UTAH GEOLOGICAL SURVEY
UTAH DEPARTMENT OF NATURAL RESOURCES
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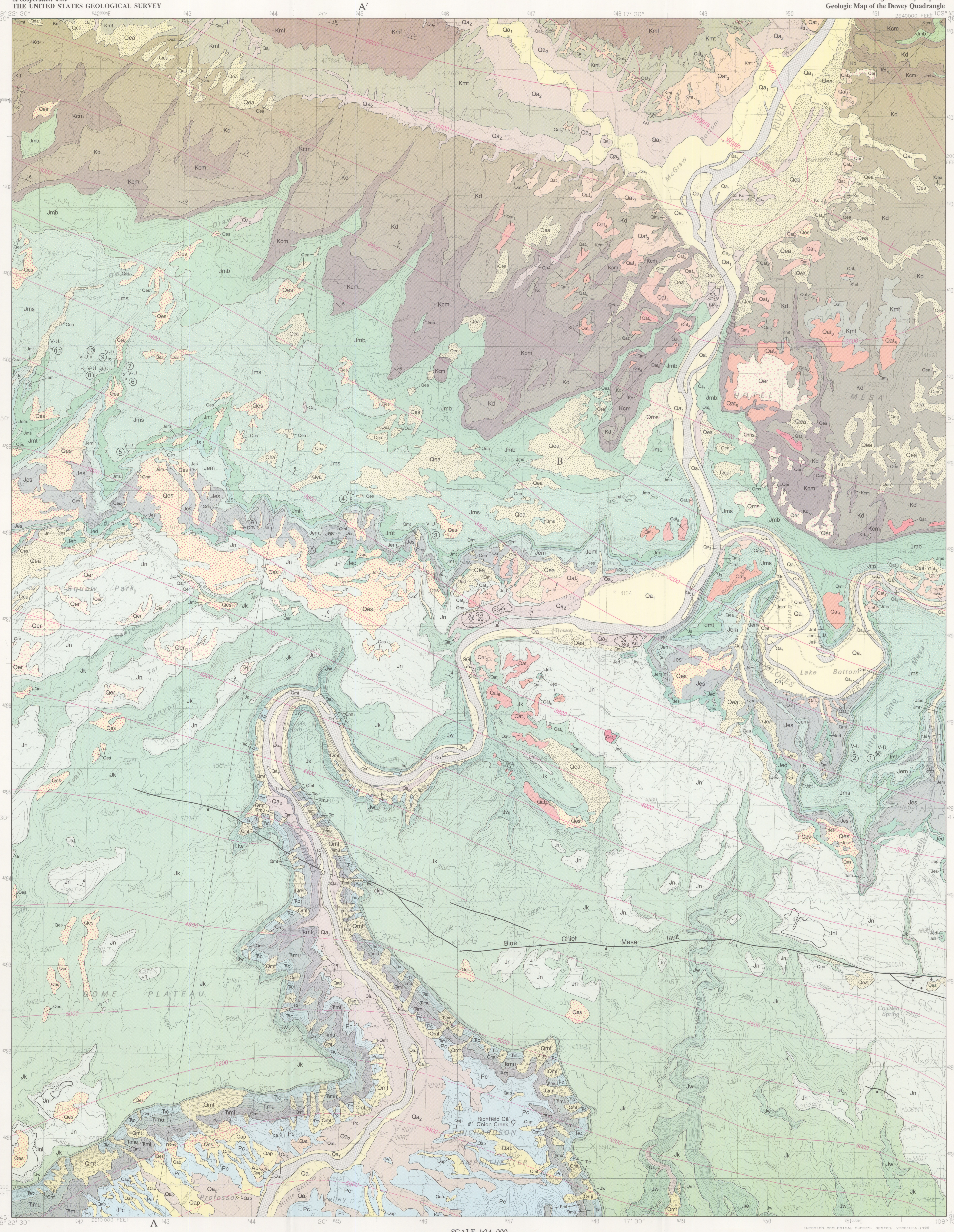
Plate 1
Utah Geological Survey Map 169
Geologic Map of the Dewey Quadrangle

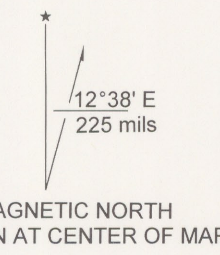


Base map from U.S. Geological Survey Dewey, Utah Provisional Edition Quadrangle, 1985.

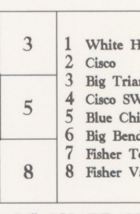
SCALE 1:24 000

CONTOUR INTERVAL 40 FEET

Field work completed 1992-94.
Cartography by Patricia H. Speranza.



1996 MAGNETIC NORTH
DECLINATION AT CENTER OF MAP.



QUADRANGLE LOCATION

1	2	3	1 White House 2 Cisco 3 Big Triangle 4 Cisco SW 5 Blue Chief Mesa 6 Big Bend 7 Fisher Towers 8 Fisher Valley
4		5	
6	7	8	

ADJOINING 7.5′ QUADRANGLE NAMES

GEOLOGIC MAP OF THE DEWEY QUADRANGLE, GRAND COUNTY, UTAH

by

Hellmut H. Doelling

1996

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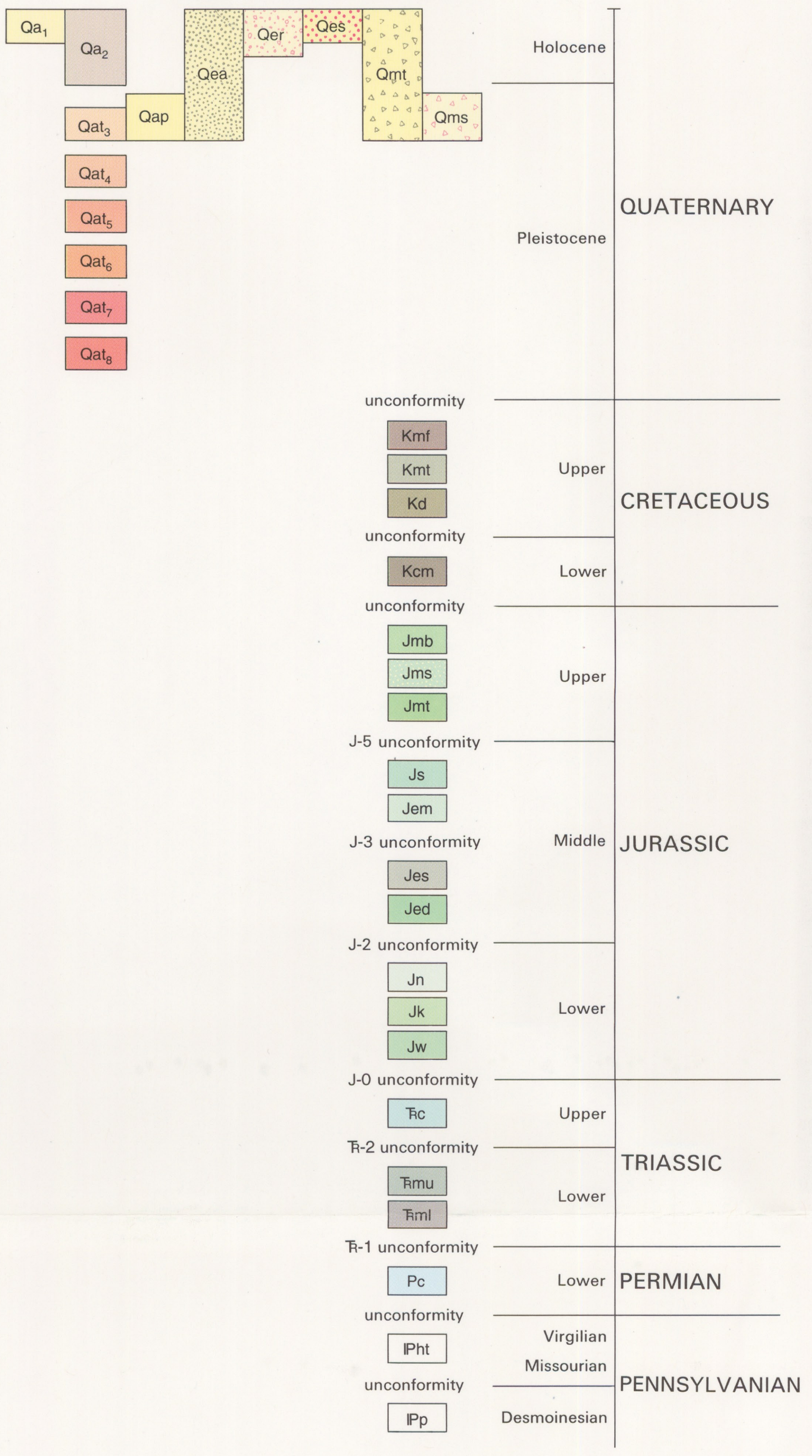
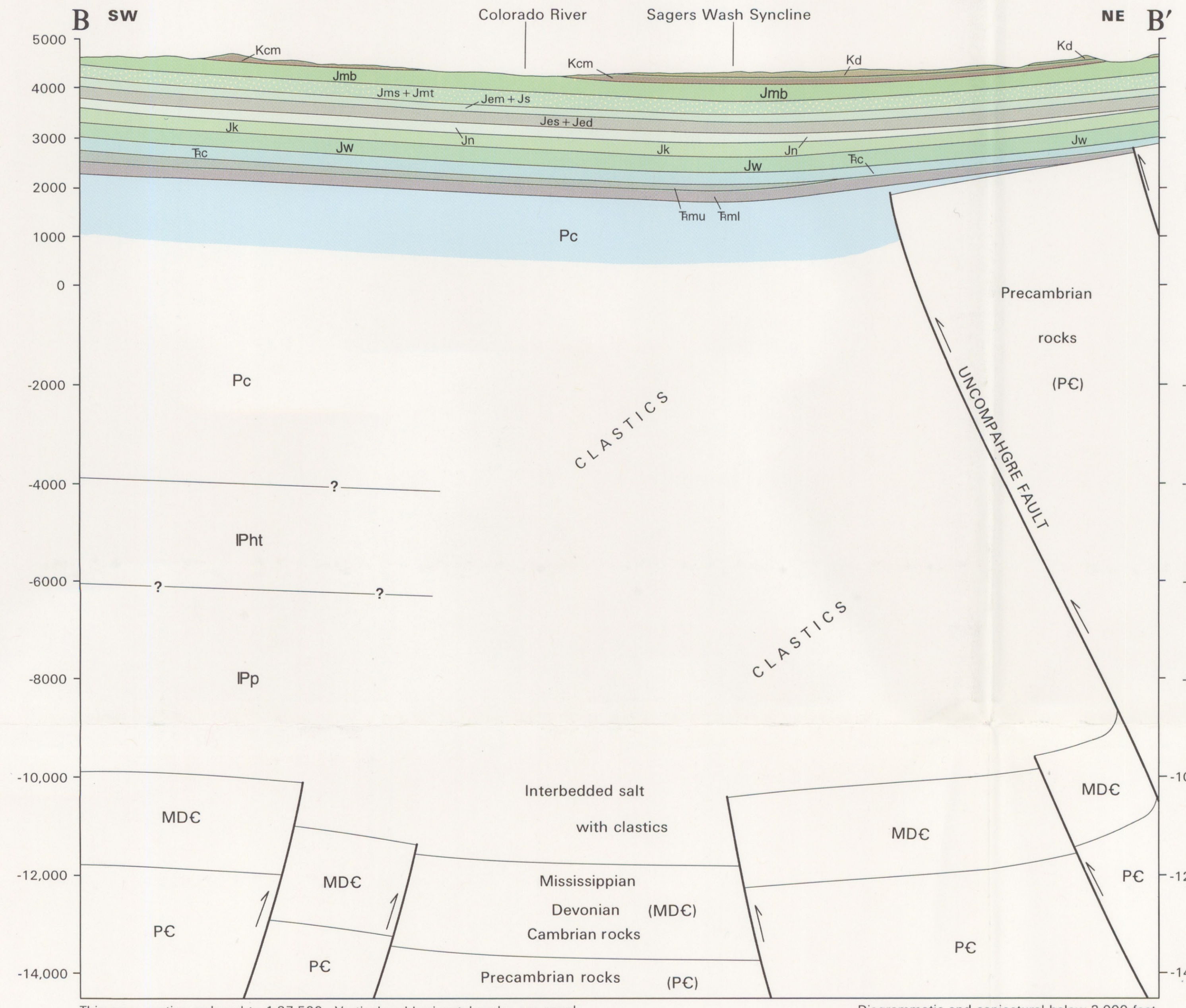
CORRELATION OF MAP UNITS



MAP SYMBOLS

- Contact - dashed where approximately located
- Fault - dotted where concealed, bar and ball on downthrown side
- 19 Strike and dip of bedding
- Trace of axial surface of syncline
- Au Prospect - principal commodity designated (gold)
- 4 V-U Adit - principal commodities designated (vanadium-uranium); circled numbers referenced in text
- Cu Mine - principal commodity designated (copper)
- SG Sand and gravel pit
- SG Large sand and gravel pit
- Au Large gold placer pit
- Plugged and abandoned oil or gas test well
- 4200 Structure contour - 200-foot (61-m) interval developed on base of Wingate Sandstone
- A Arch

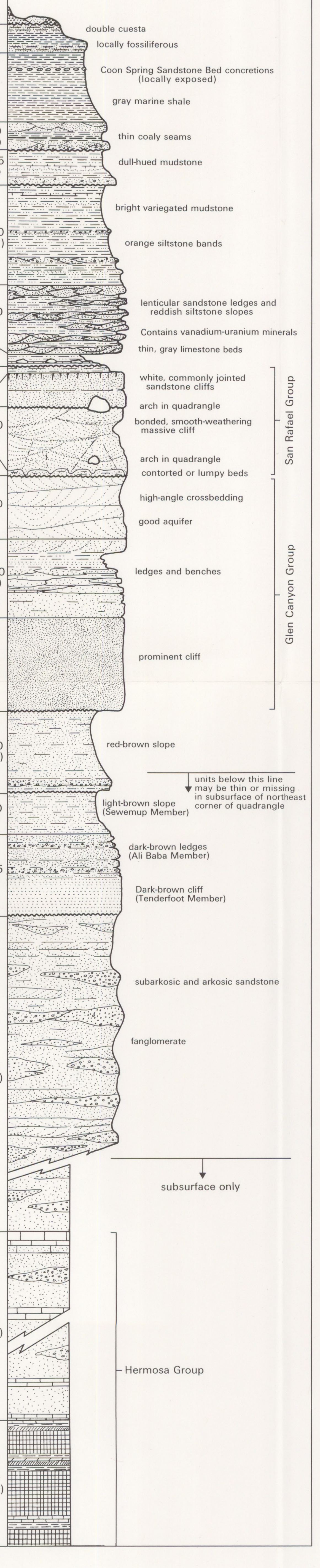


This cross-section reduced to 1:37,500. Vertical and horizontal scales are equal. Quaternary units not shown on cross-section.

Diagrammatic and conjectural below 3,000 feet, follows model of White and Jacobsen, 1983.

