U.S. DEPARTMENT OF THE INTERIOR TO ACCOMPANY MF-2364
U.S. GEOLOGICAL SURVEY

GEOLOGIC MAP OF THE HOUSE ROCK QUADRANGLE, COCONINO COUNTY, NORTHERN ARIZONA

By George H. Billingsley

INTRODUCTION

This geologic map is part of a cooperative project between the U.S. Geological Survey and the Kaibab National Forest Service to provide geologic information for the Paradine Plains Cactus (*Pediocactus pardinei* Benson, 1957) Conservation Assessment and Strategy conducted by the Kaibab National Forest, Williams, Arizona. The map area includes part of House Rock Valley and part of the Kaibab Plateau, sub-physiographic provinces of the Colorado Plateau. This part of the Colorado Plateau was not previously mapped in adequate geologic detail. This map completes one of several remaining areas where uniform quality geologic mapping was needed. The geologic information in this report may be useful to future biological studies, land management, range management, and flood control programs for all federal, state, and private agencies.

The map area is in the North Kaibab Ranger District of the Kaibab National Forest and the Arizona Strip Field Office of the Bureau of Land Management (BLM). The nearest settlement is Jacob Lake about 8 km (5 mi) west of the map area (fig. 1). Elevations range from about 2,305 m (7,560 ft) on the Kaibab Plateau in the northwest corner of the map area to about 1,555 m (5,100 ft) in House Rock Valley in the east-central edge of the map area. Primary vehicle access is by U.S. Highway 89A in the northern part of the map area. Four-wheel-drive roads access most of the map area. Dirt roads are not passable in winter snow conditions.

The Bureau of Land Management Arizona Strip Field Office in St. George, Utah, manages the public lands, and the North Kaibab Ranger District in Fredonia, Arizona manages the U.S. National Forest system land. Other lands include one quarter of a section belonging to the State of Arizona, about 0.7 of a section of private land, and about 1.5 sections within the BLM-administered Paria Canyon-Vermilion Cliffs Wilderness Area (U.S. Department of the Interior, 1993). The private land is in House Rock Valley near State Highway 89A.

Lower elevations within upper House Rock Valley support a sparse growth of cactus, grass, and a variety of desert shrubs. Sagebrush, grass, cactus, cliffrose bush, pinion pine trees, juniper trees, ponderosa pine, and oak trees thrive at elevations above 1,830 m (6,000 ft).

Surface runoff in the map area drains eastward toward the Colorado River through House Rock Valley and into Marble Canyon of the Colorado River at Mile 17 (17 miles downstream from Lees Ferry, Arizona).

PREVIOUS WORK

Early photo reconnaissance geologic mapping of this area by Pomeroy (1957) and Wells (1960) was compiled onto an Arizona state geologic map by Wilson and others (1969) and recompiled by Reynolds (1988). Billingsley and Hampton (2001) compiled a geologic map of the House Rock Spring quadrangle that borders the north edge of the map area. Bush (1983) compiled a geologic map of the Vermilion Cliffs-Paria Canyon Wilderness area that is partly within the northeast corner of the map area.

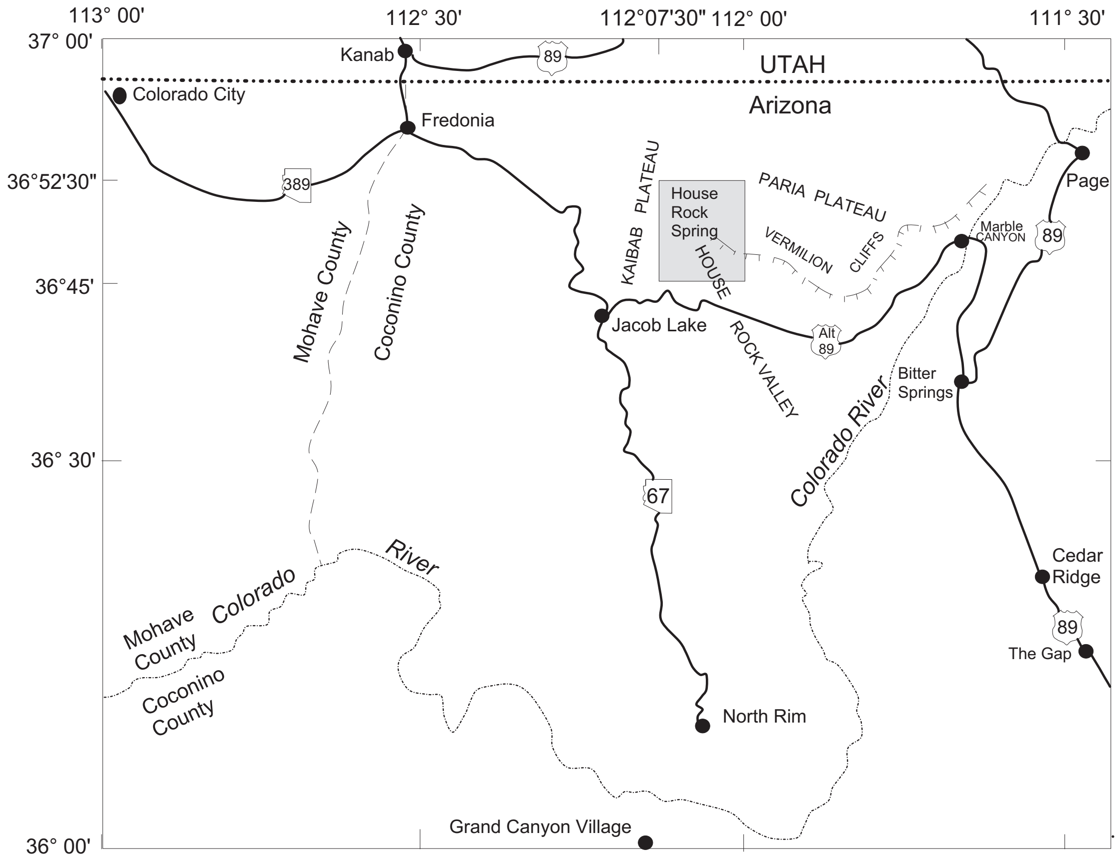

Figure 1. Map showing location of the House Rock 7.5 minute quadrangle, northern Coconino County, northern Arizona.

