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

Dinosaur National Monument

GRI Ancillary Map Information Document

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

dino_geology.pdf

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Geologic Resources Inventory Map Document for Dinosaur National Monument

Table of Contents

Geologic Resources Inventory Map Document 1
About the NPS Geologic Resources Inventory Program 2
GRI Digital Maps and Source Map Citations 4
Map Unit List 6
Map Unit Descriptions 10
Qfp - Floodplain deposits (Holocene) 10
Qdf - Debris fan deposits (Holocene) 11
Qd - Dune sand/Sand dune (Holocene) 11
Qe - Eolian sand (Holocene) 12
Qal - Alluvium (Holocene) 12
Qac - Alluvial and colluvial deposits, undivided (Holocene) 13
Qavb - Alliuvium in valley bottoms (Holocene) 13
Qaf - Alluvial fan (Holocene) 13
Qavb2 - Alluvium in valley bottoms (Holocene and Pleistocene?) 14
Qac2 - Alluvium and colluvium (Holocene and Pleistocene) 14
Qas - Alluvium and slope w ash (Holocene and Pleistocene) 14
Qp - Pediment deposits (Holocene and Pleistocene) 14
Qt - Terrace deposits (Holocene and Pleistocene) 15
Qt1 - Terrace deposits 1 (Holocene and Pleistocene) 15
Qt2 - Terrace deposits 2 (Holocene and Pleistocene) 15
Qt3 - Terrace deposits 3 (Holocene and Pleistocene) 16
Qt4 - Terrace deposits 4 (Holocene and Pleistocene) 16
Qtafc - Talus and alluvial fan deposits and colluvium (Holocene and Pleistocene) 16
Qtc - Talus and other undifferentiated colluvium (Holocene and Pleistocene) 16
Ql - Landslide deposits (Holocene and Pleistocene) 17
Qg - Gravel deposits (Quaternary) 19
Qop - Older pediment deposits (Pleistocene) 19
Qdi - Dissected fan deposits (Pleistocene) 19
Qod - Older debris fan deposits (Pleistocene) 20
Qr - River-terrace deposits (Pleistocene) 20
Qc - Channel deposits (Pleistocene) 20
Qot - Terrace gravel (Pleistocene) 20
Qoa - Older alluvium (Pleistocene) 20
QTs - Sediments of East Cactus Flat (Quaternary and Tertiary?) 21
Tbp - Brow ns Park Formation (Miocene) 21
Tbpb - Brow ns Park Formation and Bishop (?) Conglomerate 21
Tb - Bishop Conglomerate (Oligocene) 22
Tge - Green River Formation, Evacuation Canyon Member (Eocene) 24
Tgp - Green River Formation, Parachute Creek Member (Eocene) 24
Tgpm - Green River Formation, Parachute Creek Member, base of main oil-shale zone (Eocene) 24
Tgg - Green River Formation, Garden Gulch Member (Eocene) 24
Tgd - Green River Formation, Douglas Creek Member (Eocene) 24
Tw t - Tongue of Wasatch Formation (Eocene) 24
Tw - Wasatch Formation (Eocene) 24
Kmvu - Mesa Verde Group, upper unit (Upper Cretaceous) 25

Kmvc - Mesa Verde Group, main coal unit (Upper Cretaceous) 25
Kmvm - Mesa Verde Group, minor coal unit (Upper Cretaceous) 25
Kmvs - Mesa Verde Group, Sego Sandstone (Upper Cretaceous) 25
Kwf - Williams Fork Formation (Lower Cretaceous) 25
Kit - Iles Formation, Trout Creek Member (Lower Cretaceous) 25
Ki - Iles Formation, main body (Lower Cretaceous) 25
Kc - Castlegate Sandstone, undivided (Upper Cretaceous) 25
Kcu - Castlegate Sandstone, upper unit (Upper Cretaceous) 25
Kcl - Castlegate Sandstone, lower unit (Upper Cretaceous) 26
Kms - Mancos Shale, upper shale member (Upper and Lower Cretaceous) 26
Kmu - Mancos Shale, upper unit (Upper and Lower Cretaceous) 26
Kmlo - Mancos Shale, base of Loyd Sandstone Member (Upper and Lower Cretaceous) 26
Kmsc - Mancos Shale, base of sandstone unit C (Upper and Lower Cretaceous) 27
Kmmb - Mancos Shale, main body (Upper and Lower Cretaceous) 27
Kmb - Buck Tongue of Mancos Shale (Upper Cretaceous) 27
Kmsb - Mancos Shale, base of sandstone unit B (Upper and Lower Cretaceous) 27
Kme - Mancos Shale, base of Emery (?) Sandstone member (Upper Cretaceous) 27
Kmf - Mancos Shale, Frontier Sandstone (Upper and Lower Cretaceous) 27
Kmm - Mancos Shale, Mowry Member (Upper and Lower Cretaceous) 28
Kd - Dakota Sandstone (Lower Cretaceous) 29
Kcm - Cedar Mountain Formation (Lower Cretaceous) 30
Kcs - Cedar Mountain Formation, shale member (Lower Cretaceous) 31
Kcb - Cedar Mountain Formation, Buckhorn Conglomerate Member (Lower Cretaceous and Upper Jurassic) 31
KJum - Undifferentiated Lower Cretaceous Rocks and Morrison Formation (Lower Cretaceous and Upper Jurassic) 31
KJcm - Cedar Mountain Formation and Morrison Formation (Lower Cretaceous and Upper Jurassic) 31
Jm - Morrison Formation (Upper Jurassic) 33
Js - Stump Formation (Upper Jurassic and Middle Jurassic) 34
Jsr - Stump Formation, Redwater Member (Upper Jurassic) 34
Jsc - Stump Formation, Curtis Member (Middle Jurassic) 35
Je - Entrada Sandstone (Middle Jurassic) 36
JTReg - Entrada Sandstone and Glen Canyon Sandstone (Jurassic and Triassic) 37
Jca - Carmel Formation (Middle Jurassic) 37
JTRg - Glen Canyon Sandstone (Lower Jurassic and Upper Triassic) 39
TRc - Chinle Formation (Upper Triassic) 40
TRcm - Chinle Formation, Main body (Upper Triassic) 41
TRcg - Chinle Formation, Garta Member (Upper Triassic) 43
TRm - Moenkopi Formation (Lower Triassic) 44
TRPmp - Moenkopi Formation and Park City Formation, undivided (Triassic and Permain) 45
Pp - Park City Formation (Permian) 46
Ppu - Park City Formation, Upper soft member (Upper and Lower Permian) 46
Ppc - Park City Formation, Main body (Upper and Lower Permian) 48
Ppl - Park City Formation, Lower unit (Permian) 49
PNw - Weber Sandstone (Middle Pennsylvanian) 49
PNm - Morgan Formation (Middle Pennsylvanian) 51
PNmu - Morgan Formation, Upper Member (Middle Pennsylvanian) 51
PNml - Morgan Formation, Lower Member (Middle Pennsylvanian) 52
PNrv - Round Valley Limestone (Lower Pennsylvanian) 54
Mdh - Doughnut Shale and Humbug Formation (Upper Mississippian) 55
Ms - Shale and dolomite (Mississippian) 58
Mm - Madison Limestone (Lower Mississippian) 58
MDm - Madison Limestone and older rocks (Mississippian and Devonian) 59
OCd - Dike (Lower Ordovician or Upper Cambrian) 59

Cr - Cambrian rocks and overlying rocks of unknown age (Cambrian and younger) ... 60
Cl - Lodore Formation (Upper Cambrian) ... 60
Yu - Uinta Mountain Group, undivided (Precambrian Y/Proterozoic Y) ... 61
Yus - Uinta Mountain Group, sandstone (Precambrian Y/Proterozoic Y) ... 62
Yuss - Uinta Mountain Group, shale and sandstone (Precambrian Y/Proterozoic Y) ... 62
Yus4 - Uinta Mountain Group, unit 4 (Precambrian Y/Proterozoic Y) ... 63
Yus3 - Uinta Mountain Group, unit 3 (Precambrian Y/Proterozoic Y) ... 63
Yus2 - Uinta Mountain Group, unit 2 (Precambrian Y/Proterozoic Y) ... 63
Yus1 - Uinta Mountain Group, unit 1 (Precambrian Y/Proterozoic Y) ... 63

Geologic Cross Sections ... 64

Cross Section A-A' ... 64
Cross Section B-B' ... 64
Cross Section C-C' ... 64
Cross Section D-D' ... 65
Cross Section E-E' ... 65
Cross Section F-F' ... 65
Cross Section G-G' ... 66
Cross Section H-H' ... 66
Cross Section I-I' ... 66
Cross Section J-J' ... 66
Cross Section K-K' ... 67
Cross Section L-L' ... 67
Cross Section M-M' ... 67
Cross Section N-N' ... 68
Cross Section O-O' ... 68
Cross Section P-P' ... 68
Cross Section Q-Q' ... 69
Cross Section R-R' ... 69
Cross Section S-S' ... 69
Cross Section T-T' ... 69
Cross Section U-U' ... 70
Cross Section V-V' ... 70
Cross Section W-W' ... 70
Cross Section X-X' ... 71
Cross Section Y-Y' ... 71
Cross Section Z-Z' ... 71

GRI Source Map Citations ... 72

Geologic Map of the Canyon of Lodore North Quadrangle ... 74
- Ancillary Map Notes ... 74
- Table 1 ... 80
- Figure 1 ... 80
- Figure 2 ... 81
- Figure 3 ... 81
- Correlation of Map Units ... 82
- Map Location ... 82
- Index Map ... 83
- References ... 83

Geologic Map of the Canyon of Lodore South Quadrangle ... 85
- Ancillary Map Notes ... 85
- Correlation of Map Units ... 89
- Map Location ... 89
- Index Map ... 90
- References ... 90

Geologic Map of the Crouse Reservoir Quadrangle 92
Ancillary Map Notes 92
Correlation of Map Units 93
Map Location 94
Index Map 94
References 94
Geologic Map of the Dinosaur Quarry Quadrangle 96
Ancillary Map Notes 96
Correlation of Map Units 101
Map Location 101
Index Map 102
References 102
Geologic Map of the Haystack Rock Quadrangle 106
Correlation of Map Units 106
Map Location 106
Index Map 107
Geologic Map of the Hells Canyon Quadrangle 108
Ancillary Map Notes 108
Correlation of Map Units 109
Map Location 110
Index Map 110
Sketch Map 111
References 111
Geologic Map of the Hoy Mountain Quadrangle 112
Ancillary Map Notes 112
Figure 1 114
Correlation of Map Units 115
Map Location 115
Index Map 116
References 116
Geologic Map of the Indian Water Canyon Quadrangle 118
Ancillary Map Notes 118
Correlation of Map Units 123
Map Location 123
Index Map 124
References 124
Geologic Map of the Island Park Quadrangle 128
Correlation of Map Units 128
Map Location 129
Index Map 129
References 129
Geologic Map of the Jones Hole Quadrangle 131
Ancillary Map Notes 131
Correlation of Map Units 132
Map Location 132
Index Map 133
Schematic Columnar Section 133
Geologic Map of the Mellen Hill Quadrangle 134
Ancillary Map Notes 134
Correlation of Map Units 136
Map Location 137
Columnar Section 138
References 139
Geologic Map of the Plug Hat Rock Quadrangle 141

Ancillary Map Notes ... 141
Correlation of Map Units ... 146
Map Location ... 146
Index Map ... 147
References ... 147
Geologic Map of the Split Mountain Quadrangle ... 151
Ancillary Map Notes ... 151
Correlation of Map Units ... 156
Map Location ... 157
Index Map ... 157
References ... 157
Geologic Map of the Stuntz Reservoir Quadrangle ... 162
Ancillary Map Notes ... 162
Correlation of Map Units ... 164
Map Location ... 164
Index Map ... 165
References ... 165
Geologic Map of the Tanks Peak Quadrangle ... 166
Ancillary Map Notes ... 166
Correlation of Map Units ... 168
Map Location ... 168
Index Map ... 169
References ... 169
Geologic Map of the Zenobia Peak Quadrangle ... 170
Ancillary Map Notes ... 170
Map Location ... 170
Index Map ... 171
References ... 171
Geologic Map of the Elk Springs Quadrangle ... 172
Ancillary Map Notes ... 172
Correlation of Map Units ... 173
Map Location ... 174
GRI Digital Data Credits ... 175

Geologic Resources Inventory Map Document

Dinosaur National Monument, Colorado and Utah

Document to Accompany Digital Geologic-GIS Data

dino_geology.pdf

Version: 7/12/2013

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

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:

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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:

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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

The GRI digital geologic-GIS maps for Dinosaur National Monument, Colorado and Utah (DINO):

The GRI compiled monument extent and vicinity map (sources are listed with the individual 7.5' quadrangle component maps below),

Digital Geologic Map of Dinosaur National Monument and Vicinity, Colorado and Utah (*GRI MapCide DINO*)

Individual 7.5' quadrangle GRI maps with source publication,

Digital Geologic Map of the Canyon of Lodore North Quadrangle, Colorado (*GRI MapCode CALN*)
Hansen, W.R., Carrara, P.E., and Rowley, P.D., 1982, Geologic Map of the Canyon of Lodore North Quadrangle, Moffat County, Colorado, U.S. Geological Survey, Geologic Quadrangle Map GQ-1568, 1:24,000 scale. (*GRI Source Map ID 31*)

Digital Geologic Map of the Canyon of Lodore South Quadrangle, Colorado (*GRI MapCode CALS*)
Hansen, W.R., 1977, Geologic Map of the Canyon of Lodore South Quadrangle, Moffat County, Colorado, U.S. Geological Survey, Geologic Quadrangle Map GQ-1403, 1:24,000 scale. (*GRI Source Map ID 32*)

Digital Geologic Map of the Crouse Reservoir Quadrangle, Utah (*GRI MapCode CRRE*)
Hansen, W.R., Carrara, P.E., and Rowley, P.D., 1981, Geologic Map of the Crouse Reservoir Quadrangle, Uintah and Daggett Counties, Utah, U.S. Geological Survey, Geologic Quadrangle Map GQ-1554, 1:24,000 scale. (*GRI Source Map ID 33*)

Digital Geologic Map of the Dinosaur Quarry Quadrangle, Utah (*GRI MapCode DIQU*)
Rowley, P.D., Kinney, D.M., and Hansen, W.R., 1979, Geologic Map of the Dinosaur Quarry Quadrangle, Uintah County, Utah, U.S. Geological Survey, Geologic Quadrangle Map GQ-1513, 1:24,000 scale. (*GRI Source Map ID 34*)

Digital Geologic Map of the Northern Elk Springs Quadrangles, Colorado (*GRI MapCode ELKN*) - Cross Mountain Canyon Quadrangle and Twelvemile Mesa Quadrangle
Dyni, John R., 1968, Geologic Map of the Elk Springs Quadrangle, Moffat County, Colorado, U.S. Geological Survey, Geologic Quadrangle Map GQ-702, 1:62,500 scale. (*GRI Source Map ID 1545*)

Digital Geologic Map of the Haystack Rock Quadrangle, Colorado (*GRI MapCode HARO*)
Hansen, W.R., Carrara, P.E., and Rowley, P.D., 1980, Geologic Map of the Haystack Rock Quadrangle, Moffat County, Colorado, U.S. Geological Survey, Geologic Quadrangle Map GQ-1535, 1:24,000 scale. (*GRI Source Map ID 35*)

Digital Geologic Map of the Hells Canyon Quadrangle, Colorado (*GRI MapCode HECA*)
Hansen, W.R., and Rowley, P.D., 1980, Geologic Map of the Hells Canyon Quadrangle, Moffat County, Colorado, U.S. Geological Survey, Geologic Quadrangle Map GQ-1536, 1:24,000 scale. (*GRI Source Map ID 36*)

Digital Geologic Map of the Hoy Mountain Quadrangle, Utah and Colorado (*GRI MapCode HOMO*)
Hansen, W.R., and Rowley, P.D., 1991, Geologic Map of the Hoy Mountain Quadrangle, Daggett and

Uintah Counties, Utah, and Moffat County, Colorado, U.S. Geological Survey, Geologic Quadrangle Map GQ-1695, 1:24,000 scale. (*GRI Source Map ID 37*)

Digital Geologic Map of the Indian Water Canyon Quadrangle, Colorado (*GRI MapCode INWC*)
Rowley, P.D., Dyni, J.R., Hansen, W.R., and Pipiringos, G.N., 1979, Geologic Map of the Indian Water Canyon Quadrangle, Moffat County, Colorado, U.S. Geological Survey, Geologic Quadrangle Map GQ-1516, 1:24,000 scale. (*GRI Source Map ID 38*)

Digital Geologic Map of the Island Park Quadrangle, Utah (*GRI MapCode ISPA*)
Rowley, P.D., Hansen, W.R., and Carrara, P.E., 1981, Geologic Map of the Island Park Quadrangle, Uintah County, Utah, U.S. Geological Survey, Geologic Quadrangle Map GQ-1560, 1:24,000 scale. (*GRI Source Map ID 39*)

Digital Geologic Map of the Jones Hole Quadrangle, Colorado (*GRI MapCode JOHO*)
Hansen, W.R., 1977, Geologic Map of the Jones Hole Quadrangle, Uintah County, Utah, and Moffat County, Colorado, U.S. Geological Survey, Geologic Quadrangle Map GQ-1401, 1:24,000 scale. (*GRI Source Map ID 40*)

Digital Geologic Map of the Mellen Hill Quadrangle, Colorado (*GRI MapCode MEHI*)
Cullins, H.L., 1969, Geologic Map of the Mellen Hill Quadrangle, Rio Blanco and Moffat Counties, Colorado, U.S. Geological Survey, Geologic Quadrangle Map GQ-835, 1:24,000 scale. (*GRI Source Map ID 41*)

Digital Geologic Map of the Plug Hat Rock Quadrangle, Colorado (*GRI MapCode PLHR*)
Rowley, P.D., and Hansen, W.R., 1979, Geologic Map of the Plug Hat Rock Quadrangle, Moffat County, Colorado, U.S. Geological Survey, Geologic Quadrangle Map GQ-1514, 1:24,000 scale. (*GRI Source Map ID 42*)

Digital Geologic Map of the Split Mountain Quadrangle, Utah (*GRI MapCode SPMO*)
Rowley, P.D., and Hansen, W.R., 1979, Geologic Map of the Split Mountain Quadrangle, Uintah County, Utah, U.S. Geological Survey, Geologic Quadrangle Map GQ-1515, 1:24,000 scale. (*GRI Source Map ID 43*)

Digital Geologic Map of the Stuntz Reservoir Quadrangle, Utah and Colorado (*GRI MapCode STRE*)
Hansen, W.R., and Rowley, P.D., 1980, Geologic Map of the Stuntz Reservoir Quadrangle, Utah-Colorado, U.S. Geological Survey, Geologic Quadrangle Map GQ-1530, 1:24,000 scale. (*GRI Source Map ID 44*)

Digital Geologic Map of the Tanks Peak Quadrangle, Colorado (*GRI MapCode TAPE*)
Hansen, W.R., and Carrara, P.E., 1980, Geologic Map of the Tanks Peak Quadrangle, Moffat County, Colorado, U.S. Geological Survey, Geologic Quadrangle Map GQ-1534, 1:24,000 scale. (*GRI Source Map ID 45*)

Digital Geologic Map of the Zenobia Peak Quadrangle, Colorado (*GRI MapCode ZEPE*)
Hansen, W.R., 1978, Geologic Map of the Zenobia Peak Quadrangle, Moffat County, Colorado, U.S. Geological Survey, Geologic Quadrangle Map GQ-1408, 1:24,000 scale. (*GRI Source Map ID 46*)

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

Map Unit List

The geologic units present in the digital geologic-GIS data produced for Dinosaur National Monument, Colorado and Utah (DINO) are listed below. Units are listed with their assigned unit symbol and unit name (e.g., Qal - Alluvium). Units are listed from youngest to oldest. No description for water is provided. Information about each geologic unit is also presented in the Geologic Unit Information (DINOUNIT) table included with the GRI geology-GIS data.

Cenozoic Era

Quaternary Period

Holocene Epoch

Qfp - Floodplain deposits (Qfp)
Qdf - Debris fan deposits (Qdf)
Qd - Dune sand/Sand dune (Qd)
Qe - Eolian sand (Qe)
Qal - Alluvium (Qal)
Qac - Alluvial and colluvial deposits, undivided (Qac)
Qavb - Alluvium in valley bottoms (Qavb)
Qaf - Alluvial fan (Qaf)

Holocene and Pleistocene Epochs

Qavb2 - Alluvium in valley bottoms, older (Qavb2)
Qac2 - Alluvium and colluvium (Qac2)
Qas - Alluvium and slope wash (Qas)
Qp - Pediment deposits (Qp)
Qt - Terrace deposits (Qt)
Qt1 - Terrace deposits 1 (Qt1)
Qt2 - Terrace deposits 2 (Qt2)
Qt3 - Terrace deposits 3 (Qt3)
Qt4 - Terrace deposits 4 (Qt4)
Qtafc - Talus and alluvial fan deposits and colluvium (Qtafc)
Qtc - Talus and other undifferentiated colluvium (Qtc)
Ql - Landslide deposits (Ql)
Qg - Gravel deposits (Qg)

Pleistocene Epoch

Qop - Older pediment deposits (Qop)
Qdi - Dissected fan deposits (Qdi)
Qod - Older debris fan deposits (Qod)
Qr - River-terrace deposits (Qr)
Qc - Channel deposits (Qc)
Qot - Older terrace gravels (Qot)
Qoa - Older alluvium (Qoa)

Quaternary and Tertiary Periods?

QTs - Sediments of East Cactus Flat (QTs)

Tertiary Period

Miocene Epoch

Tbp - Browns Park Formation (Tbp)

Miocene and Oligocene Epochs

Tbpb - Browns Park Formation and Bishop (?) Conglomerate (Tbpb)

Oligocene Epoch

Tb - Bishop Conglomerate (Tb)

Eocene Epoch

Tge - Green River Formation, Evacuation Canyon Member (Tge)
Tgp - Green River Formation, Parachute Creek Member (Tgp)
Tgpm - Green River Formation, Parachute Creek Member, base of main oil-shale zone (Tgpm)
Tgg - Green River Formation, Garden Gulch Member (Tgg)
Tgd - Green River Formation, Douglas Creek Member (Tgd)
Twt - Tongue of Wasatch Formation (Twt)
Tw - Wasatch Formation (Tw)

Mesozoic Era

Cretaceous Period

Kmvu - Mesa Verde Group, upper unit (Kmvu)
Kmvc - Mesa Verde Group, main coal unit (Kmvc)
Kmvm - Mesa Verde Group, minor coal unit (Kmvm)
Kmvs - Mesa Verde Group, Sego Sandstone (Kmvs)
Kwf - Williams Fork Formation (Kwf)
Kit - Iles Formation, Trout Creek Member (Kit)
Ki - Iles Formation, main body (Ki)
Kc - Castlegate Sandstone, undivided (Kc)
Kcu - Castlegate Sandstone, upper unit (Kcu)
Kcl - Castlegate Sandstone, lower unit (Kcl)
Kms - Mancos Shale, upper shale member (Kms)
Kmu - Mancos Shale, upper unit (Kmu)
Kmlo - Mancos Shale, base of Loyd Sandstone Member (Kmlo)
Kmsc - Mancos Shale, base of sandstone unit C (Kmsc)
Kmmb - Mancos Shale, main body (Kmmb)
Kmb - Buck Tongue of Mancos Shale (Kmb)
Kmsb - Mancos Shale, base of sandstone unit B (Kmsb)
Kme - Mancos Shale, base of Emery (?) Sandstone member (Kme)
Kmf - Mancos Shale, Frontier Sandstone (Kmf)
Kmm - Mancos Shale, Mowry Member (Kmm)
Kd - Dakota Sandstone (Kd)
Kcm - Cedar Mountain Formation (Kcm)
Kcs - Cedar Mountain Formation, shale member (Kcs)
Kcb - Cedar Mountain Formation, Buckhorn Conglomerate Member (Kcb)

Cretaceous and Jurassic Periods

KJum - Undifferentiated Lower Cretaceous Rocks and Morrison Formation (KJum)
KJcm - Cedar Mountain Formation and Morrison Formation (KJcm)

Jurassic Period

Jm - Morrison Formation (Jm)
Js - Stump Formation (Js)
Jsr - Stump Formation, Redwater Member (Jsr)
Jsc - Stump Formation, Curtis Member (Jsc)
Je - Entrada Sandstone (Je)

Jurassic and Triassic Periods

JTReg - Entrada Sandstone and Glen Canyon Sandstone (JTReg)

Jurassic Period

Jca - Carmel Formation (Jca)

Jurassic and Triassic Periods

JTRg - Glen Canyon Sandstone (JTRg)

Triassic Period

TRc - Chinle Formation (TRc)
TRcm - Chinle Formation, Main body (TRcm)
TRcg - Chinle Formation, Garta Member (TRcg)
TRm - Moenkopi Formation (TRm)

Mesozoic and Paleozoic Eras

Triassic and Permian Periods

TRPmp - Moenkopi Formation and Park City Formation, undivided (TRPm)

Paleozoic Era

Permian Period

Pp - Park City Formation (Pp)
Ppu - Park City Formation, Upper soft member (Ppu)
Ppc - Park City Formation, Main body (Ppc)
Ppl - Park City Formation, Lower unit (Ppl)

Pennsylvanian Period

PNw - Weber Sandstone (PNw)
PNm - Morgan Formation (PNm)
PNmu - Morgan Formation, Upper member (PNmu)
PNml - Morgan Formation, Lower member (PNml)
PNrv - Round Valley Limestone (PNrv)

Mississippian Period

Mdh - Doughnut Shale and Humbug Formation (Mdh)
Ms - Shale and dolomite (Ms)
Mm - Madison Limestone (Mm)

Mississippian and Devonian Periods

MDm - Madison Limestone and older rocks (MDm)

Ordovician Period

OCd - Dike (OCd)

Cambrian Period

Cr - Cambrian rocks and overlying rocks of unknown age (Cr)

Cl - Lodore Formation (Cl)

Precambrian/Proterozoic

Yu - Uinta Mountain Group, undivided (Yu)

Yus - Uinta Mountain Group, sandstone (Yus)

Yuss - Uinta Mountain Group, shale and sandstone (Yuss)

Yus4 - Uinta Mountain Group, unit 4 (Yus4)

Yus3 - Uinta Mountain Group, unit 3 (Yus3)

Yus2 - Uinta Mountain Group, unit 2 (Yus2)

Yus1 - Uinta Mountain Group, unit 1 (Yus1)

Map Unit Descriptions

Descriptions of all geologic map units, generally listed from youngest to oldest, are presented below.

Qfp - Floodplain deposits (Holocene)

Qfp - Flood-Plain Deposit (Holocene)
Mostly pebble gravel and sand; locally cobbly and bouldery especially in Canyon of Lodore. Mostly overbank deposits but includes islands and river bars in channel of Green River exposed during low-water. Maximum thickness a few tens of meters. (*GRI Source Map ID 31).* (GQ-1568).

Qfp - Floodplain and Channel Deposits of Yampa River (Holocene)
Mostly gravel and sand, locally cobbly and bouldery. Includes islands and river bars in channels of Green and Yampa Rivers exposed during low-water stages. Maximum thickness a few tens of meters. (*GRI Source Map ID 32).* (GQ-1403).

Qfp - Floodplain and Channel Deposits (Holocene)
Mostly gravel and sand, locally cobbly and bouldery, along the Green River and Brush Creek. Includes islands and bars exposed in the river channel during low-water stages. Maximum thickness a few tens of meters (100 feet). (*GRI Source Map ID 34).* (GQ-1513).

Qfp - Floodplain and Channel Deposits of Yampa River (Holocene)
Mostly pebble gravel and sand, locally very cobbly and bouldery. Includes islands and river bars exposed during low water stages. Maximum probable thickness a few meters. (*GRI Source Map ID 35).* (GQ-1535).

Qfp - Flood-Plain Deposit (Holocene)
Mostly pebble gravel and sand, locally cobbly and bouldery. Includes islands and river bars in channel of Yampa River exposed during low-water stages. Maximum thickness a few tens of meters. (*GRI Source Map ID 36).* (GQ-1536).

Qfp - Floodplain and Channel Deposits (Holocene)
Mostly gravel and sand, locally cobbly and bouldery, along the Yampa River. Includes islands and bars exposed in the river channel during low-water stages. Maximum thickness a few tens of meters (30 feet). (*GRI Source Map ID 38).* (GQ-1516).

Qfp - Floodplain and Channel Deposits along the Green River (Holocene)
Mostly gravel and sand, locally cobbly and bouldery. Maximum thickness about 10 m. (*GRI Source Map ID 39).* (GQ-1560).

Qfp - Flood-plain deposit (Holocene)
Mostly gravel and sand, locally cobbly and bouldery. Includes islands and bars exposed in channel of Green River during low-water stages. Maximum thickness a few tens of meters. (*GRI Source Map ID 40).* (GQ-1401).

Qfp - Floodplain and Channel Deposits (Holocene)
Mostly gravel and sand, locally cobbly and bouldery, along the Green River. Includes islands and bars exposed in the river channel during low-water stages. Maximum thickness about ten meters (30 feet). (*GRI Source Map ID 43).* (GQ-1515).

Qfp - Floodplain and Channel Deposits of Yampa River (Holocene)
Mostly gravel and sand, locally cobbly and bouldery. Includes islands and river bars exposed during low

water stages. Maximum probable thickness a few tens of meters. (*GRI Source Map ID 45).* (GQ-1534).

Qdf - Debris fan deposits (Holocene)

Qdf - Debris Fan (Holocene)
Silt, sand, pebbles, cobbles, and boulders; very heterogenous size mixtures deposited chiefly by torrential flooding. Grades into talus (Qtc) and alluvium (Qa). Maximum thickness a few tens of meters. (*GRI Source Map ID 31).* (GQ-1568).

Qdf - Debris Fan (Holocene)
Very heterogeneous mixture of silt, sand, cobbles, and boulders deposited by torrential flooding and/or debris flowage. Maximum thickness a few tens of meters. (*GRI Source Map ID 32).* (GQ-1403).

Qdf - Debris Fan Deposits (Holocene)
Heterogeneous mixture of silt, sand, gravel, cobbles, and boulders deposited by torrential flooding and (or) debris flowage. Maximum thickness about 15 m. (50 ft.). (*GRI Source Map ID 34).* (GQ-1513)

Qdf - Debris Fan (Holocene)
Heterogeneous mixture of silt, sand, cobbles, and boulders deposited by torrential flooding and/or debris flowage. Maximum thickness a few tens of meters. (*GRI Source Map ID 35).* (GQ-1535).

Qdf - Debris Fan Deposits (Holocene)
Heterogeneous mixture of silt, sand, gravel, cobbles, and boulders deposited by torrential flooding and (or) debris flowage. Maximum thickness about 15 m. (50 ft.). (*GRI Source Map ID 38).* (GQ-1516).

Qdf - Debris Fan Deposits (Holocene)
Heterogeneous mixture of silt, sand, pebbles, cobbles, and boulders deposited by torrential flooding and (or) debris flowage. Maximum thickness about 15 m. (*GRI Source Map ID 39).* (GQ-1560).

Qdf - Debris Fan (Holocene)
Very heterogeneous mixture of silt, sand, gravel, cobbles, and boulders deposited by torrential flooding and/or debris flowage. Merges laterally with alluvium (Qa). Maximum thickness a few tens of meters. (*GRI Source Map ID 40).* (GQ-1401).

Qdf - Debris Fan Deposits (Holocene)
Heterogeneous mixture of silt, sand, gravel, cobbles, and boulders deposited by torrential flooding and (or) debris flowage. Maximum thickness about 15 m. (50 ft.). (*GRI Source Map ID 43).* (GQ-1515).

Qdf - Debris Fan (Holocene)
Very heterogeneous mixture of silt, sand, pebbles, cobbles, and boulders deposited by torrential flooding and/or debris flowage. Maximum thickness a few tens of meters. (*GRI Source Map ID 45).* (GQ-1534).

Qd - Dune sand/Sand dune (Holocene)

Qd - Dune Sand (Holocene)
Well-sorted fine- to medium-grained eolian sand, largely stabilized by vegetation. Most sand derived from Glen Canyon Sandstone. Many small patches unmapped. Maximum thickness a few meters (10 feet). (*GRI Source Map ID 34).* (GQ-1513).

Qd - Dune Sand (Holocene)

Well-sorted mostly fine-grained eolian sand, commonly stabilized by vegetation. Many small patches unmapped. Maximum thickness a few meters. (*GRI Source Map ID 39).* (GQ-1560).

Qd - Sand Dune (Holocene)
Well-sorted, fine to medium, eolian sand. Caps ridge on west side of Red Wash; many small patches unmapped. Maximum thickness a few meters. (*GRI Source Map ID 40).* (GQ-1401).

Qd - Dune Sand (Holocene)
Additional unit description not provided. (*GRI Source Map ID 41).* (GQ-835).

Qd - Dune Sand (Holocene)
Well-sorted mostly fine-grained eolian sand, largely stabilized by vegetation. Most sand derived from Glen Canyon Sandstone. Many small patches unmapped. Maximum thickness a few meters. (*GRI Source Map ID 42).* (GQ-1514).

Qd - Dune Sand (Holocene)
Well-sorted mostly fine-grained eolian sand, largely stabilized by vegetation. Most sand derived from Glen Canyon Sandstone. Many small patches unmapped. Maximum thickness a few meters (10 ft). (*GRI Source Map ID 43).* (GQ-1515).

Qe - Eolian sand (Holocene)

Qe - Eolian Sand (Holocene)
Fine sand in irregular sheets and patches. Rarely forms dunes. Derived from Weber Sandstone and locally intermixed with alluvium. Many small patches unmapped. Possibly includes some Pleistocene deposits. Maximum thickness a few meters. (*GRI Source Map ID 35).* (GQ-1535).

Qe - Eolian Sand (Holocene)
Fine sand in irregular sheets and patches. Rarely forms dunes. Derived from Weber Sandstone (PNw) and locally intermixed with alluvium. Many small patches unmapped. Possibly includes some Pleistocene deposits. Maximum thickness a few meters. (*GRI Source Map ID 45).* (GQ-1534).

Qal - Alluvium (Holocene)

Qa - Alluvium (Holocene)
Silty sand and gravel, poorly sorted, locally cobbly and bouldery in tributary valleys and ravines. In some places, contains appreciable organic matter, especially toward top. Commonly grades into colluvium. Maximum thickness a few meters. (*GRI Source Map ID 31).* (GQ-1568).

Qa - Alluvium (Holocene)
Possibly includes some Pleistocene deposits. Poorly sorted silty sand and gravel, locally cobbly and bouldery. In some places, contains appreciable organic matter. Maximum thickness a few meters. (*GRI Source Map ID 44).* (GQ-1530).

Qa - Alluvium (Holocene)
Poorly sorted silty sand and gravel, locally cobbly and bouldery. In some places, contains appreciable organic matter. Maximum thickness a few tens of meters. (*GRI Source Map ID 45).* (GQ-1534).

Qa - Alluvium (Holocene)
Possibly includes some Pleistocene deposits. Poorly sorted silty sand and gravel, locally cobbly and

bouldery. In some places, contains appreciable organic matter. Maximum thickness a few meters. (*GRI Source Map ID 46).* (GQ-1408).

Qal – Alluvium (Quaternary)
Silt, sand and gravel in flood plains of Yampa and Little Snake Rivers. (*GRI Source Map ID 1545).* (GQ-702).

Qac - Alluvial and colluvial deposits, undivided (Holocene)

Qac - Alluvial and colluvial deposits, undivided (Holocene)
Additional unit description not provided. (*GRI Source Map ID 41).* (GQ-835).

Qac - Alluvial and colluvial deposits (Holocene)
Silt, sand, and gravel along tributary streams; includes coalescent alluvial fans of same material along Yampa and Little Snake Rivers. (*GRI Source Map ID 1545).* (GQ-702).

Qavb - Alliuvium in valley bottoms (Holocene)

Qa - Alluvium in Valley Bottoms (Holocene)
Poorly sorted silty sand and gravel, locally cobbly and bouldery. Some slope wash. In some PL aces, contains appreciable organic matter. Maximum thickness a few tens of meters. (*GRI Source Map ID 32).* (GQ-1403).

Qa - Alluvium in Valley Bottoms (Holocene)
Poorly sorted silty sand and gravel, locally very cobbly and bouldery. In some places contains appreciable disseminated organic matter. Grades into colluvium. Maximum thickness several meters. (*GRI Source Map ID 33).* (GQ-1554).

Qa - Alluvium in Valley Bottoms (Holocene)
Poorly sorted silty sand and gravel, locally cobbly and bouldery. Some slope wash. In some PL aces, contains appreciable organic matter. Possibly includes some Pleistocene deposits. Maximum thickness a few meters. (*GRI Source Map ID 35).* (GQ-1535).

Qa - Alluvium in Valley Bottoms (Holocene)
Poorly sorted silty sand and gravel, locally very cobbly and bouldery. Includes some colluvium. In some places, contains appreciable organic matter. Maximum thickness a few tens of meters. Possibly includes some Pleistocene deposits. (*GRI Source Map ID 36).* (GQ-1536).

Qa - Alluvium in Valley Bottoms (Holocene)
Poorly sorted silty sand and gravel, locally cobbly and bouldery, along intermittent drainages. In some places contains appreciable organic matter. Maximum thickness a few meters. (*GRI Source Map ID 40).* (GQ-1401).

Qaf - Alluvial fan (Holocene)

Additional unit description not provided. (*GRI Source Map ID 41).* (GQ-835).

Qavb2 - Alluvium in valley bottoms (Holocene and Pleistocene?)

Poorly sorted silty sand and gravel, locally very cobbly and bouldery. In some places contains appreciable disseminated organic matter. Grades into colluvium. Maximum thickness several meters. (*GRI Source Map ID 37).* (GQ-1536).

Qac2 - Alluvium and colluvium (Holocene and Pleistocene)

Poorly sorted sand, silt, and gravel deposited in channels, bordering flood plains, and in intermittent tributary streams, and as alluvial slope wash. Includes colluvium on and below steep slopes adjacent to streams. Contact transitional with other surficial deposits. Maximum thickness about 10 m. *(GRI Source Map ID 39).* (GQ-1560).

Qas - Alluvium and slope wash (Holocene and Pleistocene)

Qa - Alluvium and Slope Wash (Holocene and Pleistocene)
Poorly sorted sand, silt, and gravel deposited in channels, on bordering flood plains, and in side-streams of mostly intermittent tributary streams, and as alluvial slope wash. Includes colluvium on and below steep slopes adjacent to streams. Contact transitional with other surficial units. Maximum thickness a half dozen meters (20 ft.). (*GRI Source Map ID 34).* (GQ-1513).

Qa - Alluvium and Slope Wash (Holocene and Pleistocene)
Poorly sorted sand, silt, and gravel deposited in channels, on bordering flood plains, and in sidestreams of mostly intermittent tributary streams, and as alluvial slope wash. Includes colluvium on and below steep slopes adjacent to streams. In southwestern part of quadrangle, consists largely of Holocene and Pleistocene sidestream deposits and slope wash in valleys that probably were cut in Tertiary time. Locally includes dissected Pleistocene deposits, as in sec. 1, T. 5 N., R. 100 W. and sec. 36, T. 6 N., R. 100 W. Contact transitional with other surficial units. Maximum thickness a half dozen meters (20 ft.). (*GRI Source Map ID 38).* (GQ-1516).

Qa - Alluvium and Slope Wash (Holocene and Pleistocene)
Poorly sorted sand, silt, and gravel deposited in channels, on bordering flood plains, in side-streams of mostly intermittent tributary streams, and as alluvial slope wash. Includes colluvium on and below steep slopes adjacent to streams. Contact transitional with other surficial units. Maximum thickness a half dozen meters (20 ft). (*GRI Source Map ID 42).* (GQ-1514).

Qa - Alluvium and Slope Wash (Holocene and Pleistocene)
Poorly sorted sand, silt, and gravel deposited in channels, on bordering flood plains, and in sidestreams of mostly intermittent tributary streams, and as alluvial slope wash. Includes colluvium on and below steep slopes adjacent to streams. Contact transitional with other surficial deposits. Maximum thickness a half dozen meters (20 ft). (*GRI Source Map ID 43).* (GQ-1515).

Qp - Pediment deposits (Holocene and Pleistocene)

Qp - Pediment Deposits (Holocene and Pleistocene)
Poorly sorted silt, sand, and gravel deposited on pediments cut on soft rocks. Locally includes fan deposits and colluvium. Maximum thickness about 10 m (30 ft.). (*GRI Source Map ID 34).* (GQ-1513).

Qp - Pediment Deposits (Holocene and Pleistocene)

Poorly-sorted silt, sand, and gravel deposited on pediments cut on soft rocks. Locally includes fan deposits and colluvium. Maximum thickness about 10 m (30 ft.). (*GRI Source Map ID 38).* (GQ-1516).

Qp - Pediment Deposits (Holocene and Pleistocene)
Poorly sorted silt, sand, and gravel deposited on surfaces cut on mostly soft rocks. Locally includes fan deposits and colluvium. Maximum thickness about 10 m. (*GRI Source Map ID 39).* (GQ-1560).

Qp - Pediment Deposits (Holocene and Pleistocene)
Poorly sorted silt, sand, and gravel deposited on pediments cut on soft rocks. Locally includes fan deposits and colluvium. Maximum thickness about 10 m (30 ft.). (*GRI Source Map ID 43).* (GQ-1515).

Qt - Terrace deposits (Holocene and Pleistocene)

Qt - Terrace Deposits (Holocene and Pleistocene)
Alluvial remnants on benches along the Green and Yampa Rivers. Silt, sand, gravel, cobbles, and boulders. Maximum thickness a few meters. (*GRI Source Map ID 32)*. (GQ-1403).

Qt - Terrace Deposits (Holocene and Pleistocene)
Small alluvial remnants on benches a few meters above the Yampa River and its tributaries. Silt, sand, pebbles, cobbles, and boulders. Maximum thickness a few meter. (*GRI Source Map ID 36*). (GQ-1536).

Qt - Terrace Deposits (Holocene and Pleistocene)
Alluvial remnants on benches along the Green River and tributaries. Silt, sand, gravel, cobbles, and boulders, locally cemented to conglomerate. Maximum thickness a few tens of meters. (*GRI Source Map ID 40*). (GQ-1401).

Qt - Terrace Deposits (Holocene and Pleistocene)
Small alluvial remnants on benches along the Yampa River and tributaries. Silt, sand, gravel, cobbles, and boulders. Maximum thickness a few metes. *(GRI Source Map ID 45*). (GQ-1534).

Qt - Terrace Deposits (Quaternary)
Silt, sand, and gravel; caps several undifferentiated strath and pediment surfaces in Yampa and Little Snake River valleys; 0 to about 30 feet thick. (*GRI Source Map ID 1545).* (GQ-702).

Qt1 - Terrace deposits 1 (Holocene and Pleistocene)

Alluvial gravel remnants on stream-cut benches in Browns Park. Silt, sand, pebbles, cobbles, and boulders, commonly topped by a meter or so of eolian sand. The stones are chiefly red quartzite and gray limestone. Qt1 is youngest and lowest; Qt4 is oldest and highest. Maximum thickness on each terrace is a few meters. (*GRI Source Map ID 31).* (GQ-1568).

Qt2 - Terrace deposits 2 (Holocene and Pleistocene)

Alluvial gravel remnants on stream-cut benches in Browns Park. Silt, sand, pebbles, cobbles, and boulders, commonly topped by a meter or so of eolian sand. The stones are chiefly red quartzite and gray limestone. Qt1 is youngest and lowest; Qt4 is oldest and highest. Maximum thickness on each terrace is a few meters. (*GRI Source Map ID 31).* (GQ-1568).

Qt3 - Terrace deposits 3 (Holocene and Pleistocene)

Alluvial gravel remnants on stream-cut benches in Browns Park. Silt, sand, pebbles, cobbles, and boulders, commonly topped by a meter or so of eolian sand. The stones are chiefly red quartzite and gray limestone. Qt1 is youngest and lowest; Qt4 is oldest and highest. Maximum thickness on each terrace is a few meters. (*GRI Source Map ID 31).* (GQ-1568).

Qt4 - Terrace deposits 4 (Holocene and Pleistocene)

Alluvial gravel remnants on stream-cut benches in Browns Park. Silt, sand, pebbles, cobbles, and boulders, commonly topped by a meter or so of eolian sand. The stones are chiefly red quartzite and gray limestone. Qt1 is youngest and lowest; Qt4 is oldest and highest. Maximum thickness on each terrace is a few meters. (*GRI Source Map ID 31).* (GQ-1568).

Qtafc - Talus and alluvial fan deposits and colluvium (Holocene and Pleistocene)

Qt - Talus and Alluvial Fan Deposits, and Colluvium (Holocene and Pleistocene)
Angular rock fragments deposited below cliffs and steep slopes. Heterogeneous mixtures of silt, sand, gravel, cobbles, and boulders. Contact transitional with alluvium and slope wash (Qa). Maximum thickness a few tens of meters (100 ft.). *(GRI Source Map ID 34).* (GQ-1513).

Qt - Talus and Alluvial Fan Deposits, and Colluvium (Holocene and Pleistocene)
Angular rock fragments deposited below cliffs and steep slopes. Heterogeneous mixtures of silt, sand, gravel, cobbles, and boulders. Contact transitional with alluvium and slope wash (Qa). Maximum thickness a few tens of meters (100 ft). *(GRI Source Map ID 38).* (GQ-1516).

Qt - Talus and Alluvial Fan Deposits, and Colluvium (Holocene and Pleistocene)
Angular rock fragments deposited below cliffs and steep slopes. Heterogeneous mixtures of silt, sand, gravel, cobbles, and boulders. Contact transitional with alluvium and slope wash (Qa). Maximum thickness about 10 m (30 ft). *(GRI Source Map ID 42).* (GQ-1514).

Qt - Talus and Alluvial Fan Deposits, and Colluvium (Holocene and Pleistocene)
Angular rock fragments deposited below cliffs and steep slopes. Heterogeneous mixtures of silt, sand, gravel, cobbles, and boulders. Contact transitional with alluvium and slope wash (Qa). Maximum thickness a few tens of meters (100 ft). *(GRI Source Map ID 43).* (GQ-1515).

Qtc - Talus and other undifferentiated colluvium (Holocene and Pleistocene)

Qtc - Talus and Other undifferentiated Colluvium (Holocene and Pleistocene)
Talus (predominant): Coarse rock fragments below cliffs and steep slopes; other colluvium: heterogeneous mixtures of silt, sand, and angular pebble-, cobble-, and boulder-size fragments. Mass movement in some talus deposits is indicated by lobate ridges and furrows. Includes a few debris-flow deposits in secs. 11, 12, and 13, T. 9 N., R. 103 W. Commonly grades into alluvium. Maximum thickness a few tens of meters. (*GRI Source Map ID 31).* (GQ-1568).

Qtc - Talus and undifferentiated Colluvium (Holocene and Pleistocene)
Angular fragments of rock below cliffs and steep slopes; heterogeneous mixtures of silt, sand, gravel, cobbles, and boulders. Maximum thickness a few tens of meters. (*GRI Source Map ID 32).* (GQ-1403).

Qtc - Talus and other Colluvium (Holocene and Pleistocene)
Angular fragments of rock below cliffs and steep slopes; heterogeneous mixture of silt, sand, pebbles, cobbles, and boulders. Grades into alluvium and into landslide deposits. Maximum thickness may be a few tens of meters. (*GRI Source Map ID 33)*. (GQ-1554).

Qtc - Talus and other Colluvium (Holocene and Pleistocene)
Talus: Angular fragments of rock below cliffs and steep slopes. Colluvium: heterogeneous mixtures of silt, sand, pebbles, cobbles, and boulders. Maximum thickness several tens of meters. (*GRI Source Map ID 35).* (GQ-1535).

Qtc - Talus and other Colluvium (Holocene and Pleistocene)
Talus: angular fragments of rock below cliffs and steep slopes; other colluvium contains heterogeneous mixtures of silt, sand, pebbles, cobbles, and boulders. Maximum thickness a few tens of meters. (*GRI Source Map ID 36).* (GQ-1536).

Qtc - Talus and other Colluvium (Holocene and Pleistocene)
Angular fragments of rock below cliffs and steep slopes; heterogeneous mixture of silt, sand, pebbles, cobbles, and boulders. Grades into alluvium and into landslide deposits. Maximum thickness may be a few tens of meters. (*GRI Source Map ID 37)*. (GQ-1695).

Qtc - Talus and Undifferentiated Colluvium (Holocene and Pleistocene)
Talus: Angular fragments of rock below cliffs and steep slopes. Undifferentiated colluvium: Chiefly slopewash; heterogeneous mixtures of silt, sand, gravel, cobbles, and boulders; grades into talus. Maximum thickness a few tens of meters. (*GRI Source Map ID 40)* (GQ-1401).

Qtc - Talus and other Colluvium (Holocene and Pleistocene)
Talus includes angular fragments of rock below cliffs and steep slopes. Colluvium includes slope wash. Heterogeneous mixtures of silt, sand, gravel, cobbles, and boulders; intergrades with talus. Maximum thickness a few tens of meters. (*GRI Source Map ID 44).* (GQ-1530).

Qtc - Talus and other Colluvium (Holocene and Pleistocene)
Talus consists of angular fragments of rock below cliffs and steep slopes; colluvium consists of heterogeneous mixtures of silt, sand, pebbles, cobbles, and boulders. Maximum thickness a few tens of meters. (*GRI Source Map ID 45).* (GQ-1534).

Qtc - Talus and Colluvium (Holocene and Pleistocene)
Talus: Angular fragments of rock below cliffs and steep slopes. Colluvium: Slope wash. Heterogeneous mixtures of silt, sand, gravel, cobbles, and boulders, intergrades with talus. Maximum thickness a few tens of meters. (*GRI Source Map ID 46).* (GQ-1408).

Ql - Landslide deposits (Holocene and Pleistocene)

Ql - Landslide Deposits (Holocene and Pleistocene)
Very heterogeneous mixtures of rock fragments and soil. Maximum thickness several tens of meters. (*GRI Source Map ID 31).* (GQ-1568).

Ql - Landslide Deposits (Holocene and Pleistocene)
Very heterogeneous mixture of rock fragments and soil derived from nearby bedrock and surficial material. Maximum thickness several tens of meters. (*GRI Source Map ID 32).* (GQ-1403).

Ql - Landslide Deposits (Holocene and Pleistocene)

Heterogeneous mixture of earth and rock fragments. Grades into colluvium. Maximum thickness probably several tens of meters. (*GRI Source Map ID 33*). (GQ-1554).

Ql - Landslide Deposits (Holocene and Pleistocene)
Mostly angular very poorly-sorted debris that has moved downslope from nearby bedrock. Maximum thickness several tens of meters (100 ft.). (*GRI Source Map ID 34).* (GQ-1513).

Ql - Landslide Deposits (Holocene and Pleistocene)
Heterogeneous mixture of rock fragments and soil derived from nearby bedrock and surficial material. Maximum thickness several tens of meters. (*GRI Source Map ID 35).* (GQ-1535).

Ql - Landslide Deposits (Holocene and Pleistocene)
Heterogeneous mixtures of rock fragments and surficial material. Maximum thickness several tens of meters. (*GRI Source Map ID 36).* (GQ-1536).

Ql - Landslide deposits (Holocene and Pleistocene)
Heterogeneous mixtures of earth and rock fragments derived most commonly from Bishop Conglomerate. Grade into colluvium. Maximum thickness probably several tens of meters. (*GRI Source Map ID 37*). (GQ-1695).

Ql - Landslide Deposits (Holocene and Pleistocene)
Mostly angular, very poorly-sorted debris that has moved downslope from nearby bedrock. Maximum thickness a few tens of meters (100 ft). (*GRI Source Map ID 38).* (GQ-1516).

Ql - Landslide Deposits (Holocene and Pleistocene)
Mostly angular, very poorly-sorted debris that has moved downslope from nearby and underlying bedrock. Maximum thickness several tens of meters. (*GRI Source Map ID 39).* (GQ-1560).

Ql - Landslide Deposit (Holocene and Pleistocene)
Very heterogeneous mixture of rock fragments and soil derived from nearby bedrock and surficial material. Maximum thickness several tens of meters. (*GRI Source Map ID 40).* (GQ-1401).

Qls - Landslide Deposits (Holocene)
Generally composed of fragments of Dakota Sandstone. (*GRI Source Map ID 41).* (GQ-853).

Ql - Landslide Deposits (Holocene and Pleistocene)
Mostly angular, very poorly-sorted debris that has moved downslope from nearby bedrock. Most of the huge landslide that extends from west to east across the center of the map consists of rotated blocks, some as large as a city block, but generally less than the size of a small house, and boulders of the Buckhorn Member of the Cedar Mountain Formation. A lesser volume of debris is derived from Dakota Sandstone and Frontier Sandstone Member of the Mancos Shale. All this material is enclosed in a matrix of light-gray to light-greenish-gray clay of the Morrison Formation. The slide contains the hummocky topography and abundant springs that characterize many landslides. Maximum thickness probably about 50 m (150 ft). (*GRI Source Map ID 42).* (GQ-1514).

Ql - Landslide Deposits (Holocene and Pleistocene)
Mostly angular, very poorly-sorted debris that has moved downslope from nearby bedrock. Maximum thickness several tens of meters (100 ft.). (*GRI Source Map ID 43).* (GQ-1515).

Ql - Landslide Deposits (Holocene and Pleistocene)
Very heterogeneous mixture of rock fragments and soil. Maximum thickness several tens of meters. (*GRI Source Map ID 44).* (GQ-1530).

Ql - Landslide Deposits (Holocene and Pleistocene)
Very heterogeneous mixture of rock fragments and soil derived from nearby bedrock and surficial material. Symbols in parentheses indicate chief formational sources. Maximum thickness several tens of meters. (*GRI Source Map ID 45).* (GQ-1534).

Ql - Landslide Deposits (Holocene and Pleistocene)
Very heterogeneous mixtures of rock fragments and soil. Maximum thickness several tens of meters. (*GRI Source Map ID 46).* (GQ-1408).

Ql - Landslide Deposits (Recent)
Coherent glide blocks to heterogeneous mixtures of angular rock fragments; includes talus deposit in Cross Mountain Canyon and some slope wash along south slope of Elk Springs Ridge. (*GRI Source Map ID 1545)* (GQ-702).

Qg - Gravel deposits (Quaternary)

Caps probable pediment surfaces south of Elk Springs Ridge; thickness ranges from thin veneer to a few feet. (*GRI Source Map ID 1545).* (GQ-702).

Qop - Older pediment deposits (Pleistocene)

Qop - Older Pediment Deposits (Pleistocene)
Remnants of alluvial deposits on dissected surfaces above present streams. Silt, sand, and gravel, locally cemented. Maximum thickness about 10 m (30 ft.). (*GRI Source Map ID 34).* (GQ-1513).

Qop - Older Pediment Deposits (Pleistocene)
Remnants of alluvial deposits on dissected surfaces above present streams. Silt, sand, and gravel, locally cemented. Maximum thickness about 10m (30 ft). (*GRI Source Map ID 38).* (GQ-1516).

Qop - Older Pediment Deposits (Pleistocene)
Remnants of alluvial deposits on dissected surfaces above, and no longer at grade with, present streams. Silt, sand, and gravel, locally cemented by caliche. Maximum thickness about 10 m. (*GRI Source Map ID 39).* (GQ-1560).

Qop - Older Pediment Deposits (Pleistocene)
Remnants of alluvial deposits on dissected surfaces above present streams. Silt, sand, and gravel, locally cemented. Maximum thickness about 10 m (30 ft.). (*GRI Source Map ID 43).* (GQ-1515).

Qdi - Dissected fan deposits (Pleistocene)

Remnants of fan deposits on dissected surfaces above, and no longer at grade with, present streams. Silt, sand, and gravel, locally cemented by calcium carbonate. Maximum thickness about 30 m. (*GRI Source Map ID 39).* (GQ-1560).

Qod - Older debris fan deposits (Pleistocene)

Dissected by Holocene drainage. Very heterogeneous mixture of silt, sand, pebbles, cobbles, and boulders deposited by torrential flooding and (or) debris flowage. Maximum thickness a few tens of meters. (*GRI Source Map ID 45).* (GQ-1534).

Qr - River-terrace deposits (Pleistocene)

Qr - River Terrace Deposits (Pleistocene)
Remnants of alluvial deposits on dissected benches along the Green River. Silt, sand, and gravel, locally cemented. Maximum thickness about 10 m (30 ft.). (*GRI Source Map ID 34).* (GQ-1513).

Qr - River Terrace Deposits (Pleistocene)
Remnants of alluvial deposits on dissected benches along the Green River. Silt, sand, and gravel, locally cemented by calcium carbonate. Several terrace levels represented. Maximum thickness about 10 m. (*GRI Source Map ID 39).* (GQ-1560).

Qr - River Terrace Deposits (Pleistocene)
Remnants of alluvial deposits on dissected benches along the Green River. Silt, sand, and gravel, locally cemented. Maximum thickness about 10 m (30 ft.). (*GRI Source Map ID 43).* (GQ-1515).

Qc - Channel deposits (Pleistocene)

Gravel deposited in an abandoned rock-walled channel of the Green River about 150 m (500 ft) above present river level. Contains well-rounded, flattened pebbles and small cobbles mostly less than 10 cm in diameter of light-gray to dark-gray metaquartzite foreign to the Uinta Mountains but lithologically like Precambrian quartzite carried by the Green River from northwestern Wyoming. Also contains subangular gray to greenish gray metaquartzite derived from the Red Creek Quartzite exposed near the northwest end of Browns Park and pebbles and cobbles derived from the nearby Uinta Mountain Group. Channel deposit is mantled with locally derived slope wash and eolian sand. (*GRI Source Map ID 31).* (GQ-1568).

Qot - Terrace gravel (Pleistocene)

Additional unit description not provided. (*GRI Source Map ID 41).* (GQ-835).

Qoa - Older alluvium (Pleistocene)

Qoa - Older Alluvium (Pleistocene)
Dissected alluvial fans and related deposits. Poorly sorted calcareous sand and pebble gravel, locally cobbly and bouldery. Maximum thickness probably 10-15 m. (*GRI Source Map ID 35).* (GQ-1535).

Qoa - Older Alluvium (Pleistocene)
Alluvial remnants of varied Pleistocene age. Silt, sand gravel, cobbles, and boulders. Maximum thickness a few meters. (*GRI Source Map ID 46).* (GQ-1408).

QTs - Sediments of East Cactus Flat (Quaternary and Tertiary?)

