Geologic Map of Hidden Hills and Vicinity, Mohave County, Northwestern Arizona

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INTRODUCTION

The geologic map of the Hidden Hills and vicinity is part of a cooperative project between the U.S. Geological Survey, the U.S. National Park Service at Grand Canyon National Park and Lake Mead National Recreational area, and the Bureau of Land Management, Arizona Strip Field Office, St. George, Utah, to provide geologic framework information of the Arizona Strip area of northwest Arizona. This geologic map depicts the Hidden Hills area, which is about 13 km (8 mi) north of the Lake Mead National Recreation Area and the western part of Grand Canyon National Park. This map completes one of the remaining areas where uniform quality geologic mapping at the 1:24,000-scale was needed to complete part of the Mount Trumbull 1:100,000-scale map of the Grand Canyon area. The map area includes part of the Sanup and Shivwits Plateaus of the southwestern Colorado Plateau and part of the Grand Wash Cliffs Wilderness Area. The geologic information in this report may be useful in other geologic or related scientific studies and resource land management programs such as range management and flood control for all federal and state agencies and private affairs.

The map area lies in a remote region of the Arizona Strip of northwest Arizona about 64 km (40 mi) south of St. George, Utah, the nearest significant town (fig. 1). Elevations range from about 2,057 m (6,748 ft) at Hudson Point on Hidden Rim of the upper Grand Wash Cliffs (west-central edge of the map area) to about 1,300 m (4,260 ft) in Pigeon Canyon on the Sanup Plateau (southwest edge of the map area). Primary vehicle access is by dirt road and unimproved jeep trails that traverse various parts of the map area,
except within the Grand Wash Wilderness Area. Maps, extra fuel, two spare tires, extra food, and water are highly recommended when traveling in this remote region.

Land in the map area is managed by the Bureau of Land Management, but also includes 12 sections of land belonging to the State of Arizona and about three sections of private land in the Wildcat Ranch area on the Shivwits Plateau, southeast quarter of the map area (U.S. Department of the Interior, 1993). The Grand Wash Cliffs Wilderness Area was designated as a wilderness in 1984 (Becky Hammond, Bureau of land Management, written commun., summer 1998).

Lower elevations of the Sanup Plateau support a sparse growth of sagebrush, cactus, grass, joshua trees, and a variety of desert shrubs. Sagebrush, grass, cactus, cliffrose bush, pinion pine trees, and juniper trees thrive at higher elevations above 1,525 m (5,000 ft) on the Shivwits Plateau. Surface runoff in the western two-thirds of the map area drains west towards the Grand Wash Trough through numerous canyon drainages that have eroded into the Grand Wash Cliffs and Hidden Hills area. Hidden and Pigeon Canyons are the two principal drainages. The eastern one-third of the map area drains east toward the Grand Canyon down two principal drainages, Parashant Canyon and Agway Valley, which become Andrus Canyon southeast of the map area. The entire map area eventually drains to the Colorado River south of the map.

PREVIOUS WORK

Early reconnaissance photo geologic mapping of this area is compiled onto Arizona state geologic maps by Wilson and others (1969) and Reynolds (1988). A preliminary geologic map of the Grand Wash Wilderness Area was produced by Billingsley and others (1986). A geologic map of the Poverty Spring quadrangle is compiled onto the northeastern quarter of this map (Billingsley, 1997). Geologic mapping of adjacent areas include (1) the Sullivan Draw and vicinity which adjoins the northern edge of this map area (Billingsley, 1994), (2) the upper Hurricane Wash and vicinity which adjoins the northeast corner of the map area (Billingsley and others, unpub. data), (3) the upper Parashant Canyon and vicinity which lies along the east edge of the map area (Billingsley and others, 2000), (4) the lower Granite Gorge and vicinity map which borders the southern edge of the map area (Huntoon and others, 1982; upgraded version by Wenrich and others, 1996), and (5) the breccia-pipe and geologic map of the northwestern part of the Hualapai Indian Reservation (Wenrich and others, 1996) which also borders the southern edge of the map area .

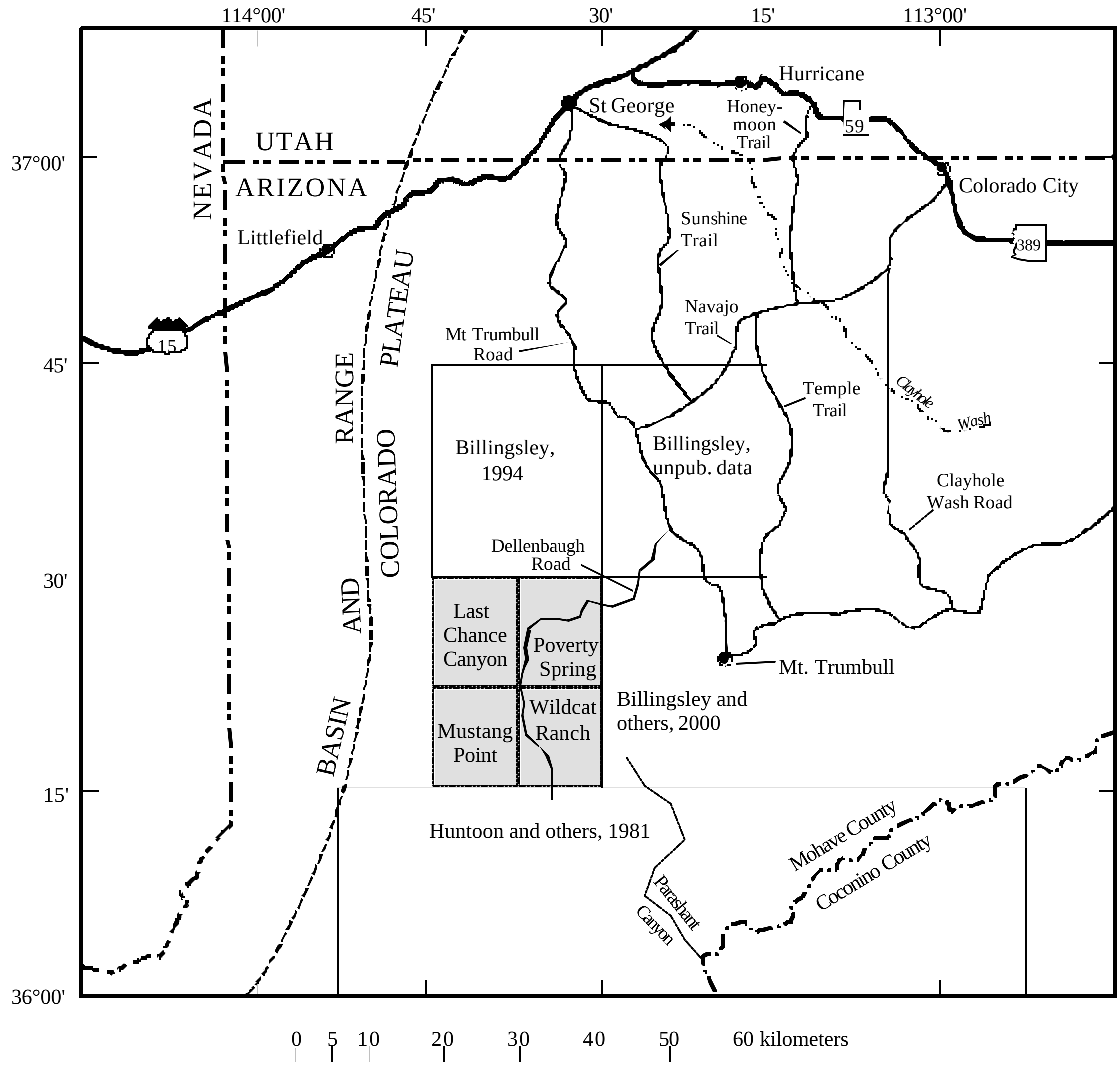

Figure 1. Index map showing the 7.5-minute quadrangles that form the Hidden Hills and vicinity and adjacent mapped areas, northern Mohave County, northwestern Arizona.

