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

Geologic map of the Moriah Knoll quadrangle, northern Mohave County, Arizona

by
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INTRODUCTION

The Moriah Knoll 7.5′ quadrangle is located in northern Mohave County, northwestern Arizona. The quadrangle is about 48 km south of the Arizona/Utah State line and about 56 km southwest of Colorado City, Arizona, the nearest settlement (fig. 1). Elevations range from about 1,426 m (4,680 ft) in the northwest corner of the quadrangle to 2,007 m (6,585 ft) at Berry Knoll in the south-central edge of the quadrangle. Access to the area is by improved dirt road locally referred to as the Temple Trail. The Temple Trail branches south from the Navajo Trail. The Navajo Trail extends to Colorado City, Arizona (fig. 1). Several unimproved dirt roads lead from the Temple Trail to various locations within the quadrangle area. Travel on the Temple Trail can be done with 2 wheel drive vehicles, all other roads require a high-clearance vehicle, or 4 wheel drive in wet weather.

The area is managed by the U.S. Bureau of Land Management, including about 4 sections belonging to the state of Arizona. There is less than one section of private land near Langs Run drainage in the south-central part of the quadrangle. The area supports a sparse growth of sagebrush, cactus, cliffrose bush, grass, juniper and pinion pine trees.

PREVIOUS WORK

The quadrangle area is included on two Arizona State geologic maps, one by Wilson and others (1969), and the other by Reynolds (1988). A geologic map is available of the upper Hurricane Wash and vicinity (Billingsley, in press, b), and the Russell Spring 7.5′ quadrangle (Billingsley, 1993b), which borders the west edge of this quadrangle. A Geologic map of the Antelope Knoll 7.5′ quadrangle borders this area on the north (Billingsley, 1994b), and the Hat Knoll 7.5′ quadrangle borders on the east (Billingsley, 1994c). Preliminary geologic maps are also available for the Grand Canyon area about 31 km south of this quadrangle (Huntoon and others, 1981; Billingsley and Huntoon, 1983; Wenrich and others, 1986).

MAPPING METHODS

A preliminary geologic map of this quadrangle was made from 1:24,000 scale aerial photographs. In particular, many of the Quaternary alluvial units having similar lithologies and intertonguing boundaries were mapped using photogeologic methods. Detailed field investigations were then conducted to check photo interpretations and to obtain descriptions of map units.

GEOLOGIC SETTING

The map area lies within the Uinkaret Plateau, a subplateau of the southwestern part of the Colorado Plateau physiographic province. A small part of the Shivwits Plateau is included in the extreme northwest corner of the quadrangle. The physiographic boundary between the high elevation Uinkaret Plateau and the low elevation Shivwits Plateau is along the upper part of the Hurricane Cliffs escarpment, a youthful fault scarp (fig. 2; Hamblin and Best, 1970). The Shivwits and Uinkaret Plateaus are characterized by relatively flat-lying Paleozoic and Mesozoic strata that have an average regional dip of less than 2° east, except along the base of the Hurricane Cliffs where dips reach as much as 24° east (Billingsley, in press, b).

The Hurricane Fault and Monocline is the major structural feature of the quadrangle. The resulting fault scarp, the Hurricane Cliffs, exposes more than 300 m of Permian strata. Vertical displacement of strata along the Hurricane Fault is estimated to be over 510 m. East of the Hurricane Cliffs,