Mostly locally-derived unconsolidated light-gray or tan fluvial sandstone. Boulders as much as 0.5 m (1.5 ft) long of red sandstone derived from the Uinta Mountain Group (Precambrian) and light- to medium-gray limestone derived from Paleozoic formations were observed at the base of the unit at the western edge of East Cactus Flat. The presence of these boulders suggests that some of the unit may be correlative with the Browns Park Formation (Miocene); alternatively, these boulders could be derived from Browns Park Formation in nearby areas. Maximum thickness about 10 m (30 ft). (*GRI Source Map ID 38).* (GQ-1516).

Tbp - Browns Park Formation (Miocene)

Tbp - Browns Park Formation (Miocene)
Light-gray to chalky white, friable, calcareous to tuffaceous sandstone, and white friable, earthy to vitric rhyolitic tuff. A single K-Ar radiometric age of 11.8 +/- 0.4 million years was dated by P.E. Damon from glass from a vitric tuff sampled by G.R. Winkler in Browns Park valley 25 km northwest of the quadrangle (G.R. Winkler, U.S. Geological Survey, written commun., 1970). A zircon fission-track age of 9.1 +/- 1.0 was measured by C.W. Naeser (cited by Izett, 1975, p. 187) from a tuff sampled high in the formation just north of the Canyon of Lodore North quadrangle near the mouth of Vermillion Creek. A tuff bed near the base of the formation, 47 km east of the quadrangle along the Little Snake River, but stratigraphically lower than any exposure in this quadrangle, has a K-Ar age (biotite) of about 25 m.y. (Izett and others, 1970, p. C150). Thickness ranges upward from an irregular edge to a maximum of about 150 m (500 ft), but thicker sections underlie nearby areas--at least 290 m (950 ft) in adjacent Jack Springs quadrangle and more than 368 m (1,200 ft) in the adjoining Vermillion Mesa quadrangle (S.J. Luft, U.S. Geological Survey, written commun., 1980); the top of the formation is everywhere erosional, hence these thicknesses are minimal. (*GRI Source Map ID 31).* (GQ-1568).

Tbp - Browns Park Formation (Miocene)
Light-gray to chalky-white friable tuffaceous sandstone and friable earthy to vitric rhyolitic tuff. (*GRI Source Map ID 46).* (GQ-1408).

Tbp - Browns Park Formation (Miocene)
Light-gray to white fine- to medium-grained soft friable crossbedded sandstone containing small amounts of conglomerate; includes thick evenly bedded light-gray clayey sandstones along Yampa River in T. 6 N., R. 97 W.; basal part is conglomerate consisting of poorly lithified pebbles, cobbles and boulder s of limestone, dolomite, chert and lesser amounts of red conglomeratic sandstone, 0 to about 135 feet thick but averages between 40 and 90 feet; owing to erosion, original thickness of formation is unknown but a remaining thickness of as much as 1,500 feet is present east of Cross Mountain. (*GRI Source Map ID 1545).* (GQ-702).

Tbpb - Browns Park Formation and Bishop (?) Conglomerate

Poorly consolidated light-gray, tan, white, and pinkish-gray poorly sorted medium-grained fluvial sandstone and interbedded poorly sorted pebble, cobble, and boulder fluvial conglomerate. Locally tuffaceous. Boulders as much as 1 m (3 ft) long in conglomerate consist largely of light- to medium-gray limestone and red chert derived from Round Valley Limestone (Lower Pennsylvanian) and Morgan Formation (Middle Pennsylvanian), and red sandstone derived from the Uinta Mountain Group (Precambrian). Coarsest material occurs at the base of the unit in most places, and the unit overlies erosion surfaces cut on Paleozoic and Mesozoic rocks. Locally overlain by Quaternary deposits. Unit probably mostly Browns Park Formation except for some rocks exposed on the highest erosion surfaces, which may be Bishop Conglomerate. Browns Park Formation is thicker in the adjacent Elk

Springs quadrangle (Dyni, 1968) and in Browns Park (see Hansen, 1965), which is about 10 km (6 mi) north of the quadrangle. The age of the two formations is problematical, but based on K-Ar ages of tuff beds exposed in the units elsewhere in the eastern Uinta Mountains, the Browns Park is considered Miocene, and the Bishop Conglomerate is considered Oligocene (Izett, Denson, and Obradovich, 1970; G.R. Winkler, written commun., 1969). Thickness is highly varied, but is at least 10 m (30 ft) thick in the southeastern corner of the mapped area and at least 60 m (200 ft) thick in the Klauson Pasture area. Boulders as much as 0.5 m (1.5 ft) long also are abundant at the base of the unit near its northern and eastern extent, at and southeast of Badger Flat; here the unit probably does not exceed 10 m (30 ft) in thickness. *GRI Source Map ID 38* (GQ-1516).

Tb - Bishop Conglomerate (Oligocene)

Tb - Bishop Conglomerate (Oligocene)
Conglomerate and sandstone, pinkish gray to nearly white, very poorly sorted, calcareous, friable. Pebbles, cobbles, and boulders derived mostly from Uinta Mountain Group. Underlies colluvium in Zenobia Basin. Biotite and hornblende from an interbedded tuff collected by G.A. Izett and W.R. Hansen in the nearby Blair Basin quadrangle in the SW ¼ , sec. 13, T. 2 S., R. 23 E., Uintah County, Utah, have K-Ar ages of about 29 m.y., as determined by H.H. Mehnert, U.S. Geological Survey. Thickness highly varied; may exceed 25 m (80 ft) at Pot Creek and Hoy Flat; top is erosional. (*GRI Source Map ID 31).* (GQ-1568).

Tb - Bishop (?) Conglomerate (Oligocene)
Pinkish-gray to nearly white, very poorly sorted friable calcareous pebbly to cobbly conglomerate and sandstone. Altered tuff and tuffaceous sandstone exposed in adjacent areas to west and south but not exposed in quadrangle. Thickness highly varied; may exceed 30 m in Zenobia Basin. (*GRI Source Map ID 32).* (GQ-1403).

Tb - Bishop Conglomerate (Oligocene)
Light gray to pink poorly sorted, friable sandstone and loosely cemented cobbly to bouldery conglomerate. Stones locally derived. Gray, earthy tuff beds and tuffaceous sandstone, poorly exposed, in upper part of formation in southern part of quadrangle. Upper surface appears to be erosional everywhere in quadrangle in the SW 1/4, sec. 13, T. 2 S., R. 23 E. have radiometric K-Ar ages of about 29 m.y. (million years) (biotite - 29.50±1.08 m.y.; hornblende 28.58±0.86 m.y.), as determined by Harald H. Mehnert, U.S. Geological Survey. Thickness highly varied; maximum may exceed 125 m. (*GRI Source Map ID 33*). (GQ-1554).

Tb - Bishop Conglomerate (Oligocene)
Light-gray, very poorly sorted friable calcareous pebbly to cobbly to bouldery conglomerate and sandstone derived chiefly from nearby Paleozoic formations. Clasts are mostly limestone, quartzite, and chert. Maximum thickness at least 14 m. (*GRI Source Map ID 35).* (GQ-1535).

Tb - Bishop Conglomerate (Oligocene)
Light-gray, very poorly sorted, friable calcareous pebbly to cobbly to bouldery conglomerate and sandstone. Clasts derived chiefly from Paleozoic limestones and Uinta Mountain Group. Locally tuffaceous. Thickness varied; may exceed 50 m along Mud Springs Draw and may reach 60 m along The Slough, but its basal contact is generally concealed by slope wash. (*GRI Source Map ID 36).* (GQ-1536).

Tb - Bishop Conglomerate (Oligocene)
Light-gray to pale pink, poorly sorted, friable sandstone and loosely cemented, cobbly to bouldery conglomerate. Stones locally derived. Gray, earthy tuff and tuffaceous sandstone, poorly exposed, in

upper part of formation. Upper surface appears to be erosional everywhere in quadrangle. Thickness highly varied, maximum may exceed 60 m. (*GRI Source Map ID 37*). (GQ-1695).

Tb - Bishop Conglomerate (Oligocene)
Poorly to moderately consolidated, light-gray and pink, poorly sorted, pebble, cobble, and boulder conglomerate, medium-grained sandstone, and conglomeratic sandstone. Of fluvial origin. Except in cliff faces, surface exposures are mostly loose grave. Boulders as much as 1 m long consist largely of light-gray to medium-gray limestone derived from Paleozoic rock units and of red sandstone derived from the Uinta Mountain Group (Precambrian). Locally overlain by Quaternary deposits. The age of the Bishop, based on K-Ar ages of biotite and hornblende collected from tuff beds in the upper part of the formation exposed in the adjacent Blair Basin quadrangle, is late Oligocene (H.H. Mehnert, U.S. Geological Survey, written commun., 1980). Maximum thickness about 130 m. (*GRI Source Map ID 39).* (GQ-1560).

Tb - Bishop (?) Conglomerate (Oligocene)
Light-gray to pinkish-gray, very poorly sorted, loosely cemented, pebbly, cobbly to bouldery conglomerate and sandstone. Stones were derived from nearby Paleozoic and Precambrian terranes. Tuffaceous interbeds. Thickness highly varied; may be as much as 150 m on Diamond Mountain. (*GRI Source Map ID 40).* (GQ-1401).

Tb - Bishop Conglomerate (Oligocene)
Poorly consolidated light-gray, tan, or white thin-bedded poorly sorted medium-grained fluvial sandstone and interbedded poorly sorted pebble, cobble, and boulder fluvial conglomerate. Locally tuffaceous. Boulders as much as 1 m (3 ft) long in conglomerate consist largely of red sandstone derived from the Uinta Mountain Group (Precambrian Y) and to a lesser extent of light- to medium-gray limestone derived from Paleozoic rock units. Unit fills a broad valley cut on Mesozoic rocks. Unit in large part overlain by tan sandy Quaternary deposits, mostly derived from erosion of the Glen Canyon Sandstone. Unit might be correlated with the Browns Park Formation (Miocene), but its high present elevation near the crest of this part of the Uinta Mountains, and its lithology suggest that it is better assigned to the Bishop Conglomerate. The age of the Bishop Conglomerate is problematic, but based on K-Ar ages of tuff beds exposed in the unit elsewhere in the eastern Uinta Mountains (G.R. Winkler, written commun., 1969), it is generally considered to be Oligocene. Thickness probably as much as 50 m (150 ft). (*GRI Source Map ID 42).* (GQ-1514).

Tb - Bishop Conglomerate (Oligocene)
Poorly consolidated light-gray or pink poorly sorted pebble, cobble, and boulder fluvial conglomerate and lesser volumes of poorly sorted medium-grained fluvial sandstone. Consists mostly of a cover of loose gravel. Boulders as much a 1 m (3 ft) long in conglomerate consist largely of light-gray to medium-gray limestone derived from Paleozoic rock units and red sandstone derived from Uinta Mountain Group (Precambrian). Locally overlain by Quaternary deposits. Unit may be correlated with Browns Park Formation (Miocene), but its high present elevation near the crest of this part of the Uinta Mountains, and its lithology suggest that it is better assigned to the Bishop Conglomerate. The age of the Bishop is problematical, but based on K-Ar ages of tuff beds exposed in the unit elsewhere is the eastern Uinta Mountains (G.R. Winkler, written commun., 1969), it is generally considered to be Oligocene. Patches of conglomerate on the Yampa Plateau probably as much as 20 m (65 ft) thick. Probably at least 30 m (100 ft) thick near Ruple Point. (*GRI Source Map ID 43).* (GQ-1515).

Tb - Bishop Conglomerate (Oligocene)
Light-gray to pinkish-gray very poorly sorted loosely cemented pebbly, cobbly to bouldery conglomerate and sandstone. Some boulders exceed 2 m in diameter. Boulders and roundstones derived from nearby Paleozoic and Precambrian terranes. Tuffaceous interbeds. Thickness highly varied; may locally exceed 60 m. (*GRI Source Map ID 44).* (GQ-1530).

Tb - Bishop Conglomerate (Oligocene)

Light-gray very poorly sorted friable calcareous pebbly to cobbly bouldery conglomerate and sandstone derived chiefly from nearby resistant Paleozoic formations. Local thickness may exceed 20-30 m. (*GRI Source Map ID 45).* (GQ-1534).

Tb - Bishop (?) Conglomerate (Oligocene)
Light-gray to nearly white very poorly sorted friable calcareous pebbly to cobbly to bouldery conglomerate and sandstone. Derived chiefly from Madison Limestone and Uinta Mountain Group. Thickness varied; may exceed 60 m on Douglas Mountain. (*GRI Source Map ID 46).* (GQ-1408).

Tge - Green River Formation, Evacuation Canyon Member (Eocene)

Additional unit description not provided. (*GRI Source Map ID 41).* (GQ-835).

Tgp - Green River Formation, Parachute Creek Member (Eocene)

Additional unit description not provided. (*GRI Source Map ID 41).* (GQ-835).

Tgpm - Green River Formation, Parachute Creek Member, base of main oil-shale zone (Eocene)

Additional unit description not provided. (*GRI Source Map ID 41).* (GQ-835).

Tgg - Green River Formation, Garden Gulch Member (Eocene)

Additional unit description not provided. (*GRI Source Map ID 41).* (GQ-835).

Tgd - Green River Formation, Douglas Creek Member (Eocene)

Additional unit description not provided. (*GRI Source Map ID 41).* (GQ-835).

Twt - Tongue of Wasatch Formation (Eocene)

Additional unit description not provided. (*GRI Source Map ID 41).* (GQ-835).

Tw - Wasatch Formation (Eocene)

Additional unit description not provided. (*GRI Source Map ID 41).* (GQ-835).

Kmvu - Mesa Verde Group, upper unit (Upper Cretaceous)

Additional unit description not provided. (*GRI Source Map ID 41).* (GQ-835).

Kmvc - Mesa Verde Group, main coal unit (Upper Cretaceous)

Additional unit description not provided. (*GRI Source Map ID 41).* (GQ-835).

Kmvm - Mesa Verde Group, minor coal unit (Upper Cretaceous)

Additional unit description not provided. (*GRI Source Map ID 41).* (GQ-835).

Kmvs - Mesa Verde Group, Sego Sandstone (Upper Cretaceous)

Additional unit description not provided. (*GRI Source Map ID 41).* (GQ-835).

Kwf - Williams Fork Formation (Lower Cretaceous)

Interbedded buff sandstone, gray shale, brown carbonaceous shale, and coal beds as much as 10 feet thick; contains much poorly exposed shale in middle part; about 2,500 to 2,900 feet thick. (*GRI Source Map ID 1545).* (GQ-702).

Kit - Iles Formation, Trout Creek Member (Lower Cretaceous)

Whitish-gray fine-grained crossbedded sandstone; ranges from 0(?) to more than 100 feet in thickness. (*GRI Source Map ID 1545).* (GQ-702).

Ki - Iles Formation, main body (Lower Cretaceous)

Interbedded buff fine-grained sandstone, gray shale, brown carbonaceous shale, and a few thin beds of coal; about 1,100 feet thick. (*GRI Source Map ID 1545).* (GQ-702).

Kc - Castlegate Sandstone, undivided (Upper Cretaceous)

Additional unit description not provided. (*GRI Source Map ID 41).* (GQ-835).

Kcu - Castlegate Sandstone, upper unit (Upper Cretaceous)

Additional unit description not provided. (*GRI Source Map ID 41).* (GQ-835).

Kcl - Castlegate Sandstone, lower unit (Upper Cretaceous)

Additional unit description not provided. (*GRI Source Map ID 41).* (GQ-835).

Kms - Mancos Shale, upper shale member (Upper and Lower Cretaceous)

Kms - Mancos Shale (Upper and Lower Cretaceous)
Soft, poorly exposed dark-gray or greenish-gray fissile shale; weathers light-gray or light-yellow. Includes beds of siltstone and bentonitic clay, and several thin beds of fine-grained sandstone. Locally subject to landsliding. Pavement of some roads crossing the unit are made hummocky by the swelling bentonitic clays. Correlative with the Hilliard Shale of the Flaming Gorge area (Hansen, 1955, 1965) and southwestern Wyoming. Partial section about 300 m (1000 ft) thick; unit about 1,500-1,550 m (4,910-5,070 ft) thick in the Jensen area (Walton, 1944; Kinney, 1955) just south of the quadrangle. (*GRI Source Map ID 34).* (GQ-1513).

Kms - Mancos Shale (Upper and Lower Cretaceous)
Soft, poorly exposed dark-gray fissile shale; weathers light-gray or light-yellow. Includes beds of siltstone and bentonitic clay. Includes beds of siltstone and bentonitic clay. Includes thin beds of fine-grained sandstone at the base. Locally subject to landsliding. Pavement of some roads crossing the unit are made hummocky by the swelling bentonitic clays. Correlative with the Hilliard Shale of the Flaming Gorge area (Hansen, 1955, 1965) and southwestern Wyoming, and the Baxter Shale of south-central Wyoming. Partial section, about 150 m (500 ft) thick; unit nearly 1,700 m (5,500 ft) thick in the Elk Springs quadrangle (Dyni, 1968). (*GRI Source Map ID 38).* (GQ-1516).

Kms - Mancos Shale (Upper and Lower Cretaceous)
Soft, poorly exposed dark-gray fissile shale; weathers light-gray or light-yellow. Includes beds of siltstone and bentonitic clay. Highly susceptible to landsliding. Partial section exposed; where exposed in nearby areas, the member is as much as 1,500 m thick. (*GRI Source Map ID 39).* (GQ-1560).

Kms - Mancos Shale (Upper and Lower Cretaceous)
Soft poorly exposed dark-gray or greenish-gray fissile shale; weathers light-gray or light-yellow. Includes beds of siltstone and bentonitic clay. Correlative with the Hilliard Shale of the Flaming Gorge area (Hansen, 1955, 1965) and southwestern Wyoming. Partial section, about 10 m (30 ft) thick; unit about 1,500-1,550 m (4,910-5,070 ft) thick in the Jensen area (Walton, 1944; Kinney, 1955) about 8 km (5 mi) west-southwest of the quadrangle. (*GRI Source Map ID 43).* (GQ-1515).

Kmu - Mancos Shale, upper unit (Upper and Lower Cretaceous)

Dark-gray partly sandy marine shale containing a few zones of limestone concretions; about 450 feet thick. (*GRI Source Map ID 1545).* (GQ-702).

Kmlo - Mancos Shale, base of Loyd Sandstone Member (Upper and Lower Cretaceous)

Member is gray very fine grained sandstone containing large spheroidal limy concretions and many invertebrate marine fossils, ranges from 0 to about 50(?) feet in thickness and occurs about 75 to 100 feet below top. (*GRI Source Map ID 1545).* (GQ-702).

Kmsc - Mancos Shale, base of sandstone unit C (Upper and Lower Cretaceous)

Unit is light-yellowish-brown and whitish-gray very fine- to fine-grained shaly sandstone ranging from a few feet to about 75 feet in thickness; occurs at base. (*GRI Source Map ID 1545).* (GQ-702).

Kmmb - Mancos Shale, main body (Upper and Lower Cretaceous)

Chiefly dark-gray marine shale; about 5,100 feet thick. (*GRI Source Map ID 1545).* (GQ-702).

Kmb - Buck Tongue of Mancos Shale (Upper Cretaceous)

Additional unit description not provided. (*GRI Source Map ID 41).* (GQ-835).

Kmsb - Mancos Shale, base of sandstone unit B (Upper and Lower Cretaceous)

Unit is lithologically similar to sandstone unit C above but ranges from 0 to about 35 feet in thickness; occurs about 160 feet below top. (*GRI Source Map ID 1545).* (GQ-702).

Kme - Mancos Shale, base of Emery (?) Sandstone member (Upper Cretaceous)

Additional unit description not provided. (*GRI Source Map ID 41).* (GQ-835).

Kmf - Mancos Shale, Frontier Sandstone (Upper and Lower Cretaceous)

Kmf - Mancos Shale (Upper and Lower Cretaceous)
Upper part is resistant light-brown or light-greenish-gray (light-gray weathering), mostly thin-bedded fine-grained fossiliferous calcareous locally crossbedded sandstone. At many places consists of two sandy sequences, separated by shale as much as 15 m (50 ft) thick. Lower part is soft mostly dark-gray (light-yellow weathering), fissile shale, siltstone, and silty shale. In the northwestern corner of the quadrangle (sec. 6, T. 4 S., R. 23 E.) the upper sandy part contains two beds of coal and carbonaceous shale, the lower one 1 m (3 ft) thick and the upper one 4 m (13 ft) thick. Spherical concretions, as much as 1.5 m (5 ft) in diameter, occur at the top of the member in the Bean Draw area, and nearby are as much as 5 m (15 ft) in diameter and enclose fossils (Untermann and Untermann, 1954). Lower contact, generally covered, is approximately located. Member thins eastward in the quadrangle. Just west of Bean Draw, upper sandstone part is about 51 m (167 ft) thick, and lower shale part is at least 32 m (105 ft) thick. In Orchid Draw, upper part is 47 m (154 ft) thick, and lower part is 21 m (70 ft) thick (Kinney, 1955). Near Dinosaur Quarry the upper part is 44 m (145 ft) thick and the lower part is 24 m (80 ft) thick (Untermann and Untermann, 1954). It is slightly thicker west of the quadrangle and slightly thinner north of it (Kinney, 1955; Hansen, 1965; Untermann and Untermann, 1968). (*GRI Source Map ID 34).* (GQ-1513).

Kmf - Mancos Shale (Upper and Lower Cretaceous)
Upper part is resistant light-brown or light-greenish-gray, light-gray weathering, mostly thin-bedded fine-

grained fossiliferous calcareous locally crossbedded sandstone and local thin poorly exposed carbonaceous shale or coal beds. Lower part is soft mostly dark-gray light-yellow weathering, fissile shale, silty shale, and siltstone. Lower contact, generally covered, is approx. located. West of Calico Draw, the upper sandstone part is about 24 m (80 ft) thick and the lower shale part is about 40 m (130 ft) thick. Thicker to the south (Thomas and others, 1945). (*GRI Source Map ID 38).* (GQ-1516).

Kmf - Mancos Shale (Upper and Lower Cretaceous)
Resistant, light-brown, buff, and light-greenish-gray mostly thin-bedded, fine-grained fossiliferous calcareous locally crossbedded sandstone containing abundant fossil worm burrows, and soft light-brown and light-greenish-gray fissile shale, carbonaceous shale, silty shale, and sandstone. About 10-75 m thick. (*GRI Source Map ID 39).* (GQ-1560).

Kmf - Mancos Shale, Frontier Sandstone Member (Upper Cretaceous)
Additional unit description not provided. (*GRI Source Map ID 41).* (GQ-835).

Kmf - Mancos Shale (Upper and Lower Cretaceous)
Upper part is resistant light-brown or light-greenish-gray (light-gray weathering), mostly thin-bedded fine-grained fossiliferous calcareous locally crossbedded sandstone and local thin poorly exposed beds of carbonaceous shale. Lower part is mostly dark-gray (light-yellow weathering), fissile shale, silty shale, and siltstone. Lower contact, generally covered, is approx. located. About 40 m (130 ft) thick north of Buckwater Ridge, but the upper part probably was removed by erosion. It is about 80-90 m (260-300 ft) thick south and east of the mapped area (Cullins, 1969; Thomas and others, 1945). (*GRI Source Map ID 42).* (GQ-1514).

Kmf - Mancos Shale (Upper and Lower Cretaceous)
Upper part is resistant light-brown, buff, and light-greenish-gray, light-gray weathering, mostly thin-bedded fine-grained fossiliferous calcareous locally crossbedded sandstone, containing abundant fossil worm burrows. Lower part is mostly dark-gray (light-yellow weathering), fissile shale, silty shale, and siltstone. Lower contact, generally covered, is approx. located. Poorly exposed but probably at least 60 m (200 ft) thick. Just west of the mapped area, near Dinosaur Quarry, the upper sandstone part is 44 m (145 ft) thick and the lower shale part is 24 m (80 ft) thick (Untermann and Untermann, 1954). The member is thicker west of the quadrangle and slightly thinner north of it (Kinney, 1955; Hansen, 1965); Untermann and Untermann, 1968). (*GRI Source Map ID 43).* (GQ-1515).

Kmf - Mancos Shale (Upper and Lower Cretaceous)
Upper part is interbedded gray and tan fossiliferous calcaeous sandstone and gray shale; lower part is soft brownish-gray shale containing thin beds of bentonite; about 200 feet thick. (*GRI Source Map ID 1545).* (GQ-702).

Kmm - Mancos Shale, Mowry Member (Upper and Lower Cretaceous)

Kmm - Mancos Shale (Lower Cretaceous)
Distinctive soft silver-gray or bluish-gray fissile siliceous shale and bentonite. Contain abundant fish scales. Covered in most places by debris from the overlying Frontier Sandstone Member, but the presence of the member is indicated by chips of silver-gray shale in soil. About 37 m (120 ft) thick just west of Bean Draw, but contacts are poorly exposed and unit may be slightly thicker. About 29 m (95 ft) thick in Orchid Draw (Kinney, 1955), and 38 m (125 ft) thick near Dinosaur Quarry (Untermann and Untermann, 1954). Ranges from about 10 to 65 m (30 to about 215 ft) thick west and north of the quadrangle (Kinney, 1965; Hansen, 1965; Untermann and Untermann, 1968). (*GRI Source Map ID 34).* (GQ-1513).

Kmm - Mancos Shale (Upper and Lower Cretaceous)

Distinctive soft silver-gray or bluish-gray fissile siliceous shale and bentonite. Contains abundant fish scales. Covered in most places by debris from the overlying Frontier Sandstone Member, but the presence of the member is indicated by chips of silver-gray shale in the soil. At least 10 m (30 ft) thick just west of Calico Draw. (*GRI Source Map ID 38).* (GQ-1516).

Kmm - Mancos Shale (Upper and Lower Cretaceous)
Soft, silver-gray, or bluish-gray, fissile siliceous shale and bentonite. Contains abundant fish scales. Covered in most places by debris from the overlying Frontier Sandstone Member, (Kmf), but the presence of the Mowry Member is indicated by chips of silver-gray shale in the soil. About 40 m thick. (*GRI Source Map ID 39).* (GQ-1560).

Kmm - Mancos Shale, Mowry Shale Member (Upper Cretaceous)
Additional unit description not provided. (*GRI Source Map ID 41).* (GQ-835).

Kmm - Mancos Shale (Upper and Lower Cretaceous)
Distinctive soft silver-gray or bluish-gray fissile siliceous shale and bentonite. Contains abundant fish scales. Covered in most places by debris from the overlying Frontier Sandstone Member, but the presence of the Mowry is indicated by chips of silver-gray shale in the soil. At least 15 m (50 ft) thick north of Buckwater Ridge. (*GRI Source Map ID 42).* (GQ-1514).

Kmm - Mancos Shale (Upper and Lower Cretaceous)
Distinctive soft silver-gray or bluish-gray fissile siliceous shale and bentonite. Contains abundant fish scales. Covered in most places by debris from the overlying Frontier Sandstone Member, but the presence of the member is indicated by chips of silver-gray shale in the soil. About 30 m (100 ft) thick. Ranges from about 10 to about 65 m (30-215 ft) thick west and north of the mapped area (Kinney, 1965; Hansen, 1965; Untermann and Untermann, 1968). (*GRI Source Map ID 43).* (GQ-1515).

Kmm - Mancos Shale (Upper and Lower Cretaceous)
Gray siliceous shale interbedded with many thin beds of bentonite; contains many fish scales and bones; weathers to distinctive light ash gray; about 100 feet thick. (*GRI Source Map ID 1545).* (GQ-702).

Kd - Dakota Sandstone (Lower Cretaceous)

Kd - Dakota Sandstone (Lower Cretaceous)
Resistant light-gray or light-yellow, medium- to thick-bedded, crossbedded medium- to coarse-grained sandstone, pebbly medium- to coarse-grained sandstone, and less abundant pebble conglomerate (Vaughn and Picard, 1976). Contains sparse but conspicuous black, red, and yellow chert grains and white fossil shell fragments. Contains minor dark-gray fissile shale. At least 27 m (90 ft) thick west of Bean Draw; about 15 m (50 ft) thick near Dinosaur Quarry (Untermann and Untermann, 1954). Locally 60 or more meters (200 + feet) thick west and north of the quadrangle (Kinney, 1955; Hansen, 1965). (*GRI Source Map ID 34).* (GQ-1513).

Kd - Dakota Sandstone (Lower Cretaceous)
Resistant light-gray or light-yellow medium- to thick-bedded crossbedded medium- to coarse-grained sandstone, pebbly medium- to coarse-grained sandstone, and less abundant pebble conglomerate (Vaughn and Picard, 1976). Contains sparse but conspicuous black and red chert grains and white fossil shell fragments. Contains minor dark-gray fissile shale. At least 30 m (100 ft) thick just west of Calico Draw. (*GRI Source Map ID 38).* (GQ-1516).

Kd - Dakota Sandstone (Lower Cretaceous)
Resistant to moderately resistant, light-gray, white, and light-yellow, medium- to thick-bedded,

crossbedded, medium- to coarse-grained sandstone, pebbly medium- to coarse-grained sandstone, pebble conglomerate, and subordinate black and dark-gray carbonaceous shale. Contains sparse but conspicuous black and red chert grains and white shell fragments. About 5-30 m thick. (*GRI Source Map ID 39).* (GQ-1560).

Kd - Dakota Sandstone (Upper Cretaceous)
Additional unit description not provided. (*GRI Source Map ID 41).* (GQ-835).

Kd - Dakota Sandstone (Lower Cretaceous)
Resistant light-gray or light-yellow, medium- to thick-bedded, crossbedded medium- to coarse-grained sandstone, pebbly medium- to coarse-grained sandstone, and less abundant pebble conglomerate (Vaughn and Picard, 1976). Contains conspicuous black and red chert grains and white fossil shell fragments. Contains minor dark-gray fissile shale. At least 12 m (40 ft) thick on Buckwater Ridge northwest of Gadd Cabin. (*GRI Source Map ID 42).* (GQ-1514).

Kd - Dakota Sandstone (Lower Cretaceous)
Resistant light-gray or light-yellow medium- to thick-bedded crossbedded medium- to coarse-grained sandstone, pebbly medium- to coarse-grained sandstone, pebbly medium- to coarse-grained sandstone, and less abundant pebble conglomerate. Contains sparse but conspicuous black, red, and yellow chert grains and white fossil shell fragments. Contains minor dark-gray fissile shale. Poorly exposed but at least 10 m (30 ft) thick. West of the quadrangle, near Dinosaur Quarry, about 15-19 m (50 ft) thick (Untermann and Untermann, 1954; Vaughn and Picard, 1976). Locally 60 or more meters (200 ft) thick west and north of the quadrangle (Kinney, 1955; Hansen, 1965). (*GRI Source Map ID 43).* (GQ-1515).

Kd - Dakota Sandstone (Lower Cretaceous)
Upper part is light-gray quartzitic sandstone containing dark chert pebbles and a few thin beds of dark-gray shale; middle part is chiefly dark-gray fissile shale; lower part, locally absent, is light-gray sandstone containing dark chert pebbles; thickness of formation ranges widely but generally is about 70 to 100 feet. (*GRI Source Map ID 1545).* (GQ-702).

Kcm - Cedar Mountain Formation (Lower Cretaceous)

Kcm - Cedar Mountain Formation (Lower Cretaceous)
Gray shale, mudstone, sandstone, and pebble conglomerate. Section is poorly exposed and incomplete, but full thickness may be as much as 60 m in adjacent Plug Hat Rock quadrangle (Rowley and Hansen, 1979). (*GRI Source Map ID 36).* (GQ-1536).

Kcm - Cedar Mountain Formation (Lower Cretaceous)
Contains two members; an upper shale member of soft purple, gray, and greenish-gray shale, mudstone, and minor limestone; and the lower Buckhorn Conglomerate Member of resistant medium-gray, light-gray, and tan medium-bedded, crossbedded sandy pebble conglomerate, grit, pebbly sandstone, and fine- to coarse-grained sandstone. Overlying shale member rarely exposed. As much as 50 percent by volume of the clasts in the Buckhorn Conglomerate Member consist of gray to black chert. Correlation and usage after Anderman (1961), Cullins (1969), and Hansen (1969a). Unit correlated with the Burro Canyon (?) Formation in the Skull Creek area 15 km (9 mi) east of the mapped area (Cadigan, 1972). Formation about 32 m (105 ft) thick--equally divided between the shale member and the Buckhorn Member--on Buckwater Ridge northwest of Gadd Cabin, but is estimated at as much as 60 m (200 ft) thick elsewhere in the mapped area. (*GRI Source Map ID 42).* (GQ-1514).

Kcs - Cedar Mountain Formation, shale member (Lower Cretaceous)

Additional unit description not provided. (*GRI Source Map ID 41).* (GQ-835).

Kcb - Cedar Mountain Formation, Buckhorn Conglomerate Member (Lower Cretaceous and Upper Jurassic)

Additional unit description not provided. (*GRI Source Map ID 41).* (GQ-835).

KJum - Undifferentiated Lower Cretaceous Rocks and Morrison Formation (Lower Cretaceous and Upper Jurassic)

Soft green, greenish-gray, light-gray, red, and purple shale, claystone, and siltstone and subordinate lenticular interbedded, medium-bedded, and crossbedded fine- to coarse-grained sandstone.

Several lenticular light-gray, greenish-gray, or light-yellow crossbedded sandstone and conglomerate beds, as much as 8 m (25 ft) thick, form ledges in the middle and upper part of the unit, as in the SE ¼ sec. 32, T. 6 N., R. 99 W., and SE ¼ sec. 9, T. 5 N., R. 99 W. These beds are rich in black chert clasts and resemble conglomerate and sandstone of the Buckhorn Conglomerate Member of the Cedar Mountain Formation (Lower Cretaceous), which is exposed in northeastern Utah near the Dinosaur National Monument headquarters (Cullins, 1969; Hansen, 1969a) and at least as far east as the community of Blue Mountain. Young (1975) correlated rocks in the eastern part of the quadrangle (his Lily Park section) with the Cedar Mountain Formation; he estimated the thickness of the Buckhorn Member to be about 6 m (20 ft) and of an upper mudstone to be about 12 m (40 ft).

In the upper part of Morrison, mudstone and marlstone predominate, but in the lower part of the Morrison fissile shale is more abundant. Includes local conglomerate and limestone. Contains bentonite clay beds and locally is subject to landsliding. Contact with the underlying Redwater Member is poorly exposed and approximately located in some places. Undivided Lower Cretaceous rocks and Upper Jurassic Morrison Formation are about 170 m (570 ft) thick. Morrison is slightly thicker east and southeast of the quadrangle. The Morrison thickens west of the mapped area and thins east of it (Hansen, 1965, fig. 30).

An extensive pink, tan, and yellow crumbly ripplemarked thin- to medium-bedded, medium-grained sandstone, about 6 m (20 ft) thick, occurs at the base of the Upper Jurassic Morrison Formation. This sandstone is correlative with the Windy Hill Member of the Sundance Formation (Upper Jurassic) of Wyoming and north-central Colorado (Pipiringos, 1968, 1972; Pipiringos and others, 1969; Pipiringos and O'Sullivan, 1978). It is well exposed about 100 m (300 ft) southwest of Bill White Spring, where it is overlain by purple and gray shale in turn overlain by a massive white eolian sandstone, both of the Morrison Formation. The Windy Hill is thinner southwest of the quadrangle; in adjacent areas to the northeast and east it unconformably truncates the underlying members of the Stump Formation (Pipiringos, 1968; 1972). (*GRI Source Map ID 38)* (GQ-1516).

KJcm - Cedar Mountain Formation and Morrison Formation (Lower Cretaceous and Upper Jurassic)

KJcm - Cedar Mountain (?) Formation (Lower Cretaceous) and Morrison Formation (Upper Jurassic)
Undifferentiated - soft green, white, greenish-gray, light-gray, light-yellow, red, and purple shale,

claystone, and siltstone; less abundant interbedded, medium-bedded crossbedded fine- to coarse-grained lenticular sandstone.

The upper part (top 30-60 m or 100-200 ft) of the mapped unit probably is correlative with the Cedar Mountain Formation, but the presence of the resistant basal conglomerate and sandstone (Buckhorn Conglomerate Member) that elsewhere enables this formation to be mapped separately from the lithologically-similar Morrison Formation is discontinuous. Lenticular beds of sandstone and conglomerate, which contain abundant black chert and which probably are correlative with the Buckhorn Member, occur in several places. One such bed, about 6 m (20 ft) thick and stratigraphically about 30-40 m (100-130 ft) below the base of the Dakota Sandstone, consists of resistant light- to medium-gray or brown crossbedded small-pebble conglomerate and coarse-grained sandstone; it extends westward past the quadrangle boundary and eastward as far as Orchid Draw and intermittently as far as the Dinosaur Quarry area, where it is about 16 m (52 ft) thick (Untermann and Untermann, 1968). Other lenses occur just south of the Blue Mountain road in SW 1/4 sec. SW 1/4 sec. 30, T. 4 S., R. 24 W. and near the east-west dirt road in S 1/2 sec. 5 and 6, T. 4 S., R. 23 E. Gray and red shale, perhaps correlative with the shale member of the Cedar Mountain Formation, overlies these beds. The Cedar Mountain Formation has been identified near the town of Dinosaur (Anderman, 1961; Cullins, 1969; Hansen, 1969a; Rowley and Hansen, 1979), where it has a thickness of about 30-60 m (100-200 ft).

In the upper part of the Morrison, mudstone and marlstone predominate, but in the lower part, fissile shale is more abundant. Includes local conglomerate and limestone. Chert grains of several colors are common in the sandstone and conglomerate. The dinosaur bones from the famous Dinosaur Quarry are from a greenish-gray pebbly sandstone bed in the Morrison Formation; this bed contains abundant chert clasts of various colors, especially black. The contact with the underlying Redwater Member of the Stump Formation is poorly exposed and approx. located. The Morrison near Dinosaur Quarry is about 260 m (850 ft) thick (Untermann and Untermann, 1954, 1968), but it is thinner than this near the eastern edge of the quadrangle. The Morrison thickens west of the mapped area and thins east of it (Hansen, 1965, fig. 30).

A mostly soft but extensive white, pink, or light-yellow fine- to medium-grained thin-bedded ripplemarked sandstone, locally more than 15 m (50 ft) thick, occurs at the base of the Morrison Formation. This sandstone may be correlative with the Windy Hill Member of the Sundance Formation (Upper Jurassic) of Wyoming and north-central Colo. (Pipiringos, 1968, 1972); Pipiringos and others, 1969; Pipiringos and O' Sultan, 1977; Imlay, 1980). The Windy Hill is 2 m (6 ft) thick near the water tank about 450 m (1,500 ft) northwest of Dinosaur Quarry (Pipiringos, unpublished data; Imlay, 1980). (*GRI Source Map ID 34).* (GQ-1513).

KJcm - Cedar Mountain (?) Formation (Lower Cretaceous) and Morrison Formation Undifferentiated (Upper Jurassic)
Soft green, greenish-gray, light-gray, red, greenish-yellow, and purple shale, claystone, and siltstone; and less abundant interbedded, medium-bedded, and crossbedded fine- to coarse-grained lenticular sandstone.
The upper part (top 30-60 m) of the mapped unit probably is correlative with the Cedar Mountain Formation, but the presence of the resistant basal conglomerate and sandstone (Buckhorn Conglomerate Member) that elsewhere enables this formation to be differentiated from the lithologically-similar Morrison Formation is absent in the quadrangle. The Cedar Mountain Formation has been identified near the town of Dinosaur (Anderman, 1961; Cullins, 1969; Hansen, 1969a; Rowley and Hansen, 1979), where it has a thickness of about 30-60 m (100-200 ft).

In the upper part of the Morrison, mudstone and marlstone predominate, but in the lower part, fissile shale is more abundant. This includes local conglomerate, limestone, and bentonite. Locally is subject to landsliding. Chert grains of several colors are common in the sandstone and conglomerate. The contact with the underlying Redwater Shale Member of the Stump Formation is poorly exposed and thus

approx. located in some places. Thickness of the mapped unit probably is at least 250 m (800 ft). The Morrison thickens west of the quadrangle and thins east of it (Hansen, 1965, fig. 30).

A mostly soft but extensive white, pink, and light-yellow fine- to medium-grained thin-bedded ripplemarked sandstone, locally more than 15 m (50 ft) thick in the Dinosaur Quarry quadrangle (Rowley and others, 1979), occurs at the base of the Morrison Formation. This sandstone may be correlative with the Windy Hill Sandstone Member of the Sundance Formation (Upper Jurassic) of Wyoming and north-central Colorado (Pipiringos, 1968, 1972; Pipiringos and others, 1969; Pipiringos and O'Sullivan, 1978; Imlay, 1979). (*GRI Source Map ID 43).* (GQ-1515).

Jm - Morrison Formation (Upper Jurassic)

Jm - Morrison Formation (Upper Jurassic)
Soft variegated shale, claystone, siltstone, and sandstone. Section is poorly exposed and incomplete, but full thickness exceeds 200 m in adjacent Plug Hat Rock quadrangle (Rowley and Hansen, 1979). (*GRI Source Map ID 36).* (GQ-1536).

Jm - Morrison Formation (Upper Jurassic)
Soft, green, greenish-gray, light-gray, red, purplish-red, dark-yellow, purple, and white shale, claystone, and siltstone, and less abundant interbedded thin- to medium-bedded, crossbedded, fine- to coarse-grained lenticular sandstone. Includes local mudstone and marlstone predominant, but in the lower part, fissile shale is more abundant. Chert grains of several colors are common in the sandstone and conglomerate. The upper part may include rocks assigned elsewhere to the Cedar Mountain Formation (Lower Cretaceous). Locally is subject to landsliding. The contact with the underlying Redwater Shale Member of the Stump Formation (Jsr) is poorly exposed and thus only approx. located in some places. About 200-300 m thick. (*GRI Source Map ID 39).* (GQ-1560).

Jm - Morrison Formation (Upper Jurassic)
Additional unit description not provided. (*GRI Source Map ID 41).* (GQ-835).

Jm - Morrison Formation (Upper Jurassic)
Soft olive-gray, gray, red, light-purple, and bluish-gray shale, claystone, and siltstone; less abundant interbedded medium-bedded, crossbedded fine- to coarse-grained sandstone in lenticular beds. In upper part of Morrison Formation, mudstone and marlstone predominate, but in lower part fissile shale is more abundant. Includes local conglomerate and limestone. Contains bentonite clay beds, and commonly is subject to landsliding. An extensive crumbly gray thin- to medium-bedded medium-grained sandstone, about 15 m (50 ft) or more thick, occurs at the base of the unit. This sandstone is correlative with the Windy Hill Sandstone Member of the Sundance Formation (Upper Jurassic) of Wyoming and north-central Colorado (Pipiringos, 1968, 1972; Pipiringos, Hail, and Izett, 1969; Pipiringos and O'Sullivan, 1977; Imlay, 1979). It is about 14 m (45 ft) thick in the NE 1/4 NE. 1/4 sec. 8, T. 3 N., R. 103 W., but is thinner east of the quadrangle (Imlay, 1979; G.N. Pipiringos, unpub. data). Contact of the sandstone with the Redwater Member of the Stump Formation is poorly exposed and approx. located. Thickness estimated at more than 200 m (650 ft). (*GRI Source Map ID 42).* (GQ-1514).

Jm - Morrison Formation (Upper Jurassic)
Interbedded varicolored siltstone and claystone, light-gray sandstone, and some chert-pebble conglomerate; a few lenticluar beds of nodular limestone near top; whitish-gray massive very fine- to fine-grained sandstone ranging from 25 to as much as 130 feet in thickness at base; about 600 feet thick. (*GRI Source Map ID 1545).* (GQ-702).

Js - Stump Formation (Upper Jurassic and Middle Jurassic)

Shown only in cross section A-A'. (*GRI Source Map ID 36).* (GQ-1536).

Jsr - Stump Formation, Redwater Member (Upper Jurassic)

Jsr - Stump Formation (Upper and Middle Jurassic), Redwater Member (Upper Jurassic)
Soft olive-green and light-green mostly fissile glauconitic shale and siltstone, as well as sparse interbeds of distinctive resistant tan, purplish-gray, or greenish-gray, thin-bedded (mostly less than 10 cm, or 4 in), locally ripplemarked vaguely crossbedded sandy glauconitic oolitic limestone and fossiliferous sandstone. Some limestone beds contain a coquina of oysters, clams, and belemnites. Locally contains concretions, cone-in-cone structure, and bedded chert. Correlation based on studies by Pipiringos (1968, 1972); Pipiringos, Hail, and Izett (1969); Pipiringos and O'Sullivan (1977); and Imlay (1980). Unit included in the upper part of the Curtis Formation as previously mapped in Dinosaur National Monument (Untermann and Untermann, 1954, 1968) and nearby areas (Cullins, 1969; Kinney, 1955). About 40 m (130 ft) thick in the quadrangle (G.N. Pipiringos, unpub. data). (*GRI Source Map ID 34).* (GQ-1513).

Jsr - Stump Formation, Redwater Member (Upper Jurassic)
Soft, olive-green, and light-green, mostly fissile, glauconitic shale and siltstone with sparse interbeds of resistant tan, purplish-gray, and greenish-gray thin-bedded (mostly less than 10 cm), locally ripple marked, vaguely crossbedded, sandy glauconitic oolitic limestone and fossiliferous sandstone. Some limestone beds are coquina made up of oyster, clam, and belemnite shells. Locally contains calcareous concretions and cone-in-cone structure. About 15-60 m thick. (*GRI Source Map ID 38).* (GQ-1516).

Jsr - Stump Formation, Redwater Member (Upper Jurassic)
Soft olive-green and light-green mostly fissile glauconitic shale and siltstone as well as sparse interbeds of distinctive resistant tan, purplish-gray, and greenish-gray thin-bedded (mostly less than 10 cm, or 4 in.) locally ripplemarked vaguely crossbedded sandy glauconitic oolitic limestone and fossiliferous sandstone. Some limestone beds, including one that occurs locally at the base, contain a coquina of oysters, clams, and belemnites. Member locally contains concretions and cone-in-cone structure. Correlation based on studies by Pipiringos, (1968, 1972); Pipiringos, Hail, and Izett (1969); and Pipiringos and O'Sullivan (1978). Included in the upper part of the Curtis Formation as previously mapped in Dinosaur National Monument (Untermann and Untermann, 1954) and nearby areas (Hansen, 1955, 1965; Dyni, 1968). About 27 m (90 ft) thick west of Calico Draw and about 22 m (70 ft) thick, 100 m (300 ft) southwest of Bill White Spring. (*GRI Source Map ID 39).* (GQ-1560).

Jsr - Stump Formation, Redwater Member (Upper Jurassic)
Soft olive-green and light-green mostly fissile glauconitic shale and siltstone as well as sparse interbeds of distinctive resistant tan, purplish-gray, and greenish-gray, thin-bedded (mostly less than 10 cm, or 4 in), locally ripplemarked, vaguely crossbedded sandy glauconitic oolitic limestone and fossiliferous sandstone. Some limestone beds contain a coquina of oysters, clams, and belemnites. Locally contains concretions and cone-in-cone structure. Correlation based on studies by Pipiringos (1968, 1972); Pipiringos, Hail, and Izett (1969); and Pipiringos and O'Sullivan (1977); and Imlay (1979). Unit included in the upper part of the Curtis Formation as previously mapped in Dinosaur National Monument (Untermann and Untermann, 1954) and nearby areas (Hansen, 1955, 1965; Cullins, 1969; Kinney, 1955). Thickness about 34 m (110 ft) near well in NW 1/4 sec. 7, T. 3 N., R. 103 W.; about 40 m (130 ft) in SE 1/4 SW 1/4 sec. 5, T. 3 N., R 103 W. (G.N. Pipiringos, unpub. data) and somewhat thicker east of the quadrangle (Imlay, 1979). (*GRI Source Map ID 42).* (GQ-1514).

Jsr - Stump Formation, Redwater Member (Upper and Middle Jurassic)
Soft olive-green and light-green mostly fissile glauconitic shale and siltstone as well as sparse interbeds of distinctive resistant tan, purplish-gray, and greenish-gray thin-bedded (mostly less than 10 cm, or 4

in.) locally ripplemarked vaguely crossbedded, sandy glauconitic oolitic limestone and fossiliferous sandstone. Some limestone beds contain a coquina of oysters, clams, and belemnites. Locally contains concretions and cone-in-cone structure. Correlation based on studies by Pipiringos, (1968, 1972); Pipiringos, Hail, and Izett (1969); and Pipiringos and O'Sullivan (1978), and Imlay (1979). Unit included in the upper part of the Curtis Formation as previously mapped in Dinosaur National Monument (Untermann and Untermann, 1954) and nearby areas (Hansen, 1955, 1965; Cullins, 1969: Kinney, 1955). Probably about 40 m (130 ft) thick in the quadrangle. (*GRI Source Map ID 43).* (GQ-1515).

Jsc - Stump Formation, Curtis Member (Middle Jurassic)

Jsc - Stump Formation, Curtis Member (Middle Jurassic)
Distinctive resistant light-gray or light-greenish-gray thin- to medium-bedded, crossbedded fossiliferous locally ripplemarked glauconitic medium- to coarse-grained sandstone. Locally fine-grained at base. Commonly contains clay galls and carbonaceous trash and is speckled with chert grains of various colors. At southern edge of Split Mountain Gorge Campground, includes weak greenish-gray and grayish-green fissile shale about 6 m (20 ft) thick, the base of which is 5 m (16 ft) above the base of the member. Previously, the type Curtis was thought to equal all of the Curtis Formation of the Uintas, but regional stratigraphic studies (Pipiringos and Imlay, 1979) indicate that it equals only the lower part and is the Curtis Member of the Stump Formation. About 18 m (59 ft) thick in W1/2S E1/4 sec. 5, T. 4 S., R. 23 W.; about 24 m (79 ft) thick in Dinosaur Quarry area (Untermann and Untermann, 1954; Imlay, 1980; Pipiringos, unpub. data); and about 33 m (108 ft) thick at southern edge of Split Mountain Gorge Campground. Apparently of comparable thickness to the north (Hansen, 1965), but thins west and east of the quadrangle (Kinney, 1955; Cullins, 1969; Rowley and Hansen, 1979). (*GRI Source Map ID 34).* (GQ-1513).

Jsc - Stump Formation, Curtis Member (Middle Jurassic)
Distinctive resistant light-gray or light-greenish-gray and locally pink thin- to medium-bedded crossbedded fossiliferous glauconitic medium- to coarse-grained sandstone. Commonly contains clay galls and carbonaceous trash. Sandstone speckled with chert grains of various colors. Previously the type Curtis was thought to equal all of the Curtis Formation of the Uintas, but regional stratigraphic studies (Pipiringos and Imlay, 1979) indicate that it equals only the lower part and is the Curtis Member of the Stump Formation. About 7 m (23 ft) thick at Bill White Spring and for about 1 km (0.8 mi) along strike to the south; as much as 8 m (26 ft) thick near southeastern edge of quadrangle. Pinches out and is absent in the central part of the outcrop area. Slightly thinner southwest of the quadrangle, but generally thickens west of the quadrangle (Kinney, 1955). (*GRI Source Map ID 38).* (GQ-1516).

Jsc - Stump Formation, Curtis Member (Middle Jurassic)
Resistant, light-gray or light-greenish-gray, thin- to medium-bedded, ripplemarked, crossbedded, fossiliferous, glauconitic, medium- to coarse-grained sandstone. Commonly contains clay galls and carbonaceous plant fragments. Sandstone speckled with chert grains of various colors; locally contains gray or pink coquina limestone or fossil-rich sandstone containing oyster and clam shells. About 10-25 m thick. (*GRI Source Map ID 39).* (GQ-1560).

Jc - Curtis Formation (Upper Jurassic)
Additional unit description not provided. (*GRI Source Map ID 41).* (GQ-835).

Jsc - Stump Formation (Upper and Middle Jurassic), Curtis Member (Middle Jurassic)
Distinctive resistant light-gray or light-greenish-gray thin- to medium-bedded, crossbedded fossiliferous glauconitic medium- to coarse-grained sandstone. Commonly contains clay galls and carbonaceous trash. Sandstone speckled with chert grains of various colors. Previously the type Curtis was thought to equal all of the Curtis Formation of the Uintas, but regional stratigraphic studies (Pipiringos and Imlay,

1979) indicate that it equals only the lower part and is considered to be the Curtis Member of the Stump Formation. Thickness 0 m to at least 10 m (30 ft). About 8 m (26 ft) thick in the road cut about 1 km (0.8 mi) east of Plug Hat Rock. About 1 m (3 ft) thick near well in NW 1/4 sec. 7, T. 3 N., R. 103 W. Thickens to about 5 m (15 ft) on the eastern side of the road in the NE 1/4 sec. 8, but in NE 1/4 NW 1/4 sec. 9, T. 3 N R. 103 W., only a coquina limestone--less than 1 m (3 ft) thick--of the Redwater Member is present; about 1 km (0.8 mi) east of this location, sandstone of the Curtis Member is about 0.5 m (1.5 ft) thick. At least 2 m (6 ft) thick near Fletcher Cabin in northeastern part of the quadrangle. Generally thickens west of the quadrangle (Kinney, 1955) and southward in the subsurface (G.N. Pipiringos, unpub. data). (*GRI Source Map ID 42).* (GQ-1514).

Jsc - Stump Formation, Curtis Member (Middle Jurassic)
Distinctive resistant light-gray or light-greenish-gray and locally pink thin- to medium-bedded crossbedded fossiliferous glauconitic medium- to coarse-grained sandstone. Commonly contains clay galls and carbonaceous trash. Sandstone speckled with chert grains of various colors; locally contains gray or pink coquina limestone or fossil-rich sandstone containing oysters and clams. Previously the type Curtis was thought to equal all of the Curtis Formation of the Uintas, but regional stratigraphic studies (Pipiringos and Imlay, 1979) indicate that it equals only the lower part and should be called the Curtis Member of the Stump Formation. About 15-30 m (50-100 ft) thick. Apparently of comparable thickness to the north (Hansen, 1965), but thins west (Kinney, 1955) and east of the quadrangle (Cullins, 1969; Rowley and Hansen, 1979). (*GRI Source Map ID 43).* (GQ-1515).

Jc - Curtis Formation (Upper and Jurassic)
Interbedded sandstone, shale and oolitic limestone; predominantly olive gray and greenish gray; glauconitic and fossiliferous; about 100 feet thick. *(GRI Source Map ID 1545).* (GQ-702).

Je - Entrada Sandstone (Middle Jurassic)

Je - Entrada Sandstone (Middle Jurassic)
Moderately resistant pink, gray, buff, and locally light-green prominently crossbedded medium- to thick-bedded fine- to medium-grained sandstone. Resembles Glen Canyon Sandstone except generally is softer and not as markedly crossbedded. About 53 m (174 ft) thick in W1/2 S E 1/4 sec. 5, T. 4 S., R. 23 W.; about 31 m (102 ft) thick just north of the quadrangle (Otto and Picard, 1975); about 42-50 m (138-164 ft) thick at the southern end of Split Mountain Gorge Campground. Thickens west of the mapped area and thins east of it (Hansen, 1965; Otto and Picard, 1975, 1976). (*GRI Source Map ID 34).* (GQ-1513).

Je - Entrada Sandstone (Middle Jurassic)
Pink fine- to medium-grained crossbedded quartzose sandstone. Exposed section is incomplete, but full thickness is as much as 45 m in adjacent Plug Hat Rock quadrangle (Rowley and Hansen, 1979). (*GRI Source Map ID 36).* (GQ-1536).

Je - Entrada Sandstone (Middle Jurassic)
Moderately resistant, pink, gray, and buff, prominently crossbedded, medium- to thick-bedded, fine- to medium-grained sandstone. Resembles Glen Canyon Sandstone except generally is softer and not as markedly crossbedded. About 30 m (100 ft) thick just west of Bill White Spring; thins to the southeast and is about 21 m (70 ft) thick in SE ¼ NW ¼ sec. 4, T. 5 N., R. 99 W., and about 12 m (40 ft) thick in the SW ¼ sec. 9, T. 5 N., R. 99 W. Thickens west and southwest of the quadrangle and thins east of it (Hansen, 1965; Otto and Picard, 1975, 1976). (*GRI Source Map ID 38).* (GQ-1516).

Je - Entrada Sandstone (Middle Jurassic)
Moderately resistant, pink, white, gray, and buff, prominently crossbedded, medium- to thick-bedded,

fine- to medium-grained sandstone. Resembles Glen Canyon Sandstone (JTRg), except generally is softer and not as markedly crossbedded. About 25-50 m thick. (*GRI Source Map ID 39).* (GQ-1560).

Je - Entrada Sandstone (Upper Jurassic)
Additional unit description not provided. (*GRI Source Map ID 41).* (GQ-835).

Je - Entrada Sandstone (Middle Jurassic)
Moderately resistant gray, buff, and less commonly pink, prominently crossbedded medium- to thick-bedded fine- to medium-grained sandstone. Resembles Glen Canyon Sandstone except generally is softer and not as markedly crossbedded. About 45 m (150 ft) thick near well in NW 1/4 sec. 7, T. 3 N., R. 103 W., and about 37 m (120 ft) thick on the southern side of Plug Hat Rock. Thickens west of the mapped area and thins east of it (Hansen, 1965; Otto and Picard, 1975, 1976). (*GRI Source Map ID 42).* (GQ-1514).

Je - Entrada Sandstone (Middle Jurassic)
Moderately resistant pink, gray, and buff prominently crossbedded medium- to thick-bedded fine- to medium-grained sandstone (Otto and Picard, 1976). Resembles Glen Canyon Sandstone, except generally is softer and not as markedly crossbedded. About 34 m (100 ft) thick just east-southeast of Daniels Ranch (Otto and Picard, 1975). Probably similar in thickness to the section measured just south of Split Mountain Gorge Campground, just west of the quadrangle, where the Entrada is 38 m (125 ft) thick (Rowley and others, 1979), and near Island Park just north of the quadrangle, where it is 41 m (135 ft) thick (Untermann and Untermann, 1954). Thickens west of the quadrangle and thins east of it (Hansen, 1965; Otto and Picard, 1975). (*GRI Source Map ID 43).* (GQ-1515).

JTReg - Entrada Sandstone and Glen Canyon Sandstone (Jurassic and Triassic)

Grayish-orange very fine- to fine-grained crossbedded sandstone; about 700 to 800 feet thick; scattered chert pebbles in thin zone 50 to 75 feet below top mary mark vestigial edge of Carmel Formation which separates the two sandstones west of quadrangle1. (*GRI Source Map ID 1545).* (GQ-702).

