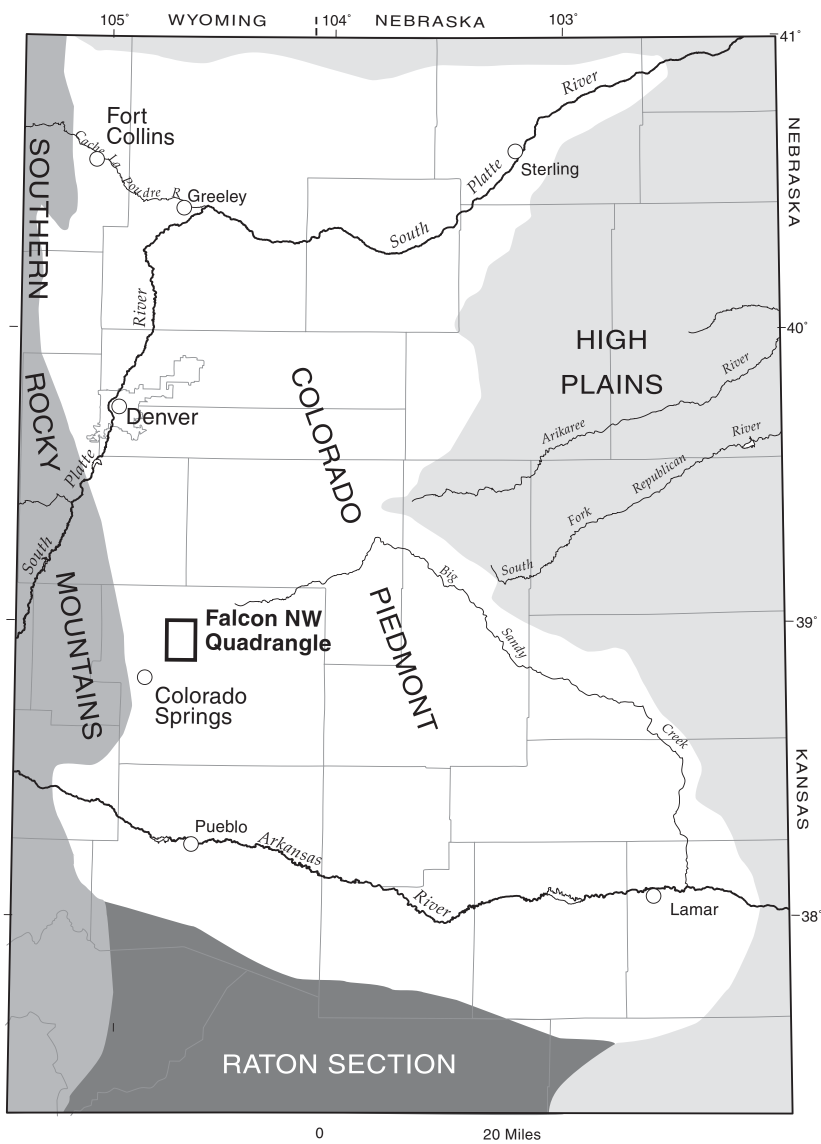

Figure 1. Map showing the location of the Falcon NW quadrangle and the Colorado Piedmont (white area) with respect to the Southern Rocky Mountains and other sections of the Great Plains defined by Fenneman (1931).