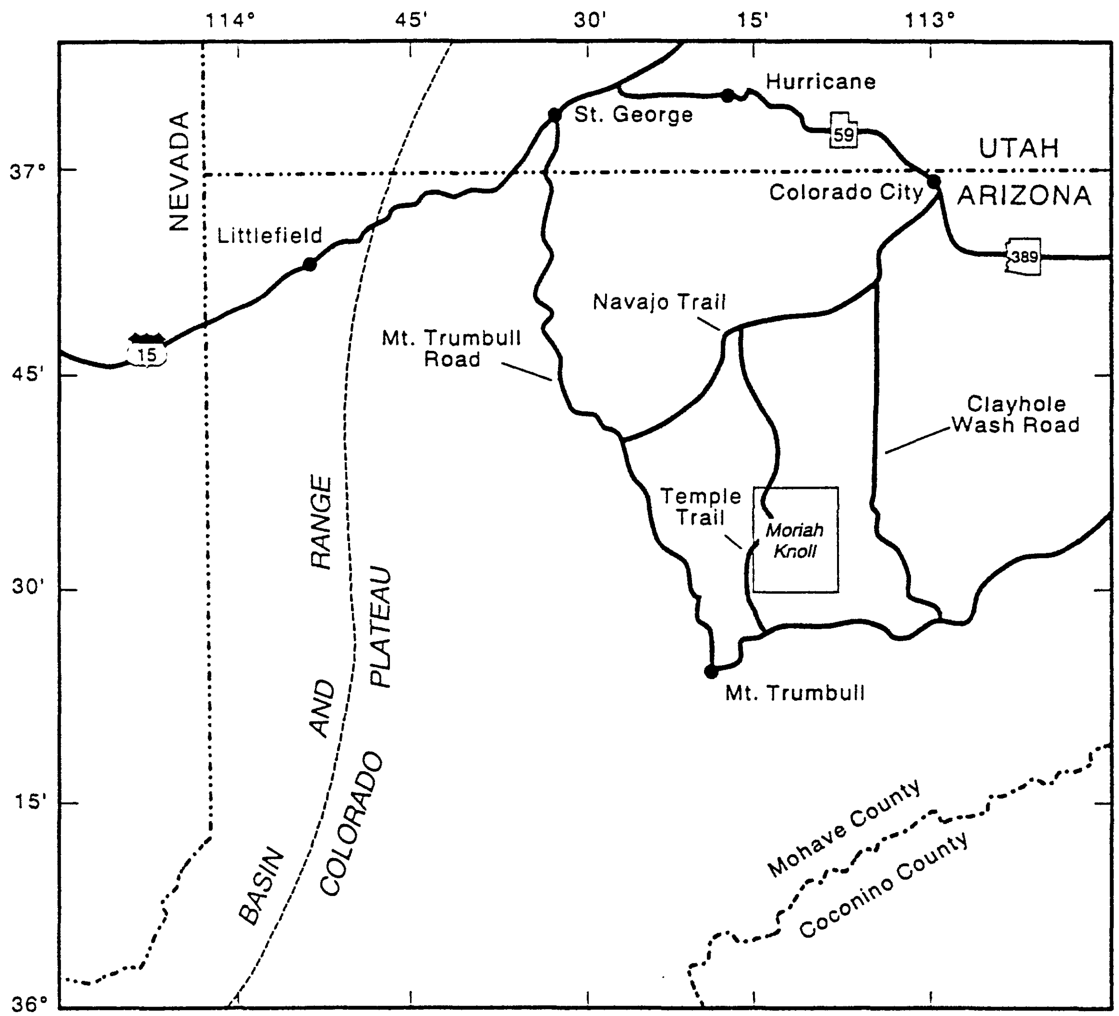

Figure 1. Index map of northern Mohave County, northwestern Arizona, showing the Moriah Knoll 7.5′ quadrangle.

on the Uinkaret Plateau, small outcrops of the lower Moenkopi Formation (Triassic) strata are exposed in isolated areas.

Cenozoic map units consist of igneous, surficial alluvial, and landslide deposits of Quaternary age. The igneous rocks are mapped as vent areas, pyroclastic deposits, and basalt flows. The surficial deposits include artificial-fill and quarries, stream-terraces, alluvial-fans, talus, and landslide debris. These alluvial deposits form geomorphic features and erosional deposits have intertonguing or gradational contacts. The distribution of these Quaternary deposits are an important factor to consider in future environmental, land, and range management planning in this area by federal, state, and private organizations, as to flood-control, roads, erosion control, endangered plant or animal habitats, etc.

STRATIGRAPHY

The Paleozoic and Mesozoic units are, from oldest to youngest, the Hermit, Toroweap, and Kaibab Formations (Lower Permian), and the lower part of the Moenkopi Formation (Lower Triassic). Only about 43 m of the upper Hermit Formation (Ph) is exposed along the base of the Hurricane Cliffs, just east of the Hurricane Fault. The Coconino Sandstone (Lower Permian), found above the Hermit Formation (Shale) in the Grand Canyon pinches out just south of this quadrangle. The Toroweap Formation (Pts, Ptb, Ptw) is well exposed in the lower steep slopes and ledges of the Hurricane Cliffs; it is gray siltstone, sandstone, gypsum, and limestone. The Kaibab Formation (Pkf, Pkh) forms the upper part of the Hurricane Cliffs and much of the bedrock surface of the Uinkaret Plateau where not covered by Quaternary volcanic rocks or alluvial deposits. Bedrock of the Kaibab is composed of gray cherty limestone and gray to white siltstone and gypsum. Most of the Moenkopi Formation crops out in paleovalleys eroded into the Kaibab Formation (fig. 2). The Timpoweap Member and lower red member of the Moenkopi Formation is composed of gray conglomerate and sandstone, light-brown to red siltstone and sandstone, gray gypsum, and minor gray limestone.

