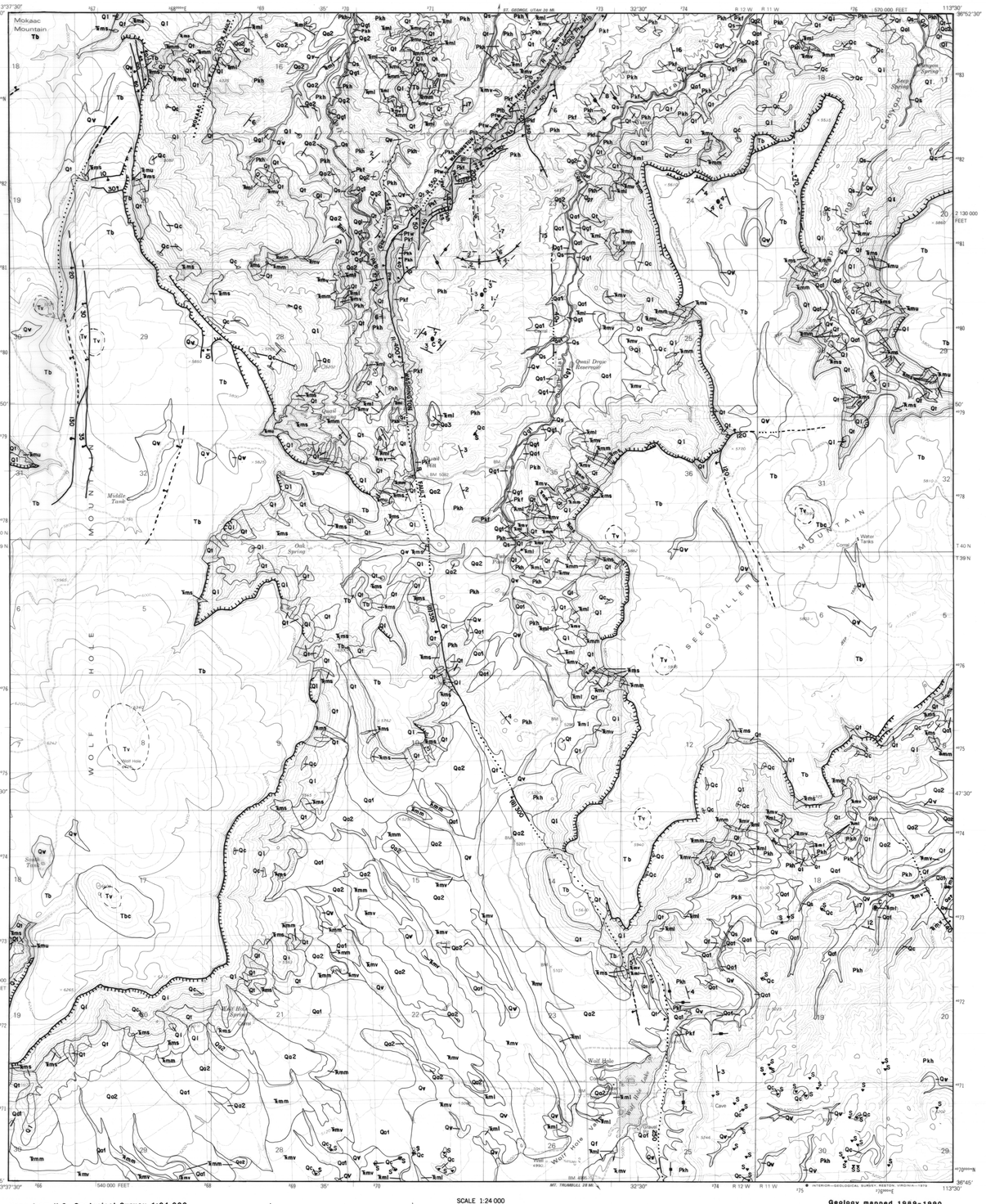
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

OPEN-FILE REPORT
90-644



Base from U.S. Geological Survey 1:24,000
Wolf Hole Mtn. East, Arizona, 1979

Geology mapped 1989-1990

UTM GRID AND 1979 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

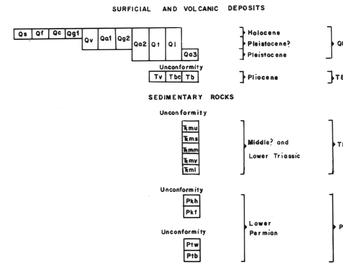
QUADRANGLE LOCATION

GEOLOGIC MAP OF THE WOLF HOLE MOUNTAIN EAST QUADRANGLE, NORTHERN MOHAVE COUNTY, ARIZONA

By
George H. Billingsley

1990

CORRELATION OF MAP UNITS



INTRODUCTION

Wolf Hole Mountain East quadrangle is located in northern Mohave County Arizona, about 8 miles south of the Utah-Arizona State line (fig. 1). The map area encompasses approximately 63 sq mi of northwestern Arizona. Elevations range from 3,880 ft at Quail Canyon to 6,416 ft on Wolf Hole Mountain. The nearest settlement is St. George, Utah, about 15 miles north of the map area. The main access to the area is by dirt road locally referred to as the Mt. Trumbull road that leads from St. George.