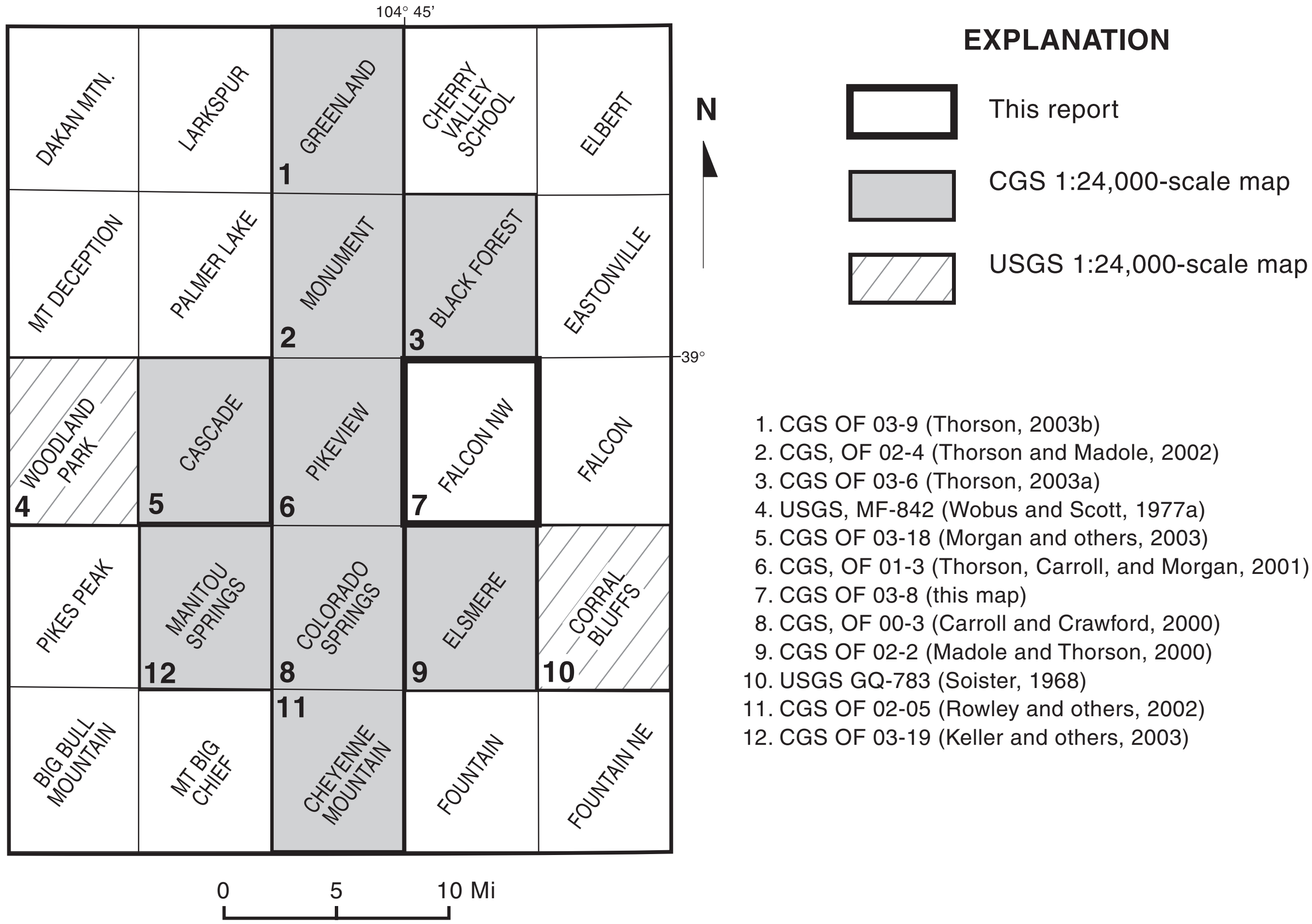

Figure 2. Index to 1:24,000-scale geologic maps in the vicinity of the Falcon NW quadrangle.

PREVIOUS GEOLOGIC MAPPING

A large-scale (1:24,000 or larger) geologic map has not been made previously of the Falcon NW quadrangle. However, both the Colorado Geological Survey and U.S. Geological Survey have mapped adjacent 1:24,000-scale quadrangles (Fig. 2). In addition, Finlay (1916), Scott and Wobus (1973), and Trimble and Machette (1979) made small-scale geologic maps (1:125,000, 1:62,500, and 1:100,000, respectively) of large areas that include the Falcon NW quadrangle.

SURFICIAL GEOLOGY

The Falcon NW 7.5-minute quadrangle is in the Colorado Piedmont (Fig. 1), a region that is distinguished primarily by the fact that is it has been stripped of the Miocene fluvial rocks that cap the adjoining High Plains Section of the Great Plains physiographic province (Fenneman, 1931). Older Cenozoic strata also have been eroded from most of the Colorado Piedmont, except at the higher, western part of the interfluve between the South Platte and Arkansas Rivers, which is the location of the Falcon NW quadrangle. Lower Cenozoic (Paleocene) rocks are at the surface or underlie surficial deposits everywhere in the quadrangle, except perhaps in the southeasternmost part of the area.

Sand is conspicuously abundant in the Falcon NW quadrangle because the bedrock (Dawson Formation) at and near the surface consists chiefly of arkosic sandstone and pebble conglomerate, much of which is weakly cemented. Sandy alluvial and eolian deposits blanket nearly half of the quadrangle, and thick (5 ft or more), sandy residuum (unconsolidated material derived from weathering of the underlying bedrock) is widespread. Bedrock outcrops are relatively small and few in number. Most are on valley sides 1) in the Cottonwood Creek drainage basin (northwestern part of the map area), 2) in the Jimmy Camp Creek drainage basin (southeast corner of the map area), and 3) along Sand Creek (central and southwestern parts of the map area).

Most Quaternary alluvium in the Falcon NW quadrangle is related to six streams, which today are ephemeral but at times in the past were probably perennial. The streams head in or near the Black Forest just south (2–5 mi) of the Palmer Divide, the local name for the drainage divide between the South Platte and Arkansas rivers. Initially, most streams in the quadrangle drained from north to south across the map area. However, during the late Pleistocene, Cottonwood Creek, which drains to Monument Creek about 3.5 mi west of the map area, captured the small south-trending valleys in the northwestern part of the quadrangle. The valley of Cottonwood Creek and the lower reaches of the captured streams are more deeply incised than the other valleys in the quadrangle and, thus, have the best exposures of bedrock and Quaternary alluvial strata. Because upper Cottonwood Creek is deeply incised, all alluvial units there, except the youngest one, are notably higher above stream level than their equivalents in the other drainage basins in the map area.

Most deposits of Pleistocene alluvium are broad, relatively thin, and consist chiefly of coarse sand and very fine to medium pebble (about 0.1–0.6 in. in maximum dimension) gravel . In the upper reaches of the larger drainage basins, fluvial deposits are typically 7–16 ft thick and as much as a mile wide. The extent and nature of the alluvium indicate that it was deposited during times when climate was effectively much wetter than today. Braided streams appear to have spread broadly near valley heads, and then narrowed southward into well-defined valleys.

The windblown sand that mantles parts of the Falcon NW quadrangle was derived chiefly from alluvial sand on valley floors. Because moisture and vegetation greatly increase the threshold velocity required to entrain sand, it is likely that winds mobilized valley-floor alluvium during times when the alluvium was dry and relatively free of vegetation. Most eolian sand is in sheets rather than dunes and is most extensive on the eastern sides of the larger valleys because the dominant sand-moving winds were northwesterly. Conditions favorable for sustained wind erosion and deposition probably occurred many times during the Quaternary, but in the absence of deep exposures and evidence of unconformities within these deposits, only one unit of eolian sand is shown on the map.

DELINATION OF UNITS

Interpretations based on stereoscopic examination of airphotos were verified in places on the ground and were supplemented with data collected along traverses and from detailed fieldwork in selected areas. Map unit contacts were transferred from photogrammetric models of annotated aerial photographs to the topographic map of the Falcon NW quadrangle using the ERDAS (Earth Resource Data Analysis System) stereographic program. The black and white photography used to map the Falcon NW quadrangle was taken in 1969 and 1992 at scales of 1:28,000 and 1:24,000, respectively. Urbanization has so profoundly altered the landscape in parts of the quadrangle that it made more sense to map the surficial geology as it was in 1969 rather than show numerous, large tracts of artificial fill.