Two Triassic paleovalleys are eroded into the Harrisburg Member of the Kaibab Formation; the paleovalleys are filled with conglomerate, limestone, and sandstone strata of the Timpoweap Member of the Moenkopi Formation (fig. 2). The paleovalley northwest of Berry Knoll is called Sullivan valley and is mapped for more than 20 km west of this quadrangle (Billingsley, in press, b). Sullivan valley is covered by igneous rocks of Berry Knoll in the central part of the quadrangle where it joins a large, unnamed paleovalley coming into the quadrangle from the south (A on fig. 2). Sullivan paleovalley turns to a northerly course in the central part of the quadrangle where it is covered by igneous rocks of Moriah Knoll volcano (fig. 2). Imbrication of pebbles in the conglomerate of the Timpoweap have an eastward and northward paleocurrent direction.

The outcrops of igneous rocks consists of basalt flows and pyroclastic deposits that overly strata of the Kaibab and Moenkopi Formations. The basalt flows originate from vent areas which are associated with thick deposits of pyroclastic cinder and scoria deposits which form prominent cinder cones on basalt flows. The igneous rocks are part of the Uinkaret Volcanic Field (Koons, 1945; Hamblin and Best, 1970; Hamblin, 1970).

Moriah Knoll, a cinder cone in the northwest part of the Quadrangle, is composed of cinder and scoria deposits as much as 92 m thick. The cinder cone and associated basalt flow are informally named Moriah Knoll basalt, for

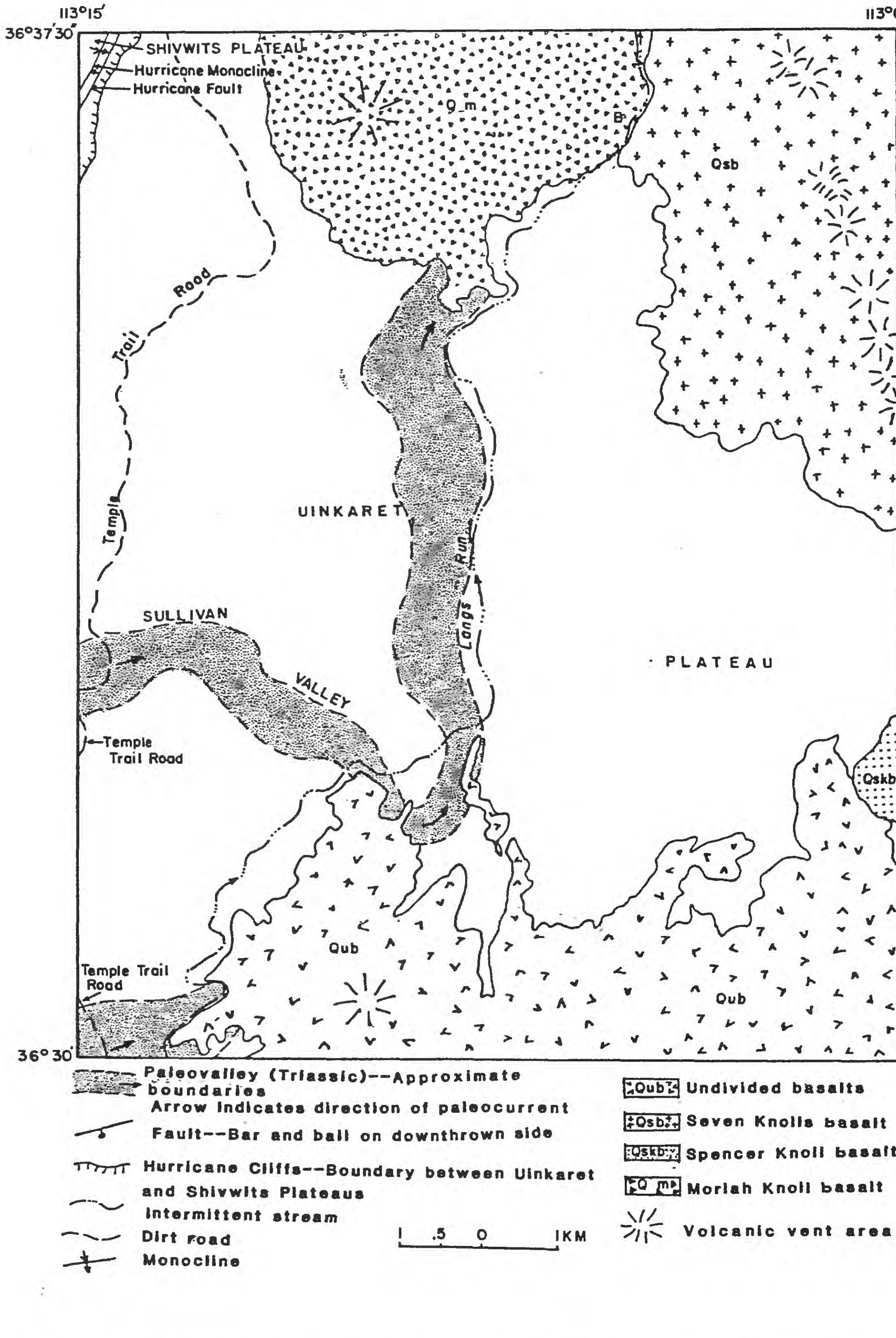

Figure 2. Selected geographic and geologic features of the Moriah Knoll quadrangle, northwestern Arizona.

