U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

# Geologic map of the Gyp Pocket quadrangle, northern Mohave County, Arizona

by
George H. Billingsley[1]

Open-File Report OF92-412

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards or with the North American Stratigraphic Code. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

1992

[1]U.S. Geological Survey, Flagstaff, Arizona

## INTRODUCTION

The Gyp Pocket 7.5' quadrangle (96 sq km) is located in northern Mohave County, Arizona, about 40 kilometers (25 mi) south of Hurricane, Utah, the nearest settlement (fig. 1). Elevations range from about 1,158 m (3,800 ft) at Hurricane Wash (northwest corner of quadrangle) to about 1,660 m (5,446 ft), at Navajo bench mark on top of the Hurricane Cliffs (central part of quadrangle). Access to the quadrangle area is by dirt road about 40 km (25 mi) west from Colorado city, Arizona, locally referred to as the Navajo Trail (fig. 1). Several unimproved dirt roads lead north from the Navajo Trail to various locations within the quadrangle.

The area is managed entirely by the U.S. Bureau of Land Management, including 2 sections belonging to the State of Arizona in the southeast part of the quadrangle. The area is sparsely covered by vegetation, which includes sagebrush, cactus, grass, and cliff rose shrubs.

## PREVIOUS WORK

There are no previous detailed geologic maps of this area. Prior to this work, the area was included in two Arizona state geologic maps at a scale of 1:500,000 (Wilson and others, 1969), and 1:1,000,000 (Reynolds, 1988). Geologic maps in preparation by the author of bordering areas include the Rock Canyon (north), Lost Spring Mountain West (east), The Grandstand (south), and Hole-N-Wall Canyon (west) quadrangles Arizona, scale 1:24,000.

## MAPPING METHODS

Geologic mapping of this quadrangle began with a general knowledge of Colorado Plateau geology based on literature and previous mapping experience on the Colorado Plateau. First, an overall preliminary field investigation of the map area was conducted to gain a general sense of the geological formations and structures. Second, a preliminary photogeologic interpretation of the area was made. Third, a major field investigation covered at least 85% of the map area to verify geologic photo interpretations. Many of the Quaternary units are identified by photogeologic methods as to regional morphological characteristics but have similar lithology. Fourth, a further photogeologic study was conducted to provide consistency in map units and overall geologic map sense. Finally, a field investigation to problem areas was conducted to insure accuracy and consistency of map units for descriptive purposes. The Quaternary map units herein described are important for future environmental management planning for this map area by federal, state and private concerns. The Quaternary units are also important for geomorphic interpretation of landscape development.

## GEOLOGIC SETTING

The map area lies within the Shivwits and Uinkaret Plateaus of the Colorado Plateau geologic province. The physiographic boundary between the higher elevation Uinkaret and lower Shivwits

