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

Geologic map of the Rock Canyon quadrangle, northern Mohave County, Arizona

by
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Open-File Report OF92-449

1992

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INTRODUCTION

The Rock Canyon 7.5' quadrangle (96 sq km) is located in northern Mohave County, Arizona, about 21 kilometers south of Hurricane, Utah, the nearest settlement (fig. 1). Elevations range from about 927 m (3,040 ft) at Fort Pearce Wash (northwest corner of quadrangle) to about 1,656 m (5,432 ft) on the Hurricane Cliffs (southwest corner of quadrangle). Access to the quadrangle is by dirt road locally referred to as the Sunshine Trail, west of the quadrangle, and the Navajo Trail, south of the quadrangle (fig. 1). Several unimproved dirt roads lead off from these trails to various locations within the quadrangle.

The quadrangle area is managed entirely by the U.S. Bureau of Land Management including about 6 sections belonging to the State of Arizona and about 3 sections of private land in the vicinity of Clayhole Wash. The area is sparsely vegetated with sagebrush, cactus. Apache plume, cliff rose shrubs, and tamarisk (salt ceder) trees grow along main drainages.

PREVIOUS WORK

There is a previous photo-geologic map of this area by Marshall (1957). Prior to this work, the area was included in two Arizona state geologic maps at a scale of 1:500,000 (Wilson and others, 1969), and 1:1,000,000 (Reynolds, 1988). Geologic maps in preparation by the author of bordering areas include the Yellowhorse Flat (west), the Gyp Pocket (south), and the Lost Spring Mountain (east), 7.5' quadrangles, Arizona. The Hurricane 15' quadrangle, Utah (north) is in preparation by W.K. Hamblin, Brigham Young University, Provo, Utah.

MAPPING METHODS

Geologic mapping of the Rock Canyon quadrangle began with a general knowledge of Colorado Plateau geology based on literature and previous mapping experience on the 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 done covering at least 85% of the map area to verify geologic photo interpretations. Many of the alluvial Quaternary units are differentiated as to regional morphological characteristics by photogeologic methods, but have similar lithology. Fourth, a further photogeologic study was conducted to provide consistency of 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 herein described are considered important for future environmental and land management planning of this quadrangle by federal, state and private concerns. The alluvial and igneous Quaternary units are key deposits that aid geomorphic interpretation of landscape development.

GEOLOGIC SETTING

The map area lies within the Colorado Plateau geologic province and includes the sub-provinces of the St. George Basin, and the Shivwits and Uinkaret Plateaus. The physiographic boundary between the lower elevations of the Shivwits Plateau and St. George Basin and the higher Uinkaret Plateau is

