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

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

by
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INTRODUCTION

Mustang Knoll quadrangle (approximately 96 sq km) is located in northern Mohave County Arizona, about 27 kilometers south of the Utah-Arizona state line (fig. 1). Elevations range from about 3,960 ft at Hobble Canyon to about 6,085 ft on Mustang Knoll. The nearest settlement is St. George, Utah, about 56 kilometers north of the quadrangle. The main access is by improved dirt road, locally referred to as the Mt. Trumbull road that leads south from St. George, Utah to Wolf Hole, Arizona, an abandoned ranch. A unimproved dirt road least west from Wolf Hole about 15 kilometers to the quadrangle area (fig. 1).

The area is managed entirely by the U.S. Bureau of Land Management. Below about 4,500 ft elevation, the area is sparsely vegetated with sagebrush, cactus, pinion pine, and juniper; higher elevations have thick growths of sagebrush in alluvial valleys and moderate cover of pinion pine and juniper trees.

PREVIOUS WORK

There are no previous small-scale geologic maps of this area. The area is included in two Arizona state geologic maps, one at a scale of 1:500,000 (Wilson and others, 1969), and the other at 1:1,000,000 (Reynolds, 1988). Geologic maps that border this quadrangle include, on the north, the Wolf Hole Mountain West 7.5 quadrangle, Arizona (Billingsley, 1990). Geologic maps in preparation of bordering areas include, on the west, the Cane Springs 7.5 quadrangle, Arizona; to the south, the St. George Canyon 7.5 quadrangle, Arizona; and to the east, the Sullivan Draw North 7.5 quadrangle Arizona.

GEOLOGIC SETTING

The quadrangle lies in the northern part of the Shivwits Plateau, a sub-physiographic plateau of the southwestern Colorado Plateau Geologic Province. The quadrangle is characterized by flat-lying Mesozoic and Paleozoic strata with a regional dip east and northeast of about 4° along the western third of the quadrangle, and less than 2° east elsewhere. The main structural feature is a large graben, herein named Hobble graben from a canyon of that name in the graben. Hobble graben displaces strata down about 200 m, has a northwest strike, and is about 1.6 kilometers wide (fig. 2). The strata are cut by a few small normal faults that have a general north or northwest strike.

Mustang Knoll, and a nearby similar unnamed knoll, are composed of nearly flat lying soft Mesozoic strata about 244 m thick. The soft bedrock of the knolls are protected from erosion by basalt flows capping the knolls. Cenozoic deposits are widely distributed and are characterized as geomorphic surficial alluvial or mass-wasted erosional deposits based on landform development and their relationship to underlying structures and erosional changes. The surficial units often merge or intertongue and share an arbitrary map boundary.

STRATIGRAPHY

About 427 m of Triassic and Permian rock strata are exposed in the quadrangle. The formations exposed are, in ascending order, the Toroweap and Kaibab Formations (Lower Permian), and the Moenkopi Formation (Middle? and Lower Triassic). The oldest map unit, the Woods Ranch Member of the Toroweap Formation, crops out in