The cultural features of the topographic base map were revised in 1994. Thus, roads, reservoirs, and buildings that were constructed after 1994 are not on the map base, and human-made deposits that postdate the 1992 aerial photography may not be on the map. The scale of the base map and aerial photographs governed the minimum size of the deposits shown. With few exceptions, deposits that have minimum dimensions of less than 150 ft were not mapped. Also, deposits that are less than about 3–4 ft thick were not mapped unless they are coincident with landforms that can be delineated on aerial photography.

The surficial geologic units of the Falcon NW quadrangle are referred to by informal names based on genesis. The common practice of naming units after the landform with which they are associated or the material of which they are composed is not useful in the Falcon NW quadrangle. Many surficial deposits are not uniquely associated with a single landform, such as a terrace or flood plain, and the physical character of the sediment in most deposits is similar. The units are allostratigraphic rather than lithostratigraphic; which is to say, they are mappable stratiform bodies that are defined and identified on the basis of their bounding unconformities rather than their lithic characteristics and stratigraphic position (North American Commission on Stratigraphic Nomenclature, 1983). Because the surficial units do not conform to the Law of Superposition, time terms, such as early and late, are used for them in the description of map units rather than position terms, such as lower and upper.

MATERIAL PROPERTIES AND TERMINOLOGY

The surficial deposits of the Falcon NW quadrangle are not well exposed. Consequently, the thickness of most units is estimated and descriptions of physical characteristics such as texture, stratification, and composition are based on observations at a small number of localities.

Particle size is expressed in terms of the modified Wentworth scale (Ingram, 1989), and the terms used to describe sorting (a measure of the range in particle sizes present) are those of Folk and Ward (1957). All surficial deposits in the map area are poorly sorted to extremely poorly sorted. In the modified Wentworth scale, gravel includes pebbles, cobbles, and boulders. Also, because gravel has the connotation of rounded rock fragments (Bates and Jackson, 1995), angular rock fragments larger than 1/12 in. (2 mm) are referred to as pebble size or cobble size, as the case may be. Clast, as used here, is limited to rock fragments (rounded or angular) that are larger than 1/12 in. (2 mm) in maximum dimension, and matrix refers to fragments that are smaller than 1/12 in. (i.e., sand-, silt-, and clay-size particles). The colors of surficial map units were determined using Munsell Soil Color charts (Munsell Color, 1973) and are for dry materials only.

CHRONOLOGY

The sidereal age limits of early, middle, and late Pleistocene time are shown in Figure 3. The date for the Pliocene-Pleistocene boundary, 1.806 Ma (Mega-annum, 106 yr), is the astronomically tuned age calculated by Lourens and others (1996). The 11.5 ka date for the Pleistocene-Holocene boundary is the calibrated equivalent of 10,000 radiocarbon years, the date proposed in 1969 for this boundary by the INQUA Commission for the Study of the Holocene (Farrand, 1990). The boundary between the early and middle Pleistocene is the time of the Matuyama-Brunhes magnetic reversal, which was about 778 ka (Tauxe and others, 1992). The boundary between oxygen-isotope (($^{18}O/^{16}O$) stage 6 and stage 5 is the boundary between middle and late Pleistocene time. Bassinot and others (1994) place this boundary at 127 ka, which is a refinement of the 128-ka date calculated by Imbrie and others (1984).

Holocene geochronology is a work in progress, and the age limits used here for its divisions are informal and arbitrary. They are based chiefly on paleontological data compiled for the southwestern United States, including the Colorado Plateau, such as described by Van Devender and others (1987). The data define times of widespread climatically driven shifts in the limits of vegetation associations, changes in lake levels and chemistry, and so forth. The limits used for early, middle, and late Holocene are 11.5–8 ka, 8–4 ka, and 4–0 ka, respectively.

The ages assigned to most surficial deposits of the Falcon NW quadrangle are estimates based chiefly on stratigraphic relations, position in the landscape, and differences in degree of soil-profile development. Degree of soil development refers to attributes such as thickness, horizon complexity, soil structure, quantities of translocated clay or calcium carbonate present, depth of leaching, and so forth. On stable surfaces (those not significantly modified by either erosion or deposition), soil development tends to produce more complex and generally thicker horizon sequences with time, proceeding from thin, simple A/C profiles to more complex, thicker A/B/C profiles.

DESCRIPTION OF SURFICIAL MAP UNITS

HUMAN-MADE DEPOSITS—Earth materials emplaced by human beings.

af — **Artificial fill (late Holocene)**—Sand, silt, clay, and rock debris emplaced to construct highways, railroad beds, earthen dams, and residential and commericial buildings. Many fills emplaced after 1969 are not shown, especially in the southewestern part of the map area, for reasons discussed previously. Unit is 3–30 ft thick.

ALLUVIAL DEPOSITS—Sand, silt, gravel, and clay transported and deposited by flowing water in channels and as unconfined runoff or sheet flow. Deposits resulting from sheet flow, also called overland flow, are referred to here as sheetwash alluvium. Sheetwash alluvium exists primarily along valley sides and footslopes. Stream alluvium is the principal deposit underlying flood plains and stream terraces.

Qay_1 — **Young alluvium one (late Holocene)**—Chiefly pale-brown, thinly bedded, poorly sorted sand, silty sand, and fine pebble gravel that underlie flood plains. Locally, streams flow in bedrock channels, notably in the valley of Cottonwood Creek. However, in most places on the map where streams are shown as being on bedrock, they actually flow on deposits of Qay_1 that are too narrow to show at a scale of 1:24,000. Unit differs from Qay_2 in that it is coarser grained, lighter in color (pale brown as opposed to gray), and lacks soil development. Much of the unit probably was deposited during historic time. Exposed thickness is 1–7 ft.

