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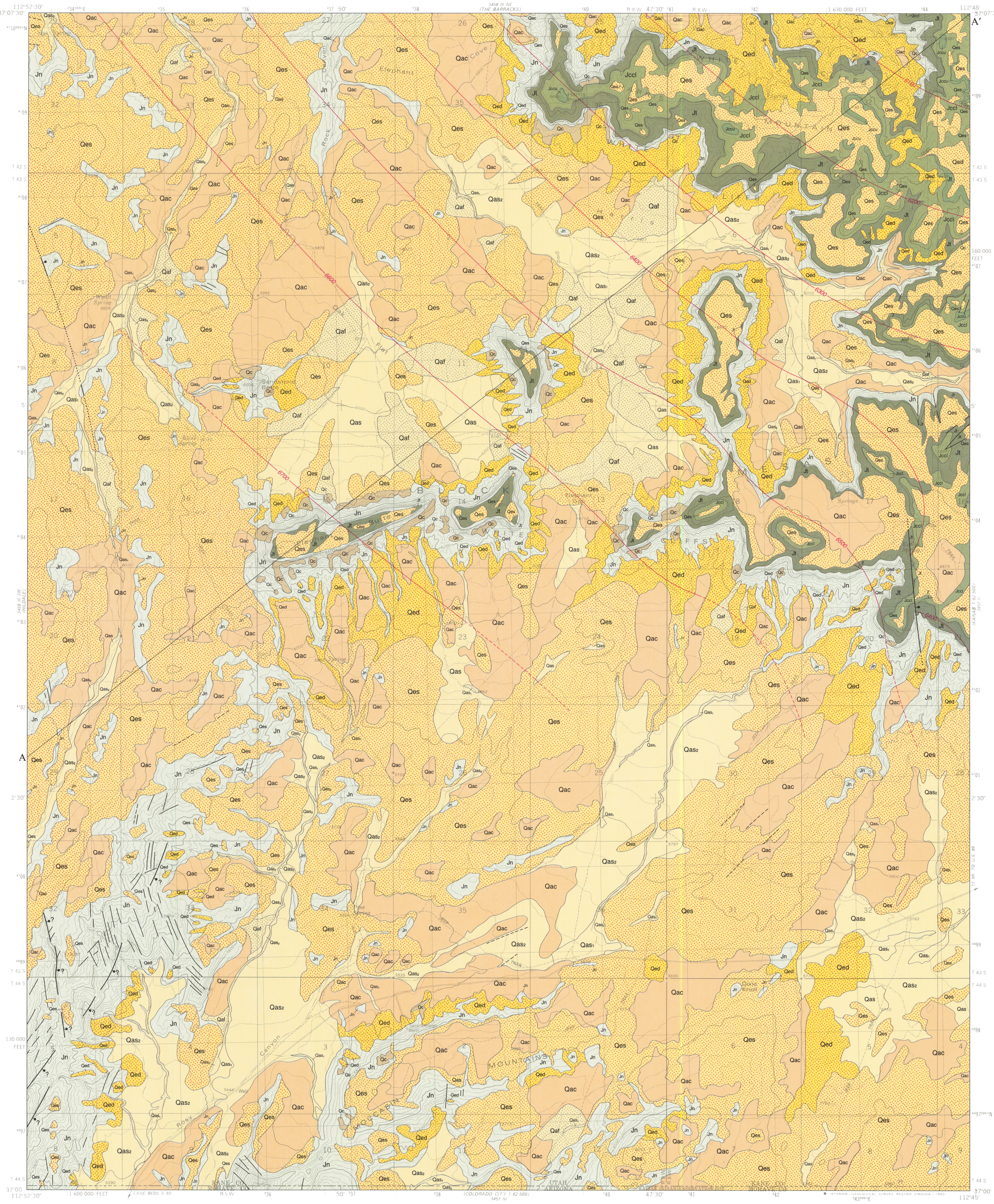

Base map from U.S. Geological Survey,
Elephant Butte 7.5′ quadrangle, 1980

SCALE 1:24 000

1 MILE

7000 FEET

1 KILOMETER

CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Field work completed in 1985-86 by authors
Cartography by J.W. Parker

UTM GRID AND 1989 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

GEOLOGIC MAP OF THE ELEPHANT BUTTE QUADRANGLE, KANE COUNTY, UTAH, AND MOHAVE COUNTY, ARIZONA

QUADRANGLE LOCATION

by
Edward G. Sable and Hellmut H. Doelling

1990

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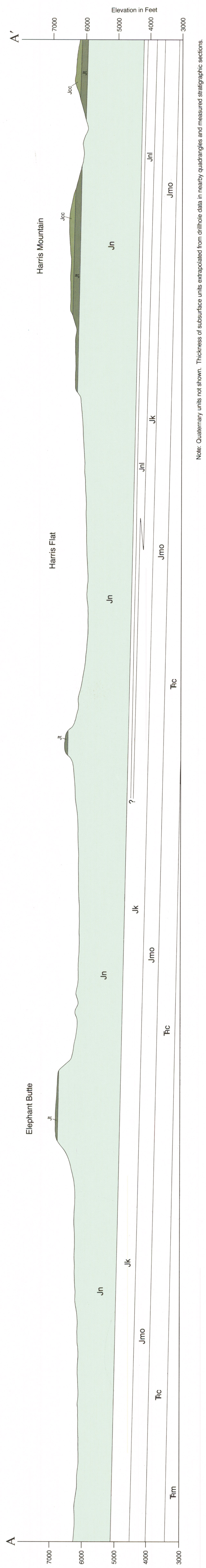
CORRELATION OF MAP AND SUBSURFACE UNITS

Qas (Qas1, Qas2), Qac, Qaf, Qes, Qed, Qc	Holocene and Pleistocene	Quaternary
Unconformity		
Jcc (Jccu, Jccl)	Middle Jurassic	Jurassic
J-2 unconformity		
Jt	Middle Jurassic	Jurassic
J-1 unconformity		
Jn	Lower Jurassic	Jurassic
Surface / *Subsurface*		
Jk, Jkt, Jnl	Lower Jurassic	Jurassic
Jmo	Lower Jurassic	Jurassic
J-0 unconformity		
TRc	Upper Triassic	Triassic
TR-3 unconformity		
TRm	Middle (?) and Lower Triassic	Triassic
TR-1 unconformity		



DESCRIPTION OF MAP UNITS

Qas (Qas1, Qas2) Alluvium — *Predominantly sand, fine to medium, derived from Temple Cap Sandstone and Navajo Sandstone, locally contains poorly interstratified sandstone pebbles, silt, clay, limestone platelets derived from the Co-op Creek Limestone Member of the Carmel Formation, and organic debris; commonly contains some interstratified eolian sand; 0-40 feet thick, thickest in lower parts of valleys. Qas1, younger alluvium in and adjacent to modern stream channels and as overbank and fan deposits. Qas2, older alluvium as floodplain deposits adjacent to modern streams; in part includes alluvial fans, aprons, and colluvium along valley walls.*

