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

by
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INTRODUCTION

The Hat Knoll 7.5′ quadrangle is in northern Mohave County, about 43 km south of Colorado City, Arizona (fig. 1). Elevations range from about 1,539 m (5,050 ft) in Little Clayhole Valley (north-central edge of quadrangle) to 1,872 m (6,140 ft) at Pugh Knoll (southwest edge of quadrangle). Access to the quadrangle is by improved dirt road, locally referred to as the Clayhole Wash Road from Colorado City, Arizona (fig. 1). Several unimproved dirt roads lead from Clayhole Wash Road to various locations within the quadrangle area. Travel on the Clayhole Wash Road is accessible to two wheel drive vehicles; all other roads require high clearance vehicles and 4 wheel drive in muddy conditions.

The area is managed entirely by the U.S. Bureau of Land Management including about three sections that belong to the state of Arizona. At the lower elevations, the area supports sparse growths of sagebrush, cactus, and grasses. At higher elevations, moderate growths of sagebrush thrive in alluvial valleys, and pinyon pine and juniper trees are scattered in the southern quarter of the quadrangle.

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). Geologic maps of the Grand Canyon area about 30 km south of this quadrangle are available (Billingsley and Huntoon, 1983; Wenrich and others, 1986). Other geologic maps west and northwest of this quadrangle are available (Billingsley, in press, a and b).

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 and igneous units having similar lithologies and merging boundaries were mapped using photogeologic methods. Detailed field investigations were then conducted to check photo interpretations and to obtain descriptions for all map units.

GEOLOGIC SETTING

The map area lies within the Uinkaret Plateau, a subplateau of the southwestern part of the Colorado Plateaus physiographic province. The Uinkaret Plateau, in this quadrangle, is characterized by relatively flat lying bedrock strata having an average regional dip of about 2° northeast. About 90 m of Triassic strata are partly exposed in the quadrangle. They are mostly covered by igneous rocks and talus deposits in the Seven Knolls Bench and Hat Knoll areas. The upper part of the Permian strata of the Kaibab Formation is exposed mainly in the southwest quarter of the quadrangle.

Cenozoic map units consist of igneous rocks, surficial alluvium, and minor 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, alluvial fans, stream terraces, talus, and landslide debris. Many of the alluvial deposits form geomorphic features and have intertonguing or gradational contacts. The distribution of the Quaternary deposits is an important factor in planning for future environmental, land, and range management by federal, state, and private organizations. The surficial map units are useful for studies of local geomorphology.