Formal time divisions		Informal time terms	Age (sidereal years)
Quaternary Period	Holocene Epoch	late Holocene	
			4,000[a]
		middle Holocene	
			8,000
		early Holocene	
			~11,500[b]
	Pleistocene Epoch	late Pleistocene	
			~127,000[c]
		middle Pleistocene	
			~778,000[d]
		early Pleistocene	
			~1,806,000[e]
Tertiary Period (part)	Pliocene Epoch		

[a] Limits used in this paper for divisions of the Holocene are based chiefly on paleontological data compiled for the southwestern United States; see, for example, Van Devender and others (1987).

[b] Approximate calibrated equivalent of 10,000 ^{14}C years, the date proposed in 1969 for this boundary by the INQUA Commission for the Study of the Holocene (Farrand, 1990).

[c] Based on the boundary between oxygen-isotope stages 5 and 6 (Bassinot and others, 1994).

[d] Based on the time of Matuyama-Bruhnes magnetic reversal (Tauxe and others, 1992).

[e] Astronomically tuned date calculated by Lourens and others (1996).

Figure 3. Quaternary time chart (modified from Fullerton and others, in press).

Qay$_2$ **Young alluvium two (late and middle? Holocene)**—Chiefly dark-gray and grayish-brown, thinly bedded to massive (in the sense of appearing to have no internal structure), poorly sorted fine and medium sand, silty sand, and minor pebble gravel. Beds of massive silty sand in which very fine to medium pebbles (about 0.1–0.6 in. in maximum dimension) are more or less uniformly dispersed are characteristic of Qay$_2$. Unit underlies low terraces (typically 5-6 ft higher than channel level) in most main valleys, except that of Cottonwood Creek, where remnants of Qay$_2$ are 22 ft higher than channel level. In the uppermost reaches of most drainage basins, Qay$_2$ also covers the floors of small, shallow (unincised) first-order channels. A very weakly developed soil (A/C horizon sequence) has formed in Qay$_2$. Two ^{14}C ages (2210 ± 60 and 1110 ± 70 yr B.P.; Table 1) of organic-rich sediment indicate that the upper half of Qay$_2$ was deposited during the interval between 2340 and 920 cal yr B.P. Both dates are the average age of humus that formed over a period of time. The older ^{14}C age is of a thin bed of organic-rich sediment that is about 16 ft higher than Cottonwood Creek and nearly 7 ft below the ground surface. The younger age is of a thin buried soil that is only 20–23 in. below the ground surface. Qay$_2$ is correlated with the Piney Creek Alluvium of Hunt (1954) in the

Table 1. Sediment in conventional[1] radiocarbon ages and corresponding tree-ring calibrated ages[2] of organic-rich alluvium in upper Cottonwood Creek and Sand Creek, Falcon NW quadrangle, Colorado.

Locality[3]	Stratigraphic Unit	Method[4]	Laboratory[5] Sample No.	Radiocarbon age ± 1σ (^{14}C yr B.P.)	$\delta^{13}C$ (‰)	Calibrated age ± 2σ (cal yr B.P.)
1B	Qay_2	RAD	Beta-172829	1110 ± 70	-22.5	1180–920
1A	Qay_2	RAD	Beta-172828	2210 ± 60	-22.1	2340–2050
2	Qam	RAD	Beta-172830	8260 ± 110	-23.6	9500–9000

[1] Conventional radiocarbon age; i.e., corrected for isotopic fractionation but not reservoir effects. Age was calculated using a half-life of 5568 years. The ± 1σ standard deviation represents the combined error in counting the radioactive disintegration of the modern standard, the background, and the sample.

[2] INTCAL98 (Stuiver and others, 1998) is the database used for calibration.

[3] See map for sample locations. 1B and 1A are from the same locality; sample depths below surface are ~2 ft and ~7 ft, respectively.

[4] RAD—Radiometric, as opposed to accelerator mass spectrometer

[5] Beta—Beta Analytic Inc., Miami Florida

Denver area. Except in places along Cottonwood Creek, Qay_2 is subject to infrequent large floods. Thickness is 3–15 ft.

Qay **Young alluvium, undivided (late and middle? Holocene)**—Unit consists of Qay_1 and Qay_2 undivided because exposures are poor or deposits of the two units are too small to show separately at a scale of 1:24,000. Estimated thickness is 5–15 ft.

Qam **Middle alluvium (early Holocene and late Pleistocene)**—Chiefly pale-brown, light-yellowish-brown, and grayish-brown poorly sorted sand, silty and clayey sand, and beds of very fine to medium pebble gravel. Unit underlies a terrace that is 10–15 ft higher than stream channels, except along Cottonwood Creek and its tributaries where Qam is as much as 40 ft higher than the channel. A soil profile consisting of an A/Bw/BC/C horizon sequence (Blendon soil series, Larsen, 1981) is developed in the upper few feet of Qam. Organic-rich sediment in Qam about 5 ft below the ground surface provided a ^{14}C age of 8260 ± 60 yr B.P. (9,500–9,000 cal yr B.P.; Table 1). Unit is coeval with at least part of the Broadway Alluvium in the Denver area. Estimated thickness is 10–30 ft.

