U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science Directorate
Geologic Resources Division

Colorado National Monument

GRI Ancillary Map Information Document

Produced to accompany the Geologic Resources Inventory (GRI) Digital Geologic Data for Colorado National Monument

colm_geology.pdf

Version: 2/4/2015

Geologic Resources Inventory Map Document for Colorado National Monument

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Geologic Resources Inventory Map Document

Colorado National Monument, Colorado

Document to Accompany Digital Geologic-GIS Data

colm_geology.pdf

Version: 2/4/2015

This document has been developed to accompany the digital geologic-GIS data developed by the Geologic Resources Inventory (GRI) program for Colorado National Monument, Colorado (colm).

Attempts have been made to reproduce all aspects of the original source products, including the geologic units and their descriptions, geologic cross sections, the geologic report, references and all other pertinent images and information contained in the original publication.

National Park Service (NPS) Geologic Resources Inventory (GRI) Program staff have assembled the digital geologic-GIS data that accompanies this document.

For information about the status of GRI digital geologic-GIS data for a park contact:

Tim Connors
Geologist/GRI Mapping Contact
National Park Service Geologic Resources Division
P.O. Box 25287
Denver, CO 80225-0287
phone: (303) 969-2093
fax: (303) 987-6792
email: Tim_Connors@nps.gov

For information about using GRI digital geologic-GIS data contact:

Stephanie O'Meara
Geologist/GIS Specialist/Data Manager
Colorado State University Research Associate, Cooperator to the National Park Service
1201 Oak Ridge Drive, Suite 200
Fort Collins, CO 80525
phone: (970) 491-6655
fax: (970) 225-3597
e-mail: stephanie.omeara@colostate.edu

About the NPS Geologic Resources Inventory Program

Background

Recognizing the interrelationships between the physical (geology, air, and water) and biological (plants and animals) components of the Earth is vital to understanding, managing, and protecting natural resources. The Geologic Resources Inventory (GRI) helps make this connection by providing information on the role of geology and geologic resource management in parks.

Geologic resources for management consideration include both the processes that act upon the Earth and the features formed as a result of these processes. Geologic processes include: erosion and sedimentation; seismic, volcanic, and geothermal activity; glaciation, rockfalls, landslides, and shoreline change. Geologic features include mountains, canyons, natural arches and bridges, minerals, rocks, fossils, cave and karst systems, beaches, dunes, glaciers, volcanoes, and faults.

The Geologic Resources Inventory aims to raise awareness of geology and the role it plays in the environment, and to provide natural resource managers and staff, park planners, interpreters, researchers, and other NPS personnel with information that can help them make informed management decisions.

The GRI team, working closely with the Colorado State University (CSU) Department of Geosciences and a variety of other partners, provides more than 270 parks with a geologic scoping meeting, digital geologic-GIS map data, and a park-specific geologic report.

Products

Scoping Meetings: These park-specific meetings bring together local geologic experts and park staff to inventory and review available geologic data and discuss geologic resource management issues. A summary document is prepared for each meeting that identifies a plan to provide digital map data for the park.

Digital Geologic Maps: Digital geologic maps reproduce all aspects of traditional paper maps, including notes, legend, and cross sections. Bedrock, surficial, and special purpose maps such as coastal or geologic hazard maps may be used by the GRI to create digital Geographic Information Systems (GIS) data and meet park needs. These digital GIS data allow geologic information to be easily viewed and analyzed in conjunction with a wide range of other resource management information data.

For detailed information regarding GIS parameters such as data attribute field definitions, attribute field codes, value definitions, and rules that govern relationships found in the data, refer to the NPS Geology-GIS Data Model document available at: http://science.nature.nps.gov/im/inventory/geology/GeologyGISDataModel.cfm

Geologic Reports: Park-specific geologic reports identify geologic resource management issues as well as features and processes that are important to park ecosystems. In addition, these reports present a brief geologic history of the park and address specific properties of geologic units present in the park.

For a complete listing of Geologic Resource Inventory products and direct links to the download site visit the GRI publications webpage http://www.nature.nps.gov/geology/inventory/gre_publications.cfm

GRI geologic-GIS data is also available online at the NPS Data Store Search Application: http://irma.nps.gov/App/Reference/Search. To find GRI data for a specific park or parks select the appropriate park (s), enter “GRI” as a Search Text term, and then select the Search Button.

For more information about the Geologic Resources Inventory Program visit the GRI webpage: http://www.nature.nps.gov/geology/inventory, or contact:

Bruce Heise
Inventory Coordinator
National Park Service Geologic Resources Division
P.O. Box 25287
Denver, CO 80225-0287
phone: (303) 969-2017
fax: (303) 987-6792
email: Bruce_Heise@nps.gov

The Geologic Resources Inventory (GRI) program is funded by the National Park Service (NPS) Inventory and Monitoring (I&M) Division.

GRI Digital Maps and Source Map Citations

Multiple digital geologic-GIS maps were produced for this park two 7.5' quadrangle (1:24,000 scale) component maps, and a compiled park extent and vicinity map.

The GRI compiled park extent and vicinity map,

GRI Digital Geologic Map of the Colorado National Monument and Vicinity, Colorado (*GRI MapCode COLM*)

Source maps used in the compiled map are listed with the 7.5' minute quadrangle component maps.

Individual GRI component 7.5' quadrangle maps and their source maps,

GRI Digital Geologic Map of the Colorado National Monument and Adjacent Areas, Colorado (*GRI MapCode CNMO*)

Scott, R.B., Harding, A.E., Hood, W.C., Cole, R.D., Livaccari, R.F., Johnson, J.B., Shroba, R.R., and Dickerson, R.P., 2001, Geologic Map of the Colorado National Monument and Adjacent Areas, Mesa County, Colorado: U.S. Geological Survey, Geologic Investigations Series Map, I-2740, scale 1:24,000. (Colorado NM and Adjacent Areas). (*GRI Source Map ID 1088*).

GRI Digital Geologic Map of the Grand Junction Quadrangle, Colorado (*GRI MapCode GRJU*)

Scott, R.B., Carrara, P.E., Hood, W.C., and Murray, K.E., 2002, Geologic Map of the Grand Junction Quadrangle, Mesa County, Colorado: U.S. Geological Survey, Miscellaneous Field Studies Map, MF-2363, scale 1:24,000. (Grand Junction Quadrangle). (*GRI Source Map ID 1815*).

Additional information pertaining to each source map is also presented in the GRI Source Map Information (COLMMAP) table included with the GRI geologic-GIS data.

Map Unit List

The geologic units present in the digital geologic-GIS data produced for Colorado National Monument, Colorado (colm) are listed below. Units are listed with their assigned unit symbol and unit name (e.g., Qal - Alluvium). Surficial units were grouped based on surficial process (e.g. Alluvial Deposits) first and then sorted chronologically within the groups. Bedrock map units, generally listed from youngest to oldest, are presented below. No description for water is provided. Information about each geologic unit is also presented in the GRI Geologic Unit Information (COLMUNIT) table included with the GRI geology-GIS data. Some source unit symbols, names and/or ages may have been changed in this document and in the GRI digital geologic-GIS data. This was done if a unit was considered (by the GRI) to be the same unit as a unit on the other source map and these unit symbols, names and/or ages differed. In this case a single unit symbol and name, and the unit's now recognized age, was adopted. Unit symbols, names and/or ages in a unit descriptions, or on a correlation of map units or other source map figure were not edited. If a unit symbol, name or age was changed by the GRI the unit's source map symbol, name and/or age appears with the unit's source map description.

Surficial Units

Cenozoic Era

Quaternary Period

Artificial Fill Deposits

- Qaf - Artificial fill

Alluvial Deposits

- Qal - Alluvium
- Qalc1 - Youngest alluvium deposited by the Colorado River
- Qalg - Youngest alluvium deposited by the Gunnison River
- Qfp - Flood-plain and stream-channel deposits
- Qa - Alluvium deposited by tributary streams
- Qvf - Valley-fill deposits
- Qalc2 - Oldest alluvium deposited by the Colorado River
- Qrg - River-gravel deposits
- Qtgu - Terrace alluvium of the Gunnison River, undivided
- Qt30 - Terrace alluvium 30 of the Colorado River
- Qt60c - Terrace alluvium 60 of the Colorado River
- Qt60g - Terrace alluvium 60 of the Gunnison River
- Qtc/Qtg - Terrace alluvium of the Colorado River over terrace alluvium of the Gunnison River
- Qt100 - Terrace alluvium 100 of the Colorado River
- Qt170 - Terrace alluvium 170 of the Colorado River

Alluvial and Colluvial Deposits

- Qfy - Young fan-alluvium and debris-flow deposits
- Qac - Alluvium and colluvium, undivided
- Qasy - Younger alluvial-slope deposits
- Qaso - Older alluvial-slope deposits
- Qpwf - Pediment deposits of Walker Field
- Qlg - Local gravel deposits
- Qlg/Qt30 - Local gravel deposits over terrace alluvium 30 of the Colorado River

Colluvial Deposits

- Qlsy - Younger landslide deposits

Qc - Colluvium, undivided
Qr - Rockfall deposits
Qsw - Sheetwash deposits
Qlso - Older landslide deposits

Eolian Deposits
Qe - Eolian sand

Eolian and Colluvial Deposits
Qse - Eolian sand and sheetwash deposits
Qse/Qt30 - Eolian sand and sheetwash deposits over terrace alluvium 30 of the Colorado River

Marsh Deposits
Qcg - Cienaga deposits

Bedrock Units

Mesozoic Era

Cretaceous Period
Km - Mancos Shale
Kd - Dakota Formation
Kb - Burro Canyon Formation

Jurassic Period
Jmb - Morrison Formation, Brushy Basin Member
Jms - Morrison Formation, Salt Wash Member
Jmt - Morrison Formation, Tidwell Member
Jw - Wanakah Formation
Jwe - Wanakah Formation and Entrada Sandstone, undivided
Jwek - Wanakah Formation, Entrada Sandstone and Kayenta Formation, undivided
Jeb - Entrada Sandstone, board beds unit
Jes - Entrada Sandstone, Slick Rock Member
Jk - Kayenta Formation
Jwg - Wingate Sandstone

Triassic Period
TRc - Chinle Formation

Late Proterozoic Era

Yl - Lamprophyre dikes

Middle Proterozoic Era

Xi - Meta-igneous gneiss
Xm - Migmatic meta-sedimentary rocks
Xu - Meta-igneous gneiss and migmatic meta-sedimentary rocks, undivided

Map Unit Descriptions

Surficial unit descriptions were grouped based on surficial process (e.g. Alluvial Deposits) first and then sorted chronologically within the groups. Descriptions of bedrock map units, generally listed from youngest to oldest, are presented below.

Surficial Units

Artificial Fill Deposits

Artificial-fill deposits include compacted and uncompacted material composed mostly of silt, sand, and rock fragments placed beneath and adjacent to highways, an airstrip, stock ponds, and earthen dams. (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Compacted and uncompacted material composed mostly of silt, sand, and rock fragments placed beneath and adjacent to highways, railroads, airstrips, stock ponds, and earthen dams. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Qaf - Artificial fill (latest Holocene)

af - Artificial fill (latest Holocene)
Most of the artificial fill consists of compacted and uncompacted fill material composed of silt, sand, and rock fragments. The map unit was mapped beneath segments of the Interstate 70 overpass at the junction with U.S. Highway 6-50 and beneath segments of Rim Rock Drive, the road that follows the canyon rims in Colorado National Monument, particularly where road reconstruction required fill after the flash flood of 1968 in Fruita Canyon.

Small amounts of fill beneath the nearby tracks of the Denver and Rio Grande Western Railroad were not mapped. Artificial fill was also used in constructing the reservoir in lower Fruita Canyon and in many minor dams for stock ponds on private land. A dirt airstrip near the southern border of the map area is underlain in part by artificial fill. Generally the map unit is less than 10 m thick, but beneath Rim Rock Drive, artificial fill is locally greater than 50 m thick. (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

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) and the Denver and Rio Grande Western Railroad. Besides the normal aggregate sub-base, fill beneath I-70 consists of local additions of predominantly locally (but outside the map area) derived materials consisting mostly of massive, silty sand containing scattered pebble- and cobble-size angular clasts derived from Mesaverde Group sandstone. Fill beneath the Denver and Rio Grande Western Railroad consists of unstratified, well-sorted, pebble- and cobble-size, angular to subangular basaltic rocks. The fill beneath the airstrips at Walker Field was not observed but must be substantial, particularly where runways overlie the Mancos Shale (Km). Poorly compacted fills may be subject to settlement when loaded. Thickness ranges from about 1 to 5m. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Alluvial Deposits

Alluvial deposits include silt, sand, and gravel in flood plains, stream channels, and terraces along the Colorado River and its tributaries. (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Silt, sand, and gravel in stream channels, floodplains, and terraces along the Colorado and Gunnison Rivers and tributaries. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Qal - Alluvium (Holocene)

Alluvium consists chiefly of stream-channel deposits along streams that are tributaries of the Colorado River.

The map unit includes minor undifferentiated colluvial deposits such as young fan-alluvium and debris-flow deposits (Qfy), debris-flow deposits (not shown as a separate map unit), and sheetwash deposits (Qsw). Locally, the unit includes boulders as large as 2 m in diameter. Unit Qal typically consists of interbedded sand, pebbly sand, and pebble gravel and ranges from thin-bedded (0.1 to 0.5 cm) clayey, silty sand to thick-bedded (>1 m), poorly sorted, both clast- and matrix-supported, slightly bouldery, pebble and cobble gravel with a sand matrix. Little or no secondary carbonate is present.

Low-lying areas of the map unit are prone to periodic flooding and debris-flow deposition, particularly during and after major thunderstorms. Associated flash floods pose a serious hazard in narrow, restricted canyons of Colorado National Monument. Significant potential for flash flood and debris flow hazards also exists in and near stream channels between the highlands of the Monument and the Colorado River. The exposed thickness of alluvium is about 1 to 4 m. (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Qalc1 - Youngest alluvium deposited by the Colorado River (Holocene)

Alluvium underlying the Colorado River channel and floodplain. The upper 1–2 m of the unit is commonly an overbank deposit and 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. The lower part of the unit, which is poorly exposed, consists of well-sorted, rounded and well-rounded, slightly bouldery pebble-cobble gravel derived from a variety of igneous, metamorphic, and sedimentary rocks in a sandy matrix. Along the Colorado River, upstream from the confluence with the Gunnison River, clasts consist mainly of basaltic rocks, quartzite, pale-red micaceous sandstone derived from the Maroon Formation, light- to medium-gray, fine-grained and medium-grained porphyritic granitic rocks, and distinctive, very pale orange weathering, "oil shale" clasts of the Green River Formation. Downstream from the confluence of the Colorado and Gunnison Rivers, clasts consist of similar rock types with the addition of intermediate-composition volcanic and hypabyssal rocks derived from the San Juan Mountains to the southeast and the West Elk Mountains to the east. Exposures in gravel pits (boundary of pits delineated by short dashed lines) locally display scour-and-fill structures. 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. The map unit includes low terraces along the floodplain. Along the Colorado River, the northern boundary of the map unit was covered by a wedge of undivided alluvium and colluvium (Qac) derived from the Book Cliffs, which are north of the Grand Junction quadrangle. The boundary of unit Qalc1 north of the Colorado River is only approximately located where the alluvial and colluvial wedge is thought to be less than 2 m thick, based on analysis of well-log data (Schneider, 1975; Phillips, 1986). The map unit is subject to periodic flooding, particularly during spring runoff from snow melt. The map unit is an important 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. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Qalg - Youngest alluvium deposited by the Gunnison River (Holocene)

Alluvium underlying the Gunnison River channel and floodplain. The upper 1–2 m of the unit, commonly an overbank deposit, consists of light-yellowish-brown (10YR 6/4), massive, silty fine sand to medium sand. The lower part of the unit, which is poorly exposed, consists of well-sorted, rounded and well-rounded pebble-cobble gravel derived from a variety of igneous, metamorphic, and sedimentary rocks. Clasts consist mainly of intermediate-composition volcanic rocks, basaltic rocks, quartzite, red sandstone, and gray fine-grained and medium-grained granitic rocks in a sandy matrix. Alluvium deposited by the Gunnison River (Qalg) differs from younger alluvium deposited by the Colorado River (Qalc1) by containing intermediate-composition volcanic clasts, by not containing clasts of the Green River Formation and the micaceous sandstone of the Maroon Formation, and by not containing boulder-size clasts. 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. The map unit includes low terraces along the floodplain and is subject to periodic flooding particularly during spring runoff from snow melt. The map unit is a gravel resource; based on the thickness of similar gravels on terraces bordering the river, the gravel in this unit is generally 5–10 m thick. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Qfp - Flood-plain and stream-channel deposits (Holocene)

Most of the flood-plain and stream-channel deposits consist of clast-supported, slightly bouldery, pebble and cobble gravel in a sand matrix deposited along the Colorado River.

The unit contains lenses of gravelly sand to sandy silt. A thin upper part is locally present and consists of gravelly sand or sandy silt. In the lower part, clasts are generally less than 40 cm in diameter, subrounded to well rounded, and poorly to moderately well sorted. Clasts were derived from bedrock units upstream along the Colorado River and its tributaries. The unit contains an assortment of clasts of Cenozoic, Mesozoic, and Paleozoic sedimentary rocks, which include the yellowish-gray (5Y7/2) weathering "oil shale" of the Green River Formation and moderate-red (5R5/4) Maroon Formation. The clasts also include igneous rocks of several ages, which include granitic rocks as well as rhyolitic and basaltic volcanic rocks, numerous Proterozoic metamorphic rocks, and minor hornfels from contact metamorphism of the Morrison Formation. Sediments exposed in gravel pits (boundary of pits are delineated by dashed lines) locally display scour-and-fill structure. Elongate clasts are inclined upstream forming an overlapping imbricate structure.

Unit Qfp is in low-lying areas and is subject to flooding, particularly during spring runoff from snow melt in mountainous areas upstream along the Colorado River and its tributaries. Gravel is an important resource that is becoming increasingly scarce in and near the map area. Drill-hole data for the area north of the Colorado River indicate that 3 to 15 m of sheetwash deposits (Qsw) overlie 3 to 7 m of Colorado River gravel in unit Qfp, which in turn overlies Mancos Shale (Km) (Ken Weston; U.S. Bureau of Reclamation, written commun., 1999; Phillips, 1986). These data, however, may not represent the entire thickness of unit Qfp, because it is difficult to distinguish in drilling records between sheetwash deposits (Qsw) and lenses of sandy silt in the upper part of unit Qfp. The thickness of unit Qfp locally may exceed 7 m. (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Qa - Alluvium deposited by tributary streams (Holocene and late Pleistocene)

Alluvium underlying stream channels, floodplains, and low terraces deposited by small tributary streams. North of the Colorado River, the unit consists of poorly stratified to well-stratified, poorly sorted to well-sorted, cobbly pebble gravel layers in a light-yellowish-brown (10YR 6/4) fine sand and silty sand matrix.

Clasts are commonly subrounded to rounded, and consist of shale and sandstone fragments derived from the Mancos Shale (Km) and the Mesaverde Group. In places it also consists of light-brownish-gray (2.5Y 6/2), massive sand and sandy silt that contains scattered pebble layers or lenses generally less than 10 cm thick. South of the Colorado River, the map unit includes minor undifferentiated colluvial deposits such as young fan-alluvium and debris-flow deposits (Qfy) and sheetwash deposits. Locally, the map unit includes boulders as large as 2 m in diameter. The map unit typically consists of interbedded sand, pebbly sand, and pebble gravel, and ranges from thin-bedded (0.5–0.10 cm) clayey, silty sand to thick-bedded (> 1 m), poorly sorted, both clast- and matrix-supported, slightly bouldery, pebble and cobble gravel with a sand matrix. Little or no secondary carbonate is present. Low-lying areas of the map unit are prone to periodic flooding and debris-flow deposition from summer thunderstorms. Maximum thickness of the map unit is about 5 m. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Qvf - Valley-fill deposits (Holocene and late Pleistocene)

Valley-fill deposits that floor parts of many canyons of the Monument consist chiefly of sand and silt of stream-terrace alluvium and probably sandy debris-flow deposits, but also locally includes stony colluvium on valley sides as well as minor deposits of eolian sand (Qe) and sheetwash (Qsw).