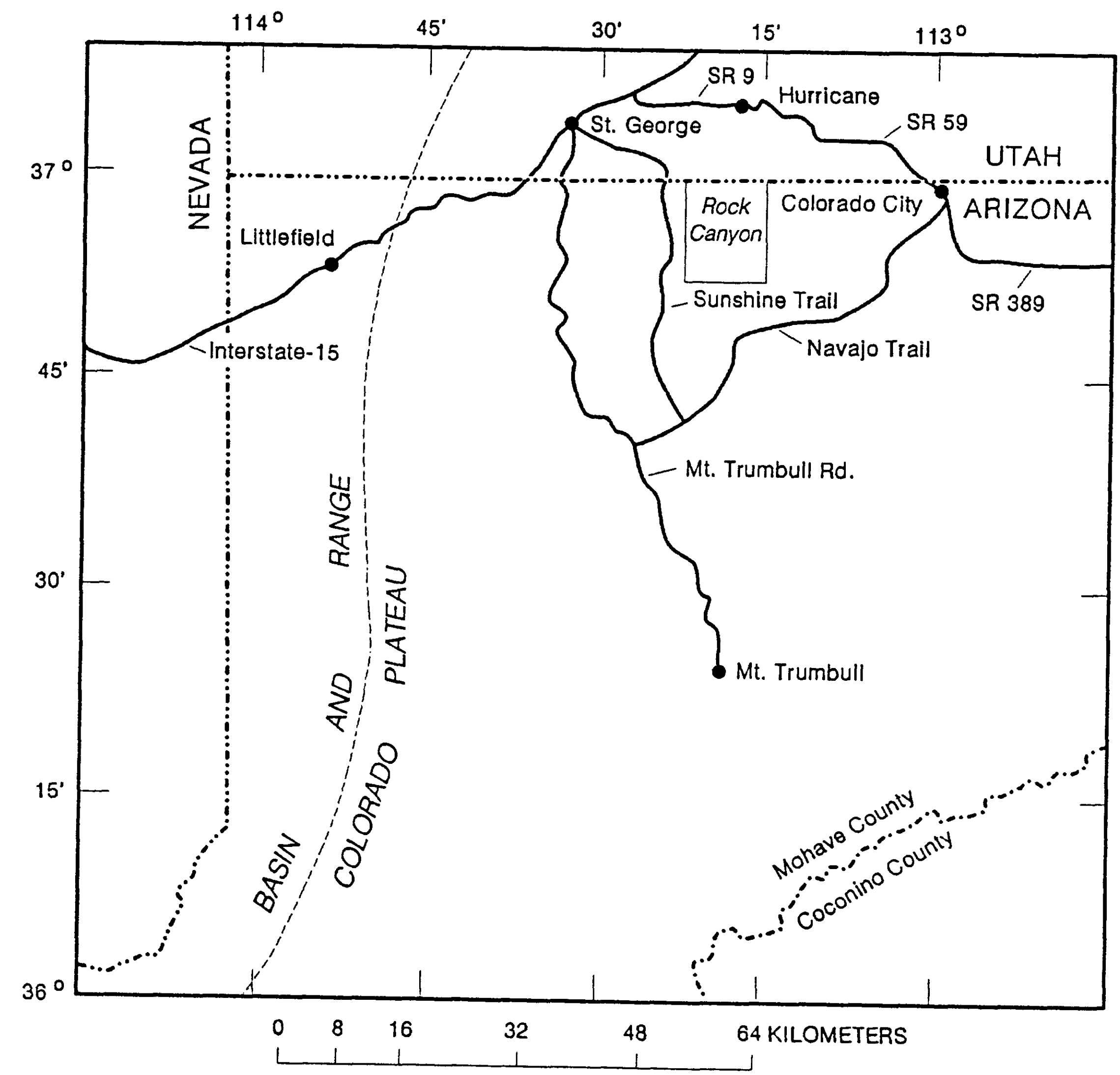

Figure 1. Index map of northern Mohave County, northwestern Arizona, showing Rock Canyon 7.5' quadrangle mapped in this report.

located along the rim of the Hurricane Cliffs, a prominent eroded fault scarp of the Hurricane fault (fig. 2). The boundary between the Shivwits Plateau and the St. George Basin is arbitrarily placed between the highest topography west of Hurricane Wash to the highest point of the Hurricane Cliffs east of Hurricane Wash (southwest corner of quadrangle; fig. 2).

The map area is characterized by nearly flat-lying Mesozoic and Paleozoic strata on the Shivwits and Uinkaret Plateaus with a regional average dip east of about 2°. The regional dip increases along the Hurricane monocline which parallels the Hurricane fault where dips are as much as 20° east. In the St. George Basin, an area more structurally deformed than the Shivwits or Uinkaret Plateaus, the strata are folded into locally plunging anticlines and synclines with general north-south trends. The Hurricane Cliffs, a large eroding fault scarp of the Hurricane fault, bisects the quadrangle in a general northeast-southwest strike exposing more than 610 m (2,000 ft) of Permian strata. West of the Hurricane fault in the St. George Basin, about 400 m (1,300 ft) of Mesozoic strata are exposed in folded terrain. Thickness of the Mesozoic strata is based on nearly flat-lying exposures at Lost Spring Mountain, about 12.8 km (8 mi) east of this quadrangle (Lost Spring Mountain West 7.5′ quadrangle). The Hurricane fault displaces strata down to the west about 1,000 m (3,300 ft) in the southern part of the quadrangle. Displacement increases to about 1,825 m (6,000 ft) near the Utah/Arizona State line, increasing to a possible 3,000 m (10,000 ft) north of Hurricane, Utah (Hamblin and Best, 1970).