Jca - Carmel Formation (Middle Jurassic)

Jca - Entrada Sandstone, Carmel Formation (Middle Jurassic)
Soft and moderately resistant medium- to dark-red sandy shale, thin- to medium-bedded fine- to medium-grained sandstone, siltstone, and mudstone. Locally contains several thin beds of light-green to light-greenish-gray siltstone and limestone. Thickens westward across the quadrangle. About 32 m (105 ft) thick west of Split Mountain Gorge Campground (Thomas and Krueger, 1946); about 31-38 m (102-125 ft) thick in the Dinosaur Quarry area (Untermann and Untermann, 1954; Imlay, 1980; Pipiringos, unpub. data); and about 40 m (130 ft) thick in W1/2 S E 1/4 sec. 5, T. 4 S., R. 23 W. It thins eastward and northeastward and pinches out about 50 km (30 mi.) east-southeast of the quadrangle (Pipiringos, unpub. data) and it thickens considerably west and north of the mapped area (Kinney, 1955; Hansen, 1965).
The basal contact of the Carmel Formation is an unconformity, marked by chert pebbles, that occurs over broad areas of the Western Interior of North America (Pipiringos, 1968; Pipiringos and O' Sullivan, 1975). This unconformity occurs at, or several meters (10 ft.) below, the lithologic boundary separating red beds typical of the Carmel from light-gray, pink, and buff fine-grained sandstone that resembles Glen Canyon Sandstone. The interval between the chert pebble layer and typical red Carmel is interpreted to represent reworked Glen Canyon and is considered to be part of the Carmel Formation. Most chert grains are 1-2 mm (0.05-0.1 in.) in diameter and rarely as large as 1-2 cm (0.5-1 in.), and are

white, light-gray, tan, yellow, pink, and black. the chert pebble zone is generally only one grain thick. (*GRI Source Map ID 34).* (GQ-1513).

Jc - Carmel Formation (Middle Jurassic)
Soft red sandy shale, fine- to medium grained sandstone, shale, siltstone, and mudstone, poorly exposed. Estimated thickness about 15 m. (*GRI Source Map ID 36*). (GQ-1536)

Jca - Carmel Formation (Middle Jurassic)
Soft and moderately resistant, medium- to dark-red sandy shale, thin- to medium-bedded, fine- to medium-grained sandstone, siltstone, and mudstone. Locally contains several 1-5 cm thick beds of light-gray siltstone or bentonite in the middle part. About 15-40 m thick. (*GRI Source Map ID 39).* (GQ-1560).

Jca - Carmel Formation (Middle and Upper Jurassic)
Shown only in cross section. (*GRI Source Map ID 41).* (GQ-835).

Jca - Carmel Formation (Middle Jurassic)
Soft and moderately resistant medium- to dark-red, thin- to medium-bedded sandy shale, fine- to medium-grained sandstone, siltstone, and mudstone. Locally contains thin beds of light-yellow sandstone, light-gray gypsum, and--at the top of the unit--purplish-red and gray laminated siltstone and shale. About 19 m (60 ft) thick at Plug Hat Rock and north of the well in NW 1/4 sec. 7, T. 3 N., R. 103 W. Thins eastward and northeastward and pinches out about 15 km (9 mi) east of the quadrangle (Imlay, 1979; Pipiringos, unpub. data). It thickens west and north of the quadrangle (Kinney, 1955; Hansen, 1965).

The basal contact of the Carmel Formation is an unconformity, marked by chert pebbles, that occurs over broad areas of the Western Interior of North America (Pipiringos, 1968; Pipiringos and O'Sullivan, 1975). This unconformity occurs at or several meters (10 ft) below the lithologic boundary separating red beds typical of the Carmel from light-gray, pink, and buff fine-grained sandstone that resembles Glen Canyon Sandstone. The interval between the chert pebble unconformity and typical red Carmel is interpreted to represent reworked Glen Canyon and is considered to be part of the Carmel Formation. Most chert grains are 1-2 mm (0.05-0.1 in) in diameter to rarely as large as 1-2 cm (0.5-1 in), and are white, light-gray, tan, yellow, pink, and black. The chert pebble zone is general only one grain thick. (*GRI Source Map ID 42).* (GQ-1514).

Jca - Carmel Formation (Middle Jurassic)
Soft and moderately resistant medium- to dark-red sandy shale,, thin- to medium-bedded fine- to medium-grained sandstone, siltstone, and mudstone. Locally contains several thin beds of light-bluish-gray siltstone or bentonite (?) in the upper part. About 33 m (110 ft) thick south of Cub Creek (SE 1/4 sec. 4, T. 5 S., R. 24 E.), and about 40 m (130 ft) thick near Island Park just north of the quadrangle (Untermann and Untermann, 1954). It thins eastward and northeastward and pinches out about 40 km (25 mi) east-southeast of the quadrangle (Pipiringos, unpub. data). It thickens considerably, west and northwest of the mapped area (Kinney, 1955; Hansen, 1965).

The basal contact of the Carmel Formation is an unconformity, marked by chert pebbles, that occurs over broad areas of the Western Interior of North America (Pipiringos, 1968; Pipiringos and O'Sullivan, 1975). This unconformity occurs at or several meters (10 ft) below the lithologic boundary separating red beds typical of the Carmel from light-gray, pink, and buff fine-grained sandstone that resembles Glen Canyon Sandstone. The interval between the chert pebble unconformity and typical red Carmel is interpreted to represent reworked Glen Canyon and is considered to be part of the Carmel Formation. Most chert grains are 1-2 mm (0.05-0.1 in) in diameter to rarely as large as 1-2 cm (0.5-1 in), and are white, light-gray, tan, yellow, pink, and black. The chert pebble zone is general only one grain thick. (*GRI Source Map ID 43).* (GQ-1515).

JTRg - Glen Canyon Sandstone (Lower Jurassic and Upper Triassic)

JTRg - Glen Canyon Sandstone (Lower Jurassic and Upper Triassic)
Pink, light-gray, and buff moderately resistant prominently crossbedded medium- to thick-bedded fine- to medium-grained sandstone. In this and nearby quadrangles, the formation has been called Navajo Sandstone, but as it may not be entirely correlative with the Navajo, the name Glen Canyon now is used (MacLachlan, 1957; Pool and Stewart, 1964). The Glen Canyon is also correlated with the Nugget Sandstone of Wyoming (Pipiringos and O' Sultan, 1975; Picard, 1975). Most workers consider the Glen Canyon and its correlatives to be of Early Jurassic age. The Glen Canyon appears to be conformable with the underlying Chinle Formation, but regionally is unconformable according to Pipiringos and O' Sultan (1977). Thickness about 204-213 m (670-700 ft) in the Dinosaur Quarry area (Untermann and Untermann, 1954; Imlay, 1980); and about 238 m (780 ft) 2.7 km (1.7 mi.) east of the Quarry (Thomas and Krueger, 1946). the formation thins eastward and pinches out in the sub-surface along the eastern boundary of Moffat County, COLORADO due to erosional beveling beneath the chert pebble unconformity (Pipiringos and O' Sultan 1975, 1977). It thickens west of the mapped area (Kinney, 1955). (*GRI Source Map ID 34).* (GQ-1513).

JTRg - Glen Canyon Sandstone (Lower Jurassic and Upper Triassic)
Pink highly crossbedded, medium- to thick-bedded, fine- to medium-grained eolian quartzose sandstone. Forms cliffs and ledges. Thickness about 200 m. (*GRI Source Map ID 36).* (GQ-1536).

JTRg - Glen Canyon Sandstone (Lower Jurassic and Upper Triassic)
Pink, light-gray, and buff moderately resistant, prominently crossbedded, medium- to thick-bedded, fine- to medium-grained sandstone, locally ripplemarked in the lower part. In this and nearby quadrangles, the formation has been called the Navajo Sandstone, but as it may not be entirely correlative with the Navajo, the name Glen Canyon now is used (MacLachlan, 1957; Poole and Stewart, 1964). The Glen Canyon Sandstone also is correlated with the Nugget Sandstone of Wyoming (Pipiringos and O'Sullivan, 1975; Picard, 1975). Most workers consider the Glen Canyon and its correlatives to be early Jurassic age. The Glen Canyon appears to be conformable with the underlying Chinle Formation, but regionally is unconformable according to Pipiringos and O'Sullivan (1978). Thickness 180 m (590 ft) west of Bill White Spring and about 190 m (625 ft) in Lily Park, just east of the quadrangle. The formation thins eastward and pinches out in the subsurface approximately along the eastern boundary of Moffat County, Colorado, due to erosional beveling beneath the chert pebble unconformity (Pipiringos and O'Sullivan, 1975, 1978). It thickens southwest and west of the quadrangle (Kinney, 1955).(Rowley, Dyni, Hansen, and Pipiringos, GQ-1516).

The contact with the overlying Entrada Sandstone is an unconformity, marked by chert pebbles, that occurs over broad area of the Western Interior of North America (Pipiringos, 1968; Pipiringos and O'Sullivan, 1975). Most chert grains are 1-2 mm (0.05-0.1 in.) in diameter and rarely as large as 1.5 cm (0.5 in.), and are white, light-gray, pink, yellow, tan, and black. Chert grains are mostly subrounded to rounded and always fresh; they are not to be confused with small lichens or calcareous concretions that also are locally comMonument The chert pebble zone is in general only one grain thick, but locally there may be as many as five such beds within an interval of 0.5 m (1.5 ft). The chert pebble unconformity commonly occurs at the lowermost of several soft eroded-out beds within the Entrada, about 22-26 m (70-85 ft) below the top of the Entrada-Glen Canyon cliff; just west of Bill White Spring the unconformity occurs at the base of the lower of two soft weathered-out 1-2 m (3-6 ft) thick pink and yellow beds. (*GRI Source Map ID 38).* (GQ-1516).

JTRg - Glen Canyon Sandstone (Lower Jurassic and Upper Triassic)
Pink, light-gray, and buff, moderately resistant, prominently crossbedded, medium- to thick-bedded, fine- to medium-grained sandstone. Thickness estimated at about 200 m. (*GRI Source Map ID 39).*

(GQ-1560).

JTRg - Glen Canyon Sandstone (Lower Jurassic and Upper Triassic)
Pink, highly crossbedded, fine-grained, eolian sandstone. About 200 m thick. (*GRI Source Map ID 40).* (GQ-1401).

JTRg - Glen Canyon Sandstone (Lower Jurassic and Upper Triassic)
Pink, light-gray, and buff moderately resistant prominently crossbedded medium- to thick-bedded fine- to medium-grained sandstone. In this and nearby quadrangles, the formation has been called the Navajo Sandstone, but as it may not be entirely correlative with the Navajo, the name Glen Canyon now is used (MacLachlan, 1957; Poole and Stewart, 1964). The Glen Canyon also is correlated with the Nugget Sandstone of Wyoming (Pipiringos and O' Sultan, 1975; Picard, 1975). Most workers consider the Glen Canyon and its correlatives to be of Early Jurassic age. The Glen Canyon appears to be conformable with the underlying Chinle Formation but regionally is unconformable according to Pipiringos and O' Sultan (1977). Thickness estimated at about 200 m (650 ft). The formation thins eastward and pinches out in the subsurface along the eastern boundary of Moffat County, Colorado, due to erosional beveling beneath the chert pebble unconformity (Pipiringos and O' Sultan, 1975, 1977). The unit thickens west of the mapped area (Kinney, 1955). (*GRI Source Map ID 42).* (GQ-1514).

JTRg - Glen Canyon Sandstone (Lower Jurassic and Upper Triassic)
Pink, light-gray, and buff moderately resistant, prominently crossbedded, medium- to thick-bedded, fine- to medium-grained sandstone. In this and nearby quadrangles, the formation has been called the Navajo Sandstone, but as it may not be entirely correlative with the Navajo, the name Glen Canyon now is used (MacLachlan, 1957; Poole and Stewart, 1964). The Glen Canyon also is correlated with the Nugget Sandstone of Wyoming (Pipiringos and O' Sultan, 1975; Picard, 1975). Most workers consider the Glen Canyon and its correlatives to be of Early Jurassic age. The Glen Canyon appears to be conformable with the underlying Chinle Formation but regionally is unconformable according to Pipiringos and O' Sultan (1978). Thickness estimated at about 200 m (650 ft). The formation thins eastward and pinches out in the subsurface along the eastern boundary of Moffat County, Colorado, due to erosional beveling beneath the chert pebble unconformity (Pipiringos and O' Sultan, 1975, 1978). The unit thickens west of the mapped area (Kinney, 1955). (*GRI Source Map ID 43).* (GQ-1515).

JTRg - Glen Canyon Sandstone (Lower Jurassic and Upper Triassic)
Pink, highly crossbedded fine-grained eolian sandstone. About 230-240 m thick, but exposed only in a partial section at south boundary of quadrangle. (*GRI Source Map ID 44).* (GQ-1530).

JTRg - Glen Canyon Sandstone (Lower Jurassic and Upper Triassic)
Concealed and shown only on cross section. (*GRI Source Map ID 45).* (GQ-1534).

TRc - Chinle Formation (Upper Triassic)

TRc - Chinle Formation (Upper Triassic)
Consists of five informal members, established by Poole and Stewart (1964). Overall color of the formation is light-red and subordinate gray, and overall thickness at Disappointment Draw and Vale of Tears is about 90 m. Members described from top to bottom are: (1) Upper member. resistant medium-red, pink, and tan thin- to medium-bedded ripplemarked crossbedded fine-grained sandstone, and siltstone and soft red and purple thin-bedded claystone and shale; about 3 m or less thick. (2) Red siltstone member: soft to moderately resistant medium- to dark-red, pink, and pinkish-purple, thin- to medium-bedded siltstone and subordinate fine-grained sandstone and soft red, splotchy dark-purple, and rarely splotchy light-green thin- to medium-bedded claystone and shale; about 27-43 m (90-140 ft) thick. (3) Sandstone and conglomerate member: resistant pink and gray medium- to thick-bedded fine-grained sandstone; about 15-24 m (50-80 ft) thick. (4) Ocher siltstone member: soft conspicuous bright-yellow and red siltstone and

claystone; about 6 m (20 ft) thick but locally absent. (5) Mottled member: soft light-gray, medium-red, and reddish-purple, thin- to medium-bedded sandy mudstone and mottled siltstone and sandstone that locally contain bedded red and gray chert: about 12-30 m (40-100 ft) thick. Basal part of the Chinle generally is gritty or sandy, in contrast to the silty top of the Moenkopi. High and others (1969) and Picard (1975) included the upper and red siltstone members of Poole and Stewart (1964) in the Nugget Sandstone, and the sandstone and conglomerate, ocher, and mottled members of Poole and Stewart (1964) in the Popo Agie Formation. The Chinle thins eastward until it disappears by erosional beveling beneath the chert-pebble unconformity on the eastern side of the Park Range west of Kremmling, Colorado (Pipiringos and others, 1969). It thickens southward in the Colorado Plateaus province (Stewart and others, 1972). (*GRI Source Map ID 38*). (GQ-1516).

TRc - Chinle Formation (Upper Triassic)
Shown only on cross section. (*GRI Source Map ID 41*). (GQ-835).

TRc - Chinle Formation (Upper Triassic)
Soft to moderately resistant medium-red and pink, or subordinate light-gray and light-green, thin- to medium bedded ripplemarked crossbedded siltstone, fine-grained sandstone, claystone, and shale. Only a partial section, about 40 m (130 ft) thick, is exposed. It belongs to the upper member and the upper siltstone member of Poole and Stewart (1964). high and others (1969) and Picard (1975), however, included the upper and red siltstone member of Poole and Steward in the Nugget Sandstone. Map unit about 65-80 m (215-260 ft) thick in nearby areas (Poole and Stewart, 1964), and generally thickens southward in the Colorado Plateaus province (Stewart and others, 1972). (*GRI Source Map ID 42*). (GQ-1514).

TRc - Chinle Formation (Upper Triassic)
Pink to red (predominant) to light-gray and greenish-gray siltstone, shale, and sandstone; poorly exposed. Pebbly gray Gartra Member at base of formation is exposed in south half, NE 1/4, sec. 30, T. 6 N., R. 101 W. Maximum thickness may exceed 100 m. (*GRI Source Map ID 45*). (GQ-1534)

TRc - Chinle Formation (Upper Triassic)
Interbedded siltstone, claystone, shale, and locally conglomeratic sandstone; includes a few beds of distinctive siltstone- and mudstone-pebbly conglomerate; varicolored red, gray, green, and yellow, but over-all color is reddish brown; distinctively colored ocher siltstone member about 65 feet above base, consists of 20 fee of dusky-yellow claystone and minor amounts of red shale and siltstone; about 285 feet thick. (*GRI Source Map ID 1545*). (GQ-702).

TRcm - Chinle Formation, Main body (Upper Triassic)

TRc - Chinle Formation, Main body (Upper Triassic)
Consists of five informal members, established by Poole and Stewart (1964). Overall color of the map unit is light-red and subordinate gray. Overall thickness at Red Wash is 71 m (235 ft) (Poole and Stewart, 1964), 70 m (230 ft) in the Dinosaur Quarry area (Untermann and Untermann, 1954), and 65 m (210 ft) in the Cliff Creek area, 5 km (8 mi.) south-southeast of the quadrangle (Poole and Stewart, 1964). Members described from top to bottom are: (1) Upper member: soft to moderately resistant medium-red, pink and gray thin- to medium-bedded claystone, shale, and siltstone, and light-brown, reddish-brown, pink, and gray ripplemarked crossbedded fine-grained sandstone. Member about 34 m (112 ft) thick at Red Wash (Poole and Stewart, 1964) and about 12 m (40 ft) thick at Dinosaur Quarry (Untermann and Untermann, 1954). (2) Red siltstone member: soft to moderately-resistant, medium- to dark-red, brown, light-gray, pink, and pinkish-purple, thin- to medium-bedded siltstone and subordinate fine-grained sandstone, and soft red and pink claystone and shale; about 24 m (80 ft) thick near Dinosaur Quarry (Untermann and Untermann, 1954) and about 11 m (35 ft) thick in the Cliff Creek area (Poole and Stewart, 1964). (3) Sandstone and conglomerate member: resistant pink and gray medium-

to thick-bedded fine-grained sandstone, pink siltstone, and red silty shale; present, but not measured, at Red Wash (Poole and Stewart, 1964) and may be correlative with a sandstone and siltstone unit that is about 15 m (50 ft) thick at Dinosaur Quarry (Untermann and Untermann, 1954); it is absent or not exposed in the Cliff Creek area (Poole and Stewart, 1964). (4) Ocher siltstone member: soft but conspicuous bright-yellow and subordinate brown, gray, and red claystone; about 15 m (50 ft) thick near Dinosaur Quarry (Untermann and Untermann, 1954) and about 21 m (70 ft) thick in the Cliff Creek area (Poole and Stewart, 1964). (5) Mottled member: soft light-gray, medium-red, and reddish-purple, thin- to medium-bedded sandy mudstone, siltstone and sandstone that locally contains bedded red and gray chert. Member about 9 m (30 ft) thick near Dinosaur Quarry (Untermann and Untermann, 1954) and about 15 m (50 ft) thick in the Cliff Creek area (Poole and Stewart). High and others (1969) and Picard (1975) included the upper and red siltstone members of Poole and Stewart in the Nugget Sandstone, and the sandstone and conglomerate, ocher, and mottled members of Poole and Stewart in the Popo Agie Formation. Map unit generally thickens southward in the Colorado Plateaus province (Stewart and others, 1972). (*GRI Source Map ID 34).* (GQ-1513).

TRc - Chinle Formation, Main Body (Upper Triassic)
Pink to red (predominant) to light-gray and greenish-gray, thin- to medium-bedded ripple marked crossbedded siltstone, claystone, shale, and fine-grained sandstone. Forms slopes. Estimated thickness about 65-70 m. (*GRI Source Map ID 36).* (GQ-1536).

TRc - Chinle Formation, Main Body (Upper Triassic)
Dark-red shale and siltstone underlain by pale-pink medium-grained sandstone, underlain by red, yellow, and purple shale and sandy shale. Forms ledgy slopes. About 50-70 m thick. (*GRI Source Map ID 39).* (GQ-1560).

TRc - Chinle Formation, Main body (Upper Triassic)
Dark-red shale and siltstone about 15 m thick, underlain by pale-pink medium-grained sandstone about 5 m thick, underlain by vari-colored red, yellow, and lavender shale and sandy shale about 52 m thick at the base. Forms ledgy slopes. About 72 m thick overall. (*GRI Source Map ID 40).* (GQ-1401).

TRc - Chinle Formation (Upper Triassic)
Consists of five informal members, established by Poole and Stewart (1964). Overall color of the formation is light-red and subordinate gray. Overall thickness in the quadrangle is estimated at about 80 m (260 ft), slightly thicker than in adjacent areas (Untermann and Untermann, 1954; Poole and Stewart, 1964; Rowley and others, 1979). Members described from top to bottom are: (1) Upper Member: mostly soft gray, pink, and medium-red thin- to medium-bedded claystone, shale, and siltstone, and light-brown, reddish-brown, red, pink, and gray ripplemarked crossbedded fine-grained sandstone. It is about 12 m (40 ft) thick near Dinosaur Quarry (Untermann and Untermann, 1954), just west of the quadrangle. (2) Red siltstone member: soft to moderately-resistant, medium- to dark-red, brown, light-gray, pink, and pinkish-purple, thin- to medium-bedded siltstone and subordinate fine-grained sandstone, and soft red and pink claystone and shale. It is about 24 m (80 ft) thick near Dinosaur Quarry (Untermann and Untermann, 1954). (3) Sandstone and conglomerate member: resistant pink, medium red, and gray medium- to thick-bedded fine-grained sandstone, pink siltstone, and red silty shale. It is about 15 m (50 ft) thick at Dinosaur Quarry (Untermann and Untermann, 1954). (4) Ocher siltstone member: soft but conspicuous bright-yellow and subordinate brown, gray, and red claystone and siltstone. It is about 15 m (50 ft) thick near Dinosaur Quarry (Untermann and Untermann, 1954). (5) Mottled member: soft light-gray, purple, pink, medium-red, and reddish-purple, thin- to medium-bedded sandy mudstone, siltstone and sandstone that locally contains bedded red and gray chert. It is about 9 m (30 ft) thick near Dinosaur Quarry (Untermann and Untermann, 1954). High and others (1969) and Picard (1975) included the upper and red siltstone members of Poole and Stewart in the Nugget Sandstone, and the sandstone and conglomerate, ocher, and mottled members of Poole and Stewart (1964) in the Popo Agie Formation. Map unit generally thickens southward in the Colorado Plateaus Province (Stewart and others, 1972). (*GRI Source Map ID 43).* (GQ-1515).

TRc - Chinle Formation, Main Body (Upper Triassic)
At top, dark-red shale and siltstone about 15 m thick, pale-pink medium-grained sandstone about 5 m thick in middle, and vari-colored red, yellow, and lavender shale and sandy shale about 52 m thick at the base. (*GRI Source Map ID 44).* (GQ-1530).

TRcg - Chinle Formation, Garta Member (Upper Triassic)

TRcg - Chinle Formation, Gartra Member (Upper Triassic)
Gray to tan to red, medium- to coarse-grained, pebbly conglomeratic, crossbedded sandstone. Contains petrified wood locally. Pebbles mostly gray quartzite and chert. Forms cliffs and dipslopes. About 18 m thick in southwest corner of quadrangle. (*GRI Source Map ID 32).* (GQ-1403).

TRcg - Chinle Formation, Gartra Member (Upper Triassic)
Resistant light-gray, light-yellow, and pink medium- to thick-bedded crossbedded coarse-grained sandstone, pebbly sandstone, and minor small pebble sandy conglomerate. Generally coarser-grained near the base. Formerly correlated with the Shinarump Conglomerate Member, but regional stratigraphic studies (Stewart, 1957) showed that the Shinarump does not extend north of central Utah; the Gartra, moreover, is higher stratigraphically (Poole and Stewart, 1964). Thickness about 16 m (50 ft) at Red Wash (Poole and Stewart, 1964) and 15-18 m (50-60 ft) near Dinosaur Quarry (Untermann and Untermann, 1954; McCormick and Picard, 1969); it is absent in the Cliff Creek area and in many places east of the quadrangle (Poole and Stewart, 1964). (*GRI Source Map ID 34).* (GQ-1513).

TRcg - Chinle Formation, Gartra Member (Upper Triassic)
Gray to tan to red to yellow, medium- to coarse-grained pebbly conglomeratic crossbedded sandstone. Pebbles mostly gray quartzite and chert. Forms cliffs and ledges. Thickness varied but estimated to be as much as 20-30 m. (*GRI Source Map ID 36).* (GQ-1536).

TRcg - Chinle Formation, Gartra Member (Upper Triassic)
Resistant, pink and light-gray, medium- to thick-bedded, crossbedded coarse-grained sandstone, pebbly coarse-grained sandstone, and some small-pebble sandy conglomerate. Clasts mostly of quartz but include subordinate amounts of chert and limestone. Thickness 10-20 m. (*GRI Source Map ID 39).* (GQ-1560).

TRcg - Chinle Formation, Gartra Member (Upper Triassic)
Gray to tan to red, medium- to coarse-grained, pebbly conglomeratic, crossbedded sandstone. Pebbles are mostly gray quartzite and chert. Forms cliffs and dipslopes. About 10-18 m thick. (*GRI Source Map ID 40).* (GQ-1401).

TRcg - Gartra Member of Chinle Formation (Upper Triassic)
Formation shown only on cross section. (*GRI Source Map ID 42).* (GQ-1514).

TRcg - Gartra Member of Chinle Formation (Upper Triassic)
Resistant light-yellow upper part and light-gray to buff or locally pink lower part, medium- to thick-bedded crossbedded coarse-grained sandstone, pebbly sandstone, and minor small pebble sandy conglomerate. Clasts mostly quartz but included subordinate amounts of chert and limestone. Formerly correlated with the Shinarump Conglomerate Member, but regional stratigraphic studies (Stewart, 1975) showed that the Shinarump does not extend north of central Utah; the Gartra, moreover, is higher stratigraphically (Poole and Stewart, 9164). Thickness about 30 m (100 ft) just southwest of Morris Ranch, and about 1-10 m (3-30 ft) thick northwest of Bourdette Draw. It is about 11 m (35 ft) thick near Island Park (Untermann and Untermann, 1954), just north of the quadrangle and of comparable thickness

in most places west and north of the quadrangle, but it is absent at Cliff Creek, just south of the quadrangle, and in many places east of the quadrangle (Poole and Stewart, 1964; McCormick and Picard, 1969). (*GRI Source Map ID 43).* (GQ-1515).

TRcg - Gartra Member of Chinle Formation (Upper Triassic)
Gray to tan to red medium- to coarse-grained pebbly conglomeratic crossbedded sandstone. Pebbles mostly gray quartzite and chert. Forms cliffs and dipslopes. Thickness about 10-18 m. (*GRI Source Map ID 44).* (GQ-1530).

TRm - Moenkopi Formation (Lower Triassic)

TRm - Moenkopi Formation (Lower Triassic)
Vari-colored red (predominant), brown, green, and gray (subordinated) shale, mudstone, and siltstone underlain by light-gray, greenish-gray, to yellowish-gray silty shale in lower part (+/- 30m). In part, crossbedded and ripplemarked. Middle part of formation contains thin beds and stringers of gypsum. Forms slopes and low hills. Thickness about 220-240 m. (*GRI Source Map ID 32).* (GQ-1403).

TRm - Moenkopi Formation (Lower Triassic)
Mostly soft to locally resistant reddish-brown and medium- to dark-red or less commonly purplish-red, thin- to medium-bedded, locally ripplemarked siltstone and shale. Contains several zones of resistant medium-red siltstone. Locally sandy and gypsiferous. Near its base, the unit consists of mostly soft light-gray gypsiferous siltstone and shale interbedded with light-gray and red siltstone and shale. At least 230 m (755 ft) thick in the quadrangle. About 244 m (800 ft) thick north of Dinosaur Quarry (Untermann and Untermann, 1954), but the basal 6 m (20 ft) or so of this section is mapped herein as the upper soft member of the Park City Formation (Ppu), following the stratigraphic work of Schell and Yochelson (1966). The formation generally thickens west of the quadrangle and thins east of it (Kinney, 1955; Rowley and others, 1979). (*GRI Source Map ID 34).* (GQ-1513).

TRm - Moenkopi Formation (Lower Triassic)
Red (predominant), brown, green, and gray (subordinated) shale, mudstone, and siltstone; poorly exposed. Thickness may be as much as 170 m. (*GRI Source Map ID 35).* (GQ-1535).

TRm - Moenkopi Formation (Lower Triassic)
Vari-colored red (predominant), brown, green, and gray (subordinate) shale, mudstone, and siltstone, and fine-grained sandstone. Ripplemarks. Near base contains light-gray gypsiferous siltstone and shale. About 160-180 m. (*GRI Source Map ID 36).* (GQ-1536).

TRm - Moenkopi Formation (Lower Triassic)
Mostly soft to locally resistant reddish-brown and medium- to dark-red or less commonly purplish-red thin- to medium-bedded locally ripplemarked siltstone and shale. Contains several zones of resistant medium-red siltstone. Locally sandy and gypsiferous. Lower 5-10 m (15-30 ft) of the unit is poorly exposed and consists of light-gray gypsiferous siltstone and shale. A similar 5 m (15 ft) thick interval of light-gray shale, siltstone, and fine-grained sandstone that contains gypsum occurs about 30 m (100 ft) above the basal light-gray sequence. About 171 m (560 ft) thick in Disappointment Draw just south of the Yampa River. The formation generally thickens west of the quadrangle and thins east of it (Kinney, 1955; Hansen, 1965). (*GRI Source Map ID 38).* (GQ-1516).

TRm - Moenkopi Formation (Lower Triassic)
Mostly soft to locally resistant, reddish-brown and medium- to dark-red and less commonly purplish-red, light-yellow, and light-gray, thin- to medium-bedded, locally ripplemarked siltstone and shale. Contains several zones of resistant light-gray and medium-red siltstone. Locally sandy and gypsiferous. Near

base, unit consists of mostly soft, light-gray gypsiferous siltstone and shale interbedded with light-gray and red siltstone and shale. About 220-240 m thick. (*GRI Source Map ID 39).* (GQ-1560).

TRm - Moenkopi Formation (Lower Triassic)
Vari-colored red (predominant), brown, green, and gray (subordinated) shale, mudstone, and siltstone underlain by light-gray, greenish-gray, to yellowish-gray silty shale in lower (+/- 30 m) part. In part, crossbedded and ripplemarked. Middle part of formation contains thin beds and stringers of gypsum. Forms slopes and low hills. About 220-240 m thick. (*GRI Source Map ID 40).* (GQ-1401).

TRm - Moenkopi Formation (Lower Triassic)
Included Gartra Member. Shown only on cross section. (*GRI Source Map ID 41).* (GQ-835).

TRm - Moenkopi Formation (Lower Triassic)
Formation shown only on cross section. (*GRI Source Map ID 42).* (GQ-1514).

TRm - Moenkopi Formation (Lower Triassic)
Mostly soft to locally resistant reddish-brown and medium- to dark-red or less commonly purplish-red thin- to medium-bedded locally ripplemarked siltstone and shale. Contains several zones of resistant medium-red siltstone. Locally sandy and gypsiferous. Near base, unit consists of mostly soft light-gray gypsiferous siltstone and shale interbedded with light-gray and red siltstone and shale. Thickness about 240 m (800 ft). The formation generally thickens west of the quadrangle and thins east of it (Kinney, 1955; Rowley and others, 1979). (*GRI Source Map ID 43).* (GQ-1515).

TRm - Moenkopi Formation (Lower Triassic)
Vari-colored red (predominant), brown, green, and gray (subordinate) shale, mudstone, and siltstone, and fine-grained sandstone. Near base contains light-gray gypsiferous siltstone and shale. As much as 230 m thick, but on the poorly exposed flank of the Mud Springs monocline may be thinned tectonically or faulted to only about 110 m. (*GRI Source Map ID 44).* (GQ-1530).

TRm - Moenkopi Formation (Lower Triassic)
Red (predominant), brown, green, and gray shale, mudstone, and siltstone; poorly exposed. Maximum thickness may be as much as 170 m. (*GRI Source Map ID 45).* (GQ-1534).

TRm - Moenkopi Formation (Lower Triassic)
Light-gray, greenish-gray, to yellowish-gray silty shale in lower +/- 30 m overlain by vari-colored red (predominant), brown, green, and gray (subordinate) shale, mudstone, and siltstone. In part, crossbedded and ripplemarked. Poorly exposed in southwest corner of quadrangle, where it caps isolated knobs. Total thickness about 220-240 m, but only lower part is preserved in the quadrangle. (*GRI Source Map ID 46).* (GQ-1408).

TRPmp - Moenkopi Formation and Park City Formation, undivided (Triassic and Permain)

Chiefly reddish-brown siltstone and shale; partly sandy and gypsiferous; lower 150 feet (Park City Formation) consists chiefly of yellowish- and brownish-gray calcareous siltstone with a distinctive thin yellow phosphatic dolomite bed at top; about 700 feet thick. *(GRI Source Map ID 1545).* (GQ-702).

Pp - Park City Formation (Permian)

Ppc - Park City Formation (Permian)
Light-gray to brownish-gray unevenly bedded sandy cherty fossiliferous limestone. Subordinate light-brown sandstone and gray shale. Forms cap rock on cliffs and dipslopes. About 15 meters thick. (*GRI Source Map ID 32*). (GQ-1403).

Pp - Park City Formation (Permian)
Light-gray, light-greenish-gray, and light-yellow thin-bedded shale, siltstone, fine-grained sandstone, dolomite, limestone, and phosphate rock. Poorly exposed in Diamond Gulch, but basal beds locally form resistant outcrops in section 22. Thickness measured in adjacent Jones Hole quadrangle is about 37 m (Elmer M. Schell, written communication, 1978). (*GRI Source Map ID 33*). (GQ-1554).

Pp - Park City Formation (Permian)
Mostly soft light yellowish gray shale and thinly bedded gray siltstone, limestone, dolomite, and sandstone. Ripple marks. Poorly exposed. Probably equivalent to the Meade Peak Phosphatic Member of the Park City Formation exposed elsewhere in the Uinta Mountains (E. M. Schell, U.S. Geological Survey, written commun., 1978). Thickness undetermined; possibly 30-40 m. (*GRI Source Map ID 35*). (GQ-1535).

Ppc - Park City Formation, undivided (Permian)
Shown only on cross sections. (*GRI Source Map ID 36).* (GQ-1536).

Ppc - Park City Formation (Permian)
Light-gray to brownish-gray, unevenly bedded, sandy, cherty, fossiliferous limestone. Subordinate light-brown sandstone and gray shale. Forms cap rock on cliffs and dipslopes. About 30 m thick. (*GRI Source Map ID 40*). (GQ-1401).

Ppc - Park City Formation, undivided (Permian)
Shown only on cross section. (*GRI Source Map ID 41*). (GQ-835).

Ppc - Park City Formation, undivided (Permian)
Shown only on cross section. (*GRI Source Map ID 42*). (GQ-1514).

Pp - Park City Formation (Permian)
Undifferentiated, on cross section only. (*GRI Source Map ID 44).* (GQ-1530).

Pp - Park City Formation (Permian)
Differentiated into upper and lower units only in western part of quadrangle. Exposures in eastern part probably are largely equivalent to the upper part. Total thickness of Park City Formation about 45 m. (*GRI Source Map ID 45).* (GQ-1534).

Ppc - Park City Formation (Permian)
Light gray to brownish-gray unevenly bedded sandy cherty fossiliferous limestone. Subordinate light-brown sandstone and gray shale. Forms cap rock on cliffs and dip slopes. About 15 meters thick. (*GRI Source Map ID 46*). (GQ-1408).

Ppu - Park City Formation, Upper soft member (Upper and Lower Permian)

Ppu - Park City Formation, Upper soft member (Upper and Lower Permian)
Mostly soft and poorly exposed light-gray, light-greenish-gray, and light-yellow thin-bedded shale, fine-grained sandstone, dolomite, and limestone. Upper part is generally yellow and contains small amounts

of resistant thin-bedded (less than 2 cm or 1 in.) fine-grained sandstone, siltstone, and dolomite. As mapped, the upper soft member may include some beds of the Moenkopi Formation. Untermann and Untermann (1954) included the upper soft member (Ppu) within the Moenkopi Formation. Probably, however, the upper soft member is equivalent to the tawny beds of Schell and Yochelson (1966) who made a regional stratigraphic study of the Park City Formation in the Vernal-Dinosaur area. Schell and Yochelson identified a phosphatic dolomite marker bed near the top of the tawny beds. They found Permian fossils below the marker bed at Red Wash in the northern part of the quadrangle. They correlated the tawny beds with the upper part of the Franson Member of the Park City Formation. In the quadrangle, the member is much softer than the ledgy main body of the Park City and the dolomite marker bed is discontinuous. The contact with the lower reddish-brown and yellowish-gray soft ripplemarked gypsiferous siltstone of the Moenkopi is poorly exposed and approx. located. The member probably is about 5-25 m (15-80 ft) thick in the quadrangle (Schell and Yochelson, 1966) and of comparable thickness east and west of the quadrangle (Schell and Yochelson, 1966). (*GRI Source Map ID 34).* (GQ-1513).

Ppu - Park City Formation, Upper unit (Permian)
Mostly soft light-gray to pale-yellowish-orange to pale-brown, thin-bedded limestone, siltstone, sandstone, and dolomite. Overall color is tawny gray. Boundary with overlying Moenkopi Formation (TRm) is mapped at the color change from light-red above to tawny-gray below. (*GRI Source Map ID 36).* (GQ-1536).

Ppu - Park City Formation, Upper soft member (Upper and Lower Permian)
Mostly soft and poorly exposed, light-gray, light-greenish-gray, and light-yellow, thin-bedded shale, siltstone, fine-grained sandstone, dolomite, and limestone. Locally contains pyrite. Upper part is generally yellower and contains small amounts of resistant, thin-bedded (less than 2 cm, or 1 in. thick), fine-grained sandstone. As mapped, the member may include some beds of the Moenkopi Formation. Untermann and Untermann (1954) included the upper soft member (Ppu) within the Moenkopi Formation. Probably, however, the upper soft member is equivalent to the tawny beds of Schell and Yochelson (1966), who made a regional stratigraphic study of the Park City Formation in the Vernal-Dinosaur area. Schell and Yochelson identified a phosphatic dolomite marker bed near the top of the tawny beds. They found Permian fossils below the marker bed. They correlated the tawny beds with the upper part of the Franson Member of the Park City Formation. Dyni (1968) and Cadigan (1972) mapped the tawny beds in areas near the quadrangle. In the quadrangle, the member is much softer than the ledgy main body of the Park City. In one location, (SE ¼ SW ¼ NW ¼ sec. 29, T. 6 N., R. 99 W) a pyrite-bearing greenish-gray silty dolomite bed is exposed along Disappointment Draw; this may be the marker bed of Schell and Yochelson, and we consider it near the top of the upper soft member. The contact with the lower soft reddish-brown and yellowish-gray ripplemarked gypsiferous siltstone of the Moenkopi is poorly exposed and approx. located. In most places, the contact is 5-10 m (15-30 ft) below the color change between light-gray beds and overlying mostly red beds. The upper soft member (Ppu) is about 21 m (70 ft) thick in Disappointment Draw just south of the Yampa River. (*GRI Source Map ID 38).* (GQ-1516).

Ppu - Park City Formation, Upper soft unit (Lower Permian)
Mostly soft and poorly exposed, light-gray, light-greenish-gray, and light-yellow, thin-bedded shale, siltstone, fine-grained sandstone, dolomite, and limestone. Upper part is generally yellower and contains small amounts of resistant thin-bedded (less than 2 cm) fine-grained sandstone, siltstone, and dolomite. As mapped, the member may include some beds of the Moenkopi Formation; Untermann and Untermann (1954) included the upper soft member (Ppu) within the Moenkopi Formation. Probably, however, the member is equivalent to the tawny beds of Park City Formation of Schell and Yochelson (1966). Schell and Yochelson identified a phosphatic dolomite marker bed near the top of the tawny beds; they found Permian fossils below the marker bed. About 15 m thick. (*GRI Source Map ID 39).* (GQ-1560).

Ppu - Park City Formation, Upper soft member (Upper and Lower Permian)

Mostly soft and poorly exposed light-gray, light-greenish-gray, and light-yellow, thin-bedded shale, siltstone, fine-grained sandstone, dolomite, and limestone. Upper part is generally yellower and contains small amounts of resistant thin-bedded (less than 2 cm, or 1 in. thick), fine-grained sandstone, siltstone and dolomite. As mapped, the member may include some beds of the Moenkopi Formation. Untermann and Untermann (1954) included the upper soft member (Ppu) within the Moenkopi Formation. Probably, however, the upper soft member is equivalent to the tawny beds of Schell and Yochelson (1966), who made a regional stratigraphic study of the Park City Formation in the Vernal-Dinosaur area. Schell and Yochelson identified a phosphatic dolomite marker bed near the top of the tawny beds; they found Permian fossils below the marker bed. They correlated the tawny beds with the upper part of the Franson Member of the Park City Formation. In the quadrangle, the member is much softer than the ledgy main body of the Park City. The dolomite marker bed is discontinuous in the quadrangle. The contact with the lower reddish-brown and yellowish-gray soft ripplemarked gypsiferous siltstone of the Moenkopi is poorly exposed and approx. located. The member probably is less than 30 m (100 ft) thick in the quadrangle (Schell and Yochelson, 1966) and of comparable thickness east and west of the quadrangle, and of comparable thickness to the east and west (Schell and Yochelson, 1966). (*GRI Source Map ID 43).* (GQ-1515).

Ppu - Park City Formation, Upper unit (Permian)
Mostly soft light-gray, light-greenish-gray, and light-yellow thin-bedded shale, siltstone, fine-grained sandstone, dolomite, and limestone; poorly exposed. Boundary with overlying Moenkopi Formation (TRm) is placed at the color change from overall tawny gray to light red above. As mapped, upper unit may is as thick as 40 m but may include some beds that could be assigned to the Moenkopi. (*GRI Source Map ID 44).* (GQ-1530).

Ppu - Park City Formation, Upper unit (Permian)
Mostly soft light- yellowish-gray thin-bedded limestone, siltstone, sandstone, and dolomite. Ripplemarks. Poorly exposed. (*GRI Source Map ID 45).* (GQ-1534).

Ppc - Park City Formation, Main body (Upper and Lower Permian)

Ppc - Park City Formation, Main body (Permian)
Resistant light-gray, tan, and subordinate light-yellow, medium-bedded fine-grained sandstone, sandy cherty limestone, claystone, and phosphatic shale. About 16 m (50 ft) thick north of Dinosaur Quarry (Untermann and Untermann, 1954) and 18 m (60 ft) thick south of Red Wash. Thickens west of the quadrangle and thins east of it (Kinney, 1955; Hansen, 1965, fig. 20; Untermann and Untermann, 1968). (*GRI Source Map ID 34).* (GQ-1513).

Ppc - Park City Formation, Main body (Permian)
Resistant, light-gray, tan, and subordinate light-yellow, medium-bedded, fine-grained sandstone and sandy cherty limestone. Basal contact locally obscure because of lithologic similarity to the Weber Sandstone; top contact with upper weak member is rarely exposed. About 6-12 m (20-40 ft) thick, thickening west of the mapped area and thinning east of it (Hansen, 1965, fig. 20). (*GRI Source Map ID 38).* (GQ-1516).

Ppc - Park City Formation, Main body (Permian)
Resistant light-gray, tan, and subordinate light-yellow, medium-bedded fine-grained sandstone, sandy cherty limestone, claystone, and phosphatic shale. About 20 m thick. (*GRI Source Map ID 39).* (GQ-1560).

Ppc - Park City Formation, Main body (Permian)
Resistant light-gray, tan, and subordinate light-yellow, medium-bedded fine-grained sandstone, sandy

cherty limestone, claystone, and phosphatic shale. Top contact with upper soft member is rarely exposed. Estimated to be less than 30 m (100 ft) thick. Thickens west of the mapped area and thins east of it (Kinney, 1955; Hansen, 1965, fig. 20; Untermann and Untermann, 1968). (*GRI Source Map ID 43).* (GQ-1515).

Ppl - Park City Formation, Lower unit (Permian)

Ppl - Park City Formation, Lower unit (Permian)
Light-grayish-brown, unevenly bedded, fossiliferous phosphatic limestone, shaly limestone, dolomite, and sandstone. Forms caprock on cliffs and dipslopes. As mapped, the total thickness of the Park City Formation is about 45-60 m, but a section measured in 1964 by Elmer M. Schell of the U.S. Geological Survey (written commun., 1978) totaled only 30.8 m. Part of the difference might be due to the placement of the contacts. According to Schell, the upper unit as here mapped is correlative with the Franson Member of the Park City Formation and the lower unit is correlative with the Meade Peak Phosphatic Shale Member. The Franson Moenkopi contact is gradational. (*GRI Source Map ID 36).* (GQ-1536).

Ppl - Park City Formation, Lower unit (Permian)
Light-gray to brownish-gray unevenly bedded fine-grained sandstone, sandy cherty limestone, and claystone. Forms caprock on cliffs and dipslopes. Thickness about 15-18 m. (*GRI Source Map ID 44).* (GQ-1530).

Ppl - Park City Formation, Lower unit (Permian)
Light-grayish-brown unevenly bedded limestone, shaly limestone, dolomite, and sandstone. Forms caprock on cliffs and dipslopes. Thickness about 15 m. (*GRI Source Map ID 45).* (GQ-1534).

PNw - Weber Sandstone (Middle Pennsylvanian)

PNw - Weber Sandstone (Middle Pennsylvanian)
Light-gray to yellowish-gray, very thick-bedded, highly crossbedded fine-grained sandstone. Forms massive cliffs. Totally exposed at Warm Springs Cliff, where it is about 300 m thick. (*GRI Source Map ID 32).* (GQ-1403).

PNw - Weber Sandstone (Middle Pennsylvanian)
Light-gray thick-bedded, fine-grained sandstone. Large-scale eolian crossbedding (Fryberger, 1979). Forms conspicuous outcrops. About 390 m thick (Kinney, 1955, p. 46) but thickens westward and thins eastward. (*GRI Source Map ID 33*). (GQ-1554).

PNw - Weber Sandstone (Middle Pennsylvanian)
Moderately resistant light-gray, white, and buff medium- to thick-bedded prominently crossbedded fine-grained sandstone. Thickness (Untermann and Untermann, 1954) about 300 m (1,000 ft) both north of Dinosaur Quarry and near Island Park just north of the quadrangle. About 302-307 m (990-1,010 ft) thick just north of Split Mountain Gorge Campground (McCann and others, 1946; Bissell and Childs, 1958; Bissell, 1964). Thickens west of the quadrangle and thins east of it (Kinney, 1955; Hansen, 1965, fig. 17; Rowley and others, 1979). (*GRI Source Map ID 34).* (GQ-1513).

PNw - Weber Sandstone (Middle Pennsylvanian)
Light-gray to yellowish-gray, very thick-bedded, highly crossbedded fine-grained quartzose sandstone. Forms massive cliffs and steep bare slopes. Thickness about 300 m. (*GRI Source Map ID 35).* (GQ-1535).

PNw - Weber Sandstone (Middle Pennsylvanian)
Light-gray to yellowish-gray, very thick bedded, highly crossbedded fine-grained quartzose sandstone. Forms massive cliffs and steep bare slopes. Thickness about 300 m. (*GRI Source Map ID 36*). (GQ-1536).

PNw - Weber Sandstone (Middle Pennsylvanian)
Moderately resistant light-gray, white, and buff medium- to thick-bedded prominently crossbedded fine-grained sandstone. Thickness 281 m (920 ft) along the Yampa River just west of the mouth of Disappointment Draw (Bissell and Childs, 1958; Bissell, 1964). Thickens west and thins east of the quadrangle (Hansen, 1965, fig. 17). (*GRI Source Map ID 38).* (GQ-1516).

PNw - Weber Sandstone (Middle Pennsylvanian)
Moderately resistant, light-gray, white, and buff, medium- to thick-bedded, prominently crossbedded, fine-grained sandstone. Incompletely exposed in the northern and southeastern parts of the quadrangle; about 300 m thick in adjacent areas (Hansen, 1977; Rowley and Hansen, 1979). (*GRI Source Map ID 39).* (GQ-1560).

PNw - Weber Sandstone (Middle Pennsylvanian)
Light-gray to yellowish-gray, very thick bedded, highly crossbedded, fine-grained sandstone. Forms massive cliffs. About 300 m thick. (*GRI Source Map ID 40).* (GQ-1401).

PNw - Weber Sandstone (Middle Pennsylvanian)
Formation shown only on cross section. (*GRI Source Map ID 41*). (GQ-835).

PNw - Weber Sandstone (Middle Pennsylvanian)
Formation shown only on cross section. (*GRI Source Map ID 42).* (GQ-1514).

PNw - Weber Sandstone (Middle Pennsylvanian)
Moderately resistant light-gray, white, and buff medium- to thick-bedded prominently crossbedded fine-grained sandstone. About 302 m (990 ft) thick north of Split Mountain Gorge Campground just west of the quadrangle and 330 m (1,080 ft) thick near Morris Ranch (Bissell and Childs, 1958; Bissell, 1964). Thickens west of the quadrangle and thins east of it (Kinney, 1955; Hansen, 1965, fig. 17; Rowley and others, 1979). (*GRI Source Map ID 43).* (GQ-1515).

PNw - Weber Sandstone (Middle Pennsylvanian)
Light-gray to yellowish-gray very thick-bedded highly crossbedded fine-grained sandstone. Forms massive cliffs and steep bare slopes. Thickness about 300 m. (*GRI Source Map ID 44).* (GQ-1530).

PNw - Weber Sandstone (Middle Pennsylvanian)
Light-gray to yellowish-gray very thick-bedded highly crossbedded fine-grained sandstone. Forms massive cliffs and steep bare slopes. Thickness about 300 m. (*GRI Source Map ID 45).* (GQ-1534).

PNw - Weber Sandstone (Middle Pennsylvanian)
Light-gray to yellowish-gray very thick-bedded highly crossbedded fine-grained sandstone. Forms massive cliffs and steep bare slopes. About 300 m thick. (*GRI Source Map ID 46).* (GQ-1408).

PPNw – Weber Sandstone (Permian and Pennsylvanian)
Grayish-orange very fine- to fine-grained crossbedded sandstone; estimated thickness about 800 feet. Shown only in cross sections. (*GRI Source Map ID 1545).* (GQ-702).

PNm - Morgan Formation (Middle Pennsylvanian)

PNm - Morgan Formation (Lower and Middle Pennsylvanian)
Shown only in cross section. (*GRI Source Map ID 41).* (GQ-835).

PNm - Morgan Formation (Middle Pennsylvanian)
Interbedded gray fossiliferous cherty limestone, buff crossbedded sandstone, and lesser amounts of gray, red, and green shale; upper part not exposed in quadrangle; estimated total thickness about 1,000 feet. (*GRI Source Map ID 1545*). (GQ-702).

PNmu - Morgan Formation, Upper Member (Middle Pennsylvanian)

PNmu - Morgan Formation, Upper member (Middle Pennsylvanian)
Red fine-grained crossbedded to planar bedded sandstone and interbedded gray to pale-lavender, cherty, fossiliferous limestone. Individual beds less than 1 m to several meters thick. Forms cliffs. Total thickness about 210 m. (*GRI Source Map ID 32).* (GQ-1403).

PNmu - Morgan Formation, Upper member (Middle Pennsylvanian)
Red, fine-grained, crossbedded to planar bedded sandstone and interbedded gray to pale-lavender, cherty, fossiliferous limestone. Red chert nodules and lenses. Forms ledges and dip slopes. About 200 m thick. (*GRI Source Map ID 33*). (GQ-1554).

PNmu - Morgan Formation (Middle Pennsylvanian)
Subdivision follows that of Hansen (1977a, 1977b, 1978) in areas to the north and east. Equivalent to the upper member of the Morgan of Kinney (1955). The formation is about 217 m (710 ft) thick in Mitten Canyon (McCann and others, 1946) about 3 km (2 mi) east of the quadrangle. Thickens west of the quadrangle (Kinney, 1955). (*GRI Source Map ID 34).* (GQ-1513).

PNmu - Morgan Formation, Upper member (Middle Pennsylvanian)
Red fine-grained crossbedded to planar bedded sandstone and interbedded gray to pale-lavender cherty fossiliferous limestone. Individual beds less than 1 m to several meters thick. Forms cliffs and ledgy slopes. Total thickness about 210 m. (*GRI Source Map ID 35).* (GQ-1535).

PNmu - Morgan Formation, Upper member (Middle Pennsylvanian)
Red fine-grained crossbedded to planar bedded sandstone and interbedded gray to pale-lavender cherty fossiliferous limestone. Individual beds less than 1 m to several meters thick. Contains pink to red chert nodules and lenses. Forms cliffs and ledgy slopes. Total thickness about 210 m. (*GRI Source Map ID 36).* (GQ-1536).

PNmu - Morgan Formation, Upper member (Middle Pennsylvanian)
Red, fine-grained, crossbedded to planar-bedded sandstone and interbedded gray to pale-lavender, cherty, fossiliferous limestone. Red chert nodules and lenses. Forms ledges and dip slopes. About 200 m thick. (*GRI Source Map ID 37*). (GQ-1695).

PNmu - Morgan Formation, Upper member (Middle Pennsylvanian)
Resistant light- to medium-red, medium-bedded crossbedded to horizontally-bedded, fine-grained sandstone, subordinate interbedded, resistant light- to medium-gray, medium-bedded mostly coarsely crystalline limestone and minor soft red shale. Limestone in some places contains abundant marine fossils and red chert concretions as much as a meter long. Top intertongues with the base of the Weber Sandstone; following the convention of Hansen (1965), the top of the formation herein is placed at the top of the highest limestone or red sandstone. Estimated to be 150 m (490 ft) thick. (*GRI Source Map ID 38).* (GQ-1516).

PNmu - Morgan Formation, Upper member (Middle Pennsylvanian)
Resistant, light- to medium-red, medium-bedded, crossbedded, fine-grained sandstone and subordinate interbedded resistant light- to medium-gray, medium-bedded mostly coarsely crystalline limestone. Limestone in some places contains abundant marine fossils and red chert concretions more than a meter long. Partial section exposed in the northeastern corner of the quadrangle; member about 200 m thick in adjoining areas (Hansen, 1977; Rowley and Hansen, 1979). (*GRI Source Map ID 39).* (GQ-1560).

PNmu - Morgan Formation, Upper member (Middle Pennsylvanian)
Red fine-grained crossbedded to planar bedded sandstone and interbedded gray to pale-lavender cherty fossiliferous limestone. Individual beds less than 1 m to several meters thick. Red chert nodules and lenses. Forms cliffs and ledgy slopes. Total thickness about 210 m. (*GRI Source Map ID 40).* (GQ-1401).

PNmu - Morgan Formation (Middle Pennsylvanian)
Resistant light- to medium-red, medium-bedded crossbedded to horizontally-bedded, fine-grained sandstone, subordinate interbedded, resistant light- to medium-gray, medium-bedded mostly coarsely crystalline limestone, and minor soft red shale. Limestone in some places contains abundant marine fossils and red chert concretions more than a meter (several feet) long. Top intertongues with the base of the Weber Sandstone; following the convention of Hansen (1965), the top of the formation herein is placed at the top of the highest limestone or red sandstone. Estimated to be 200 m (650 ft) thick. Assigned to the Morgan Formation by Thompson (1945) and Sadlick (1957). Probably equivalent to the upper member of the Morgan Formation of Untermann and Untermann (1954), which is about 175 m (575 ft) thick at Split Mountain and 201 m (660 ft) thick near Island Park to the north of the quadrangle. (*GRI Source Map ID 43).* (GQ-1515).

PNmu - Morgan Formation (Middle Pennsylvanian)
Red fine-grained crossbedded to planar bedded sandstone and interbedded gray to pale-lavender cherty fossiliferous limestone. Individual beds less than 1 m to several meters thick. Pink to red chert nodules and lenses. Forms cliffs and ledgy slopes. Total thickness about 210-230 m, but not fully exposed. (*GRI Source Map ID 44).* (GQ-1530).

PNmu - Morgan Formation, Upper member (Middle Pennsylvanian)
Red fine-grained crossbedded to planar bedded sandstone and interbedded gray to pale-lavender cherty fossiliferous limestone. Individual beds less than 1 m to several meters thick. Lenses and nodules of red chert. Forms cliffs and ledgy slopes. Total thickness about 210 m. (*GRI Source Map ID 45).* (GQ-1534).

PNmu - Morgan Formation, Upper member (Middle Pennsylvanian)
Red fine-grained crossbedded to planar bedded sandstone and interbedded gray to pale-lavender cherty fossiliferous limestone. Individual beds less than 1 m to several meters thick. Forms cliffs and ledgy slopes. Total thickness about 210 m. (*GRI Source Map ID 46).* (GQ-1408).

PNml - Morgan Formation, Lower Member (Middle Pennsylvanian)

PNml - Morgan Formation, Lower member (Middle Pennsylvanian)
Red, gray, and lavender shale and siltstone and subordinate lavender to pink fossiliferous cherty limestone and limy sandstone. Forms slopes. Thickness about 60 m. (*GRI Source Map ID 32).* (GQ-1403).

PNml - Morgan Formation, Lower member (Middle Pennsylvanian)
Light-gray, red, and green shale, siltstone, sandstone, and cherty, fossiliferous limestone. Poorly exposed. Estimated thickness about to be about 25-35 m. (*GRI Source Map ID 33*). (GQ-1554).

PNml - Morgan Formation, Lower member (Middle Pennsylvanian)
Mostly soft light-gray, red, and green thin- to medium-bedded shale, siltstone, sandstone, and limestone. Poorly exposed; contacts with overlying and underlying units approx. located. Probably equivalent to the middle member of Untermann and Untermann (1954). Named Hells Canyon Formation by Thompson (1945) and Sadlick (1957). Partial section, about 60 m (200 ft) thick. About 41-69 m (135-225 ft) thick in the Split Mountain area (Untermann and Untermann, 1954; Sadlick, 1957) and 113 m (370 ft) thick near Island Park, just north of the quadrangle (Untermann and Untermann, 1954). (*GRI Source Map ID 34).* (GQ-1513).

PNml - Morgan Formation, Lower member (Middle Pennsylvanian)
Gray (predominant), red, and lavender shale and siltstone and subordinate lavender to pink fossiliferous cherty limestone and limy sandstone. Red chert nodules and lenses. Forms mantled slopes. Thickness about 90 m. (*GRI Source Map ID 35).* (GQ-1535).

PNml - Morgan Formation, Lower member (Middle Pennsylvanian)
Gray (predominant), red, and lavender shale and siltstone and subordinate lavender to pink fossiliferous limestone and limy sandstone. Forms slopes. Thickness about 90 m. (*GRI Source Map ID 36).* (GQ-1536).

PNml - Morgan Formation, Lower member (Middle Pennsylvanian)
Light-gray, red, and green shale, siltstone, sandstone, and cherty, fossiliferous limestone. Poorly exposed. Estimated thickness about 25-35 m. (*GRI Source Map ID 37*). (GQ-1695).