Qac Alluvium and colluvium — *Sand of eolian origin reworked mostly by sheet flow; surfaces are low angle, planar to gently curving, and relatively smooth.*

Qaf Alluvial fan deposits — *Sand, very fine to medium; orange, pink, and gray; with distinct fan morphology; in part appears to overlie alluvial fans and aprons mapped in unit Qas2 and eolian sand of unit Qes.*

Qes Eolian deposits and residuum undivided — *Sand, fine to medium; orange, pink, and yellowish-gray; occurs as veneer of mostly stabilized sheet sand and irregular fillings of bedrock hollows and intermittent drainages in lowland areas and on mesas and buttes; includes some small dunes; grades downslope to alluvium. Locally includes small outcrops of bedrock. Unit includes red-orange clay residuum with limestone clasts on parts of mesas and buttes underlain by the Co-op Creek Limestone Member of the Carmel Formation. Unit may be as much as 30 feet thick.*

Qed Eolian sand in dunes and ramps — *Sand as above chiefly in stabilized dune fields in southeastern part of quadrangle and as ramps and aprons flanking cliffs and steep slopes of buttes and mesas and grading downslope to unit Qes. May be as much as 50 feet thick.*

Qc Colluvium — *Sand and sandstone talus blocks at base of and on sides of mesas and buttes.*

Jcc (Jccu, Jccl) Co-op Creek Limestone Member of Carmel Formation — *Limestone, limy shale, and shale; limestone and limy shale, yellowish-gray and light-olive-gray, micritic to finely crystalline and oolitic, thin- to medium-bedded; contains few sandstone and siltstone beds; locally fossiliferous with pelecypods, gastropods, and crinoid columnals including* Pentacrinus asterious. *Lower unit (Jccl) with basal ledge-forming limestone overlain by slope-forming shale and limestone; upper unit (Jccu), ledge-forming limestone. Unit Jcc shown on cross section only. Maximum incomplete thickness of member about 200 feet.*

Jt Temple Cap Sandstone — *Sandstone and siltstone. Formation composed of two members (not differentiated on map), the White Throne Member, mostly pinkish-gray, fine- to medium-grained, weakly calcite-cemented, massive cliff- to slope-forming sandstone with high-angle crossbeds, and the underlying Sinawava Member, pink to reddish-brown, slope-forming siltstone and sandstone. Thickness of formation ranges from 140 to 200 feet.*

Jn Navajo Sandstone — *Sandstone, quartzose, mostly fine- to medium-grained; frosted subangular to subrounded equant grains with calcareous, siliceous, or iron-oxide cement; massive, with sweeping high-angle crossbeds in sets 10 to 30 feet thick; upper 400 feet is cliff forming, weathers pinkish to yellowish gray to white; lower part weathers to rounded hills, ledges, sloping rock faces and knolls. Incomplete exposed thickness about 1,300 feet.*

MAP SYMBOLS

CONTACT — *Approximate and inferred included.*

FAULT — *bar and ball on downthrown block; dotted where concealed, queried where sense of movement is uncertain.*

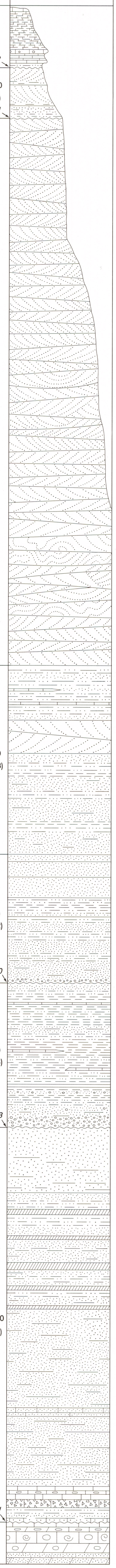
JOINT IN NAVAJO SANDSTONE

LINEAR FEATURE OBSERVED ON AERIAL PHOTOGRAPHS — *may be fault or joint trace.*

6400 STRUCTURE CONTOUR — *Datum, top of Navajo Sandstone; extrapolated where land surface is below datum; contour interval 100 feet.*

2 STRIKE AND DIP OF BEDS

PERIOD	EPOCH	FORMATION	MEMBER	SYMBOL	THICKNESS Feet (Meters)	LITHOLOGY
JURASSIC	Middle Jurassic	Carmel Formation	Co-op Creek Limestone Member	Jcc (Jccu, Jccl)	200+ (61+)	
					J-2	
JURASSIC	Middle Jurassic	Temple Cap Sandstone	White Throne Member	Jt	140-200 (43-61)	
JURASSIC	Middle Jurassic	Temple Cap Sandstone	Sinawava Member	Jt		
					J-1	
JURASSIC	Lower Jurassic	Navajo Sandstone	"white" unit	Jn	1800± (549±)	
			—?—?—			
JURASSIC	Lower Jurassic	Navajo Sandstone	"pink" or "vermillion" unit	Jn		
			Surface rocks / Subsurface rocks			
			—?—?—			
JURASSIC	Lower Jurassic	Navajo Sandstone	"gray and reddish-brown" unit	Jn		
JURASSIC (?)	Lower Jurassic (?)	Kayenta Formation	Tenney Canyon Tongue	Jkt	550-700 (167-213)	
JURASSIC (?)	Lower Jurassic (?)	Kayenta Formation	Lamb Point Tongue of Navajo Sandstone	Jnl		
JURASSIC (?)	Lower Jurassic (?)	Kayenta Formation	main body	Jk		
JURASSIC (?)	Lower Jurassic (?)	Moenave Formation	Springdale Sandstone Member	Jmo	350-500 (106-152)	
JURASSIC (?)	Lower Jurassic (?)	Moenave Formation	Whitmore Point Member	Jmo		
JURASSIC (?)	Lower Jurassic (?)	Moenave Formation	Dinosaur Canyon Member	Jmo		
					J-0	
TRIASSIC	Upper Triassic	Chinle Formation	Petrified Forest Member	TRc	450-550 (137-168)	
TRIASSIC	Upper Triassic	Chinle Formation	Shinarump Member	TRc		
					TR-3	
TRIASSIC	Middle (?) and Lower Triassic	Moenkopi Formation	upper red member	TRm	1200-1350 (365-411)	
TRIASSIC	Middle (?) and Lower Triassic	Moenkopi Formation	Schnabkaib Member	TRm		
TRIASSIC	Middle (?) and Lower Triassic	Moenkopi Formation	middle red member	TRm		
TRIASSIC	Middle (?) and Lower Triassic	Moenkopi Formation	Virgin Limestone Member	TRm		
TRIASSIC	Middle (?) and Lower Triassic	Moenkopi Formation	lower red member	TRm		
TRIASSIC	Middle (?) and Lower Triassic	Moenkopi Formation	Timpoweap Member	TRm		
					TR-1	
PERMIAN	Lower Permian	Kaibab Limestone				