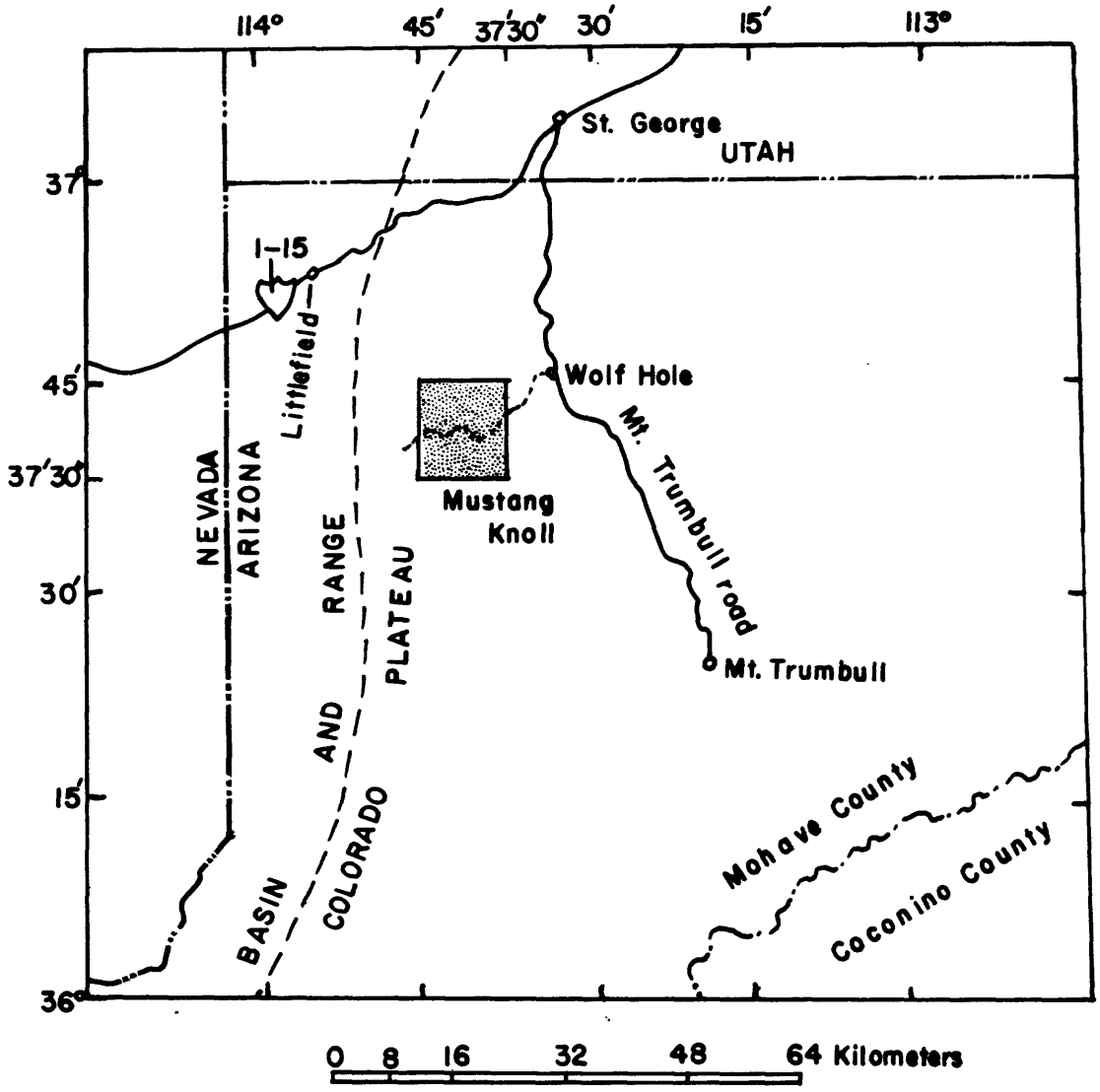


Figure 1. Mustang Knoll 7.5 quadrangle, northern Mohave County, northwestern Arizona, showing 7.5 quadrangle mapped in this report.

canyon drainages east of Hobble graben (southwest quarter of map). Mustang Knoll, a nearby similar unnamed knoll and vicinity are composed of nearly flat-lying soft Mesozoic strata capped by remnants of Tertiary basalt flows. Remnants of the Moenkopi are also found in Permian-Triassic paleovalleys, and in Hobble graben. About half the surface bedrock of this quadrangle is gray, cherty or sandy limestone of the Kaibab Formation or gray and red limestone, siltstone, and gypsum of the Moenkopi Formation. Cenozoic deposits include alluvial stream and mass-moved deposits. Details of the stratigraphy are given in the description of map units.

The basalt flows on Mustang Knoll and unnamed knoll 2.4 kilometers northwest, may be equivalent to basalt flows of Wolf hole Mountain (3.1±0.4 Ma) about 5 kilometers northeast of Mustang Knoll, or to Black Rock Mountain (3.7±0.6 Ma; Billingsley, in press). Basalt flows at these locations occupy similar elevations, stratigraphic position, and are lithologically similar. The basalt flow in the southwest corner of the quadrangle, herein named the Hobble flow, is probably of similar age. The source of the Hobble flow is likely the basalt dike on the west fault of Hobble graben.