PNml - Morgan Formation, Lower member (Middle Pennsylvanian)
Mostly soft, light-gray, red, and green, thin- to medium-bedded shale siltstone, sandstone, and limestone. Poorly exposed; contacts with overlying and underlying units approximately located. Estimated to be 90 m thick. (*GRI Source Map ID 38).* (GQ-1516).

PNml - Morgan Formation, Lower member (Middle Pennsylvanian)
Red, gray, and lavender shale and siltstone and subordinate lavender to pink fossiliferous limestone and limy sandstone. Forms slopes. About 60 -80 m thick. (*GRI Source Map ID 40).* (GQ-1401).

PNml - Morgan Formation, Lower member (Middle Pennsylvanian)
Mostly soft light-gray, red, and green thin- to medium-bedded shale, siltstone, sandstone, and limestone. Poorly exposed; contacts with overlying and underlying units approx. located. Estimated to be 75 m (250 ft) thick. Probably equivalent to the middle member of Untermann and Untermann (1954), which is abut 69 m (225 ft) thick at Split Mountain and 113 m (370 ft) thick near Island Park north of the quadrangle. Named Hells Canyon Formation by Thompson (1945) and Sadlick (1957); this unit is about 41 m (135 ft) thick in Split Mountain Canyon (Sadlick, 1957). (*GRI Source Map ID 43).* (GQ-1515).

PNml - Morgan Formation, Lower member (Middle Pennsylvanian)
Shown in cross section only. (*GRI Source Map ID 44).* (GQ-1530).

PNml - Morgan Formation, Lower member (Middle Pennsylvanian)
Gray (predominant), red, and lavender shale and siltstone and subordinate lavender to pink fossiliferous limestone and limy sandstone. Forms slopes. Thickness about 90 m. (*GRI Source Map ID 45).* (GQ-1534).

PNml - Morgan Formation, Lower member (Middle Pennsylvanian)
Red, gray, and lavender shale and siltstone and subordinate lavender to pink fossiliferous limestone and limy sandstone. Forms slopes. About 60 m thick. (*GRI Source Map ID 46).* (GQ-1408).

PNrv - Round Valley Limestone (Lower Pennsylvanian)

PNrv - Round Valley Limestone (Lower Pennsylvanian)
Light-gray to pale-lavender, fine-grained, thick-bedded, cherty fossiliferous limestone and thin partings of gray to red shale. Forms cliffs, ledges, and dipslopes. Nodules and irregular layers of chert are pink to dark-red. About 90-120 thick. (*GRI Source Map ID 32).* (GQ-1403).

PNrv - Round Valley Limestone (Lower Pennsylvanian)
Light-gray to pale-lavender, fine-grained, thick-bedded, cherty, fossiliferous limestone and thin interbeds of red to gray shale. Forms prominent ledges and dip slopes. Pink to red chert in nodules and lenses. Estimated thickness about 110 m; at nearby Split Mountain thickness is 89 m (Kinney, 1955, p. 40). (*GRI Source Map ID 33*).
(GQ-1554).

PNrv - Round Valley Limestone (Lower Pennsylvanian)
Light-gray to pale-lavender, fine-grained, thick-bedded, cherty fossiliferous limestone and thin partings of gray to red shale. Forms cliffs, ledges, and dipslopes. Pink to dark-red chert in nodules and irregular layers. Massive blue-gray limestone at the base contains abundant horn corals of the species Neokoninckophyllum aff. N. hematilis Sando and the conodont Adetognathus (USGS 27035-PC). These fossils indicate a Lower Pennsylvanian (Morrowan) age (W.J. Sando and B.R. Wardlaw, U.S. Geological Survey, written communs., 1977, 1978). Thickness about 100 m. (*GRI Source Map ID 35).* (GQ-1535).

PNrv - Round Valley Limestone (Lower Pennsylvanian)
Light-gray to pale-lavender fine-grained thick-bedded cherty fossiliferous limestone and thin partings of gray to red shale. Forms cliffs, ledges, and dipslopes. Contains pink to dark-red chert nodules and irregular layers. Thickness about 100 m. (*GRI Source Map ID 36).* (GQ-1536).

PNrv - Round Valley Limestone (Lower Pennsylvanian)
Light-gray to pale-lavender, fine-grained, thick bedded, cherty, fossiliferous limestone and thin interbeds of red to gray shale. Forms prominent ledges and dip slopes. Pink to red chert in nodules and lenses. Estimated thickness about 110 m. (*GRI Source Map ID 37*). (GQ-1695).

PNrv - Round Valley Limestone (Lower Pennsylvanian)
Resistant light- to medium-gray and blue-gray, medium-bedded limestone and interbedded soft light-gray thin-bedded poorly exposed shale. Forms ledgy slopes. Limestone generally fossiliferous and contains red and pink chert concretions. Mapped as part of the Morgan Formation by Untermann and Untermann (1954). Correlated herein with the Round Valley Limestone of the Whirlpool Canyon area of Dinosaur National Monument (Sadlick, 1957). Upper and lower contacts poorly exposed and approximately located. Estimated to be 120 m (400 ft) thick. Thickens west of the quadrangle and thins east of it (Hansen, 1965, fig. 16). (*GRI Source Map ID 38).* (GQ-1516).

PNrv - Round Valley Limestone (Lower Pennsylvanian)
Light-gray to pale-lavender, fine-grained, thick-bedded, cherty fossiliferous limestone and thin partings of gray to red shale. Forms cliffs, ledges, and dipslopes. Chert, found in nodules and irregular layers, is pink to dark red. About 90-120 m thick. (*GRI Source Map ID 40).* (GQ-1401).

PNrv - Round Valley Limestone (Lower Pennsylvanian)
Resistant light- to medium-gray and blue-gray, medium-bedded limestone and interbedded soft light-gray thin-bedded poorly exposed shale. Forms ledgy slopes. Limestone generally fossiliferous and contains red and pink chert concretions. Probably equivalent to the middle member of the Morgan Formation of Thomas, McCann, and Raman, (1945) and McCann, Raman, and Henbest (1946), which is 90 m (295 ft)

thick in Mitten Canyon. Probably equivalent to the lower member of the Morgan Formation of Untermann and Untermann (1954) and Kinney (1955). Correlated herein with the Round Valley Limestone of Sadlick (1957). About 65-95 m (215-310 ft) thick in the Split Mountain area and 71 m (230 ft) thick near Island Park to the north of the quadrangle (Untermann and Untermann, 1954; Kinney, 1955; Sadlick, 1957). Upper and lower contacts poorly exposed and approximately located. Thickens west of the quadrangle and thins east of it (Kinney, 1955; Hansen, 1965, fig. 16). (*GRI Source Map ID 43).* (GQ-1515).

PNrv - Round Valley Limestone (Lower Pennsylvanian)
Shown in cross section only. (*GRI Source Map ID 44).* (GQ-1530).

PNrv - Round Valley Limestone (Lower Pennsylvanian)
Light-gray to pale-lavender, fine-grained, thick-bedded, cherty fossiliferous limestone and thin partings of gray to red shale. Forms cliffs, ledges, and dipslopes. Pink to dark-red chert in nodules and irregular layers. Thickness about 100 m. (*GRI Source Map ID 45).* (GQ-1534).

PNrv - Round Valley Limestone (Lower Pennsylvanian)
Light-gray to pale-lavender, fine-grained, thick-bedded, cherty, fossiliferous limestone and thin partings of gray to red shale. Forms cliffs, ledges, and dipslopes. Pink to dark-red chert in nodules and irregular layers. About 90-120 m thick. (*GRI Source Map ID 46).* (GQ-1408).

Mdh - Doughnut Shale and Humbug Formation (Upper Mississippian)

Mdh - Doughnut Shale and Humbug Formation (Upper Mississippian)
Doughnut Shale: Dark-gray clayey shale (predominant) and red shale (subordinate) towards base. Poorly exposed.
Humbug Formation: Light-gray to red, fine-grained to very fine-grained, interbedded with light-gray marine limestone and red to black shale. Forms ledgy slopes. Combined thickness of Doughnut and Humbug about 90 m. (*GRI Source Map ID 32).* (GQ-1403).

Mdh - Doughnut Shale and Humbug Formation (Upper Mississippian)
Doughnut Shale consists of dark-gray, clayey shale (predominant) and red shale; poorly exposed. Humbug Formation is light-gray to red, fine-grained to very fine grained sandstone interbedded with light-gray limestone and red to black shale. Combined thickness of Doughnut and Humbug estimated at about 90-100 m. (*GRI Source Map ID 33).* (GQ-1554).

Mdh - Doughnut Shale and Humbug Formation (Upper Mississippian)
Doughnut Shale: Poorly exposed red clay shale (predominant) and interbedded pale-blue limestone. At the top, a bed of vuggy pale-yellow sandstone about 2 m thick.
Humbug Formation: Light-gray to red, fine-grained to very fine-grained, interbedded with light-gray marine limestone and red to black shale. Forms ledgy slopes. Combined thickness of Doughnut and Humbug about 90 m. (*GRI Source Map ID 35).* (GQ-1535).

Mdh - Doughnut Shale and Humbug Formation (Upper Mississippian)
Doughnut Shale: Poorly exposed dark-gray clayey shale (predominant) and red clayey shale (subordinate).
Humbug Formation: Light-gray to red, fine- to very fine-grained sandstone interbedded with light-gray limestone and red to black shale. Forms ledgy slopes. Appears to truncate underlying Madison Limestone. Combined thickness of Doughnut and Humbug about 75-90 m. (*GRI Source Map ID 36).* (GQ-1536).

Mdh - Doughnut Shale and Humbug Formation (Upper Mississippian)

Doughnut Shale consists of dark-gray, clayey shale (predominant) and red shale; poorly exposed. Humbug Formation is light-gray to red, fine-grained to very fine grained sandstone interbedded with light-gray limestone and red to black shale. Combined thickness of Doughnut and Humbug estimated at about 90-100 m. (*GRI Source Map ID 37).* (GQ-1695).

Mdh - Doughnut Shale and Humbug Formation (Upper Mississippian)
Poorly exposed sequence consisting mostly of soft shale and moderately resistant tan and gray sandstone, limestone, and dolomite. The sequence was assigned to Carboniferous beds of undetermined age and the Humbug Formation by Untermann and Untermann (1954). Dyni (1968) assigned them to an unnamed unit, 30-45 m thick, in the Elk Springs quadrangle to the east. The upper shale herein is correlated with the Doughnut Shale, and the lower sandstone and limestone are correlated with the Humbug Formation, both on the basis of lithologic similarity where well exposed along the Green River in the Jones Hole and Canyon of Lodore areas about 30 km (19 mi) to the west (Hansen, 1977a, 1977b). The units have a combined thickness there of 75-90 m (250-300 ft) (Hansen, 1977a, 1977b). The Doughnut consists of light-gray clay shale and subordinate red shale, and the Humbug consists of light-gray, yellow, and red fine-grained sandstone and interbedded light-gray limestone and red to black shale. In the Indian Water Canyon quadrangle, contacts are approximately located, and the two formations are estimated to be about 30-70 m (100-230 ft) thick, decreasing northward. These and related Mississippian rocks generally thicken westward across Utah (Hansen, 1965, figs. 14, 15). (*GRI Source Map ID 38).* (GQ-1516).

Mdh - Doughnut Shale and Humbug Formation (Upper Mississippian)
Doughnut Shale: Dark-gray clayey shale (predominant) and red shale (subordinate) towards base. Poorly exposed.
Humbug Formation: Light-gray to red, fine-grained to very fine grained sandstone interbedded with light-gray limestone and red to black shale. Hematitic sandstone at top locally. Forms ledgy slopes. Appears to truncate underlying Madison Limestone. Total combined thickness of Doughnut and Humbug is about 75-90 m. (*GRI Source Map ID 40).* (GQ-1401).

Mdh - Doughnut Shale and Humbug Formation (Upper Mississippian)
Poorly exposed dark-gray, light-green, and red clay shale and subordinate moderately resistant light-gray or light-yellow sandstone and limestone (Doughnut Shale); underlain by soft to resistant tan, pink, light-gray, or red fine-grained sandstone and interbedded light-gray limestone and red to black shale (Humbug Formation). The formations have a combined thickness of about 100 m (330 ft) in the quadrangle. They apparently thicken west of the quadrangle and thin east of it (Kinney, 1955; Sadlick, 1957; Hansen, 1965).

Rocks herein assigned to the Doughnut Shale were called “Carboniferous beds of undetermined age” by Untermann and Untermann (1954) in the Split Mountain and Island Park areas where they are 52-56 m (170-185 ft) thick. The same unit, named the black shale unit of Late Mississippian age by Kinney (1955), was called the lower member of the Morgan Formation by Thomas, McCann, and Raman (1954) but considered perhaps correlative with the Molas Formation; they found it to be about 50 m (165 ft) thick in Mitten Canyon. It was called the “upper shale unit of probable Late Mississippian age” by Hansen (1965). The same unit was assigned to the Manning Canyon Shale by Sadlick (1957) and Untermann and Untermann (1968); Sadlick (1957) concluded that it was 41 m (135 ft) thick in Split Mountain Canyon. The Manning Canyon Shale, typically exposed in the Oquirrh Mountains of western Utah in the thick Mississippian-Pennsylvanian miogeosynclinal section west of the Charleston thrust fault, has never been demonstrably correlated with strata across the fault in the thinner shelf sequence of the central Wasatch and Uinta Mountains. The Doughnut Shale, on the other hand, occupies the same stratigraphic niche in the western and eastern Uinta Mountains that it occupies in its type locality in the shelf sequence in the Wasatch Range, is lithologically nearly identical in the two area, and contains the same faunas. The Doughnut generally thickens westward (Kinney, 1955; Hansen, 1965, fig. 15).

Rocks assigned to the Humbug Formation (Sadlick, 1957; Untermann and Untermann, 1968) are about 53-61 m (175-200 ft) thick in the Split Mountain area (Untermann and Untermann, 1954; Sadlick 1957). The were called “beds of undetermined age” by McCann, Raman, and Henbest (1946), who found them to be 56 m (185 ft) thick in Mitten Canyon. They were included in the “limestone unit of Mississippian age” by Kinney (1955), and were termed a “middle sandstone and limestone unit of Mississippian age” by Hansen (1965). Correlation of all these named units with the Humbug remains tentative, however. (*GRI Source Map ID 43).* (GQ-1515).

Mdh - Doughnut Shale and Humbug Formation (Upper Mississippian)
Doughnut Shale: Shown in cross section only. Humbug Formation: Shown in cross section only. (*GRI Source Map ID 44).* (GQ-1530).

Mdh - Doughnut Shale and Humbug Formation (Upper Mississippian)
Doughnut Shale: Doughnut Shale at top consists of dark-gray clayey shale (predominant) and red shale (subordinate) towards base; poorly exposed. Humbug Formation: Humbug Formation consists of light-gray to red, fine- to very fine-grained sandstone interbedded with light-gray limestone and red to black shale;. forms ledgy slopes. Combined thickness of Doughnut and Humbug about 75-90 m. (*GRI Source Map ID 45).* (GQ-1534).

Mdh - Doughnut Shale and Humbug Formation (Upper Mississippian)
Doughnut Shale: Dark-gray clayey shale (predominant) and red shale (subordinate) towards base. Poorly exposed.
Humbug Formation: Light-gray to red, fine-grained to very fine-grained sandstone interbedded with light-gray limestone and red to black shale. Hematitic sandstone at top locally. Forms ledgy slopes. Total combined thickness of Doughnut and Humbug is about 75-90 m. (*GRI Source Map ID 46).* (GQ-1408).

Ms - Shale and dolomite (Mississippian)

Interbedded sandy and cherty dolomite, shale, claystone, and sandstone; varicolored red, green and gray; partly carbonaceous and hematitic; poorly exposed and commonly forms swale; about 100 to 145 feet thick. (*GRI Source Map ID 1545).* (GQ-702).

Mm - Madison Limestone (Lower Mississippian)

Mm - Madison Limestone (Lower Mississippian)
Light-gray to dark-gray, fine- to medium-grained, thick bedded and unevenly bedded, cherty limestone and dolomitic limestone, sparsely fossiliferous. Chert mostly light gray. Forms cliffs and dipslopes. About 180 m thick. (*GRI Source Map ID 32).* (GQ-1403).

Mm - Madison Limestone (Lower Mississippian)
Light- to dark-gray, fine- to medium-grained, thick- and unevenly-bedded, cherty limestone and dolomitic limestone, sparsely fossiliferous. Light-gray chert lenses and nodules. Forms cliffs, ridge tops and dip slopes. Estimated thickness about 180-200 m. (*GRI Source Map ID 33).* (GQ-1554).

Mm - Madison Limestone (Lower Mississippian)
Light-gray to dark-gray, fine- to medium-grained, thick bedded and unevenly bedded, cherty limestone and dolomitic limestone, sparsely fossiliferous. Chert mostly light gray (in contrast with the pink or red Pennsylvanian cherts). Forms cliffs. Thickness about 180 m. (*GRI Source Map ID 35).* (GQ-1535).

Mm - Madison Limestone (Lower Mississippian)
Light-gray to dark-gray, fine- to medium-grained, thick-bedded unevenly bedded cherty limestone and dolomitic limestone. Chert mostly light gray. Sparsely fossiliferous. Forms cliffs, ridgetops, and dipslopes. Thickness about 180 m. (*GRI Source Map ID 36).* (GQ-1536).

Mm - Madison Limestone (Lower Mississippian)
Light- to dark-gray, fine- to medium-grained, thick-bedded and unevenly bedded, cherty limestone and dolomitic limestone, sparsely fossiliferous. Light-gray chert lenses and nodules. Forms cliffs, ridge tops, and dip slopes. Estimated thickness about 180-200 m. (*GRI Source Map ID 37).* (GQ-1695).

Mm - Madison Limestone (Lower Mississippian)
Resistant light-gray and tan medium- to thick-bedded fossiliferous cherty limestone, locally dolomitic. Formerly assigned to the Deseret Limestone and underlying Madison Limestone (Untermann and Untermann, 1954, 1968), based on earlier correlations by Baker, Huddle, and Kinney (1949, p. 1174). Because of faunal evidence given by H.M. Duncan (Crittenden, 1959), however, the rocks are too old to be correlated with the Deseret Limestone. Thus, Kinney (1955) included these rocks within his limestone unit of Mississippian age and Hansen (1955) called them the lower limestone unit of Mississippian age. Faunas indicate a Madison age of the whole sequence (Mackenzie Gordon, Jr., and H.M. Duncan, written commun., 1961), and they were mapped as such by Hansen (1977a, 1977b). Only a partial section, about 40 m (130 ft) thick is exposed at the western edge of the quadrangle. (*GRI Source Map ID 38).* (GQ-1516).

Mm - Madison Limestone (Lower Mississippian)
Light-gray to dark-gray, fine- to medium-grained, thick bedded and unevenly bedded, cherty limestone and dolomitic limestone, sparsely fossiliferous. Chert mostly light gray. Forms cliffs and dipslopes. About 180-200 m thick. (*GRI Source Map ID 40).* (GQ-1401).

Mm - Madison Limestone (Lower Mississippian)
Formation shown only on cross section. *(GRI Source Map ID 42).* (GQ-1514).

Mm - Madison Limestone (Lower Mississippian)
Resistant tan mostly thick-bedded fossiliferous cherty limestone, locally dolomitic. Formerly assigned to the Desert Limestone and underlying Madison Limestone (Untermann and Untermann, 1954, 1968), based on earlier correlations by Baker, Huddle, and Kinney (1949, p. 1174). The Deseret is about 137 m (450 ft) thick in the Jones Hole--Whirlpool Canyon area (Untermann and Untermann, 1954). Because of faunal evidence given by H.M. Duncan (Crittenden, 1959), however, the rocks are too old to be correlated with the Deseret Limestone. Thus, Kinney (1955) included these rocks within his limestone unit of Mississippian age and Hansen (1955) called them the lower limestone unit of Mississippian age. Faunas indicate a Madison age of the whole sequence (Mackenzie Gordon, Jr., and H.M. Duncan, written commun., 1961), and they were mapped as such by Hansen (1977a, 1977b). Only a partial section, about 40 m (130 ft) thick is exposed in Split Mountain Canyon. (*GRI Source Map ID 43).* (GQ-1515).

M - Madison Limestone (Lower Mississippian)
Shown in cross section only. (*GRI Source Map ID 44).* (GQ-1530).

Mm - Madison Limestone (Lower Mississippian)
Light-gray to dark-gray fine- to medium-grained thick-bedded unevenly bedded cherty limestone and dolomitic limestone, sparsely fossiliferous. Chert mostly light gray (in contrast with the pink or red Pennsylvanian cherts). Forms cliffs. Thickness about 180-200 m. (*GRI Source Map ID 45).* (GQ-1534).

Mm - Madison Limestone (Lower Mississippian)
Light-gray to dark-gray, fine- to medium-grained, thick bedded and unevenly bedded, cherty limestone and dolomitic limestone, sparsely fossiliferous. Chert mostly light gray. Forms cliffs, ridgetops, and dipslopes. About 180 m thick. (*GRI Source Map ID 46).* (GQ-1408).

MDm - Madison Limestone and older rocks (Mississippian and Devonian)

Light-gray microcrystalline partly brecciated cherty dolomite; forms thick massive cliffs and ledges; about 15 to 25 feet above base is thin zone of flat dolomite-pebble conglomerate which is underlain by thin beds of varicolored dolomite, sandy dolomite, and shale; about 500 feet thick. (*GRI Source Map ID 1545).* (GQ-702).

OCd - Dike (Lower Ordovician or Upper Cambrian)

Tephritic leucitite (in the terminology of Rittman, 1952, based on chemical composition, but the rock contains no mineralogically identified leucite). Exposed in a side ravine in the west wall of Canyon of Lodore 0.55 km (0.3 mi) upriver from the mouth of Pot Creek; the only known dike in Dinosaur National Monument. Dike is medium dark gray, slightly brown, aphanitic, and microporphyritic (less than 3% phenocrysts of sanidine about 1 mm long). Dark color is caused by disseminated hematite and abundant needles of rutile and anatase < ½ mm long (electron-microprobe determination by George A. Desborough, U.S. Geological Survey, written commun., 1979). Thin amygdaloidal zones parallel to dike walls. Very fine grained black dikelets cut the main dike. (*GRI Source Map ID 31).* (GQ-1568).

Cr - Cambrian rocks and overlying rocks of unknown age (Cambrian and younger)

Shown in cross section only. (*GRI Source Map ID 42*). (GQ-1514).

Cl - Lodore Formation (Upper Cambrian)

Cl - Lodore Formation (Upper Cambrian)
At the top, light-brown to greenish-gray ledgy sandstone as much as 15 m thick. In middle, pink to tan to pale-greenish-gray glauconitic locally fossiliferous-slope-forming shale, interbedded with tan to pale-green sandstone; as much as 50 m thick. Variegated pink to gray to pale-green coarse to medium grained crossbedded somewhat friable sandstone at the base; locally pebbly and quartzitic. Forms cliffs. About 85 m thick. Total thickness of formation as much as 180 m in Lodore Canyon near Rippling Brook, but top has been beveled by pre-Mississippian erosion, and formation thins eastward. (*GRI Source Map ID 32).* (GQ-1403).

Cl - Lodore Formation (Upper Cambrian)
Pink to gray, coarse- to medium-grained, crossbedded, somewhat friable, pebbly, arkosic (Kinney, 1955, p. 23) sandstone; concealed in many places by colluvium or landslides. An upper unit of green glauconitic to red shale and interbedded fine-grained, thin-bedded sandstone is well exposed in adjacent areas (Hansen, 1977a,b) but may be discontinuous or lacking here. Estimated thickness about 90 m. (*GRI Source Map ID 33).* (GQ-1554).

Cl - Lodore Formation (Upper Cambrian)
Pink to gray coarse- to medium-grained crossbedded sandstone, locally quartzitic; locally pebbly; pebbles mostly gray quartz. Forms cliffs, ledges, and slopes. Varied thickness, but locally at least 70 m. (*GRI Source Map ID 35).* (GQ-1535).

Cl - Lodore Formation (Upper Cambrian)
Mostly pink to gray, coarse- to medium-grained, crossbedded somewhat friable, locally quartzitic, sandstone. Locally pebbly; pebbles mostly gray quartz. Forms cliffs and ledges. Thickness about 70-80 m. (*GRI Source Map ID 36).* (GQ-1536).

Cl - Lodore Formation (Upper Cambrian)
Pink to gray, coarse- to medium-grained, crossbedded, somewhat friable, pebbly, arkosic sandstone (Kinney, 1955, p. 23; Herr, 1979; Herr and Picard, 1981); concealed in many places by colluvium or landslides. An upper unit of green glauconitic to red shale and interbedded fine-grained, thin-bedded sandstone is well exposed in adjacent areas but may be discontinuous or lacking here. Estimated thickness about 90-120 m. (*GRI Source Map ID 37).* (GQ-1695).

Cl - Lodore Formation (Upper Cambrian)
At the top, light-brown to greenish-gray ledgy sandstone as much as 15 m thick. Underlain by pink to tan to pale-greenish-gray glauconitic slope-forming shale, locally fossiliferous, interbedded with tan to pale-green ledge forming sandstone; as much as 50 m thick. At the base, variegated pink to gray to pale-green, coarse- to medium-grained, crossbedded, somewhat friable sandstone; locally pebbly and locally quartzitic; pebbles mostly gray quartz. Lower unit forms cliff and is about 85 m thick. Total thickness of formation is as much as 180 m. (*GRI Source Map ID 40).* (GQ-1401).

Cl - Lodore Formation (Upper Cambrian)
Shown in cross section only. (*GRI Source Map ID 44).* (GQ-1530).

Cl - Lodore Formation (Upper Cambrian)
Pink to gray coarse- to medium-grained crossbedded sandstone, locally quartzitic; locally pebbly; pebbles mostly gray quartz. Forms cliffs, ledges, and slopes. Thickness at least 70-80 m. (*GRI Source Map ID 45).* (GQ-1534).

Cl - Lodore Formation (Upper Cambrian)
At the top, pink to tan to pale greenish-gray glauconitic sandy slope-forming shale about 15 m thick, but non-existent locally. Bulk of formation is variegated pink to gray to pale green coarse- to medium-grained crossbedded somewhat friable, locally quartzitic, sandstone; locally pebbly; pebbles mostly gray quartz. Forms slopes. About 85 m thick. Top of formation has been beveled by pre-Mississippian erosion, and formation thins eastward. (*GRI Source Map ID 46).* (GQ-1408).

Cl – Lodore Formation (Upper Cambrian)
Light-gray and pale-green glauconitic fine- to coarse- grained thin- to thick-bedded conglomeratic sandstone and quartzite; contains a few beds of red and green shale and siltstone; about 300 feet thick. (*GRI Source Map ID 1545)* (GQ-702).

Yu - Uinta Mountain Group, undivided (Precambrian Y/Proterozoic Y)

Yu - Uinta Mountain Group (Precambrian Y)
Light- to dark-red coarse to medium-rained pebbly quartzitic crossbedded sandstone, locally friable. Contains several beds of red to gray silty shale, especially just below contact with Lodore Formation below Limestone Ridge and in rim of canyon above (north of) Hells Half Mile. Base unexposed in quadrangle but thickness in adjacent areas exceeds 7,000 m in adjacent areas. (*GRI Source Map ID 32).* (GQ-1403).

Yu - Uinta Mountain Group (Precambrian Y)
Light- to dark-red coarse-grained pebbly crossbedded quartzitic sandstone. Base unexposed in quadrangle but thickness in adjacent areas exceeds 7,000 m. (*GRI Source Map ID 35).* (GQ-1535).

Yu - Uinta Mountain Group (Precambrian Y)
Light- to dark-red, coarse- to medium-grained, pebbly crossbedded quartzitic sandstone. Contains sparse thin beds of red to gray silty shale. Base not exposed in quadrangle but the thickness of the group exceeds 7,000 m in adjacent areas. (*GRI Source Map ID 36).* (GQ-1536).

Yu - Uinta Mountain Group (Precambrian Y)
Light- to dark-red, coarse- to medium-grained, pebbly, quartzitic, crossbedded sandstone. Base unexposed in quadrangle, but thickness exceeds 7,000 m in adjacent areas. (*GRI Source Map ID 40).* (GQ-1401).

Yu - Uinta Mountain Group (Precambrian Y)
Formation shown only on cross section. (*GRI Source Map ID 42).* (GQ-1514).

Yu - Uinta Mountain Group (Precambrian Y)
Shown in cross section only. (*GRI Source Map ID 44).* (GQ-1530).

Yu - Uinta Mountain Group (Precambrian Y)
Light- to dark-red coarse-grained pebbly crossbedded quartzitic sandstone. Base unexposed in quadrangle but thickness exceeds 7,000 m in adjacent areas. (*GRI Source Map ID 45).* (GQ-1534).

PCu – Uinta Mountain Group (Precambrian)

Interbedded red fine- to coarse-grained conglomeratic partly quartzitic sandstone and red and green shale; hematitic; typically weathers dark reddish brown; sandstone is thick bedded, commonly crossbedded and forms cliffs; at least 500 feet exposed in Cross Mountain Canyon. (*GRI Source Map ID 1545).* (GQ-702).

Yus - Uinta Mountain Group, sandstone (Precambrian Y/Proterozoic Y)

Yu - Uinta Mountain Group (Proterozoic Y)
Sandstone--light- to dark-red, coarse- to medium-grained, pebbly, quartzitic, crossbedded. Grains subangular to sub-rounded, cemented by quartz overgrowths and (or) hematite. Local beds of pebble conglomerate; pebbles gray to pink quartz and metaquartzite. Contains some red to gray silty shale and (or) siltstone with mica concentrated along bedding planes. Forms cliffs and ledges. The rocks of the Uinta Mountain Group stratigraphically below shale 1 are more massive and form bolder, more rugged outcrops containing less soil cover than the rocks above unit 1, but in the Canyon of Lodore the distinction is masked by the sheer canyon walls. The exposed thickness of the Uinta Mountain Group in the Canyon of Lodore area is about 2,700 m (8,900 ft), but the base is not exposed. Thicker sections, including the base, are exposed on the northeast flank of the Uinta Mountains north of Dinosaur National Monument. (*GRI Source Map ID 31).* (GQ-1568).

Yu - Uinta Mountain Group (Proterozoic Y)
Sandstone - Light- to dark-red, coarse- to medium-grained, pebbly, quartzitic, crossbedded sandstone, locally friable. Forms cliffs and ledges. A few thin beds of red to gray, silty shale, poorly exposed. About 1,200 m of exposed Uinta Mountain Group in quadrangle, but base is unexposed. Thickness exceeds 7,000 m in adjacent areas (Hansen, 1965, p. 33). (*GRI Source Map ID 33).* (GQ-1554).

Yu - Uinta Mountain Group (Middle Proterozoic)
Sandstone - Light-to dark-red, coarse- to medium-grained, pebbly, quartzitic, crossbedded sandstone, locally friable. Forms cliffs and ledges. A few thin beds of red to gray, silty shale, poorly exposed. About 2,700 m of exposed Uinta Mountain Group in quadrangle, but base is unexposed. (*GRI Source Map ID 37).* (GQ-1695).

Yu - Uinta Mountain Group (Precambrian Y)
Sandstone - Light to dark-red coarse- to medium-grained pebbly quartzitic crossbedded sandstone, locally friable. A few thin beds of red to gray silty shale. Base unexposed in quadrangle but thickness exceeds 7,000 meters in adjacent areas. (*GRI Source Map ID 46).* (GQ-1408).

Yuss - Uinta Mountain Group, shale and sandstone (Precambrian Y/Proterozoic Y)

Yus - Uinta Mountain Group (Proterozoic Y)
Shale and sandstone - Gray (predominant), pale-olive-green, and red, silty shale interbedded with red sandstone. Poorly exposed; about 70 m thick. Shale sampled in the Graystone quadrangle, about 50 km east of the Crouse Reservoir quadrangle and probably at about the same stratigraphic horizon, has a radiometric age of 1,090±50 m.y. (whole rock rubidium-strontium age determined by Sambhudas, Chaudhuri, Kansas State University, oral commum., 1979). (*GRI Source Map ID 33).* (GQ-1554).

Yus - Uinta Mountain Group (Middle Proterozoic)
Shale and sandstone - Gray (predominant), pale-olive-green, and red, silty shale interbedded with red sandstone, totaling about 100 m in thickness. Poorly exposed. (*GRI Source Map ID 37).* (GQ-1695).

Yus - Uinta Mountain Group (Precambrian Y)
Shale and sandstone : Red to olive-green to gray silty shale interbedded with sandstone. (*GRI Source Map ID 46).* (GQ-1408).

Yus4 - Uinta Mountain Group, unit 4 (Precambrian Y/Proterozoic Y)

Unit 4 and unit 3 --Shale (predominant), siltstone, and sandstone, (subordinate). Mica along bedding planes. Units 3 and 4 are interlayered gray, pale olive green, and red, very evenly bedded clayey to silty shale and siltstone and interbedded sandstone. South of the quadrangle in Canyon of Lodore they are truncated by the unconformity at the top of the Uinta Mountain Group. Unit 3 sampled in the NE ¼ sec. 6, T. 7 N., R. 100 W., about 2.4 km (1 ½ mi) south of Greystone, Colorado, has a whole-rock Rb-Sr age of 1,090 +/- 50 million years, as determined by Sambhudas Chandhuri, Kansas State University, 1980). (*GRI Source Map ID 31).* (GQ-1568).

Yus3 - Uinta Mountain Group, unit 3 (Precambrian Y/Proterozoic Y)

Unit 4 and unit 3 --Shale (predominant), siltstone, and sandstone, (subordinate). Mica along bedding planes. Units 3 and 4 are interlayered gray, pale olive green, and red, very evenly bedded clayey to silty shale and siltstone and interbedded sandstone. South of the quadrangle in Canyon of Lodore they are truncated by the unconformity at the top of the Uinta Mountain Group. Unit 3 sampled in the NE ¼ sec. 6, T. 7 N., R. 100 W., about 2.4 km (1 ½ mi) south of Greystone, Colorado, has a whole-rock Rb-Sr age of 1,090 +/- 50 million years, as determined by Sambhudas Chandhuri, Kansas State University, 1980). (*GRI Source Map ID 31).* (GQ-1568).

Yus2 - Uinta Mountain Group, unit 2 (Precambrian Y/Proterozoic Y)

Light gray clayey slope-forming shale. Exposed high in the walls of Canyon of Lodore from Jack Springs Draw south into the Canyon of Lodore South quadrangle, where it passes underground. (*GRI Source Map ID 31).* (GQ-1568).

Yus1 - Uinta Mountain Group, unit 1 (Precambrian Y/Proterozoic Y)

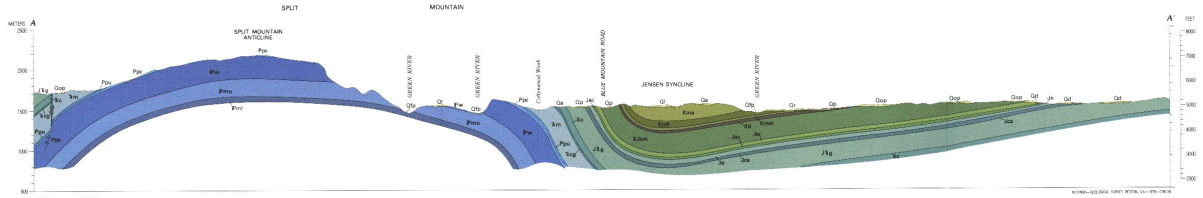
Mostly light greenish gray shale. It can be traced with the aid of aerial photographs about 33 km (20 mi) northwestward from the Gates of Lodore toward the head of Browns Park in Utah, where it passes underground. Thicknesses of shale units are a few tens of meters. (*GRI Source Map ID 31).* (GQ-1568).

Geologic Cross Sections

The geologic cross sections present in the GRI digital geologic-GIS data produced for Dinosaur National Monument, Colorado and Utah (DINO) are presented below. Cross section graphics were scanned at a high resolution and can be viewed in more detail by zooming in (when viewing the digital format of this document).

Note that cross section abbreviations (e.g., A - A') are very likely to have been changed from their source map abbreviation in the GRI data so that each cross section abbreviation is unique.

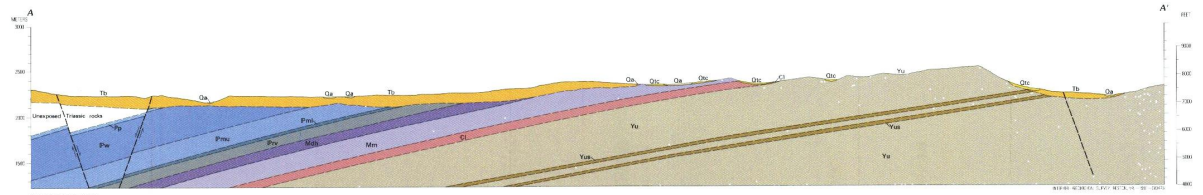
Cross Section A-A'



Dinosaur NM
GQ-1513: Geologic Cross Section A-A'
Geologic Map of the Dinosaur Quarry Quadrangle, Uintah County, Utah
by Peter D. Rowley, Douglas M. Kinney, and Wallace R. Hansen
U.S. Geological Survey, 1979

Extracted from: GRI Source Map ID 34 (GQ-1513).

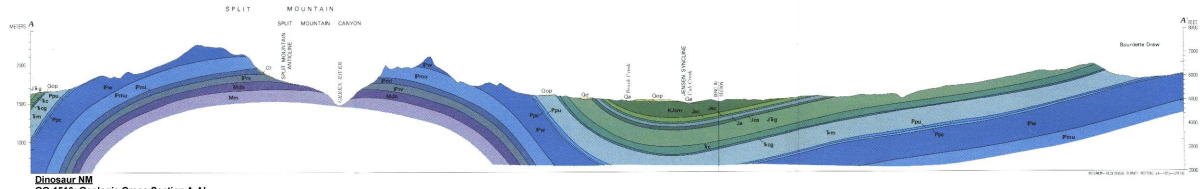
Cross Section B-B'



Dinosaur NM
GQ-1554: Geologic Cross Section A-A'
Geologic Map of the Crouse Reservoir Quadrangle, Uintah and Daggett Counties, Utah
by Wallace R. Hansen, Paul E. Carrara, and Peter D. Rowley
U.S. Geological Survey, 1981

Extracted from: GRI Source Map ID 33 (GQ-1554). Cross section A-A' on source map.

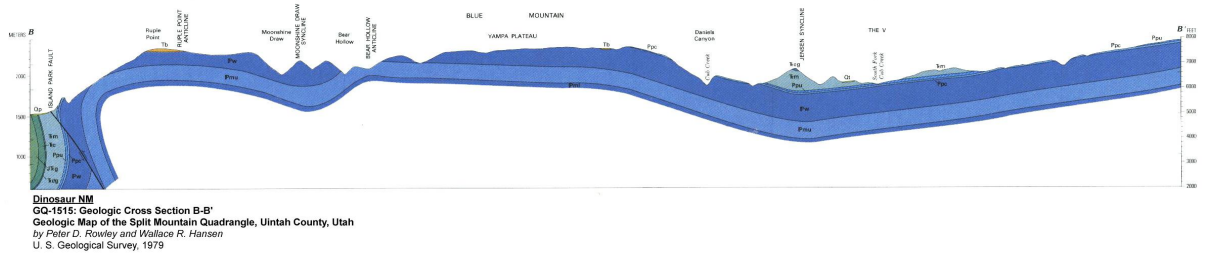
Cross Section C-C'



Dinosaur NM
GQ-1516: Geologic Cross Section A-A'
Geologic Map of the Split Mountain Quadrangle, Uintah County, Utah
by Peter D. Rowley and Wallace R. Hansen
U.S. Geological Survey, 1979

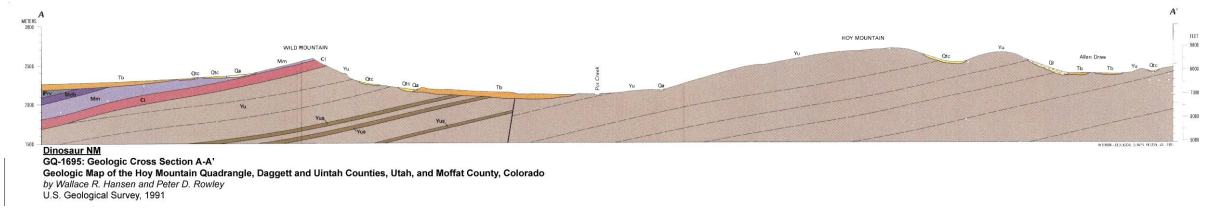
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Cross Section D-D'



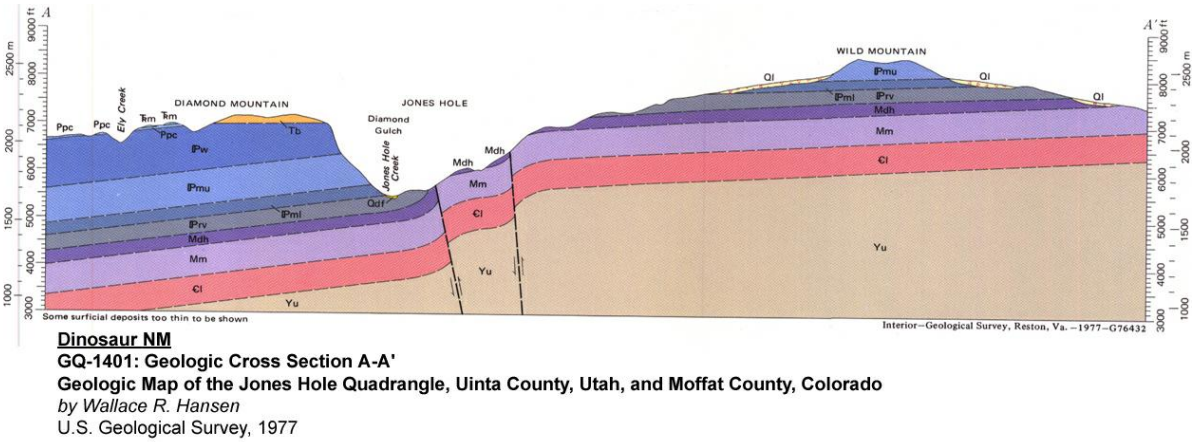
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Cross Section E-E'



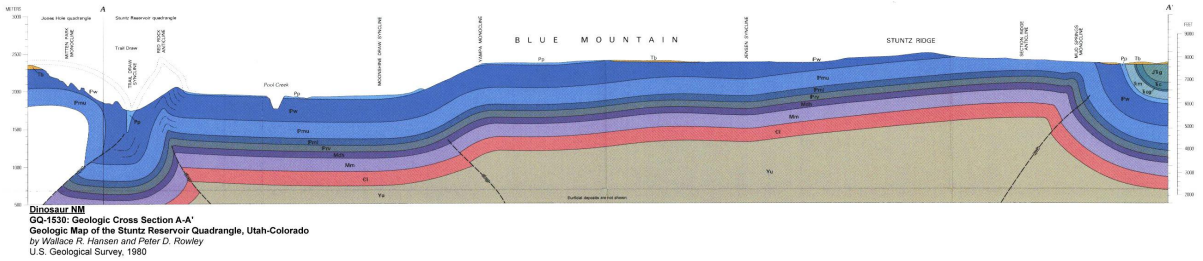
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Cross Section F-F'



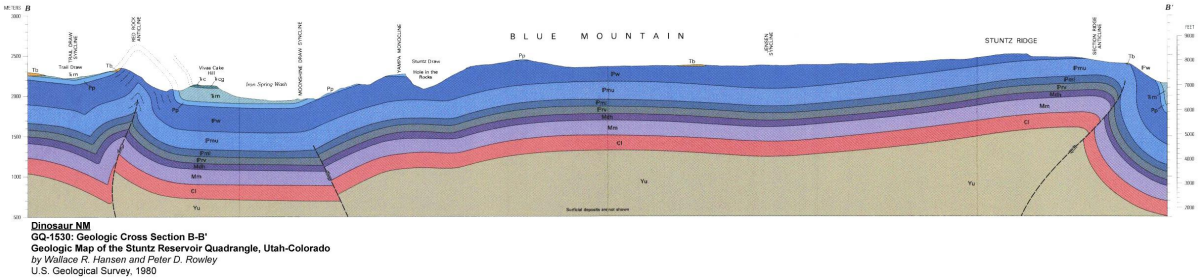
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Cross Section G-G'



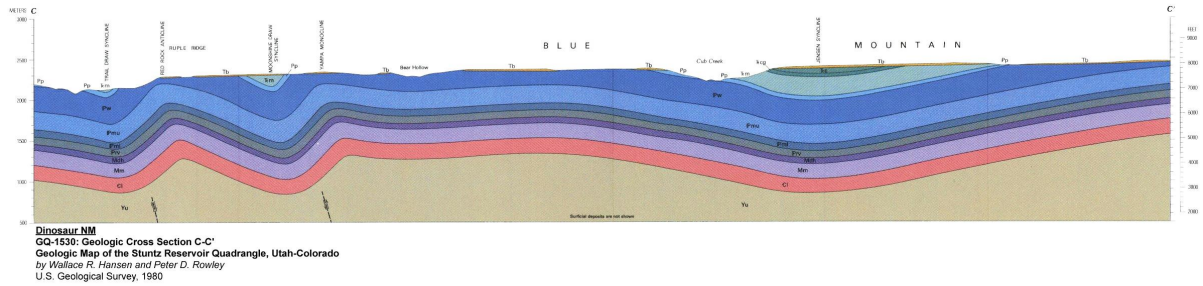
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Cross Section H-H'



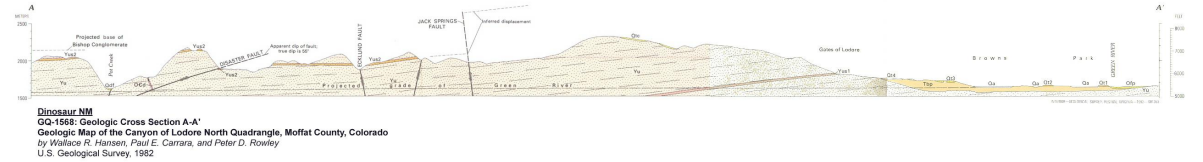
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Cross Section I-I'



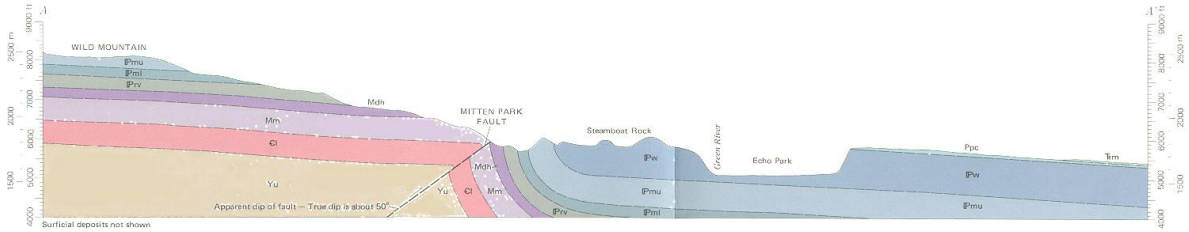
Extracted from: GRI Source Map ID 44 (GQ-1530). Cross section C-C' on source map.

Cross Section J-J'



Extracted from: GRI Source Map ID 31 (GQ-1568). Cross section A-A' on source map.

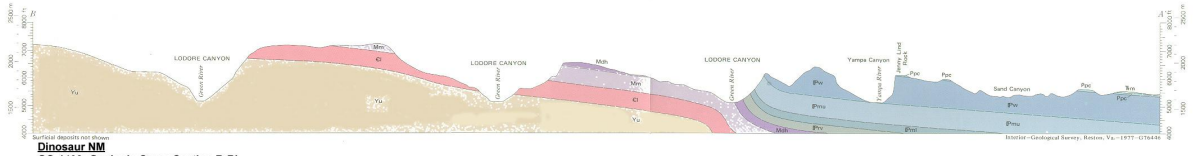
Cross Section K-K'



Dinosaur NM
GQ-1403: Geologic Cross Section A-A'
Geologic Map of the Canyon of Lodore South Quadrangle, Moffat County, Colorado
by Wallace R. Hansen
U.S. Geological Survey, 1977

Extracted from: GRI Source Map ID 32 (GQ-1403). Cross section A-A' on source map.

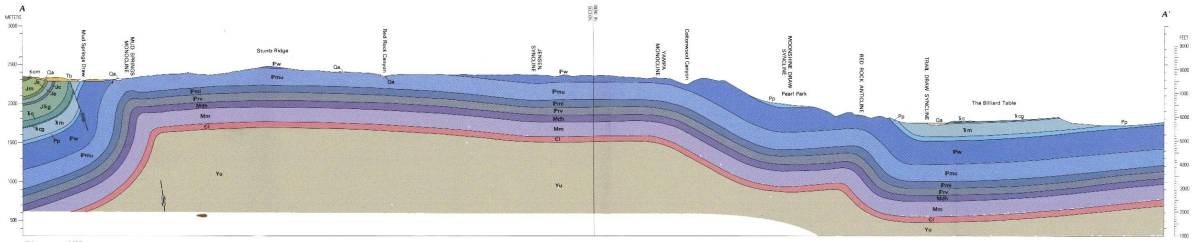
Cross Section L-L'



Dinosaur NM
GQ-1403: Geologic Cross Section B-B'
Geologic Map of the Canyon of Lodore South Quadrangle, Moffat County, Colorado
by Wallace R. Hansen
U.S. Geological Survey, 1977

Extracted from: GRI Source Map ID 32 (GQ-1403). Cross section B-A' on source map.

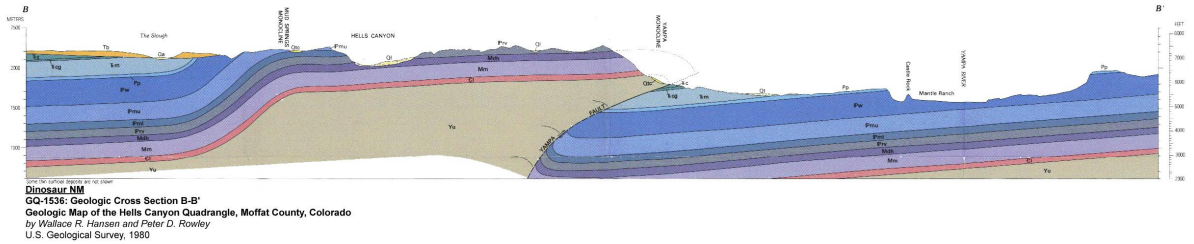
Cross Section M-M'



Dinosaur NM
GQ-1536: Geologic Cross Section A-A'
Geologic Map of the Hells Canyon Quadrangle, Moffat County, Colorado
by Wallace R. Hansen and Peter D. Rowley
U.S. Geological Survey, 1980

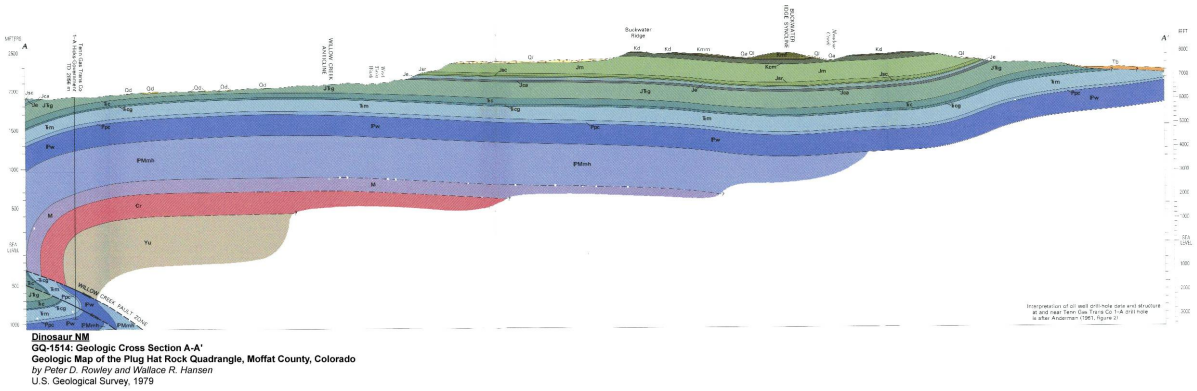
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Cross Section N-N'



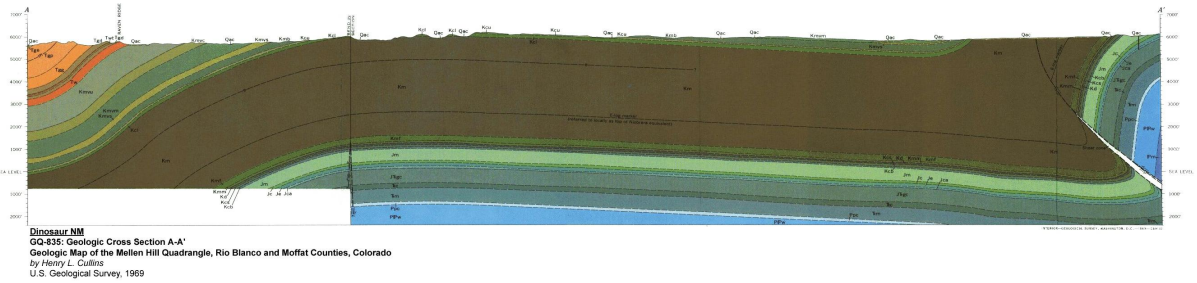
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Cross Section O-O'



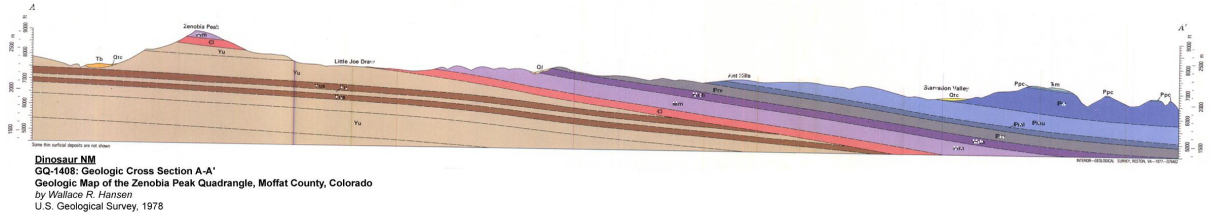
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Cross Section P-P'



Extracted from: GRI Source Map ID 41 (GQ-835). Cross section A-A' on source map.

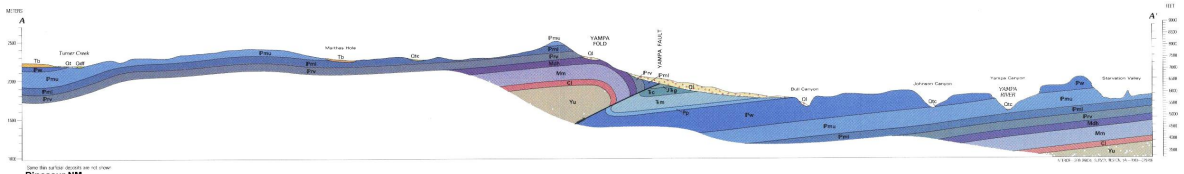
Cross Section Q-Q'



Dinosaur NM
GQ-1408: Geologic Cross Section A-A'
Geologic Map of the Zenobia Peak Quadrangle, Moffat County, Colorado
by Wallace R. Hansen
U.S. Geological Survey, 1978

Extracted from: GRI Source Map ID 46 (GQ-1408). Cross section A-A' on source map.

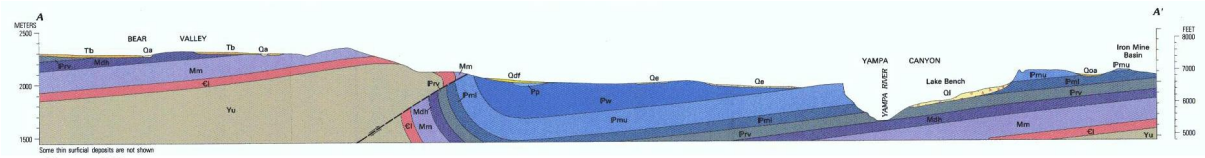
Cross Section R-R'



Dinosaur NM
GQ-1534: Geologic Cross Section A-A'
Geologic Map of the Tanks Peak Quadrangle, Moffat County, Colorado
by Wallace R. Hansen and Paul E. Carrara
U.S. Geological Survey, 1980

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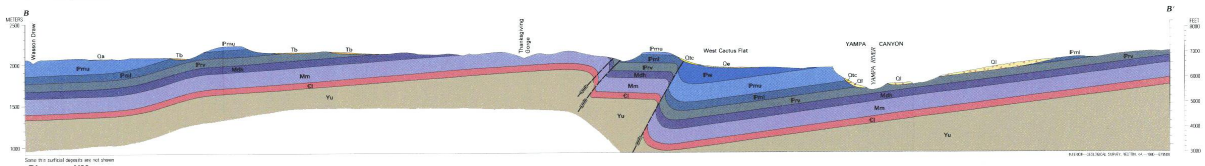
Cross Section S-S'



Dinosaur NM
GQ-1535: Geologic Cross Section A-A'
Geologic Map of the Haystack Rock Quadrangle
by Wallace R. Hansen, Paul E. Carrara, and Peter D. Rowley
U.S. Geological Survey, 1980

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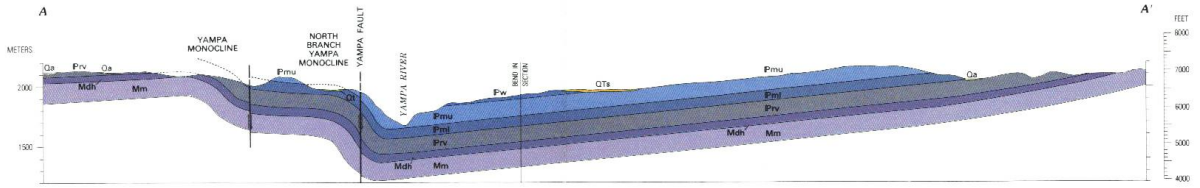
Cross Section T-T'



Dinosaur NM
GQ-1535: Geologic Cross Section B-B'
Geologic Map of the Haystack Rock Quadrangle, Moffat County, Colorado
by Wallace R. Hansen, Paul E. Carrara, and Peter D. Rowley
U.S. Geological Survey, 1980

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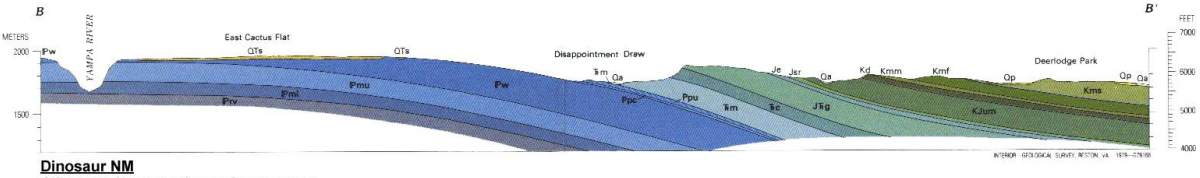
Cross Section U-U'



Dinosaur NM
GQ-1516: Geologic Cross Section A-A'
Geologic Map of the Indian Water Canyon Quadrangle, Moffat County, Colorado
by Peter D. Rowley, John R. Dyni, Wallace R. Hansen, and George N. Pipiringos
U.S. Geological Survey, 1979

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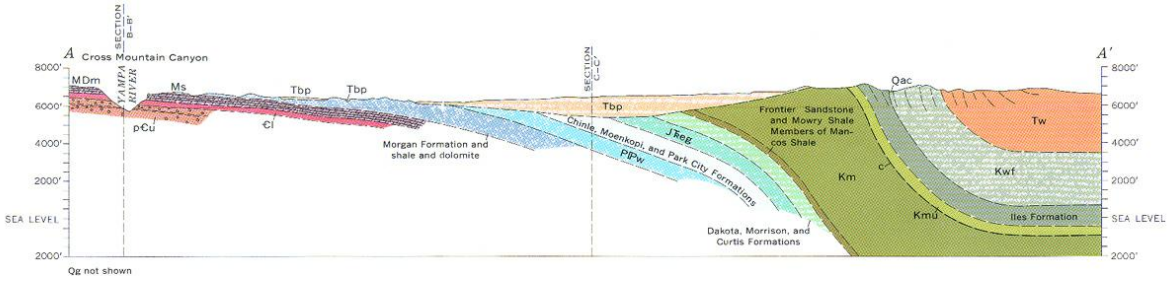
Cross Section V-V'



Dinosaur NM
GQ-1516: Geologic Cross Section B-B'
Geologic Map of the Indian Water Canyon Quadrangle, Moffat County, Colorado
by Peter D. Rowley, John R. Dyni, Wallace R. Hansen, and George N. Pipiringos
U.S. Geological Survey, 1979

Extracted from: GRI Source Map ID 38 (GQ-1516). Cross section B-B' on source map.

