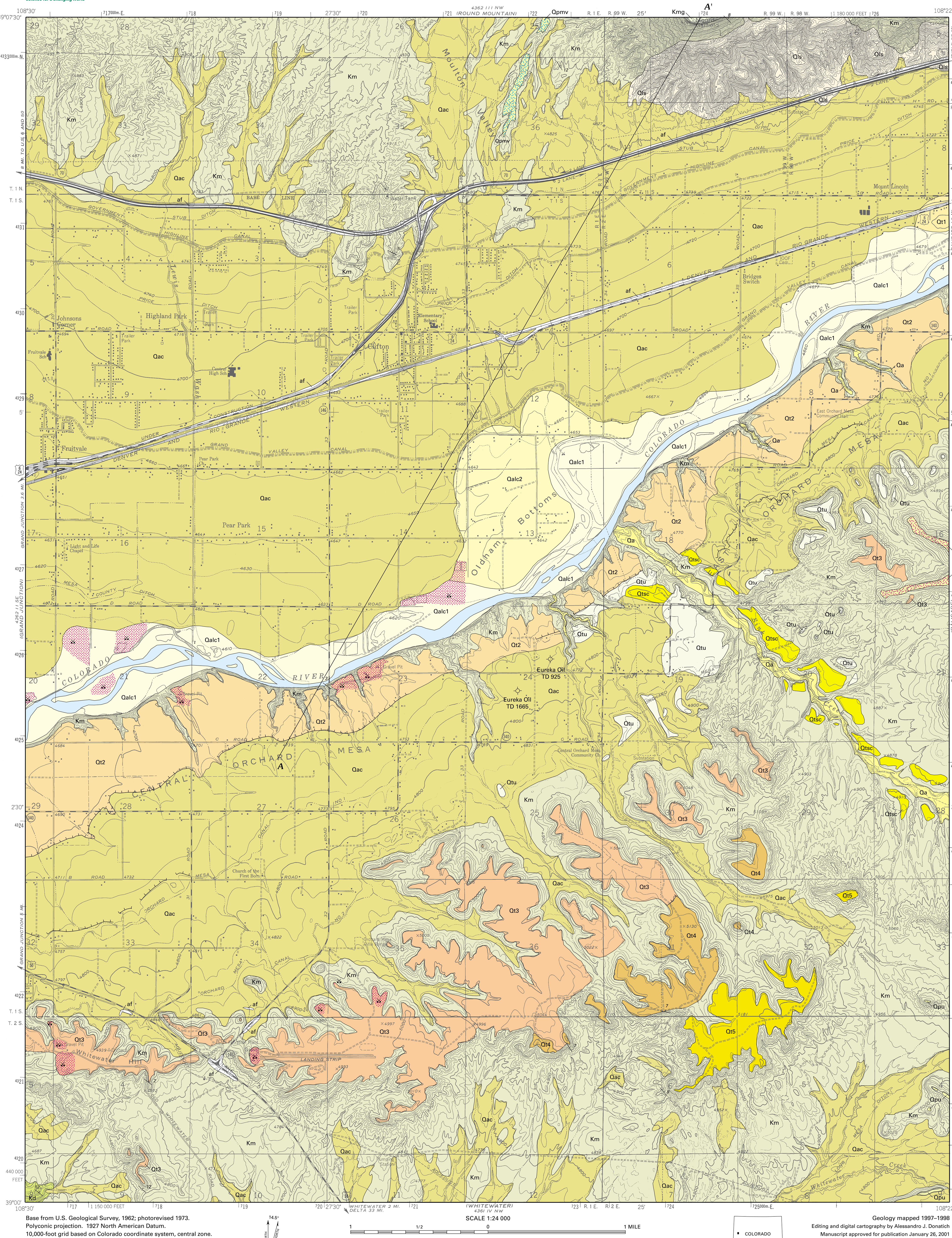
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES MAP MF–2359
Version 1.0



Base from U.S. Geological Survey, 1962; photorevised 1973.
Polyconic projection. 1927 North American Datum.
10,000-foot grid based on Colorado coordinate system, central zone.
1,000-meter Universal Transverse Mercator grid ticks, zone 12.

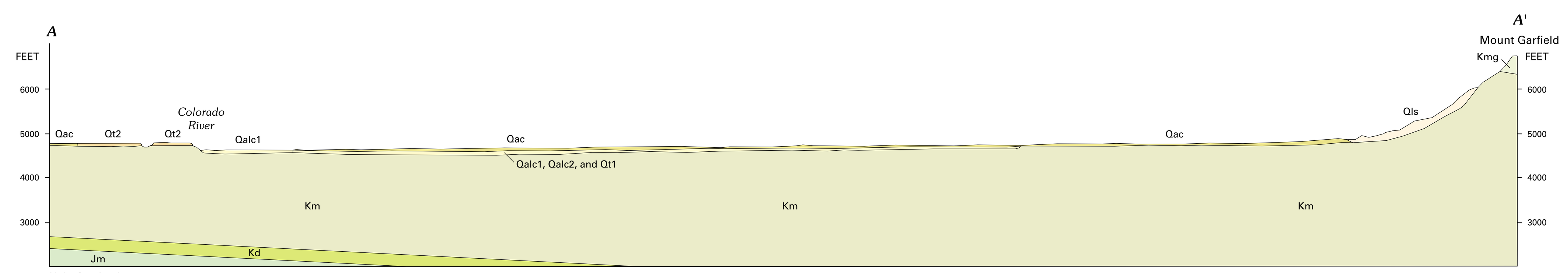
APPROXIMATE MEAN DECLINATION, 1973

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
DOTTED LINES REPRESENT 10-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