GEOLOGIC MAP OF THE ELEPHANT BUTTE QUADRANGLE, KANE COUNTY, UTAH AND MOHAVE COUNTY, ARIZONA

by E.G. Sable, U.S. Geological Survey, Denver
and H.H. Doelling, Utah Geological and Mineral Survey

UTAH GEOLOGICAL AND MINERAL SURVEY
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MAP 126 **1990**

UTAH GEOLOGICAL AND MINERAL SURVEY

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GEOLOGIC MAP OF THE ELEPHANT BUTTE QUADRANGLE, KANE COUNTY, UTAH AND MOHAVE COUNTY, ARIZONA

by E.G. Sable[1] and H.H. Doelling[2]

ABSTRACT

Field mapping supplemented by aerial photograph interpretation has delineated exposures of three bedrock formations of Jurassic age and eight informal surficial units of Quaternary age in the scenic Elephant Butte quadrangle. About 1300 feet (396 m) of the middle (pink) and upper (white) units of the Navajo Sandstone, predominantly highly cross-bedded sandstone of probable eolian origin, are exposed. The Temple Cap Sandstone, 140 to 200 feet (43-61 m) thick, consists of 40 to 50 feet (12-15 m) of reddish and pinkish sandstone and shale of the Sinawava Member and 100 to 150 feet (30-45 m) of the overlying probably eolian-derived sandstone of the White Throne Member. Sharp, nearly planar surfaces interpreted as unconformities mark the bottom and top of the Temple Cap. Incomplete sections as much as 200 feet (61 m) thick of the Co-op Creek Limestone Member of the Carmel Formation include dominant light-colored marine limestone and limy shale, which locally contain Middle Jurassic fauna. Quaternary deposits are dominantly locally derived sand and are mapped as alluvium, eolium, and colluvium. Structure is relatively simple and consists of a gentle northeast-dipping homocline broken by high-angle extensional faults with small displacements and joints with dominant north-northeast and north-northwest trends.

No known mineral or fuel resource exploitation or subsurface exploration has occurred in the quadrangle. The potential for surface geologic hazards is low. Seismic events (earthquakes) of Richter magnitudes of 2.0 and greater have been recorded with epicenters east of the quadrangle. Surface water potential is very limited but ground-water potential is considered good.

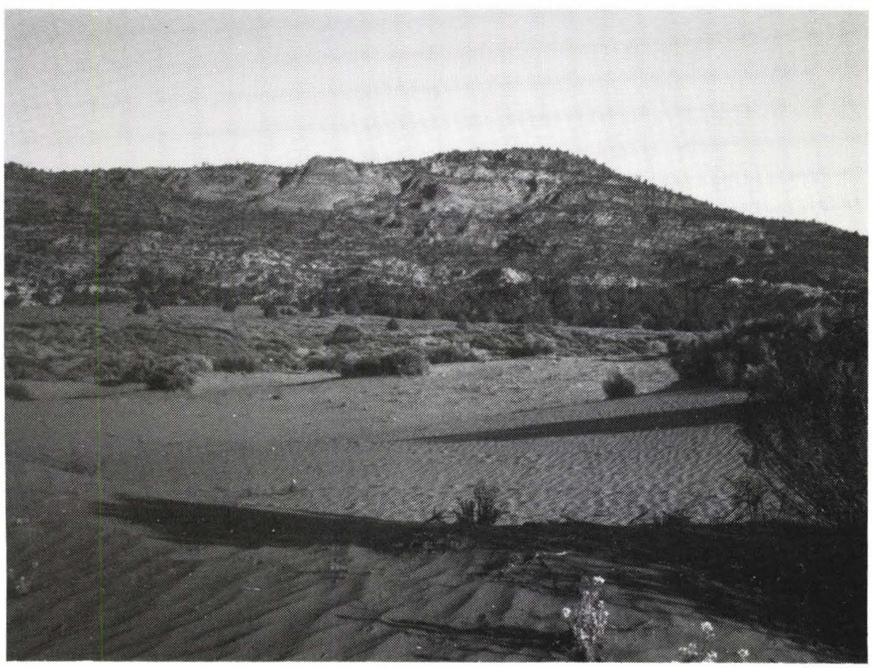

Figure 1. *A typical scene in the Elephant Butte quadrangle, view looking west across eolian and alluvial sand to outcrops of the "pink" Navajo.*

[1]*U.S. Geological Survey, Denver*
[2]*Utah Geological and Mineral Survey*

Figure 2. *Elephant Butte and small butte to the east, the highest and westernmost of the Block Mesas capped by thin remnants of the Temple Cap Sandstone (Sinawava Member).*

INTRODUCTION

The Elephant Butte quadrangle is located near the southwest corner of Kane County, Utah, along the Arizona border. A narrow strip about 150 feet (45 m) wide along the southern margin of the quadrangle is in Mohave County, Arizona. The quadrangle is bounded by The Barracks, Yellowjacket Canyon, and Hildale 7 ½-minute quadrangles on the north east, and west respectively. The area is located entirely within the Colorado Plateaus physiographic province; landforms are typically buttes and mesas rising above rolling to flat, largely sand-covered land informally known as the Moccasin Terrace (figures 1 and 2). Altitudes range from 5390 feet to about 6200 feet (1643-1890 m); the highest point is on Elephant Butte at 6812 feet (2076 m) above mean sea level.

The principal access road into the quadrangle extends across the southern part. It is a well-maintained gravel road locally known as the "sand dunes" road, because it passes through Coral Pink Sand Dunes State Park 1 to 4 miles (1.6-6.4 km) east of the quadrangle. The east margin of the quadrangle is 13 miles (21 km) southwest of U. S. Highway 89 and 12 miles (19 km) west of Kanab, Utah; the southwest corner is about 5 miles (8 km) north of Cane Beds, Arizona.

The mesas and buttes include those of Harris Mountain in the northeastern part of the quadrangle and the Block Mesas which trend east-west across the center. There are no permanent streams; Rosy Canyon and its tributaries drain the area south of the Block Mesas and flow southwesterly into Arizona, while Rock Canyon and other streams north of the Block Mesas drain northerly into the Virgin River.