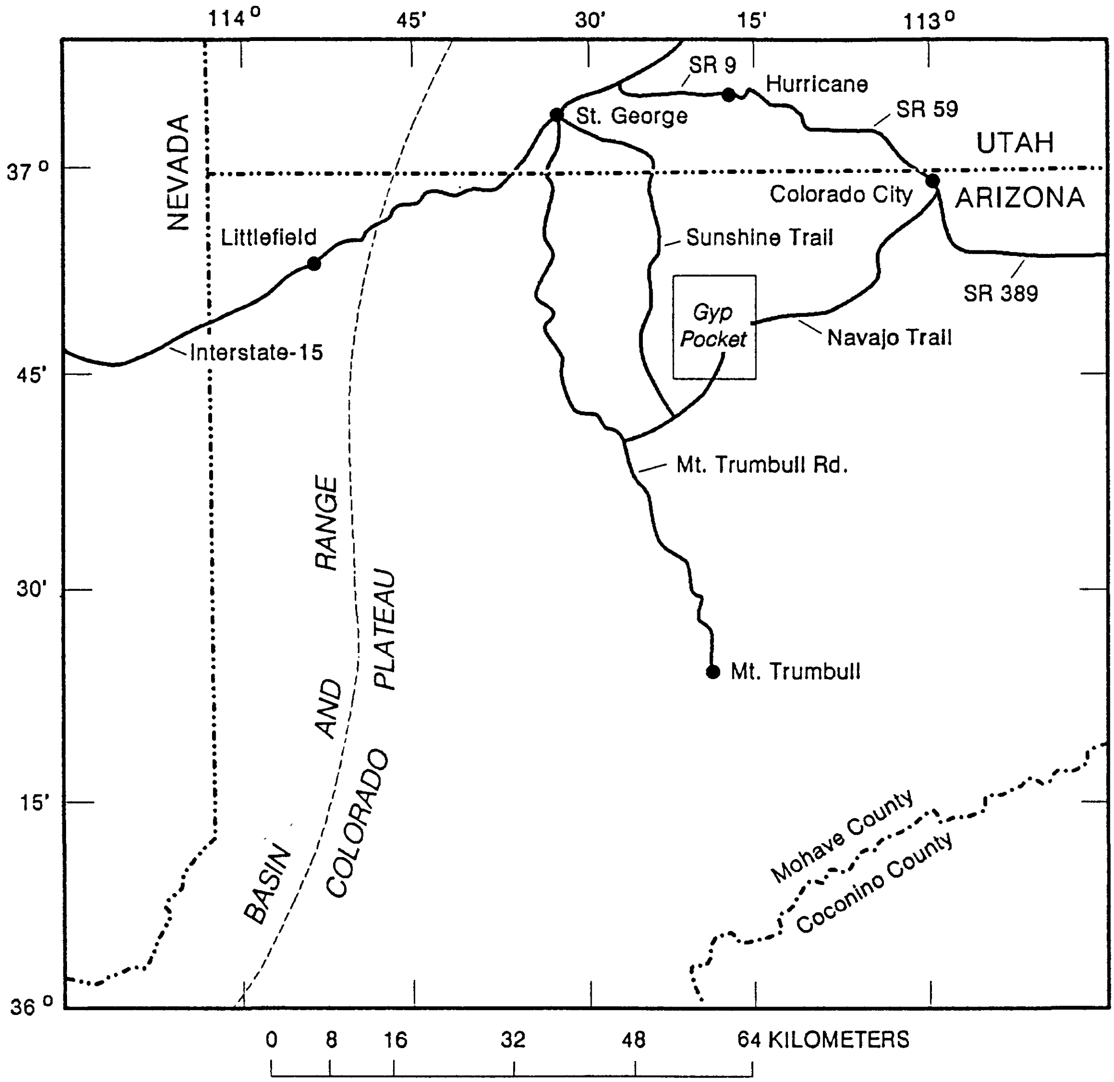



**Figure 1.** Index map of northern Mohave County, northwestern Arizona, showing the Gyp Pocket 7.5' quadrangle mapped in this report.

Plateaus is drawn along the rim of the Hurricane Cliffs, a fault scarp (fig. 2). The map area is characterized by nearly flat-lying Mesozoic and Paleozoic strata with an average regional northeast dip of about 2°. The Hurricane fault scarp exposes more than 350 m (1,150 ft) of Permian strata. Some Triassic strata are partly exposed along Hurricane Wash northwest corner of the quadrangle but are mostly buried under alluvial fan debris along the base of the Hurricane cliffs. Thickness of the Moenkopi strata is about 335 m (1,100 ft) based on bedrock exposures just north of this quadrangle. The Hurricane fault transects the map area, northwest to southeast, displacing strata up to about 900 m (2,950 ft) or more. A local northeast trending graben disrupts strata in the northwest quarter of the quadrangle with displacements of about 92 m (300 ft).

Cenozoic deposits are widely distributed and are distinguished as fluvial, eolian, or landslide deposits based on their geomorphology and relations to structures and erosional surfaces. The surficial units locally intertongue and share arbitrary map boundaries.

## STRATIGRAPHY

The sedimentary bedrock strata include, in ascending order, the Hermit Shale, Toroweap and Kaibab Formations (all Lower Permian), the Moenkopi Formation, and lower part of the Chinle Formation (Upper? Middle? and Lower Triassic). The Hermit Shale crops out at the base of the Hurricane Cliffs but is mostly covered by alluvial fan and talus debris. About three-fourths of the exposed bedrock in the map area is gray cherty limestone and gray to white siltstone and gypsum of the Kaibab Formation. The remaining exposed bedrock is gray siltstone, gypsum, limestone and sandstone of the Toroweap Formation, and red siltstone and gray limestone and sandstone of the Moenkopi Formation.

The Quaternary age assigned to the alluvial deposits is based on field relationships of alluvial deposits with Tertiary basalt flows of Seegmiller, Wolf Hole, and Black Rock Mountains northwest of this quadrangle (Billingsley, 1990, in press). Details of the stratigraphic sequence are given in the description of map units.

## STRUCTURAL GEOLOGY

The Hurricane fault and monocline are the main structural features of this quadrangle with a northwest-southeast strike. The axis of the Hurricane monocline is parallel to the Hurricane fault and on the downthrown side, with strata dipping east an average of about 12°. The monocline axis is approximately located based on deep exposures in the Grand Canyon 65.5 kilometers (41 mi) south of this quadrangle (fig 3). Tertiary compressional stresses resulted in the development of the Hurricane monocline in Laramide time (Huntoon, 1989). Later, Quaternary tensional stresses reactivated the deep seated fault plane allowing the normal fault to cut all Paleozoic and Mesozoic