QUADRANGLE LOCATION

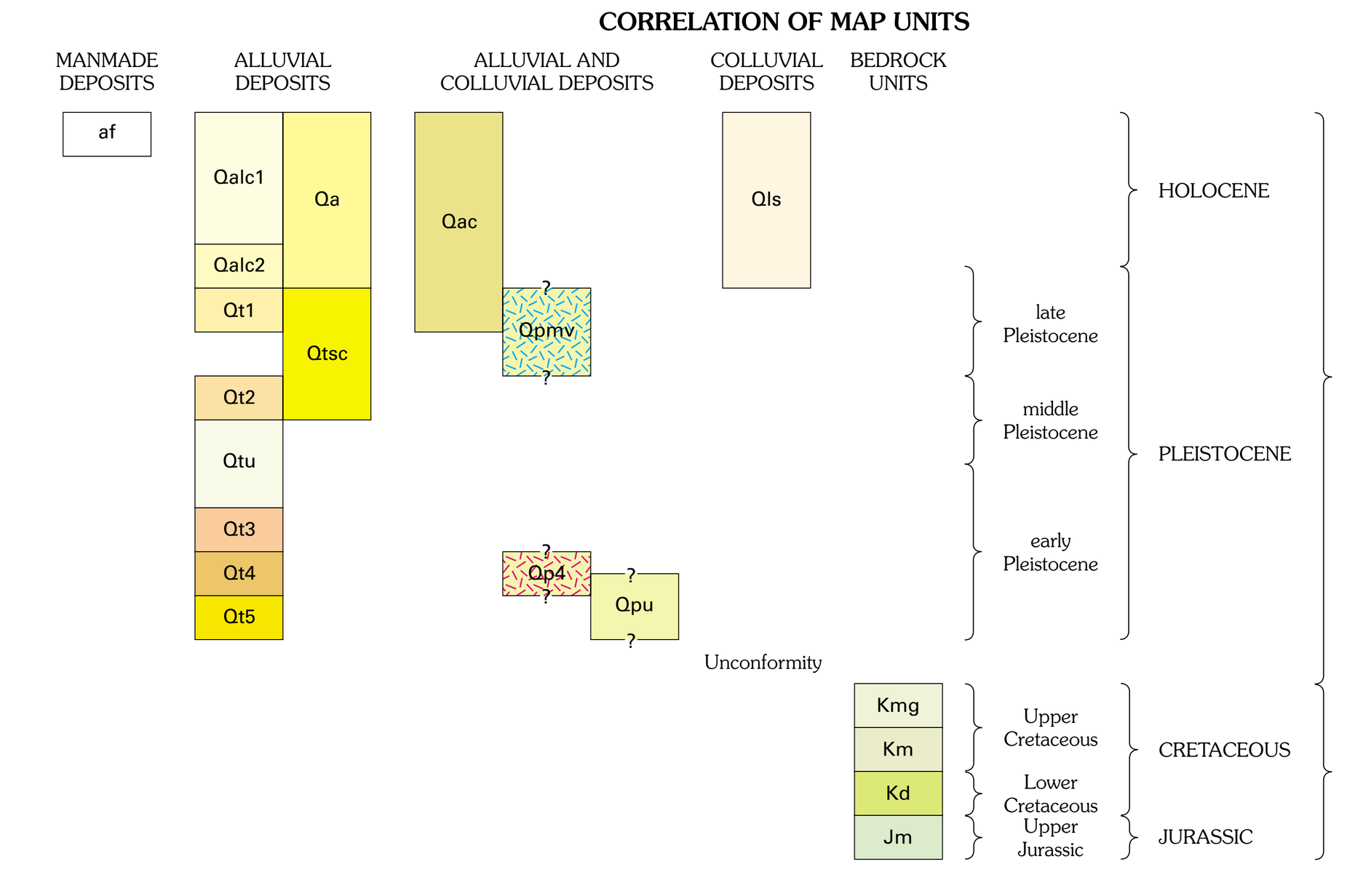
Geology mapped 1997–1998
Editing and digital cartography by Alessandro J. Donatich
Manuscript approved for publication January 26, 2001



GEOLOGIC MAP OF THE CLIFTON QUADRANGLE, MESA COUNTY, COLORADO

By
Paul E. Carrara
2001

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

Surficial deposits shown on this map are generally at least 1 m thick; thinner deposits are not shown. Thin, discontinuous colluvial deposits, residual material on bedrock, and some artificial fills were not mapped. Many contacts of surficial deposits are approximate because the contacts are poorly exposed or gradational (for instance, the contacts between undivided alluvium and colluvium (**Qac**) and alluvial deposits (**Qalc1** and **Qalc 2**) north of the Colorado River.

Divisions of Quaternary time are modified from Richmond and Fullerton (1986). They are: Holocene, 0–11,390 yr ago; late Pleistocene, 11,390–127,000 yr ago; middle Pleistocene, 127,000–778,000 yr ago; and early Pleistocene 778,000–1,806,000 yr ago (D.S. Fullerton, written commun., 1997).

Age assignments for surficial deposits are based chiefly on stratigraphic relationships, degree of erosional modification of original surface morphology, and degree of soil development. In addition, age assignments for alluvial deposits are based on the height of the deposit above the Colorado River. Age assignments for map units **Qtu**, **Qt3**, **Qt4**, and **Qt5** are inferred chiefly on the basis of this regional rate of stream incision of about 0.125 m/ky (ky = thousand years). This incision rate is based on a value for stream incision since the deposition of the 640±4 ka (ka = thousand years ago) Lava Creek B volcanic ash (M.A. Lanphere, oral commun., 2000), which is about 80 m above the White River near Meeker, Colo. (Whitney and others, 1983). In addition, terraces along the Colorado River farther upvalley in the Rifle quadrangle that are also about 80 m above the river have been correlated with terraces that contain (or are overlain by) the Lava Creek B volcanic ash (Shroba and Scott, 1997).

Grain-size terminology for the surficial deposits and bedrock are based on visual estimates and follow the modified Wentworth grade scale (American Geological Institute, 1982). In descriptions of surficial deposits, the term "clast" refers to particles greater than 2 mm in diameter, whereas the term "matrix" refers to particles less than 2 mm in size.