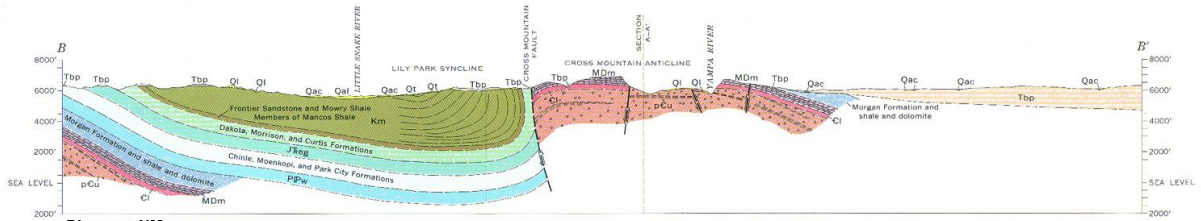
Cross Section W-W'



Dinosaur NM
GQ-702: Geologic Cross Section A-A'
Geologic Map of the Elk Springs Quadrangle Moffat County, Colorado
by John R. Dyni
U.S. Geological Survey, 1968

Extracted from: GRI Source Map ID 1545 (GQ-702). Cross section A-A' on source map.

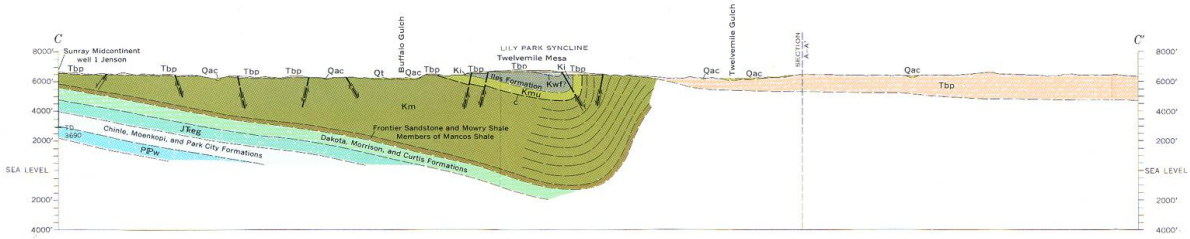
Cross Section X-X'



Dinosaur NM
GQ-702: Geologic Cross Section B-B'
Geologic Map of the Elk Springs Quadrangle Moffat County, Colorado
by John R. Dyni
U.S. Geological Survey, 1968

Extracted from: GRI Source Map ID 1545 (GQ-702). Cross section B-B' on source map.

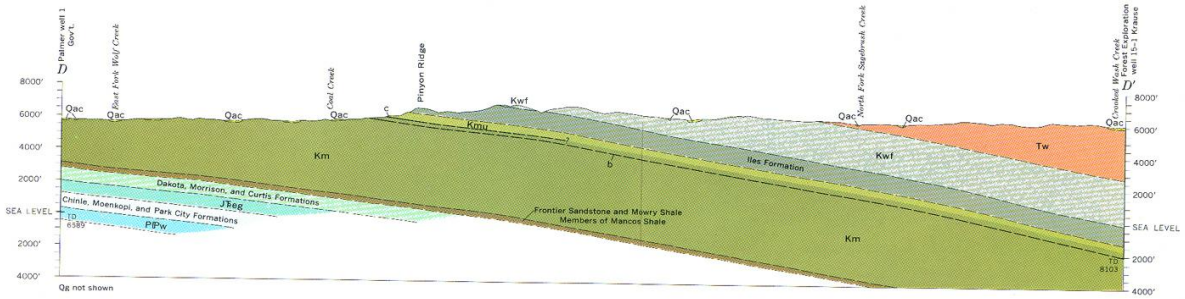
Cross Section Y-Y'



Dinosaur NP
GQ-702: Geologic Cross Section C-C'
Geologic Map of the Elk Springs Quadrangle Moffat County, Colorado
by John R. Dyni
U.S. Geological Survey, 1968

Extracted from: GRI Source Map ID 1545 (GQ-702). Cross section C-C' on source map.

Cross Section Z-Z'



Dinosaur NP
GQ-702: Geologic Cross Section D-D'
Geologic Map of the Elk Springs Quadrangle
by John R. Dyni
U.S. Geological Survey, 1968

Extracted from: GRI Source Map ID 1545 (GQ-702). Cross section D-D' on source map.

GRI Source Map Citations

The GRI digital geologic-GIS maps for Dinosaur National Monument, Colorado and Utah (DINO) were compiled from the following sources:

Cullins, H.L., 1969, Geologic Map of the Mellen Hill Quadrangle, Rio Blanco and Moffat counties, Colorado,U.S. Geological Survey, Geological Quadrangle Map GQ-835, 1:24,000 scale. (*GRI Source Map ID 41*). (GQ-835).

Dyni, J.R., 1968, Geologic Map of the Elk Springs Quadrangle, Moffat County, Colorado,U.S. Geological Survey, Geological Quadrangle Map GQ-702, 1:24,000 scale. (*GRI Source Map ID 1545*). (GQ-702).

Hansen, W.R., 1977, Geologic Map of the Jones Hole Quadrangle, Uinta County, Utah, and Moffat County, Colorado,U.S. Geological Survey, Geological Quadrangle Map GQ-1401, 1:24,000 scale. (*GRI Source Map ID 40*). (GQ-1401).

Hansen, W.R., 1977, Geologic Map of the Canyon of Lodore South Quadrangle, Moffat County, Colorado,U.S. Geological Survey, Geological Quadrangle Map GQ-1403, 1:24,000 scale. (*GRI Source Map ID 32*). (GQ-1403).

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

Geologic Map of the Canyon of Lodore North Quadrangle

Hansen, W.R., Carrara, P.E., and Rowley, P.D., 1982, Geologic Map of the Canyon of Lodore North Quadrangle, Moffat County, Colorado,U.S. Geological Survey, Geological Quadrangle Map GQ-1568, 1:24,000 scale. (*GRI Source Map ID 31*).

Ancillary Map Notes

FURTHER DESCRIPTION OF THE DIKE IN LADORE CANYON

A whole rock Rb-Sr age of 483 +/- 29 million years was determined by Sambhudas Chaudhuri (written commun., 1980), Kansas State Univ., from a sample collected by Carrara in 1978; initial 87Sr/86Sr ratio of 0.7062. +/- 0.0009. Igneous rocks of this general age are not widely recognized in the Middle and Southern Rocky Mountains*. The south border of the dike, and the adjacent wall rock are highly sheared. Though the time of shearing is uncertain, it probably is Laramide or, late Miocene or, perhaps both.

Because of its age, the dike must have been emplaced shortly after deposition of the Lodore Formation (lower Upper Cambrian) and at a depth of about 1,200 m (4,000 ft), which is the depth of the dike below the top of the Lodore Formation.

The unusual chemical composition of this rock, notable for its high content of TiO2 and paucity of Na2O, is shown by the following analyses of samples collected along the length and breadth of the dike:

Table 1

The following elements were detected in ppm by semi-quantitative spectrographic analysis (N.M. Conklin, analyst, U.S. Geol. Survey):

Mn	B	Ba	CO	Cr	Cu	Ni	Sc	Sr	V	Y	Zr	Ga	Yb
700	20	700	30	70	15	30	70	70	300	70	150	30	7

The high content of Fe2O3 indicates oxidation of microcrystalline ferromagnesian minerals at the time the dike was emplaced. The rutile and anatase seem to be alteration products of titaniferous magnetite (G.A. Desborough, written commun., 1979).

The dike contains several thin vesicular bands filled with zoned ovoid amygdules, mostly less than a centimeter in length. These amygdules were analyzed mineralogically by Phoebe Hauff, of the U.S. Geol. Survey, using X-rays and microprobe. A reddish outer shell a millimeter or so thick consists largely of dolomite but also contains calcite and mica. Scattered crystals of pyrite and dark red garnet, mostly less than a half a millimeter across, border the vesicle walls. An inner greenish core showed X-ray patterns for chlorite and mica, although some cores consist of gray calcite. Miss Hauff also noted X-ray patterns for minor amounts of plagioclase, either andesine or anorthite, in the matrix of the rock.

*Several dikes of this general age in the western Uinta Mountains have recently been described by H.R. Ritzma (Utah Geological and Mineral Survey. Survey Notes. Nov., 1981, p. 9).

STRUCTURAL HIGHLIGHTS

The Canyon of Lodore North quadrangle is on the homoclinal southwest limb of the eastern dome of the large Uinta anticline (Hansen, 1957, fig. 1; 1965, fig. 45). Here, the simple south-southwesterly regional

dip is modified only by slight local warping and faulting. Inasmuch as the dip, though gentle, much exceeds the gradient of the Green River, progressively younger rocks appear downstream along the Canyon of Lodore. The axis of the Uinta anticline is a few km northeast of the quadrangle, trending about N. 50-60 degrees W., but in the eastern Uinta Mountains it is largely concealed by the Browns Park Formation. This great fold has an axial length of about 240 km (about 150 mi.).

FAULTS

Most faults in the quadrangle belong to either of two sets, one trending northeast to north-northeast and another trending west-northwest. These trends are very prevalent in the eastern Uinta Mountains (Rowley and others, 1979) and over much of the adjacent northern and eastern Colorado Plateau. In the Canyon of Lodore North quadrangle, marker beds (shale units 1, 2, 3, and 4) provide datum planes for determining fault attitudes and displacements in the thick Uinta Mountain Group; most faults in the quadrangle have rather small displacements for their lengths. The Disaster fault and the Jack Springs fault are exceptions, having sizeable throws.

The Disaster fault, a southeast-dipping high-angle reverse fault, has a throw of about 330 m (1,100 ft) near the mouth of Pot Creek, as indicated by the displacement of shale unit 2 (Yus 2) of the Uinta Mountain Group. To the northeast this fault abuts the Jack Springs fault and seems to be displaced horizontally, but its apparent offset can be explained better by a simple vertical throw on the Jack Springs fault of about 600 m (2,000 ft) if, as is probable, the north side of the Jack Springs fault is upthrown (fig. 1). (Hansen, Carrara, and Rowley, GQ-1568)

Figure 1

In the adjacent Jack Springs quadrangle, the Jack Springs fault appears to have had a second, smaller movement that dropped the north side down, perhaps as a consequence of late Tertiary gravitative subsidence of the Uinta anticline. This movement of the Jack Springs fault is suggested by a conspicuous north-facing escarpment along the fault line about 60 m (200 ft) high. If this movement took place in the Canyon of Lodore North quadrangle also, it is masked by rugged topography. Incidentally, the Disaster fault shares its trend in the adjacent Canyon of Lodore South quadrangle with the large Mitten Park fault. The two faults are discontinuous at the ground surface but conceivably may merge at depth (Hansen, 1977).

The Pot Creek fault belongs to the same set of fractures as the Jack Springs fault. Despite its small throw of only about 60-120 m (200-400 ft), it is one of a trend of faults having an inferred overall length of perhaps 45 km (28 mi). Its offset is apparent only in the Canyon of Lodore, but its concealed extension to the west-northwest is suggested by a well-defined topographic lineament. Faulting along this lineament has been inferred by Ritzma (1959, p. 88), Stokes and Madsen (1961), and more recently, by Rowley and others (1979). In the Crouse Reservoir area, two quadrangles to the west, faults of this trend have Quaternary displacements (Hansen and others, 1981), as do parallel faults on Diamond Mountain Plateau a few kilometers farther south. Discontinuous faults follow the same trend to the east-southeast in the adjacent Zenobia Peak quadrangle (Hansen, 1978).

Contrary to popular belief, there is no evidence of faulting between the Gates of Lodore and Browns Park. Browns Park is considerably, though discontinuously faulted along its northeast margin, but along its southwest margin the Browns Park Formation and the Uinta Mountain Group are in unconformable contact; the so-called Browns Park graben does not exist. (Hansen, Carrara, and Rowley, GQ-1568)

Time of Faulting

Fault movements in the eastern Uinta Mountains extended over a very long time, although critical dating of many individual faults is not possible. The large leucitite dike, of Late Cambrian or Early Ordovician age, in Canyon of Lodore near Pot Creek intrudes a west northwest-trending fracture and has been

marginally sheared by renewed movement (of undetermined age) since its emplacement. This fracture terminates against the Disaster fault, which does not displace the Lodore Formation (Upper Cambrian) to the south in the Canyon of Lodore South quadrangle. Some faults in the same trend, however, have large Laramide offsets (for example, the Mitten Park and Island Park faults of adjacent areas). Faults of the west-northwest trend seem to have been the more active set in later geologic time--several of them strongly displace the Browns Park Formation (Miocene) in adjacent areas, and a few have Quaternary displacements. On the other hand, the many northeast-trending faults in this quadrangle and adjacent areas are not know to displace either the Bishop Conglomerate (Oligocene) or the Browns Park Formation, although at least 2 such faults farther west displace the Gilbert Peak erosion surface (lower Oligocene?) on the north slope of the Uinta Mountains.

JOINTS

Two or more sets of conspicuous , well-defined joints cut nearly every outcrop of the Uinta Mountain Group, but only joints are readily distinguished on aerial photographs are plotted on the map. One set strikes about N. 50-70 degrees W. and dips steeply northeast; another strikes N. 10-30 degrees E., and dips eastward. Faults and joints of similar strikes cut Paleozoic and Mesozoic rocks in adjacent areas.

PHYSIOGRAPHIC SETTING AND DEVELOPMENT OF CANYON OF LADORE

For more than 100 years geologists have pondered the course of Green River through the Uinta Mountains. Most rivers flow away from mountains, not toward them. But the Green, draining the mountains and plains of southern Wyoming, cuts sharply into the Uinta Mountains at the Utah State line, then flows 180 km east and south across the range through Utah and Colorado without regard for topographic relief or geologic structure. Why, at the Gates of Lodore, does the river turn south from the wide valley of Browns Park, where logical egress is eastward, reenter the mountains to the south, and for the next 80 km drain one canyon after another before reaching the Uinta Basin?

The hypothesis advanced here, in brief, and earlier by Hansen (1969a, p. 42-44, 58; 1969b), is that the river was flowing southeast through the valley of Browns Park in late Tertiary time on a thickening fill (the Browns Park Formation) toward a junction with the Yampa River and ultimately, perhaps, the White River. The fill eventually over-topped the valley rim to the south, and the river, turning southward at the site of the present Canyon of Lodore, found a new course across the Uinta Mountains toward the Uinta Basin. From the Gates of Lodore southward, the river established itself on the old upland surface of the Bishop Conglomerate, ultimately eroding its way down through the underlying rocks to the present canyon bottom. Then, as now, the Bishop Conglomerate extended deep into the mountains as a network of coalesced alluvial fills. South of the quadrangle the Bishop is still so widely disposed along and near both rims of the canyon that there can be no doubt about the superposition of the river through it.

This concept calls for a much-thickened valley fill in Browns Park and for the subsequent removal of much of it by the Green River, but the evidence seems irrefutable. East of Canyon of Lodore the Browns Park Formation still reaches altitudes comparable to the rims of the canyon, which are about 2,300 m (7,500-7,640 ft). The highest undeformed remnant is at John Weller Mesa on the drainage divide between the Green River and the Little Snake River 30 km (20 mi) southeast of the Gates of Lodore. There, the eroded top of the Browns Park Formation is about 2,200 m (7,200 ft) above sea level. Two townships north of John Weller Mesa at Dry Mountain, remnants of Browns Park Formation stand even higher (2,340 m; 7,680 ft), but that area has been involved in strong late-Tertiary warping. Its former altitude may have been even higher, in view of the widespread northerly tilting of the eastern Uinta Mountains in late Tertiary time (Hansen and Rowley, 1980; Hansen, 1965, p. 164, 1969a, p. 121).

In any event, a vast amount of material has been removed from the valley since the onset of canyon cutting. The highest part of John Weller Mesa is 540 m (1,770 ft) above the level of the Green River at the Gates of Lodore. This height is within about 120 m of the height of the canyon rim, or about 82 % of the

height of the canyon wall. A rough guess would place the volume of material removed from the old valley of Browns Park below the level of John Weller Mesa at 200 km3. (In the sense of the meaning here, the old valley of Browns Park is the area between the head of modern Browns Park to the northwest in Utah and Lone Mountain to the southeast in Colorado, a total length of about 70 km, or 44 mi). If, as postulated here, the fill reached the added 18% of height to the rim of Canyon of Lodore, 80 km3 or so of additional fill must have been removed. Much more of the Browns Park Formation has been eroded from areas far to the east in Moffat County near Maybell.

The above hypothesis varies from views of earlier workers. Major Powell (1875), using the Uinta canyons as his type example, advanced the then-new concept of antecedence, which assumed erroneously that the Green River predated Laramide uplift of the Uinta Mountains and that as uplift progressed the river kept pace in eroding its canyon. Powell alluded to a stationary saw cutting a moving log--"the river was running ere the mountains were formed...before the rocks were folded" (Powell, 1875, p. 152). Antecedence is an elegant concept that has been authenticated for some river basins, but cogent evidence rules it out for the eastern Uinta Mountains, as S.F. Emmons (in Hage and Emmons, 1877) was the first to point out.

Emmons advocated simple superposition, noting the widespread occurrence of high-level Tertiary deposits in the mountains, a concept that nearly coincides with the view expressed here. Bradley (1936, p. 189) agreed that the Green was superimposed upstream and down from Canyon of Lodore but doubted the supposed depth and extent of the old Tertiary fill and, eleborating on a suggestion of Sears (1924), proposed instead that an ancestral east-flowing Green River was captured by a small but vigorous stream in Canyon of Lodore, "Lodore Branch of Cascade Creek," and was thus diverted southward. Cascade Creek is the present Pot Creek. This concept disavows any extraordinary thickness of Browns Park fill and calls for headward erosion by Lodore Branch, rather than a spillover by the Green, as postulated here. Bradley did not address the difficult problem as to how a small stream could erode across a divide to capture a much larger stream--a problem obviated by spillover. Hunt (1969, p. 90-99), in a brilliant analysis of the history of the Colorado River and its tributaries, proposed a compromise position between Powell and Emmons, a combination of antecedence and superposition, which he called "anteconsequence" or "anteposition." Also questioning the extent of the fill, Hunt suggested that much of the depth of Canyon of Lodore is an erosive response to renewed uplift of the range since the drainage was established, which probably is true, but there is not known demonstrable evidence that the canyon area has been uplifted differentially relative to the valley of Browns Park in a way that would account for the depth of Canyon of Lodore. The evidence seems to indicate otherwise. After all, the Green has eroded hundreds of meters downward in Browns Park also. If renewed uplift has occurred, as seems likely, it probably was region-wide and included Browns Park as well as Canyon of Lodore. Trimble (1980) recently reached much the same conclusion with respect to late Cenozoic uplift of the Southern Rocky Mountain and the Great Plains.

CANYON PROFILE AND SIGNIFICANCE

Despite the steepness of the walls of Lodore Canyon, cross-canyon topography profiles show a distinct slope break, steepening downward, abut 240-300 m (800-1,000 ft) above the canyon floor (fig. 2). The canyon profile is compound in form, most pronouncedly so down spurs or lateral ridgelines. Unrelated to lithology or stratigraphic shelving, the break in the profile is regarded as a result of accelerated downcutting and re-entrenchment by the river, probably in early Pleistocene time after the Green had eroded Canyon of Lodore to a depth of about 450 m (1,500 ft), downcutting slowed and the river began to widen its valley bottom. But the river was then rejuvenated, and it resumed cutting downward an additional 240 m (800 ft) or so to its present level. (Hansen, Carrara, and Rowley, GQ-1568)

Figure 2

Tributaries of the Green in Canyon of Lodore responded similarly by renewed cutting themselves, which

led to breaks in their gradient at heights above the Green River in accordance with the breaks in the cross-canyon profiles (fig. 3).

Figure 3

Other Canyons of the Green River in Dinosaur National Monument, such as Whirlpool Canyon and Split Mountain Canyon, must have been re-entrenched also, although the effects there are obscured by stair-step cross profiles, caused by differential erosion of the many varied rock formations--profiles that reflect lithologic differences rather than changed rates of downcutting. Far upstream in Utah, profiles comparable to those in Lodore are preserved in Red Canyon where the lithology of the Uinta Mountain Group is similar to that in Canyon of Lodore (Hansen, 1969b, p. 100).

The cause and timing of renewed downcutting are uncertain. Regional uplift in response to unloading could have rejuvenated the entire drainage system through the mountains. Hunt (1967, 1969) has argued intuitively and persuasively for local uplift of the mountains, but we are unaware of any clear evidence that the Canyon of Lodore area has been elevated differentially--indications of re-entrenchment extend upstream through Browns Park into Red Canyon and even into southern Wyoming.

Regional northeastward tilting, some of which may postdate the Browns Park Formation, surely has raised the south flank of the Uinta Mountains relative to the crestline. In the Stuntz Reservoir area southwest of Canyon of Lodore, this tilting was about 28 m/km (Hansen and Rowley, 1980). Though clearly postdating the Bishop Comglomerate, the actual timing is uncertain and may or may not predate the onset of canyon cutting. But, inasmuch as Canyon of Lodore and the adjacent Browns Park are both parts of one structural block, differential movement between them would have been negligible in any event and could not have caused the imposing facade of the Gates of Lodore.

Possible drainage captures far upstream, which would have greatly increased the discharge and competence of the Green River, could have caused re-entrenchment (Hansen, 1969b). Evidence in the Rock Springs area of Wyoming suggests that an ancestral Green River once crossed the Rock Springs uplift enroute to a confluence with the North Platte River (Hansen, 1969b). Bradley suggested as much in 1936. The Rock Springs airport, at an altitude of 2,057 m (6,750 ft), is on a mesa-like remnant of a gravel-capped terrace that contains pebbles lithologically like gravels in terraces along the Green River to the west, although the airport is 48 km (30 mi) east of the river. This site may thus mark the old course of the river.

No direct evidence is yet available to date the onset of re-entrenchment. The altitude at which the river would have been flowing in Canyon of Lodore at the time of entrenchment--about 180-200 m above the present level--is higher than any of the alluvial terraces remaining in Browns Park, and is about 30 m higher than the old river channel preserved in the northern part of the quadrangle. If initial cutting began in latest Miocene time after the Uinta Mountains had been overtopped at Canyon of Lodore, most of Pliocene time might have elapsed during the erosion of the upper 450 m of the canyon. Re-entrenchment, then, may have followed in early Pleistocene time (Hansen, 1969b, p. 99).

SCENERY AND WILDLIFE

Anyone looking into the Gates of Lodore can sense the awe that gripped Powell and his men when, in 1869, they first glimpsed the canyon. Major Powell was leading his historic exploration of the Green and Colorado Rivers, and as his boats slowly drifted into the slot-like cleft, the towering red walls must have glowed like burning coals, just as they do today in the harsh brilliance of the morning sun. Although cliffs 680 m high crowd the canyon floor, the first thundering rapid is more than 3 km downstream. Murmuring softly, the river glides smoothly into the gorge, a stillness broken only by the dipping of oars and the raucous chatter, perhaps, of a pinyon jay. In the haze of evening, deep shadows fill the canyon with the quiet tranquillity of a Maxfield Parrish painting.

Nearly all visitors are duly impressed by the varied landscape. The broad, flat valley of Browns Park yields abruptly to the narrow canyon, famed for its stunning cliffs, ledgy slopes, and tumultuous rapids. This precipitous gorge bisects a mountainous terrain of old mature topography exposed to the elements since middle Tertiary time. In these mountains, back from the canyon rims, rather open upland valleys are bottomed with Bishop Conglomerate or sandy rubbly alluvium. Stony hillsides are dotted with a pygmy forest of pinyon pine and juniper or, locally, with handsome groves of ponderosa pine. Bare rocks are everywhere. Soil is thin, dry, and patchy, but in favorable northerly exposures, deeper moister soils encourage the growth of dense brush and stands of tall Douglas fir. Curlleaf mountain mahogany here attains the stature of small trees 3-5 m high with trunks 10-15 cm in diameter.

Despite the semiarid climate, the checklist of flora in Dinosaur National Monument includes 553 vascular species (Broderick, 1964, p. 7), and most of these grow in the Canyon of Lodore North quadrangle. Big sagebrush is the dominant ground cover on alluvium, on the Browns Park Formation, and on the Bishop Conglomerate, but after a wet spring, grasses and wild flowers burst forth in early summer in unexpected profusion. On the debris fans and riverbanks are boxelders, willows, squawbush, and various reeds and horsetails. Saltcedar, an exotic species, has gained a recent foothold and may someday be a problem. In the fall, showy yellow rabbit brush and purple asters add a pleasant contrast. In winter, the snowy landscape intensifies the stark outlines of the great red cliffs.

Abundant wild creatures large and small add lasting pleasure to a canyon visit. Dinosaur National Monument is a wildlife sanctuary closed to hunting and trapping. About 40 species of native mammals and 120 species of birds have been tabulated by the National Park Service (Barmore, 1964, p. 17). To see wildlife in its native habitat is to enjoy it, and the alert watcher in Dinosaur National Monument will not be disappointed.

Extracted from: GRI Source Map ID 31 (GQ-1568).

Table 1

Lab No.	D229312[1/]	W188569[2/]	D230244[3/]	D230246[3/]
SiO_2	45.92	48.3	47.4	46.8
Al_2O_3	12.66	10.6	11.4	12.3
Fe_2O_3	14.68	15.53	19.6	17.3
FeO	1.31	N	N	N
MgO	5.51	7.8	5.44	6.20
CaO	2.79	1.71	1.61	1.52
Na_2O	0.12		<0.2	<0.2
K_2O	6.99	5.04	6.87	7.52
H_2O+	3.14	N	N	N
H_2O-	0.60	N	N	N
TiO_2	3.94	4.36	3.99	4.20
P_2O_5	0.90	1.05	1.2	1.0
M_nO	0.09	0.08	0.06	0.04
CO_2	1.06	N	N	N
C1	0.02	N	N	N
F	0.08	N	N	N
Lost on ignition	NA	NA	3.19	3.62
Total	99.77	100.0	101.0	100.7

1/ Standard rock analysis by E. E. Engleman, U.S. Geological Survey.
2/ X-ray spectroscopy by P. P. Hearn and S. Wargo, U.S. Geological Survey.
3/ Rapid rock analyses by J. S. Wahlberg, J. E. Taggart, and J. W. Baker, U.S. Geological Survey.
N indicates not analyzed for.
NA indicates not applicable.

Extracted from: GRI Source Map ID 31 (GQ-1568).

Figure 1

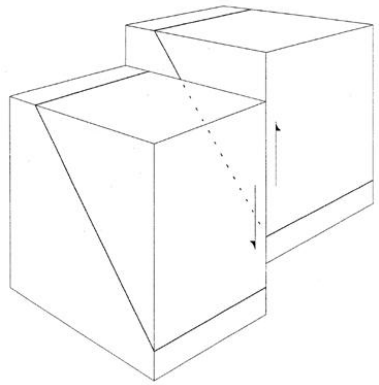


Figure 1. - Apparent horizontal displacement of a dipping plane caused by simple vertical throw .

Extracted from: GRI Source Map ID 31 (GQ-1568).

Figure 2

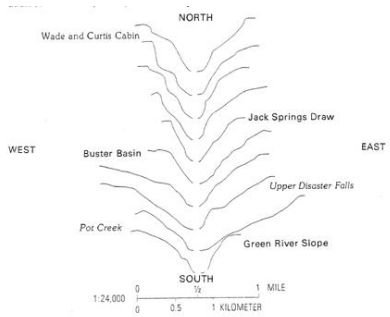


Figure 2. - Topographic profiles across Canyon of Lodore spaced at about 1/2 - 1 km intervals, showing breaks in canyon profiles about 240 - 300 m above river level. Profiles are drawn down ridgelines and do not necessarily meet at river level. Vertical and horizontal scales are equal.

Extracted from: GRI Source Map ID 31 (GQ-1568).

Figure 3

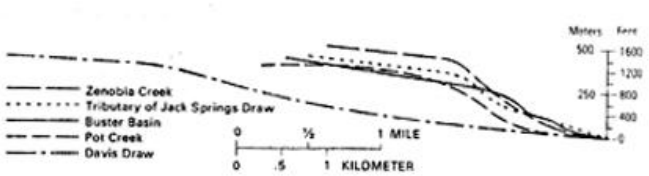
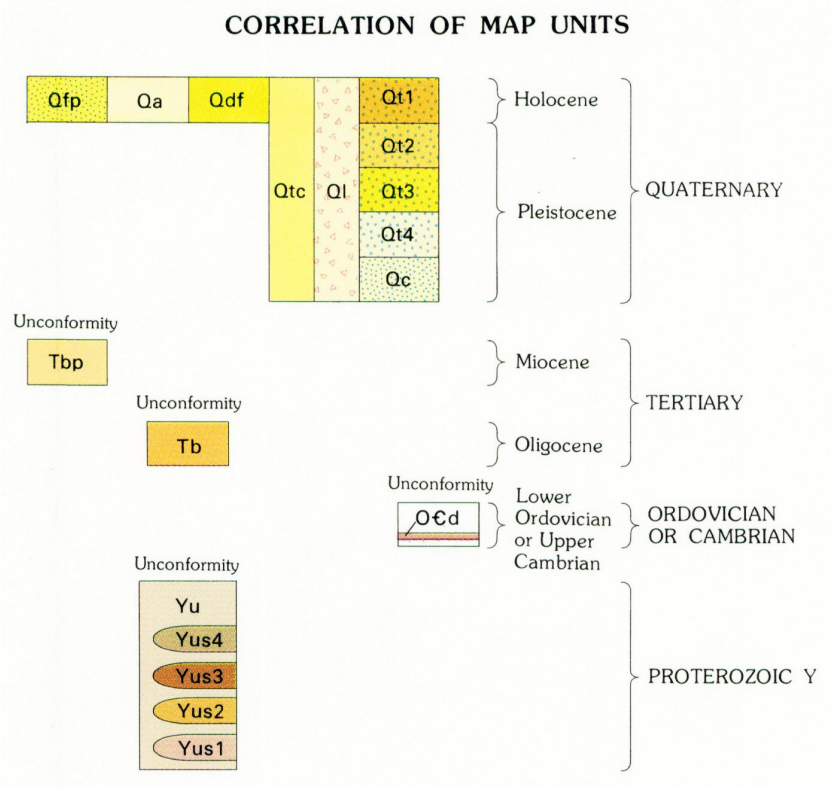


Figure 3. - Topographic profiles of tributary gulches drawn to their heights above river level (at right edge of figure). Davis Draw joins the Green River upstream from Canyon of Lodore in Browns Park. Vertical scale is twice horizontal scale.

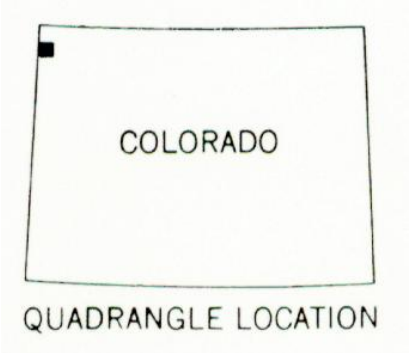
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Correlation of Map Units



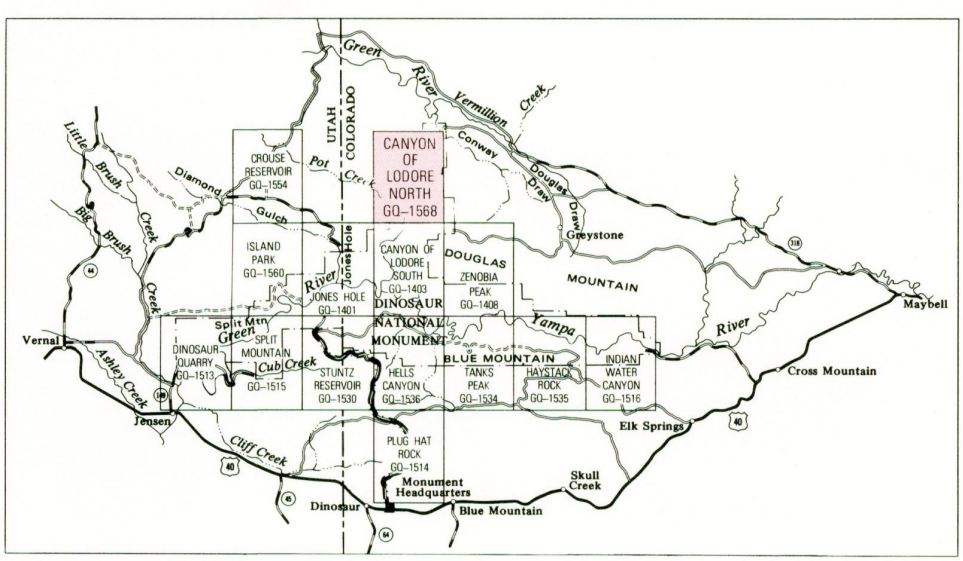
Extracted from: GRI Source Map ID 31 (GQ-1568).

Map Location



Extracted from: GRI Source Map ID 31 (GQ-1568).

Index Map



MAP SHOWING LOCATIONS OF 7½-MINUTE GEOLOGIC QUADRANGLES OF THE DINOSAUR NATIONAL MONUMENT AREA

Extracted from: GRI Source Map ID 31 (GQ-1568).

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Geologic Map of the Canyon of Lodore South Quadrangle

Hansen, W.R., 1977, Geologic Map of the Canyon of Lodore South Quadrangle, Moffat County, Colorado,U.S. Geological Survey, Geological Quadrangle Map GQ-1403, 1:24,000 scale. (*GRI Source Map ID 32*).

Ancillary Map Notes

SETTING

The Canyon of Lodore South quadrangle is in the heart of the famous wilderness canyon country of Dinosaur National Monument, on the south flank of the eastern Uinta Mountains. Possibly the best-known landmarks in this area are Echo Park, named by John Wesley Powell more than 100 years ago, and its monolithic companion, Steamboat Rock. Echo Park is accessible to passenger cars by way of a fair-weather road that connects to U.S. Highway 40 south of Dinosaur National Monument, but most of the quadrangle can be reached only by foot, horseback, or river raft. Rafting on the Green and Yampa Rivers has become very popular in recent years, and thousands of enthusiasts brave the rapids annually.

ROCK FORMATIONS

In terms of geologic eras and periods represented by exposed rock formations, Dinosaur National Monument has the most nearly complete stratigraphic record of any park in the National Park System. These formations include rocks of all the systems from Precambrian to Quaternary except the Ordovician, Silurian, and Devonian (Untermann and Untermann, 1954, p. 170). Most of these formations, moreover, crop out within the Canyon of Lodore South quadrangle. Precambrian rocks are represented by the thick Uinta Mountain Group, which is superbly exposed along Lodore Canyon and along the Green River west of the Mitten Park fault. In other parts of the quadrangle, Paleozoic rocks predominate, and they are equally well exposed.

GEOLOGIC STORY

Floaters on the Green River in Lodore Canyon can view the entire Paleozoic section between Alcove Brook and Echo Park. At the base of this section, near Alcove Brook, the Lodore Formation rests on the Uinta Mountain Group with an angular unconformity of about 2-3 degrees. This relationship is more obvious from the canyon rim than from the river. The dip of the Lodore Formation is slightly steeper than that of the underlying Uinta Mountain Group, indicating that the group was first tilted northward a few degrees and than was truncated by erosion before the Lodore was deposited. The present southerly dip of the whole section was caused by the uplift of the Uinta Mountains in Cretaceous time.

In detail, the unconformity at the base of the Lodore is very uneven, having a local relief of several tens of meters. The Lodore Formation was deposited along the strand of an expanding seaway, and, as the ancient shoreline yielded slowly to the onslaught of the waves, eroded remnants of the Uinta Mountain Group persisted offshore as stacks, skerries, and reefs. Although the barren landscape was totally devoid of life, small creatures flourished in the sea, especially marine worms and brachiopods, less commonly trilobites, and, of course, the ubiquitous seaweeds and other primitive marine plants.

After the Lodore was deposited, the sea withdrew, and non-marine conditions lasted for the millions of years of the Ordovician, Silurian, and Devonian Periods. During this long time interval, the area must have stood only slightly above sea level, because the unconformity between the Mississippian and the Cambrian rocks is scarcely discernible, even though it represents a hiatus of perhaps 155 million years.

Unrecognized Devonian strata, however, might exist at the top of rocks mapped as Cambrian. Rocks referred to as the Chaffee Formation have been tentatively identified elsewhere in northwestern Colorado

and could be present in the eastern Uinta Mountains. (See Anderman, 1961, fig. 2, for example). In Lodore Canyon, and to the west in the Jones Hole quadrangle, irregularly bedded gray sandstone at the top of the Lodore Formation resembles the Chaffee Formation of central Colorado (Kirk, 1931).

The overlying later Paleozoic formations of the quadrangle are predominantly marine, and most of them contain fossilized remains of marine organisms. The Madison Limestone is the sea-bottom deposit of a very extensive interior seaway that once reached from the Arctic Ocean to the Gulf of Mexico. The succeeding Humbug and Doughnut Formations are considerably more restricted regionally and they crop out poorly, but together they make up a stratigraphic interval because of their varied lithology and color in the middle of a thick sequence of otherwise monotonous gray limestones. Traces of coal found in the Doughnut Shale in some places in the Uinta Mountains (Kinney, 1955, p. 38; Hansen, 1965, p. 41). Because coal accumulates in fresh- or brackish-water swamps that are rank in vegetation, its occurrence in the Doughnut Shale indicates a short-lived suspension of normal marine conditions. Northwest of Manila, Utah, the Doughnut also contains freshwater ostracods (I.G. Sohn, written commun., 1953). Marine conditions returned again with the deposition of the overlying Round Valley Limestone of Early Pennsylvanian age.

Pennsylvanian rocks cover most of the southern half of the quadrangle. The Weber Sandstone, which is largely eolian in origin, and the upper member of the Morgan Formation, which accumulated on a beach and just offshore, together form the most picturesque scenery in Dinosaur National Monument. Both the Weber and the upper member of the Morgan are totally exposed in the sheer northeast face of Warm Springs Cliff which, rising to a height of 515 m (1,700 ft), is one of the most impressive landmarks in the eastern Uinta Mountains. Steamboat Rock, Jennie Lind Rock, and the intricate canyon country in the southeast part of the quadrangle are other notable landmarks carved from the Weber Sandstone. A thin but resistant Park City Formation caps Warm Springs Cliff and other buttes and mesas nearby.

With the onset of the Mesozoic Era, depositional conditions and the character of the resulting rock formations began to fluctuate widely. Marine waters withdrew and re-advanced repeatedly as the shoreline fluctuated across the region in response to gentle oscillations of the Earth's crust. Near the end of Cretaceous time, the Rocky Mountains began to rise and the sea drained away for the last time. By early Tertiary time, debris from the newly formed mountains began to accumulate in the adjacent basins and at the flanks of the mountains themselves.

The upland valleys above Lodore Canyon in the northern part of the quadrangle are filled with inconspicuous but physiographically significant deposits of Bishop (?) Conglomerate, a sequence of partly consolidated gravely alluvium and volcanic tuff. The exact correlation of these deposits with rocks elsewhere is uncertain; but they almost surely are equivalent to the typical Bishop Conglomerate of northwestern Colorado, and they might also contain equivalents of the Browns Park Formation, which is widely and typically exposed just a few km north of the quadrangle.

During the middle and latter part of the Tertiary Period, the Bishop (?) Conglomerate was much more extensive than it is now. It must have blanketed almost the whole Uinta Mountains, extending up all the major valleys and filling in around the peaks and ridges, just as it does today in the Diamond Gulch and Pot Creek drainage areas west of the quadrangle. Downcutting by the Green and Yampa Rivers through these deposits was a critical step in the development of the present drainage pattern and in the subsequent erosion of the marvelous canyon system of the eastern Uinta Mountains (Sears, 1924; Bradley, 1936; Hansen, 1969a, 1969b; Hunt, 1969).

SURFICIAL DEPOSITS

Surficial deposits, as the map shows, are subordinate, relatively inconspicuous features of a landscape dominated by monumental outcrops of bedrock. These deposits, nevertheless, are products of the same processes that shaped and continue to shape the grand scenery of the area--processes of weathering,

mass wasting, and erosion and deposition of running water. Not surprisingly, many of the surficial deposits are plainly linked in origin to specific physical properties and physiographic settings of the bedrock. Talus and landslides, for example, both accumulate below steep hillslopes. Talus, however, accumulates chiefly below brittle competent bedrock, whereas most landslides in the area occur on incompetent shale units in the Lodore, Doughnut, and Morgan Formations.

The extensive landsliding at Warm Springs Cedars, a case in point near the center of the quadrangle, began when the Yampa River undercut the Morgan Formation. Large-scale failure followed removal of support of the lower member of the Morgan. Landsliding probably started first near river level, then extended upward incrementally by the process of undercutting and sapping away at the upper member of the Morgan. Gullying in Warm Springs Draw and Iron Mine Draw has since cut completely through the landslide down into bedrock, baring the Round Valley Limestone and exposing excellent sectional views of the slide in many places.

Many similar large landslides have developed progressively along the length of the Yampa Canyon east of the quadrangle, wherever the river has cut down into the lower member of the Morgan Formation. Sears (1962, p. 1-9), unaware of this cause and effect, mistakenly attributed the resultant cirque-like landforms to early high-level meandering of the Yampa River.

Torrential runoff in Warm Springs Draw and Iron Mine Draw has built the large debris fan and is accompanying rapid below Warm Springs Cedars. Many smaller debris fans in Lodore Canyon have similar origins; the size of each fan is about proportional to the drainage area of its source and, hence, to the size of flash floods that a tributary is able to mount during a heavy rainstorm.

All major rapids on the Green and Yampa Rivers in the quadrangle are at the toes of debris fans. Thus, at Triplet Falls on the Green River, a debris fan on the left bank has forced the river against it's right bank, causing the current to undercut the cliff and dislodge huge blocks of rock into the channel. At Hells Half Mile, debris fans obstruct the channel from both sides.

The treacherous rapid in the Yampa River at the mouth of Warm Springs Draw was formed June 10, 1965, when a flash flood deposited a great volume of bouldery debris in the river. A rockfall dropped into the river from the face of Warm Springs Cliff during the same storm (Hayes and Simmons, 1973, p. 48). Such flash floods are common in Dinosaur National Monument during rainy weather, and boaters camped on debris fans in the canyons should recognize the potential danger.

GEOLOGIC STRUCTURES

FAULTS AND FOLDS

Within the boundaries of the Canyon of Lodore South quadrangle, the geologic structure is relatively simple. In the broader regional context, it is more diversified. The whole Dinosaur National Monument area is on the south flank of the large Uinta anticline, which stretches more than 240 km (150 mi) west to east across northeastern Utah and northwestern Colorado and has a mean width of about 55 km (34 mi). Along the southern flank of the anticline the rock formations dip southward, one successively overlapping another; the oldest is at the north and youngest at the south. The basic simplicity of this arrangement is modified by subordinate folding and faulting, some of which involve large-scale displacements of the Earth's outer crust.

One such feature is the Mitten Park fault. This spectacular fault is seen to advantage from river level at Mitten Park or from the canyon rim just west of the quadrangle boundary at Harpers Corner. The Mitten Park fault is a rupture along the synclinal bend of a large monocline, here referred to as the "Mitten Park monocline," and most of the crustal displacement across the Mitten Park fault--about 800 m (2,900 ft) at a maximum--is taken up by monoclinal folding rather than faulting.

This monocline and other similar structural features in the eastern Uinta Mountains appear to be “draped” across deep-seated faults in the Precambrian basement (Cook and Stearns, 1975, p. 21). Some of these faults are clearly Precambrian in age but have moved repeatedly during different episodes of deformation since then.

The surface trace of the Mitten Park fault dies out rapidly along strike away from its exposure in the canyon near Mitten Park; south-southwest of Mitten Park, in the adjacent Jones Hole quadrangle, the fault passes into and is overlain by the synclinal bend of the monocline; north-northeast of Mitten Park it dies out rapidly in a trapdoor-like displacement in the Madison Limestone. Farther north, in Lodore Canyon, discontinuous faulting along the same general trend as the Mitten Park fault breaks the Uinta Mountain Group but not the overlying Lodore Formation. This faulting, therefore, is discontinuous at the surface but might be continuous with the Mitten Park fault at depth. In all probability, both faults first moved in Precambrian time. The Mitten Park fault, at least, moved a second time during the Laramide orogeny, and possibly again in Tertiary time. Note that the sense of displacement on the fault in Lodore Canyon at Hells Half Mile is opposite that of the Mitten Park fault--the west wall of the fault is “down” at Hells Half Mile but is “up” at Mitten Park.

Another monocline, here referred to as the Warm Springs monocline, is depicted in section B-A1. It trends east-southeast from a junction with the Mitten Park fault at the mouth of Lodore Canyon through the Warm Springs Cedars area and beyond, gradually diminishing in amplitude. In all probability it, too, is draped across a deeply buried fault.

The concealed fault shown crossing Zenobia Basin in the northeast corner of the quadrangle is exposed in Lodore Canyon near Pot Creek in the Canyon of Lodore North quadrangle. Northwest beyond the Lodore Canyon, the fault again is concealed, but the long linear valley of Pot Creek probably marks its course. On strike southeast of Zenobia Basin, the fault fails to offset the Lodore Formation. In Lodore Canyon, the fault zone contains a large vesicular mafic dike which, as best can be determined, in not exposed elsewhere.

JOINTS

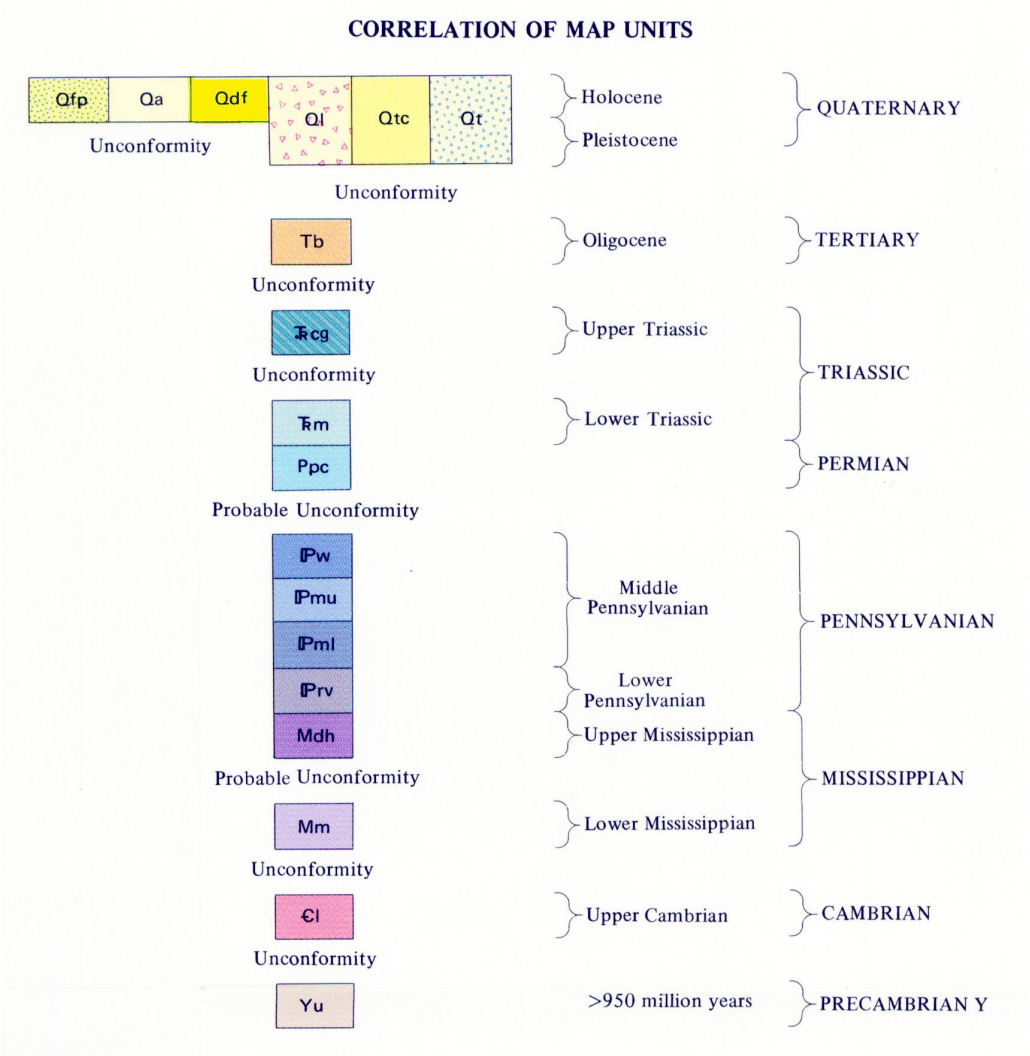
Joints in rocks are fractures that--unlike faults--have had little or no movement of one side of the fracture past the other. Most rocks in the quadrangle are well jointed, especially rocks of the Weber Sandstone and the Uinta Mountain Group. Many joints in the Weber and Uinta Mountain Group are long enough to be shown on the map at true scale; note the abundant large joints in the Weber in the southern part of the quadrangle. Joints are abundant in other formations also, but are individually much shorter and are much less conspicuous.

Most joints in the area belong to either of two sets of families. A predominant set strikes mostly about N. 45 degrees-60 degrees W., and a subordinate set strikes about N. 30 degrees. Inasmuch as the predominant set is parallel to the main axis of the Uinta anticline, which trends N. 60 degrees W. in the eastern Uinta Mountains, one can reasonably postulate that the joints are extensional fracture related in origin to the folding and uplift of the range.

Joints are avenues for the entry of water and frost into the rocks. They are foci, therefore, of weathering and erosion. Weathering and erosion along joints, especially in the Weber Sandstone, have greatly influenced the character and quality of the canyon scenery.

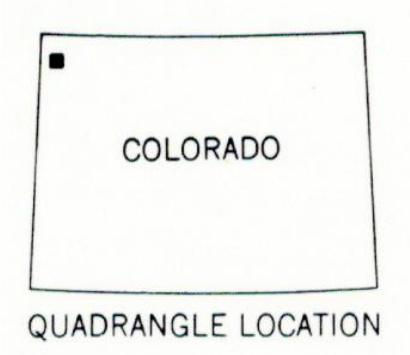
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Correlation of Map Units



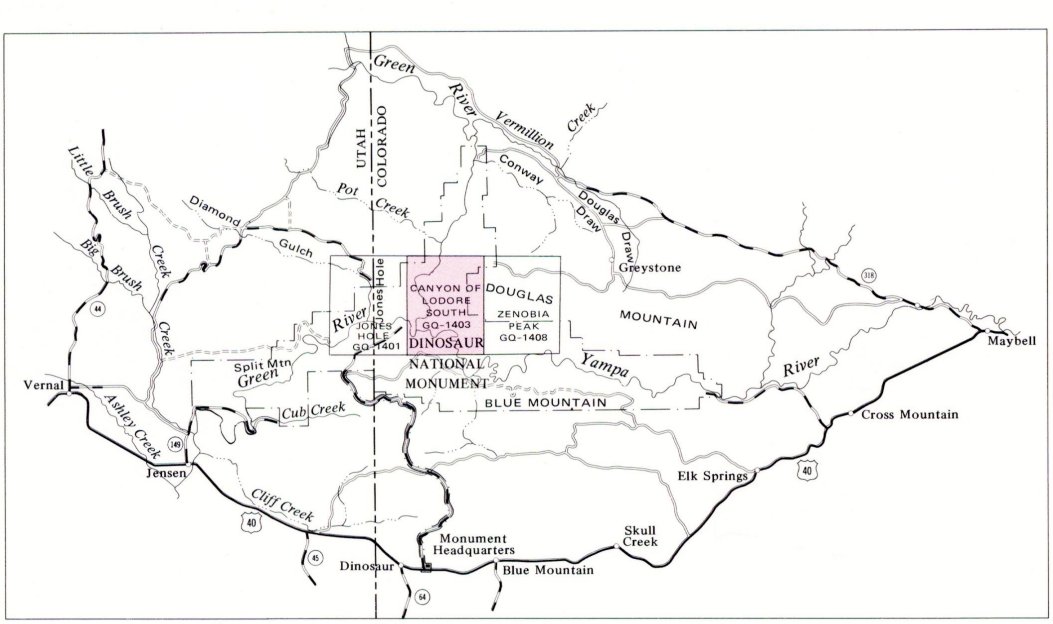
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Map Location



Extracted from: GRI Source Map ID 32 (GQ-1403).

Index Map



INDEX MAP SHOWING LOCATION OF CANYON OF LODORE SOUTH QUADRANGLE

Extracted from: GRI Source Map ID 32 (GQ-1403).

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Extracted from: GRI Source Map ID 32 (GQ-1403).

Geologic Map of the Crouse Reservoir Quadrangle

Hansen, W.R., Carrara, P.E., and Rowley, P.D., 1981, Geologic Map of the Crouse Reservoir Quadrangle, Uintah and Daggett Counties, Utah, U.S. Geological Survey, Geological Quadrangle Map GQ-1554, 1:24,000 scale. (*GRI Source Map ID 33*).

Ancillary Map Notes

GEOLOGIC HIGHLIGHTS

The Crouse Reservoir quadrangle is on the south flank of the Uinta Mountains and the southwest limb of the large east dome of the Uinta anticline (Hansen,1957, fig. 1;1965, fig. 45). Strata of Proterozoic and Paleozoic age strike west northwest across the quadrangle and dip gently south southwest toward the Uinta Basin. These rocks are partly covered by a widespread blanket of Tertiary Bishop Conglomerate; in adjacent areas, Mesozoic rocks are covered also. Most of this cover was locally derived, chiefly from the Uinta Mountain Group, but some of it consists of interlayered ash-fall tuff that was erupted from distant volcanoes.

At one time the Bishop Conglomerate must have formed a continuous bajada that extended many kilometers along the south flank of the Uinta Mountains and sloped south well into the Uinta Basin. In part, the bajada spread across a very broad pediment, now high on the flank of the range, that probably is equivalent to the Gilbert Peak erosion surface on the north slope of the range (Bradley, 1936). The Bishop Conglomerate was once much thicker and more extensive then now, but it still covers most of the Crouse Reservoir quadrangle, and only the higher summits of the ancient topography protrude as isolated mountains and hills. The distribution of these hills and the intervening fill material defines a pattern of former dendritic drainage in which the tributary streams converged southward. The present drainage is largely unrelated.

As much as 90 m of the old Bishop Conglomerate blanket has probably been eroded horn the Diamond Gulch area in the southern part of the quadrangle since late Oligocene time. A hundred meters or more still remains. South of the quadrangle, post-Oligocene erosion has lowered the floor of the nearby Uinta Basin several hundred meters and, consequently, remnants of Bishop Conglomerate stand high above the present basin floor. Erosion continues, and drainages such as Pot Creek and Diamond Gulch are cutting down through the Bishop Conglomerate into the older rocks below. Note that Pot Creek has been incised into the Uinta Mountain Group across many partly exhumed ridge spurs. Pot Creek now flows alternately on discontinuous reaches of flood plain on the Bishop Conglomerate and through short narrow gorges superimposed on the Uinta Mountain Group.

Note also the imminent capture of Pot Creek by northeast-flowing Crouse Creek in sec. 19, T.1 S., R. 25 E. Owing to a much shorter route to the Green River, Crouse Creek has a steeper gradient than Pot Creek and, hence, has a hydraulic advantage. Crouse Creek enters the Green River about 40 km upstream from Pot Creek. Part of its hydraulic advantage must also be due to the northward regional tilting of the eastern Uinta Mountains since Oligocene time (Hansen and Rowley, 1980). The capture of Pot Creek, in fact, has been partly fulfilled by a diversion ditch that directs water from Pot Creek across the low divide into Crouse Creek to irrigate hay fields in Browns Park, 10 km northeast of the quadrangle. Eventually, if left to itself, the entire discharge of Pot Creek above the diversion ditch would flow into Crouse Creek.