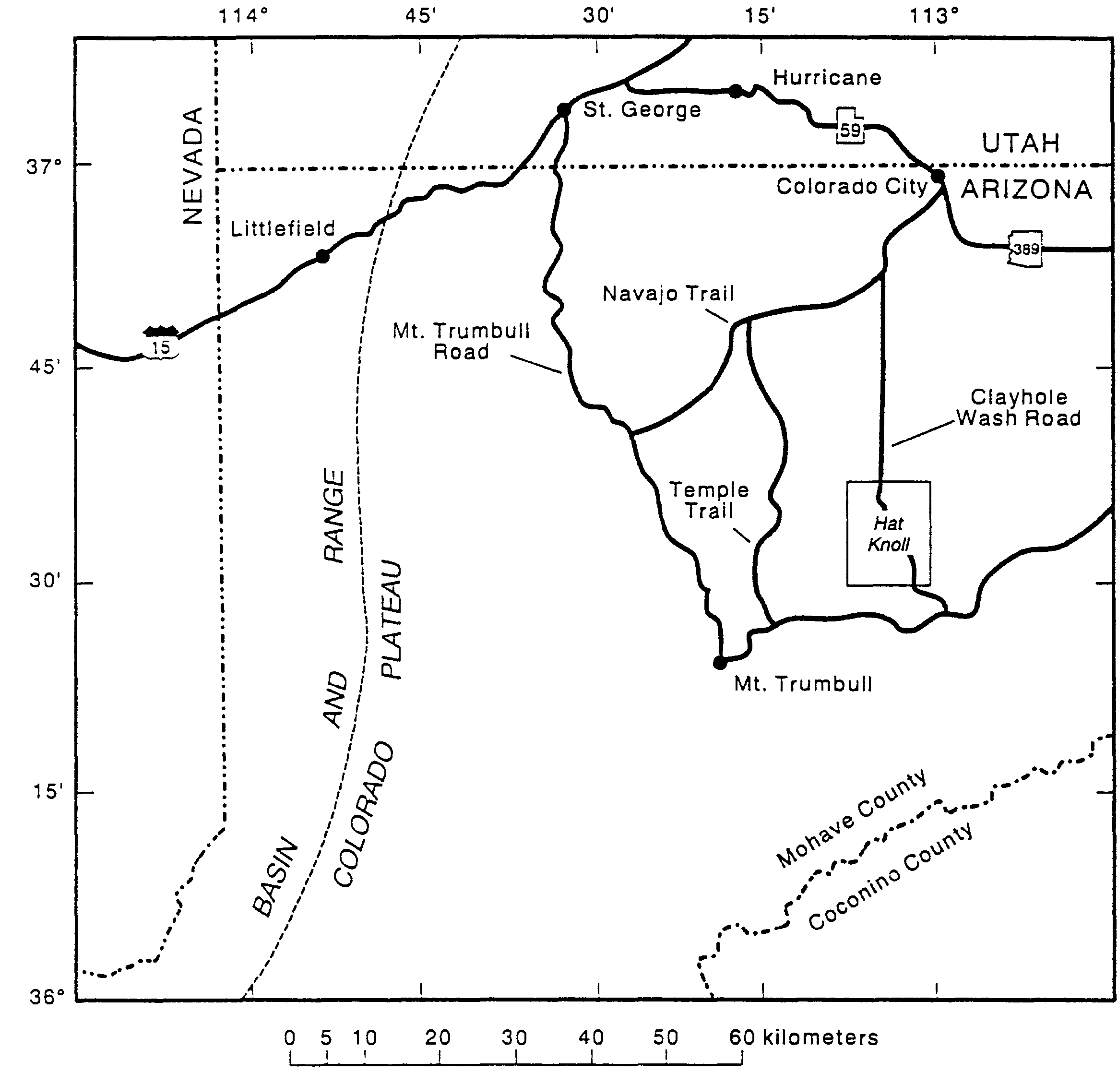

Figure 1. Index map of northern Mohave County, northwestern Arizona, showing the Hat Knoll 7.5' quadrangle.

STRATIGRAPHY

The Paleozoic and Mesozoic stratigraphic units within the quadrangle area include, in order of decreasing age, the Kaibab Formation (Lower Permian) and the Moenkopi Formation (Middle? and Lower Triassic). Gray cherty limestone and gray to white siltstone and gypsum of the Harrisburg Member of the Kaibab Formation crop out at various locations throughout the quadrangle. The lower part of the Moenkopi Formation also crops out at various locations throughout the northeast half of the quadrangle area as red siltstone and sandstone and gray gypsum and dolomite.

Basalt flows and pyroclastic deposits overly strata of the Kaibab and Moenkopi Formations. The basalt flows originate from vent areas associated with thick deposits of pyroclastic cinder and scoria that form prominent cinder cones on basalt flows. The igneous rocks are part of the Uinkaret Volcanic Field (Hamblin and Best, 1970; Hamblin, 1970). Whole-rock K-Ar ages have been obtained from three basalt flows north of this quadrangle, and several more ages are pending. The age of basaltic rocks at Black Knolls is 0.58±0.30 Ka (Billingsley, 1994a); the Antelope Knoll basalt is 0.83±0.28 Ka (Billingsley, 1994b); and the Moriah Knoll basalt is 2.3±1.5 Ma (Billingsley, in press, b).

The youngest basalt flow in this quadrangle, currently undergoing K-AR analysis, is assumed to be a Pleistocene age based on similar basalts north of this quadrangle (Billingsley, 1994a, b). This young basalt is informally named Cave basalt after the feature labeled "cave" in the type area, northern Mohave County, Arizona (T. 37 N., R. 7 W., NE quarter of Sec. 33), central part of the quadrangle. The cave is a sinkhole that formed in gypsum beds of the Harrisburg Member of the Kaibab Formation, thus allowing the basalt to collapse. Numerous sinkholes have formed in the Cave basalt since the basalt flowed.

