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MISCELLANEOUS FIELD STUDIES MAP MF–2388
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PAMPHLET

GENERALIZED SURFICIAL GEOLOGIC MAP OF THE PUEBLO 1° × 2° QUADRANGLE, COLORADO

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CONTENT AND PURPOSE

This map depicts the distribution of surficial geologic deposits in the Pueblo quadrangle. The companion pamphlet (this document) describes physical properties of the deposits, including thickness and predominant grain size and mineral composition. Also identified are age, origin, and hazards related to the deposits.

The purpose of the map is both educational and practical. The properties of materials at the surface affect the suitability of land for societal uses, for example, large landfill sites, gravel pits, large-scale residential developments, greenbelts, buried utility lines, and roads. Planners, zoning officials, builders, and interested citizens should understand clearly how the properties of surficial deposits affect the growing urban sector in the Colorado Springs–Pueblo region. This map can be used to derive other maps that show the suitability of the land for specific purposes.

The map also provides information about biogeographical habitats and geomorphology. For example, the map is useful for ecosystem surveys that differentiate wetlands, mountain, foothill, and plains habitats. These habitats, which are influenced by soil-related factors, correlate well with the mapped surficial geologic materials and deposits. Furthermore, the age and origin of the Quaternary surficial deposits are basic to any geomorphologic study in the Pueblo quadrangle.

MAP UNIT NAMES

The map unit names derive from a classification of geologic surficial materials. The names are based on the prevalent grain size, minerals (or rock types), and geologic origin. Examples are “Granodiorite-block debris-avalanche deposit” and “Stabilized dune sand.” Large areas (generally >1 km^2) of exposed bedrock, mostly devoid of surficial materials, were mapped with a symbol “R.”

PARTICLE SIZE AND COLOR TERMINOLOGY

We used geological and soil textural terms to describe the size of particles in the surficial deposits. We had to draw upon the reported data of both disciplines to fully characterize the deposits. Particle sizes ranged from microns to meters in diameter. We used geologic size terms to describe the **clasts**, which are particles larger than 2 mm in diameter. Particles 2 mm or smaller in diameter make up the **matrix** of the deposits. Both geologic and agronomic size terms describe the matrix.

The clasts are divided into granules (2–4 mm; 1/12–1/6 in.), pebbles (4–64 mm; 1/6–2.5 in.), cobbles (64–256 mm; 2.5–10 in.), and boulders (>256 mm; >10 in.) (see Jackson, 1997). The matrix consists of three particle-size classes: clay (<1/256 mm; <0.00016 in.), silt (1/256–1/16 mm; 0.00016–0.0025 in.), and sand (1/16–2 mm; 0.0025–0.08 in.). Clay, silt, and sand exist in varying proportions in the mapped deposits. Terms like “sandy silt”and “gravelly sand” reflect visual estimates of geologists. We accepted some of these terms from previously published reports and assigned some terms ourselves. In doing so, we compared samples of surficial deposits to standard grain-size samples on an American Geological Institute chart.

We also used soil science terms to characterize the matrix. For example, “clay loam” conforms to U. S. Department of Agriculture (USDA) terminology in the Soil Survey Manual (Soil Survey Staff, 1951). These are **soil** textural **class** names (fig. 1), which describe the proportions of sand, silt, and clay. Soil survey reports identified the soil textural class of the C horizon and parent materials in selected areas of the Pueblo quadrangle.

Our fieldwork required another source of grain-size terms. This terminology used the USDA **field determination** of soil textural class method (Soil Survey Staff, 1951, p. 212). This method requires deformation (squeezing) of samples of the matrix by using the thumb and fingers. The manner by which samples deform indicates a basic soil textural class.

Color terms describe clasts and the matrix of materials and deposits. Colors of clasts follow geologic convention. Some terms derive from published reports, and some we assigned from color terms in the Rock Color Chart (Goddard and others, 1970). Colors of the matrix conform to the Munsell Soil Color Charts (Munsell Color, 1973), which are used by soil scientists and Quaternary geologists.

UPLAND MATERIALS

The origins of names we apply to many deposits, such as “stabilized dune sand,” are obvious. However, we use two terms, “colluvium” and “residuum,” which have several meanings. We define them here for the purposes of our map. Colluvium and residuum cover hillslopes and uplands, respectively. **Colluvium** is unconsolidated rock detritus and soil material that was very slowly, usually imperceptibly, transported and deposited mainly by gravity (some also by runoff). Because colluvium creeps downslope, hillslopes covered by it may be unsuitable for building and slope-stabilization work may be required. Colluvium is mapped in areas dominated by hillslopes steeper than about an 8 percent (4° 34′) gradient and mapped in areas larger than 2 km^2. **Residuum** is derived primarily by in-place disintegration of rock. Surface processes have not transported the material far. We mapped residuum on nearly level land that lacks widespread deposits of other origins. It was not mapped on slopes steeper than about 8 percent. Eight percent is a standard slope category boundary in the USDA land classification (Soil Survey Staff, 1951, p. 163). That system separates level and nearly level land from more sloping land. The system is consistent in most USDA county soil reports that we consulted (for example, Larsen, 1981), as is our distinction of colluvium and residuum on the surficial geologic map.

METHOD OF MAPPING

We generalized the boundaries of some units on this map from some geologic unit boundaries shown on the “Geologic Map of the Pueblo 1° × 2° Quadrangle” (Scott and others, 1978). Many of our unit boundaries, however, were drawn on the basis of our field observations and on our verification of the boundaries shown on other published, detailed geologic maps. We also used agronomic soil surveys in which a soil unit or units correspond closely to landforms and geologic surficial units. Our geologic map unit descriptions incorporate color, grain size, thickness, and chemical data from the weathered zone (C soil horizon) immediately above bedrock, or non-soil. We did not incorporate properties of the solum (A and B horizons) of modern soils.

Diverse residual, colluvial, eolian, and alluvial deposits and materials are present in the quadrangle. In general, the most widespread of these was mapped in a given polygon. Materials or deposits other than the prevalent one may be present in a mapped polygon. Hence, the reader should not extend the generalized map data into small areas without consulting supplemental data. Our map does not show variation at the scale of most home and small commercial construction sites. In general, soils engineers and engineering geologists should investigate specific sites prior to construction. Some users of the map may wish to examine the detailed maps of Varnes and Scott (1967) and Scott (1969b).

BASE MAP

The base map is the Pueblo 1:250,000-scale metric topographic map, 1989, U.S. Geological Survey 38104–A1–TM–250. The base, printed on clear film, was scanned to make a raster image (tiff file) and was imported as screened black lines to computer software that made the map layout. The Pueblo base map is available as a paper topographic map on which roads, streams, place names, and contours are printed in different colored inks. Some users may prefer to locate places on the paper base map while viewing the surficial geologic map.

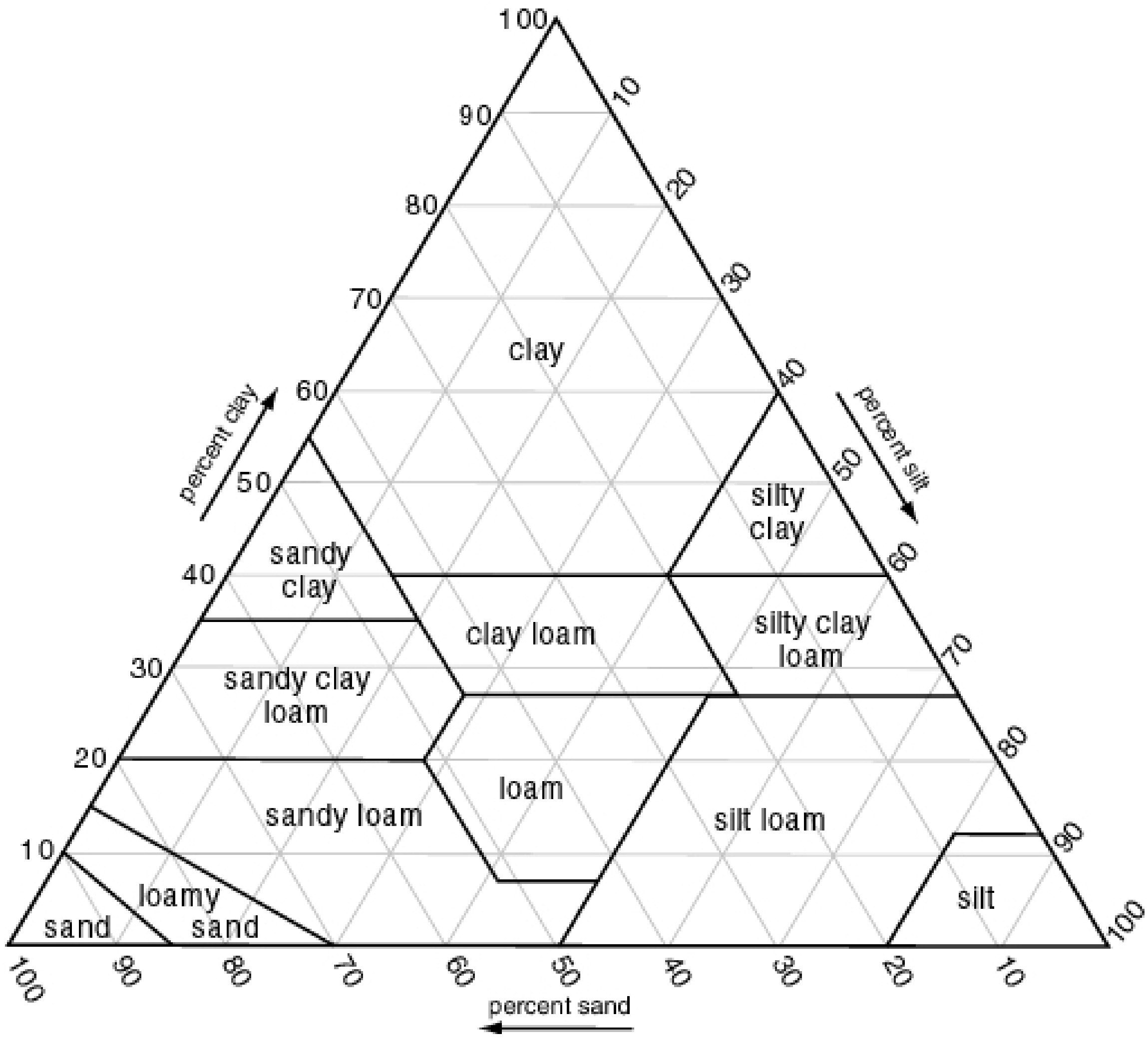

Figure 1. Chart showing the percentages of clay, silt, and sand in the basic soil textural classes (Soil Survey Staff, 1951).

ACKNOWLEDGMENTS

This map is based in part on the map of Scott and others (1978), but differs from the latter in that our map does not show or describe bedrock units and fully describes the unconsolidated, geologically young, surficial deposits and materials. We thank Glenn Scott, who shared his knowledge and unpublished information. We thank Ted Brandt for assistance with computer applications, and Diane Lane for advice in preparing the map layout.

