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Geologic map of the Hole-N-Wall Canyon quadrangle, northern Mohave County, Arizona

by
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INTRODUCTION

The Hole-N-Wall Canyon 7.5'quadrangle (96 sq km) is located on the Shivwits Plateau in northern Mohave County, Arizona, about 42 kilometers south of Hurricane or St. George, Utah, the nearest settlements (fig. 1). Elevations range from about 1,183 m (3,880 ft) in the northeast corner of the quadrangle to about 1,842 m (6,043 ft) at Seegmiller Mountain. Access to the map area is by an improved dirt road, locally referred to as the Sunshine Trail, south from St. George, Utah (fig. 1). Several unimproved dirt roads lead from the Sunshine Trail to various locations within the quadrangle area.

The area is managed entirely by the U.S. Bureau of Land Management including a small part of one section in the north-central part of the quadrangle belonging to the State of Arizona. The area is sparsely vegetated with sagebrush, cactus, grasses, and some greasewood shrubs in lower elevations. Pinion pine and juniper trees, sage brush, apache plume and cliff rose shrubs, grow at higher elevations around Seegmiller Mountain.

PREVIOUS WORK

There are no previous small geologic maps of this area. The area was included in two Arizona state geologic maps at scales of 1:500,000 (Wilson and others, 1969), and 1:1,000,000 (Reynolds, 1988). Geologic maps bordering this area include the Wolf Hole Mountain East quadrangle (Billingsley, 1990) and the Wolf Hole Mountain and vicinity, Arizona, scale 1:31,680 (Billingsley, in press). Geologic maps in preparation by the author bordering this area include the Yellowhorse Flat, Gyp Pocket, and Dutchman Draw 7.5'quadrangles.

MAPPING METHODS

Geologic mapping of this quadrangle began with a general knowledge of the 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 present. Second, a preliminary photogeologic interpretation of the area was made. Third, a major field investigation was conducted covering at least 85% of the map area to verify photogeologic interpretations. Many of the alluvial Quaternary units are identified by photogeologic methods as to regional geomorphological characteristics, but have similar lithology. Fourth, another photogeologic study was conducted to provide consistency in map units and overall geologic map sense. Finally, a field investigation of problem areas was done to insure accuracy and consistency of map units for descriptive purposes. The alluvial Quaternary map units described are important for future environmental, land, and range management planning of this quadrangle by federal, state, and private concerns. The alluvial Quaternary units are key deposits which aid geomorphic interpretation of landscape development.

GEOLOGIC SETTING

The quadrangle lies within the Shivwits Plateau, a sub-province of the southwestern part of the Colorado Plateau geologic province (fig. 2). The map area is characterized by nearly flat-lying Mesozoic and Paleozoic strata with a regional northeast dip of about 2°. The strata are disrupted by several

