PRELIMINARY GEOLOGIC MAP OF THE GLEN CANYON DAM AREA, GLEN CANYON NATIONAL RECREATION AREA, COCONINO COUNTY, ARIZONA, AND KANE AND SAN JUAN COUNTIES, UTAH

by

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Scale 1:24,000

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DESCRIPTION OF MAP UNITS

QUATERNARY

Qfd **Artificial fill and disturbed areas** (Historical)—Gravel, sand, and other earth fill emplaced by humans, and large areas that have been significantly disturbed; mapped where natural materials have been covered, removed, or disturbed by construction, gravel excavation, and other operations, making mapping of natural materials impractical or impossible; generally contrasts sharply with undisturbed areas on aerial photographs; most changes occurred after 1956.

Qfdc **Concrete in Glen Canyon Dam** (Historical)—Concrete used to construct Glen Canyon Dam; dam was begun in 1956 and completed in 1964 and contains 4,901,000 cubic yards (3,745,000 m^3) of concrete; dam is 710 feet (216 m) high, has a crest length of 1560 feet (475 m), and a crest elevation of 3715 feet (1132 m) above sea level; its height above the Colorado River is 583 feet (178 m); the dam's foundation extends about 127 feet (38 m) below river level; the dam is 25 feet (8 m) wide at the crest and 300 feet (90 m) wide at the maximum base; normal high water level is 3700 feet (1128 m) elevation; reservoir storage capacity is about 27 million acre-feet (33.3 billion m^3) (Bureau of Reclamation, undated).

Qal_1 **Younger alluvial deposits** (mostly late Holocene; locally to late Pleistocene)—Interbedded gravel, sand, silt, and clay deposited by the Colorado River and larger tributaries (most deposits in map area are covered by Lake Powell and thus not mapped); generally moderately to well sorted; clasts are well rounded to subrounded and uniformly sized with most less than 6 inches (15 cm) in diameter; small-scale trough cross-bedding, climbing ripple laminations, and imbricated cobbles are common; locally includes poorly sorted debris-flow deposits and talus derived from side canyons and cliffs where too small to map separately; forms sand and gravel bars in river channel and small remnants on steep canyon slopes adjacent to rivers; typically, deposits are up to 20 feet (6 m) above river or stream channels; 0 to 30 feet (0-9 m) thick.

Qat_2 to Qat_{13}
Alluvial terrace gravel deposits (Holocene to early Pleistocene [see age discussion below])—Pebble- to cobble-gravel with less common boulders, sand, and silt deposited by Colorado River and Wahweap Creek, then preserved as terraces; moderately to well sorted and rounded; Colorado River clasts have distinctly better sorting, rounding, and flattening than Wahweap Creek clasts; clasts are mostly durable rock types, including quartzite, chert, and igneous rocks, and less common sandstone, limestone, and gneiss; clasts are better rounded and sorted than 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; commonly armored by gravel lag; generally includes minor talus and colluvial debris from adjacent bedrock units; map unit locally includes terrace gravel that drapes downslope from the original terrace deposits in areas where the terraces are being eroded or undercut; larger deposits are locally partially mantled by thin eolian sand; forms terraces at several levels from about 20 feet (6 m) to over 1100 feet (335 m) above the modern river channels (most low- and middle-level deposits are now covered by the lake); numbers denote relative height (and by inference, relative age) above the modern channel (see discussion below); larger mapped deposits locally include deposits of more than one level —assigned number is based on the height of the main part of the deposit; not all levels are preserved in this map area; 0 to 30 feet (0-10 m) thick. Near Navajo Canyon a possible terrace-gravel deposit visible on aerial photographs is queried (?) because it has not been verified in the field and it could be altered Navajo Sandstone rather than surficial terrace gravel.

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

The Colorado River establishes the primary base level throughout the Glen Canyon area. In Glen Canyon, the river has a fairly uniform gradient of about 3 to 5 feet per mile (0.6-1 m/km); just upstream in Cataract Canyon the gradient increases to 8 to 12 feet per mile (1.6-2.4 m/km) and downstream in the Grand Canyon it is about 7.7 feet per mile (1.5 m/km) (Baars, 1987; Darling and others, 2012). 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 (Hereford and others, 2000, Pederson, 2009). This continued incision has left remnants of strath terraces and correlative surficial deposits "stranded" at many levels up to nearly 1600 feet (500 m) above the modern river and its

