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

Geologic map of the Russell Spring quadrangle, northern Mohave County, Arizona

by
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INTRODUCTION

The Russell Spring 7.5' quadrangle (96 sq km) is located in northern Mohave County, Arizona, about 70 km south of St. George, Utah, and 11 km north of the abandoned settlement of Mt. Trumbull, Arizona (fig. 1). Altitudes range from about 1,390 m at in the northeast corner of the quadrangle to 1,967 m on the Hurricane Cliffs (south-central edge of quadrangle). Vehicle access to the quadrangle is by improved dirt road, locally referred to as the Mt. Trumbull Road, from St George, Utah (fig. 1). Several unimproved dirt roads lead from the Mt. Trumbull Road to various locations within the quadrangle area.

The area is managed entirely by the U.S. Bureau of Land Management including about seven sections belonging to the state of Arizona. There are about four sections of private land in the vicinity of Hurricane Wash. At lower elevations, the area supports a moderate to thick growth of sagebrush, cactus, cliffrose bush, grass, and various high-desert shrubs. At higher elevations, moderate growths of sagebrush thrive in alluvial valleys and a forest of pinyon pine and juniper trees occurs east of the Hurricane cliffs.

PREVIOUS WORK

The area was previousely mapped photogeologically and included on a Arizona state geologic map by Wilson and others (1969), and again by Reynolds (1988). A geologic map of The Grandstand 7.5' quadrangle is available bordering the north edge of this quadrangle (Billingsley, 1993b), and a geologic map of the Sullivan Draw and vicinity, Arizona is located about 13 km west of this quadrangle (Billingsley, 1994). Geologic maps are also available of the Grand Canyon area about 30 km south of this quadrangle (Huntoon and others, 1981; Wenrich and others, 1986).

MAPPING METHODS

A preliminary geologic map was made from aerial photographs at a scale of 1:24,000. In particular, many of the Quaternary alluvial units having similar lithologies were mapped using photogeologic methods based on regional geomorphic characteristics. Detailed field investigations were then conducted to insure accuracy and consistency of all map units for descriptive purposes.

GEOLOGIC SETTING

The quadrangle area lies within the Shivwits and Uinkaret Plateaus, subplateaus of the southwestern part of the Colorado Plateaus physiographic province. The physiographic boundary between the higher elevation Uinkaret Plateau and the lower elevation Shivwits Plateau is demarcated by the upper part of the Hurricane Fault scarp, the Hurricane Cliffs (fig. 2). The Shivwits and Uinkaret Plateaus in this quadrangle are characterized by relatively flat lying bedrock strata having an average regional dip of less than 2° east. About 350 m of Triassic strata and 365 m of Permian strata are exposed in the quadrangle.

The Hurricane Fault and Monocline are the major structural features of this quadrangle having a northeast strike in the north half of the quadrangle and a southerly strike in the south half. The Hurricane Monocline developed in Laramide time by compressional stresses, then later, Quaternary tensional stresses reactivated the deep-seated fault plane allowing development of the Hurricane Fault. Vertical displacement of the Hurricane Fault is about 518 m in the northern part of the quadrangle, and about 670 m in the south part.