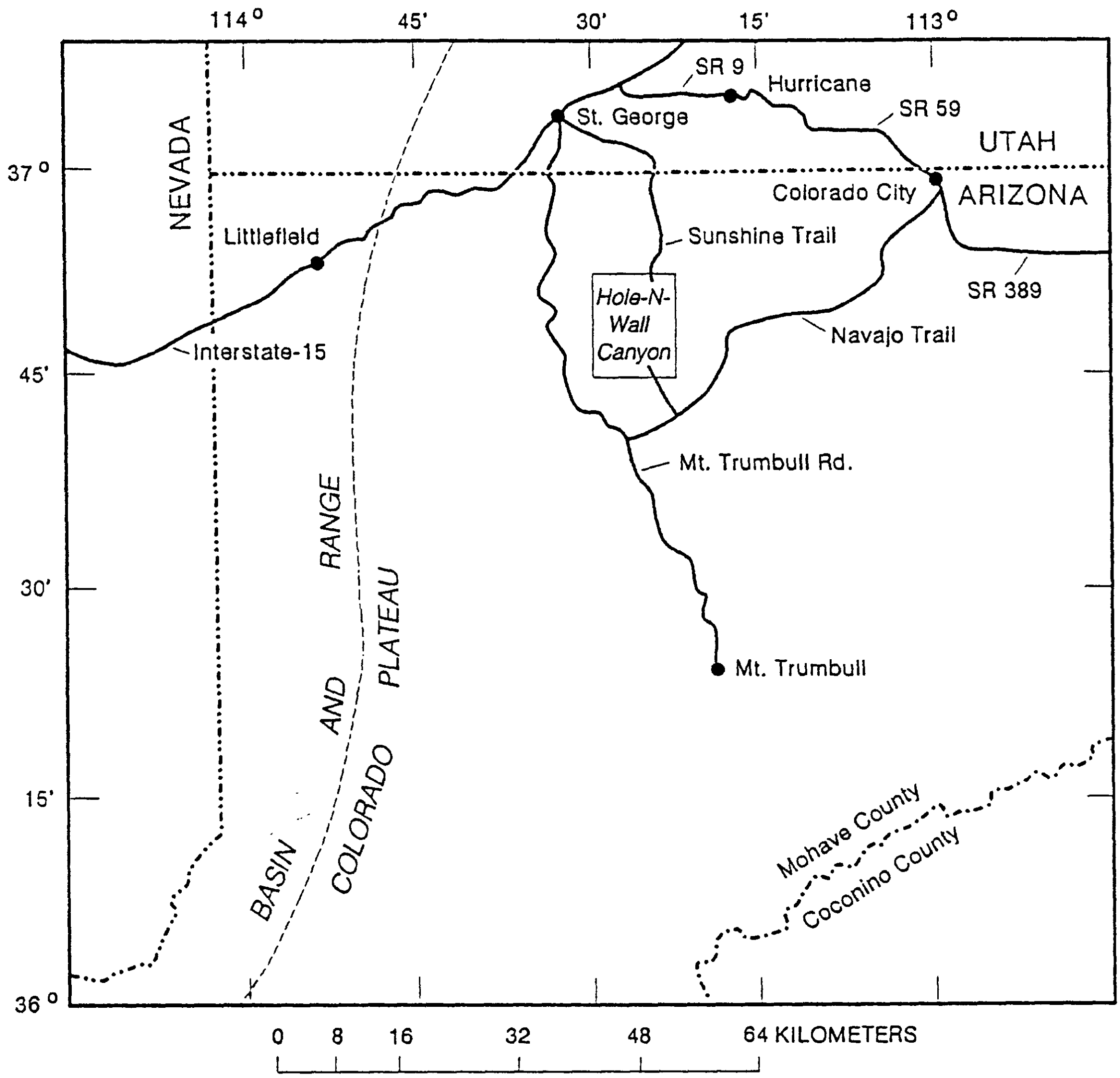

Figure 1. Index map of northern Mohave County, northwestern Arizona, showing Hole-N-Wall Canyon 7.5′ quadrangle mapped in this report.

graben and horst structures with less than 60 m (200 ft) of displacement. Pliocene basalt flows cap about 244 m (800 ft) of the Triassic Moenkopi Formation at Seegmiller Mountain at the western edge of the quadrangle.

Widely distributed Cenozoic deposits are distinguished as fluvial and 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 bedrock strata include, in ascending order, the Toroweap and Kaibab Formations (Lower Permian) and the Moenkopi Formation (Middle? and Lower Triassic). The Woods Ranch Member of the Toroweap Formation, crops out in the Hole-N-Wall Canyon drainage in the southwest quarter of the quadrangle. The youngest bedrock map unit, the Shnabkaib Member of the Moenkopi Formation, crops out at higher elevations on Seegmiller Mountain in Swiss Canyon. About two-thirds of the exposed bedrock of the quadrangle consists of gray cherty limestone and gray to white siltstone and gypsum of the Kaibab Formation. The remaining exposed bedrock is red siltstone and sandstone and gray limestone and gypsum of the Moenkopi Formation. The Moenkopi Formation is mostly removed by erosion except where protected by Pliocene basalt flows of Seegmiller Mountain and Quaternary basalt flows of West Mesa (fig. 2).