tributaries (Hunt, 1969); the highest deposits recognized in the map area are about 1100 feet (335 m) above the modern channels. In some areas, the ages of these deposits can be determined by dating specific minerals in rare volcanic ash beds, basalt flows, cave deposits, and fine-grained sediment; using various methods to measure sun exposure time or length of burial (absence of sun exposure); radiocarbon dating; comparing the paleomagnetism of these deposits with others of known age; and other methods (see references cited in table 1, below). Using these ages in conjunction with the elevation of the deposits above the modern river channel allows calculation of average long-term incision rates. Most calculated rates along the Colorado River range from about 0.6 feet per thousand years (0.18 m/kyr [meters per thousand years]) near the Utah-Colorado state line and near the western Grand Canyon, to 1.3 to 2.3 feet per thousand years (0.4-0.7 m/kyr) in the central Glen Canyon area near Navajo Mountain and the Henry Mountains (table 1) (Hanks and others, 2001; Garvin and others, 2005; Cook and others, 2009; Darling and others, 2012). The latter rates are some of the highest measured in any part of the Colorado River system and suggest that the lower 1500 feet (450 m) of Glen Canyon may have been cut in the last one million years. Part of this unusually rapid incision may be due to isostatic rebound from crustal unloading caused by erosion of vast amounts of relatively nonresistant Triassic to Cretaceous sedimentary strata in the Glen Canyon area over the past couple of million years (Pederson, 2009), a residual effect of cutting of the Grand Canyon about 5.5 million years ago (Lucchitta, 1989; Cook and others, 2009).

Table 2 shows calculated ages of major terraces and related deposits based on estimated average incision rates for the last one million years. These derived ages have a large uncertainty because dateable materials are rare and are not always in ideal settings, some sample sites are over 100 miles (160 km) 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 some sediment derived 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 historical and prehistoric artifacts, buried organic debris, and other materials using 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).

Table 1. *Selected long-term incision rates of the Colorado River and major tributaries. These rates vary widely throughout the Colorado River basin; they seem to be lower near the Utah-Colorado border and in the western Grand Canyon, and higher in central GCNRA. Part of the variation can be attributed to difficulties in dating fluvial deposits, including less-than-ideal sample sources, sampling different kinds of materials, using different dating methods, and applying different interpretations to resultant data. Estimated rates near the map area (first three lines in table) range from 0.46 to 1.6 feet (0.14-0.5 m) per thousand years calculated over the last 0.72 million years. Darling and others (2012) summarized results for the region, provided additional detail on most rates listed below, and discussed some of the challenges and uncertainties of determining incision rates. Note that calculated rates throughout the region vary greatly, and rates appear to have been higher during the last 250,000 years and along tributaries (for example: Cook and others, 2009; Marchetti and others, 2012).*

Average calculated incision rate per 1000 years	**Time/basis for calculation kyr=thousand yrs myr=million yrs**	**Location/Comments**	**References**
0.49–0.95 feet (0.15–0.289 m)	77–142 kyrs	Colorado River, Lees Ferry, Az (close to map area)	Cragun, 2007; Hidy and others, 2010
0.46–0.5 feet (0.14–0.18 m)	500 kyrs	Eastern Grand Canyon, Az (close to map area)	Pederson and others, 2002; Karlstrom and Kirby, 2004; Karlstrom and others, 2007
1.02–1.6 feet (0.31–0.5 m)	600 kyrs	Eastern Grand Canyon and Glen Canyon, Az-Ut (close to map area)	Davis and others, 2001; Lucchitta and others, 2001
0.16–0.30 feet (0.05–0.09 m)	720 kyrs	Western Grand Canyon, Az-Nv	Pederson and others, 2002; Karlstrom and Kirby, 2004; Karlstrom and others, 2007
0.3–0.5 feet (0.09–0.16 m)	600 kyrs	Western Grand Canyon, Az-Nv	Davis and others, 2001; Lucchitta and others, 2001
0.18–0.4 feet (0.06–0.12 m)	17 myrs	Western Grand Canyon, Az-Nv	Polyak and others, 2008
0.41 feet (0.126 m) 1.29 feet (0.395 m)	1.5 myrs 479 kyrs	Colorado River, Bullfrog, Ut (0.41 rate most reliable; Darling and others, 2012)	Darling and others, 2012 Davis and others, 2012
1.21 feet (0.369 m)	290 kyrs	Colorado River, Hite, Ut	Darling and others, 2012
1.1–2.0 feet (0.35–0.6 m)	267 kyrs	Trachyte Creek near Hite, Ut, in central GCNRA	Cook and others, 2009
0.59 feet (0.18 m)	620 kyrs	Colorado River, Westwater Canyon northeast of Moab, Ut	Willis, 1992, 1994; Willis and Biek, 2001; Aslan and others, 2008
1.25–1.57 feet (0.38–0.48 m)	189 kyrs	Fremont River (upper Dirty Devil River), Ut	Marchetti and Cerling, 2001; Marchetti and others, 2012
1.09–2.82 feet (0.33–0.86 m)	60–151 krs	Fremont River, Ut	Repka and others, 1997
0.36 feet (0.11 m)	1.4 myrs	San Juan River at Bluff, Ut, about 30 miles (50 km) east of GCNRA	Wolkowinsky and Granger, 2004; Karlstrom and Kirby, 2004
0.02–0.09 feet (0.006–0.027 m)	8.25–9.9 myrs	Green Rvr. near Browns Park, Ut	Luft, 1985; Izett, 1985
0.79 feet (0.24 m)	3 myrs	Glenwood Springs, Co	Kirkham and others, 2001; and references cited therein
0.54–1.35 feet (0.17–0.41 m)	3.7 myrs	Eastern Grand Canyon, Az	Polyak and others, 2008