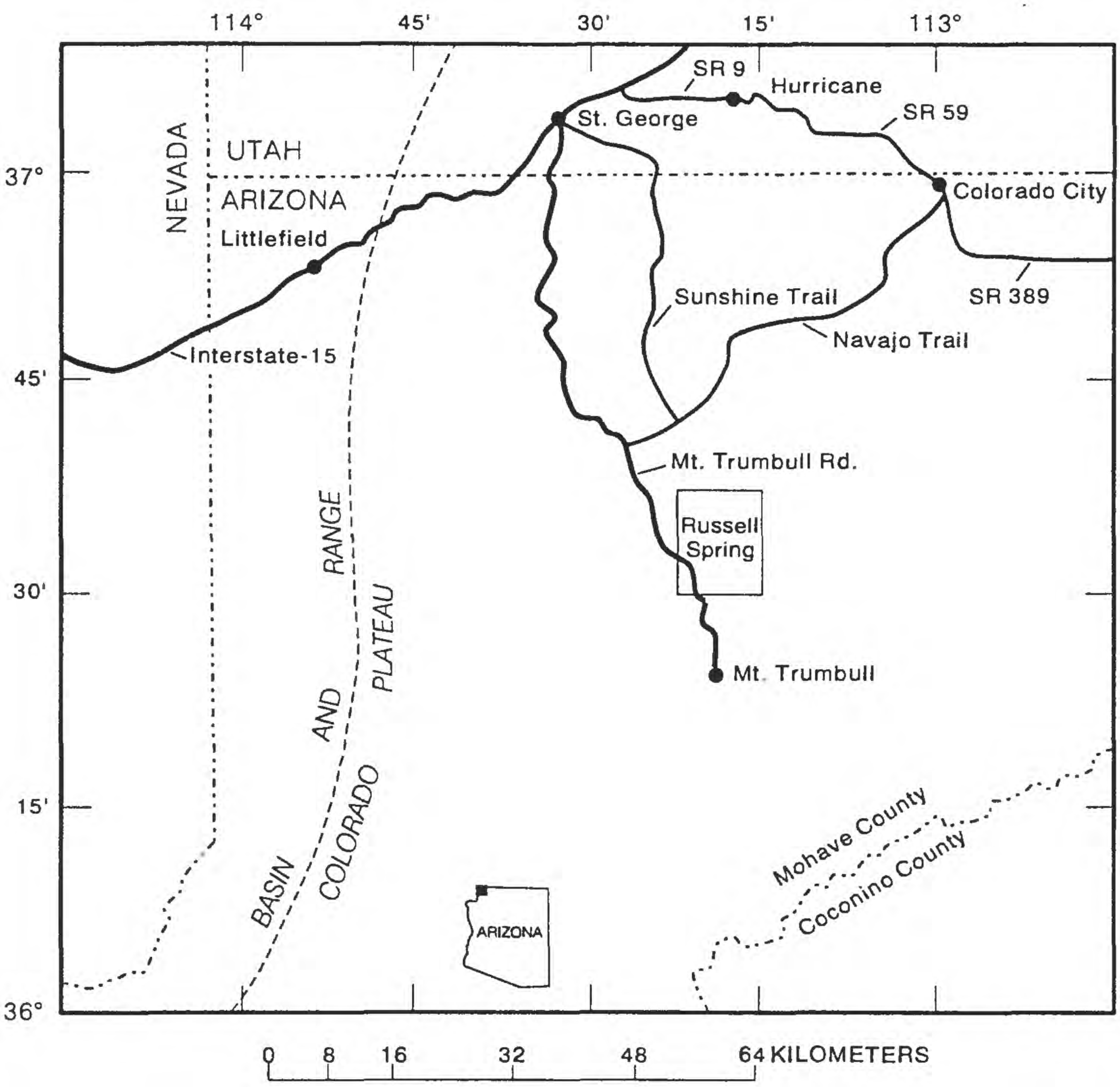


Figure 1. Index map of the northern part of Mohave County, northwestern Arizona, showing the Russell Spring 7.5' quadrangle mapped in this report. SR = State route.