MAPPING METHODS

This map was produced using 1:24,000- and 1:12,000-scale color aerial photographs, 1981 and 1986 respectively, courtesy of the U.S. National Forest Service. Additional aerial photos at 1:24,000 scale, 1976, were provided courtesy of the Bureau of Land Management in St. George, Utah. Aerial photo work was extensively field checked. Quaternary alluvial deposits having similar lithology but different geomorphic characteristics were mapped almost entirely by photogeologic methods. Stratigraphic position, soil development, and amount of erosional degradation were used to determine the relative ages of alluvial deposits.

GEOLOGIC SETTING

House Rock Valley occupies the eastern third of the map area while Little Mountain forms a benchland plateau between the lower and upper parts of the East Kaibab Monocline of the Kaibab Plateau in the western two-thirds of the map area. The Kaibab Plateau and House Rock Valley are subphysiographic features within the Colorado Plateaus physiographic province (Billingsley and others, 1997).

The Kaibab Plateau is characterized by gently dipping Paleozoic sedimentary strata of early Permian age that form a regional broad anticline with a general north-south axial trend just west of the map area. Permian strata on the eastern flank of the Kaibab Plateau dip steeply east as much as 21 degrees at various locations on the upper and lower segments of the East Kaibab Monocline. The greater dips of the East Kaibab Monocline, averaging about

20 degrees, generally occur along the southeasterly trends of the monocline; the lesser dips are generally found along northerly trends. The East Kaibab Monocline bifurcates into an upper and lower segment about 5 km (3 mi) north of the map area and coalesces back into a single monocline about 19 km (12 mi) south of the map area. The vertical physiographic relief produced by both segments of the East Kaibab Monocline is estimated at about 760 m (2,500 ft).

Quaternary surficial deposits are widely distributed in the map area and cover large areas of Paleozoic and Mesozoic strata. The deposits are mapped as terrace gravel, alluvial fans, talus slopes, sand sheets, dunes, and landslide masses. Artificial fill and quarries are mapped. Map contacts between most Quaternary alluvial deposits are intertonguing and (or) gradational, both laterally and vertically. The subdivision of Quaternary alluvial units are intentionally detailed because they strongly influence the planning of road construction, wildlife and biological range management, flood control, and soil erosion programs. In this study, the Quaternary deposits provide basic geologic information for soil and biological studies such as the Paradine Plains Cactus Conservation Assessment and Strategy. The Quaternary deposits added significant details to the geomorphic development of the landscape of this region for the last several hundred thousand years. All surficial deposits in the map area are assumed to be Quaternary in age because they are similar to deposits west of the map area, where volcanic deposits bracket alluvial deposits as late Quaternary in age (Billingsley and Workman, 1999; Billingsley and Hampton, 2000).

PALEOZOIC AND MESOZOIC SEDIMENTARY ROCKS

There are about 335 m (1,100 ft) of Permian strata and about 90 m (300 ft) of Triassic strata in the map area, but only about 45 to 50 m (150 to 165 ft) are exposed. The Paleozoic and Mesozoic rocks are sedimentary and are, in order of decreasing age, the Hermit Formation, Coconino Sandstone, Toroweap Formation, Kaibab Formation (Permian), and the Moenkopi Formation and Chinle Formation (Triassic). The Coconino Sandstone (Permian) is not present 19 km (12 mi) north of the map area but is present in Cane Canyon about 5 km (3 mi) south of the map area. The Coconino Sandstone gradually thickens southward and southeastward into the Grand Canyon (Billingsley and Hampton, 2000).

The Paleozoic rocks are best exposed in the South Fork Rock Canyon, southeast quarter of the map area. Only the top 73 m (240 ft) of the Hermit Formation are exposed in the bottom of South Fork Rock Canyon as a red siltstone and sandstone. Based on exposures at Marble Canyon 40 km (25 mi) east of the map area, the Hermit Formation is probably about 100 to 150 m (330 to 500 ft) thick in the subsurface of the map area. Gray to reddish interbedded siltstone, sandstone, limestone, and gypsiferous siltstone of the Harrisburg Member of the Kaibab Formation forms much of the bedrock surface of Little Mountain of the Kaibab Plateau between the upper and lower segments of the East Kaibab Monocline.

Triassic rocks of the Moenkopi and Chinle Formations are mostly eroded or covered by alluvium and landslide deposits in House Rock Valley. These rocks are composed mostly of soft mudstone, siltstone, and sandstone. Only minor exposures of the Moenkopi Formation are found along the lower flanks of the upper and lower segments of the East Kaibab Monocline. An incomplete section of the Chinle Formation is exposed near the base of the Vermilion Cliffs in the northeast corner of the map area. Details of the Paleozoic and Mesozoic rock strata are given in the description of map units.

House Rock Valley is filled to an unknown depth with alluvium, perhaps as much as 22 m (65 ft) thick based on exposures southeast of the map area where House Rock Wash has eroded through the alluvium to bedrock. Alluvial deposits west of House Rock Valley Wash consist of poorly sorted angular to subangular limestone, sandstone, chert, gravel, and sand locally derived from the erosion of nearby Permian strata along the East Kaibab Monocline and Kaibab Plateau. Alluvium east of House Rock Valley Wash consists of red silt and sand derived from the erosion of Triassic and Jurassic rocks along the Vermilion Cliffs and is partly covered by wind-blown sand sheets and small dune deposits.

House Rock Valley is parallel to the east side of the East Kaibab Monocline. The softer Triassic and Jurassic strata present in the Vermilion Cliffs north of the map area are remnants of the deposits that once covered the Kaibab Plateau, and have eroded away and down-dip towards House Rock Valley.