The Cave basalt originates from 5 vent areas that form 5 unnamed cinder volcanoes aligned in a N 10° W strike in the southeast quarter of the quadrangle. The pyroclastic deposits, associated with the vent areas, accumulated on the Cave basalt after the basalt ceased to flow. The Cave basalt flowed north about 15 km down and around the elevated basalt-capped mesa of Hat Knoll. The flow continued north of Hat Knoll and across a small fault where the flow was constricted to less than 300 m wide. Offset of Moenkopi strata along the fault is about 43 m down to the northwest. Presumably, the drainage along which the Cave basalt flowed had eroded headward into the upthrown side of the fault (southeast side) forming a narrow channel. As a result, the Cave basalt is narrower on the upthrown side of the fault, but is itself not faulted. Once across the fault, the flow spreads out into the Little Clayhole Valley and continues north of this quadrangle for 3 km down a gentle gradient of the upper reaches of Little Clayhole Wash. The Cave basalt descends about 213 m in a 15 km distance, a gradient of about 7 m/km.

The Cave basalt merges or shares a common boundary with two other basalt flows; one lies in the southeast corner of the quadrangle and the other is from the Pugh Knoll area (southwest part of quadrangle). The Cave basalt appears to overly part of the basalt flow from Pugh Knoll, but merges with or abuts the undivided basalt in the southeast corner of the quadrangle. The undivided basalts are mapped separately because the extent of these flows is unmapped south of this quadrangle. The undivided basalts are of similar composition, overly similar strata of the Harrisburg Member of the Kaibab Formation, and share a common boundary with the Cave basalt. Therefore, the undivided basalts are probably of similar Pleistocene age. Olivine is a common constituent in both the undivided basalts and the Cave basalt.

The Seven Knolls basalt (Billingsley, 1994b) forms the Seven Knolls Bench, northwest corner of this quadrangle. Three of the Seven Knolls vent areas in this quadrangle represent the southeastern continuation of several volcanoes northwest of this quadrangle, and contribute basaltic flows to the Seven Knolls basalt. The northwest alignment of the Seven Knolls volcanoes matches the northwest strike of near vertical joints in the underlying bedrock strata. The joints provide zones of weakness in which the volcanic eruptions occurred.

The Seven Knolls basalt flowed east and northeast onto relatively flat bedrock strata of the Harrisburg Member of the Kaibab Formation and the lower red member, Virgin Limestone Member, and middle red member of the Moenkopi Formation. Most of the basalt overlies the Harrisburg, but a fold in strata with dips as much as 8° northeast beneath the Seven Knolls Bench has allowed the basalt to overlie various members of the Moenkopi.

Hat Knoll, a cinder volcano and associated basalt flow, forms an isolated mesa similar in elevation to the Seven Knolls Bench. The igneous rocks of Hat Knoll are mapped separately from the Seven Knolls basalt because, 1) flow directions indicate a single source at Hat Knoll, 2) boundaries of the two flows are clearly mappable, and 3) Hat Knoll is not aligned with the Seven Knolls volcanoes. The cinder cone and associated pyroclastic basalt flows is informally named Hat Knoll basalt for Hat Knoll volcano, the type area, northern Mohave County, Arizona (T. 37 N., R. 7 W., Sec. 20).

The igneous rocks of Hat Knoll have formed a protective caprock overlying softer strata of the Harrisburg Member of the Kaibab Formation and the lower red member and Virgin Limestone Member of the Moenkopi Formation. Only a small part of the basalt overlies the Harrisburg at its southwestern edge, while most of the basalt overlies the Virgin Limestone. Most of the basalt flowed east about 2 km onto relatively flat bedrock of the Virgin Limestone. A small lobe of basalt flowed west for a few hundred meters, and another lobe flowed north about 0.5 km.