DESCRIPTION OF MAP UNITS

HOLOCENE

f **Artificial landfill**—Heterogeneous mixtures of clay, silt, sand, and rocks and (or) compacted graded granular material used as earthen or earth-core dam

s **Slag—**Reddish-brown, dark-brown, gray, and black fused rock. Glassy, vesicular to dense, cellular texture and density of about 35–60 pounds per cubic foot. Material is 35–38 percent silica and 44–50 percent oxides of calcium, aluminum, magnesium, and iron (Bush, 1951). Contains <10 percent broken and whole firebricks from the linings of iron-smelting furnaces. Forms mounds 5–10 m high. Mapped at only one location, about 3 km south of Pueblo

wla **Loamy or clayey sheetwash alluvium**—Pale-brown silt loam and silty clay loam. Locally stratified, silty, very fine sand that contains clayey lenses. Well drained, hard and very friable when dry, slightly sticky and plastic when wet. Calcareous, moderately alkaline. Locally contains soft masses of whitish calcium carbonate and (or) finely crystalline gypsum. The lower part is stratified silty sand, sand, and gravelly sand. Unit is present south of Arkansas River and east of Pueblo on terraces that are 1–3 km wide and slope gently (1–2 percent) to north. Some areas appear to have been leveled by agriculture. Thickness is 2–4 m

afa **Alluvial-fan deposit**—Reddish-brown, brown, and brownish-gray, gravelly and clayey granules and coarse to fine sand; locally abundant boulders. Particle size ranges from clay to boulders. Crudely to moderately sorted. Locally composed of cobbles and pebbles of pale-red to reddish-brown biotite or hornblende-biotite granite or quartz monzonite, gneissic granodiorite, and quartz diorite. Locally, sandstone, limestone, and dolomite clasts are abundant at the east edge of the Front Range between Colorado Springs and Cañon City. Clast lithologies reflect the source rock lithologies, which vary locally. Stratified, torrential crossbedding in which gravel is concentrated in lowest part of bedding sets; cut-and-fill structures are common. Deposits overlying shale and limestone contain fragments of chalky shale, shale, and limestone in clayey matrix. Some matrix-supported gravel probably is unsorted mudflow deposits. The high parts of fans (apex and proximal part) are moderately steep and bouldery. Deposit was mapped if >600 m across. Smaller, unmapped alluvial-fan deposits are present in the quadrangle. Thickness near the center of deposits may be as much as about 10–15 m and less than 1 m near the edges

cac **Arkosic loamy colluvium and sheetwash alluvium—**Light-yellowish-brown, pale-brown, and olive-brown loam, sandy loam, very fine gravelly loamy sand, and locally sandy clay to clayey sand. Granules and coarse sand grains of granite, quartz, feldspar (commonly kaolinized), and mica form a surficial lag. The surficial layer grades downward through the oxidized colluvium to slightly weathered, moderately or poorly cemented, interbedded clayey sandstone, sandy claystone, and siltstone, all of which locally are andesitic. Particles are mostly quartz, granite, feldspar, and, locally, andesitic or rhyolitic rock detritus. Near Colorado Springs, the map unit includes 10–30 percent outcrops of interbedded clayey arkose and siltstone, and lag deposits of rounded pebbles, cobbles, and sparse boulders of granite, vein quartz, gneiss, and schist. Within 10 km of the mountain front, the alluvium contains minor, light-red arkosic sandstone and conglomerate. Along some streams, the unit includes unmapped, small remnants of gravelly, fluvial terrace deposits. In northern

Colorado Springs, around the Austin Bluffs area, a hazard to building foundations and roads caused by expansive clay mineral in the deposits is documented (Hart, 1974; Himmelreich and others, 1996). On nearly level uplands of El Paso County, the unit includes unmapped, discontinuous eolian sand deposits and thin, brown, clayey loess. Locally, the eolian deposits contain slowly permeable clayey layers. In western Teller County, near Florissant, the unit is developed on old alluvial fill in the valleys of Grape and Twin Creeks. There it is arkosic, sandy sheetwash alluvium 2–4 m thick, including minor gravel of sanidine-biotite-plagioclase welded, rhyolitic ash-flow tuff. In the Grape Creek and Twin Creek valleys, the deposit grades downward to conglomerate, volcanic mudflow breccia, fossiliferous, thinly bedded, water-laid volcanic ash, and tuffaceous mudstone. Unit is 0.3–4 m thick

cbv **Metamorphic and metavolcanic blocky colluvium**—Dark-brown and dark-gray, angular gravel composed of meta-gabbro, metavolcanic, and meta-sedimentary rocks at north end of Sangre de Cristo Mountains, north and south of the Arkansas River (near the west edge of the quadrangle). Micaceous silty and slightly clayey sand matrix makes up a minor amount of this unit. White calcium carbonate forms thin coatings on clasts. Thickness of colluvium is generally 1–4 m

xch **Clayey, calcareous disintegration residuum**—Dark-grayish-brown, light-yellowish-brown, olive, and light-olive-brown, clayey, fine, platy shale residuum. Clay, silt, and minor sand are present in variable proportions (clay loam and silty clay loam in the upper 1 m and at increasing depth, silty clay and clay). The residuum is very calcareous, locally micaceous and (or) carbonaceous and contains limestone concretions. It is firm or plastic when moist, hard when dry. It is generally gypsiferous and locally contains small (0.2–1 cm) crystals of selenite (gypsum). The residuum may be saline and (or) alkaline at shallow depth. Near the Arkansas River, scattered, discontinuous veneers of quartz and feldspar sand, granules, rounded pebbles, and small cobbles (chiefly granite and quartz) are present as a surface lag, derived from old terrace deposits. In places, thin residuum abruptly overlies silty, hard shale that contains thin beds (1–10 cm thick) of bentonite (swelling clay largely composed of smectite clay minerals and formed by the alteration of volcanic ash in place). Where these beds dip about 30° or more, they are susceptible to differential expansion toward the land surface (“heaving”), owing to sorption of water by the bentonitic clay. The expansion can damage dwellings, roads, and buried utility lines. Most of the recent damage has occurred in the urban corridor east of the Colorado Front Range (including El Paso County). Repairs in the urban corridor east of the Front Range have cost tens of millions of dollars (Noe, 1997). This hazard is further described under map unit ccd. Local shale- and (or) limestone-chip residuum (unit xlh) and colluvium exist on low hills of well-cemented shale or limestone outcrops, and on “teepee” buttes capped by ironstone (siderite, calcite, or pyrite) and limestone concretions. The residuum is on nearly level to gently sloping land. Locally, it includes severely eroded, sloping land where the residuum is very thin or eroded completely, for example, in southeastern Fremont County at the abandoned town of Coal Creek. Present here on widely exposed, interbedded shale and pale-brown, soft sandstone are discontinuous, pale-brown residuum, minor colluvium of pebbly sand, sheetwash alluvium 1–2 m thick, and fallen sandstone blocks 0.5–2 m across. The colluvium and alluvium are mainly composed of granitic and gneissic sandy gravel. Near the mountains, in stream alluvium (not mapped) the map unit generally contains 1- to 2-m-thick, brown, granitic cobbly sand beds. In places, the residuum grades down to silty or sandy claystone or clayey, thin-bedded sandstone. South and east of Pueblo, the residuum grades down to weathered, chalky shale or disintegrated platy limestone. East of Fountain Creek (El Paso and Pueblo Counties), residuum is thin over silty, hard shale that contains thin beds (1–10 cm thick) of bentonite and zones of ledge-forming, platy limestone concretions as much as 2–4 m in diameter. In most mapped areas the residuum is 0.5–1.5 m thick

HOLOCENE AND LATE PLEISTOCENE

Disintegrated deposits, periglacial deposits, bouldery till, and rock outcrop—Disintegrated, nonsorted, blocky deposits in high alpine and montane glaciated areas. Silt to boulders;

matrix commonly is sandy and micaceous. Angular rocks form talus cones and aprons, protalus ramparts, rock-glacier deposits, block-field deposits, solifluction or frost-heave deposits, and colluvium. Unit includes small, unmapped areas of fan alluvium and debris-flow deposits. The genesis of deposits varies within short distances. The map unit includes some small, discontinuous deposits of bouldery Pinedale till, and scattered erratic clasts on glacier-scoured bedrock. Excludes till in large end and lateral moraines (mapped separately as unit tbg, tbi, or tbj). Clasts generally are angular, subangular, or subrounded, and in places exceed 5 m in diameter. Map unit includes ridges and peaks of bare bedrock. Till, rock glacier deposits, and local lake deposits are present in ice-carved basins at heads of valleys. Talus accumulates on and below steep valley sides. Colluvium, solifluction deposits, and frost-heaved deposits locally cover gently or moderately sloping uplands, high tundra-covered surfaces, and moderate slopes on valley sides. Locally includes deposits of alpine debris flows and mudflows. Snowmelt and heavy rain may trigger debris flows (Curry, 1966). Debris-flow deposits are composed of randomly oriented, angular gravel supported in a fine-grained matrix. These deposits commonly form fans, aprons, and concentric constructional ridges at the bases of steep slopes. More extensive lichen cover, well-developed soil, and pronounced rock-weathering phenomena characterize older deposits that are included in this map unit. The youngest (Holocene) deposits range from unoxidized deposits lacking soil development to oxidized ones having weakly developed B horizons. Loess veneers some older deposits. Locally, the unit includes disintegrated deposits that accumulated during the Little Ice age (A.D. 1450–1850) and the neoglacial interval (younger than 6,000 years) (Richmond, 1986)

dba **Crystalline-clast deposits**—Disintegrated deposits, periglacial deposits, and bouldery till that are composed mostly of coarse-grained biotite and biotite-hornblende granite. The granite contains large feldspar phenocrysts. Matrix is absent in upper part of coarse talus deposits. A matrix is present in other deposits and commonly is a gray and grayish- or yellowish-brown sand and silt. Unit mapped in the Pikes Peak area. Estimated thickness of deposits is 1–8 m

dbc **Sedimentary-clast deposits**—Disintegrated deposits, periglacial deposits, and till that are composed mostly of grayish-red, greenish-gray, and gray sandstone, shale, siltstone, conglomerate, and minor gray limestone in the Sangre de Cristo Mountains. Matrix is commonly gray, reddish-gray, or grayish-brown silty and (or) clayey sand. Includes rubble in rock glaciers, which are generally a few hundred meters long; a few are as much as 2 km long. Exposed bedrock is mostly Paleozoic sedimentary rock. Thickness of deposits estimated to be 1–8 m

dbd **Mixed-lithology-clast deposits**—Disintegrated deposits, periglacial deposits (includes rubble in rock glaciers), bouldery till, and ice-scoured bedrock of sedimentary rock (sandstone, conglomerate, shale, and limestone), rhyolite, and tonalite. Mapped in the Sangre de Cristo Mountains. Estimated thickness is 1–8 m

asa **Alluvial sand, silt, clay, and gravel (post–Piney Creek alluvium, Piney Creek Alluvium, and pre–Piney Creek alluvium of Hunt, 1954, and Scott, 1960; Broadway Alluvium)—** Underlies flood plains and low stream terrace surfaces (mapped where width >0.2 km). Low parts of mapped areas are susceptible to stream flooding. Recently, disaster assistance of almost six million dollars was provided by governmental agencies to people in several counties, including El Paso, Pueblo, and Otero, for relief from damage caused by storms and flooding of April 29–30, 1999. Only low-lying areas along major streams in the map unit were flooded. Following is a general description of alluvium in the quadrangle, alluvium in the Arkansas River, in El Paso County, and in the San Luis Valley.

