GEOLOGIC MAP OF THE HITE CROSSING–LOWER DIRTY DEVIL RIVER AREA, GLEN CANYON NATIONAL RECREATION AREA, GARFIELD AND SAN JUAN COUNTIES, UTAH

by Grant C. Willis

UTAH DNR GEOLOGICAL SURVEY

MAP 254DM
UTAH GEOLOGICAL SURVEY
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UTAH DEPARTMENT OF NATURAL RESOURCES
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Cover photo: *View southeastward of Lake Powell near mouth of North Wash. Organ Rock Formation, White Rim Sandstone, and Moenkopi Formation form prominent ledges and cliffs.*

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DESCRIPTION OF MAP UNITS

Quaternary

Qal **Alluvium (Holocene to upper Pleistocene)** – Moderately to well-sorted silt, sand, and pebble- to boulder-gravel deposited along Dirty Devil River and North Wash; most clasts are moderately to very well rounded showing significant transport from outside of map area; map unit includes deposits in active channel and in low terraces up to about 6 meters (20 ft) above channel; up to 6 meters (20 ft) thick. Most Qal deposits on the geologic map are Holocene (probably late Holocene) in age, and a large percentage are probably of Historic age (past 150 years), but because channels in the Colorado Plateau undergo cycles of cutting, back-filling, and then more cutting, some channels may contain older sediment. For example, Pederson (2009) showed that Late Pleistocene sediments may underlie the modern Colorado River channel in some areas.

Qat **Alluvial terrace-gravel deposits (Holocene to lower(?) Pleistocene)** – Pebble- to cobble-gravel with less common boulders, sand, and silt deposited by rivers and large streams and preserved as terraces; moderately to well sorted and rounded; clasts are mostly quartzite, chert, and igneous rocks, and less common sandstone, limestone, and gneiss (along Colorado River); clasts are better rounded and sorted than those in local alluvial deposits, and were derived primarily from outside the map area, but include small amounts of poorly sorted, locally derived sediment from side channels and adjacent slopes; mapped along Colorado and Dirty Devil Rivers and North Creek; locally partially mantled by thin eolian sand; forms terraces at many levels from about 6 meters (20 ft) to about 290 meters (950 ft) above the modern channel; highest-level deposits may exceed 1 million years in age (see tables 1 and 2 and discussion below); 0 to 10 meters (0–30 ft) thick.

Qae **Alluvial and eolian deposits (Holocene to upper Pleistocene)** – Mostly small boulder- to pebble-gravel, sand, silt, and clay deposited in small drainages and mixed with or covered by minor to moderate amounts of windblown sand and silt; poorly to moderately sorted and poorly rounded to subangular; locally includes minor colluvium and angular rubble from rock falls, landslides, and debris flows; clast composition reflects local lithologies; mapped in small washes where it includes deposits in active part of wash bottom to about 12 meters (40 ft) above wash floor; 0 to 6 meters (0–20 ft) thick.

Qaeo **Older alluvial and eolian deposits (lower[?] Pleistocene)** – Course angular gravel deposits preserved on a high bench on Trachyte Point in the western part of the map area are mapped as older alluvial and eolian deposits; consist of poorly sorted, angular to subrounded boulders up to 1 meter (3 ft) across to sand and calcic soil; the deposits are about 470 meters (1550 ft) above the floor of nearby North Creek; Cook and others (2009) determined an incision rate of 1.1 to 2.0 feet (0.35–0.6 m) per thousand years for terrace gravels up to 110 meters (360 ft) above nearby Trachyte Creek (about 5 kilometers [3 mi] southwest of North Creek); using these rates, these deposits are estimated to be 0.8 to 1.4 million years old (tables 1 and 2); 3 to 6 meters (10–20 ft) thick.

Long-Term Incision Rates and Ages of River-Terrace Gravel and Correlative Deposits

The Colorado River and its major tributaries establish the primary base level throughout the Glen Canyon area. In Glen Canyon, the river has a fairly uniform gradient of about 0.6 to 1 meter per kilometer (3–5 ft/mi) (just upstream in Cataract Canyon the gradient increases to 1.6 to 2.4 meters per kilometer [8–12 ft/mi]) with several locally steeper stretches. In general, over the last few million years the river has been in a state of incision, though evidence exists for periods of backfilling during short-term cut-and-fill cycles. This continued incision has left remnants of strath terraces and correlative surficial deposits “stranded” at many levels up to nearly 500 m (1600 ft) above the modern river and its tributaries (Hunt, 1969). The ages of these deposits can be determined by dating specific minerals in rare volcanic ash beds, basalt flows, and fine-grained sediment; measuring sun exposure times of boulders; and comparing the paleomagnetism of these deposits with others of known age (Willis, 1992; Hanks and others, 2001; Willis and Biek, 2001; Garvin and others, 2005; Karlstrom and others, 2007; Cook and others, 2009; Pederson, 2009). Using these ages in conjunction with the elevation of the deposits above the modern river channel allows calculation of average long-term incision rates. Calculated rates along the Colorado River range from about 0.18 meter (0.6 ft)/ka (per thousand years) near the Utah-Colorado state line and near the western Grand Canyon, to 0.4 to 0.7 meter (1.3–2.3 ft)/ka in central Glen Canyon National Recreation Area (GCNRA) near Navajo Mountain and the Henry Mountains (table 1) (Hanks and others, 2001; Garvin and others, 2005; Cook and others, 2009). The latter rates are some of the highest of any part of the Colorado River system and suggest that the lower 450 meters (1500 ft) of Glen Canyon were cut in just the last one million years! Part of this unusually high incision may be due to isostatic rebound from crustal unloading caused by rapid erosion of relatively nonresistant Triassic to Cretaceous sedimentary strata in the Glen Canyon area (Pederson, 2009), a residual effect of cutting of the Grand Canyon about 5.5 million years ago (Lucchitta, 1990; Cook and others, 2009). Table 2 shows calculated ages of major terrace and related deposits based on estimated

Table 1. *Selected long-term incision rates of the Colorado River and major tributaries. These rates vary widely throughout the Colorado River basin. Part of the variation can be attributed to difficulties in dating fluvial deposits, including less than ideal sampling conditions, sampling different kinds of materials, using different dating methods, and applying different interpretations to resultant data. Lowest rates are near the Utah-Colorado border and in the western Grand Canyon, and highest rates are in central GCNRA. Rates in side drainages are higher than along the main river channel. Based on these data, the estimated incision rate for the river in the Hite Crossing area over the last million years is about 0.4 meter (1.3 ft) per thousand years (see table 2).*