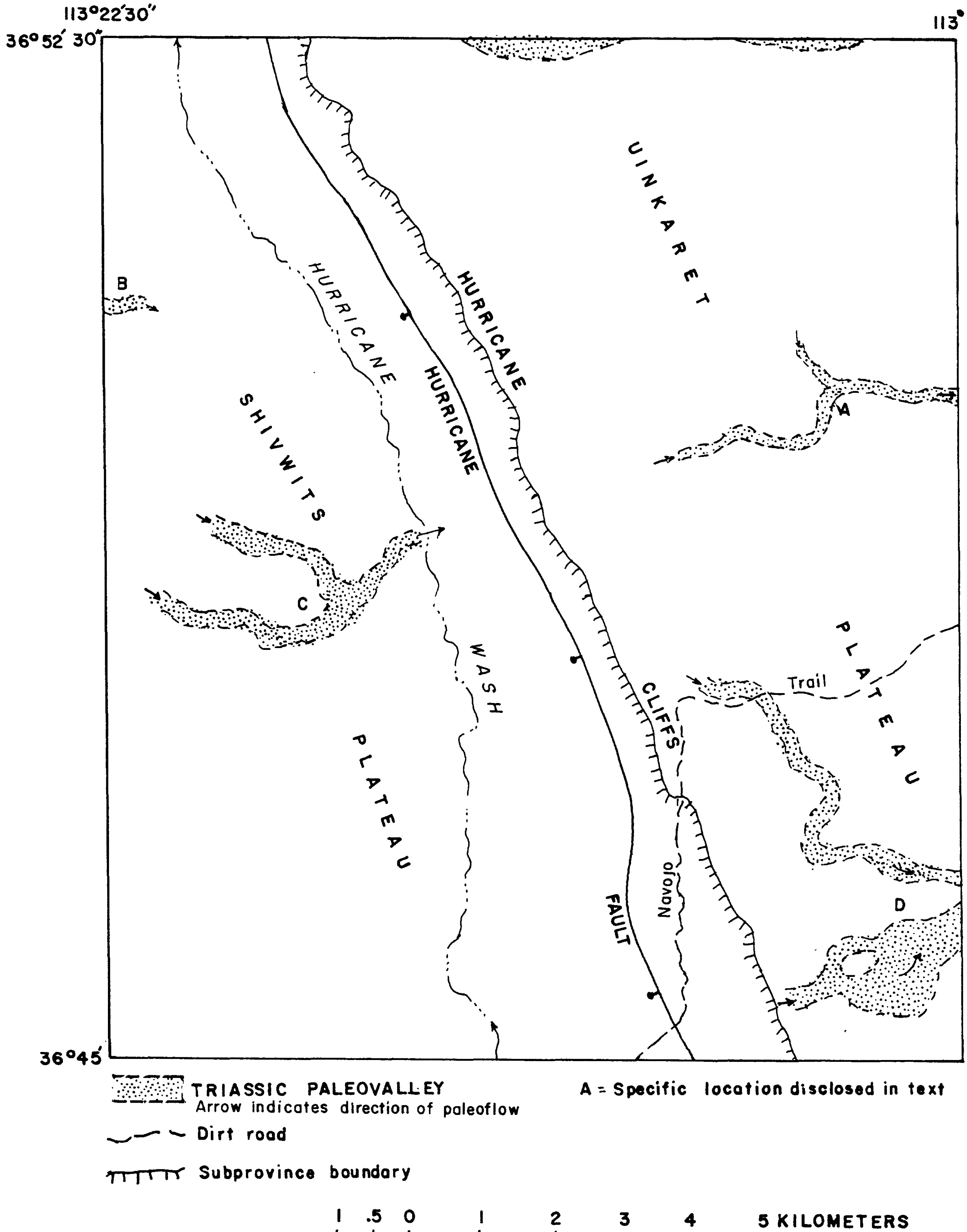



Figure 2. Selected geographic and geologic features of the Gyp Pocket quadrangle, northwestern Arizona.

strata, but reversing the displacement of strata down to the west (Huntoon, 1989). The average displacement of strata along the Hurricane fault in this quadrangle is about 700 m (2,300 ft), down to the west, with east dipping strata on both sides of the fault (fig. 3). The Hurricane fault has an enechelon break along strike at the southeast corner of the quadrangle. A tilted ramp of strata provides access across the fault scarp for the Navajo Trail (fig. 2).

The grabens and fault structures show up particularly well on X-Band, side-looking radar imagery of the Grand Canyon quadrangle, Arizona (scale 1:250,000). This imagery helps give an overall perspective of the structural fabric of this part of Arizona, especially in flatland areas (S.A.R. System, 1988).

The Quaternary development of the Hurricane fault and associated faults and grabens, began after deposition of late Pliocene basalt flows north and northwest of the map area (Best and others, 1980; Billingsley, 1990 and in press). Fault displacement of the basalt and underlying strata are the same at Seegmiller, Wolf Hole, and Black Rock Mountains.

Gyp Pocket Reservoir is located in a large graben that appears not to intersect the Hurricane fault (northwest quarter of quadrangle). The graben averages about 1 km (0.50 mi) wide; bounding faults have a maximum displacement of about 92 m (300 ft) and northeast strike. The graben breaks up into smaller horsts and grabens gradually merging with other horsts and grabens south of the quadrangle.

The Hurricane fault and associated faults and grabens were probably activated in early or middle Pliocene time. Horst and graben structures cut Pleistocene basalts of the adjacent Hole-N-Wall Canyon quadrangle indicating a Pleistocene age for most of these structures in this quadrangle. Relatively recent movement (Holocene) has occurred along parts of the Hurricane fault as indicated by small fault scarps in talus and alluvial fan deposits. The scarps are not sharply defined in the field because mass-wasting has shed soft and loose debris over the scarps. The fault line is easily seen on aerial photos. Thus, most of the faults are shown dotted in surficial alluvial map units, including where alluvium abuts against bedrock. A solid fault line is shown where faults cut alluvial deposits when clearly seen in the field and on aerial photos.