Cenozoic deposits are widely distributed and 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 sedimentary bedrock strata include, in ascending order, the Esplanade Sandstone, Hermit Shale, Toroweap and Kaibab Formations (Lower Permian), and the Moenkopi and Chinle Formations (Upper, Middle? and Lower Triassic). The Esplanade Sandstone crops out at the bottom of the Hurricane Cliffs in Hurricane Wash, locally called Black Rock Canyon (southwest corner of quadrangle). About two-thirds of the exposed bedrock of the quadrangle consists of gray cherty limestone and gray-white siltstone and gypsum of the Kaibab Formation. The remaining exposed bedrock is red siltstone and sandstone, white gypsum and siltstone of the Moenkopi Formation, and small outcrops of red sandstone and siltstone of the Hermit Shale and Esplanade Sandstone. The Moenkopi Formation is mostly removed by erosion east of the Hurricane Cliffs, but significant patches of the formation remain in the northeast part of the quadrangle. Scattered outcrops of the Chinle Formation are exposed at various localities along the west side of the Hurricane fault but are mostly covered by alluvial surficial units.

The basalt flows in the southwest corner of the quadrangle, are assumed to be Pleistocene age because they rest on stratigraphy 430 m (1,400 ft) lower than stratigraphy capped by the Pliocene basalt flows of Seegmiller Mountain (2.35±0.3 to 2.44±0.5 Ma; Reynolds and others, 1986) about 11 km (7 mi) southwest of this quadrangle (Billingsley, in press). The basalt flows traveled east and downslope over an eroded Tertiary surface on dipping bedrock