Moriah Knoll volcano, the type area, northern Mohave County, Arizona (Secs. 12, 13, 7, and 18, T. 37 N., Rs. 8 and 9 W.; fig. 2; Billingsley, 1993b, in press, b). Whole-rock K-Ar age of the Moriah Knoll basalt is 2.3±1.5 Ma from a sample at the base of the Hurricane Cliffs just north of this quadrangle (Antelope Knoll quadrangle) and 1.5±1.5 Ma from a sample on the west side of Moriah Knoll volcano (Harold Mehnert, U.S. Geological Survey, Denver, Colo. written commun., 1993). However, both samples are extensively altered which produced the large error of ±1.5 Ma. Therefore, the 2.3 and 1.5 Ma age is not considered a reliable age for the Moriah Knoll basalt. The Moriah Knoll basalt occupies the same erosional surface as the 0.83±0.28 Ma Antelope Knoll basalt just north of this quadrangle. Thus, the Moriah Knoll basalt is considered a Pleistocene age (Billingsley, 1994b).

The Moriah Knoll basalt flowed in a radial direction from Moriah Knoll, but most of the flow traveled north, east, and southeast over gently, east-dipping bedrock surfaces of the Harrisburg Member of the Kaibab Formation, and the Timpoweap Member of the Moenkopi Formation. The flow, or flows, are mapped as one unit because the boundaries are mappable.

Part of the Moriah Knoll basalt flowed southeast to Langs Run drainage, then east down the drainage for about 3 km temporarily blocking the drainage. Basalt flows from the Seven Knolls volcanoes, east of Langs Run drainage, partly overlapped the Moriah Knoll basalt which further blocked Langs Run. The blockage was temporary, allowing alluvial sediment to accumulate for nearly 4 km upstream formiung a flat valley floor of accuulated fluvial alluvium. The overflow of Langs Run drainage is now eroding into the surface of the Moriah Knoll basalt and parallel's the Seven Knolls basalt flow for about 1 km. Thus, the regional landscape at the time of the Moriah Knoll basalt flow was similar to that of today, and the basalt flow from the Seven Knolls volcanoes is slightly younger then the Moriah Knoll basalt. A part of the Moriah Knoll basalt flow traveled northwest down a small drainage and over the Hurricane Cliffs fault scarp just north of this quadrangle (Antelope Knoll quadrangle). The basalt was later offset by the Hurricane Fault after it cooled (Billingsley, in press b).

Other basalt flows and associated igneous rocks are mapped separately from the Moriah Knoll basalt. The basalt flows and pyroclastic deposits associated with the Seven Knolls volcanoes, informally named Seven Knolls basalt, was sampled for a whole-rock K-Ar age, but the results are not available at this time.

Other vent areas associated with the Seven Knolls basalt are in the Antelope Knoll 7.5' quadrangle, and the Hat Knoll quadrangle (north and east of this quadrangle). The north-northwest alignment matches the north-northwest strike of the near vertical joints in underlying bedrock. The joints provide zones of weakness in the bedrock strata favorable for volcanic intrusions.

The basalt flows of Berry Knoll volcano, southwest part of the quadrangle, appear to share common boundaries with other basalt flows that originate from Craig Knoll, Pugh Knoll, and several unnamed volcanoes south of this quadrangle. These flows are probably Pleistocene as are most of the volcanic rocks in this part of the Uinkaret Volcanic Field. These basalts are mapped as undivided basalts.

The assortment of volcanic deposits at Spencer Knoll, a pyroclastic volcano about 2 km east of this quadrangle, is mapped separately because it has mappable boundaries within this quadrangle and the Hat Knoll quadrangle (west of this quadrangle). Future whole-rock K-Ar ages will help to establish a probable Pleistocene age for most, if not all, of the basalts in and around this quadrangle.

The Quaternary age assigned to the alluvial deposits in this quadrangle is based mainly on field relationships of these deposits to the Pleistocene basalts of this quadrangle and other nearby quadrangles (Billingsley, 1993a, 1994a, in press, a and b). Many of the alluvial deposits contain basaltic clasts that are downslope from Pleistocene basaltic outcrops. Therefore, all alluvial and surficial deposits of this quadrangle are Pleistocene and younger. Details of the stratigraphic sequence of alluvial deposits are given in the description of map units.