The valley-fill deposits can be subdivided into a thicker bedded (> 30 cm), slightly calcareous, upper part and a thinner bedded (< 30 cm), calcareous, lower part. Both parts consist mostly of sand and silt that contain small, discontinuous lenses of gravel. Cobbles are as large as 25 cm in diameter. Both parts locally contain several buried, weakly developed paleosols and common small (< 2 mm) charcoal fragments. Some of these paleosols are darker than the rest of unit Qvf because of the accumulation of organic matter; they contain abundant charcoal, presumably from burnt woody vegetation. Charcoal not associated with paleosols is concentrated at bedding breaks in the sediments, but charcoal also occurs within beds. The age of the valley-fill deposits, based on calibrated 14C ages (Table 4), ranges from at least 1,180 to 6,200 years BP (before present, actually before 1954) in the upper part to at least as old as 10,360 years BP in the lower part (Scott, Hood, and others, 1999). The discovery in No Thoroughfare Canyon of a mastodon tooth, which was probably eroded from the undated lowest part of the unit, is consistent with a late Pleistocene age for the lower part of the map unit (for more information see the text under SELECTED STRATIGRAPHIC TOPICS and GEOCHRONOLOGY).

The upper part of unit Qvf has beds that range typically from 0.1 to 2 m thick, is generally reddish brown (5YR 5/4) to yellowish red (5YR 5/8), contains minor charcoal fragments, and has a 0.5-m-thick surface soil. The upper part is weakly indurated in part by calcium carbonate. In the upper part, gravel lenses range from 0.1 to 0.7 m thick. Clasts consist of angular to subangular sandstone and minor sedimentary quartzite that range in size from 2-mm granules to 25-cm cobbles. They are coated with secondary calcium carbonate.

The lower part typically has beds 5 to 50 cm thick, is yellow (2.5Y 7/6) to reddish yellow (7.5YR 6/6) and locally light olive brown (2.5Y 5/4), has iron oxide staining, and contains more charcoal fragments and fewer gravel lenses than the upper part. The lower part is weakly indurated, due in part to secondary calcium carbonate in a stage II horizon. Thin beds of fine sand and silt in the lower part are slightly wavy and can be traced for more than 40 m along some exposures. The gravel lenses in the lower part can be traced only a few meters at most, are about 2 to 5 cm thick, and consist chiefly of small granules and pebbles.

Valley-fill deposits are best exposed in terrace scarps in the upper part of No Thoroughfare Canyon, but isolated remnants of the unit Qvf are widespread in most canyons throughout the Monument. The upper part is as thick as about 10 m, but it is thinner where it overlies bedrock near canyon walls. The top of the lower part of unit Qvf is commonly 10 m below the top of the unit, and the lower part of unit Qvf is commonly less than 10 m thick. Unit Qvf is locally as much as 30 m thick. (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Qvf - Valley-fill deposit (Holocene and late Pleistocene)
Chiefly stream-terrace alluvium and probably sandy debris-flow deposits, but also locally includes stony colluvium on valley sides as well as minor deposits of eolian sand and sheetwash. The only exposure of the map unit exists in the southwestern part of the map area within the Colorado National Monument. In the adjacent Colorado National Monument 7.5' quadrangle, valley-fill deposits can be subdivided into a thicker bedded (>30 cm), slightly calcareous upper part and a thinner bedded (<30 cm), calcareous lower part (Scott and others, 2001). Both parts are largely composed of sand and silt that contain small, discontinuous lenses of gravel. Both parts locally contain several buried, weakly developed paleosols and common small (<2 mm) charcoal fragments. Some of these paleosols are darker than the rest of the map unit Qvf from the accumulation of organic matter, and contain abundant charcoal, presumably from burnt woody vegetation. Charcoal not associated with paleosols is concentrated at bedding breaks in the sediments, but charcoal also occurs within beds. Charcoal 14C laboratory values range from 1,280±50 to 9,190±50 years BP (before present, referenced at 1950) (Scott and others, 1999), and calibrated ages (Stuiver and others, 1998) range from 1,180 to 10,360 years BP. The discovery in No Thoroughfare Canyon of a mastodon tooth, which was probably eroded from the undated lowest part of the map unit, is consistent with a late Pleistocene age for the oldest part of the unit. The upper part of unit Qvf has beds that are typically 0.1–2 m thick, is generally reddish brown (5YR 5/4) to yellowish red (5YR 5/8), and contains minor charcoal fragments. The lower part typically has beds 5–50 cm thick, is yellow (2.5Y 7/6) to reddish yellow (7.5YR 6/6), and locally light olive brown (2.5Y 5/4), has iron oxide staining, and contains more charcoal fragments and fewer gravel lenses than the upper part. The lower part is weakly indurated, due in part to secondary calcium carbonate in a stage II Bk horizon. The gravel lenses in the lower part can be traced only a few meters at most, are about 2–5 cm thick, and consist chiefly of small granules and pebbles. Unit Qvf may be as much as 18 m thick in the map area. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Qalc2 - Oldest alluvium deposited by the Colorado River (Holocene and latest Pleistocene)

Alluvium that underlies an area along the north side of the Colorado River west of Grand Junction. This area is about 3–5 m above the river and is not considered to be part of the active floodplain of the younger alluvium deposited by the Colorado River (Qalc1). The map unit is poorly exposed; locally, rounded and well-rounded pebble-cobble gravel of Colorado River origin is exposed at surface or in shallow excavations. Clasts include mainly basaltic rocks, light- to medium-gray fine-grained granitic rocks, fine-grained red micaceous sandstone, quartzite, and very light gray and pinkish-gray coarse-grained granitic rocks. Some clasts have a thin (1–2 mm), white carbonate coat. Gravel is commonly overlain by 1–2 m of overbank deposit and possibly eolian materials consisting of massive, light-yellowish-brown (10YR 6/4) silty fine sand and fine sand. Lower parts of the map unit may be subject to flooding by infrequent large flood events. The map unit is a gravel resource, and well-log data (Schneider, 1975; Phillips, 1986) indicate that it is about 5 m thick>. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Qrg - River-gravel deposits (late? and middle Pleistocene)

River-gravel deposits are chiefly clastsupported, bouldery, cobble and pebble gravel in a sand matrix left as isolated remnants on hilltops on the south side of the Colorado River. The clasts are generally less than 50 cm in diameter, subrounded to well rounded, and poorly to moderately sorted. Gravel and lenses of gravelly sand to sandy silt are exposed in gravel pits. These pits also reveal scour-and-fill structures as well as an imbricate clast fabric that is consistent with the westward flow direction of the Colorado River. Clasts include the diagnostic moderate-red Maroon Formation and the yellowish-gray Green River Formation among other rock types typical of those transported by the Colorado River that are listed in the description for unit Qfp. Secondary calcium carbonate coatings on clasts have stage III morphology. Unit Qrg caps hills on the south side of the Colorado River and locally underlies unit Qaso. The tops of the river-gravel deposits are about 15, 35, 65, 75, and 110 m above the Colorado River. The heights of these deposits suggest that unit Qrg is equivalent in age to late and middle Pleistocene terrace alluvium (units Qty, Qto, and Qtt) outside the map area farther upstream along the Colorado River near Rifle and New Castle, Colorado (Shroba and Scott, 1997; Scott and Shroba, 1997). The presence of deposits of unit Qrg on or near the northdipping Dakota Formation (Kd) suggests that as the Colorado River cut downward, it migrated northward, eroding the less resistant Mancos Shale (Km) rather than the more resistant underlying Dakota Formation (Kd). The lowest gravel is about 15 m above the Colorado River in a terrace mantled by unit Qaso. It is as much as 3 m thick and it can be traced in poor exposures in gullies in the Redlands area where it thins to about 1 to 2 m thick (indicated on the map by a single dashed line). The thickness of unit Qrg is 1 to 4 m.. (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Qtgu - Terrace alluvium of the Gunnison River, undivided (middle to late Pleistocene)

Alluvium deposited by the Gunninson River that underlies small terrace remnants between about 10 and 90 m above the river in the southeast part of the map area. The map unit consists mainly of well-sorted, rounded to well-rounded pebble-cobble gravel with some boulders. Clasts consist mainly of intermediate-composition volcanic rocks, basaltic rocks, quartzite, and gray fine-grained and medium-grained granitic rocks in a sandy matrix. The matrix of the gravel component of the map unit consists of very pale brown (10YR 7/4) sandy silt and silty sand. Gravels are commonly overlain by 1–2 m of massive, light 4 yellowish-brown (10YR 6/4) clayey silt, silty fine sand, and fine sand containing scattered pebbles and cobbles. The map unit is commonly 5–10 m thick. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Qt30 - Terrace alluvium 30 of the Colorado River (middle Pleistocene)

Alluvium deposited by the Colorado River along its south side underlies a prominent terrace about 24–37 m above the river. The map unit consists mainly of well-sorted, rounded to well-rounded pebble-cobble gravel with some boulders. Above the confluence with the Gunnison River, clasts consist predominantly of basaltic rocks (29%), quartzite (25%), fine-grained granitic rocks (15%), and fine-grained micaceous red sandstone (11%). Below the confluence with the Gunnison River, gravel also contains andesitic and dacitic clasts. All clasts of the “oil shale” of the Green River Formation in exposures are highly shattered and (or) thoroughly weathered. The matrix consists of pale-brown (10YR 6/3) silty sand and sand, forming about 5–10% of the map 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 Qt30 contains lenses of light-gray (10 YR 7/2), well-sorted, cross-bedded, coarse to medium sand that are 25–50 cm thick containing thin (< 5 cm) pebble layers. In places, the upper 30 cm of gravel contains abundant platy shale clasts derived from the Green River Formation. The map unit underlies Orchard Mesa and much of The Redlands, south of the Colorado River. In The Redlands area, probably some unmapped old alluvial-slope deposits (Qaso) locally overlie unit Qt30; extensive landscaping has made more detailed subdivisions impractical. On Orchard Mesa, an alluvial and colluvial (Qac) wedge composed of fine-grained sediment was deposited northward from hills to the south to cover the southern boundary of this unit (Schwochow, 1978). The southern boundary is only approximately located where the alluvial and colluvial wedge is thought to be less than 2 m thick (Schwochow, 1978).

Based on the height of this map unit above the Colorado River, it is equivalent to unit Qt2 in the adjacent Clifton quadrangle (Carrara, 2001) and is probably equivalent in part to outwash of the Bull Lake glaciation, which is about 140–150 ka (Pierce and others, 1976). If so, the rate of incision during the past 150 ky was about 0.16–0.26 m/ky, probably higher than the rate of 0.15 m/ky that was determined for the past 620 ky. The map unit was actively mined for gravel during 1999 on the Clifton quadrangle to the east, near the junction of C1/2 and 32 Roads, and at the northern end of 31 Road south of the Colorado River (Carrara, 2001). The thickness of unit Qt30 is commonly 5–10 m. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Qt60c - Terrace alluvium 60 of the Colorado River (middle Pleistocene)

Alluvium deposited by the Colorado River that underlies terrace remnants about 64–67 m above the river south of The Redlands area in the west-central part of the map area. The map unit consists of abundant well-sorted, rounded to well-rounded pebble-cobble gravel and less common boulders. Clasts consist predominantly of basaltic rocks, quartzite, fine-grained granitic rocks, fine-grained micaceous red sandstone, and intermediate-composition volcanic rocks such as andesitic and dacitic rocks. All “oil shale” clasts of the Green River Formation are highly shattered and (or) thoroughly weathered. The matrix consists of pale-brown (10YR 6/3) silty sand and sand, forming about 5–10% 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. The map 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. Based on the height of this unit above the Colorado River and a regional rate of stream incision of about 0.15 m/ky, the terrace remnants of this unit may be about 425–445 ka. Unit Qt60c is commonly 5– 10 m thick. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Qt60g - Terrace alluvium 60 of the Gunnison River (middle Pleistocene)

Alluvium deposited by the Gunnison River that underlies terrace remnants about 55–64 m above the river south of The Redlands area in the west-central part of the map area near Little Park Road and in the southeast part of the map area. The map unit consists mainly of well-sorted, rounded to well-rounded pebble-cobble gravel with some boulders. Clasts consist predominantly of basaltic rocks, quartzite, fine-grained granitic rocks, fine-grained red sandstone, and intermediate-composition volcanic rocks such as andesitic and dacitic rocks. The matrix consists of pale-brown (10YR 6/3) silty sand and sand, forming about 5–10% of the map 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. The map unit contains lenses of light-gray (10YR 7/2), well-sorted, cross-bedded, coarse to medium sand that is 25–50 cm thick and contains thin (<5 cm) pebble layers. There is no terrace alluvium upstream in the Clifton quadrangle that occurs at heights equivalent to those of this map unit; in the Colorado National Monument quadrangle downstream from this map area, terrace alluvium heights include those at about 65 and 75 m above the river. Based on the height of this unit above the Colorado River and a regional rate of stream incision of about 0.15 m/ky, the terrace remnants of this unit may be about 365–425 ka. The thickness of unit Qt60g commonly is 5–10 m. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Qtc/Qtg - Terrace alluvium of the Colorado River over terrace alluvium of the Gunnison River (middle Pleistocene)

Remnant terrace alluvium of the Colorado River overlies the terrace alluvium of the Gunnison River in at least two localities north of the Gunnison River. The lowest (65–75 m above the river) is 1 km southeast of the AEC (DOE) Grand Junction Compound just upstream from the junction of the Gunnison with the

Colorado, and the highest (90–105 m above the river) is 1.5 km northeast of Horse Point in the southeastern part of the map area. Clasts described for terrace alluvium 60 of the Gunnison River (Qt60g) and for terrace alluvium 100 of the Colorado River (Qt100) are similar to those found in this map unit. Based on the heights above the Gunnison River and a regional rate of stream incision of about 0.15 m/ky, the lowest terrace remnant is 445–485 ka and the highest terrace is 600–700 ka. The map unit ranges from about 8 to 15 m thick. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Qt100 - Terrace alluvium 100 of the Colorado River (middle Pleistocene)

Alluvium deposited by the Colorado River that underlies terrace remnants between about 80–100 m above the river. The map unit consists mainly of well-sorted, rounded to well-rounded pebble-cobble gravel containing less abundant boulders. Upstream from the junction with the Gunnison River, clasts consist mainly of quartzite, basaltic rocks, intermediate-composition volcanic rocks, fine-grained red micaceous sandstone, and fine-grained granitic rocks. Downstream from the confluence of the Colorado and Gunnison Rivers, clasts consist of similar clast rock types with the addition of intermediate-composition volcanic rocks carried by the Gunnison River from the San Juan Mountains to the south. Many clasts have thin (1–2 mm) carbonate coatings. All “oil shale” clasts of the Green River Formation in exposures are highly shattered or thoroughly weathered. The matrix consists of pale-brown (10YR 6/3) silty sand and sand, forming about 5–10% of the unit. Locally, gravels are overlain by 1–2 m of massive, light-yellowish-brown (10YR 6/3) silty fine sand and fine sand; at one terrace remnant located 0.4 km northwest of No Thoroughfare Canyon, this fine-grained deposit is at least 3m thick. Several exposures display stage III carbonate (Gile and others, 1966). The map unit contains lenses of light-gray (10YR 7/2), well-sorted, cross-bedded, coarse to medium sand 25–50 cm thick. In places, the upper 25 cm of gravel contains abundant platy shale clasts derived from the Green River Formation. The map unit forms dissected and discontinuous terrace remnants that can be traced across the map area. Based on the height of this unit above the Colorado River and a regional rate of stream incision of about 0.15 m/ky, the terrace remnants of this unit may range from about 645 to about 685 ky. This map unit is equivalent to map unit Qt3 on adjacent Clifton quadrangle (Carrara, 2001). The map unit has been mined for gravel in the past on the Clifton quadrangle (Carrara, 2001). Unit Qt100 is commonly 3–6 m thick, and the maximum thickness is about 12 m. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Qt170 - Terrace alluvium 170 of the Colorado River (early Pleistocene)

Alluvium deposited by the Colorado River that underlies several terrace remnants about 163–175 m above the river. The map unit consists mainly of well-sorted, rounded and well-rounded pebble-cobble gravel. Clasts consist mainly of quartzite, fine-grained micaceous red sandstone, fine-grained granitic rocks (many of which are disintergrated to grus), and basaltic rocks. Many clasts have thin carbonate coatings 1–3 mm thick. “Oil shale” clasts of the Green River Formation were not found and may have been too weathered to be recognized. The matrix consists of pale-brown (10YR 6/4 or 7/4) fine sand and silty fine sand, forming about 5–10% of the unit. In places, the clasts exposed on the terrace surface have rock varnish coatings. Locally, gravels are overlain by 1 m of light-brown (7.5YR 6/4), massive, silty fine sand and fine sand displaying stage III carbonate (Gile and others, 1966). In places, the map unit contains lenses of light-olive-gray (5Y 6/2), well-sorted, cross-bedded, coarse to medium sand 10–30 cm thick. The map unit forms three isolated terrace remnants west of the Gunnison River in the south-central part of the map area. Based on the height of this unit above the modern rivers and a regional rate of stream incision of about 0.15 m/ky, the terrace remnants of this unit may range from about 1,085 to about 1,165 ka. The map unit is probably equivalent to map unit Qt4 on the adjacent Clifton quadrangle (Carrara, 2001). The map unit has a maximum thickness of about 10 m. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Alluvial and Colluvial Deposits

Alluvial and colluvial deposits are mostly silt, sand, and gravel in fans on flood plains, in alluvial-slope deposits on river gravel and bedrock, in remnants of tributary stream alluvium and debris-flow deposits, and in deposits of pebbly silty sand that locally mantle canyon bottoms. (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Mostly silt, sand, and gravel in alluvial and colluvial slope deposits and old dissected debris-flow deposits on pediment surfaces. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Qfy - Young fan-alluvium and debris-flow deposits (Holocene)

Qfy - Young fan-alluvium and debris-flow deposits (Holocene)
Young fan-alluvium and debrisflow deposits consist chiefly of well-sorted silty sand and subordinate, discontinuous lenses and layers of clast-supported gravel present on the south side of the Colorado River. Beds of silty sand are chiefly massive (> 1 m thick), but are locally present in beds as thin as 1.5 cm. Some of the silty sand may have been deposited as eolian sand, but much of it is probably reworked by water. Gravel layers are commonly 5 to 45 cm thick. Unit Qfy consists of material reworked from unit Qaso, silty eolian sand, and, locally, Colorado River gravel reworked from unit Qrg. Gravel clasts range from 2-mm granules to boulders greater than 1 m in diameter near active stream channels. These clasts are rounded to subrounded, moderately to poorly sorted, and were derived mostly from Proterozoic and Mesozoic units exposed in the highlands to the south in the Uncompahgre Plateau. The gravel was probably deposited by streams and locally by debris flows . Colors of the unit, where silty sand dominates, range from yellowish red (5YR5/8) to reddish yellow (5YR6/6). The gravel lends a gray color to the unit. There is little or no secondary carbonate on clasts and in the matrix . Unit Qfy forms a few small fans on flood-plain and stream-channel deposits (Qfp) along the south bank of the Colorado River. The base of unit Qfy is as low as 1.5 m above the river. The exposed thickness is about 1 to 4 m, and the maximum thickness is about 20 m. (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Qfy - Young fan-alluvium and debris-flow deposits (Holocene)
Chiefly well sorted silty sand and subordinate discontinuous lenses and layers of clast-supported gravel. Silty sand is generally greater than 1 m thick, but is also locally present in beds as thin as 2 cm. Some of the silty sand may have been deposited as eolian sand, but much of it is probably reworked by water. Gravel layers are commonly 5–45 cm thick, and clasts range from 2-mm granules to boulders greater than 1 m in diameter near active stream channels. These clasts are rounded to subrounded and moderately to poorly sorted, and were derived largely from Mesozoic and Proterozoic units exposed in the highlands to the southwest on the Uncompahgre Plateau. The gravel was probably deposited by streams and locally by debris flows. Colors of the unit, where silty sand dominates, range from yellowish red (5YR 5/8) to reddish yellow (5YR 6/6). A high gravel content lends a gray color to the unit. There is little or no secondary carbonate on clasts and in the matrix. The map unit forms several fans on younger alluvium deposited by the Colorado River (Qalc1) and alluvium deposited by the Gunnison River (Qalg). The base of the map unit is as low as 1.5 m above the river. Exposed thickness of Qfy is about 1–5 m; maximum thickness is about 12 m. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Qac - Alluvium and colluvium, undivided (Holocene and late Pleistocene)

Predominantly a mix of alluvium, sheetwash, and debris-flow deposits. Extensive agricultural, industrial, and housing development in much of the map area has modified, covered, and obscured contacts between this unit and adjacent units. North of the Colorado River, the map unit consists of light-gray

(10YR 7/2, 2.5Y 7/2) and light-olive-gray (5Y 6/2), massive, fine sandy silt and clayey silt that forms a broad gentle slope with a gradient of about 6–7 m/km. Locally, the map unit contains scattered angular and subangular platey shale and sandstone pebbles derived from the Mancos Shale (Km) and the overlying Mesaverde Group. The map unit also contains scattered sandstone boulders, as large as 1 m in diameter, derived from the Mesaverde Group. South of the Colorado River, the map 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 form 5–20% of the deposit, and are chiefly rounded to well-rounded pebbles and cobbles of Colorado River origin that have been reworked from nearby terraces. Many clasts have thin carbonate coatings 2–5 mm thick. Locally, the map unit contains pebble-cobble gravel lenses 1–1.5 m thick consisting of rounded to well-rounded pebbles and cobbles of Colorado River origin. The matrix in the gravels consists of light-yellowish-brown (10YR 6/4) sand and silty sand. In places, the presence of desiccation cracks suggests that the map unit contains expansive clays that may cause stability problems for roads and buildings. The thickness of the map unit, based on U.S. Bureau of Reclamation well logs (Phillips, 1986), is about 3–5 m near the Colorado River and as much as 20 m farther from the river. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Qasy - Younger alluvial-slope deposits (late Pleistocene)

Younger alluvial-slope deposits consists chiefly of well-sorted silty sand and subordinate, discontinuous lenses and layers of clast-supported gravel and are found along the south side of the Colorado River.