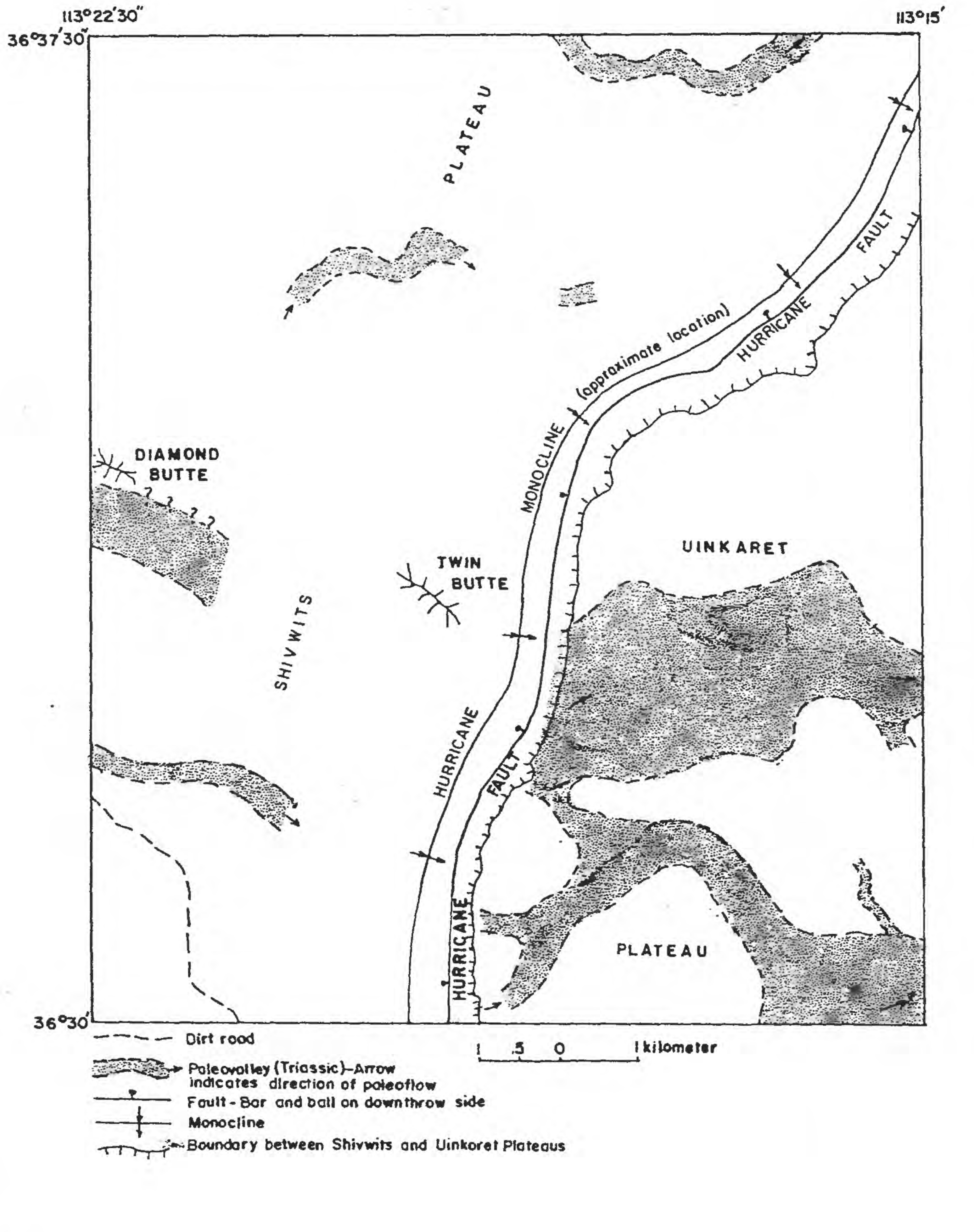


Figure 2. Selected geographic and geologic features of the Russell Spring 7.5' quadrangle, northwestern Arizona.

Cenozoic deposits are widely distributed in the quadrangle area consisting of igneous rocks of Pliocene and Quaternary age and surficial alluvium and landslide deposits of Quaternary age. The surficial deposits were differentiated by photogeologic techniques based on their geomorphic relations to structural features and erosional surfaces.

STRATIGRAPHY

The sedimentary bedrock strata of this quadrangle include, in ascending order, the Hermit, Toroweap, and Kaibab Formations (Lower Permian), and the Moenkopi Formation (Upper, Middle? and Lower Triassic). Only a few hundred meters of the upper part of the Hermit Formation is exposed along the base of the Hurricane Cliffs. The Toroweap Formation overlies the Hermit and is well exposed in the lower part of the Hurricane Cliffs. About two-thirds of the surface bedrock of the quadrangle is composed of gray cherty limestone and gray to white siltstone and gypsum of the Kaibab Formation. The other third of the surface bedrock is gray siltstone, sandstone, gypsum, and limestone of the Toroweap Formation underlain by gray conglomerate and sandstone, red siltstone and sandstone, gray gypsum and dolomite of the Moenkopi Formation.

A basalt flow on Diamond and Twin Buttes, herein referred to as the Diamond Butte Basalt, caps the upper Moenkopi Formation and is stratigraphically at a similar position as the Mount Trumbull Basalt 11 km southeast of this quadrangle, and the Bundyville Basalt along the Hurricane Cliffs 17 km south of Diamond Butte (Hamblin and Best, 1970). The K-Ar age of the Mount Trumbull Basalt is 3.47±0.6 Ma and the Bundyville Basalt is 3.60±0.1 Ma (Reynolds and others, 1986). A sample from the Diamond Butte Basalt yielded a K-Ar age of 4.3±0.6 Ma (Harold Mehnert, U.S. Geological Survey Isotope Laboratories, Denver, Colorado, written commun., 1993).