MAPPING METHODS

This map was produced using 1976 infrared 1:24,000-scale aerial photographs followed by extensive field checking. Map contacts between members of the Permian Kaibab and Toroweap Formations in the Hidden Hills area of the Shivwits Plateau are approximately located in some areas because of extensive forest cover and poor exposure. Many of the Quaternary alluvial deposits have similar lithology but different geomorphic characteristics and were mapped almost entirely by photogeologic methods. Stratigraphic position and the amount of erosional degradation were used to determine relative ages of alluvial deposits having similar lithologies such as young and old alluvial fan deposits. Each map unit and structure was investigated in the field to insure accuracy of description.

GEOLOGIC SETTING

The map area lies within the Shivwits and Sanup Plateaus, which are subplateaus within the Colorado Plateaus physiographic province (herein referred to as the Colorado Plateau; Billingsley and others, 1997). The Grand Wash Fault, about 3 km (2 mi) west of the northwest corner of the map area, marks the structural boundary between the Colorado Plateau and the Basin and Range geologic province. Maximum vertical separation of strata across the Grand Wash Fault is estimated at about 3,000 m (10,000 ft) down to the west (Lucchitta, 1979). The boundary between the higher Shivwits and lower Sanup Plateau is marked along the top of the Grand Wash Cliffs. The Sanup Plateau, also known on some maps as the Grand Gulch Bench, lies between the upper and lower Grand Wash Cliffs. The Shivwits and Sanup Plateaus are characterized by nearly flat lying Paleozoic sedimentary strata that have an average regional dip of about 2° northeast. There are no major geologic structures within the map area, but small normal faults and grabens are present.

Tertiary volcanic rocks and Quaternary surficial deposits are widely distributed in the map area. The volcanic rocks are alkali-olivine basalt flows with a few associated pyroclastic deposits on top of the flows. The volcanic rocks overlie Paleozoic and Mesozoic strata at Poverty Mountain (east-central edge of the map area) and an area west of Agway Valley, southeast quarter of the map area. Alkali-olivine basalt dikes are present in Pigeon Canyon and are assumed to be Tertiary in age because they align with similar north-south-trending, 9-Ma-old dikes about 11 km (7 mi) south of the map area (Wenrich and others, 1995; Wenrich and others, 1997).

Surficial deposits include terrace-gravel, alluvial fan, talus slope, and landslide debris masses throughout the map area. Artificial man-made stock tanks are also mapped. Map contacts between most of the Quaternary deposits are intertonguing and (or) gradational, both laterally and vertically. The subdivision of Quaternary surficial units is intentionally detailed because these units strongly influence the planning of road construction, range management, flood control, soil erosion, and other environmental or biological resource studies of this region. All surficial deposits in the map area are assumed to be Quaternary in age because they are related to similar deposits east and north of the map area where they contain clasts derived from Quaternary basalts (Billingsley, 1994, 1997; Billingsley and others, 2000; Billingsley and others, 2001; and Billingsley and others, unpub. data).

PALEOZOIC AND MESOZOIC SEDIMENTARY ROCKS

There are about 18 m (60 ft) of Pennsylvanian strata exposed in Pigeon Canyon and about 777 m (2,550 ft) of Permian strata and about 365 m (1,200 ft) of Triassic strata exposed in the map area. The Triassic strata are mostly covered by Tertiary basalt flows and Quaternary landslide debris. The Paleozoic and Mesozoic strata include, in order of decreasing age, part of the Supai Group, which includes the upper part, undivided (Upper Pennsylvanian), the Pakoon Limestone (Permian), and the Esplanade Sandstone (Permian); the Hermit Formation (Permian); the Toroweap Formation (Permian), which includes the Seligman, Brady Canyon, and Woods Ranch Members; the Kaibab Formation (Permian), which includes the Fossil Mountain and Harrisburg Members; and the Moenkopi Formation (Triassic), which includes the Timpoweap, lower red, Virgin Limestone, middle red, and Shnabkaib Members. Small fragments of petrified wood and quartz pebbles similar to the Shinarump Member of the Chinle Formation (Triassic) are present in small amounts in the southeastern quarter of the map area as a lag gravel (QTa), but strata of the Chinle Formation was not found. The Coconino Sandstone is too thin and discontinuous to be mapped as a separate unit and is included as part of the Seligman Member of the Toroweap Formation. Measured sections by Fisher (1961) and Schleh (1966) and mapping by Billingsley and others (2000) demonstrate that the Coconino Sandstone intertongues within the lower part of the Seligman Member of the Toroweap Formation in Parashant Canyon just west of the map area.

The Permian rocks are well exposed along the Grand Wash Cliffs (west quarter of the map area) but are poorly exposed in the Hidden Hills area due to forest cover. Gray limestone and reddish-gray sandstone of the Pakoon Limestone and red to white sandstone of the Esplanade Sandstone form the Grand Gulch Bench (Sanup Plateau on smaller maps) at the west edge of the map area. Gray to reddish-brown interbedded siltstone, sandstone, limestone, and gypsum of the Harrisburg Member of the Kaibab Formation and cherty limestone and sandy limestone of the Fossil Mountain Member of the Kaibab Formation form the bedrock surface of the Shivwits Plateau where it is not covered by Mesozoic strata, volcanic rocks, or alluvial deposits. The contact between the Harrisburg and Fossil Mountain Members of the Kaibab Formation is approximate in the Hidden Hills area due to talus deposits that cover the contact and is based on exposed thickness along the Grand Wash Cliffs and in Hidden Canyon.

The Mesozoic rocks are composed mainly of red and white siltstone and sandstone of the Moenkopi Formation that are mostly covered by Tertiary basalt flows and landslide debris in the Poverty Mountain and Agway Valley areas. Early Tertiary and Quaternary erosion removed an unknown thickness of the upper part of the Triassic rocks and all subsequent younger strata above the Moenkopi Formation that were present in the map area before deposition of the Tertiary basalts. Details of the Paleozoic and Mesozoic rock strata are given in the Description of Map Units.

VOLCANIC ROCKS

The Tertiary basalt flows at Poverty Mountain and west of Agway Valley are generally associated with fissure eruptions along northwest-trending fractures or joints in the bedrock. In the dying stages of the eruptions, gaseous vents formed a few small pyroclastic cone deposits on the basalt flows. The Tertiary basalts generally flowed west and northwest down low-gradient drainages over a low-relief bedrock landscape of Moenkopi and Kaibab strata. The regional dip of strata is about 1º to 2° east-northeast. The retreat of the Mesozoic strata by erosion towards the northeast produced northwest-southeast-striking drainages on the Shivwits Plateau west of Agway Valley that basalts flowed down. There are no basalt flows associated with dikes in the Pigeon Canyon area because the resultant basalt flows have been eroded away.