Silty sand ranges commonly from 20 to 80 cm thick, but locally forms beds as thin as 1 cm that probably represent eolian material that was reworked by water. Gravel layers are commonly 3 to 70 cm thick. Unit Qasy consists of material reworked from unit Qaso as well as primary and reworked silty eolian sand. Gravel clasts range from granules to boulders larger than 1 m in diameter near active stream channels. These clasts are poorly sorted and subrounded and were derived mostly from Proterozoic and Mesozoic units exposed in the highlands to the south in the Uncompahgre Plateau. The gravel was probably deposited by streams and locally by debris flows. Colors of the silty sand range from yellowish red (5YR5/8) to reddish yellow (5YR6/6); gravel lends a gray color to the unit. Secondary carbonate morphology on clasts and in the matrix is stage I-II.

Unit Qasy overlies Mancos Shale (Km) and Dakota Formation (Kd) on the south side of the Colorado River. The upper part of the unit Qasy is partly covered by unmapped thin sheetwash (Qsw) and colluvial debris (Qc) derived from bedrock units upslope and by thin, unmapped deposits of eolian sand (Qe). The maximum thickness is about 15 m. (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Qaso - Older alluvial-slope deposits (late Pleistocene)

Qaso - Older alluvial-slope deposits (late Pleistocene)
Older alluvial-slope deposits consists chiefly of layers and lenses of poorly sorted, matrix- and clast-supported gravel and well-sorted silty sand and are found at the base of the mountain front.

The gravel clasts range in size from granules to boulders 1.5 m in diameter. These clasts are predominately metamorphic and igneous rocks derived from Proterozoic rocks and less abundant sandstone and limestone clasts derived from Mesozoic rocks to the south in the highlands in the Uncompahgre Plateau. The matrix of the gravel is silty sand. Gravel has light- to dark-gray colors from the clasts and a pink (5YR7/3-4) matrix. Gravelly zones exceed 6 m in thickness, and silty sand beds are 0.2 to 6 m thick. Most clasts are subangular to subrounded, but some of the angularity of the clasts appears to be related to weathering after deposition. The gravel layers are massive to poorly bedded, and, locally, gravel forms discontinuous lenses in thick beds of silty sand. Zones of non-sorted to very poorly sorted bouldery deposits suggest deposition as debris flows; some gravel deposits are better sorted and were probably deposited by alluvial processes. In the upper 0.3 m of the unit, secondary calcium carbonate in the matrix and on clasts has stage II morphology; at a depth of 5 to 6 m, gravel is indurated by secondary calcium carbonate that has strong stage III morphology.

The silty sand layers are generally massive to weakly bedded and have colors that range from yellowish red (5YR5/8) to reddish yellow (5YR6/6). Where bedding is more distinct, the beds of silty sand are 0.1 to 0.5 m thick, and massive silty sand is locally as thick as 6 m. Eolian processes may have initially deposited much of this silty sand. Some of it probably was reworked by stream and sheetwash processes. Unmapped discontinuous eolian deposits (Qe) and locally thin sheetwash deposits (Qsw) as much as 1 to 3 m thick partly mantle unit Qaso. Silty sand has stage I-II secondary calcium carbonate morphology at a depth of 6 m.

Map unit Qaso commonly overlies Colorado River gravel (Qrg) near the bluffs on the south side of the Colorado River. Unit Qaso is locally exposed in the area between the Colorado River and the faulted front of the Uncompahgre Plateau. The top of unit Qaso is about 10 to 65 m above the Colorado River. Exposed thicknesses are at least 6 m, and the maximum thickness suggested by topography is in excess of 20 m. (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Qaso - Old alluvial-slope deposit (late Pleistocene)
Chiefly layers and lenses of poorly sorted, matrix- and clast-supported gravel and well-sorted silty sand. The gravel clasts range in size from granules to boulders 1.5 m in diameter. These clasts are predominantly metamorphic and igneous rocks derived from Precambrian rocks and less abundant sandstone and limestone clasts derived from Mesozoic rocks to the south in the highlands of the Uncompahgre Plateau. The matrix of the gravel is silty sand. Gravel has light- to dark-gray colors from the clasts and a pink (5YR7/3–4) matrix. Gravelly zones may exceed 6 m in thickness, and silty sand beds are 0.2–6 m thick. Most clasts are subangular to subrounded, but some of the angularity appears to be related to weathering after deposition. The gravel layers are massive to poorly bedded, and local gravel forms discontinuous lenses in thick beds of silty sand. Zones of nonsorted to very poorly sorted bouldery deposits suggest deposition as debris flows; some gravel deposits are better sorted and were probably deposited by fluvial processes. In the upper 0.3 m of the unit, secondary calcium carbonate in the matrix and on clasts has stage II morphology; at a depth of 5–6 m, gravel is indurated by secondary calcium carbonate that has strong stage III morphology. The silty sand layers are generally massive and weakly bedded, and have colors that range from yellowish red (5YR5/8) to reddish yellow (5YR6/6). Where bedding is more distinct, the beds of silty sand are 0.1–0.5 m thick, and massive silty sand is locally as thick as 6 m. The unit includes eolian sand and silt that probably has been reworked by stream and sheetwash processes. Unit Qaso locally overlies Colorado River gravel (Qt30) near the bluffs on the south side of the Colorado River on the western side of the map area where it is exposed west of the mouth of No Thoroughfare Canyon. Exposed thickness of unit Qaso is at least 10 m. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Qpwf - Pediment deposits of Walker Field (late? Pleistocene)

Predominantly debris-flow and alluvial deposits from the Book Cliffs that underlie pediment surfaces (Whitney, 1981). The map unit forms a thin discontinuous deposit overlying the pediment surfaces in the northern part of the map area. Extensive agricultural, industrial, and housing development in the map area has modified, covered, and obscured contacts between this unit and adjacent units. The pediment surface is 5–15 m above surrounding areas. The map 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 Mesaverde Group. The matrix consists of a pale-brown (10YR 6/3) silty sand and sand. The largest boulders are about 1 m in diameter. The map unit has a maximum thickness of about 3 m. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Qlg - Local gravel deposits (middle to late? Pleistocene)

Qlg - Local gravel deposits (late? to middle Pleistocene)
Local gravel deposits are poorly sorted, subrounded, clast - and matrix-supported pebble and cobble gravel that locally contains boulders as long as 2 m. Unit Qlg was deposited by streams tributary to the Colorado River, and it probably includes both stream alluvium (Qal) as well as debris-flow deposits . Clasts consist primarily of metamorphic and igneous Proterozoic rocks and secondarily of sedimentary rocks eroded from the adjacent highlands in the Uncompahgre Plateau. These deposits form isolated remnants on hilltops in the Redlands area. Thin lenses of silty sand and scattered granules and pebbles are present locally in unit Qlg. In the upper 2 m of the unit, secondary calcium carbonate coats clasts , and the matrix consists of yellowish- red (5YR5/6), calcium carbonate-rich (stage II), silty sand and granules. Unit Qlg probably consists of remnants of stream-channel and debris-flow deposits that accumulated below the mouths of canyons along the front of the Uncompahgre Plateau. Eroded remnants of these former valley floors are preserved on hilltops at different heights between about 6 and 67 m above modern intermittent tributary streams. Assuming an incision rate of about 0.14 m/ky for the Colorado River and its tributary streams, unit Qlg was deposited at different times between about 42 ka and 480 ka. Gravel locally fills channels as deep as 1 m that are cut in the underlying bedrock. At one locality, east of Riggs Hill in the eastern part of the map area, unit Qlg overlies Colorado River gravel (Qrg). This indicates deposition of tributary gravel on a former flood plain or terrace of the Colorado River. The weathering of clasts, as indicated by the angularity of Proterozoic metamorphic and igneous clasts, is greater with age of the deposit and therefore is greater with height above stream level. Clasts of biotite-rich schist are particularly susceptible to both disaggregation and spheroidal weathering. Thin, unmapped veneers of Holocene eolian sand (Qe) mantle most of unit Qlg. The thickness of unit Qlg is as much as 6 m. (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Qlg - Local gravel deposits (middle Pleistocene)
Poorly sorted, subrounded, clast- and matrix-supported pebble and cobble gravels that locally contain boulders as long as 2 m. Unit Qlg was deposited by streams tributary to the southern side of the Colorado River. Clasts consist primarily of metamorphic and igneous Proterozoic rocks and secondarily of sedimentary rocks eroded from the highlands in the Uncompahgre Plateau, which is exposed in the adjacent Colorado National Monument quadrangle (Scott and others, 2001). Thin lenses of silty sand and scattered granules and pebbles are present locally in unit Qlg. In the upper 2 m of the unit, secondary calcium carbonate coats clasts. The matrix consists of yellowish-red (5YR5/6), pedogenic, calcium carbonate-rich (stage II) silty sand and granules. Unit Qlg probably consists of remnants of stream-channel and debris-flow deposits that accumulated below the mouths of canyons southwest of the map area along the front of the Uncompahgre Plateau. Eroded remnants of the unit are preserved on hilltops about 55–79 m above modern intermittent tributary streams. Assuming an incision rate of about 0.15 m/ky for the Colorado River and its tributary streams, unit Qlg was deposited between about 365 and 525 ka. Gravel locally fills channels as deep as 1 m that are cut in the underlying bedrock. At four localities in the western part of the map area, unit Qlg overlies two Colorado River gravels (Qt60 and Qt100). The degree of weathering of clasts, as indicated by the angularity of Precambrian metamorphic and igneous clasts, is greater with age, and therefore is greater with height above stream level. Biotite-rich schist is particularly susceptible to both disaggregation and spheroidal weathering. Thin, unmapped veneers of Holocene eolian sand mantle of most of unit Qlg. Thickness of unit Qlg is as much as 6 m (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Qlg/Qt30 - Local gravel deposits over terrace alluvium 30 of the Colorado River (middle Pleistocene)

Unit present west of the junction of the Colorado and Gunnison Rivers. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Colluvial Deposits

Colluvial deposits include silt, sand, and rock fragments on valley sides and hill slopes that were mobilized, transported, and deposited by gravity and sheet erosion. (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Silt, sand, and rock fragments on valley sides and hill slopes that were mobilized, transported, and deposited by gravity. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Qlsy - Younger landslide deposits (Holocene)

Qlsy - Younger landslide deposits (Holocene)
Younger landslide deposits are mostly intact, active or recently active earth-block slides (Varnes, 1978). These slides commonly have cresentic headwall scarps and form where the south side of the Colorado River has locally cut steep slopes on the uppermost Dakota Formation (Kd) and the lowermost Mancos Shale (Km).

The sizes and rock type of the clasts and the grain-size distributions and colors of the matrices of these slides reflect those of the displaced bedrock units and surficial deposits. Landslide deposits are prone to continued movement or reactivation due to natural as well as human-induced processes.

Blocks capped by units Qasy and Qaso have been downdropped to form small grabens, open tension gashes, and a series of slide blocks that step down toward the Colorado River. Closer to the river, these slide blocks are more disrupted. Upslope from the main scarp, incipient landsliding is indicated by cracks as much as 80 m from the river, where future breakaways will form. The toes of the landslides are being removed by the Colorado River. The presence of these young landslides indicates slope instability, which poses a hazard to roads or structures built on bluffs close to the river. In the adjacent Grand Junction 7.5 minute quadrangle, young landslides have damaged a sewage treatment plant and an irrigation pump station. An active landslide was destroying a house near the eastern border of the map area south of the Colorado River as this map was being prepared. The thickness of unit Qlsy is at least 8 m and possibly as much as 35 m. (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Qlsy - Younger landslide deposits (latest Holocene)
Unit consists of two small landslide deposits along the south side of the Colorado River near the center of the map area, derived from the Mancos Shale (Km), which contains expansive clays and bentonite layers. The map unit consists of unstratified, pale-brown (10YR 6/3) sandy silt, silt, clayey silt, and silty clay. The map unit consists largely of rotational types of landslides as defined by Varnes (1978). These landslides should be considered active. In the 1980's, reactivation of the eastern landslide resulted in severe damage and forced the abandonment of several homes that were only a few years old at the time (Jochim and others, 1988). Small landslides are likely to form elsewhere along the south bluff of the Colorado River. Roads and structures are subject to landslide hazards, especially those that are close to river bluffs where excess irrigation or lawn water has been applied or the river has undercut the bluffs. Along active cut banks, the Colorado River probably removed evidence of similar landslide deposits. Also in this map area, young landslides too small to map have damaged a sewage treatment plant and

an irrigation pump station near the eastern part of The Redlands. The thickness of unit Qlsy is about 20 m. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Qc - Colluvium, undivided (Holocene and late Pleistocene)

Qc - Colluvium, undivided (Holocene and late Pleistocene)
Colluvium, undivided, consists mostly of clast-supported pebble, cobble, and boulder gravel with a matrix of silty sand, minor clayey silt, and, locally, gravelly silt and is found along the steeper slopes of the mountain front.

Rock type and colors of colluvium reflect the bedrock and surficial units from which the colluvium was derived. Unit Qc is commonly associated with rockfall deposits (Qr) at the base of cliffs of the Wingate Sandstone (Jwg). Locally, unit Qc includes sheetwash (Qsw), debris-flow, and landslide (Qlso and Qlsy) deposits. Colluvium derived from the Morrison Formation, contains expansive clays. Colluvium derived from the Chinle Formation (TRc) is silty and non-expansive. Clasts are angular to subangular and are as large as 2 m in diameter. Secondary carbonate coatings on clasts in the upper part of the unit are thin and have stage I morphology. The maximum thickness is about 5 m. (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Qc - Colluvium (Holocene and late Pleistocene)
Mostly clast supported pebble, cobble, and boulder gravel containing a matrix of silty sand, minor clayey silt, and locally gravelly silt. Lithologies and colors of colluvium reflect the bedrock and surficial units from which the colluvium was derived. Unit Qc is commonly formed at the base of cliffs or steep hills. The map unit locally includes sheetwash, debris-flow, and landslide deposits. Colluvium derived from the Morrison Formation contains expansive clays. Clasts are angular to subangular and are as large as 2 m in diameter. Secondary carbonate coatings on clasts in the upper part of the unit are thin and have stage I morphology. Maximum thickness is about 5 m. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Qr - Rockfall deposits (Holocene and late Pleistocene)

Rockfall deposits include boulders and smaller debris deposited on slopes at the base of cliffs, particularly cliffs of the Wingate Sandstone (Jwg).

The matrix is probably non-calcareous to calcareous, clast-supported, sandy rubble. Clasts are typically 1 to 2 m in diameter, but some exceed 12 m in length. Clasts on younger rockfall deposits are unweathered and have light bedrock colors. Clasts on older rockfall deposits are weathered and coated with a brownish-gray to brownish-black desert varnish. The thickness of unit Qr is 1 m to greater than 3 m. (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Qsw - Sheetwash deposits (Holocene and late Pleistocene)

Sheetwash deposits consist chiefly of light-gray (10YR7/2 and 2.5Y7/2) sandy clay and silty clay. These sheetwash deposits form on a very gentle slope with a gradient of about 3 to 4 m/km north of the Colorado River where they were derived from erosion of the Mancos Shale (Km).

The upper 1 m of sheetwash deposits is more clay rich than the lower part. Both the upper and lower parts have weak sub-horizontal layering and are slightly calcareous. Unit Qsw commonly has vertical desiccation cracks that are partly filled with clay, which probably washed down from the upper part.

Extensive agricultural, industrial, and housing development has modified, covered, or partly removed the upper part of much of unit Qsw near the northeast corner of the map area. This unit description is based on observations of exposures in an eroded bank of a 4-m-deep agricultural drainage ditch located 3.2 km north and 0.2 km west of the intersection of H Road and 21 Road in the adjacent Fruita 7.5 minute quadrangle.

The presence of desiccation cracks suggests that the map unit contains expansive clays that may cause stability problems for roads and buildings. Our examination of construction excavations and records from numerous drill holes on the north side of the Colorado River (Ken Weston, U.S. Bureau of Reclamation, written commun., 1999; Phillips, 1986) indicate that sheetwash deposits are 3 to 8 m thick close to the river, but increase to nearly 15 m thick at the northeastern corner of the map area. (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Qlso - Older landslide deposits (Holocene and middle Pleistocene)

Qlso - Older landslide deposits (late to middle? Pleistocene)
Older landslide deposits consist chiefly of unsorted and unstratified rock debris characterized by hummocky topography. Many of the landslides are complex (Varnes, 1978). All of them formed on unstable slopes that are underlain by the Brushy Basin Member of the Morrison Formation (Jmb). These landslide deposits include debris from the Brushy Basin Member of the Morrison Formation (Jmb), the Burro Canyon Formation (Kb), and the Dakota Formation (Kd), and are particularly abundant on the slopes of Black Ridge. Landslide deposits are prone to continued movement or reactivation due to natural as well as human-induced processes. Most of the map unit lacks distinctive landforms such as crescentic headwall scarps and lobate toes, but the deposits have hummocky surfaces. Rejuvenated parts of unit Qlso have crescentic headwall scarps shown on the map by hachured lines. Unit Qlso includes debris-slide, rock-slide, debris-slump, rock-slump, slumpearth- flow, earth-flow, and debris-flow deposits as defined by Varnes (1978). The sizes and rock types of the clasts and the grain-size distributions and colors of the matrices of these deposits reflect those of the displaced bedrock units and surficial deposits. Deposits derived from the Dakota Formation (Kd) and the Burro Canyon Formation (Kb) contain blocks of rock as long as 6 m. Landslide deposits derived from the Brushy Basin Member of the Morrison Formation (Jmb) are rich in clay. Brushy Basinderived clay contains expansive smectitic clay and locally has high shrink-swell potential. In the west-central part of the map area, landslides as long as 2.5 km flank the west, north, and east sides of Black Ridge. These landslides flowed over the rim of Monument Canyon and locally cover the Proterozoic rocks exposed on the canyon floor. The northeast-dipping Brushy Basin Member of the Morrison Formation (Jmb), the Burro Canyon Formation (Kb), and the Dakota Formation (Kd) have been involved in landslides that have moved toward the Colorado River. Housing or other development in this area may encounter landslide hazards. The exposed thickness is about 5 m, and the maximum thickness is possibly 20 m. (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Qlso - Older landslide deposits (Holocene to middle Pleistocene)
The map unit includes debris-slide, rock-slide, debris-slump, rock-slump, slump-earth-flow, earth-flow, debris-flow, and complex landslide deposits as defined by Varnes (1978). The map unit consists of mainly unsorted and unstratified rock debris characterized by hummocky topography. The sizes and lithologies of the clasts and the grain-size distributions and colors of the matrices of these deposits reflect those of the displaced bedrock units and surficial deposits. Many of the landslides in the southwestern and southern parts of the map area formed on unstable slopes that are underlain by the Brushy Basin Member of the Morrison Formation (Jmb) that contains abundant smectitic expansive clays. These landslide deposits include debris from the Brushy Basin Member of the Morrison Formation (Jmb), the Burro Canyon Formation (Kb), and the Dakota Formation (Kd). Some of these landslides lack distinctive landforms such as crescentic headwall scarps and lobate toes, but still have hummocky

surfaces. Rejuvenated parts of these landslides may have crescentic headwall scarps. However, no headwall scarp remains along the highest part of the large (2.5 km by 3.5 km) older landslide deposit exposed along the upper part of Little Park Road because all stratigraphic material younger than the Brushy Basin Member has already slid downhill. Where Little Park Road descends from the landslide deposits onto the yet-intact dipslope of the Dakota and Burro Canyon Formations, numerous homes have been built. At the base of the dipslope, several homes were built on Burro Canyon Formation that dips into the hill, typical of incipient rotated landslide blocks, rather than parallel to the dip slope. Extensive watering of lawns on the dip slope of Little Park Road may increase the probability of activating a landslide and should be avoided. The older landslide deposits between the Gunnison River and Horse Point south of the river have morphologies that suggest that the oldest parts of the deposits are closest to the river and the youngest are closest to Horse Point. The river appears to be eroding these deposits as they are moved downward in a conveyor-belt fashion. Deposits derived from the Dakota and the Burro Canyon Formations (Kd and Kb) contain blocks of rock as long as 6 m. Landslide deposits are prone to continued movement or reactivation due to natural as well as human-induced processes, such as excavations and irrigation. The exposed thickness of the map unit is at least 65 m and may be as great as 85 m. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Eolian Deposits

Eolian deposits consist of silty sand that mantles level to gently sloping surfaces. Locally they include colluvial material. (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Qe - Eolian sand (Holocene and late Pleistocene)

Eolian sand consists of silty, very fine to fine wind-blown sand that blankets upland areas of the Uncompahgre Plateau.