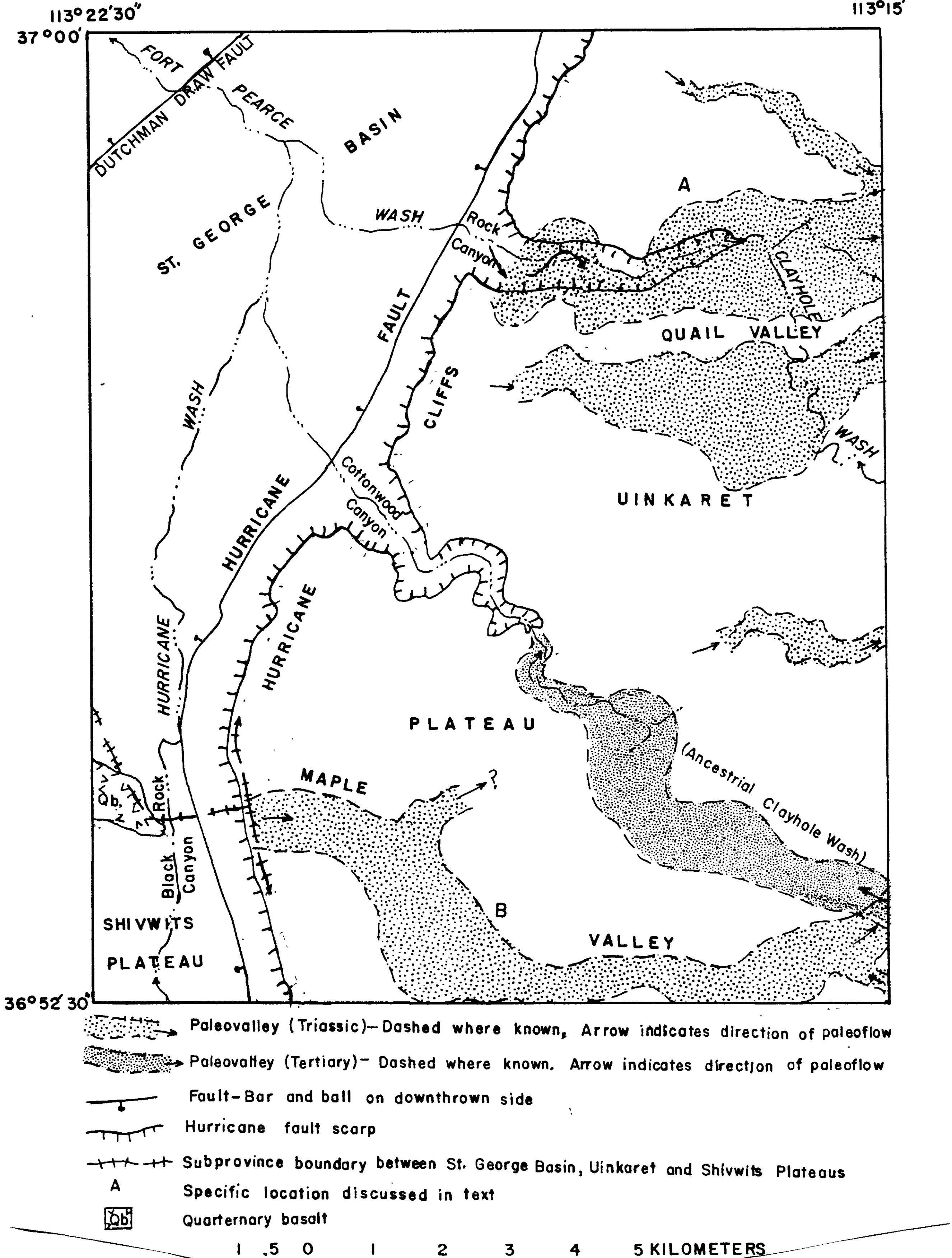

Figure 2. Selected geographic and geologic features of the Rock Canyon 7.5' quadrangle, northwestern Arizona.

strata (10° east) to the base of the Hurricane Cliffs. The bedrock strata are composed of gypsum and siltstone of the Shnabkaib Member of the Moenkopi Formation and conglomerate and mudstone of the Shinarump and Petrified Forest Members of the Chinle Formation. The basalt flows originated from several dike sources about 1.6 km (1 mi) west of the quadrangle (Yellowhorse Flat 7.5′ quadrangle). The basalt abutted against the Hurricane fault scarp then traveled north about one kilometer down Hurricane Wash.

Sometime after the basalt cooled, segments of the flows and underlying strata slid as a landslide mass down east-dipping Chinle mudstone towards Hurricane Wash. Erosion and removal of the basalt and Chinle sediments at Hurricane Wash has allowed large blocks of basalt and Chinle shales to gradually slide into Hurricane Wash, especially during wet conditions. It is possible that Holocene movement along the Hurricane fault triggered movements of the landslides.

The Quaternary age assigned to the alluvial deposits is based on field relationships of alluvial deposits with the Tertiary basalt flows of Seegmiller, Wolf Hole, and Black Rock Mountains west of this quadrangle (Billingsley, in press), and the Quaternary basalt (this quadrangle). Details of the stratigraphic sequence are given in the description of map units.

STRUCTURAL GEOLOGY

The Hurricane fault and monocline are the major structural features of this quadrangle. They parallel one another with a northeast-southwest strike in the northern three-quarters of the quadrangle, and a general north-south strike in the south quarter of the quadrangle. The axial trace of the Hurricane monocline is arbitrarily placed along the base of the present day Hurricane cliffs where stratigraphic dips of the bedrock, although mostly covered by alluvial deposits, are the greatest. The Mesozoic and Paleozoic strata dip southeast an average of 7° along the upthrown side of the Hurricane fault, northeast part of quadrangle. The monoclinal dip increases to about 14° east southwest part of quadrangle. The monocline flexure is about 3 km (2 mi) wide and the axial trace is shown as approximately midway between the upper and lower hinges of the fold.

The Dutchman Draw fault, in the northwest corner of the quadrangle, displaces strata down to the northwest about 18 m (60 ft). Minor faults and grabens and folds parallel the strike of the Hurricane fault.

Relatively recent movement (Holocene?) has occurred along parts of the Hurricane fault and lesser faults as evidenced by small fault scarps in talus and alluvial fans clearly seen on aerial photos. However, some of the scarps are not sharply defined in the field because mass-wasting of unconsolidated alluvial material has shed soft and loose debris over the scarps. Therefore, most of the Hurricane fault is shown dotted in the alluvial units, but where the fault line is prominent in the field and on aerial photos, a solid line is shown.

Short, plunging anticlines and synclines are present in the northwest quarter and other areas of the map. These folds, like others found elsewhere on the Colorado Plateau, are probably related to early Laramide compressional stresses (Huntoon, 1989). Warped and bent strata, too small to show at map scale, are the result of solution of gypsum in the Harrisburg Member of the Kaibab Formation and are often 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 of the Kaibab and Toroweap Formations. 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 Sutphin, 1989). Such features in the present map area, 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-related 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 when forming 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. Several drainages originate at sinkhole depressions in the southeast half of the quadrangle.