The basalt flows capping Seegmiller Mountain (informally the Seegmiller basalt) are 2.357±0.31 and 2.44±0.51 Ma (Reynolds and others, 1986). The basalts rest on a Tertiary bedrock erosion surface sloping gently northwest and south on Seegmiller Mountain. The Seegmiller basalt traveled down an eroded (peneplained) surface of the Shnabkaib Member of the Moenkopi Formation. The Main Street fault cuts the Seegmiller basalt and underlying Moenkopi strata with equal displacement, which makes the fault younger than the basalt. The general age of the basalt is about 2.4 Ma, and assuming most of the surrounding plateau surface was at or near the same general level as the basalt, the denudation of the surrounding plateau is about 425 m (1,400 ft) or 178 m (583 ft)/ m.y. or 1.8 m (5.8 ft)/10,000 yrs.

The basalt flows capping West Mesa in the north-central part of the quadrangle, are herein referred to as the West Mesa basalt for location and descriptive purposes. The West Mesa basalt averages about 425 m (1,400 ft) lower in elevation than the Seegmiller basalt flows and rest on strata of the lower Moenkopi and upper Kaibab Formations. The West Mesa basalt came from several source vents mapped as cinder cones on the basalt surfaces of West Mesa. The West Mesa basalt traveled mostly north and partly south down a wide valley surface with a northerly gradient of about 15 m per kilometer (50 ft per mile). the basalt now occupies an inverted valley. The West Mesa basalt is about 20 m (70 ft) above the surrounding drainages at the south end of the mesa and about 60 m (200 ft) above drainages at the north end. Thus, given the rate of denudation of the plateau at Seegmiller Mountain as 1.8 m (5.8 ft) per 10,000 years, and an average of 41.2 m (135 ft) of denudation since the West Mesa basalt flowed, the assumed age of the West Mesa basalt is about 783,000 years old.

The inverted valley of West Mesa was probably an ancestral drainage of Dutchman Draw which now parallels the west side of West Mesa. The West Mesa basalt flowed a short distance south (up) the ancestral valley and later

