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

Geologic map of the Mount Trumbull NW quadrangle, northern Mohave County, Arizona

by
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[1]U.S. Geological Survey, Flagstaff, Arizona

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INTRODUCTION

This report of the Mount Trumbull NW quadrangle of the Colorado Plateau is part of a cooperative U.S. Geological Survey and National Park Service project to provide geologic information of areas in or near the Grand Canyon of Arizona. Most of the Grand Canyon and parts of the adjacent plateaus are geologically mapped at the 1:500,000 scale. This map contributes detailed geologic information to a previously inadequately mapped area. The geologic information presented here will assist in future geological studies related to land use management, range management, and flood control programs by federal and state agencies and private enterprises.

The nearest settlement to this map area is Colorado City, Arizona, about 83 km (52 mi) north in a remote region of the Arizona Strip, northwestern Arizona (fig. 1). Elevations in the map area range from about 1,780 m (5,840 ft) in the northeast corner of map to 2,447 m (8,029 ft) at Mount Trumbull (southeast quarter of the map). Primary vehicle access to this area is by dirt road locally known as the Mount Trumbull Road (fig. 1); unimproved dirt roads, such as the Temple Trail in the northwest corner of the map and jeep trails, lead to various locations within the map area. Travel on the Mount Trumbull road and the Temple Trail is possible with 2-wheel-drive vehicle, except during wet conditions. Four-wheel drive vehicles are recommended for all other roads and trails in the map area. Extra fuel, two spare tires, extra food and water are highly recommended when traveling in this remote area.

The map area is managed by the U.S. Bureau of Land Management, Arizona Strip District, St. George, Utah, and includes about 3 sections of land belonging to the State of Arizona, and about 2.5 sections of private land. The private land is mostly in Potato Valley and the Lake Valley area. Part of the Sawmill Mountains and Mount Trumbull were originally established in 1904 as part of the Dixie National Forest. In 1924 the Dixie National Forest became the Kaibab National Forest. On February 13, 1974, this part of the Kaibab National Forest was transferred to the Bureau of Land Management (Personal communication, Becky Hammond, Bureau of Land Management, Spring, 1997). Mount Trumbull and part of the Sawmill Mountains are now part of designated wilderness areas (not shown on map). Lower elevations within the map area support a moderate growth of sagebrush, cactus, and grass. Sagebrush, grass, cliffrose bush, pinion pine, juniper, ponderosa pine, and oak forest thrive at elevations above 1,830 m (6,000 ft).

PREVIOUS WORK

Reconnaissance photo geologic mapping of this area was compiled onto Arizona state geologic maps by Wilson and others (1969) and revised by Reynolds (1988). A preliminary geologic map of the southern half of this map area was produced by Billingsley and Huntoon, 1983. Geologic mapping of adjacent areas include (fig. 1): (1) the upper Hurricane Wash and vicinity, which adjoins the northwest corner of this map

(Billingsley, in press a), (2) the Clayhole Valley and vicinity, which adjoins the north edge of this map (Billingsley, in press b), (3) the upper Parashant Canyon and vicinity, which adjoins the west edge of this map (Billingsley, in press c), and (4) the Mount Logan quadrangle, which borders this area on the south (Billingsley, 1997; fig. 1).

MAPPING METHODS

This map was produced by interpretation of 1976 infrared 1:24,000-scale aerial photographs, followed by extensive field checking. Volcanic rock deposits were mapped as separate mappable units when possible and identified by the highest associated cinder cone or local ranch. Some lava flows and associated cinder cones at similar stratigraphic levels could not be distinguished with certainty from one another and were mapped as a general undifferentiated Quaternary basalt unit. Many of the Quaternary alluvial deposits having similar lithology, but different geomorphic characteristics, were mapped almost entirely by photogeologic methods. Stratigraphic position and amount of erosional degradation helped determine differences between young and old alluvial deposits of similar lithology. Each map unit and structure was investigated in detail in the field to insure accuracy and consistency of description.

GEOLOGIC SETTING

The map area lies within the Uinkaret Plateau, a subplateau of the Colorado Plateaus physiographic province. This part of the Uinkaret Plateau is characterized by nearly flat-lying and gently east-dipping Paleozoic and Mesozoic sedimentary strata that are warped by minor folds. These strata have an average regional dip of about 1° or 2° east-northeast. This map lies between two major structures, the Hurricane Fault and Monocline, about 1.5 km (1 mi) west of the map, and the Toroweap Fault and Monocline, about 6.5 km (4 mi) east of the map. Vertical displacement of the Paleozoic and Mesozoic strata across the Hurricane Fault is estimated at about 610 m (2,000 ft) down to the west, and across the Toroweap Fault at about 110 m (350 ft) down to the west.

Tertiary and Quaternary volcanic deposits are widely distributed in the map area representing part of the Uinkaret Volcanic Field. The volcanic rocks consist mostly of alkali olivine basalt flows, dikes, and pyroclastic deposits (Hamblin, 1994). The Quaternary alluvial deposits include artificial fill and quarries, terrace-gravels, alluvial fans, valley fill, talus, and landslides. Map contacts between various surficial deposits are intertonguing and/or gradational, both laterally and vertically. All alluvial and colluvial deposits in the map area are assigned a Quaternary age because they contain clasts derived from Quaternary and older basaltic rocks of this map, as they do in adjacent areas (Billingsley, 1997; in press a, b, and c). The subdivision of alluvium on the map is intended to be useful for planning of roads, flood control, vegetation studies, soil investigations, erosion control, and other environmental land management decisions.