DESCRIPTION OF MAP UNITS

Surficial and volcanic deposits

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

Qs **Stream-channel alluvium (Holocene)**--Gray, unconsolidated and poorly sorted, interstratified silt, sand, and pebble to boulder gravel. Clasts are angular to rounded. Intertongues, or merges with alluvial fan (Qa_1), terrace-gravel (Qg_1 and Qg_2), valley fill (Qv), and talus (Qt) deposits. Stream channels subject to high-energy flows and flash floods and support little or no vegetation. Contacts with other map units are approximate. Estimated thickness 0.5 to 2.0 m (1 to 6 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. Partly cemented by calcite and gypsum. Accumulates in enclosed basins created by landslide debris. Supports little or no vegetation. Estimated thickness 3 to 9 m (10 to 30 ft)

Qg_1 **Young terrace-gravel deposits (Holocene)**--Light-brown, unconsolidated, pebble to boulder gravel and interstratified lenses of silt and sand. Large clasts composed about equally of well-rounded limestone and sandstone, angular and subrounded chert. Locally includes basalt clasts along Hurricane Wash. contains reworked materials from alluvial fans (Qa_1 and Qa_2), intermediate terrace-gravel (Qg_2 and Qg_3), landslide (Ql), and talus (Qt) deposits. Forms bench about 1 to 3 m (3 to 9 ft) above modern stream beds. Supports moderate to thick desert vegetation. Thickness averages about 1 to 6 m (3 to 20 ft)

Qa_1 **Young alluvial fan deposits (Holocene)**--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 west quarter of quadrangle; partly cemented by gypsum and calcite. Intertongues with stream-channel (Qs), valley-fill (Qv), and low terrace-gravel deposits (Qg_1); overlaps terrace-gravels (Qg_1, Qg_2, Qg_3), and older alluvial fan (Qa_2 and Qa_3) deposits near their downslope ends. Alluvial fan subject to erosion by sheet wash and flash floods. Supports sparse vegetation of greasewood shrubs, sagebrush, cactus, and grass. Thickness as much as 6 m (20 ft)

Qv **Valley-fill deposits (Holocene and Pleistocene?)**--Partly consolidated silt, sand, and interbedded lenses of pebble to small-boulder gravel. Intertongues with talus (Qt), young terrace-gravel (Qg_1), and alluvial fan (Qa_1, Qa_2) deposits. Valleys subject to sheetwash flooding and temporary ponding; arroyo cutting in some valleys. Support thick vegetation of greasewood shrubs, sagebrush, grass, and cactus. Thickness as much as 9 m (30 ft)

Qg_2 **Low terrace-gravel deposits (Holocene and Pleistocene?)**--Similar to young terrace-gravel deposits (Qg_1), partly consolidated; on benches and abandoned stream channels about 4 to 9 m (12 to 30 ft) above modern stream beds. Intertongues with alluvial fan (Qa_1, Qa_2) deposits, locally overlain by talus (Qt). Thickness about 2 to 5 m (5 to 15 ft)

Qa_2 **Intermediate alluvial fan deposits (Holocene and Pleistocene)**--Similar to young alluvial fan deposits (Qa_1), partly cemented by calcite and gypsum. Generally lies above, but often overlain or surrounded by young alluvial fan (Qa_1) and talus (Qt) deposits. Intertongues with or inset against older alluvial fan (Qa_3) deposits. Locally includes basalt clasts, southwest quarter of quadrangle. Moderately vegetated by greasewood shrubs, sagebrush, cactus, and some 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), terrace-gravels (Qg_1 and Qg_2), and valley-fill (Qv) deposits. Supports sparse vegetation of greasewood shrubs, 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. Consists of blocks of detached segments of strata that have rotated backward and slid downslope as loose, incoherent mass of broken rock and deformed strata over gypsum slopes of Toroweap Formation, commonly surrounded by talus in Cottonwood and Rock Canyons. Includes basalt flows and strata of Chinle Formation that have slid down over weak mudstone of Petrified Forest Member of the Chinle, southwest corner of quadrangle. Supports sparse vegetation of sagebrush, cactus, and grass. Unstable when wet. Thickness probably as much as 43 m (140 ft)

Qg_3 **Low intermediate terrace-gravel deposits (Pleistocene)**--Similar to young and low terrace-gravel deposits (Qg_1 and Qg_2), but 6 to 11 m (20 to 35 ft) higher than Qg_2 and about 8 to 18 m (25 to 50 ft) above modern drainages. Composed of well-rounded limestone, sandstone, and chert clasts in sandy gravel matrix. Locally includes abundant, well-rounded clasts of basalt. Partly consolidated by calcite, gypsum, and clay 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. Often adjacent to or overlapped by younger alluvial fans (Qa_1, Qa_2) and talus (Qt) deposits. Sparsely vegetated with grass, sagebrush, and cactus. Thickness about 3 to 6 m (10 to 20 ft)