STRUCTURAL GEOLOGY

The Hurricane Fault scarp forms the Hurricane Cliffs, a prominent landmark in northwestern Arizona. The Hurricane Fault line is mostly covered by talus and alluvial deposits, but appears to be a normal vertical fault as suggested by Hamblin and Best (1970). Other normal faults in the quadrangle have a northwest strike that parallel the near vertical joint system in bedrock strata.

Locally, warped and bent strata are too small to show at map scale and are the result of solution of gypsum in the Harrisburg Member of the Kaibab Formation. These folded strata are commonly associated with solution of gypsum along drainages.

A few circular collapse structures, usually about 100 m in diameter, are found in the Permian and Triassic strata; these structures are mostly due to solution of gypsum and gypsifereous siltstone in the Harrisburg Member of the Kaibab Formation. However, some circular, bowl-shaped areas that have inward-dipping strata may be collapse-formed breccia pipes that originate in the deeply buried Mississippian Redwall Limestone (Wenrich and Huntoon, 1989; Wenrich and Sutphin, 1989). Such features on this quadrangle are marked by a dot and the letter C to denote possible deep-seated breccia pipes. However, they cannot be distinguished with certainty from shallow collapse structures caused by dissolution of gypsum in the Kaibab or Toroweap Formations. Moreover, some deep-seated breccia pipes are known to be overlain by gypsum collapse features (Wenrich and others, 1986). The deep-seated breccia pipes potentially contain economic deposits of copper and uranium minerals (Wenrich, 1985).

Shallow sinkhole and karst caves are associated with the solution of gypsum in the Harrisburg Member of the Kaibab Formation. The sinkholes developing in the Kaibab are responsible for several sinkholes in the basalt flows. The sinkholes are relatively young features of Holocene and probable Pleistocene age because of their young appearance in the Kaibab Formation and basalt flows. Only sinkholes that form an enclosed basin or depression are shown by a triangular symbol. Several minor drainages originate at sinkhole depressions in the quadrangle area.

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

Qaf **Artificial fill and quarries (Holocene)**--Alluvial and bedrock material removed from pits and trenches to build stock tanks and drainage diversion dams. Includes quarries

Qs **Stream-channel alluvium (Holocene)**--Unconsolidated and poorly sorted, interlensing silt, sand, and pebble to boulder gravel. Active wash or large arroyo. Intertongues, inset to, or locally overlies valley-fill (Qv), alluvial-fan (Qa_1), and terrace-gravel (Qg_1) deposits. Stream channel subject to high-energy flows and flash floods; supports little or no vegetation. Contacts approximate. Estimated thickness 1 to 3 m

Qf **Flood-plain deposit (Holocene)**--Flat valley or ponded areas containing unconsolidated white to light-gray or tan silt, sand, and lenses of pebble to cobble gravel. Includes gypsum and calcite cement. Locally contains reworked black and reddish, fine-grained cinder fragments and lesser amounts of angular scoria and basalt fragments; locally consolidated. Intertongues or inset against, or locally overlies valley-fill (Qv), alluvial-fan (Qa_1), and terrace-gravel (Qg_1) deposits. Forms flat valley floor as opposed to concave valley floor for valley-fill (Qv) deposits. Subject to frequent flooding and ponding. Sparsely vegetated by grass or no vegetation. Thickness about 2 to 6 m

Qg_1 **Young terrace-gravel deposit (Holocene)**--Unconsolidated, light-brown to pale-red siltstone, sandstone, and lenses of gravel containing pebbles and boulders of well-rounded limestone and sandstone and angular and subrounded chert derived mainly from the Kaibab Formation. Locally includes reworked cinder, scoria, and subangular to angular basalt clasts. Includes reworked materials from alluvial-fans (Qa_1), older terrace-gravel (Qg_2), and talus (Qt) deposits. Locally cut by arroyos as much as 3 m deep. Forms alluvial benches about 1 to 3 m above local stream beds. Averages about 1 to 4 m thick

Qa_1 **Young alluvial fan deposit (Holocene)**--Unconsolidated gray silt and sand. Contains lenses of coarse gravel composed of subangular to rounded pebbles and cobbles of limestone, chert, and sandstone locally derived from the Hermit, Toroweap, and Kaibab Formations below the Hurricane Cliffs; and mostly from the Kaibab and Moenkopi Formations on Uinkaret Plateau. Locally, includes pyroclastic basaltic material on or near volcanic outcrops. Partly cemented by gypsum and calcite. Overlaps, intertongues, or partly includes reworked materials from stream-channel (Qs), valley-fill (Qv), terrace-gravel (Qg_1 and Qg_2) deposits. Alluvial-fans subject to erosion by sheet wash and flash floods. Supports sparse growths of sagebrush, cactus, and grass. Greater than 4 m thick