General description: Light-yellowish-gray, grayish-brown, moderate-brown, locally reddish-brown quartz sand; sand commonly includes minor feldspar and mica particles; gravelly near the mountains. Commonly, the uppermost 0.4–2 m of the deposit on existing floodplains is dark-gray and dark-grayish-brown, humic, noncalcareous silt and clay and (or) fine sand. The next layer below varies in thickness and commonly is yellowish-brown, calcareous, moderately alkaline loam and sandy loam. Near the base, sandy, rounded gravel and gravelly sand is common. In or near (as far as 15 km east of) mountainous areas, 40–70 percent of the alluvium is gravel; 10–30 percent of the gravel typically is cobbles and boulders. The unit interfingers laterally with fan alluvium and colluvium on valley sides.

Poorly to well stratified, planar bedded and crossbedded. Older parts of the unit have a minor accumulation of secondary calcium carbonate; relatively young alluvium has little secondary calcium carbonate and contains sparse fossil bison and mule deer bones. On the Great Plains, alluvium is chiefly quartz sand containing pebbles of quartz, sandstone, limestone, feldspar, petrocalcic carbonate (caliche), marl, and shale. Gravel deposits of rivers that head, or previously headed, in the mountains are granitic, including biotite and hornblende-biotite granite, biotite gneiss, felsic gneiss, schist, and, locally, quartzite, metaquartzite, mafic-rich intrusive rocks, amphibolite, and hornblende schist. Granitic and quartzite gravel of unit asa is a valued aggregate for concrete and road metal because it is sound, contains little interstitial carbonate and deleterious materials, and is present in large quantities. The alluvium of major rivers includes buried clay beds as thick as 4 m. The lower part of alluvium that is >10 m below surface may be middle Pleistocene in age (unit ags). Thickness of unit asa is generally 2–10 m.

Arkansas River: In and near the mountains, the alluvium consists of beds of massive, crystalline-clast-supported gravel that alternate with thinly bedded sand and organic-rich sediment. On the plains east of Pueblo, the upper 1–3 m of alluvium is stratified, humic silt and sand underlain by interbedded silty, clayey sand and sandy pebble to cobble gravel. Grain size varies from gravel to clay; engineering properties are given by Scott (1969a). Between Pueblo and the east edge of the quadrangle, alluvium of the Arkansas River fills a broad trough cut in Cretaceous shale and generally is 3–10 m thick, locally as thick as 18 m (Major and others, 1970; Hurr and Moore, 1972; Nelson and others, 1989). A generalized composite vertical profile (based on drill hole logs) through the valley fill, including modern flood deposits, from top to bottom, is the following: 0–2 m, light-brownish-gray silt loam, sandy clay, silt loam, and silty clay; 2–10 m, interbedded and intermixed fine sand, silt, and clay deposits colored brown, light brownish gray, yellowish gray, and light olive gray. In the lower part of the 2- to 10-m interval (and locally deeper) is interbedded coarse to medium sand and subangular to subrounded gravel. Cemented zones were penetrated in some drill holes. Clasts noted in sample logs include granite, granodiorite and migmatitic gneiss, schist, porphyritic volcanic rocks, vein quartz, quartzite, and some limestone and petrocalcic clasts (caliche). Alluvium in the streams tributary to the Arkansas River near Pueblo consists of yellowish-gray sand, silt, and clay matrix that contains limestone, sandstone, and calcareous shale pebbles.

El Paso County: Flood-plain alluvium is about 3 m thick in the valley of Monument Creek and 5–8 m thick (18 m thick locally) in the valleys of the Black Squirrel and Jimmy Camp Creeks. In the Fountain Creek valley, between Colorado Springs and the Pueblo County line, test holes penetrated sandy and gravelly (minor silty) alluvium 15–18 m thick (except near the channel, where it is 3–7 m thick) (Jenkins, 1964). A well near Fountain penetrated 24–27 m of alluvium (Jenkins, 1961).

San Luis Valley: (near southwest corner of map area) Alluvium is calcareous clayey sand, sandy silt, and clay, gravelly in part. The axial river has reworked valley fill in the subsiding San Luis Basin, producing alluvium that is pale-brown, light-brownish-gray, light-gray, or brown, stratified gravelly sand, silt, and clay. Upper 0.5–1 m typically is sulfate-rich clay loam or clay that is plastic, sticky, and montmorillonitic. Locally, the unit includes loamy coarse sand to very gravelly (granules, pebbles, and cobbles) sand. Alluvium contains interstratified fine sand and silt. Clasts are composed of sedimentary and crystalline rocks from the Sangre de Cristo Mountains. Unit may be tens of meters thick and overlies older (middle Pleistocene to Neogene) alluvial valley-fill deposits hundreds of meters to more than 1 km thick (Rogers and Larsen, 1992)

ed **Stabilized dune sand**—Grayish-brown (at surface), light-yellowish-brown, and yellowish-gray, well sorted to moderately well sorted, from the coarser part of the very fine sand grade to the finer part of the medium sand grade (3/16 to 3/8 mm diameter (2.5 to 1.5 phi) Muhs and others, 1996). In soil terms, unit commonly is a loamy sand. Composed almost entirely of subangular to rounded quartz grains; feldspar is subordinate. Mapped only in the San Luis Valley (near southwest corner of map area), where the deposit is sparsely vegetated dunes. Locally, the sand contains 10–15 percent clay and 10–30 percent silt. Sand is calcareous below about 1 m deep; locally, it contains white calcium carbonate and sodium bicarbonate in soft masses. Scattered blowout depressions and minor active dunes indicate that the deposit is susceptible to wind erosion. Parts of the map unit include low-lying, broad, sheetlike deposits of wind-blown sand (weakly cemented by sodium bicarbonate), interdune playa deposits of silt and clay, stabilized parabolic sand dunes, and blowout depressions (too small to map). Commonly, the dune sand is crossbedded and locally contains planar beds. Dune sand locally contains buried, discontinuous, calcium carbonate–cemented layers, organic-rich silt layers, and (or) buried paleosols. These features suggest that intervals of dune building were interrupted by periods of stability. Intervals of dune formation may have been characterized by a copious supply of sand, strong winds, and (or) relatively sparse vegetation. Thickness generally is 3–10 m

es **Eolian sand—**Yellowish-brown, dark-yellowish-brown, and light-olive-brown, chiefly very fine to medium quartz sand; some coarse sand and, locally, silty and slightly clayey sand. Well to moderately well sorted. Less than 5 percent feldspar grains, 2–5 percent lithic grains, and about 2 percent heavy-mineral grains. Sand is generally a sheetlike deposit. Some deposits have characteristic large-scale crossbedding. Locally, the deposit contains small, unmapped areas of vegetated, stabilized dune sand, degraded parabolic dunes, and blowout depressions. South and east of Pueblo, the deposit buries terrace gravel deposits (unit ags) of the Arkansas River. Locally, the unit has been leveled for building and (or) agriculture. The deposits mantle gently undulating uplands and pre-Holocene terraces of the Arkansas River. The unit contains many unmapped, small depressions that flood occasionally and contain thin deposits of lake silt and clay, such as mapped unit oc. The eolian sand interfingers with, or grades into, sandy and silty sheetwash alluvium and residuum. The upper part of the eolian sand commonly contains a well-developed Brown soil (formerly a Great Soil group of zonal soils having a brown surface and light-colored subsurface zones over an accumulation of calcium carbonate; now classified as Ustoll or Xeroll soil). Regarding the age of the eolian sand, Scott and Lindvall (1970) stated, “we believe it was deposited starting in Pinedale time and ending when the ‘Altithermal’ soil was formed ca. 4,500 yrs ago.” Recent studies in eastern Colorado indicate several intervals of dune building during the past 20,000 years. Because unit es is chiefly a mantle that contains stabilized dunes, we assume that it was mostly deposited during periods of dune building. The presence of buried soils, changes in kinds of fossil pollen, and ages obtained by radiocarbon and thermoluminescence dating techniques in eastern Colorado indicate dune reactivation about 6,000, 4,500, and 1,000 years ago and a longer episode of dune formation during the last glacial cycle, about 20,000–12,000 years ago (Forman and others, 1995). Reduced grass cover associated with regional drought may have contributed to the reactivation of dunes. Other studies (Madole, 1994; Muhs and others, 1997) indicate that upper parts of the dune deposits in northeastern Colorado and in Nebraska accumulated less than 1,000 years ago, possibly as recently as during the last two centuries. Thickness of the unit usually is less than 6 m, locally greater than 9 m. South of the Arkansas River, the thickness ranges from 1 to 11 m in sample logs of test holes (Major and others, 1970)

jea **Slump-block landslide deposits, earthflow and mudflow deposits**—Products of gravitational downslope movement of partly disaggregated sedimentary bedrock and (or) surficial materials. The older parts of the deposits probably date to the latest glacial epoch. Parts of the deposit have moved in the late 1990’s (Himmelreich and others, 1996). Bedrock sources of most deposits are shale, marl, clayey sand, mudstone, or claystone, locally interbedded with sandstone and (or) thin limestone. Landslide deposits derived from weathered claystone and shale; locally contain expansive clay minerals and have high potential for swelling upon sorption of water (Hart, 1974). Gray and brown color and composition of deposits are those of the source rock and materials. In places, deposits include clayey disintegration residuum and sheetwash alluvium and may include rounded gravel derived from alluvial-terrace deposits. Matrix variable, but commonly it is silty and clayey sand to sandy clay. Landslide deposits may be unstable, have low compressive strength, and are poor foundation materials for man-made structures. Some of the deposits recently moved during wet periods, notably in the spring and early summer of 1995, damaging roads, homes, drainage improvements, and graded slopes in housing areas (Himmelreich and others, 1996).

Slump-block deposits: Masses of bedrock and unconsolidated materials that have rotated or slid downslope as a unit, with little or no flow; properties of materials are not greatly altered, and original bedding, textures, and sedimentary structures are retained. Stability of the deposits is indeterminate at the scale of this map and requires on-site analysis. Historically, translational and rotational sliding in shale bedrock that underlies parts of the map unit in Colorado Springs has resulted in damaged homes, roads, and graded slopes in housing subdivisions. Low, hummocky ridges commonly are separated by depressions that may contain bogs. Thickness 2–20 m.

Earthflow deposits: Heterogeneous mixtures of clay, silt, and sand containing scattered clasts. Plastic movement of material and slumping of coherent rock or soil masses combines to move masses downslope slowly. Some deposits are chiefly reworked slump-block deposits; others are mostly reworked sheetwash alluvium or colluvium. Recently active deposits commonly have an abrupt scarp at their upslope limits and crevassed, bulbous masses at the downslope limit. Thickness 1–5 m.

