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

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INTRODUCTION

The geologic map of the House Rock Spring quadrangle is part of a cooperative project between the U.S. Geological Survey and the Kaibab National Forest 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 the upper part of House Rock Valley and part of the Kaibab and Paria Plateaus 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 for biological studies, land management, range management, and flood control programs for 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. The nearest settlement is Jacob Lake about 8 km (5 mi) southwest of the map area (fig. 1). Elevations range from about 2,250 m (7,375 ft) on the Kaibab Plateau, in the west-central edge of the map area to about 1,625 m (5,325 ft) in House Rock Valley, at the south-central edge of the map area. Primary vehicle access is by a dirt road that traverses the middle of House Rock Valley from its junction with U.S. Highway 89A about 1.5 km (1 mi) south of the map area. Four-wheel drive roads provide access to most of the map area except in the Paria Canyon-Vermilion Cliffs Wilderness, in the southeast quarter of the map area. Travel on dirt roads on the Paria Plateau is by 4-wheel drive vehicle only.

The Bureau of Land Management Arizona Strip Field Office (BLM), St. George, Utah, manages the public lands, and the North Kaibab Ranger District, Fredonia, Arizona, manages U.S. National Forest lands. Other lands include one quarter of a section belonging to the State of Arizona, about 1.7 sections of private land, and about 3 sections within the BLM-administrated Paria Canyon-Vermilion Cliffs Wilderness Area (U.S. Department of the Interior, 1993). The private land is at and near several springs along the east side of House Rock Valley.

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

Surface runoff in the southwestern two-thirds of the map area drains south toward the Colorado River through House Rock Valley, which becomes Rider Canyon. Rider Canyon empties into the Colorado River at Mile 18 in Marble Canyon. Surface runoff in the northwestern quarter of the map area drains north into Coyote Wash and eventually into the Paria River, which empties into the Colorado River at Lees Ferry, Arizona. There is no surface runoff from the Paria Plateau because of the thick, porous sand-dune and sand-sheet deposits that cover outcrops of the porous Navajo Sandstone, which forms the plateau surface. Precipitation that falls on the Paria Plateau generally evaporates but some is absorbed into the ground and migrates downward through the near vertical joint systems in the Navajo Sandstone until it encounters the nonpermeable Kayenta Formation. The groundwater of the Paria Plateau is perched on siltstone beds of the Kayenta Formation and travels down-dip toward outcrops or via joint systems to emerge as springs in upper House Rock Valley.

PREVIOUS WORK

Early photo-reconnaissance geologic mapping of this area by Wells (1958, 1960) was compiled onto an Arizona state geologic map by Wilson and others (1969) and recompiled by Reynolds (1988). Bush (1983) compiled a geologic map of the Vermilion Cliffs-Paria Canyon Wilderness area that is partly within the eastern quarter of the map area.