An interval of erosion after deposition of the Tertiary basalts removed most of the Moenkopi Formation and some of the upper Kaibab Formation that were not covered by a protective caprock of basalt. The soft strata of the Moenkopi Formation is readily subject to erosion around the edge of the Tertiary basalt flows allowing for steep, unstable hillside failures to form as landslide blocks. Headward erosion by sapping along joints and fractures in the basalt flows is the major mass-wasting erosional process carving into the Tertiary basalts of the map area. Several additional Tertiary dike sources for the Poverty Mountain Basalt and the basalt of the Shivwits Plateau are suspected to be present in the map area but are either covered by basalt flows or landslide debris.

The basalt of the Shivwits Plateau

The basalt of the Shivwits Plateau is informally named the Shivwits Plateau basalt by Best and others (1980) and Reynolds and others (1986). The basalt of the Shivwits Plateau includes a widespread mass of several basaltic flows and associated pyroclastic vents on the Shivwits Plateau west of Agway Valley. Several volcanic mountains south of the map area such as Mount Dellenbaugh, Blue Mountain, and Yellow John Mountain comprise the majority of the basalt of the Shivwits Plateau (Best and others, 1980; Lucchitta and McKee, 1974; Reynolds and others, 1986; Huntoon and others, 1981, 1982).

The basalt flows that cap Grassy and Poverty Mountains were included in the basalt of the Shivwits Plateau (Shivwits Plateau basalt) nomenclature by Reynolds and others (1986) probably because of their approximate association to Tertiary volcanic mountains on the Shivwits Plateau. But Billingsley and others (2000) have formally named the Grassy Mountain Basalt and Poverty Mountain Basalt as individual map units separate from the basalt of the Shivwits Plateau because these basaltic rocks are not physically connected to the Shivwits basalt masses and are identified as separate mappable units of a similar age.

There are five K/Ar ages from alkali olivine basalts reported from the basalt of the Shivwits Plateau south of the map area: 6.78±0.30 and 7.64±0.30 Ma near Mount Dellenbaugh (Lucchitta and McKee, 1974); 6.78±0.15 Ma at Mount Dellenbaugh, informally named the Dellenbaugh basalt by Reynolds and others (1986); 7.06±0.49 Ma at Mount Dellenbaugh (Reynolds and others, 1986); and 8.2±0.1 Ma at Price Point (southeast of Mount Dellenbaugh), informally named the Price Point basalt (Wenrich and others, 1995). These K/Ar dates probably represent the youngest flows of the area except at Price Point where the flow was sampled by the author from the bottom and oldest of several flows.

The Tertiary flows west of Agway Valley are connected to basalt flows at Yellow John Mountain southeast of the map area, but most of the basalt flows along the west rim of Agway Valley came from local dike fissures that are aligned N. 30° W. as are those at Yellow John Mountain (Huntoon and others, 1981), indicating a similar eruptive event for flows in this part of the Shivwits Plateau. Most of the basalt of the Shivwits Plateau flowed west and northwest down a wide ancestral Hidden Canyon paleovalley near Wildcat Ranch that now forms an inverted ridge east of the present valley drainage.

The basalt flows on the Shivwits Plateau provide a unique geomorphic view of the Tertiary landscape of this part of the Colorado Plateau, but further studies and accurate age determinations of the basalts are needed. The average age of the basalt of the Shivwits Plateau in the map area is estimated to be about 6 Ma based on K/Ar ages of samples taken farther south.

Poverty Mountain Basalt

The basaltic rocks at Poverty Mountain were formally named the Poverty Mountain Basalt for Poverty Mountain, the type area, northern Mohave County, Arizona (Billingsley and others, 2000). The Poverty Mountain Basalt is comprised of one or more alkali olivine basalt flows and associated pyroclastic deposits. The sources for most of the basalt flows are dikes and pyroclastic vents at the east end of Poverty Mountain, east-central edge of the map area. A sample of the Poverty Mountain Basalt collected by Best and others (1980) at the west end of Poverty Mountain (sec. 22, T. 35 N., R. 12 W.) yielded a K/Ar age of 4.75±0.25 Ma.

Poverty Mountain is a conspicuous, but low-lying, flat-topped mountain that forms a regional landmark for this part of the Shivwits Plateau. Poverty Mountain is comprised of Triassic strata of the Moenkopi Formation having a regional dip of about 2° east. The east-dipping Moenkopi strata were beveled by Tertiary erosion along a west-facing slope. When the Poverty Mountain Basalt erupted, it flowed west down the west-facing slope toward an ancestral northwest flowing Hidden Canyon drainage. The basalt flowed about 8 km (5 mi) descending about 153 m (500 ft) for a general gradient of about 30 m/km (100 ft/mi). Flows of the basalt clearly followed local tributary drainages west towards Hidden Canyon, now preserved as narrow inverted valleys.

The Hidden Canyon drainage eroded headward from the Grand Wash Cliffs before the eruption of the Poverty Mountain Basalt and was the principal drainage for most of the southern Shivwits Plateau prior to stream capture by Parashant Canyon drainage. Sometime near or after the 4.7 Ma Poverty Mountain Basalt flows, headward erosion of Parashant Canyon drainage captured the Hidden Canyon drainage about 4 km (2.5 mi) south of Poverty Mountain near the southeast quarter of sec 3, T. 34 N., R. 12 W. The stream capture diverted the upper Hidden Canyon drainage into the steeper gradient of Parashant Canyon. The lack of erosion in Hidden Canyon west of Poverty Mountain allowed for local accumulations of alluvium in the lower reaches of that drainage. Headward erosion north from Parashant Canyon into the abandoned Hidden Canyon drainage reversed that part of the drainage south into Parashant Canyon. As a result of stream capture, the upper part of the original Hidden Canyon drainage on the Shivwits Plateau is now called Parashant Wash. The current Hidden Canyon drainage has deepened only about 90 m (300 ft) in the last 4.7 Ma since the Poverty Mountain Basalt flowed.

STRUCTURAL GEOLOGY

Gently tilted Paleozoic and Mesozoic strata offset by near-vertical normal faults represent the structural character of this part of the Shivwits Plateau. The regional dip of the Paleozoic and Mesozoic strata increases to about 3º or 4° east-northeast along the Hidden Rim of Hidden Hills and the upper Grand Wash Cliffs, west side of the Shivwits Plateau.

The southern extension of Hobble Graben, a late Miocene structure, extends into the northwest quarter of the map area (Billingsley, 1994). Hobble Graben appears to have partly controlled the headward erosion of some tributaries of Hidden Canyon, but the general trend of the Hidden Canyon drainage appears to have been initiated as a strike valley along retreating Mesozoic strata before Hobble Graben formed. Other minor structures include the Pigeon Fault, a normal near-vertical fault at the head of Pigeon Canyon and a graben and horst structure in the Agway Valley area.

Locally warped and bent strata too localized to show at map scale are the result of Pleistocene and Holocene dissolution of gypsum in the Harrisburg Member of the Kaibab Formation, mostly in the east half of the map area. These bent strata are commonly associated with the dissolution of gypsum along drainages or joints in the Kaibab Formation on the Shivwits Plateau.

Gypsum dissolution in the Harrisburg Member of the Kaibab Formation has resulted in several small sinkholes and caves on the Shivwits Plateau. The karst depressions are Holocene and Pleistocene in age because of their young appearance, and they are similar to other sinkholes mapped east and north of this map area (Billingsley, 1994; Billingsley and others, 2000; Billingsley and others, 2001; Billingsley and others, unpub. data). Locations of sinkholes that form enclosed basins or depressions are indicated on the map by a triangle symbol.