The Hat Knoll and Seven Knolls basalt flows are currently 0.4 km apart and at the same elevation. Yet there is no current evidence to indicate that they abutted to form a common boundary. The erosion of Black Canyon has formed a valley about 90 m deep between the basalts. Thus, Black Canyon has eroded between the basalt flows indicating that there was probably no basaltic caprock to protect the softer sedimentary rocks from erosion. The Hat Knoll and Seven Knolls basalts are stratigraphically above the Cave basalt which flows around Hat Knoll.

Basalts originating from the Pugh Knoll volcano, southwest corner of the quadrangle, flowed several kilometers north and northeast. This basalt, which contains green phenocrysts of olivine, is classified as undivided basalt along with a basalt flow in the extreme southeast corner of the quadrangle. The two undivided basalts originate from volcanoes within this quadrangle and from a combination of several other volcanoes south of this quadrangle. Since the regional extent of these basalt flows is not known and most of the source vent areas are not identified, the basalts are undivided in this quadrangle. Jackson (1990a, b) obtained a K-Ar date of 0.64 Ka from the undivided basalt near the Toroweap Fault, southeast corner of the quadrangle. A similar age is assumed for the Cave basalt as it abuts or may be part of the undivided basalt complex.

The predominantly Quaternary age assigned to the alluvial deposits in this map area is based mainly on field relationships of these deposits to the Pleistocene and Pliocene basalt flows west and north of this quadrangle (Billingsley, 1994a, b, in press a, b). The alluvium contains fragments of various Pleistocene basalts in this quadrangle. The oldest unit of alluvium, alluvial fan (Qa_2) deposit, is partly overlain by the Cave basalt, north edge of the quadrangle, but contains cobbles and pebbles of basalt presumably from the Seven Knolls and Hat Knoll basalts. Details of the stratigraphic sequence of alluvial deposits are provided in the description of map units.

STRUCTURAL GEOLOGY

Three small normal faults, one large normal fault, and minor folds are the main structural features of this quadrangle. A segment of the larger Toroweap Fault cuts across the southeast corner of the quadrangle and displaces strata down to the northwest about 43 m. The three smaller normal faults also displace strata down to the northwest. All faults, including the Toroweap, have a northeast strike of about 10° east. One of the smaller faults, northeast quarter of the quadrangle, is covered by the Hat Knoll and Cave basalt flows, but the basalts are not offset. The strike of another small normal fault in the south-central part of the quadrangle does offset undivided basalts that aligns up with a large collapse depression in the basalt. Solution of gypsum in the Harrisburg Member of the Kaibab along the fault is the likely cause of the collapse. The faults are assumed to be late Pliocene and Pleistocene age, similar to those mapped northwest and west of this quadrangle (Billingsley, in press a, b). The Hat Knoll and Cave basalts are younger than the faults. A minor fault, central part of the quadrangle, has offset the undivided basalt. The Toroweap Fault has offset the undivided basalt 36 m in the southeast part of the quadrangle. The age of this undivided basalt is about 0.64 Ka, yielding an average displacement rate of about 56 m/m.y. since the middle Pleistocene (Jackson, 1990a, b). Displacement along the Toroweap Fault in this region has offset the underlying Permian and Triassic strata a few hundred meters more than the basalt. Thus, the Toroweap Fault has been active prior to and since 0.64 Ka. Near the Colorado River in Grand Canyon, 29 km south of this quadrangle, the Toroweap Fault displaces Paleozoic and Mesozoic strata about 175 m, and local Pleistocene basalt flows as much as 5 m (Billingsley and Huntoon, 1983).

The bedrock strata have a regional northeast to slightly east dip averaging about 2 to 3° in the southwest half of the quadrangle, and less then 1° in the northeast half. The small folds present in the northeast part of the quadrangle are probably related to early Laramide compression (Huntoon, 1989). Warped and bent strata of the Harrisburg Member of the Kaibab Formation are too small to show at map scale and are the result of gypsum dissolution. These folded strata are commonly associated with solution of gypsum along drainages.

Shallow sinkholes and caves are associated with the solution of gypsum in the Harrisburg Member of the Kaibab Formation. The sinkholes are relatively young features of Holocene and probable Pleistocene age. Sinkholes that form an enclosed basin or depression are shown on the map by a triangle symbol. Several sinkholes have developed in the Harrisburg since the Cave basalt was extruded, and basaltic rocks have collapsed into the sinkholes indicating that many sinkholes are young and still active.