Qv **Valley-fill deposit (Holocene and Pleistocene)**--Partly consolidated gray and light-brown silt, sand, and lenses of pebble to small-boulder gravel. Intertongues or overlaps talus (Qt), terrace-gravel (Qg_1 and Qg_2) deposits, and alluvial-fan (Qa_1) deposits. Subject to sheetwash flooding and temporary ponding; cut by arroyos as much as 3 m deep in larger valleys. Supports sparse growths of sagebrush, grass, and cactus. As much as 4 m thick

Qt **Talus deposit (Holocene and Pleistocene)**--Unsorted debris consisting of breccia composed of small (less than 0.5 m in diameter) and large (as much as 2 m in diameter) angular blocks of basalt bedrock of the Kaibab Formation. Includes silt, sand, and gravel eroded from the Kaibab Formation; partly cemented by calcite and gypsum. Intertongues with young alluvial-fan (Qa_1), valley-fill (Qv), and young terrace-gravel (Qg_1) deposits. Supports sparse growths of sagebrush, cactus, and grass. Only relatively extensive deposits shown. As much as 2 m thick

Ql **Landslide deposit (Holocene and Pleistocene)**--Unconsolidated and unsorted masses of rock debris, including detached blocks of bedrock strata that have rotated backward and slid downslope as loose, coherent mass of broken rock and deformed strata, often surrounded by talus. Includes blocks of basalt in Langs Run drainage. Supports sparse growths of sagebrush, cactus, and grass. Unstable when wet. Only large masses are shown. As much as 20 m thick

Qg_2 **Older terrace-gravel deposit (Holocene and Pleistocene)**--Similar to young terrace-gravel deposits (Qg_1). Locally contains rounded basalt clasts as much as 12 cm or more in diameter in Langs Run drainage. Forms benches as abandoned stream channels about 2 to 4 m above local stream beds and about 1 to 2 m above young-terrace gravel (Qg_1) deposits. Intertongues with and locally overlain by valley-fill (Qv) and young alluvial-fan (Qa_1) deposits. Approximately 2 to 4 m thick

Qa_2 **Older alluvial fan deposit (Holocene and Pleistocene)**--Similar to young alluvial-fan (Qa_1) deposits and partly cemented by calcite and gypsum. Locally overlapped by young alluvial-fan (Qa_1) deposit below Hurricane Cliffs. Locally includes abundant subrounded to subangular boulders derived from Permian strata exposed on Hurricane Cliffs. Supports sparse growths of sagebrush, cactus, and grass. Ranges from 4 to 8 m thick

IGNEOUS ROCKS

Seven Knolls basalt (Pleistocene)--Named for Seven Knolls volcanos, type area for Seven Knolls basalt, northern Mohave County, Arizona, Secs. 10, 15, 22, 23 and 26, T. 37 N., R. 8 W., northeastern part of Moriah Knoll quadrangle, and northwest part of Hat Knoll quadrangle. Includes basalt flows and associated pyroclastic deposits. Divided into:

Qsi **Vent area**--Includes 9 vent areas, approximate location on quadrangle, source for red, reddish-brown, and black cinder and scoria deposits forming cinder cones and basalt flows, northeastern part of quadrangle

Qsc **Pyroclastic deposit**--Red, reddish-brown and black fragments of angular basaltic scoria and cinder deposits; partly consolidated. Associated with Seven Knolls vent areas and basalt flows. Forms cinder cones 45 to 122 m thick

Qsb **Basalt flow(s)**--Dark-gray, finely crystalline, aphanitic groundmass. Surface is partly covered by pyroclastic (Qsc) deposits within 1 to 2 km of vent areas (Qsi). Overlies thin alluvium, Harrisburg Member of Kaibab Formation, or Timpoweap Member? lower red member, Virgin Limestone Member, and middle red member of Moenkopi Formation (not exposed in this quadrangle, but exposed in adjacent Hat Knoll quadrangle) northeast corner. Ranges from 2 to 15 m thick

Qskb **Spencer Knoll basalt (Pleistocene)**--Named for Spencer Knoll volcano, type area for Spencer Knoll basalt. Spencer Knoll is in Sec. 11, T. 36 N., R. 8 W., northern Mohave County, Arizona, Hat Knoll 7.5′ quadrangle (about 1.5 km east of this quadrangle). Olivine basalt, dark-gray, finely crystalline, aphanitic groundmass composed of plagioclase, olivine, and augite(?); olivine phenocrysts common. Flow abuts and partly overlaps undivided basalt, southeast corner of quadrangle. Surface is partly covered by cinders and alluvium. Overlies Harrisburg Member of Kaibab Formation. Flow extends about 3 km west of Spencer Knoll. Thickness about 18 m