Although all streams in the quadrangle are ephemeral (figure 4), the larger drainages are prone to flooding, especially after severe summer storms. The flooding locally damages roads, trails, and artificial catchment basins. The area is principally used for winter grazing of cattle. Several springs and seeps which issue from the Navajo Sandstone are used by

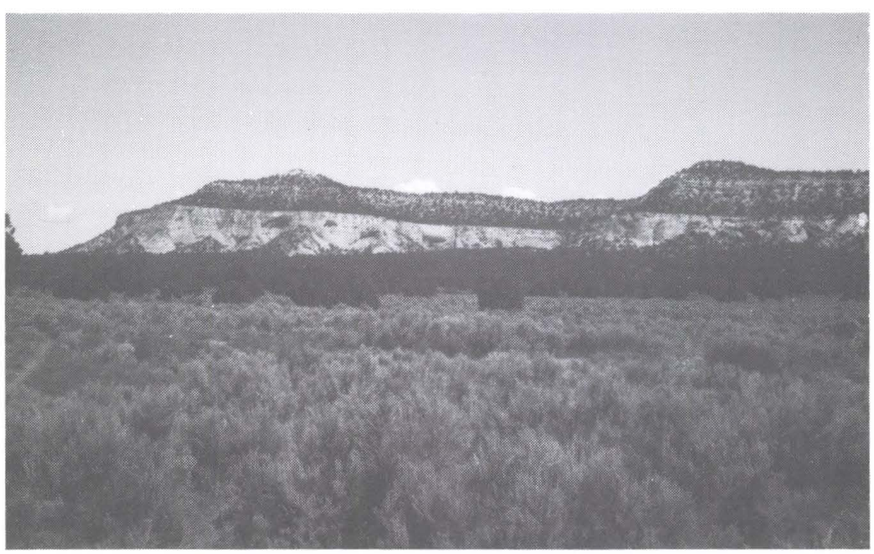

Figure 3. *View looking north to the west end of Harris Mountain. The "white" sandstone unit of the Navajo Sandstone forms the White Cliffs, which are capped by the Temple Cap Sandstone and the Co-op Creek Limestone Member of the Carmel Formation.*

the local ranchers. There are no mines or habitations within the quadrangle.

There has been relatively little previous geologic work in the area. Published maps have been of small scale (Gregory, 1950; Hintze, 1963 and 1980) or have been photogeologic interpretation (Pillmore, 1956). The quadrangle was mapped in part by E.G. Sable in 1986 as part of the U.S. Geological Survey investigation of the Parunuweap Canyon Wilderness Study Area (Van Loenen and others, 1988b) and by Sable in 1986 supplemented by interpretation of vertical aerial photographs. The aerial photographs included black-and-white photography at 1:33,200 scale flown for U.S. Government agencies and color photography at 1:24,000 scale obtained from Intrasearch, a private organization.

Figure 4. *Typical ephemeral drainage in the southern part of the Elephant Butte quadrangle, flowing over bare rock with hollows filled with sandy alluvium.*

STRATIGRAPHY

MESOZOIC ROCKS

About 1800 feet (549 m) of Jurassic sediments are exposed in the quadrangle. They are divided into three formations on plate 1, (ascending) the Navajo Sandstone, Temple Cap Sandstone, and Carmel Formation. Large areas of rock are veneered by unconsolidated Quaternary deposits that have been divided into eight units of alluvium, eolium (eolian deposits), and colluvium.

Mesozoic units underlying the quadrangle are exposed to the south between the Arizona border and the Grand Canyon and to the east in and near Zion National Park; their estimated subsurface thicknesses are shown in the lithologic column (plate 2) and were used to construct the cross section. Additional stratigraphic information was obtained from Wilson (1958) and Tapp (1963).

The oldest Mesozoic rocks which occur in the subsurface are strata of the Lower and Middle (?) Triassic Moenkopi Formation, including, in ascending order, the Timpoweap Member, largely sandy limestone; the lower red member, reddish-brown siltstone and shale with thin sandstone beds and minor gypsum; the Virgin Limestone Member, in part fossiliferous limestone interbedded with marine shale; the middle red member, similar to the lower red member; the Shnabkaib Member, reddish siltstone and sandstone with abundant gypsum and gypsiferous shale; and the upper red member, siltstone and sandstone with an upward increase in sandstone beds. The base of the Moenkopi coincides with the TR-1 unconformity of Pipiringos and O'Sullivan (1978).

The Chinle Formation (Upper Triassic), overlying the Moenkopi, consists of the basal Shinarump Member, gray cross-bedded sandstone and conglomerate with minor shale, and the overlying Petrified Forest Member, mostly variegated shale containing volcanically derived clay minerals and fluvial channel-fill sandstone units. The base of the Chinle corresponds with the TR-3 unconformity of Pipiringos and O'Sullivan (1978).

The Moenave Formation (Lower Jurassic(?)) consists of three members, in ascending order, the Dinosaur Canyon, Whitmore Point, and Springdale Sandstone Members, consisting respectively of red siltstone and shale with minor thin sandstone beds, gray to red siltstone and shale, and pink, crossbedded resistant sandstone. The base of the Moenave represents the J-0 unconformity of Pipiringos and O'Sullivan (1978). The Kayenta Formation, overlying the Moenave, is an upward-coarsening unit of red to reddish-orange silty shale, siltstone, and sandstone. Relationships of the Kayenta with the Moenave Formation appear to be conformable.

Navajo Sandstone

The oldest unit exposed in the Elephant Butte quadrangle is the Navajo Sandstone. It consists mostly of fine- to medium-grained, well-sorted, quartzose sandstone that likely was deposited by the wind. Perhaps the most striking characteristic of the Navajo Sandstone is its sweeping thick sets of high-angle, wedge-planar and tabular-planar, tangential crossbeds and its massive character. The sandstone is composed of about 65 and 35 percent fine and medium grains, respectively. Less than 2 percent of the grains consist of feldspar, staurolite, tourmaline, biotite, zircon, magnetite, and garnet (Gregory, 1950, p. 86). Most sand grains are frosted, subangular to subrounded, and equant. In places, coarse and very fine grains are concentrated along crossbed laminae, and partings and thin lenses of dark red, silty sandstone or sandy mudstone are present between crossbed sets. The cementation is siliceous, ferruginous-manganiferous, and calcareous. Although most of the rock is loosely cemented and friable, in places it is hard and well-indurated; the calcareous harder part is the upper 300-400 feet (91-122 m). Thin, gray limestone beds present in the unit elsewhere in the Colorado Plateaus were not seen in the quadrangle.

C.D. Walcott measured the Navajo Sandstone along Kanab Valley, 11 miles (17 m) east of the quadrangle, in 1879 (Cross, 1908). Although he did not name the unit, he divided the stratigraphic interval into an upper white cliffy sandstone 585 feet (178 m) thick, a middle vermilion or pink sandstone 650 feet (198 m) thick, and a lower gray and reddish-brown sandstone 300 feet (91 m) thick. These color units are not limited by lithostratigraphic boundaries so the tripartite division has never been accepted as a means of regionally dividing the Navajo Sandstone. The upper two subdivisions are exposed in the Elephant Butte quadrangle, and the entire Navajo Sandstone is exposed in the adjoining The Barracks quadrangle immediately to the north. Even there it is difficult to measure the Navajo directly because of its cliffy nature, but a reasonable estimate was made by photogrammetric measurements and structural extrapolation. Along Parunuweap Canyon in The Barracks quadrangle, the upper white unit is about 400 feet (122 m) thick, the pink unit about 900 to 1000 feet (274-305 m) thick, and the lower brown unit about 400 feet (122 m) thick. The thickness of the lower unit is similar in Cottonwood Canyon, a few miles southwest of the Elephant Butte quadrangle near Cane Beds, Arizona. In the Elephant Butte quadrangle about 900 feet (274 m) of the pink unit and about 400 feet (122 m) of the white unit are exposed. The white appears to thicken eastward at the expense of the pink unit.