DESCRIPTION OF MAP UNITS

Surficial and igneous deposits

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

Qs **Stream-channel alluvium (Holocene)**--Unconsolidated and poorly sorted, interlensing silt, sand, and pebble gravel. Intertongues and overlaps valley-fill (Qv) deposits, inset against alluvial fan (Qa_1) deposits. Stream channels subject to high-energy flows and flash floods and support little or no vegetation. Contacts approximate. Estimated thickness 1 to 3 m

Qf **Floodplain deposit (Holocene)**--Flat valley or ponded area containing unconsolidated light-gray or tan silt, sand, and lenses of pebble to cobble gravel. Locally contains cinder, basalt fragments, gravel, or sand. Intertongues or overlaps valley-fill (Qv) deposits. Forms flat surface with little or no vegetation. Subject to frequent flooding and ponding. Thickness about 1 to 4 m

Qc **Colluvial deposit (Holocene)**--White to gray silt and fine-grained sand, black and reddish, fine-grained, cinder, scoria, and basalt fragments; locally consolidated by gypsum and calcite. Accumulates in enclosed basins or sinkholes on basalt flows. Similar to floodplain (Qf) deposits, but limited to local accumulations generally not associated with extensive drainages. Subject to temporary ponding. Supports sparse growths of grass. As much as 1 to 3 m thick

Qg_1 **Young terrace-gravel deposit (Holocene)**--Unconsolidated, gray siltstone, light-brown or red, pebble to boulder gravel composed about equally of well-rounded limestone and sandstone and chert. Includes lenses of pale-red silt and sand. Locally contains well-rounded basalt cobbles. Includes reworked material from alluvial fan (Qa_1) deposits. Forms bench about 1 to 3 m above local stream beds. About 1 to 2 m thick

Qa_1 **Young alluvial fan deposit (Holocene)**--Unconsolidated pale-red silt and sand. Includes lenses of coarse gravel composed of subangular to well-rounded pebbles and cobbles of limestone, chert, and sandstone. Locally includes basalt; partly cemented by gypsum and calcite. Overlaps or intertongues with stream-channel alluvium (Qs), valley-fill (Qv); inset against older alluvial fan (Qa_2) deposits. Alluvial fans subject to erosion by sheet wash and flash floods. Supports sparse growths of sagebrush, cactus, and grass. As much as 6 m thick

Qv **Valley-fill deposit (Holocene and Pleistocene)**--Partly consolidated silt, sand, and interbedded lenses of quartzite pebble gravel. Intertongues or overlapped by young alluvial fans (Qa_1) and stream deposits. Subject to sheetwash flooding and temporary ponding. Supports moderate growth of grass and cactus. Thickness as much as 6 m

Qt **Talus deposit (Holocene and Pleistocene)**--Unsorted debris consisting of breccia composed of small and large angular blocks of local basalt as much as 1 m in diameter. Includes silt, sand, and gravel; partly cemented by calcite and gypsum. Intertongues with alluvial fan (Qa_1 and Qa_2) deposits. Supports sparse growth of sagebrush, cactus, grass, and some juniper trees. Only relatively extensive deposits shown. As much as 9 m thick

Ql **Landslide deposit (Holocene and Pleistocene)**--Unconsolidated masses of unsorted rock debris. Includes detached blocks of strata that have rotated backward and slid downslope as loose, incoherent masses of broken rock and deformed strata, often partly surrounded by talus. Occurs principally below edges of Seven Knolls basalt flow. Supports growths of sagebrush, cactus, and grass. Unstable when wet. Thickness probably as much as 6 m

Qa_2 **Older alluvial fan deposit (Holocene and Pleistocene)**--Similar to young alluvial fan (Qa_1) deposits; light brown and light gray, partly cemented by calcite and gypsum; basalt boulders common. Often overlapped by young alluvial fan (Qa_1) and intertongues with or inset against talus (Qt) deposits. Fans support moderate growth of sagebrush, cactus, and grass. Ranges from 3 to 10 m thick