Dry matrix colors of the surficial deposits in the map area were determined by comparison with a Munsell Soil Color Chart (Munsell Color, 1973). The colors of the surficial deposits reflect those of the sediments and (or) bedrock from which they are derived.

Manmade deposits

af — **Artificial fill (latest Holocene)**—Compacted and uncompacted fill material composed mostly of varying amounts of silt, sand, and rock fragments. Unit includes fills beneath Interstate 70 (I-70), Colorado Highway 6, and the Denver and Rio Grande Western Railroad. Fill beneath I-70 and Highway 6 predominantly consists of locally derived massive, pale-olive (5Y 6/3) silty sand containing scattered pebble- and cobble-size angular clasts derived from Mount Garfield Formation (**Kmg**) sandstone. Fill beneath the Denver and Rio Grande Western Railroad consists of unstratified, well-sorted, pebble- and cobble-size, angular to subangular basalt. Poorly compacted fills may be subject to settlement when loaded. Thickness ranges from about 1 to 5 m

Alluvial deposits

Qalc1 — **Alluvium deposited by the Colorado River (Holocene)**—Alluvium underlying the Colorado River channel, floodplain, and low terraces. Upper 1–2 m of unit, commonly an overbank deposit, consists of light-yellowish-brown (10YR 6/4), massive, silty fine sand to medium sand that locally contains minor amounts of pebbles and cobbles in lenses generally less than 20 cm thick. Lower part of unit, which is poorly exposed, consists of well-sorted, rounded pebble-cobble gravel derived from a variety of igneous, metamorphic, and sedimentary rocks. Clasts consist mainly of basalt, quartzite, red sandstone, and gray fine-grained and medium-grained granitic rocks. Some clasts have thin (1–2 mm), white carbonate coats. Matrix in gravel part of unit consists of very pale brown (10YR 7/4) sandy silt and silty sand. Unit may include low terraces along the floodplain. Along the Colorado River an alluvial and colluvial (**Qac**) wedge has spread southward from the Book Cliffs, which are predominantly north of the Clifton quadrangle but include the Mount Garfield area in the northeastern part of the map area, and covered the northern boundary of this unit. Hence, the boundary of this unit north of the Colorado River is only an approximation where the alluvial and colluvial wedge is thought to be less than 2 m, based on analysis of well-log data (Schneider, 1975; Phillips, 1986). In fact, this well-log data indicates that gravels deposited by the Colorado River extend to the north under the alluvial and colluvial (**Qac**) wedge as much as several kilometers (see cross section). Unit subject to periodic flooding. Unit is a gravel resource. Based on the thickness of similar gravels on terraces bordering the floodplain and on well-log data (Schneider, 1975; Phillips, 1986), the gravel in this unit is generally 5–12 m thick

Qa — **Alluvium deposited by tributary streams (Holocene and late Pleistocene)**—Alluvium underlying stream channels, floodplain, and low terraces deposited by small tributary streams on the south side of the Colorado River. Unit consists of (1) pale-brown (10YR 6/3), well-sorted, well-bedded and cross-bedded, medium to fine sand and silty fine sand in beds commonly 0.5–10 cm thick, (2) light-brownish-gray (2.5Y 6/2), massive, fine sandy silt that contains scattered pebble layers or lenses generally less than 10 cm thick, and (3) cobbly pebble gravel with a light-brownish-gray, coarse to medium sand matrix. Clasts are mainly basalt, with subordinate amounts (about 25 percent) of pebbles and cobbles of Colorado River origin reworked from nearby terrace remnants. Clasts are subrounded to rounded. In places, unit contains lenses of angular to subangular pebbles of shale and sandstone derived from the Mancos Shale (**Km**) and the Mount Garfield Formation (**Kmg**), and subrounded pebbles of basalt. Basal part of unit, where exposed, commonly contains a poorly bedded pebble, cobble, and boulder gravel 45–100 cm thick. Clasts in basal part are mainly subrounded and rounded basalt in a pale-brown (10YR 6/3) silty sand matrix. Largest boulders about 1 m in diameter. Low-lying areas within unit may be subject to flash floods or debris flows. Maximum thickness about 5 m

Qalc2 — **Alluvium deposited by the Colorado River (Holocene and late Pleistocene)**—Alluvium that underlies an area along the north side of the Colorado River about 2 km southeast of Clifton. This area is about 3–5 m above the river and is not considered to be part of the active floodplain (**Qalc1**). Unit is poorly exposed; in places rounded pebble-cobble gravel of Colorado River origin exposed at surface or in shallow excavations. Clasts include mainly basalt, gray fine-grained granitic rocks, red fine-grained sandstone, quartzite, and white and pink coarse-grained granitic rocks. Some clasts have a thin (1–2 mm), white carbonate coat. Gravels are commonly overlain by 1–2 m of overbank and possibly eolian materials consisting of massive, light-yellowish-brown (10YR 6/4) silty fine sand and fine sand. Lower parts of unit may be subject to flooding by infrequent large events. Unit is a gravel resource. Well-log data (Schneider, 1975; Phillips, 1986) indicate that unit is about 5 m thick

Qt1 — **Terrace alluvium of the Colorado River (late Pleistocene)**—Alluvium deposited by the Colorado River, underlying a terrace along the north side of the river, at the eastern border of the map area. Terrace is about 8–10 m above the river. Unit consists mainly of well-sorted, imbricated, rounded pebble-cobble gravel. Clasts consist mainly of coarse-grained granitic rocks (27 percent), quartzite (20 percent), red fine-grained sandstone (16 percent), fine-grained granitic rocks (16 percent), oil shale (9 percent), and basalt (4 percent). Some clasts have a thin (<1 mm), white carbonate coating. Matrix, forming about 5–10 percent of unit, consists of pale-brown (10YR 6/3) silty sand and sand. Gravels are commonly overlain by 1–2 m of overbank materials consisting of massive, light-yellowish-brown (10YR 6/4) silty fine sand and fine sand. An alluvial and colluvial (**Qac**) wedge that has spread southward from the Book Cliffs, which are predominantly north of the Clifton quadrangle but include the Mount Garfield area in the northeastern part of the map area, has covered the northern boundary of this unit (Schwochow, 1978). Hence, the northern boundary is only an approximation where the colluvial wedge is thought to be less than 2 m thick. Based on the height of this unit above the Colorado River, it is probably equivalent in part to outwash of the Pinedale glaciation, which is about 12–35 ka (Richmond, 1986, chart 1A). A similar terrace, about 6 m above the Colorado River at Glenwood Springs, contained a thin peat layer that yielded a radiocarbon age of 12,410±60 (USGS-3544) (Kirkham and others, 1997). Unit is a gravel resource. Thickness commonly 5–10 m