Undivided basalt flow(s) undivided (Pleistocene(?)--Includes basalt flows and pyroclastic deposits from Craig Knoll, Pugh Knoll, and several unnamed pyroclastic volcanoes south of this quadrangle (Mount Trumbull NW, 7.5′ quadrangle). Locally includes basalt flows and pyroclastic deposits of Berry Knoll. Divided into:

Qui **Intrusive vent area**--Vent area of Berry Knoll. Vent area is approximately located owing to thick cover of reddish-black cinder and scoria (Quc) deposits Includes isolated dike east-central edge of map

Quc **Undivided cinder and pyroclastic deposit**--Reddish-black and brown fragments of angular basaltic cinder and scoria deposits. Includes dark-gray augite(?), olivine, and glass fragments; partly consolidated as welded scoria. Overlies basalt flows. About 170 m thick at Berry Knoll

Qub **Undivided basalt flow(s)**--Olivine basalt, dark to medium gray, fine-grained, glassy. Flows originate from Berry Knoll volcano, merging into basaltic flows from Craig, Pugh, and several unnamed volcanos farther south of quadrangle. Contains small phenocrysts of plagioclase, olivine and augite(?), olivine is most common phenocrysts. Partly overlapped by Spencer Knoll basalt. Thickness ranges from 4 to grater than 45 m

Moriah Knoll basalt (Pleistocene)--Named for Moriah Knoll volcano in Secs. 12 and 13, T. 37 N., Rs. 8 and 9 W., northern Mohave County, Arizona (Billingsley, 1993b; in press, b). Moriah Knoll is type area for Moriah Knoll basalt. Black, aphanitic, vesicular basalt. Includes minor phenocrysts of olivine. Vesicles commonly filled with calcite. K-Ar whole rock age is 2.3±1.5 and 1.5±1.5 Ma (Harold Mehnert, U.S. Geological Survey Isotope Laboratories, Denver, Colo., written commun., 1993, 1994). Thickness about 2 to 7 m

Qmi **Intrusive vent area**--Approximately marked on map near to of Moriah Knoll volcano; includes two vent areas for Moriah Knoll basalt and pyroclastic deposits

Qmc **Cinder and scoria deposit**--Red-brown and reddish-black fragments of angular basaltic scoria, glass, and cinder deposit; unconsolidated. Forms part of Moriah Knoll volcano. As much as 92 m thick

Qmb **Basalt flow**--Black, aphanitic, vesicular basal. Includes minor olivine phenocrysts, vesicles commonly filled with calcite. One flow, about 3 to 30 m thick

SEDIMENTARY ROCKS

Moenkopi Formation (Lower Triassic)--Includes, in descending order, lower red member, and Timpoweap Member as used by Stewart and others (1972). Virgin Limestone Member and middle red member may be covered by basalt in this quadrangle, otherwise they are removed by erosion. Divided into:

ŦRml **Lower red member**--Interbedded red, fine-grained, thin-bedded, gypsiferous sandy siltstone and sandstone. Interbedded or gradational contact with sandstone or calcareous conglomerate of Timpoweap Member, arbitrarily placed at lowermost red siltstone\sandstone bed. Unconformable contact with Kaibab Formation. Forms slope. Mostly removed by erosion but as much as 7 m thick

ŦRmt **Timpoweap Member**--Light gray conglomerate and sandstone in light gray limestone matrix. Conglomerate composed of subangular and rounded pebbles and cobbles of gray and dark gray limestone, white and brown chert, and rounded quartzite in matrix of gray to brown, coarse-grained, calcareous sandstone and limestone; conglomerate and sandstone derived from Kaibab Formation. Forms slope. Deposited in Triassic paleovalley eroded into Kaibab Formation, estimated as much as 50 m deep and as much as 1,500 m wide. Rocks of Timpoweap occupy two major paleovalleys, one is an eastern extension of Sullivan valley (fig. 2; Billingsley, 1994a; in press b) and another is an unnamed paleovalley joining Sullivan valley, southwest corner of quadrangle (junction covered by basalt). Imbrication of pebbles in conglomerate show an east and northward paleocurrent. As much as 50 m thick

ŦRmlt **Lower red member and Timpoweap Member undivided**--Same lithologies as ŦRml and ŦRmt, but interbedded. Consists of reddish conglomerate and brown sandy limestone lenses within red siltstone and gray gypsum. Occupies shallow paleovalley cut as much as 60 m into underlying Harrisburg Member of Kaibab Formation, southeast quarter of quadrangle. Unconformable contact with Kaibab, locally covered by surficial deposits. Forms slope. Approximately 5 to 20 m thick

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

Pkh **Harrisburg Member**--Includes an upper, middle and lower part. Upper part consists mainly of slope-forming, red and gray, interbedded gypsiferous siltstone, sandstone, gypsum, and thin-bedded gray limestone. Includes an upper resistant, pale-yellow or light-gray, fossiliferous (mollusks and algae), sandy limestone bed averaging about 1 m thick that weathers black or brown. Most of upper part is eroded from quadrangle except in northeast quarter.