PERIOD	EPOCH	FORMATION AND MEMBERS		SYMBOL	THICKNESS feet (meters)
Quaternary	Holocene Pleistocene	Surficial deposits		Q	0-50 (0-15)
CRETACEOUS	Upper	Mancos Shale	Ferron Sandstone Member	Kmf	~90 (~27)
			Tununk Shale Member	Kmt	~220 (~67)
		Dakota Sandstone		Kd	80-100 (24-30)
	Lower	Cedar Mountain Formation		Kcm	100-115 (30-35)
JURASSIC	Upper	Morrison Formation	Brushy Basin Member	Jmb	290-350 (88-107)
			Salt Wash Member	Jms	190-250 (58-76)
			Tidwell Member	Jmt	38-48 (12-15)
	Middle	Summerville Formation		Js	25-45 (7-14)
		Entrada Sandstone	Moab Member	Jem	70-140 (21-43)
			Slick Rock Member	Jes	180-220 (55-67)
			Dewey Bridge Mem.	Jed	0-35 (0-11)
	Lower	Navajo Sandstone		Jn	180-220 (55-67)
		Kayenta Formation		Jk	240-280 (73-85)
		Wingate Sandstone		Jw	~300 (~91)
TRIASSIC	Upper	Chinle Formation		TRc	250-350 (76-107)
	Lower	Moenkopi Formation	upper member	TRmu	110-280 (34-85)
			lower member	TRml	250-265 (76-81)
PERMIAN	Lower	Cutler Formation		Pc	~5,000 (~1,524)
PENNSYLVANIAN	Virgilian Missourian	Honaker Trail Formation		IPht	~4,000 (~1,219)
	Desmoinesian	Paradox Formation		IPp	5,000+ (1,524+)

LITHOLOGY



DESCRIPTION OF MAP UNITS

Qa_1 — Alluvium -- *Gravel, sand, silt, and mud deposits along the Colorado River and along the larger rivers and washes. 0-20 feet (0-6 m) thick.*

Qa_2 — Alluvium and older alluvium -- *Mostly sand, with considerable mud, silt, and gravel deposited by rivers, ephemeral streams, sheet wash, and by debris flows; mixed with smaller amounts of colluvial and eolian deposits; contains both locally and distantly derived materials. 0-40 feet (0-12 m) thick.*

Qat_3, Qat_4, Qat_5, Qat_6, Qat_7, Qat_8 — Terrace deposits -- *Gravel, sand, and silt, mostly from metamorphic and igneous terranes deposited by the ancestral Colorado River, Dolores River, and from sedimentary terranes deposited by Sagers Wash; ancestral Colorado and Dolores River deposits coarser than those of Sagers Wash. 0-20 feet (0-6 m) thick.*

Qap — Pediment-mantle deposits -- *Poorly sorted, sand, silt, and matrix-supported, angular to subangular sandstone clasts; locally contains lenses of sand and/or clast-supported boulders; clasts range from pebble to boulder size; deposits are locally derived and have an orange-red-purple shading; detritus deposited as a relatively thin veneer on uneven pediment surfaces; mixed alluvial fan, ephemeral stream, colluvial, and eolian processes; deposit age is same or slightly younger than Qat_3 deposits. 0-30 feet (0-9 m) thick.*

Qes — Eolian sand deposits -- *Generally fine- to medium-grained quartzose sand forming accumulations of sand sheets and small dunes. Especially prominent in protected areas in the vicinity of the Entrada Sandstone. 0-30 feet (0-9 m) thick.*

Qea — Mixed eolian and alluvial deposits -- *Moderately well- to very well-sorted sand, silt, sandstone fragments, and local gravel; eolian component generally more abundant than alluvial component, although locally the alluvial may exceed the eolian component; commonly present on older surfaces in areas of limited alluvial influence; gradational with Qes and Qa_2. 0-20 feet (0-6 m) thick.*

Qer — Mixed eolian and residual deposits -- *Rubbly deposits of sandstone or limestone clearly derived from underlying bedrock unit; mixed with red silt and yellow, fine- to medium-grained, generally well-sorted sand. 0-2 feet (0.6 m) thick.*

Qmt — Talus deposits and colluvium -- *Very poorly sorted, angular boulders and smaller sized materials on, and at the base of, steep slopes; derived from resistant overlying units; small deposits are not mapped; thickness varies 0-35 feet (0-9 m).*

Qms — Landslide deposits -- *Very poorly sorted boulder- to clay-sized material on slopes, with hummocky upper surfaces; also slumps and large, slightly rotated blocks of the parent bedrock unit; large enough to map only where derived from the Brushy Basin Member of the Morrison Formation. Minimum and maximum thicknesses not determinable.*

Mancos Shale

Kmf — Ferron Sandstone Member -- *Medium- to dark-gray, interlayered mudstone and shale, and pale- to medium-gray-brown, medium- to very fine-grained sandstone; small pods or concretion-like bodies of calcareous, fine-grained sandstone mark the base; unit forms two cuestas of fine-grained sandstone and siltstone, divided by an interval of dark, carbonaceous fissile to laminated shale; bivalves, trace fossils, and calcite-cored concretions are locally present; has ripple laminations, sole marks, and a gradational upper contact; lower cuesta, middle dark shale, and upper cuesta each about 30 feet (9 m) thick. About 90 feet (27 m) thick.*

Kmt — Tununk Shale Member -- *Light- to dark-gray, brown-gray, or black mudstone, siltstone, and shale; weathers to lighter shades; contains several 0.5- to 2-inch (1-5 cm) thick layers of white to light-gray bentonite and a few dense, thin, very fine-grained sandstone beds; trace fossils are locally common; contains Coon Spring Sandstone Bed, identified by large, rounded, light brown sandstone concretions in the upper third of the Tununk; the Coon Spring Sandstone Bed is poorly displayed in the Dewey quadrangle and best developed in the area north of McGraw Bottom. About 220 feet (67 m) thick.*

Kd — Dakota Sandstone -- *Pale-yellow-orange, yellow-gray, or gray, fine- to coarse-grained, quartz sandstone, conglomeratic sandstone and conglomerate; yellow-gray to dark-gray mudstone, claystone, and siltstone; medium- to dark-gray carbonaceous shale or mudstone; and very thin coal seams; lower part is medium- to thick-lensed and generally cross-bedded sandstone, conglomeratic sandstone, and conglomerate; clasts in the conglomerate are generally less than 2 inches (5 cm) in diameter; middle part contains most of the mudstone, claystone, siltstone, carbonaceous shale and coal; upper part is fine- to medium- grained, cross-bedded sandstone; upper contact is a sharp, irregular surface; upper and lower parts are resistant and cliff forming, middle part is generally non-resistant; thicknesses of three parts vary dramatically across the quadrangle. 80-100 feet (24-30 m) thick.*

Kcm — Cedar Mountain Formation -- *Variegated, slope-forming mudstone interbedded with ledge-forming, gray and brown quartzite and sandstone, conglomerate, and gritstone; mudstone mostly light green, gray, lavender, and white; contains local resistant, light-gray limestone nodules that litter the slopes; upper contact at base of irregular and channel-fill sandstone and conglomerate of the overlying Dakota Sandstone; lower part is generally a cliff-forming quartzite, sandstone, or gritstone. 100-115 feet (30-35 m) thick.*

Morrison Formation

Jmb — Brushy Basin Member -- *Interbedded silt and clay mudstone and muddy sandstone; commonly banded maroon, orange, green, gray, and lavender; forms steep slope with slight ledges that are more numerous in the lower part; locally contains small, light-gray, resistant, limestone nodules. 290-350 feet (88-107 m) thick.*

Jms — Salt Wash Member -- *Interbedded sandstone and mudstone; sandstone is light to yellow gray, medium to coarse grained, cross-bedded in lenses as much as 25 feet (7.5 m) thick, and resistant; mudstone is generally red with less common green horizons, and forms slopes. 190-250 feet (58-76 m) thick.*

Jmt — Tidwell Member -- *Red, lavender, and brown siltstone containing thin, nodular, gray, hard limestone beds and local large concretions of white chalcedony and quartz; slope forming. 38-48 feet (11.5-14.5 m) thick.*

Js — Summerville Formation -- *Interbedded sandstone and silt stone; sandstone is white, yellow gray, or light brown, fine to medium grained, thin to medium bedded, forms an especially resistant ledge with ripple marks near top of unit; siltstone is mostly red, some green gray, and forms partings between sandstone beds and is found in thick, indistinctly bedded intervals; unit forms a ledgy steep slope. 25-45 feet (7-14 m) thick; thinner in western half of quadrangle.*

Entrada Sandstone

Jem — Moab Member -- *Pale-orange, gray-orange, pale-yellow-brown, or light-gray, fine- to medium-grained, calcareous, massive, cliff-forming sandstone; upper surfaces prominently jointed; sucrosic weathering. 70-140 feet (21-43 m) thick.*

Jes — Slick Rock Member -- *Red-orange or light-brown, very fine- to fine-grained eolian sandstone; calcareous and iron oxide cemented; cross-bedded, massive, weathers to form smooth cliffs and bare rock slopes; commonly covered with residual sand; not as resistant as Moab Member above, but more resistant than Dewey Bridge Member below; common "stonepecker" holes and commonly color banded; deep alcoves have formed along upper contact with Moab Member. 180-220 feet (55-67 m) thick.*

Jed — Dewey Bridge Member -- *Dark-red, fine-grained, silty sandstone; mostly iron oxide cemented; in irregular contorted, indistinct "lumpy" medium to thick beds; upper contact with Slick Rock Member is very irregular. 0-35 feet (0-11 m) thick.*

Jn — Navajo Sandstone -- *Orange to light-gray, eolian sandstone, mostly fine grained, cemented with silica and calcite; crops out as vertical cliffs in deep canyons and as domes and rounded knolls elsewhere; well displayed, high-angle cross beds; contains local thin, hard, gray carbonate beds (Jnl). 180-220 feet (55-67 m) thick; may thin to 100 feet (30 m) in the subsurface under the northeast corner of the quadrangle.*

Jk — Kayenta Formation -- *Moderate-orange-pink, red-brown, and lavender sandstone interbedded with subordinate dark-red-brown to gray-red silty mudstone, lavender-gray intraformational conglomerate, and limestone of fluvial or lacustrine origin; light-orange, light-gray, or white eolian sandstone beds become more prominent in upper third of unit; commonly micaceous; mostly calcite cemented; resistant, forms thick step-like ledges between the more massive Navajo and Wingate Sandstones; upper part less resistant, important bench former in quadrangle. 240-280 feet (73-85 m) thick.*

Jw — Wingate Sandstone -- *Mostly light-orange-brown, moderate-orange-pink, or moderate red-orange, fine-grained, well-sorted, cross-bedded sandstone; calcareous and siliceous cement; forms nearly vertical cliffs along canyon walls; cliff surfaces commonly with dark-brown desert varnish veneer. About 300 feet (91 m) thick.*

TRc — Chinle Formation -- *Moderate-red-brown or gray-red, fine- to coarse-grained sandstone and siltstone with subordinate pebble- or gritstone, and gray limestone; slope-forming with prominent ledges; slope-forming units fine grained and indistinctly bedded; ledge formers are fine to coarse grained, and platy to very thick bedded; strong ledge of sandstone or pebble conglomerate near base underlain with mottled siltstone. 250-350 feet (76-107 m) thick, thinning northeasterly; may be as thin as 100 feet (30 m) in subsurface in northeast corner of the quadrangle.*

Moenkopi Formation

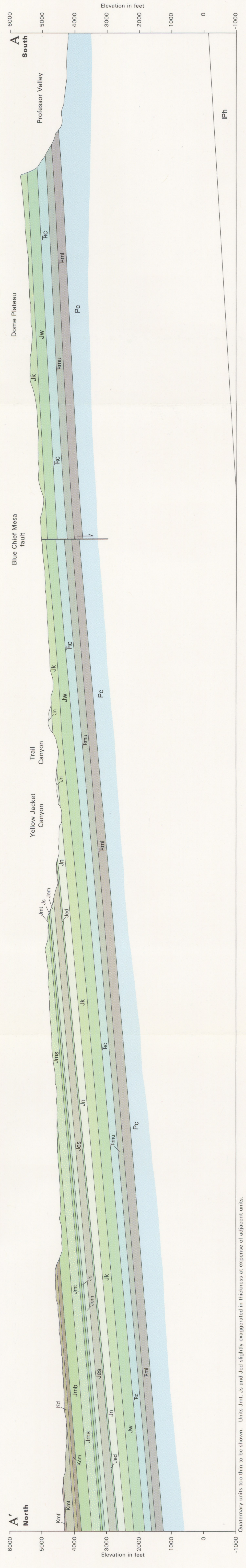
TRmu — Upper member -- *Pale-red-orange to gray-red, slope-forming siltstone with subordinate red-brown, fine-grained sandstone; thinly laminated to thin bedded; commonly cemented with gypsum; sandstone is commonly ripple marked; forms slope. 110-280 feet (34-85 m) thick; thinning to northeast; may be missing in subsurface in northeast corner of quadrangle.*

TRml — Lower member -- *Upper part is dark red-brown and lavender, silty, mica- and feldspar-bearing, platy to thick-bedded, commonly ripple-marked, ledge-forming sandstone and conglomeratic sandstone interbedded with slightly darker red-brown to red-orange, slope- and recess-forming sandstone, siltstone, and silty mudstone (Ali Baba Member); lower part slightly lighter red-brown, fine-grained, micaceous and feldspar-bearing, thick bedded to massive, and cliff-forming sandstone (Tenderfoot Member). 250-265 feet (76-81 m) thick along outcrops; may be missing under northeast corner of quadrangle.*

Pc — Cutler Formation -- *Red-brown and red-purple, subarkosic to arkosic sandstone, conglomeratic sandstone, and conglomerate interbedded with silty and sandy mud stone and shale; thin bedded to massive; forms steep slopes, ledges, and cliffs. About 5,000 feet (1,524 m) thick in southeast corner of quadrangle; maximum of 800 feet (244 m) exposed in quadrangle.*

IPht — Honaker Trail Formation -- *Interbedded micaceous sandstone, conglomerate and limestone. Unit in subsurface only. About 4,000 feet (1,219 m) thick in Richfield Oil Onion Creek Unit #1, NE1/4, SW1/4, section 31, T. 23 S., R. 24 E., in southeast corner of quadrangle.*

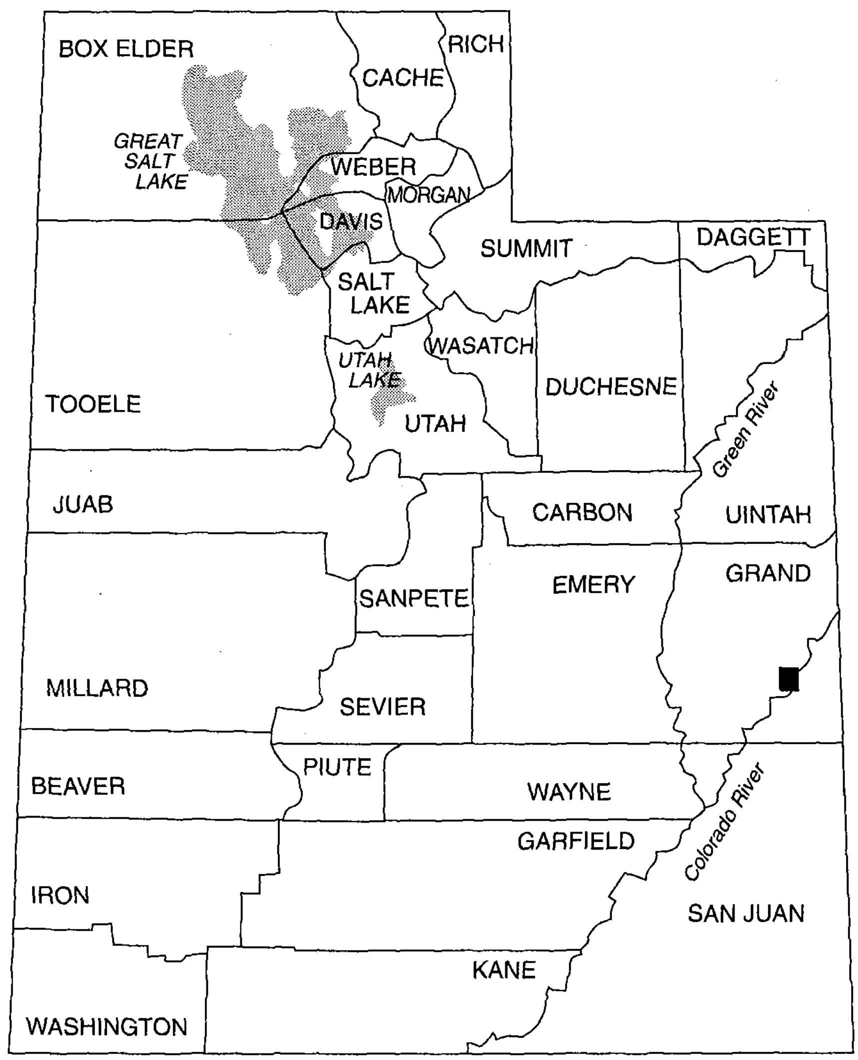
IPp — Paradox Formation -- *Salt, shale, gypsum, and limestone. Unit in subsurface only. 5,000+ feet (1,524+ m) thick in southeast corner of quadrangle.*



ISBN 1-55791-571-7
Dewey geology

GEOLOGIC MAP OF THE DEWEY QUADRANGLE, GRAND COUNTY, UTAH

by
Hellmut H. Doelling



MAP 169 **1996**
UTAH GEOLOGICAL SURVEY
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Doelling
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Utah Geological Survey Map 169