Mudflow deposits: Chaotic, matrix-supported mixtures of clay, silt, sand, and rock. Emplaced by rapid flow of such mixtures in a saturated state, commonly involving weathered shale or mudstone. Many mudflow deposits form lobate, fanlike landforms in areas of weathered shale, mudstone, and interbedded sandstone, thin limestone, and shale. Thickness 1–5 m

ccd **Calcareous clayey colluvium—**Gray and olive-gray clay, silty clay, and sandy clay. Locally contains irregular fragments of white and light-gray, chalky limestone, sandstone gravel, and (or) discontinuous lag of crystalline rock fragments. In some areas, colluvium is 5–10 percent granules or chips of grayish-brown shale and, locally, clayey limestone or marl, from which it is derived. Also contains masses of secondary calcium carbonate. The colluvium is moderately alkaline, locally gypsiferous. Clay minerals include mixed-layer illite-montmorillonite, montmorillonite or smectite (20–40 percent), illite (15–30 percent), kaolinite (10–15 percent), and minor chlorite. Consistency of the colluvium matrix varies with moisture content. The colluvium is very hard when dry, sticky and plastic when wet. Internal drainage (loss of sorbed water) is slow. The map unit includes small, unmapped areas of residuum (corresponds to unit xch mapped elsewhere) and veneers of silty sheetwash alluvium on nearly level land. Unit ccd grades downward to gray and olive-gray shale, claystone, and very clayey siltstone. In places, swelling of the colluvium and heaving of claystone or shale layers under the colluvium have damaged homes, pavement, and utilities that were built on or in these materials. Most of the recent damage has occurred in the urban corridor east of the Front Range, where repairs have cost tens of millions of dollars (Noe, 1997). Where the colluvium contains much expandable clay mineral, it expands volumetrically as these minerals and exchangeable ions take up water. The closely related problem of heaving ground occurs in shallow, dipping shale bedrock that underlies thin colluvium. Locally, expansive shale and claystone can swell along certain beds as water is sorbed following load removal (excavation of overburden for building purposes). This is especially true where the bedding dips about 30° or more. Most heaving bedrock deformation in Colorado Springs is concentrated in the west-central part of the city, near Old Colorado City (Himmelreich and others, 1996, p. HB–1). In terms of economic loss to urban infrastructure, swelling soil and heaving bedrock are regarded to be the chief geologic hazard in the Front Range urban corridor. The potential for this hazard is mapped in the piedmont east of the Colorado Front Range (Hart, 1974; Noe and Dodson, 1997). During the 1990’s in Colorado Springs, localized landsliding occurred within the unit, especially on slopes of mesas capped by old alluvium (for example, unit agm of this map), damaging dwellings, roads, drainage improvements, and graded subdivision slopes (Himmelreich and others, 1996, p. LS–2). The unit includes unmapped scattered, surficial lags of coarse sandy and gravelly, granitic and quartzitic alluvium on eroded terrace deposits west of Monument Creek and Fountain Creek (El Paso County). Colluvium is 0.5–3 m thick

ccm **Andesitic clayey colluvium—**Yellowish-brown, clayey, very fine to very coarse quartz sand in upper few centimeters. Grades downward through 0.1–0.3 m of brown, clayey silt to silty clay (includes common feldspar and weathered volcanic-rock sand grains) to varicolored (olive-green, pale-yellow, and light-gray) clay, silty clay, and weathered, interbedded, tuffaceous siltstone, claystone, andesitic shale, siltstone, sandstone, and some conglomerate. The colluvium locally contains rounded pebbles and cobbles of quartzite, granitic rock, gneiss, and vein quartz. Secondary calcium carbonate commonly is present as patchy, thin coatings on clasts. Friable and soft, white veinlets and small masses of pedogenic calcium carbonate are common at depths of 1.5–2.5 m. The unit is slowly permeable, calcareous, moderately alkaline, and gypsiferous in places. Locally, bentonite clay mineral (smectite) is concentrated sufficiently to have the potential to expand upon sorption of water and damage building foundations. This hazard is documented in detail in the north part of Colorado Springs (Hart, 1974; Himmelreich and others, 1996). Present on sloping land, dissected by ravines. Mapped north of Colorado Springs. About 1.5–2 m thick

clx **Clay loam colluvium**—Light-yellowish-brown and brownish-yellow clay loam, clay, and silty clay loam containing scattered shale, sandstone, or clayey limestone chips, locally abundant limestone chips, and clusters of selenite (gypsum) crystals <5 mm in diameter. Locally, micaceous and many angular pebbles of ironstone concretions and mantled by lag deposits of granitoid alluvial gravel. Unit is strongly calcareous, moderately alkaline, and easily eroded. In hilly areas (>25 percent slope), as much as 20–40 percent of the mapped area is outcrops of sedimentary rock, chiefly shale. The unit grades down to interbedded fine- to medium-grained sandstone, carbonaceous or lignitic shale, and local coal beds. Mapped north of Colorado Springs. Colluvium is 0.5–2 m thick

cck **Tuff-clast loam and clay loam colluvium**—Yellowish-brown, light-brown, or brown loam to clay loam colluvium. Lags and pockets of pebbles and cobbles of ash-flow tuff and calcareous mudstone are abundant in places. Volcanic tuff crops out locally on ridges, buttes, and edges of mesas. Also includes small, unmapped areas of andesitic and rhyolitic colluvium (unit cbs). Volcanic ash, ashy silt, and fine sand composed of grains of silicic volcanic rock and quartz are present locally. Mapped mainly in the northwest part of the quadrangle (Thirtynine Mile volcanic field in western Park and Fremont Counties) and in northern Wet Mountain Valley (western Custer County). Thickness is generally 1–3 m; thinner on steep slopes

clo **Shale-, chalk-, and chalky limestone-clast loamy colluvium**—Light-brownish-gray and gray sandy silt loam and clay loam colluvium and locally clay loam residuum. Calcareous and moderately alkaline. When wet, the colluvium is nonsticky and slightly plastic to sticky and plastic. Moderately hard when dry. Locally includes sandstone and silty limestone in platy pieces and a thin surface lag of chalk and chalky limestone chips. Grades down to, and overlies with abrupt contact, weathered light-yellowish-brown shale and chalky limestone, and minor sandstone. The map unit includes relatively small areas of gently sloping land (3–5 percent) mantled by disintegration residuum (unit xlh) of pale-brown, very fine sand and silty clay to clayey, very fine sand containing sandstone and limestone chips. The chips commonly have thin, white coatings of secondary calcium carbonate. Near the St. Charles River, about 20 km southwest of Pueblo, the unit includes local badlands and much exposed limestone and shale bedrock. Colluvium is generally 0.5–1 m thick; as much as 3 m thick below escarpments

csm **Tuffaceous colluvium**—Pale-brown, light-yellowish brown, and light-grayish-orange, tuffaceous clayey to sandy loam colluvium containing variable proportions of granules, pebbles, cobbles, and boulders. The colluvium is formed on tuffaceous, basin-fill sediments in the west-central part of the quadrangle and on one small, deep graben 8 km northeast of Westcliffe (Custer County). Clasts are mainly volcanic and crystalline rocks, which include boulders 1–2 m in diameter near the edges of the basins. A cobbly surface layer characterizes the unit locally. Unit may contain swelling clay and thin beds of clayey silt and sandy alluvium. Mapped areas include small areas of bedrock and some sandy sheetwash alluvium near base of slopes. Grades downward to bedrock composed of tuffaceous sandy siltstone, friable sandstone, conglomerate, and a few sandy volcanic ash beds. Colluvium is commonly 1–3 m thick but may be thinner on steep slopes

csk **Grus, crystalline-clast colluvium, alluvium, and rock outcrop—**Surficial detritus, commonly gravelly sandy loam, and bare rock in mountainous areas where bedrock is mostly granite, felsite, or granitoid plutonic rock, migmatitic gneiss, biotite gneiss, schist, quartz monzonite, and metagabbro. In the Cripple Creek (southern Teller County) and Bare Hills (northern Fremont County) areas the unit also overlies weathered crystalline rocks including phonolite plugs, andesitic volcanic rocks, and rhyolitic tuff. On Iron Mountain, 22 km southwest of Cañon City, iron oxide–rich, sandy gravel colluvium is derived from weathered ultramafic rocks. Material and degree of weathering vary on a fine scale (for details, see Schmidt and Pierce, 1976). Map unit includes grus, colluvium, steep rock outcrop, and alluvium on foot slopes, flats, and in drainages. The proportions of these materials and deposits vary among locations. Generally, within mapped areas they are about 30 percent saprolite, 40 percent crystalline-clast colluvium, 20 percent rock outcrop, and 10 percent arkosic sandy alluvium.

Grus is gravelly, sandy detritus produced by in-place disintegration of coarse-grained crystalline rock. Grus typically is brown and very pale orangish brown, fine to very coarse sand that includes abundant granules and pebble-sized angular pieces, individual or aggregated, of quartz, feldspar, biotite, and trace iron-magnesium minerals. Acidic at high elevations, generally alkaline and calcareous below about 2,500 m. Grus locally contains subangular punky rock and rounded, unweathered corestones 0.5–3 m in diameter. In crystalline bedrock, granular disintegration is concentrated along sets of tension joints and microjoints. The distribution of deposits of thick (>10 m) grus is not predictable; the deposits are present on some gently rolling uplands and are exposed in roadcuts. Blair (1975) noted that the depth of weathering (and thickness of grus) of crystalline bedrock in the Rampart Range is generally 6–30 m thick on north-facing hillslopes and 3–4 m thick on south-facing hillslopes. Grus is easily excavated by mechanized equipment. Generally, land underlain by thick grus is gently rolling, for example the Granite Hills west of Pikes Peak (near lat 38°47´N., long 105°15´W.) and an old erosion surface south of Woodland Park (Teller County).

Colluvium in unit csk is mostly a mixture of sand, granules, and blocks of crystalline rock deposited by gravity on steep (about 30–70 percent, 13º–35º) hillslopes. On moderately steep hillslopes (15–30 percent), generally it is finer grained and has a matrix of brown, micaceous, silty, fine- to coarse-grained quartz and lithic sand and granules containing 5–35 percent angular crystalline-rock clasts. On relatively gentle hillslopes (less than 15 percent), colluvium commonly grades laterally to sandy alluvium in fans and aprons. Quartzose silt, 0.5–2 m thick, mantles some toe slopes on fractured crystalline bedrock. Gravelly, matrix-supported debris-flow deposits are present commonly on the steep sideslopes of major valleys and canyons in the Front Range west of Denver (James Soule, oral commun., 1999). Presumably, they are present in similar physiographic settings in the Pueblo quadrangle and indicate that a hazard of storm-triggered debris flows exists on the steep slopes within the map unit. Debris flows have the consistency of wet concrete, carry boulders, and can rapidly traverse large distances with forces sufficient to destroy buildings (Jeff Coe, written commun., 2000). Thickness estimated to be 0.5–4 m.

Alluvium in map unit csk is gravelly, quartzose and feldspathic sand and silt or sandy, crystalline-rock gravel in drainages, on flats, and in small fans. At the east front of the Wet Mountains is a discontinuous north-south band of fan-shaped deposits of brown silty sand colluvium and alluvium 3–10 m thick.