Qtsc — **Terrace alluvium of Sink Creek (late to middle Pleistocene)**—Alluvium deposited by Sink Creek, underlying terraces along the eastern border of the map area. Terrace surfaces are about 10–20 m above the creek. Unit is poorly exposed and consists of poorly stratified, poorly sorted, matrix- to clast-supported gravel. Clasts consist mainly of subangular to rounded basalt of pebble, cobble, and boulder sizes with subordinate amounts (about 10 percent) of pebbles and cobbles of Colorado River origin reworked from nearby terrace remnants and sandstone clasts derived from the Mount Garfield Formation (**Kmg**). Some clasts have a thin (1–5 mm), white carbonate coating. Matrix consists of pale-brown (10YR 6/4) sand and fine sand. In places overlain by 1 m of massive, light-yellowish-brown (10YR 6/4) silty fine sand and fine sand. In places, unit may contain poorly exposed debris flow deposits consisting of clast-supported, unsorted, unstratified to poorly stratified, pebbly, cobble-boulder basalt gravel with a silty sand to sandy silt matrix. Unit forms dissected and discontinuous terrace remnants that can be traced for about 3 km along Sink Creek. Thickness commonly about 5 m

Qt2 — **Terrace alluvium of the Colorado River (middle Pleistocene)**—Alluvium deposited by the Colorado River, underlying a prominent terrace about 30–35 m above the river. Unit consists mainly of well-sorted, rounded pebble-cobble gravel with some boulders. Clasts predominantly consist of basalt (29 percent), quartzite (25 percent), fine-grained granitic rocks (15 percent), and red fine-grained sandstone (11 percent). All oil-shale clasts in exposures are highly shattered or thoroughly weathered. Matrix consists of pale-brown (10YR 6/3) silty sand and sand, forming about 5–10 percent of the unit. Gravels are commonly overlain by 1–2 m of massive, light-yellowish-brown (10YR 6/4) clayey silt, silty fine sand, and fine sand containing scattered pebbles and cobbles. Unit contains lenses of light-gray (10 YR 7/2), well-sorted, cross-bedded, coarse to medium sand 25–50 cm thick containing thin (<5 cm) pebble layers. In places, upper 30 cm of gravel contains abundant platy shale clasts derived from the Green River Formation, which underlies Grand Mesa about 25 km to the east. Unit underlies the northern part of both Central and East Orchard Mesas, south of the Colorado River. On both mesas an alluvial and colluvial (**Qac**) wedge, composed of fine-grained sediment, has spread northward from hills to the south and covered the southern boundary of this unit (Schwochow, 1978). Hence, the southern boundary is only an approximation where the alluvial and colluvial wedge is thought to be less than 2 m thick (Schwochow, 1978). Based on the height of this unit above the Colorado River, it is probably equivalent in part to outwash of the Bull Lake glaciation, which is about 140–150 ka (Pierce and others, 1976). Unit is actively mined (as of 1998) for gravel near the junction of C1/2 and 32 Roads and at the northern end of 31 Road south of the Colorado River. Thickness commonly 5–10 m

Qtu — **Terrace alluvium, undifferentiated (middle to early Pleistocene)**—Alluvium deposited by the Colorado River, underlying small scattered terrace remnants 45–105 m above the river. Unit consists mainly of well-sorted, rounded pebble-cobble gravel with some boulders. Clasts consist mainly of quartzite, basalt, fine-grained granitic rocks, and red fine-grained sandstone. Many clasts have thin carbonate coatings. All oil-shale clasts in exposures are highly shattered or thoroughly weathered. Matrix consists of pale-brown (10YR 6/3) silty sand and sand. Unit contains lenses of light-gray (10YR 7/2), well-sorted, cross-bedded, coarse to medium sand 25–50 cm thick. Unit forms isolated terrace remnants above terrace alluvium **Qt2** and below terrace alluvium **Qt3** that can be traced for about 8 km along the south side of the Colorado River. Based on the height of this unit above the Colorado River and a regional rate of stream incision of about 0.125 m/ky, the terrace remnants forming this unit may range in age from about 360 to 840 ka. Unit is a gravel resource. Thickness of gravels commonly 3–6 m; maximum thickness about 10 m