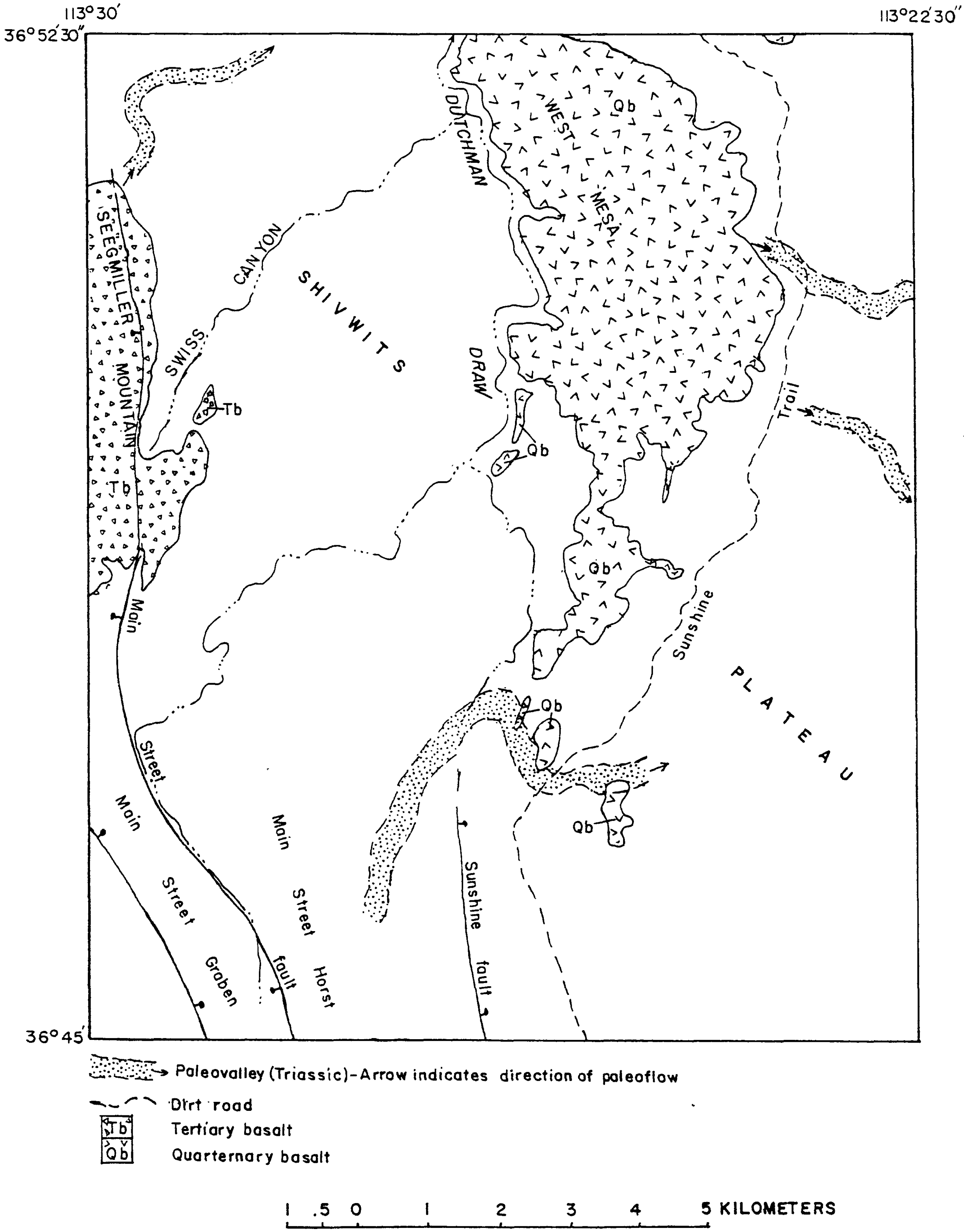

Figure 2. Selected geographic and geologic features of the Hole-N-Wall Canyon 7.5′ quadrangle, northwestern Arizona.

faulted down to the present drainage level. Therefore, faults cutting the West Mesa basalt suggest a Pleistocene tectonic development or activity for the horst and graben terrain in this quadrangle.

The Quaternary age assigned to the alluvial deposits is based on field relationships to Tertiary basalt flows of Seegmiller Mountain and Quaternary basalt flows of West Mesa. Further age determinations are based on geologic mapping west of this quadrangle (Billingsley, in press). Details of the stratigraphic sequence are given in the description of map units.

STRUCTURAL GEOLOGY

The Main Street fault (Hamblin and Best, 1970) is named from a fault-line valley called Main Street Valley, south of this quadrangle. The fault and associated graben, herein named Main Street graben, are the main structural feature of this quadrangle with a general north-south strike. The Main Street fault displaces strata down to the west an average of 90 m (300 ft) in the southwest corner of the quadrangle and is the east-bounding fault of Main Street graben. The graben is about 1 km (0.7 mi) wide and bounded by an unnamed fault on the west side with displacement of strata about 50 m (160 ft). Thus, the overall net displacement of strata across Main Street Graben is about 43 m (140 ft), down to the west.

The Main Street fault dies out at the north end of Seegmiller Mountain in the northwest corner of the quadrangle. Adjacent to and east of the Main Street Graben is the Main Street Horst. The Sunshine fault bounds the east side of Main Street Horst while Main Street fault bounds the west side (fig. 2). Elsewhere, a few horst and graben structures are located in the south half of the quadrangle with north-south strikes, bending to northeast strikes in the central part of the quadrangle.

The grabens and other faulted 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 forested and flatland areas (S.A.R. System, 1988).

Holocene movement has occurred along parts of the Main Street and Sunshine faults and graben as shown by solid fault lines in talus and alluvial fans. The faults are not sharply defined in the field because mass-wasting has shed soft and loose debris over the fault scarps, but are clearly delineated on aerial photos. Therefore, the faults are shown dotted in alluvial units of the map, even where they mark map-unit contacts. The Main Street Graben and Horst, as well as other horst and graben structures, began to develop after deposition of the late Pliocene basalt flows on Seegmiller Mountain and probably during or after deposition of the West Mesa basalt. Holocene movement of the horst and graben structures must have occurred because alluvial fans and talus slopes are offset by horst and graben faults.