Table 2. *Estimated ages of terrace deposits in Glen Canyon Dam/Lees Ferry/Eastern Grand Canyon Area based river incision rates. Published rates near the map area range from 0.46 to 1.6 feet (0.14-0.5 m) per thousand years (see discussion and table 1 above; also see Darling and others, 2012). A median rate of 1.0 feet (0.3 m) is used; higher or lower rates would change the estimated ages of the terrace deposits.*

Terace Level	**Height Above Rivers feet (meters)**	**Ages Using Estimated Average Long-term Incision Rate of <u>1.0 foot (0.3 m)/kyr)</u>**	**Epoch/Age** Late Pleist. = 0.0117–0.126 Ma (Tarantian age) Mid Pleist. = 0.126–0.781 Ma (Ionian age) Early Pleist. = 0.781–2.588 Ma (Calabrian and Gelasian ages)
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; mostly late Holocene based on local setting, soil and eolian sand and silt accumulation, 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; mostly Holocene based on local setting, soil and eolian sand and silt accumulation, dating prehistoric artifacts and 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)	80–130 ka	late to middle Pleistocene
5	130–230 (40–70)	130–230 ka	late to middle Pleistocene
6	230–330 (70–100)	230–330 ka	middle Pleistocene
7	330–430 (100–130)	330–430 ka	middle Pleistocene
8	430–530 (130–160)	430–530 ka	middle Pleistocene
9	530–630 (160–190)	530–630 ka	middle Pleistocene
10	630–730 (190–220)	630–730 ka	middle Pleistocene
11	730–830 (220–250)	730–830 ka	middle to early Pleistocene
12	830–930 (250–280)	830–930 ka	early Pleistocene
13	930+ (280+)	930+ ka	early Pleistocene

Qae **Alluvial and eolian deposits** (Holocene)—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 include minor amounts of colluvium and angular rubble from adjacent stream banks and slopes; clast composition reflects local lithologies; mapped in small washes where includes deposits in active part of wash bottom to about 40 feet (12 m) above wash floor; 0 to 20 feet (0-6 m) thick.

Qaec **Mixed alluvial-fan, eolian, and colluvial deposits** (Holocene to middle(?) Pleistocene)—Poorly to moderately sorted boulder- to pebble-gravel, sand, silt, and clay deposited on low-relief slopes and benches and in gullies, washes, and small stream channels where slopes reduce gradient as they cross from more-resistant to less-resistant bedrock units, and in poorly developed terraces along washes; sparsely to moderately mantled by eolian sand in some areas; includes mixed alluvial-fan, debris-flow, slope-creep, slope-wash, eolian, and alluvial ephemeral stream deposits; common on slopes below cliff- and ledge-forming units; distal parts commonly have more eolian cover and are gradational with eolian and alluvial deposits (Qes and Qea); 0 to 30 feet (0-10 m) 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 gravel deposited by alluvial processes; 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; mostly derived from and present on Navajo Sandstone; residual lag of underlying rock is common; 0 to 50 feet (0-15 m) thick.

Qeao **Older eolian and alluvial deposits** (mostly middle to early(?) Pleistocene)—Similar to Qea except cap higher slopes, benches, and mesas and have thicker calcic soil horizon; though deposits are on older inactive surfaces, they continue to accumulate windblown sediment; 0 to 50 feet (0-15 m) thick.

Qes **Eolian sand** (Holocene to early(?) 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 slightly reworked by water, rooting, and burrowing animals; mostly derived from and present on Navajo Sandstone, but also locally present on other formations; 0 to 45 feet (0-15 m) thick.

Qmte **Mass-movement talus with eolian sand mantle** (Holocene to early(?) Pleistocene)—Broken, angular rock-fall material that forms loose debris layer on and at the base of steep slopes, and commonly mantled by moderate to large amounts of well-sorted eolian sand that locally completely covers the rock-fall debris; non- to poorly cemented; most common on steep slopes at the base of the Entrada Sandstone, but present beneath other cliff- and ledge-forming units; thickness generally less than 30 feet (10 m).