ACKNOWLEDGMENTS

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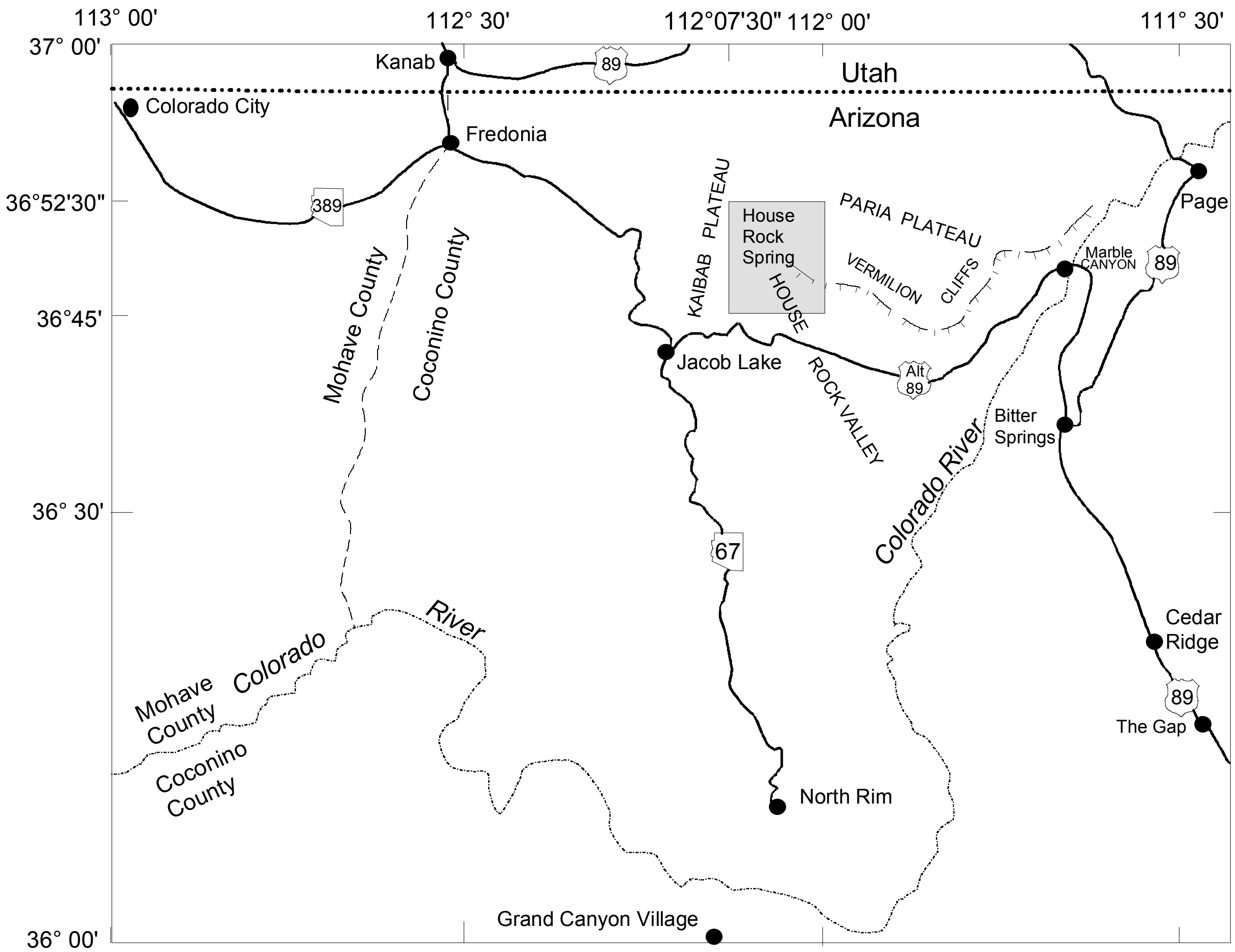

Figure 1. Map showing location of the House Rock Spring 7.5 minute quadrangle, northern Coconino County, northern Arizona.

MAPPING METHODS

This map was produced using 1:24,000-scale (1981) and 1:12,000-scale (1986) color aerial photographs provided by the U.S. National Forest Service, Fredonia, Arizona, and 1:24,000-scale (1976) infrared aerial photographs provided by the Bureau of Land Management Field Office, St. George, Utah. Aerial photo work was extensively field checked. Many of the 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 relative ages of alluvial deposits.

GENERAL GEOLOGIC SETTING

House Rock Valley is flanked on the east by the Vermilion Cliffs of the Paria Plateau and on the west by the East Kaibab Monocline of the Kaibab Plateau. The Paria and Kaibab Plateaus are subphysiographic plateaus within the Colorado Plateau physiographic province (Billingsley and others, 1997; fig. 1).

The Kaibab Plateau is characterized by gently dipping Paleozoic sedimentary strata of Permian age that forms a broad regional anticline with a general north-south axial trend and gentle northerly plunge. Permian strata on the eastern flank of the Kaibab Plateau dip steeply east, northeast, and southeast to form the East Kaibab Monocline at various locations. In general, the net dip of strata is easterly with dips as much as 27 degrees. The highest degree of dip is associated with the southeasterly segments of the monocline, and the lowest degree of dip is associated with the northeasterly trends of the monocline. The vertical physiographic relief produced by the East Kaibab Monocline is estimated at about 400 m (1,300 ft) in the northern edge of the map area and about 550 m (1,800 ft) in the southern part. The southern part of the East Kaibab Monocline bifurcates into an upper and lower segment in the southern third of the map area.