These deposits are commonly massive to weakly bedded and lack eolian sedimentary structures, which may have been obliterated by biotic processes. Deposits at depths greater than 1 m are typically weakly indurated by secondary calcium carbonate that has stage I morphology. Colors generally range from yellowish red (5YR5/8) to reddish yellow (5YR6/6). The sand is derived chiefly from weathering of the poorly cemented Slick Rock Member (Jes) and the "board beds" unit (Jeb) of the Entrada Sandstone and of the Wingate Sandstone (Jwg); lesser amounts are derived from sandstone of the members of the Morrison Formation (Jmt, Jms, and Jmb). Deposits of eolian sand below bedrock exposures locally may contain a significant amount of colluvial debris. Clast sizes in colluvial debris range from granules to boulders. On slopes, eolian sand is subject to redeposition as sheetwash. Several climbing dunes are banked against bedrock and are as thick as 5 m.

Thin, discontinuous, unmapped deposits of eolian sand mantle other surficial deposits and bedrock on the upland areas of the Uncompahgre Plateau and in the Redlands area near the Colorado River. In the upland areas, deposits of eolian sand locally form subdued, stabilized dunes and blankets of eolian sand. Eolian sand on the uplands is locally stabilized by pinon and juniper trees and in other areas by sage, rabbitbrush, bunch grass, and cheat grass. Structures built on unit Qe commonly sustain minor damage that suggests slight settling, probably chiefly related to hydrocompaction. Deposits of eolian silt (loess) were not observed in the map area, although they are locally common further upstream along the Colorado River between Rifle and Glenwood Springs (Shroba, 1994). The thickness of unit Qe may locally be in excess of 8 m. (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Eolian and Colluvial Deposits

Eolian and colluvial deposits include silty sand, which mantles level to gently sloping surfaces, as well as silt, sand, and rock fragments on valley sides and hill slopes, which were mobilized, transported, and deposited by gravity and sheet erosion. (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Wind-deposited silty sand, which chiefly mantles level to gently sloping surfaces, intertongues with colluvial deposits of silt, sand, and rock fragments and with sheet wash, which generally mantle valley sides and hill slopes. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Qse - Eolian sand and sheetwash deposits (Holocene and late Pleistocene)

Qse - Eolian sand and sheetwash deposits (Holocene and late Pleistocene)
Eolian sand and sheetwash deposits consist chiefly of silty, very fine to fine sand that commonly contains scattered granule- to cobble-size fragments from bedrock units that are exposed up slope, particularly between the mountain front and the Colorado River.

Unit Qse accumulated on gentle to moderate slopes with gradients between about 50 m/km and 100 m/km. Unit Qse is similar to unit Qe, but unit Qse contains more abundant clasts derived from local bedrock units. On steeper slopes near upslope bedrock exposures, unit Qse is likely to contain a significant amount of colluvial clasts. Sheetwash deposits in unit Qse contain discontinuous layers and lenses of poorly sorted clasts. Colors of the unit range from yellowish red (5YR5/8) to reddish yellow (5YR6/6). Where wind and sheetwash erosion have winnowed out sand and finer sediment, a lag of granules, pebbles, and sparse cobbles covers the surface. Unit Qse formed along the front of the Uncompahgre Plateau where it mantles unit Qaso and other units. The thickness of unit Qse may be about 5 m. (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Qse - Eolian sand and sheetwash deposits (Holocene and late Pleistocene)
Chiefly silty very fine to fine sand that commonly contains scattered granules to cobbles from bedrock units exposed upslope. Unit Qse accumulated on gentle to moderate slopes with gradients between about 50 m/km and 100 m/km. On steeper slopes near upslope bedrock outcrops, unit Qse is likely to contain significant amounts of colluvial clasts. Sheetwash deposits in unit Qse contain discontinuous layers and lenses of poorly sorted clasts. Colors of the unit range from yellowish red (5YR 5/8) to reddish yellow (5YR 6/6). Where wind and sheetwash erosion have winnowed out sand and finer sediment, a lag of granules, pebbles, and sparse cobbles covers the surface. Unit Qse is mainly found in southwestern part of the map area along the flank of the Uncompahgre Plateau. Maximum thickness of the map unit is about 5 m. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Qse/Qt30 - Eolian sand and sheetwash deposits over terrace alluvium 30 of the Colorado River (middle Pleistocene to Holocene)

Unit present southwest of junction of Colorado and Gunnison Rivers. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Marsh Deposits

Marsh deposits include wind- and (or) sheetwash-deposited sand and silt that accumulated in a wet environment. (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Qcg - Cienaga deposits (Holocene)

Cienaga deposits consist of silty sand, that has chiefly an eolian and (or) sheetwash origin; the deposits accumulated in marshy places in the Redlands area.

These marshy areas are fed by seeps, are generally well vegetated, and are upstream from constrictions formed by resistant beds of the Burro Canyon Formation (Kb) and the Dakota Formation (Kd). Unit Qcg overlies the relatively impermeable Brushy Basin Member of the Morrison Formation (Jmb). The deposits in unit Qcg are massive, well sorted, structureless, and lack gravelly layers. Locally they may contain some sandy stream alluvium. Colors are commonly light reddish brown (2.5YR6/4) to pale red (10R6/3) at a depth of 10-24 cm and red (2.5YR5/6) at a depth of greater than 40 cm. The upper 10 to 24 cm of unit Qcg is moderately indurated and slightly calcareous, whereas sediment below a depth of 40 cm is weakly indurated and very slightly calcareous.

Unit Qcg is soft when saturated with water, and the underlying Brushy Basin Member (Jmb) contains abundant expansive clay (smectite). As a result, unit Qcg has low bearing capacity and poses a hazard to roads and structures built on it. In a few low areas where the water table is at or near the surface, evaporation of the dissolved load precipitates an alkali crust on unit Qcg. Areas that have this crust are designated on the map by a dotted perimeter and the symbol "a". This alkali crust is commonly a few centimeters thick, white (5YR8/1), and mostly devoid of vegetation. The thickness of unit Qcg is 1 to 3 m. (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Bedrock Units

Km - Mancos Shale (Upper Cretaceous)

Km - Mancos Shale (Upper Cretaceous; Turonian and Cenomanian)
The Mancos Shale is chiefly a medium-dark-gray, dark-gray, brownish-gray, and brownish-black fissile shale that forms gentle slopes, which are broken at wide intervals by thin, brownish-gray sandstone ledges and sparse, white bentonite beds. Only the lowermost Mancos Shale is exposed along the northern boundary of the map area near the Colorado River. This lowermost Mancos was deposited in a shallow marine subtidal setting, similar to the modern Texas Gulf Coast.

Exposures of the Mancos Shale can most readily be viewed on the south side of the Colorado River, northwest of a new bridge that has been constructed at the east boundary of the map area. This bridge is not shown on the topographic base map available for this geologic map, but it can be reached on a newly constructed continuation of South Broadway northeast of the intersection with Broadway in the Redlands area.

In addition to the dominant dark fissile shale that weathers light gray, the lowermost Mancos contains sparse beds of thinly laminated, fissile-weathering, partly bioturbated, calcareous and carbonaceous siltstone and sandy siltstone, which contain sparse interbeds of sandstone. The unit is well defined by Cobban and others (1994). The sandstone beds typically are < 10 cm thick, very fine to fine grained, well sorted, and calcareous. The beds commonly exhibit ripple lamination, including both oscillation and combined flow ripples, and locally display hummocky cross-lamination. Several light-gray to yellowish-gray thin stringers and beds of volcanic ash have been altered to nearly pure, highly expansive bentonite and are as much as 20 cm thick.

The lowermost Mancos is fossiliferous, but pelecypods and cephalopods are generally found only in recent roadcuts and excavations because rapid weathering breaks up fossils. Marine trace fossil burrows are common. The base of the Mancos was mapped at the base of the nearly continuous dark fissile shale above the uppermost prominent set of thin sandstone beds and carbonaceous interbeds of the Dakota Formation (Kd). The map unit reaches a thickness in excess of 1,370 m in western Colorado; however, less than 20 m of the lowermost Mancos is exposed south of the Colorado River in the map area (Cole and Moore, 1994; Cole and others, 1999). (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Km - Mancos Shale (Upper Cretaceous; Campanian to Cenomanian)
Chiefly a medium-dark-gray, dark-gray, brownish-gray, and brownish-black fissile shale that weathers light gray. The upper part of the Mancos is locally exposed in the northern part of the map area. It is a massive and monotonous, fissile shale that contains expansive smectitic clays, particularly in bentonite beds. The lower part of the Mancos was mapped above the base of the nearly continuous dark fissile shale that overlies the uppermost prominent set of thin sandstone beds and carbonaceous interbeds of the Dakota Formation (Kd). The lowermost Mancos also contains sparse interbeds of thinly laminated, fissile-weathering, partly bioturbated, calcareous and carbonaceous siltstone and sandy siltstone, which contain sparse interbeds of sandstone. The sandstone typically forms beds <10 cm thick and is very fine to fine grained, well sorted, and calcareous. The beds commonly exhibit ripple lamination, including both oscillation and combined flow, and locally display hummocky cross lamination. Several light-gray to yellowish-gray thin stringers and beds of volcanic ash are altered to nearly pure highly expansive bentonite and are as much as 20 cm thick. The lowermost Mancos is fossiliferous, but pelecypods and cephalopods are generally only found in recent roadcuts or excavations where disaggregation due to rapid weathering has not occurred. Marine trace fossil burrows are common. These lower Mancos strata are equivalent to the Tununk Member of the Mancos Shale recognized in Utah (Fouch and others, 1983; Cole, 1987). The unit is prone to failure (landsliding and debris flows) where exposed on steep slopes, such as along the bluffs along the south side of the Colorado River. The map unit may have moderate to high swelling potential due to the presence of expansive clays, and it contains sulfate minerals (largely gypsum and thenardite) that are corrosive to conventional concrete and metal pipes. Unimproved roads are virtually impassable when wet. The age of the Mancos Shale in the Grand Junction area has been assigned to the Campanian to Cenomanian Ages (Young, 1959). The map unit reaches a thickness in excess of 1,370 m in the western Colorado region (Cole and others, 1999; Cole and Moore, 1994), but lack of exposures of the middle part of the Mancos does not permit a precise estimate of the thickness of the map unit here. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Kd - Dakota Formation (Upper and Lower? Cretaceous)

Kd - Dakota Formation (Upper and Lower? Cretaceous; Cenomanian and Albian?)
Sandstone and conglomerate of the Dakota Formation form prominent and resistant ledges and ridges, whereas mudstone and interbedded sandstone and shale generally form slopes. The Dakota Formation caps Black Ridge near the central western boundary of the map area and forms a series of low hogbacks in the Redlands area south of the Colorado River. Locally in the Redlands area, dinosaur tacks are preserved in sandstone beds.

The sandstone and mudstone of the upper parts of the Dakota were deposited in estuaries, tidal channels, distributary channels, bays, lagoons, strandlines, and barrier islands, an environment similar to the Texas Gulf Coast today. Bioturbation is common throughout the map unit and includes plant roots and burrows. Burrows in the lower Dakota are terrestrial in origin, whereas those in the upper Dakota are marginal-marine. The lowest part of the Dakota, which is dominated by channel-form sandstone and conglomerate bodies, was deposited by slightly to moderately sinuous streams flowing across broad, well-defined floodplains that were densely vegetated and contained numerous abandoned channels that formed oxbow lakes. The carbonaceous mudstone and associated coal were deposited in freshwater swamp and marsh environments.

The Dakota Formation is not easily reached in the map area. However, on public land, a trail on the south side of Riggs Hill leads from a parking area on South Broadway to the top of the hill that is capped by the Dakota.

The unit consists of about 20 to 50% sandstone, 5 to 20% conglomerate, 40 to 60% mudstone, and less than 5% impure coal. There are four parts to the map unit: from top to bottom these are the interbedded sandstone and shale part, a sandstone part, a mudstone part, and a conglomeratic part. The interbedded sandstone and shale part is dominantly shale or shaley mudstone, thin sandstone beds, and stringers of coal. Shale in the uppermost part of the Dakota is interbedded with channel-form sandstone, is usually much less carbonaceous than elsewhere in the unit, and consists of brownish-gray to greenish-gray, thinly laminated, fissile-weathering, slightly carbonaceous, slightly calcareous, siltstone and clayey siltstone; this interbedded sandstone and shale part is are bioturbated by roots and indistinct burrows. This upper part is transitional with the overlying Mancos Shale (Km).

The sandstone part contains predominately sandstone with subordinate conglomerate, stringers of coal, and minor mudstone. Sandstone beds are commonly light gray to pale yellowish orange, white, pinkish gray or very pale orange, thickly bedded to very thinly bedded, very fine to fine grained, moderately to poorly sorted, bioturbated, locally argillaceous, and slightly calcareous to non-calcareous. Thicker sandstone bodies (1 to 5 m) have a channel-form geometry with associated scour surfaces and lag gravels, which include blebs of mudstone, chert, quartz, and rock fragments. Stratification consists of small- to medium-scale trough and tabular-tangential cross-stratification, symmetric and asymmetric ripple lamination, horizontal lamination, and contorted bedding.

The mudstone part is chiefly mudstone and subordinate impure coal. Mudstone consists of brownish-gray to grayish-black, medium- to thinly laminated, platy to fissile weathering, carbonaceous to very carbonaceous, bioturbated, silty claystone and clayey siltstone containing thin beds and lenses of very fine to fine-grained, quartz-cemented sandstone and white, altered volcanic ash. Fragments of plant fossils are very common. Impure coal seams and stringers, ranging in thickness from 5 to 40 cm, are found within the carbonaceous mudstone. The ash content in the coal is estimated at 15 to 35 percent.

The base of the conglomeratic part is predominately conglomerate but is capped by sandstone. Conglomerate beds have grain sizes that range from granules to pebbles, contain sandstone interbeds, are typically light gray to white or pinkish gray, and are medium bedded to very thickly bedded, blocky and slabby weathering, fine to very coarse grained, poor to moderately sorted, slightly argillaceous, slightly calcareous to non-calcareous, and friable. Clasts are commonly graded and consist of mudchips, chert, quartz, and other rock fragments. Stratification in conglomerate is generally indistinct, consisting of poorly defined low-angle (<15º) scour surfaces.

The map unit may rest disconformably on the underlying Burro Canyon Formation. The base of the Dakota Formation was arbitrarily defined during mapping as the first carbonaceous mudstone above the Burro Canyon Formation (Kb). The first thick sandstone interval above the carbonaceous mudstone of the Dakota Formation commonly has been bleached white in contrast to light yellow and orange elsewhere. The thickness of the map unit exposed at Black Ridge is about 31 m where the uppermost part of the unit has been removed by erosion, and the total unit thickness is estimated to be about 45 to 50 m (Cole and others, 1999). (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Kd - Dakota Formation (Upper and Lower? Cretaceous; Cenomanian and Albian?)
Consists of about 20–50% sandstone, 40–60% mudstone, 5–20% conglomerate, and less than 5% impure coal, similar to exposures in the adjacent Colorado National Monument quadrangle (Scott and others, 2001). There are four parts in the map unit: from top to bottom these are an interbedded sandstone and shale part, a sandstone part, a mudstone part, and a conglomeratic part.

The interbedded sandstone and shale part is dominantly shale or shaley mudstone, thin sandstone beds, and stringers of coal. This upper part is gradational with the overlying Mancos Shale (Km). Shale in the uppermost part of the Dakota is interbedded with channel-form sandstones, is usually much less carbonaceous than elsewhere in the unit, and consists of brownish-gray to greenish-gray, thinly laminated, fissile-weathering, slightly carbonaceous, slightly calcareous siltstone and clayey siltstone, which are bioturbated by roots and indistinct burrows.

The sandstone part also contains subordinate conglomerate, stringers of coal, and minor mudstone. Sandstone is commonly light gray to pale yellowish orange, white, and pinkish gray or very pale orange, forms thick to very thin beds, and is very fine to fine grained, moderately to poorly sorted, bioturbated, locally argillaceous, and slightly calcareous to noncalcareous. Thicker sandstone bodies (1–5 m) have channel-form geometries and associated scour surfaces and lag gravels, which include blebs of mudstone and clasts of chert, quartz, and rock fragments. Stratification consists of small- to medium-scale trough and tabular-tangential cross stratification, symmetric and asymmetric ripple lamination, horizontal lamination, and contorted bedding.

The mudstone part is chiefly mudstone and subordinate impure coal. Mudstone consists of brownish-gray to grayish-black, medium to thinly laminated (platy to fissile weathering), carbonaceous to very carbonaceous, bioturbated, silty claystone and clayey siltstone, containing thin beds and lenses of very fine to fine grained, quartz-cemented sandstone and white altered volcanic ash. Fossil plant fragments are very common. Impure coal seams and stringers, ranging in thickness from 5 to 40 cm, are present within the carbonaceous mudstone.

Although the conglomeratic part is capped by sandstone, conglomerate predominates. The conglomerate part contains clasts that range in size from fine sand to pebbles and is typically light gray to white or pinkish gray, poor to moderately sorted, slightly argillaceous, slightly calcareous to noncalcareous, and friable. Also,the conglomerate part has medium to very thick beds and blocky and slabby weathering and contains minor sandstone interbeds. Clasts are commonly graded and consist of mudchips, chert, quartz, and rock fragments. Stratification in conglomerate is generally indistinct, consisting of poorly defined low-angle scour surfaces.

In the map unit, bioturbation is common and includes fossil plant roots and burrows. Burrows in the upper Dakota are marginal marine in origin, whereas those in the lower Dakota are terrestrial. Sandstone and conglomerate intervals form prominent, resistant ledges and ridges, whereas mudstone and interbedded sandstone and shale intervals generally form slopes. The Dakota Formation forms the uppermost unit of the prominent dipslope that dominates the area south of the Gunnison and Colorado Rivers because the Mancos Shale (Km) has largely been eroded as the Colorado River migrated northward with time. The Dakota Formation rests disconformably(?) on the underlying Burro Canyon Formation (Kb). The base of the Dakota Formation was arbitrarily defined during mapping as the base of the lowest carbonaceous mudstone above the Burro Canyon Formation (Kb). The lowest thick sandstone interval above the carbonaceous mudstone of the Dakota Formation commonly has been bleached white in contrast to light yellow and orange colors elsewhere. According to William A. Cobban (U.S. Geological Survey, oral commun., 1999), the upper part of the Dakota contains Cenomanian Age fauna near Delta, Colo., 60 km to the southeast of the map area, and the lower Dakota is probably Albian Age near the map area.