Cretaceous

Kd **Dakota Formation** (Upper Cretaceous, Cenomanian, with possible upper Lower Cretaceous, Barremian to Albian) (called Dakota Sandstone on some older maps)—Interbedded grayish-orange to light-brown sandstone, sandy mudstone and shale, carbonaceous mudstone, shaley sandstone, pebble conglomerate, and dark-brown to black carbonaceous shale and coal; upper part is sandstone with marine fossils; middle part is ledge and slope-forming sandstone, mudstone, and coal-bearing unit; lower part is a discontinuous local basal conglomerate that fills paleotopographic lows and may be at least partly Early Cretaceous in age and thus may be Cedar Mountain Formation equivalent (see discussion in Biek and others, 2009); forms ledges and slopes; deposited unconformably (K-0 unconformity) on surface eroded across Morrison, Romana, and Entrada Formations; varies but generally 30 to 100 feet (10-30 m) thick.

K-0 Unconformity

Jurassic

Jm **Morrison Formation** (Upper Jurassic, Tithonian-Kimmeridgian)—Pale- to medium-yellowish-gray, reddish-gray, and greenish-gray, weathering to dark brown, very fine to medium-grained, cross-bedded sandstone, pebble conglomerate, and conglomeratic sandstone, interbedded with minor pale-grayish-green, medium-reddish-brown, or

medium-purplish-gray siltstone and smectitic (swelling clay) mudstone; beveled throughout map area – cut out in west part of map area due to K-0 unconformity at base of Dakota Formation that cuts increasingly down-section to the west; upper unconformable contact sharp but commonly poorly exposed; outcrops in map area are primarily Salt Wash Member but thin Tidwell Member that is mapped with Romana Sandstone may be locally present below the Salt Wash; overlies Middle and Upper Jurassic units above J-5 unconformity; deposited in fluvial-lacustrine "savannah-like" environment; age from Litwin and others (1998), Turner and Peterson (2004), and Kowallis and others (2007); 0 to 410 feet (0-125 m) thick.

J-5 Unconformity

Jr **Romana Sandstone** (Upper Jurassic, Oxfordian)—Grayish-yellow, greenish-gray, yellowish-gray, and light-tan, very fine to fine-grained, medium-bedded to massive, planar to cross-bedded, calcareous sandstone with thin planar beds of reddish-brown, calcareous, sandy siltstone; outcrops commonly stained to reddish-brown; forms massive to ledgy cliff; overlies Entrada Sandstone above J-3 unconformity; can be difficult to distinguish from Entrada but Romana is generally more blocky and reddish-brown; deposited in sabkha, tidal-flat, and eolian environments; cut out by K-0 unconformity in western part of map area; 0 to 150 feet (0-45 m) thick (Peterson and Barnum, 1973; Doelling and Davis, 1989; Doelling and Willis, 2006).

J-3 Unconformity

Je **Entrada Sandstone** (Middle Jurassic, Callovian)—Regionally, consists of three members, but within map area, upper (Escalante Member) has been cut out by the J-3 unconformity; middle and lower members are combined into one map unit in map area; the middle (Cannonville Member) consists chiefly of 250 to 300 feet (75-90 m) of reddish-brown, grayish-yellow, and gray, banded, slope-forming, silty sandstone and sandy siltstone; lower (Gunsight Butte Member) is chiefly reddish-brown to yellowish-gray, fine-grained, cross-bedded, cliff-forming, "slickrock" sandstone or earthy-weathering, silty sandstone and is 400 to 500 feet (120-150 m) thick; the lower member commonly has abundant convoluted bedding, including internal slumps, fluid-escape structures, pipes, load casts, and related features, and has commonly "sagged" or settled into the underlying Carmel Formation, which was non- or weakly lithified at the time the Entrada was deposited; mostly eolian with interbedded playa and fluvial deposits; total Entrada is 640 to 790 feet (195-240 m) thick in the map area (Peterson and Barnum, 1973; Doelling and Davis, 1989; Doelling and Willis, 2006).

Jc **Carmel Formation, undivided (combined Paria River and Winsor Members)** (Middle Jurassic, Callovian-Bathonian)—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 locally present in uppermost part of map unit; the Winsor and Paria River Members of the Carmel Formation are 164 to 167 Ma (Bathonian to early Callovian) (Sprinkel and others, 2011); in map area upper part (Winsor) is typically 130 to 255 feet (40-78 m) thick, and lower part (Paria River) is 36 to 40 feet (11-12 m) thick; total thickness is 170-294 feet (50-90 m) (Peterson and Barnum, 1973; Doelling and Davis, 1989; Doelling and Willis, 2006; D.A. Sprinkel, written communication, February 2012).