Qao_1 **Old alluvium one (late middle-Pleistocene)**—Chiefly brown and light-yellowish brown, thinly bedded, extremely poorly sorted, very fine to medium pebble gravel and pebbly fine to very coarse sand. Locally, the unit also contains large pebbles and small cobbles. Unit underlies terraces that, depending on the drainage basin, are 20–45 ft higher than stream channels. Qao_1 may include deposits of more than one age that are undivided because they are nearly at the same level in the landscape and relative-age dating techniques based on weathering and soil formation are not useful in differentiating them. Unit is oxidized to depths of 5 ft or more, but soil development generally is weaker than in Qam. Soils in Qao_1 consist of A/AC/C and A/Bw/C horizon sequences. In places, clay lamellae, which are indicative of soil formation, are present in the upper 3–5 ft of the unit. However, in other places, distinct primary stratification is within 2 ft of the ground surface, indicating that the upper part of Qao_1 has been reworked or stripped. The upper limit of stratification marks the depth to which rooting, burrowing, and B-horizon development have penetrated. Unit may correlate with the Louviers Alluvium in the Denver area. The thin weakly developed weathering profile in this unit is inconsistent with the age indicated by its position in the landscape. Scott and Wobus (1973) mapped much of the unit as Piney Creek Alluvium, presumably because of the weak soil development. However, it seems unlikely that ephemeral streams like those in the northern part of the map area would have spread alluvium, typically 7–16 ft thick, over areas as broad as 0.5–1.0 mi during the late Holocene. Piney Creek Alluvium along streams of comparable size elsewhere in the region are much less voluminous, and model simulations of atmospheric circulation (Kutzbach, 1987) do not support the possibility of extensive sheet flooding during the late Holocene. The models indicate that average surface temperature and estimated annual precipitation have varied only slightly in the region during the late Holocene. Estimated thickness is 7–20 ft.

Qao_2 **Old alluvium two (late middle-Pleistocene)—** Chiefly brown and light-yellowish brown, thinly bedded, extremely poorly sorted, very fine to medium pebble gravel and pebbly fine to very coarse sand. Unit underlies terraces that are 20–30 ft higher than Qao_1. The unit is oxidized to depths of 5 ft or more, but soil development, which is similar to that in Qao_1, is unusually weak given the apparent age of the parent material. Estimated thickness is 7–20 ft.

Qao_3 **Old alluvium three (middle Pleistocene)—** Chiefly reddish-brown to light-yellowish-brown, extremely poorly sorted, thinly bedded to massive, very fine to medium pebble gravel and fine to very coarse sand. Locally, deposits contain a small percentage of small and medium cobbles of Dawson Formation. Unit caps ridges in the southwestern part of the map area. Deposits are remnants of a paleochannel that formerly drained from north to south. The upper surface of Qao_3 is about 220 ft higher than Sand Creek. Although poorly exposed, it is apparent that the unit is more deeply oxidized than Qao_2, but lacks the prominent soil K horizon that is typical in deposits older than a few hundred thousand years in other parts of the Colorado Piedmont (Madole, 1991). Estimated thickness is 30–60 ft.

Qao_4 **Old alluvium four (middle? Pleistocene)—** The physical characteristics and weathering profiles of Qao_4 and Qao_3 are similar. Qao_4 is distinguished primarily by its position in the landscape. It caps the highest interfluve in the southwestern part of the map area and is all that remains of a northwest-southeast trending paleochannel. The upper surface of Qao_4 is about 280 ft higher than Sand Creek. Estimated thickness 10–60 ft.

Qsf **Sheetwash and fan alluvium, undivided (Holocene and late Pleistocene)—**Brown, pale-brown, and light-yellowish-brown, extremely poorly sorted sand, silty and clayey sand, and minor amounts of very fine and fine pebble gravel. Unit consists chiefly of sheetwash that mantles valley-side slopes and locally forms small alluvial fans. Sheetwash alluvium is common in the hilly northern part of the map area and on valley-side slopes in the upper reaches of the larger streams, but most is too thin to show at the scale of this map. In places, sheetwash alluvium is difficult to distinguish from residuum. Sheetwash was mapped only where deposits are thick enough (typically > 3–4 ft) to delineate on aerial photography. Estimated thickness is 3–25 ft.

EOLIAN DEPOSITS—Wind-deposited sediment.

Qes **Eolian sand (middle and early Holocene and late Pleistocene?)—**Very pale-brown, pale-brown, and light-yellowish-brown, poorly sorted, fine to very coarse sand that was deposited primarily in sheets rather than dunes. Unit typically has thin, weakly developed soils (4- to 12-in.-thick A horizons and A/AC/C profiles). However, these soils are thicker, have better developed (albeit weakly developed) soil structure, and are more organic-rich than soils in late Holocene eolian sand elsewhere in eastern Colorado (Madole, 1994, 1995). Soils of the Blakeland series (Larsen, 1981) are developed in unit Qes, whereas more weakly developed soils of the Valent series (A/C and A/AC/C profiles) are developed in most late Holocene sand in eastern Colorado. Typically Qes is 1–10 ft thick, but was mapped only where thickness exceeds 3–4 ft.

BEDROCK GEOLOGY

The Falcon NW quadrangle is near the southwestern margin of the Denver Basin, which is an elongated structural downwarp bordering the east sides of the Front Range and Laramie Mountains (Fig. 4). The basin is deep and markedly asymmetrical. The surface of the Precambrian basement is as much as 7,500 ft below sea level (Hansen and Crosby, 1982), and rocks on the west side of the basin dip steeply to the east, whereas those on the east side dip gently westward. In the central part of the basin, the axis on the Precambrian surface is only about 8 mi. east of the mountain front, but at successively higher stratigraphic levels, the axis shifts eastward (Hansen and Crosby, 1982). The basin axis during Paleocene and Eocene time appears to