Qg_4 **High intermediate terrace-gravel deposits (Pleistocene)**--Similar to young, low, and low-intermediate terrace-gravel deposits (Qg_1, Qg_2, Qg_3), but 3 to 2 m (10 to 20 ft) higher than Qg_3 and about 14 to 18 m (45 to 60 ft) above modern drainages. Composed of well-rounded basalt, limestone, sandstone and chert clasts in sandy, fine-grained matrix. Partly consolidated by calcite, and clay cement. Thickness as much as 9 m (30 ft)

Qg_5 **High terrace-gravel deposits (Pleistocene)**--Similar to young, low, low intermediate, and high intermediate terrace-gravel deposits (Qg_1, Qg_2, Qg_3, Qg_4), but 8 m (25 ft) higher than Qg_4 deposits and about 25 m (80 ft) above modern drainages. Composed of well-rounded chert, basalt, and limestone clasts in sandy matrix. Partly consolidated by calcite and clay cement. Thickness as much as 5 m (15 ft)

Qb **Basalt flows (Pleistocene)**--Dark-gray, massive, finely crystalline, aphanitic basalt; some large columnar joints **at** base of flows, but not common. Surfaces are blocky and irregular, partly covered by calcrete incorporating locally eroded clasts of basalt. Source of basalt flows are dikes and necks about 1 km west of the west-central map edge. Consists of one or more flows about 3 to 9 m (10 to 30 ft) thick

QTa **Older alluvial gravel deposits (Pleistocene? or Pliocene)**--Unconsolidated conglomerate, gravel, sandstone, and siltstone. Partly cemented with gypsum. Contains numerous black, brown, and yellow, well-rounded chert and quartzite pebbles averaging less than 2.4 cm (1 in) in diameter, and rare, rounded, petrified wood fragments derived from erosion of Shinarump Member of Chinle Formation. Deposits are thin, mostly stream lag gravel on Harrisburg Member of Kaibab Formation surface in ancestral Clayhole Wash valley. Ancestral Clayhole Wash responsible for existence of Cottonwood Canyon (fig. 2). Headward erosion of Rock Canyon drainage captured Clayhole Wash near southeast corner of quadrangle. Thickness 1 to 3 m (2 to 10 ft)

Sedimentary Rocks

Chinle Formation (Upper? Triassic)--Includes, in descending order, Petrified Forest and Shinarump Members as used by Stewart and others (1972)

ℜcp **Petrified Forest Member**--White, blue-gray, green-gray, pale-red, purple-red mudstone, siltstone, and some sandstone. Contains bentonitic clays derived from volcanic ash (Stewart and others, 1972). Petrified wood fragments common. Only lower part is exposed, upper two-thirds or more is eroded away. Commonly covered by talus or alluvial deposits. Gradational contact with underlying Shinarump Member. Forms slope. Thickness estimated about 24 m (80 ft)

Ꞧcs **Shinarump Member**--Orange-brown to tan, cobble to coarse-grained, thin-bedded and massive conglomerate and sandstone. Weathers dark-brown. Includes stream-channel deposits largely composed of well-rounded chert or quartzite clasts and gravel, about 30% of clasts are well-rounded black chert? or schist? Contains petrified log and wood fragments. Fills erosion channels cut into upper red member of Moenkopi Formation as much as 30 m (100 ft) deep. Unconformable contact with Moenkopi Formation. Forms cliff. Variable thickness 10 to 30 m (3 to 100 ft)

Moenkopi Formation (Upper?, Middle? and Lower Triassic)--Includes, in descending order, upper red member, Shnabkaib Member, middle red member, Virgin Limestone Member, lower red member, and Timpoweap Member as used by Stewart and others (1972). The Middle?-Lower Triassic boundary probably lies within the upper red member

Ꞧmu **Upper red member**--Heterogeneous sequence of red sandstone, siltstone, mudstone, conglomerate, and minor gray gypsum. Includes dark-red, thin-bedded, cliff-forming, sandstone in upper part. Gradational contact with Shnabkaib Member placed at color change from red to white bedded siltstone and sandstone. Forms ledge and slope sequence about 60 m (200 ft) thick