The Diamond Butte Basalt rests on a Tertiary erosion surface at Diamond and Twin Buttes that slopes gently eastward over truncated east dipping strata of the upper Moenkopi Formation. The Diamond Butte Basalt is not found on the upthrown (east) side of the Hurricane Fault and the eastern extent of the flow is interpreted to have been just west of the Hurricane Fault. The Hurricane Fault displaces the Bundyville Basalt (3.6 Ma) with about as much offset as the underlying strata indicating that most, if not all displacement along this section of the Hurricane Fault, occurred within the last 3.6 Ma. The Diamond Butte Basalt is older than the Bundyville Basalt and would most likely have been offset by the Hurricane Fault if it had extended across the fault. It is possible that the Diamond Butte Basalt did extend onto what is now the Uinkaret Plateau, and if it did, all traces of the basalt along with almost all of the underlying Moenkopi strata have been eroded away.

A younger basalt flow overlies alluvial deposits and bedrock strata of the Harrisburg Member of the Kaibab Formation, and the lower red member of the Moenkopi Formation about 6 km south of Diamond Butte (southwest corner of quadrangle). This unnamed basalt occupies a position about 335 m lower then the Diamond Butte Basalt. A sample obtained from this basalt yielded a K-Ar age of 1.0±0.4 Ma (Harold Mehnert, U.S. Geological Survey, Denver, Colorado, written commun., 1993). Thus, approximately 335 m of denudation of the surrounding landscape has occurred within 3.3 Ma suggesting a rate of erosion of the Moenkopi strata at about 1 m per 10,000 years. The Quaternary basalt overlies a flat peneplained alluvial and bedrock surface about 1.5 km west of Hurricane Wash. Currently, Hurricane Wash is about 1 km east of the young basalt flow and about 50 m lower in elevation. Assuming Hurricane Wash was at or near its present location 1 million years ago, then the rate of erosion is about 0.5 m per 10,000 years since the extrusion of the younger basalt.

The Quaternary age assigned to all alluvial deposits of the quadrangle is based mainly on field relationships to the Pleistocene, and Pliocene basalts of this quadrangle and elsewhere (Billingsley, 1993a, 1994). Many of the alluvial deposits contain basalt clasts downslope from Pliocene and Pleistocene basaltic outcrops. Given time for erosion and deposition, it is likely that all alluvial and surficial deposits of this quadrangle are Pleistocene and younger. The oldest alluvial unit of this quadrangle, alluvial-fan (Qg_3), contains basalt clasts derived from the 4.3 Ma Diamond Butte Basalt.

The distribution of Quaternary alluvial deposits are an important factor in future environmental, land-use, and range management planning in this area by federal, state, and private organizations. The surficial units are useful in the study of local geomorphology and have intertonguing and gradational contacts. Details of the stratigraphic sequence of alluvial deposits are given in the description of map units.

STRUCTURAL GEOLOGY

The structural features in this quadrangle area show up particularly well on X-Band, side-looking radar image of the Grand Canyon quadrangle, Arizona (scale 1:250,000). This image gives an overall perspective of the structural fabric of this part of Arizona, especially in flatland areas (S.A.R. System, 1988).

The Hurricane Monocline and Fault have a northeast strike in the northeast corner of the quadrangle and a southerly strike in the south-central part (fig. 2). The axial trace of the Hurricane Monocline lies parallel to and on the downthrown side of the Hurricane Fault, with strata dipping east as much as 12°. The trace of the Hurricane Monocline is located approximately west of the downthrown side of the Hurricane Fault because the greatest bend of strata is found on the downthrown block at Twin Butte. The monocline axis is approximately located based on deep exposures in the Grand Canyon about 40 kilometers south of this quadrangle, and about 8 kilometers north of this quadrangle (Huntoon and others, 1981; Wenrich and others, 1986; Billingsley, 1993b; fig. 3). Strata east of the approximate axis of the Hurricane Monocline has a regional dip of less than 2° east. Dip of strata along the northeast trend of the monocline is unknown and, in fact, may not exist. Changes in strike of exposed monoclines of the eastern Grand Canyon area are linked to intersecting basement faults that have been reactivated during the Late Cenozoic (Huntoon, 1989).