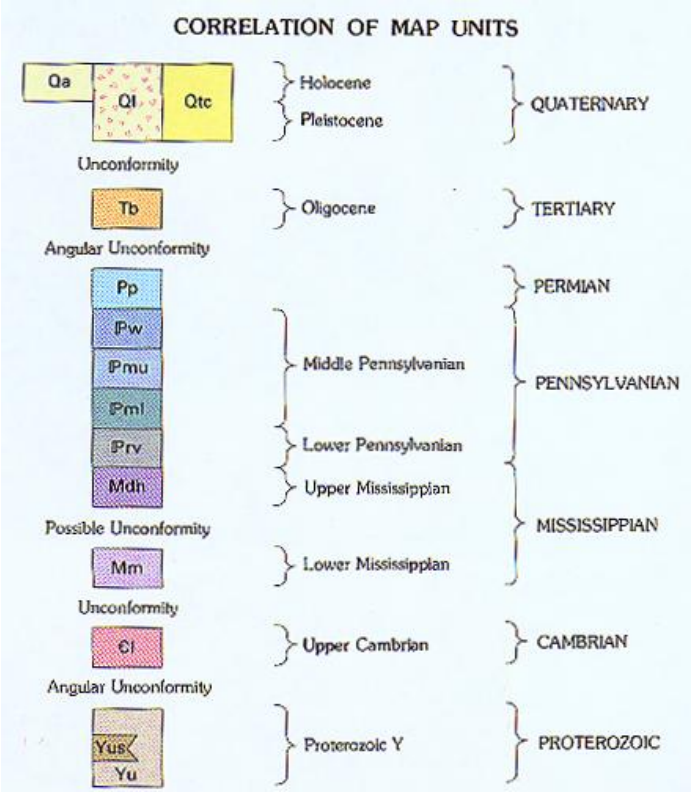
Two sets of faults that are prevalent in the eastern Uinta Mountains cross the Crouse Reservoir quadrangle. One set trends northeast to east northeast; the other trends west northwest. Bath sets have been intermittently active since at least Cambrian or Ordovician time. In the Crouse Reservoir quadrangle the west-northwest set displaces the Bishop Conglomerate of Oligocene age. Very little Quaternary faulting is known to exist in the Uinta Mountains, but the displaced topography on the Bishop is clearly

of Quaternary age, and some of the faulting, therefore, must also be Quaternary. Inasmuch as the fault lines are very subdued, however, the most recent movements probably are early Pleistocene.

Two sets of strongly developed joints are widespread in the Crouse Reservoir quadrangle and elsewhere in the eastern Uinta Mountains, especially in the Uinta Mountain Group. They are generally about parallel in trend to the faults and about normal in attitude to the bedding. A predominant set trends west northwest and dips steeply northeast; the other set trends north northeast and dips steeply northwest. Joints facilitate the entry of moisture into the rocks and thus promote weathering. On bare outcrops they lend a picturesque quality to the scenery.

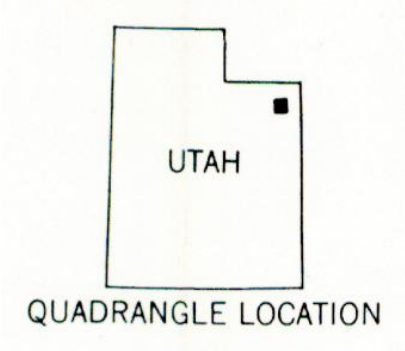
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Correlation of Map Units



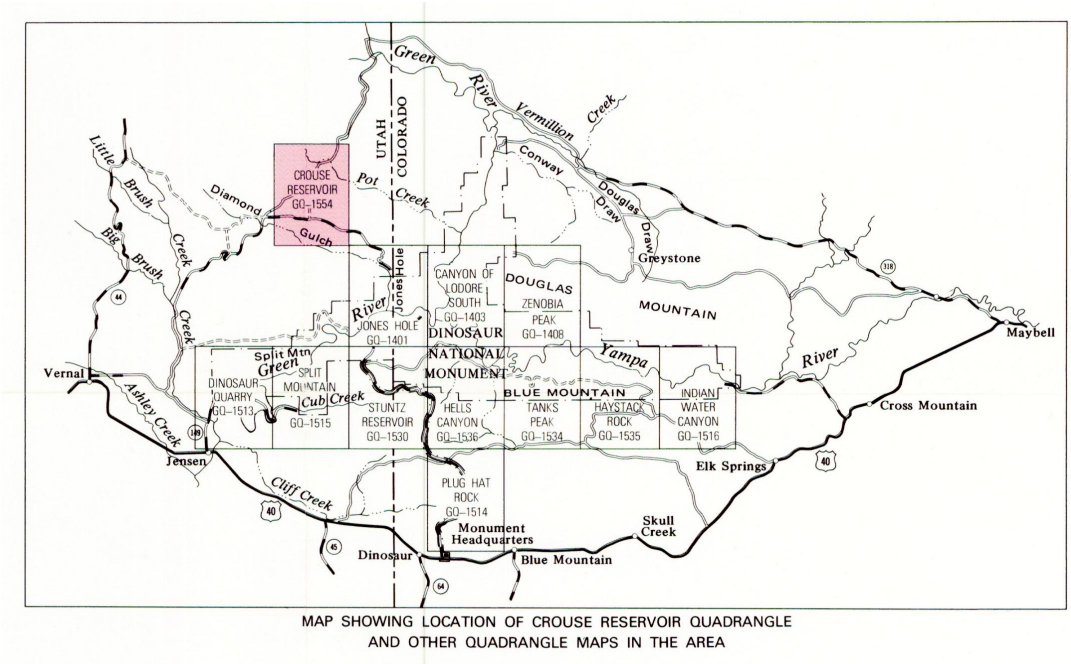
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Map Location



Extracted from: GRI Source Map ID 33 (GQ-1554).

Index Map



MAP SHOWING LOCATION OF CROUSE RESERVOIR QUADRANGLE
AND OTHER QUADRANGLE MAPS IN THE AREA

Extracted from: GRI Source Map ID 33 (GQ-1554).

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Extracted from: GRI Source Map ID 33 (GQ-1554).

Geologic Map of the Dinosaur Quarry Quadrangle

Rowley, P.D., Kinney, D.M., and Hansen, W.R., 1979, Geologic Map of the Dinosaur Quarry Quadrangle, Uinta County, Utah, U.S. Geological Survey, Geological Quadrangle Map GQ-1513, 1:24,000 scale. (*GRI Source Map ID 34*).

Ancillary Map Notes

SETTING

The Dinosaur Quarry quadrangle is in the southwestern part of Dinosaur National Monument on the southeastern flank of the Uinta Mountains. As its name indicates, the quadrangle contains famous Dinosaur Quarry, the world's greatest collecting site of fossil dinosaurs of Jurassic age and the main reason for establishing the Monument, one of the most beautiful in the National Park System.

The Monument part of the quadrangle is accessible chiefly by foot, horseback, or boat. Rafting down the Green and Yampa Rivers has become very popular in the past decade, and thousands of adventurers annually brave the rapids (Hayes and Simmons, 1973). Beautiful Split Mountain Canyon, so named because the deep, river-carved chasm appears to cut the mountain in two, is one of the sights that rafters long remember. Split Mountain Gorge Campground, at the eastern edge of the quadrangle, is the terminus of most raft trips in the Monument.

ROCK FORMATIONS

In terms of geologic eras and periods represented by exposed rock formations, Dinosaur National Monument has the most nearly complete stratigraphic record of any park in the National Park System. These formations include rocks of all the systems from Precambrian to Quaternary except the Ordovician, Silurian, and Devonian (Untermann and Untermann, 1954, 1965, 1968, 1969). Most of these formations, moreover, crop out within the Dinosaur Quarry quadrangle. Mesozoic rocks predominate areally in the quadrangle, but Paleozoic rocks form the flanks and core of Split Mountain and the walls of Split Mountain Canyon.

GEOLOGIC STORY

As the rafter navigates the last few kilometers (2 mi.) of the river in Split Mountain Canyon before landing at Split Mountain Gorge Campground, he quickly passes from the oldest rocks exposed in the Dinosaur Quarry quadrangle through most of the formations exposed in the area. These formations dip steeply southward, along the flank of the Split Mountain anticline, and become increasingly younger southward. During the automobile ride from the campground west and south to the Vernal-Dinosaur Highway (U.S. Hwy 40), the visitor will see most of the younger formations.

The oldest formation exposed in the quadrangle is the Morgan Formation (Middle Pennsylvanian, about 300 m.y. old). It forms the beautiful red cliffs in Split Mountain Canyon and the lower gray slope just below them. The formation was deposited in marine water, mostly on a beach and just offshore in a shallow ocean in which lived bryozoans, brachiopods, echinoderms, fusulinids, and other invertebrates. Overlying the Morgan Formation is the tan or cream-colored Weber Sandstone also of Middle Pennsylvanian age, which forms some of the most spectacular scenery in Dinosaur National Monument, including the imposing pale-gray strike ridge just north of Split Mountain Gorge Campground, and most of Split Mountain itself. In the Dinosaur Quarry quadrangle it displays sweeping crossbeds indicative of a beach and sand dune origin; outside the quadrangle, fossil fusulinids, corals, and brachiopods have been found in interlayered limestone beds. The Park City Formation (Permian age, about 250 m.y. old) consists of gray resistant beds, which occur discontinuously on Split Mountain. It is largely of marine origin, as it contains fossil pelecypods, gastropods, scaphopods, cephalopods, and brachiopods. Rich

deposits of phosphate rock, which accumulated where deep cold ocean water welled up to warmer zones or encountered warmer currents, are mined in the Brush Creek area north of Vernal, Utah, for the production of fertilizer.

Depositional conditions fluctuated greatly at the beginning of the Mesozoic Era, and the resulting rocks varied accordingly. Marine water withdrew and re-advanced repeatedly as the shoreline advanced and retreated across the region in response to gentle oscillations of the earth's crust. The red Moenkopi Formation (Lower Triassic, about 220 m.y. old) is a soft unit that was eroded in Quaternary time to form the floors of the strike valleys (valleys parallel to the strike of the bedding) of Red Wash and Cottonwood Wash. It is deposited mostly in a near-shore marine and fresh-water environment. Gypsum beds accumulated in the Moenkopi Formation in times of high aridity, perhaps in a desiccating lagoon. Organisms were rare in that hostile environment, but some marine mollusks and tracks of early reptiles have been found in the formation.

The Gartra Member of the Chinle Formation (Upper Triassic), which forms a narrow strike ridge, was deposited by streams and rivers that meandered across broad piedmont plains; silicified wood is locally abundant. Unlike the Gartra, the main body of the Chinle Formation erodes easily and forms a narrow red strike valley that surrounds Split Mountain. Most beds of the main body were deposited by streams and lakes. Fossil remains of reptiles, amphibians, mollusks, and petrified wood have been found.

The buff and red Glen Canyon Sandstone (Lower Jurassic and Upper Triassic) forms another massive strike ridge surrounding Split Mountain. The Glen Canyon is barren of fossils, but displays spectacular crossbeds that are interpreted as the foreset beds of ancient sand dunes formed under desert or coastal conditions.

The Carmel Formation (Middle Jurassic, about 155 m.y. old) generally forms the floor of another, but narrower, red strike valley. It was deposited in freely circulating shallow marine water, but at times, in some places, gypsum formed under conditions of water stagnation and evaporation. Fossil pelecypods, echinoderms, and gastropods have been collected from the Carmel in many places outside the quadrangle. The Entrada Sandstone (Middle Jurassic) closely resembles the Glen Canyon and also was deposited largely by eolian processes, although the sands probably were locally reworked by marine water during temporary re-advances of the sea. Both the resistant gray Curtis Member and the overlying soft olive-green Redwater Member of the Stump Formation (Upper and Middle Jurassic), on the other hand, were deposited by marine water. The Curtis contains sparse pelecypods and furrowed trails made by bottom crawlers, and the Redwater contains locally abundant brachiopods, pelecypods, echinoderms, and cephalopods, especially belemnites.

The soft gray and multi-colored Morrison Formation (Upper Jurassic) and rocks of the Lower Cretaceous Cedar Mountain (?) Formation mapped with the Morrison form a strike valley that is traversed by the Blue Mountain road several kilometers (1.5 mi.) east of Dinosaur Quarry. Far more important paleontologically is the famous dinosaur-bearing bed of the Morrison Formation at Dinosaur Quarry. This bed was discovered in 1909 by Earl Douglass, a paleontologist from the Carnegie Museum in Pittsburgh. The bed was quarried for dinosaurs mostly from 1909-1923, during which time the quarry reached a length of 120 m (400 ft) and a depth of 20 m (60 ft). Partial or complete fossil skeletons from about 300 dinosaurs, representing 14 species, as well as fossil crocodiles, fresh-water turtles, fresh-water pelecypods, and silicified wood, have been recovered from the quarry (Untermann and Untermann, 1968). Many skeletons still remain. The dinosaurs range from types less than a meter (3 ft) tall to animals that measured more than 25 m (80 ft) long. Most of them were plant feeders, including specimens of armored Stegosaurus as long as 6 m (20 ft) and as tall as 3 m (10 ft), of Apatosaurus (Brontosaurus) as long as 22 m (70 ft) and as tall as 5 m (15 ft), and Diplodocus as long as 25 m (80 ft). Fossil specimens of carnivorous dinosaurs are much less common but include Antrodemus (Allosaurus), which stood on its hind legs and--at about 10 m (30 ft) long--was the reigning predator of its time (Good and others, 1958; Lewis, 1966; Untermann and Untermann, 1968). The dinosaur bed represents low-flow and storm deposits in bars and the channel

of an eastward-flowing braided river on a delta plain (Lawton, 1977). The rest of the rocks in the Morrison Formation and rocks mapped with the Morrison likewise were deposited primarily by streams and rivers, but some accumulated in shallow lakes.

The buff Dakota Sandstone (Lower Cretaceous, about 110 m.y. old) forms a narrow strike ridge just south of Dinosaur Quarry and surrounding Split Mountain. It was deposited mainly by streams and rivers; in some places it contains petrified wood. The gray Mowry Member (Lower Cretaceous) of the Mancos Shale, which forms a narrow strike valley, and the buff Frontier Sandstone Member (Upper Cretaceous) of the Mancos Shale, which forms the outermost prominent strike ridge, also are exposed south of Dinosaur Quarry and surrounding Split Mountain. The Mowry is of marine origin, and contains abundant fish bones, fish scales, and occasional ammonites. The Frontier was deposited in near-shore marine water and onshore swamps; it locally contains coal and fossil pelecypods, ammonites, gastropods, and petrified wood. The gray upper shale member (Upper Cretaceous) of the Mancos Shale forms smooth low slopes and badland topography in the southern part of the quadrangle. It contains abundant fossils in some places, especially cephalopods and oysters that indicate an origin in freely circulating marine waters.

Near the end of Cretaceous time, the Rocky Mountains began to rise, and the sea drained away for the last time. Stream and river sediments were deposited less than 40 million years ago, in Tertiary time, in many nearby areas, but if they were ever deposited in the quadrangle, as seems likely, they have since been removed by erosion. The ancestral Green River flowed on these deposits and cut down through them to form the deep superposed canyons of the eastern Uinta Mountains (Sears, 1924, 1962; Bradley, 1936; Hansen, 1969a, 1969b; Hunt, 1969).

SURFICIAL DEPOSITS

Surficial deposits are unconsolidated patchy sediments of Quaternary age (less than a few million years old). These sediments were deposited by the same processes that shaped and continue to shape the scenery of the area--processes of weathering, mass wasting, and erosion and deposition by running water. Landslide deposits, for example, accumulate below steep slopes underlain by soft incompetent rocks, such as shales in the Mancos Shale and Morgan Formation. the landslide in Split Mountain Canyon probably formed when the Green River undercut and removed the support of the lower member of the Morgan.

Gravel and sand currently being transported and deposited by the Green River are mapped as flood plain and channel deposits (Qfp). As suggested by the name, all such deposits are covered intermittently by the river, especially during early spring runoff or after severe storms; campers on the river should be aware of this potential flooding. Far more surficial deposits in the quadrangle, however, were deposited by much smaller streams, most of which contain water only after storms. Where stream deposits are sufficiently large, they are mapped as alluvium (Qa) and as debris fans at the base of steep channels (Qdf). Where the streams and tributaries are small, and form coalescing smooth surfaces of erosion (pediments) or coalescing smooth surfaces of deposition (alluvial fans), the resultant deposits are given a different map symbol. Thus pediments (Qp) are mapped where the bedrock is soft and easily eroded, as in the Mancos Shale in the southern part of the quadrangle, and the drainage is at grade; talus and alluvial fan deposits (Qt) occur below cliffs, such as along the Green River. In some places, similar surfaces and the deposits on them are graded to former higher stream levels above and dissected by present streams; these deposits are somewhat older, and have been mapped separately as Qop. River terrace deposits (Qr) are remnants of former flood plain deposits left behind as the river cut downward; these deposits also are being dissected by present streams.

The origin of side-stream surficial deposits has important implications for the rafter and camper. Alluvium, fan deposits, talus deposits, and pediment deposits largely resulted from torrential runoff following storms. The size of fans is about proportional to the size of the drainage area of the streams

that deposit them and to the volume of the flash flood in that drainage area. Some debris fans in the canyon of the Green River may have accumulated in large part during one storm. All major rapids on the Green and Yampa Rivers in Dinosaur National Monument are at the toes of debris fans; thus, when rafting upon rough water, almost invariably an arroyo enters from the left or right. Some debris fans are large enough to force the river to the opposite side of its canyon, where the river may undercut a cliff and create talus cones and hazards from falling rock. The rapids at the mouth of Warm Springs Draw--perhaps the worst rapid in Dinosaur National Monument and about 27 km (17 mi.) east-northeast of the quadrangle--were formed June 10, 1965, when a flash flood deposited a great volume of bouldery debris in the river; rockfall from the facing a Warm Springs Cliff added to the deposit (Hayes and Simmons, 1973). such flash floods are common in Dinosaur National Monument, and boaters camped on debris fans, including small fans that are not mapped, should recognize the potential danger.

Sand (Qd), mostly in vegetated dunes, is locally abundant. Most of it was derived from the overlies the friable Glen Canyon Sandstone, which itself is mainly of eolian origin. Some dunes form from reworking by wind of alluvial sand deposited on flood plains and river terraces.

FAULTS AND FOLDS

Dinosaur National Monument is on the southern flank of the large Uinta anticline, which is about 55 km (35 mi.) wide and stretches more than 240 km (150 mi) from west to east across northeastern Utah and northwestern Colo. This huge fold forms the eastern end of the Uinta Mountains. Along the southern flank of the anticline, the rocks dip southward, each younger formation successively overlies the older, the oldest to the north and the youngest to the south. But this simple pattern is modified in the Dinosaur Quarry quadrangle by two major west-plunging folds, the Split Mountain anticline and the Jensen syncline, both named by Schultz (1918). The Jensen syncline also has been called Daniels Draw syncline (Kinney, 1955). The Split Mountain anticline is a symmetrical fold, one of the few in the eastern Uinta Mountains, while the Jensen syncline is very asymmetrical, consisting of a steeply-dipping northern limb and a gently-dipping southern limb. The western part of the crest of the Split Mountain anticline in the quadrangle developed a synclinal crinkle, flanked by small anticlinal noses. Asymmetrical folds, notably monoclines, are common elsewhere in Dinosaur National Monument and the eastern Uinta Mountains. They are considered to have formed by “draping” of the sedimentary rocks across the blocks of the Precambrian basement rocks during vertical offset along deep-seated faults (Cook and Stearns, 1975). Most such faults have reverse movement and steep to moderate dips. These faults generally die out upward, and most younger overlying rocks are affected by monoclinal or asymmetrical folds. Where these reverse faults die out upward, their dips commonly flatten upward, as recognized by Sanford (1959). Data from exploratory wells drilled for oil on the southern side of the Section Ridge anticline (Campbell, 1975), just south and southwest of the quadrangle, and also on the southern side of the Willow Creek anticline (Anderman, 1961, fig. 2; Berg, 1962; Cullins, 1969; Rowley and Hansen, 1979), about 30 km (19 mi.) southeast of the quadrangle, indicate that faults--having dips toward the north as low as 20 degrees--underlie the southern limbs of these anticlines. Displacement along such low-angle reverse faults probably is responsible for the anticlinal folding. The Split Mountain anticline geometrically resembles the Section Ridge and Willow Creek anticlines and may, likewise, be the product of reverse faulting at depth.

Some faults in the Precambrian basement rocks of the Uinta Mountains are demonstrably Precambrian in age but have moved repeatedly during subsequent deformation. The two folds in the quadrangle affect rocks as young as Late Cretaceous, and were formed during Laramide deformation beginning near the end of the Cretaceous Period and continuing into the Tertiary Period.

Three small faults, two on the northern limb of the Split Mountain anticline and one on the southern limb are probably not controlled by basement-type faults. They are believed to be secondary features resulting from sharp anticlinal folding, whereby deformation locally was breaking instead of by bending. The relative movement on the faults is the same as on the folds, that is, down toward the limbs of the

anticline.

JOINTS

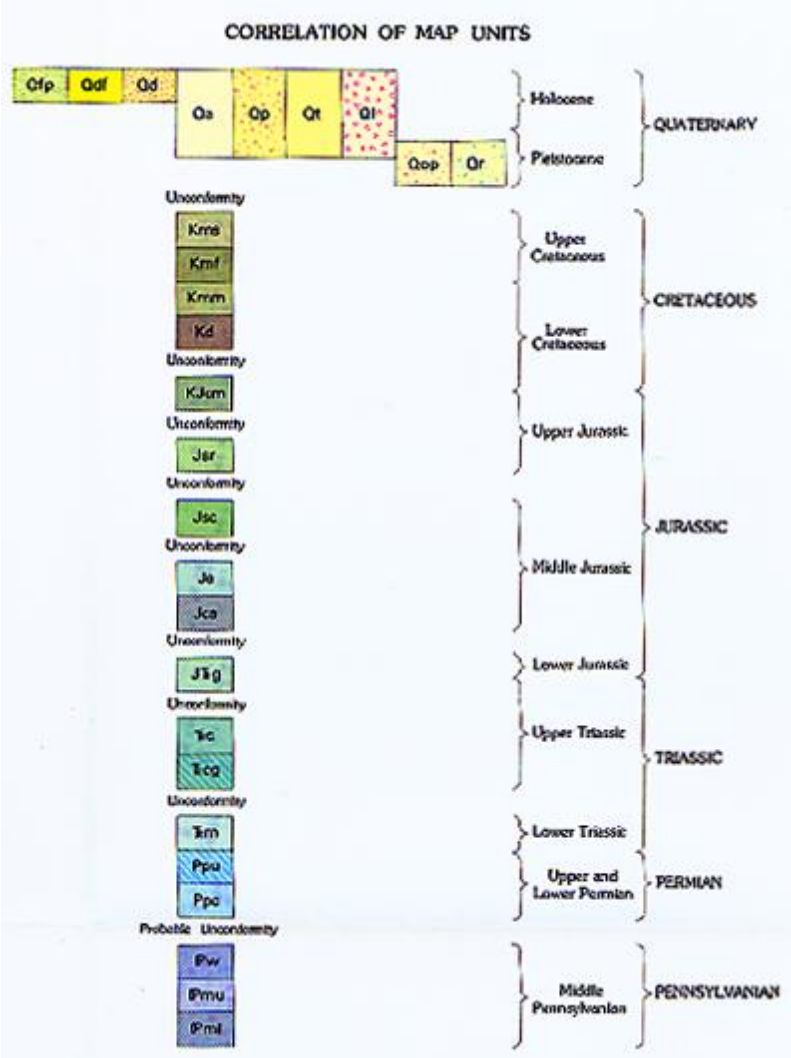
Joints in rocks are fractures that--unlike faults--have had little or no movement. Most rocks in the quadrangle are well jointed but at a scale that is too small to be shown on the map. Some joints in the Weber and Glen Canyon Sandstones, however, are large enough to be shown at true scale on the map. Most joints shown are extension fractures related in origin to folding and uplift of the eastern end of the Uinta Mountains. Water commonly follows such joints, which, therefore are the loci of frost heaving, weathering, and erosion that contribute to the development of the scenery in the Dinosaur National Monument area.

CONCLUSIONS

The geology and scenery we see today in the Dinosaur Quarry quadrangle are the result of a varied sequence of events that have taken place over 300 million years. The sedimentary rocks were formed by processes of erosion and deposition. Many different depositional environments, some on the continent and some in the ocean, are represented by the rock sequences present today. Faulting and folding in latest Cretaceous and early Tertiary time tilted, bent, and fractured the rocks. Deep erosion of the displaced strata and local deposition of some of the eroded debris since Tertiary time has produced the present scenery. Yet the present spectacular landscape is not an end point, for the processes we know are active in the past will continue in the future. We now witness just a small episode in the overall geologic evolution of this area.

Extracted from: GRI Source Map ID 34 (GQ-1513).

Correlation of Map Units



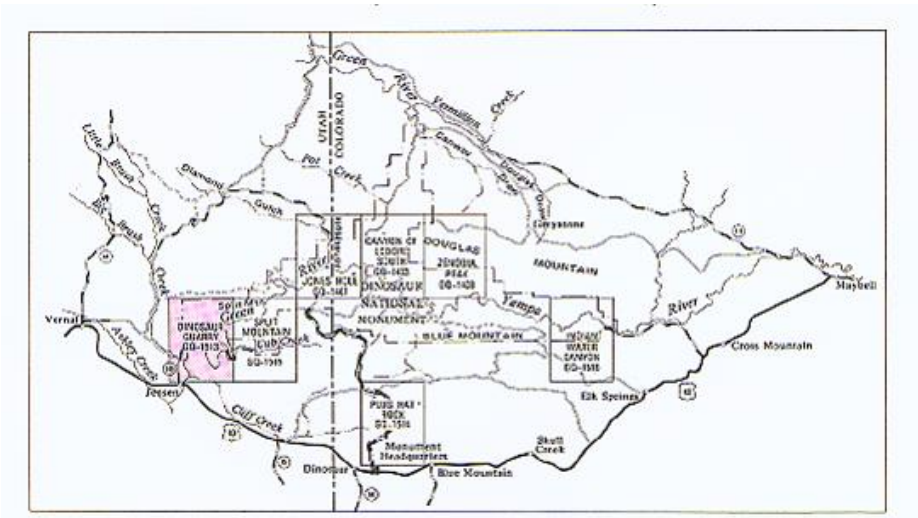
Extracted from: GRI Source Map ID 34 (GQ-1513).

Map Location



Extracted from: GRI Source Map ID 34 (GQ-1513).

Index Map



MAP SHOWING LOCATION OF DINOSAUR QUARRY QUADRANGLE AND OTHER QUADRANGLE MAPS IN THE AREA

Extracted from: GRI Source Map ID 34 (GQ-1513).

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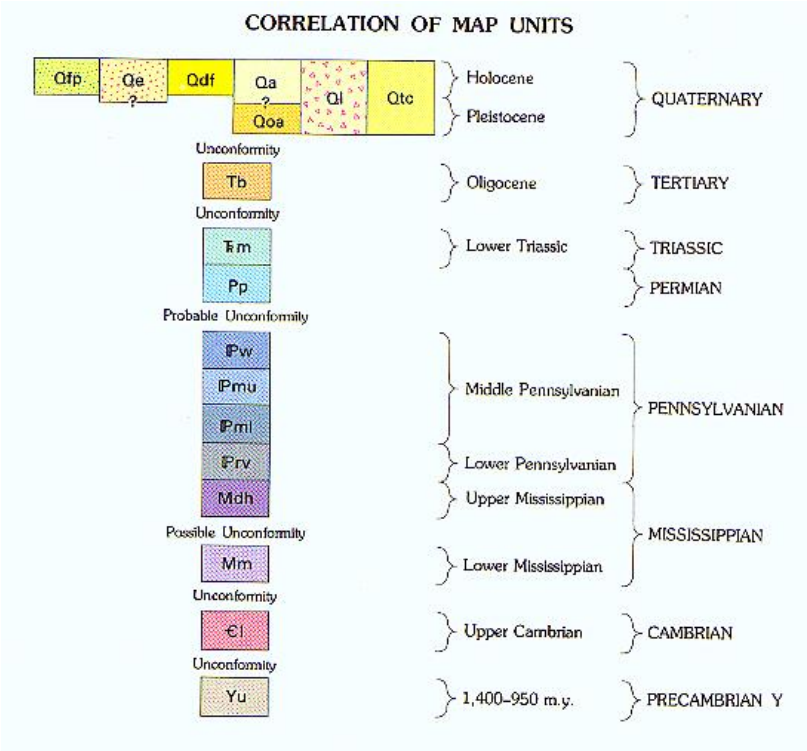
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Extracted from: GRI Source Map ID 34 (GQ-1513).

Geologic Map of the Haystack Rock Quadrangle

Hansen, W.R., Carrara, P.E., and Rowley, P.D., 1980, Geologic Map of the Haystack Rock Quadrangle, Moffat County, Colorado,U.S. Geological Survey, Geological Quadrangle Map GQ-1535, 1:24,000 scale. (*GRI Source Map ID 35*).

Correlation of Map Units



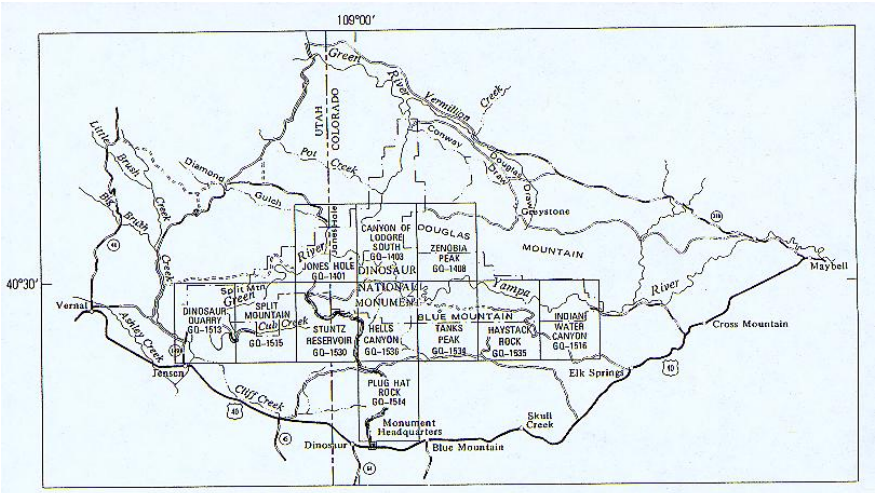
Extracted from: GRI Source Map ID 35 (GQ-1535).

Map Location



Extracted from: GRI Source Map ID 35 (GQ-1535).

Index Map



INDEX MAP SHOWING LOCATION OF HAYSTACK ROCK QUADRANGLE

Extracted from: GRI Source Map ID 35 (GQ-1535).

Geologic Map of the Hells Canyon Quadrangle

Hansen, W.R., and Rowley, P.D., 1980, Geologic Map of the Hells Canyon Quadrangle, Moffat County, Colorado,U.S. Geological Survey, Geological Quadrangle Map GQ-1536, 1:24,000 scale. (*GRI Source Map ID 36*).

Ancillary Map Notes

GEOLOGIC HIGHLIGHTS

Round Top Mountain (el. 2,614 m-8,575 ft), at the geographic center of the Hells Canyon quadrangle, is the highest point on the broad Blue Mountain highland south of Dinosaur National Monument. Its northern slope rises 1,053 m (3,455 ft) above the Yampa River at Castle Park and is one of the great declivities in the Dinosaur area. Its summit provides outstanding views in all directions of the stunning geology and physiography of this region. Capped with hard limestone, Round Top owes it preeminence to the erosive resistance of the upper member of the Morgan Formation.

Just below Round Top Mountain the deep gorge of Hells Canyon exposes a thick section of Paleozoic rocks and several hundred feet of the underlying Precambrian. Hells Canyon has the largest watershed--about 170 km2--of any drainage basin off Blue Mountain into the Yampa River and, with its steep gradient, is prone to flash flooding during thunderstorms. At such times it erodes its bed by moving boulder-laden debris toward and into the Yampa River.

Hells Canyon has more than quadrupled its watershed at the expense of adjacent streams that formerly flowed east into Wolf Creek and west into K Creek beyond the limits of the quadrangle (fig.). The chief point of capture was at the head of the canyon where its north-flowing drainage beheaded the formerly east-flowing headwaters of Wolf Creek. This drainage adjustment happened sometime after the Bishop Conglomerate was deposited, probably in late Pliocene or early Pleistocene time. Post-Bishop regional tilting toward the north (Hansen, 1965, p. 164 and 174; 1969, p. 121; Hansen and Rowley, in press) very likely lent impetus to the capture by increasing the already steep gradient of Hells Canyon and reinforcing its hydraulic advantage over the flatter eastward flow of Wolf Creek. Turner Creek, in the southwestern corner of the quadrangle, formerly drained into Wolf Creek, but has had its drainage direction reversed, and now flows into Hells Canyon.

Hells Canyon also provides a good perspective of the Yampa fault. This large fault arises just north of the center of the quadrangle and extends east 26 m or so through the adjacent Tanks Peak, Haystack Rock, and Indian Water Canyon quadrangles. At depth it probably extends west into the adjacent quadrangle, also. The actual fault surface is not exposed, as such surfaces seldom are, but the topographic relations of its well-defined trace indicate that the fault dips southward at Hells Canyon at an angle of about 22 degrees. With the Uinta Mountain Group (Precambrian) thrust northward up over the Chinle Formation (Triassic), the stratigraphic throw is about 1,500 m. The net slip, up the fault surface, must be on the order of 2,400 m.

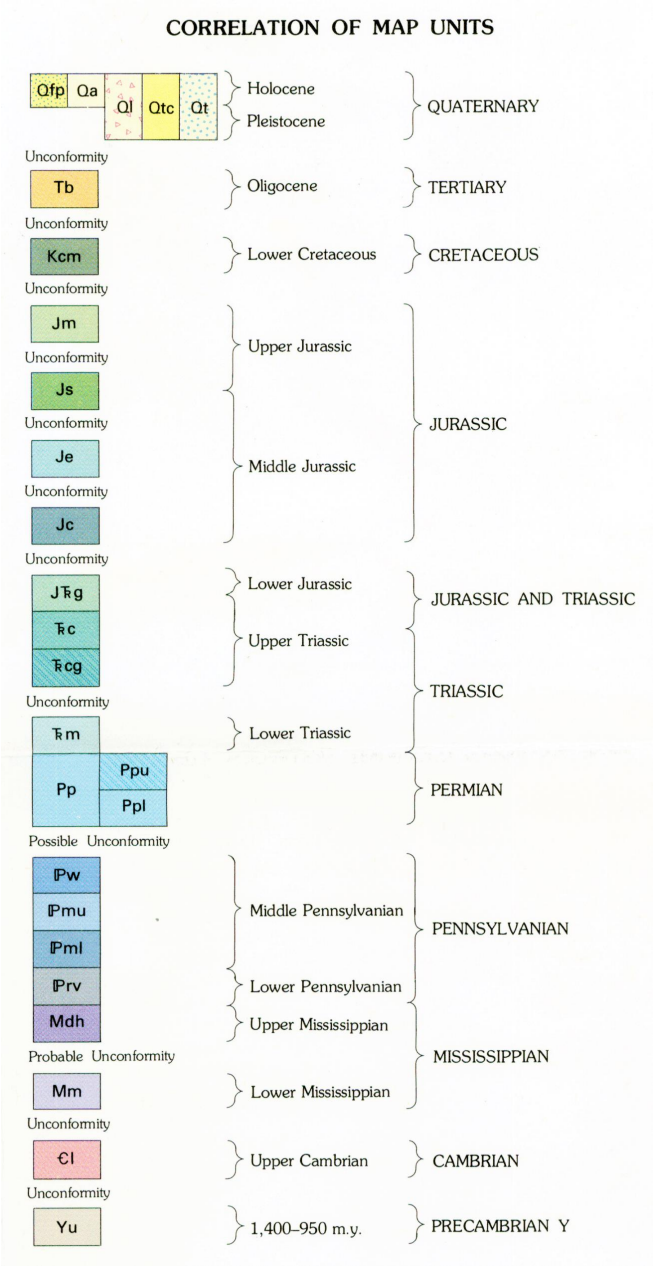
To the west the displacement of the Yampa fault is taken up by flexing along the Yampa monocline and Red Rock anticline and their synclinal counterparts. Although these remarkable folds are unfractured at the ground surface west of the terminus of the Yampa fault, they surely pass into faults at depth.

In the southern part of the quadrangle, the Mud Springs monocline elevates the Round Top Mountain block on the south. This sharp flexure, probably faulted at depth also, is en echelon to the large asymmetric Section Ridge anticline to the west beyond the quadrangle. Both folds are part of a zone of generally east-west crustal displacements that approximately bisect the Blue Mountain highland (Rowley, Tweto, and Hansen, 1978). Untermann and Untermann (1954, p. 141) referred to this zone as

the Miners Draw-Wolf Creek fault, although it is flexed rather than fractured through most its length.

Extracted from: GRI Source Map ID 36 (GQ-1536).

Correlation of Map Units



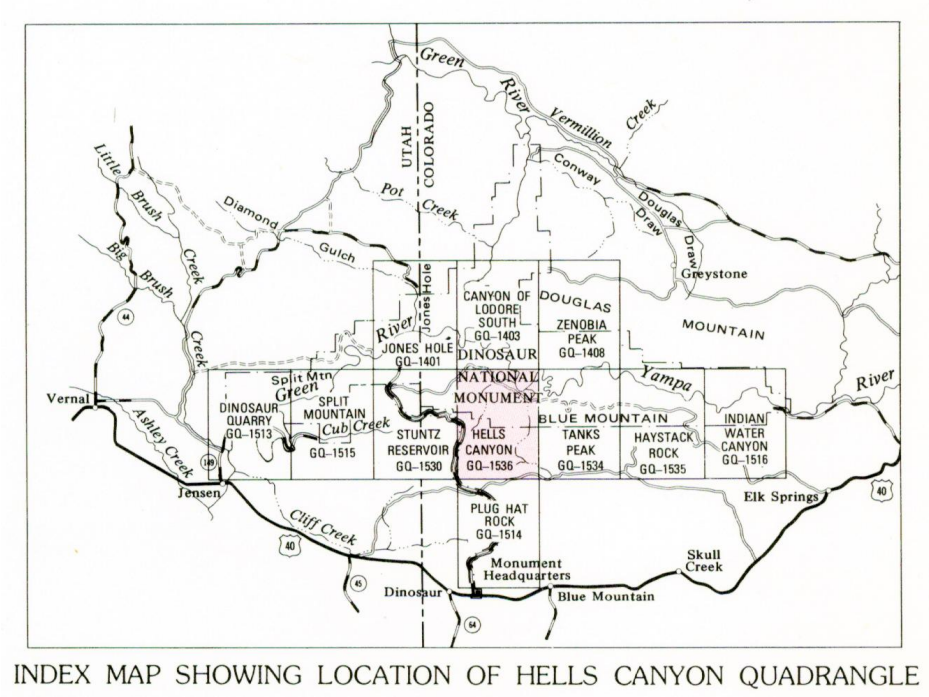
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Map Location



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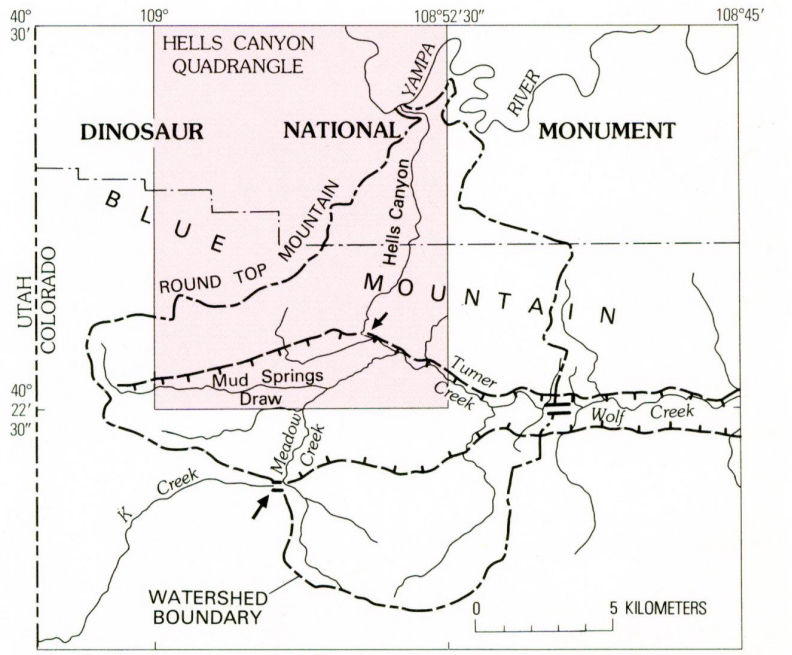
Index Map



INDEX MAP SHOWING LOCATION OF HELLS CANYON QUADRANGLE

Extracted from: GRI Source Map ID 36 (GQ-1536).

Sketch Map



SKETCH MAP SHOWING SETTING OF HELLS CANYON WATERSHED
Hachures outline old east-trending valley floored by Bishop Conglomerate. Parallel bars indicate low saddles between drainage basins. Arrows indicate drainage-diversion points

Extracted from: GRI Source Map ID 36 (GQ-1536).

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Extracted from: GRI Source Map ID 36 (GQ-1536).

Geologic Map of the Hoy Mountain Quadrangle

Hansen, W.R., and Rowley, P.D., 1981, Geologic Map of the Hoy Mountain Quadrangle, Daggett and Uintah Counties, Utah, and Moffat County, Colorado,U.S. Geological Survey, Geological Quadrangle Map GQ-1695, 1:24,000 scale. (*GRI Source Map ID 37*).

Ancillary Map Notes

GEOLOGIC AND GEOGRAPHIC HIGHLIGHTS

The Hoy Mountain quadrangle is on the south limb of the large Uinta anticline (fig.l), where the strata dip rather uniformly to the south-southwest, as shown by the cross section. Because of an angular unconformity at the top of the Middle Proterozoic Uinta Mountain Group, however, the Paleozoic rocks in this area dip a bit more steeply than the underlying Proterozoic rocks. John Wesley Powell (1876, p. 145, figs. 13-14) first noted this unconformity many years ago in the nearby canyons of the Green River, but in his cross sections he depicted the dip of the Uinta Mountain Group as steeper, not flatter, than that of the overlying Lodore Formation (Cambrian). Powell did not realize that the Uinta Mountain Group was tilted northward and truncated by erosion before the Lodore was deposited, and that the Lodore, therefore, was deposited on progressively older rocks, not younger ones, from north to south. With the Laramide arching of the Uinta anticline, starting near the end of Cretaceous time, the whole south limb of the fold was rotated southward enough to reverse the dip direction of the Uinta Mountain Group from northeastward before arching to southwestward after (Hansen, 1986a, b). This relationship is less obvious from the river, where Powell saw it, than from the canyon rim.

ACCESS

Access to much of the Hoy Mountain quadrangle is poor, but many points of interest can be reached easily by short hikes from fair-weather jeep roads and tracks. Some private lands are posted and padlocked. The summits of Hoy Mountain and Wild Mountain, accessible by foot, offer impressive panoramas east into Colorado, north into Wyoming, west toward the High Uintas', and south toward the Uinta Basin. From these summits, a viewer can readily appreciate the grandeur of the regional geologic framework and such details as the extent of the Bishop Conglomerate spread out below and its relationship to the underlying tilted rocks and the modern drainage.

FAULTS AND JOINTS

The several inferred concealed faults shown on the map are either (1) extensions of known faults outside the quadrangle or (2) surmised faults along strongly defined linear trends akin to the trends of demonstrable faults in adjacent areas. The concealed and inferred fault mapped in the southeastern part of the quadrangle (from sec. 2, T. 2 S., R. 25 E., Daggett Co., Utah, to sec. 8, T. 8 N., 8.104 W., Moffat Co., Colo.) follows a west-northwest linear trend, expressed by topography, that has a total length of about 55 km. The strike of bedding on opposite sides of this fault(?) diverges as much as 30°-45°. A conspicuous escarpment in the Uinta Mountain Group just south of the fault(?) and parallel to it, near the Utah-Colorado State Line in sec. 12 in Moffat County, may be a fault-line scarp.

West-northwest is a conspicuous and long-enduring structural direction in the Uinta Mountains and adjacent parts of the Colorado Plateau and Southern Rocky Mountains provinces, and it contains many faults, joints, folds, and igneous dikes of various ages-some as old as Precambrian over an area of thousands of square kilometers. In the adjacent Crouse Reservoir quadrangle to the west, several subdued Quaternary fault scarps follow this trend in the Bishop Conglomerate (Hansen and others, 1981; Hansen, 1986b). In Dinosaur National Monument, just east of the Hoy Mountain quadrangle, a fault of this trend contains a dike of Late Cambrian or Early Ordovician age (dated at 483±29 Ma by Sambhudas Chaudhuri in Hansen and others, 1982). This dike in turn has been partially sheared by subsequent

renewed movement on the fault. Dikes of similar age and trend crop out to the west in the High Uintas (Crittenden and others, 1967; Ritzma,1983) and elsewhere in the Southern Rocky Mountains and Colorado Plateau provinces (Hansen and Peterman,1968; Larson and others, 1985). Moreover, in the Uinta Basin near Bonanza, Utah, about 65 km south of the Hoy Mountain area, west-northwest-trending fractures in the Green River and Uinta Formations (Eocene) contain deposits of gilsonite, a shiny black asphaltite. Evidence thus indicates a long history of widespread, intermittent, regional crustal unrest related to the west-northwest trend direction.

Joints are far more widespread and conspicuous in the Hoy Mountain quadrangle than the map itself suggests, especially in the Uinta Mountain Group, where their abundance and length contrast with a much lower frequency and length in the overlying formations. Several sets of joints can be identified readily on the ground and on aerial photographs. Possibly the clearest and most accessible examples are in the large outcrop in the NW1/4 sec. 9, T. 2 S., R. 25 E., at the west border of the quadrangle. At that locality two sets of wellformed, widely spaced, nearly vertical joints have been so accentuated by weathering that they yield striking rectilinear landforms. The very long traces of joints shown there and elsewhere on the map may in fact be weathered composites of multiple, colinear fractures.

BISHOP CONGLOMERATE

By early Eocene time the Uinta anticline was eroded to its Precambrian core, and by early Oligocene time the broad Gilbert Peak erosion surface (Bradley, 1936) had begun to form on both flanks of the range. This erosion surface penetrated into the heart of the range in the Hoy Mountain quadrangle and adjacent areas as a dendritic network of wide, flat-bottomed valleys that concomitantly were buried under a thick blanket of loosely cemented sand and gravel, the Bishop Conglomerate. Farther south, the valleys and their cover of conglomerate merged into a great bajada that spread far into the Uinta Basin. Rubidium-strontium dating of a volcanic tuff bed in the Bishop Conglomerate yielded a radiometric age of about 29 Ma from samples of biotite and hornblende analyzed by Harald H. Mehnert of the U.S. Geological Survey (Hansen and others, 1981).

The Bishop Conglomerate is widespread in the quadrangle, but it formerly was even more widespread than now and was considerably thicker, reaching a thickness of perhaps 130 m or more. Its pattern of converging valley fills is more obvious on the smaller-scale (1:250,000) Vernal 1 °X 2° sheet than on the Hoy Mountain quadrangle (Rowley and others, 1985). In all probability, both Hoy Mountain and Wild Mountain at one time were completely surrounded by Bishop Conglomerate, just as several isolated hills and mountains still are in the adjacent Crouse Reservoir quadrangle (Hansen and others, 1981) and in areas farther west (Kinney, 1955 pl. 1). Fills in separate valleys merged southward into a broad alluvial plain (the bajada noted previously) along the sloping border between the Uinta Mountains and the Uinta Basin. The present drainage pattern is markedly different, being dominated by Pot Creek, which postdates the Bishop Conglomerate. Pot Creek drains about 70 percent of the quadrangle and flows east-southeastward into the Green River in the Canyon of Lodore, just east of the quadrangle. The drainage direction of Pot Creek is about 90° from the old regional slope of the Bishop Conglomerate, which was south-southwest down the regional dip; the course of Pot Creek is a hydrographic response of the drainage system to middle Tertiary northward and eastward tilting of the eastern Uinta Mountains (Hansen, 1984, 1986a). Note also that Pot Creek flows alternately across narrow, discontinuous flood plains built on Bishop Conglomerate and through short, shallow bedrock gorges superimposed into the Uinta Mountain Group. These gorges are effective local base levels that resist downcutting and cause Pot Creek to meander extensively on its flood plain. Sharp bends in the gorges themselves suggest local fracture control in the bedrock.

CLIMATE AND ITS EFFECT ON VEGETATION

Because the climate is semi-arid, most rock formations in the area are well exposed, especially on south-facing slopes. Annual precipitation is about 40-50 cm; mean annual temperature is only about 4 °

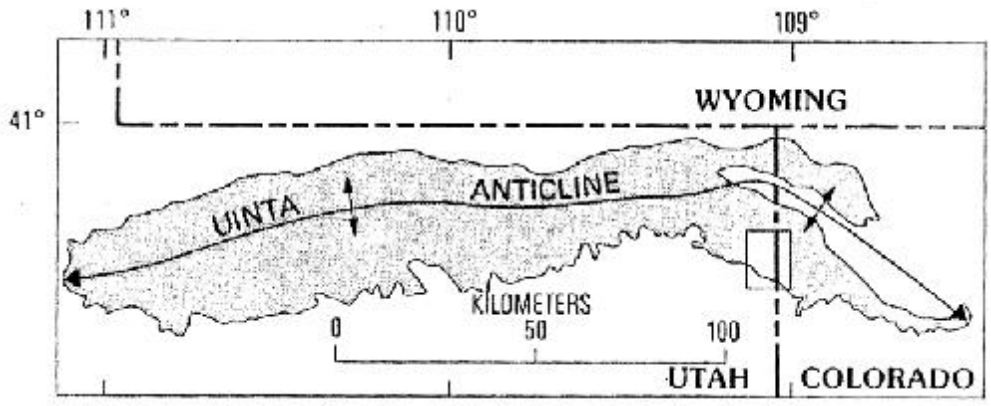
C (Fields and Adams, 1975). The low precipitation, often-clear skies, and high solar radiation join to produce distinctive local microclimates characterized by marked local variations in air temperature and soil moisture. Inasmuch as precipitation is most effective on cool north-facing slopes, soil is deeper and moister there than elsewhere. Consequently, vegetation is heaviest on the north sides of hills, and the asymmetry of its pattern is striking. For example, the north side of Hoy Mountain supports a forest of Douglas fir and aspen, but the top and south side support mostly brush and open stands of juniper and pinyon (and some ponderosa pine in well-drained places on sandstone). The vegetation pattern of Wild Mountain is even more striking: though its north slope is heavily forested, its rocky south slopes are dominated by sagebrush, forbs, grasses, and patchy shrubbery.

LANDSLIDES

Landslides, like trees, are larger and more abundant on north slopes than on other exposures, and for the same basic reasons: higher moisture infiltration rates and retention, and lower insolation and transpiration. Most local landslides have resulted from rotational slumping, followed by further ground disruption in Bishop Conglomerate, although other rock formations here and there have also been involved. Bear in mind that much of the Bishop in this area is finer grained material, not just conglomerate. The fact that many landslides abut slopes on the Uinta Mountain Group suggests failure and slippage on the interface between the group and the overlapping Bishop Conglomerate. Landslides in the quadrangle, however, appear to be largely inactive; none shows the usual symptoms of obvious movement, such as cracked ground, tilted trees, dead or dying vegetation, or blocked drainageways. Climatic conditions wetter than now probably led to slumping originally. Similarly, a shift back to a moister regime would perhaps set off renewed movements.

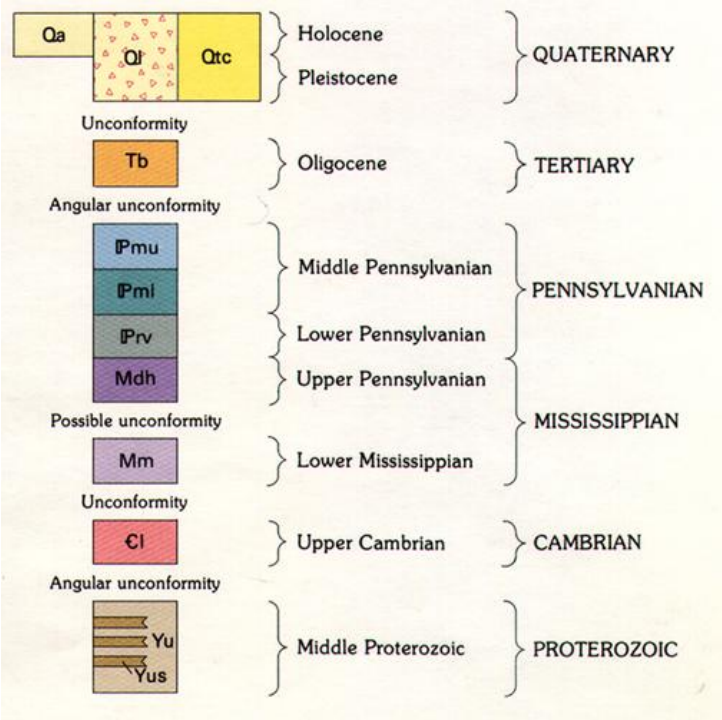
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Figure 1



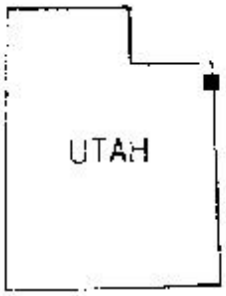
Extracted from: GRI Source Map ID 37 (GQ-1695).

Correlation of Map Units



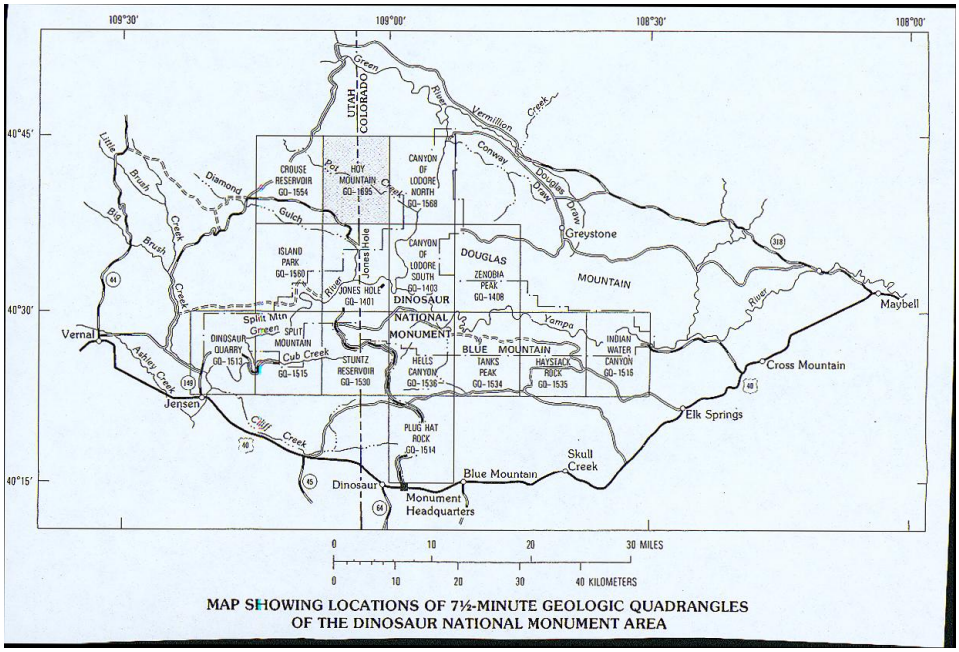
Extracted from: GRI Source Map ID 37 (GQ-1695).

Map Location



Extracted from: GRI Source Map ID 37 (GQ-1695).

Index Map



Extracted from: GRI Source Map ID 37 (GQ-1695).

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Extracted from: GRI Source Map ID 37 (GQ-1695).

Geologic Map of the Indian Water Canyon Quadrangle

Rowley, P.D., Dyni, J.R., Hansen, W.R., and Pipiringos, G.N., 1979, Geologic Map of the Indian Water Canyon Quadrangle, Moffat County, Colorado, U.S. Geological Survey, Geological Quadrangle Map GQ-1516, 1:24,000 scale. (*GRI Source Map ID 38*).

Ancillary Map Notes

SETTING

The Indian Water Canyon quadrangle is in the eastern part of Dinosaur National Monument on the eastern flank of the Uinta Mountains. With the exception of several dirt roads in the southern part of the quadrangle, a jeep trail at the northern edge of the quadrangle, and the paved road into Deerlodge Park, most of the quadrangle is accessible only by foot, horseback, or boat. Rafting down the Yampa River has become very popular in the past decade, and thousands of adventurers annually brave the rapids (Hayes and Simmons, 1973). Deerlodge Park, where most raft trips start down the Yampa River, is at the eastern entrance of the spectacularly beautiful steep-walled canyon of the Yampa River.

ROCK FORMATIONS

In terms of geologic eras and periods represented by exposed rock formations, Dinosaur National Monument has the most nearly complete stratigraphic record of any park in the National Park System. These formations include rocks of all the systems, from Precambrian to Quaternary except the Ordovician, Silurian, and Devonian (Untermann and Untermann, 1954, 1965, 1968). Most of these formations, moreover, crop out within the Indian Water Canyon quadrangle. Mesozoic rocks underlie most of the eastern part of the quadrangle, while Paleozoic rocks underlie most of the rest of the quadrangle.

GEOLOGIC STORY

The oldest rocks in the Indian Water Canyon quadrangle belong to the Madison Limestone of Early Mississippian age (about 340 million years old), exposed at the western edge of the quadrangle. These rocks were deposited in a shallow ocean that once covered much of the Western Interior of North America. Fossil corals, echinoderms, brachiopods, pelecypods, and gastropods have been found in this rock unit. The Humbug Formation and Doughnut Shale (Upper Mississippian), next in succession, are poorly exposed in the quadrangle. These two formations elsewhere contain evidence that they were deposited under near-shore marine conditions. The Doughnut Shale contain a fauna of brachiopods and fish remains in some places in the Uinta Mountains, but it also contains coal (Kinney, 1955; Hansen, 1965). Coal accumulates in fresh-water or brackish-water swamps that are rich in vegetation, and its presence in the Doughnut Shale indicates a short-lived suspension of normal marine conditions.

Marine conditions returned again and deposited the overlying Round Valley Limestone and Early Pennsylvanian age (about 310 million years old). This unit is well-exposed as a gray ledgy slope or multi-tiered cliff along and just above river level in Anderson Hole, and also is poorly exposed in the northern part of the map. Fossil brachiopods, bryozoan, echinoderms, and molluscs have been found in this formation. The sheer red walls of the canyon and cuestas north of the canyon, as well as the gray slope just below the red rocks, belong to the Morgan Formation of Middle Pennsylvanian age, which was deposited on a beach and just offshore in a shallow ocean in which lived abundant bryozoans, brachiopods, echinoderms, fusulinids, and other invertebrates. Overlying the Morgan is the tan or cream-colored Weber Sandstone of Middle Pennsylvanian age, which forms some of the most spectacular scenery in Dinosaur National Monument; it makes up most of the white and buff cliffs of sandstone west of Disappointment Draw and Vale of Tears. In the quadrangle, it displays sweeping crossbeds indicative of a beach and sand dune origin; outside the quadrangle, fossil fusulinids, corals, and brachiopods have

been found in interlayered limestone beds.