Rock outcrop includes ledges, cliffs, and pinnacles of mostly bare gray, grayish-brown (weathers brownish-yellow), pale-red, and reddish-brown crystalline rock (mostly granite and gneiss). Intersecting joints, shear zones, layering, and foliation cause the rock to break into blocks and crude rhombohedral pieces, centimeters to several meters across. Rock outcrops may contain soil-filled crevices

cgg **Sandstone-clast sandy loam to clay loam colluvium—**Light-brown, reddish-brown, or light-brownish-gray, fine sandy loam to clay loam sandstone-clast colluvium. Granules, pebbles, and minor cobble- and boulder-size flaggy sandstone clasts and scarce platy shale clasts make up 20–75 percent of colluvium. Whitish accumulations of soil carbonate are common below depths of 30–50 cm. Unit grades downward to weathered, interbedded sandstone and shale bedrock that commonly is calcareous. Locally, map unit cgg includes four types of non-colluvial materials or deposits that are too small to map separately: (1) sandstone or interbedded sandstone and shale outcrops, mainly in canyons, deep gullies, and along escarpments; (2) remnants of old gravelly alluvial fans, as well as young, scattered sheetwash deposits and alluvial deposits of stratified pale-brown pebbly sand; (3) flood-plain and channel deposits of small streams that contain granitic, cobbly, brown sand, 1–2 m thick; and (4) grayish-brown calcareous loess and residuum, which discontinuously mantles gently sloping (3–8 percent gradient), broad uplands. The colluvium thickness generally is 0.25–2 m, thinner on very steep slopes

cgh **Arkose-clast loamy colluvium—**Pale-red and reddish-brown sandy loam and coarse sandy loam colluvium containing 10–35 percent subangular to subrounded gravel of moderate-reddish-brown arkosic sandstone, notably in foothill regions of the Garden of the Gods area in west El Paso County and in the Woodland Park area at north-central edge of quadrangle. In the Woodland Park area, as much as half of clasts may be pale-red, coarse-grained granite (Pikes Peak Granite). In places, the pebbly sandy loam grades down to sandy loam that is sticky to slightly sticky and plastic to slightly plastic when wet. The colluvium forms sloping colluvial fans and slope deposits derived from weathered granite and (or) arkosic sandstone. Cliffs, ledges, and rounded, monolithic outcrops of arkosic sandstone locally make up about 20–40 percent of the map unit and more than half of the unit in canyons. A rockfall hazard exists in the canyon of Fountain Creek. In 1995, emergency crews constructed a steel cable restraining sling to prevent a huge rock from falling onto homes along El Paso Boulevard in Manitou Springs (Himmelreich and others, 1996, p. RF–1). Movement gauges were installed on other parts of the sandstone ledge susceptible to falling. The colluvium grades down to, or abruptly overlies, pale-red arkosic alluvium and sandstone. Thickness of unit is 0.20–3 m

cgc **Gneiss- and granite-clast gravelly colluvium—**Brown, cobbly sandy loam. Pale-red, white, and gray, rounded and subrounded granules, pebbles, cobbles, and boulders in a dark-grayish-brown and light-reddish-brown clayey sand and coarse sandy loam matrix. Sandy and locally silty matrix makes up 20–60 percent volume of deposit. Clasts are chiefly gneiss, granite, pegmatite, and biotite-quartz-plagioclase schist. Minor rock types include amphibolite, mica schist, andesite, white vein quartz, and volcanic rocks, both porphyritic and aphanitic. In the mountains 32–40 km northwest of Colorado Springs near Divide, Colo., and along U.S. Highway 24, the unit is present on rolling uplands formed on 10- to 15-km-long deposit(s) of river alluvium of Tertiary age. The colluvium derived from these deposits is brown, silty and clayey sandy gravel containing boulders as large as 1 m in diameter, composed mainly of andesite and other volcanic rocks from the Thirtynine Mile volcanic field (southern Park County and northwestern Fremont County) and phonolite from the Cripple Creek volcanic center (32 km west-southwest of Colorado Springs). Clasts include Pikes Peak Granite and Wall Mountain Tuff. Low erosion susceptibility and low water-holding capacity. Deposits in the western and southwestern parts of the quadrangle contain more volcanic rocks than the deposits northwest of Colorado Springs. Deposits in the Wet Mountain Valley and foothills of the Sangre de Cristo Mountains (Custer County, Colo.), especially around volcanic centers at Silvercliff and Rosita, include much andesite, rhyolite, latite, and trachyte. Clasts of these types accumulate on pediment surfaces and in valley-fill deposits (Santa Fe Formation) in the Wet Mountain Valley. The unit locally includes small, unmapped areas of residuum. The colluvium is generally 0.2–0.5 m thick, 1–2.5 m locally under some concave hillslopes, toe slopes, and small colluvial-fan deposits

cbh **Blocky sedimentary-rock colluvium—**Pale-red, reddish-brown, grayish-brown, and yellowish-brown sand, sandy loam, sandy clay loam, or clay loam colluvium that contains 20–60 percent of granule- to boulder-size clasts of sedimentary rocks. The larger clasts are commonly slabby and platy limestone, angular and blocky arkosic sandstone, calcareous sandstone, conglomerate, siltstone, dolomite, and minor quartzite. Clasts of shale and evaporitic rocks are scarce. Outcrops on steeper hillslopes generally make up 10–35 percent, and locally up to 65 percent, of the area mapped. The unit includes small, unmapped deposits of landslides, debris-flows, talus, and fan alluvium. In small valleys, the colluvium grades laterally into unmapped sheetwash alluvium on gentle alluvial slopes within 300–400 m of the stream channel. The sheetwash alluvium is grayish-brown, pebbly, fine-grained material, generally clay loam, silty clay loam, and (or) silt loam. Unit grades laterally into terrace gravel near rivers. Unit is mapped along flanks of the Sangre de Cristo Mountains at west edge and southwest part of the quadrangle. Thickness of unit cbh is generally 0.10–1 m on steep slopes and 1–3 m elsewhere; locally, the unit is as thick as 6 m at the bases of steep slopes

cbm **Carbonate-clast loamy colluvium—**Brown and grayish-brown stony loam colluvium that contains abundant (35–50 percent) pebble- to cobble-size, angular, subangular, and subrounded clasts of gray limestone and dolomite. Locally, sandstone or quartzite gravel is abundant. The granular matrix is friable when dry or moist, and is slightly sticky and slightly plastic when wet. Grades downward to weathered and fractured bedrock. Map unit locally includes outcrops of limestone, dolomite, and relatively minor sandstone and quartzite. In small stream valleys, the colluvium grades laterally into unmapped sheetwash alluvium on gentle alluvial slopes. The sheetwash alluvium is grayish-brown clay loam that contains pebbles of limestone. In larger river valleys, the colluvium locally grades to terrace gravel. Thickness of colluvium generally less than 0.5 m on steep slopes and 0.5–1.5 m elsewhere

cbs **Rhyolite- and andesite-clast colluvium—**Gravelly, loamy, or sandy colluvium containing common to abundant (50 percent or more) angular and subangular granules, pebbles, cobbles, and boulders of dark-gray, grayish-brown, and rhyolitic porphyritic volcanic rock and (or) light-gray andesitic rock. The clasts are mainly subangular to angular. The colluvium is widespread in the northwest part of quadrangle (Park County and western Fremont County), near Black Mountain and Thirtynine Mile Mountain. The unit grades downward to volcanic rocks and volcaniclastic sedimentary rocks that vary widely in texture and composition. The colluvium includes fine-grained and porphyritic tuffs, glassy, brecciated, and vesicular volcanic rocks, and relatively small areas of feldspathoid-rich, fine-grained rocks in dikes and plugs (phonolite); locally includes laharic and tuffaceous claystone, siltstone and volcanic sandstone, and arkosic volcanic-clast conglomerate. Some mesas within the map unit are capped by basalt. In the Bare Hills (20 km north-northwest of Cañon City), bouldery volcanic-rock clasts are interspersed with crystalline and sedimentary clasts. The colluvium includes local, relatively small, unmapped areas of dark-brownish-gray, poorly sorted bouldery alluvium on pediment surfaces that slope away from lava flows or volcanic mudflow remnants. Clasts are weathered and coated by calcium carbonate, which forms rinds in places. Colluvium is generally 2–8 m thick

cbu **Mixed-lithology blocky colluvium**—Grayish-brown, yellowish-brown, or reddish-brown to very pale brown silty sand, loam, or sandy colluvium that contains 30–80 percent angular to subangular, granule- to boulder-size clasts of crystalline, sedimentary, and (or) volcanic rocks. Clasts are generally blocklike, platy, flaggy, or subangular to subrounded in shape. Mapped where colluvial units having differing lithologies are too small to map separately. Map unit includes scattered landslide and talus deposits. The unit is generally 2–4 m thick

cbw **Blocky basalt- and andesite-clast colluvium**—Brown, pale-brown, medium-gray, and dark-gray, clayey to loamy colluvium commonly containing abundant (35–80 percent), angular to subrounded, boulder- to granule-size blocky clasts of gray, dark-gray, and grayish-brown basalt, basaltic andesite, or andesite. Locally includes outcrops, 2–100 m across, of these rock types. Whitish accumulations of calcium carbonate commonly are present at depths of 0.2–1.5 m and are common to abundant in the weathered and oxidized zone to depths of 2–2.5 m. Grades downward to volcanic bedrock of intermediate to mafic composition. Mapped 40 km west-northwest of Cañon City. Unit generally is 1–3 m thick

cby **Blocky feldspathic-sandstone colluvium**—Pale-yellow, pale-brown, and yellowish-gray sandy loam and loam colluvium mixed with abundant to common feldspathic sandstone gravel (granules to boulders). Abundant sandstone ledges crop out within the map unit. Mapped 5–10 km south of Cañon City. The unit mantles moderately to steeply sloping, dissected terrain on gently dipping beds of sandstone and minor shale. The unit is generally 0.3–3 m thick

xci **Sandy clay disintegration residuum**—White, light-yellowish-brown, very pale brown, calcareous sandy clay, clay loam, silty clay loam, and, less commonly, loam. The residuum grades downward to thick yellow chalk, minor thin beds of bentonitic claystone, minor, clayey sandstone in thin interbeds, light-gray to dusky-yellow, calcareous and (or) slightly gypsiferous shale, and, locally, thin beds of light-gray limestone. About 5 percent of the mapped area includes linear, low escarpments and cuestas of bedrock and local, surficial veneers of flat, thin fragments of limestone or sandstone. The residuum is easily eroded, slightly saline, and alkaline. It is hard when dry, sticky and plastic when wet. Locally, at depths of 1.5–2.5 m, the residuum contains powdery or finely crystalline gypsum. The unit forms on plains in the Arkansas River watershed, which are dissected by the river and its tributary streams. Ten to fifteen percent of map unit is veneered with silty, fine sand sheetwash alluvium, generally less than 2 m thick, and present downslope from low escarpments of sedimentary bedrock. Residuum is 0.3–2 m thick