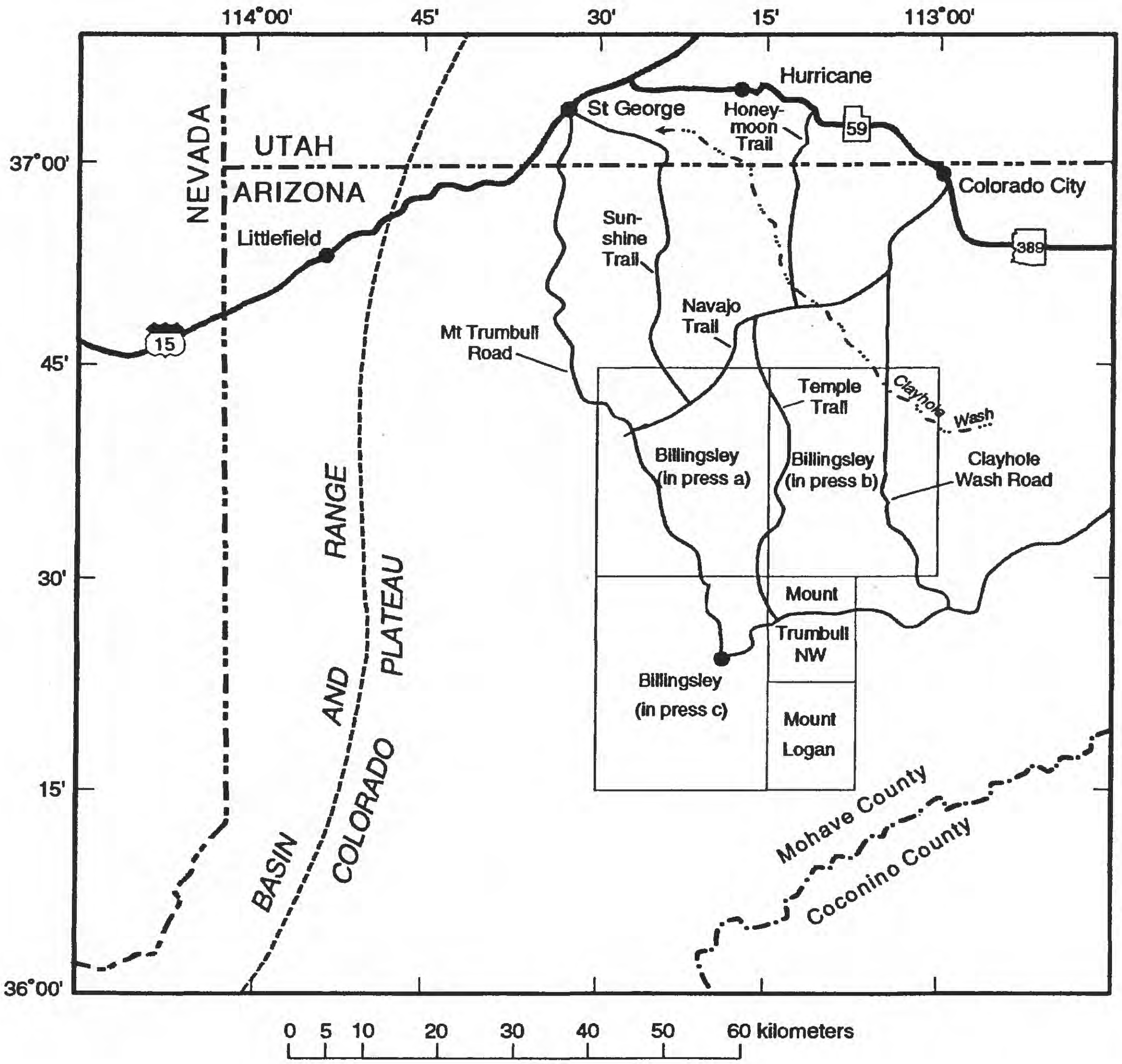

Figure 1. Index map for the Mount Trumbull NW quadrangle, northern Mohave County, northwestern Arizona.

PALEOZOIC AND MESOZOIC SEDIMENTARY ROCKS

About 60 m (200 ft) of Permian strata and about 300 m (1,000 ft) of Triassic strata are present in the map area, but these strata are largely covered by volcanic rocks or landslide debris. The Paleozoic and Mesozoic rocks, in order of decreasing age, are the Kaibab Formation (Lower Permian), the Moenkopi Formation (Upper, Middle and Lower Triassic), and the Chinle Formation (Upper Triassic). About 60 m (200 ft) of pale-red and gray gypsifereous sandstone and limestone of the Harrisburg Member of the Kaibab Formation are exposed in the northwest quarter of the map area. Some of the Harrisburg Member is removed by Tertiary and Quaternary erosion where not unconformably overlain by strata of the Moenkopi Formation or volcanic rocks.

A regional unconformity separates the Permian and Triassic strata. After deposition of the Harrisburg Member of the Kaibab Formation, stream channels were eroded into the Harrisburg forming paleoriver valleys and associated tributaries as much as 50 m (160 ft) deep in the map area. A large paleovalley, designated as Parashant valley (Billingsley, in press c) is exposed in the northwest corner of the map and filled with sediments of the Timpoweap Member of the Moenkopi Formation. Parashant valley joins with another paleovalley called Poverty valley, just west of this map (Billingsley, in press c). Parashant valley is traced for about 24 km (15 mi) west of this map to Poverty Mountain, and Poverty valley is traced about 24 km (15 mi) west of the map. Imbrication of pebbles in the conglomerate beds of the Timpoweap indicate deposition of sediment was by streams that flowed towards the north and east, mainly east. The chert, limestone, and sandstone clasts of the Timpoweap are locally derived from the Kaibab Formation.