Average calculated incision rate per 1000 years meters	**(feet)**	**Time interval forming basis for calculation**	**Location**	**References**
0.24	(0.79)	3 million years	Glenwood Springs, Colo.	Kirkham and others, 2001; and references cited therein
0.18	(0.59)	620,000 years	Westwater Canyon northeast of Moab, Utah	Willis, 1992, 1994; Willis and Biek, 2001
0.4 0.12	(1.3) (0.4)	500,000 years 500,000 years	Eastern Grand Canyon and Glen Canyon Western Grand Canyon	Davis and others, 2001
0.5	(1.6)	500,000 years	Navajo Mtn pediment near central GCNRA	Hanks and others, 2001
0.4 0.7	(1.3) (2.3)	250,000–500,000 yr 0–250,000 years	Navajo Mtn pediment near central GCNRA	Garvin and others, 2005
0.31–0.5 0.09–0.15	(1.02–1.6) (0.3–0.5)	600,000 years	Eastern Grand Canyon and Lake Powell Western Grand Canyon	Lucchitta and others, 2001
0.38–0.48	(1.25–1.57)	189,000 years	Fremont River (upper Dirty Devil River) about 80 miles (130 km) northwest of Lake Powell	Marchetti and Cerling, 2001
0.14 0.07–0.09	(0.46) (0.24–0.30)	500,000 years 600,000 years	Eastern Grand Canyon Western Grand Canyon	Pederson and others, 2002; Karlstrom and Kirby, 2004
0.11	(0.36)	1.4 million years	San Juan River at Bluff about 30 miles (50 km) east of the eastern part of GCNRA	Wolkowinsky and Granger, 2004; Karlstrom and Kirby, 2004
0.15–0.18 0.05–0.08	(0.49–0.6) (0.16–0.25)	500,000 years 720,000 years	Eastern Grand Canyon Western Grand Canyon	Karlstrom and others, 2007
0.17–0.41 0.06–0.12	(0.54–1.35) (0.18–0.4)	3.7 million years 17 million years	Eastern Grand Canyon Western Grand Canyon	Polyak and others, 2008
0.35–0.6	(1.1–2.0)	267,000 years	Trachyte Creek near Hite in central GCNRA	Cook and others, 2009

average incision rates for the last one million years. These derived ages have a high uncertainty because dateable materials are rare and are not always in ideal settings, some sample sites are over 160 kilometers (100 mi) away, interpretation of some samples is debatable, and incision rates undoubtedly varied over time. However, the data still yield meaningful estimates. These average rates must be applied with caution to low-level deposits because short-term cut-and-fill cycles may overwhelm long-term incision processes. For example, Pederson (2009) pointed out that the sediment flux from the Pinedale glaciation of 15,000 to 25,000 years ago in the upper Colorado River basin is probably still buried below the modern river channel in the Lees Ferry area. Dating of historic and prehistoric artifacts, buried organic debris, and other materials using ^{14}C radiocarbon and other dating methods provides additional aid in determining the ages of low-level fluvial and correlative deposits (Hereford and others, 1996, 2000; Pederson, 2009).

Qaec **Mixed alluvial-fan, eolian, and colluvial deposits (Holocene to upper Pleistocene)** – Poorly to moderately sorted sand to large boulders with interstitial sand to clay deposited as alluvial fan, ephemeral stream, and colluvial deposits on low-relief slopes and benches in areas where gullies, washes, and small stream channels reduce gradient as they cross from more-resistant to less-resistant bedrock units, and in poorly developed terraces along ephemeral streams; sparsely to moderately mantled by eolian sand in some areas; includes mixed alluvial-fan, debris-flow, slope-creep, slope-wash, eolian, and ephemeral-stream deposits; common on slopes and benches below cliff- and ledge-forming units; distal parts

Table 2. *Estimated ages of terrace deposits in Glen Canyon National Recreation Area. Ages are based on incision rates calculated for various parts of the Glen Canyon/Grand Canyon/ Colorado Plateau area (table 1). Incision rates in the Hite Crossing area are probably typical of the central/northern part of GCNRA. Ages have large ranges because the data has several different types of uncertainty and because incision rates appear to differ throughout the area (see discussion above, and Pederson, 2009). In addition, rates appear to have been higher during the past 250,000 years and along tributaries (Garvin and others, 2005; Cook and others, 2009).*

Terrace Level	**Height Above Rivers feet (meters)**	**Ages Using Estimated Average Long-term Incision Rates (ka=thousand years BP; Ma=million years BP)**		**Epoch/Age**
		Southern Part 0.3 m (1 ft) /ka	Central/Northern Part 0.4 m (1.3 ft) /ka	
1	0–20 (0–6) (locally higher along major rivers; lower along small ephemeral washes)	long-term incision rates don't apply due to short-term cut-and-fill cyclicity, seasonal fluctuations, and other events; ages based on dating of plant fragments and prehistoric and historic human artifacts (pottery shards, cut wood, plastic, etc) (Hereford and others, 1996, 2000)		mostly late Holocene historic to late-prehistoric; locally may include late Pleistocene
2	20–40 (6–12)	long-term incision rates probably don't apply due to short-term cut-and-fill cyclicity; ages based on dating prehistoric artifacts, plant fragments, and comparison to other areas where ages of deposits in similar position have been determined (Hereford and others, 1996, 2000)		Holocene; locally may include late Pleistocene
3	40–80 (12–24)	long-term incision rates may be applicable under some conditions		mostly early Holocene to late Pleistocene
4	80–130 (24–40)	90–150ka	60–100ka	late to middle Pleistocene
5	130–230 (40–70)	150–260ka	100–175ka	late to middle Pleistocene
6	230–330 (70–100)	260–375ka	175–250ka	middle Pleistocene
7	330–430 (100–130)	375–500ka	250–325ka	middle Pleistocene
8	430–530 (130–160)	500–600ka	325–400ka	middle to early Pleistocene
9	530–630 (160–190)	600–710ka	400–475ka	middle to early Pleistocene
10	630–730 (190–220)	710–825ka	475–550ka	middle to early Pleistocene
11	730–830 (220–250)	825–940ka	550–625ka	middle to early Pleistocene
12	830–930 (250–280)	940ka–1.05Ma	625–700ka	middle to early Pleistocene
13	930+ (280+)	1.05Ma+	700ka+	middle to early Pleistocene

commonly have more eolian cover and are gradational with eolian sand deposits (Qea and Qes); 0 to 10 meters (0–30 ft) thick.

Qea **Eolian and alluvial sand and silt (Holocene to middle[?] Pleistocene)** – Well- to very well sorted, well-rounded sand and silt deposited by wind; locally mixed with sand, silt, and fine- to boulder-gravel deposited or reworked by alluvial processes; locally includes minor silt to boulder colluvium, talus, and residual lag of underlying rock; forms poorly developed dunes, mounds, and sheet-like deposits in depressions and areas protected from erosion for long periods of time; similar in setting and composition to Qes deposits except evidence of alluvial activity is more common and dune forms are less developed; 0 to 15 meters (0–50 ft) thick

Qes **Eolian sand (Holocene to middle[?] Pleistocene)** – Very well-sorted, well-rounded, mostly fine- to medium-grained, frosted quartz sand derived from the weathering of sandy bedrock; deposited by wind in sheets, mounds, and small dunes in protected areas on benches and slopes; locally includes minor alluvial and colluvial deposits; locally reworked by water; 0 to 15 meters (0–50 ft) thick.