J-2 unconformity(?): Pipiringos and O'Sullivan (1978) proposed that an unconformity is present in this position; however, recent work is questioning its presence (see discussion in Anderson and others, 2010; Sprinkel and others, 2011).

Jp **Page Sandstone** (Middle Jurassic, Bathonian-Bajocian)—Pale-grayish-yellow to pale-reddish-brown, thick- to massive-bedded, large-scale cross-bedded, fine-to medium-grained sandstone interbedded with minor 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 uniform cliff-forming sandstone with a few horizontal partings; locally the partings grade into thin siltstone or silty sandstone zones a few

inches to a few feet thick; to the west, one of these thickens to become the Judd Hollow Tongue of the Carmel Formation (Phoenix, 1963, 2009), however, no Judd Hollow is recognized within this map area; where the Judd Hollow is present in areas to the west, the lower sandstone interval is called the Harris Wash Tongue, and the upper sandstone is called the Thousand Pockets Tongue; the lower unconformable contact with the Navajo Sandstone is sharp to obscure, planar to slightly undulating, and commonly marked by evidence of bioturbation, mudcracks, and a sparse lag of slightly coarser sand grains with scattered angular chert clasts up to about 0.4 inches (1 cm) 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 Page is 167-170 Ma (Bajocian to early Bathonian), the same age as the lower part of the Carmel Formation in areas to the west (Sprinkel and others, 2009, 2011; Anderson and others, 2010; Dickinson and others, 2010); type section is within map area on northwest side of Manson Mesa (SW1/4 NW1/4 sec 19, T.14N., R.9E.) where the Page is 183 feet (55.8 m) thick (Peterson and Pipiringos, 1979); thickness quite variable within map area; ranges from about 40 feet (12 m) in southeast part of map area to about 230 feet (70 m) locally in western part of map area (R.C. Blakey, Northern Arizona University, written communication, May 2004).

J-1 unconformity: Unconformity is difficult to identify in many areas because underlying and overlying units are similar eolian sandstone; however, locally, scour surfaces, a grit- to small chert-pebble lag, root casts, mudcracks, and mottled strata just below the unconformity provide evidence of its presence (see discussion in Anderson and others, 2010; Sprinkel and others, 2011).

Jn **Navajo Sandstone** (Lower Jurassic, Toarcian-Pliensbachian)—Pale-yellowish-gray, moderate-reddish-brown, and moderate-reddish-orange, fine- to medium-grained, massive, cross-bedded sandstone; grains are primarily rounded to subrounded, frosted, well-sorted and equant quartz; conspicuously cross-bedded with cross-bed sets that range up to 60 feet (20 m) thick; contains scattered thin discontinuous beds of gray sandy limestone, dolomite, and siltstone up to 50 feet thick (15 m) and that range up to 3 miles (5 km) long with common algae laminae, ripple marks, and mudcracks; lower contact not exposed in map area; forms rounded knobs, buttes, and mesa rims marked by large parallel to conjugate near-vertical joints that are locally mapped and smaller weathering and unloading fractures; 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 deposited in a vast coastal and inland dune field with prevailing winds principally from the north (Blakey, 1994; Peterson, 1994); ranges from about 1675 to 1860 feet (510-565 m) thick where fully exposed approximately 4 miles (6 km) southwest of map (Phoenix, 1963, 2009; Hintze and Kowallis, 2009; Billingsley and Priest, 2012), with a maximum of about 1100 feet (340 m) exposed in Glen Canyon below the dam.

Subsurface Units – Shown on cross section only; see Phoenix (1963, 2009; Billingsley and Priest, 2012) for descriptions from exposures in Lees Ferry area; also see Hintze and Kowallis (2009) for summary of ages.

Jk **Kayenta Formation** (Lower Jurassic, Pliensbachian-Sinemurian)

Jurassic-Triassic

JTRwm **Wingate Sandstone and Moenave Formation** (Lower Jurassic to Upper Triassic, Sinemurian-Rhaetian)

Tr-5 Unconformity (probably within upper part of Chinle Formation)

Triassic

TRc **Chinle Formation** (Upper Triassic, Norian-Carnian)

Tr-3 Unconformity

TRm **Moenkopi Formation** (Lower Triassic, Spathian-Diegenerian)

Tr-1 Unconformity

Pz **Paleozoic strata**

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References

References with numbers refer to geologic maps that are the primary sources for a composite geologic map of Glen Canyon National Recreation Area in preparation by the Utah Geological Survey. These source maps are shown on the index map on plate 1.