The Park City Formation (Permian age, about 250 million years old) consists of gray resistant beds and overlying gray and yellow soft beds on the western side of Vale of Tears and Disappointment Draw. It is largely of marine origin, as it contains fossil pelecypods, gastropods, scaphopods, cephalopods, and brachiopods. Rich deposits of phosphate rock which accumulate where deep cold ocean water welled up to warmer zones or encountered warmer currents, are mined in the Brush Creek area north of Vernal, Utah, for the production of fertilizer.

Depositional conditions fluctuated greatly at the beginning of the Mesozoic Era, and the resulting rocks varied accordingly. Marine water withdrew and re-advanced repeatedly as the shorelines advanced and retreated across the region in response to gentle oscillations of the earth's crust. The red Moenkopi Formation of Early Triassic age (about 220 million years old) is a soft unit that was eroded in Quaternary time to form the floor of the strike valley (a valley parallel to the strike of the bedding) of Disappointment Draw and Vale of Tears. It was deposited mostly in a near-shore marine and fresh-water environment. Gypsum beds accumulated in the Moenkopi Formation in times of high aridity, perhaps in a desiccating lagoon. Organisms were rare in that hostile environment, but some marine molluscs and tracks of early reptiles have been found in the formation.

The red Chinle Formation (Upper Triassic) forms the eastern side of Disappointment Draw and Vale of Tears. Most beds were deposited by streams and lakes. Fossil remains of reptiles, amphibians, molluscs, and petrified wood have been found. The buff and red Glen Canyon Sandstone of Early Jurassic and Late Triassic age forms the massive strike ridge (a ridge parallel to the strike of the bedding) west of Deerlodge Park. The Glen Canyon is barren of fossils, and displays spectacular crossbeds that are interpreted as the forset beds of ancient sand dunes formed under desert or coastal conditions. The Entrada Sandstone (Middle Jurassic, about 150 million years old), like the Glen Canyon, also was deposited largely by eolian processes, although the sands probably were locally reworked by marine water during temporary advances of the sea. Both the resistant gray Curtis Member and the overlying soft olive-green Redwater Member of the Stump Formation (Upper and Middle Jurassic) were deposited by marine waters. The Curtis contains sparse pelecypods and furrowed trails made by bottom crawlers, and the Redwater contains locally abundant brachiopods, pelecypods, echinoderms and cephalopods, especially belemnites.

The soft multi-colored Morrison Formation of Late Jurassic age, as well as Cretaceous rocks, occur in the eastern part of the quadrangle. The Morrison and Lower Cretaceous rocks mapped with the Morrison were deposited mostly by streams and rivers; in some places, fossil charophytes and ostracodes that lived in freshwater lakes or ponds have been found in the Morrison. Far more important paleontologically is the famous dinosaur-bearing bed of the Morrison Formation at Dinosaur Quarry about 55 km (34 mi) west of the quadrangle. In addition to fossil crocodiles, turtles, pelecypods, and silicified wood, many varieties have been collected from this stream-deposited bed.

The resistant buff Dakota Sandstone of Early Cretaceous age (about 110 million years old) was deposited mainly be streams and rivers; in some places it contains petrified wood. The soft gray Lower Cretaceous Mowry Member of the Mancos Shale is of marine origin, and contains abundant fish bones, fish scales, and occasional ammonites. The resistant buff Upper Cretaceous Frontier Sandstone Member of the Mancos Shale was deposited in near-shore marine water and onshore swamps; it locally contains coal and fossil pelecypods, ammonites, gastropods, and petrified wood. The soft gray Upper Cretaceous upper shale member of the Mancos Shale forms smooth low slopes and badland topography in Deerlodge Park. It contains abundant fossils in some places, especially cephalopods and oysters that indicate a freely circulating marine water.

Near the end of Cretaceous time, the Rocky Mountains began to rise, and the sea drained away for the last time. Less than 40 million years ago, in early Tertiary time, sand and gravel eroded from the newly

formed Uinta Mountains began to accumulate in the adjacent basins and at the flanks of the mountains themselves, and eventually attained a thickness of at least 1,000 m (3,000 ft). Upland areas, such as Badger Flat and Klauson Pasture, as well as, large areas east of the quadrangle, were part of a broad valley, east of the newly formed mountains, that was beveled by streams and partly filled with stream deposited gravel and sand of Tertiary age. Distant volcanoes far outside the area rained ash that was incorporated into the gravel and sand. The exact correlation of the gravel, sand, and ash-fall tuff with elsewhere is uncertain, but the oldest gravel and sand may be equivalent with Miocene Browns Park Formation, which is typically exposed in the valley of Browns Park north of the quadrangle.

During early and middle Tertiary time the Bishop Conglomerate was much more extensive than it is now. It must have once blanketed an extensive erosion surface cut near the top of the Uinta Mountains. It extended up all the major valleys and filled in around the high peaks and ridges. After deposition of the Bishop Conglomerate, rivers cut and widened valleys in the region, forming a lower level of erosion. The Browns Park Formation overlies this lower surface cut on the flanks of the Uinta Mountains, and filled in the broad east-west valley now known as Browns Park (Hansen, 1969a) about 10 km (6 mi) north of the quadrangle. The ancestral Green and Yampa Rivers flowed on these Tertiary deposits and cut down through them to form the deepened canyons of the eastern Uinta Mountains (Sears, 1924, 1962; Bradley, 1936; Hansen, 1969a, 1969b; Hunt, 1969).

SURFICIAL DEPOSITS

Surficial deposits are unconsolidated or poorly consolidated patchy sediments of Quaternary age (less than a few million years old). These sediments were deposited by the same processes that shaped and continue to shape the scenery of the area--processes of weathering, mass wasting, and erosion and deposition by running water. Landslide deposits, for example, accumulate below steep slopes underlain by soft incompetent rocks, such as shales in the Morgan Formation, Morrison Formation, and Mancos Shale. The extensive landslide deposits in Anderson Hole formed after the Yampa River undercut and removed the support of the lower member of the Morgan Formation. Landsliding probably started near river level, then progressed upslope. Recent gullies have cut completely through the landslide deposits down into bedrock, which is the Round Valley Limestone. Many similar large landslides have developed along the canyon of the Yampa River west of the quadrangle, wherever the river has cut down into the lower member of the Morgan Formation. Sears (1962) did not recognize the presence of the landslide deposits, and erroneously attributed the resultant circular scarps on the canyon walls to ancient meander scars, formed when the river was at a higher level.

Gravel and sand currently being transported and deposited by the Yampa River are mapped as flood-plain and channel deposits (Qfp). As suggested by the name, all such deposits are covered intermittently by the river, especially during early spring run-off or after severe storms; campers on the river should be aware of such potential for flooding. Far more surficial deposits in the quadrangle, however, were formed by much smaller streams, most of which contain water only after storms. Where stream deposits are sufficiently large, they are mapped separately as alluvium (Qa) and as debris fans at the base of steep channels (Qdf). Where the streams and tributaries are small, and form coalescing smooth surfaces of erosion (pediments) or coalescing smooth surfaces of deposition (alluvial fans), the resultant deposits are given a different map symbol. Thus pediments (Qp) are mapped where the bedrock is soft and easily eroded, as in the Mancos Shale in Deerlodge Park, and the drainage is at grade; talus and alluvial fan deposits (Qt) occur below cliffs, such as along the Yampa River. In some places, similar surfaces and the deposits on them are graded to former higher stream levels above and dissected by present streams; these deposits are somewhat older, and have been mapped separately (Qop).

The origin of side-stream surficial deposits has important implications for the rafter and camper. Alluvium, fan deposits, talus deposits, and pediment deposits largely resulted from torrential runoff following storms. The size of fans is about proportional to the size of the drainage area of the streams

that deposit them and to the volume of the flash flood in that drainage area . Some debris fans in the canyon of the Yampa River may have accumulated in large part during one storm. All major rapids on the Green and Yampa Rivers in Dinosaur National Monument are at the toes of debris fans; thus when rafting upon rough water, almost invariably an arroyo enters from the left or right. Some debris fans are large enough to force the river to the opposite side of its canyon, where it may undercut a cliff and create talus cones and hazards from falling rock. The rapids at the mouth of Warm Springs Draw--perhaps the worst rapids in Dinosaur National Monument and about 25 km (16 mi) west of the quadrangle--were formed June 10, 1965, when a flash flood deposited a great volume of bouldery debris in the river; rockfall from the facing Warm Springs Cliff added to the deposit (Hayes and Simmons, 1973). Such flash floods are common in Dinosaur National Monument and boaters camped on debris fans, including many small ones that are not mapped, should recognize the potential danger.

FAULTS AND FOLDS

Dinosaur National Monument is on the southern flank of the large Uinta anticline, which is about 55 km (35 mi) wide and stretches more than 240 km (150 mi) from west to east across the northeastern Utah and northwestern Colorado. This huge fold forms the eastern end of the Uinta Mountains. Along the southern flank of the anticline the rocks dip southward, each younger formation successively overlying the next older, the oldest to the north and the youngest to the south, as in the northern and eastern parts of the quadrangle. The Indian Water Canyon quadrangle lies near the eastern end of this broad anticline, and thus in the eastern part of the area the rocks dip east-southeast off the structurally high area to the west. As elsewhere in the Monument, these simple patterns are modified by smaller folds and faults, some of which involve spectacular offsets of the earth's outer crust.

One such feature is the Yampa monocline, a fold of large-scale amplitude west of the quadrangle that decreases in magnitude eastward across the area of the quadrangle. A second flexure exhibiting the same configuration as the Yampa monocline, and here called the North Branch Yampa monocline, represents a northern splay of the Yampa monocline. In the Thanksgiving Gorge area the strata were affected by major uplift. This uplift caused a sharp flexure of the beds on the northern side of the monocline; here the beds previously dipping gently to the south, dip to the north-northeast at angles that are very steep in some places. In some locations, as where the North Branch Yampa monocline crosses Indian Water Canyon, the beds dip in opposite directions away from the crest of the flexure to form an anticline; but in most other places, the steepest dip is toward the north-northeast off the crest of the flexure.

Monoclines are common in the eastern Uinta Mountains. They are considered to have formed by "draping" of the sedimentary rocks across blocks of the Precambrian basement rocks during vertical offset along deep-seated faults (Cook and Stearns, 1975). Most such faults have reverse movement and steep to moderate dips. These faults generally die out upward, and most younger overlying rocks are affected by monoclinal folds instead. Where these reverse faults die out upward, their dips commonly flatten upward, as recognized by Sanford (1959). Data from exploratory wells drilled for oil near Dinosaur, Utah, 26 km (16 mi) west-southwest of the quadrangle (Anderman, 1961, fig. 2; Berg, 1962; Cullins, 1969; Rowley and Hansen, 1979) and also near Jensen, Utah, 64 km (40 mi) west of the quadrangle (Campbell, 1975) indicate that such faults--having dips toward the north as low as 20 degrees--underlie the southern limbs of these anticlines there. Displacements along such low-angle reverse faults probably are responsible for the anticlinal folding.

Some faults in the Precambrian basement rocks of the Uinta Mountains are demonstrably Precambrian in age but have moved repeatedly during subsequent deformations. The two monoclines in the quadrangle affect rocks as young as Late Cretaceous, and were formed during Laramide deformation beginning near the end of the Cretaceous Period and continuing into the Tertiary Period.

The Yampa fault is related in origin and age to the North Branch Yampa Monocline, and its trace occurs

discontinuously north of the trace of the monocline in this quadrangle, as well as the Yampa monocline west of the quadrangle. It probably is the surface expression of a large fault at depth that produced the monocline. In this quadrangle, the fault probably nowhere exhibits more than 10 m (30 ft) of offset. Displacement on this fault is downward on the northern side, in keeping with the overall displacement on the monocline. The Weber Sandstone is broken and brecciated near where the fault crosses Indian Water Canyon, but the amount of offset apparently is minor; faulting at this place may be more a reflection of the hingeline of the tight flexure than of any significant vertical shearing. Similar beds are 500 m (1,600 ft) higher north of the Yampa monocline in the Thanksgiving Gorge area than they are south of it. Contrary to the views of Untermann and Untermann (1954, 1965, 1968, 1969), almost all the difference in structural position has been done by folding, and the Yampa fault accounts for almost none of it. At great depth beneath this monocline, however, it is likely that most offset was by faulting.

Slickensides, which are polished and grooved surfaces where opposite sides of the ruptured rocks moved past each other, are exposed along a fault east of Thanksgiving Gorge in the SW ¼ NW ¼ sec. 35, T. 6 N., R. 100 W., but it is unlikely that significant vertical offset occurred along the fault. This fault probably has a similar relation to the Yampa monocline that the Yampa fault has to the North Branch Yampa monocline.

JOINTS

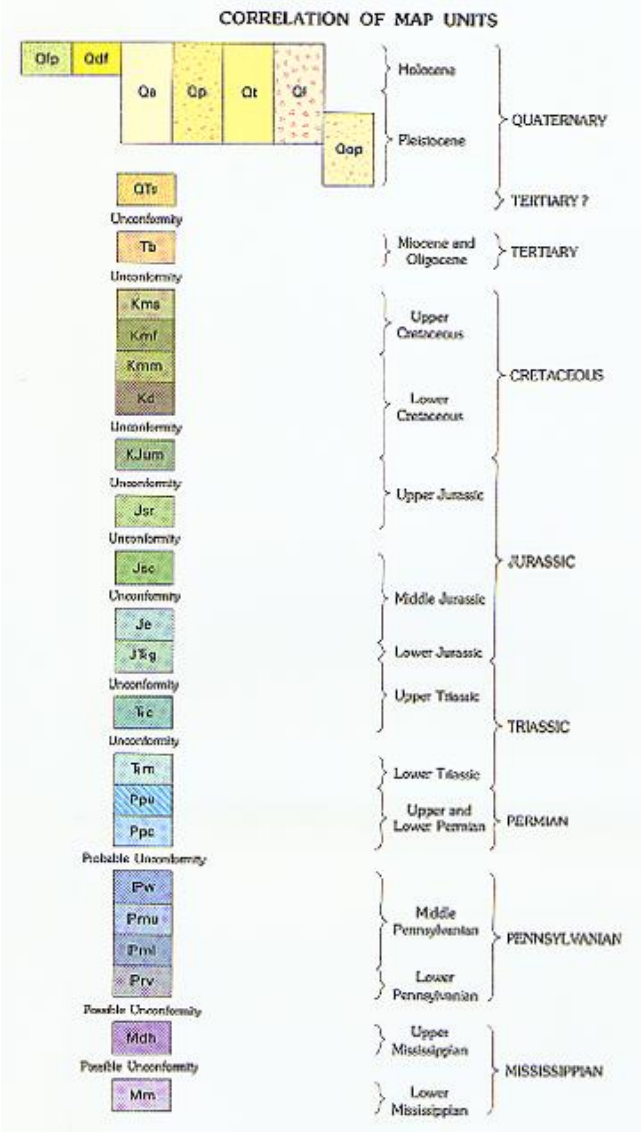
Joints in rocks are fractures that--unlike faults--have had little or no movement. Most rocks in the quadrangle are well jointed, but at a scale that is too small to be shown on the map. Some joints in the Weber and Glen Canyon Sandstones, however, are large enough to be shown at true scale on the map. Most joints shown are extension fractures related in origin to folding and uplift of the eastern end of the Uinta Mountains. Water commonly follows such joints, which, therefore, are the loci of frost-heaving, weathering, and erosion that contribute to the development of the scenery in the Dinosaur National Monument area.

CONCLUSIONS

The geology and scenery we see today in the Indian Water Canyon quadrangle are the result of a varied sequence of events that have taken place over about 300 million years. The sedimentary rocks were formed by processes of erosion and deposition. Many different depositional environments, some on the continent and some in the ocean, are represented by the rock sequences present today. Faulting and folding in latest Cretaceous and early Tertiary time tilted, bent, and fractured the rocks. Deep erosion of the displaced strata and local deposition of some of the eroded debris since Tertiary time has produced the present scenery. Yet the present spectacular landscape is not an end point, for the processes we know were active in the past will continue in the future. We now witness just a small episode in the overall geologic evolution of this area.

Extracted from: GRI Source Map ID 38 (GQ-1516).

Correlation of Map Units



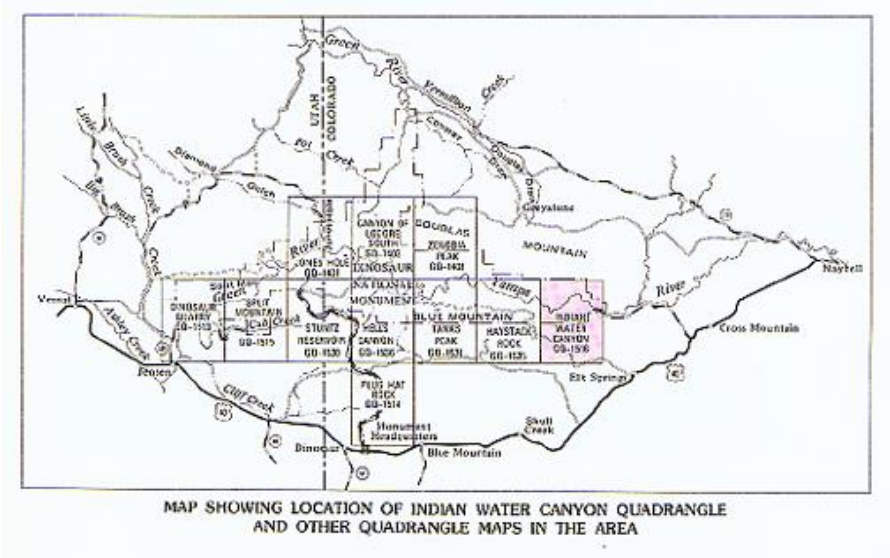
Extracted from: GRI Source Map ID 38 (GQ-1516).

Map Location



Extracted from: GRI Source Map ID 38 (GQ-1516).

Index Map



MAP SHOWING LOCATION OF INDIAN WATER CANYON QUADRANGLE AND OTHER QUADRANGLE MAPS IN THE AREA

Extracted from: GRI Source Map ID 38 (GQ-1516).

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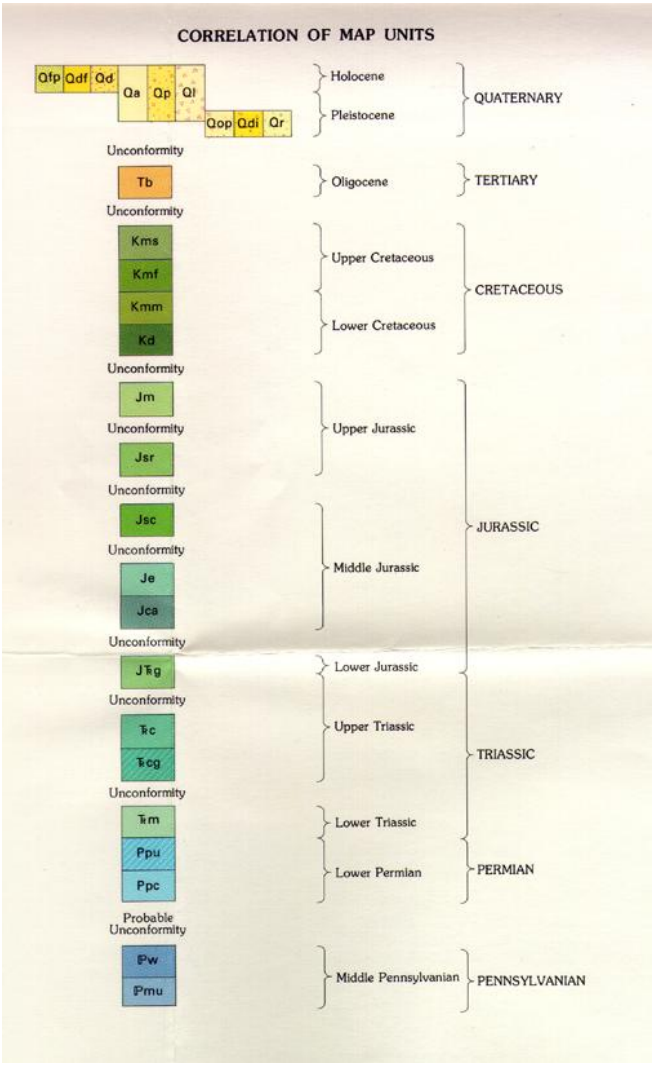
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Extracted from: GRI Source Map ID 38 (GQ-1516).

Geologic Map of the Island Park Quadrangle

Rowley, P.D., Hansen, W.R., and Carrara, P.E., 1981, Geologic Map of the Island Park Quadrangle, Uintah County, Utah, U.S. Geological Survey, Geological Quadrangle Map GQ-1560, 1:24,000 scale. (*GRI Source Map ID 39*).

Correlation of Map Units



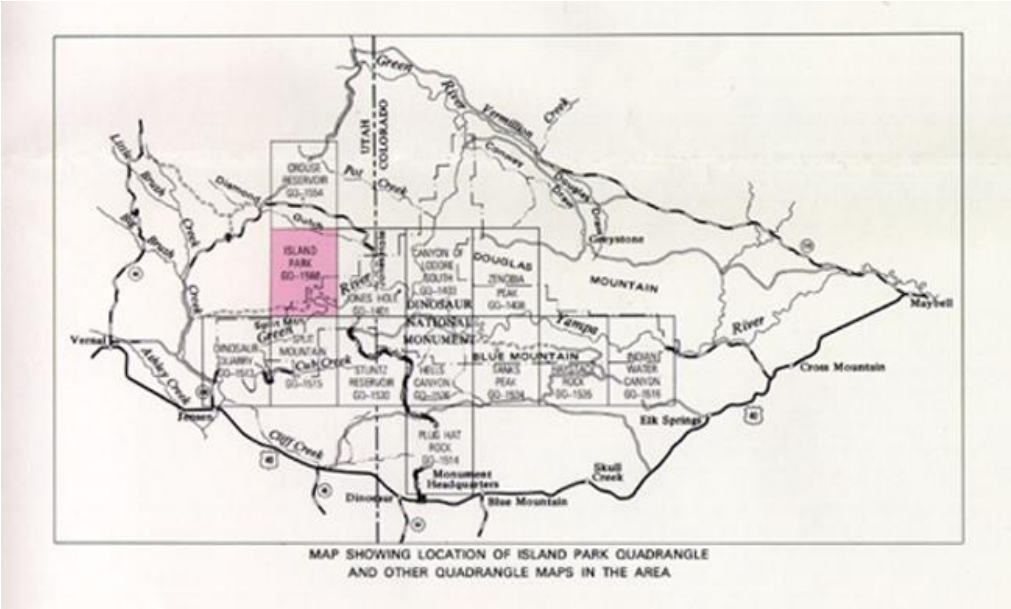
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Map Location



Extracted from: GRI Source Map ID 39 (GQ-1560).

Index Map



Extracted from: GRI Source Map ID 39 (GQ-1560).

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Geologic Map of the Jones Hole Quadrangle

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Ancillary Map Notes

NOTE REGARDING THE LANDSLIDE AT DIAMOND GULCH

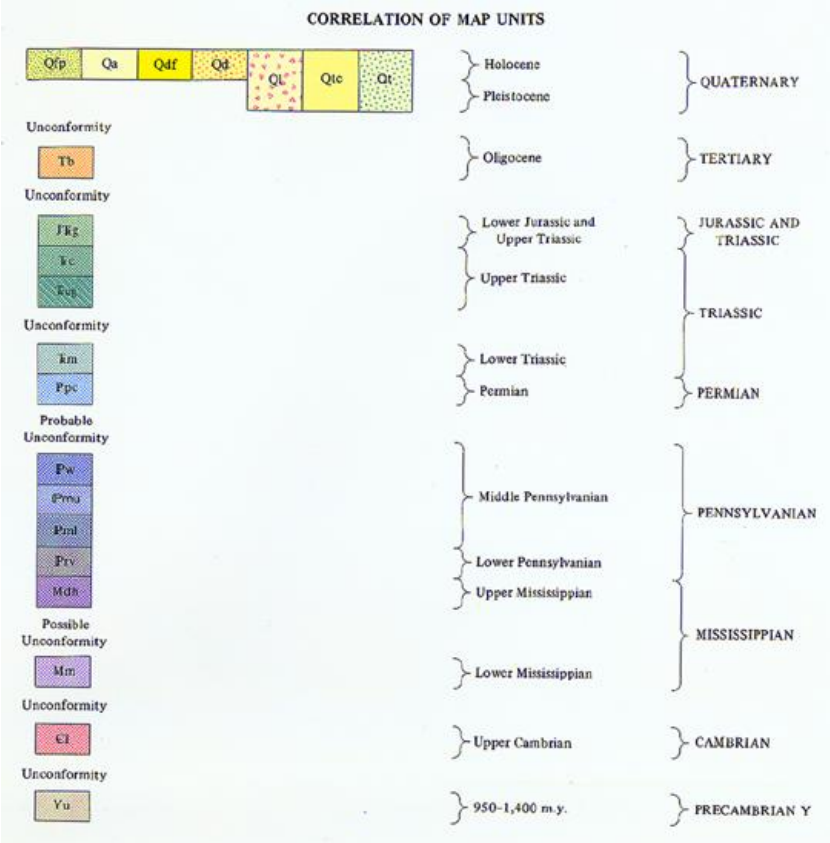
The large landslide on the north side of Diamond Gulch, chiefly in secs. 25, 26, 35, and 36, T. 2 S., R. 25 E., has gradually expanded along dipslopes in the Round Valley Limestone and the Morgan Formation. Erosion at the bottom of Diamond Gulch has removed support from the foot of the Morgan (Pnml). The top of the underlying Round Valley Limestone (Pnrv) has acted as a slip surface. In sec. 1, T. 3 S., R. 25 E., the Doughnut and Humbug Formations are involved also. The most active part of the slide seems to be the western part.

Some parts of the slide have moved only slightly--en masse, with little distortion of the ground--but most of the slide has deteriorated into a chaotic jumble of soil and rock. In the western part of the slide, the more competent upper member of the Morgan Formation has ridden downslope on the underlying lower member and in the process has broken into enormous slide blocks in helter-skelter disarray separated by deep trough-like depressions.

At the head of the slide in sec. 26, the ground is torn by many open fractures. At the foot of the slide, Diamond Gulch is being crowded by continued encroachment; concomitant stream erosion in Diamond Gulch at the toe of the slide is maintaining the imbalance of the slope.

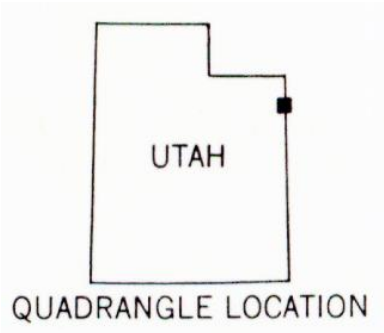
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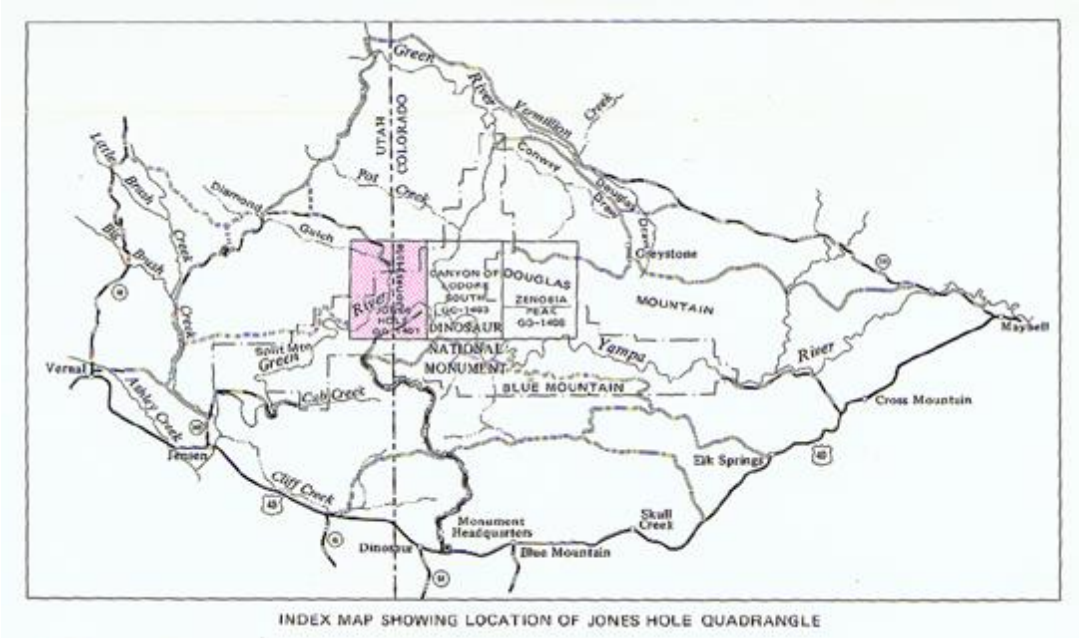
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Map Location



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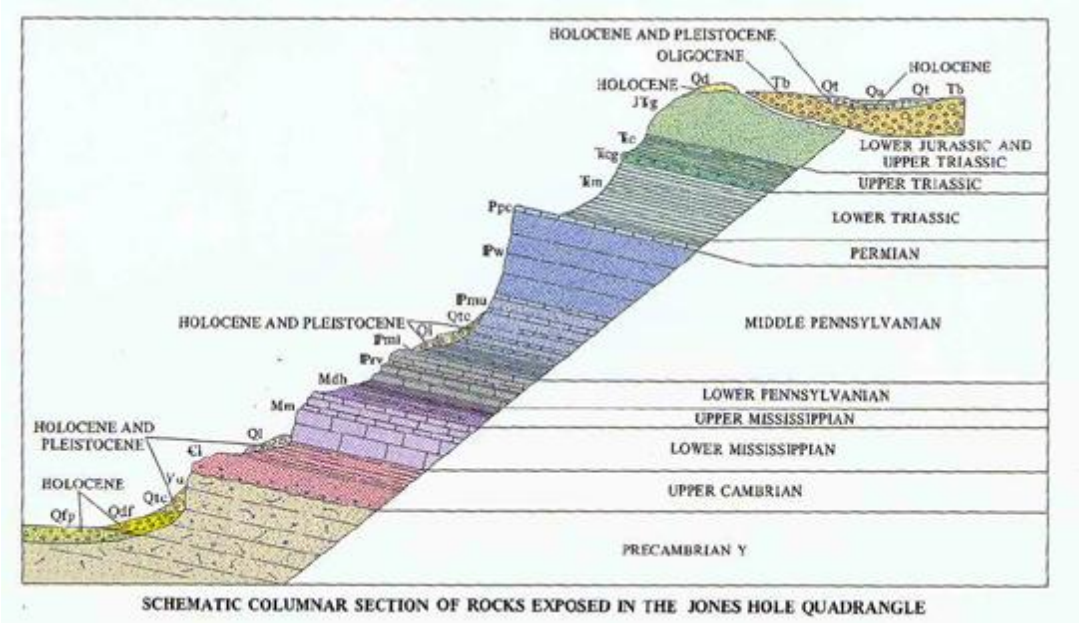
Index Map



INDEX MAP SHOWING LOCATION OF JONES HOLE QUADRANGLE

Extracted from: GRI Source Map ID 40 (GQ-1401).

Schematic Columnar Section



SCHEMATIC COLUMNAR SECTION OF ROCKS EXPOSED IN THE JONES HOLE QUADRANGLE

Extracted from: GRI Source Map ID 40 (GQ-1401).

Geologic Map of the Mellen Hill Quadrangle

Cullins, H.L., 1969, Geologic Map of the Mellen Hill Quadrangle, Rio Blanco and Moffat counties, Colorado,U.S. Geological Survey, Geological Quadrangle Map GQ-835, 1:24,000 scale. (*GRI Source Map ID 41*).

Ancillary Map Notes

ECONOMIC GEOLOGY AND STRUCTURE

The quadrangle was mapped as part of the U.S. Geological Survey program of classifying and evaluating lands in the Public Domain. Oil and gas, coal, oil shale, sodium zeolites, and sand and gravel occur within the map area, but only oil and gas and sand and gravel were being exploited in 1968.
The Rangely oil field, part of which lies in the map area, produces oil from several formations at depths ranging from about 560 feet to more than 6,700 feet along the flanks and crest of a large northwest-trending asymmetric fold, the Rangely anticline. The first well in the Rangely field was drilled during the summers of 1901 and 1902, and oil shows were found at 750 feet (Gale, 1908, p. 40-41); the well was abandoned at a total depth of 2,130 feet in the Mancos Shale. Oil was discovered in the Weber Sandstone in March 1933 in the California Co. A-1 Raven well in sec. 30, T2N, R102W. The well had a potential of 213 barrels of oil per day, but it was shut in due to lack of market and refining problems created by the relatively high sulfur content of the oil. From 1933 to 1944 oil exploration in the Rangely field consisted only of shallow drill holes. In 1944 active development of the Weber Sandstone reservoir started. The following table shows cumulative production figures for each formation that has produced oil or gas (Colorado Oil and Gas Conservation Commission, 1967)

Currently, oil is produced in the Rangely field from the Weber Sandstone. the Morrison Formation, and the Mancos Shale. At the present time, only the Mancos and the Weber produce oil in the Mellen Hill quadrangle. The Gartra Member of the Chinle Formation produced oil from a well in sec. 15. T2N, R103 W., but the well is now abandoned. During 1966, 314 wells produced 16,212,520 barrels of oil and 22,604,837,000 cubic feet of gas from the Weber Sandstone in the Rangely field (Colorado Oil and Gas Conservation Commission, 1967). Average daily production of the Mancos wells was about 16 barrels of oil; the median value of daily Mancos production was about 8 barrels of oil per well. Only one well, the Pan American Petroleum 1 UPRR (NE1/4NW1/4 sec. 32, T2N, R102 W.), produced from the Morrison in 1966. This well was completed in January 1966 and produced 12,264 barrels of oil and 1,326,000 cubic feet of gas during the year. The following table lists general characteristics of the crude oil from the various formations. No analysis was available for crude oil from the Morrison Formation.

The thickest coal bed occurs in the main coal unit of the Mesaverde Group in the southwestern part of the quadrangle. The coal beds strike northwest and dip 20°-30° southwest. Coal thicknesses in the Mesaverde are variable, and the coal beds do not seem to be as thick as those farther southeast in the adjoining Banty Point quadrangle (Cullins, 1968). The maximum measured coal thickness in the Mellen Hill quadrangle was 6.2 feet, whereas a coal bed as much as 12 feet thick was measured in the Banty Point quadrangle. The only coal bed that can be traced for any appreciable distance along the outcrop is the thick bed at the base of the main coal unit of the Mesaverde Group. The minor coal unit contains thin discontinuous coals no thicker than 2 feet. Locally, a thin (0.6 ft) coal is present at the top of the Castlegate Sandstone.

No coal mines are operating in the map area, and no fresh unweathered samples were available for analysis. The Mesaverde coals in the region are similar in Btu, sulfur, and ash content. In the Rangely 7 1/2-minute quadrangle to the southeast, Gale (1910, p. 196, 197, 250) collected Mesaverde coal samples from a mine in sec. 14, T1N, R102 W. Analyses on an "air-dried" basis indicated a calorific value of 11,080-11,490 Btu; average sulfur content was 0.40-0.46 percent. The coal is classified as high volatile C bituminous (Landis, 1959, p. 150).

Oil shale occurs in the Parachute Creek Member of the Green River Formation in the southwest corner of the quadrangle, and analyses of weathered outcrop oil-shale samples indicate oil yields ranging from 10 to 25 gallons per ton. Somewhat larger yields could reasonably be expected from unweathered shale. The highest grade oil shale occurs in a 175-foot interval of rock above bed m in strata from 5 to 15 feet thick interlayered with leaner oil shale. The strata above bed m are correlative in part with the Mahogany ledge of the Uinta basin. Bed m may be correlative in part with the "B groove", an electric log marker used in the subsurface throughout much of the Piceance Creek basin.

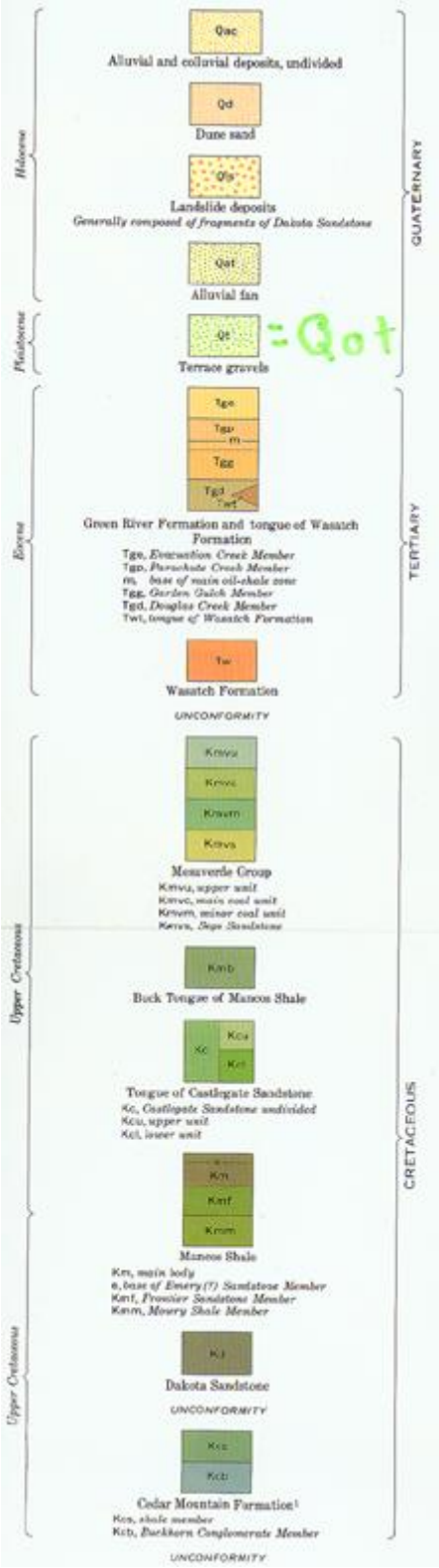
The sodium zeolite analcime (NaAlSi2O6.H2O) occurs upward from the Parachute Creek Member of the Green River Formation into the lower part of the overlying Uinta Formation of late Eocene age. The thickest bed of analcime is 1.4 feet. Analcime is not present in sufficient quantities to be considered economically valuable in the foreseeable future. Dawsonite [Na3Al(CO3)3.2Al(OH)3)] may be present in trace amounts, but X-ray diffraction analyses of 29 samples taken from various parts of the Green River Formation did not reveal its presence.

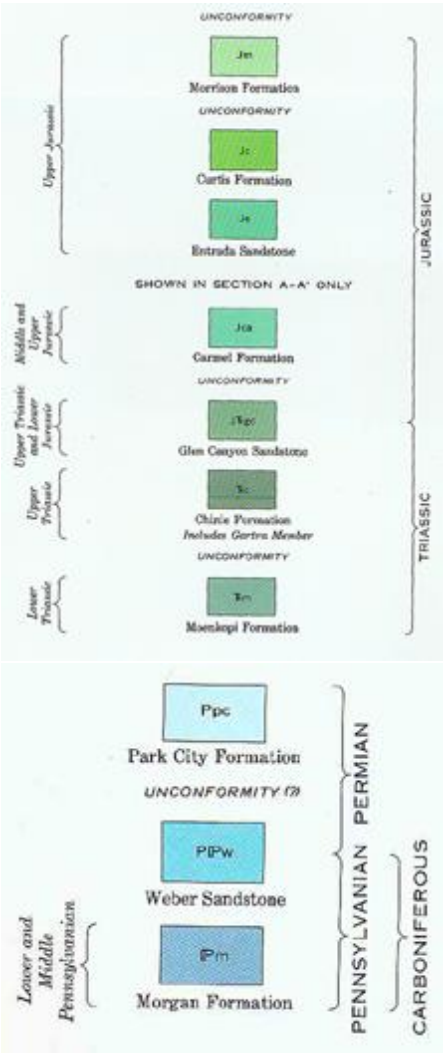
Sand and gravel are obtained from terrace deposits as needed for use on the county roads.

The largest structural feature other than the Rangely anticline is a fault, here named the Blue Mountain thrust fault, in the northern part of the map area. The fault has been discussed briefly by Anderman (1961, p. 103, 104) and his interpretation of it is believed to be essentially correct. The thrust passes into a left lateral fault on the section line between secs. 7 and 18, T3N, R102 W. The fault extends westward out of the map area. The exact location of the surface trace of the thrust fault is conjectural but it probably lies south of the dry hole in sec. 15, T3N, R103 W. Whether or not the fault actually reaches the surface is unknown at this time, but a line of deformed bedding in the Mancos Shale could mark the trace of the fault. Frank Tully (oral commun., 1966) believes that the thrust fault may be of economic significance in that oil or gas may be trapped somewhere along the subthrust plate.

Extracted from: GRI Source Map ID 41 (GQ-835).

Correlation of Map Units





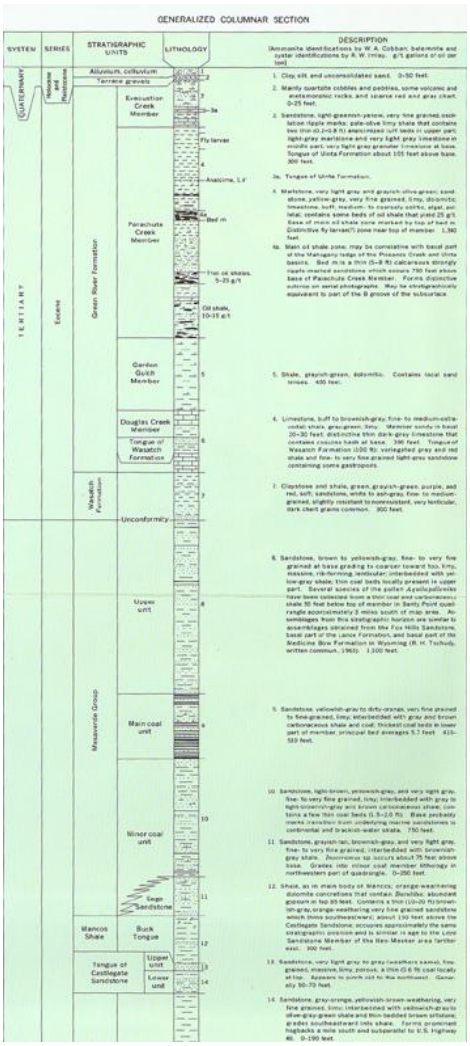
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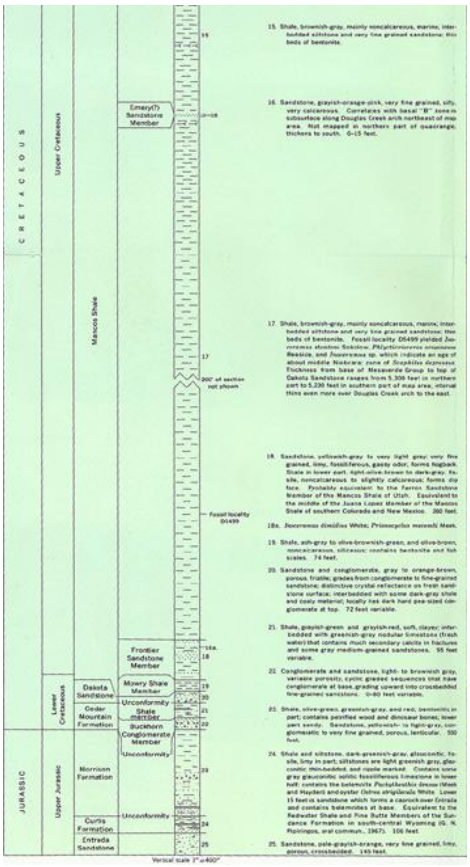
Map Location



Extracted from: GRI Source Map ID 41 (GQ-835).

Columnar Section





Extracted from: GRI Source Map ID 41 (GQ-835).

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Extracted from: GRI Source Map ID 41 (GQ-835).

Geologic Map of the Plug Hat Rock Quadrangle

Rowley, P.D., and Hansen, W.R., 1979, Geologic Map of the Plug Hat Rock Quadrangle, Moffat County, Colorado,U.S. Geological Survey, Geological Quadrangle Map GQ-1514, 1:24,000 scale. (*GRI Source Map ID 42*).

Ancillary Map Notes

SETTING

The Plug Hat Rock quadrangle is south of Dinosaur National Monument, but the north-to-south paved road that crosses the quadrangle is the main access road to the Canyon Section of the Monument (Hansen, 1977a, 1977b, 1977c). The right-of-way of this highway, which is traveled by thousands of tourists annually, is part of the Monument and has several highway overlooks that afford views of the spectacular scenery and geology. The headquarters of Dinosaur National Monument is less than a kilometer (about 0.5 miles) south of the Plug Hat Rock quadrangle. The geology of the Mellen Hill quadrangle to the south, which contains the headquarters, has been mapped and described by Cullins (1969); it contains the northern side of the Rangely oil field, the most productive oil and gas field in Colorado.

ROCK FORMATIONS

The oldest rocks exposed in the Plug Hat Rock quadrangle belong to the red Chinle Formation of Late Triassic age (about 200 million years old), but these rocks found in several canyon bottoms, are rather inaccessible. Most beds of the Chinle were deposited by streams and lakes. Fossil remains of reptiles, amphibians, mollusks, and petrified wood have been found. The buff and red Glen Canyon Sandstone of Late Triassic and Early Jurassic age, the second oldest formation in the mapped area, is well-exposed south of Plug Hat Rock along the main highway. It is barren of fossils, but displays spectacular cross beds that are interpreted as the foreset beds of ancient sand dunes formed under desert or coastal conditions.

The Carmel Formation of Middle Jurassic age (about 155 million years old) forms the red slope at the base of Plug Hat Rock and under the ledges east and west of Plug Hat Rock at about the same elevation. It was deposited in freely circulating shallow marine water, but at times in some places gypsum formed under conditions of water stagnation and evaporation. Fossil pelecypods and echinoderms have been collected from the Carmel in many places west of the quadrangle. The Entrada Sandstone (Middle Jurassic) and the Curtis Member of the Stump Formation (Middle Jurassic) form the cliff of Plug Hat Rock and the rim rocks east and west of Plug Hat Rock. The Entrada closely resembles the Glen Canyon Sandstone and also was deposited largely by eolian processes, although the sands probably were reworked locally by marine water during temporary re-advances of the sea. Both the resistant gray Curtis Member and the overlying soft olive-green-Redwater Member of the Stump Formation (Middle and Upper Jurassic), on the other hand, were deposited by marine water. The Curtis contains sparse pelecypods and furrowed trails made by bottom crawlers, and the Redwater contains locally abundant brachiopods, pelecypods, echinoderms, and cephalopods, especially belemnites.

The soft olive-gray and interbedded red rocks of the Morrison Formation of Late Jurassic age (about 140 million years old) are well displayed in views west and northwest of Plug Hat Rock. The overlying Cedar Mountain of Early Cretaceous age (about 120 million years old) is seen on the lower slopes of Buckwater Ridge. The rocks of both formations were deposited mostly by streams and rivers; in some places, fossil charophytes and ostracods that lived in freshwater lakes or ponds have been found in the Morrison. Far more important paleontologically is the famous dinosaur-bearing bed of the Morrison Formation at Dinosaur Quarry, about 27 km (17 mi.) west-northwest of the quadrangle. Fossil crocodiles, turtles, pelecypods, and silicified wood, in addition to many varieties of dinosaurs, have been collected

from this stream-deposited bed.

Near the end of Cretaceous time the Rocky Mountains began to rise, and the sea drained away for the last time. Less than 40 million years ago, in Tertiary time, sand and gravel debris eroded from the newly formed Uinta Mountains began to accumulate in the adjacent basins and at the flanks of the mountains themselves and eventually attained a thickness of more than 1,000 m (3,000 ft). A broad east-draining valley was formed in the northern part of the mapped area, where the present drainage of Basin Springs Draw and Antelope Draw are located. The Tertiary streams in this valley beveled the Mesozoic rocks and deposited sand and gravel upon the beveled surfaces. Distant volcanoes far outside the area rained ash that was incorporated into the gravel and sand. The exact correlation of the gravel, sand, and ash-fall tuff with rocks elsewhere is uncertain, but probably these materials are equivalent to the Oligocene Bishop Conglomerate. During early and middle Tertiary time, the Bishop Conglomerate was much more extensive than it is now. It must have blanketed an extensive erosion surface cut near the top of the Uinta Mountains. It extended up all the major valleys and filled in and around the high peaks and ridges. The ancestral Green and Yampa Rivers flowed on these deposits and cut down through them to form the deep superposed canyons of the eastern Uinta Mountains (Sears, 1924, 1962; Bradley, 1936; Hansen, 1969a, 1969b; Hunt, 1969).

GEOLOGIC STORY

As the rafter navigates the last few kilometers (2 mi.) of the river in Split Mountain Canyon before landing at Split Mountain Gorge Campground, he quickly passes from the oldest rocks exposed in the Dinosaur Quarry quadrangle through most of the formations exposed in the area. These formations dip steeply southward, along the flank of the Split Mountain anticline, and become increasingly younger southward. During the automobile ride from the campground west and south to the Vernal-Dinosaur Highway (U.S. Hwy 40), the visitor will see most of the younger formations.

The oldest formation exposed in the quadrangle is the Morgan Formation (Middle Pennsylvanian, about 300 m.y. old). It forms the beautiful red cliffs in Split Mountain Canyon and the lower gray slope just below them. The formation was deposited in marine water, mostly on a beach and just offshore in a shallow ocean in which lived bryozoans, brachiopods, echinoderms, fusulinids, and other invertebrates. Overlying the Morgan Formation is the tan or cream-colored Weber Sandstone also of Middle Pennsylvanian age, which forms some of the most spectacular scenery in Dinosaur National Monument, including the imposing pale-gray strike ridge just north of Split Mountain Gorge Campground, and most of Split Mountain itself. In the Dinosaur Quarry quadrangle it displays sweeping crossbeds indicative of a beach and sand dune origin; outside the quadrangle, fossil fusulinids, corals, and brachiopods have been found in interlayered limestone beds. The Park City Formation (Permian age, about 250 m.y. old) consists of gray resistant beds, which occur discontinuously on Split Mountain. It is largely of marine origin, as it contains fossil pelecypods, gastropods, scaphopods, cephalopods, and brachiopods. Rich deposits of phosphate rock, which accumulated where deep cold ocean water welled up to warmer zones or encountered warmer currents, are mined in the Brush Creek area north of Vernal, Utah, for the production of fertilizer.

Depositional conditions fluctuated greatly at the beginning of the Mesozoic Era, and the resulting rocks varied accordingly. Marine water withdrew and re-advanced repeatedly as the shoreline advanced and retreated across the region in response to gentle oscillations of the earth's crust. The red Moenkopi Formation (Lower Triassic, about 220 m.y. old) is a soft unit that was eroded in Quaternary time to form the floors of the strike valleys (valleys parallel to the strike of the bedding) of Red Wash and Cottonwood Wash. It is deposited mostly in a near-shore marine and fresh-water environment. Gypsum beds accumulated in the Moenkopi Formation in times of high aridity, perhaps in a desiccating lagoon. Organisms were rare in that hostile environment, but some marine mollusks and tracks of early reptiles have been found in the formation.

The Gartra Member of the Chinle Formation (Upper Triassic), which forms a narrow strike ridge, was deposited by streams and rivers that meandered across broad piedmont plains; silicified wood is locally abundant. Unlike the Gartra, the main body of the Chinle Formation erodes easily and forms a narrow red strike valley that surrounds Split Mountain. Most beds of the main body were deposited by streams and lakes. Fossil remains of reptiles, amphibians, mollusks, and petrified wood have been found.

The buff and red Glen Canyon Sandstone (Lower Jurassic and Upper Triassic) forms another massive strike ridge surrounding Split Mountain. The Glen Canyon is barren of fossils, but displays spectacular crossbeds that are interpreted as the foreset beds of ancient sand dunes formed under desert or coastal conditions.

The Carmel Formation (Middle Jurassic, about 155 m.y. old) generally forms the floor of another, but narrower, red strike valley. It was deposited in freely circulating shallow marine water, but at times, in some places, gypsum formed under conditions of water stagnation and evaporation. Fossil pelecypods, echinoderms, and gastropods have been collected from the Carmel in many places outside the quadrangle. The Entrada Sandstone (Middle Jurassic) closely resembles the Glen Canyon and also was deposited largely by eolian processes, although the sands probably were locally reworked by marine water during temporary re-advances of the sea. Both the resistant gray Curtis Member and the overlying soft olive-green Redwater Member of the Stump Formation (Upper and Middle Jurassic), on the other hand, were deposited by marine water. The Curtis contains sparse pelecypods and furrowed trails made by bottom crawlers, and the Redwater contains locally abundant brachiopods, pelecypods, echinoderms, and cephalopods, especially belemnites.

The soft gray and multi-colored Morrison Formation (Upper Jurassic) and rocks of the Lower Cretaceous Cedar Mountain (?) Formation mapped with the Morrison form a strike valley that is traversed by the Blue Mountain road several kilometers (1.5 mi.) east of Dinosaur Quarry. Far more important paleontologically is the famous dinosaur-bearing bed of the Morrison Formation at Dinosaur Quarry. This bed was discovered in 1909 by Earl Douglass, a paleontologist from the Carnegie Museum in Pittsburgh. The bed was quarried for dinosaurs mostly from 1909-1923, during which time the quarry reached a length of 120 m (400 ft) and a depth of 20 m (60 ft). Partial or complete fossil skeletons from about 300 dinosaurs, representing 14 species, as well as fossil crocodiles, fresh-water turtles, fresh-water pelecypods, and silicified wood, have been recovered from the quarry (Untermann and Untermann, 1968). Many skeletons still remain. The dinosaurs range from types less than a meter (3 ft) tall to animals that measured more than 25 m (80 ft) long. Most of them were plant feeders, including specimens of armored Stegosaurus as long as 6 m (20 ft) and as tall as 3 m (10 ft), of Apatosaurus (Brontosaurus) as long as 22 m (70 ft) and as tall as 5 m (15 ft), and Diplodocus as long as 25 m (80 ft). Fossil specimens of carnivorous dinosaurs are much less common but include Antrodemus (Allosaurus), which stood on its hind legs and--at about 10 m (30 ft) long--was the reigning predator of its time (Good and others, 1958; Lewis, 1966; Untermann and Untermann, 1968). The dinosaur bed represents low-flow and storm deposits in bars and the channel of an eastward-flowing braided river on a delta plain (Lawton, 1977). The rest of the rocks in the Morrison Formation and rocks mapped with the Morrison likewise were deposited primarily by streams and rivers, but some accumulated in shallow lakes.

The buff Dakota Sandstone (Lower Cretaceous, about 110 m.y. old) forms a narrow strike ridge just south of Dinosaur Quarry and surrounding Split Mountain. It was deposited mainly by streams and rivers; in some places it contains petrified wood. The gray Mowry Member (Lower Cretaceous) of the Mancos Shale, which forms a narrow strike valley, and the buff Frontier Sandstone Member (Upper Cretaceous) of the Mancos Shale, which forms the outermost prominent strike ridge, also are exposed south of Dinosaur Quarry and surrounding Split Mountain. The Mowry is of marine origin, and contains abundant fish bones, fish scales, and occasional ammonites. The Frontier was deposited in near-shore marine water and onshore swamps; it locally contains coal and fossil pelecypods, ammonites, gastropods, and petrified wood. The gray upper shale member (Upper Cretaceous) of the Mancos Shale forms smooth low slopes and badland topography in the southern part of the quadrangle. It contains abundant fossils in

some places, especially cephalopods and oysters that indicate an origin in freely circulating marine waters.

Near the end of Cretaceous time, the Rocky Mountains began to rise, and the sea drained away for the last time. Stream and river sediments were deposited less than 40 million years ago, in Tertiary time, in many nearby areas, but if they were ever deposited in the quadrangle, as seems likely, they have since been removed by erosion. The ancestral Green River flowed on these deposits and cut down through them to form the deep superposed canyons of the eastern Uinta Mountains (Sears, 1924, 1962; Bradley, 1936; Hansen, 1969a, 1969b; Hunt, 1969).

SURFICIAL DEPOSITS

Surficial deposits are unconsolidated or poorly consolidated patchy sediments of Quaternary age (less than a few million years old). These sediments were deposited by the same processes that shaped and continue to shape the scenery of the area--processes of weathering, mass wasting, and erosion and deposition by running water. Landslide deposits, for example, accumulate below steep slopes underlain by soft incompetent rocks, such as shales in the Morrison Formation in the Frontier and Mowry Members of the Mancos Shale, and in the Dakota Sandstone. The huge landslide deposit south of Buckwater Ridge is an impressive example of such failure by downslope movement and is typical of many areas where the Morrison is exposed. Where the road crosses this landslide deposit, the pavement is hummocky and bumpy, either because of continued movement within the slide or because of swelling of bentonitic clays within the Morrison and, thus, within the slide.

Alluvium (Qa) is an abundant surficial deposit that is laid down by streams, most of which, in this area, are small and contain water only after storms. Sand (Qd), mostly in vegetated dunes, is locally abundant. Most of it was derived from and overlies the friable Glen Canyon Sandstone, which itself is mainly of eolian origin.

The broad drainage basin of Basin Springs Draw and related streams in and outside the northern part of the quadrangle is largely underlain by Bishop Conglomerate, which in turn is almost totally mantled by alluvium, colluvium, and slopewash. Bedrock is exposed in few places, and this large flat valley has rounded covered slopes reminiscent of an Appalachian topography and quite unlike the angular features typical of most other arroyos in the quadrangle and in other places of the Intermountain West. This drainage basin is a second cycle valley, having been carved in early Tertiary time prior to and during deposition of the Bishop Conglomerate. Present streams have cut into this ancient topography but have done surprisingly little to modify it.

FAULTS AND FOLDS

Dinosaur National Monument is on the southern flank of the large Uinta anticline, which is about 55 km (35 mi.) wide and stretches more than 240 km (150 mi) from west to east across northeastern Utah and northwestern Colo. This huge fold forms the eastern end of the Uinta Mountains. Along the southern flank of the anticline, the rocks dip southward, each younger formation successively overlies the older, the oldest to the north and the youngest to the south. But this simple pattern is modified in the Plug Hat Rock quadrangle by two plunging folds. The northern fold is here called the Buckwater Ridge syncline. The southern fold is the Willow Creek anticline named by Ritzma (1957), who recognized that this structure is distinct from, though nearly on line with, the Skull Creek anticline to the east. In most places, both the Buckwater Ridge syncline and the Willow Creek anticline are asymmetrical; the latter is almost a monocline.