Tertiary compressional stresses resulted in the development of the Hurricane Monocline in Laramide time (Huntoon, 1989; Elston and Young, 1991). Later, Quaternary tensional stresses reactivated the deep-seated fault plane allowing the normal fault to cut all Paleozoic and Mesozoic strata, but reversing the displacement of strata down to the west (fig. 3; Huntoon, 1989). The graben structures shown on the downthrown side of the monocline in figure 3 are likely buried under thick alluvial deposits in this quadrangle.

The Hurricane Fault scarp forms the Hurricane Cliffs, a prominent landmark in this part of Arizona. The Hurricane Fault is mostly covered by talus and alluvial deposits but appears to be a normal fault as suggested by

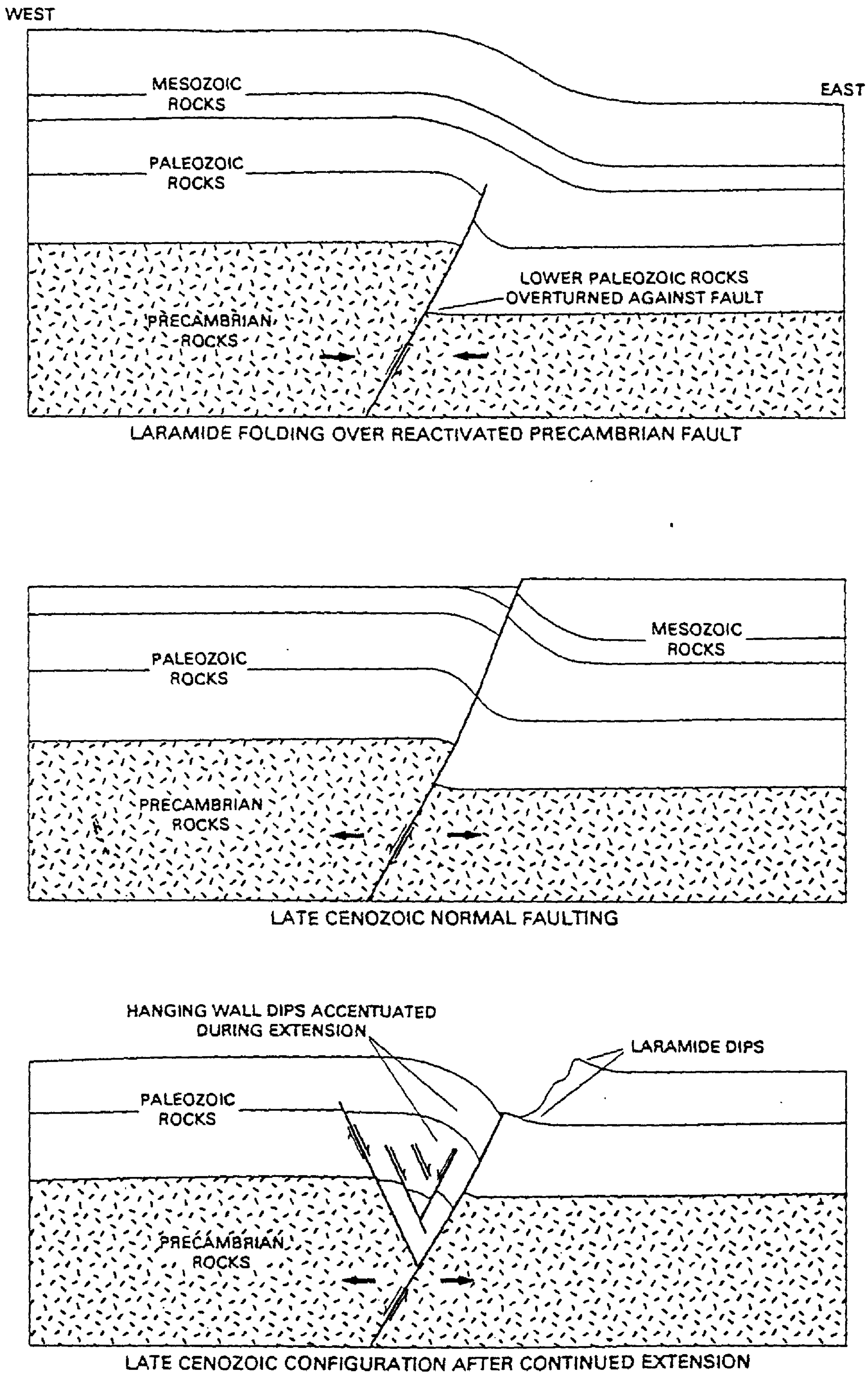


Figure 3. Stages in the development of a typical north-trending monocline-fault zone, Grand Canyon region, Arizona (Huntoon, 1989, p. 80).