Breccia pipe structures

Circular collapse structures, minor folds, and other surface irregularities are due to dissolution of gypsum and gypsiferous siltstone in the Kaibab or Toroweap Formations. Some bowl-shaped depressions in the Kaibab Formation, characterized by inward-dipping strata, may be the surface expression of a breccia pipe originating from dissolution of the deeply buried Mississippian Redwall Limestone (Wenrich and Huntoon, 1989; Wenrich and Sutphin, 1989). Such features usually have inward dipping strata and are marked on the map by a dot and the letter C. One breccia pipe in particular that forms a resistant, calcium-rich, circular collared-rim typical of a breccia pipe reinforced with calcite cementation is well defined about 3 km (2 mi) north of Agway Valley in the Harrisburg Member of the Kaibab Formation. The extra calcite cement has enhanced erosional resistance and preserved the inward dipping strata.

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DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

Surficial deposits (Quaternary and Tertiary)—Surficial deposits are differentiated from one another chiefly by photogeologic techniques on the basis of difference in morphologic character and physiographic position. Older alluvial fans and terrace-gravel deposits generally exhibit extensive erosion and are high in topographic relief; whereas, younger deposits either are actively accumulating material or are lightly eroded as observed on 1976 aerial photographs

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

Qs **Stream-channel alluvium (Holocene)—**Interlensing clay, silt, sand, and pebble to boulder gravel; unconsolidated and poorly sorted. Locally overlaps alluvial fan (Qa1 and Qa2), terrace-gravel (Qg1), upper part of valley-fill (Qv), and floodplain (Qf) deposits. Erodes into some younger intermediate alluvial fan (Qa2) and intermediate terrace-gravel (Qg2) deposits. Stream channels subject to intermittent high-energy flows and flash floods. Little or no vegetation in stream channels except for sagebrush and low, short-lived shrubs. Contacts with other alluvial deposits are approximate, but shown as a solid contact. Thickness, 1 to 3 m (2 to 10 ft)

Qf **Floodplain or ponded deposits (Holocene)—**Light-gray or tan clay, silt, sand, and lenses of pebble to cobble gravel; unconsolidated. Intertongue with or overlap valley-fill (Qv) or young alluvial fan (Qa1) deposits. Form relatively flat surfaces having little vegetation. Subject to frequent flooding or ponding. Thickness, 1 to 3 m (3 to 10 ft)

Qg1 **Young terrace-gravel deposits (Holocene)—**Light-brown, pale-red, and gray clay, silt, sand, and pebble to boulder gravel composed of well-rounded limestone and sandstone and angular to subrounded chert clasts, locally derived from the Esplanade Sandstone and the Hermit, Toroweap, and Kaibab Formations, and rounded to subrounded basalt clasts derived from locally exposed basalt flows. Form terraces about 1 to 3 m above modern streambeds. Locally inset into intermediate terrace-gravel (Qg2) deposits. Thickness, 1 to 4 m (3 to 12 ft)

Qa1 **Young alluvial fan deposits (Holocene)—**Gray-brown clay, silt, and gravel and boulders. Include lenses of coarse gravel composed of subangular to rounded pebbles and cobbles of limestone, chert, and sandstone locally derived from Permian formations along the Grand Wash Cliffs and on the Shivwits Plateau. Locally include well-rounded to subangular basalt clasts and Triassic sandstone clasts near Tertiary basalt flows west of Agway Valley and Poverty Mountain. Partly cemented by gypsum and calcite. Overlapped by or intertongue with upper part of valley-fill (Qv) and floodplain (Qf) deposits. Intertongue with or overlap young and old intermediate alluvial fan (Qa2 and Qa3) deposits. Subject to extensive sheet wash erosion, flash flood debris flows, and minor arroyo erosion. Support moderate growths of sagebrush, cactus, and grass. Thickness, 1 to 10 m (3 to 30 ft)

Qc **Colluvial deposits (Holocene and Pleistocene)—**White to gray clay, silt, fine-grained sand, and basalt fragments. Locally confined to basins or depressions formed within landslide debris areas around Poverty Mountain and west side of Agway Valley. Similar to floodplain and ponded (Qf) deposits but limited to local accumulations generally not associated with stream drainages. Subject to temporary ponding. Support sparse growth of grass and trees. Thickness, 1 to 3 m (2 to 10 ft)

Qv **Valley-fill deposits (Holocene and Pleistocene)—**Gray and light-brown clay, silt, sand, and lenses of pebble to small-boulder gravel; partly consolidated. Include well-rounded clasts of limestone and subrounded to angular chert. Also include subrounded to angular basalt clasts near Poverty Mountain and west side of Agway Valley. Intertongue or overlap young and young intermediate alluvial fan (Qa1 and Qa2) deposits. Represent relatively less active, low-gradient alluvial stream-channel or shallow drainage valley accumulating sediment. Subject to sheetwash flooding and temporary ponding; cut by arroyos as much as 2 m (6 ft) deep. Support moderate growths of sagebrush, grass, cactus, and some juniper trees. Thickness, 1 to 4 m (3 to 12 ft)

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 outcrops. Include clay, silt, sand, and gravel partly cemented by calcite and gypsum. Intertongue with or overlap alluvial young, young intermediate, and old intermediate alluvial fan (Qa1, Qa2, and Qa3) and landslide (Ql) deposits. Support sparse growth of sagebrush, cactus, grass, and pinion, juniper, and oak trees. Only thick or extensive deposits shown. Thickness, 2 to 6 m (6 to 20 ft)

Ql **Landslide deposits (Holocene and Pleistocene)—**Unconsolidated masses of unsorted rock debris. Include detached blocks of rock that have rotated backward and slid downslope as loose incoherent masses of broken igneous rock and deformed strata. Found principally below Tertiary basalt flows west side of Agway Valley and the Poverty Mountain Basalt. Support sparse to moderate growth of sagebrush, cactus, grass, and pinion, juniper, and oak trees. May become unstable in very wet conditions. Thickness, 3 to 18 m (10 to 60 ft)

Qg2 **Young intermediate terrace-gravel deposits (Holocene and Pleistocene)—**Similar to young terrace-gravel deposits (Qg1), unconsolidated. Composed mainly of gray to brown clay, silt, sand, and coarse-grained gravel formed by subangular to rounded pebbles and boulders supported by fine-grained clay, silt, and sand matrix. Includes well-rounded basalt and limestone clasts as much as 1 m (3 ft) in diameter in Parashant Wash, Parashant Canyon, and Agway Valley. Form terraces about 2 to 12 m (6 to 35 ft) above modern stream beds and about 1 to 9 m (3 to 30 ft) above young terrace-gravel (Qg1) deposits. Terraces are slightly higher in the Parashant Canyon area. Locally intertongue or inset into young intermediate alluvial fan (Qa2) deposits. Intertongue or locally overlain by talus (Qt), young alluvial fan (Qa1), and valley-fill (Qv) deposits. Thickness, 2 to 3 m (6 to 10 ft)

Qa2 **Young intermediate alluvial fan deposits (Holocene and Pleistocene)—**Similar to young alluvial fan (Qa1) deposits, but partly cemented by calcite and gypsum. Surfaces are rocky and eroded by arroyos as much as 3 m (10 ft) deep. Commonly overlapped by young alluvial fan (Qa1) deposits; intertongue with or overlap valley-fill (Qv) and talus (Qt) deposits. Include abundant subrounded to subangular basalt clasts on west side of Agway Valley and south and north side of Poverty Mountain. Support moderate growth of sagebrush, cactus, grass, and some juniper trees. Thickness, 2 to 15 m (6 to 50 ft)