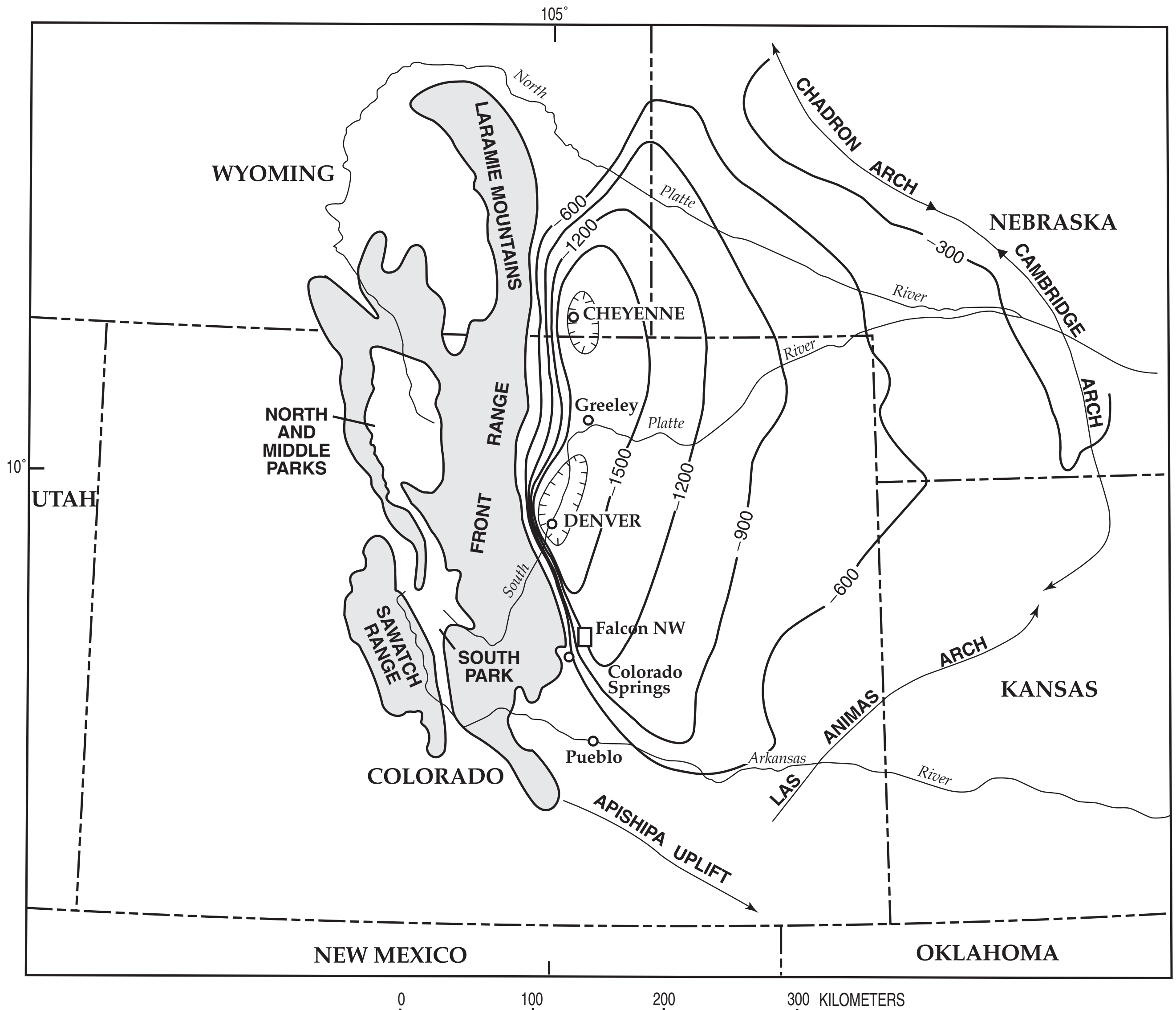

Figure 4. Structure contour map showing the Denver Basin and adjacent mountain ranges and uplifts. The top of Precambrian rocks is contoured in meters. Shading indicates outcropping crystalline rocks. Mountains of western Colorado are not shown (after Hansen and Crosby, 1982).

pass through or near the northeastern part of the Falcon NW quadrangle. Rocks cropping out in the western and central parts of the quadrangle dip northeast at 2° to 5°. However, the attitude of the rocks in the eastern part of the map area is undefined because there are few exposures.

The Dawson Formation is at the surface or underlies surficial deposits throughout the Falcon NW quadrangle. It consists of synorogenic sediment, predominantly sand and pebble gravel, that was derived from the Front Range and deposited along its east flank during the Laramide orogeny, which occurred between about 70 and 45 million years ago (Tweto, 1975). The lower part of the upper Dawson Formation, as defined by Scott and Wobus (1973) spans the Cretaceous-Tertiary boundary. The exact location of the K-T boundary has not been identified in the Falcon NW quadrangle, but Thorson (in Madole and Thorson, 2002) mapped it in the Elsmere quadrangle, which adjoins Falcon NW on the south (Fig. 2). In the Elsmere quadrangle, the K-T boundary is about 370 ft above the base of the upper part of the Dawson Formation (Benson, 1998; Benson and Johnson, 1998; Johnson and Raynolds, Denver Museum of Nature and Science, unpub. report, 2001; Madole and Thorson, 2002). In the Monument quadrangle, just northwest of the map area (Fig. 2), strata about 600 ft above the base of the upper part of the Dawson Formation contain fossil leaves of Paleocene age (Johnson, Denver Museum of Nature and Science, unpub. abstract, 2001; Thorson and Madole, 2002). Most of the Dawson Formation in the Falcon NW quadrangle is Paleocene, although some of the Dawson in the southwestern part of the quadrangle may be Cretaceous.

At one time, the Dawson Formation was buried by post-orogenic sediment of Eocene, Oligocene, and Miocene age, but the South Platte and Arkansas Rivers and their tributaries have removed most of the post-orogenic rocks in the region. In the Denver area, which is near the center of the Denver Basin, an estimated thickness of 1,000-1,400 ft of Cenozoic and Upper Cretaceous rocks were eroded from the western edge of the Great Plains in response to late Cenozoic uplift. Thickness estimates are based primarily on consolidation-test data in downtown Denver (Committee on Denver Subsoils, 1954) and the thickness of the Denver Formation eroded from the vicinity of Green Mountain near the west edge of Denver.