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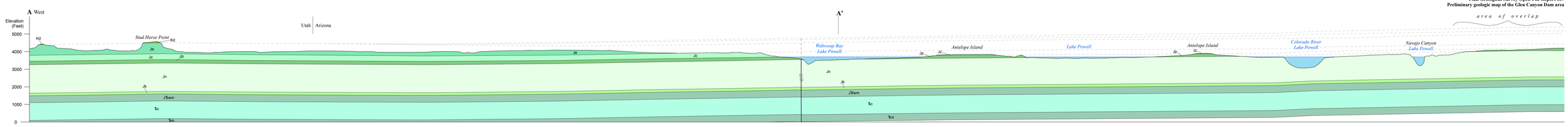
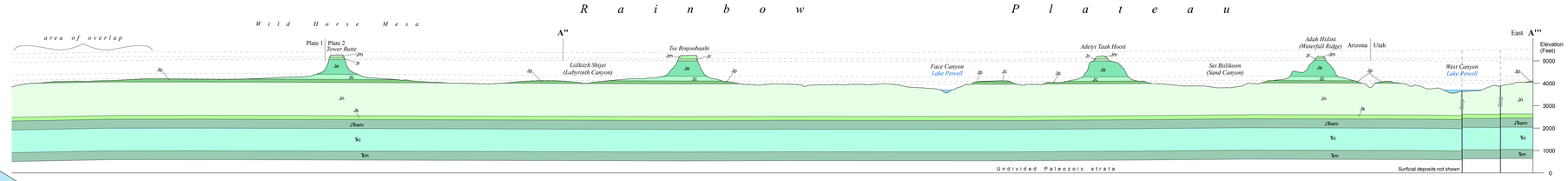
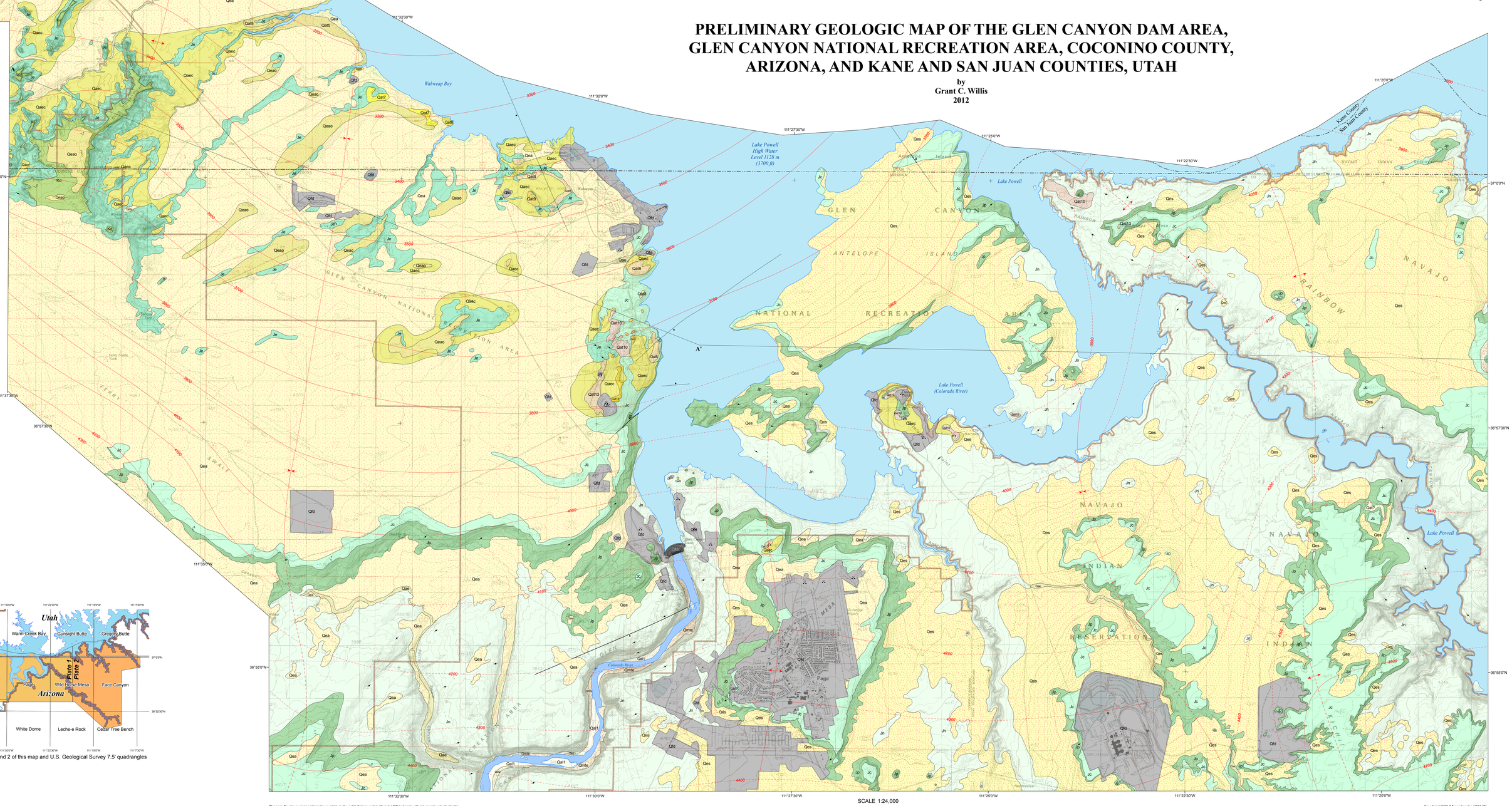
Plate 1
Utah Geological Survey Open-File Report 607
Preliminary geologic map of the Glen Canyon Dam area