PALEOZOIC AND MESOZOIC SEDIMENTARY ROCKS

There are about 195 m (630 ft) of Permian strata and about 900 m (3,000 ft) of Mesozoic (both Triassic and Jurassic) strata in the map area; however, the Triassic rocks are not well exposed. The Paleozoic and Mesozoic rocks are all sedimentary and are, in ascending order, the Permian Hermit Formation, Toroweap Formation, and Kaibab Formation; the Triassic Moenkopi Formation and Chinle Formation; and the Jurassic Moenave Formation, Kayenta Formation, and Navajo Sandstone. The Permian Coconino Sandstone is not present between the Toroweap and Hermit Formations in the map area, but it is present about 10 km (6 mi) south of the map area.

The Permian rocks are best exposed in Burro Canyon in the west-central part of the map area. Thin deposits of gray to red interbedded siltstone, sandstone, limestone, and gypsiferous siltstone of the Harrisburg Member of the Kaibab Formation form much of the bedrock surface of the Kaibab Plateau and East Kaibab Monocline. Complete sections of the Fossil Mountain Member of the Kaibab Formation, all of the members of the Toroweap Formation, and only the top 6 m (20 ft) of the Hermit Formation are exposed in the walls of Burro Canyon (Wells, 1960). 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.

Triassic rocks of the Moenkopi and Chinle Formations are generally covered by alluvium and landslide deposits in House Rock Valley. These rocks are composed primarily of soft mudstone, siltstone, and sandstone that easily and rapidly erode to form the strike-valley characteristics of House Rock Valley. Only the lower part of the Moenkopi Formation is exposed along the lower flanks of the East Kaibab Monocline; elsewhere, the Moenkopi Formation is generally covered by alluvium. An incomplete section of the Chinle Formation is exposed near the base of the Vermilion Cliffs in the southeast corner of the map area, but alluvium, sand deposits, and landslide debris cover the Chinle in most of the map area. Complete sections of the Moenave and the Kayenta Formations are exposed in the lower half of the Vermilion Cliffs. Early Tertiary and Quaternary erosion has removed an unknown thickness of the upper part of the Navajo Sandstone and all subsequent younger strata above the Navajo that may have been present on the Paria Plateau. Details of the Paleozoic and Mesozoic rock strata are given in the Description of Map Units.

House Rock Valley averages about 1.5 km (1 mi) wide in the upper half of the map area and about 5 km (3 mi) wide in the lower half. House Rock Valley is filled to an unknown depth with alluvium, perhaps as much as 22 m (65 ft) thick in some areas. Based on exposures of alluvium farther southeast of the map area, the alluvial deposits probably average about 10 m (30 ft) thick. Alluvium west of House Rock Wash generally consists of poorly sorted, angular to subangular limestone, sandstone, and cherty gravel probably derived from erosion of the Permian strata of the East Kaibab Monocline and Kaibab Plateau. Alluvium east of House Rock Wash consists mainly of red silt and sand probably derived from the erosion of Triassic and Jurassic strata along the Vermilion Cliffs. Much of the alluvial deposits east of House Rock Wash are partly covered by a thin cover of wind-blown sand-sheet and dune deposits.

House Rock Valley is a strike valley that parallels the northerly trend of the East Kaibab Monocline. The Triassic and Jurassic strata that once covered the Kaibab Plateau have been eroded from this location down-dip towards the Paria Plateau. The Triassic and Jurassic strata that are more easily eroded from below the resistant Navajo Sandstone have allowed development of the Vermilion Cliffs. The Navajo Sandstone is fractured with numerous joints that allow large segments of Jurassic rock to break away from the Vermilion Cliffs, rotate backward, and slowly creep down and into House Rock Valley. The jumbled landslide blocks dip as much as 40° toward the parent cliff. Landslide erosion is the major mass-wasting weathering process eroding into the Vermilion Cliffs. Older landslide blocks that are farthest out into the valley have disintegrated into blocky talus deposits that eventually erode further to become alluvial deposits.