Qg3 **Old intermediate terrace-gravel deposits (Pleistocene)—**Similar to young and young intermediate terrace-gravel (Qg1 and Qg2) deposits, partly cemented by calcite and gypsum. Include well-rounded basalt clasts from Poverty Mountain Basalt in Parashant Canyon area. Form terraces about 8 to 37 m (25 to 120 ft) above modern stream bed of Parashant Canyon, about 40 to 60 m (130 to 200 ft) above modern stream bed of Hidden Canyon, and about 3 to 12 m (10 to 40 ft) above modern stream bed of Pigeon Canyon. Inset into old intermediate terrace-gravel (Qg4) deposits in Parashant Wash. Thickness, 1 to 2 m (2 to 5 ft)

Qa3 **Old intermediate alluvial fan deposits (Pleistocene)—**Similar to young and young intermediate alluvial fan (Qa1 and Qa2) deposits, partly cemented by calcite and gypsum. Surface has thin soil development forming a smooth surficial texture, except on steeper slopes of the Grand Wash Cliffs area where surfaces are very rocky. Contain basalt clasts from Poverty Mountain Basalt where arroyos have eroded about 1 to 3 m deep into unit on north side of Poverty Mountain. Commonly overlapped by or intertongue with talus (Qt), landslide (Ql), and young and young intermediate alluvial fan (Qa1 and Qa2) deposits. Include abundant basalt clasts that form a thin desert pavement near landslide masses (Ql) west of Agway Valley and around Poverty Mountain. Support moderate growths of grass, cactus, sagebrush, and juniper and pinion pine trees. Thickness, 2 to 6 m (5 to 20 ft)

Qg4 **Old terrace-gravel deposits (Pleistocene)—**Similar to younger terrace gravel (Qg1, Qg2, and Qg3) deposits. Contain chert and limestone clasts derived from the Kaibab Formation and abundant subrounded basalt clasts from the Poverty Mountain Basalt at Parashant Canyon. Form terraces about 27 to 43 m (90 to140 ft) above modern drainage of Parashant Canyon representing post-stream-capture deposits of Hidden Canyon drainage. Thickness, 7 m (24 ft)

Qa4 **Old alluvial fan deposits (Pleistocene)—**Similar to younger alluvial fan (Qa1, Qa2, and Qa3) deposits. Includes weathered and strongly pitted boulders of limestone as much as 1 m (3 ft) or more in diameter along slopes of Grand Wash Cliffs. Partly consolidated, mostly unsorted, and deeply weathered mixture of angular boulders and pebbles. Overlapped by younger alluvial fan deposits in some areas, but commonly forms caprock material on high areas along lower slopes of Grand Wash Cliffs. Thickness, 3 m (12 ft)

Qa5 **Oldest alluvial fan deposits (Pleistocene)—**Similar to old alluvial fan (Qa4) deposits, partly consolidated, mostly fluvial boulders and gravel in sandy clay matrix. Contains angular to subrounded clasts of limestone and chert in gravelly matrix of same rock types, weakly cemented by calcite and gypsum. Forms protective caprock on small hill tops in Pigeon Canyon about 30 m (100 ft) above modern drainage. Thickness, 3 to 7 m (10 to 24 ft)

QTa **Tertiary and Quaternary alluvium (Pliocene and Pleistocene)**—White, gray, and reddish-brown, slope-forming, partly unconsolidated caliche, siltstone, calcareous coarse gravel, and conglomerate. Angular white and gray chert pebbles are dominant lithology averaging about 5 cm (2 in) in diameter that are derived from the Kaibab Formation. Includes yellow, brown, white, and red, well-rounded, multicolored quartzite pebbles 2.5 to 19 cm (1 to 8 in) in diameter and small-petrified wood fragments 7 cm (3 in) long that are derived from the Shinarump Member of the Chinle Formation. Locally includes small fragments of basalt derived from underlying basalt of the Shivwits Plateau. Caliche forms thin, lumpy, discontinuous beds producing white patches of caliche gravel and alluvium on weathered surface of basalt of the Shivwits Plateau flows, which is easily recognized by color contrast of black basalt flows on aerial photographs. Unconformable contact with underlying basalt of the Shivwits Plateau

(Tsb). Unit may have formed an extensive thick deposit over basalt of the Shivwits Plateau now partly removed by modern erosion. Thickness, 1 to 10 m (3 to 30 ft)

VOLCANIC ROCKS

Poverty Mountain Basalt (Pliocene)—Formally named for Poverty Mountain, Shivwits Plateau, northern Mohave County, Arizona, (secs. 20 and 32, T. 35 N., R. 11 W.), east-central edge of map area (Billingsley and others, 2000). K/Ar age, 4.75±0.0.26 Ma (Reynolds and others, 1986)

Tpi **Intrusive dike—**Dark-gray alkali-olivine basalt. Dike is near vertical and has variable widths, 1 to 4 m (3 to 11 ft). Source area for part of Poverty Mountain Basalt, includes dikes just east of map area (Billingsley and others, 2000)

Tpp **Pyroclastic deposits**—Reddish-gray fragments of scoria, cinders, and small ribbon bombs; unconsolidated. Form partial cone overlap by basalt flow and interbedded with basalt flows near vent area. Thickness, about 12 m (40 ft)

Tpb **Basalt flows**—Medium-gray to light-gray, finely crystalline, alkali-olivine basalt. Groundmass contains augite and olivine phenocrysts less than 1 mm in diameter. Consist of several basalt flows that form caprock overlying east-dipping (2° average) red and white siltstone, sandstone, gypsiferous siltstone, and dolomite beds of the Moenkopi Formation and gray to reddish-gray siltstone and limestone beds of the Harrisburg Member of the Kaibab Formation. Basalt flowed west about 8 km (5 mi) over gently rolling terrain and down small paleovalley tributary drainages into Hidden Canyon. Thickness, 30 to 92 m (100 to 300 ft)

Basalt of the Shivwits Plateau (Miocene)—Informally named for Shivwits Plateau (Best and others, 1980), northern Mohave County, Arizona (southeast quarter of map area). K/Ar age estimated to be about 6.0 to 7.0 Ma based on similar Tertiary basalts in the vicinity of the Shivwits Plateau

Tsi **Intrusive rocks**—Gray-black, finely crystalline, alkali-olivine basalt. Approximate map contact. Forms highest plateau terrain west of Agway Valley (average elev 5,900 ft). Source for basalt of the Shivwits Plateau, southeast quarter of map area. Dikes align about N. 30° W. Average widths about 2 m (6 ft)

Tsp **Pyroclastic deposits**—Reddish-black scoria and cinder fragments, partly consolidated. Form three small cones along west rim of Agway Valley, one of which is partly covered by basalt flows. Thickness, 12 m (37 ft)

Tsb **Basalt flows**—Gray-black, finely crystalline, alkali-olivine basalt. Groundmass contains olivine phenocrysts and plagioclase laths. Comprised of one or more thin basalt flows overlying red and white mudstone, siltstone, sandstone, and gypsiferous siltstone beds of the Moenkopi Formation and gray siltstone and limestone of the Kaibab Formation. Partly covered by Quaternary and Tertiary alluvium (QTa) east of Wildcat Ranch. Thickness, 3 to 42 m (8 to 140 ft)

Ti **Intrusive dikes in Pigeon Canyon (Miocene)—**Dark-gray, dark-greenish-gray, finely crystalline, alkali-olivine basalt. Contains phenocrysts of augite and olivine less than 1 mm in diameter. Weathers to crumbly decomposed basalt. Near vertical dikes are mostly covered by alluvium. Dikes orientated in north-south alignment similar to Garrett dikes about 11 km (7 mi) south of map area. K/Ar age of Garrett dikes, 9.20±0.13 and 9.07±0.8 Ma (Wenrich and others, 1995, 1997). Average dike width, about 0.5 m (2 ft)