Short, doubly plunging anticlines and synclines, generally with northwest strike are present in the quadrangle. These folds, like others found elsewhere on the Colorado Plateau, are probably related to early Laramide compressional stresses (Huntoon, 1989). Warped and bent strata, too small to show at map scale, are the result of solution of gypsum and are commonly associated with collapse structures or drainage erosion.

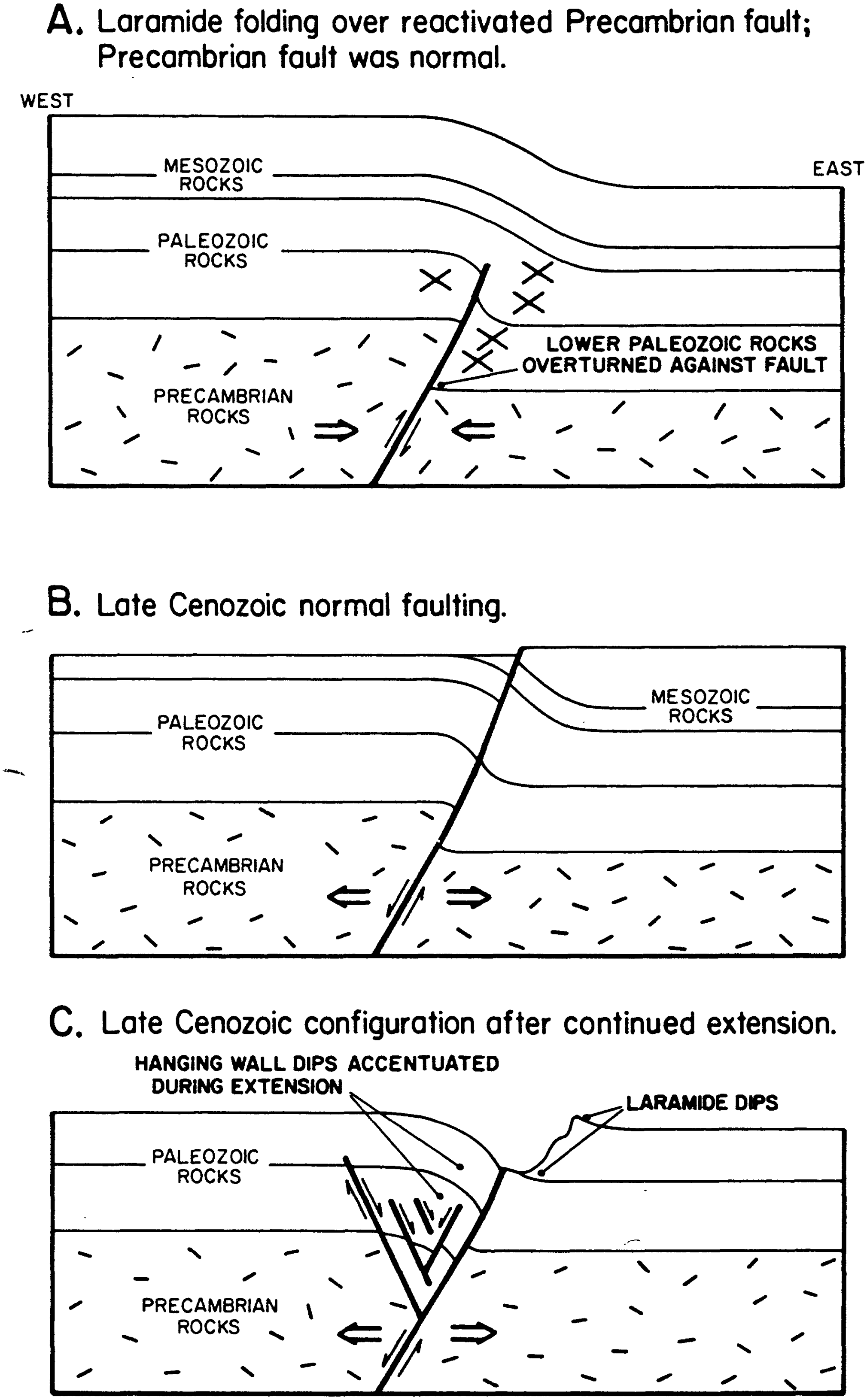



**Figure 3.** Stages in the development of a typical north-trending monocline-fault zone, Grand Canyon region, Arizona (Huntoon, 1989, p. 80).

## Collapse Structures

Circular collapse structures and surface sinkhole irregularities are mostly due to solution of gypsum and gypsiferous siltstone. However, some circular, bowl-shaped areas that have inward-dipping strata may be collapse-formed breccia pipes originating in the deeply buried Mississippian Redwall Limestone (Wenrich and Sutphin, 1989). Such features in the present map area, commonly with inward-pointing dip symbols, are marked by a dot and the letter "C" to denote possible deep-seated breccia pipes. They cannot with certainty be distinguished by surface forms from shallow collapse structures caused by removal of gypsum. Moreover, some deep-seated breccia pipes are known to be overlain by gypsum-related collapse features (Wenrich and others, 1986). The deep-seated breccia pipes are possible hosts for economical deposits of copper and uranium minerals (Wenrich, 1985).