STRUCTURAL GEOLOGY

Hobble graben averages about 1.6 kilometers wide and about 6.5 kilometers long with a strike of north 20° west. The graben dies out in the west-central part of the quadrangle and does not intersect the Grand Wash fault about 3.2 kilometers east. Hobble graben continues southeast into the adjoining St. George 7.5 quadrangle for about 16 kilometers. The east fault of the graben averages about 244 m of displacement down to the west. The west fault averages about 183 m down to the east. Thus, the overall net displacement of strata across Hobble graben is about 61 m down to the west. Small normal faults, synclines, and anticlines parallel the northeast side of the graben and are scattered elsewhere. A well defined, southwest-dipping monocline at the upper reach of Hobble graben strikes southeast towards upper Hobble Canyon where it becomes a normal fault with displacement down to the southwest about 74 m.

A circular fault in the northwest quarter of the quadrangle may reflect the outline of a large collapse structure. This structure is adjacent to a similar sized collapse structure known as the Nina Pipe (named by personnel of Southern Pacific Resources Company, personal commun. 1991). Numerous local small sags and folds associated with solution of gypsum in the Kaibab and Moenkopi Formations, especially in drainages, are too small and irregular to show at map scale.

Collapse Structures

Circular collapse structures, and other surface 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 Huntoon, 1989). Such features on this quadrangle, 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 collapse features (Wenrich and others, 1986). The deep-seated breccia pipes are potential host for economic deposits of copper and uranium; the shallow structures