Gray conglomerate and sandstone, light-brown to red siltstone and sandstone, gray gypsum, and gray limestone of the Triassic Moenkopi Formation unconformably overlie the Permian Kaibab Formation, but much of these rocks are covered by alluvium or volcanic rocks. However, about 475 m (1,579 ft) of the Moenkopi Formation, and about 120 m (400 ft) of the Chinle Formation is exposed at Hells Hole, about 1.5 km (1 mi) south of the southwest corner of this map area (Billingsley, 1997). Strata of the Moenkopi and Chinle Formation are mostly covered by talus, landslide debris, or basalt flows in the Mount Trumbull area. Float material containing petrified wood fragments at scattered locations on the west side of Mount Trumbull suggest that part of the Chinle Formation is present under the basalt flows that cap the mountain, but the Chinle strata are not exposed. Other than minor outcrops of the Timpoweap Member and lower red member of the Moenkopi Formation in the northwest corner of the map area, most of the Moenkopi strata is covered by basalt flows or landslide debris at Mount Trumbull and the Sawmill Mountains.

VOLCANIC ROCKS

More than 30 cinder cones of the Uinkaret Volcanic Field, Tertiary and Quaternary age, dot the landscape in this map area. The most prominent landmark of the maps area is Mount Trumbull, a nearly flat-lying section of Moenkopi and Chinle strata capped by Tertiary basalt flows. The basalt flows have formed a protective caprock preserving the underlying soft strata of the Chinle and Moenkopi Formations. The Chinle and Moenkopi strata are easily eroded, and seepage of water through the basalt flows toward the edges of the flows have helped to induce landslide development on the soft strata around the entire basalt caprock.

There are three whole-rock K-Ar ages of the Tertiary basalt flows in or near this map area: (1) a 3.67±0.09 Ma age from the Mount Trumbull Basalt (Best and others, 1980; (2) a 3.6±0.18 Ma age from the Bundyville basalt just east of this map (Reynolds and others, 1986); and (3) a 2.63±0.34 Ma age from the Mount Logan basalt just south of this map area (Reynolds and others, 1986). There have been no age determinations of any of the younger basalt flows in the map area. Jackson (1990) reported a whole rock K-Ar age of 0.635±0.24 Ma from a basalt flow about 8 km (5 mi) east of this map near the upper end of Toroweap Valley; Wenrich and others (1995) have reported a whole rock K-Ar age of 760±0.08 Ma for the Tuckup Canyon basalt flow about 25.5 km (16 mi) east of the map area; and Billingsley (1994a) reported a whole rock K-Ar age of 0.83±0.28 Ma age from the Antelope Knoll Basalt about 29 km (18 mi) north of this map. There are several K-Ar ages between 1.2 and 0.17 Ma from basaltic rocks within the Grand Canyon about 24 km (15 mi) south of this map (Hamblin, 1994). The youngest basalt flow, the Little Spring basalt (Billingsley, 1997), flowed into the map area from the south (south edge of the map), and appears to be only a few thousand years old at most. The surface freshness of this basalt flow is comparable to the thousand year old surface basalt flows of Sunset Crater near Flagstaff, Arizona.

Most of the basalt flows erupted from dikes or vent areas identified by cinder cones. Several dikes are suspected of being buried by subsequent flows, cinder cones, or landslide masses. The volcanic rocks have preserved a unique part of the geomorphic landscape history of the this part of the Arizona Strip. However, age determinations of these rocks are currently inadequate to establish a detailed chronological order of events that helped shape this landscape within the last 2 to 3 million years.

Most of the volcanic rocks of this map area are assumed to be Quaternary age, except for the Mount Trumbull basalt on Mount Trumbull. Some of the Quaternary basalt flows and pyroclastic deposits have formed isolated mappable units that abut against or overlap similar age basalt flows within this map and north of this map (Billingsley, in press b). For descriptive and location purposes, the mappable basalt units of this map area are informally named for nearby ranches, or the elevation of the highest cinder cone that the flows came from. The basaltic rocks are briefly described as follows; oldest to youngest:

Mount Trumbull Basalt

Hamblin (1970) was the first to mention the basaltic rocks on top of Mount Trumbull and informally referred to them as the Mount Trumbull basalt as they are in this report. The Mount Trumbull basalt caps Mount Trumbull, the highest mountain in the Uinkaret Volcanic Field (El. 8,029 ft; southeast quarter of the map area). The K-Ar age of the Mount Trumbull basalt is 3.67±0.09 Ma (Best and others, 1980). The basalt erupted from one large dike or neck on the north side of the mountain, the highest part of the mountain. Part of the basalt flowed west about 1.5 km (1 mi) into what may have been a nearly flat, narrow, paleovalley less than a quarter mile wide eroded into the Shinarump or Petrified Forest Member of the Chinle Formation. But most of the basalt flowed east and southeast down the widening paleovalley descending over 300 m (1,000 ft) in 2.5 km (1.5 mi). Since the eruption of the Mount Trumbull basalt, the Triassic strata is now eroded away around Mount Trumbull, leaving the Mount Trumbull basalt preserving an inverted paleovalley. The steepened soft slopes around Mount Trumbull have subsequently become covered by landslide debris.