SEDIMENTARY ROCKS

Moenkopi Formation (Lower Triassic)—Includes, in descending order, the Shnabkaib Member, middle red member, Virgin Limestone Member, lower red member, and Timpoweap Member as used by Stewart and others (1972). The upper red member (Middle? Triassic) has been removed by Tertiary erosion and is not present in map area. Divided into:

^ms **Shnabkaib Member (Lower Triassic)—**White, laminated, slope-forming, aphanitic dolomite interbedded with light-gray, calcareous, silty gypsum. Unconformably overlain by Poverty Mountain Basalt (Tpb) at Poverty Mountain and unconformably overlain by basalt of the Shivwits Plateau (Tsb) west side of Agway Valley. Gradational lower contact with middle red member placed at lowest, thick white or light-gray calcareous silty dolomite of the Shnabkaib Member. Unit thins south and west, thickens north. Thickness, 125 m (410 ft)

^mm **Middle red member (Lower Triassic)—**Red-brown, thin-bedded to laminated, slope-forming siltstone and sandstone. Includes white and gray gypsum beds, minor white platy dolomite, green siltstone, and gray-green to red gypsiferous mudstone. Gradational contact with underlying gray limestone bed of Virgin Limestone Member. Unit thins west, south, and east, thickens north. Thickness, 83 to 94 m (275 to 300 ft)

^mv **Virgin Limestone Member (Lower Triassic)—**Consists of one light-gray, thin-bedded to thinly laminated, ledge- and slope-forming silty limestone, 0.5 to 2 m (1 to 3 ft) thick, and underlying, pale-yellow, red, and bluish-gray, thin-bedded, slope-forming gypsiferous siltstone. Unit thins south and west, thickens north to include two limestone beds just northeast of map area. Unconformable contact with underlying lower red member of Moenkopi Formation at base of limestone bed. Unit locally pinches out onto or unconformably overlies paleohills of Harrisburg Member of the Kaibab Formation. Thickness, 0 to 3 m (0 to 10 ft)

^ml **Lower red member (Lower Triassic)—**Red, fine-grained, thin-bedded, gypsiferous, slope-forming, sandy siltstone; and gray, white, and pale-yellow laminated gypsum and minor sandstone. Lower part contains redeposited gypsum and siltstone of Harrisburg Member of the Kaibab Formation. Gradational contact with underlying Timpoweap Member of the Moenkopi Formation placed at lowermost red non-pebbly siltstone bed. Unconformably overlies Harrisburg Member of the Kaibab Formation where Timpoweap Member of the Moenkopi Formation is absent. Locally thickens within paleovalleys and pinches out onto eroded paleohills of underlying Harrisburg Member of the Kaibab Formation. Thickness, 0 to 20 m (0 to 65 ft)

^mt **Timpoweap Member (Lower Triassic)—**Light-gray to reddish-brown, slope-forming conglomerate and light-gray to light-red, slope-forming calcareous sandstone. Conglomerate composed of subangular to rounded pebbles and cobbles of gray and dark-gray limestone, white and brown chert, and gray sandstone in matrix of gray to brown, coarse-grained to gravelly sandstone. Includes calcite and gypsum cement. All detritus in the Timpoweap Member is derived from the Kaibab Formation. Fills paleovalleys eroded into Harrisburg Member of the Kaibab Formation as much as 80 m (260 ft) deep, northeast quarter of map area. Imbrication of pebbles in conglomerate shows general eastward flow of depositing streams. Thickness, 0 to 80 m (0 to 260 ft)

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

Pkh **Harrisburg Member (Lower Permian)**—Includes an upper, middle, and lower part. Upper part composed mainly of slope-forming, red and gray, interbedded gypsiferous siltstone, sandstone, gypsum, and thin-bedded gray limestone capped by resistant, pale-yellow or light-gray, fossiliferous (mollusks and algae) sandy limestone averaging about 1 m (3 ft) thick. Gradational contact with middle part. Middle part composed mainly of two cliff-forming limestone beds as much as 2 m (6 ft) thick; upper bed is gray, thin-bedded, cherty limestone that weathers dark brown or black; lower bed is light-gray, thin-bedded, sandy limestone. Both middle beds thicken and thin locally, gradually thickening east and north, thinning west. Minor erosional unconformity separates middle part from lower part. Lower part consists of slope-forming, light-gray and reddish-gray, gypsiferous siltstone; fine- to medium-grained calcareous sandstone; and gray, medium-grained, thin-bedded sandy limestone. Solution of gypsum in lower part has locally dissolved limestone beds of middle part causing them to slump or bend into local drainages on Shivwits Plateau. Gradational contact with underlying cliff-forming Fossil Mountain Member of the Kaibab Formation. Contact obscured in Hidden Hills area. Thickness, 75 m (250 ft)

Pkf **Fossil Mountain Member (Lower Permian)**—Light-gray, fine- to medium-grained, thin-bedded, fossiliferous, cliff-forming, cherty limestone. Unit characterized by cliffs of cherty limestone. Erodes into conical pillars or spires along upper Grand Wash Cliffs. Unconformable contact with underlying slope-forming Woods Ranch Member of the Toroweap Formation. Contact locally obscured by talus deposits due to recessive nature of Woods Ranch Member of the Toroweap Formation. Thickness, 60 to 65 m (200 to 215 ft)

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 (Lower Permian)**—Yellow-gray to reddish-gray, slope-forming gypsiferous siltstone and pale-red silty sandstone interbedded with white laminated gypsum. Forms recess in cliff sections of upper Grand Wash Cliffs. Beds are locally distorted due to gypsum dissolution. Gradational contact with underlying Brady Canyon Member of the Toroweap Formation marked at top of limestone cliff of Brady Canyon Member. Upper and lower contacts of unit on map are approximately shown in Hidden Hills area and locally obscure. Unit is thicker in north half of map area. Thickness, 3 to 36 m (10 to 40 ft)

Ptb **Brady Canyon Member (Lower Permian)**—Gray, cliff-forming, medium-bedded, fine- to coarse-grained, fetid when freshly broken, fossiliferous limestone; weathers dark gray. Includes thin-bedded dolomite in upper and lower parts. Limestone beds average about 0.5 m (2 ft) thick and include bedded chert lenses and nodules. Contact with underlying Seligman Member is gradational, marked at base of limestone cliff. Contact with Seligman Member is commonly covered by minor slump or talus deposits. Unit thins east, thickens west. Thickness, 90 to 122 m (300 to 400 ft)

Pts **Seligman Member (Lower Permian)**—Gray to yellowish-red and purple, thin-bedded, slope-forming dolomite and gypsiferous sandstone. Includes gray to red, thinly-interbedded siltstone, sandstone, and gypsum. Lower part of unit includes brown, purple, and yellow, fine- to medium-grained, thin-bedded, low- to high-angle crossbedded and flat-bedded Coconino Sandstone. Coconino Sandstone is not mapped because it is too thin to show at map scale. The Coconino Sandstone intertongues with the basal part of the Seligman Member of the Toroweap Formation (Fisher, 1961; Schleh, 1966; Rawson and Turner, 1974; Billingsley 1997; Billingsley and others, 2000). Unit mostly covered by talus and alluvial fan deposits; thickens northward. Thickness, 6 to 24 m (20 to 80 ft)