The area is mostly managed by the U.S. Bureau of Land Management with some privately owned land at Wolf Hole Lake (fig. 2). Below 5,000 ft, the area is sparsely vegetated with sagebrush, greasewood shrubs, cactus, and desert grasses; at higher elevations are sagebrush, pinion pine, juniper, and oak trees.

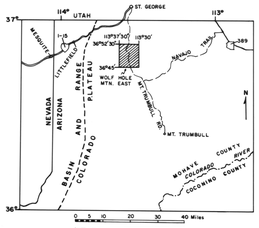


Figure 1. Location map of Wolf Hole Mountain East 7.5-minute quadrangle, northern Mohave County, Arizona.

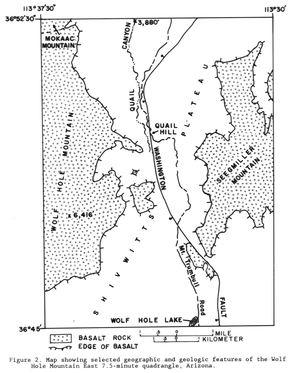


Figure 2. Map showing selected geographic and geologic features of the Wolf Hole Mountain East 7.5-minute quadrangle, Arizona.

PREVIOUS WORK

A preliminary geologic map of the Washington Fault zone covering part of the quadrangle at a scale of 1:24,000 was made by Petersen (1983). The area was included in state geologic maps at a scale of 1:500,000 (Wilson and others, 1969) and at a scale of 1:1,000,000 (Reynolds, 1988). Geologic maps in preparation of bordering areas include, on the north, the Lizard Point 7.5-minute quadrangle, Arizona; to the northwest, the Purgatory Canyon 7.5-minute quadrangle, Arizona; and to the west, the Wolf Hole Mountain West 7.5-minute quadrangle, Arizona.

GEOLOGIC SETTING

The quadrangle lies in the northern part of the Shivwits Plateau, a subplateau of the southwestern Colorado Plateau Geologic Province characterized by Mesozoic and Paleozoic strata that dip about 3° to the east and northeast. The area is cut by the Washington fault, a high-angle reverse fault that displace the strata about 250-550 ft up to the east (fig. 2).

STRATIGRAPHY

About 1,600 ft of Permian and Triassic rock strata are exposed in the quadrangle. Lower Triassic rocks once covered the entire area but have been eroded away except where protected by Late Tertiary basalt flows. The formations exposed are, in ascending order; the Toroweap and Kaibab Formations (lower Permian), and the Moenkopi Formation (Middle? and Lower Triassic). The oldest formation, the Brady Canyon Member of the Toroweap Formation, crops out along the northern part of the Washington fault. Some of the bedrock at the surface of this quadrangle, away from the basalt capped mountains, is gray soil of the Moenkopi Formation; it is commonly covered by talus and colluvium. The less resistant strata of the Moenkopi Formation crop out in patches below basalt-capped highlands.

The K-Ar age of the youngest basalt flow on Seegmiller Mountain is 2.35 ± 0.31 m.y. and 2.44 ± 0.51 m.y., a late Pliocene age (Reynolds and others, 1986). The basalt flows of Wolf Hole and Mokaac Mountains are assumed to be of similar age because they occupy similar elevations and stratigraphic position, and appear to be lithologically the same. Stream-deposited and mass-moved surficial deposits cover much of the bedrock area. Details of the stratigraphy are given in the description of map units.

GEOMORPHOLOGY

Erosion of Mesozoic and Paleozoic strata that dip about 3° easterly to northeasterly has resulted in the development of cuestas and strike valleys perpendicular to regional dip. During much of the tertiary, the cuestas and associated strike valleys have migrated some distance down-dip to the east. Late Pliocene basalt flows occupy former strike valleys and one paleo-valley cut across the dip. The flows have been eroded away from the dip slope near Quail Hill (fig 2). The basalts are not regionally tilted but some are locally faulted.