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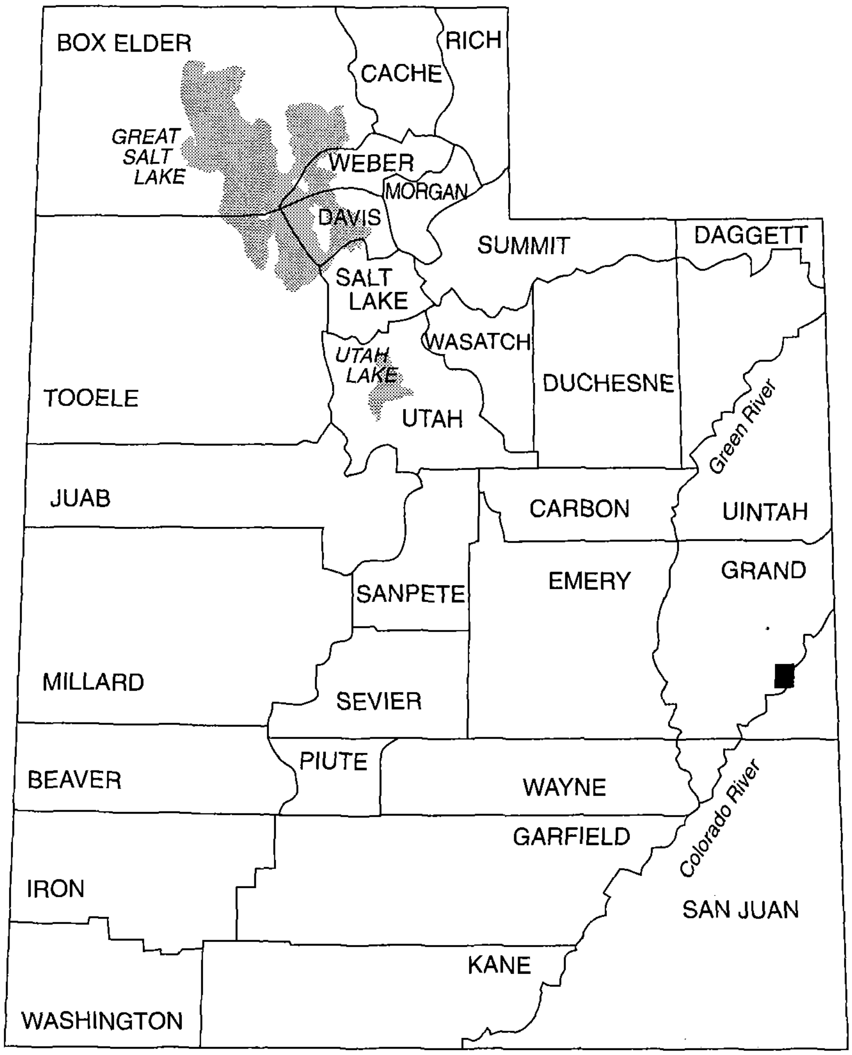

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GEOLOGIC MAP OF THE DEWEY QUADRANGLE GRAND COUNTY, UTAH

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ABSTRACT

The Dewey quadrangle is located on the northeast edge of the salt anticline region of the Paradox basin in east-central Utah. Exposed consolidated formations range in age from Permian to Cretaceous. In ascending order, these units include the Permian Cutler Formation, about 5,000 feet (1,524 m) thick; the Triassic Moenkopi Formation, 350 to 465 feet (110 to 142 m) thick, and Chinle Formation, 250 to 350 feet (76 to 107 m) thick; the Jurassic Wingate Sandstone, about 300 feet (90 m) thick, Kayenta Formation, 240 to 280 feet (73 to 85 m) thick, Navajo Sandstone, 100 to 220 feet (30 to 67 m) thick, Entrada Sandstone 310 to 350 feet (94 to 107 m) thick, Summerville Formation, 25 to 45 feet (7 to 14 m) thick, and Morrison Formation, about 580 feet (177 m) thick; and the Cretaceous Cedar Mountain Formation, 100 to 115 feet (30 to 35 m) thick, Dakota Sandstone, 80 to 100 feet (24 to 30 m) thick, and the Tununk and Ferron Members of the Mancos Shale, about 310 feet (94 m) thick. Mapped surficial deposits are of alluvial, eolian, mass-movement, mixed eolian and alluvial, and mixed eolian and residual origin.

The dominant structure in the Dewey quadrangle is a homocline that dips 4 to 7 degrees north by northeast. The Sagers Wash syncline trends west-northwest across the northeast corner of the quadrangle and dips increase to 5 or 6 degrees on the northeast flank. The east-west-trending Blue Chief Mesa normal fault, in the southern part of the quadrangle, reaches a maximum displacement of 120 feet (37 m); the downthrown block is to the south. The buried Pennsylvanian to Triassic-age Uncompahgre fault probably underlies and parallels the Sagers Wash synclinal axis in the northeast corner of the quadrangle.

Sand and gravel and small quantities of gold from alluvial placer deposits have been produced. Other potentially economic substances include oil and natural gas, chalcedony, gold in the Mancos Shale, and ground water. Minor occurrences of coal, humates, copper, and barite are also present.

Principal geologic hazards include debris flows, stream flooding, rock fall, problem soils, and blowing sand, which primarily affect roadways. The earthquake and landslide hazard is presumed low.

INTRODUCTION

The Dewey quadrangle is named for a small settlement near the confluence of the Colorado and the Dolores Rivers. The quadrangle is located in east-central Utah, about 35 miles northeast and upstream from Moab on Utah Highway 128 (U-128). The Colorado River flows across the quadrangle from northeast to southwest; the Dolores River flows easterly into the Colorado along the east margin of the quadrangle (figure 1).

Altitudes in the quadrangle range from a little less than 4,100 feet (1,250 m) on the Colorado and Dolores River drainages to about 5,890 feet (1,795 m) on the Dome Plateau. Except for the Colorado River drainage, the land surface slopes northward 5 to 7 degrees. The tops of mesas are bare sandstone or sandy soils with stands of pinyon and juniper trees dominating the higher

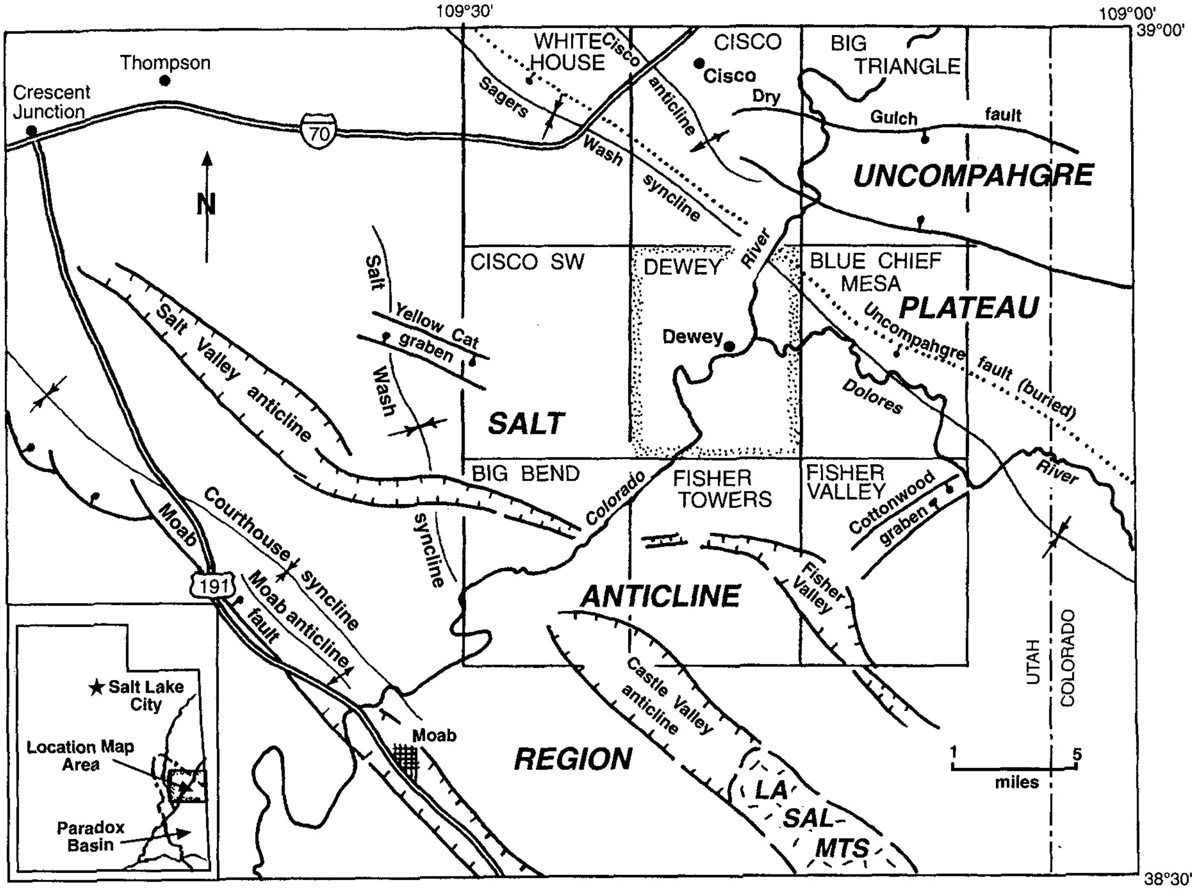

Figure 1. Map showing area of Dewey and adjacent quadrangles in east-central Utah. Principal structural features and settlements are also shown. Lower left inset map shows location of larger map with respect to the state of Utah.

elevations. At lower elevations desert shrubbery and grasses are common. Bitterbrush, blackbrush, Mormon tea, prickly pear cactus, rice grass, and scattered juniper trees are common in the canyons and below the cliffs.

Cattle are grazed both on mesas and along the rivers. Hay and pasture fields are maintained along the Colorado River in McGraw Bottom and in the area immediately east of Dewey. The principal access route is U-128, which follows the Colorado River along most of its length in the quadrangle. Other areas may be reached by county or four-wheel-drive roads which extend from the highway. The area northeast of the Colorado and Dolores Rivers can only be reached by driving from Grand Junction, Colorado through Glade Park.

The Dewey quadrangle area was first mapped geologically by Dane (1935), at a scale of 1:63,500. It was later mapped by Williams (1964) at a scale of 1:250,000 (Moab 2-degree quadrangle). Doelling (1993) included the area in mapping the Moab 30 x 60-minute quadrangle at a scale of 1:100,000.

STRATIGRAPHY

Rock formations exposed in the Dewey quadrangle range in age from Early Permian to Late Cretaceous (plates 1 and 2). In addition, there are several mappable surficial deposits. One drill hole, located in the south-central part of the quadrangle, reached Middle Pennsylvanian rocks. Exposed strata in the quadrangle are about 3,600 feet (1,097 m) thick. The older bedrock units are generally exposed in the southern part of the quadrangle and the younger units are exposed in the northern part.

Subsurface Rocks

The Richfield Oil #1 Onion Creek unit was drilled in the NE¼SW¼ section 31, T. 23 S., R. 24 E. to a depth of 13,922 feet (4,243 m) in 1961. The well log indicates the Honaker Trail Formation (Early Pennsylvanian) was penetrated at a depth of 4,738 feet (1,444 m) or 570 feet (174 m) below sea level. The Paradox Formation (salt) was penetrated at a depth of 8,736 feet (2,663 m) or 4,426 feet (1,349 m) below sea level. At total depth, the drill bit was still in the Paradox Formation, indicating a thickness of at least 5,186 feet (1,581 m) for that unit, including more than 2,400 feet (732 m) of salt. It is assumed that Pennsylvanian, Mississippian, Devonian, and Cambrian rocks normally found above the Proterozoic basement underlie the Paradox Formation (Doelling and Ross, 1993).

The Sagers Wash syncline trends northwest across the northeast corner of the quadrangle. The subsurface Uncompahgre fault parallels the synclinal axis and is thought to lie a short distance northeast of it (White and Jacobsen, 1983). No drill holes are available to more accurately delineate the Uncompahgre fault in the Dewey quadrangle. The Proterozoic basement is elevated northeast of the fault and may be overlain directly by the Triassic Chinle Formation (Case, 1991; Willis and others, 1993).

Permian Rocks

Cutler Formation (Pc)

The Cutler Formation consists primarily of subarkosic to arkosic sandstone, conglomeratic sandstone, and conglomerate interbedded with silty and sandy mudstone. Subordinate lithologies are quartzose sandstone, cherty limestone, and hard, dense mudstone. Because of lithologic heterogeneity and variable cementation, exposures range from nearly vertical cliffs to alternating ledges and slopes that form step-like escarpments. Outcrops are mostly reddish brown, reddish purple, reddish orange, and maroon, with subordinate brownish orange, pale red, gray, grayish red, and grayish white hues.

The arkosic and subarkosic sandstone is fine- to very coarse-grained and micaceous. Grains are generally subangular to subrounded and individual beds vary from poor to well sorted. Many beds of arkosic sandstone display small-scale trough cross-bedding and cut-and-fill structures with basal gravel lenses, suggesting deposition by fluvial processes (figure 2). The conglomerate varies from moderately sorted granule and pebble conglomerate to poorly sorted cobble conglomerate. Small clasts are primarily quartz, feldspar, and mica; pebbles and cobbles are granite, gneiss, schist, and quartzite. The subarkosic to quartzose sandstone is composed of fine- to medium-grained, subrounded, moderately well-sorted grains. Tabular planar cross-stratification and laminations with inverse graded bedding suggest deposition by eolian processes (Campbell, 1979). These subarkosic to quartzose sandstones generally display more of an orange to reddish tint, in contrast to the reddish-purple shades of the fluvial arkosic sandstones. The mudstones and siltstones are micaceous and generally structureless.

Rocks of the Permian Cutler Formation represent a large alluvial-fan complex shed from the ancestral Uncompahgre highland. Campbell (1979, 1980) and Campbell and Steele-Mallory (1979) presented extensive information on the depositional environment of this formation which is summarized here. The fluvial system consisted of braided streams on a fan surface. The toe of the fan was near sea level, periodically allowing marine conditions to influence sedimentation. The Cutler Formation in the Dewey quadrangle was deposited in the upper to medial parts of the fan.

The upper 800 feet (244 m) of the Cutler Formation are exposed in the Dewey quadrangle. The Richfield Oil #1 Onion Creek drill hole was spudded more than 240 feet (73 m) below the top of the unit and penetrated 4,738 feet (1,444 m) of Cutler. The unit is therefore estimated to be about 5,000 feet (1,524 m) thick. Doelling (1981) reported an incomplete surface measurement of more than 3,000 feet (914 m) in the Fisher Towers quadrangle, about 4 miles south of the Richfield # 1 Onion Creek well. The top of the Cutler is an angular unconformity observable along the cliff face across the river from Hittle Bottom (section 35, T. 23 S., R. 23 E.) above which the Triassic Moenkopi Formation was deposited. The unconformity and contact are marked by a color change from gray-red or lavender to the medium-brown of the lower member of the Moenkopi Formation. The Cutler displays indistinct bedding whereas the Moenkopi is well-bedded. At this site the apparent dip in the Moenkopi beds is about 1 degree west, whereas the Cutler dips about 5 degrees west.

Figure 2. *Sandstone and conglomeratic sandstone in the Cutler Formation in the Richardson Amphitheater. The Cutler Formation represents the deposits of an ancient coalesced alluvial-fan complex that was shed from the ancestral Uncompahgre highland.*

Triassic Rocks

Moenkopi Formation

The Moenkopi Formation of Early Triassic age is missing over the Uncompahgre Plateau to the northeast (Shoemaker and Newman, 1959; Case, 1991; Willis and others, 1993) and regionally thickens westward toward the Cordilleran miogeocline (Baars, 1987; Doelling, 1988). The Moenkopi is a sequence of intertonguing deltaic and paralic (coastal) deposits that represent the initial Mesozoic marine transgression in the Colorado Plateau region (Stewart and others, 1972a). The Moenkopi Formation consists of interbedded, orange-brown to red-brown, thinly laminated to thin-bedded, micaceous mudstone, siltstone, and fine-grained sandstone. Subordinate lithologies include shale, gypsum, and conglomerate. The formation is characterized by ubiquitous oscillation ripples and mudcracks (Stewart and others, 1972a; Molenaar, 1987; Doelling, 1988).

Shoemaker and Newman (1959) investigated the Moenkopi Formation in the salt-anticline region and divided it into four members, in ascending order, the Tenderfoot, Ali Baba, Sewemup, and Pariott Members. These are well developed in the Big Bend quadrangle to the southwest (Doelling and Ross, 1993). The Moenkopi is much thinner in the Dewey quadrangle; the Tenderfoot and Ali Baba Members cannot easily be subdivided, and the Pariott Member is probably missing (Shoemaker and Newman, 1959). Therefore, I have mapped the Moenkopi in lower and upper members, a division that is easily recognizable in the field (figure 3). The lower member of the Moenkopi Formation is a dark-brown cliff- and ledge-forming unit whereas the upper member is a light-brown slope-former. The Moenkopi Formation is exposed in the cliffs marginal to Professor Valley and the Richardson Amphitheater, and for a mile or two up the Colorado River canyon.