Shallow sinkholes and karst caves are associated with the solution of gypsum in the Harrisburg Member of the Kaibab Formation. The sinkholes are denoted with the letter "S" and a triangle symbol when the feature forms an enclosed depression or cave on the land surface. The sinkholes are young features of Holocene and probable Pleistocene age. Hundreds of sinkhole depressions breached by drainages are found on the Shivwits and Uinkaret Plateau surface. Several drainages originate at sinkhole depressions in the southwest half of the quadrangle.

## DESCRIPTION OF MAP UNITS
### Surficial and volcanic deposits

Qaf **Artificial fill (Recent)**--Stock tank and drainage diversion material quarried form surficial and bedrock deposits

Qs **Stream-channel alluvium (Holocene)**--Unconsolidated and poorly sorted, interlensing silt, sand, and pebble to boulder gravel. Intertongue, or merges with alluvial fan ($Qa_1$), terrace-gravel ($Qg_1$ and $Qg_2$), and valley-fill (Qv) deposits. Stream channels are subject to high-energy flows and flash floods. Alluvial deposits support little or no vegetation. Contacts approximate. Estimated thickness 1 to 5 m (3 to 15 ft)

Qf **Floodplain deposits (Holocene)**--Unconsolidated, light-gray or brown silt, sand, and lenses of pebble to cobble gravel. Intertongue with valley-fill (Qv), alluvial fan ($Qa_1$), and talus (Qt) deposits. Form wide flat valley floors as opposed to small concave valley profiles of valley-fill (Qv) deposits. Deposits are sparsely vegetated by cactus and sagebrush. Cut by arroyos up to 9 m (30 ft) deep in Hurricane Wash. Floodplain subject to flooding and local temporary ponding. Thickness about 30 m (100 ft)

$Qg_1$ **Low terrace-gravel deposits (Holocene)**--Unconsolidated light-brown, pebble to boulder gravel composed about equally of well-rounded limestone and sandstone, angular and subrounded chert; include interstratified lenses of silt and sand. Locally include some basalt clasts along Hurricane Wash. Include reworked materials from alluvial fans ($Qa_1$ and $Qa_2$), terrace-gravels ($Qg_2$ and $Qg_3$), and talus (Qt) deposits. Form benches about 1 to 3 m (3 to 10 ft) above alluvial-filled valleys. Thickness averages about 1 to 6 m (3 to 20 ft)

$Qa_1$ **Young alluvial fan deposits (Holocene)**--Unconsolidated silt and sand; contain lenses of coarse gravel composed of subangular and rounded pebbles to cobbles of limestone, chert, sandstone, and some basalt clasts in the northwest quarter of map area; partly cemented by gypsum and calcite. Intertongue with stream-channel (Qs), valley-fill (Qv), floodplain (Qf), and low terrace-gravel ($Qg_1$); overlap and partly include reworked materials from low and intermediate terrace-gravels ($Qg_1$ and $Qg_2$) and older alluvial fan ($Qa_2$ and $Qa_3$) deposits near their downslope ends. Alluvial fans subject to erosion by sheet wash and flash floods. Support sparse to moderate vegetation of sagebrush, cactus, and grass. Thickness as much as 6 m (20 ft)

Qv **Valley-fill deposits (Holocene and Pleistocene?)**--Partly consolidated silt, sand, and interbedded lenses of pebble to small-boulder gravel. Intertongues with talus (Qt), low terrace-gravel ($Qg_1$), and alluvial fan ($Qa_1$ and $Qa_2$) deposits. Valleys subject to sheetwash flooding and temporary ponding; cut by arroyos in some larger valleys. Support thick vegetation of sagebrush, grass, and cactus. Thickness as much as 9 m (30 ft)

$Qg_2$ **Intermediate terrace-gravel deposits (Holocene and Pleistocene?)**--Similar to low terrace-gravel deposits ($Qg_1$), partly consolidated; on benches and abandoned stream channels about 4 to 12 m (12 to 40 ft) above modern stream beds. Include rounded basalt clasts up to 24 cm (10 in) diameter eroded from outcrops about 15 km (9 mi) south of this quadrangle. Intertongue with and locally overlain by talus (Qt) deposits. Thickness about 2 to 7 m (5 to 23 ft)

$Qa_2$ **Intermediate alluvial fan deposits (Holocene and Pleistocene)**--Similar to young alluvial-fan deposits ($Qa_1$), partly cemented by calcite and gypsum; generally lie above but merge with young alluvial fan ($Qa_1$) and valley-fill (Qv) deposits. Intertongue with or inset against alluvial fan ($Qa_3$) and talus (Qt) deposits. Locally include basalt clasts northwest quarter of map area. Fans are moderately vegetated by sagebrush, cactus, and some grass. Thickness about 3 to 12 m (6 to 40 ft)

Qt **Talus deposits (Holocene and Pleistocene)**--Unsorted debris consisting of breccia and large (up to 1 m) angular blocks of local bedrock. Includes silt, sand and chert gravel, partly cemented by calcite and gypsum. Intertongues with alluvial fans ($Qa_1$, $Qa_2$, and $Qa_3$), valley-fill (Qv), and terrace-gravels ($Qg_1$ and $Qg_2$) deposits. Supports sparse to moderate vegetation of sagebrush, cactus, and grass. Only relatively extensive deposits shown. Thickness as much as 9 m (30 ft)