Ꞧms **Shnabkaib Member**--Interbedded, white, laminated, aphanitic dolomite and silty gypsum. Includes thin red beds of mudstone, siltstone and sandstone in lower and extreme upper parts. Gradational contact with middle red member placed arbitrarily at lowest, white, thick siltstone bed. Forms steep slope with ledges. Thickness as much as 107 m (350 ft)

Ꞧmm **Middle red member**--Interbedded, red-brown, laminated siltstone and sandstone, white and gray gypsum, thin, white platy dolomite, green siltstone, and gray-green gypsiferous mudstone. Gradational contact with Virgin Limestone Member arbitrarily placed at top of highest bed of light-gray Virgin Limestone bed. Forms slope. Thickness about 45 to 55 m (150 to 180 ft)

Ꞧmv **Virgin Limestone Member**--Consists of one, light gray, ledge forming, limestone bed. Unconformable, erosional contact with lower red member south and east of this quadrangle. Forms ledge in slope. Thickness about 10 m (35 ft)

TRml **Lower red member**--Interbedded red, thin-bedded, sandy siltstone, gray, white, and pale-yellow laminated gypsum, and dark-red, thin-bedded sandstone. Lower beds contain reworked gypsum and siltstone of Harrisburg Member of Kaibab Formation. Includes marker bed of light red, fine- to medium-grained, thinly-laminated to thin-bedded, calcareous, ledge-forming sandstone about 1 to 1.5 m (3 to 5 ft) thick. Marker bed contains raindrop impressions and rare carbonaceous plant fossils with malachite copper staining. Gradational contact with underlying limestone, sandstone, and conglomerate of Timpoweap Member, arbitrarily drawn at lower-most red siltstone bed. Unconformable contact with Harrisburg Member of Kaibab Formation. Locally thickens and thins in shallow Triassic paleovalleys eroded into underlying Kaibab Formation. Forms slope. Thickness about 37 m (120 ft)

TRmt **Timpoweap Member**--Light gray conglomerate and limestone. Upper part consists of fine-grained, thick-bedded limestone and interbedded gray, coarse-grained, low-angle, cross-bedded sandstone. Gradational with lower conglomerate and sandstone, unconformable with underlying Harrisburg Member of Kaibab Formation. Lower part consists of interbedded conglomerate and coarse-grained 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, derived from Kaibab Formation. Conglomerate beds are mostly clast supported, with matrix of light-gray limestone or gray, coarse-grained quartz sandstone, gravel, and minor siltstone with calcite and gypsum cement. Name Rock Canyon Conglomerate was proposed and abandoned by Gregory (1948; 1952), used by Nielson and Johnson, (1979), and Nielson, (1986 and 1991). Informally, conglomerate considered to be Permian, limestone considered to be Triassic by Nielson (1991), Conglomerate and limestone are considered Triassic this report. Fills Triassic paleovalleys eroded into Kaibab Formation estimated as much as 75 m (250 ft) deep and about 600 m (2,000 ft) wide (A and B, fig. 2). Erosion surface represents significant hiatus between Permian Kaibab and Triassic Moenkopi Formations. Quail valley (A, fig. 2), named by Billingsley (1990a), traced from Quail Canyon 23 km (15 mi) west of quadrangle. Maple valley (B, fig. 2), named by Billingsley (1990b) traced from Maple Canyon 24 km (15 mi) west of quadrangle. Imbrication of pebbles in paleovalleys show an easterly paleoflow of depositing streams. Upper limestone in Rock Canyon suggests westward extent of marine seas east of Hurricane, Utah (Nielson, 1986, 1991). Limestone and Conglomerate form cliff. Thickness 0 to 60 m (0 to 200 ft)