A 60 m (200 ft) high cinder cone (cinder cone 7847) on the south rim of Mount

Trumbull appears to be a younger Quaternary age volcano that erupted on top of the Mount Trumbull basalt. The basalt flows that came from cinder cone 7847 flowed down the south flank of Mount Trumbull and were later subjected to landslide disruption. Cinder cone 7847 is in alignment with other nearby north-south oriented Quaternary cinder cones north and south of Mount Trumbull. For this reason, cinder cone 7847 on top of Mount Trumbull is here considered to be Quaternary age. Future studies and age determinations are needed to confirm the Quaternary age for this small volcano.

Craigs Knoll and Berry Knoll basalt

Craigs Knoll is the second highest volcano in the map area that forms a prominent landmark about 300 m (1,000 ft) high, about 5 km (3 mi) northeast of Mount Trumbull mountain. Craigs Knoll is named for Craig Ranch, which lies at the lower eastern slope of Craigs Knoll. Berry knoll is a 110 m (360 ft) high cinder cone just north of this map area, and part of the cone is in the extreme northwest edge of this map area. Lava flows from Berry Knoll, Craigs Knoll, and another unnamed cinder cone were mapped as undivided basalts along the north edge of this map by Billingsley (1994b). The basalt flows from Craigs Knoll, Berry Knoll, and the unnamed cinder cone cannot be mapped with certainty from one another and the three volcanoes appear to have erupted simultaneously, therefore, they and are mapped as one informal unit, the Craigs Knoll/Berry Knoll basalt. The Craigs Knoll/Berry Knoll basalt is named from the basalt flows and pyroclastic deposits associated with Craigs Knoll (sec. 4, T. 35 N., R. 8 W), Berry Knoll (sec. 24, T. 36 N., R. 9 W), and the unnamed cinder cone (sec. 30, T. 36 N., R. 8 W), northern Mohave County, Arizona (northwest quarter of this map). Berry Knoll is on the Moriah Knoll 7.5' quadrangle, that borders the north edge of this map.

Craigs Knoll is extensively eroded on its eastern side revealing at least two eruptive phases. The first phase one was the eruption of a basalt flow onto a nearly flat, low-hilly terrain of the Harrisburg Member of the Kaibab Formation. The extent of the first phase flows are not known because they were subsequently covered by basalt flows of the phase two eruption. A gray and tan pyroclastic cone, as much as 245 m (800 ft) high (Craigs Knoll), was formed on top of the first phase basalt flows before the second eruptive phase began.

The second eruptive phase, a fissure-like eruption of basalt on the north flank of Craigs Knoll, began shortly after the Craigs Knoll cinder cone was formed, but the time interval of this hiatus is unknown. The second eruptive phase produced a thick series of basalt flows that flowed out and down in a radial pattern from Craigs Knoll, covering the northern half of Craigs Knoll cinder cone and the landscape west, north, and east of Craigs Knoll. This second eruptive phase formed an additional hill on the north side of Craigs Knoll, which may have been a partial cinder cone because of the crater-like shape of the vent area, now mostly covered by basalt flows.

The second phase basalt of Craigs Knoll flowed mostly north about 8 km (5 mi; undivided basalt of Billingsley, 1994b and in press b). On the west flank of Craigs Knoll, about 1.5 km (1 mi), the second phase basalt flow is offset about 60 m (200 ft) along a north-south fault. Just north of this map (Billingsley, 1994b), displacement of the basalt and underlying strata are the same indicating the fault is younger than the Craigs Knoll and Berry Knoll basalt. There are no age determinations for either the first or second eruptive phases of the Craigs Knoll basalt.

Berry Knoll and the unnamed cinder cone (hill elevation 6,342) and associated basalt flows cannot, with certainty on aerial photos or in the field, be separated from basalt flows that came from Craigs Knoll. Hand samples of basalt from all three have a very similar composition and texture. Therefore, the basaltic rocks from these three volcanoes are all mapped as one unit, the Craigs Knoll/Berry Knoll basalt. It is probable that all three volcanoes erupted simultaneously and their lava flows coalesced as one north of this map area.

STRUCTURAL GEOLOGY

High angle to nearly vertical normal faults and gently tilted strata are the structural characteristic of this part of the Uinkaret Plateau. There may be several north-south trending faults in the map area that parallel the north-south cinder cone alignment, but they are covered by alluvium or basalt flows. Based on the evidence of volcanic dikes and cone alignments mapped in adjacent areas, the north-south cone alignments of this map area are mainly a reflection of the north-south joints and fractures in the bedrock, although joints in the bedrock are not clearly visible on aerial photographs in this map area.

Locally warped and bent strata too localized to show at map scale are the result of Pleistocene and Holocene solution of gypsum in the Harrisburg Member of the Kaibab Formation. These bent strata are commonly associated with the solution of gypsum along drainages or joints in the Langs Run drainage area, northwest quarter of the map area. The solution of gypsum is also responsible for several sinkhole depression near the Langs Run drainage. Sink Valley and Lake Valley are formed by local Quaternary basalt flows that have encircled the areas forming enclosed drainage valleys. The valley areas have accumulated temporary lake or valley-fill deposits. Temporary ponded water has enhanced the solution of gypsum in the underlying Kaibab Formation, which in turn helps deepen these valleys.