Forms gradational contact with middle part. Middle part consists mainly of two cliff-forming marker limestone beds. Top marker bed consists of gray, thin-bedded, cherty limestone; weathers dark brown or black and often forms bedrock surface of exposed Harrisburg Member. Bottom marker bed consists of light-gray, thin-bedded, sandy limestone; both beds are a few meters thick. An Erosional unconformable separates middle part from lower part. Lower part consists of slope-forming, light-gray, fine- to medium-grained, gypsiferous siltstone, sandstone, medium-grained, thin-bedded gray limestone, and gray massive bedded gypsum. Dissolution of gypsum in lower part has locally distorted limestone beds of middle part causing them to slump or bend into local drainages. Gradational and arbitrary contact between siltstone slope of Harrisburg Member and limestone cliff of Fossil Mountain Member. Harrisburg generally forms slope with middle limestone cliff. As much as 92 m thick

Pkf **Fossil Mountain Member**--Light-gray, fine- to medium-grained, thin-bedded, fossiliferous, sandy, cherty limestone. Chert weathers black. Contact with Woods Ranch Member of Toroweap Formation marked by solution and channel erosion with relief as much as 3 m; contact locally obscured by talus and minor landslides. Forms cliff. About 80 m thick

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

Ptw **Woods Ranch Member**--Gray gypsiferous siltstone and pale-red silty sandstone interbedded with medium-bedded white laminated gypsum. Beds are locally distorted due to gypsum solution. Gradational and arbitrary contact between slope-forming Woods Ranch Member and cliff-forming Brady Canyon Member of Toroweap. Variable thickness from 55 to 80 m due to solution of gypsum

Ptb **Brady Canyon Member**--Gray, fetid, medium-bedded, fine- to coarse-grained, fossiliferous limestone; weathers dark dray. Includes thin-bedded dolomite in upper and lower part. Limestone beds average about 0.5 m thick. Includes chert lenses and nodules but 50% less than in Fossil Mountain Member of Kaibab. Gradational and arbitrary contact between cliff-forming limestone of Brady Canyon Member and slope-forming siltstone and gypsum of Seligman Member of Toroweap. Forms cliff. Approximately 70 m thick

Pts **Seligman Member**--Consists of an upper gray, interbedded, thin-bedded dolomite and gypsiferous sandstone; a middle gray to red, thin-bedded, interbedded siltstone, sandstone, and gray gypsum; and a lower brown, purple, and yellow, fine- to medium-grained, thin-bedded, low- to high-angle cross-bedded and planar-bedded sandstone, mostly covered. Contact with underlying Hermit Formation is unconformable with as much as 1 m of erosional relief. Contact often covered by talus and alluvial deposits. Forms slope with ledges. About 51 m thick

Ph **Hermit Formation (Lower Permian)**--Light-red, yellowish-white, fine-grained, thin- to medium-bedded sandstone and siltstone. Includes yellowish-white, ledge-forming sandstone beds as much as 2.5 m thick, separated by beds of red, slope-forming siltstone and silty sandstone as much as 1 m thick in upper part. Upper reddish sandstone beds commonly contain yellowish bleached spots, locally all beds are partly or completely bleached yellowish-white, gradually thickens northward towards Utah becoming a white sandstone, thins southward to red sandstone beds in Grand Canyon. Most of Hermit is covered alluvial deposits. Middle and lower part not exposed. About 43 m of upper part exposed

Contact--Dashed where approximately located

12+ **Fault**--Dashed where inferred or approximately located; dotted where concealed; bar and ball on downthrown side. Number is estimated displacement in meters. Number with plus denotes minimum estimated displacement

Landslide detachment--Headward scarp of landslide, hachures point in direction of slide

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

Syncline

Strike and dip of beds--Showing dip where known

8 **Inclined**

2 **Approximate**--Estimated from aerial photographs

Implied--Interpreted from aerial photographs, dip amount not determined

Strike of vertical and near-vertical joints--Interpreted from aerial photographs

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

▲ **Sinkhole**--Steep-walled or enclosed depression or cave

Flow direction of basalt

REFERENCES CITED

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CORRELATION OF MAP UNITS

SURFICIAL DEPOSITS AND IGNEOUS ROCKS