Cave basalt (Pleistocene)--Informally named after a sinkhole labeled "Cave," type area for Cave basalt (T. 37 N., R. 7 W., NE¼ of Sec. 33), northern Mohave County, Arizona, central part of Hat Knoll quadrangle. Includes basalt flows and associated pyroclastic deposits. Divided into:

Qci **Cave basalt vent area**--Includes 5 vent areas aligned in a north-south strike, approximately located on cinder cones; source vent areas for Cave basalt flows, southeastern quarter of quadrangle

Qcc **Cave basalt pyroclastic deposit**--Red and reddish black fragments of angular basaltic scoria and cinder deposits; partly consolidated. Associated with Cave basalt vent areas and basalt flows. Forms cinder cones 30 to 135 m thick

Qcb **Cave basalt**--Dark-gray, finely crystalline to aphanitic groundmass, olivine basalt; two or more flows that have coalesced into one flow. Contains abundant olivine phenocrysts 0.25 to 1 mm. Originates from 5 vent areas marked as unnamed cinder cones in southeast quarter of quadrangle. Appears to overlap undivided basalt flow from Pugh Knoll; abuts or merges with undivided basalt flows in southeast corner of quadrangle. Ranges from about 1 to 25 m thick

Spencer Knoll basalt (Pleistocene)--Informally named after 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. Includes basalt flow and associated pyroclastic deposit. Divided into:

Qski **Spencer Knoll vent area**--Approximately marked near center of Spencer Knoll cinder cone. Source vent for Spencer Knoll pyroclastic deposit and basalt flow

Qskc **Spencer Knoll pyroclastic deposit**--Black and red fragments of angular basaltic scoria and cinder deposits. Associated with Spencer Knoll vent area and basalt flow. Forms cinder cone 110 m thick

Qskb **Spencer Knoll basalt flow**--Olivine basalt, dark gray to black, finely crystalline, aphanitic groundmass composed of plagioclase, olivine, and augite(?); olivine phenocrysts common. Flow abuts or overlaps undivided basalt flow from Pugh Knoll area. Overlies Harrisburg Member of Kaibab Formation. Flow extends for about 1.5 km northeast of Spencer Knoll and about 3 km west and is overlapped by alluvial fan (Qa_2) and valley-fill (Qv) deposits along its southern margin. Locally covered by pyroclastic (Qskc) deposits. As much as 20 m thick

Undivided basalt flows and pyroclastic deposit (Pleistocene)--Includes dark-gray basalt flows and pyroclastic deposits of Pugh Knoll, basalt from Craig Knoll (south of quadrangle, Mount Trumbull NW 7.5′ quadrangle), and basalt flows and pyroclastic deposits in southeast corner of quadrangle. Undivided basaltic rocks in southeast corner of quadrangle may by equivalent to Cave basalt. Divided into:

Qui **Undivided basalt vent area**--Includes three vent areas of Pugh Knoll (southwest corner of quadrangle), and three vent areas of unnamed volcanoes in southeast corner of quadrangle

Quc **Undivided basalt pyroclastic deposit**--Mostly black, includes light-red fragments of angular basaltic scoria and cinder deposits; partly consolidated. Forms Pugh Knoll cinder cone, southwest corner of quadrangle, and two, small, unnamed cinder cones, extreme southeast corner of quadrangle. As thick as 30 to 110 m

Qub **Undivided basalt flow(s)**--Dark-gray to black, fine-grained, glassy groundmass, olivine basalt in southwest and southeast corners of quadrangle. Contains small phenocrysts of plagioclase and olivine. Appears to be overlapped by Spencer Knoll and Cave basalt flows in southwest quarter of quadrangle; may merge into or abut Cave basalt in southeast corner of quadrangle. K-Ar age of 0.64 Ka, southeast corner of quadrangle (Jackson, 1990a, b). As much as 4 to 20 m thick

Seven Knolls basalt (Pleistocene)--Informally named for Seven Knolls volcanoes, 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 7.5′ quadrangle and northwestern part of Hat Knoll quadrangle. Includes basalt flows and associated pyroclastic deposits. Divided into:

Qsi **Seven Knolls vent area**--Includes 3 vent areas approximately located in northwestern corner of quadrangle; source vents for part of Seven Knolls pyroclastic deposits and basalt flows

Qsc **Seven Knolls 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 and cinder blanket on basalt flows. As much as 76 m thick

Qsb **Seven Knolls 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), and thin valley fill (Qv) and young alluvial fan (Qa_1) deposits. Basalt flowed 3 km east and 4 km north from vent areas. Forms protective caprock called Seven Knolls Bench which overlies thin alluvium and strata of Harrisburg Member of Kaibab Formation, and strata of lower red member, Virgin Limestone Member, and middle red member of Moenkopi Formation. Ranges from 6 to 40 m thick

Hat Knoll basalt (Pleistocene)--Informally named for Hat Knoll volcano, type area for Hat Knoll basalt, northern Mohave County, Arizona, T. 37 N., R. 7 W., Sec. 20, north-central part of Hat Knoll 7.5′ quadrangle. Includes basalt flows and associated pyroclastic deposits. Divided into:

Qhi **Hat Knoll vent area**--Includes 2 vent areas, approximate location on quadrangle. Source area for cinder and scoria deposits and basalt flow, north-central part of quadrangle

Qhc **Hat Knoll pyroclastic deposit**--Red to reddish-brown fragments of angular basaltic scoria and cinder deposits; partly consolidated. Overlies Hat Knoll basalt flow and siltstone of middle red member of Moenkopi Formation. Forms prominent cinder cone. As much as 115 m thick

Qhb **Hat Knoll basalt**--Dark-gray, finely crystalline, olivine basalt. Contains olivine and plagioclase phenocrysts 1 to 5 mm in diameter. Surface is partly covered by pyroclastic (Qhc) deposits near vent area. Basalt overlies middle red member of Moenkopi, west half of flow, Virgin Limestone and lower red members in east part. Bulk of basalt flowed southeast and east about 2 km, one small flow traveled north less than 0.4 km, and one flow traveled west a few hundred meters. Flow occupies similar bedrock surface at Seven Knolls basalt 1.3 km west of Hat Knoll and are likely similar age. Ranges from 6 to 60 m thick

Sedimentary Rocks

Moenkopi Formation (Middle? and Lower Triassic)--Includes, in descending order, middle red member, Virgin Limestone Member, lower red member, and Timpoweap Member as used by Stewart and others (1972). Erosion has removed part of the middle red and all upper members of the Moenkopi Formation. Divided into:

₸mm **Middle red member**--Red-brown, thin-bedded, laminated siltstone and sandstone, white and gray gypsum, minor white platy dolomite, green siltstone, and gray-green gypsiferous mudstone. Gradational contact with Virgin Limestone Member placed at top of highest gray limestone bed of Virgin Limestone. Forms slope. About 55 m thick

₸mv **Virgin Limestone Member--Consists of two light-gray, thin-bedded to thinly-laminated, ledge-forming limestone beds, 1 to 2 m thick, separated by white, pale-yellow, red, and blue-gray slope-forming, thin-bedded, gypsiferous siltstone. Includes thin beds of brown, red, and green siltstone, gray limestone, and brown platy calcarenite. Erosional unconformity at base of lowest gray Virgin Limestone bed truncates underlying siltstone of lower red member as much as 1 m deep that thickens and thins as channel fill deposit. Forms small cliffs in slope. About 25 m thick**

₸ml **Lower red member**--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. Includes marker bed of grayish red, cross-bedded, calcareous, coarse-grained, ledge-forming sandstone ranging about 1 to 2 m thick. Base placed at lowermost red siltstone bed of lower red member. Locally fills small channels eroded into underlying Kaibab Formation. Gradational contact with Timpoweap Member. Forms slope. As much as 40 m thick

₸mt **Timpoweap Member**--Light-gray conglomerate and coarse-grained sandstone; calcite cement. Conglomerate composed of subangular to rounded pebbles and cobbles of gray and dark gray limestone, white, brown, and gray chert, and rounded quartzite in matrix of gray to light-brown, coarse-grained, calcareous sandstone and gravel, all derived from Kaibab Formation. Unconformable contact with Harrisburg Member of Kaibab Formation. Forms ledges in slope. As much as 8 m thick