A number of residential subdivisions in The Redlands area on the dipslope of the Dakota Sandstone display evidence of unstable foundations. Cracked streets, unevenly closing garage doors, and slumping slopes in areas of heavily watered lawns are commonly observed characteristics. Apparently the clay-rich layers in the Dakota become unstable when saturated with water.

The total map unit thickness is estimated to be about 45–50 m (Cole and others, 1999). (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Kb - Burro Canyon Formation (Lower Cretaceous)

Kb - Burro Canyon Formation (Lower Cretaceous; Albian and Aptian)
In most localities, the upper part of the Burro Canyon Formation is dominated by mudstone and forms slopes, whereas the lower third to two-thirds of the unit is dominated by sandstone and forms cliffs.

The thick mudstone sequence at the top of the unit represents flood plain and lacustrine deposition. The sandy lower part of the Burro Canyon was deposited by braided streams on narrow flood plains. Modern rivers draining the Rocky Mountains, such as the parts of the South Platte and Rio Grande Rivers in the plains, are possible analogs for the depositional systems that deposited the Burro Canyon.

The Burro Canyon Formation can most readily be reached by following the same trail as that used to reach the Dakota Formation. Go part way up the trail on the south side of Riggs Hill from South Broadway to the first exposures of coarse conglomerate, which marks the base of the Burro Canyon.

The map unit consists of about 40 to 80% mudstone, 20 to 60% sandstone, and 0 to 15% conglomerate. Mudstone is typically medium to thinly laminated (platy to fissile weathering), slightly bentonitic to non-bentonitic, slightly calcareous, and commonly bioturbated by roots and some burrows. Mudstone consists of pale-red, pale-olive to yellowish-green siltstone, clayey siltstone and silty claystone and ranges from thin interbeds within channel-form sandstone bodies to discrete sequences more than 10 m thick. Thin (less than 1 m thick) paleosol horizons that are composed of white to light-gray, earthy carbonate nodules may be interbedded with mudstone in the upper Burro Canyon.

Sandstone intervals are laterally discontinuous. Sandstone forms channel-shaped bodies and is typically white to yellowish gray, thick bedded to thinly laminated, blocky to flaggy weathering, fine to medium grained, moderately sorted, and quartz-cemented. Locally the sandstone includes large amounts of petrified wood. Sandstone sequences contain numerous laterally and vertically amalgamated scour surfaces accentuated by thin lag gravels, which include green mudstone clasts, chert, quartz, petrified wood, and dinosaur bone. Medium-scale trough and tabular-planar cross-stratification is common in sandstone bodies; contorted bedding and bioturbation including roots and elongate vertical burrows are also present.

Locally, conglomerate beds are as much as 3 m thick near the base of the map unit; they are commonly yellowish gray, moderately sorted, well rounded, massive to poorly bedded, channel form, and discontinuous laterally. The conglomerate clasts consist mostly of chert and quartz pebbles but include minor petrified wood and dinosaur bones.

The base of the map unit is arbitrarily defined as the lowest thick sandstone or conglomerate bed above the mudstone of the Brushy Basin Member of the Morrison Formation (Jmb) (Aubrey, 1998). The thickness of the map unit is 29.3 m at Black Ridge (Cole and others, 1999). (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Kb - Burro Canyon Formation (Lower Cretaceous; Albian and Aptian)
Consists of about 20–60% sandstone, 40–80% mudstone, and 0–15% conglomerate. In most localities, the upper part is dominated by mudstone and forms slopes, whereas the lower third to two-thirds of the unit is dominated by sandstone and forms cliffs or steep hillsides.

Mudstone is typically medium to thinly laminated (platy to fissile weathering), slightly bentonitic to nonbentonitic, slightly calcareous, and usually bioturbated (roots and some burrows). Thin (less than 1 m thick) paleosol horizons that are composed of white to light-gray, earthy carbonate nodules are locally interbedded with mudstone in the upper Burro Canyon.

Laterally discontinuous sandstone occurs in channel-form bodies and is typically white to yellowish gray, thick bedded to thinly laminated, blocky to flaggy weathering, fine to medium grained, moderately sorted, and quartz cemented. Locally, the sandstone includes large amounts of petrified wood. Sandstone sequences contain numerous laterally and vertically amalgamated scour surfaces accentuated by thin lag gravels, which include clasts of green mudstone, chert, quartz, petrified wood, and dinosaur bone. Medium-scale trough and tabular-planar cross stratification is common in sandstone beds; contorted bedding and bioturbation (roots and elongate vertical burrows) may also occur. Mudstone consists of pale-red, pale-olive to yellowish-green siltstone, clayey siltstone and silty claystone and ranges from thin interbeds within the channel-form sandstone bodies to discrete sequences more than 10 m thick. Locally, conglomerate beds are as much as 3 m thick near the base of the map unit; they are commonly yellowish gray, moderately sorted, well rounded, massive to poorly bedded, channel form, and discontinuous laterally. The conglomerate clasts consist largely of chert and quartz pebbles but include minor petrified wood and dinosaur bone.

The base of the Burro Canyon Formation rests on the K-1 (basal Cretaceous) unconformity (Peterson, 1994; Peterson and Turner, 1998) above the Brushy Basin Member of the Morrison Formation (Jmb), but that unconformity was impractical to map because it is defined by microfossils and a poorly exposed paleosol. Therefore, the base of the Burro Canyon was arbitrarily defined as the lowest thick sandstone or conglomerate bed above the mudstone of the Brushy Basin Member (Jmb). As a result, an undetermined interval of lowermost Burro Canyon mudstones above the unconformity may have been included in the Brushy Basin (Aubrey, 1998). Because of the discontinuous and lenticular character of the sandstone and conglomerate beds in the Burro Canyon, the basal contact and the thickness of the rock unit differ from place to place.

The Burro Canyon Formation is of Albian and Aptian Ages according to palynological evidence (Craig, 1981). The thickness of the map unit is about 60 m at the prominent point 0.6 km east of the west boundary and 2.5 km north of the southern boundary of the map area; this is considerably thicker than the 30 m measured at Black Ridge in the Colorado National Monument quadrangle (Cole and others, 1999). (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Morrison Formation

Morrison Formation (Upper Jurassic)

The Morrison Formation consists of three members: a slope-forming upper member, the Brushy Basin Member; a cliff-forming middle member, the Salt Wash Member; and a slope-forming lower member, the Tidwell Member. The Morrison Formation is about 160 m thick based on the total measured thickness of the three members (Cole and others, 1999); however, individual members do not have laterally consistent thicknesses, and the total thickness probably also has a large thickness range. (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Morrison Formation (Upper Jurassic)

Consists of three members from top to bottom: the Brushy Basin Member, the Salt Wash Member, and the Tidwell Member. The Morrison Formation is about 170 m thick at the point 0.6 km east of the west boundary and 2.5 km north of the southern boundary of the map area, but individual members do not have laterally consistent thicknesses. Contacts between the Morrison Formation members were located at horizons that could be readily followed on aerial photographs and easily located in the field rather than horizons defined by micropaleontological or 40Ar/39Ar isotopic dating evidence. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Jmb - Morrison Formation, Brushy Basin Member (Upper Jurassic)

Jmb - Brushy Basin Member (Tithonian and Kimmeridgian)
The multicolored mudstone of the Brushy Basin Member forms gentle rounded slopes. The Brushy Basin Member was deposited in a mud flat to saline lacustrine setting (Turner and Fishman, 1991) characterized by associated highly sinuous fluvial systems. Volcanic basins in New Zealand are possible modern-day analogs.

Like the Dakota and Burro Canyon Formations, the Brushy Basin Member of the Morrison Formation can be reached by following the trail from the parking area off South Broadway up Riggs Hill. The mudstone is partly covered by blocks of sandstone and conglomerate that tumbled from exposures of the Dakota and Burro Canyon.

The unit consists of 85 to 95% mudstone, 5 to 15% sandstone, and a trace of limestone. About 75% of the mudstone consists of bentonitic, variegated grayish-yellow-green, greenish-gray, yellowish-gray, brownish-gray, grayish-red, greenish-yellow, and grayish-orange-pink, medium to thinly laminated (platy to fissile weathering), mottled, bioturbated (?), earthy, slightly calcareous, clay-rich siltstone, mudstone, and silty mudstone. The silty mudstone contains thin interbeds of very fine grained, well-sorted, bioturbated sandstone and gray, nodular, finely crystalline limestone (possible soil nodules?). Both barite nodules and dinosaur bones are present. Bentonitic mudstone expands and dries to form a popcorn-like weathered surface. Bentonite, a rock consisting of swelling, mixed-layer, smectitic clay minerals, is derived from diagenetic alteration of volcanic ash.

The remaining 25% of the mudstone that is not conspicuously bentonitic consists of variegated pale-olive, reddish-brown, greenish-gray, grayish-yellow-green, yellowish-gray, yellowish-orange, and grayish-red, thickly to thinly laminated (flaggy to fissile weathering), partly bioturbated, slightly calcareous to non-calcareous, siltstone, sandy siltstone, and silty mudstone. The silty mudstone also contains thin interbeds of very fine grained sandstone. Sandstone sequences are most common in the lowermost and uppermost Brushy Basin Member. They typically form channels and range in thickness from less than 1 m to more than 4 m. Sandstone is typically greenish yellow to dusky yellow green and greenish gray, thickly laminated to medium bedded, slabby to flaggy weathering, very fine to coarse grained, poor to moderately sorted, slightly calcareous to non-calcareous, and locally bioturbated by burrows and roots and contorted by soft-sediment deformation. The thicker channel sequences commonly have small-scale trough cross-stratification and scour surfaces accentuated by basal layers of pebble-size mudchips and granules of chert and quartz, whereas thinner sandstone beds are commonly bioturbated.

Because of its susceptibility to mass wasting, particularly landsliding, the Brushy Basin Member is one of the most poorly exposed units in the map area. The Brushy Basin Member underlies the K-1 unconformity (Peterson, 1994; Peterson and Turner, 1998) below the Burro Canyon Formation and rests disconformably above the Salt Wash Member (unnamed unconformity; R.G. Young, oral commun., Grand Junction, Colo., 1999). The Brushy Basin Member is about 95 m thick at exposures about 1 km east of the east boundary of the map area near Little Park Road in the adjacent Grand Junction 7.5'quadrangle (Cole and others, 1999). (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Jmb - Brushy Basin Member (Tithonian and Kimmeridgian)
Consists of mudstone (85–95%), sandstone (5–15%), and sparse limestone.

About 75% of the mudstone consists of variegated grayish-yellow-green, greenish-gray, yellowish-gray, brownish-gray, grayish-red, greenish-yellow, and grayish-orange-pink, medium to thinly laminated (platy to fissile weathering), mottled, bioturbated (?), earthy, bentonitic, slightly calcareous, clay-rich siltstone, mudstone, and silty mudstone. The silty mudstone contains thin interbeds of very fine grained, well-sorted, bioturbated sandstone and gray, nodular, finely crystalline limestone (possible soil nodules?). Nodular barite and dinosaur bone are present. Bentonitic mudstone expands and dries to form a popcorn-like weathered appearance. The remaining 25% of the mudstone that is not conspicuously bentonitic consists of variegated pale-olive, reddish-brown, greenish-gray, grayish-yellow-green, yellowish-gray, yellowish-orange, and grayish-red, thickly to thinly laminated (flaggy to fissile weathering), partly bioturbated, slightly calcareous to noncalcareous, siltstone, sandy siltstone, and silty mudstone. The silty mudstone also contains thin interbeds of very fine grained sandstone.

Sandstone sequences are most common in the lowermost and uppermost Brushy Basin Member. They typically form channels and range in thickness from less than 1 m to more than 4 m. Sandstone is typically greenish yellow to dusky yellow green and greenish gray, medium bedded to thickly laminated, slabby to flaggy weathering, very fine to coarse grained, poorly to moderately sorted, slightly calcareous to noncalcareous, locally bioturbated by burrows and roots, and contorted by soft-sediment deformation. The thicker channel sequences usually have small-scale trough cross stratification and scour surfaces accentuated by pebble-size mudchips and chert and quartz granules, whereas thinner sandstone beds are commonly bioturbated.

Limestone is light gray, thinly to medium bedded and similar to the limestone in the underlying Salt Wash and Tidwell Members.

Because of its susceptibility to mass wasting, particularly landsliding, the Brushy Basin Member is relatively poorly exposed. Where exposed, it forms slopes. The Brushy Basin Member of the Morrison Formation rests disconformably above the Salt Wash Member (unnamed unconformity; R.G. Young, oral commun., Grand Junction, Colo., 1999). The contact between the two members was defined as the top of the highest thick sandstone of the Salt Wash below the mudstones of the Brushy Basin. Single-crystal, 40Ar/39Ar ages of feldspars from the Brushy Basin Member indicate that the age of the member is probably Tithonian and Kimmeridgian (Kowallis and others, 1991; Kowallis and others, 1998). The Brushy Basin Member is about 95 m thick at the prominent point 0.6 km east of the west boundary and 2.5 km north of the southern boundary of the map area near Little Park Road (Cole and others, 1999). (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Jms - Morrison Formation, Salt Wash Member (Upper Jurassic)

Jms - Salt Wash Member (Kimmeridgian)

The Salt Wash Member is a sandstone-rich cliff-forming unit sandwiched between the mudstone-rich, slope-forming Brushy Basin and Tidwell Members of the Morrison Formation. The Salt Wash Member was deposited in a fluvial setting iincluding associated flood plains and shallow ponds. The architecture of the channel-form sandstone bodies suggests that the fluvial channels were relatively thin (1 to 7 m), narrow (5 to 30 m), and moderately sinuous. An analog for this depositional setting exists where rivers empty into the modern-day Texas Gulf Coast.

Some of the best exposures of the Salt Wash Member of the Morrison Formation can easily be seen in road cuts on Rim Rock Drive south of Highland View Overlook.

The unit consists of 30 to 80% sandstone, 20 to 70% mudstone, and traces of limestone; the unit is well defined by Peterson (1994). Sandstone typically forms very pale orange, yellowish-gray and light-gray, channel-shaped bodies that range from 1 to 5 m thick and are very thinly bedded to very thickly bedded, slabby to blocky weathering, fine to medium grained, moderately sorted, slightly calcareous, and friable. Thicker sand bodies commonly exhibit small- to large-scale trough, tabular-tangential, and sigmoidal cross-bedding, as well as scour surfaces accentuated by granule- to pebble-size lag gravels composed of red and green mudstone, quartz, and chert. Elongate, narrow burrows are common near the tops of the thicker sand bodies.

Mudstone intervals consist of pale-brown to greenish-yellow, grayish-red, and yellowish-gray, silty claystone, siltstone, sandy siltstone, and mudstone. Mudstone ranges from 0.1- to 1-m-thick interbeds between sandstone channels, but can also exist as sequences as much as 15 m thick where sandstone channels are poorly developed. These mudstone bodies are commonly thickly to thinly laminated, flaggy to fissile weathering, slightly calcareous, slightly bentonitic, and commonly bioturbated by insect burrows and plant roots. Well-cemented, mottled mudstone intervals weather to form nodules. Thicker mudstone sequences commonly have thin interbeds and lenses of very fine to fine-grained, well-sorted sandstone.

Minor limestone beds are very similar to the limestone beds in the underlying Tidwell Member, are usually light gray to light olive gray, slightly sandy to silty, mottled, bioturbated, finely crystalline, slightly fossiliferous, containing ostracodes and charophytes, and have the mud-matrix-supported fabrics of carbonate mudstone, wackestone, and boundstone. These beds are present as scattered discontinuous beds less than 0.3 m thick and as beds of nodules within mudstone.

The Salt Wash-Brushy Basin contact is commonly obscured because of mass wasting. The base of the Salt Wash Member was defined during mapping as the top of the uppermost major limestone bed of the Tidwell Member (Jmt) below the thick sandstone beds of the Salt Wash Member. The Salt Wash Member exhibits considerable lateral variation in thickness and rock type within the quadrangle; on the east side of the map area, the member becomes only a few meters thick and may be locally absent in the adjacent Grand Junction quadrangle. The thickness of the member is 31 m at Artists Point on Rim Rock Drive (Cole and others, 1999). (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Jms - Salt Wash Member (Kimmeridgian)
Consists of sandstone (30–80%), mudstone (20–70%), and sparse limestone.

Sandstone is very pale orange, yellowish gray, and light gray, fine to medium grained, moderately sorted, slightly calcareous, and friable; it typically forms channel-form beds that range from 1 to 5 m thick, are very thinly to very thickly bedded, and are slabby to blocky weathering. Thicker sand bodies commonly exhibit small- to large-scale trough, tabular-tangential, and sigmoidal cross bedding, as well as scour surfaces accentuated by granule- to pebble-size lag gravels composed of red and green mudstone, quartz, and chert. Elongate, narrow burrows are common near the tops of the thicker sand bodies.

Mudstone intervals consist of pale-brown to greenish-yellow, grayish-red, and yellowish-gray, silty claystone, siltstone, sandy siltstone, and mudstone. Mudstone forms 0.1- to 1-m-thick interbeds between sandstone channels, but can also form sequences as thick as 15 m where sandstone channels are poorly developed. These mudstone bodies are commonly thickly to thinly laminated, flaggy to fissile weathering, slightly calcareous, slightly bentonitic, and commonly bioturbated by insect burrows and plant roots. Well-cemented, mottled mudstone intervals weather to form nodules. Thicker mudstone sequences commonly have thin interbeds and lenses of very fine to fine-grained, well-sorted sandstone.

Minor limestone is similar to limestone in the underlying Tidwell Member; it is typically light gray to light olive gray, slightly sandy to silty, mottled, bioturbated, finely crystalline and is slightly fossiliferous containing ostracodes and charophytes. It has the mud-supported fabrics of carbonate mudstone and wackestone. Limestone beds are laterally discontinuous, are less than 0.3 m thick, and form nodules within mudstone.

The Salt Wash Member is a cliff- and ledge-forming unit in contrast to the slope-forming Brushy Basin and Tidwell Members of the Morrison Formation. The base of the Salt Wash Member was defined during mapping as the top of the uppermost major limestone bed of the Tidwell Member (Jmt) below the thick sandstone beds of the Salt Wash Member. The Salt Wash Member exhibits considerable lateral variation in thickness and lithology within the quadrangle. Exposures are limited to the southwestern part of the map area. As the overlying Brushy Basin Member (Jmb) was assigned to the Tithonian and

Kimmeridgian Ages (Kowallis and others, 1991; Kowallis and others, 1998) and the underlying Tidwell Member (Jmt) was assigned to the Kimmeridgian and latest Oxfordian Ages (Kowallis and others, 1998), the Salt Wash is restricted to the Kimmeridgian. On the west side of the map area, the map unit is about 50 m thick but thins to only a few meters thick and may be locally absent south of the prominent point near Little Park Road. Farther to the southeast, the map unit thickens to as much as 30 m. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Jmt - Morrison Formation, Tidwell Member (Upper Jurassic)

Jmt - Tidwell Member (Kimmeridgian and Oxfordian)

The mudstone-rich Tidwell Member forms slopes that are broken by relatively thin ledges of sandstone and limestone; with rare exception, this is the only limestone in the map area. Within the Tidwell Member, the character and thickness of mudstone, sandstone, and limestone change significantly laterally.

The heterolithic nature of the Tidwell indicates that it was deposited in several environments. The green mudstone sequences and all of the limestone were probably deposited in a fresh- to brackish-water lacustrine setting. Tabular sandstone bodies characterized by horizontal stratification and oscillation ripples were deposited on beaches in lake-margin settings, whereas the channel-form sandstone bodies with cross-stratification were deposited by fluvial and distributary channel systems.

Excellent exposures of the Tidwell Member of the Morrison Formation can be seen in road cuts along Rim Rock Drive between Artists Point and Highland View Overlook.

The unit consists of laterally variable proportions of interbedded 50 to 70% mudstone, 10 to 40% sandstone, and 5 to 20% limestone; the unit is well defined by Peterson (1994). Mudstone typically consists of grayish-red to grayish-yellow-green sequences of siltstone, sandy siltstone, silty claystone, and mudstone, ranging in thickness from a few centimeters to more than 4 m. These sequences are commonly very thin bedded to thinly laminated, slabby to fissile weathering, mottled, bioturbated by roots and burrows, and slightly calcareous to very calcareous. Calcareous mudstone intervals have a nodular weathering aspect.