STRUCTURAL GEOLOGY

The East Kaibab Monocline overlies deep-seated reverse faults where compressional forces have folded the strata up-to-the-west during Late Cretaceous and early Tertiary time (Huntoon, 1990). During Pliocene and Pleistocene time, extension has formed normal fault separations between the upper and lower segments of the East Kaibab Monocline. Along parts of the upper and lower segments of the East Kaibab Monocline, late Tertiary extension has reactivated some of the deep-seated faults producing normal down-to the west fault separations that reverse the Cretaceous and Tertiary offset.

The north-south-trending East Kaibab Monocline bifurcates into an upper and lower segment about 5 km (3 mi) north of the map area. The upper segment is partly exposed along the western edge of the map area as a general north-south fold. The lower segment has a southeasterly trend of about 17° SE. Both segments join to become one fold about 19 km (12 mi) south of the map area (Billingsley and Wellmeyer, 2001). The benchland between the two fold segments is called Little Mountain, which forms the eastern part of the Kaibab Plateau.

Trail Canyon Fault is a normal high-angle fault with the west side down that parallels the upper segment of the East Kaibab Monocline in Trail Canyon (northwest corner of the map area) and is the result of Miocene to Pliocene extension. The down-to-the-west displacement reverses the monoclinal offset of strata. There is no exposure of the Trail Canyon Fault plane to determine actual direction of fault separation, but since most faults in this region are normal high-angle vertical separations of strata, it is assumed that the Trail Canyon Fault is a normal high-angle vertical fault. Net-slip or lateral-slip separation along the Trail Canyon Fault is possible, as suggested by Billingsley and Hampton (2001). Similar normal faults are present along the lower segment of the East Kaibab Monocline along the north-south orientation of the fold in the eastern edge of the map area.

The joint trends shown on the map indicate regional stress patterns that may be related to Laramide monoclinal development and (or) more recent tensional stresses. The bedrock joints are useful indicators for direction of ground water flow toward local springs in the North and South Forks of Rock Canyon.

Strata on Little Mountain of the Kaibab Plateau were warped and gently bent as a result of Laramide compressional stresses. Locally bent strata in stream drainages are the result of solution of gypsiferous siltstone or joints in the Harrisburg Member of the Kaibab Formation and consequent slumping along canyon rims.

Gypsum dissolution in the Woods Ranch Member of the Toroweap Formation has resulted in large sinkholes on the Kaibab Plateau. The karst is probably Holocene and Pleistocene in age based on the youthfulness of sinkhole walls and recent rock falls into them. Locations of sinkholes that form enclosed basins or depressions are indicated on the map by a triangle symbol. Circular collapse structures, minor folds, and other surface irregularities are formed by dissolution of gypsum and gypsiferous siltstone in the Kaibab or Toroweap Formations. One sinkhole in the Kaibab strata near the rim of North Fork Rock Canyon has shear vertical walls of nearly 30 m (100 ft).

Breccia pipe structures

Some bowl-shaped depressions in the Kaibab Formation, characterized by inward-dipping strata, may be the surface expression of a breccia pipe, which developed by dissolution of the deeply buried Mississippian Redwall Limestone (Wenrich and Huntoon, 1989; Wenrich and Sutphin, 1989). Such features generally have inward dipping strata and are marked on the map by a dot and the letter C for collapse.

ACKNOWLEDGMENTS

We appreciate the advice, revisions, and information for this report by Michael H. Ort, Northern Arizona University, and Becky Hammond, Bureau of Land Management. We also appreciate the assistance of Fred (Pete) Peterson, Russell Dubiel, Jan Zigler, and Charles Powell of the U.S. Geological Survey for their scientific advice and guidance in regards to the Mesozoic stratigraphy of the map area. Gary Holstein of the U.S. National Forest Service, North Kaibab Ranger District, and Becky Hammond of the Bureau of Land Management helped provide access to color aerial photographs of the map area.

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-fan and terrace-gravel deposits generally exhibit extensive erosion and most commonly occupy higher terrain, whereas younger deposits are either actively accumulating material or lightly eroding and generally occupy lower terrain as observed on 1976, 1981, and 1986 aerial photographs.

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

Qs **Stream-channel alluvium (Holocene)**—Interlensing silt, sand, and pebble gravel; unconsolidated and poorly sorted. Inset against young-intermediate alluvial fan (Qa_2) and young and old terrace-gravel (Qg_1, Qg_2) deposits. Stream channels subject to intermittent 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 (3 to 6 ft) thick

Qd **Sand-sheet and dune deposits (Holocene)**—Reddish-brown, fine- to medium-grained, silty sand. Form sand sheets and small complex dunes on young and young-intermediate alluvial fan (Qa_1 and Qa_2) deposits east of House Rock Wash. Sand is derived mainly from House Rock Wash and its tributaries and blown toward the east and northeast. Sand deposits also form climbing and falling dunes and sand sheet deposits over landslide deposits near base of Vermilion Cliffs. Contacts are approximate. Deposits are 0.5 to 3 m (1 to 30 ft) thick

Qg_1 **Young terrace-gravel deposits (Holocene)**—Light-brown, pale-red, and gray silt, sand, and pebble gravel composed of well-rounded limestone and sandstone clasts and angular to subrounded chert clasts. Forms terraces about 1 to 2 m (2 to 5 ft) above modern streambeds in House Rock Wash. Locally inset into old terrace-gravel (Qg_2) deposits. Commonly covered by sand sheet deposits (Qd) east of House Rock Wash. About 1 to 3 m (2 to 10 ft) thick

Qa_1 **Young alluvial fan deposits (Holocene)**—West of House Rock Wash: gray-brown silt, sand, gravel, and boulders as debris flows; poorly sorted, unconsolidated. Include lenses of coarse gravel composed of angular to subrounded pebbles and cobbles of limestone, chert, and sandstone locally derived from the Kaibab and Toroweap Formations along the flank of the East Kaibab Monocline. East of House Rock Wash: red and reddish-brown, fine-grained sand. Includes some well-rounded sandstone pebbles and purplish mudstone matrix, often integrated with wind blown sand (Qd) and landslide (Ql) deposits locally derived from Vermilion Cliffs area. Partly cemented by gypsum and calcite. Overlap young-intermediate and old-intermediate alluvial fan (Qa_2 and Qa_3) deposits. Subject to extensive erosion by sheet wash, flash flood debris flows, and arroyo erosion. Support moderate to sparse growth of cactus and grass. About 1 to 3 m (2 to 10 ft) thick or more