DESCRIPTION OF BEDROCK MAP UNITS

[Descriptions of bedding thickness follow Ingram's (1954) classification. Rock colors were not determined from Munsell charts.]

Dawson Formation (Eocene, Paleocene, and Upper Cretaceous)—The Dawson Formation in the Colorado Springs area is divided into an upper part that is of Eocene, Paleocene, and Late Cretaceous age, and a lower part that is Late Cretaceous (Scott and Wobus, 1973). Only the upper part of the Dawson Formation crops out in the Falcon NW quadrangle

Upper part of Dawson Formation—Thorson, in a series of maps (Thorson and others, 2001; Thorson and Madole, 2002; Madole and Thorson, 2002; and Thorson, 2003a, 2003b), divided the upper part of the Dawson Formation into five facies. Only four facies—$TKda_1$, $TKda_2$, $TKda_3$, and $TKda_4$—underlie the map area, although the basal part of $TKda_5$ may be present in the northeastern part of the quadrangle. The contact between $TKda_4$ and $TKda_5$ is distinguished by a paleosol developed in the uppermost part of $TKda_4$. However, the paleosol is either weakly developed or absent in the Black Forest quadrangle (Thorson, 2003a). Judging from the strike of the paleosol in the Monument quadrangle, the contact between $TKda_4$ and $TKda_5$ may project into the northeastern corner of the Falcon NW quadrangle. However, because $TKda_5$ cannot be positively identified in the map area it is neither mapped nor described here. Readers interested in additional details about the age, origin, lithostratigraphy, and regional stratigraphic relationships of the Dawson Formation facies are referred to Thorson's work in the references cited above.

$TKda_4$ **Facies four (Paleocene)**—Consists chiefly of light-colored, thick (12-40 in.) beds of massive (in the sense of appearing to have no internal structure) or cross-stratified arkose, pebbly arkose, and arkosic pebble conglomerate. Unit also contains: 1) beds of light-gray to light-brown, crossbedded, friable, poorly sorted, fine- to medium-grained feldspathic sandstone, in which wavy bedding and ripple cross-laminations are common; and 2) rare thin (0.4–4 in.) beds of gray claystone and sandy claystone, dark-brown to brownish-gray, organic-rich siltstone, and coarse sandstone that contains plant fragments. In places, dark-colored, organic-rich zones are present in the uppermost part of some massive, coarse-grained beds. Only 100–150 ft of the basal part of the unit are present in the map area.

$TKda_3$ **Facies three (Paleocene)**—Unit is made up of nearly equal amounts of three lithologies: arkose and arkosic conglomerate, micaceous feldspathic sandstone, and sandy claystone. The arkosic rocks are white, tan, and light gray, thick-bedded, massive (in the sense of appearing to have no internal structure) or cross-stratified, and contain pebbles that are as large as a 0.5 in. These strata resemble arkoses in $TKda_1$, but are finer grained, generally thinner, and commonly more quartz rich. Furthermore, pebble compositions may be more varied than in $TKda_1$ and include quartz, white and pink feldspar, white and pink granite, and small amounts of tan vuggy dolomite and red, black, and orange-brown chert. A few subrounded to rounded pebbles of altered volcanic rocks also are present. The beds of micaceous feldspathic sandstone are chiefly light green to olive gray, fine to medium grained, thin- to thick-bedded (0.4–40 in.), and clay rich. The beds of sandy claystone are dark gray to greenish gray and thin- to thick-bedded. The feldspathic sandstones and sandy claystone resemble the lithologies in the lower part of $TKda_2$ in the Pikeview and Elsmere quadrangles (Thorson and others, 2001 and Madole and Thorson, 2002). The greenish colors of the fine-grained lithologies suggest that they contain abundant montmorillonitic clay (Varnes and Scott, 1967). The best exposures of $TKda_3$ are in the valley sides of Cottonwood Creek between Woodmen and Black Forest Roads (sec. 31, T. 12 S., R. 65 W.; sec. 6, T. 13 S., R. 65 W.; sec. 1, T. 13 S., R. 66 W.). Some of the fine-grained sandstone and claystone beds contain fossil leaves, and coarse-grained beds contain large carbonized logs and wood fragments. $TKda_3$ contains masses of iron-oxide-cemented sandstone and pebble conglomerate that resemble beds in the Pikeview and Monument quadrangles that have anomalously high concentrations of uranium (Thorson and others, 2001, Thorson and Madole, 2002). In the northwestern part of the Colorado Springs area, the uranium content of some strata is high enough that it poses a hazard to human health, and construction projects there are required to mitigate the hazard (J.W. Himmelreich, Jr., Engineering Geologist, Colorado Springs, Colo., oral commun., 2001). Estimated thickness is 500–600 ft.

$TKda_2$ **Facies two (Paleocene and Upper Cretaceous)**—Unit consists of thick (12–40 in.), commonly massive or cross-stratified, brownish-gray, yellowish-gray, and light-yellowish-brown, pebbly sandstones. These sandstones are interbedded with yellowish-gray to grayish-green, fine- to coarse-grained micaceous sandstone and sandy claystone, and with dark-gray, greenish-gray, and dark-brown sandy claystones that contain variable amounts of organic material. Clasts in the pebbly sandstones are as large as 1.5 inches in diameter and consist chiefly of quartz, although some clasts also include coarse grains of feldspar, which indicate that granitic rock was present in a relatively nearby source terrane. In some beds of arkosic conglomerate, 30–40 percent of the clasts are greenish-gray biotite andesite or hornblende andesite, and a small percentage are light-gray biotite dacite. Strata containing andesite and dacite pebbles weather to a yellowish-gray to yellowish-brown "mustard color," which suggests that the sandstone matrix contains considerable montmorillonite. Varnes and Scott (1967, p. 16–17) recognized that kaolinite is the principal clay mineral in the arkosic facies ($Tkda_1$), whereas montmorillonite is the principal clay mineral in the andesitic facies (TKda$_2$), which upon weathering changes from greenish-gray to yellowish colors. In places, the sandstones and pebble conglomerates of TKda$_2$ contain petrified logs and large fragments of carbonized wood. They also contain clasts of claystone, some as large as 2 ft, that were eroded from the channels through which sediment was transported. The logs and claystone clasts were transported in high-energy streams, which according to the orientation of petrified logs and trough-crossbed axes flowed to the north or northeast. Good exposures of TKda$_2$ are present 1) along Cottonwood Creek (sec. 11, T. 13 S., R. 66 W.), 2) near Sand Creek Park (SE1/4 sec. 19, T. 13 S., R. 65 W.), and 3) in the drainage basin of Jimmy Camp Creek (southeast corner of the map area). Estimated thickness is 600–900 ft.