QUATERNARY GEOLOGY

Quaternary surficial deposits are widely distributed in the map area and cover large areas of Paleozoic and Mesozoic strata as terrace-gravel, alluvial fan, talus, sand-sheet, dune, and landslide deposits. Artificial fill and quarries are also mapped. Map contacts between most Quaternary deposits are arbitrary because of intertonguing and (or) gradational lateral and vertical changes. The subdivision of Quaternary surficial units is intentionally detailed because these units strongly influence range management, flood control, soil erosion, and the planning of road construction. The Quaternary deposits also provide basic geomorphic information for landscape development studies and biological studies, such as for the Paradine Plains Cactus. All surficial deposits in the map area are assumed to be late Quaternary in age because they are similar to deposits of this age west of the map area (Billingsley and Workman, 1999; Billingsley and Hampton, 2000).

STRUCTURAL GEOLOGY

The East Kaibab Monocline overlies deep-seated reverse faults in which compressional forces have folded the strata up-to-the-west during the Late Cretaceous and early Tertiary time (Huntoon, 1990). During the Pliocene and Pleistocene, extension has reactivated some of these deep-seated faults, producing normal down-to-the-west fault separations that reverse the Cretaceous and Tertiary offset. Erosion of the softer Triassic and Jurassic rocks has produced the House Rock strike valley, reducing a once larger Paria Plateau to its present area.

In general, the East Kaibab Monocline has a north-south orientation in the map area. The East Kaibab Monocline consists of one fold in the northern two-thirds of the map area that separates into an upper and lower segment in the southern third of the map area. The upper segment trends about 35° southwest, becoming more southerly in trend south of the map area. The lower segment trends about 17° southeast at the southern edge of the map area. Both segments eventually become one fold again about 32 km (20 mi) south of the map area.

Trail Canyon Fault is a normal high-angle fault composed of two segments that parallel the base of the upper segment of the East Kaibab Monocline near Trail Canyon in the southwest corner of the map area. The collective offset of strata is down-to-the-west about 122 m (400 ft), which partly reverses the Laramide monoclinal uplift. A small down-to-the east fault west of the Trail Canyon Fault has produced a small graben structure, which contributes offset to form Trail Canyon. The Trail Canyon Fault appears to vertically offset the lower segment of the East Kaibab Monocline in House Rock Valley, giving the topographic appearance of lateral-slip offset. There is no exposure of the Trail Canyon Fault plane to determine the direction of slip, but since most faults in this area contain normal high-angle vertical fault separations, it is assumed that the Trail Canyon Fault is a high-angle to vertical normal fault, but net-slip or lateral-slip separation along the Trail Canyon Fault is possible.

On the Paria Plateau, gently tilted Mesozoic strata are offset by small near-vertical normal faults oriented N.

45° W. in the northeast quarter of the map area. The regional joint trends shown on the map suggest regional stress patterns that may relate to Laramide compressional stresses and to recent tensional stresses. The bedrock joints mapped on the Paria Plateau are useful in that they probably indicate a direction of ground water flow along strongly jointed areas towards local spring discharge areas along the west side of the plateau.

Locally folded strata on the Kaibab Plateau, too localized to show at map scale, formed as a result of Pleistocene and Holocene solution of gypsum in the Harrisburg Member of the Kaibab Formation. These folded strata are commonly associated with the solution of gypsum or gypsiferous siltstone along drainages or joints on the plateau.

Gypsum dissolution in the Woods Ranch Member of the Toroweap Formation has resulted in the development of large sinkholes on the Kaibab Plateau. The karst is probably Holocene and Pleistocene in age based on the youthfulness of some sinkhole walls and recent rock falls into the depressions. Circular collapse structures, minor folds, and other surface irregularities are formed by dissolution of gypsum and gypsiferous siltstone in the Kaibab or Toroweap Formations or both. Locations of sinkholes that form enclosed basins or depressions are indicated on the map by a triangle symbol.

Breccia pipe structures

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

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 variations in morphologic character and physiographic expression. Older alluvial fan and terrace-gravel deposits generally exhibit extensive erosion, whereas younger deposits either are actively accumulating material or are lightly eroded as observed on 1976, 1980, and 1986 aerial photographs. Contacts between most surficial deposits are commonly arbitrary