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

Surficial deposits (Holocene and Pleistocene)--Surficial deposits are differentiated from one another chiefly by photogeologic techniques on the basis of difference in morphologic character and physiographic position. Older alluvial fans and terrace-gravel deposits generally exhibit extensive erosion whereas younger deposits are either actively accumulating material, or are lightly eroded as observed on 1976 aerial photographs. Surficial units on this map may have slightly different names and descriptions than units with the same map symbols on adjoining maps, but are characteristically the same

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

Qs **Stream-channel alluvium (Holocene)**--Interlensing silt, sand, and pebble to boulder gravel; unconsolidated and poorly sorted. Locally overlaps alluvial-fan (Qa_1), terrace-gravel (Qg_1), and upper part of valley-fill (Qv) deposits. Inset against intermediate alluvial fan (Qa_2) and older terrace-gravel (Qg_2) deposits. Stream channels subject to high-energy flows and flash floods. Little or no vegetation in stream channels. Contacts with other alluvial deposits are approximate. About 1 to 2 m thick

Qf **Floodplain deposits (Holocene)**--Gray and brown, fine-grained, silt, sand, and cinder deposits; nearly flat-bedded, partly consolidated with gypsum cement. Contains abundant local basaltic cinder and scoriaceous sand. Contacts with young alluvial fan (Qa_1) and valley-fill (Qv) deposits approximate. Accumulates fine-grained sediments in enclosed drainage basins formed by Quaternary basalt flows. Subject to frequent flooding and local ponding. Supports sparse growth of grass. More than 10 m thick

Qg_1 **Young terrace-gravel deposits (Holocene)**--Light-brown, pale-red, and gray silt, sand, and pebble to boulder gravel composed about equally of well-rounded limestone and sandstone clasts and angular to subrounded chert clasts derived from the Kaibab Formation. Includes abundant well-rounded to subangular basalt clasts. Forms benches about 1 to 3 m above modern stream beds; locally inset into older terrace-gravel (Qg_2), and older alluvial fan (Qa_2) deposits. About 1 to 3 m thick

Qa_1 **Young alluvial fan deposits (Holocene)**--Gray-brown silt and sand. Includes lenses of coarse gravel composed of subangular to rounded pebbles and cobbles of limestone, chert, and sandstone locally derived from Permian and Triassic strata; locally includes abundant well-rounded to sub-angular basalt clasts. In volcanic areas, composed mainly of pyroclastic debris and basalt fragments. Intertongues with young terrace-gravel (Qg_1) deposits, overlaps older alluvial fan (Qa_2) deposits. Subject to extensive erosion by sheet wash and flash flood debris flows and minor arroyo erosion. Supports moderate growth of sagebrush, cactus, and grass. 1 to 4 m or more thick

Qc **Colluvial deposits (Holocene and Pleistocene)**--Black and reddish, coarse grained, fragmentary, cinder, scoria, ash, and basalt clasts; locally consolidated by siltstone and calcite cement. Common in enclosed basins or depressions in landslide areas. Limited to local accumulations generally not associated with stream drainages. Subject to temporary ponding. Supports sparse growths of grass and juniper trees. About 1 to 3 m thick

Qv **Valley-fill deposits (Holocene and Pleistocene)**--Gray and light-brown silt, sand, and lenses of pebble to small-boulder gravel; partly consolidated; includes well-rounded clasts of limestone, sandstone, and angular chert fragments derived from Kaibab Formation; includes basaltic rock fragments and cinder sand. Intertongues or overlaps talus (Qt), young and old terrace-gravel (Qg_1 and Qg_2), and young and old alluvial fan (Qa_1 and Qa_2) deposits. Represents relatively less-active, low-gradient, alluvial stream-channel or shallow valley drainage deposits. Subject to sheetwash flooding; locally cut by arroyos as much as 2 m deep. Supports moderate growth of sagebrush, grass, and cactus. About 1 to 5 m thick

Qt **Talus deposits (Holocene and Pleistocene)**--Unsorted breccia debris composed of small and large angular blocks of local basalt on steep to moderately steep slopes below landslide debris. Includes, in minor amounts, silt, sand, and gravel; partly cemented by calcite and gypsum. Intertongues with alluvial fans (Qa_1 and Qa_2), valley-fill (Qv), and landslide (Ql) deposits. Supports moderate growth of sagebrush, cactus, grass, pinyon pine and juniper trees. Only thick or extensive deposits shown. About 2 to 6 m thick

Ql **Landslide deposits (Holocene and Pleistocene)**--Unconsolidated masses of unsorted rock debris. Includes detached blocks of basalt and bedrock that have rotated backward and slid downslope as loose incoherent masses of broken rock and deformed strata. Includes large angular blocks of basalt as much as 3 m in diameter. Found principally below Tertiary basalt flows of Mount Trumbull and in the Sawmill Mountains. Supports moderate to dense growth of sagebrush, grass, oak brush, juniper trees, pinyon trees, and ponderosa pine trees. Unstable when wet. Thickness ranges from 3 to 45 m, averages about 12 m thick

Qa_2 **Young intermediate alluvial fan deposits (Holocene and Pleistocene)**--Similar to young alluvial fan (Qa_1) deposits, but partly cemented by calcite and gypsum. Commonly overlapped by young alluvial fan (Qa_1) or young terrace-gravel (Qg_1) deposits; intertongues with or overlaps valley-fill (Qv) and talus (Qt) deposits. Includes abundant, subrounded to subangular basalt cobbles and boulders. Supports moderate growth of sagebrush, cactus, grass, juniper trees, and pinyon pine trees. Ranges from 2 to 25 m thick

VOLCANIC ROCKS

Little Spring basalt (Holocene)--Informally named for Little Spring (SE 1/4, sec. 16, T. 34 N., R. 8 W. (Mount Logan 7.5' quadrangle, Arizona), just west of Arkansas Ranch, northern Mohave County, Arizona (Billingsley, 1997). The olivine basalt represents the youngest volcanic rocks in the map area as well as the Uinkaret Volcanic Field. There are no Whole-rock K-Ar age determinations, but based on freshness of basalt flow surfaces and their similarity to basalt flows at Sunset Crater near Flagstaff, Arizona, this volcanic deposit is probably less than 2,000 years old