Sandstone is light gray to light greenish gray, very thinly bedded to very thickly bedded, slabby to blocky weathering, fine to medium grained, moderately to well sorted, calcareous, and locally bioturbated by roots and burrows. Sedimentary structures in sandstone include horizontal lamination; discontinuous, wispy, bedding-parallel lamination; wavy, bedding-parallel, hummocky lamination; small- to medium-scale trough and tabular-tangential cross-stratification; and asymmetric current and symmetric wave ripple stratification. Sandstone beds range in thickness from less than 1 cm to about 2 m and exhibit both tabular and channel-form cross-sectional geometry.

The lowermost sandstone package that defines the base of the Tidwell is informally called "A" bed, rests on the J-5 unconformity (Pipiringos and O'Sullivan, 1978), and is continuous throughout the quadrangle. The "A" bed, which is approximately 1 m thick, has a basal lag composed of oversize (medium-grained to granule) chert and lithic grains; similar granule lenses also occur within this bed.

Between 2 and 7 limestone beds are present and are most abundant in the upper half of the Tidwell. Limestone is typically light gray to light olive gray, dense, hard, slightly sandy or silty, very fine to finely crystalline, and resistant to weathering, forming slabby to blocky exposures. Most limestone is mottled and bioturbated by burrows, although stromatolitic lamination produced by algal (cyanobacteria?) growth is locally present. Oncolites (algal biscuits) are also found. Fossils are sparse and consist of ostracodes, charophytes, and very small gastropods. Petrographically, the Tidwell limestone is classified as carbonate mudstone, packstone, and boundstone (Dunham, 1962). Limestone beds range in thickness from several centimeters to about 1 m.

The Tidwell rests on the Wanakah Formation (Jw), which is below the J-5 unconformity (Peterson, 1994), whereas the upper contact with the overlying Salt Wash Member of the Morrison Formation is transitional. Because the map unit does not contain thin, parallel-bedded gypsiferous strata typical of the Summerville Formation south and west of the map area (Anderson and Lucas, 1998), the name Tidwell Member of the Morrison Formation is retained locally. The Tidwell Member is about 38 m thick at Artists Point along Rim Rock Drive (Cole and others, 1999). (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Jmt - Tidwell Member (Kimmeridgian to latest Oxfordian)
Consists of laterally variable proportions of interbedded mudstone (50–70%), sandstone (10–40%), and limestone (5–20%) (Cole and others, 1999).

Mudstone typically consists of grayish-red to grayish-yellow-green sequences of siltstone, sandy siltstone, silty claystone, and mudstone, ranging in thickness from a few centimeters to more than 4 m. These sequences are commonly very thin bedded to thinly laminated, slabby to fissile weathering, mottled, bioturbated by roots and burrows, and slightly calcareous to very calcareous. Calcareous mudstone intervals weather to form nodules.

Sandstone is light gray to light greenish gray, very thinly bedded to very thickly bedded, slabby to blocky weathering, fine to medium grained, moderately to well sorted, calcareous, and locally bioturbated by roots and burrows. Sedimentary structures in sandstone include horizontal lamination, discontinuous wispy bedding-parallel lamination, wavy bedding-parallel hummocky lamination, small- to medium-scale trough and tabular-tangential cross stratification, and asymmetric current and symmetric wave ripple stratification. Sandstone beds range in thickness from less than 1 cm to about 2 m and exhibit both tabular and channel-form cross-sectional geometries. The lowermost sandstone bed that defines the base of the Tidwell is informally called "A" bed (Pipiringos and O'Sullivan, 1978), rests on the J-5 unconformity, (Peterson, 1994), and is continuous throughout the quadrangle. The "A" bed, which is approximately 1 m thick, has a basal lag composed of medium-grained sand to granule composed of chert and lithic grains; similar granule lenses also occur within this bed.

Limestone is typically light gray to light olive gray, dense, hard, slightly sandy or silty, very fine to finely crystalline, and resistant to weathering forming slabby to blocky exposures. Most limestone is mottled and bioturbated by burrows, although stromatolitic lamination produced by algal (cyanobacteria?) growth and oncoids is locally present. Fossils are sparse and consist of ostracodes, charophytes, and very small gastropods. Petrographically, the Tidwell limestones are classified as carbonate mudstone and packstone (Dunham, 1962). Limestone beds range in thickness from several centimeters to about 1 m and are most abundant in the upper half of the Tidwell. Between two and seven limestone beds are present.

Within the Tidwell Member, the lithologic character of mudstone, sandstone, and limestone significantly changes laterally. This slope-forming unit rests on the Wanakah Formation (Jw), which is below the J-5 unconformity (Peterson, 1994), whereas the upper contact with the overlying Salt Wash Member of the Morrison Formation is transitional. For mapping purposes, the upper contact of the Tidwell Member was placed at the base of the thick sandstone intervals of the Salt Wash Member. These sandstone intervals are discontinuous and lenticular, and therefore this contact and thicknesses of adjacent units are irregular. Anderson and Lucas (1998) considered the strata below the Salt Wash Member southwest of the map area to be the Summerville Formation because of the presence of thin, parallel-bedded gypsiferous strata typical of the Summerville Formation there. The lack of this distinctive lithology in the map unit indicates that the Tidwell Member of the Morrison Formation nomenclature should be retained in the map area. Also, most of the Summerville is truncated beneath the J-5 unconformity (O'Sullivan 1991). O'Sullivan (1992) indicated that the Tidwell is Kimmeridgian Age, but subsequent 40Ar/39Ar sanidine dating suggest that the Tidwell is Kimmeridgian to latest Oxfordian (Kowallis and others, 1998). The Tidwell Member ranges from about 30 to 45 m thick where exposed in the southwestern part of the map area. (*GRI Source Map ID 1815*) (Grand Junction Quadrangle).

Jw - Wanakah Formation (Middle Jurassic)

Jw - Wanakah Formation (Middle Jurassic; Callovian)
In Colorado National Monument, the mudstone-rich, slope-forming Wanakah is recognized easily by its distinctive green-over-red colors and by a noticeable reduction of vegetation. The depositional setting for the Wanakah is nonmarine mudflat and (or) shallow lacustrine environment.

Total exposure of the Wanakah Formation is available at Artists Point on Rim Rock Drive.

The Wanakah Formation consists of 80 to 90% interstratified mudstone, 5 to 15% sandstone and silty sandstone, 0 to 5% impure limestone, and traces of volcanic ash and gypsum. Mudstone consists of reddish-brown, grayish-red-purple, yellowish-brown, pale-olive, and greenish-gray siltstone, sandy siltstone, and mudstone. The greenish-gray mudstone is dominant in the upper half of the unit. Mudstone intervals are medium to thinly laminated and are platy, fissile and nodular weathering, mottled, bioturbated by burrows and roots, slightly calcareous, and non-bentonitic.

Sandstone, which occurs as very thin to thin, slabby weathering interbeds and discontinuous lenses in mudstone, is typically light brown to light gray, very fine to fine grained, moderately to well sorted, silty, bioturbated, and calcareous. The sandstone displays discontinuous horizontal lamination and asymmetric ripple lamination.

Limestone forms gray to grayish-red and light-gray, sandy to silty, bioturbated, discontinuous nodules that are usually less than 5 cm in diameter.

Radiometric analysis shows a large positive gamma-ray anomaly approximately 5 m above the base that is associated with several light-grayish-green, volcanic ash laminae less than 1 cm thick (Cole and others, 1999). The Wanakah is truncated by the J-5 unconformity (Pipiringos and O'Sullivan, 1978), which shows minimal erosional relief throughout the map area. Beneath the unconformity, the upper several meters of the Wanakah have numerous well-developed root traces. The base of the Wanakah Formation is defined at the base of the red mudstone that rests on the very pale orange to very light gray sandstone beds of the upper informal "board beds" unit of the Entrada Sandstone. The map unit is 9.4 m thick at Artists Point on Rim Rock Drive, which rims the canyons at the Monument (Cole and others, 1999). (*GRI Source Map ID 1088*) (Colorado NM and Adjacent Areas).

Jw - Wanakah Formation (Middle Jurassic; Callovian)
Consists of interstratified mudstone (70–80%), sandstone and silty sandstone (5–15%), impure limestone (0–5%), and traces of volcanic ash and gypsum.

Mudstone consists of reddish-brown, grayish-red-purple, yellowish-brown, pale-olive, and greenish-gray siltstone, sandy siltstone, and mudstone. The greenish-gray mudstone occurs chiefly in the upper half of the unit. Mudstone intervals are medium to thinly laminated and are platy, fissile and nodular weathering, mottled, bioturbated by burrows and roots, slightly calcareous, and nonbentonitic. Sandstone forms very thin to thin, slabby weathering interbeds and discontinuous lenses in the mudstone sequence and is typically light brown to light gray, very fine to fine grained, moderately to well sorted, silty, bioturbated, and calcareous.

The sandstone displays discontinuous horizontal lamination and asymmetric ripple lamination, and the limestone forms gray to grayish-red and light-gray, sandy to silty, bioturbated, discontinuous nodules that are commonly less than 5 cm in diameter.

Radiometric analysis of the formation shows a large positive gamma-ray anomaly, which is associated with several light-grayish-green, volcanic ash laminae less than 1 cm thick, approximately 5 m above the base of the unit (Cole and others, 1999). This interval and adjacent layers contain expansive clay that is associated with damaged road surfaces. The Wanakah is a slope-forming unit.

The Wanakah is truncated by the J-5 unconformity (Pipiringos and O'Sullivan, 1978), which shows minimal erosional relief throughout the quadrangle. Beneath this unconformity, the upper several meters of the Wanakah have numerous well-developed root traces. The base of the Wanakah Formation is defined at the base of the red mudstone that rests on the very pale orange to very light gray sandstone beds of the upper informal "board beds" unit of the Entrada Formation. The Wanakah Formation was previously called the Summerville Formation in Colorado National Monument (Lohman, 1963, 1981). Although stratigraphic correlations by O'Sullivan (1980, 1992) suggest that the Summerville does not exist in western Colorado, more recent work of Anderson and Lucas (1998) proposed that the name Summerville Formation is appropriate for strata below the Salt Wash Member south and west of the map area. Whether the Summerville Formation as defined by Anderson and Lucas includes the Wanakah is unclear, but in the map area the term Wanakah is retained. The base of the Wanakah Formation is readily recognized in the field or on aerial photographs because of the distinctive red color of the lower part of the map unit. The Wanakah is assigned to the Callovian Age (O'Sullivan, 1992; Peterson, 1994). The map unit is 10 m thick where exposed in the southwestern part of the map area. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Jwe - Wanakah Formation and Entrada Sandstone, undivided (Middle Jurassic)

These undivided units are shown in cross sections only. (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Jwek - Wanakah Formation, Entrada Sandstone and Kayenta Formation, undivided (Middle and Lower Jurassic)

At localities along the mountain front where these steeply dipping, thin map units are exposed, the units are undivided. (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Entrada Sandstone

Entrada Sandstone (Middle Jurassic; Callovian)
The Entrada Sandstone consists of two parts, the prominent white cap of the upper unit informally called the "board beds" and the pale-orange, ribbon-like lower Slick Rock Member. (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Entrada Formation (Middle Jurassic; Callovian)
Consists of two parts, an upper informal unit locally called the "board beds" and the lower Slick Rock Member. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Jeb - Entrada Sandstone, board beds unit (Middle Jurassic)

Jeb - “Board beds” unit (Middle Jurassic)
Interbedded resistant sandstone and less resistant mudstone form slabby exposures that resemble a stack of boards, giving the "board beds" unit its informal name. This unit was deposited in a wet sand flat environment in a coastal setting. The western coast of Baja California, Mexico, at Guerrero Negro, may be a possible modern-day analog (Fryberger and others, 1990).

Good road cut exposures of the "board beds" unit of the Entrada Sandstone are found along Rim Rock Drive north of Artists Point.

The "board-beds" unit consists of 60 to 70% interbedded sandstone and 30 to 40% mudstone. Sandstone is very pale orange to very light gray, white, and pinkish gray, thin to thick bedded, slabby to blocky weathering, very fine to fine grained, moderately to well sorted, intensely mottled by bioturbation, and calcareous. Stratification is rare and consists of discontinuous, wispy horizontal lamination and small-scale sets of tabular-tangential cross-lamination of grain flow and wind ripple structures. Southwest of No Thoroughfare Canyon, sandstone beds locally contain gray petroleum residue (dead oil).

Mudstone is reddish brown to grayish red, thickly to thinly laminated, flaggy to fissile weathering and contains siltstone and sandy siltstone, which is typically bioturbated.

The base of the unit is defined as the top of the orange-pink, cross-bedded Slick Rock Member (Jes) of the Entrada. The thickness of the "board beds" unit is about 13 m along Upper Monument Canyon Trail (Cole and others, 1999). (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Jeb - “Board beds” unit (Middle Jurassic)
Consists of interbedded sandstone (60–70%) and mudstone (30–40%). Sandstone is very pale orange to very light gray, white, and pinkish gray, thin to thick bedded, slabby to blocky weathering, very fine to fine grained, moderately to well sorted, intensely mottled by bioturbation, and calcareous. Internal stratification is rare and consists of discontinuous, wispy horizontal lamination and small-scale sets of tabular-tangential cross lamination of grain flow and wind ripple. Mudstone consists of reddish-brown to grayish-red, thickly to thinly laminated, flaggy to fissile weathering, siltstone and sandy siltstone, which is typically bioturbated. The base of the unit is defined at the top of the orange-pink, cross-bedded Slick Rock Member (Jes) of the Entrada.

The prominent white cap of the “board beds” unit above the Slick Rock Member differs significantly from the Moab Member of the Entrada Sandstone that is present southwest of the map area. Therefore, the stratigraphic nomenclature of Lohman (1963, 1981) for this unit is not retained in this report, and an informal name “board beds” unit is accepted here following O’Sullivan and Pipiringos (1983) until further stratigraphic studies are performed. The thickness of the “board beds” unit ranges from about 10 to 15 m where exposed in the southwestern part of the map area. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Jes - Entrada Sandstone, Slick Rock Member (Middle Jurassic)

Jes - Slick Rock Member (Middle Jurassic)
The Slick Rock Member of the Entrada Formation forms a conspicuous pale-orange, ribbon-like cliff or rounded bench that is almost totally free of vegetation below its white cap of the "board beds" unit.

The Slick Rock Member was deposited in a coastal eolian setting. Dunes were probably not large and had maximum heights between 10 and 20 m. Sand transport was toward the west, southwest, and northwest. Wet sand flats, which were related to high water tables and interdune areas, were commonly associated with dunes. An analog for the Slick Rock eolian system can be found in Baja California, Mexico, at Guerrero Negro (Fryberger and others, 1990).

One of the best places to observe the Slick Rock Member of the Entrada Sandstone is the isolated hill by the north side of the roadway about 400 meters west of the Red Canyon Overlook on the north side of Rim Rock Drive.

The map unit consists almost entirely (99%) of cross-bedded sandstone. The sandstone is orange pink to pale reddish orange, very thinly to very thickly bedded, slabby to blocky weathering, very fine to fine grained, moderately to well sorted, commonly mottled by bioturbation, and calcareous. Cementation is weak. Stratification, when present, consists of small- to large-scale sets of trough, tabular-tangential, tabular-planar, and wedge-planar cross-stratification, as well as discontinuous, wispy horizontal lamination structures. Cross-strata sets are mainly composed of wind-ripple lamination; grain-flow lamination is rare. Bioturbation increases upward and is commonly associated with first-order bounding surfaces.

This member rests on the reddish-orange, thinly bedded sandstone of the Kayenta Formation. The thickness of the Slick Rock Member is 34 m along the Upper Monument Canyon Trail (Cole and others, 1999). (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Jes - Slick Rock Member (Middle Jurassic)
Consists almost entirely (99%) of sandstone, which is orange pink to pale reddish orange, very thinly to very thickly bedded, slabby to blocky weathering, very fine to fine grained, moderately to well sorted, commonly mottled by bioturbation, calcareous, and weakly cemented. Stratification, where present, consists of small- to large-scale sets of trough, tabular-tangential, tabular-planar, and wedge-planar cross stratification, as well as discontinuous, wispy horizontal lamination. Cross-strata sets are mainly composed of wind-ripple lamination; grain-flow lamination is rare. Bioturbation increases upward and is commonly associated with first-order bounding surfaces. The member commonly forms a conspicuous rounded bench or cliff and rests on the reddish-orange, thinly bedded sandstone of the Kayenta Formation. The Slick Rock Member of the Entrada Formation rests on the J-2 unconformity (Pipiringos and O'Sullivan, 1978; O'Sullivan and Pipiringos, 1983); erosional relief on the J-2 unconformity is as much as 3 m. The Slick Rock Member is Callovian Age (Peterson, 1988a). The thickness of the Slick Rock Member is about 30 m in the southwestern part of the map area. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Jk - Kayenta Formation (Lower Jurassic)

Jk - Kayenta Formation (Lower Jurassic; Pliensbachian)
The Kayenta Formation commonly forms resistant ledges above the cliff-forming Wingate Sandstone (Jwg) and also forms cliffs in several areas. Sandstone is present throughout the Kayenta, whereas conglomerate and mudstone are found mainly in the upper half.

The formation was deposited by high-energy braided-river systems. Sediment transport directions were to the west-northwest. Modern rivers draining the Rocky Mountains, such as the parts of the South Platte and Rio Grande Rivers that are in the plains, are good analogs for the depositional systems of the Kayenta Formation.

The ledge formed by the Kayenta Formation is followed by Rim Rock Drive in many areas; the Kayenta is particularly well exposed in road cuts between above the Monument Headquarters and the tunnels uphill from the West Entrance of the Monument.

The Kayenta consists of 80 to 90% sandstone, 0 to 10% conglomerate, and 0 to 10% mudstone; the unit is well defined by Peterson (1994). Sandstone is typically reddish orange, grayish orange pink, light greenish gray, or white, thin to very thin bedded with slabby bedding, fine to medium grained, moderately to well sorted, and cemented by a mixture of carbonate and quartz. Sandstone sequences in the Kayenta contain numerous amalgamated scour surfaces that commonly have lag gravels consisting of mudstone clasts. Conglomerate is found in channel-form sequences composed of granule- to cobble-size clasts of reddish-orange mudstone in a matrix of medium-grained, moderately sorted, light-greenish-gray sandstone; clasts are typically graded.

Mudstone consists of reddish-brown to grayish-red, thinly laminated, fissile-weathering, moderately to well-sorted siltstone and sandy siltstone; mudstone may be locally bioturbated.

Stratification is well developed in the Kayenta Formation and consists of small- to medium-scale sets of low-angle, even-parallel lamination, tabular-tangential cross-stratification, and trough cross-stratification; streaming and parting lineations are also common. The base of the Kayenta Formation is marked by the sharp break from small- to medium-scale cross-beds of siliceously cemented sandstone and mudstone to the more massive, large-scale sets of cross-stratification of the sandstone of the Wingate Sandstone. The Kayenta Formation is about 23.5 m thick along Upper Monument Canyon Trail (Cole and others, 1999). (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Jk - Kayenta Formation (Lower Jurassic; Pliensbachian and Sinemurian)
Consists of sandstone (80–90%), conglomerate (0–10%), and mudstone (0–10%).

Sandstone is present throughout the Kayenta, whereas conglomerate and mudstone are found mainly in the upper half. Sandstone is typically reddish orange, grayish orange pink, light greenish gray, or white, fine to medium grained, moderately to well sorted, and cemented by a mixture of carbonate and quartz; it forms thin to very thin beds and slabby beds. Sandstone sequences in the Kayenta contain numerous amalgamated scour surfaces that commonly have lag gravels consisting of mudstone clasts.

Conglomerate forms channel-form sequences composed of granule- to cobble-size clasts of reddish-orange mudstone in a matrix of medium-grained, moderately sorted, light-greenish-gray sandstone; clasts are typically graded.

Mudstone consists of reddish-brown to grayish-red, thinly laminated, fissile-weathering, moderately to well-sorted siltstone and sandy siltstone; mudstone may be locally bioturbated.