Ql **Landslide deposits (Holocene and Pleistocene)**--Unconsolidated masses of unsorted rock debris, including blocks of detached strata that have rotated backward and slid downslope, commonly partly surrounded by talus. Occur along the Hurricane Cliffs rims where strata of the Kaibab and Toroweap Formations have detached from cliff rims. Support sparsely vegetated sagebrush, cactus. Unstable when wet. Thickness probably as much as 43 m (140 ft)

$Qg_3$ **High terrace-gravel deposits (Pleistocene)**--Similar to low and intermediate terrace-gravel deposits ($Qg_1$ and $Qg_2$), but 6 to 11 m (20 to 35 ft) higher than $Qg_2$ and about 11 to 18 m (35 to 50 ft) above modern drainages. Composed of well-rounded limestone, sandstone and chert clasts in sandy gravel matrix. Locally include abundant, well-rounded clasts of basalt in northwest quarter of the quadrangle. Partly consolidated by calcite and gypsum cement. Thickness as much as 6 m (20 ft)

$Qa_3$ **Older alluvial fan deposits (Pleistocene)**--Similar to younger and intermediate alluvial fan deposits ($Qa_1$ and $Qa_2$). Merge with talus (Qt) and valley-fill (Qv) deposits. Often adjacent to or overlapped by younger alluvial fans ($Qa_1$ and $Qa_2$), talus (Qt), and low terrace-gravel ($Qg_1$) deposits. Thickness about 3 to 5 m (10 to 15 ft)

## Sedimentary Rocks

**Chinle Formation (Upper Triassic)**--Includes the Petrified Forest and Shinarump Members as used by Stewart and others (1972). Petrified Forest Member is mostly covered

₸cp **Petrified Forest Member**--White, blue-gray, mudstone and siltstone. Contains bentonitic clays derived from volcanic ash. Only lower part exposed in northwest corner of quadrangle, commonly covered by alluvial fan material. Gradational contact with underlying cliff-forming Shinarump Member. Forms slope. About 25 m (80 ft) exposed

₸cs **Shinarump Member**--Tan to orange-brown, coarse-grained, thick-bedded, pebbly or gritty sandstone and conglomeratic sandstone. Includes flat-bedded and medium trough cross-bedding sets with interbedded, medium-grained sandstone and conglomerate lenses. Contains petrified wood fragments and small, very well-rounded black chert or quartzite pebbles. Unconformable contact with underlying upper red member of Moenkopi Formation. Forms cliff. Thickness about 50 m (160 ft)

**Moenkopi Formation (Middle? and Lower Triassic)**--Includes, in descending order, upper red member, Shnabkaib Member, middle red member, Virgin Limestone Member, lower red member, and Timpoweap Member as used by Stewart and others (1972). The Middle-Lower Triassic boundary probably lies in the upper red member

₸mu **Upper red member**--Heterogeneous sequence of red sandstone, siltstone, mudstone, conglomerate, and minor gray gypsum. Includes marker bed of dark-red, cliff-forming, thin-bedded sandstone in upper part. Most outcrops are in northwest corner of quadrangle and along base of the Hurricane Cliffs. Gradational contact with Shnabkaib Member placed at top of white dolomitic siltstone of Shnabkaib. Forms ledge and slope, about 55 m (180 ft) thick

₸ms **Shnabkaib Member**--Interbedded, white, laminated, aphanitic dolomite and silty gypsum; includes thin, red beds of mudstone, siltstone and sandstone in lower part. Gradational contact with middle red member placed arbitrarily at lowest thick, white siltstone unit. Forms steep slope with ledges. Thickness as much as 146 m (480 ft)

Ⓣmm **Middle red member**--Interbedded, red-brown, laminated siltstone and sandstone, white and gray gypsum, minor white platy dolomite, green siltstone, and gray-green gypsiferous mudstone. Gradational and lithologic contact with Virgin Limestone Member arbitrarily placed at top of highest light-gray limestone bed of Virgin Limestone. Poorly exposed in slopes at base of Hurricane Cliffs. Forms slope. Thickness about 45 to 60 m (150 to 200 ft)

Ⓣmv **Virgin Limestone Member**--Consists of three, light gray, ledge forming, limestone beds 0.5 to 3 m (2 to 10 ft) thick, separated by white, pale-yellow, and gray, slope-forming, thin-bedded, gypsiferous siltstone and sandstone. Includes thin beds of brown, red, and green siltstone, gray limestone, and brown platy calcarenite in slope-forming units. Erosional contact with lower red member at bottom of lowest bed of gray limestone of Virgin Limestone. Thickness about 40 m (130 ft)

Ⓣml **Lower red member**--Interbedded red, thin-bedded, sandy siltstone, gray, white, and pale-yellow laminated gypsum, and minor sandstone. Lower beds contain reworked gypsum and siltstone of Harrisburg Member of Kaibab Formation. Gradational contact with Timpoweap Member arbitrarily placed at top of highest conglomerate bed of Timpoweap. Where not overlying Timpoweap, has erosional, unconformable contact with Harrisburg Member of the Kaibab Formation. Forms slope. Averages about 9 m (30 ft) thick, locally thickens to as much as 48 m (160 ft) in Triassic paleovalleys eroded into underlying Kaibab Formation