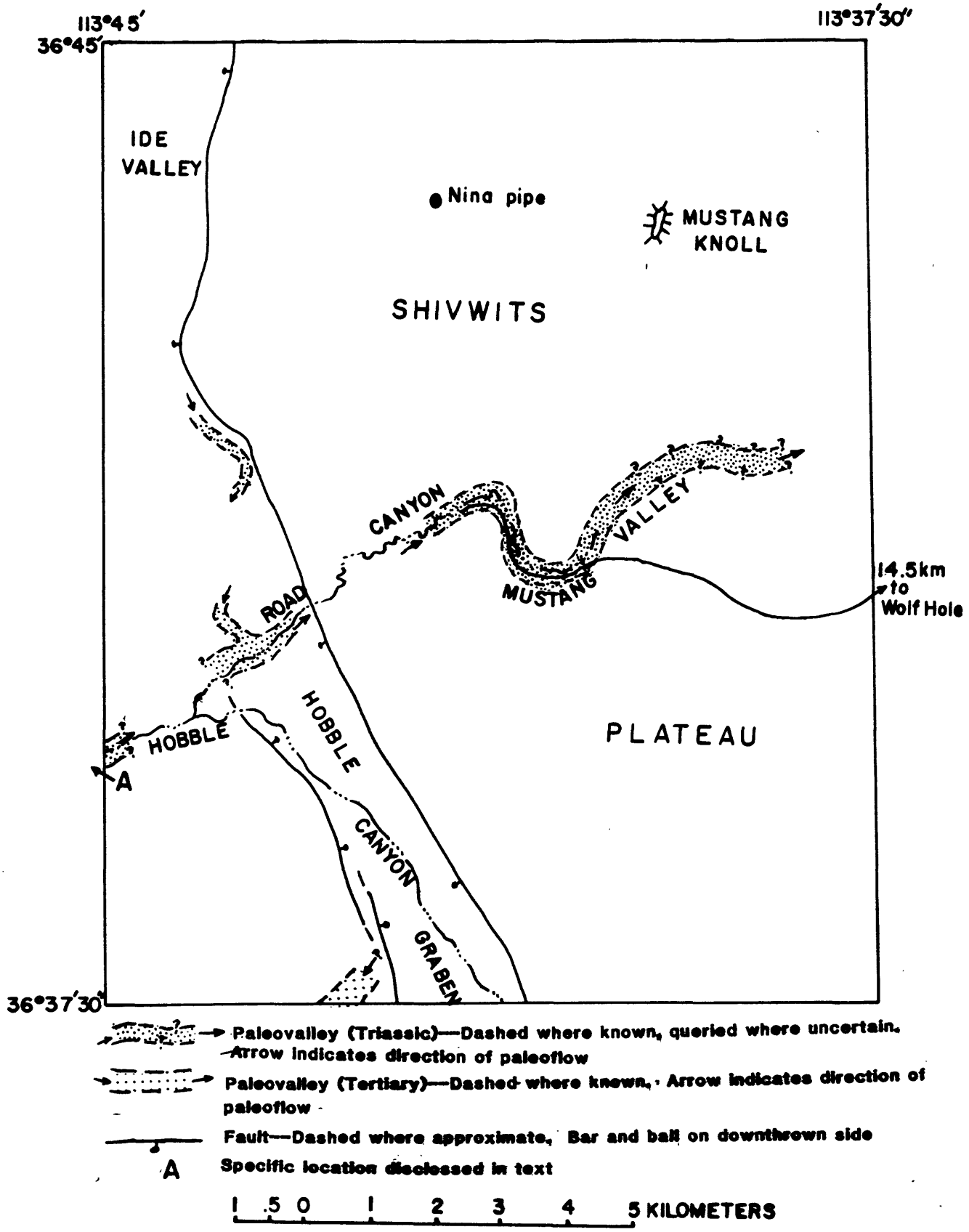


Figure 2. Selected geographic and geologic features of the Mustang Knoll 7.5 quadrangle, northwestern Arizona.

are unlikely to be mineralized (Wenrich, 1985).

The Nina pipe, about 3.2 kilometers west of Mustang Knoll, may be a deep-seated breccia pipe and has been drilled by Union Pacific Resources Company during 1987 and 1990. Breccia and alteration of strata is found down to the base of the Toroweap Formation, but not below. A breccia pipe below the Toroweap is still suspected but has not been found at this time (Neil Brown, Union Pacific Resources Co., oral commun., 1991).

Shallow sinkholes and karst caves are associated with the solution of gypsum in the Harrisburg Member of the Kaibab Formation and Virgin Limestone Member of the Moenkopi 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. Many local drainages originate at open sinkhole depressions that are not marked on the map. The sinkholes are young features, Holocene and probably as old as Pleistocene.

DESCRIPTION OF MAP UNITS

Surficial Deposits

Qs **Stream-channel alluvium (Holocene)**--Unconsolidated to poorly sorted, interlensing silt, sand, and pebble to boulder gravel. Merges with or erodes floodplain (Qf), terrace (Qg_1), alluvial fan (Qa_1), and valley-fill (Qv) deposits. Subject to high-energy flows and flash floods. Little or no vegetation. Contacts approximate. Estimated thickness 1.5 to 3 m

Qf **Floodplain deposits (Holocene)**--Unconsolidated, light-gray or brown silt, sand, and lenses of pebble to cobble gravel. Intertongues and merges with valley-fill (Qv), and talus (Qt) deposits. Partly consolidated with gypsum and calcite. Thickly vegetated by sagebrush and cactus. Subject to periodic flooding and local temporary ponding. Thickness about 3 to 12 m

Qg_1 **Low terrace-gravel deposits (Holocene)**--Unconsolidated pebble to boulder gravel composed about equally of well-rounded limestone, sandstone, angular and subrounded chert clasts; contains well-rounded basalt clasts, northwest quarter of quadrangle. Includes lenses of silt and sand. Commonly merges with stream-channel (Qs), alluvial fan (Qa_1 and Qa_2), higher terrace (Qg_2), talus (Qt), and valley-fill (Qv) deposits. Forms a bench about 1 to 3 m above modern stream beds. Thickness about 1 to 3 m