The pink unit exhibits a variety of color shades ranging from moderate reddish orange (10R 6/6) to moderate reddish brown (10R 4/6), pale reddish brown (10R 5/4), light red (5R 6/6), and moderate red (5R 5/4). Surfaces of sand grains are stained with red and orange iron oxides. Iron oxide cementation is weak and the rock is porous; the sandstone is friable enough to be disintegrated with the fingers. Most crossbed laminae dip from the southwest 20-30° but commonly exceed angles of 35° from the horizontal. Crossbed sets commonly range from 10 to 25 feet (3-7.6 m) thick; a few exceed 30 feet (9 m). The bare rock outcrops are either smooth or exhibit etched crossbed laminae and set boundaries as rough ledges. The pink unit forms rolling land beneath cliffs of the white unit and crops out in sloping cliffs, bare rock knolls, rounded hills, ledges, and hollows.

The grain sizes and compositions, crossbedding characteristics, and massive character of the white unit are similar to those of the pink unit, but the cementation is calcareous and the rock is more strongly indurated than the pink unit. The white unit stands in relief above the less-resistant pink unit to form the well-known White Cliffs and other steep-sided buttes and mesas. Weathered colors of the white sandstone are very light gray (N8), pinkish gray (5YR 8/1), and yellowish gray (5Y 8/1). The fresh color is commonly very pale orange (10YR 8/2).

The contact between the pink and white Navajo units is approximately at the base of the White Cliffs. The color change for the most part does not coincide with the bedding; it is irregular and unpredictable within about a 50-foot (15 m) interval. The upper contact with the Temple Cap Sandstone is a sharp and nearly planar surface. There, a tabular 1- to 2-foot zone (30-60 cm) of reworked fine- to medium-grained sandstone commonly truncates crossbeds at the top of the Navajo.

In the subsurface, the Navajo Sandstone intertongues with the generally underlying Kayenta Formation. The distal edge of the intertonguing unit of the Navajo, the Lamb Point Tongue, probably trends northwesterly in the subsurface of the Elephant Butte quadrangle. To the southwest of this line the Kayenta Formation is estimated to be 580 to 650 feet (177-198 m) thick. To the northeast of the line the Kayenta-Navajo interval consists of (ascending) the main body of the Kayenta Formation, the Lamb Point Tongue of the Navajo Sandstone, the Tenney Canyon Tongue of the Kayenta, and the main body of the Navajo. Their combined thickness (omitting the main body of the Navajo) is probably 550 to 700 feet (168-213 m) thick. The Lamb Point Tongue crops out along the western edge of the Moquith Mountains about 2 miles (3 km) east of Elephant Butte quadrangle. It is not present to the southwest near Cane Beds, Arizona. Wilson (1958, p. 112) reports as much as 50 feet (15 m) of the Lamb Point Tongue in the eastern part of Zion Canyon and 210 feet (64 m) of the Tenney Canyon Tongue at Indian Point, Arizona. In the latter area, which is 7 miles (11 km) southwest of the Moquith Mountains, the Tenney Canyon merges with the main body of the Kayenta Formation. In this quadrangle, the main body of the Kayenta underlying the Lamb Point Tongue is probably 280-370 feet (85-113 m) thick and thickens westward; the Lamb Point Tongue is 0 to 110 feet (0-34 m) thick and reciprocally thickens northeastward; and the Tenney Canyon Tongue is 180 to 210 feet (55-64 m) thick.

Temple Cap Sandstone

The Temple Cap Sandstone unconformably overlies the Navajo Sandstone. The Temple Cap, formerly a member of the Navajo, was raised to formational status by Peterson and Pipiringos (1979, p. B7). They subdivided the formation into the lower Sinawava Member and the upper White Throne Member; both are present in the Elephant Butte quadrangle. The type and reference sections for the formation and members are about 10 miles (16 km) north-northwest in Zion National Park.

The Temple Cap Sandstone is the only bedrock formation of which the complete thickness is exposed in the quadrangle; it ranges in thickness from 140 to 200 feet (43-61 m). Although the two members are present, they were not mapped separately, because both are poorly exposed and commonly covered by vegetation and surficial deposits. Only the Sinawava Member is exposed in the Block Mesas area, specifically Elephant Butte, the small butte to the east, and the two small buttes to the north. Where the Sinawava is covered with sand, some part of the White Throne Member may be buried.

The Sinawava Member, about 40 to 50 feet (12-15 m) thick, is a slope-forming unit of reddish-weathering sandstone and siltstone. The overlying White Throne Member consists of about 100 to 150 feet (30-46 m) of sandstone closely resembling that in the Navajo Sandstone, the contact of the Temple Cap with the overlying Carmel Formation is sharp and planar, and in some places, white or very light gray clasts of chert as much as 2 inches (5 cm) in diameter occur in sandstone above the contact. These are especially noticeable in sections examined in the eastern parts of the Block Mesas, Sec. 18, T. 43 S., R. 8 W. The contact is considered to correspond to the J-2 unconformity of Pipiringos and O'Sullivan (1978).

Stratigraphic section of the Temple Cap Sandstone measured on Harris Mountain, SESESE Sec. 31, T. 42 S., R. 8 W. near where the old Shunesburg road descends from the mountain to Harris Flat.

Co-op Creek Limestone Member of the Carmel Formation: Siltstone and sandstone, mostly light brown (5YR 6/4) but with some very pale orange sandstone streaks, grains are very fine (vfL) to medium (mL); very soft, forms a deep undercut above the Temple Cap Sandstone and below a resistant sandstone ledge. Basal unit is sandstone and conglomeratic sandstone 16 to 18 inches (41-46 cm) thick, resistant, contains white and very light gray chert clasts, truncates crossbedding of unit 1 below along a nearly flat surface that corresponds to the J-2 unconformity of Pipiringos and O'Sullivan (1978).

TEMPLE CAP SANDSTONE

White Throne Member:

1. Sandstone, very pale orange (10YR 8/2), weathers very light gray (N8), pinkish gray (5YR 8/1) and yellowish gray (5Y 8/1); fine to medium grained (vfU-mU), mostly quartzose with about 2 percent dark and opaque grains, frosted and equant; slightly calcareous and weakly cemented, upper part more firmly cemented than lower; high-angle eolian crossbeds, massive, cliff-forming; crossbeds are somewhat etched in relief by weathering .... 37.5 feet

2. Sandstone, pinkish gray (5YR 8/1); fine to medium grained (vfU-mU), similar to unit 1; very friable and lightly cemented; forms slope and weak, thin ledges, poorly exposed slope former, grades upward into unit 1 .... 19.0 feet

3. Sandstone, weathered color is light gray (N7-N8), otherwise like unit 1, but more calcareous and better cemented. Upper 15 feet is a massive cliff, upper surface is nearly planar .... 43.8 feet