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 7 ft) thick

Qd **Sand-sheet and dune deposits (Holocene)**—In House Rock Valley, reddish-brown, fine- to medium-grained, silty sand. Forms 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 mainly derived from House Rock Wash and its tributaries and is blown in an easterly and northeasterly direction. Forms climbing and falling dunes and sand-sheet deposits on landslide blocks near base of Vermilion Cliffs. On Paria Plateau, light-red, thin to thick, sand-sheet and small, complex dune deposits locally derived from erosion of the Navajo Sandstone (Jn). Contacts are approximate. Thickness 0.5 to 3 m (1 to 30 ft) east of House Rock Wash; 1 to 11 m (3 to 35 ft) thick on Paria Plateau

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. 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; poorly sorted, unconsolidated. Include lenses of coarse gravel composed of angular to subrounded pebbles and cobbles of limestone, chert, and sandstone locally derived from Kaibab and Toroweap Formations along East Kaibab Monocline. East of House Rock Wash, red and reddish-brown, fine-grained sand. Includes some well-rounded sandstone pebble clasts and purple mudstone matrix, often integrated with wind blown sand (Qd) deposits that are locally derived from House Rock Wash and its tributaries. 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; include well-rounded clasts of limestone and subrounded to angular chert fragments. Represents relatively less active, low-gradient, alluvial stream-channel or shallow valley drainage deposits; mainly on Kaibab Plateau. Subject to sheetwash flooding and temporary ponding; 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 cliffs. 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. Include detached blocks of Triassic and Jurassic strata that have slid downslope and rotated backward toward the parent cliff as a loose incoherent mass of broken rock and deformed strata; found principally below Vermilion Cliffs. Includes minor deposits in Burro Canyon. 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 (Qg_1) deposits but partly consolidated. Composed mainly of gray to reddish-brown, fine-grained sand and silt matrix. Form terraces about 2 m (6 ft) above modern stream floors and about 1 m (3 ft) above young terrace-gravel (Qg_1) deposits. Locally inset into young-intermediate age alluvial fan (Qa_2) deposits. Intertongue with or locally overlain by alluvial fan (Qa_1 and Qa_2) and sand (Qd) deposits. 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 development in low-lying areas. 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. East of House Rock Wash, wind-blown sand sheets and small complex dunes cover much of the deposits toward the base of the Vermilion Cliffs. Support sparse growth of sagebrush, cactus, and grass. Ranges from 2 to 10 m (5 to 30 ft) thick

Qa_3 **Old-intermediate alluvial fan deposits (Pleistocene)**—Similar to young and young-intermediate alluvial fan (Qa_1 and Qa_2) deposits, partly cemented by calcite and gypsum. Surface has thin soil development 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 the downslope ends, commonly overlapped by alluvial fan (Qa_1 and Qa_2) deposits at upslope ends. Support sparse to moderate growth of grass and cactus. About 2 to 8 m (6 to 25 ft) thick

Qa_4 **Old alluvial fan deposits (Pleistocene)**—Gray, gravelly alluvial deposits that may have been part of an older alluvial fan deposit at south-central edge of map area. Similar to old (Qa_4) alluvial fans south of map area. About 4.5 m (15 ft) thick

SEDIMENTARY ROCKS

Glen Canyon Group (Lower Jurassic)—Includes, in descending order, the Navajo Sandstone, the Kayenta Formation, and the Moenave Formation

Jn **Navajo Sandstone (Lower Jurassic)**—Reddish-orange, medium-grained, well-sorted, massive to crossbedded, cliff-forming sandstone. Includes local thin lenses of red sandy dolomite. Contains large-scale crossbed sets, some of which are contorted by slumping that occurred during or shortly after deposition. In some areas there is little or no crossbeds, shows massive or flat-bedded sandstone. Forms well-jointed, prominent upper part of Vermilion Cliffs and surface bedrock of Paria Plateau. Sharp to gradational contact with underlying Kayenta Formation is placed at base of massive, cliff-forming, crossbedded sandstone. Incomplete section due to erosion of upper part but is as much as 520 m (1,700 ft) thick just east of map area (Wells, 1960). About 30 to 110 m (100 to 360 ft) thick

Jk **Kayenta Formation (Lower Jurassic)**—Purple-red and reddish-brown, fine-grained, slope-forming siltstone and sandstone. Consists of a sequence of alternating beds of cliff-forming sandstone and slope-forming siltstone. Siltstone is thin bedded and locally crossbedded on a small scale, and sandstone is thin to thick bedded, ripple marked, and crossbedded on a small to medium scale. Thin lenticular conglomerate beds of angular siltstone fragments are common. Sharp conformable contact with underlying cliff of Springdale Sandstone Member of the Moenave Formation. Thickness, 85 to 95 m (285 to 310 ft)