Qv **Valley-fill deposits (Holocene and Pleistocene)**—Gray and light-brown silt, sand, and lenses of pebble to small-boulder gravel; partly consolidated by gypsum or calcite cement. Include well-rounded clasts of limestone, subrounded to angular chert fragments derived mainly from the Kaibab Formation. Represents relatively less active, low-gradient alluvial stream-channel or shallow valley drainage deposits, primarily on the Kaibab Plateau. Unit subject to sheetwash flooding and temporary ponding; occasionally cut by arroyos as much as 2 m (6 ft) deep. Support moderate growth of sagebrush, grass, and cactus. About 1 to 4 m (3 to 12 ft) thick

Qt **Talus deposits (Holocene and Pleistocene)**—Unsorted breccia debris composed of small and large angular blocks of local bedrock on steep to moderately steep slopes below cliffed outcrops. Include silt, sand, and gravel partly cemented by calcite and gypsum. Intertongue with alluvial fan (Qa_1 and Qa_2) and landslide

(Ql) deposits. Support sparse growth of cactus, grass, and some pinion pine and juniper trees. Only thick or extensive deposits shown. About 2 to 3 m (4 to 10 ft) thick

Ql **Landslide deposits (Holocene and Pleistocene)**—Unconsolidated masses of unsorted rock strata and angular fragmental debris along base of Vermilion Cliffs and within South Fork Rock Canyon. At base of Vermilion cliffs, include detached blocks of Triassic and Jurassic strata that slid downslope and rotated backward toward the parent cliff as a loose incoherent mass of broken rock and deformed strata. Support sparse to moderate growth of cactus and grass at elevations below 1,525 m (5,000 ft), and sparse oak, juniper, and pinion trees at higher elevations. May become unstable in very wet conditions. Thickness about 3 to 18 m (10 to 60 ft)

Qg_2 **Old terrace-gravel deposits (Holocene and Pleistocene)**—Similar to young terrace-gravel deposits (Qg_1) but partly consolidated. Composed mainly of gray to reddish-brown, fine-grained sand and silt matrix. Form terraces about 2 m (7 ft) above House Rock Wash and about 1 m (4 ft) above young terrace-gravel (Qg_1) deposits. Locally inset into young-intermediate alluvial fan (Qa_2) deposits. Intertongue with or locally overlain by alluvial fan (Qa_1 and Qa_2) and sand (Qd) deposits. Isolated deposits on lower segment of the East Kaibab Monocline indicate abandoned stream channels due to stream capture. Approximately 2 to 5 m (5 to 15 ft) 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. West of House Rock Wash, surfaces are rocky and eroded by arroyos as much as 2 m (6 ft) deep. Some thin soil has developed in low-lying areas. Very large boulders 1 to 3 m (3 to 10 ft) in diameter of the Kaibab Formation are commonly scattered about at the apex of fan deposits as old debris flows near mouths of drainages from the East Kaibab Monocline. Commonly overlapped by young alluvial fan (Qa_1) deposits near East Kaibab Monocline. Intertongue with or overlap terrace-gravel (Qg_1 and Qg_2) deposits at House Rock Wash. Include abundant subrounded to subangular limestone and chert clasts. On east side of House Rock Wash, wind-blown sand sheets and small complex dunes cover much of the deposit toward the base of the Vermilion Cliffs. Support sparse growth of sagebrush, cactus, and grass. Thickness, about 2 to 10 m (5 to 30 ft)

Qa_3 **Old-intermediate alluvial fan deposits (Pleistocene)**—Similar to young and young-intermediate alluvial fan (Qa_1 and Qa_2) deposits, partly consolidated by calcite and gypsum cement. Surface has developed a thin soil that forms a pebbly smooth texture; eroded by arroyos as much as 1 to 2 m (2 to 6 ft) deep. Forms elevated ridges at downslope ends, commonly overlapped by young and young-intermediate alluvial fan (Qa_1 and Qa_2) deposits near the flank of the East Kaibab Monocline. Support sparse to moderate growth of grass and cactus. About 2 to 6 m (6 to 20 ft) thick

Qa_4 **Old alluvial fan deposits (Pleistocene)**—Gray, sandy, gravelly alluvial deposits that were once part of a more extensive older alluvial fan at the mouth of Rock Canyon and on Little Mountain, southwest corner of map area. About 4.5 m (15 ft) thick

SEDIMENTARY ROCKS

Chinle Formation, undivided (Upper Triassic)—Includes, in descending order, the Owl Rock, Petrified Forest, and Shinarump Members as defined by Dubiel (1994). The Owl Rock Member is covered by landslide and alluvial deposits in northeast corner of map area, but is present just northwest of the map area. The Shinarump Member is combined with the Petrified Forest Member in the map area because of mixed conglomerate and siltstone lithologies that do not form a typical cliff for the Shinarump

^ cp **Petrified Forest and Shinarump Members, undivided**—White, blue-gray, pale-red, gray-green, gray-blue, and purple, slope-forming bentonitic mudstone, siltstone, and coarse-grained sandstone; contains small, very well rounded pebbles of yellow, brown, and red quartzite in white, coarse-grained, ledge-forming sandstone at base equivalent to Shinarump Member of the Chinle Formation; contain brown, yellow, white, and red petrified wood fragments in lower part. Unit mostly covered by alluvium (Qa_1), sand (Qd), and landslide debris (Ql). Unconformable contact with underlying slope-forming upper red member of the Moenkopi Formation east of map area. Unit thickens eastward to as much as 240 m (800 ft) thick near Lees

Ferry, Arizona. About 90 m (300 ft) exposed at base of Vermilion cliffs, northeast corner of map area