Small monoclines and synclines with a general northeast strike are present in the quadrangle and are partly beveled by Tertiary and recent erosion. These folds, like others found elsewhere on the Colorado Plateau, are probably related to early Laramide compressional stresses (Huntoon, 1989). Local warped and bent strata, too small to show at map scale, are the result of solution of gypsum and commonly associated with collapse structures or drainage erosion.

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 Huntoon, 1989; Wenrich and Sutphin, 1989). Such features in the present map area, are marked on the map 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 possible host for potential 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 on the map where 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 are breached by drainages on the Shivwits Plateau surface. Several drainages originate at sinkhole depressions in the south half of the quadrangle area.

DESCRIPTION OF MAP UNITS
Surficial deposits and igneuos rocks

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

Qs **Stream-channel alluvium (Holocene)**--Unconsolidated and poorly sorted, interlensing silt, sand, and pebble to boulder gravel. Intertongues with alluvial fan (Qa_1), terrace-gravel (Qg_1), talus (Qt), 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. Intertongues with valley-fill (Qv), alluvial fans (Qa_1 and Qa_2), terrace-gravels (Qg_1 and Qg_2), and talus (Qt) deposits. Forms wide flat valley floors as opposed to small concave valley profiles of valley-fill (Qv) deposits. Deposits are thickly vegetated by cactus, sagebrush, and grass. Floodplain subject to flooding and local temporary ponding. Thickness about 3 to 30 m (10 to 100 ft)

Qc **Colluvial deposits (Holocene)**--Tan and light gray, fine-grained silt and sand. Includes lesser amounts of angular, pebble to cobble basalt clasts and coarse-grained gravel. Locally cemented by calcite and gypsum. Accumulates in enclosed basins created by landslide debris or sinkhole depressions. Supports sparse or no vegetation. Estimated thickness 3 to 9 m (10 to 30 ft)

Qg_1 **Low terrace-gravel deposits (Holocene)**--Light-brown, unconsolidated pebble to boulder gravel composed about equally of well-rounded limestone and sandstone clasts, angular and subrounded chert clasts; includes interstratified lenses of silt and sand. Locally includes some basalt clasts in northwest quarter of quadrangle. Contains reworked materials from alluvial fans (Qa_1 and Qa_2), intermediate terrace-gravel (Qg_2), and talus (Qt) deposits. Forms bench about 1 to 3 m (3 to 10 ft) above modern stream beds. Thickness averages about 1 to 6 m (3 to 20 ft)

Qa_1 **Young alluvial fan deposits (Holocene)**--Light-gray, unconsolidated silt and sand; contains lenses of coarse gravel composed of subangular to rounded pebbles and cobbles of limestone, chert, and sandstone. Includes basalt clasts in the northwest quarter of quadrangle, partly cemented by gypsum and calcite. Intertongues with stream-channel (Qs), valley-fill (Qv), and low terrace-gravel (Qg_1) deposits; overlaps and partly includes reworked materials from low and intermediate terrace-gravel (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. Supports sparse to moderate vegetation of sagebrush, cactus, and grass. Thickness as much as 9 m (30 ft)

Qv **Valley-fill deposits (Holocene and Pleistocene?)**--Light brown, partly consolidated silt and sand, with interbedded lenses of pebble to small-boulder gravel. Interbedded 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. Supports thick vegetation of sagebrush, grass, and cactus. Thickness as much as 12 m (40 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. Intertongues with and locally overlain by talus (Qt) deposits. Thickness about 2 to 7 m (6 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; lies above young alluvial fan (Qa_1) but intertongues with valley-fill (Qv) deposits. Intertongues with or inset against alluvial fan (Qa_3) and talus (Qt) deposits. Locally includes basalt clasts northwest quarter of quadrangle. Fans moderately vegetated by sagebrush, cactus, and grass. Thickness about 3 to 12 m (6 to 40 ft)