Qmt **Mass-movement talus deposits (Holocene to middle[?] Pleistocene)** – Broken, angular rock-fall debris that forms loose, very poorly sorted deposits on and at the base of steep slopes; non- to poorly cemented; most common on steep slopes at the base of the Wingate Sandstone, but present beneath other cliff- and ledge-forming units; thickness generally less than 10 meters (30 ft).

Qms **Mass-movement landslide and slump deposits (Holocene to lower[?] Pleistocene)** – Sand- to large boulder-size rock fragments that have slid down slopes; includes intact to partially intact blocks of rock up to several hundred meters long that have slumped down-slope; Wingate Sandstone rubble that has slid on the Chinle Formation is most common, but other formations locally produce slides and slumps; slump blocks are commonly rotated backwards and dip toward the nearby cliff; thickness highly variable.

Unconformity

Jurassic

San Rafael Group

Je **Entrada Sandstone (Middle Jurassic)** – Pale-red-brown to yellow-gray, fine-grained, cross-bedded to contorted, cliff-forming sandstone; forms small erosional remnant under gravel-capped knob in western part of map area; small outlying blocks of Entrada not mapped separately are "foundered" into the underlying Carmel Formation in the same area; has abundant secondary alteration and bleaching that creates mottled, streaked, and banded appearance; weathers to smooth slickrock cliffs and steep slope; only about 10 meters (30 feet) preserved.

Jc **Carmel Formation, undivided (combined Winsor and Paria River Members) (Middle Jurassic)** – Upper part (Winsor Member) is mostly medium- to dark-reddish-brown to brown, slope forming, earthy weathering, silty sandstone and siltstone intercalated with sporadic irregular beds of very pale yellowish-gray, calcareous, fine-grained sandstone that is locally gypsiferous; lower part (Paria River Member) is mostly dark reddish-brown siltstone and silty sandstone with a few tan to brown, fine-grained sandstone beds capped by silty to sandy, pale-gray to pink, chippy weathering limestone; lower contact is gradational and laterally variable and is picked at top of eolian sandstone-dominated interval; deposited in shallow-marine, sabkha, and tidal-flat environment near southeast side of an inland sea (Peterson, 1994); bedding is commonly slightly warped to locally strongly contorted (probably due to loading and foundering of the overlying Entrada Sandstone before lithification, and to dissolution and movement of gypsum); small remnants of foundered Entrada Sandstone may be present in uppermost part of map unit; the Winsor and Paria River Members are 162–166 Ma (Sprinkel and others, 2011); in Glen Canyon area upper part (Winsor) is typically 18 to 45 meters (60–150 ft) thick, and lower part (Paria River) is 15 to 20 meters (50–70 ft) thick.

Jpj **Page Sandstone and Judd Hollow Tongue of Carmel Formation (Middle Jurassic)** – Pale-yellow to pale-reddish-brown, thick- to massive-bedded, large-scale cross-bedded, fine- to medium-grained sandstone interbedded with reddish-brown, planar- to lenticular-bedded siltstone and reddish-brown to grayish-orange, thin-bedded, fine-grained sandstone; sand grains are mostly well-rounded and frosted; in most areas consists of a thick, cliff-forming sandstone bed (lower Page Sandstone [Harris Wash Tongue?]) overlain by thin slope-forming siltstone beds (Judd Hollow Tongue of Carmel Formation), then by a laterally variable interval of less-resistant, cross-bedded eolian sandstone (Thousand Pockets Tongue of Page Sandstone) (Sprinkel and others, 2009; Anderson and others, 2010; Dickinson and others, 2010); lower unconformable contact is the J-1 unconformity and is sharp to obscure and planar to slightly undulating; the beveled unconformable surface is commonly marked by evidence of bioturbation, mud or dessication cracks, and locally by a sparse lag of subrounded to angular chert and quartzite grains that range from medium sand up to about 1 centimeter (0.4 in) in diameter; the Page was deposited in an eolian erg environment, but the interbedded finer-grained intervals show sabkha, ephemeral stream, and tidal flat influence (Blakey, 1994; Jones and Blakey, 1997); the lower tongue is 168 to about 172 Ma and the upper tongue is about 165–166 Ma (the age of the Crystal Creek Member of the Carmel Formation in areas to the west) (Sprinkel and others, 2009, 2011; Dickinson and others, 2010); in the Hite area the combined Page/Judd Hollow interval is typically 18 to 30 meters (60–100 ft) thick.

J-1 Unconformity (significance and extent discussed in Anderson and others, 2010)

Glen Canyon Group

Jn **Navajo Sandstone (Lower Jurassic)** – Pale-yellowish-gray to reddish-orange, massive, cross-bedded eolian sandstone with fine- to medium-grained, well-rounded, frosted quartz grains; interlayered horizontal and cross-bedding near base; has local limestone, dolomite, and siltstone interdunal lenses up to 6 meters (20 ft) thick and 5 kilometers (3 mi) long; forms massive rounded cliffs and domes; gradational with underlying Kayenta Formation; main part deposited in large sand desert (erg) with local interdunal playas (oasis-like setting), basal part deposited in sabkha with abundant wind-blown sand; 180 to 200 meters (590–660 ft) thick.

Jk **Kayenta Formation (Lower Jurassic)** – Pale-reddish-brown to purplish-red, lenticular, planar- to cross-bedded, fine- to medium-grained sandstone and silty sandstone with a few thin lenses of intraformational conglomerate, claystone, limestone, and siltstone; weathers to alternating cliffs and steep slopes; deposited in fluvial-lacustrine environment with abundant eolian input (Peterson, 1994); lower contact is sharp to interfingering; 56 to 90 meters (185–300 ft) thick.

Jurassic-Triassic

JŦw **Wingate Sandstone (Lower Jurassic to Upper Triassic)** – Reddish-brown, massive, fine-grained, cross-bedded, eolian sandstone with well-rounded, frosted grains, and with rare lenses of silty sandstone; forms massive vertical cliff; 85 to 95 meters (280–320 ft) thick.

Triassic

Ŧc **Chinle Formation (Upper Triassic)** – Undivided on cross section; deposited in fluvial-lacustrine and floodplain environments (Lucas, 1993; Lucas and others, 1997); generally 165 to 240 meters (540–800 ft) thick, but locally thicker; I measured 166 meters (546 ft) near the mouth of North Wash, Hunt and others (1953) measured 165 meters (542 ft) near the same spot, and Stewart and others (1972a) measured 176 meters (576 ft) near South Block in the north part of the map area; Lucas (1993) proposed elevating the Chinle to group status, but that change has not been formally completed.