^ m **Moenkopi Formation, undivided (Middle? and Lower Triassic)**—Includes, in descending order, the upper red member, Shnabkaib Member, middle red member, Virgin Limestone Member, and lower red member, undivided, as used by Stewart and others (1972). The basal Timpoweap Member was not recognized in the map area but is present farther north and west. Consists mainly of dark-red, thin-bedded, slope-forming siltstone and sandstone and gray-white siltstone and gypsum. Most of Moenkopi Formation is covered by alluvial fan (Qa_1, Qa_2, Qa_3, Qa_4) deposits, making individual member identification impractical. About 30 m (100 ft) of the lower Moenkopi Formation is exposed along the upper and lower flanks of the East Kaibab Monocline. Approximate 122 m (400 ft) of the Moenkopi Formation is present east of the map area near the base of the Vermilion Cliffs

Kaibab Formation (Lower Permian)—Includes, in descending order, the Harrisburg and Fossil Mountain Members as defined by Sorauf and Billingsley (1991). Divided into:

Pkh **Harrisburg Member**—Grayish-orange, ledge- and slope-forming, dolomite, gray to yellowish-brown calcareous siltstone, interbedded gypsiferous siltstone, sandstone, gypsum, and thin-bedded gray limestone and dolomite capped by a resistant, pale-yellow or orange-gray, fossiliferous (mollusks and algae) sandy limestone. Includes light-gray and red gypsiferous siltstone and fine- to medium-grained calcareous sandstone beds. Gradational and arbitrary contact with underlying Fossil Mountain Member placed near top of cliff-forming, white cherty limestone of Fossil Mountain Member. Contact is approximate in tilted strata of upper and lower segments of the East Kaibab Monocline because of local erosion or forest cover and may not accurately portray the actual contact. Unit thickens west and north, thins east. About 43 m (140 ft) thick

Pkf **Fossil Mountain Member**—Yellowish-gray to white, fine- to medium-grained, medium- to thick-bedded (1 to 2 m [3 to 6 ft]), fossiliferous, cliff-forming, cherty limestone and sandy limestone. Unit characterized by abundance of chert nodules and fragments in upper part and intraformational chert breccia beds as much as 1.5 m (4 to 5 ft) thick. Includes white, low-angle, crossbedded sandstone that weathers light gray in middle part and gray brown dolomite that weathers dark brown in lower part. Unconformable contact with underlying Woods Ranch Member of the Toroweap Formation marked by solution and channel erosion with relief as much as 2 m (6 ft) locally. Contact locally obscured by talus and minor landslide debris in North and South Forks of Rock Canyon and in Valley Canyon. Generally uniform thickness throughout area. About 75 m (250 ft) thick

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

Ptw **Woods Ranch Member**—Gray, white, slope-forming gypsum, gray gypsiferous siltstone, and pale-red to gray silty sandstone. Beds are locally distorted or wavy due to gypsum solution. Gradational contact with Brady Canyon Member arbitrarily marked between base of slope-forming Woods Ranch Member and top of cliff-forming limestone of Brady Canyon Member. Unit thins south and east, thickens slightly north and west. Thickness 40 to 60 m (130 to 200 ft)

Ptb **Brady Canyon Member**—Yellowish-gray, cliff-forming, medium- to thick-bedded (0.5 to 2 m [2 to 6 ft]), fine- to coarse-grained, fossiliferous limestone and dolomitic sandy limestone. Includes chert nodules in upper part. Vuggy appearance. Gradational lower contact with Seligman Member arbitrarily marked at base of limestone cliff of Brady Canyon Member. Unit thins east and south, thickens slightly to west. About 48 m (160 ft) thick in South Fork Rock Canyon

Pts **Seligman Member**—Yellowish-gray, medium- to thin-bedded, ledge- and slope-forming dolomite, sandstone, and gypsiferous sandstone; predominantly sandstone. Includes some beds of gray, thin-bedded limestone. Basal part includes yellow, fine- to medium-grained, thin-bedded, low- to high-angle crossbedded and planar-bedded sandstone lenses of the Coconino Sandstone (Rawson and Turner, 1974). Coconino Sandstone is mapped separately, but intertongues with basal Seligman Member of the Toroweap Formation west of map area (Billingsley and Workman, 1999). About 9 to 15 m (30 to 50 ft) thick

Pc **Coconino Sandstone (Lower Permian)**—White to yellowish-brown, fine- to coarse-grained, high-angle crossbedded, cliff-forming sandstone. Crossbedded sets are 3 to 4.5 m (6 to 15 ft) thick. Forms gradational or sharp planar contact with flat-bedded sandstone and crossbedded sandstone within lower part of Seligman Member of the Toroweap Formation. Unconformable, low relief, erosional contact with underlying Hermit Formation and abrupt color change from white Coconino and Toroweap to red Hermit. Upper part of the Hermit Formation is bleached yellowish-white near spring locations. Unit pinches out in north part of map area, thickens rapidly southeastward. About 15 to 17 m (50 to 55 ft) thick in South Fork Rock Canyon

Ph **Hermit Formation (Lower Permian)**—Light-red, fine- to coarse-grained, thin- to medium-bedded, slope-forming silty sandstone and siltstone. Reddish sandstone beds commonly contain yellowish-white bleached spots; some thin sandstones are partly or completely bleached yellowish-white near contact with overlying Seligman Member of the Toroweap Formation or the Coconino Sandstone near springs in Rock Canyon. Incomplete section, only top 73 m (240 ft) exposed in South Fork Rock Canyon

REFERENCES CITED

Benson, B.W., 1957, A new cactus from Arizona: Cactus and Succulent Journal v.29, p. 136-137.

Billingsley, G.H., and Hampton, H.M., 2000, Geologic map of the Grand Canyon 30' x 60' quadrangle, Coconino and Mohave County, northern Arizona: U.S. Geological Survey Geologic Investigations Series Map I-2688, scale 1:100,000.

Billingsley, G.H., and Hampton, H.M., 2001, Geologic map of the House Rock Spring quadrangle, Coconino County, northern Arizona: U.S. Geological Survey Miscellaneous Field Studies Map MF-2367, scale 1:24,000.