4. Sandstone, yellowish gray (5Y 8/1), like unit 2, weathers to sandy slope .... 22.2 feet

5. Sandstone, very light gray (N8), medium grained (mL-mU), hard and calcareously cemented, not crossbedded; forms single resistant bed or ledge, probably lenticular .... 1.0 feet

Total White Throne Member .... 123.5 feet

Sinawava Member:

6. Sandstone, moderate pink (10YR 8/2), fine to medium grained (fU-mU), contains a few siltstone beds; slope forming and platy weathering .... 21.3 feet

7. Sandstone, very pale orange (10YR 8/2); upper part is mottled moderate pink (5R 7/4), fine to medium grained; weathers blocky and forms a ledge .... 10.5 feet

8. Siltstone and sandstone, pale reddish brown (10R 5/4) to moderate reddish brown (10R 4/6), very fine-grained, slope forming .... 15.7 feet

Total Sinawava Member .... 47.5 feet

Total Temple Cap Sandstone .... 171.0 feet

Upper part of the Navajo Sandstone: Sandstone, pinkish gray (5YR 8/1), fine to medium grained, with calcareous cement, massive, with eolian crossbeds, forms cliffs. Upper 1 to 2 feet (30-60 cm) consist of bed of reworked sandstone with nearly planar top, which corresponds to the J-1 unconformity of Pipiringos and O'Sullivan (1978).

Carmel Formation

The youngest bedrock unit in the Elephant Butte quadrangle is the Carmel Formation; only its lowermost member, the Co-op Creek Limestone Member, is exposed. Most of this member (limestone member of Cashion, 1967) is present as capping remnants on Harris Mountain and in the eastern part of the Block Mesas. The overlying Crystal Creek Member (banded member of Cashion, 1967) has been eroded and is not present in the quadrangle. The strata presently assigned to the Co-op Creek Limestone Member were originally considered to be the entire Carmel Formation in the Kane County area (Gregory and Moore, 1931, p. 72-74 and Gregory, 1950, p. 92-94). Thompson and Stokes (1970) included this limestone unit and rocks above it as parts of the Carmel Formation and named several members. Because the name "Kolob" given by Thompson and Stokes to the limestone unit was pre-empted, Doelling and Davis (1989) have proposed the name Co-op Creek Limestone Member for this lowest unit of the Carmel from a location in The Barracks quadrangle, north of the Elephant Butte quadrangle.

The Co-op Creek Limestone Member in the Elephant Butte quadrangle contains micritic limestone weathering light-gray or white, calcareous shale, sandy limestone, oolitic limestone, and siltstone (figure 5). As much as 200 feet (61 m) of the unit have been measured; this section can be roughly divided into three subunits. The lower subunit, about 60 to 70 feet (18-21 m) thick, is resistant limestone and forms a strong ledge. This subunit contains algal laminae, rip-up clasts, and "birdseye" structure; it is fossiliferous, containing pelecypods, gastropods, and crinoids, including the easily identifiable star-shaped columnal segments of the crinoid *Pentacrinus astericus*. These fossils are similar to those in the Twin Creek Formation of northern Utah, with which the Carmel correlates (Peterson, 1972). The middle subunit, 110 to 130 feet (33-40 m) thick, is a steep slope former of calcareous shale with ledges of platy-weathering limestone that increase upward. The upper subunit is ledgy, in part fossiliferous limestone similar to that in the lower subunit. Total thickness of the member in the adjoining Kanab 15-minute quadrangle is 215 feet (65 m) (Sargent and Philpott, 1987).

Figure 5. *Platy limestone litter marks outcrops of the Co-op Creek Limestone Member of the Carmel Formation exposed on Harris Mountain.*

Stratigraphic section (incomplete) of the Co-op Creek Limestone Member of the Carmel Formation on Harris Mountain at SENESW Sec 31, T. 42 S., R. 8 W.

CARMEL FORMATION:

Co-op Creek Limestone Member:

1. *Limestone, yellowish-gray (5Y 8/1), very fine to fine grained (vfL-fL), medium bedded (1 to 2.5-foot beds); weathers into plates ½ to 6 inches thick, resistant, forms hard ledge, contains scattered fossil debris .... 10.0+ feet*
2. *Limey shale, light olive gray (5Y 6/1), poorly exposed, slope former .... 7.5 feet*
3. *Limestone, yellowish-gray (5Y 8/1), sandy, fine-grained, weathers into 1/16 to 2 inch plates .... 7.0 feet*
4. *Limey shale, like unit 2 .... 19.5 feet*
5. *Limestone, like unit 3 .... 8.0 feet*
6. *Limey shale, like unit 2, forms steep slope ..... 56.0 feet*
7. *Sandstone, yellowish gray (5Y 8/1), very fine grained (vfU), calcareous, hard, forms ledge .... 3.6 feet*
8. *Limey shale, very light gray (N8),like unit 2, littered with platy limestone and sandy limestone from above .... 20.0 feet*
9. *Limestone, yellowish gray (5Y 8/1) to very light gray (N8), oolitic and sandy, medium bedded, forms hard and resistant ledge, weathers to 1 inch to 2 foot plates and blocks, grades upward to very thin platy limestone; contains abundant fossil fragments of pelecypods and crinoids including* Pentacrinus asteriscus *........... 25.3 feet*
10. *Limey shale, light olive gray (5Y 6/1), poorly exposed; forms a slope littered with platy limestone from unit 9 above .... 11.5 feet*
11. *Sandstone, yellowish gray (5Y 8/1), very fine grained (vfL-vfU), calcareous and hard; forms resistant ledge; scattered chert or white quartz concretionary bodies up to ½ inch in diameter throughout .... 4.3 feet*
12. *Limestone, yellowish gray (5Y 8/1), fine to very fine-grained, sandy with sandy laminae each 1/16 to ¼ inch thick; forms strong ledge, weathers into ¼ to 6 inch plates .... 13.7 feet*
13. *Limestone, moderate pink (5R 7/4), fine grained, indistinct bedding; more resistant than unit 14, but not as resistant as unit 12, weathers to rough surfaces .... 2.5 feet*
14. *Siltstone, moderate reddish brown (10R 4/6), forms earthy slope .... 2.5 feet*
15. *Sandstone bed, pale red (5R 6/2), very fine grained (vfL-vfU), calcareous, very hard, weathers blocky and platy, oscillation ripple-marked and finely laminated .... 3.0 feet*
16. *Siltstone and sandstone, mostly light brown (5YR 6/4) but with some very pale orange streaks, very fine to medium grained (vfL-mL). The lighter streaks are mostly medium grained, thinly laminated, very soft; forms deep undercut between the top of the Temple Cap Sandstone and unit 15 .... 3.3 feet*
17. *Sandstone, tabular, reworked; base truncates crossbedding in underlying Temple Cap Sandstone along a nearly planar surface which corresponds to the J-2 unconformity of Pipiringos and O'Sullivan (1978) .... 0.5 .... to 1.5 feet*

Incomplete Co-op Creek Limestone Member ... 198.6 feet

Temple Cap Sandstone, White Throne Member: Sandstone, very pale orange (10YR 8/2), weathering very light gray (N8) and yellowish gray (5YR 8/1), very fine to medium grained (vfU-mU), calcareous, friable, cliff forming, cross bedded and massive.