Qa_1 **Young alluvial fan deposits (Holocene)**--Unconsolidated silt and sand; contains lenses of coarse gravel composed of subangular to rounded pebbles, cobbles and boulders of limestone, chert, and some sandstone; partly cemented by gypsum and calcite. Includes basalt boulders in northwest quarter of quadrangle. Merges with stream-channel (Qs), terrace-gravel (Qg_1 and Qg_2), valley-fill (Qv), talus (Qt), and older alluvial fans (Qa_2 and Qa_3) deposits near their downslope ends. Subject to erosion by flash floods and sheet wash. Sparse to moderate vegetation of pinion pine and juniper trees, cliff rose bush, sagebrush and cactus. Thickness about 3 to 6 m

Qv **Valley-fill deposits (Holocene and Pleistocene?)**--Partly consolidated silt, sand, and lenses of pebble to small boulder gravel. Consists partly of local talus (Qt), alluvial fan (Qa_1), and stream-channel (Qs) deposits in small drainage valleys. Pebble clasts are dominated by angular chert fragments. Some deposits spread out as alluvial fans (Qa_1) and merge with stream-channel (Qs) or other valley-fill (Qv) deposits at some drainage junctions. Subject to sheetwash and ponding; cut by arroyos in larger valleys. Thickly vegetated by sagebrush, grass and some juniper and pinion pine trees. Thickness as much as 6 to 12 m

Qg_2 **High terrace-gravel deposits (Holocene and Pleistocene?)**--Similar to low terrace-gravel deposits (Qg_1); partly consolidated; on abandoned stream benches about 3 to 10 m above modern stream beds. Includes abundant, rounded basalt cobbles and boulders, northwest quarter of quadrangle. Merges with and locally overlain by talus (Qt) and alluvial fans (Qa_1, Qa_2, and Qa_3) deposits. Thickness about 1.5 to 6 m

Qa_2 **Intermediate alluvial fan deposits (Holocene and Pleistocene)**--Similar to young alluvial fan deposits (Qa_1); partly cemented by calcite and gypsum. Generally at higher elevations then Qa_1 but can be overlain by Qa_1 in Hobble graben. Moderately vegetated by pinion pine and juniper trees, sagebrush, cliff rose bush, cactus, and some grass. Thickness about 3 to 18 m

Qt **Talus deposits (Holocene and Pleistocene)**--Unsorted debris consisting of small to large brecciated gravel and blocks of limestone, chert, and basalt; includes sand and silt. Unconsolidated to partly consolidated and partly cemented by calcite and gypsum. Locally includes small, well-rounded pebbles of petrified wood, chert and quartzite in northwest quarter of quadrangle. Merges with alluvial fan (Qa_1, Qa_2, and Qa_3), terrace-gravels (Qg_1 and Qg_2), and stream-channel (Qs) deposits. Moderate vegetation of pinion pine and juniper trees, sagebrush, cactus, cliff rose bush, and grass. Only relatively extensive deposits are shown. Thickness as much as 8 m

Ql **Landslide debris (Holocene and Pleistocene)**--Unconsolidated masses of unsorted rock debris, including blocks of strata that have rotated backward and slid downslope. Occurs principally around Mustang Knoll and adjacent highlands north quarter of quadrangle where basalt and underlying non-resistant rock has broken from rim and slid down as loose incoherent jumbled mass of broken rock and deformed strata. Locally includes blocks of Kaibab Formation on canyon rims west-central part of quadrangle. Moderately vegetated by sagebrush, cactus, pinion pine and juniper trees. Unstable when wet. Thickness as much as 31 m

Qa_3 **Medium-intermediate alluvial fan deposits (Pleistocene? and Pleistocene)**--Similar to younger alluvial fan deposits (Qa_1, and Qa_2); clasts are coated with desert varnish. Basalt clasts are round and common in northwest quarter of quadrangle; no basalt clasts in Hobble graben area. Includes subrounded to well-rounded clasts of quartzite, chert, and limestone. Quartzite and black chert pebbles derived from local talus (Qt) deposits in northwest quarter of quadrangle which in turn are derived from eroded Chinle Formation in north adjoining Wolf Hole Mountain West quadrangle. White chert and gray limestone are locally derived from Kaibab Formation in Hobble graben area. Forms alluvial slopes about 12 to 18 m higher than Qa_2 deposits. Merges with younger alluvial fans (Qa_1 and Qa_2) at downslope ends. Thickness about 3 to 4 m