Billingsley, G.H., Spamer, E.E., Menkes, Dove, 1997, Quest for the pillar of gold, the mines and miners of the Grand Canyon: Grand Canyon Association Monograph 10, 112 p.

Billingsley, G.H., and Wellmeyer, J.L., 2001, Geologic map of the Cane quadrangle, Coconino County, northern Arizona: U.S. Geological Survey Miscellaneous Field Studies Map MF-2366, scale 1:24,000.

Billingsley, G.H., and Workman, J.B., 1999, Geologic map of the Littlefield 30' x 60' quadrangle, Mohave county, northwestern Arizona: U.S. Geological Survey Geologic Investigations Series Map I-2628, scale 1:100,000.

Bush, A.L., 1983, Geologic map of the Vermilion Cliffs-Paria Canyon Instant Study Area and adjacent wilderness study areas, Coconino County, Arizona, and Kane County, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-1475-A, one sheet, scale 1:62,500.

Dubiel, R.F., 1994, Triassic deposystems, paleogeography, and paleoclimate of the western interior, *in* Caputo, M.V., Peterson, J.A., and Franczyk, K.J., eds., Mesozoic Systems of the Rocky Mountain Region, USA, Rocky Mountain section, September Meeting, p. 133-168.

Huntoon, P.W., 1990, Phanerozoic structural geology of the Grand Canyon, *in* Beus, S.S., and Morales, Michael, eds., Grand Canyon Geology: Flagstaff, Arizona, New York Oxford, Oxford University Press and the Museum of Northern Arizona Press, p. 261-310.

Pomeroy, J.S., 1957, Photogeologic map of the House Rock Spring SW quadrangle, Coconino county, Arizona: U.S. Geological Survey Miscellaneous Investigations Series Map I-254, scale 1:24,000.

Rawson, R.R., and Turner, C.E., 1974, The Toroweap Formation; a new look, *in* Karlstrom, T.N.V., Swann, G.A., and Eastwood, R.L., eds., Geology of northern Arizona with notes on archaeology and paleoclimate: Part 1, Regional studies: Geological Society of America Rocky Mountain Section Meeting, Flagstaff, Arizona, p. 155-190.

Reynolds, S.J., 1988, Geologic map of Arizona: Arizona Geological Survey, Map 26, scale 1:1,000,000.

Sorauf, J.E., and Billingsley, G.H., 1991, Members of the Toroweap and Kaibab Formations, Lower Permian, northern Arizona and southwestern Utah: Rocky Mountain Geologist, v. 28, no. 1, p. 9-24.

Stewart. J.H., Poole, F.G., and Wilson, R.F., 1972, Stratigraphy and origin of the Triassic Moenkopi Formation and

related strata in the Colorado Plateau region: U.S. Geological Survey Professional Paper 691, 195 p.
U.S. Department of the Interior, 1993, Arizona Strip District visitor map, Arizona: Bureau of Land Management, scale 1:168,960.
Wells, J.D., 1960, Stratigraphy and structure of the House Rock Valley area, Coconino County, Arizona: U.S. Geological Survey Bulletin 1081-D, p. 117-158.
Wenrich, K.J., and Huntoon, P.W., 1989, Breccia pipes and associated mineralization in the Grand Canyon region, northern Arizona, *in* Elston, D.P., Billingsley, G.H., and Young, R.A., eds., Geology of Grand Canyon, Northern Arizona (with Colorado River Guides): Washington, D.C., American Geophysical Union, 28th International Geological Congress Field Trip Guidebook T115/315, p. 212-218.
Wenrich, K.J., and Sutphin, H.B., 1989, Lithotectonic setting necessary for formation of a uranium-rich, solution-collapse breccia-pipe province, Grand Canyon region, Arizona: U.S. Geological Survey Open-File Report OF89-0173, 33 p.
Wilson, E.D., Moore, R.T., and Cooper, J.R., 1969, Geologic map of the State of Arizona: Arizona Bureau of Mines, University of Arizona, scale 1:500,000.

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

TO ACCOMPANY MAP MF-2364

DIGITAL DATABASE DESCRIPTION FOR THE GEOLOGIC MAP OF THE HOUSE ROCK QUADRANGLE, COCONINO COUNTY, NORTHERN ARIZONA

By
Jessica L. Wellmeyer and Debra L. Block

INTRODUCTION

This digital map database, compiled from previously published and unpublished data, and new mapping by the authors, represents the general distribution of bedrock and surficial deposits in the House Rock quadrangle. Together with the accompanying text file (hrgeo.txt or hrgeo.eps), it provides current information on the geologic structure and stratigraphy of the area covered. The database delineates map units that are identified by general age and lithology following the spatial resolution (scale) of the database to 1:24,000 or smaller. The content and character of the database, as well as three methods of obtaining the database, are described below.

FOR THOSE WHO DON'T USE DIGITAL GEOLOGIC MAP DATABASES

Two sets of plotfiles containing images of much of the information in the database are available to those who do not use an ARC/INFO compatible Geographic Information System (GIS). Each set contains an image of a geologic map sheet and the accompanying explanatory pamphlet. There is a set available in PostScript format, and another in Acrobat PDF format. (See sections below). Those who have computer capability can access the plotfile packages in either of the two ways described below, however, these packages do require ZIP utilities to access the plot files. Requests for a tape copy of the digital database or plotfiles can be made by sending a tape with request and return address to: Database Coordinator, U.S. Geological Survey, 345 Middlefield Road, M/S 975, Menlo Park, CA 94025. Plot files can also be acquired online at http://geopubs.wr.usgs.gov/map-mf/mf2364

Those without computer capability can obtain plots of the map files through USGS Plot-On-Demand service for digital geologic maps. To obtain plots of the map sheet and accompanying pamphlet, contact the USGS Information Services office at the following address: U. S. Geological Survey Information Services, Box 25286, Federal Center, Denver, CO 80225-0046. Or by phone (303)202-4200, fax (303)202-4695, or e-mail: infoservices@usgs.gov. Be sure to include the map reference MF-2364.

DATABASE CONTENTS

This digital database package consists of the geologic map database and supporting data including base maps, map explanation, geologic description, and references. A second package consists of PostScript plot files of a geologic map and geologic description.