Hamblin and Best (1970). Late Cenozoic displacement of the Hurricane Fault and associated faults were probably initiated in late Pliocene time with most of the activity occurring in Pleistocene time based on the faulted 3.6 Ma Bundyville Basalt about 13 km south of this quadrangle. Holocene movement has probably occurred along parts of the Hurricane Fault as demonstrated by scarps in the alluvial deposits. Fault scarps in the talus and alluvial deposits are easily defined in the field and on aerial photographs. Because erosion and mass wasting has shed soft and loose debris over fault scarps in unconsolidated alluvial deposits, the faults are shown dotted on the map often forming alluvial contacts. A solid fault line is shown on the map where faulting is not covered by recent alluvium.

A small dome structure is located in the northwest quarter of the quadrangle and is interpreted to be the result of a possible volcanic intrusion. Small folds present in the north half of the quadrangle are probably related, in part, to early Laramide compressional stresses (Huntoon, 1989), and later by extensional stresses allowing strata to bend or fold into graben structures. Locally, warped and bent strata are too small to show at map scale and are the result of solution of gypsum in the Harrisburg Member of the Kaibab Formation. These bent strata are commonly associated with solution of gypsum along drainages.

A few circular bowl-shaped collapse structures, usually about 100 m in diameter, are found on the surface of the quadrangle and are mostly due to solution of gypsum and gypsiferous siltstone in the Harrisburg Member of the Kaibab Formation. However, some circular, bowl-shaped areas that have inward-dipping strata may be collapse-formed breccia pipes that originate in the deeply buried Mississippian Redwall Limestone (Wenrich and Huntoon, 1989; Wenrich and Sutphin, 1989). Such features on this map are marked by a dot and the letter C to denote possible deep-seated breccia pipe. However, they cannot be distinguished with certainty from shallow collapse structures caused by removal of gypsum in the Kaibab or Toroweap Formations. Moreover, some deep-seated breccia pipes are known to be overlain by gypsum collapse features (Wenrich and others, 1986). The deep-seated breccia pipes potentially contain economic deposits of copper and uranium minerals (Wenrich, 1985).

Small, shallow sinkholes and karst caves are associated with the solution of gypsum in the Harrisburg Member of the Kaibab Formation. The sinkholes are relatively young features of Holocene and probable Pleistocene age as judged by their young appearance. Hundreds of sinkhole depressions are breached by drainages on the Shivwits and Uinkaret Plateaus but are not marked on this map. Sinkholes that form an enclosed basin or depression are shown by a triangle symbol.

DESCRIPTION OF MAP UNITS

SURFACIAL DEPOSITS

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

Qs **Stream-channel alluvium (Holocene)**--Alluvium in active wash or large arroyo. Includes unconsolidated and poorly sorted, interlensing silt, sand, and pebble to boulder gravel. Intertongues with or inset against, or locally overlies valley-fill (Qv), alluvial-fan (Qa_1, Qa_2), and terrace-gravel (Qg_1) deposits. Stream channels subject to high-energy flows and flash floods and support little or no vegetation. Contacts approximate. Estimated thickness 1 to 2 m

Qf **Flood-plain deposits (Holocene)**--Flat valleys containing unconsolidated light-gray or brown silt, sand, and lenses of pebble to cobble gravel. Deposits intertongue, merge with, inset against, or locally overlie valley-fill (Qv), and alluvial-fan (Qa_1 and Qa_2) deposits. Forms wide, flat valley floor as opposed to narrow concave valley profile of valley-fill (Qv) deposits. Deposits are sparsely vegetated by grass. Locally cut by arroyos. Flood-plain subject to flooding and local temporary ponding. Thickness about 2 to 20 m

Qg_1 **Young terrace-gravel deposits (Holocene)**--Unconsolidated, light-brown, pebble and boulder gravel composed about equally of well-rounded limestone and sandstone and angular and subrounded to angular chert derived from the Kaibab and Toroweap Formations. Includes lenses of gray silt and sand and locally well-rounded to subangular basalt clasts. Includes reworked materials from alluvial-fans (Qa_1, Qa_2, and Qa_3), terrace-gravels (Qg_2 and Qg_3), talus (Qt), and landslide (Ql) deposits. Locally cut by arroyos as much as 2 m deep and eroded into intermediate terrace-gravel (Qg_2) deposits along Hurricane Wash. Forms alluvial benches or abandoned stream channels about 1 to 3 m above local stream beds. Average thickness 1 to 3 m