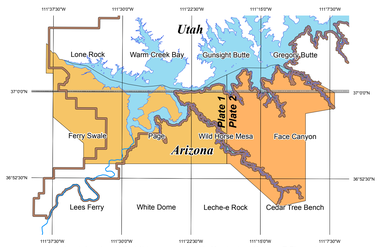




PRELIMINARY GEOLOGIC MAP OF THE GLEN CANYON DAM AREA, GLEN CANYON NATIONAL RECREATION AREA, COCONINO COUNTY, ARIZONA, AND KANE AND SAN JUAN COUNTIES, UTAH

by
Grant C. Willis
2012





Index to plates 1 and 2 of this map and U.S. Geological Survey 7.5' quadrangles

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SCALE 1:24,000

0 0.5 1 2 3 4 5 6 MILES

0 5000 10000 15000 20000 25000 30000 FEET

0 0.5 1 2 3 4 5 6 7 8 KILOMETERS

CONTOUR INTERVAL 20 AND 40 FEET
STRUCTURAL CONTOUR INTERVAL 100 FEET

11°15'
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 2012

Base from USGS 7.5' quadrangles (1991-95)
Projection: UTM Zone 12 Units: Meters
Datum: NAD 1927 Spheroid: Clarke 1866

Project Manager: Robert F. Biek
GIS and digital cartography: J. Buck Ellner

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UTAH GEOLOGICAL SURVEY
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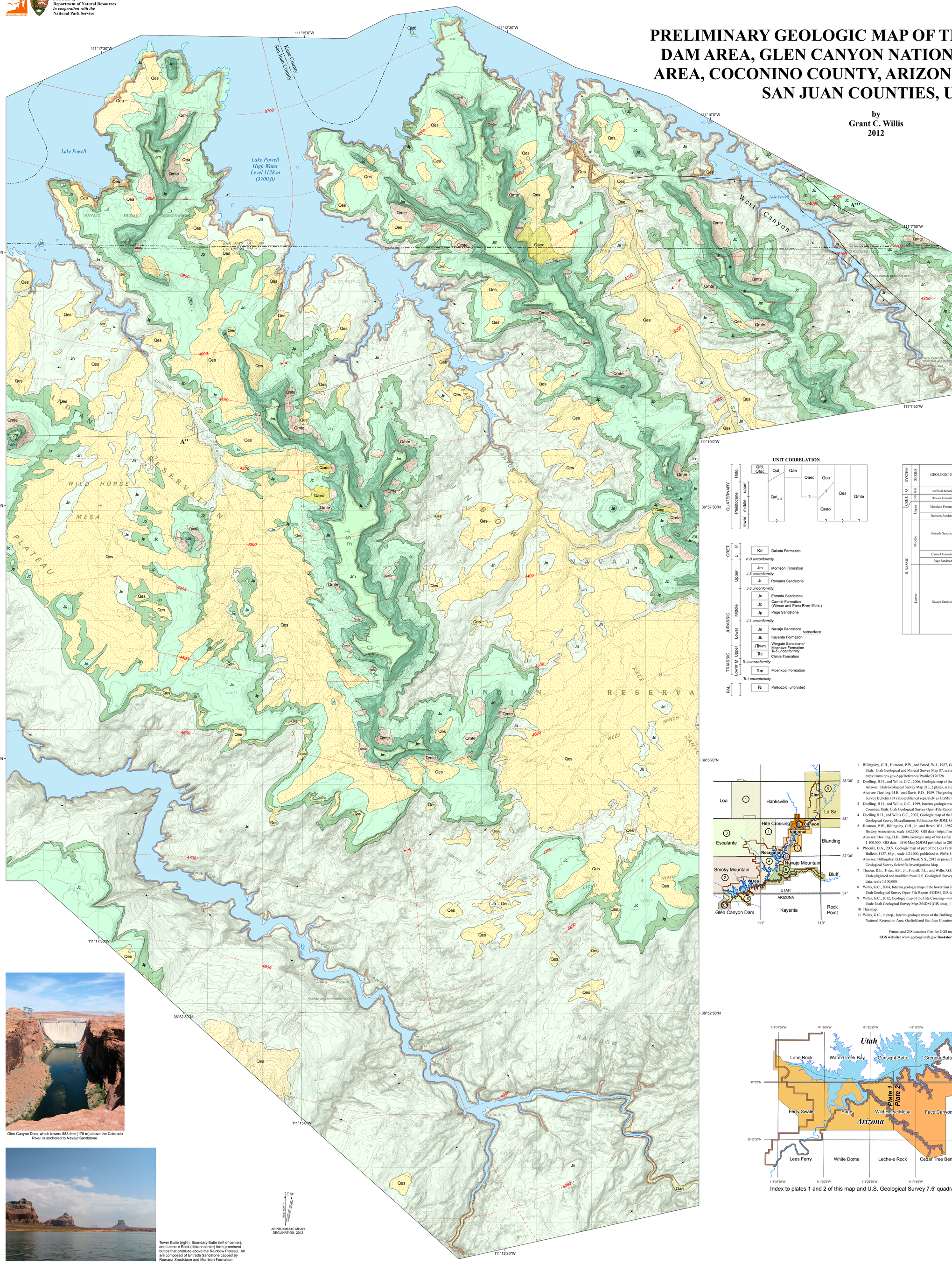
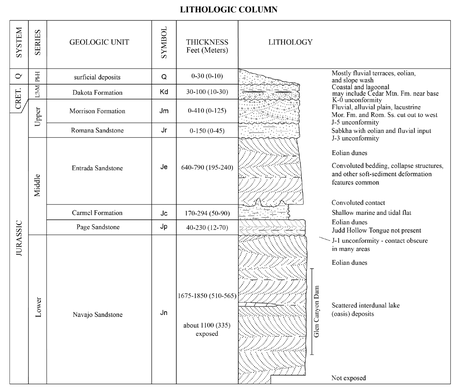


Map Symbols

- Contact
- Normal fault – dashed where approximately located; dotted where concealed; bar and ball on downthrown side
- Structural contours – drawn on top of Page Sandstone; dashed where projected above ground surface; contour interval 100 feet (30 m)
- Anticline – dashed where approximately located; dotted where concealed