TKda$_1$ **Facies one (Paleocene and Upper Cretaceous)**—Unit is present in a small area near the southwest corner of the quadrangle, but it is not well exposed. Exposures in nearby quadrangles indicate that it probably consists chiefly of white to light-gray, crossbedded or massive, very coarse arkosic sandstone and pebble conglomerate. The arkosic rocks in the adjacent Elsmere quadrangle are remarkably free of andesitic material, even though the units above and below have abundant andesitic detritus (Thorson in Madole and Thorson, 2002). The non-andesitic arkose of TKda$_1$ is lithified debris that was shed from a granitic source west of the Denver basin. The rocks form a wedge or lobe that thins southeastward across the Falcon NW quadrangle (Fig. 5 and cross section A–A′). Estimated to be as much as 300 ft thick.

Kda **Lower part of the Dawson Formation (Upper Cretaceous)**—Unit shown only on cross section A–A′.

Kl **Laramie Formation (Upper Cretaceous)**—Unit shown only on cross section A–A′.

Kfh **Fox Hills Sandstone (Upper Cretaceous)**—Unit shown only on cross section A–A′.

Kp **Pierre Shale (Upper Cretaceous)**—Unit shown only on cross section A–A′.

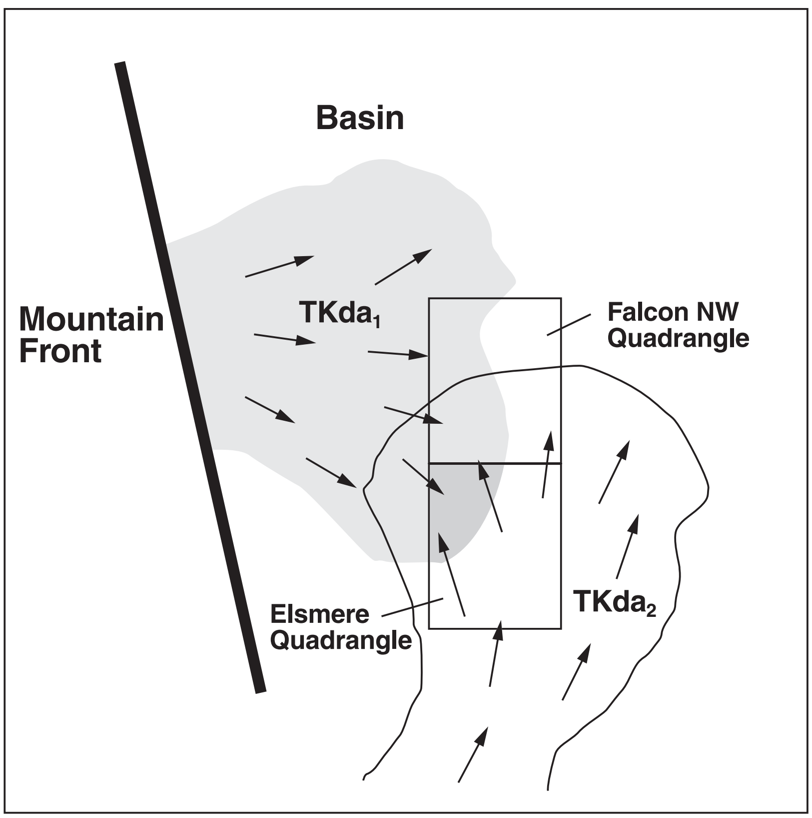

Figure 5. Overlapping depositional systems of facies TKda$_1$ and TKda$_2$ (after J.P. Thorson, written commun., 2002).

ECONOMIC GEOLOGY

Fossil fuels have not been economically significant in the Falcon NW quadrangle as they have elsewhere in the Colorado Springs area, including in the Elsmere quadrangle to the immediate south (Fig. 2). Coal-bearing strata are too far below the surface in the Falcon NW quadrangle to be exploited. According to the records of the Colorado Oil and Gas Conservation Commission, no wells have been drilled for oil and gas in the map area.

Nonmetallic resources, namely, eolian sand and alluvial sand and gravel, have been mined at several localities in the Falcon NW quadrangle. The most extensive mining has been in the central part of the quadrangle (secs. 32 and 33, T. 12 S., R. 65 W. and secs. 5, and 7, T. 13 S., R. 65 W.), which is the only part of the map area where mining is ongoing. In addition, borrow pits have been excavated in the east-central (sec. 2, T. 13 S., R. 65 W.) and southeast (secs. 23 and 26, T. 13 S., R. 65 W.) parts of the quadrangle.

Alluvium derived from the Dawson Formation has been mined at several places in the Colorado Springs area because many deposits contain large amounts of clean (minimal silt and clay), coarse-grained sand that consists chiefly of quartz (that is, has a high silica content). These properties make it useful for a variety of purposes that include glass making, hydraulic fracturing of oil-field reservoirs, blast sand, well-pack sand, filter sand, pipeline sand, and engine sand (Schwochow and others, 1974).

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