The gypsum in individual beds and in gypsiferous siltstone and mudstone in the Moenkopi Formation is easily removed in solution. As a consequence, Moenkopi strata cropping out on steep slopes beneath the basalt-capped highlands are unstable. Shallow blocks of Moenkopi strata give way and in sliding down, sap the basalt capcock, which becomes part of the landslide. Breaks to small to show on the map, have developed on Wolf Hole Mountain where the dip facilitates slippage along bedding planes. The landslide masses probably began their movement in the Pleistocene and have continued to slide intermittently.

STRUCTURAL GEOLOGY

Faults

The Washington fault, named by Petersen (1983), is a high-angle reverse fault with displacement down to the west. It has a north strike in the central part of the quadrangle, and a northeast strike in the northern part. The fault plane dips to the southeast in the northern part about 80-86° visible on a slope just east of the Mt. Trumbull Road in the northeast quarter of section 22, T40N, R12W. Moenkopi strata in the footwall of the fault displays reverse fault drag with overturned strata. The Washington fault has an estimated maximum stratigraphic throw of about 760 ft in the northern part, decreasing to about 300 ft along in the south. The author is uncertain how far south the fault maintains its high-angle reverse characteristic. The fault probably continues south to the east side of Wolf Hole Mountain and Wolf Hole Lake but the fault plane at that vicinity is not exposed (fig. 2).

Most of the movement along the Washington fault occurred after deposition of late Pliocene basalt flows because they and underlying strata are about equally displaced. Recent movement has occurred along the fault as evidenced by a poorly defined fault scarp up to 12 ft high in steep talus on deposits a few miles north of the quadrangle, and up to 8 ft in alluvium south of Wolf Hole Lake. Fault traces of different displacements are shown as a solid line on the map with estimated displacements in parenthesis.

A north-trending fault cuts the basalt flows on Wolf Hole Mountain with displacement down to the west. The fault and associated faults may reflect a southern extension of the Mokaac fault farther to the northeast because of a similar strike and sense of displacement.

Folds

A small doubly plunging syncline is in the north-central part of the map. Numerous local small anticlines and synclines associated with solution of gypsum near drainages are too small to show at map scale.

Collapse Structures

Circular collapse structures, minor folds, and other surface irregularities in the Kaibab and Moenkopi Formations are mostly due to solution of gypsum and gypsiferous siltstone.

Some circular, bowl-shaped areas in the Kaibab Formation that have toward-dipping strata may be collapse-formed breccia pipes, originating in the underlying Mississippian Redwall Limestone (Wenrich, 1985; Wenrich, 1986). On this map such features, commonly with inward-pointing dip symbols, are marked by a dot, 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 collapse features related to solution of gypsum (Wenrich and others, 1986). The deep-seated breccia pipes are potential host for economic deposits of copper and uranium; the shallow structures are unlikely to be mineralized (Wenrich, 1985).

Sinkholes are depressions in the land surface caused with the solution of gypsum in the Harrisburg Member of the Kaibab and Virgin Limestone Member of the Moenkopi Formation. These are denoted with the letter "S" and a small triangle symbol when the sinkhole forms an enclosed depression or cave on the land surface. The sinkholes are young features, Holocene and perhaps as old as Pleistocene, and are often partly filled with colluvial deposits.

DESCRIPTION OF MAP UNITS

Surficial Deposits

Qs **Stream-channel alluvium (Holocene)**--Unconsolidated to poorly sorted, interlensing silt, sand, and pebble to boulder gravel. Intermingled with colluvial, alluvial-fan, and valley-fill deposits. Subject to high-energy flows and flash floods. Little or no vegetation. Contacts approximate. Estimated thickness 10-30 ft

Qf **Floodplain deposits (Holocene)**--Interbedded, unconsolidated, silt, sand, and pebble to boulder gravel; intertongues with stream-channel, valley-fill, alluvial-fan, and talus deposits. Subject to flooding. Sparse grass, cactus, rabbitbrush, and sagebrush. Thickness about 5-20 ft

Qc **Colluvial deposits (Holocene)**--Chiefly silt and fine-grained sand, and lesser amounts of angular pebble to cobble gravel; locally consolidated. Accumulates in enclosed basins created by landslide debris or sinkhole depressions. Subject to temporary ponding. Sparse or no vegetation. Estimated thickness about 10-30 ft

Qg1 **Young terrace deposits (Holocene)**--Unconsolidated pebble to cobble gravel, composed chiefly of equally of well-rounded limestone, sandstone, and basalt clasts and interstratified lenses of silt and sand. Commonly merges with stream-channel, floodplain, alluvial-fan, talus, and valley-fill deposits. Forms a bench about 3-15 ft above modern stream beds. Thickness averages about 3-20 ft