Kaibab Formation (Lower Permian)--Includes the Harrisburg Member as defined by Sorauf and Billingsley (1991), Fossil Mountain Member not exposed

Pkh **Harrisburg Member**--Only upper and middle part exposed in this quadrangle. Upper part consists mainly of slope-forming, red and gray, interbedded gypsifereous siltstone, sandstone, gypsum, and thin-bedded gray limestone; mostly removed by erosion. Includes a pale-yellow or light-gray, thin-bedded, fossiliferous (molluscan faunas), sandy limestone caprock averaging about 1 m thick. Middle part consists of two prominent limestone beds, an upper, gray, thin-bedded, cherty limestone and a lower, light-gray, thin-bedded, sandy limestone. Cherty limestone bed weathers dark brown or black. Lower part not exposed. Solution of gypsum has locally distorted limestone beds of middle and upper part causing them to slump or bend into local drainages. As much as 60 m thick

REFERENCES CITED

Billingsley G.H., 1994a, Geologic map of the Formaster Well quadrangle, Mohave County, northwestern, Arizona: U.S. Geological Survey Open-File Report 94-243, scale 1:24,000, includes pamphlet 10 p.

_____ 1994b, Geologic map of the White Pockets quadrangle, Mohave County, northwestern Arizona: U.S. Geological Survey Open-File Report 94-244, scale 1:24,000, includes pamphlet 11 p.

_____ in press a, Geologic map of the Lower Hurricane Wash and vicinity, Mohave County, northwestern Arizona: U.S. Geological Survey Miscellaneous Investigations Map Series I-2481, scale 1:31,680.

_____ in press b, Geologic map of the upper Hurricane Wash and vicinity, Mohave County, northwestern Arizona: U.S. Geological Survey Miscellaneous Investigations Map Series I- , scale 1:31,680.

Billingsley, G.H., and Huntoon, P.W., 1983, Geologic map of Vulcan's Throne and vicinity, western Grand Canyon, Arizona: Grand Canyon Natural History Association, Grand Canyon, Arizona, scale 1:48,000.

Hamblin, W.K., 1970, Late Cenozoic basalt flows of the western Grand Canyon: in Hamblin, W.K., and Best, M.G., eds., The western Grand Canyon district, Guidebook to the geology of Utah, no. 23, Brigham Young University, Utah Geological Society, Distributed by Utah Geological and Mineralogical Survey, University of Utah, Salt Lake City, Utah, p. 21-37.

Hamblin, W.K., and Best, M.G., 1970, The western Grand Canyon district, Guidebook to the geology of Utah, no. 23, Brigham Young University, Utah Geological Society, Distributed by Utah Geological and Mineralogical Survey, University of Utah, Salt Lake City, Utah, 156 p.

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.

Jackson, G.W., 1990a, Tectonic geomorphology of the Toroweap Fault, western Grand Canyon, Arizona: Implications for transgression of faulting on the Colorado Plateau: Arizona Geological Survey Open-File Report 90-4, 67 p.

_____ 1990b, The Toroweap Fault: One of the most active faults in Arizona: Arizona Geological Survey v. 20, no. 3, p. 7-10.

Reynolds, S.J., 1988, Geologic map of Arizona: Arizona Geological Survey, Tucson, Arizona, Map 26, scale 1:1,000,000.

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 and origin of the Triassic Moenkopi Formation and related strata in the Colorado Plateau region: U.S. Geological Survey Professional Paper 691, 195 p.

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.

Wilson, E.D., Moore, R.T., and Cooper, J.R., 1969, Geologic map of the State of Arizona: Arizona Bureau of Mines, University of Arizona, scale 1:500,000.

Contact--Dashed where approximately located

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

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

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

Syncline

Anticline

Doubly plunging anticline

Dome

Strike and dip of beds

Inclined

Approximate--Estimated photogeologically

Implied--Determined photogeologically, amount of dip undetermined

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

Sinkholes--Steep-walled or enclosed depression or cave

Flow direction of basalt

CORRELATION OF MAP UNITS