Qlsb **Basalt flow**--Dark-gray, finely crystalline to glassy, alkali olivine basalt. Groundmass composed of plagioclase and olivine. Forms clinkers and highly broken aa surface. Includes one flow that reaches the map area from the vent area about 1.8 km (1.3 mi) south of this map. Overlies older Quaternary basalt flows (Qub) and valley fill (Qv) deposits. About 4 m thick

Quaternary basalt deposits, undivided (Pleistocene)--Includes basalt flows, pyroclastic deposits, dikes and or necks. Several flows and cinder cones that are difficult to separate on aerial photographs or in the field, and have adjoining boundaries are mapped as undifferentiated basalt deposits. Quaternary flows that have mappable boundaries and can be identified to one or more cinder cones, are informally designated with an elevation number or name of the highest associated cinder cone, or a name of a local nearby ranch for location and description purposes. These basalt units are randomly listed and not assigned in order of increasing or decreasing age

Basalt of Kenworthy Ranch--Informally named for the Kenworthy Ranch in Sink Valley, Uinkaret Plateau, northern Mohave County, Arizona (sec. 1, T. 35 N., R. 9 W). Divided into:

Qkrp **Pyroclastic deposits**--Reddish-black and red tuff, ash, scoriaceous ejecta, and cinders; unconsolidated. Overlies associated basalt flows. Map contact is approximate. Includes three unnamed cinder cones that are aligned in a north-south strike. The northern cinder cone (hill 6430) is about 49 m (160 ft) high and is just west of the Kenworthy Ranch buildings, the middle cinder cone (hill 6348) is about 24 m (80 ft) high, and the southern cinder cone (hill 6355) is also about 24 m (80 ft) high

Qkrb **Basalt flows**--Light- to dark-gray, finely crystalline alkali-olivine basalt. Includes small phenocrysts of augite and olivine in glassy groundmass. Flows radiate out all directions from all three cones coalescing to form a large elongated north-south oval mass. Overlies Harrisburg Member of the Kaibab Formation. Thickness averages about 15 m.

Basalt of Marshall Ranch--Informally named for Marshall Ranch about 2.5 km (1.5 mi) south of the Kenworthy Ranch, Uinkaret Plateau, northern Mohave County, Arizona (sec. 13, T. 35 N., R., 9 W). Divided into:

Qmrp **Pyroclastic deposits**--Reddish-black and red tuff, ash, scoriaceous ejecta, and cinders; unconsolidated. Deposits overly associated basalt flows. Includes two unnamed cinder cones and three small secondary cinder cones (spatter cones). The secondary cones appear to have erupted from the basalt flows that came from the southern-most cinder cone (hill 6633). The northern cinder cone (hill 6538) is about 73 m (240 ft) high and the southern cinder cone (hill 6633) is about 85 m (280 ft) high

Qmrb **Basalt flows**--Gray-black, finely crystalline, alkali-olivine basalt. Most of the basalt came from the southern cinder cone (hill 6633) and flowed out in a radial pattern from the cone. Most of the basalt flowed in a westerly direction about 3 km (2 mi). Partly overlies the basalt of Potato Valley at its southern margin, and overlies the Harrisburg Member of the Kaibab Formation elsewhere. Thickness ranges from about 12 to 36 m (40 ft to 120 ft)

Basalt of hill 6375--Informally named for an unnamed cinder cone (hill 6375 elevation) at the north end of Sink Valley, Uinkaret Plateau, northern Mohave County, Arizona (sec. 31, T. 35 N., R. 8 W). Divided into:

Qp6375 **Pyroclastic deposits**--Reddish-black cinder and scoria that overly an associated basalt flow. Includes a small deposit on and at the north end of the associated basalt flow that may be a local splatter cone deposit from the basalt flow. The main deposit at hill 6375 is about 64 m (210 ft) thick

Qb6375 **Basalt flow**--Dark-gray olivine basalt. Consists of one basalt flow that flowed west 0.5 km (0.25 mi), and north about 1.5 km (1 mi). Overlies the Harrisburg Member of the Kaibab Formation. 1 to 12 m (3 to 40 ft) thick

Basalt of hill 6646--Informally named for an unnamed cinder cone (hill 6646 elevation) at the northwest end of Sink Valley, Uinkaret Plateau, northern Mohave County, Arizona (sec. 35, T. 36 N., R. 9 W). Divided into:

Qp6646 **Pyroclastic deposits**--Red and black cinder and scoria deposits that overly an associated basalt flow. Includes one large cinder cone and two adjacent small cone deposits. There are three vent eruptive centers with the main cone that are aligned in a north-south strike, which also aligns with the north-south strike of the Kenworthy Ranch cinder cones south of this area. The cone is about 76 m (250 ft) high

Qb6646 **Basalt flow**--Dark-gray alkali-olivine basalt. Consist of one basalt flow that flowed north about 3 km (2 mi). Overlies the Harrisburg Member of the Kaibab Formation. Ranges in thickness from about 10 to 30 m (30 to 100 ft)

Basalt of hill 6457--Informally named for an unnamed cinder cone (hill 6457 elevation) north of and below Mount Trumbull, Uinkaret Plateau, northern Mohave County, Arizona (sec. 16, T. 35 N., R. 8 W). Divided into:

Qp6457 **Pyroclastic deposits**--Reddish-black cinder and scoria deposits. Includes two small cinder cones that partly overlie the associated basalt flow. The northern cone appears to have erupted from the basalt flow, which came from the southern cone because they are only 0.4 km (0.25 mi) apart. The southern cone (hill 6457) is 36 m (120 ft) high, and the northern cone (no number) is about 24 m (80 ft) high

Qb6457 **Basalt flow**--Dark-gray olivine basalt. Consists of one flow that came from hill 6457 and flowed about 0.8 km (0.50 mi) north onto a flat alluvial filled valley. The basalt accumulated to a thickness of about 36 m (120 ft

Basalt of Potato Valley--Informally named from Potato Valley, Uinkaret Plateau, northern Mohave County, Arizona (sec. 25, T. 35 N., R. 9 W). Includes several cinder cones and associated basalt flows along the north and west side of Potato Valley. Divided into:

Qpvp **Pyroclastic deposits**--Red and black cinder, tuff, ash, and scoriaceous ejecta. Includes two main cinder cones and five associated cinder or vent areas. The main cinder cone on the north side of Potato Valley is not named or numbered, but forms a cone to about elevation 6680, and the main cinder cone (hill 6744) is on the west side of Potato Valley. These two cinder cones, hill 6744 and 6689, appear to be the main producers of associated basalt flows the ring the northern and western side of Potato Valley. Several smaller cinder cones on the associated basalt flows appear to have erupted from the flows, such as hill 6370, 6484, 6482, and two other unlabeled deposits. The thickest deposit on the west side of Potato Valley is about 106 m (350 ft), and on the north side of Potato Valley, about 85 m (280 ft)

Qpvb **Basalt flows**--Dark-gray alkali-olivine basalt. Flows on the north side of Potato Valley came mostly from an unnamed cinder cone (hill elevation about 6680) and flowed northwest about 3 km (2 mi). These flows appear to have merged or coalesce with flows from cinder cone hill 6744 on the west side of Potato Valley, and together have formed a basalt dam that is responsible for the accumulation of alluvial sediments that now fill Potato Valley. The basalt flows on the west side of Potato Valley flowed mostly north about 5 km (3 mi). Thickness ranges about 2 to 25 m (6 to 50 ft)

Undifferentiated basalt flows and pyroclastic deposits--Includes several unnamed cinder cones and associated basalt flows along the eastern edge of the map area north of Mount Trumbull, and along the southern edge of the map area south and southwest of Mount Trumbull. Divided into:

Qui **Intrusive dikes or necks**--Dark-gray to black olivine basalt. Forms ridges or round necks that protrude above cinder cone deposits or basalt flows, south-central edge of map. Widths of dikes shown on map are approximate

Qup **Pyroclastic deposits**--Reddish-black, red, and gray tuff, ash, scoriaceous ejecta, cinder, and bombs; deposits north of Mount Trumbull are partly consolidated, deposits south of Mount Trumbull are largely unconsolidated. Includes one 60 m (200 ft) high cinder cone on top of Mount Trumbull. Deposits overlie associated basalt flows as cinder cones or thick cinder sheet deposits. Map contacts are approximate and show thickest deposits. No whole rock K-Ar ages are available. Most cinder cones average about 60 m (200 ft) high

Qub **Basalt flows**--Dark-gray to black olivine basalt. Basalt flows intertongue or coalesce to form massive flows that erupted simultaneously along north-south fissure zones that formed one or more cinder cones along the east edge of this map area. Most of the thick basalt flows are east of this map area. Thickness ranges from 6 to 60 m (12 to 200 ft)

Craigs Knoll/Berry Knoll basalt (Pleistocene)--Informally named from Craigs Knoll (sec. 4, T. 35 N., R. 8 W), and Berry Knoll (sec. 24, T. 36 N., R. 9 W), northern Mohave County, Arizona. Includes dikes, pyroclastic deposits and basalt flows that appear to have erupted simultaneously at Craigs Knoll, Berry Knoll and another unnamed cinder cone (hill 6342) between Craigs Knoll and Berry Knoll

Qcbi **Intrusive dikes or necks**--Greenish-black olivine basalt. Widths of dikes shown are approximate

Qcbp **Pyroclastic deposits**--Gray and reddish-gray to black cinder, tuff, ash, and scoriaceous ejecta; mostly consolidated into welded tuff. Forms a cliff on the east side of Craigs Knoll, and a steep slope on the south and west side. Deposits are mostly covered by dark-gray basalt on the north side of Craigs Knoll. Includes a small cinder deposit on the southern flank of Craigs Knoll. Overlies an associated basalt flow exposed on the south flank of Craigs Knoll. Deposits are about 183 m (600 ft) thick

Qcbb **Basalt flows**--Light-gray and dark-gray alkali-olivine basalt. Includes a lower basalt and an upper basalt. There are no K-Ar age determinations for these flows. The lower basalt flow accumulated on the Harrisburg Member of the Kaibab Formation, and perhaps part of the lower members of the Moenkopi Formation. Estimated thickness of lower flow, about 40 m (130 ft). The upper basalt, a dark-gray, alkali-olivine basalt, erupted near the top of Craigs Knoll on the north flank and flowed to the west, north, and east of Craigs Knoll. The most extensive basalt flows went north as far as 8 km (5 mi). Estimated thickness, 3 to 20 m (10 to 65 ft)

Mount Trumbull basalt (Pliocene)--Informally named for Mount Trumbull (Hamblin and Best, 1970; Hamblin, 1970), Uinkaret Plateau, northern Mohave County, Arizona, (sec, 27, T. 35 N., R. 8 W.; southeast quarter of map area). Whole-rock K-Ar age, 3.6±0.0.18 Ma (Reynolds and others, 1986). Divided into:

Tmi **Intrusive rocks**--Gray-black, finely crystalline, alkali-olivine basalt. Approximate map contact. Forms highest point of Mount Trumbull (el. 8,029 ft), north side of Mount Trumbull. Source for Tertiary basalt flows on Mount Trumbull. Width, about 120 m (400 ft) or more

Tmb **Basalt flow(s)**--Gray-black, finely crystalline, alkali-olivine basalt. Groundmass contains olivine phenocrysts and plagioclase laths. Consists of one or more thin basalt flows that now form caprock overlying concealed purple and white mudstone and sandstone beds of Petrified Forest Member of Chinle Formation at west side of mountain (exposed in landslide float material), overlies upper red member and possible Shnabkaib Member of Moenkopi Formation, east side of mountain (as exposed in landslide blocks just east of map area). Partly covered by Quaternary cinder cone southeast of Nixon Spring. Ranges about 30 to 60 m thick

SEDIMENTARY ROCKS

Chinle Formation (Middle Triassic)--Concealed by Mount Trumbull basalt and landslide debris, but found in float material in landslide debris. Not shown on map. Exposed beneath Tertiary Mount Logan basalt about 7.2 km (4.5 mi) southwest of Mount Trumbull (Billingsley, 1997). Includes Shinarump? and Petrified Forest Members. At Mount Logan, includes Shinarump and Petrified Forest Members, Shinarump Member locally missing or has undergone local facies change to white sandstone lithology similar to Petrified Forest Member lithology

Moenkopi Formation (Lower Triassic)--Includes, in descending order, the upper red member, Shnabkaib Member, middle red member, Virgin Limestone Member, lower red member, and Timpoweap Member as used by Stewart and others (1972). Upper red, and Shnabkaib units are present only in landslide debris around Mount Trumbull. Divided into:

TRmm **Middle red member**--Red-brown, thin-bedded to laminated, slope-forming siltstone and sandstone. Includes white and gray gypsum beds, minor white platy dolomite, green siltstone, and gray-green to red gypsifereous mudstone. Gradational and arbitrary lower contact with Virgin Limestone Member placed about 10 m above gray limestone bed of Virgin Limestone (southwest corner of map). Top part covered by landslide debris. Average thickness for this area, about 120 m (Billingsley, 1997). About 15 m exposed

Ꞧmv **Virgin Limestone Member**--Consists of one, sometimes two light-gray, thin-bedded to thinly laminated, ledge-forming limestone bed, 0.5 to 2 m thick; includes overlying, pale-yellow, red, and bluish-gray, thin-bedded, slope-forming gypsifereous siltstone. Unit thins south and west, thickens north. Erosional contact with underlying lower red member of Moenkopi Formation placed at base of lowest limestone bed. Thickness about 20 m

Ꞧml **Lower red member**--Red, fine-grained, thin-bedded, gypsifereous, slope-forming, sandy siltstone; and gray, white, and pale-yellow laminated gypsum and minor sandstone. Lower part contains redeposited gypsum and siltstone of Harrisburg Member of Kaibab Formation. Gradational contact with underlying Timpoweap Member of Moenkopi Formation placed at lowermost red siltstone bed. Locally, unconformably overlies Harrisburg Member of Kaibab Formation where Timpoweap is absent. Locally thickens in paleovalleys, and thins onto eroded paleohills of underlying Harrisburg. Ranges from 5 to 18 m thick

Ꞧmt **Timpoweap Member**--Light-gray, slope and cliff-forming conglomerate in lower part and light-gray to light-red, slope-forming calcareous sandstone in upper part. Conglomerate composed of subangular to rounded pebbles and cobbles of gray and dark-gray limestone, white and brown chert, and gray sandstone in matrix of gray to brown, coarse-grained sandstone. Upper part includes beds of low-angle cross-bedded, calcareous, yellowish sandstone, conglomerate, and minor red siltstone. Includes calcite and gypsum cement. All detritus in Timpoweap derived from Kaibab Formation. Fills paleovalley (Parashant valley of Billingsley, in press c) about 1,500 m wide and as much as 70 m deep that eroded into Harrisburg Member of Kaibab Formation (northwest quarter of map area). Imbrication of pebbles in conglomerate show general northeastward flow of depositing streams. Ranges from 0 to 70 m thick

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

Pkh **Harrisburg Member**--Includes two parts, middle and lower; upper part is not exposed in map area. Middle part is gray, thin-bedded, ledge-forming, cherty limestone that weathers dark brown or black often forming bedrock surface of exposed Harrisburg Member. Lower part is light-gray or yellow, thin-bedded, slope-forming sandy limestone and light-gray, gypsifereous siltstone and fine- to medium-grained calcareous sandstone; gray, medium-grained, thin-bedded sandy limestone; and gray, massive bedded gypsum. Solution of gypsum in lower part has locally distorted limestone beds of middle part, causing them to slump or bend into local drainages in the Langs Run drainage area and Lake Valley area. Gradational and arbitrary contact with underlying Fossil Mountain Member at top of cherty limestone cliff of Fossil Mountain just west of this map area (Billingsley, in press c). As much as 76 m thick

Contact

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

Landslide scarp--Headward scarp of landslide; hachures point in direction of slide

Flow direction of basalt--Interpreted from aerial photographs of flow channels, collapsed lava tubes, marginal flow levees, and frontal lobes

Volcanic vent area

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CORRELATION OF MAP UNITS