Ph **Hermit Formation (Lower Permian)—**Light-red, yellowish-white, fine-grained, thin- to medium bedded, slope and ledge-forming sandstone and siltstone. Sandstone beds as much as 3 m (10 ft) thick separated by dark-red, slope-forming, thin-bedded siltstone and yellowish-gray silty sandstone beds as much as 2 m (7 ft) thick. Reddish-brown sandstone beds commonly contain yellowish-white bleached spots; some thin sandstone is partly or completely bleached yellowish-white near contact with overlying Toroweap Formation due to groundwater alteration and bleaching. Unconformable contact with underlying Esplanade Sandstone; erosional relief averages about 1 to 2 m (3 to 6 ft). Unit mostly covered by alluvial fan (Qa1, Qa2, Qa3, Qa4, and Qa5), and talus (Qt) deposits along upper Grand Wash cliffs, west edge of map area. Thickness, 244 to 260 m (800 to 860 ft)

Supai Group (Lower Permian and Upper Pennsylvanian)—Includes, in descending order, the Esplanade Sandstone (Pe) and the Wescogame Formation. The Wescogame Formation is included as the lower Supai Group, undivided on this map (*s) as defined by McKee (1982). The rest of the lower Supai Group is not exposed. The Pakoon Limestone (Permian) intertongues within the lower half of the Esplanade Sandstone but is not considered as part of the Supai Group according to McKee (1982). Thus, the Pakoon Limestone is mapped as a separate map unit

Pe **Esplanade Sandstone (Lower Permian)—**Light-red and light-pinkish-gray, ledge- and slope-forming, fine- to medium-grained, medium-bedded (1-3 m [3-10 ft]), well-sorted, calcareous sandstone and interbedded, dark-maroon-red, slope-forming siltstone. Forms a ledge and slope separated by cliff-forming beds of the Pakoon Limestone (McNair 1951) and a lower red siltstone slope unit. Includes small- to medium-scale, planar low-angle and high-angle crossbeds of sandstone and calcareous sandstone in upper half and flat, massive, light-red to gray, low-angle crossbedded sandstone and calcareous sandstone in lower half. Gray limestone beds of the Pakoon Limestone (McNair, 1951) intertongue in lower part of the middle cliff-forming Esplanade Sandstone. Thickness, 122 m (400 ft)

Pkl **Pakoon Limestone (Lower Permian)—**Gray, medium- to coarse-grained, thin-bedded, cliff-forming limestone and sandy dolomite; weathers brown-gray with sugary texture. Limestone and dolomite beds separated by gray-purple, thin-bedded siltstone and sandstone beds; limestone is fossiliferous in upper part; include lenses and pods of brown chert; locally cross-stratified. Forms disconformable contact with underlying lower part of the Supai Group, undivided (Upper Pennsylvanian). Thickness, 40 m (130 ft)

*s **Lower Supai Group, undivided (Upper Pennsylvanian)—**Includes only the upper part of the lower Supai Group, undivided. Light-red, pale-yellow, and light-gray, fine- to coarse-grained sandstone, dolomitic sandstone, siltstone, mudstone, and conglomerate. Forms an upper slope unit and a lower cliff unit in Pigeon Canyon, southwest corner of map. Upper slope unit is a dark-red, fine-grained siltstone and mudstone and light-red sandstone. Lower cliff unit is a light-red to gray, high-angle, large- and medium-scale, tabular-planar, crossbedded sandstone sets as much as 12 m (40 ft) thick. Base of unit not exposed in map area. Incomplete section in Pigeon Canyon. Thickness, 48 m (160 ft)

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APPENDIX

DIGITAL DATABASE DESCRIPTION FOR THE GEOLOGIC MAP OF HIDDEN HILLS AND VICINITY, MOHAVE COUNTY, NORTHWESTERN ARIZONA

INTRODUCTION

This report includes, in addition to cartographic and text products, geospatial (GIS) databases and other digital files. The database files are particularly useful because they can be combined with any other type of geospatial data for purposes of display and analysis. The other files include digital files that support the databases and digital plot files that can be used to display and print the cartographic and text products in this publication.

The digital map database, compiled from previously published and unpublished data and new mapping by the author, represents the general distribution of bedrock and surficial deposits in the mapped area. The database delineates map units that are identified by age and lithology following the stratigraphic nomenclature of the U.S. Geological Survey. The scale of the source maps limits the spatial resolution (scale) of the database to 1:31,680 or smaller. The content and character of the database, as well as two methods of obtaining the database are described below.

FOR THOSE WHO DON'T USE DIGITAL GEOLOGIC MAP DATABASES

Two sets of plot files 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 the geologic map sheet and explanation and the database description. 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 plot file packages in either of the two ways described below (see the section "Obtaining the Digital Data"); however, these packages do require gzip or WinZip utilities to access the plot files.

Those without computer capability can obtain plots of the map files through U.S. Geological Survey Information Services. Be sure to request Map MF-2387.

U.S. Geological Survey Information Services
Box 25286
Denver, CO 80225

1-888-ASK-USGS
e-mail:ask@usgs.gov

DATABASE CONTENTS

The database consists of three digital packages. The first is the PostScript Plotfile Package, which consists of PostScript plot files of the geologic map and map explanation. The second is the PDF Plotfile Package, and contains the same plot files as the first package, as well as the database description, but in Portable Document Format (PDF). The third is the Digital Database Package that contains the geologic map database itself and the supporting data.

Postscript Plotfile Package

This package contains the PostScript image described below:

hhmap.eps	A PostScript plotfile containing the complete map composition with geology, correlation chart, and geologic description at a scale of 1:31,680

The PostScript image of the geologic map and map explanation is 56 inches high by 36 inches wide, so it requires a large plotter to produce paper copies at the intended scale. The PostScript plotfile of the geologic map was initially produced by the 'postscript' command with compression set to zero in ARC/INFO version 8.0. The geologic description and correlation chart were created in Adobe Illustrator 8.0.

PDF Plotfile Package

This package contains the PDF images described below:

hhmap.pdf	A PDF file containing the complete map composition with geology, correlation chart, and geologic description at a scale of 1:31,680
hhgeo.pdf	A PDF file containing an image of the accompanying pamphlet containing detailed geologic information and unit descriptions, in addition to sources of data and references cited
hhreadme.pdf	This document

The Acrobat files were created from corresponding .eps files and are compatible with Adobe Acrobat version 4.0 and higher.

To use PDF files, the user must get and install a copy of Adobe Acrobat Reader. This software is available **free** from the Adobe website (http://www.adobe.com/). Please follow the instructions given at the website to download and install this software. Once installed, the Acrobat Reader software contains an on-line manual and tutorial.

Digital Database Package

The database package includes geologic map database files for the Hidden Hills area. The digital maps, or coverages, and their associated INFO directories 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. Please refer to your GIS documentation.