Lower member of the Moenkopi Formation (Ꞧml): The lower member of the Moenkopi Formation consists of the Tenderfoot and Ali Baba Members of Shoemaker and Newman (1959). In the Dewey quadrangle, the Tenderfoot consists of red-brown sandstone that is mostly fine grained, but that contains streaks of medium to coarse grains. It is micaceous and has thin siltstone interbeds. The lower half of the Tenderfoot Member consists of medium, blocky to lumpy-weathering beds. The top of the lower half of the Tenderfoot consists of 2 to 3 feet (0.6-0.9 m) of sandy, dark-red-brown siltstone that forms a slight recess in the cliff. The upper half is massive weathering except for a few lumpy-weathering beds at the top. The Tenderfoot forms a nearly vertical cliff above the Cutler Formation 110 to 120 feet (33 to 37 m) high.

The Ali Baba Member consists of well-bedded, ledge-forming sandstone. Red-brown, mostly fine-grained sandstone alternates with medium- to coarse-grained subarkosic sandstone and subordinate mudstone and sandy siltstone. The fine-grained sandstone contains streaks of coarse grains (as much as 20 percent of the rock), including some pebbles and cobbles, is micaceous, and weathers into blocky thin to thick beds. Many of the beds are ripple marked. The medium to coarse-grained subarkosic sandstone contains angular grains, conglomerate lenses, and is dark red brown, cross bedded, and generally softer and more friable than the fine-grained sandstone. The pebbles and cobbles consist mostly of quartzite, gneiss, granite, and amphibolite. The mudstone or sandy siltstone is dark red brown, thinly laminated to thin bedded, and forms recesses between the ledges. The amount of fine-grained sandstone increases stratigraphically upward, except for the uppermost 20 to 30 feet (6-9 m), where mudstone increases. The contact between the lower and upper members is gradational.

Dane (1935) measured a 251-foot (77 m) section of the lower member of the Moenkopi Formation northeast of Hittles ranch (probably near Hittle Bottom), on the southeast side of the Colorado River. Stewart and others (1972a) measured a 264-foot (80 m) lower member nearby on the southwest-facing cliff on the east side of the Colorado River, in section 25, T. 23 S., R. 23 E. They divided the lower member into about 112 feet (34 m) of Tenderfoot Member and 152 feet (46 m) of the Ali Baba Member. I measured about 151 feet (46 m) of Ali Baba Member on the north side of the Blue Chief Mesa fault on the east side of the Colorado River in the NE¼ SW¼ SW¼ section 24, T. 23 S., R. 23 E., where the Tenderfoot is incompletely exposed. The lower member of the Moenkopi Formation thickens southwesterly in the quadrangle. The lower member is assumed to be thin or missing in the subsurface in the northeast of the Uncompahgre fault in the northeast corner of the Dewey quadrangle.

Upper member of the Moenkopi Formation (Ꞧmu): The upper member of the Moenkopi Formation is mostly light brown, silty to fine grained, micaceous sandstone. It is finely laminated to indistinctly bedded with some platy beds that are generally ripple-marked or mud-cracked, and it forms a slope. Slight ledges are common where banks of thin beds are present. The unit is commonly cemented with gypsum. The contact between the upper member of the Moenkopi Formation and the Chinle Formation is a disconformity with minor relief.

The upper member of the Moenkopi Formation is about 150 feet (46 m) thick northeast of Hittle Bottom, on the southeast side of the Colorado River (Dane, 1935). Stewart and others (1972a) measured 173 feet (53 m) near the same place. I measured 113 feet (34 m) of a thinning upper member just north of the fault in the NE¼SW¼SW¼, section 24, T. 23 S., R. 23 E. The unit thickens to about 280 feet (85 m) near the southwest corner of the quadrangle. The upper member is probably thin or missing in the subsurface in the northeast corner of the Dewey quadrangle.

Chinle Formation (Ꞧc)

In the region northeast of Moab, previous investigators subdivided the Chinle Formation into formal and informal units; in ascending order, mottled strata, basal sandstone unit, and Church Rock Member, which includes the "Black Ledge" (Stewart and others, 1972b). I did not subdivide the Chinle in the Dewey quadrangle (figure 3). At some localities, however, a thin basal sandstone or gritstone unit is present that includes mottled strata. Dane (1935) recognized at least 22 feet (7 m) of such beds in his section northeast of Hittle ranch (Hittle Bottom); I recognized 28 feet (8.5 m) of the same at the base of my section north of the Blue Chief Mesa fault.

The upper contact with the Wingate Sandstone is generally sharp and may be a disconformity. Generally, sandstones on both sides of the contact are similar, but the sandstone in the uppermost Chinle is thick bedded rather than massive.

Chinle Formation outcrops are present on the cliff margins of Professor Valley and Richardson Amphitheater, and extend northward into the canyon of the Colorado River to about 1½ miles (2.4 km) southwest of Dewey. North of the Blue Chief Mesa fault the Chinle is largely masked by a veneer of talus. Dane (1935) measured 264 feet (80 m) of Chinle Formation northeast of Hittle Bottom on the southeast side of the Colorado River. Stewart and others (1972b) reported that the Chinle is about 296 feet (90 m) thick in the Richardson Amphitheater in section 25, T. 23 S., R. 23 E. I measured 252 feet (77 m) of Chinle Formation north of the Blue Chief Mesa fault. Like the Moen-

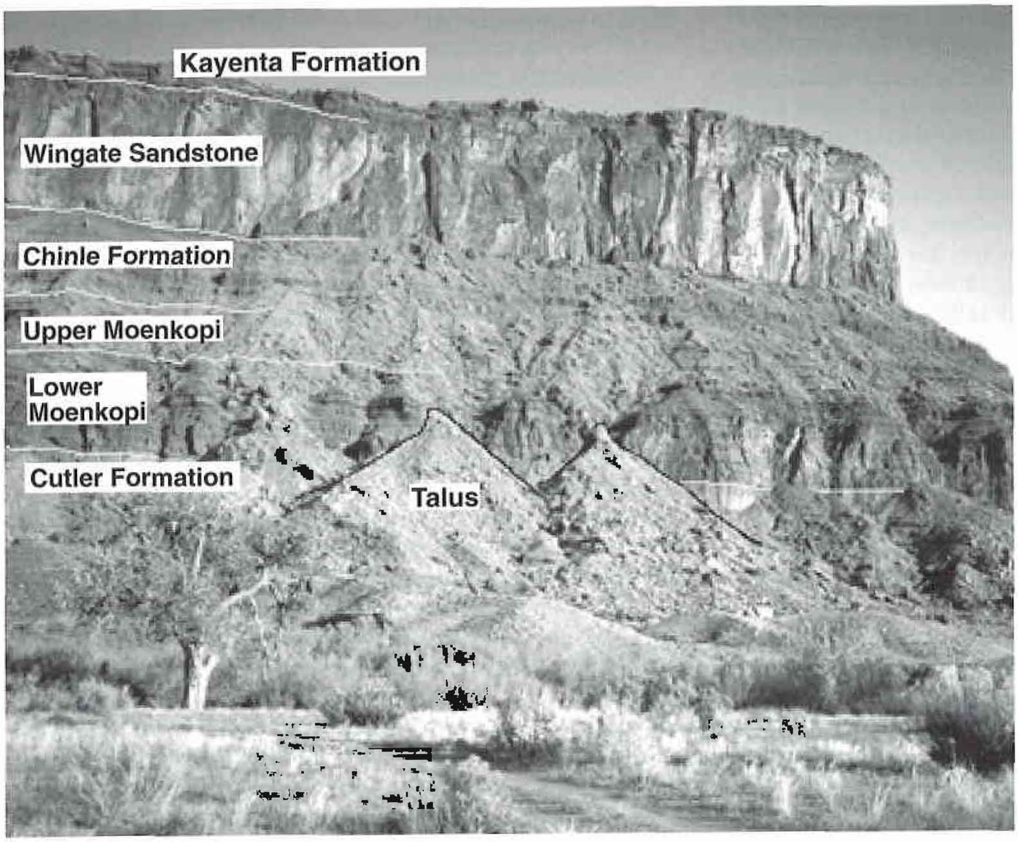

Figure 3. *Northwestward view of the Wingate Sandstone cliff and adjacent formations in the southern part of the Dewey quadrangle, in the NW¼ section 36, T. 23 S., R. 23 E. Triangular-shaped accumulations of the talus mark the foot of the cliff.*

kopi Formation, the Chinle thickens southwesterly. It is about 350 feet (107 m) thick in exposures in the southwest corner of the Dewey quadrangle, below the Dome Plateau, and is more than 400 feet (122 m) thick below the Priest and the Nuns six miles (9.5 km) to the southwest. The Chinle is about 100 feet (30 m) thick on the Uncompahgre Plateau in exposures about 8 miles (13 km) northeast of the Dewey quadrangle.

Jurassic Rocks

Jurassic rocks of the Dewey quadrangle are more than 1,700 feet (518 m) thick and consist of three major packages. The lowermost package is the 770-foot-thick (235 m) Lower Jurassic Glen Canyon Group consisting of the Wingate Sandstone, Kayenta Formation, and Navajo Sandstone. The medial package, 310 to 350 feet (94-107 m) thick, is the Middle Jurassic Entrada Sandstone, divided into the Dewey Bridge, Slick Rock, and Moab Members. The upper package is the 500-foot-thick (177 m) Upper Jurassic Morrison Formation, divided into the Tidwell Member, Salt Wash Member, and Brushy Basin Member. A thin sliver, 25 to 45 feet (7-14 m) thick, of the Middle Jurassic Summerville Formation persists between the Entrada Sandstone and the Morrison Formation.

Wingate Sandstone (Jw)

The Wingate Sandstone is the lowermost formation of the Early Jurassic Glen Canyon Group (Pipiringos and O'Sullivan, 1978). The Wingate Sandstone forms the most prominent cliff along the margins of Richardson Amphitheater and Professor Valley in the southern part of the Dewey quadrangle (figure 3). It is a red-brown, nearly vertical cliff, commonly streaked and stained to a dark brown or black by desert varnish. Erosion of the Wingate is characterized by separation of thick slabs from the cliff along vertical joints, as the formation is undercut by erosion of the weaker underlying Chinle Formation. Wingate Sandstone rubble is ubiquitous on the slopes below the cliffs.

The Wingate Sandstone is mostly light-orange-brown, moderate-orange-pink, moderate-red-orange, pink-gray, or pale-red-brown, fine-grained, well-sorted, cross-bedded sandstone. High-angle, large-scale cross-beds indicate that the Wingate was deposited primarily by eolian processes. It generally appears massive and uniform from top to bottom; partings and other dividing features are present, but are difficult to see at most locations. They are more common near the base of the unit. The upper contact with the Kayenta Formation is conformable and placed where the lighter colored massive sandstone of the Wingate is overlain by thick-bedded, darker red-brown sandstone. Kayenta sandstone beds, although thick bedded to massive, exhibit bedding or lens boundaries in outcrop.

Although the Wingate Sandstone is prominently exposed in the quadrangle, the vertical outcrop habit restricts direct measurement. No drill-hole data are available in the quadrangle. In the Dewey quadrangle the thickness of the Wingate is about 300 feet (91 m), as estimated from the topographic map and through use of a stereoplotter. Regionally the Wingate is 250 to 400 feet (76-122 m) thick (Doelling, 1981).

Kayenta Formation (Jk)

The Kayenta Formation overlies the Wingate Sandstone and is the middle unit of the Glen Canyon Group. The Kayenta caps the Dome Plateau and the unnamed mesa on the east side of the Colorado River in the southeast part of the quadrangle. The lower part of the Kayenta commonly merges with the Wingate Sandstone to form a vertical cliff. Although individual beds and lenses of the formation can be found in various hues, the dominant colors of the Kayenta are red-brown and lavender. Prominent benches generally form on top of thick sandstone lenses. Bare rock surfaces are normal; surficial deposits where present are typically thin.

The Kayenta is dominated by fluvial sandstone, but eolian and lacustrine interbeds or lenses are present, especially in the upper third of the formation. Most of the fluvial sandstone is moderate orange pink; silty mudstone interbeds are dark red-brown or gray-red. The lenses normally exhibit low-angle cross-bedding and display channeling, current ripple marks, and primary slump features. The grain size is variable, ranging from very fine grained to medium grained. Very fine flakes of mica are common in some of the sandstone beds and cementation is principally calcareous. Other lithologic types more commonly found in the upper part of the Kayenta include: intraformational pebble conglomerate; cliff-forming, light-colored eolian sandstone; slope-forming, red-brown to dark red-brown, sandy siltstone; very fine-grained, silty sandstone; and rarely, very thin beds of gray limestone.

The lower fourth of the formation is dominated by very thick to massive fluvial sandstone lenses. Rare, very thin partings of dark-red-brown siltstone locally separate the sandstone lenses, which collectively form a vertical cliff above the Wingate cliff. The middle half of the Kayenta contains medium to thick sandstone beds, sporadic intraformational conglomerate lenses, and abundant siltstone partings that form benches between the lenses, giving the outcrop a step-like configuration. The upper fourth is generally slope forming with scattered thick lenses of fluvial or eolian sandstone. In some areas these light-hued sandstones form a final cliff-forming sequence under the overlying Navajo Sandstone. The Kayenta-Navajo contact is placed at the top of a white-weathering, cliff-forming unit (figure 4). The Navajo above may or may not be a cliff former, and weathers tan or light brown.

Dane (1935) indicated the Kayenta is 320 feet (98 m) thick a mile east of the Colorado River, southeast of Dewey, which seems high. He estimated that the Kayenta ranges from 200 to 320 feet (61-98 m) thick in an area that includes the Dewey quadrangle. I measured 246 feet (75 m) of Kayenta Formation on the east side of Bull Canyon in the NW¼ NW¼ section 13, T. 23 S., R. 23 E., and 262 feet (80 m) on the west side of Waring Canyon in the SE¼ SE¼ section 20, T. 23 S., R. 24 E. I believe the Kayenta Formation thickness varies from 240 to 280 feet (73-85 m) across the quadrangle.

Navajo Sandstone (Jn)

The Navajo Sandstone is mostly orange to light-gray, fine-grained sandstone cemented with silica and calcite. Medium to coarse grains of quartz sand are common along cross-bed laminae. Even though the Navajo is a cliff former, the sandstone is friable in hand specimen. The sandstone is mostly massive and is divided into cross-bed sets15 to 25 feet thick (4.6 - 7.6 m). Cross-bedding angles locally exceed 30 degrees.

The Navajo Sandstone, dominantly eolian, has thin limestone beds and many flat-bedded units near the base of the formation. The basal 35 to 80 feet (11-24 m) of sandstone, with cross-bed sets as thick as 15 feet (4.6 m), form a continuous flat-bedded-appearing cliff. Locally, this interval weathers into rough ledges, highlighting the cross-bed set boundaries. Above this basal interval are 30 feet (9 m) of poorly exposed, non-cliffy sandstone, followed by typical cross-bedded sandstone that weathers into domes and monuments. Flattened "logs" of gray-brown sandstone are locally found in the upper third of the basal unit, engulfed in eolian cross-bedded sandstone.

Locally, thin, gray, commonly cherty limestone beds (Jnl) are found at any level in the Navajo Sandstone. Thin, red, silty sandstone partings separate the 1 to 4 inch (2.5 - 10 cm) limestone beds that aggregate to as much as 4 feet (1.2 m) in thickness. These lacustrine or playa limestones commonly extend over several hundred acres (80+ hectares). At the margins of the deposits, the beds grade laterally into flat-bedded ledges of fine-grained calcareous sandstone. They thin out into the massive sandstones as partings. The limestone outcrops commonly form a resistant bench covered with a dark sandy or rubbly soil.

A sequence of light-brown, low-angle, cross-bedded sand-

Figure 4. *Navajo Sandstone (Jn)-Kayenta Formation (Jk) contact, center, section 12, T. 23 S., R. 23 E. A white eolian sandstone generally marks the uppermost Kayenta Formation(Jk) unit. Lowermost Navajo Sandstone (Jn) is well cross-bedded and light brown in comparison.*

stone at the top of the formation may correlate with the Page Sandstone in southern Utah (Peterson and Pipiringos, 1979) or to the overlying Dewey Bridge Member of the Entrada Sandstone. This brown sandstone ranges to 25 feet (7.6 m) thick across the quadrangle and may be locally missing. Above is the dark red-brown, contorted, fine-grained sandstone of the Dewey Bridge Member of the Entrada Sandstone. I mapped the light-brown sandstone with the Navajo Sandstone. The contact between the Navajo and Dewey Bridge Member of the Entrada Sandstone is a disconformity of regional extent (Pipiringos and O'Sullivan, 1978), separating Lower Jurassic from Middle Jurassic rocks.