Qt3 — **Terrace alluvium of the Colorado River (early Pleistocene)**—Alluvium deposited by the Colorado River, underlying several terrace remnants about 120 m above the river. Unit consists mainly of well-sorted, rounded pebble-cobble gravel with some boulders. Clasts consist mainly of quartzite (29 percent), basalt (25 percent), fine-grained granitic rocks, many of which are disintegrated and grussified (17 percent), and red fine-grained sandstone (16 percent). Many clasts have thin (1–2 mm) carbonate coatings. All oil-shale clasts in exposures are highly shattered or thoroughly weathered. Matrix consists of pale-brown (10YR 6/3) silty sand and sand, forming about 5–10 percent of unit. Gravels are commonly overlain by 1–2 m of massive, light-yellowish-brown (10YR 6/3) silty fine sand and fine sand. Several exposures display stage lll carbonate (Gile and others, 1966). Unit contains lenses of light-gray (10YR 7/2), well-sorted, cross-bedded, coarse to medium sand 25–50 cm thick. In places, upper 25 cm of gravel contains abundant platy shale clasts derived from the Green River Formation. In places unit overlain by debris-flow deposits derived from Grand Mesa, which consist of clast-supported, unsorted, unstratified to poorly stratified pebbly, cobble-boulder gravel with a light-yellowish-brown (10YR 6/4) silty sand to sandy silt matrix. Clasts in these deposits consist mainly of subangular to rounded basalt of pebble, cobble, and boulder sizes with subordinate amounts of pebble- and cobble-size sandstone clasts derived from the Mount Garfield Formation (**Kmg**). Surface clasts are angular to subangular and have dark rock varnish coating. Largest boulders about 1 m in diameter. Thickness of debris-flow material commonly 1–3 m. Unit forms dissected and discontinuous terrace remnants that can be traced for about 15 km south of the Colorado River. Based on the height of this unit above the Colorado River and a regional rate of stream incision of about 0.125 m/ky, the terrace remnants forming this unit may be about 960 ka. Unit is actively mined for gravel east of 32 Road along B Road and about 1.4 km northeast of the intersection of 32 Road and Highway 50. Thickness of gravels commonly 3–6 m; maximum thickness about 10 m

Qt4 — **Terrace alluvium of the Colorado River (early Pleistocene)**—Alluvium deposited by the Colorado River, underlying several terrace remnants about 150 m above the river. Unit consists mainly of well-sorted, rounded pebble-cobble gravel. Clasts consist mainly of quartzite (28 percent), red fine-grained sandstone (26 percent), fine-grained granitic rocks, many of which are disintegrated and grussified (21 percent), and basalt (17 percent). Many clasts have thin carbonate coatings 1–3 mm thick. All oil-shale clasts in exposures are highly shattered or thoroughly weathered. Matrix consists of pale-brown (10YR 6/4 or 7/4) fine sand and silty fine sand, forming about 5–10 percent of the unit. In places, the clasts exposed on the terrace surface have rock varnish coatings, although along the edges of these terraces many clasts appear to be ventifacted. In places, gravels are overlain by 1 m of light-brown (7.5YR 6/4), massive, silty fine sand and fine sand displaying stage lll carbonate (Gile and others, 1966). In places, unit contains lenses of light-olive-gray (5Y 6/2), well-sorted, cross-bedded, coarse to medium sand 10–30 cm thick. At some localities, a very pale brown (10YR 7/4 or 8/3), well-lithified, coarse, cross-bedded sandstone about 60 cm thick is exposed at the base of the gravel. In other places, unit contains poorly exposed debris flow deposits derived from Grand Mesa. These deposits consist of clast-supported, unsorted, unstratified to poorly stratified, pebbly cobble-boulder gravel with a silty sand to sandy silt matrix. Clasts consist mainly of subangular to rounded basalt of pebble, cobble, and boulder size with subordinate amounts of pebble and cobble sandstone clasts derived from the Mount Garfield Formation (**Kmg**). Thickness of debris flow deposits commonly 1 m. Unit forms several isolated terrace remnants south of the Colorado River. Based on the height of this unit above the Colorado River and a regional rate of stream incision of about 0.125 m/ky, the terrace remnants forming this unit may be about 1,200 ka. Maximum thickness about 10 m

Qt5 — **Terrace alluvium of the Colorado River (early Pleistocene)**—Alluvium deposited by the Colorado River, underlying two terrace remnants about 180 m above the river. Unit consists of well-sorted, rounded pebble-cobble gravel. Clasts consist mainly of basalt (31 percent), quartzite (24 percent), red fine-grained sandstone (21 percent), and fine-grained granitic rocks, many of which are disintegrated and grussified (14 percent). All oil-shale clasts in exposures are highly shattered or thoroughly weathered. Matrix consists of pale-brown (10YR 6/3) silty sand and sand. At some localities, a light-gray (10YR 7/2), well-lithified, medium- to coarse-grained, cross-bedded sandstone about 30–50 cm thick is exposed at the base of the gravel. In places, unit contains lenses of light-olive-gray (5Y 6/2), well-sorted, cross-bedded, medium to coarse sand 10–30 cm thick. Unit forms two isolated terrace remnants south of the Colorado River, near the southeast map boundary. Rounded pebble-cobble gravel of weather-resistant lithologies (mainly quartzites and basalt) are found on the terrace surface. Based on the height of this unit above the Colorado River and a regional rate of stream incision of about 0.125 m/ky, the terrace remnants forming this unit may be about 1,440 ka. Maximum thickness about 10 m

Alluvial and colluvial deposits

Qac — **Alluvium and colluvium, undivided (Holocene and late Pleistocene)**—Predominantly a mix of alluvium, sheetwash, and debris flow deposits. North of Colorado River, unit consists of light-gray (2.5Y 7/2) and light-olive-gray (5Y 6/2), massive, fine sandy silt and clayey silt. Locally contains scattered angular and subangular platy shale and sandstone pebbles derived from the Mancos Shale (**Km**) and the Mount Garfield Formation (**Kmg**). Also contains scattered sandstone boulders, as large as 1 m in diameter, derived from the Mount Garfield Formation (**Kmg**). South of the Colorado River, unit consists of poorly exposed, very pale brown (10YR 7/3) and pale-brown (10YR 6/3), unstratified to poorly stratified fine sand, silty fine sand, and clayey silt containing scattered clasts. Clasts, forming 5–20 percent of deposit, are mainly rounded pebbles and cobbles of Colorado River origin reworked from nearby terraces. Many clasts have thin carbonate coatings 2–5 mm thick. Locally contains pebble-cobble gravel lenses 1–1.5 m thick consisting of rounded pebbles and cobbles of Colorado River origin. Matrix in gravels consist of light-yellowish-brown (10YR 6/4) sand and silty sand. Maximum thickness of unit, based on U.S. Bureau of Reclamation well logs (Phillips, 1986), is about 20 m north of the Colorado River and about 15–20 m south of the river