Ⓣmt **Timpoweap Member**--Gray conglomerate, consists of subangular to rounded pebbles and cobbles of gray and dark gray limestone, white and brown chert, and rare rounded quartzite. Chert and gray limestone derived from Kaibab Formation. Dark gray limestone and quartzite may originate from older Paleozoic rocks from source west of quadrangle. Mostly clast supported but includes matrix of coarse-grained quartz sandstone, gravel, and minor siltstone. Includes thin unit of light-gray, thick-bedded, non-fossiliferous limestone bed above conglomerate at some locations (Nielson, 1986). Unconformable contact with underlying Harrisburg Member of Kaibab Formation. Fills Triassic paleovalleys eroded into Kaibab Formation estimated as much as 37 m (120 ft) in depth, and about 92 m (300 ft) wide representing significant hiatus between Permian Kaibab and Triassic Moenkopi Formations (A, fig. 2). Rocks of undivided Timpoweap Member and lower red member occupy tributary paleovalleys in this quadrangle (B, C,and D, fig. 2). Smaller tributary paleovalleys are scattered throughout map area; to small to show in figure 2. Imbrication of pebbles in paleovalleys show an east paleoflow of depositing streams. Forms ledge. Thickness as much as 37 m (120 ft)

ℜ mlt **Lower red member and Timpoweap Member undivided**--Same lithologies as ℜ ml and ℜ mt above. Clasts up to 6 cm (2.5 in) in diameter. Consists of lenses of conglomerate, typical of Timpoweap lithology, intertonguing with siltstone and gypsum lithology typical of lower red member. Occupies paleovalleys cut into underlying Harrisburg Member of the Kaibab Formation. Forms slope with ledges. Thickness about 5 to 15 m (16 to 50 ft)

**Kaibab Formation (Lower Permian)**--Includes, in descending order, Harrisburg and Fossil Mountain Members as defined by Sorauf and Billingsley (1991)

Pkh **Harrisburg Member**--Upper part consists of slope forming, red and gray, interbedded gypsifereous siltstone, sandstone, gypsum, and thin-bedded, gray limestone; mostly eroded away except northeast quarter of map area. A resistant, pale-yellow or light-gray, fossiliferous, sandy limestone bed, averaging about 1 m (3 ft) thick forms a caprock ledge at top of upper part. Middle part is cliff forming marker bed consisting of basal light-gray, thin-bedded, sandy limestone, and upper gray, thin-bedded, cherty limestone; chert weathers dark brown or black and often forms the surface bedrock of map area. Lower part consists of slope-forming, light-gray, fine- to medium-grained, gypsiferous siltstone, sandstone, thin-bedded gray limestone, and gray gypsum. Solution of interbedded gypsum has locally distorted limestone beds of middle part causing them to slump or bend into local drainages. Gradational contact between siltstone slope of Harrisburg Member and limestone cliff of Fossil Mountain Member. Forms slope with middle limestone cliff. Thickness as much as 92 m (300 ft)

Pkf **Fossil Mountain Member**--Light-gray, fine- to medium-grained, thin-bedded, fossiliferous, sandy, cherty limestone. Chert weathers black. Unconformable upper contact with Toroweap Formation marked by solution and channel erosion with relief as much as 5 m (15 ft). Map contact generalized because of extensive talus cover. Forms cliff. Thickness about 76 m (250 ft)

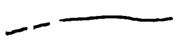
**Toroweap Formation (Lower Permian)**--Includes, in descending order, Woods Ranch, Brady Canyon, and Seligman Members as defined by Sorauf and Billingsley (1991)

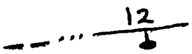
Ptw **Woods Ranch Member**--Gray, gypsiferous siltstone and pale-red silty sandstone with interbedded medium-bedded white gypsum. Commonly covered by talus. Beds are locally distorted due to solution of gypsum. Gradational contact between slope-forming siltstone of Woods Ranch Member and cliff-forming limestone of underlying Brady Canyon Member. Thickness about 18 to 55 m (60 to 180 ft)

Ptb **Brady Canyon Member**--Gray, medium-bedded, medium- to coarse-grained, fetid, fossiliferous limestone; weathers dark gray. Includes thin-bedded dolomite in upper and lower part. Gradational contact between limestone cliff of Brady Canyon Member and siltstone and gypsum slope of underlying Seligman Member. Forms cliff. Thickness about 85 m (280 ft)

Pts **Seligman Member**--Consists of an upper gray unit of interbedded, thin-bedded, dolomite and gypsiferous sandstone, a middle unit of gray to red, thin-bedded, interbedded, siltstone, sandstone, and gray gypsum, and a basal brown and yellow, fine-grained, thin-bedded, low-angle cross-bedded and flat-bedded sandstone. Unconformable, sharp, planar contact with overlying light red sandstone of the Hermit Shale. Forms slope with ledges in upper and lower parts. Thickness about 43 m (140 ft)

Ph **Hermit Shale (Lower Permian)**--Red, pale-red and white, fine-grained, thin- to medium-bedded sandstone and siltstone. Red sandstone beds form ledges in upper part with red siltstone slopes. Lower part not exposed. Thickness about 73 m (240 ft)