The thickness of the Navajo Sandstone in the Dewey quadrangle is estimated to range between 180 and 220 feet (55-67 m) along outcrop and between 100 and 220 feet (30-67 m) in the subsurface. The Navajo Sandstone is about 220 feet (67 m) thick near Buck Spring in the NE¼ NE¼ section 12, T. 23 S., R. 23 E., a thickness corroborated by Dane (1935). Regionally, the Navajo Sandstone thins from west to east due to erosional truncation (Doelling, 1981). It is completely or nearly missing in the Big Triangle quadrangle, four or five miles (6-8 km) to the northeast of the Dewey quadrangle and may be as thin as 100 feet (30 m) in the subsurface in the northeast corner of the quadrangle. It is 250 to 400 feet (76-122 m) thick in the Big Bend quadrangle to the southwest (Doelling and Ross, 1993).

Entrada Sandstone

Dewey Bridge Member of the Entrada Sandstone (Jed): The Dewey Bridge Member is an easily recognized marker unit at the base of the Entrada Sandstone (figure 5). It consists of a thin interval of dark-red-brown, silty and muddy, fine-grained sandstone between the light-hued bench of the Navajo and the cliff of the Slick Rock Member of the Entrada. Bedding is irregular to lumpy and commonly contorted. A reworked zone of Navajo sand as much as 5 feet (1.5 m) thick is identifiable at several locations in the Dewey quadrangle. This reworked zone is more resistant than the remainder of the Dewey Bridge Member.

The upper contact with the Slick Rock is crenulated or contorted at most quadrangle locations (figure 5). Arcuately shaped boundaries are common, with fingers of the light-hued Slick Rock sandstone extending deeply into the dark-red-brown Dewey Bridge Member. In a few places the Slick Rock Member rests directly on the reworked sandstone at the base of the Dewey Bridge Member.

The Dewey Bridge Member was once mapped as the Carmel Formation (Dane, 1935), but Wright, Shawe, and Lohmann (1962) proposed a change consistent with lithologic criteria. The unit ranges from 20 to 45 feet (6-14 m) thick (except where the Slick Rock fingers dip deeply into the unit) in the Dewey quadrangle.

Slick Rock Member of the Entrada Sandstone (Jes): The Slick Rock Member is a massive, fine-grained, banded sandstone locally exhibiting discontinuous partings (figure 5). Coarse, frosted and equant grains are common along cross-bed laminae. Cementation is calcareous and hematitic. The Slick Rock Member weathers into cliffs and steeply rounded smooth slopes.

The unit is cross-bedded with long, sweeping foresets in angles locally exceeding 45 degrees. Major cross-sets are commonly 20 to 40 feet (6-12 m) thick; however, major set boundaries cannot be traced for long distances. Locally cross-beds are complexly intermeshed and laced with healed hair-line faults. Thick color banding is noticeable at most exposures. This banding is mostly nearly horizontal and generally cuts across the sedimentary structures, but locally follows the major set boundaries. Outcrop colors include pink gray, yellow gray, gray, light brown, orange, and pink.

From a distance the upper contact is identified by a color

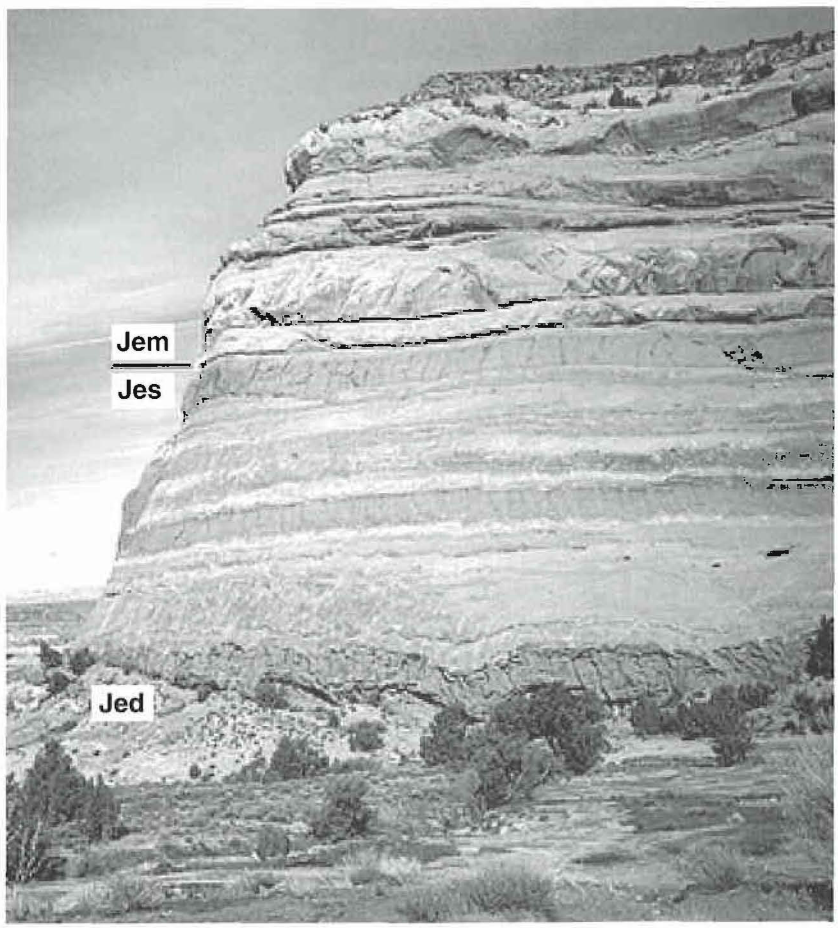

Figure 5. *Members of the Entrada Sandstone, SE¼NW¼ section 21, T. 23 S., R. 24 E. The uppermost Moab Member (Jem) is generally lighter, sucrosic-weathering sandstone; the middle Slick Rock Member (Jes) is banded and contains abundant "stonepecker" holes. At the base is the contorted, "lumpy," red-brown, fine-grained sandstone of the Dewey Bridge Member (Jed).*

change from the light brown, orange, or pink of the Slick Rock, to the white or very light gray of the Moab Member (figure 5). The contact is a nearly flat erosional surface with little relief, except locally, where the contact dips deeply into the Slick Rock. Sandstone of the Moab Member displays horizontal laminations or medium- to large-scale cross-beds, is generally more resistant, and generally weathers to a sugary rather than a smooth surface. The Slick Rock commonly contains "stonepecker" holes, with diameters up to 6 inches (15 cm), whereas the Moab Member does not. I believe this contact may be the J-3 unconformity (Pipiringos and O'Sullivan, 1978) though in a correlation diagram of the area, O'Sullivan and Pipiringos (1983) did not show an unconformity in this position.

The Slick Rock Member, north of Yellow Jacket Canyon, in the NW¼ NW¼ section 11, T. 23 S., R. 23 E. is 208 feet (63 m) thick according to the criteria indicated in the previous paragraph. At Roberts Mesa, NE¼ SE¼ NE¼ section 11, T. 23 S., R. 24 E., the Slick Rock Member is 190 feet (58 m) thick. At the north end of Little Pinto Mesa, in the SE¼ NE¼ section 21, T. 23 S., R. 24 E., the Slick Rock is 220 feet (67 m) thick. In the Dewey quadrangle the Slick Rock Member varies from 180 to 220 feet (55-67 m) thick along outcrop.

Published measured sections indicate that previous workers placed the Slick Rock-Moab Member contact higher in the section than I have elected to do and therefore report a thicker member. Dane (1935) may have chosen the first deep notch below the top of the Moab Member, when he measured 65 feet (20 m) of Moab Member and 230 feet (70 m) of Slick Rock one mile east of Dewey. Wright and Dickey (1979) indicated the Moab Member to be only 51 feet (15.5 m) thick and the Slick Rock Member to be 273 feet (83 m) thick in sections 7 and 8, T. 23 S., R. 24 E. in the Dewey quadrangle.

Moab Member of the Entrada Sandstone (Jem): White, bare-rock outcrops of the Moab Member of the Entrada Sandstone trend east-west across the middle of the Dewey quadrangle on top of the banded Slick Rock Member (figure 5). The outcrops form cliffs, and the upper surfaces commonly exhibit distinctive large-scale, polygonal joints that form a "biscuit" pattern.

The Moab Member is a white, yellow-orange, or light-pink-gray, fine-grained sandstone with irregular yellow and pale-red patches. The grains, which are mainly quartz, are frosted, subangular to subrounded, and equant in shape. The unit is cemented with calcite and minor hematite. Cementation varies from friable to indurated, but generally the Moab Member is more resistant and cliff-forming than the Slick Rock Member. The Moab Member also differs from the Slick Rock Member in that it has a larger percentage of low-angle to horizontal surfaces. Also, in the Moab Member, cross-set boundaries are accentuated by weathering, forming prominent indentations in outcrops (figure 5), and weathered surfaces appear sucrosic rather than smooth.

The upper contact of the Moab Member with the Summerville Formation is easy to recognize. It is a nearly flat erosional surface overlain by a resistant 6- to 18-inch (15-45 cm) bed of light-colored, reworked sandstone. The Moab Member tongues into the Curtis Formation in western Grand County as observable in section 5, T. 24 S., R. 18 E. Here the Curtis grades upward into the overlying Summerville Formation several feet above the tongue of the Moab Member. In the Dewey quadrangle the Moab Member-Summerville contact is probably an unconformity of very short duration. The Moab Member is late Middle Jurassic (Callovian) in age (Hintze, 1988).

The thickness of the Moab Member in the Dewey quadrangle is variable and increases where the lower unconformable contact cuts out more of the upper Slick Rock Member. The thickness of the Moab Member ranges from 70 to 140 feet (21-43 m) along outcrops. Thicker Moab Member sections generally correspond with thinner Slick Rock sections. The total Entrada Sandstone probably ranges between 310 and 350 feet (94-107 m) thick.

Summerville Formation (Js)

The Summerville Formation and Tidwell Member of the Morrison Formation are thin units that together form a dark-red marker zone between the white cliff-forming sandstones of the Moab Member of the Entrada Sandstone and the cliffy, light-hued, lenticular sandstone of the Salt Wash Member of the Morrison Formation (figure 6). The Summerville Formation consists of thin- to medium-bedded, tan to brown, ledgy sandstone and slope-forming, red, sandy siltstone that form a steep slope capped by a prominent, thin- to medium-bedded, blocky to platy sandstone ledge at the top. Several thin ledges of sandstone are commonly present that are fine to medium grained, well sorted, and quartzose. The upper ledge of sandstone is commonly ripple marked.

The upper contact of the Summerville Formation is the J-5 unconformity (Pipiringos and O'Sullivan, 1978; O'Sullivan and Pipiringos, 1983; O'Sullivan, 1984). It is commonly poorly exposed in the Dewey quadrangle, but is placed at the base of slope-forming, maroon to lavender siltstone of the Tidwell Member. In most places the contact is mapped directly above the upper ledge of the Summerville Formation. However, in a few places yellow-gray, chippy weathering, soft sandstone is present above the ledge, which is probably a part of the Summerville Formation.

The thickness of the Summerville Formation in the Dewey quadrangle varies from 25 to 45 feet (7-14 m), thickening eastward. In the SW¼ NE¼ NE¼ section 4, T. 23 S., R. 23 E. the Summerville is 28 feet (8.5 m) thick; it is 43 feet (13 m) thick at the north end of Little Pinto Mesa in NE¼ SW¼ NE¼ section 21, T. 23 S., R. 24 E. Random measurements made between the two locations show the Summerville to be 35 feet (10.6 m) or less on the west side of the Colorado River and 35 feet (10.6 m) or more on the east side. The Summerville Formation is late Middle Jurassic (Callovian) in age.

Morrison Formation

Tidwell Member of the Morrison Formation (Jmt): The lowermost mappable unit of the Morrison Formation in the Dewey quadrangle is the Tidwell Member. Together with the underlying Summerville Formation, it forms an easily recognized red marker horizon (figure 6). The outcrops form gentle slopes that are less resistant than the Summerville below and the Salt Wash Member above.

Most of the Tidwell Member consists of siltstone that weathers to red, maroon, lavender, or light gray. Discontinuous zones

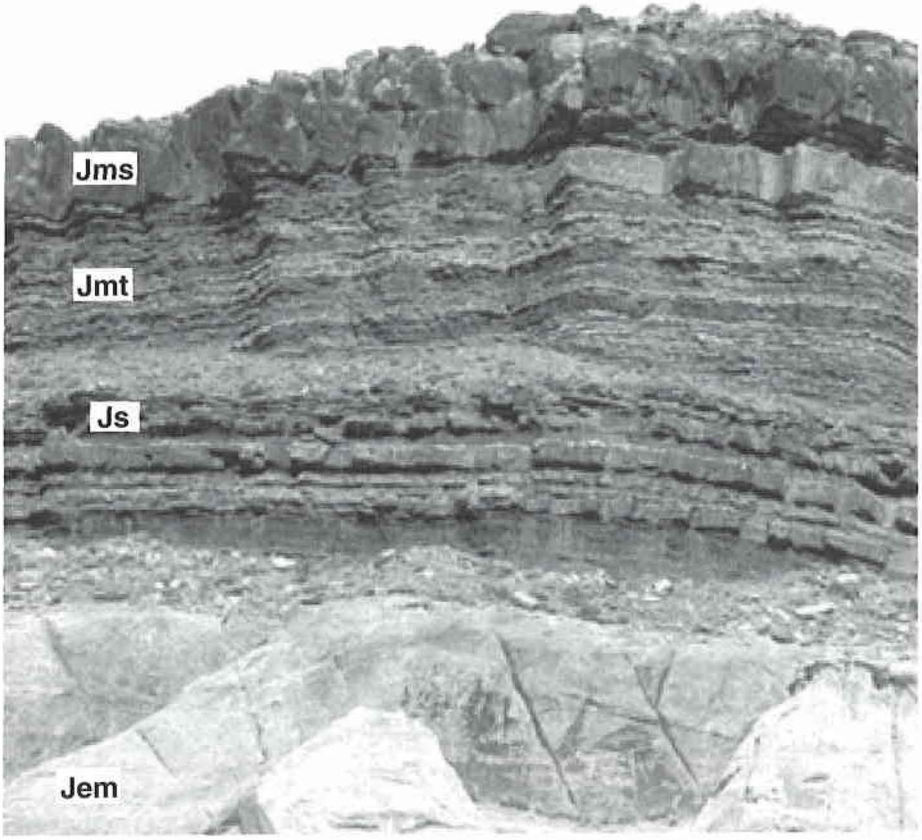

Figure 6. *Outcrop of Summerville Formation (Js) and Tidwell Member of the Morrison Formation (Jmt), north of Lake Bottom on the Dolores River. The Salt Wash Member of the Morrison Formation (Jms) overlies and the Moab Member of the Entrada Sandstone (Jem) underlies the sequence.*

of light-gray carbonate nodules are interspersed throughout the siltstone, but are more common near the base and top of the unit. In many places thin, gray limestone beds less than 1.5 feet (0.5 m) thick are present. In several places in the Dewey quadrangle large, mostly white, chert concretions are found immediately above such limestone beds. Some of these concretions are as much as 6 feet (2 m) in diameter and a few contain irregular red and brown patches of jasper.

Tidwell Member thickness across the quadrangle varies from 38 to 48 feet (12-15 m). The upper contact with the Salt Wash Member is generally placed at the base of the first thick, resistant lens of yellow-gray or light-brown sandstone.

Salt Wash Member of the Morrison Formation (Jms): The Salt Wash Member is composed of interbedded, lenticular, ledge-forming sandstone and slope-forming mudstone. The unit forms benches and cliffs. In this quadrangle it is the uppermost unit on the mesas on the east side of the Colorado River and south of the Dolores River.

The Salt Wash Member is composed of 25 to 40 percent sandstone lenses alternating with 60 to 75 percent red and green mudstone. Sandstone lenses range from 2 to 20 feet (0.6-6 m) thick, but most are 2 to 4 feet (0.6 - 1.2 m) thick; thickness generally increases up section with a corresponding decrease in the mudstone intervals. Typically, there are six or seven thick vertically stacked sandstone lenses in the Salt Wash Member.

Quartzose sandstone in the Salt Wash is cross bedded, fine to coarse grained, moderately to poorly sorted, and calcareous. The well-indurated sandstone forms resistant ledges that are generally light gray, yellow gray, or light brown, but weather to various shades of brown. The mudstone intervals consist of red, greenish-gray, maroon, and lavender siltstone and fine-grained clayey sandstone. Thin limestone beds and nodules are present in the Salt Wash Member mudstones.