xlh **Limestone-chip loamy disintegration residuum—**Light-brownish-gray and pale-brown sand, silt, and clay (chiefly loam, silt loam, and silty clay loam) having abundant to common limestone chips; well-drained; highly calcareous. Alkaline, hard to slightly hard when dry, nonsticky and slightly plastic when wet. Mapped predominantly on slopes of 1–5 percent in the south-central map area. Residuum grades down to, or overlies with abrupt contact soft to hard, light-gray limestone or soft marl interbedded with shale. Map unit includes unmapped areas of hillslopes having 5–15 percent gradients, stream-dissected land characterized by limestone and shale escarpments and low hogbacks. Present on these hillslopes is brownish-gray loamy colluvium containing as much as 15–50 percent limestone chips and flat pieces 1–20 cm in diameter (as does unit clo). Locally, sand and finer grains decrease and limestone chips increase downward to shallow, interbedded limestone and shale beds that are 0.02–0.65 m thick. In other places, shale immediately underlies the surficial material. The shallow rock may impede excavations for utilities or foundations, but in general it is easily excavated by heavy equipment. Thickness of residuum is 0.5–1.5 m

xlj **Silty-loam disintegration residuum—**Dark-yellowish-orange and very pale brown silty loam and local loam mixed with abundant, angular fragments of oxidized, marly shale or interbedded clayey limestone and marly shale. Includes thin silty loam sheetwash alluvium on gentle toe slopes near minor drainageways. Strongly calcareous; moderately alkaline. Grades down to platy or earthy, pale-yellowish-brown, light-gray, and very pale brown marly shale and, locally, argillaceous limestone. Hard when dry, friable when moist, and slightly sticky and slightly plastic when wet. The mapped unit includes about 15–25 percent of unmapped colluvium on escarpments (25–65 percent gradient; limestone breaks present within about 50–200 m of the boundary with unit xlh at the south edge of the quadrangle) that is equivalent to unit clo and too narrow to map. Many of these unstable slopes have slumped, forming slump-block deposits of shale, sandstone, and clayey limestone. The colluvium and escarpments differ markedly from the grass-covered residuum unit in that they are vegetated by grass, sagebrush, juniper, pinyon pine, mountain mahogany, skunkbush, and yucca. Thickness of unit is 0.3–1.5 m

xlu **Feldspathic loamy disintegration residuum**—Light-gray, pale-brown, light-yellowish-brown, and olive-brown loamy sand, coarse sandy loam, and abundant granules of granite, quartz, feldspar, and mica. Locally, the unit includes clayey sand, pebbly clayey sand, swelling clay, and andesitic detritus. Mapped on the gently rolling land surfaces northeast of Colorado Springs. The residuum grades down to slightly weathered feldspathic sandstone, siltstone, and sandy claystone. Locally some minor andesitic sandstone is present. These sedimentary rocks formed in Tertiary time from the detritus washed eastward off the Pikes Peak Batholith, the granitic core of the Front Range and original source of the quartz, feldspar, and mica in the residuum. Sparse to common, rounded to subrounded pebbles of granitic rock, vein quartz, gneiss, schist, and 5 percent maroon arkosic sandstone are scattered on the land surface; locally, cobbles and a few boulders are on the surface. Included in the map unit are unmapped, scattered, small eolian sand dunes stabilized by vegetation and having the characteristics of map unit ed. Residuum generally is 1–2 m thick

HOLOCENE TO MIDDLE PLEISTOCENE

oc **Playa clay—**Light-gray, very dark gray, light-grayish-brown, pale-brown, and brownish-gray sandy clay and silty, sandy clay. Calcareous; laminated and locally massive; very hard when dry and very sticky and plastic when wet. Deposits of playa clay accumulate in closed depressions and deflation lakes, which are flooded intermittently. Deposits are slowly permeable to very slowly permeable. Locally, the unit contains decomposed, finely comminuted plant material and organic carbon. Films, threads, and soft masses of calcium carbonate and small pebbles of limestone commonly make up 5–8 percent of the unit. The unit is deposited by sheetwash and accumulation of clay that settles from standing muddy water, and by the downward transport of clay and colloid-size organic particles by infiltrating ground water (piping and eluviation). When dry, the sites are salt and (or) alkaline flats that are deflated by wind. The closed depressions are 50 m to several kilometers across. Hundreds dot the plains in the east and southeast part of the quadrangle, but most are too small to show on the map and only the largest were mapped. These depressions form in the eolian sand, silt, and clay (map unit es) by wind erosion and (or) dissolution of near-surface carbonate above the water table. Thickness of the deposits commonly is 0.5–5 m

esa **Eolian sheet sand and loess (Included in the "cover sand" of Frye and Leonard, 1957, and Blackwater Draw Formation of Reeves, 1976, described by Holliday, 1989)—**Grayish-red, reddish-brown, or very light brown, fine to medium quartz sand; silty and clayey. Bedding includes planar, crossbedding, and massive beds. The eolian deposits appear to contain disconformities. The upper part of this deposit locally contains massive to layered clay and loam believed to be loess, sheetwash, and loessial colluvium. The unit includes loess and eolian sand so intricately interspersed that mapping them separately was impracticable. Wind and sheetwash have reworked an indefinite thickness of the upper part of the unit in historic time. Locally, thin beds of organic-carbon-enriched, gray lake silt and clay (unit oc) are present. At the base of the main body of the eolian sand is pebbly sand and alluvial sand that fills channels in places. We mapped a small area of this deposit at the south margin of the quadrangle (about 27 km south-southeast of Pueblo). Farther south and southeast (off the quadrangle), the unit is a mantle on parts of the High Plains and locally grades laterally into dune sand deposits. Unit overlies calcrete or Tertiary, Cretaceous, or Triassic bedrock. Contains several vertically overlapping, buried soils that have brown and reddish-brown, clay-rich B horizons, containing pedogenic calcium carbonate in the form of filaments, coatings, nodules, and small concretions, and scarce laminar concentrations. Calcic C horizons are present locally. The buried soils lack A horizons. Near Lubbock, Texas (600 km south-southeast of Pueblo), a volcanic ash layer in lower part of similar deposits is compositionally similar to the 1.4-Ma Guaje Pumice Bed in northern New Mexico (Izett and others, 1972). At Tule Canyon (Briscoe County, Texas, about 450 km southeast of Pueblo), similar deposits contain the ~0.6-Ma Lava Creek B volcanic ash bed. The unit appears to have accumulated cyclically through most of Quaternary time as a series of sand sheets formed during semiarid to arid periods of eolian deposition between longer subhumid to semiarid intervals characterized by concurrent erosion, local playa-lake deposition, and soil formation. Thickness 2–6 m

jba **Bouldery volcanic-rock landslide deposit**—Angular boulders and finer debris mainly on flanks of buttes and benches underlain by weak, clay-rich rock layers such as shale and claystone and capped by, or interbedded with, hard, brittle extrusive volcanic rocks, dikes, and sills. Mass-movement deposits formed by slumping, debris flows, earthflows, and rockfall associated with mafic, intermediate, and silicic extrusive volcanic rocks and near-surface (hypabyssal) intrusive igneous rock bodies, including dikes and sills. Common rock types are basalt, andesitic flows and laharic breccia, silicic tuff (chiefly rhyolite, rhyodacite, dacite, latite, felsite), agglomerates, and volcanic conglomerate. Deposit is a heterogeneous mixture of angular and subangular gravel in a brown, gray, or white, fine-grained, calcareous matrix. Layers of carbonate formed by soil processes are typically developed at depth of 0.2–1 m. Mapped 20–40 km northwest of Cañon City. Thickness of the unit is approximately 2–15 m

jbc **Bouldery crystalline-rock landslide deposit—**Bouldery and rubbly landslide deposits chiefly in mountainous areas underlain by igneous and metamorphic rocks. In the absence of destabilizing, man-made excavations on slopes, many of these deposits appear to have been stable for longer time than landslide deposits that are derived from the softer sedimentary rocks (unit jea). In general, evidence of recent movement of unit jbc is uncommon, although clear diagnostic age criteria are rare. Nevertheless, some deposits may be Holocene in age. Thickness is approximately 2–15 m

xsg **Feldspathic quartz-sand disintegration residuum—**Pale-brown, light-yellowish-brown, and brown feldspathic quartz sand that commonly contains pebbles and granules. The unit on the plains (northeastern part of quadrangle) is chiefly medium-grained quartz sand; locally, silt, fine-grained sand, and coarse-grained sand are present. Quartz constitutes most of the sand, and feldspar is 5 percent or less. On Baculite Mesa, 10 km north-northeast of Pueblo, it is chiefly quartz and feldspar sand and contains less than 10 percent granules and small pebbles of granite, quartz, sandstone, and feldspar. The residuum on Baculite Mesa and the underlying sandy deposits (Nussbaum Alluvium) on which the residuum is developed, have been mined commercially for sand. Most crystalline clasts have calcium carbonate rinds and are weathered and crumble under pressure. This residuum is developed on old alluvium that overlies high-level pediment surfaces (?) (Nussbaum Alluvium of Gilbert, 1897) of probable late Tertiary to early Quaternary age. In Twelvemile Park (15 km northwest of Cañon City), the residuum grades down to grayish and reddish-brown, poorly sorted, compacted, stratified, gravelly alluvium composed mostly of granodiorite, gneiss, and sandstone. In the extensive deposits in the northeast part of the Pueblo quadrangle, the unit is mostly quartz and as much as 25 percent granules of olive-green shale. Locally contains a trace of pebble-size fossilized wood. Thickness 2–4 m

LATE PLEISTOCENE

elb **Loess (Peoria Formation)**—Moderate-yellowish-brown, light-brown, yellowish-brown, and olive-gray quartzose sandy silt, and silty or clayey fine sand. Deposited by wind. One probable source of the silt was major rivers that carried voluminous rock flour (silt) abraded from bedrock by alpine and valley glaciers. Also probably derived from volcaniclastic silt and clay of bedrock outcrops in the plains region (Aleinikoff and others, 1999). In northeastern Colorado, the mean particle size of about 100 grain-size analyses is fine sand (0.20 mm) to silt (0.02 mm) (Muhs and others, 1999). The loess is 60 percent or more silt. It is slightly to strongly calcareous, and it contains calcium carbonate spots, nodules, and veinlets to depths of 1–1.5 m. Locally, it may contain lenses of sand and small pebbles. The loess is nonstratified, massive, blocky or columnar structure, friable, and weakly compact. It stands in nearly vertical faces several meters high. Hard and conspicuously vertically jointed when dry; nonsticky to slightly sticky when wet. Some previous workers who mapped the loess in the plains of Colorado interpreted a paleosol to be present in the loess. They described it as a strong Brown soil having distinct prismatic or columnar structure and clay enrichment (also developed in Louviers alluvium) and inferred that it formed in mid-Wisconsin time. This distinctive soil is about 2.5 m thick. Other workers in the Great Plains east of Colorado recognized an organic-rich paleosol in the upper part of the Peoria Loess and named it the "Brady soil." Because these paleosols are geographically separated and have not been traced into one another, it is uncertain if they formed simultaneously. Three loess stratigraphic units have been named in the Great Plains, the Peoria Formation being the most widespread. In Nebraska and Kansas, radiocarbon ages of the Peoria Formation range from about 21,000 to 10,000 yrs before present (Muhs and others, 1999). We assume that map unit elb is mostly Peoria Loess, although relatively small deposits of loess probably formed in Holocene time. Loess mantles undulatory uplands, shallow deflation basins, and mounds, and thins downwind (east and southeast) from eolian sand deposits (unit es) and river valleys. In places, the loess grades laterally to eolian sand, sheetwash alluvium, colluvium, and residuum. Boundaries between such units and the loess are approximate. Locally, the loess includes small areas of intensely weathered upland gravel, stony and clayey colluvium, and undifferentiated bedrock outcrops of shale and sandstone. The unit is generally less than 3 m thick and locally eroded entirely in and near deep drainageways that cross the map unit

LATE AND MIDDLE PLEISTOCENE

Bouldery till (**of Pinedale and Bull Lake glaciations**)—Generally a nonsorted, nonstratified, heterogeneous mixture of subangular to subrounded boulders, cobbles, pebbles, and granules in a generally sandy matrix. The relative abundance of pebbles, cobbles, or boulders varies. No mechanical size analysis has been done on the till to determine which of these clast sizes predominates. However, boulders typically are conspicuously present and commonly abundant. Some boulders are more than 5 m in diameter. Locally, till is overlain by unmapped, thin loess, and the map units include minor amounts of stratified glaciofluvial deposits near the lower altitude limit of glaciation.