Qpmv — **Pediment deposit east of Moulton Valley (late? Pleistocene)**—Predominantly debris-flow deposits underlying a surface east of Moulton Valley in the northern map area. Surface is 5–15 m above surrounding areas. Unit consists of clast- to matrix-supported, unsorted to poorly sorted, unstratified to poorly stratified, pebbly cobble-boulder gravel. Clasts consist of angular to subrounded sandstone derived from the Mount Garfield Formation (**Kmg**). Matrix consists of a pale-brown (10YR 6/3) silty sand and sand. Largest boulders are about 1 m in diameter. Maximum thickness about 3 m

Qp4 — **Pediment deposit north of Sink Creek (early? Pleistocene)**—Debris-flow and alluvial deposits underlying a surface in the east-central map area. Surface is about 75 m above base of surrounding drainages. Unit consists of unsorted, unstratified to poorly stratified, pebbly cobble-boulder gravel with a very pale brown (10YR 7/4) sandy silt to silty sand matrix. Clasts consist of subangular to subrounded basalt (55 percent) of cobble and boulder sizes and subangular to rounded sandstone (45 percent) pebbles and cobbles derived from the Mount Garfield Formation (**Kmg**). On the pediment surface, the clasts consist of angular and subangular basalt cobbles and boulders; many have a rock varnish coating. Clasts in upper 1 m have thin (1–5 mm) coating of calcium carbonate. Largest boulders are about 1 m in diameter. Surface overlain locally by thin (<50 cm), discontinuous deposits of pale-brown (10YR 6/3) eolian silt. In places, unit overlies Colorado River gravels, which consist of well-sorted, well-rounded pebbles and cobbles, about 1–1.5 m thick, indicating that debris flows of unit covered terraces of the Colorado River. These Colorado River gravels, found along edge of this pediment in the Clifton quadrangle, as well as in the Palisade quadrangle to the east (Carrara, 2000), range in height from 135 to195 m above river. Because this unit now consists of an isolated erosional remnant, a substantial amount of time elapsed since it was deposited; hence it is estimated to be early Pleistocene (or older) in age. Unit is a potential aggregate resource. Thickness about 3–6 m

Qpu — **Pediment deposits, undifferentiated (early? Pleistocene)**—Unit consists of small isolated remnants of pediments in southeastern part of map area. Unit consists of clast-supported, unsorted, unstratified to poorly stratified, pebbly cobble-boulder gravel with a pale-brown (10YR 6/3) or pale-yellow (2.5Y 7/4) silty sand to sandy silt matrix. Clasts consist of subequal amounts of subrounded to rounded basalt of cobble and boulder sizes and subangular to rounded sandstone pebbles and cobbles derived from the Mount Garfield Formation (**Kmg**). On the pediment surface, clasts consist of angular and subangular basalt cobbles and boulders; many have a rock varnish coating. Clasts in upper 1 m have thin (1–5 mm) coating of calcium carbonate. Largest boulders about 1 m along edge. Thickness about 3–6 m

Colluvial deposits

Qls — **Landslide deposit (Holocene and late Pleistocene)**—Includes large, mainly rotational (Varnes, 1978), landslide on the south flank of Mount Garfield, near northern map boundary. Unit consists of mainly pale-brown (10YR 6/3), unstratified sandy silt, silt, clayey silt, and silty clay. Contains scattered angular to subangular sandstone blocks derived from the Mount Garfield Formation (**Kmg**) exposed in cliff above unit. Unit is highly dissected. Small debris flows, originating from the steep slopes north of I-70, can close the highway as they did in September 1997, during a period of high rainfall. Maximum thickness probably exceeds 100 m

BEDROCK UNITS

Kmg — **Mount Garfield Formation and tongues of Mancos Shale (Upper Cretaceous)**—Gray to brown sandstone, siltstone, shale, and coal. Locally, contains sandstone and minor conglomerate, and conglomeratic sandstone. Deposited mainly by streams in backshore areas on coastal plains, containing coal swamps, marshes, and mudflats (Johnson, 1989). Sandstone beds in lower part of unit were deposited in shoreline areas (Johnson, 1989). Lower part of unit contains commercially important coal beds. Unit is present in the map area only in the Mount Garfield area along the northern map border, where the lower part is exposed. On this map, the lower boundary of the Mount Garfield Formation is placed at the base of the Corcoran Sandstone Member. The lower part of the Mount Garfield Formation includes three well-defined cliff-forming sandstone members, separated from one another by tongues of Mancos Shale. From top to bottom these are the Rollins, Cozzette, and Corcoran Sandstone Members (Johnson, 1989). The Rollins Sandstone Member, although not present in the Clifton quadrangle, is present immediately north of the map area and on the adjacent Palisade quadrangle to the east (Carrara, 2000). In the Palisade quadrangle it is a light-gray to white, fine- to medium-grained, prominent, massive sandstone, about 25–35 m thick (Carrara, 2000). The Cozzette Sandstone Member consists of a 30- to 40-m-thick interval of interbedded tan sandstone and gray shale containing horizonal to low-angle cross laminations (Johnson, 1989). In the map area, the Corcoran Sandstone Member consists of a 20- to 30-m-thick sequence of interbedded tan sandstone containing ripple marks and low-angle cross laminations and gray shale (Johnson, 1989). The Palisade coal zone overlies the Corcoran Member, minor coal beds overlie the Cozzette Member, and the Cameo coal zone overlies the Rollins Member. In the Clifton quadrangle only about the lower 100 m of the Mount Garfield Formation is exposed