The upper contact is placed at the top of an interval dominated by light-gray sandstone lenses and below dark conglomeratic sandstone lenses and brightly colored, banded mudstone of the Brushy Basin Member. Salt Wash sandstone lenses are quartzose whereas Brushy Basin sandstone beds are more commonly lithic, gritty, and conglomeratic. Salt Wash mudstone beds are dominantly red whereas Brushy Basin mudstone beds are variegated maroon, orange, green, gray, and lavender. Sand is more common in Brushy Basin mudstone than in Salt Wash mudstone.

The Salt Wash Member ranges from 190 to 250 feet (58 - 76 m) thick in the Dewey quadrangle. A nearly complete section of 190 feet (58 m) is present on Little Pinto Mesa, E½ section 21, T. 23 S., R. 24 E. Dane and Vanderwilt measured a section 217 feet thick (66 m) of the Salt Wash Member near the mouth of the Dolores River, about 1 mile (1.6 km) southeast of the Colorado River (Dane, 1935).

Brushy Basin Member of the Morrison Formation (Jmb): The Brushy Basin Member in the Dewey quadrangle is mostly silty and clayey mudstone and muddy sandstone interbedded with a few local conglomeratic sandstone lenses (figure 7). The steep-sloped outcrops are banded in various shades of maroon, orange, green, gray, and lavender. Most of the rock is indistinctly bedded, and has a high clay content as is evident from "popcorn" weathered surfaces. Many of the mudstones are probably decomposed, reworked, waterlain, volcanic tuff beds. The sandstone is commonly cross-bedded, coarse grained to gritty, with local pebblestone lenses. The sandstones locally form low to medium ledges and, less commonly, cliffs. About 75 percent of the unit is mudstone.

The upper contact with the Cedar Mountain Formation is probably an unconformity and is placed at the base of a persistent cliff-forming sandstone (figure 7) that is 10 to 30 feet (3-9 m)

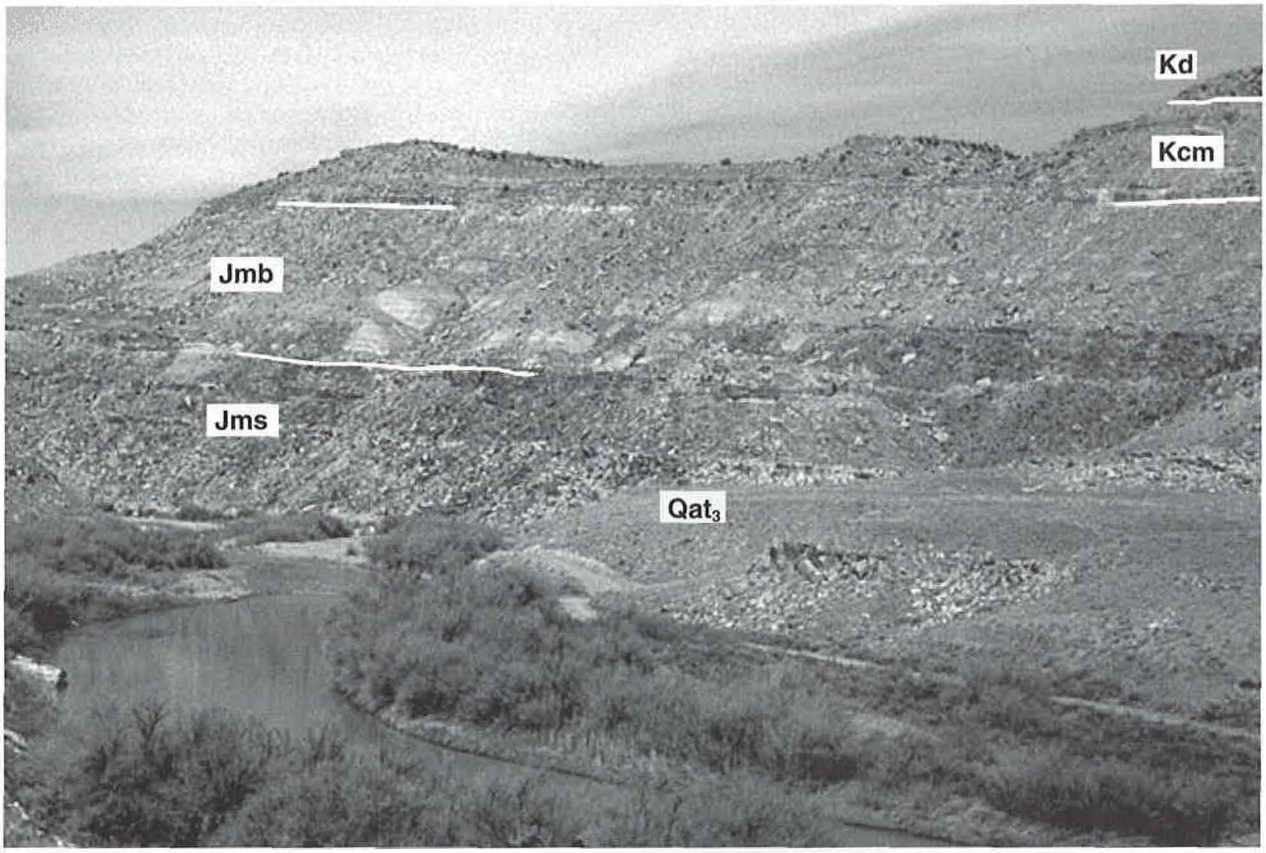

Figure 7. Outcrop of the Salt Wash (Jms) and Brushy Basin (Jmb) Members of the Morrison Formation, the Cedar Mountain Formation (Kcm), and the Dakota Sandstone (Kd) near the mouth of the Dolores River, section 10, T. 23 S., R. 24 E. The flat surface of a Dolores River terrace deposit (Qat_3) can be seen in the foreground.

thick (Molenaar and Cobban, 1991). Farther west, near Green River and the Henry Mountains region, the Buckhorn Conglomerate Member of the Cedar Mountain Formation rests unconformably upon the Brushy Basin Member (Trimble and Doelling, 1978; Peterson and others, 1980). Stokes (1950a, 1950b, 1952), who named the Buckhorn (Stokes, 1944), suggested that the hiatus is not great, but radiometric dates indicate that 20 million years of Lower Cretaceous deposits are not represented (Hintze, 1988).

In the E½, E½, section 9, T. 23 S., R. 24 E., north of the Dolores River below Hotel Mesa, the Brushy Basin Member of the Morrison Formation is 314 feet (96 m) thick. Other reconnaissance measurements, use of the stereoplotter, and other methods indicate the member ranges from 290 to 350 feet (88-107 m) thick at outcrop. The Brushy Basin Member is considered to be Late Jurassic (Tithonian) in age (Hintze, 1988).

Cretaceous Rocks

Cretaceous rocks are exposed in the northern part of the Dewey quadrangle and include, in ascending order, the Cedar Mountain Formation, Dakota Sandstone, and the Tununk and Ferron Members of the Mancos Shale. The exposed thickness of Cretaceous rocks is about 500 feet (152 m).

Cedar Mountain Formation (Kcm)

The Cedar Mountain Formation consists of a lower cliff-forming sandstone and a steep slope of silty mudstone containing lenses of sandstone. The unit, in fact, is similar to the Brushy Basin Member of the Morrison Formation, but colors are not as brilliant (figure 7). The lower sandstone unit is mostly light to dark brown, weathering to a darker hue. Desert varnish is common at many exposures. The grain size may be fine, medium, coarse, gritty, or conglomeratic. It is generally a massive unit, although in places it is weathered into lenses. The mudstone is silty, contains sandy intervals and is usually drab gray green or lavender. Locally nodular gray limestone is present with sporadic chert nodules. These are more likely to be found near the top of the unit.

The upper boundary is an unconformity; yellow-gray and brown, cliff-forming sandstone and conglomerate of the overlying Dakota Formation rest in shallow channels cut into the lower unit. The unconformity represents a hiatus of about 4 million years (Molenaar and Cobban, 1991). The thickness of the Cedar

Mountain Formation ranges from 100 to 115 feet (30-35 m) in the quadrangle. It is 114 feet (35 m) thick at the east edge of section 9, T. 23 S., R. 24 E., north of the Dolores River and 107 feet (33 m) thick along the west edge of section 5, T. 23 S., R. 24 E., on the west side of the Colorado River. The Cedar Mountain Formation is considered to be latest Early Cretaceous (Barremian to Albian) in age (Fouch and others, 1983; Kirkland, 1992).

Dakota Sandstone (Kd)

The Dakota Sandstone is divisible into a lower conglomerate and sandstone interval, a middle carbonaceous shale, coal and sandstone interval, and an upper sandstone interval. The various lithologies contained in the Dakota suggest the unit may more appropriately be called the Dakota "Formation." The lower conglomerate and sandstone interval forms a continuous cliff that caps the steep slope created by the Brushy Basin Member of the Morrison Formation and the Cedar Mountain Formation. It consists of interbedded pebble or cobble conglomerate, conglomeratic sandstone, sandstone, and gray mudstone partings. The conglomerate is light to medium gray, varies from matrix to clast supported, and is moderately cemented. Cobbles range to as much as 3 inches (7.6 cm) in diameter, though most are 2 inches (5 cm) or less. Cobbles are gray, white, or black chert, dense sandstone, and quartzite. They are moderately to well sorted and are subrounded to rounded. The sandstone is mostly medium grained, calcareous, cross-bedded, and forms thick lenses interlayered with the conglomerate beds.

The middle interval of the Dakota Sandstone is composed of interbedded carbonaceous shale, mudstone, fine- to medium-grained sandstone, coal, and bentonitic clay. It is generally nonresistant and poorly exposed. The sparse coal beds are thin, mostly under 6 inches (15 cm) thick.

The upper interval of the Dakota Sandstone is composed of resistant, thick-bedded to massive, locally pebbly, sandstone. Carbonaceous shale and mudstone partings are locally present. The sandstone varies from very fine to medium grained, and grains are rounded to subrounded. The upper sandstone is yellowish orange to yellow gray, planar to lenticular, and cross-bedded.

The upper contact of the Dakota is a hummocky to channeled surface with up to 10 feet (3 m) of relief. The contact is commonly sharp and is placed at the change from resistant sandstone to a reworked thin sandy mudstone, followed by thinly laminated gray mudstone and shale of the Tununk Shale Member of the Mancos Shale.

The thickness of the Dakota Sandstone ranges from 80 to 100 feet (24-30 m) in the quadrangle. The thicknesses of the individual intervals vary considerably. In the SW¼ section 26, T. 22 S., R. 23 E., near Owl Draw, the Dakota is 86 feet (26 m) thick with 22 feet (6.7 m) of the lower, 42 feet (12.8 m) of the middle, and 22 feet (6.7 m) of the upper interval. In the northeast corner of the quadrangle a nearly complete section of the Dakota is 94 feet (29 m) thick, with 24 feet (7 m) of the lower, 50 feet (15 m) of the middle, and 20 feet (6 m) for the upper interval. Middle to late Cenomanian in age, the Dakota Sandstone represents the last terrestrial and marginal marine deposition prior to transgression of the Mancos sea (Young, 1960; Fouch and others, 1983; Molenaar and Cobban, 1991).

Mancos Shale

Tununk Shale Member of the Mancos Shale (Kmt): The Tununk Shale Member of the Mancos Shale forms a strike valley between the Dakota Formation dipslope and the cuesta formed by the overlying Ferron Sandstone Member in the northwest part of the map area. Remnants of the unit are also present on Hotel Mesa, east of the Colorado River and north of the Dolores River. The Tununk Shale Member consists mostly of light- to dark-gray marine shale and silty shale that weathers to pale yellowish brown. It also contains a few thin, fine-grained sandstone beds. Most Tununk bedding is thinly laminated. The upper part of the member forms a slope that rises to the base of a cuesta formed by the more resistant Ferron Sandstone Member. The Tununk contains the Coon Spring Sandstone Bed, which is very poorly exposed in the quadrangle and could not be accurately traced. Locally, however, a few large rounded sandstone concretions, as much as 2 feet (0.6 m) in diameter mark its position. Generally, these sandstone concretions are the only well exposed part of the bed. In nearby areas where the Coon Spring Sandstone Bed has been identified, the interval is 35 to 45 feet (10.6-13.7 m) thick (Willis and others, 1993; Willis, 1994). The Coon Spring Sandstone Bed commonly contains marine fossils.

The upper contact of the Tununk is considered to be a major sequence boundary between the Greenhorn cyclothem below and the Niobrara cyclothem above (Molenaar and Cobban, 1991; Willis and others, 1993). A sequence is a relatively conformable, genetically related succession of strata bounded by unconformities or their correlative conformities (Mitchum, 1977; Van Wagoner and others, 1990). Poor exposures and a wide outcrop belt prevent an accurate measurement of the Tununk Shale in the Dewey quadrangle. I estimate its thickness at about 220 feet (67 m). The Tununk is late Cenomanian to late middle Turonian in age (Willis and others, 1993).

Ferron Sandstone Member of the Mancos Shale (Kmf): The youngest bedrock unit exposed in the Dewey quadrangle is the Ferron Sandstone Member. Its upper contact is not present in the quadrangle. The Ferron forms a uniform double cuesta that stands as much as 80 feet (24 m) above the surrounding topography. It consists of fissile silty shale, sandy shale, and sandstone. Its pale- to medium-gray-brown, laminated to thin-bedded, quartzose sandstones are well sorted and range from mostly very fine grained to fine grained. Two cuestas are formed by these resistant sandstones, separated by medium- to dark-gray, marine, organic shale. Gypsiferous nodules and veinlets often accompany the dark shales. Fossils are common, especially on the dip slope of the upper cuesta, and include oysters (*Lopha lugubris*), bivalves (*Inoceramus dimidius* and *Inoceramus perplexus*), and ammonites (*Prionocyclus macombi*, *Prionocyclus wyomingensis* and two or three species of *Scaphites*) (Molenaar and Cobban, 1991).

The thickness of the Ferron is about 90 feet (27 m); each cuesta-forming sandstone is about 30 feet (9 m) thick and the intervening dark marine shale is about 30 feet (9 m) thick. The Ferron Sandstone Member is late Turonian in age.

Quaternary Deposits

The quadrangle is in an area that is undergoing relatively rapid downcutting and erosion. Thus, surficial deposits are mostly young, thin, and scattered. Older surficial deposits are limited to eolian and alluvial deposits on protected benches, pediments, and terraces. All surficial deposits in the quadrangle are probably Quaternary in age (first letter in the map symbol). The surficial deposits are categorized by the dominant environment of deposition (second letter in the map symbol), then by subenvironment, landform occurrence, or texture (generally the third letter in the map symbol). Where possible, relative age is indicated by a number subscript, with higher numbers designating older deposits.

Alluvial Deposits

The map symbols for the several varieties of alluvial deposits in the Dewey quadrangle all begin with Qa on the geologic map (plate 1). Materials in the deposits came from several upstream sources. Terrace deposits were formed from sediment carried in by the Colorado River and two principal tributaries, the Dolores River and Sagers Wash. Pediment-mantle deposits contain materials eroded from nearby areas that were carried to their present positions and deposited as alluvial fans. These alluvial fans have been extensively eroded so the remaining deposits are only found on divides between the washes. The pediment-mantle deposits are graded from the foot of the cliffs adjacent to Professor Valley and Richardson Amphitheater toward the Colorado River. The stream deposits (Qa_1, Qa_2) are younger lithologic equivalents of terrace gravel deposits (Qat_3 - Qat_8).

The oldest Qat deposits are abandoned high on the flanks of the parent river or wash and are labeled with the highest numbers. They roughly follow the relatively gentle gradient of their parent stream, but at a higher elevation. Alluvial deposits (Qa_2) that flank the youngest Qa_1 deposits are older stream alluvium presently being covered by alluvial-fan, sheetwash, ephemeral-wash, and flood deposits on an intermittent basis.