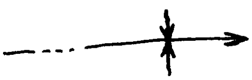

**Contact**--Dashed where approximately located

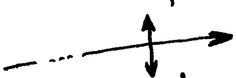


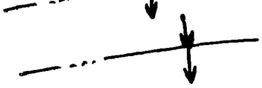
**Fault**--Dashed where approximately located, short dashed where inferred, dotted where concealed; bar and ball on downthrown side. Number is estimated displacement in meters


**Landslide detachment**--Headward scarp of landslide

**Folds**--Showing trace of axial plane and direction of plunge; dashed where approximately located; dotted where concealed

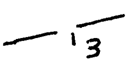

**Syncline**


**Anticline**


**Monocline**

**Strike and dip of strata**

**Inclined**



**Approximate**--Estimated photogeologically


**Implied**--Determined photogeologically, no estimate of amount of dip determined


**Strike and dip of near-vertical joints**--Determined photogeologically

**Collapse structure**--Circular collapses, strata dipping inward toward central point. May reflect deep-seated breccia pipe collapse originating in Redwall Limestone

**Sinkholes**--Steep walled or enclosed depression or cave

## REFERENCES CITED


Best, M.G., McKee, E.H., and Damon, P.E., 1980, Space-time composition patterns of late Cenozoic mafic volcanism, southwestern Utah and adjoining areas: American Journal of Science, v. 280, p. 1035-1050.

Billingsley, G.H., 1990, Geologic map of the Lizard Point quadrangle, northern Mohave County, Arizona: U.S. Geological Survey Open-File Report 90-643, scale 1:24,000.

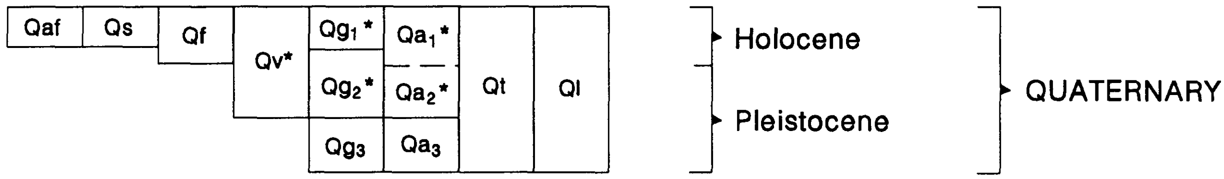
-----, in press, Geologic map of Wolf Hole Mountain and vicinity, Mohave County, northwestern Arizona: U.S. Geological Survey Miscellaneous Investigation Map I-2296, scale 1:31,680.

Huntoon, P. W., 1989, Phanerozoic tectonism, Grand Canyon, Arizona, in Elston, D.P., Billingsley, G.H., and Young, R.A., eds., Geology of Grand Canyon, northern Arizona (with Colorado River guides): 28th International Geological Congress Field Trip Guidebook T115/315, American Geophysical Union, Washington D.C., p. 76-89.
Nielson, R.L., 1986, The Toroweap and Kaibab Formations, southwestern Utah: in Grifen, D.T., and Phillips, W.R., eds., Thrusting and extensional structures and mineralization in the Beaver Dam Mountains, southwestern Utah, Utah geological Association, Utah Geological Association publication 15, Salt Lake City, Utah, p. 37-54.
Reynolds S.J., 1988, Geologic map of Arizona: Arizona Geological Survey, Tucson, Arizona, Map 26, scale 1:1,000,000.
S.A.R. System, 1988, Grand Canyon, Arizona, Synthetic Aperture Radar Imagery X-band, near-range, east-look: Produced for the U.S. Geological Survey by Aero Service Division, Western Atlas International, Inc., Radar Image Mosaic, scale 1:250,000.
Sorauf J.E., and Billingsley, G.H., 1991, Members of the Toroweap and Kaibab Formations, Lower Permian, northern Arizona and southwestern Utah: Rocky Mountain Geologists, v. 28, no. 1, p. 9-24.
Stewart, J.H., Poole, F.G., and Wilson, R.F., 1972, Stratigraphy of the Triassic Moenkopi Formation and related strata in the Colorado Plateau region, with a section on sedimentary petrology: in Cadigan, R.A., U.S. Geological Survey Professional Paper 691, 195 p.
Wenrich, K.J., 1985, Mineralization of breccia pipes in northern Arizona: Economic Geology, v. 80, no. 6, p. 1722-1735.
Wenrich, K.J., Billingsley, G.H., and Huntoon, P.W., 1986, Breccia pipe and geologic map of the northeastern Hualapai Indian Reservation and vicinity, Arizona: U.S. Geological Survey Open-File Report 86-458-A, scale 1:48,000, includes pamphlet, 26 p.
Wenrich, K.J., and Sutphin, H.B., 1989, Lithotectonic setting necessary for formation of a uranium-rich, solution-collapse breccia-pipe province, Grand Canyon region, Arizona: U.S. Geological Survey Open-File Report 89-0173, 33 p.
Wilson, E.D., Moore, R.T., and Cooper, J.R., 1969, Geological map of the State of Arizona: Arizona Bureau of Mines, University of Arizona, scale 1:500,000.

# CORRELATION OF MAP UNITS

## SURFICIAL AND VOLCANIC DEPOSITS

* See description of map units for exact unit age assignment




## SEDIMENTARY ROCKS