Km — **Mancos Shale (Upper Cretaceous)**—Mostly a thick sequence of gray to black fissile shale and minor tan siltstone and fine sandstone beds generally less than 25 cm thick. Unit is marine in origin and fossiliferous in places. Intertongues with the lower part of the Mount Garfield Formation (**Kmg**). On this map the upper boundary of the Mancos Shale is placed at the base of the Corcoran Sandstone Member of the Mount Garfield Formation. Hillslopes cut into the Mancos Shale underlying Pleistocene terrace deposits are in places veneered with a thin, discontinuous (< 0.5 m) mantle of reworked terrace alluvium not shown on this map. Similarly, hillslopes beneath outcrops of Mount Garfield sandstone may be covered with a thin mantle of sandstone boulders not shown on this map. Unit prone to landsliding and debris flows where exposed on steep slopes, such as along the southern side of Mount Garfield. Unit may have moderate to high swelling potential due to presence of expansive clays; contains sulfate minerals that are corrosive to conventional concrete and metal pipes. When wet, the surface of the Mancos becomes sticky and very slippery. Unimproved roads are virtually impassable when wet. Thickness of unit in the Grand Valley area is about 1,200 m

Kd — **Dakota Sandstone (Lower Cretaceous)**—Light-gray to tan, medium-grained to very coarse grained, quartzose sandstone interbedded with carbonaceous siltstone, sandstone, and shale. Sandstone commonly well sorted, with angular to subrounded sand grains. Basal part of unit consists of a conglomerate or conglomeratic sandstone, about 12 m thick, overlain by carbonaceous and lignitic shale and lignite (Lohman, 1965). Conglomeratic clasts generally consist of black and white pebble-size chert and quartz (Kirkham and others, 1997). Unit is present only in southwest corner of map area, where upper part of unit is exposed. Thickness in map area about 60 m (Lohman, 1965)

Jm — **Morrison Formation (Upper Jurassic)**—Shown only in cross section. Light-greenish-gray to dark-greenish-gray and pale-reddish-purple to grayish-red-purple siltstone and claystone interbedded with intervals of very light gray to medium-gray, medium- to fine-grained sandstone. Locally, pebble and granule conglomerate occurs, and light-gray to medium-light-gray limestone beds are present in lower part of unit. The Morrison Formation may locally contain expansive clays with high shrink-swell potential. Thickness in the Grand Valley region about 150–180 m (Lohman, 1965)

Contact

Strike and dip of bedding

Terrace scarp

Gravel pit

Eureka Oil TD 925 — **Dry hole**—Showing total depth (TD) in ft and company that drilled hole (T. Hemborg, Colorado Geological Survey, written commun.,1998)

GEOLOGIC HAZARDS

Various geologic hazards exist on the Clifton quadrangle, including landslides, erosional processes, such as gullying and piping, expansive soils, and flooding. These hazards are commonly associated with specific geologic units (table 1).

MASS WASTING

As used in this report, landslide (a form of mass wasting) is a general term that includes a wide variety of mass movement landforms and processes involving the slow to rapid downslope transport of surficial materials and bedrock blocks by gravity. This definition includes various types of flows, slumps, slides, and combinations thereof. In the Clifton quadrangle, the only landslide mapped (**Qls**) is a large, mainly rotational, highly dissected, landslide on the south flank of Mount Garfield, near the northern map boundary. This landslide involves failure of the steep hillslope cut into the Mancos Shale (**Km**), with accompanying collapse of large sandstone blocks of the Mount Garfield Formation (**Kmg**). The landslide consists of mainly pale-brown (10YR 6/3), unstratified, sandy silt, silt, clayey silt, and silty clay, containing scattered angular to subangular sandstone blocks derived from the overlying Corcoran and Cozzette Sandstone Members of the Mount Garfield Formation (**Kmg**). Although this landslide appears to be stable, small debris flows originating on the steep slopes north of I-70 can close the highway as they did in September 1997, during a period of high rainfall. In addition, low-lying areas within map unit **Qa** may be subject to debris flows.

GULLYING

Gullying is the process whereby erosion of soil or soft rock by running water forms distinct, narrow channels. Usually these channels carry water only during and immediately after heavy rains. In the Clifton quadrangle, units **Qa**, **Qac**, and **Km** are prone to gullying (table 1). Over time the process of gullying can lead to the formation of deep channels that can disrupt roads and irrigation systems, clog downstream areas with excess sediment, and ruin the environmental and aesthetic attraction of areas.

PIPING

Piping is the process whereby erosion by percolating water results in the formation of tunnels (pipes) through which fine-grained material is removed. In the Clifton quadrangle, those areas underlain by units **Qa** and **Qac** are prone to piping in some areas (table 1). Piping can lead to the formation of large cavities, which may be prone to collapse, endangering roads, irrigation systems, power lines, and structures.

EXPANSIVE SOILS

Soils that tend to shrink or swell due to changes in moisture content are commonly known as expansive soils. Expansive soils are common in those areas underlain by sedimentary rock containing clay minerals or surficial deposits derived from those rocks. The potential volume change of a given soil depends on the type and amount of clay minerals it contains. Due to differential expansion, concrete foundations, floors, and walls may develop cracks, doors may not close, and buildings may tilt slightly. It has been estimated that as many as 60 percent of homes built on swelling clays will undergo minor damage whereas 10 percent may suffer significant damage (Jones and Holtz, 1973). In semiarid areas such as the Clifton quadrangle, soils containing swelling clays will often have a characteristic "popcorn" texture when dry. On the map, those areas underlain by the Mancos Shale (**Km**) or alluvium and colluvium (**Qac**) derived from the Mancos Shale are known to contain varying amounts of swelling clays. These areas may have moderate to high swelling potential and, in addition, may contain sulfate minerals that are corrosive to conventional concrete and metal pipes. Because of its high clay content, the surface of the Mancos Shale becomes sticky and very slippery when wet, making unimproved roads virtually impassable.

FLOODING

The town of Clifton, about 30 m above the Colorado River, is relatively safe from any flood hazard from the river. However, as the town expands care should be taken to avoid those areas south of town mapped as **Qalc1** as these areas are thought to be prone to periodic flooding. Low-lying areas within map unit **Qalc2** may also be subject to Colorado River floods of large magnitude. In addition, low-lying areas within map unit **Qa** may be subject to flash floods or debris flows.