Qv **Valley-fill deposits (Holocene and Pleistocene?)**--Partly consolidated silt, sand, and pebble to boulder gravel; small boulder gravel; a combination of playa, and sheetwash alluvium; commonly adjacent to talus and alluvial fans. Subject to sheet wash and ponding; cut by arroyos in larger valleys. Thickly vegetated by sagebrush and grass. Thickness about as much as 30 ft

Qa1 **Low alluvial-fan deposits (Holocene and Pleistocene?)**--Unconsolidated silt and sand; containing gravel composed of subangular to rounded pebbles to boulders of basalt and chert; locally cemented by calcite and gypsum. Merges with stream-channel, valley-fill, floodplain, and older alluvial-fan deposits near their downslope ends. Subject to erosion by flash floods and sheet wash. Sparse to moderate vegetation by pinion pine, juniper trees, and sagebrush. Thickness probably as much as 20 ft

Qg2 **Low terrace-gravel deposits (Holocene and Pleistocene?)**--Similar to younger terrace-gravel deposits (Qg1) but contains beaches and abandoned stream channels about 15-30 ft above modern stream beds. Merges with and locally overlain by talus, alluvial-fan, and alluvium shed from older surficial deposits. Thickness about 3-20 ft

Qa2 **Low-intermediate alluvial-fan deposits (Holocene and Pleistocene)**--Similar to low alluvial-fan deposits (Qa1) but contains more basalt clasts; partly cemented by calcite and gypsiferous caliche, which resembles a sandy plaster, and generally lies at higher elevations. Sparse to moderate vegetation of pinion pine juniper trees, sagebrush, and some grass. Thickness ranges from about 10 to 60 ft

Qt **Talus deposits (Holocene and Pleistocene)**--Unsorted debris consisting of small to very large angular blocks, sand, and silt; unconsolidated to partly consolidated, in part cemented by calcite and gypsum. Merges with landslide and alluvial-fan material. Sparse to moderate vegetation of pinion pine or juniper trees at higher elevations, sagebrush, cactus, and desert grasses at lower elevations. Only the relatively extensive deposits are shown. Thickness is as much as 25 ft

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 highlands where basalt and underlying non-resistant rock has broken from rim and slid down as a loose incoherent jumbled mass. Subject to further movement. Sparse vegetation dominated by sagebrush, cactus, grass, pinion pine and juniper trees. Unstable when wet. Thickness probably as much as 100 ft

Qa3 **High-intermediate alluvial-fan deposits (Pleistocene)**--Similar to younger alluvial-fan deposits (Qa1 and Qa2), but basalt clasts are more common and the clasts are coated with desert varnish. Isolated remnants form a protective caprock over non-resistant beds of the Kaibab Formation on Seegmiller Mountain.

Tv **Volcanic center and vent area (Pliocene)**--A probable vent area with scattered deposits of light-red basaltic cinder and scoria. Some vents erode out in a circular drainage pattern; others have dikes and plugs of dark gray, dense, fine-grained olivine basalt. Source areas for one or more basalt flows of Wolf Hole and Seegmiller Mountains

Tbc **Basalt scoria and cinder deposits (Pliocene)**--Red-brown clasts of fragmentary, angular, basaltic cinder and scoria deposits; contains dark-gray olivine basalt clasts; unconsolidated. Associated with volcanic vent areas. Little to moderate vegetation of pinion pine and juniper trees. Forms slope. Thickness as much as 300 ft

Tb **Basalt flows (Pliocene)**--Dark-gray, olivine basalt; finely crystalline olivine in an aphanitic groundmass. Seegmiller Mountain flows are dated at ages of 2.35 ± 0.31 and 2.44 ± 0.51 m.y. old (Reynolds and others, 1986). Locally covered by caliche cemented silt, sand, and angular fragments of basalt up to about 10 ft thick at some locations. Forms unconformable caprock over less resistant beds of the Moenkopi and Kaibab Formations at Seegmiller, Mokaac, and Wolf Hole Mountains. Basalt flows fill pre-late Pliocene strike valleys, which have a northerly gradient of about 300 ft per mile. Unit consists of several flows, attains a maximum thickness of about 320 ft on Wolf Hole and Seegmiller Mountains

SEDIMENTARY ROCKS

Moenkopi Formation (Middle? and Lower Triassic)--Includes, in descending order, the upper red, Shinarump, middle red, Virgin Limestone, and lower red as defined by Stewart and others (1972). The Timpoweap Member is not present in this quadrangle

Ꞧ mu **upper red member**--Interbedded sandstone of conglomerate, sandstone, siltstone, mudstone, and minor gypsum. Forms ledges and slopes. Top has been eroded away. Thickest sequence, about 200 ft under basalt flows of Wolf Hole Mountain