Moenave Formation (Lower Jurassic)—Includes, in descending order, Springdale Sandstone Member and Dinosaur Canyon Sandstone Member as defined by Colbert and Mook (1951)

Jmos **Springdale Sandstone Member**—Reddish-brown to purplish, medium- to fine-grained, micaceous, thick-bedded, cliff-forming sandstone; stained black in places. Includes lenses of siltstone and conglomerate. Conformable and gradational contact with underlying Dinosaur Canyon Member. About 45 m (150 ft) thick

Jmod **Dinosaur Canyon Member**—Orange-red, varicolored, coarse- to fine-grained, thin- to thick-bedded, slope-forming siltstone and mudstone. Sharp unconformable contact with light-gray and purple mudstone of Owl Rock Member of the Chinle Formation. About 30 to 45 m (100 to 150 ft) thick

Chinle Formation (Upper Triassic)—Includes, in descending order, the Owl Rock, Petrified Forest, and Shinarump Members as defined by Dubiel (1994)

^co **Owl Rock Member**—Light-gray to purplish-gray ledge-forming siliceous and calcareous-nodular limestone separated by interbedded purple-red to blue-white, slope-forming mudstone. Gradational contact with underlying Petrified Forest Member. Thickness about 38 m (125 ft)

^cp **Petrified Forest Member**—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 that may be equivalent to Shinarump Member. Contains brown, yellow, white, and red petrified wood 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. About 90 m (300 ft) exposed at base of Vermilion cliffs in map area. Probably as much as 240 m (800 ft) thick as exposed near Lees Ferry, Arizona

^cs **Shinarump Member—**Brown, cliff-forming, gravel to coarse-grained, crossbedded sandstone. Contains numerous scattered brown, gray, white, red, and black, very well rounded quartzite pebbles generally 3 to 4 cm (1 to 2 in) in diameter. Locally absent or covered. About 12 m (40 ft) thick

^m **Moenkopi Formation (Middle? and Lower Triassic)**—Undivided. Includes, in descending order, the upper red member, Shnabkaib Member, middle red member, Virgin Limestone Member, and lower red member as used by Stewart and others (1972). The basal Timpoweap Member was not recognized, but is present north of the map area. Consists of dark-red, thin-bedded, slope-forming siltstone and sandstone. Alluvial fan deposits, making individual identification of above members impractical, cover most of the Moenkopi Formation. Only the lower 12 m (40 ft) of the approximately 122 m (400 ft) of the Moenkopi Formation is exposed along the lower flanks of the East Kaibab Monocline

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 dolomite, gray to yellowish-brown calcareous siltstone, and 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 averaging about 3 m (7 ft) thick. Includes slope-forming, light-gray and red gypsiferous siltstone and fine- to medium-grained calcareous sandstone. Gradational and arbitrary contact with underlying Fossil Mountain Member placed near top of white cherty limestone slope or ledge of Fossil Mountain Member. Contact difficult to place in tilted strata on upper East Kaibab Monocline due to local erosion and forest cover. Unit thickens west and north, thins east. As much as 40 m (130 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 layers of chert nodules in upper part and intraformational chert breccia beds. Includes white, low-angle, crossbedded sandstone in middle part and gray-brown dolomite in lower part. Unit weathers light gray in upper part and dark brown in lower part. Unconformable contact with underlying Woods Ranch Member of the Toroweap Formation marked by solution and channel erosion with local relief as much as 2 m (6 ft). Contact locally obscured by talus and minor landslide debris in Burro Canyon. Unit thickens west, thins east. About 75 m (250 ft) thick

Toroweap Formation (Lower Permian)—Includes, in descending order, the 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, gypsiferous siltstone, and pale-red to white silty sandstone. Beds are locally distorted due to gypsum dissolution. Lower contact is gradational and marked at top of limestone cliff of Brady Canyon Member. Thickness 30 to 40 m (100 to 130 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 limestone. Includes chert nodules in upper part. Vuggy appearance. Lower contact with Seligman Member is gradational and arbitrarily marked at base of limestone cliff. Unit thins east, thickens west. Approximately 18 m (60 ft) thick in Burro Canyon