ECONOMIC GEOLOGY

SAND AND GRAVEL RESOURCES

The Clifton quadrangle contains abundant sand and gravel resources. Many of the gravel pits are indicated on the map. These pits are mainly located in map units **Qalc1**, **Qalc2**, **Qt2**, and **Qt3**. These deposits consist mainly of well-sorted, rounded pebble-cobble gravel commonly 5–10 m thick. Clasts consist predominantly of basalt, red fine-grained sandstone, coarse-grained granitic rocks, fine-grained granitic rocks, and quartzite. The matrix generally consists of pale-brown (10YR 6/3) silty sand and sand. The gravels are commonly overlain by 1–2 m of overbank and possibly eolian materials consisting of massive, light-yellowish-brown (10YR 6/4) silty fine sand and fine sand. The gravels also contain about 5 to as much as 10 percent oil-shale clasts, derived from the Green River Formation, which have low bearing strength. Hence, these gravels are suitable for road base, but may be unsuitable as an aggregate for concrete and asphalt. On the older terraces (**Qt3**, **Qt4**, and **Qt5**), this unsuitability as an aggregate for concrete and asphalt may be even more pronounced as many of the granitic clasts in these gravels are throughly weathered and can be easily sliced by a shovel.

REFERENCES CITED

American Geological Institute, 1982, Grain-size scales used by American geologists, modified Wentworth scale, *in* Data sheets (2nd ed.): Falls Church, Va., American Geological Institute, sheet 17.1.
Carrara, P.E., 2000, Geologic map of the Palisade quadrangle, Mesa County, Colorado: U.S. Geological Survey Miscellaneous Field Studies Map MF–2326, scale 1:24,000.
Gile, L.H., Peterson, F.F., and Grossman, R.B., 1966, Morphological and genetic sequences of carbonate accumulation in desert soils: Soil Science, v. 101, p. 347–360.
Johnson, R.C., 1989, Geologic history and hydrocarbon potential of late Cretaceous-age, low-permeability reservoirs, Piceance Basin, western Colorado: U.S. Geological Survey Bulletin 1787–E, 51 p.
Jones, D.E., and Holtz, W.G., 1973, Expansive soils—the hidden disaster: Civil Engineering, American Society of Civil Engineers, v. 43, p. 49–51.
Kirkham, R.M., Streufert, R.K., and Cappa, J.A., 1997, Geologic map of the Glenwood Springs quadrangle, Garfield County, Colorado: Colorado Geological Survey Map Series 31, scale 1:24,000.
Lohman, S.W., 1965, Geology and artesian water supply of the Grand Junction area, Colorado: U.S. Geological Survey Professional Paper 451, 149 p.
Munsell Color, 1973, Munsell soil color charts: Baltimore, Md., Kollmorgen Corp., Macbeth Division.
Phillips, W.A., 1986, Cobble aquifer investigation: Colorado River Basin Salinity Control Project, Grand Junction Office, U.S. Bureau of Reclamation, 20 p.
Pierce, K.L., Obradovich, J.D., and Friedman, I., 1976, Obsidian hydration dating and correlation of Bull Lake and Pinedale glaciations near West Yellowstone, Montana: Geological Society of America Bulletin, v. 87, p. 703–710.
Richmond, G.M., 1986, Stratigraphy and correlation of glacial deposits of the Rocky Mountains, the Colorado Plateau, and the ranges of the Great Basin, *in* Richmond, G.M., and Fullerton, D.S., eds., Quaternary glaciations in the United States of America: Quaternary Science Reviews, v. 5, p. 99–127.
Richmond, G.M., and Fullerton, D.S., 1986, Introduction to Quaternary glaciations in the United States of America, *in* Richmond, G.M., and Fullerton, D.S., eds., Quaternary glaciations in the United States of America: Quaternary Science Reviews, v. 5, p. 3–10.
Schneider, E.J., 1975, Surficial geology of the Grand Junction–Fruita area, Mesa County, Colorado: Fort Collins, Colo., Colorado State University M.S. thesis, 132 p.
Schwochow, S.D., 1978, Mineral resources survey of Mesa County—a model study: Colorado Geological Survey Resource Series 2, 110 p.
Shroba, R.R., and Scott, R.B., 1997, Revised preliminary geologic map of the Rifle quadrangle, Garfield County, Colorado: U.S. Geological Survey Open-File Report 97–852, scale 1:24,000.
Varnes, D.J., 1978, Slope movement types and process, *in* Schuster, R.L., and Krizek, R.J., eds., Landslides, analysis, and control: National Academy of Sciences, Transportation Research Board Special Report 176, p. 11–33.
Whitney, J.W., Piety, L.A., and Cressman, S.L., 1983, Alluvial history in the White River basin, northwest Colorado: Geological Society of America Abstracts with Programs, v. 15, p. 328.

Table 1. *Map units susceptible to geologic hazards in the Clifton quadrangle*

Mass wasting[1]	Gullying	Piping[2]	Expansive soils	Flooding
Qls	Qa	Qa	Qac	Qalc1
Qa	Qac	Qac	Km	Qalc2
Kmg	Km			Qa
Km				

[1]Includes earth flows, earth slumps, debris flows, debris slumps, rock-block slides, translational slides, rockfalls, and complex landslides.
[2]Defined as erosion by percolating water resulting in the formation of tunnels (pipes) through which fine-grained material is removed.

CONVERSION FACTORS

Given	Multiply by	To obtain
centimeters (cm)	0.394	inches
meters (m)	3.28	feet
kilometers (km)	0.621	miles

Any use of trade names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Geological Survey

This map was produced on request, directly from digital files, on an electronic plotter

For sale by U.S. Geological Survey Information Services
Box 25286, Federal Center, Denver, CO 80225
1-888-ASK-USGS

ARC/INFO coverages and a PDF for this map are available at
http://geology.cr.usgs.gov/greenwood-pubs.html