Qa_1 **Young alluvial-fan deposits (Holocene)**--Unconsolidated gray silt and sand. Includes lenses of coarse gravel composed of subangular to rounded pebbles to cobbles of limestone, chert, and sandstone locally derived from Hermit, Toroweap, Kaibab, and Moenkopi Formations. Includes well-rounded to sub-angular basalt clasts from Diamond and Twin Buttes and Poverty Knoll 10 km southwest of this quadrangle; partly cemented by gypsum and calcite. Overlaps, intertongues, or partly includes stream-channel (Qs), valley-fill (Qv), young terrace-gravel (Qg_1), and older alluvial-fan (Qa_2 and Qa_3) deposits near their downslope ends. Alluvial-fans subject to erosion by sheet wash and flash floods. Supports sparse growths of sagebrush, cactus, and grass. Maxiumu thickness, about 6 m

Qv **Valley-fill deposits (Holocene and Pleistocene?)**--Partly consolidated silt, sand, and interbedded lenses of pebble- to small-boulder-gravel. Intertongues or overlaps talus (Qt), flood-plain (Qf), terrace-gravels (Qg_1, Qg_2, and Qg_3), alluvial-fan (Qa_1, and Qa_2) deposits. Subject to sheetwash flooding and temporary ponding; cut by arroyos in larger valleys. Supports moderate growths of sagebrush, grass, and cactus. Maximum thickness, about 5 m

Qt **Talus deposits (Holocene and Pleistocene?)**--Unsorted breccia composed of small and large angular blocks of local bedrock as much as 1 m in diameter. Includes silt, sand, and gravel; partly cemented by calcite and gypsum. Intertongues with alluvial-fan (Qa_1, Qa_2, and Qa_3), valley-fill (Qv), and landslide (Ql) deposits. Supports sparse to moderate growths of sagebrush, cactus, and grass. Only relatively extensive deposits shown. Maximum thickness, about 3 m

Ql **Landslide deposits (Holocene? and Pleistocene)**--Unconsolidated and unsorted rock debris, including blocks of bedrock that have rotated backward and slid downslope as loose, incoherent masses of broken rock and deformed strata. Occurs principally below basalt on Diamond and Twin Buttes. Larger masses have slid down the north side of Diamond and Twin Buttes. Includes blocks of strata of the Fossil Mountain Member of Kaibab Formation along upper Hurricane Cliffs. Supports sparse growths of sagebrush, cactus, grass, juniper and pinyon pine. Unstable when wet. Only large masses are shown. Thickness 35 to 45 m

Qg_2 **Older terrace-gravel deposits (Holocene? and Pleistocene?)**--Similar to young terrace-gravel deposits (Qg_1) but partly consolidated. Contains well-rounded basalt clasts as much as 5 cm in diameter. Forms remenant terraces about 2 to 4 m above local stream beds and about 1 to 2 m above young-terrace gravel (Qg_1) deposits. Intertongues with or locally overlain by talus (Qt) and alluvial-fan (Qa_1 and Qa_2) deposits. Locally inset against older terrace-gravel (Qg_3), and older alluvial-fan (Qa_3) deposits. Approximately 2 to 8 m thick

Qa_2 **Intermediate alluvial-fan deposits (Holocene? and Pleistocene)**--Similar to young alluvial-fan (Qa_1) deposits and partly cemented by calcite and gypsum. Locally overlapped by or merges into young alluvial-fan (Qa_1), young terrace-gravel (Qg_2), talus (Qt), and landslide (Ql) deposits. Locally inset against older alluvial-fan (Qa_3) deposits. Locally includes abundant subrounded to subangular basalt clasts. Supports moderate growth of sagebrush, cactus, and grass. Ranges from 2 to 5 m thick