Qt **Talus deposits (Holocene and Pleistocene)**--Unsorted debris consisting of breccia and large angular blocks of local bedrock up to 1 m diameter. Includes silt, sand, and gravel partly cemented by calcite and gypsum. Intertongues with alluvial fans (Qa_1, Qa_2, and Qa_3), valley-fill (Qv), terrace-gravel (Qg_1 and Qg_2), and floodplain (Qf) deposits. Supports sparse to moderate vegetation of pinion pine or juniper trees, 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 segments of strata that have rotated backward and slid downslope, often partly surrounded by talus. Occurs principally below edges of basalt flows at Seegmiller Mountain; includes basalt flows and strata of Moenkopi Formation that has slid down over weak shale and gypsum units of the Moenkopi. Supports sparse vegetation of sagebrush, cactus, pinion pine, and juniper. 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 about 11 m (35 ft) higher than Qg_2 deposits. Composed of well-rounded limestone, sandstone, and chert clasts in sandy gravel matrix. Locally includes sub-rounded to well-rounded clasts of basalt. 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). Intertongues with talus (Qt) deposits. Intertongues with talus (Qt) deposits. Thickness about 3 to 5 m (10 to 15 ft)

Qi **Basalt dikes or plugs (Pleistocene)**--Dark-gray, finely crystalline to aphanitic basalt. Source for West Mesa basalt flows; usually associate with cinder or scoria deposits

Qb **Basalt flows (Pleistocene)**--Dark-gray, finely crystalline to aphanitic basalt of West Mesa. Forms cliffs. Thickness ranges from 1 to 26 m (3 to 85 ft)

Qbc **Cinder and scoria deposits (Pleistocene)**--Red-brown and black, angular fragments of basalt. Includes aphanitic to glassy groundmass fragments as slopes on West Mesa. Associated with West Mesa vent areas. Forms slopes and thick ground cover. Thickness up to 30 m (100 ft)

Ti **Basalt dike or plug (Pliocene)**--Dark-gray basalt with olivine in aphanitic groundmass. Weathers into crumbly small fragments due to abundant cooling joints. Includes black pyroxene. Sources for Seegmiller basalt flows found on Seegmiller Mountain

Tbc **Basalt scoria and cinder deposits (Pliocene)**--Red-brown and black clasts of angular, olivine-pyroxene basalt fragments. Includes dark-gray and red basaltic glass fragments; unconsolidated. Associated with volcanic vent on Seegmiller Mountain. Forms slope. Thickness about 9 m (30 ft)

Tb **Basalt flows (Pliocene)**--Dark-gray, massive, olivine basalt. Contains olivine and pyroxene in groundmass. Forms large columnar joints at base of Seegmiller Mountain flows, but not common. Surfaces are eroded and partly covered by calcrete incorporating locally eroded pebbles of basalt. Whole-rock K-Ar dates of basalt flows on Seegmiller Mountain, 1.6 km (1 mi) west of quadrangle is 2.35±0.31 and 2.33±0.51 Ma (Reynolds and others, 1986; Billingsley, 1991). Thickness about 2 to 30 m (6 to 100 ft)

Sedimentary Rocks

Moenkopi Formation (Middle? and Lower Triassic)--Includes, in descending order, Shnabkaib Member, middle red member, Virgin Limestone Member, lower red member, and Timpoweap Member as used by Stewart and others (1972). Upper red member not present in this quadrangle, removed by erosion prior to Pliocene basalt flows. The Middle-Lower Triassic boundary probably lies in the upper red member

TRms **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 arbitrarily placed at lowest thick white siltstone unit of Shnabkaib. About 30 m (100 ft) of top part eroded away. Forms steep slope with ledges. Thickness as much as 122 m (400 ft)

TRmm **Middle red member**--Red-brown, laminated siltstone and sandstone, interbedded with white and gray gypsum, minor white platy dolomite, green siltstone, and gray-green gypsiferous mudstone. Gradational contact with Virgin Limestone Member arbitrarily placed at top bed of light-gray dolomitic limestone of Virgin Limestone Member. Poorly exposed except at Swiss Canyon, northwest quarter of quadrangle (fig. 2). Forms slope. Thickness about 60 to 73 m (200 to 240 ft)