Ti **Intrusive basalt (Pliocene)**--Dark-gray olivine basalt; finely crystalline olivine in an aphanitic groundmass. Includes black pyroxene in some dikes. Assumed to be Pliocene or equivalent to source of flows on Black Rock and Wolf Hole Mountains and Mustang Knoll because of similar lithology and regional strike of lineation. A dike in Hobble Canyon is source for Hobble basalt flow overlying lower strata of Moenkopi Formation, southwest edge of quadrangle

Tb **Basalt flows (Pliocene)**--Dark-gray, olivine basalt; finely crystalline olivine in an aphanitic groundmass. Assumed to be Pliocene age as described in Ti above. Forms unconformable contact over less resistant beds of Moenkopi Formation at Mustang Knoll, unnamed knoll 2.4 kilometers northwest of Mustang Knoll, and west side of Hobble graben. Unit consists of one or more flows to a maximum thickness about 48 m on Mustang Knoll, 36 m on unnamed knoll, and 9 m west of Hobble graben

Sedimentary Rocks

Moenkopi Formation (Middle? and Lower Triassic)--Includes, in descending order, upper red, Shnabkaib, middle red, Virgin Limestone, lower red, and Timpoweap members as defined by Stewart and others (1972)

Rmu **Upper red member**--Heterogeneous sequence of red, interbedded, mudstone, siltstone, sandstone, conglomerate, and minor gypsum. Incomplete and limited exposure due to landslide-debris cover northwest edge of map. Forms ledge and slope sequence more than 30 m thick

TRms **Shnabkaib Member**--Interbedded white, laminated, aphanitic dolomite and gypsum; red siltstone, mudstone, and sandstone are minor components. Contains thin red beds of siltstone and sandstone in lower part. Gradational contact with upper red member placed arbitrarily at highest thick white siltstone unit northwest corner of quadrangle. Upper red is eroded away at Mustang Knoll and adjacent unnamed knoll. Forms steep slope with several ledges. Thickness as much as 160 m

TRmm **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; abundant veins of gypsum in siltstone. Gradational upper contact arbitrarily placed at base of lowest bed of light gray dolomitic siltstone. Poorly exposed except at Ide Valley. Forms slope. Thickness averages about 45 to 61 m

TRmv **Virgin Limestone Member**--Consists of three, light gray, ledge forming, limestone beds (1.5 to 6 m thick), separated by white to pale-yellow, slope-forming, thin-bedded gypsum and gypsiferous siltstone. Includes thin beds of brown, red, and green siltstone, gray limestone, and brown platy calcarenite. Upper contact placed at top of highest bed of gray limestone. Lower limestone contains abundant star-shaped echinoderm plates and Composita brachiopods. Thickness about 40 m

TRml **Lower red member**--Interbedded red, thin-bedded, sandy siltstone, gray, white and pale-yellow laminated gypsum and minor sandstone. Lower units are partly reworked gypsum and siltstone of Harrisburg Member of Kaibab Formation. Upper contact placed at the base of lowest bed of gray limestone of Virgin Limestone. Forms slope. Averages about 9 m thick, locally thickens to as much as 48 m in shallow paleovalleys eroded into underlying Kaibab Formation

TRmt **Timpoweap Member**--Gray conglomerate, clast supported, consisting of subangular to rounded pebbles and cobbles of gray limestone and white chert derived from Kaibab Formation. Includes some matrix of coarse-grained sandstone and gravel. Gradational contact with lower red member arbitrarily placed at lithologic change from gray conglomerate and coarse-grained sandstone to red siltstone and gypsum. Forms ledge. Fills paleovalleys eroded into Fossil Mountain Member of Kaibab Formation. Large Permian-Triassic paleovalley is exposed in Road Canyon (central part of quadrangle), here named Mustang valley for reference purposes (fig. 2). Imbrication of pebbles indicate an east flow of depositing stream. Mustang valley averages about 400 m wide and 73 m deep. A western extension of Mustang valley is in Hobble Canyon drainage about 0.8 kilometers west of quadrangle (near A on fig. 2). Narrow tributary valley is exposed in east-central part of map (fig. 2) about 24 m thick