Ŧcc **Church Rock Member of Chinle Formation (Upper Triassic)** – Pale- to moderate-reddish-brown, irregularly laminated to cross-bedded, interbedded, fine- to coarse-grained sandstone and siltstone; weathers to alternating steep slopes and cliffs; the upper part of the unit includes a 6- to 26-meter-thick (20–85 ft) bed of coarse conglomeratic and arkosic purplish-red sandstone called the Hite bed of Stewart and others (1959) and Stewart and others (1972a); O'Sullivan (1970) stated that the base of the Hite bed is an unconformity, that the Hite bed is gradational with and should be included in the overlying Wingate Sandstone, and that the underlying Church Rock Member is gradational with the Owl Rock Member and is not equivalent to the Church Rock at its type locality; 15 to 60 meters (50–200 ft) thick; 17 meters (56 ft) thick near the mouth of North Wash.

TR-5 unconformity of Lucas (1993) near middle of Church Rock Member

Ŧcop **Owl Rock and Petrified Forest Members of Chinle Formation (Upper Triassic)** – Upper part (Owl Rock Member) is dominantly very pale grayish-red, gray, and pale-green claystone and limestone that contains some limestone breccia and is primarily stacked alluvial-plain paleosols (fossil soils); lower part (Petrified Forest Member) is dominantly variegated purple, reddish-brown, gray, greenish-gray, and grayish-yellow, smectitic and silicic claystone interbedded with resistant siltstone and medium-grained to locally pebbly sandstone beds, and was deposited in a fluvial-lacustrine environment that was sourced by volcanic terrains to the southwest; weathers to a steep slope; commonly develops massive landslides that involve overlying units; combined members are 75 to 160 meters (250–520 ft) thick; I measured the Owl Rock at 72 meters (235 ft) and the Petrified Forest at 25 meters (82 ft) near the mouth of North Wash (97 meters [317 ft] combined); Stewart and others (1972a) measured the Owl Rock at 63 meters (209 ft) and the Petrified Forest at 12 meters (41 ft) near South Block.

Ƭcms **Moss Back Member of Chinle Formation (Upper Triassic)** – Gray to pale-orange, lenticular, cross-bedded, fine- to coarse-grained sandstone and thin lenses and beds of siltstone and pebble conglomerate; deposited in a broad fluvial channel system; forms cliff to steep ledgy slope; 0 to 60 meters (0–200 ft) thick but averages about 15 meters (50 ft) thick; I measured 9 meters (30 ft) north of Hite Crossing and 11.9 meters (39 ft) near North Wash; Stewart and others (1972a) measured 12.2 meters (40 ft) near South Block.

TR-4 Unconformity

Ƭcmn **Monitor Butte Member of Chinle Formation (Upper Triassic)** – Pale-greenish-gray to reddish-gray, variegated mudstone with many lenticular, cross-stratified, gray, red, and yellowish-gray sandstone and conglomeratic sandstone beds; locally includes beds below Moss Back that are similar in lithology and color to Petrified Forest strata; forms steep slope with small cliffs; deposited in fluvial-lacustrine environment (higher energy than Petrified Forest Member); map unit may locally include thin unmapped lenses of Shinarump Conglomerate Member; unconformably overlies Moenkopi Formation where Shinarump not present; 26 to 75 meters (85–250 ft) thick; I measured 26 meters (85 ft) north of Hite Crossing and 40 meters (134 ft) near North Wash; Stewart and others (1972a) measured 32 meters (106 ft) near South Block.

Ƭcs **Shinarump Conglomerate Member of Chinle Formation (Upper Triassic)** – Gray- to yellowish-gray, lenticular, cross-bedded, fine-grained to pebbly conglomeratic sandstone with lenses and beds of mudstone; only present in a few areas where basal fluvial channels of Chinle unconformably overlie and are cut into Moenkopi Formation; locally contains uranium and copper deposits; forms prominent ledge; 0 to 24 meters (0–80 ft) thick but averages about 5 meters (15 ft) thick; 15 meters (48 ft) thick north of Hite Crossing; missing in most exposures near North Wash and near South Block.

TR-3 Unconformity

Ƭm **Moenkopi Formation, undivided (Lower Triassic)** – Undivided on cross section. Stewart and others (1972b, plate 3 and measured section U29) recognized four informal and two formal members of the Moenkopi Formation in southeastern Utah. Of these, three are present in the Hite area: lower slope-forming member, ledge-forming member, and upper slope-forming member. The Hoskinnini Sandstone Member is present in outcrops about 1 kilometer (0.6 mi) southeast of the map border (Thaden and others, 2008), but pinches out westward before entering the map area; limestone beds that define the Sinbad Limestone Member in areas to the northwest also pinch out before entering the map area; and the upper cliff-forming member grades into the upper slope-forming member west of the map area. For this map, the three informal members that are present are mapped as one unit herein called the “upper member.”

Ƭmu **Upper member of Moenkopi Formation (Lower Triassic)** – Consists of three to four distinct intervals (Stewart and others, 1972b); basal interval is a discontinuous ledge of gray, yellowish-brown, and reddish-brown, poorly to moderately sorted, calcareous, angular to subrounded chert-pebble conglomerate 0 to about 3 meters (0–10 ft) thick (Stewart and others, 1972b, lump this ledge with the second interval as their lower slope-forming member); second interval is dominantly medium- to dark-reddish-brown, calcareous, slope-forming siltstone and sandstone with a few thin resistant ledges of fine-grained sandstone; third interval is series of lenticular, medium-reddish-brown to pale-orange, ledge- to ledgy cliff-forming, very fine grained sandstone beds interstratified with reddish-brown siltstone and calcareous sandstone; fourth interval is similar to the second interval; deposited in tidal-flat, sabhka, and low coastal-plain environments (Dubiel, 1994); 74 to 100 meters (242–330 ft) thick; I measured 76 meters (248 ft) north of Hite Crossing and 74 meters (242 ft) near North Wash; Hunt and others (1953) measured 77 meters (253 ft) near North Wash; Stewart and others (1972b) measured 87 meters (287 ft) near old Hite (just south of the south map border); Baker (1946) measured 99 meters (326 ft) near South Block.

TR-0 Unconformity

Permian

Cutler Group

Late Pennsylvanian to Permian Cutler Group outcrops dominate the Hite area. The Late Pennsylvanian-Permian was a time of diverse, rapidly changing, interrelated environments in southern Utah (Blakey and Ranney, 2008), making these deposits some of the more interesting to study, but more challenging to map (Baars, 1979 and papers therein; Condon, 1997; Anderson and others, 2010; Baars, 2010; Stevenson, 2010). Northeast of the Hite area near Moab, Cutler strata consist of a single, thick, arkosic formation deposited as distal coalescing alluvial fans that spread southwest from the Pennsylvanian-Triassic Uncompahgre uplift (located on the Utah-Colorado border northeast of Moab) (Doelling, 2001, 2004). To the south, including in the Hite area, the arkosic facies grade into a series of distinct lithologic formations, and thereby the Cutler gains group status. In the Hite area the formations are (in ascending order) the Pennsylvanian-Permian lower Cutler beds (which in the Canyonlands National Park area are called Elephant Canyon Formation and in the San Juan River area are called Halgaito Formation), and the Permian Cedar Mesa Sandstone, Organ Rock Formation, and White Rim Sandstone (Anderson and others, 2010) (figure 10). These formations intertongue and record complex depositional environments that existed in the final stage of the Paradox basin, a broad basin located west of the ancestral Uncompahgre highland (Stanesco and others, 2000; Baars, 2010; Huntoon and others, 2010).