- Syncline – dashed where approximately located; dotted where concealed
- Boundary of Glen Canyon National Recreation Area
- A——A' Cross section line
- Strike and dip
- Joint – near-vertical

UNIT CORRELATION

LITHOLOGIC COLUMN



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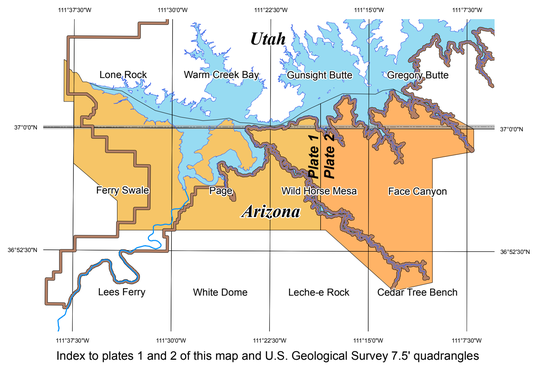
Glen Canyon Dam, which towers 583 feet (178 m) above the Colorado River, is anchored to Navajo Sandstone.

Tower Butte (right), Boundary Butte (left of center), and Leche-e Rock (distant center) form prominent buttes that protrude above the Rainbow Plateau. All are composed of Entrada Sandstone capped by Romana Sandstone and Morrison Formation.



Index to plates 1 and 2 of this map and U.S. Geological Survey 7.5' quadrangles

APPROXIMATE MEAN DECLINATION, 2012

SCALE 1:24,000

CONTOUR INTERVAL 20 AND 40 FEET
STRUCTURAL CONTOUR INTERVAL 100 FEET

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This map was created from Geographic Information System (GIS) data; it contains many features that do not meet UGS cartographic standards, such as automatically generated labels that may overlap other labels and lines.

Base from USGS 7.5' quadrangles (1981-85)
Projection: UTM Zone 12 Units: Meters
Datum: NAD 1927 Spheroid: Clarke 1866

Project Manager: Robert F. Biek
GIS and digital cartography: J. Buck Ehler

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