Stratification is well developed in the Kayenta Formation and consists of small- to medium-scale sets of low-angle, even-parallel lamination, tabular-tangential cross stratification, and trough cross stratification; streaming and parting lineations are also common. The Kayenta commonly forms resistant ledges above the cliff-forming Wingate Sandstone (Jwg), but also forms cliffs in several areas. The base of the Kayenta is marked by the sharp break from small- to medium-scale cross beds of siliceously cemented sandstone and mudstone to the more massive, large-scale sets of cross stratification of the sandstone of the Wingate Formation. The Kayenta was tentatively assigned to Pliensbachian and Sinemurian Ages by Peterson and Pipiringos (1979), then restricted by Peterson (1988b) to Pliensbachian and Sinemurian Ages, and most recently further restricted by Peterson (1994) to Pliensbachian. The Kayenta Formation is about 25 m thick in exposures in the southwestern part of the map area. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Jwg - Wingate Sandstone (Lower Jurassic)

Jwg - Wingate Sandstone (Lower Jurassic; Pliensbachian? and Hettangian)
The Wingate Sandstone forms the magnificent 100-m-high, orange cliffs that give the Colorado National

Monument its most spectacular vistas.

The map unit was deposited in an eolian setting that was on the northeast margin of a large dune area, or erg, that occupied most of the Four Corners area in Late Triassic and Early Jurassic time (Peterson, 1994). During periods of aridity, Wingate dunes were probably 30 to 45 m high, and they migrated towards the south-southeast. Smaller dune complexes, wet sandflats signifying high water tables, and interdune areas were most prevalent during more humid climatic conditions. The largest dune deposits are found in the upper half of the Wingate. An analog for the Wingate dune complex can be found in the modern-day Sahara Desert of North Africa.

Good road cut exposures of the Wingate Sandstone can be reached from the West Entrance of the Monument between the Chinle Formation (TRc) and the tunnels.

The Wingate consists of about 95% sandstone and about 5% mudstone; the unit is well defined by Peterson (1994). Sandstone is typically orange pink to reddish orange, thin to very thickly bedded, slabby to blocky weathering, very fine to fine grained, moderately to well sorted, calcareous, well stratified, and partly mottled and bioturbated by roots and burrows. Stratification, when present, consists of small- to very large scale sets of even-parallel horizontal lamination, discontinuous even-parallel lamination, tabular-tangential cross-stratification, tabular-planar cross-stratification, wedge-planar cross-stratification, and trough cross-stratification. Wind-ripple lamination dominates the horizontal stratification sets, whereas wind-ripple lamination and grain-flow lamination characterize most large-scale sets of cross-stratification.

Mudstone intervals are dominated by siltstone and sandy siltstone, which are typically light brown to light reddish brown and reddish brown, thickly to thinly laminated, flaggy to fissile weathering, and generally mottled and bioturbated by roots(?). Stratification in mudstone is sparse, usually consisting of discontinuous horizontal lamination, wispy lamination, and rare current-ripple lamination.

In the map area, at least nine first-order bounding surfaces with associated mudstone interdune deposits are found in the Wingate, suggesting that it was deposited by a series of dune complexes, or draas, that fluctuated in size and shape in accordance with climatic variations. The thickness of the map unit is 100 m along Upper Monument Canyon Trail (Cole and others, 1999). (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Jwg - Wingate Sandstone (Lower Jurassic; Pliensbachian to Hettangian)
Consists of about 95% sandstone and about 5% mudstone.

The sandstone is typically orange pink to reddish orange, thin to very thickly bedded, slabby to blocky weathering, very fine to fine grained, moderately to well sorted, calcareous, well stratified, and partly mottled and bioturbated by roots and burrows. Stratification, when present, consists of small- to very large scale sets of even-parallel horizontal lamination, discontinuous even-parallel lamination, tabular-tangential cross stratification, tabular-planar cross stratification, wedge-planar cross stratification, and trough cross stratification. Wind-ripple lamination dominates the horizontal stratification sets, whereas wind-ripple lamination and grain-flow lamination characterize most large-scale sets of cross stratification.

Mudstone is interbedded with siltstone and sandy siltstone, which are typically light brown to light reddish brown and reddish brown, thickly to thinly laminated, flaggy to fissile weathering, and generally mottled and bioturbated by roots(?). Stratification in mudstone is rare, usually consisting of discontinuous horizontal lamination, wispy lamination, and sparse current-ripple lamination.

The Wingate Sandstone is the major cliff-forming unit in Colorado National Monument in the southwestern part of the map area. The Wingate has been assigned to the Hettangian Age based on dinosaur fossils (Padian, 1989), but more recently to Pliensbachian to Hettangian Ages by Peterson

(1994). The thickness of the map unit is about 100 m. (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

TRc - Chinle Formation (Upper Triassic)

TRc - Chinle Formation (Upper Triassic; Norian and Carnian)
The distinct red slopes formed by the Chinle Formation underlie the towering cliffs of the Wingate Sandstone (Jwg), and in turn, rest on the great angular unconformity on dark Proterozoic basement rocks.

Excellent exposures of the Chinle are found in the road cut above the dark Proterozoic rocks and below the Wingate Sandstone in Fruita Canyon.

Sedimentologic characteristics of the Chinle suggest deposition in a densely vegetated flood plain or mud flat, containing localized shallow ponds and small, shallow, sinuous streams. Water-table fluctuations were common during deposition. Similar environments exist today in subtropical to tropical areas of South America and Africa.

The Chinle consists of interbedded 80 to 90% mudstone, 0 to 10% sandstone, 0 to 5% sandy conglomerate, and 0 to 5% limestone; the unit is well defined by Dubiel (1994). Mudstone consists of reddish-brown to reddish-orange and grayish-purple, thickly to thinly laminated, flaggy to fissile and nodular-weathering, calcareous to very calcareous, mottled, bioturbated, silty claystone, clayey siltstone, and sandy siltstone. Carbonate nodules (rhizocretions?), root traces, and burrows (crayfish?) are common.

Sandstone occurs as small, channel-form bodies that are reddish orange to grayish red-purple, thin to medium bedded, slabby weathering, fine to very coarse grained, and very poorly sorted. Sandstone commonly contains conglomeratic mudchips. Sedimentary structures are poorly developed, consisting of cross-stratification, ripple-stratification, and horizontal lamination.

Conglomerate also forms channel-shaped bodies that are reddish orange to grayish red-purple, medium to thick bedded, slabby to blocky weathering, calcareous, very poorly sorted, and sandy to silty. Clasts are normally graded, consisting of pebble- to cobble-size mudstone and reworked carbonate nodules.

Limestone is reddish orange, very thin to medium bedded, slabby weathering, sandy to silty, and typically mottled and bioturbated. Some limestone beds have 1-5-cm-thick stromatolitic (algal?) structures.

The map unit is about 27 m thick along the Upper Monument Canyon Trail (Cole and others, 1999). (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

TRc - Chinle Formation (Upper Triassic)
Shown in cross section only. Consists of interbedded reddish-brown to reddish-orange and grayish-purple mudstone, sandstone, sandy conglomerate, and limestone. The map unit is about 30 m thick in the Colorado National Monument quadrangle (Cole and others, 1999). (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Yl - Lamprophyre dikes (Middle Proterozoic)

Lamprophyre dikes are slightly altered, thin, dark-greenish-gray to greenish-black dikes.

One of these dikes can be visited by following the No Thoroughfare Canyon trail upstream about 0.5 km from Devils Kitchen to a major drainage junction. Follow the left drainage about 250 m to the locality where the dark dike crosses the drainage.

The rock contains phenocrysts of biotite, hornblende, and pyroxene in a fine-grained matrix. Dikes are 2 to 3 m thick and are present in the northeastern part of No Thoroughfare Canyon and at the junction of Red and Columbus Canyons. The dikes are subparallel and dip to the southeast at 50 to 73o. The lamprophyre dike in No Thoroughfare Canyon was dated at about 1,400 Ma by the 40Ar/39Ar method (M. J. Kunk, written commun., U.S. Geological Survey, 2000). (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Xi - Meta-igneous gneiss (Early Proterozoic)

Meta-igneous gneiss is metamorphosed granite that contains minor xenoliths of host rock and is exposed chiefly in the eastern part of Ute Canyon. Meta-igneous bodies in and near Ute, Red, Columbus, and Gold Star Canyons are probably part of a single pluton, here called the Ute Canyon stock.

The best access to the meta-igneous gneiss is found by following the lower trail head of the Liberty Cap trail to the junction with the Ute Canyon trail (not shown on map) below Liberty Cap. From there, non-weathered exposures can be found by following the Ute Canyon trail about 400 m upstream to stream crossings on the gneiss.

The meta-igneous gneiss is pinkish gray to medium gray, coarse grained, contains very coarse grained relict igneous phenocrysts of subhedral to euhedral alkali feldspar, and has a penetrative, but weakly to moderately developed, schistosity that is defined by aligned biotite. The xenoliths, which locally form 5 to 10% of the rock, consist of the dark-colored part of the migmatitic meta-sedimentary host rock and range from 0.1 to 3 m wide. The meta-igneous gneiss contains 20 to 40% anhedral quartz, 20 to 40% subhedral biotite, 10 to 30% euhedral, twinned, relict phenocrysts of alkali feldspar 1 to 4 cm long, and 10 to 20% subhedral plagioclase. During alteration and weathering, quartz grains were coated by a red hematitic stain and some of the biotite was altered to chlorite.

The age of emplacement of the igneous body is estimated to be 1,721±14 Ma based on the preliminary discordant U/Pb zircon date (sample Ute1, D.M. Unruh, unpub. data by written commun., U.S. Geological Survey, 1999) of the meta-igneous gneiss collected from the pluton in Ute Canyon. Nearly vertical contacts with the surrounding migmatitic meta-sedimentary gneiss (Xm) country rock are poorly exposed but appear to be discordant with structures in that country rock. The lower contact of the meta-igneous gneiss is not exposed. The upper part of the meta-igneous body has been removed by erosion and is overlain by the Chinle Formation (TRc). (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

Xm - Migmatic meta-sedimentary rocks (Early Proterozoic)

The migmatitic meta-sedimentary rocks consist of a complexly folded mixture of dark schist and light migmatitic pegmatite found in the bottoms of most of the canyons at the Monument.

Good exposures of the migmatitic meta-sedimentary rocks can be reached by trails (not shown on map) into either the North Entrance or the East Entrance to Monument Canyon. The freshest exposures are in the deepest drainages off the trails.

The sedimentary rock protolith probably included graywacke, arkose, lithic arkose, subarkose, and probably some shale. Meta-sedimentary rocks include 65% schist, 35% migmatitic pegmatite, and sparse boudins of calc-silicate rock. The map unit also includes a minor amount of post-metamorphic, tourmaline-bearing, pegmatite dikes.

Medium- to high-grade amphibolite metamorphism partially melted the original graywacke to arkosic sedimentary rocks, producing 1) unmelted masses of higher-melting-temperature ferromagnesian minerals (melanosome) that formed the schist and 2) a melt that crystallized to form the lower-temperature-melting quartz- and feldspar-bearing pegmatite (leucosome).

The schist is a mixture of streaky light-gray to dark-gray and pinkish-gray micaceous rock that contains 10 to 100% biotite, 0 to 85% quartz, 0 to 40% plagioclase, 0 to 25% alkali feldspar, 0 to 10% muscovite, 0 to 10% muscovite pseudomorphs after sillimanite, and 0 to 10% garnet. The schist has been deformed during metamorphism to create tabular, discontinuous zones of dark, well-foliated, fine- to medium-grained rock that typically has pod-shaped masses and tight elliptical to isoclinal folds. Some of the schist contains porphyroblasts of muscovite, garnet, or sillimanite. Pseudomorphs of muscovite or alkali feldspar after sillimanite(?) are common.

The calc-silicate rock is greenish white to greenish brown and fine grained. It consists of pods, or boudins, that contain 40 to 70% epidote, 20 to 50% quartz, and 1 to 10% garnet.

Migmatitic pegmatites are pinkish gray to pinkish white, are coarse grained (1-3 cm), and contain 20 to 80% alkali feldspar, 15 to 80% quartz, 0 to 10% biotite, 0 to 2% garnet, and 0 to 3% muscovite. Deformation during metamorphism has created pinch-and-swell, ptygmatic, commonly symmetrical, elliptical, and tight to isoclinal folds in the pegmatitic layers that are commonly a few millimeters to 10 cm wide; however, some sheet-like dikes are as much as 3 m wide.

The post-metamorphic pegmatite dikes are distinctly different from migmatitic pegmatites in that the post-metamorphic pegmatites intrude all the metamorphic rock types described above and are less deformed than the host rock. Post-metamorphic pegmatites form only 2-3-m-wide dikes and contain coarse- to very coarse grained minerals that consist of 35 to 85% alkali feldspar, 10 to 20% quartz, 0 to 10% plagioclase, 0 to 10% biotite, 0 to 5% muscovite, and 0 to 5% tourmaline. These dikes probably are comagmatic with the Vernal Mesa Quartz Monzonite.

The preliminary discordant U/Pb zircon date (obtained from sample NT11C, D.M. Unruh, unpub. data, written commun., U.S. Geological Survey, 1999) of the schistose part of the meta-sedimentary rocks is 1,741 ± 11 Ma; it is not clear whether the date represents the age of old rocks that were eroded to produce the sediments or the age of metamorphism. However, the short 20-m.y. interval between the dates for the intrusive meta-igneous gneiss (Xi) and the meta-sedimentary country rocks suggests that the 1,741-Ma date is the age of metamorphism. (*GRI Source Map ID 1088)* (Colorado NM and Adjacent Areas).

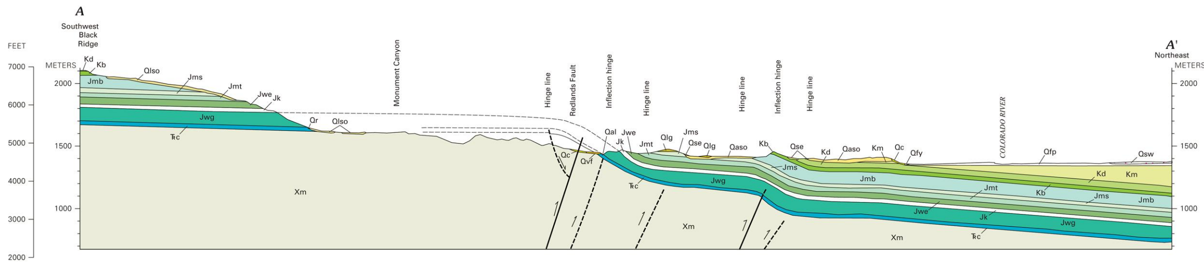
Xu - Meta-igneous gneiss and migmatic meta-sedimentary rocks, undivided (Early Proterozoic)

Shown in cross section only. For more detailed description see Scott and others (2001). (*GRI Source Map ID 1815)* (Grand Junction Quadrangle).

Geologic Cross Sections

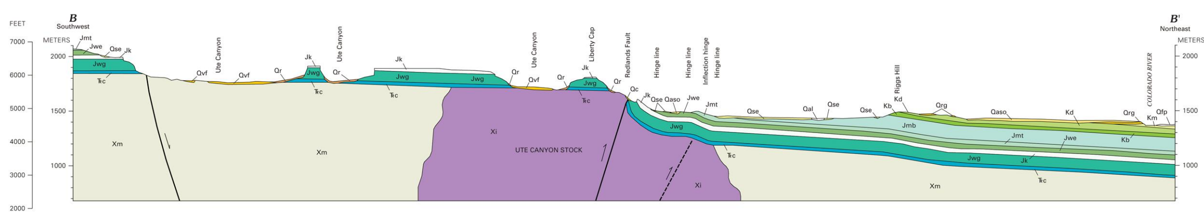
The geologic cross sections present in the GRI digital geologic-GIS data produced for Colorado National Monument, Colorado (colm) are presented below. Note that some cross section abbreviations (e.g., A - A') may have been changed from their source map abbreviation in the GRI data so that each cross section abbreviation in the GRI data is unique. Cross section graphics were scanned at a high resolution and can be viewed in more detail by zooming in (if viewing the digital format of this document).

Cross Section A-A'



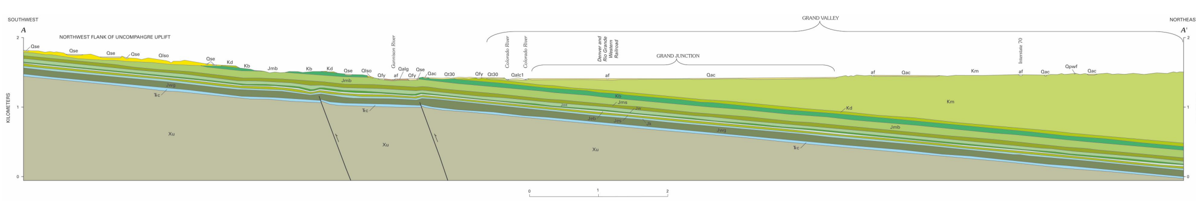
Extracted from: [Colorado NM and Adjacent Areas](#).

Cross Section B-B'



Extracted from: [Colorado NMON and Adjacent Areas](#).

Cross Section C-C'



This cross section is A-A' on the source publication, however, this was changed to C-C' upon compilation of the two source maps so that each cross section possessed a unique cross section (letter) abbreviation.

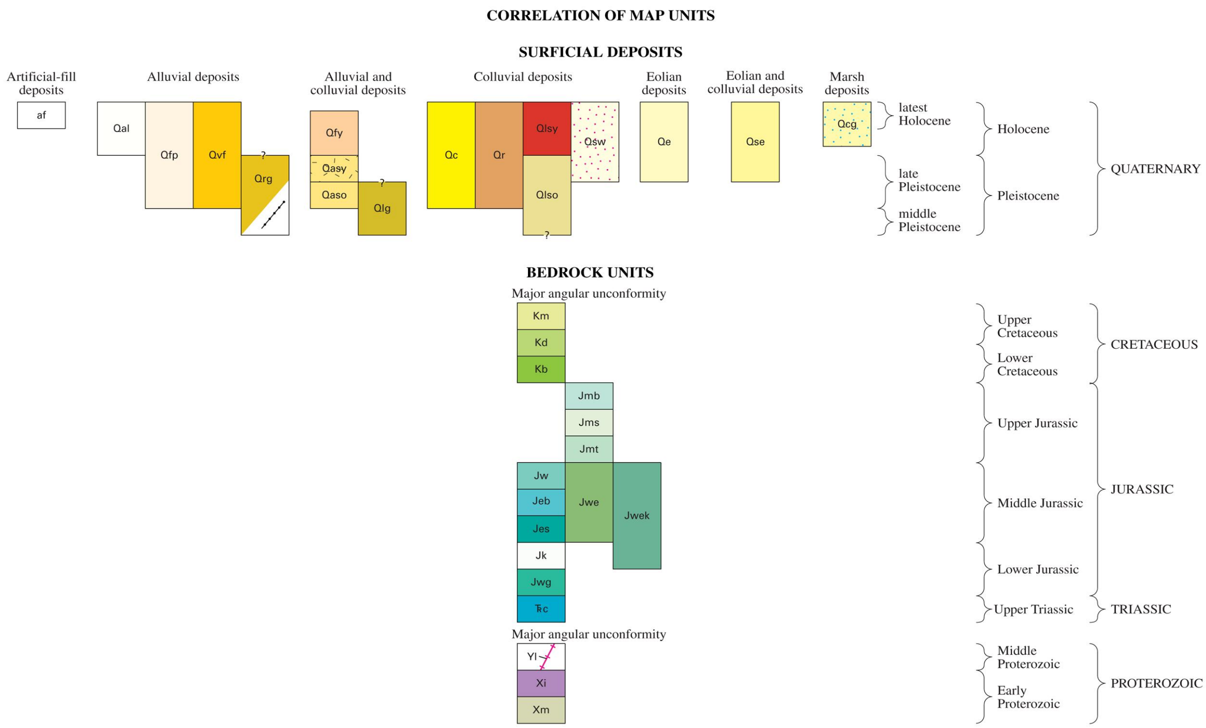
Extracted from: [Grand Junction Quadrangle](#).