Pts **Seligman Member**—Yellowish-gray, medium- to thin-bedded, ledge- and slope-forming dolomite, sandstone, and gypsiferous sandstone. Includes gray, thin-bedded limestone. Lower part includes yellow, fine- to medium-grained, thin-bedded, low- to high-angle crossbedded and planar-bedded sandstone lenses of the Coconino Sandstone in basal part of Seligman Member of the Toroweap Formation (Rawson and Turner, 1974). About 9 m (30 ft) thick

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. Incomplete section, only top 6 m (20 ft) exposed in Burro Canyon (Wells, 1960)

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

By
Haydee M. Hampton

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 Spring quadrangle. Together with the accompanying text file (hrsgeo.txt, hrsgeo.doc or hrsgeo.pdf), 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. 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 gzip or winzip utilities to access the plot files. Requests for a tape copy of the digital database or plotfiles can be made by sending an 8mm Exabyte tape with 2.3 GB or 5.0 GB capacity 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/mf2367

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-2367.

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 Spring 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:

hrspoint.e00	hrspoint	Point features including strike and dip information and annotation
hrspoly.e00	hrspoly	Faults, depositional contacts, geologic units and annotation
hrsfold.e00	hrsfold	Fold axes and annotation

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

hrs.lin.e00	hrs.lin	Lineset
hrs.mrk.e00	hrs .mrk	Markerset
color524.shd.e00	color524.shd	524 color shadeset
geopoint.lut.e00	geopoint.lut	hrspoint point lookup table
geopoly.lut.e00	geopoly.lut	hrspoly poly lookup table
geoline.lut.e00	geoline.lut	hrsfold and hrspoly line lookup table
geofont.txt.e00	geofont.txt	Textset used for all annotation, symbolset 30
hrsbase.tif.gz	Zipped background hypsography image	
hrsbase.tfw	World file accompanying drghypso.tif	
import.aml	AML to convert all the export files in the database to coverages and graphic files	

Postscript Plotfile Package

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

hrsmap.eps - Encapsulated Post Script plottable file containing complete map composition with geology, symbology, annotation, base map, correlation of map units, legend of symbols and lines and key of geologic units of the House Rock Spring quadrangle

hrsgeo.doc - 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

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

PDF file Description

hrsmap.pdf - Geologic map, correlation of map units, legend of symbols and lines and key of geologic units
hrsgeo.pdf - This file as well as the report containing detailed unit descriptions and geological information.

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, an 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 packaged 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 gzip.

DATABASE SPECIFICS

Procedure Used

Stable-base maps of geologic features 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 adapted by Marilyn Flynn. A tic file was created in lat/long and projected to UTM zone 12. Tics were defined in a 2.5 minute grid of latitude and longitude. The RLC file was converted to an ARC/INFO Grid in ARC/INFO and projected to UTM zone 12 using a first order polynomial transformation to the UTM tic marks. ARC/INFO generated the following RMS report after transforming the original grid:

Forward Transformation Coefficients

coef #	coef x	coef y
0	-68761.973	-13035.805
1	1.004	-0.017
2	0.016	1.005

Forward Transformation Errors

gcp id	input x output x	input y output y	x error	y error
1	399496.450	4081014.790		

	399734.051	4081393.737	-0.881	-0.530
2	410587.052	4081076.989		
	410875.052	4081269.748	1.093	-1.036
3	410671.147	4067279.412		
	410730.021	4067403.259	-0.879	-0.531
4	399559.410	4067217.114		
	399570.886	4067527.088	0.238	-0.439
5	403238.343	4071834.509		
	403342.934	4072106.358	1.494	0.372
6	406917.090	4076452.533		
	407110.991	4076687.244	-1.066	2.165

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Forward transformation RMS Error (X, Y) = (1.014, 1.053)
Forward transformation Chi-Square (X, Y) = (6.169, 6.656)

The linework was vectorized using ESRI's ArcScan module. Lines, points, polygons, and annotation were edited using ARCEDIT.

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 HRSPOLY. These distinctions and the geologic identities of the boundaries are stored in the LINETYPE field according to their line type.