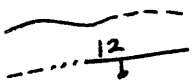
Kaibab Formation (Lower Permian)--Includes, in descending order, Harrisburg and Fossil Mountain Members as defined by Sorauf and Billingsley (1991)

Pkh **Harrisburg Member**--Consists of light-gray, fossiliferous, sandy, fine- to medium-grained, limestone. Includes interbedded red and gray gypsiferous siltstone and sandstone with gray gypsum in beds several meters thick. Gray, thin-bedded, cherty limestone and sandy limestone form resistant cliff near top of unit. Upper units of gypsum and gypsiferous siltstone (thickness unknown due to erosion) are partly preserved in north-central area of quadrangle. Solution of interbedded gypsum has locally distorted bedding. Upper contact is unconformabable and locally obscure by surficial landslide (Ql) or talus (Qt) deposits. Small paleohills of Harrisburg gypsum are exposed between Mustang Knoll and Ide Valley covered by Virgin Limestone of Moenkopi Formation. Forms slope with limestone ledges. Thickness as much as 91 m

Pkf **Fossil Mountain Member**--Yellow-gray to gray, fine- to medium-grained, thin-bedded, fossiliferous, sandy, cherty,limestone. Chert weathers black in cliff outcrops. Gradational with overlying Harrisburg; arbitrary contact between cherty limestone cliff and siltstone slope. Forms cliff. Thickness about 91 m

Toroweap Formation (Lower Permian)--Only Woods Ranch Member exposed in this quadrangle

Ptw **Woods Ranch Member**--Gray siltstone and pale-red shale with thick interbeds of massive, white to gray gypsum. Commonly covered by talus. Much subsidence and distortion of beds in drainages due to solution of gypsum. Poorly exposed in lower canyon drainages east of Hobble graben. Contact with Kaibab is unconformable marked by topographic break between cliff of Kaibab and slope of Toroweap. Unconformity caused by channel and solution erosion with local relief as much as 5 m; map contact generalized because of extensive cover of talus. Forms slope. About 18 m exposed

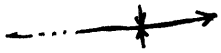


Contact--Dashed where approximately located

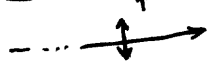
Fault--Dashed where approximately located, short dashed where inferred; dotted where concealed; bar and ball on downthrown side. Number is estimated displacement in meters

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

Strike and dip of strata

Inclined

Approximate--Estimated photogeologically

Implied--Determined photogeologically, no estimate of amount determined

Strike and dip of vertical joints

Collapse structure--Circular collapse, 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

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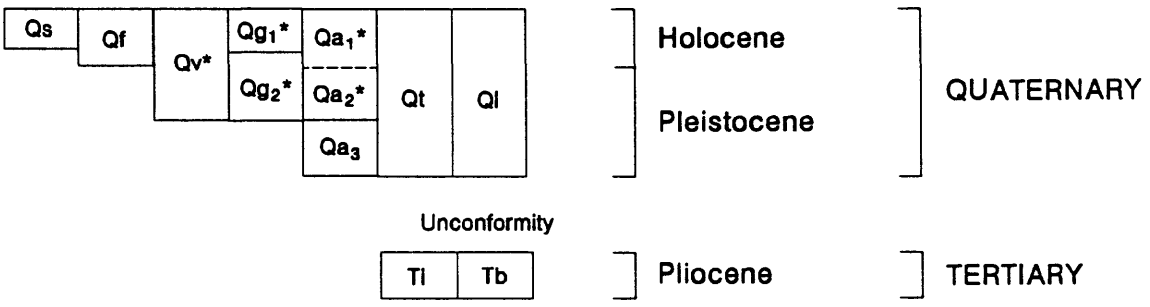
CORRELATION OF MAP UNITS

SURFICIAL AND VOLCANIC DEPOSITS

* See description of map units for exact unit age assignment



SEDIMENTARY ROCKS