GRI Ancillary Source Map Information

Colorado NMON and Adjacent Areas Map (U.S. Geological Survey Map I-2740)

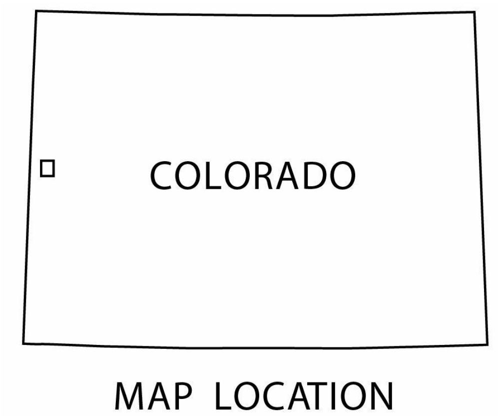
Scott, R.B., Harding, A.E., Hood, W.C., Cole, R.D., Livaccari, R.F., Johnson, J.B., Shroba, R.R., and Dickerson, R.P., 2001, Geologic Map of the Colorado National Monument and Adjacent Areas, Mesa County, Colorado: U.S. Geological Survey, Geologic Investigations Series Map, I-2740, scale 1:24,000 (*GRI Source Map ID 1088*).

Correlation of Map Units



Extracted from: Colorado NMON and Adjacent Areas.

Index/Location Map



Extracted from: Colorado NMON and Adjacent Areas.

Map Legend

Contact

High-angle reverse fault—Dashed where approximately located, dotted where concealed, teeth on upthrown side, arrow and number indicate dip of fault plane

Normal fault—Dashed where approximately located, dotted where concealed, bar and ball on downthrown side; arrow and number indicate dip of fault plane, diamond and number indicate trend and plunge of slickenlines

Area of alkali deposit on Cienaga deposits

Breakaway scarp of landslide—Hachures face landslide

Strike and dip of inclined beds

Strike and dip of overturned beds

Strike and dip of inclined bed—Calculated from map outcrop-pattern geometry

Horizontal beds—Calculated from map outcrop-pattern geometry

Strike and dip of inclined foliation of metamorphic rocks

Vertical foliation of metamorphic rocks

Trend and plunge of fold axes or mineral lineations of metamorphic rocks

Prospect pit

C10 **Radiometric date sample location**

Hinge line

Foot trail

Ephemeral artificial pond

Monument boundary

Extracted from: Colorado NMON and Adjacent Areas.

Figure 1: Regional geographic features in western Colorado and eastern Utah

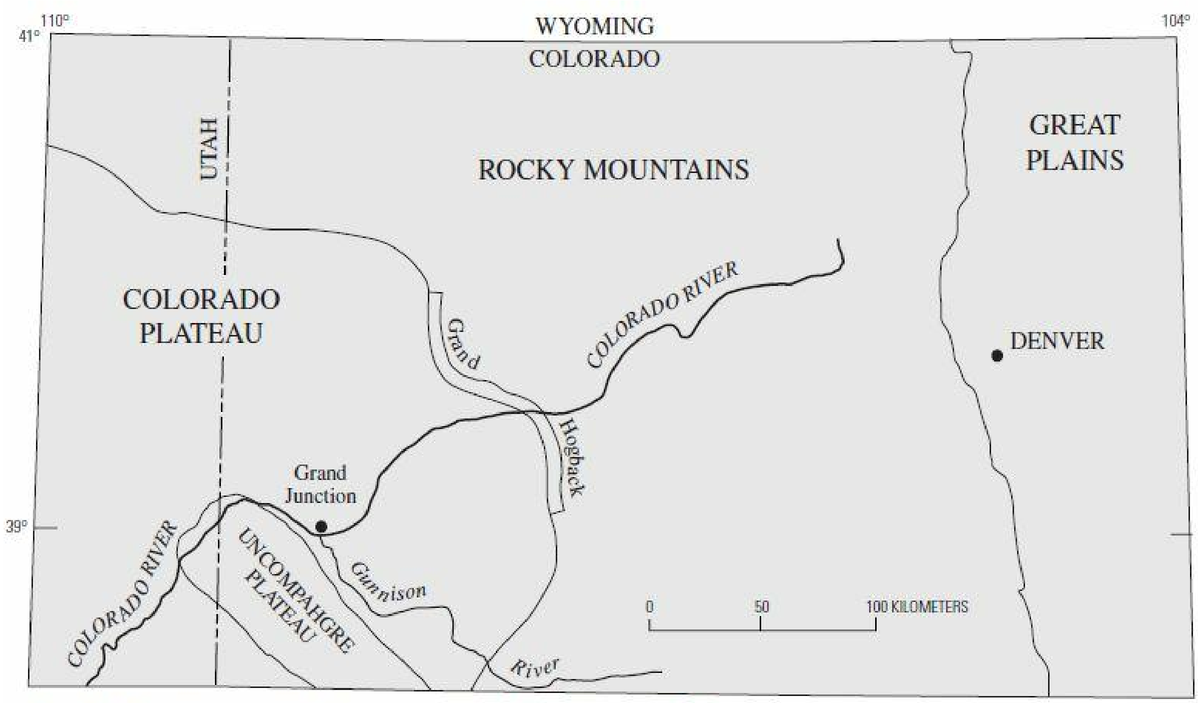


Figure 1. Regional geographic features in western Colorado and eastern Utah.

Extracted from: Colorado NMON and Adjacent Areas.

Figure 2: Geographical features near the map area

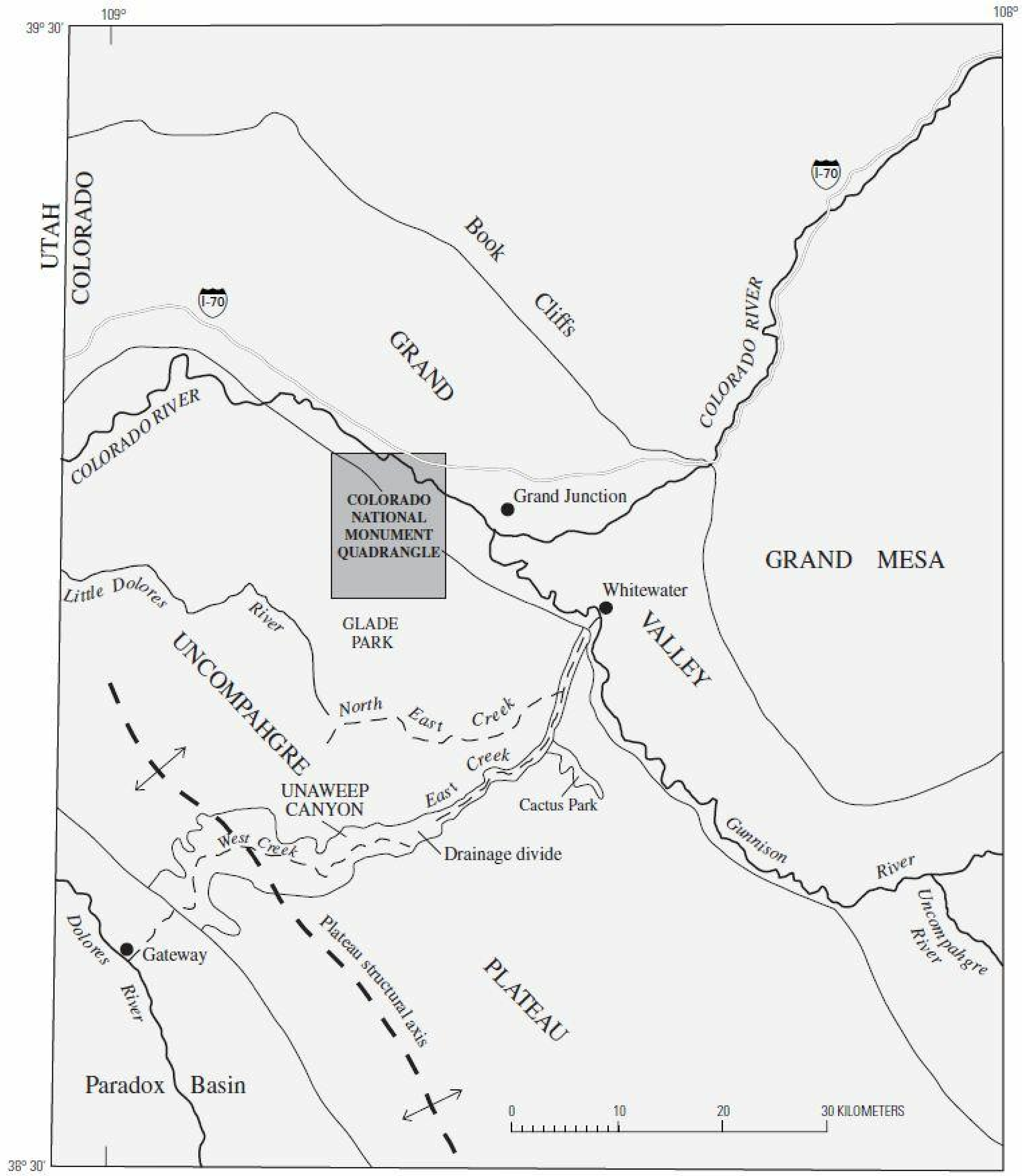


Figure 2. Geographic features near the map area.

Extracted from: Colorado NMON and Adjacent Areas.

Table 1: Grain size (AGI)

Table 1. Grain sizes in metric and English units (American Geological Institute, 1982).

Clay	less than 0.004 mm	less than 0.00016 inches
Silt	0.004 to 0.062 mm	0.00016 to 0.0025 inches
Sand	0.062 to 2 mm	0.0025 to 0.08 inches
Granule	2 to 4 mm	0.08 to 0.16 inches
Pebble	4 to 64 mm	0.16 to 2.5 inches
Cobble	64 to 256 mm	2.5 to 10 inches
Boulder	greater than 256 mm	greater than 10 inches

Extracted from: Colorado NMON and Adjacent Areas.

Table 2: Metric to English unit conversion

Table 2. Factors for conversion of metric units to English units to two significant figures.

Multiply	By	To obtain
centimeters (cm)	0.39	inches
meters (m)	3.3	feet
kilometers (km)	0.62	miles

Extracted from: Colorado NMON and Adjacent Areas.

Table 3: Geologic time

Table 3. Definitions of divisions of geologic time used in this report.

EON	ERA	Period	Epoch/Age[2]	Years
			Holocene	0 to 10 thousand
		Quaternary		
	CENOZOIC		[1]Pleistocene	10 thousand to 1.65 million
		Tertiary		1.65 to 66.4 million
		Cretaceous		
			Late Cretaceous	66.4 to 97.5 million
PHANEROZOIC-			**Turonian**	88.5 to 91 million
			Cenomanian	91 to 97.5 million
			Early Cretaceous	97.5 to 144 million
			Albian	97.5 to 113 million
			Aptian	113 to 119 million
		Jurassic		
			Late Jurassic	163 to 144 million
			Tithonian	144 to 152 million
	MESOZOIC		**Kimmeridgian**	152 to 156 million
			Oxfordian	156 to 163 million
			Middle Jurassic	163 to 187 million
			Callovian	163 to 169 million
			Lower Jurassic	187 to 208 million
			Pliensbachian	193 to 198 million
			Sinemurian	198 to 204 million
			Hettangian	204 to 208 million
		Triassic		
			Late Triassic	208 to 230 million
			Norian	208 to 225 million
			Carnian	225 to 230 million
PROTEROZOIC	EARLY PROTEROZOIC			1,600 to 2,500 million

After Hansen (1991) except for the Pleistocene.

[1]Subdivisions of Pleistocene time are informal and are as follows: late Pleistocene is 10–132 thousand years, middle Pleistocene is 132–788 thousand years, and early Pleistocene is 788–1,650 thousand years (Richmond and Fullerton, 1986). Subdivisions of the Cretaceous, Jurassic, and Triassic follow those of Geological Society of America (1999).

[2]Subdivisions of epochs are Ages, the smallest division of geologic time; Ages are shown in bold. These small subdivisions of time are most commonly used by paleontologists and stratigraphers.

Extracted from: Colorado NMON and Adjacent Areas.

Table 4: Ages of valley-fill deposits

Table 4. ^{14}C laboratory values and calibrated ages for valley-fill deposits in and near the map area.

Sample	Depth (m)	^{14}C lab value (years BP)	Calibrated age (years BP)	Lab number	Latitude	Longitude
			Uppermost part of No Thoroughfare Canyon			
C2	2.2	1,970 ± 50	1,900	W1734	38° 59.209'	108° 41.714'
			1,910			
			1,920			
C3	6	4,870 ± 50	5,600	W1735	38° 59.218'	108° 41.722'
C4	9	9,190 ± 50	10,250	W1736	38° 59.213'	108° 41.754'
			10,300			
			10,320			
			10,350			
			10,360			
			Farther downstream in No Thoroughfare Canyon			
C5	6	4,210 ± 40	4,830	W2072	38° 59.890'	108° 41.100'
C6	9	4,470 ± 50	5,050	W2071	38° 59.890'	108° 41.100'
			5,190			
			5,200			
C7	19	5,380 ± 50	6,200	W2442	38° 59.890'	108° 41.100'
C8	19.5	4,900 ± 50	5,610	W2443	38° 59.890'	108° 41.100'
C9	19.8	5,060 ± 60	5,760	W2444	38° 59.890'	108° 41.100'
			5,830			
			5,860			
			5,880			
C10	~19	4,540 ± 50	5,290	W2445	38° 59.908'	108° 41.070'
			Below the exit of No Thoroughfare Canyon from Colorado National Monument			
C1	~1.6	1,280 ± 50	1,180	W1734	39° 1.853'	108° 37.520'
			1,200			
			1,230			
			1,250			
			Upper part of Red Canyon			
C11	1.5	2,370 ± 40	2,350	W2073	39° 1.955'	108° 40.638'
			Cactus Park, 20 km southeast of the map area			
C12	~2	8,600 ± 50	9,550	W2169	38° 52.08'	108° 29.55'
			Alcove above samples C2 to C4 on western canyon wall			
C13	0.3	4410 ± 40	4,980	W2074	38° 58.710'	108° 40.887'
			5,030			

Extracted from: Colorado NMON and Adjacent Areas.

Report and References

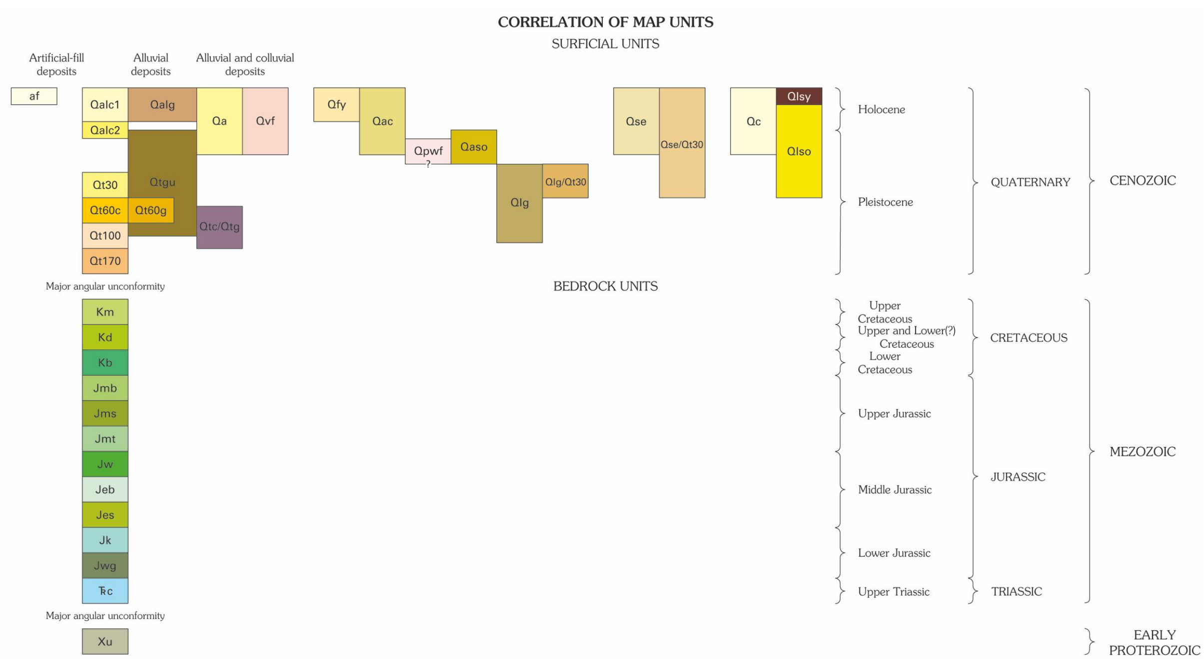
The source geologic map is accompanied by a published U.S. Geological Survey report with additional information on the local geology and references cited: I-2740 pamphlet.

Extracted from: Colorado NMON and Adjacent Areas. ** Double-click the above pamphlet link to open the document.

Grand Junction Quadrangle Map (U.S. Geological Survey Map MF-2363)

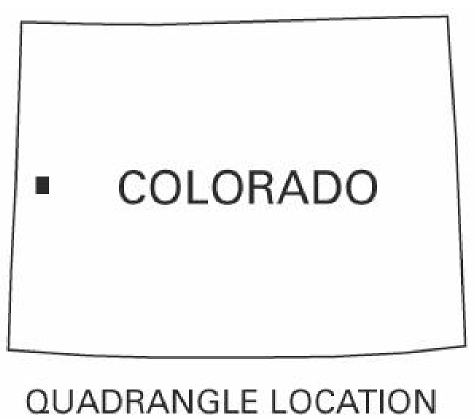
Scott, R.B., Carrara, P.E., Hood, W.C., and Murray, K.E., 2002, Geologic Map of the Grand Junction Quadrangle, Mesa County, Colorado: U.S. Geological Survey, Miscellaneous Field Studies Map, MF-2363, scale 1:24,000 (*GRI Source Map ID 1815*).

Correlation of Map Units



Extracted from: Grand Junction Quadrangle.

Index/Location Map



Extracted from: Grand Junction Quadrangle.

Map Legend

Contact—Dashed where approximately located. Hachures on the low side of a scarp terrace where contact is coincident with terrace scarp

Normal fault—Dashed where approximately located; dotted where concealed. Bar and ball on downthrown side. Arrow shows relative motion in cross section

Anticline axial trace—Dashed where approximately located; dotted where concealed

Strike and dip of bedding

Inclined

Calculated from outcrop pattern using three-point solutions

Gravel pit (g) or bentonite quarry—Approximately located

Extracted from: Grand Junction Quadrangle.

Table 1: Grain size (AGI)

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Clay	less than 0.0004 mm	less than 0.00016 in.
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Table 2. Factors for conversion of metric units to English units to two significant figures

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centimeters (cm)	0.39	inches (in)
meters (m)	3.3	feet (ft)
kilometers (km)	0.62	miles (mi)
kilograms	2.2	pounds (lb)
kilograms per cubic meter (kg/m^3)	0.062	pounds per cubic foot (lb/ft^3)

Extracted from: Grand Junction Quadrangle.

Table 3: Geologic time

Table 3. Definitions of divisions of geologic time used in this report

EON	ERA	Period	Epoch/*Age*	Years
PHANERO-ZOIC	CENOZOIC	Quaternary	Holocene	0 to 10 thousand
			[1]Pleistocene	10 thousand to 1.65 million
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Extracted from: Grand Junction Quadrangle.

Table 4: Map units susceptible to geologic hazards

Table 4. Map units susceptible to geologic hazards in the Grand Junction quadrangle.

Mass Wasting[1]	Gullying	Piping[2]	Expansive Soils		Flooding
Qlso	Qa	Qa	Qac	Qc	Qalc1
Qlsy	Qac	Qac	Qlso	Km	Qalc2
Km	Km	Qse	Kb	Jmb	Qalg
Kd			Jw	Qlsy	Qa
Jmb					

[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.

Extracted from: Grand Junction Quadrangle.

Report and References

The source geologic map is accompanied by a published U.S. Geological Survey report with additional information on the local geology and references cited: MF-2363 pamphlet.

Extracted from: Grand Junction Quadrangle. ** Double-click the above pamphlet link to open the document.

GRI Digital Data Credits

This document was developed and completed by Derek Witt (Colorado State University) for the NPS Geologic Resources Division (GRD) Geologic Resources Inventory (GRI) Program. Quality control of this document by Stephanie O'Meara (Colorado State University).

The information in this document was compiled from GRI source maps, and intended to accompany the digital geologic-GIS map(s) and other digital data for Colorado National Monument, Colorado (colm) developed by Derek Witt and Stephanie O'Meara (Colorado State University) (see the GRI Digital Maps and Source Map Citations section of this document for all sources used by the GRI in the completion of this document and related GRI digital geologic-GIS maps).

GRI finalization by Stephanie O'Meara (Colorado State University).

GRI program coordination and scoping provided by Bruce Heise and Tim Connors (NPS GRD, Lakewood, Colorado).