QUATERNARY UNITS

Eight units of Quaternary surficial deposits are mapped in the Elephant Butte quadrangle. These alluvial, eolian, and colluvial deposits cover more than 50 percent of the quadrangle. Sand, mostly derived from the Navajo Sandstone, is the predominant constituent of all the surficial units. Deposits of different origin intergrade or intertongue so that unit contacts are largely arbitrary.

Areas mapped as dominantly alluvium have little topographic relief. Alluvium (unit Qas), small-stream fluvial and fan deposits, occurs mostly in upland areas. Along the larger ephemeral streams fresh-appearing younger sandy alluvium (Qas_1) is the product of flooding during cloudbursts, much of it in recent historic time (oral communication, area residents, 1986). Older sandy alluvium (Qas_2) along these streams is largely flood plain deposits and locally includes fan and fan apron deposits along valley walls. The fan deposits included in Qas_2 are relatively indistinct compared to those mapped as unit Qaf, which show distinctive fan morphology. Many of these fans appear to overlap the less distinct fans and are more sparsely vegetated, suggesting that they represent a younger period of fan deposition.

Alluvially deposited areas are generally flatter, better compacted, and contain minor interbeds of organic debris and small sandstone pebbles. Where erosion has bared thicker deposits some stratification becomes evident. In areas near Harris Mountain some of the alluvium contains abundant plates of limestone and fine limestone mud from the Co-op Creek Limestone Member of the Carmel Formation. Exposures of the alluvium exceeding 20 feet (6 m) in thickness are rare and the thickness in this quadrangle probably does not exceed 40 feet (12 m).

Modern eolian activity is evident throughout the Elephant Butte quadrangle and eolian deposits are widespread. Morphological forms and orientation of fresh sand deposits indicate that the dominant wind direction is west and southwest. Windblown sand is by far the dominant surficial cover in the quadrangle; most of it is vegetated and relatively stable. It is mapped on the basis of morphology. Dune fields and sand ramps and aprons (Qed) occur as distinctive features different from but gradational with more widespread sheet sand and sand of irregular thickness that is mapped as undivided sand of eolian origin (Qes). Small stabilized dune fields occur mostly in the southeastern part of the area, and sand ramps and aprons flank steepsided buttes mostly on their west and south sides. The more widespread eolian sand (Qes) occurs throughout the area, filling irregularities in the underlying bedrock surface and covering in sheet fashion large areas on the upper surfaces of buttes and mesas such as Harris Mountain. Also included in this unit in the northeasternmost part of the quadrangle is red clay residuum with scattered limestone fragments derived from the Co-op Creek Limestone Member of the Carmel Formation. This residuum probably is not more than 5 feet (1.5 m) thick; it may be late Tertiary or early Quaternary.

Eolian sand in areas underlain by the pink unit of the Navajo is moderate orange pink (5YR 8/4) to grayish orange (10YR 7/4); immediately below the white cliffs it is very pale orange (10YR 8/2) and moderate orange pink (5YR 8/4). Sand grains range from very fine to medium, and are frosted, subangular to subround, and generally equant. Although the Navajo Sandstone is the main source for eolian sand in the quadrangle, a secondary contributor is the White Throne Member of the Temple Cap Sandstone. Thickness of eolian sand ranges from very thin in deposits that barely cover bedrock to perhaps more than 50 feet (15 m) in sand ramp and sand dune deposits.

Colluvium (Qc) is largely talus and rockfall at the base of or on mid-cliff ledges of the highest buttes and mesas; it consists of angular boulders and cobbles of sandstone that rest on or are buried in sand. The deposits are modified by eolian and sheet-flow reworking.

STRUCTURE

Structure in the Elephant Butte quadrangle is relatively simple. The strata form a very gentle northeast-dipping homocline in which dips rarely exceed 2°. The highest structural location is therefore in the southwest part. Datum for the structure contours is the top of the Navajo Sandstone; the contours are extrapolated to the southwest on the basis of the estimated thickness of the Navajo and regional structural considerations.

The few mapped faults are directionally related to the dominant jointing trends in the Navajo Sandstone. Some of the valleys and canyons trend in the same directions, suggesting faults or joint control. Dominant joint trends are generally N 20° to 35° E and N 10° to 15° W; joints are more noticeable in the western half of the quadrangle. Faults are more abundant in the adjacent Hildale quadrangle to the west. Because of the lack of marker beds in the massive Navajo Sandstone, it is difficult to determine the presence or degree of faulting. Most faults, however, probably have less than 50 feet (15 m) displacement, with downthrown blocks generally to the east. The Sevier fault and several fault splays cut Harris Mountain in the Yellowjacket quadrangle (northwestern quadrant of Kanab 15-minute quadrangle) to the east, but they do not extend into the Elephant Butte area.

ECONOMIC GEOLOGY

No known mines or quarries have been opened for the extraction of metallic or non-metallic minerals or construction materials in the Elephant Butte quadrangle. One prospect area in the southwestern part of the quadrangle was located in outcrops containing iron-oxide concretions. These concretions, containing as much as 15 percent iron as iron oxides are locally common in the "pink" Navajo; some of them are of unusual shape and have potential as rock shop sale items.

Sand derived from the Navajo Sandstone is suitable for filling decorative bottles or for sand paintings. Collecting of "colored sand" has been done north of Kanab, but the variety of cementing agent colors is limited and there are abundant resources of sand throughout the region. Sand in the region has been tested for use as foundry sand, for sand blasting, and for glassmaking, but the grains are generally too fine and the iron content too high for these purposes. The sandstones are generally too friable and weakly cemented for building stone or other construction purposes.

Limestone of the Co-op Creek Limestone Member of the Carmel Formation has been used as road metal or borrow and was used in construction of a few buildings during pioneer settlement. The more resistant blocky limestones could be used for rip-rap and crushed stone products. Doelling and Davis (1989) report analyses of the unit elsewhere in the region that indicate it is a possible cement rock resource.

The Virgin oil field, which has produced from the Triassic Timpoweap Member of the Moenkopi Formation and the Lower Permian Kaibab Formation is about 15 miles (24 km) west-northwest of the Elephant Butte quadrangle. Several oil tests have been drilled in the quadrangles to the east (Tapp, 1963, p. 193-198), and 19 wells in northern Arizona (Ryder, 1983). Although no commercial oil was found, many subsurface units contained oil-stained rocks and the Mississippian Redwall Limestone exhibited "live" oil stain. No structural traps are known in the Elephant Butte quadrangle. The Parunuweap Canyon and Canaan Mountain Wilderness Study Areas, north and west of the Elephant Butte quadrangle, respectively, were given moderate energy resource potential for oil and gas with a C level of certainty (certainty level C indicates that available information gives a good indication of the level of mineral resource potential) (Van Loenen and others, 1988a,b).