Digital Database Package

The first package is composed of geologic map database files for the House Rock quadrangle. The coverages and their associated INFO directory have been converted into ARC/INFO export files. These export files are uncompressed and are easily handled and compatible with some Geographic Information Systems other than ARC/INFO. The export files included are:

ARC/INFO export file	Resultant Coverage	Description
hr_anno.e00	hr_anno/	Unit annotation, fault and fold names, fault separation values, point data and annotation
hr_dip.e00	hr_dip/	Strike and dip information
hr_poly.e00	hr_poly/	Faults, depositional contacts and geologic units
hr_fold.e00	hr_fold/	Fold axes

The database package also contains the following other export files with extraneous data used in the construction of the database

ARC/INFO export file	Resultant File	Description
geo.lin.e00	geo.lin	Lineset
geo.mrk.e00	geo.mrk	Markerset
color524.e00	color524.shd	524 color shadeset
pattern.shd.e00	pattern.shd	Fill pattern set
geolin.lut.e00	geolin.lut	Line lookup table
geomrk.lut.e00	geomrk.lut	Marker lookup table
hr_poly.lut.e00	hr_poly.lut	Color lookup table

drghypso.tif.gz	Zipped background hypsography image
drghypso.tfw	World file accompanying drghypso.tif

Postscript Plotfile Package
The second digital data package available contains the Post Script images described below:

hrmap.eps	Encapsulated Post Script plottable file containing complete map composition with geology, symbology, annotation and base map of the House Rock quadrangle
hrgeo.docs	A MS Word document file of this report and the report containing detailed unit descriptions and geological information, plus sources of data and references cited

PDF Plotfile Package
This package contains the Adobe Acrobat (.pdf) portable document format files described below:

hrmap.pdf	A PDF file of the House Rock quadrangle map sheet
hrgeo.pdf	A PDF file of this report, including the full geologic report.

The Acrobat files were created from corresponding .eps files and are compatible with Adobe Acrobat version 3.0 and higher.

ACCESSING DATABASE CONTENTS

ARC/INFO Export Files

ARC export files are converted to their proper ARC/INFO format using the ARC command ‘import’ with the option proper for the format desired. To ease conversion and preserve naming convention, and AML is enclosed that will convert all the export files in the database to coverages and graphic files and will also create an associated INFO directory. From the ARC command line type:

Arc: &run import.aml

ARC export files can be read by other Geographic Information Systems. Refer to your documentation for proper procedure for retrieval of data.

Post Script and Portable Document Format Files

These files are packages separately. PDF files come as is and can be downloaded or copied directly to your hard drive with no conversion aside from opening the file from Adobe Acrobat. The Post Script documents are zipped and compressed to a smaller file size. They can be decompressed using WINZIP.

DATABASE SPECIFICS

Procedure Used

Stable-base maps were scanned at the Flagstaff USGS Field site using the Optronics 5040 raster scanner at a resolution of 50 microns (508 dpi). The resulting raster file was in RLE format and converted to the RLC format using the “rle2rlc” program written by Marilyn Flynn. The RLC file was subsequently converted to an ARC/INFO Grid in ARC/INFO. The linework was vectorized in bulk using the ARC command gridline. A tic file was created in lat/long and projected into the base map projection (Transverse Mercator) using a central meridian of –112.0625W. Tics are defined in a 2.5 minute grid of latitude and longitude in the geologic coverages corresponding with quadrangle corners both in base maps and digital maps. The tic file was used to transform the grid into universal transverse mercator. ARC/INFO generated a RMS report after transforming the original grid into universal transverse mercator.

Scale (X,Y) = (1.112,1.112) Skew (degrees) = (0.022)
Rotation (degrees) = (0.186) Translation = (6652.552,-2095.908)
RMS Error (input,output) = (0.896,0.996)

Affine X = Ax + By + C
Y = Dx + Ey + F

A =	1.112	B =	-0.003	C =	6652.552
D =	0.004	E =	1.112	F =	-2095.908

tic id	input x output x	input y output y	x error	y error
4	-1296.971	13439.995		
	5168.492	12846.363	-0.245	0.966
3	-10596.454	13468.402		

	-5168.492	12846.363	0.245	-0.967
2	-10637.445	1921.341		
	-5176.864	1.684	-0.245	0.965
1	-1322.028	1889.409		
	5176.864	1.684	0.245	-0.965

Lines, points, polygons, and annotation were edited using ARCEDIT.
Following editing and annotation, the individual coverage's were projected into UTM projection.

Map Projection:

Parameter	Description
Projection	UTM
Units	Meters on the ground
Zone	12
Datum	NAD27

The content of the geologic database can be described in terms of the lines and the areas that compose the map. Descriptions of the database fields use the terms explained below:

Database Fields:

Parameter	Description
Item name	name of database field
Width	maximum number of characters or digits stored
Output	output width
Type	B - binary integer; F- binary floating point number; I - ASCII integer; C - ASCII character string
N.dec.	number of decimal places maintained for floating point numbers

LINES
The arcs are recorded as strings of vectors and described in the arc attribute table (AAT). They define the boundaries of the map units, faults, and map boundaries in HR_POLY. These distinctions and the geologic identities of the boundaries are stored in the LTYPE field according to their line type.

Arc Attribute Table Definition:

DATAFILE NAME: HR_POLY.AAT

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N. DEC
1	FNODE#	4	5	B	-
5	TNODE#	4	5	B	-
9	LPOLY#	4	5	B	-
13	RPOLY#	4	5	B	-
17	LENGTH	8	18	F	5
25	HR_POLY#	4	5	B	-
29	HR_POLY-ID	4	5	B	-
33	LTYPE	35	35	C	-
68	PTTYPE	35	35	C	-
103	SYMBOL	3	3	I	-

The AAT defined above represents the AAT in HR_POLY.