TRmv **Virgin Limestone Member**--Consists of three, light gray, ledge forming, limestone beds 2 to 6 m (5 to 20 ft) thick, separated by white, pale-yellow, and gray, slope-forming, thin-bedded, gypsiferous siltstone. Includes thin beds of brown, red, and green siltstone, gray limestone, and brown platy calcarenite in slope-forming units. Sharp unconformable contact with lower red member at some outcrops, less than 1 m (3 ft) of relief at base of lowest gray limestone of Virgin Limestone. Lowest limestone bed contains abundant star-shaped crinoid plates and poorly preserved *Composita* brachiopods in top part. Thickness about 40 m (130 ft)

TRml **Lower red member**--Red, thin-bedded, sandy siltstone, gray, white, pale-yellow laminated gypsum, and minor red or gray sandstone. Lower beds contain reworked gypsum and siltstone of Harrisburg Member of Kaibab Formation. Unconformable contact with Harrisburg Member of the Kaibab Formation, difficult to find except for color change from red gypsum and siltstone of lower red member of Moenkopi Formtion to gray gypsum and siltstone of Harrisburg Member of Kaibab Formtion. Locally thickens and thins in shallow Triassic paleovalleys eroded into underlying Kaibab Formation with relief up to 30 m (100 ft). Gradational contact with underlying conglomerate and sandstone of Timpoweap Member arbitrarily drawn at lower-most red siltstone bed. Contact locally obscure where overlain by surficial deposits. Forms slope. Averages about 15 m (50 ft) thick

TRmt **Timpoweap Member**--Light gray or pale-red conglomerate interbedded with coarse-grained sandstone. Includes lenses or beds of low-angle crossbedded sandstone. Conglomerate contains subangular to rounded pebbles and cobbles of gray and dark gray limestone, white and brown chert, and minor, light gray, rounded quartzite. Chert and gray limestone derived from Kaibab Formation. Dark gray limestone and quartzite clasts may be derived from older Paleozoic rocks west of quadrangle. Unconformable contact with Harrisburg Member of Kaibab Formation. Fills Triassic paleovalleys as much as 24 m (80 ft) in depth and about 244 m (800 ft) wide eroded into Kaibab Formation. Imbrication of pebbles in paleovalleys show an easterly paleoflow of depositing streams. Forms cliff or weak ledge. Thickness 0 to 24 m (0 to 80 ft)

TRmlt **Lower red member and Timpoweap Member undivided**--Same lithologies as TRml and TRmt above. Consists of gray conglomerate and sandstone typical of Timpoweap Member interbedded with red siltstone and gray gypsum beds typical of lower red member of Moenkopi Formation. Occupies small Triassic paleovalleys cut into underlying Harrisburg Member of Kaibab Formation. Thickness about 3 to 37 m (10 to 130 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. A resistant, pale-yellow or light-gray, fossiliferous, sandy limestone bed, averaging about 1 m (3 ft) thick forms caprock ledge at top. Middle part is cliff-forming marker beds consisting of lower, 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 and arbitrary contact between siltstone slope of Harrisburg Member and limestone cliff of Fossil Mountain Member. Forms slope containing middle limestone cliff. Thickness as much as 110 m (350 ft)

Pkf **Fossil Mountain Member**--Light-gray, fine- to medium-grained, thin-bedded, fossiliferous, sandy, cherty limestone. Chert weathers black. Unconformable contact with Woods Ranch Member of Toroweap Formation. Unconformity is solution channel erosion with relief as much as 5 m (15 ft). Map contact generalized because of extensive talus cover. Forms cliff. Thickness about 110 m (350 ft)

Toroweap Formation (Lower Permian)--Includes Woods Ranch Member as defined by Sorauf and Billingsley (1991). Brady Canyon and Seligman Members not exposed in this quadrangle

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. Bottom not exposed. Thickness about 15 m (50 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

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, enclosed depression, or cave

Flow direction of basalt

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CORRELATION OF MAP UNITS

SURFICIAL AND VOLCANIC DEPOSITS

* See description of map units for exact unit age assignment