Alluvium and terrace gravel deposits (Qa_1, Qat_3-Qat_8): Alluvium and terrace deposits brought in by the Colorado River consist of moderately sorted sand, gravel, silt, and clay. They form sand and gravel bars near normal water level in the active channel and are present as flat-topped accumulations with steep-sided slopes in the terrace deposits (figure 7). The terrace deposits are found at various elevations above current river levels (figure 8). The gravelly clasts average between 1/2 inch and 10 inches (1.3 and 25 cm) in diameter, but locally boulders exceeding 2 feet (0.6 m) in diameter are found. Most clasts are metamorphic rock types including quartzite, pegmatite, felsite, pink granite, amphibolite, metaconglomerate, sandstone, and volcanic rocks. These were clearly derived from the metamorphic terrain in the Uncompahgre uplift and other areas in Colorado. The cobbles are rounded to subrounded, many are discoidal and some are "rollers" (figure 9). The sandy intervals are largely quartzitic with a large component of magnetite grains. These sandy intervals are commonly gold bearing. Eolian sand and silt has partially covered the tops of the older terrace deposits, which are nearly flat. In the older deposits the undersides of some of

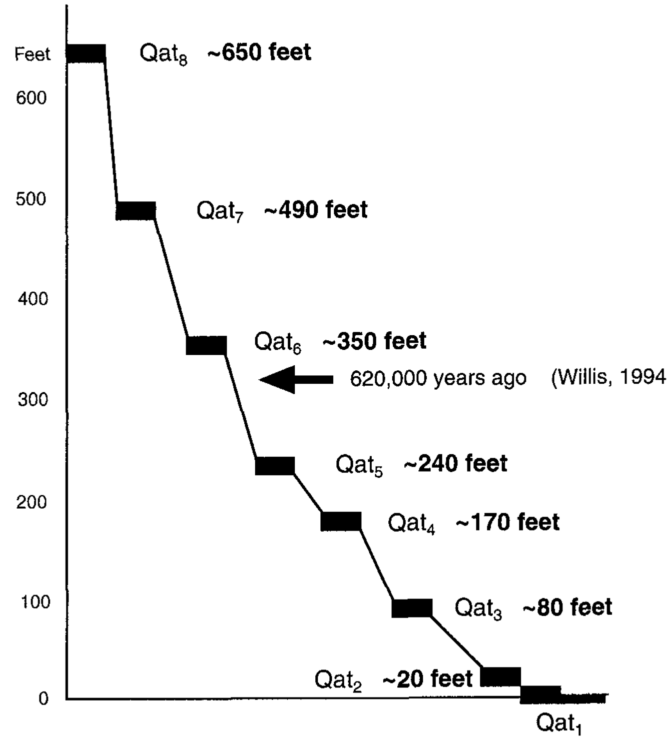

Figure 8. Elevations of alluvial-terrace deposits (Qat) above current river levels in the Dewey quadrangle. Willis (1994) discovered the 620,000-year-old Lava Creek B Ash, about 25 miles (40 km) to the northeast, in the Harley Dome quadrangle below a prominent terrace 350 feet (107 m) above the principal drainages. The ash helps constrain ages of terrace deposits in the region.

the cobbles are coated with calcium carbonate. Most terrace deposits are 10 to 15 feet (3 - 4.5 m) thick and rarely exceed 20 feet (6 m).

Alluvium and terrace deposits of the Dolores River are similar to those of the Colorado River, but they contain a large component of diorite derived from the La Sal Mountains. The diorite is found in Colorado River terraces below the confluence. Alluvium in Sagers Wash contains much mud from the Mancos Shale and also contains pebbles to small cobbles of rounded red, black, and yellow chert, limestone, and angular sandstone fragments from the Book Cliffs area. Most pebbles and cobbles range to 1 inch (2.5 cm) in diameter, but a few have diameters exceeding 2 inches (5 cm). The mud is rarely preserved in the terrace deposits. Terrace deposits found on the Dakota Sandstone on the west side of the Colorado River contain gravels derived from local conglomeratic beds.

Alluvium and older alluvial deposits (Qa_2): These deposits are found a little above the young alluvial stream deposits (Qa_1) of the Colorado and Dolores Rivers, Sagers Wash, and other washes. They consist of sand, mud, silt, and gravel transported by these drainages before they settled into their present channels. They received sediments at a reduced rate primarily during inclement weather or by flooding; in debris flows, in sheetwash, and from overbank flooding. A smaller increment is deposited by the wind and mass wastage. The older deposits are as much as 25 feet (5 m) thick.

Figure 9. *Rounded cobbles of an alluvial-terrace deposit. Most cobbles have been transported many miles by the Colorado or Dolores Rivers and consist of igneous, metamorphic, and sedimentary rocks. Some terraces are found as high as 650 feet (200 m) above the present level of the rivers. There is little difference in the lithology of the cobbles between terrace levels. The notebook is about 1 foot (30 cm) long.*

Pediment-mantle deposits (Qap): Pediment-mantle deposits were formed as alluvial fans during the Pleistocene when climatic conditions favored cliff retreat. In the Dewey quadrangle they are mostly found in the Richardson Amphitheater and Professor Valley area and consist of materials derived from the surrounding cliffs. They grade upward into talus deposits (Qmt) that mantle parts of the steep slopes below cliffs and slope riverward. They consist of orange sand and silt and angular to subangular fragments of sandstone. The diameter of a sandstone fragment or boulder may range to as much as 15 feet (5 m); most are less than 2 feet in diameter. The thickness of the pediment mantle deposits range to 15 feet (5 m).

Mass-Movement Deposits

There are two dominant types of mass-movement deposits in the Dewey quadrangle that are discussed in detail below. Additional kinds of mass-movement deposits that were not mapped separately include rock falls, common below steep cliffs, and colluvium which has collected adjacent to finer-grained sources.

Landslide deposits (Qms): Slumps, rotational blocks, and other landslide deposits are found on both sides of the Colorado River just north of the Dolores River confluence. All of these deposits involve the Brushy Basin Member of the Morrison Formation which contains much claystone. Only the larger deposits are mapped. The largest mass, on the west side of the river, is a block more than a half mile (0.8 km) long and as much as 1,000 feet (305 m) wide, that has slipped at least 100 feet (30 m) and has been rotated slightly.

Talus deposits and colluvium (Qmt): Talus deposits and colluvium are found on steep slopes along canyon walls and below most cliffs (figure 3). Talus and colluvium exhibit gradational contacts; therefore they are lumped together. Talus deposits consist of rock fall blocks, boulders, and smaller fragments. Colluvium consists mostly of slopewash material and is comprised of poorly sorted, angular to subangular rock fragments in a matrix of coarse to fine sand, silt, and clay. Some colluvium may display weak discontinuous bedding parallel to slope, but most is structureless (Richmond, 1962). Colluvium generally supports vegetation, whereas talus contains little fine material between blocks and supports little vegetation.

The best preserved Qmt deposits occur as cones and sheets on the slope of the Triassic and Permian formations beneath the overlying Jurassic Glen Canyon Group sandstone cliffs (figure 3). The deposits range from a thin veneer to a thick 10-foot (3-m) layer and have relatively smooth concave surfaces locally scored by shallow gullies. Qmt deposits are commonly gradational and interfinger with pediment-mantle (Qap) materials at their downslope extent. The contact between Qmt deposits and pediment mantle-deposits is arbitrarily placed at a break in slope.

Eolian Sand Deposits (Qes)

Areas of small-scale dunes and thin-sheet accumulations of eolian sand are present on the sandstone plateaus in the quadrangle. These relatively thin, discontinuous deposits commonly fill narrow canyons, erosional surface depressions, and accumulate on the lee sides of irregular bedrock outcrops. Most eolian deposits support sparse vegetation and are partially stabilized. The deposits are probably Holocene in age. In the Dewey quadrangle they are especially prominent adjacent to the Entrada Sandstone where they reach a maximum thickness of about 15 feet (4.5 m).

Mixed-Environment Deposits (Qea, Qer)

Many Quaternary deposits grade into one another. The most common are the mixed eolian and alluvial deposits (Qea) and the mixed eolian and residual deposits (Qer). Qea deposits generally have a higher eolian than alluvial constituent, but in the Dewey quadrangle deposits can be found that have a higher alluvial constituent. I did not attempt to map them separately and all are labelled Qea. Qea deposits are older than the eolian sand deposits (Qes). The deposits, dominantly composed of sand, are preserved in large hollows in bedrock where fluvial reworking is limited. Locally washes have cut deeply into the deposits and exposed crudely stratified sand, silt, sandstone fragments, and small pebbles. Some show the development of weak calcification below upper surfaces, indicating an older age than the Qes and Qa_2 deposits.

Mixed eolian and residual deposits are found on the limestone deposits in the Navajo Sandstone and to a lesser extent on limestone or calcareous sandstone beds in the Cedar Mountain Formation. Such deposits were also mapped on larger terrace deposits where eolian silt and sand has mixed with with residual gravel. Broken and partly dissolved fragments of the limestone lie as rubble on these surfaces and are mixed with red silt and yellow sand that was deposited by the wind. In most cases the deposits are less than a foot (30 cm) thick.

STRUCTURE

The dominant structural element in the Dewey quadrangle is a 4 to 7 degree north by northeast-dipping homocline in which all the bedrock units participate (cross section A-A′, plate 2). The formations dip into the Uinta basin, which subsided mostly in early Tertiary time. The Sagers Wash syncline, which also formed during the early Tertiary, trends northwest across the northeast corner of the quadrangle and dips increase rapidly to 5 or 6 degrees southwest on the northeast flank (cross section B-B′, plate 2). Cretaceous units are exposed in the synclinal trough.

The Cutler Formation was slightly warped by Permian salt tectonism. As attested by the slight angular unconformity at the top of its eroded surface, the Cutler is warped into very gentle flexures that trend nearly east-west across the exposures in the southern part of the quadrangle. These are not easily defined and are not mapped on plate 1. The Richfield Oil #1 Onion Creek Unit, NE¼ SW¼ section 31, T. 23 S., R. 24 E., well probably targeted one of these structures.

The Blue Chief Mesa fault extends from the west side of the Colorado River 6 miles (9.5 km) eastward into the Blue Chief Mesa quadrangle where it continues for an additional 5 miles (8 km). The displacement is about 120 feet (37 m) near the east margin of the quadrangle and gradually decreases westward. West of Waring Canyon the displacement is less than 100 feet (30 m) and on the west side of the Colorado River is less than 50 feet (15 m). Slickensides are not well preserved, but the movement appears to have been nearly vertical. Although the fault is shown as a single line, it is broken into several closely spaced branches in the cliff wall on the east side of the Colorado River. I believe the fault is either an adjustment of homoclinal tilting or is related to Laramide folding over the Onion Creek salt-cored anticline, located to the southwest.

A buried fault zone marks the southwest margin of the ancestral Uncompahgre uplift. In a map published by White and Jacobsen (1983), this buried fault zone extends across the northeast corner of the Dewey quadrangle, approximately in line with the Sagers Wash synclinal axis (cross section B-B′, plate 2). From drill-hole evidence northwest and southeast of the quadrangle, they showed that the fault zone dips 50 to 55 degrees northeast with as much as 14,000 feet (4,267 m) of measurable offset. The Upper Triassic Chinle Formation may rest directly on the Precambrian basement northeast of the fault zone. To the southwest, Cambrian, Devonian, Mississippian, thick Pennsylvanian and Permian, and Lower Triassic rocks rest on the Precambrian basement in the Paradox basin. The fault zone was intermittently active from Middle Pennsylvanian until Early Triassic time.

ECONOMIC GEOLOGY

Vanadium and Uranium

Several uranium and vanadium prospects were opened in the Dewey quadrangle during the uranium boom of 1948 - 1958 (Doelling, 1969). These are located in the Squaw Park and Dewey Bridge areas of the Thompson uranium mining district (Doelling, 1982). The boundary between the two areas is the R. 23 E./R. 24 E. township line. The mineralization is generally limited to a few feet of rock at the base of thick sandstone channels in the Salt Wash Member of the Morrison Formation. Limonitization is generally exhibited in the weakly mineralized areas, where coatings of tyuyamunite are commonly found on fracture surfaces. Such coatings and dark streaks of montroseite and uraninite are found in more strongly mineralized areas.

Two prospects on Little Pinto Mesa in the Dewey Bridge area (locations 1 and 2, plate 1) show mineralization at the base of a 20-foot (6-m) thick channel in the SW¼ SW¼ SW¼ section 15, T. 23 S., R. 24 E. It consists mostly of limonitization of sandstone, in a zone about 3 to 5 feet (0.9-1.5 m) thick and 50 feet (15 m) wide. The base of the channel is filled with sandstone, cobble and limestone-nodule conglomerate, and gritstone. Jarosite is identifiable locally. Silicified plant impressions are present at the top of the mineralized part of the channel. The working consists of a 12 x 18 foot (3.7 - 5.5 m) cut. No production was achieved, the occurrence appears to be low grade, and the reserve is small. A similar but smaller occurrence of mineralization on Little Pinto Mesa, in the SW¼ SE¼ SE¼ section 16, T. 23 S., R. 24 E. shows a limonitized channel sandstone about 5 to 6 feet (1.5-1.8 m) thick, 150 feet (46 m) long and 20 feet (6 m) wide. There a fine- to medium-grained sandstone host rock contains a few plant impressions and a few pods of cobble conglomerate are found near the base. Workings consist of a 10 x 6 x 3 foot (3 x 2 x 1 m) cut or pit and a few other diggings.

A small vanadium-uranium mine above Buck Spring in the NW¼ SE¼ NE¼ section 12, T. 23 S., R. 23 E. (location 3, plate 1) shows mineralization in the lowermost thick sandstone ledge in the Salt Wash Member of the Morrison Formation. The ore zone is as much as 2 feet (0.6 m) thick. Mineralization along 60 feet (18 m) of the channel is mostly confined to the outcrop area. Tyuyamunite and montroseite are present. Workings consist of three adits, totaling 180 feet (55 m) in length, mostly exposing barren rock.

Mineralization occurs at the base of a thick channel near the base of the Salt Wash Member (location 4, plate 1). The channel is 20 feet (6 m) thick; limonite mineralization is most evident, jarosite and perhaps a little vanadium clay is present. Carbonized wood and plant impressions occur in the sandstone. Mineralization extends 80 feet (24 m) along the outcrop, reaching a maximum thickness of 6 feet (1.8 m) in medium- to coarse-grained sandstone. Workings consist of a 6-foot (1.8-m) adit blasted into the base of the ledge.

A cut in the Salt Wash sandstone, S½ section 3, T. 23 S., R. 23 E. (location 5, plate 1) is about 40 feet (12 m) long and 3 feet (1 m) wide. Two smaller cuts or diggings are nearby. The cuts were made in dark sandstone, possibly mineralized with vanadium, 40 to 50 feet (12 to 15 m) above the Tidwell Member contact. The weakly mineralized area is 50 x 100 feet (15 x 30 m). I observed no yellow uranium minerals during field examination.

Locations 6 and 7 (plate 1) are 60 feet (18 m) apart. The workings consist of various cuts and short adits along a mineralized zone trending N. 60° W. Observable minerals which I identified include limonite, jarosite, vanadium hydromica, and tyuyamunite on fracture surfaces below a dark ore zone 1 to 2 feet (0.3 - 0.6 m) thick. At one location an unidentified bright green mineral coats fractures. Many carbonaceous impressions of bark and twigs are present. Stockpiled ore (1994) amounts to 1 or 2 tons (0.9 - 1.8 tonnes).

The largest cluster of workings, known as the Squaw Park Group, is found along two tributaries of Owl Draw near the west side of the Dewey quadrangle. Several short adits are found in the N½ section 3, T. 23 S., R. 23 E. (location 8, plate 1; figure 10). The base of a Salt Wash Member channel has a mineralized zone as much as 2.5 feet (0.8 m) thick. The mineralized zone appears as a dark streak just below the roof of the mine. Mineralization consists of limonite and vanadium hydromica disseminated in sandstone. Tyuyamunite coats fractures in the ore zone as well as below it. Plant impressions are common in the ore. The mine is credited with a production of about 5,000 pounds (2,268 kg) of U_3O_8 and an unknown amount of V_2O_5 according to unpublished U.S. Department of Energy (old Atomic Energy Commision) records.

Locations 9 and 10 (plate 1), not far from the Squaw Park workings, are two areas of rusty sandstone, both with abundant plant impressions and one with a log of splintery petrified wood. An adit at location 11 is cut into a 12- to 15-foot (3.7- to 4.5 m) thick sandstone channel. The lower part of the channel is weakly limonitized, but contains streaks of mineralized, mostly medium-grained sandstone containing vanadium hydromica and possibly uraninite. Workings consist of a 30 foot (9 m) adit, 8 feet (2.4 m) wide and 5 feet (1.5 m) high. Carbonaceous horizons are found 3 to 5 feet (0.9-1.5 m) above the base.