Till of Pinedale age (the younger till) is characterized by distinct end moraine and lateral moraine and is discontinuously covered by unweathered to slightly weathered surface boulders. Weakly developed soil profiles in the till are characterized by 10- to 40-cm-thick B horizons containing 1–7 percent more clay than is present in unweathered till. Pedogenic calcium carbonate horizons 40–80 cm thick (stage I carbonate morphology) are common in semi-arid areas. Clasts altered to grus are rare.

Till of Bull Lake age generally forms indistinct moraine. Surface boulders are moderately weathered and pitted, and soil profiles typically are characterized by 35- to 75-cm-thick B horizons that contain 5–13 percent more clay than unweathered till contains. Pedogenic carbonate horizons 60–100 cm thick, having stage II carbonate morphology of Gile and others (1966), are common in semi-arid areas (Shroba and Birkeland, 1984). Granitic and gneissic clasts in B and C horizons of soil developed in till of Bull Lake age commonly are altered to grus. The till locally is 1–15 m thick, 30 m or more thick in some lateral and end moraines.

The Pinedale glaciation occurred in the Front Range about 30–12 thousand radiocarbon years ago. This timing is based on several lines of evidence, including radiocarbon dates for glacial and lake deposits associated with valley glaciers near Winter Park, Colo. (Millington, 1977; Nelson and others, 1979) and North Boulder Creek valley (Madole, 1986), and radiocarbon-dated fossil insects from the Colorado Piedmont (Elias and others, 1991). Also, relative dating methods (for example, degrees of soil development and erosion of moraines) suggest that Pinedale glaciation in the Rocky Mountains was coeval with the well-dated Wisconsin glaciation in the North American midcontinent.

Timing of Bull Lake glaciation is not well constrained in Colorado. In the North St. Vrain valley, northeast of Allens Park, Colo., till of Bull Lake age yielded a uranium-trend age of 130,000±80,000 yr, and colluvium overlying till of pre–Bull Lake age yielded a uranium-trend age of 220,000±70,000 yr (Madole and Shroba, 1979; Rosholt and others, 1985)

tbg **Crystalline-clast bouldery till—**Light-gray to grayish-brown till having a micaceous, sandy, and grus-rich matrix (sand generally 55–70 percent of matrix). Abundant clasts are subangular to subround. In the Sangre de Cristo Mountains the clasts are composed mostly of metavolcanic rocks, muscovite-rich gneiss, metarhyodacite tuff, metabasalt, and metamorphosed sedimentary rocks or tuffs. On Pikes Peak the clasts are coarse-grained, pale-red granite in a brown, highly weathered, extremely gravelly, coarse sandy loam matrix. Locally, the crystalline-clast till includes rock-glacier deposits 0.5–2 km long of probable Holocene and late Pleistocene age

tbi **Sedimentary-clast bouldery till—**Light-brown, pale-red, reddish-gray, or reddish-yellow till having a loamy sand matrix. Clasts are predominantly Pennsylvanian-Permian grayish-red sandstone, conglomerate, and siltstone. Mapped in the southern Sangre de Cristo Mountains at the southwest edge of quadrangle, straddling the Custer–Saguache County line. Locally includes minor rock-glacier deposits

tbj **Mixed-lithology-clast bouldery till—**Locally contains granitic rock, tonalite, sandstone, conglomerate, shale, and minor limestone clasts in the Sangre de Cristo Mountains

ggq **Outwash sand and gravel (of Bull Lake, Pinedale, and post-Pinedale ages)**—Stratified sand and gravel deposited in valleys by glacial meltwater. Mapped downvalley from till (units tbg, tbi, tbj, tbk) in glaciated valleys. Includes some post-glacial alluvium. The outwash deposits generally underlie uniformly sloping (4–10 percent) terraces and coalesced alluvial-fan surfaces 3–10 m higher than adjacent stream channels. Outwash may be present farther downstream than shown on the map; the boundary between outwash and nonglacial alluvium is arbitrary in some valleys. Gravelly sand and sandy gravel, having rounded to subangular clasts, grade upvalley into till. Clasts are typically set in a granule and sand matrix. Grain size, thickness, and particle composition vary widely from one drainage basin to another. These properties reflect the distance from source glaciers and the variable lithologies of source rocks. Thus, it was impracticable to map compositional subtypes of outwash in the quadrangle. Mapped in the South Platte River Valley (northwest part of quadrangle), the upper Arkansas River valley (southwest Fremont County), and the Wet Mountain valley (northwest Custer County). Forms uniformly sloping (4–10 percent) terraces that stand higher than adjacent stream channels cut in Holocene time. Thickness 2–8 m

ags **Alluvial sand, silt, clay, and gravel (Louviers and Slocum Alluviums, undivided; late middle Pleistocene)**—Louviers Alluvium (the younger alluvium) south of Pueblo Airport is rounded cobbles and pebbles of granite, volcanic, and hypabyssal igneous rocks, sandstone, biotite and hornblende gneiss, and various fine-grained mafic rocks in a brown sandy matrix. The alluvium is concealed by eolian sand in places near the Arkansas River east of Pueblo. Locally, scarce pieces of opalized wood are present. In northern El Paso County, east of Monument Creek, arkosic sand about 7 m thick covers a broad terrace (on which the airport of the U.S. Air Force Academy is located). West of Monument Creek, six to seven remnants of pebbly, cobbly, and bouldery granitic alluvium cover pediment remnants. A relict soil commonly is developed in the upper 1 m of the alluvium. Machette (1977) interpreted the relict soil to be younger than Bull Lake glaciation. Slocum Alluvium (the older alluvium) near Cañon City is yellowish-red, stratified, sandy gravel that contains granules, pebbles, cobbles, and boulders. Slocum Alluvium is more bouldery near the mountains. Locally, the unit is mostly pebbly sand that contains some silt and clay, mainly in the matrix and (or) as thin interbeds. Stones are mainly weathered granite and some pegmatitic, metamorphic, volcanic, and sedimentary rocks. Most have calcium carbonate rinds. East of Pueblo, on terraces of the Arkansas River, clasts are granite, gneiss, hornblende and biotite schist, volcanic porphyry, quartz, and quartzite. The unit includes stratified, gravelly coarse sand, mainly feldspar, quartz, mica, and magnetite. A skull of *Bison latifrons* was excavated in this unit near Cañon City. Lumps and layers of olive-gray shale eroded from the underlying bedrock are common locally in the alluvium. The unit is commonly cross-stratified, and cut-and-fill channel structures are evident in many exposures. Typical of the Slocum Alluvium is a thick, poorly sorted, main lower gravel overlain by 1–1.5 m of very pale brown, pale-brown, white mottled pebbly sand and silt that is slightly sticky, plastic when wet, and hard when dry. Slightly cemented by clay throughout (less so in lower gravelly part) and by calcium carbonate in the upper part. Deposits underlie two terrace levels about 36 and 55 m above modern streams. Unit is 3–7 m thick near the mountain front (Scott and Lindvall, 1970) and 1–3 m thick more than about 5 km east of the mountain front. In northeast Custer County, near Wetmore, the unit is moderately reddish brown bouldery to pebbly alluvium; stones weathered and coated by calcium carbonate (Taylor and Scott, 1973)

afb **Alluvial-fan gravelly loam**—Pale-brown, light-brownish-gray, light-gray, or dark-gray, poorly sorted, crudely stratified gravelly loam containing as much as 75 percent boulders, cobbles, pebbles, and granules. The unit forms coalescing alluvial fans of extremely cobbly loam near mountain fronts. Clasts and particles become smaller and fewer toward the valley axis. The fans interfinger basinward with fine-grained alluvium in playas and terraces and floodplains of the axial river (unit asa). In the central San Luis Valley, clay and silt content increases toward the valley axis, though some gravel lenses are present. These sediments are alkaline, saline, and calcareous, and textures vary widely over short distances. Mapped in the San Luis Valley (southwest corner of quadrangle) and north of Elevenmile Canyon Reservoir (South Platte River). In the northern San Luis Valley, clasts are mainly granodiorite, quartz monzonite, and andesitic breccia and volcanic rocks (derived from the San Juan Mountains on the west), and are Precambrian migmatitic gneiss, foliated hornblende quartz diorite, and Paleozoic limestone, dolomite, and sandstone (derived from the Sangre de Cristo Mountains on the east). The unit was deposited in part as glacial outwash in channels and includes Pinedale and Bull Lake fan alluvium. Pinedale-age surfaces are slightly dissected, surface clasts are relatively unweathered, and soils are weakly developed. Bull Lake–age surfaces are moderately dissected (preserved as remnants higher than the Pinedale surfaces) and characterized by pitted and weathered surface clasts and moderately developed soils with clay-enriched B horizons. Fan surfaces are covered locally by thin deposits of eolian sand. Near Elevenmile Canyon, the unit overlies an exhumed and partly eroded late Eocene surface and contains granitic and metamorphic rocks. The unit is a potential source of gravel. Thickness of alluvium may be as much as 30 m near Elevenmile Canyon Reservoir and as much as 100 m or more in the San Luis Valley