Pwr **White Rim Sandstone (Lower Permian)** – Pale gray to yellowish-orange, cross-bedded, very fine grained, silty sandstone; deposited in mostly eolian environment with some marine influence in upper part; forms a cliff that makes a prominent marker bed throughout the region; the top of the cliff (locally including a few basal beds of Moenkopi Formation) forms a “step” or bench because the overlying Moenkopi Formation is much less resistant; 4 to 26 meters (12–85 ft) thick; thickens rapidly to north; I measured 17 meters (57 ft) near North Wash and 25 meters (83 ft) north of Hite Crossing; Hunt and others (1953) measured 4 meters (12 ft) near old Hite and 23 meters (75 ft) near the Dirty Devil River.

Po **Organ Rock Formation (Lower Permian)** – Reddish-brown and grayish-red, horizontally bedded, micaceous siltstone alternating with fine- to medium-grained sandstone; in southern part of area middle part of unit consists of a series of reddish-brown siltstone beds interbedded with and grading laterally into one or more very prominent light-brownish-pink, trough cross-bedded, medium-grained sandstone beds; much less resistant than Cedar Mesa Sandstone—forms broad slope or bench that gradually steepens up-section to steep ledgy slopes and small cliffs where protected by overlying unit; deposited in floodplain environment with abundant paleosols and local eolian dunes (Huntoon and others, 2010); 67 to 120 meters (220–394 ft) thick; thins to north; I measured 77 meters (253 ft) north of Hite Crossing; Hunt and others (1953) measured 120 meters (394 ft) near the lower Dirty Devil River.

Pcm **Cedar Mesa Sandstone (Lower Permian)** – Light-grayish-orange, cross-bedded, fine-grained sandstone interbedded with lenses of reddish-brown to grayish-green sandy siltstone that increase in upper part; convoluted bedding common; weathers to massive cliffs with scattered ledges at siltstone beds and topped by a very broad bench due to erosion of Organ Rock Formation; deposited in eolian environment occasionally overrun by small rivers or streams, floodplains, and playas (Huntoon and others, 2003) and with marine influence in areas to the north (Baars, 2010); about 300 to 365 meters (1000–1200 ft) thick (Condon, 1997).

Permian-Pennsylvanian

Permian-Pennsylvanian *The position of the Permian-Pennsylvanian boundary in southeastern Utah strata has been debated for several decades (see Condon, 1997; Baars, 2010). Interpretations of data have been complicated by revisions to the internationally accepted definition of the time boundary (Davydov and others, 1995; Chernykh and Ritter, 1997; Anderson and others, 2010; Baars, 2010). It is now generally accepted that the lower part of the lower Cutler beds are Late Pennsylvanian in age, and the middle and upper part are Permian. Scott and Sumida (2004), working in the San Juan River area, used vertebrate fauna to place the period boundary in the lower part of the Halgaito (and thus, lower part of the lower Cutler beds), which supports this time-line placement. An unconformity proposed by Baars (1962; 2010) at the base of the Elephant Canyon Formation (approximately equivalent stratigraphic interval to lower Cutler beds in the Hite Crossing area) is probably not present.*

PIPcl **Lower Cutler beds (Lower Permian to Upper Pennsylvanian)** – Dark-reddish-brown, pale-pinkish-orange, to pale-yellowish- to greenish-gray, thin- to thick-bedded, lenticular, fine- to coarse-grained, quartz and arkosic sandstone interbedded with lesser siltstone, mudstone, conglomerate, and limestone; alternating light (quartzitic) and dark (arkosic) sandstone beds give unit a banded appearance; has increasingly abundant limestone and arkosic beds to northeast (Huntoon and others, 1982; Baars, 2010); Thaden and others (1964) reported that no limestone beds were seen in the Hite area; however, Condon (1997) noted that the unit at Dark Canyon (southeast side of map area) is similar to the type locality near the confluence of the Green and Colorado Rivers where limestone is common, and that limestone is seen in many well logs near the map area; forms a ledgy slope; deposited in tidal flat, deltaic, eolian, and shallow marine environments (Condon, 1997; Anderson and others, 2010; Huntoon and others, 2010); about 115 to 140 meters (375–460 ft) thick.

Various names and unit contacts have been applied to lower Cutler Group strata throughout southeast Utah (Condon, 1997; Anderson and others, 2010; Baars, 2010). Part of the problem is that roughly age-equivalent strata range from limestone with interbedded siltstone and sandstone (Canyonlands National Park area), to interbedded sandstone, siltstone, and mudstone with no or minor limestone (San Juan River area). The limestone-dominated interval is generally called Elephant Canyon Formation (for example: Huntoon and others, 1982; Baars, 2010), and the clastic-dominated interval is called Halgaito Formation (for example: Lewis and Trimble, 1959; Scott and Sumida, 2004; Willis, 2004). Condon (1997) recommended using "lower Cutler beds" for all beds of this interval; Doelling (2004, 2006) also used this term. In the Hite and lower Cataract Canyon area, which is transitional between the two areas, I also use "lower Cutler beds," though I recognize that the other terms have validity in some areas.

The upper part of the lower Cutler beds interfingers with the Cedar Mesa Sandstone, however, the transition is fairly sharp, such that in nearly all areas the contact can be consistently placed at the top of planar-bedded, fine-grained sandstone and mudstone and below the lowest massive, cross-bedded, eolian sandstone. The lower contact has been more challenging. Some workers maintain that the lower Cutler beds are conformable and gradational with the underlying Honaker Trail Formation (Loope and others, 1990; Condon, 1997), while others maintain that the beds were deposited across an unconformity (Baars, 1962, 2010; Scott and Sumida, 2004; Stevenson, 2010). My observations suggest that the contact is conformable, though I recognize that additional work is needed to refute or confirm the unconformity.

The lower Cutler/Halgaito/Elephant Canyon strata were deposited during semi-arid to moderately wet climatic conditions in a range of environments centered around a shallow basin adjacent to the Uncompahgre uplift (Condon, 1997; Soreghan and others, 2002). The Elephant Canyon beds were deposited in a mostly shallow marine environment near the center of the basin, while the lower Cutler beds and Halgaito Formation represent marginal marine, tidal flat, and lower alluvial plain deposits with abundant eolian loess and sand input.