Asymmetrical folds, notably monoclines, are common elsewhere in the eastern Uinta Mountains. They are considered to have formed by “draping” of the sedimentary rocks across the blocks of the Precambrian basement rocks during vertical offset along deep-seated faults (Cook and Stearns, 1975).

Most such faults have reverse movement and steep to moderate dips. These faults generally die out upward, and most younger overlying rocks are affected by monoclinal or asymmetrical folds. Where these reverse faults die out upward, their dips commonly flatten upward, as recognized by Sanford (1959). Data from exploratory wells drilled for oil in sec. 3, T. 5 N., R. 103 W. given by (Anderman, 1961, fig. 2), and further discussed by Berg (1962), Campbell (1975), and Cullins (1969), indicate that faults--having a dip toward the north as low as 20 degrees--underlies the southern edge of the quadrangle (see cross section) about 2,400 m (7,900 ft) below the surface. The fault is called the Willow Creek Fault by Berg (1962). Displacement along such low-angle reverse faults probably accounts for the folding of the Willow Creek anticline. Similar faults (Campbell, 1975) occur in the Jensen area 30 km (19 mi) to the west.

Some faults in the Precambrian basement rocks of the Uinta Mountains are demonstrably Precambrian in age but have moved repeatedly during subsequent deformations. The two flexures in the quadrangle affect rocks as young as Late Cretaceous, and were formed during Laramide deformation beginning near the end of the Cretaceous Period and continuing into the Tertiary Period.

JOINTS

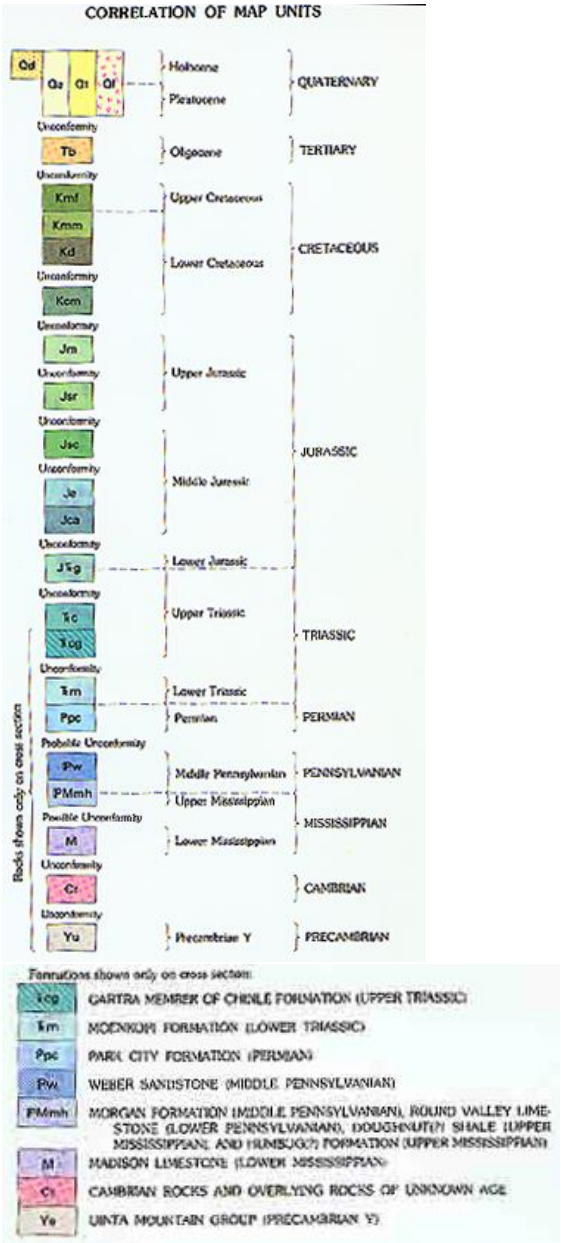
Joints in rocks are fractures that--unlike faults--have had little or no movement. Most rocks in the quadrangle are well jointed but at a scale that is too small to be shown on the map. Some joints in the Glen Canyon Sandstones, however, are large enough to be shown at true scale on the map. Water commonly follows such joints, which, therefore, are the loci of frost heaving, weathering, and erosion that contribute to the development of the scenery in the Dinosaur National Monument area.

CONCLUSIONS

The geology and scenery we see today in the Plug Hat Rock quadrangle are the result of a varied sequence of events that have taken place over 200 million years. The sedimentary rocks were formed by processes of erosion and deposition. Many different depositional environments, some on the continent and some in the ocean, are represented by the rock sequences present today. Faulting and folding in latest Cretaceous and early Tertiary time tilted, bent, and fractured the rocks. Deep erosion of the displaced strata and local deposition of some of the eroded debris since Tertiary time has produced the present scenery. Yet the present spectacular landscape is not an end point, for the processes we know are active in the past will continue in the future. We now witness just a small episode in the overall geologic evolution of this area.

Extracted from: GRI Source Map ID 42 (GQ-1514).

Correlation of Map Units



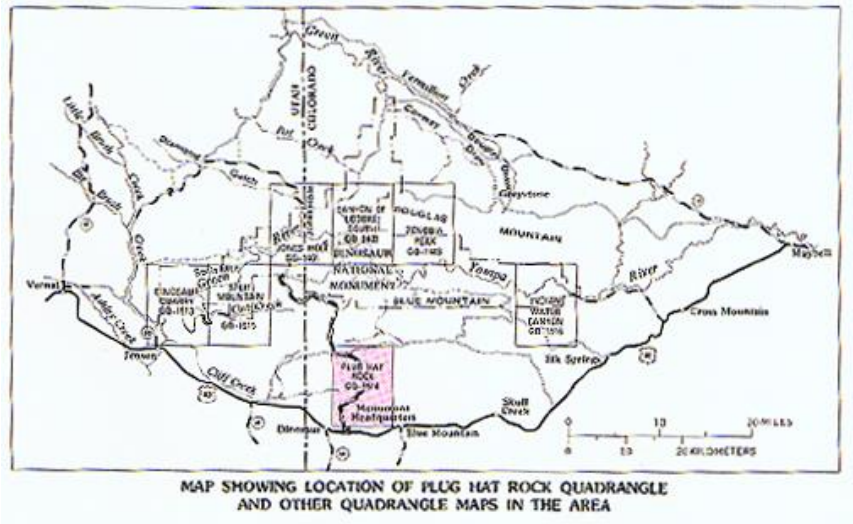
Extracted from: GRI Source Map ID 42 (GQ-1514).

Map Location



Extracted from: GRI Source Map ID 42 (GQ-1514).

Index Map



Extracted from: GRI Source Map ID 42 (GQ-1514).

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Geologic Map of the Split Mountain Quadrangle

Rowley, P.D., and Hansen, W.R., 1979, Geologic Map of the Split Mountain Quadrangle, Uinta County, Utah, U.S. Geological Survey, Geological Quadrangle Map GQ-1515, 1:24,000 scale. (*GRI Source Map ID 43*).

Ancillary Map Notes

SETTING

The Split Mountain quadrangle is in the southwestern part of Dinosaur National Monument on the southeastern flank of the Uinta Mountains. The quadrangle contains some of the most beautiful scenery and least accessible territory in the Monument. With the exception of the road to Rainbow Park Campground and several jeep trails, the northern half of the quadrangle is accessible only by foot, horseback, or boat. Rafting down the Green River has become very popular in the past decade, and thousands of adventurers annually brave the rapids (Hayes and Simmons, 1973). Beautiful Split Mountain Canyon, so named because this deep, river-carved chasm appears to cut the mountain in two, is one of the sights that rafters long remember. Split Mountain Gorge Campground, which is just west of the quadrangle, is the terminus of most raft trips in the Monument.

The famous Dinosaur Quarry, the world's greatest collection site of fossil dinosaurs of Jurassic age, is a half dozen kilometers (several miles) west of the quadrangle boundary. The all-weather paved road that connects the quarry and Split Mountain Gorge Campground to the town of Jensen and U.S. 40 extends east into this quadrangle at a point just west of the attractive valley in which the Daniels Ranch is situated. The pavement ends at the entrance to the Morris Ranch, which is now owned by the Federal Govt. and is maintained by the National Park Service as an example of a turn-of-the-century homestead in an idyllic setting. Colorful Josie Morris, born Josie Bassett, was a well-known figure in early-day Uintah County.

ROCK FORMATIONS

In terms of geologic eras and periods represented by exposed rock formations, Dinosaur National Monument has the most nearly complete stratigraphic record of any park in the National Park System. These formations include rocks of all the systems, from Precambrian to Quaternary except the Ordovician, Silurian, and Devonian (Untermann and Untermann, 1954, 1965, 1968, 1969). Most of these formations, moreover, crop out within the Split Mountain quadrangle. Mesozoic and Paleozoic rocks underlie most of the quadrangle.

GEOLOGIC STORY

The oldest rocks in the Split Mountain quadrangle are visible to the rafter at the axis of the Split Mountain anticline. These belong to the Madison Limestone of Early Mississippian age (about 340 million years old), which makes up the tan jagged cliffs at and above river level in Split Mountain Canyon. These rocks were deposited in a shallow ocean that once covered much of the Western Interior of North America. Fossil corals, echinoderms, brachiopods, pelecypods, and gastropods have been found in this rock unit. The Humbug Formation and Doughnut Shale (Upper Mississippian), next in succession, form the colorful hard and soft beds above the Madison Limestone in Split Mountain Canyon. These two formations were deposited under varied but predominantly near-shore marine conditions. The Doughnut Shale contains a fauna of brachiopods and fish remains in some places in the Uinta Mountains, but it also contains coal (Kinney, 1955; Hansen, 1965). Coal accumulates in fresh-water or brackish-water swamps that are rich in vegetation, and its presence in the Doughnut Shale indicates a short-lived suspension of normal marine conditions.

Marine conditions returned again and deposited the overlying Round Valley Limestone and Early Pennsylvanian age (about 310 million years old). This unit is well-exposed as a gray ledgy slope or multi-tiered cliff along and just above river level at the head of Split Mountain Canyon. Fossil brachiopods, bryozoan, echinoderms, and molluscs have been found in this formation.

The sheer red walls of Split Mountain Canyon, as well as the gray slope just below the red rocks, belong to the Morgan Formation of Middle Pennsylvanian age, which was deposited on a beach and just offshore in a shallow ocean in which lived abundant bryozoans, brachiopods, echinoderms, fusulinids, and other invertebrates. Overlying the Morgan is the tan or cream-colored Middle Pennsylvanian Weber Sandstone, which forms some of the most spectacular scenery in Dinosaur National Monument; it makes up most of Split Mountain and Blue Mountain. In the quadrangle it displays sweeping crossbeds indicative of a beach and sand dune origin; outside the quadrangle, fossil fusulinids, corals, and brachiopods have been found in interlayered limestone beds.

The Park City Formation (Permian age, about 250 million years old) consists of gray resistant beds on the flanks of Split Mountain and Blue Mountain, as well as overlying gray and yellow soft beds that surround these mountains. It is largely of marine origin, as it contains fossil pelecypods, gastropods, scaphopods, cephalopods, and brachiopods. Rich deposits of phosphate rock which accumulate where deep cold ocean water welled up to warmer zones or encountered warmer currents, are mined in the Brush Creek area north of Vernal, Utah, for the production of fertilizer.

Depositional conditions fluctuated greatly at the beginning of the Mesozoic Era, and the resulting rocks varied accordingly. Marine water withdrew and re-advanced repeatedly as the shorelines advanced and retreated across the region in response to gentle oscillations of the earth's crust. The red Moenkopi Formation (Early Triassic, about 220 million years old) is a soft unit that was eroded in Quaternary time to form the floor of the strike valley (a valley parallel to the strike of the bedding) that surrounds Split Mountain and the southern flanks of Blue Mountain. It was deposited mostly in a near-shore marine and fresh-water environment. Gypsum beds accumulated in the Moenkopi Formation in times of high aridity, perhaps in a desiccating lagoon. Organisms were rare in that hostile environment, but some marine molluscs and tracks of early reptiles have been found in the formation.

The Gartra Member of the Chinle Formation (Upper Triassic) forms the resistant outer ridge of the strike valley eroded into the Moenkopi. The Gartra was deposited by streams and rivers that meandered across broad piedmont plains; silicified wood is abundant locally. Unlike the Gartra, the main body of the Chinle erodes easily and form a narrow red strike valley at the foot of Split Mountain. Most beds of the main body were deposited by streams and lakes. Fossil remains of reptiles, amphibians, molluscs, and petrified wood have been found.

The buff and red Glen Canyon Sandstone (Lower Jurassic and Upper Triassic) forms wide strike ridge (a ridge parallel to the strike of the bedding) and prominent cuestas in the southwestern part of the quadrangle. The Glen Canyon is barren of fossils, and displays spectacular crossbeds that are interpreted as the forset beds of ancient sand dunes formed under desert or coastal conditions.

The Carmel Formation (Middle Jurassic, about 155 million years old), generally forms a narrow mostly soft red ribbon of rocks that separates the Glen Canyon Sandstone from the lithologically similar but thinner overlying Entrada Sandstone (Middle Jurassic).The Carmel was deposited in freely circulating shallow marine water, but at times in some places gypsum formed under conditions of water stagnation and evaporation. Fossil pelecypods, echinoderms, and gastropods have been collected from the Carmel in many places outside the quadrangle. The Entrada Sandstone, like the Glen Canyon, also largely by eolian processes, although the sands probably were locally reworked by marine water during temporary re-advances of the sea. The resistant gray Curtis Member of the Stump Formation (Middle Jurassic) forms a thin caprock to the Entrada ledge. It and the ledgy mostly soft olive-green Redwater Member above it partly enclose the valley occupied by Daniels Ranch. Both the Curtis and the Redwater were

deposited by marine water. The Curtis contains pelecypods and furrowed trails made by bottom crawlers, and the Redwater contains locally abundant brachiopods, pelecypods, echinoderms and cephalopods, especially belemnites.

The soft multi-colored Morrison Formation (Upper Jurassic) and the Cedar Mountain Formation which was mapped with the Morrison are exposed in the vicinity of Daniels Ranch. Far more important paleontologically is the famous dinosaur-bearing bed of the Morrison Formation at Dinosaur Quarry (Rowley and others, 1979). This bed was discovered in 1909 by Earl Douglass, a paleontologist from the Carnegie Museum in Pittsburg. The bed was quarried for dinosaurs mostly from 1909 to 1923. Partial or complete fossil skeletons from about 300 dinosaurs, representing 14 species, as well as fossil crocodiles, fresh-water turtles, fresh-water pelecypods, and silicified wood, have been recovered from the quarry (Untermann and Untermann, 1968). Many skeletons still remain. The dinosaurs ranged from types less than a meter (3 feet) tall to animals that measured more than 25 m (80 ft) long. Most of them were plant feeders, including specimens of armored Stegosaurs as long as 6 m (20 ft) and as tall as 3 m (10 ft), of Apatosaurus (Brontosaurus) as long as 22 m (70 ft) and as tall as 5 m (15 ft), and Diplodocus as long as 25 m (80 ft). Fossil specimens of carnivorous dinosaurs are much less common but include Antrodemus (Allosaurus), which stood on its hind legs and --at about 10 m (30 ft) long--was the reigning predator of its time (Good and others, 1958; Lewis, 1966; Untermann and Untermann, 1968). The dinosaur bed represents low-flow and storm deposits in bars and the channel of an eastward-flowing braided river on a delta plain (Lawton, 1977). The rest of the rocks in the Morrison Formation and the Cedar Mountain (?) Formation likewise were deposited primarily by streams and rivers, but some accumulated in shallow lakes.

The resistant buff Dakota Sandstone (Early Cretaceous, about 110 million years old) as well as the soft gray Mowry Member (Lower Cretaceous) and resistant buff Frontier Sandstone Member (Upper Cretaceous) of the Mancos Shale and the soft gray upper shale member (Upper Cretaceous) of the Mancos Shale are exposed only near the western margin of the quadrangle. The Dakota Sandstone was deposited mainly by streams and rivers; in some places it contains petrified wood. The Mowry Member of the Mancos Shale is of marine origin, and contains abundant fish bones, fish scales, and occasional ammonites. The Frontier Sandstone Member of the Mancos Shale was deposited in near-shore marine water and onshore swamps; it locally contains coal and fossil pelecypods, ammonites, gastropods, and petrified wood. The upper shale member contains abundant fossils in some areas, especially cephalopods and oysters that indicate an origin in freely circulating marine water.

Near the end of Cretaceous time, the Rocky Mountains began to rise, and the sea drained away for the last time. Less than 40 million years ago, in early Tertiary time, sand and gravel eroded from the newly formed Uinta Mountains began to accumulate in the adjacent basins and at the flanks of the mountains themselves, and eventually attained a thickness of one thousand meters (several thousand ft). At the flanks of the mountains themselves, upland areas, were beveled by streams and mantled with gravel derived from the crest of the range. Remnants of the resultant surface are preserved on Ruple Point and the Yampa Plateau. The exact correlation of the gravel deposits with rocks elsewhere is uncertain, but their high topographic level and lithology suggest that they are equivalent to the Oligocene Bishop Conglomerate.

During Oligocene time the Bishop Conglomerate was much more extensive than it is now. It must have once blanketed an extensive erosion surface cut near the top of the Uinta Mountains. It extended up all the major valleys and filled in around the high peaks and ridges. The ancestral Green and Yampa Rivers flowed on these deposits and cut down through them to form the deep superposed canyons of the eastern Uinta Mountains (Sears, 1924, 1962; Bradley, 1936; Hansen, 1969a, 1969b; Hunt, 1969).

SURFICIAL DEPOSITS

Surficial deposits are unconsolidated or poorly consolidated patchy sediments of Quaternary age (less

than a few million years old). These sediments were deposited by the same processes that shaped and continue to shape the scenery of the area--processes of weathering, mass wasting, and erosion and deposition by running water. Landslide deposits, for example, accumulate below steep slopes underlain by soft incompetent rocks, such as shales in the Morgan Formation and Morrison Formation. The landslide in Split Mountain Canyon probably formed when the Green River undercut and removed the support of the lower member of the Morgan Formation as well as for other formations.

Gravel and sand currently being transported and deposited by the Green River are mapped as flood-plain and channel deposits (Qfp). As suggested by the name, all such deposits are covered intermittently by the river, especially during early spring run-off or after severe storms; campers on the river should be aware of such potential for flooding. Far more surficial deposits in the quadrangle, however, were deposited by much smaller streams, most of which contain water only after storms. Where stream deposits are sufficiently large, they are mapped separately as alluvium (Qa) and as debris fans at the base of steep channels (Qdf). Where streams and tributaries are small, and form coalescing smooth surfaces of erosion (pediments) or coalescing smooth surfaces of deposition (alluvial fans), the resultant deposits are given a different map symbol. Thus pediments (Qp) are mapped where the bedrock is soft and easily eroded, as in the Morrison Formation in the vicinity of Daniels Ranch, and the drainage is at grade; talus and alluvial fan deposits (Qt) occur below cliffs, such as along the Green River. In some places, similar surfaces and the deposits on them are graded to former higher stream levels above and dissected by present streams; these deposits are somewhat older, and have been mapped separately (Qop). River terrace deposits (Qr) are remnants of former flood plains left behind as the river cut downward; these deposits also are being dissected by present streams.

The origin of side-stream surficial deposits has important implications for the rafter and camper. Alluvium, fan deposits, talus deposits, and pediment deposits largely resulted from torrential runoff following storms. The size of fans is about proportional to the size of the drainage area of the streams that deposit them and to the volume of the flash flood in that drainage area . Some debris fans in the canyon of the Green River may have accumulated in large part during one storm. All major rapids on the Green and Yampa Rivers in Dinosaur National Monument are at the toes of debris fans; thus when rafting upon rough water, almost invariably an arroyo enters from the left or right. Some lesser rapids, however, lie below landslides. Some debris fans are large enough to force the river to the opposite side of its canyon, where it may undercut a cliff and create talus cones and hazards from falling rock. The rapids at the mouth of Warm Springs Draw--perhaps the worst rapids in Dinosaur National Monument and about 17 km (11 mi) east-northeast of the quadrangle--were formed June 10, 1965, when a flash flood deposited a great volume of bouldery debris in the river; rockfall from the facing Warm Springs Cliff added to the deposit (Hayes and Simmons, 1973). Such flash floods are common in Dinosaur National Monument and boaters camped on debris fans, including many small ones that are not mapped, should recognize the potential danger.

Sand (Qd), mostly in vegetated dunes, is locally abundant. Most of it was derived from and overlies the friable Glen Canyon Sandstone, which itself is mainly of eolian origin.

FAULTS AND FOLDS

Dinosaur National Monument is on the southern flank of the large Uinta anticline, which is about 55 km (35 mi) wide and stretches more than 240 km (150 mi) from west to east across the northeastern Utah and northwestern Colorado. This huge fold forms the eastern end of the Uinta Mountains. Along the southern flank of the anticline the rocks dip southward, each younger formation successively overlying the next older, the oldest to the north and the youngest to the south. But this simple pattern is modified in the Split Mountain quadrangle by two major west-plunging folds, the Split Mountain anticline and the Jensen syncline, both named by Schultz (1918). The Jensen syncline also has been called Daniels Draw syncline (Kinney, 1955). The Split Mountain anticline is a symmetrical fold, one of the few in the eastern Uinta Mountains, while the Jensen syncline is asymmetrical, consisting of a steeply dipping

northern limb and a gently dipping southern limb.

In the eastern part of the mapped area, the crest of the Split Mountain anticlines modified by a synclinal crinkle, termed here the Moonshine Draw syncline, and thus the anticline branches into two parallel flanking anticlines, called here the Ruple Point anticline to the north and the Bear Hollow anticline to the south. The Bear Hollow anticline is the eastern extension of the Split Mountain anticline. Still farther east, near the Colorado state line, it passes into the anticlinal bend of the large Yampa monocline. The Moonshine Draw syncline is a very tight, asymmetrical, almost monoclinal fold, containing a gently dipping north limb and a very steeply dipping south limb. The change of dip south of the axis is so abrupt that Untermann and Untermann (1954, 9165, 1968, 1969) erroneously attributed it to a fault, which was inferred to extend westward along the southern flank of the syncline.

Asymmetrical folds, notably monoclines, are common elsewhere in Dinosaur National Monument and the eastern Uinta Mountains, where they are considered to have formed by “draping” of the sedimentary rocks across blocks of the Precambrian basement rocks during vertical offset along deep-seated faults (Cook and Stearns, 1975). Most such faults have reverse movement and steep to moderate dips. These faults generally die out upward, and most younger, overlying rocks are affected by monoclinal or asymmetrical folds. Where these reverse faults die out upward, their dips commonly flatten upward, as recognized by Sanford (1959). Data from exploratory wells drilled for oil on the southern side of the Section Ridge anticline (Campbell, 1975), about 14 km (9 mi) west-southwest of the quadrangle, and also on the southern side of the Willow Creek anticline (Anderman, 1961, fig. 2; Berg, 1962; Cullins, 1969; Rowley and Hansen, 1979), about 20 km (12 mi) southeast of the quadrangle indicate that faults--having dips toward the north as low as 20 degrees--underlie the southern limbs of these anticlines. Displacement along such low-angle reverse faults probably is responsible for the anticlinal folding. The Split Mountain anticline geometrically resembles the Section Ridge and Willow Creek anticlines and may likewise be the product of reverse faulting at depth.

Some faults in the Precambrian basement rocks of the Uinta Mountains are demonstrably Precambrian in age but have moved repeatedly during subsequent deformations. The folds in the quadrangle affect rocks as young as Late Cretaceous, and were formed during Laramide deformation beginning near the end of the Cretaceous Period and continuing into the Tertiary Period.

The Island Park fault, first mapped by Schultz (1918), displaces the northern flank of the Split Mountain and Ruple Point anticlines. It clearly is related in origin to the sharp flexure of the northern limbs of both these folds, for it parallels the strike of the limbs. It probably is the surface expression of a large fault at depth that produced these anticlines. In this quadrangle, however, the fault appears to have no more than about 100 m of displacement at the surface, “down” to the north, in the same sense as the much larger amplitude of the fold. Thus, almost all the displacement is by folding, and the Island Park fault accounts for very little of it. At great depth below the surface, however, it is likely that most offset resulted from faulting.

JOINTS

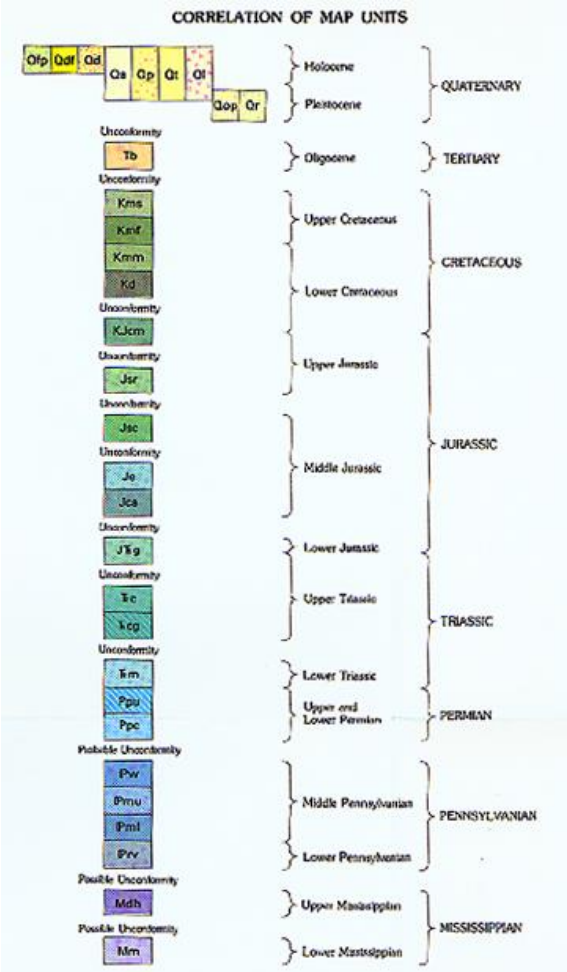
Joints in rocks are fractures that--unlike faults--have had little or no movement. Most rocks in the quadrangle are well jointed, but at a scale that is too small to be shown on the map. Some joints in the Weber and Glen Canyon Sandstones, however, are large enough to be shown at true scale on the map. Most joints shown are extension fractures related in origin to folding and uplift of the eastern end of the Uinta Mountains. Water commonly follows such joints, which, therefore, are the loci of frost-heaving, weathering, and erosion that contribute to the development of the scenery in the Dinosaur National Monument area.

CONCLUSIONS

The geology and scenery we see today in the Split Mountain quadrangle are the result of a varied sequence of events that have taken place over about 300 million years. The sedimentary rocks were formed by processes of erosion and deposition. Many different depositional environments, some on the continent and some in the ocean, are represented by the rock sequences present today. Faulting and folding in latest Cretaceous and early Tertiary time tilted, bent, and fractured the rocks. Deep erosion of the displaced strata and local deposition of some of the eroded debris since Tertiary time has produced the present scenery. Yet the present spectacular landscape is not an end point, for the processes we know were active in the past will continue in the future. We now witness just a small episode in the overall geologic evolution of this area.

Extracted from: GRI Source Map ID 43 (GQ-1515).

Correlation of Map Units



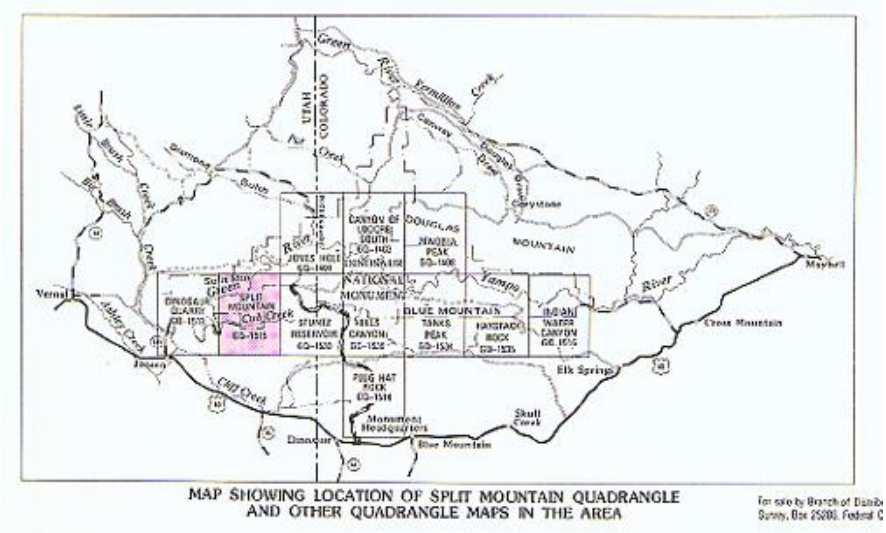
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Map Location



Extracted from: GRI Source Map ID 43 (GQ-1515).

Index Map



Extracted from: GRI Source Map ID 43 (GQ-1515).

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Extracted from: GRI Source Map ID 43 (GQ-1515).

Geologic Map of the Stuntz Reservoir Quadrangle

Hansen, W.R., and Rowley, P.D., 1980, Geologic Map of the Stuntz Reservoir Quadrangle, Utah-Colorado,U.S. Geological Survey, Geological Quadrangle Map GQ-1530, 1:24,000 scale. (*GRI Source Map ID 44*).

Ancillary Map Notes

TECTONIC HIGHLIGHTS

Large-scale geologic events are well documented in the Stuntz Reservoir quadrangle of the eastern Uinta Mountains. Huge deformed crustal blocks have surface expression in sharply asymmetrical anticline, synclines, and monoclines. Evidence from nearby areas shows that these folds pass downward and laterally into reverse faults. Cases in point are the Yampa monocline and Red Rock anticline, both well exposed within the quadrangle. As expressed by outcrops of the Park City Formation (Pp) and Weber Sandstone (PNw), the Yampa monocline flexurally displaces its south limb, the Blue Mountain block, about 425 m upward relative to its north limb, the Pearl Park block, without surface rupture. But a few km to the east, the Yampa monocline breaks along its lower limb and passes into the large low-angle Yampa fault.

The Red Rock anticline is a sharp carinate fold that increases in amplitude and complexity from east to west. It appears to have resulted from the structural accommodation of the Weber Sandstone (PNw) to the crowding of adjacent crustal blocks during Laramide uplift. A specific explanation is offered by Cook and Stearns (1975). Just north of Vivas Cake Hill, the nearly vertical south limb of the fold is so tightly flexed that some investigators have taken it to be faulted, although there is no discernible bedding offset anywhere along its length. The Trail Draw syncline (cross sections B-B' and C-C'), which bounds the Red Rock anticline on the north, branches into two troughs just north of the quadrangle, and the more northerly branch eventually passes on strike into the Mitten Park reverse fault in the Canyon of Lodore South quadrangle (Hansen, 1977). The Red Rock anticline is presumed to be faulted at depth as inferred on the cross sections.

The very asymmetrical Section Ridge anticline in the southern part of the quadrangle similarly increases in amplitude to the west; in adjacent quadrangles, its steep south limb forms the imposing escarpment of Cliff Ridge. It has no surface rupture, although it probably breaks at depth. All the faults indicated at depth on cross sections A-A' and B-B' are conjectural, both in attitude and throw.

The flattish upland surface over much of the Stuntz Reservoir quadrangle is a consequence of middle to late Cenozoic geomorphic and tectonic processes. This surface, truncating rocks of widely differing ages, is correlated with the Gilbert Peak erosion surface of the north flank of the Uinta Mountains, a very extensive mid-Tertiary pediment first described by Bradley (1936, p. 163, 199). In the Stuntz Reservoir quadrangle, the surface was once completely mantled with Bishop Conglomerate (Tb), but that formation has since been partly stripped away, leaving only irregular patches. Stuntz Ridge, in the southeast part of the quadrangle, stands above the old surface as a monadnock, and never was covered by the conglomerate.

The composition of the Bishop Conglomerate (Tb) indicates that the main source of its constituents was far to the north in the crestal part of the eastern Uinta Mountains, although deposits remaining south of Stuntz Ridge reached their present site somewhat circuitously from the west, having had to pass around the ridge. Large boulders of red quartzite, some exceeding 2 m in diameter, were derived from the Uinta Mountain Group (Yu) and must have traveled 15-30 km or more from their bedrock source. The gradient of the surface, therefore, must have been north to south, across the present canyons of the Green and Yampa Rivers, and sufficiently steep to enable the transport of very coarse debris long distances. The present rivers and canyons obviously did not exist at that time.

The erosion surface, steepest close to the crest of the range, must have flattened gradually southward, with a concave upward profile. Its original southward slope in the Stuntz Reservoir area, which is far south of the former crestline, may have been on the order of 12 m/km if gradients on other pediments are indicative. A profile of the Gilbert Peak erosion surface on the north flank of the Uinta Mountains plotted by Bradley (1936, p. 174 and fig. 21) for an area that he regarded as essentially undeformed, has a slope ranging from about 69 m/km near the crest of the range to 10 m/km near the basinward limit of the surface. An initial southward slope of 12 m/km for the Stuntz Reservoir profile, therefore, is probably minimal.

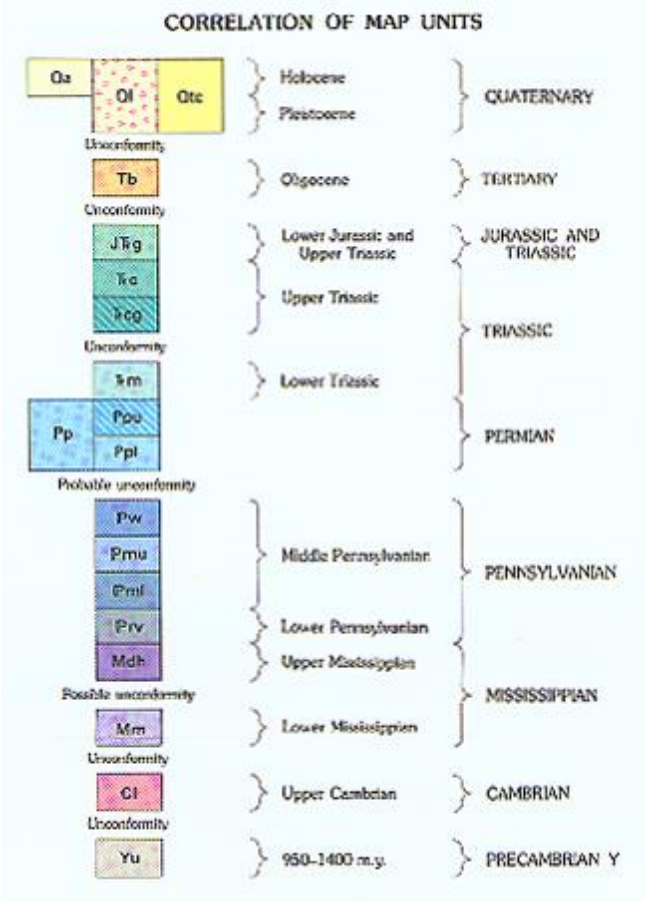
The present slope of the erosion surface, however, is in the opposite direction, to the north, and if minor irregularities are disregarded, is about 16 m/km (cross section C-C'). The surface, therefore, had to have been tilted tectonically toward the north after the Bishop Conglomerate (Tb) was deposited, as noted previously (Hansen, 1965, p. 164; 1969, p. 121). If the initial southward slope was 12 m/km, the amount of tilt has been on the order of 28 m/km. That order of tilt would amount to differential warping of about 784 m in 28 km, the distance from the north end of the adjacent Jones Hole quadrangle to the south end of the Stuntz Reservoir quadrangle. Total warping exceeded that amount, inasmuch as it extended north and south beyond the limits of those two quadrangles.

Tilting was related to the late Cenozoic gravitative collapse (that is, tectonic subsidence) of the eastern part of the Uinta anticline, as first noted by Powell (1876, p. 201, 205), and since confirmed by many other geologists. Collapse effectively destroyed the old crestline, led to a southward shift of the drainage divide, and ultimately, to the cutting of the great canyons of the Green and Yampa Rivers.

Tilting and collapse accompanied renewed tectonic activity that began in the eastern Uinta Mountains before, but culminated after, deposition of the Browns Park Formation in adjacent areas (Hansen, 1965, p. 171-174). The minimum age of this formation, based on a single K-Ar radiometric dating of glass from a vitric tuff, is less than 11.8 +/- 0.4 million years (G.R. Winkler, written commun., 1970; sample collected by Winkler in Browns Park valley 45 km north of the quadrangle, and dated by P.E. Damon). A zircon fission-track age of 9.1 +/- 1.0 was measured by C.W. Naeser for a tuff sample collected high in the formation just north of Dinosaur National Monument near the mouth of Vermillion Creek, also north of the Stuntz Reservoir quadrangle (cited by Izett, 1975, p. 187). A tuff bed near the base of the formation has a K-Ar radiometric age (biotite) of about 25 m.y. (Izett and others, 1970, p. C150). In all probability, the widespread tilting on the south flank of the eastern Uinta Mountains is appreciably younger than 9 million years.

Extracted from: GRI Source Map ID 44 (GQ-1530).

Correlation of Map Units



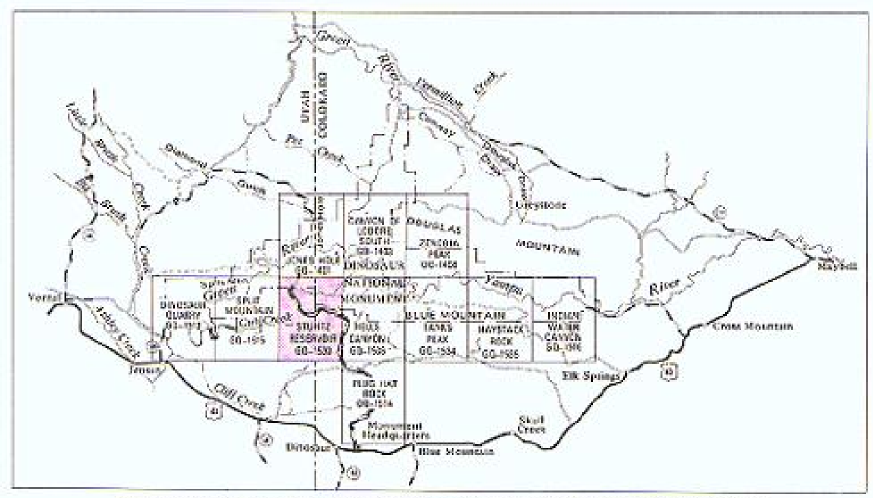
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Map Location



Extracted from: GRI Source Map ID 44 (GQ-1530).

Index Map



INDEX MAP SHOWING LOCATION OF STUNTZ RESERVOIR QUADRANGLE

Extracted from: GRI Source Map ID 44 (GQ-1530).

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Extracted from: GRI Source Map ID 44 (GQ-1530).

Geologic Map of the Tanks Peak Quadrangle

Hansen, W.R., and Carrara, P.E., 1980, Geologic Map of the Tanks Peak Quadrangle, Moffat County, Colorado,U.S. Geological Survey, Geological Quadrangle Map GQ-1534, 1:24,000 scale. (*GRI Source Map ID 45*).

Ancillary Map Notes

GEOLOGIC HIGHLIGHTS

STRUCTURE

The geologic structure of the Tanks Peak quadrangle is rather simple and straightforward, but it is grandly exposed in cliffs and canyon walls. The dominant structural element is the faulted Yampa fold which, in this area, is a very asymmetrical anticline, although in some places along its length is a monocline. It is one of several large subordinate structures on the south flank of the main Uinta anticline (Rowley, Tweto, and Hansen, 1978). The Yampa fold trends nearly east to west a distance of at least 85 km. On the east, it arises near Elk Springs, Colo. To the west, it passes into the Split Mountain anticline near Vernal, Utah. The crestline of the fold undulates gently along its length, but it culminates near the east boundary of the Tanks Peak quadrangle where the highest point on the Cambrian-Precambrian contact is about 2,330 m (7,640 ft) above sea level. This point is also the structural culmination of the entire Blue Mountain highland, which is the broad upland between the escarpment of the Yampa fold on the north and U.S. Highway 40 on the south.

In the Tanks Peak quadrangle, the structural relief on the Yampa fold is about 1,000 m. This figure is a measure of the vertical displacement of beds across the Yampa fault; the stratigraphic section exposed high on the flanks of Tanks Peak and Marthas Peak is dropped down and re-exposed to the north in Yampa Canyon (cross section A-A'). Formations such as the Weber, Park City, Moenkopi, and Chinle are preserved on the down-dropped block but have been stripped away by erosion on the upthrown block, as has part of the Morgan Formation.

OLD VALLEY FILLS

Remnants of Bishop Conglomerate of Oligocene age partly fill the bottoms of old Tertiary valleys in the southern part of the quadrangle. The Bishop in that area consists of very poorly sorted friable conglomeratic sandstone derived mostly from local source rocks. The fills in the valleys were tributary to a large fill that graded eastward down the valley of Wolf Creek. All these valleys are now being exhumed by modern drainage, but the distribution of Bishop remnants give some idea of the former extent of the fills. Note the remnants of Bishop Conglomerate at the head of Johnson Draw. Johnson Draw, draining north across the Yampa fold into the Yampa River, has reversed the flow direction of its headwaters, which formerly flowed south into Wolf Creek. A low divide now separates Johnson Draw from Wolf Creek. Note also the barbed pattern of the headwater tributaries and the deep canyon where Johnson Draw crosses the Yampa fold. Late Tertiary tilting to the north (Hansen and Rowley, 1979) probably helped trigger the drainage reversal.

LANDSLIDES

Surficial deposits are overshadowed by outcrops of bedrock in the landscape of the quadrangle, but they are noteworthy of themselves and add distinctive qualities to the appearance of the terrain. Landslides and (or) colluvium are abundant, especially along the outcrops of the lower member of the Morgan Formation and the Doughnut-Humbug interval. These stratigraphic sequences contain incompetent shales that are very vulnerable to landsliding.

The complex landslide in the west-central part of the quadrangle involves failure in several formations and lateral translations of material along the steep, faulted limb of the Yampa fold. In the western part of the slide, blocks of rock derived from the Madison, Humbug, Round Valley, and Morgan Formations have moved hundreds of meters en masse. In the central and eastern parts, rotated blocks of Glen Canyon Sandstone are such that they resemble outcrops of bedrock. Strong topographic relief and incompetent rocks along the fault zone promoted sliding, probably enhanced by a former wetter climate. Most of the slide appears to be inactive, and some parts of it are strongly dissected. Other parts of the landslide, however, apparently are still moving, especially in the vicinity of The Seeps. An earthflow lobe once extended several hundred meters beyond the main body of the slide into Bull Canyon and nearly filled the upper end of the canyon, but the canyon is now largely re-excavated.

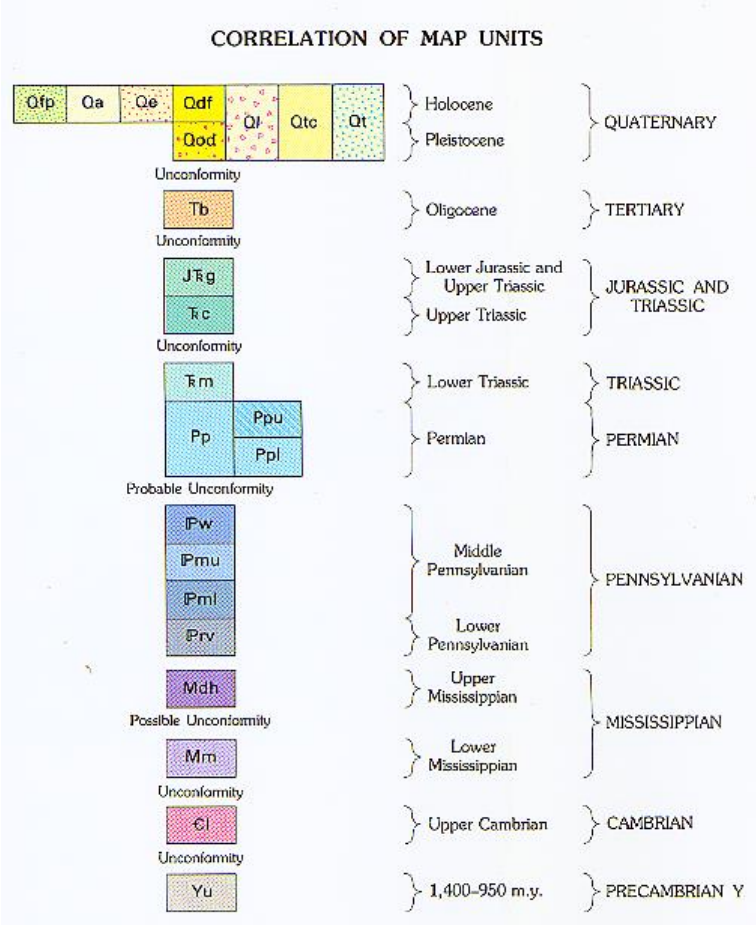
Landslides above the Yampa River in the northeast part of the quadrangle also appear to be intermittently active. Big Joe rapid, at the mouth of Starvation Valley, is caused chiefly by debris flushed out of Starvation Valley by flash floods, but landsliding on the opposite side of Yampa Canyon adds to the rapid. The slide in the extreme northeast corner of the quadrangle is part of a group of large dip-slope failures that extend along the north side of Yampa Canyon into adjacent quadrangles.

CANYON SCENERY

Yampa Canyon is one of the great river gorges of the West. In this quadrangle, the canyon scenery is dominated by the Weber Sandstone, with its picturesque array of rimrocks, cliffs, tors, alcoves, side ravines, and box canyons. In one of the most impressive landmarks in Dinosaur National Monument, the full thickness of the Weber is exposed in a smooth-faced doubly concave overhanging cliff 330 m high, undercut by the Yampa River and aptly called the “Grand Overhang” by river runners. This cliff is in an area of deeply entrenched gooseneck meanders in the northwest corner of the quadrangle at grid coordinates 4483.5 N., 680500 E., below Harding Hole. Upstream from Harding Hole, the canyon cuts down through older rocks of diverse lithology and bedding; consequently, the canyon aspect is very different, and the meander pattern is less regular, both in radius of curvature and geometry, than it is in the Weber Sandstone. The oldest rock exposed in the canyon bottom is the Madison Limestone. It and each succeeding formation lend expression to the diversity of the canyon scene.

Extracted from: GRI Source Map ID 45 (GQ-1534).

Correlation of Map Units



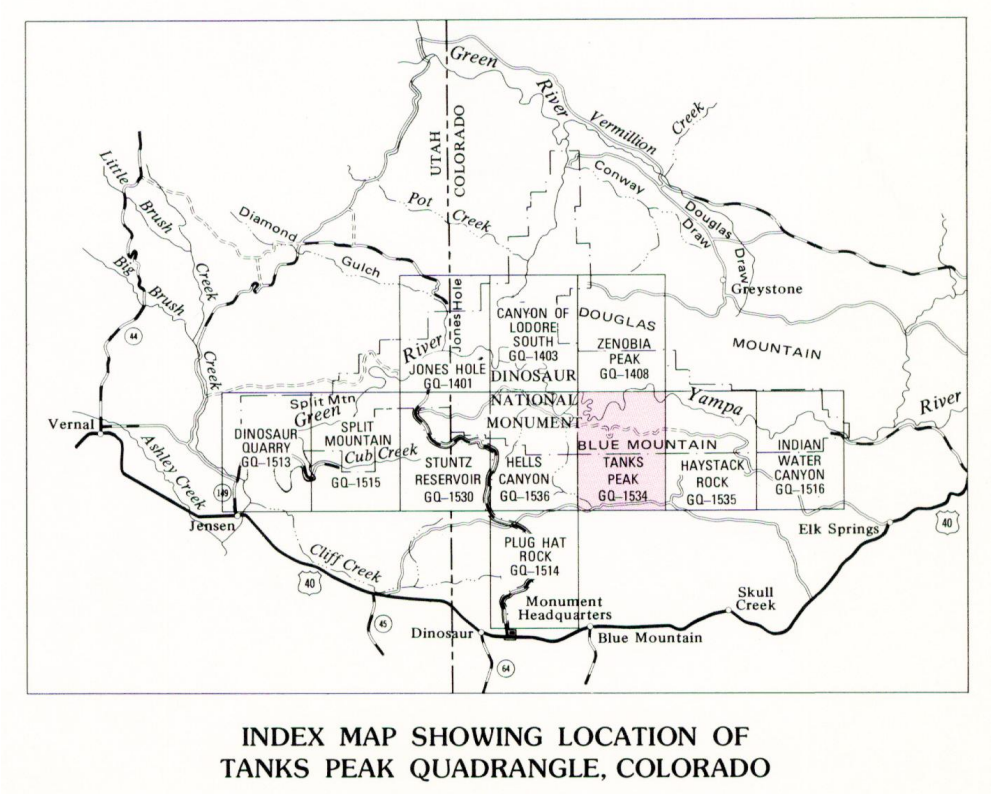
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Map Location



Extracted from: GRI Source Map ID 45 (GQ-1534).

Index Map



INDEX MAP SHOWING LOCATION OF
TANKS PEAK QUADRANGLE, COLORADO

Extracted from: GRI Source Map ID 45 (GQ-1534).

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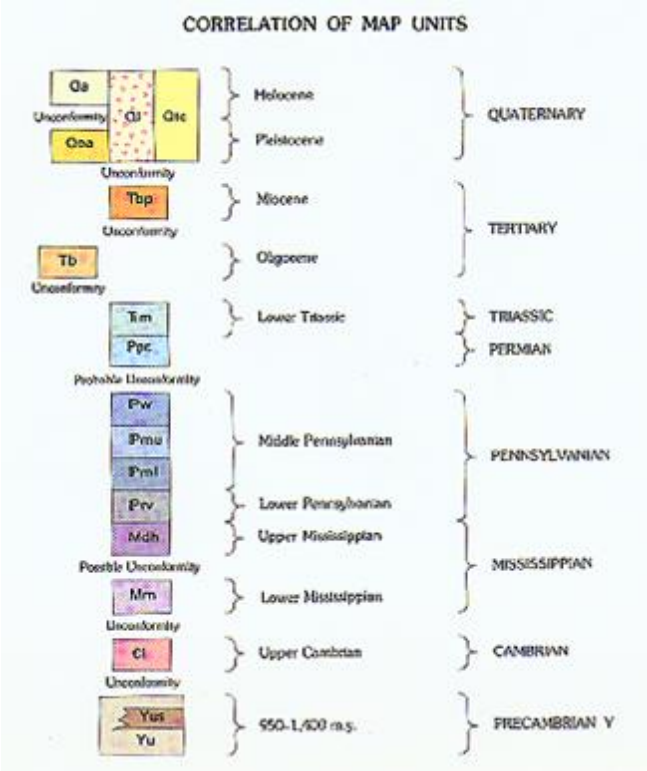
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Geologic Map of the Zenobia Peak Quadrangle

Hansen, W.R., 1977, Geologic Map of the Zenobia Peak Quadrangle, Moffat County, Colorado,U.S. Geological Survey, Geological Quadrangle Map GQ-1408, 1:24,000 scale. (*GRI Source Map ID 46*).

Ancillary Map Notes



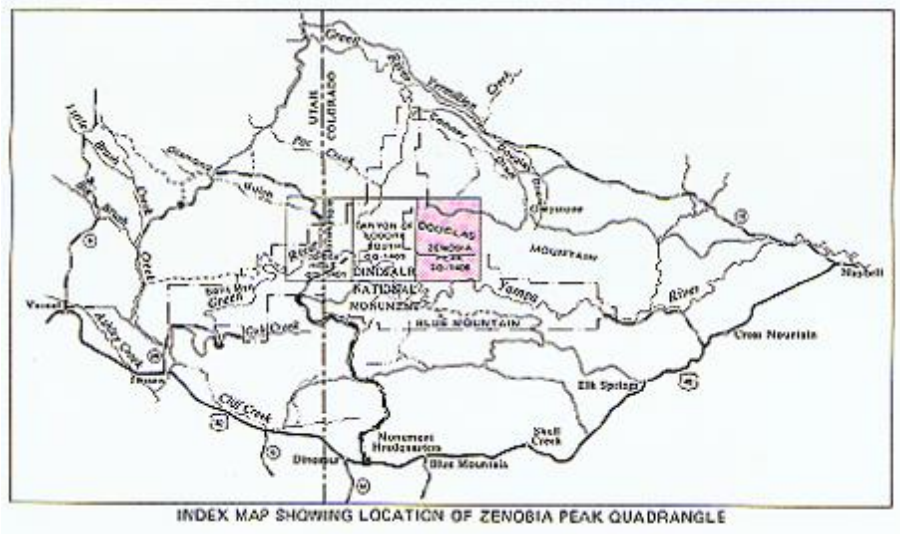
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Map Location



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Index Map



INDEX MAP SHOWING LOCATION OF ZENOBIA PEAK QUADRANGLE

Extracted from: GRI Source Map ID 46 (GQ-1408).

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Geologic Map of the Elk Springs Quadrangle

Dyni, J.R., 1968, Geologic Map of the Elk Springs Quadrangle, Moffat County, Colorado,U.S. Geological Survey, Geological Quadrangle Map GQ-702, 1:24,000 scale. (*GRI Source Map ID 1545*).

Ancillary Map Notes

ECONOMIC GEOLOGY

The mineral resources of the Elk Springs quadrangle include oil and gas, coal, sand and gravel, and water. There has been some prospecting for uranium in the area. Cross Mountain Canyon is a potential site for a dam which would create a large reservoir in the Yampa River valley east of the canyon.
Gas was discovered in the Dakota Sandstone in the Elk Springs-Winter Valley oil and gas field in the 1920's. However, the field did not start producing until the discovery of oil in the Weber Sandstone in 1946. Two wells currently produce oil of 30° API gravity from the Weber; total cumulative oil production from the field through 1965 was 506,020 barrels. Four wells completed for gas production from the Dakota are shut in for lack of a pipeline and a market.

The north half of the quadrangle is structurally more complex and may be worthy of additional oil and gas exploration. Possible deep faulting beneath the Browns Park Formation along the north flank of Elk Springs Ridge may provide structural traps for oil and gas. Elsewhere in the quadrangle possibilities for production include lenticular gasbearing sandstones in the Mesaverde Group and in the Wasatch Formation and oil-bearing fractured zones in the Mancos Shale similar to those in the Rangely field about 20 miles southwest of the quadrangle. A small oil seep associated with uranium near Elk Springs is noted below.

Three coal zones in the Cretaceous Mesaverde Group include a thin economically unimportant lower zone near the base of the Iles Formation, a middle zone containing coal beds as much as 11 feet thick at the base of the Williams Fork Formation, and an upper zone containing coal beds as much as 10 feet thick in the upper half of the Williams Fork Formation. Several prospects and a few small mines were opened years ago, but no commercial-scale coal operations have existed in the quadrangle. Strippable coal may be present in parts of 't. 5 N., R. 98 W., and T. 4 N., Rs. 97 and 98 W. One particularly favorable locality is in the E1,2 sec. 35, T. 5 N., R. 98 W., where a coal bed, 9.7 feet thick, dips eastward beneath relatively thin cover.

Several gravel pits, chiefly in the basal conglomerate of the Browns Park Formation, have been opened along U.S. Highway 40 for road construction. The gravel contains considerable amounts of cobbles and small boulders. Sand is abundant in the Browns Park Formation and in the alluvium of the Yampa and Little Snake River valleys.

Many bulldozer prospecting trenches were dug for uranium in the upper white crossbedded sandstones of the Browns Park Formation in the vicinity of Elk Springs during the 1950's. All the trenches on the map were checked with a scintillometer but only one trench just west of Continental Oil Co. well 5 in the NEt/t sec. 30, T. 5 N., R. 98 W., indicated anomalous radioactivity. A scintillometer reading of lOx background was obtained on a small patch of oil-saturated sandstone in the west end of the trench. A radiometric and chemical analysis of a 2-foot channel sample yielded 0.010 percent eU and 0.009 percent U, respectively.

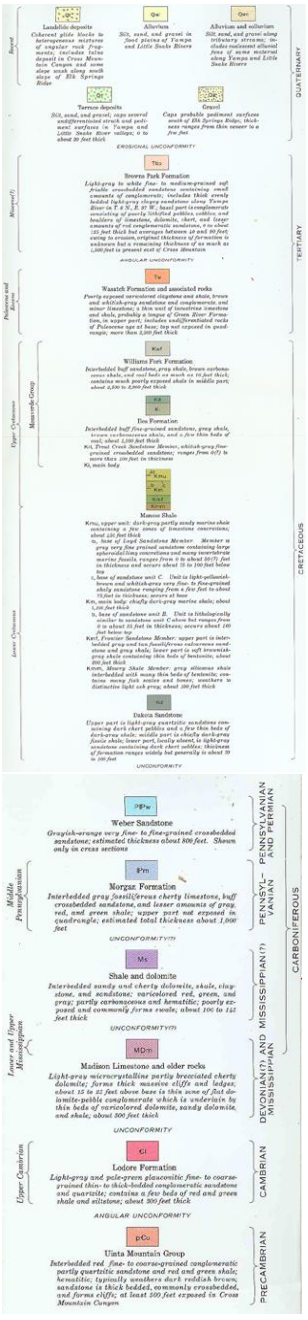
Many years ago a few prospect pits were dug presumably for copper in the Lodore and Morgan Formations on Cross Mountain. Owing to abundant glauconite, the Lodore has a greenish cast that evidently encouraged prospecting for copper.

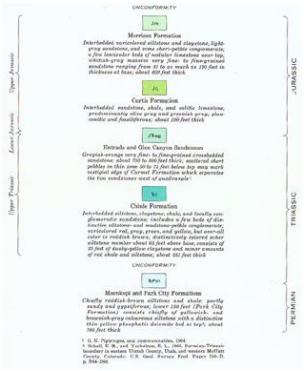
Adequate supplies of ground water for stock and domestic use can be found at relatively shallow depths

in alluvium in many of the stream valleys in the quadrangle. Large quantities of ground water are available in the Browns Park Formation south and east of Cross Mountain at depths of several hundred feet.

Extracted from: GRI Source Map ID 1545 (GQ-702).

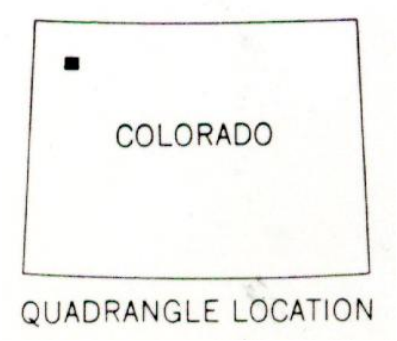
Correlation of Map Units





Extracted from: GRI Source Map ID 1545 (GQ-702).

Map Location



Extracted from: GRI Source Map ID 1545 (GQ-702).

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