GEOLOGIC HAZARDS

The potential for most geologic hazards (mudflow, swelling soils, high ground water, and subsidence) in the Elephant Butte quadrangle is low. There are also no indications of landsliding except that of occasional rockfalls along cliffs. The region receives sporadic torrential rainfall from summer thunderstorms that fill the intermittent drainages to capacity. The resultant flooding damages roads and causes gullying in some places. Undrained dirt roads often channel the flooding water that erodes so deeply as to render the roadway impassable (figure 6).

Windstorms often blow sand across roads and trails in the quadrangle so that 4-wheel drive or specialized vehicles are nearly essential for travel on all roads except the county "sand dunes" road. Very dry periods tend to reduce traction along the sand-based roads.

Earthquake epicenters have not been recorded in the Elephant Butte quadrangle but have been plotted to the east in Long Valley and near Kanab. From 1850 through 1986, 33 seismic events were felt in that region with Richter magnitudes of 2.0 and greater. The greatest magnitude earthquake recorded in that period was about 5.5 (Arabasz and others, 1979; University of Utah Seismology Catalog, 1986). These quakes are associated with the Sevier and Kanab Creek fault zones located a few miles east of the quadrangle. A small adit in SWNW Sec. 2, T. 44 S., R. 9 W. was opened in the Navajo Sandstone to house a seismometer.

WATER RESOURCES

Although all streams in the Elephant Butte quadrangle are ephemeral, the ground-water potential is considered good. A few holes have been drilled to obtain water for livestock in the southwestern corner of the quadrangle. The Navajo Sandstone is considered to be the best aquifer in Kane County (Cordova, 1981). The cities of Kanab and Fredonia obtain their water supplies from wells in the Lamb Point Tongue of the Navajo Sandstone.

Figure 6. *Very straight gullies in eolian sand were once roads. These roads were poorly located and collected water during floods. Proper siting of roads, with drainage "humps," can prevent this type of road damage.*

Limited amounts of perched water have been developed in the quadrangle. Sand saturated with water fills hollows along some intermittent drainages. In other places water seeps into the crossbeds of the Navajo and is prevented from further downward seepage by relatively impermeable crossbed set boundaries (figure 7).

SCENIC POTENTIAL

The picturesque White Cliffs, an expression of the upper white sandstone unit of the Navajo Sandstone, are exposed along the Block Mesas and the west end of Harris Mountain. Although not as spectacularly displayed as in Zion National Park, the crossbedding and vivid coloration of the Navajo give the area much scenic interest. Elephant Butte is a landmark that is easily identifiable. From the tops of the mesas there are magnificent vistas of the sandy and bare rock lands below and of the spectacular scenery of Zion National Park. Elephant Butte and the White Cliffs are plainly in view to the north of the "sand dunes" road west of the Coral Pink Sand Dunes State Park.

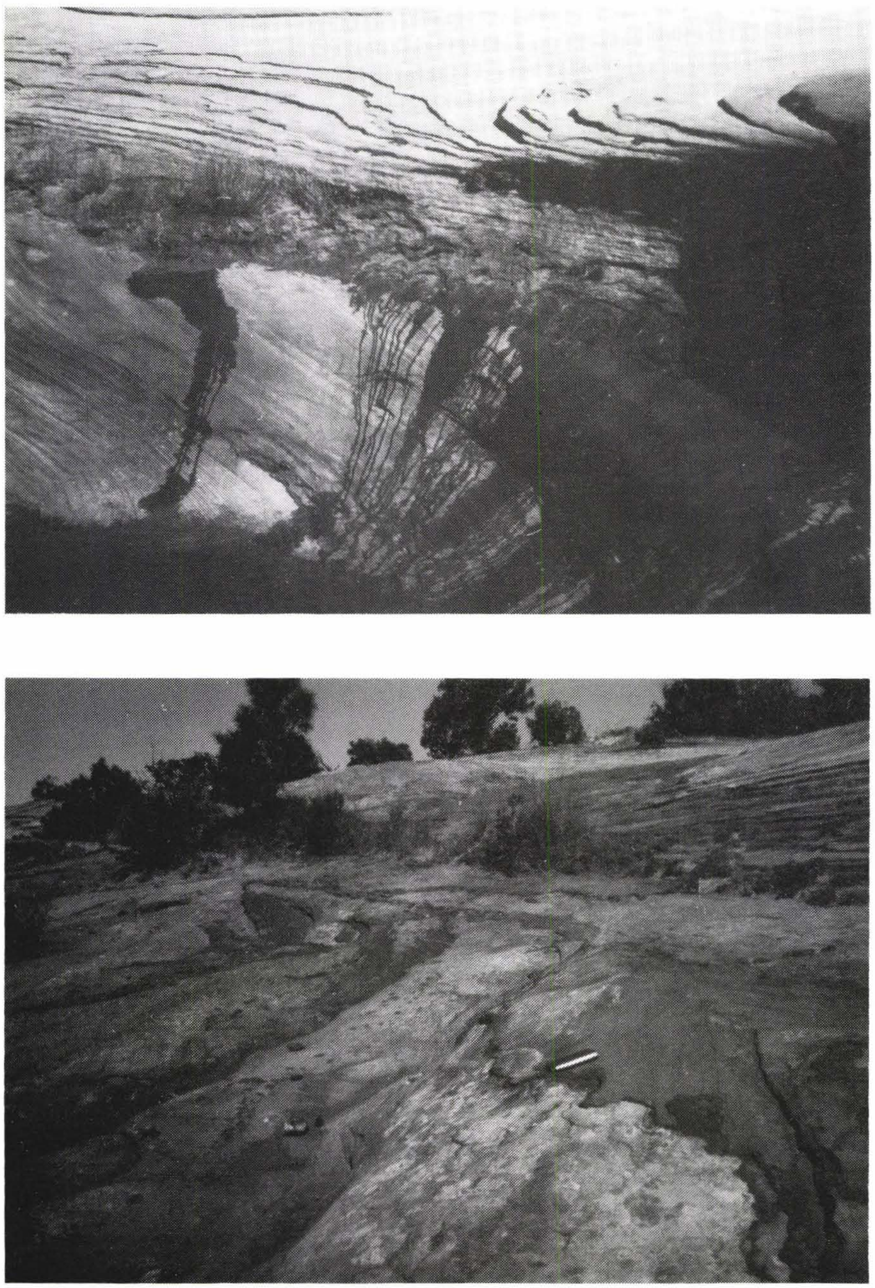

***Figure** 7. **a.** Crossbed contacts in the Navajo Sandstone commonly contain fine-grained materials that act as aquicludes. Perched water collects above the contacts and the overflow drains to the surface. Local ranchers have made use of several of such seeps to water livestock. **b.** Ground water is commonly enriched in iron. As it seeps into the underlying crossbed set, the iron oxides may be precipitated along a "mineralization front." These "fronts" contain as much as 15 percent iron and are the source of the iron concretions commonly found in the Navajo Sandstone.*

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