MIDDLE AND EARLY PLEISTOCENE

tbk **Bouldery till (of pre–Bull Lake glaciations)—**Reddish-brown and yellowish-red, generally nonsorted, nonstratified mixture of subangular to subrounded boulders, cobbles, pebbles, and granules in a loamy sand to sandy loam matrix. A cobbly to extremely cobbly sandy loam deposit that forms a subdued, morainal form (5–20 percent slopes) in a 5.2 km^2 area east of the Sangre de Cristo Mountains (western Custer County), downvalley from younger tills of Bull Lake and Pinedale ages. Generally lacks constructional morainal form. Clasts are composed mostly of red arkosic sandstone, conglomerate, syenite, and siltstone. Fewer shale and gray, fine-grained limestone clasts are present. The till locally includes stratified drift, especially at its lower elevations. Surface boulders are deeply weathered and pitted. Many subsurface clasts are altered to grus. Soils commonly have a 1-m-thick B horizon that contains three or more times the clay content of unweathered or slightly weathered till. Pedogenic carbonate horizons having stage III or IV carbonate morphology (Gile and others, 1966) are present. The till may have been deposited during two or more glaciations

gge **Outwash sand and gravel (of pre–Bull Lake glaciations)**—Stratified sand and gravel deposited by glacial meltwater, perhaps during two or more glaciations. Generally poorly to moderately sorted, sandy pebble and cobble gravel consisting of subrounded to rounded clasts. Proportions of granules, pebbles, cobbles, and boulders, to one another vary considerably, as does the amount of matrix. Loamy alluvium, colluvium, or loess deposits 0.5–2 m thick overlie the gravel in places. Clasts are mostly red and gray arkosic sandstone and conglomerate in the only area where unit is mapped, the northern Wet Mountain Valley (43 km southwest of Cañon City). Many subsurface clasts are intensely weathered. The soil commonly has a 1-m-thick B horizon containing three or more times the clay content of unweathered or slightly weathered outwash. Pedogenic carbonate horizons that show stage III or higher carbonate morphology are present in semi-arid locations. Locally, the unit contains Lava Creek B ash (0.64 Ma; Marvin Lanphere, written commun., 2001). The outwash forms terraces 80–200 m above modern stream level. Beneath terrace surfaces the outwash is 1–10 m thick. At least 3 m thick elsewhere

agm **Alluvial gravel and sand (Verdos and Rocky Flats Alluviums, undivided; early middle Pleistocene and early Pleistocene)—**Poorly sorted, intensely weathered, matrix- and clast-supported, subangular to subrounded cobble, pebble, and granule gravel, bouldery in pediment and fan deposits near mountains. Grain size decreases away from the mountains. The gravel forms lenticular and cut-and-fill channel bedding and is composed of granite, gneiss, hornblende and biotite schist, volcanic porphyry, quartz, and quartzite, especially abundant in fluvial terrace deposits along the Arkansas River and some of its tributaries. The matrix generally is light-brown, reddish-brown, or pale-red sand, silt, and clay whose proportions vary from place to place. Pedogenic clay is abundantly present as thick films and coatings on sand grains and clasts in the surficial relict soil zone (upper 1–2 m). The unit is present on pediments in the foothills near the Rampart Range (southern Front Range) and the Wet Mountains. It is also present as terrace deposits along Fountain Creek (mapped as Mesa Gravel, Jenkins, 1964) and the Arkansas River. Grain size decreases eastward to mostly sand and small, white and pale-red pebbles. Near the east front of the Rampart Range (northern El Paso County), granite boulders 5–7 m in diameter are present (Varnes and Scott, 1967). Clasts are mostly granite, gneiss, porphyritic volcanic rocks, and sandstone. Subordinate rock types are vein quartz, pegmatite, schist, and claystone. Weathered granitic and gneissic clasts (rich in mica and mafic minerals) crumble easily when struck with a hammer and are unsuitable for concrete aggregate; they are used locally for road material. In western Fremont County, near the Arkansas River, deeply weathered clasts of crystalline, sedimentary, and porphyritic volcanic rocks are coated with calcium carbonate rinds 1–4 mm thick. A white and very pale orange, calcium carbonate–enriched soil zone 0.6–1.2 m thick cements clasts and matrix in the top 2 m of the unit. Lava Creek B volcanic ash (age 0.64 Ma, Marvin Lanphere, written commun., 2001) is present in the

Verdos Alluvium (the younger part of unit agm) in places, notably at Westcliffe and 6 km south of town (76 km west-southwest of Pueblo). Tator (1952) inferred that pediment processes deposited the alluvium on high, east-sloping surfaces at the east foot of the mountains near Colorado Springs. Local matix-supported beds are deposits of debris flows.

Rocky Flats Alluvium, which has weathered longer than the Verdos Alluvium, generally is redder (reddish-brown, light-brown, and light-red) and more clayey than the Verdos Alluvium. Particle size, which varies from place to place, commonly is sandy, coarse gravel, gravelly sand, and gravelly, clayey sand. The deposits are generally about 45–70 m higher than modern streams, as high as 90 m in places. The alluvium is commonly 1–10 m thick, locally more than 10 m thick, and includes thick channel-fill deposits of gravel that may have accumulated in paleochannels. The unit contains beds and lenses of cobbly and silty clay and, near the mountains, basal boulders as large as 5 m in diameter. Many of the large boulders were possibly deposited by debris flows. Thickness of the Rocky Flats Alluvium is estimated, except at the U.S. Air Force Academy site (15 km north of Colorado Springs), where measurements in excavations averaged 6–8 m and were as much as 15 m thick (Varnes and Scott, 1967, p. 21)

afk **Alluvial-fan gravelly loam—**Brown, light-grayish-brown, and light-brownish-gray, stratified, gravelly loam alluvium in interfan remnants at or near mountain fronts. Mapped in the San Luis Valley. On the west side of the valley, clasts are mainly volcanic rock types from the San Juan Mountains. On the east side, clasts are mainly Paleozoic sedimentary and Precambrian crystalline rocks from the Sangre de Cristo Mountains (composition similar to unit afb). Fan surfaces are moderately to severely dissected and locally are covered by thin deposits of eolian sand. Surface clasts are severely pitted and weathered. A strongly developed soil is characterized by abundant pedogenic clay and carbonate accumulation. Bull Lake and younger fan deposits (unit afb) near the valley axis commonly bury the unit. At one buried locality, alluvium of this unit exposed in a mine tunnel near Wild Cherry Creek (SE¼ sec. 32, T. 45 N., R.11 E.) contains discontinuous pods of reworked Bishop Ash (McCalpin, 1983), dated at 738,000 yr (Izett and others, 1972) and confirming a pre–Bull Lake age for the unit. The Bishop ash was produced by a catastrophic volcanic eruption from the Long Valley Caldera, on the east side of the Sierra Nevada, in California. Thickness of alluvium is unknown; it may be as much as tens of meters thick

PLEISTOCENE

pga **Pediment gravel**—Gray and grayish-brown, sandy, granule to boulder alluvium that is poorly sorted, crudely stratified, and composed chiefly of andesite clasts. The unit forms pediment remnants on mountain flanks in the Thirtynine Mile Volcanic Field (75 km west-southwest of Colorado Springs). The gravel mapped north of Elevenmile Canyon Reservoir (northwest edge of map area) includes granodioritic, gravelly fan alluvium of possible Pinedale age. Within the unit are beds of reddish-brown, stratified and sorted alluvium composed of sandstone, limestone, and locally gneiss and granodiorite clasts. A strongly developed calcium-carbonate-enriched soil (20–60 percent carbonate) is present in the upper 1.5 m of the alluvium. Forms a broad terrace and gently sloping alluvial surface about 25 m above valley bottoms. Thickness about 6 m

jbg **Granodiorite-block debris-avalanche deposit—**An extensive deposit of boulders of medium-gray granodiorite and gneissic granodiorite; rocks are biotitic and medium to coarsely crystalline and porphyritic. Abundant on the surface are subrounded boulders, some fully exposed and some partly buried; most boulders are resistant above the soil line and below it are weathered to a crumbly condition. Unsorted granules, sand, silt, and clay are present in pockets and lenses within the deposit and in depressions on the deposit. These particles possibly were deposited by flowing water after the initial emplacement of the boulders. Locally, springs flow intermittently from the deposit, exacerbating slope instability, especially in excavations for home construction. Excavations reveal that most buried boulders are deeply weathered, forming a mass of weakly cemented, coarse sand and granules that can be cut by digging machinery. The deposit possibly formed by one or more catastrophic rockfalls and (or) debris flows from the east face of Cheyenne Mountain (southwest of Colorado Springs, the only place this unit is mapped on the Pueblo quadrangle). If so, this deposit manifests a potential geologic hazard to homes and residents there. Boulders are as large as 6 m in diameter, but most are 1–2 m across. The extent of deposit (8.4 km^2) and distance (3 km) that it extends from foot of Cheyenne Mountain suggest that the deposit is not ordinary talus that accumulated by countless small rock falls. Destructive debris flows occurred in 1965 on steep slopes in this area (Himmelreich and others, 1996). According to one interpretation (Scott and Wobus, 1973), the momentum of the falling rock debris carried it away from the precipitous mountain front. They speculate that the mass may have been buoyed by compressed air trapped under it during its fall, causing the debris to travel far from the east face of the mountain. The east edge of the deposit is less than 2 m thick and overlies shale. Slow slumping has been active recently along steep and thin edges of the deposit where the underlying shale is shallow (Chris Carroll, Colorado Geological Survey, oral commun., 1999). In places, slumping has damaged dwellings, roads, and graded slopes (Himmelreich and others, 1996). Base of the deposit is covered or indistinct in excavations. Estimated thickness is 2–15 m

QUATERNARY

cra **Hogback and rangefront colluvium, alluvium, and rock outcrop**—Linear rocky ridges (hogbacks) and intervening valleys eroded into steeply dipping sedimentary strata of variable composition and grain size along parts of the front of mountains. Moderately steep to very steep (15–100 percent hillslopes), wooded bedrock ridges and associated colluvial and alluvial deposits extend roughly north–south (northwest of Colorado Springs and west of Cañon City) and northwest–southeast (in the south-central part of the quadrangle). The relatively thin outcrops of compositionally different rocks are too narrow to differentiate on this map and thus were mapped as a single unit. Thick intervals of resistant arkosic sandstone, quartzose sandstone, conglomerate, and relatively thin limestone beds crop out on the ridges. The lower hillslopes of the hogbacks and valleys between overlie shale and mudstone. Blocky and sandy colluvium 2–8 m thick and talus 1–3 m thick accumulate at the foot of hogbacks and cliffs or mantle steep slopes. Along the east front of the Rocky Mountains, the hogback ridges and deposits are aligned north-south in strips too narrow to differentiate on this map. Rock ridges of steeply dipping, resistant, light-brown, yellowish-brown, or red sandstone and gray limestone are sources of colluvium, alluvium, and local landslide deposits.

Colluvium is composed of blocky sandstone or limestone rubble in a matrix of light-reddish-brown, brown, or grayish stony sand, sandy loam, and sandy clay loam.

Remnants of pediment gravel are locally present at the base of the abrupt east face of the Front Range and are included in map unit cra. The gravel is composed of granitoid plutonic rock, gneiss, schist, pegmatitic quartz and feldspar, and sandstone in a clayey sand matrix. It generally is 2–6 m thick and covers gently east-sloping, planar erosion surfaces (pediments) on divides between modern streams. The surfaces generally are 30–100 m above the streams. The deposits, which are similar to units agm and ags, are too small to map at this scale—generally 2–6 m thick and 20–200 m in width (as much as 1–2 km^2 in area). Floods and debris flows deposited this material during early and middle Quaternary time.

Piney Creek Alluvium (Holocene), generally 2–8 m thick, is present in channels and beneath flood plains of modern streams. Alluvial clasts are mainly granite, granitoid rocks, and sandstone. Grain size varies and includes gravel, clayey, fine to coarse sand, silt, and clay. The alluvium, which contains a grayish-brown humic A soil horizon, 0.3–0.5 m thick in its upper part, grades laterally to colluvium, shaley debris-apron deposits, and talus

PRE-QUATERNARY

R **Bedrock—**Various bedrock types, mostly bare excepting scattered pockets and lags of fragmented rock and scree. Includes areas of alpine tundra too small to map, alpine peaks, aretes, cols, cirque walls, and divides. In the Sangre de Cristo Mountains, the map unit includes rock-glacier and talus deposits composed of conglomerate and sandstone. Also mapped in deep canyons cut in hard bedrock

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