ARC export files are converted to ARC/INFO format using the ARC command 'import'. To ease conversion and preserve naming convention, an AML is enclosed that will convert all the export files in the database to coverages and will also create an associated INFO directory. From the ARC command line type *&r import.aml*. The export files included are listed below:

The export files included are:

ARC/INFO export file	Resultant Coverage	Description
hh_poly.e00	hh_poly/	Faults and contacts
hh_dip.e00	hh_dip/	Strike and dip information and annotation, point data and annotation
hh_fold.e00	hh_fold/	Fold axes
hh_anno.e00	hh_anno/	Unit labels, fault names, and fault separation values

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
geolin.lut.e00	geolin.lut	hhmark lookup table
geo.mrk.e00	geo.mrk	Markerset
geomrk.lut.e00	geomrk.lut	hhmark lookup table
wpgcmyk.shd.e00	wpgcmyk.shd	WPGCMYK color shadeset
pattern.shd.e00	pattern.shd	Fill pattern set
geofont.txt.e00	geofont.txt	Font for unit labels

hhdrg.tif.gz	Zipped background hypsography image
hhdrg.tfw	World file accompanying hhdrg.tif
import.aml	ARC macro language macro for inflated and importing ARC export files.
mf2387.txt	A text-only file containing an unformatted version of readme.pdf
mf2387.met	A parseable text-only file of publication level FGDC metadata for this report
mf2387.rev	A text-only file describing revisions, if any, to this publication

OBTAINING THE DIGITAL DATA

The digital data may be obtained from:

a.) The Western Region Geologic Publication Web Page at:
http://geopubs.wr.usgs.gov/docs/wrgis/mf-map.html
Follow the directions to download the files.

b.) The U.S. Geological Survey Western Region FTP server.
The FTP address is: geopubs.wr.usgs.gov
The user should log in with the user name 'anonymous" and then input their e-mail address as the password. This will give the user access to all the publications available via FTP from this server. The files in this report are stored in the subdirectory: pub/mf-map/mf2387.

DATABASE SPECIFICS

Digital Compilation

Stable-base maps were scanned at the U.S. Geological Survey Flagstaff field office 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 using gridline. A tic file was created in lat/long and projected into the base map projection (Transverse Mercator). Tics are defined in the four extreme corners of the map area 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 UTM. ARC/INFO generated a RMS report after transforming the original grid into transverse UTM.

```
Scale (X,Y) = (1.585,1.586)  Skew (degrees) = (0.004)
Rotation (degrees) = (-2.209)  Translation = (276499.259,4011920.257)
RMS Error (input,output) = (0.989,1.567)

Affine  X = Ax + By + C
        Y = Dx + Ey + F
  A =          1.584   B =            0.061   C =       276499.259
  D =         -0.061   E =            1.584   F =      4011920.257

tic id        input  x          input  y
              output x          output y           x error          y error
------ ---------------- ---------------- ---------------- ----------------
     1       -15131.900        18858.180
             253689.206      4042723.809            0.699            1.406
     2         -996.909        19015.959
             276085.494      4042113.039           -0.699           -1.406
     3         -773.144         1520.584
             275367.256      4014375.431            0.697            1.401
     4       -14955.100         1356.406
             252898.990      4014984.546           -0.697           -1.401
```

Lines, points, polygons and annotation were edited using the ARCEDIT modules.

Following editing and annotation, the individual coverages were projected into UTM projection.

Map Projection:

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

Database Fields:
The content of the geologic database can be described in terms of the lines, points, and areas that compose the map. Each line, point, or area in a map layer or index map database (coverage) is associated with a database entry stored in a feature attribute table. Each database entry contains both a number of items generated by ARC/INFO to describe the geometry of the feature and one or more items defined by the authors to describe the geologic information associated with that entry. Each item is defined as the amount and type of information that can be recorded. Descriptions of the database items use the terms explained below.

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

Definition of hh_poly and hh_fold Arc Attribute Table:

ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	DESCRIPTION
FNODE#	4	5	B	-	Starting node of the arc
TNODE#	4	5	B	-	Ending node of the arc
LPOLY#	4	5	B	-	Polygon to the left of the arc
RPOLY#	4	5	B	-	Polygon to the right of the arc
LENGTH	8	18	F	5	Length of the arc in meters
HH_POLY#	4	5	B	-	Unique internal number
HH_POLY-ID	4	5	B	-	Unique identification number
LTYPE	35	35	C	-	Line type
PTTYPE	35	35	C	-	Point type for arc markers
SYMBOL	3	3	I	-	Internal identification for line type
PLUNGE	3	3	I	-	Coded integer indicating fold plunge (in hh_fold only)

Domain of Line Types recorded in LTYPE field:

hh_poly

contact_approx
contact_certain
high_angle_flt_approx
high_angle_flt_certain
high_angle_flt_concealed
landslide_scarp
map_boundary

hh_fold

anticline_certain_red
anticline_concealed_red
basalt_flow_direction
monocline_certain_red
plunging_anticline_red
plunging_syncline_red
syncline_certain_red
syncline_concealed_red

Domain of markers recorded in PTTYPE field:

hh_poly

fault_ball_fill
xx

hh_fold

syncline_red
anticline_red
monocline_red
xx

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. The description of map units can be found on the geologic map sheet.

Definition of hh_poly Polygon Attribute Table:

ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	DESCRIPTION
AREA	8	18	F	5	Area (degenerative)
PERIMETER	8	18	F	5	Perimeter (degenerative)
HH_POLY#	4	5	B	-	Unique internal number
HH_POLY-ID	4	5	B	-	Unique identification number
PTYPE	5	5	C	-	Point type

Domain of hh_poly PTYPE (map units):

Pe	Ptw	Qf	Qv	Tsp
Ph	Qa1	Qg1	QTa	TRml
Pkf	Qa2	Qg2	Ti	TRmm
Pkh	Qa3	Qg3	Tpb	TRms
Pkl	Qa4	Qg4	Tpi	TRmt
Ps	Qa5	Ql	Tpp	TRmv
Ptb	Qaf	Qs	Tsb	
Pts	Qc	Qt	Tsi	

Plain text is substituted for conventional geologic age symbols (TR for Triassic) shown on map.

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 hh_dip has only a point attribute table, and hh_poly has only a polygon attribute table.

Definition of hh_dip Point Attribute Table:

ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	DESCRIPTION
AREA	8	18	F	5	Area (degenerative)
PERIMETER	8	18	F	5	Perimeter (degenerative)
HH_DIP#	4	5	B	-	Unique internal number
HH_DIP-ID	4	5	B	-	Unique identification number
PTTYPE	35	35	C	-	Point type
DIP	3	3	I	-	Dip angle in azimuth degrees
STRIKE	3	3	I	-	Strike angle in degrees

Domain of hh_dip PTTYPE:

bedding
collapse_structure
sinkhole
vertical_joint
volcanic_vent

ANNOTATION

The coverage hh_anno contains all annotation for the polygon coverage. It is defined somewhat differently from the 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. hh_anno contains annotation with unit labels, fault separation, and monocline names. Annotation directly related to unit labeling is contained in subclass "anno.unit" and annotation including fault separation values and fault names is contained in subclass "anno.ident".

The textset used for all annotation was geofont.txt, specifically symbolset 38. 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 or Pennsylvanian. By using this alternate text set, the character pattern '^m' prints instead as ^m and '* ' prints as *.

BASE MAP PROCEDURE

The base map was prepared by mosaicing four 1:24,000 DRGs, and scanning the resultant image to generate a georeferenced TIFF (GeoTIFF) graphic. This graphic was subsequently projected into UTM, rotated and clipped into a secondary TIFF image to be used as the topographic base map for the cartographic layout.

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 1:31,680, which means that higher resolution data is generally not present. Plotting at scales of larger than 1:31,680 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 (hh_poly) are assigned based on the PTYPE and were chosen from a shadeset called wpgcmyk.shd and a lookup table geopoly.lut. Some geologic units also display a fill pattern on top of the color set. For example, "Ql" is a quaternary landslide unit, and a small breccia pattern (hollow triangles) is displayed on top of the light brown color. 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 hh.met, the FGDC standard metadata for the database, and hh.rev, a revision list with current information on the status of all files described in this report and found in the database.

Key words:

Geologic map, Mohave County, Arizona, Hidden Hills, Grand Canyon-Parashant National Monument.