Pennsylvanian

Hermosa Group

IPht **Honaker Trail Formation (Upper Pennsylvanian)** – Only upper part of formation is exposed, which is dark-gray to grayish-brown, thick-bedded, fossiliferous (brachipods, bryozoans, crinoids, and other marine fossils) limestone interstratified with thin beds of reddish-brown to yellowish-gray sandstone and calcareous sandstone; weathers to cliffs separated by short slopes; upper bed is a prominent dark-grayish-brown limestone 4 to 6 meters (12–20 ft) thick that forms a bench beneath slope-forming lower Cutler beds; deposited in a cyclic marine environment (Wengerd, 1963; Ritter and others, 2002; Stevenson, 2010); maximum of about 120 meters (400 ft) exposed within map area, but a drill hole in a fork of Dark Canyon just east of the map area penetrated 355 meters (1165 ft) of probable Honaker Trail strata (Thaden and others, 1964).

HITE AND HITE CROSSING

The Hite area in and just south of this map has a long human history since it contains the only "good" natural crossing of the Colorado River for 480 kilometers (300 mi) between Moab, Utah and Lees Ferry, Arizona (McCourt, 2003). Three "difficult" crossing sites are downstream, all within Glen Canyon National Recreation Area: Halls Crossing, Hole-in-the-Rock, and Crossing of the Fathers. The natural crossing near Hite is due to the weak nature of the Organ Rock and Moenkopi Formations that created a wide stretch of calm water, and North Wash (west side) and White River Canyon (east side) that created well-graded canyon routes cut through otherwise nearly continuous cliffs. Native Americans, probably early Spanish traders, trappers, early settlers, ranchers, miners, and other travelers followed the canyons to the river, and then traveled downstream a short distance to a wide calm spot just south of the map border where they swam horses and floated goods across the river, then continued east on the White Rim Sandstone near the White River, or west up North Wash. This crossing became known as Hite Crossing, named for Cass Hite, a gold miner who settled at the site in 1883 and worked flour gold from the river gravel bars for many years. Arth Chaffin built a ferry at Hite Crossing in 1946 that he operated until 1966 when State Highway 95 bridges over the Colorado and Dirty Devil Rivers were completed (his last two years were at a temporary location near North Wash, as rising lake waters flooded the landings at the original ferry site). This site became the town of Hite. During the 1950s to early 1960s another small uranium "boom" town called White Canyon sat on the east side of the river near the crossing. Hite, Hite Crossing, and Hite Marina, shown on this map, borrow their names from the old crossing and town, which are now under Lake Powell. The name "Hite Crossing" was "moved" to the Highway 95 bridge over the Colorado River.

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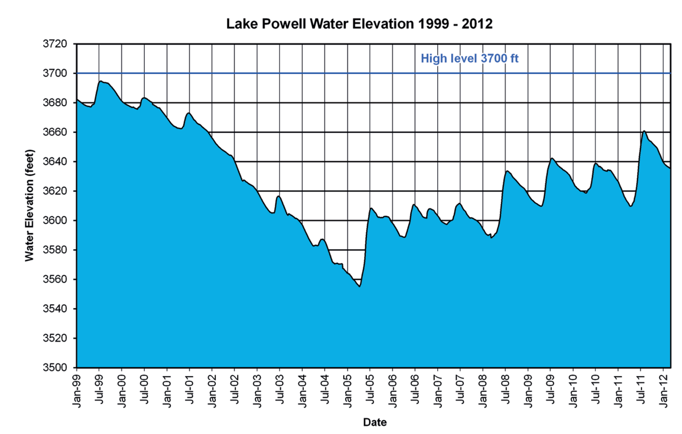

During high water levels, Lake Powell extends far up the canyons of the Colorado and Dirty Devil Rivers, but when the lake is down about 30 meters (100 feet) or more it does not extend into the map area and the rivers incise into large deltaic mudflats. State Highway 95, completed in 1966 and later designated as Utah's Bicentennial Highway, crosses both rivers just above their confluence.
(source: http://www.usbr.gov/uc/crsp/GetSiteInfo)

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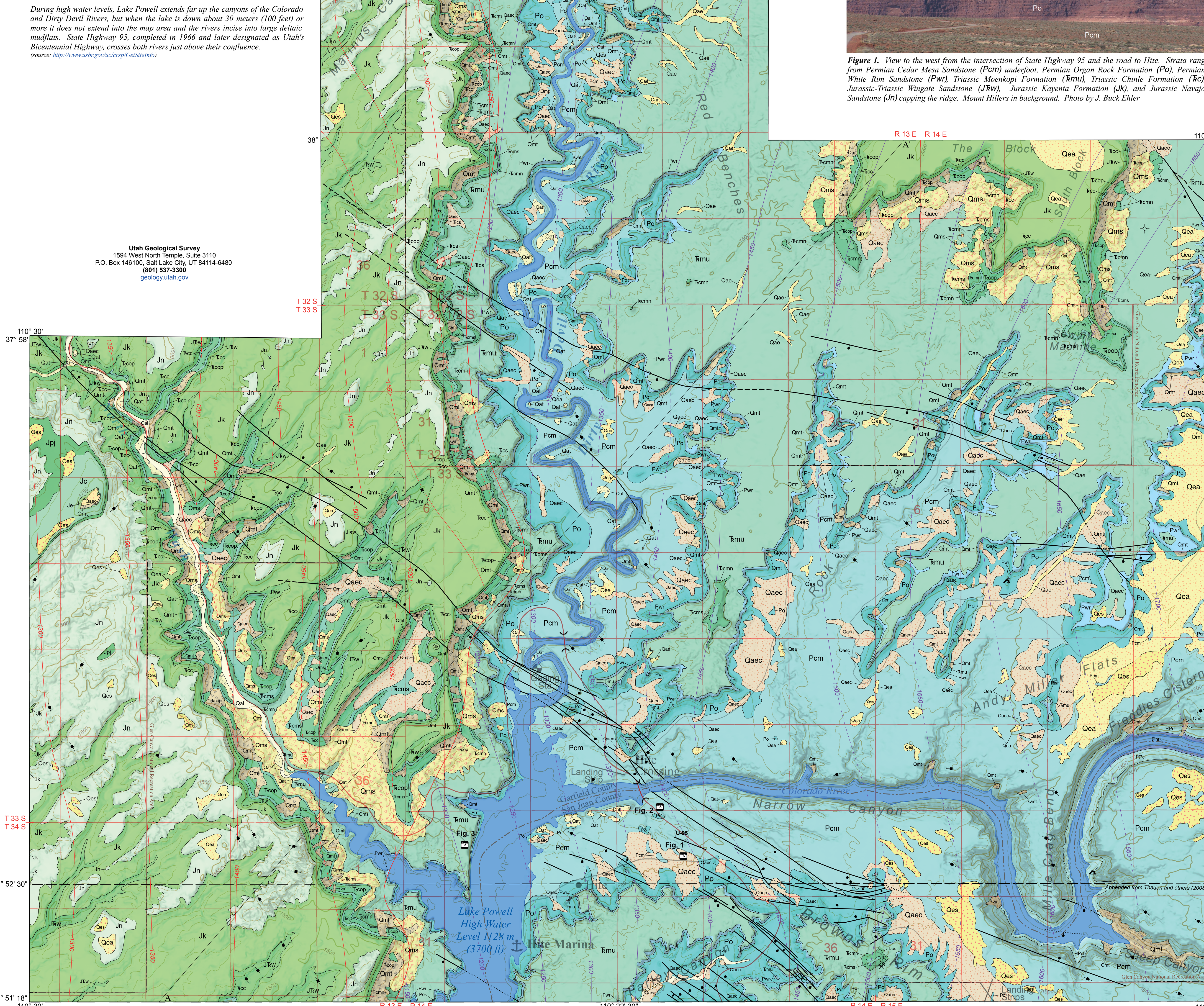