Description of AAT Items:

Item	Description
FNODE#	Starting node of the arc
TNODE#	Ending node of the arc
LPOLY#	Polygon to the left of the arc
RPOLY#	Polygon to the right of the arc
LENGTH	Length of the arc in meters
HR_POLY#	Unique internal number
HR_POLY-ID	Unique identification number
LTYPE	Line type
PTTYPE	Point type
SYMBOL	This field is not used
PLUNGE	Value of plunge of fold axis

The geologic line types relate to geologic line symbols in the line set GEO.LIN according to the lookup table GEOLIN.LUT.

Domain of Line Types recorded in LTYPE field:

map_boundary
contact_certain
high_angle_flt_certain
high_angle_flt_concealed
anticline_certain
syncline_certain
syncline_concealed
monocline_certain
monocline_concealed

Domain of Markers recorded in PTTYPE field:

fault_ball_fill
anticline
syncline
monocline
xx

Arcs with a PTTYPE value of 'xx' indicate that there is no symbol attached to the arc.

POLYGONS
Map units (polygons) are described in the polygon attribute table (PAT). This identifies the map units recorded in the PTYPE field by map label. Individual map units are described more fully in the accompanying text.

Definition of Polygon Attribute Table:

DATAFILE NAME: HR_POLY.PAT

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N. DEC
1	AREA	8	18	F	5
9	PERIMETER	8	18	F	5
17	HR_POLY#	4	5	B	-
21	HR_POLY-ID	4	5	B	-
25	PTYPE	5	5	C	-
30	PATTERN	3	3	I	-

Description of Item Names:

Item Name	Description
AREA	Area of polygon in square meters
PERIMETER	Perimeter of polygon in meters
HR_POLY#	Unique internal number
HR_POLY-ID	Unique identification number
PTYPE	Unit label
PATTERN	Designated fill patter for polygons

Domain of PTYPE (map units):

Qaf	Qv	Qa4	Ptw
Qs	Qt	^ cp	Ptb
Qd	Ql	^ m	Pts
Qg1	Qg2	Pkh	Pc
Qa1	Qa3	Pkf	Ph

P represents Permian strata, ^ represents Triassic strata, and Q represents Quaternary strata. Polygons were assigned colors based on their geologic unit. The colors were assigned from the shadeset COLOR524.SHD and are related to the lookup table HR_POLY.LUT

POINTS

Strike and dip information is recorded as coordinate data with related information. This information is described in the Point Attribute Table (PAT). ARC/INFO coverages cannot hold both point and polygon information, thus HR_DIP has only a point attribute table, and HR_POLY has only a polygon attribute table.

Definition of Point Attribute Table:

DATAFILE NAME: HR_DIP.PAT

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC.
1	AREA	8	18	F	5
9	PERIMETER	8	18	F	5
17	HR_DIP#	4	5	B	-
21	HR_DIP-ID	4	5	B	-
25	PTTYPE	35	35	C	-
60	DIP	3	3	I	-
63	STRIKE	3	3	I	-

Description of item names:

Item Name	Description
AREA	
PERIMETER	
HR_DIP#	Unique internal number
HR_DIP-ID	Unique identification number
PTTYPE	point type
DIP	dip angle in azimuth degrees
STRIKE	strike angle in degrees

The coverage HR_DIP contains strike and dip data and other pertinent structural data represented by point symbology, including collapses, sinkholes and domes. HR_FOLD and HR_POLY have point types defined in the AAT which correspond with the defined linetype for an arc. These point types are related to the lookup table GEOMRK.LUT and are from the symbolset GEO.MRK.

Domain of PTTYPE:

bedding
vertical_joint
collapse
sinkhole
dome

ANNOTATION

The coverage HR_ANNO is strictly annotation to the polygon coverage. It is defined somewhat differently from the fold, polygon and dip coverages. The arc attribute table is of negligible importance. Arcs in this coverage are merely leaders from a unit annotation to the related polygon. HR_ANNO contains annotation with unit labels, fault separation, and monocline names. All annotation was in feature subclass anno.unit.

The textset used for all annotation was geofont.txt, specifically symbolset 30. Use of this textset allows for proper symbol notation for unit symbols. The default ARC/INFO textset does not allow for a proper geologic symbol indicating 'Triassic.' By using this alternate text set, the character pattern '^m' prints instead as ^ m. The only nonconventional text symbol used, was the '^' (carat) indicating Triassic.

BASE MAP PROCEDURE

The base map image was prepared from a DRG obtained online from the ARIA image archive website located at 'http://landsat.ece.arizona.edu/images/'. The raster image was registered using a world file and imported into ARC/INFO where it was then converted to a grid. Area colors were drained from the file, resulting in a three-color image in ARC/INFO. No elements of the base layer are attributed and the base map is provided solely for reference.

SPATIAL RESOLUTION

Use of this digital geologic map database should not violate the spatial resolution of the data. Although the digital form of the data removes the constraint imposed by the scale of a paper map, the detail and accuracy inherent in map scale are also present in the digital data. This database was created and edited at a scale of 1:24,000, which means that higher resolution data is generally not present. Plotting at scales of later than 1:24,000 will not yield greater real detail but may reveal fine-scale irregularities below the intended resolution.

OTHER FILES

The lineset used to display the appropriate line weight and symbology is GEO.LIN. It is related to the database by a lookup table called GEOLIN.LUT. Similarly, the markerset for this database is GEO.MRK, and its lookup table is GEOMRK.LUT. Colors in the polygon coverage (HR_POLY) are assigned based on the PTYPE and were chosen from a shadeset called COLOR524.SHD and a lookup table HR.LUT. Some geologic units also display a fill pattern over the color set. For example, "Ql" is a quaternary landslide unit, and a small breccia pattern (hollow triangles) is displayed over the light brown color. There patterns come from a patternset called PATTERN.SHD. Because so few patterns were used, no lookup table was created, and the pattern assignments are made directly in the polygon attribute table item PATTERN. Annotation (unit labels, text labels, and printed numerical values) were displayed using a font entitled GEOFONT.TXT which has capabilities for displaying proper notation of geologic text symbols.

Also enclosed in this database package is HR.MET, the FGDC standard metadata for the database, and HRMET.REV, a revision list with current information on the status of all files described in this report and found in the database.