Sand and Gravel

Colorado River alluvium (Qa_l) and alluvial-terrace deposits (Qat) contain materials used in the construction of highways. Physical tests were conducted on samples of Colorado River deposits by the Utah Department of Transportation (about 1967) at nearby localities (not in the Dewey quadrangle) and found material suitable as base and surfacing gravel and for use in concrete and asphalt mixtures. Tested alluvium and terrace deposits were non-plastic, had swell analyses ranging from 0.008 to 0.015, and an American Association of State Highway Officials classification of A-1-a. The total amount of sand and gravel resources in the quadrangle is large. At least five pits in the quadrangle area have been exploited along the Colorado River. These are described in table 1 and located on plate 1.

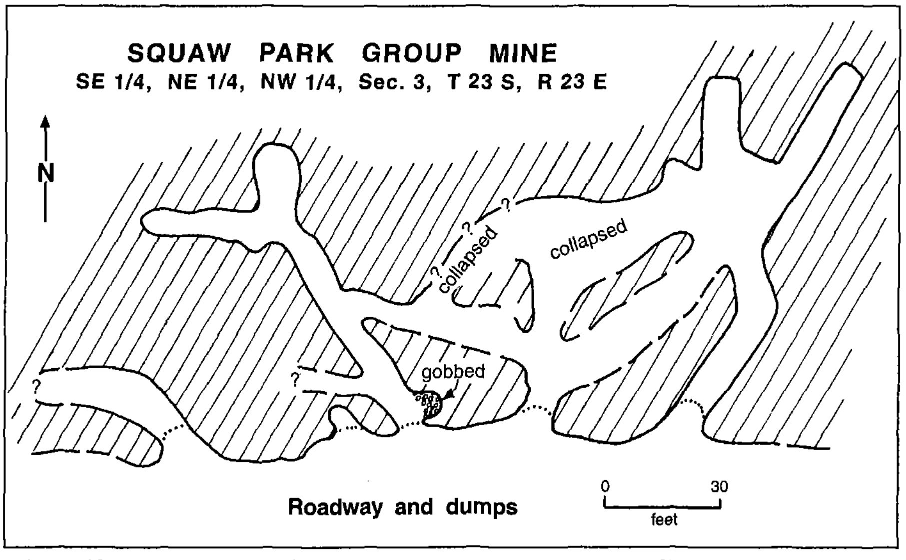

Figure 10. Brunton-pace outline map of a Squaw Park Group vanadium-uranium mine in the Dewey quadrangle. An ore zone 1 to 2 feet (30-60 cm) thick in the mine contained an average of 0.15% U_3O_8. The high-vanadium, low-lime ore consisted of impregnations of montroseite, vanadium-bearing clay, and tyuyamunite.

Oil and Natural Gas

Only one oil and gas test well has been drilled in the Dewey quadrangle. A 13,922-foot (4,243-m) hole, the Richfield Oil #1 Onion Creek unit, was drilled in the south end of the quadrangle in 1961. Several small producing fields are known 20 to 25 miles (32-40 km) to the southwest that draw oil from Cane Creek zone in the Paradox Formation (Clem and Brown, 1984; Doelling and others, 1992) and the Cane Creek zone was the apparent target for the Richfield well. The northern part of the quadrangle lies 8 to 9 miles (13 - 14.5 km) south of the Greater Cisco Area. The fields in the Greater Cisco area are primarily gas producers, though oil has also been produced. Young (1983) suggested that the gas was derived primarily from carbonaceous material in the Mancos, Dakota, Cedar Mountain, and Morrison Formations and that the oil migrated eastward and up section from Pennsylvanian strata in the Paradox basin. A few shallow wells were spudded and drilled in the Mancos Shale north of the Dewey quadrangle, but all were plugged and abandoned.

Chalcedony

Chalcedony, including jasper and agate, is present in the Tidwell and Brushy Basin Members of the Morrison Formation and in the Cedar Mountain Formation. Some of the material found in the Dewey quadrangle may be suitable for polishing. Jasper is yellow, red, or brown, impure, and slightly translucent. Agate is banded or irregularly clouded, in shades of gray, and slightly translucent. Most of the chalcedony in the Dewey quadrangle is strongly fractured. There are no specific collecting localities and good material may be found in small pieces over much of the quadrangle.

Gold in the Mancos Shale

A mine or prospect exploiting gold in the Mancos Shale is present in the NE¼SE¼NW¼ section 29, T. 22 S., R. 24 E. above McGraw Bottom, east of Utah Highway 128 (U-128), ½ mile (0.8 km) northwest of the Colorado River. Development consists of a 2.5-acre (1 ha) triangular-shaped parcel of disturbed ground in the Tununk Member of the Mancos Shale. At the time of my visit (November, 1993) the property was inactive. Facilities and equipment consisted of a small building, a hopper and small conveyor belt for receiving material, a rotary kiln, and shaker tables.

The exploited outcrops lie approximately in the middle of the Tununk Member of the Mancos Shale. Most of the material is a silty gray marine shale, but some sandy zones showing a little rusty mineralization are present. Marlatt (1991) found that gold, silver, copper, arsenic, and mercury, at higher than normal concentrations are present in the Mancos Shale in an area centered about Thompson, Utah, west of the Dewey quadrangle. He hypothesized that the metals were introduced into the Mancos from volcanic tuffs. Irregular distribution in the Mancos Shale indicates subsequent mobilization of these metals. Economically exploitable gold concentrations will probably be difficult to find; the highest sampled concentrations of Marlatt (1991) reach only 150 parts per billion (ppb).

Gold Placer Deposits

Several abandoned gold placer workings are present in the Dewey quadrangle in the terrace gravels of the Colorado and Dolores Rivers, and a small amount of gold was evidently recovered. Many of the terrace deposits have been prospected as attested by numerous trenches. Four deposits where abandoned gold extracting equipment was found are in section 9, T. 23 S., R. 24 E., on the Dolores River, and sections 17 and 18, T. 23 S., R. 24 E. and section 35, T. 23 S., R. 23 E., on the Colorado River. Some of these placer workings have also been exploited for their sand and gravel (table 1).

The gravels of the Colorado and Dolores Rivers (Qa_l) and terrace alluvium (Qat) contain small amounts of flour and rare flakes of gold. The gold occurs in black, magnetite-bearing, coarse, sandy streaks in the river alluvium. The gold content is generally uniformly distributed vertically, but the upstream ends of the gravel bars and higher terraces may be slightly richer in gold content (Butler, 1920).

Coal and Humates

The Dakota Sandstone contains a carbonaceous interval that has been investigated for both coal and humates. In the Dewey

Table 1.
Gravel pit summary for Dewey quadragle. Undeveloped gravel resources are large.

Gravel pit location	Disturbed area (yards)	Highwall (feet)	Average thickness (feet)	Estimated production (cubic yards)	Resource remarks
1. South McGraw Bottom Sec. 32, 22S, 24E	70 x 200	10	4.5	21,000	possibly 10,000 cubic yards remaining
2. Roberts Mesa Sec. 17, 23S, 24E	150 x 400	15	4.5	90,000	at least 50,000 cubic yards, worked for gold
3. Kokopelli Trail Sec. 7, 23S, 24E	70 x 180	10	3.0	12,600	small
4. West Kokopelli Sec. 7, 18, 23S, 24E	170 x 315	30	4.5	47,250	at least 30,000 cubic yards, worked for gold
5. River Bend Sec. 18, 23S, 24E	33 x 140	20	6.0	9,240	small

quadrangle, coal beds are discontinuous, lenticular, and impure. I could find no coal seams greater than 6 inches (15 cm) in thickness. Carbonaceous shale is not as well developed as in quadrangles to the northeast (Willis and others, 1993).

Copper and Barite

A small prospect in the SW¼ section 7, T. 23 S., R. 24 E. is cut through limestone into a flat-bedded calcareous sandstone host in the Navajo Sandstone. The pit is 18 x 10 x 5 feet (5 x 3 x 1.5 m) deep and trends N. 20° W. in the long direction. Malachite coats fractures and is observable in the calcareous sandstone cement. A powdery white mineral is also present. The mineralization host underlies four feet (1.2 m) of warped gray limestone. No samples were taken or analyzed.

Barite is present in the same beds that carry mineralization in the prospect mentioned above, about 1,000 feet (305 m) to the southeast. Bladed barite occurs in small rosettes that parallel bedding planes.

Water Resources

The Dewey quadrangle lies in a mid-latitude steppe climatic area receiving an average of 8 to 10 inches (20-25 cm) of precipitation per year. Average annual evaporation rates are 38 to 40 inches per year (Iorns and others, 1964). The Colorado and Dolores Rivers are perennial through-going streams that are used for irrigation in the quadrangle. Small catchment basins have been constructed locally to utilize rainfall for watering cattle on the benches. A 10-year average flow of the Dolores River 9 miles (14 km) upstream from the Colorado River confluence was 716 cfs (20.3 m^3/s) or 518,400 acre-feet (639 x 10^6 m^3) per year. A 49-year average flow for the Colorado River a mile (1.6 km) downstream from the Dolores River confluence was 8,057 cubic feet/second (cfs) (228 m^3/s) or 5,833,000 acre-feet (7,200 x 10^6 m^3) per year (Hendricks, 1964). Flow in Sagers Wash and other drainages is ephemeral. Phreatophytes commonly grow along the channels of the principal washes indicating shallow subsurface flow in the alluvial materials.

Concentrations of dissolved solids and suspended sediment load for these streams varies considerably by season and by year. The total dissolved solids in the Colorado and Dolores Rivers averages about 1,220 ppm and can vary from 500 to 2,000 ppm (Iorns and others, 1964). Dissolved solid concentration in the underflow under Sagers Wash is probably higher. Streams that cross the Mancos Shale generally carry large amounts of sulfate.

Bedrock aquifers in the Dewey quadrangle are largely untested. Sandstone formations of the Glen Canyon Group are considered the most important bedrock aquifers in the region (Feltis, 1966; Blanchard, 1990). Good potential for ground water may be present in other sandstone formations in the area. Except for the sandstones in the Dakota Sandstone, Cretaceous and Triassic units are generally regarded as aquicludes.

In sandstone units the potential for small amounts of water is good. Most springs indicated on the Dewey topographic map issue from near the base of the Navajo Sandstone or the base of the Moab Member of the Entrada Sandstone. A few issue from alluvial deposits in wash channels below these units, probably deriving their water from these two units upstream. These aquifers are probably recharged by snowmelt on the higher bench areas. The quality of water obtained from sandstone aquifers is generally good, with concentrations of dissolved solids generally less than 400 ppm. The water type is calcium bicarbonate or calcium magnesium bicarbonate, and the water is moderately hard to hard (Blanchard, 1990). Water from Cutler Formation sandstone is expected to be of lesser qualtiy. Wells dug in the Cutler in Castle Valley had dissolved solids concentrations ranging from 1,420 to 3,450 ppm (Blanchard, 1990) and had concentrations of selenium that exceeded State of Utah drinking-water standards. Water from the Cutler Formation is slightly saline to saline in quality.

GEOLOGIC HAZARDS

Debris Flows and Stream Flooding

Erosion by running water is the most active and potentially damaging hazard in the quadrangle. The sparsely vegetated steep slopes and deep, narrow ephemeral washes are subject to rapid erosion from waters generated by cloudburst storms and spring snowmelt runoff. Debris flow, debris flood (hyperconcentrated stream flow), and normal stream flow form a continuum of sediment/water mixtures. Debris flows and floods generally remain confined to stream channels in high relief areas, but may exit the channels and deposit debris where slope gradients decrease (on alluvial fans). Almost all units (except the Mancos Shale) consist of rocks conducive to the accumulation of talus and colluvium on slopes, providing ample material for debris flows. Debris-flow deposits intermittently cover sections of the back roads in the quadrangle.

Flooding of the Colorado River occurs during unusually high spring runoff years because the river is unregulated by engineered structures upstream of the Dewey quadrangle. At least three segments of U-128 along the Colorado River between McGraw Bottom and Professor Valley were damaged during the 1983 runoff (Davis, 1989). The highway was closed for several weeks in July, 1983. Pavement, embankments, and culverts all suffered damage. Cloudburst floods regularly damage the back roads by deep gullying at wash crossings and along the steeper grades.

Rock Fall

Rock falls occur sporadically throughout the rugged topography of southern Grand County. In the quadrangle, blocks of rock from Kayenta, Wingate, Chinle, Moenkopi, and Cutler Formations cliffs commonly produce rock-fall debris. The most susceptible cliffs or slopes are those broken by fractures that subparallel cliff faces.

The high cliffs that face the Richardson Amphitheater or Professor Valley are active rock-fall areas. Fortunately the area is not developed. Because few people live there, no recent events have been recorded, but several rock falls in similar terrain have been recorded in the Big Bend quadrangle to the southwest (Doelling and Ross, 1993). Joints and fractures are common in the massive cliffs of the Kayenta and Wingate Formations, which are slowly being undercut by erosion of the less resistant Chinle Formation.

Rock-fall debris may travel considerable distances down slope by rolling, bouncing, and sliding. The potentially large size of some debris and relatively high velocity of movement present a hazard to automobiles traveling along U-128 along the Colorado River canyon. Large angular boulders of Wingate Sandstone are found on both sides of the highway attesting to previous rock falls. Each spring rock-fall debris in the Canyonlands region must be cleared away by the Utah Department of Transportation to keep the highway passable for travelers.

Problem Soils

Clay- and evaporite- (mostly gypsum) bearing rock and soil that expand and contract as they absorb and lose moisture, and that flow when loaded, cause problems with road maintenance. The Morrison, Cedar Mountain, Dakota, and Mancos Formations all contain expansive clays. Large dips and swells in roads that cross these formations attest to this problem. Collapsible soils are common in mixed colluvial and alluvial deposits and are subject to volumetric changes that could damage man-made structures. Alluvial mud derived from the Mancos Shale, in the northern part of the quadrangle, and many fine-grained units (Brushy Basin Member of the Morrison Formation and Cedar Mountain Formation) are prone to piping and rapid erosion. Piping is subsurface erosion by ground water that flows into permeable noncohesive layers in unconsolidated sediments, removes fine sediments, and eventually produces a pipe-shaped cavity. Piping is especially common along stream embankments, which are weakened by the pipes and collapse during floods.

Landslides

Large landslides have formed in the Brushy Basin Member of the Morrison Formation on both sides of the Colorado River north of the Dolores River confluence. Abundant claystone makes the unit prone to landsliding, a characteristic that is exacerbated during wet climatic cycles. Small, unmapped slumps are present at many locations along the outcrops. Engineered structures constructed on the Brushy Basin Member would likely suffer structural damage. Road construction should avoid the claystones and, if possible, be built over gravelly surficial deposits.

Earthquake Hazard

The quadrangle is in the middle of the Colorado Plateau, a region with a low to moderate recurrence interval of small- to moderate-magnitude earthquakes (Wong and Humphrey, 1989). Earthquakes greater than magnitude 4 (large enough to be felt) are rare in the region, and the quadrangle is far from known Holocene faults (Arabasz and others, 1979; Hecker, 1993). The quadrangle is in Uniform Building Code seismic zone one, indicating low potential for earthquake damage (International Conference of Building Officials, 1991).

Blowing Sand

Sand, especially in the vicinity of Entrada Sandstone outcrops may cover back roads during wind storms. Deposits of eolian sand become very dry during the hot summer months, making it difficult even for four-wheel-drive vehicles to move on them.

SCENIC RESOURCES

Most of the Dewey quadrangle displays magnificent canyonland vistas. The Colorado River has incised a deep canyon across the quadrangle and high canyon walls are lined with the scenic vertical cliffs of the Glen Canyon Group. Utah Highway 128 (U-128) is a beautiful 35 mile (56 km) river drive that extends eastward from Moab to Dewey, and thence northward to join with Interstate Highway 70, 10 miles (16 km) to the north. Excellent views of monoliths called the Priest and Nuns, Castle Rock, and Fisher Towers, located in the Fisher Towers quadrangle to the south and the northern La Sal Mountains, are visible from Castle Valley. The Professor Valley-Richardson Amphitheater have been the scenic sites for the filming of several classic Hollywood western movies.

River running in rafts and canoes, bicycling, hiking, and four wheeling are popular recreational activities conducted along the Colorado River and byways in the Dewey quadrangle. Part of the enjoyment of participation is a chance to view the geologic scenery. All of the rock units exposed in the quadrangle can be seen from the river.

Several arches have formed in the Entrada Sandstone in the Dewey quadrangle. An interesting free-standing arch has formed in the center, N½ section 11, T. 23 S., R. 23 E. Another free-standing arch, originally developed as a pothole arch, is present in the Slick Rock Member in the SE¼ SE¼ NE¼ section 11, T. 23 S., R. 23 E., about ½ mile (0.8 km) east of the other. The light-hued and banded Entrada Sandstone outcrops, floored and capped by red marker beds, are eroded into many fascinating shapes and forms that provide visual enjoyment to the modern explorer.

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