Figure 1. View to the west from the intersection of State Highway 95 and the road to Hite. Strata range from Permian Cedar Mesa Sandstone (Pcm) underfoot, Permian Organ Rock Formation (Po), Permian White Rim Sandstone (Pwr), Triassic Moenkopi Formation (Trmu), Triassic Chinle Formation (Trc), Jurassic-Triassic Wingate Sandstone (JTrw), Jurassic Kayenta Formation (Jk), and Jurassic Navajo Sandstone (Jn) capping the ridge. Mount Hillers in background. Photo by J. Buck Ehler

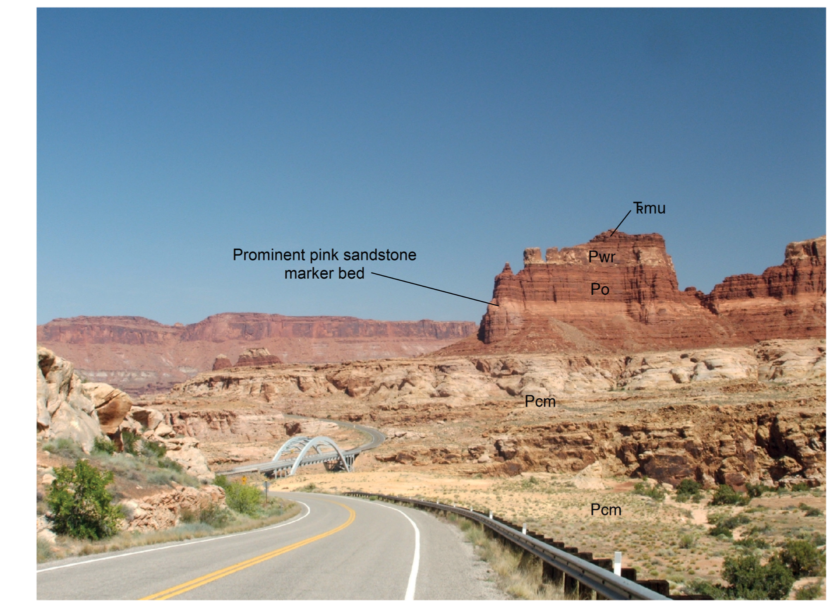
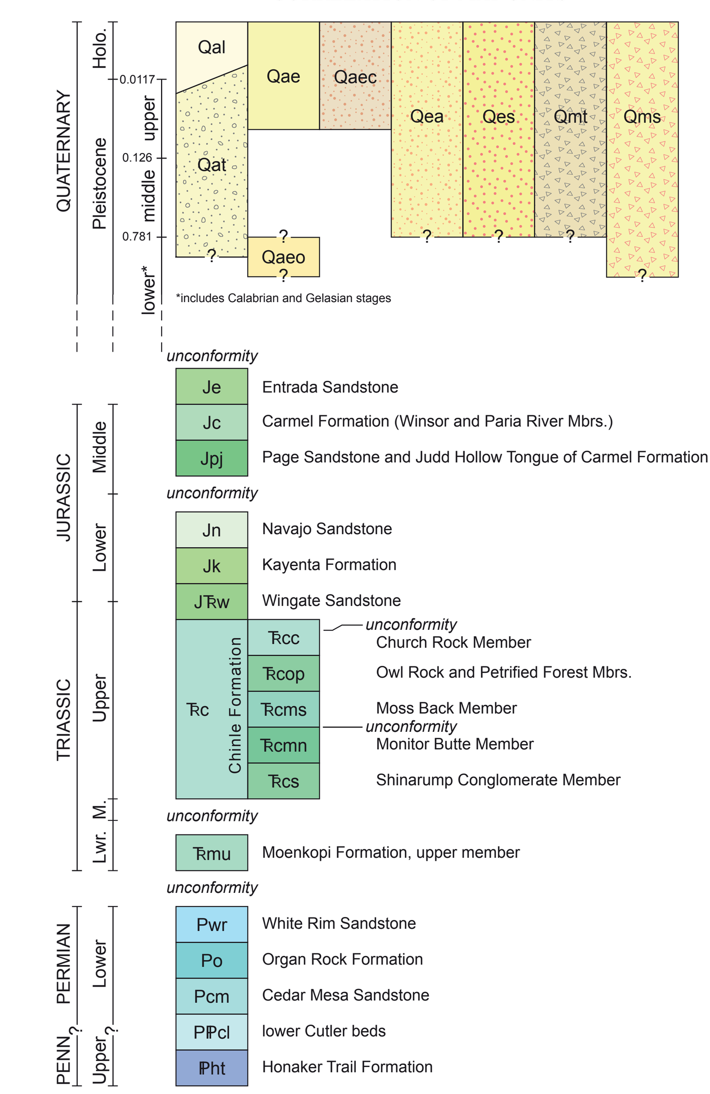


Figure 2. View north to Hite Crossing on State Highway 95. Bridge straddles the Colorado River/Lake Powell and is anchored into the Permian Cedar Mesa Sandstone (Pcm). Photo by J. Buck Ehler

Figure 3. View north from the Hite overlook. When this photo was taken (April 27, 2008), the recorded water level for Lake Powell was 1095 meters (3593 ft) above sea level, 33 m (107 ft) below the high water line of 1128 m (3700 ft). Photo by J. Buck Ehler