Ꞇml t **Lower red member and Timpoweap Member undivided**--Same lithologies as Ꞇml and Ꞇmt above. Consists of conglomerate and limestone lenses typical of Timpoweap Member interbedded with siltstone and gypsum beds typical of lower red member of Moenkopi Formation. Occupies shallow paleovalleys cut into underlying Harrisburg Member of Kaibab Formation. Unconformable contact with Kaibab Formation as local paleovalleys and paleohills with relief up to 30 m (100 ft). Contact locally obscure where overlain by surficial deposits. Forms slope with ledges. Thickness about 1 to 30 m (3 to 100 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; mostly eroded away except east-central part of quadrangle. A resistant, pale-yellow or light-gray, fossiliferous, sandy limestone bed, averaging 1 m (3 ft) thick, forms caprock ledge at top. Middle part is cliff forming marker bed consisting of upper, gray, thin-bedded, cherty limestone and lower, light-gray, thin-bedded, sandy limestone; chert weathers dark brown or black. Thickness of upper bed thickens or thins at the expense of lower. Often forms bedrock surface of quadrangle. Thinning to less than 10 m (30 ft) north part of quadrangle. Lower part of member consists of slope-forming, light-gray, fine- to medium-grained, gypsiferous siltstone, sandstone, thin-bedded gray limestone, and gray-white gypsum, mainly in southeast quarter of quadrangle. Solution of interbedded gypsum locally distorts limestone beds of middle part causing slumps or bending of strata into local drainages. Gradational and arbitrary contact between siltstone slope of Harrisburg Member and underlying limestone cliff of Fossil Mountain Member. Forms slope with middle cherty limestone cliff. Thickness as much as 75 m (250 ft)

Pkf **Fossil Mountain Member**--Light-gray, fine- to medium-grained, thin-bedded, fossiliferous, sandy, cherty limestone. Chert weathers black. Unconformable contact with Toroweap Formation marked by solution and channel erosion surface with relief estimated as much as 5 m (15 ft). Map contact generalized because of local talus cover. Forms cliff. Thickness about 90 m (300 ft)

Toroweap Formation (Lower Permian)--Includes, in descending order, Woods Ranch, Brady Canyon, and Seligman Members as defined by Sorauf and Billingsley (1991)

Ptw **Woods Ranch Member**--Gray, gypsiferous siltstone and pale-red silty sandstone with interbedded, medium-bedded, white gypsum. Commonly covered by thin talus. Beds locally distorted due to solution of gypsum. Gradational contact with underlying cliff-forming limestone of Brady Canyon Member. Thickness variable due to solution erosion, about 15 to 60 m (50 to 200 ft)

Ptb **Brady Canyon Member**--Gray, medium-bedded, medium- to coarse-grained, fetid, fossiliferous limestone; weathers dark gray. Includes thin-bedded dolomite in upper and lower part. Gradational contact with siltstone and gypsum of underlying Seligman Member. Forms cliff. Thickness about 90 m (300 ft)

Pts **Seligman Member**--Consists of an upper gray, interbedded, thin-bedded, dolomite and gypsiferous sandstone; middle gray to red, thin-bedded, interbedded, siltstone, sandstone, and gray gypsum; and lower brown and yellow, fine-grained, thin-bedded, low-angle, cross-bedded and flat-bedded sandstone. Unconformable, sharp, trough and planar contact with underlying red sandstone of the Hermit Shale. Forms slope with ledges upper and lower part. Variable thickness about 30 to 60 m (100 to 200 ft)

Ph **Hermit Shale (Lower Permian)**--Light red and white, fine-grained, thin- to medium-bedded sandstone and siltstone. Red sandstone ledges in upper part, white sandstone ledges in lower part. Upper and lower sandstone ledges separated by slope-forming, red siltstone and sandstone beds containing worm-tube? structures. Unconformable contact with underlying Esplanade Sandstone marked by shallow erosion channels with relief up to 3 m (10 ft). Erosion channels not common and laterally discontinuous. Map contact arbitrarily placed between lowest, thick-bedded, red siltstone slope and tan, thick-bedded, low-angle, cross-bedded, sandstone cliff. Thickness 230 to 245 m (760 to 800 ft)

Pe **Esplanade Sandstone (Lower Permian)**--Red, white, and tan, fine- to medium-grained, medium- to thick-bedded, low- and high-angle cross-bedded, cliff-forming, sandstone. Includes interbedded gray or red, fine-grained, thin-bedded, non-crossbedded, ledge and slope-forming, calcareous silty sandstone in upper and lower part. Sandstone cliff contains small, interbedded red siltstone recesses in upper part and pale-red, thin-bedded, slope-forming sandstone ledges in lower part. Base not exposed. Thickness about 135 m (440 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

Anticline

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 or enclosed depression or cave

Flow direction of basalt

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CORRELATION OF MAP UNITS