Arc Attribute Table Definition:

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	HRSPOLY#	4	5	B	-
29	HRSPOLY-ID	4	5	B	-
33	LINETYPE	50	50	C	-
83	NAME	50	50	C	-
133	POINTTYPE	50	50	C	-

The AAT defined above represents the AAT in HRSPOLY. The AAT for HRSFOLD is identical except for the additional item name "plunge," which is the value of the plunge of the fold axis.

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
HRSPOLY#	Unique internal number
HRSPOLY-ID	Unique identification number
LINETYPE	Line type
NAME	Feature name for annotation
POINTTYPE	Arcmarker symbol

The geologic line types relate to geologic line symbols in the lineset HRS.LIN according to the lookup table GEOLINE.LUT.

Domain of Line Types recorded in LTYPE field:

HRSPOLY

CONTACT- unit contacts mapped with certainty
NORMAL HIGH ANGLE INFERRED FAULT - inferred normal faults
NORMAL HIGH ANGLE CONCEALED FAULT - concealed faults
NORMAL HIGH ANGLE FAULT - normal faults
MAP BOUNDARY - map boundary

HRSFOLD

ANTICLINE- anticline axis
CONCEALED ANTICLINE - concealed anticline axis
CONCEALED MONOCLINE - concealed monocline axis
MONOCLINE - monocline axis
PLUNGING ANTICLINE - plunging anticline axis
SYNCLINE - syncline axis

POLYGONS

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

Definition of Polygon Attribute Table:

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

Description of Item Names:

Item Name	Description
AREA	Area of polygon in square meters
PERIMETER	Perimeter of polygon in meters
HRSPOLY#	Unique internal number
HRSPOLY-ID	Unique identification number
UNIT	Unit label
PATTERN	Fill pattern

Domain of UNIT (map units):

Qaf, Qs, Qd, Qg1, Qa1, Qv, Qt, Ql, Qg2, Qa2, Qa3, Qa4, Jn, Jk, Jmos, Jmod, Trco, Trcp, Trcs, Trm, Pkh, Pkf, Ptw, Ptb, Pts, Ph

P represents Permian strata, Tr represents Triassic strata, 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 GEOPOLY.LUT

POINTS

Geologic point feature information (ex: strike and dip) is recorded as coordinate data with related information. This information is described in the HRSPOINT Point Attribute Table (PAT).

Definition of Point Attribute Table:

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC
1	AREA	8	18	F	5
9	PERIMETER	8	18	F	5
17	HRSPOINT#	4	5	B	-
21	HRSPOINT-ID	4	5	B	-
25	NAME	30	30	C	-
55	POINTTYPE	60	60	C	-
115	DIP	3	3	I	-
118	STRIKE	3	3	I	-

Description of item names:

Item	NameDescription
AREA	
PERIMETER	
HRSPINT#	Unique internal number
HRSPOINT-ID	Unique identification number
NAME	Name of point for annotation (if applicable)
POINTTYPE	Point type
DIP	Dip angle in azimuth degrees
STRIKE	Strike angle in degrees

The coverage HRSPOINT contains strike and dip data and other pertinent structural data represented by point symbology, including joints and sinkholes. HRSFOLD and HRSPOLY also have point types defined in their respective AAT files which correspond with the defined linetype for an arc. These point types are related to the lookup table GEOPOINT.LUT and are from the symbolset HRS.MRK.

Domain of PTTYPE:

bedding
vertical joint
probable breccia pipe (c)
sinkhole

ANNOTATION

HRSPOLY, HRSFOLD, AND HRSPOINT contain the annotation for the features contained in each respective coverage. For example, HRSPOLY contains the annotation for unit labels, while HRSFOLD contains fold names. anno.unit, anno.breccia, anno.fault, anno.title

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 non-conventional 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 larger 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 HRS.LIN. It is related to the database by a lookup table called GEOLINE.LUT. Similarly, the markerset for this database is HRS.MRK, and its lookup table is GEOPOINT.LUT. Colors in the polygon coverage (HRSPOLY) are assigned based on the UNIT and were chosen from a shadeset called COLOR524.SHD and a lookup table GEOPOLY.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. These 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 HRS.MET, the FGDC standard metadata for the database, and HRSMET.REV, a revision list with current information on the status of all files described in this report and found in the database.