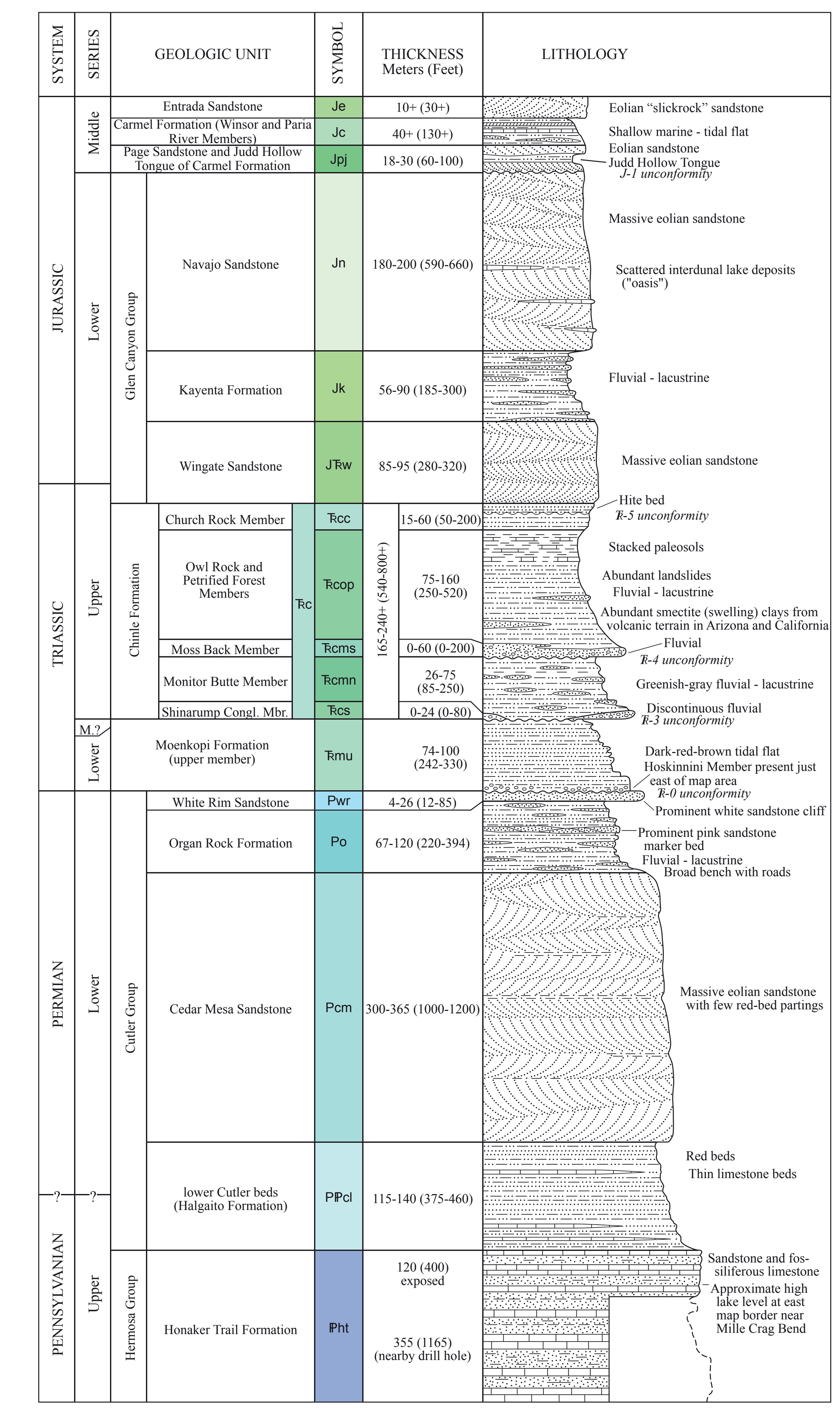
CORRELATION OF MAP UNITS

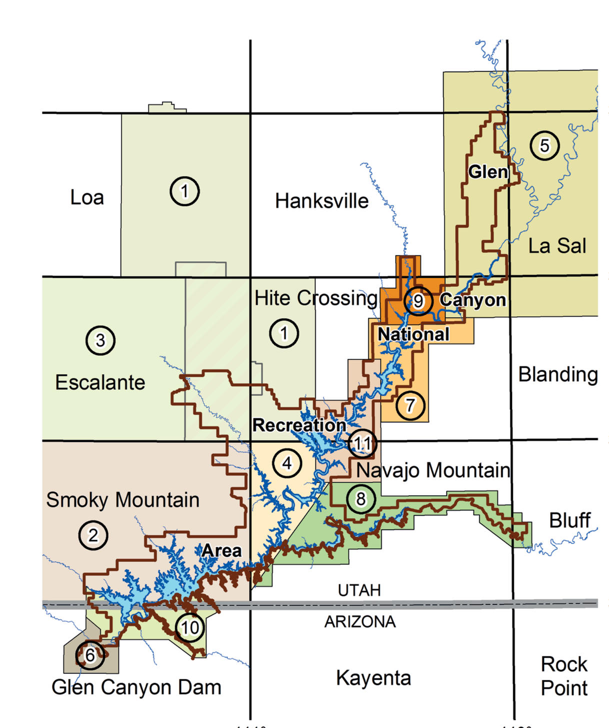


SYMBOLS

- Contact
- High-angle normal fault – Bar and ball on downthrown side (not shown if offset is unknown); dashed where approximately located; dotted where concealed
- Structural contours – Red contours drawn on top of Wingate Sandstone; purple contours drawn on top of White Rim Sandstone; dashed where projected; units are in meters above sea level. Contour interval 50 meters.
- Structure datum boundary
- Major mapped joints
- Joint set – near vertical
- A —— A' Line of cross section
- Adit
- Abandoned uranium mine
- Oil or gas exploration drill hole
- Prominent natural arch
- Glen Canyon NRA boundary

LITHOLOGIC COLUMN





This geologic map (9) is one of several maps, most produced by the Utah Geological Survey, that together provide complete printed and GIS geologic map coverage of Glen Canyon National Recreation Area. The map area includes the lowermost part of Cataract Canyon of the Colorado River and the canyon of the lower Dirty Devil River. A portion of the geologic map of the White Canyon–Good Hope Bay area (Thaden and others, 2008) is appended to the bottom of the map to fully incorporate Mille Crag Bend, a prominent geographic feature of the Colorado River.

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2 Doelling, H.H., and Willis, G.C., 2006, Geologic map of the Smoky Mountain 30' x 60' quadrangle, Kane and San Juan Counties, Utah, and Coconino County, Arizona: Utah Geological Survey Map 213, 2 plates, scale 1:100,000. GIS data - UGS Map 213DM published in 2008.
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9 This map.

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Printed and GIS database files for UGS maps available at the Utah Department of Natural Resources Map and Bookstore: website: www.mapstore.utah.gov; email: bookstore@utah.gov; phone: (801) 537-3320

SCALE 1:62,500
(Plotted at 1:48,000 scale to show detail; spatial accuracy is 1:62,500 scale)
TOPOGRAPHIC AND STRUCTURAL CONTOUR INTERVAL 50 METERS

0 0.5 1 2 3 4 5 MILE
0 0.5 1 2 3 4 5 6 KILOMETER

Base from USGS Hanksville and Hite Crossing 30' x 60' Quadrangles (1980)
Projection: UTM Zone 12
Datum: NAD 1927
Spheroid: Clarke 1886

Project Manager: Robert F. Biek
GIS and Cartography: J. Buck Ehler and Jay C. Hill

11°07'
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 2012

UTAH
MAP LOCATION

ISBN 978-1-55791-860-4

GEOLOGIC MAP OF THE HITE CROSSING–LOWER DIRTY DEVIL RIVER AREA, GLEN CANYON NATIONAL RECREATION AREA, GARFIELD AND SAN JUAN COUNTIES, UTAH

by
Grant C. Willis

2012