Ꞧ ms **Shinarump Member**--Interbedded white laminated, aphanitic dolomite and gypsum; red siltstone, mudstone, and sandstone are minor components. Exposed locally below Tertiary basalt flows of Wolf Hole, Mokaac, and Seegmiller Mountains and in landslide blocks. Top has been eroded away at Seegmiller Mountain; upper contact is placed at uppermost white siltstone bed. Forms cut slope with some ledges. Thickness ranges from about 375 to 450 ft

Ꞧ mm **middle red member**--Interbedded red-brown laminated siltstone and sandstone, white and gray gypsum, minor white platy dolomite, green siltstone, and gray-green gypsiferous mudstone; abundant veins of gypsum in siltstone. Upper contact placed at base of lowest bed of light gray dolomitic limestone. Poorly exposed; forms slope. Thickness ranges from about 145 to 580 ft.

Ꞧ mv **Virgin Limestone Member**--Light-gray, thin-bedded, ledge-forming, fossiliferous limestone beds (3-15 ft thick) separated by white to pale-yellow, slope-forming, thin-bedded gypsum and gypsiferous siltstone; includes brown, red, and green siltstone, gray limestone, and brown platy calcarenite. Upper contact placed at top of the highest bed of gray limestone. Thickness ranges from about 0 to 160 ft because of erosional unconformity at the base of the Moenkopi Formation. Average thickness about 130 ft

Ꞧ ml **lower red member**--Interbedded red, thin-bedded, sandy siltstone, gray, white, and pale-yellow laminated gypsum and minor sandstone. Sediments are in part reworked from the Harrisburg Member of the Kaibab Formation. Upper contact placed at the base of lowest bed of limestone. Forms slope. Thickness ranges from about 0 to 200 ft; thickness in paleo-valleys and pinches out locally against paleo-hills of Kaibab Formation

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

Pkh **Harrisburg Member**--Consists of light-gray, fossiliferous, sandy, fine- to medium-grained, limestone interbedded with red and gray gypsiferous siltstone and sandstone, gray gypsum in beds several feet thick. Beds, of about 20 ft thick, of cherty limestone are present in the upper part and locally near the middle of the member. Solution of interbedded gypsum has locally distorted the member. Upper contact is unconformable and locally obscure where overlain by surficial landslide or talus deposits. Forms slope with limestone ledges; thickness ranges up to about 350 ft

Pkf **Fossil Mountain Member**--Yellow-gray to gray, fossiliferous, sandy, cherty, fine- to medium-grained, thin-bedded, limestone. Chert weathers black in cliff outcrops. Intergrades with overlying Toroweap Formation and underlying Harrisburg Member. Forms a cliff and siltstone slope forms topographic break. Forms a cliff. Thickness about 250-300 ft

Toroweap Formation (Lower Permian)--Includes, in descending order, the Woods Ranch, and Brady Canyon Members as defined by Sorauf and Billingsley (in press). The Seligman Member is not exposed in this map area

Ptw **Woods Ranch Member**--Gray siltstone and pale-red shale with thick interbeds of massive, white to gray gypsum. Commonly covered by talus and landslide debris. Much subsidence and distortion of beds as a result of solution of gypsum. Forms slope. Upper contact is an unconformity marked by solution and channel erosion; has local relief of as much as 15 ft; contact generalized because of extensive cover by talus and landslide. Average thickness about 150 ft

Ptb **Brady Canyon Member**--Gray, weathers dark gray, fossiliferous, medium-bedded, medium- to coarse-grained, limestone. Thin beds of dolomite are found at upper contacts. Intergrades with overlying Woods Ranch Member; upper contact placed at top of cliff. Forms a cliff. Average thickness about 250 ft

Contact between rock units--Dashed where approximate

Fault--Dashed where approximately located, short dashed where inferred; dotted where concealed; bar and ball on downthrown side. D means reverse fault; number is estimated displacement in hundred feet; arrow shows direction of horizontal displacement of Holocene alluvium

Landslide detachment--Headward scarp of landslide

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

Strike and dip of strata
- Inclined--Strike and dip measured in the field
- Vertical--Strike and dip determined photogeologically
- Implied--Strike and dip determined photogeologically, no measurements

Strike and dip of vertical joints

Collapse structure--Circular collapses with strata dipping inward towards a central point. May reflect deep-seated breccia-pipe collapse originating in the Redwall Limestone

Sinkholes--Steep walled collapse features not associated with inward dipping strata. Sinkhole depressions are filled with colluvial deposits

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