Qa_3 **Older alluvial-fan deposits (Pleistocene)**--Similar to younger and intermediate alluvial-fan (Qa_1 and Qa_2) deposits but 2 to 3 m higher than intermediate alluvial-fan (Qa_2) deposits and about 30 m above local drainages. Intertongues with talus (Qt), landslide (Ql), and older terrace-gravel (Qg_3) deposits. Often overlapped by younger and intermediate alluvial-fan (Qa_1 and Qa_2), and talus (Qt) deposits. Basalt clasts abundant near Diamond and Twin Buttes but lacking along base of Hurricane Cliffs. Includes abundant rounded basalt clasts (southwest quarter of quadrangle) derived from Poverty Knoll 10 km southwest of quadrangle. Approximately 3 to 15 m thick

IGNEOUS ROCKS

Qb **Basalt flow (Pleistocene)**--Dark-gray, finely crystalline, aphanitic groundmass and olivine phenocrysts. Surface flow partly covered by scoria and cinders. Includes olivine phenocrysts. Sample obtained just west of this quadrangle yielded a K-Ar age of 1.0±0.4 Ma (Harold Mehnert, U.S. Geological Survey Isotope Laboratories, Denver, Colorado, written commun., 1993). Overlies older alluvial-fan (Qa_3) deposits, Harrisburg Member of Kaibab Formation, and Virgin Limestone Member and lower red member of Moenkopi Formation. Approximately 6 m thick

Td **Diamond Butte Basalt (Pliocene)**--Dark gray, massive, finely crystalline, aphanitic groundmass and sparse olivine phenocrysts. Forms caprock for Diamond and Twin Buttes. Source of basalt unknown, assumed to have originated from local feeder dikes now covered by landslide debris at Diamond Butte. K-Ar age is 4.3±0.6 Ma (Harold Mehnert, U.S. Geological Survey Isotope Laboratories, Denver, Colorado, written commun., 1993). Consists of one flow approximately 30 m thick

SEDIMENTARY ROCKS

Moenkopi Formation (Middle? and Lower Triassic)--Includes, in descending order, upper red member, Shnabkaib Member, middle red member, Virgin Limestone Member, lower red member, and Timpoweap Member as used by Stewart and others (1972). The Middle-Lower Triassic boundary probably lies in the upper red member (Morales, 1987)

Ŧmu **Upper red member**--Heterogeneous sequence of red sandstone, siltstone, mudstone, conglomerate, and minor gray gypsum. Includes thin-bedded cliff-forming sandstone in upper part. Top part is eroded and unconformably overlain by Diamond Butte Basalt at Diamond and Twin Buttes; most complete section located at Twin Butte. Gradational contact with Shnabkaib Member placed arbitrarily at top of highest, thick, white siltstone and dolomite bed of Shnabkaib. Forms slope and ledges. Maximum thickness about 105 m

TRms **Shnabkaib Member**--Interbedded, white, laminated, aphanitic dolomite, calcareous sandstone, and silty gypsum; includes red, thin-bedded mudstone, siltstone, and sandstone in lower part. Gradational contact with middle red member arbitrarily placed at base of lowest bed of light-gray dolomitic limestone or siltstone. Forms steep slope with ledges. Maximum thickness about 100 m

TRmm **Middle red member**--Interbedded, red-brown, thin-bedded, laminated siltstone and sandstone, white and gray gypsum, minor white platy dolomite, green siltstone, and gray-green gypsiferous mudstone. Gradational contact with Virgin Limestone Member placed at top of highest gray limestone bed of Virgin Limestone. Forms slope. Thickness about 80 m

TRmv **Virgin Limestone Member--Consists of two and locally three light-gray, ledge-forming limestone beds 1 to 2 m thick separated by white, pale-yellow, and gray slope-forming, thin-bedded, gypsiferous siltstone. Includes brown, red, and green thin-bedded siltstone, gray limestone, and brown platy calcarenite. Lowest limestone bed contains star-shaped crinoid plates and poorly preserved *Composita* brachiopods in top part. Erosional unconformity at base of lowest gray limestone bed truncates underlying red siltstone of lower red member about 1 m of relief. Lower limestone bed thickens and thins as channel-fill deposit. Forms ledges in slope. Thickness about 25 to 30 m**

TRml **Lower red member**--Red, fine-grained, thin-bedded, gypsiferous sandy siltstone interbedded with gray, white, and pale-yellow laminated gypsum and minor sandstone. Lower beds contain reworked gypsum and siltstone of Harrisburg Member of Kaibab Formation. Interbedded or gradational contact with sandstone or conglomerate of Timpoweap Member. Unconformable contact with Kaibab Formation. Locally fills paleovalleys eroded into underlying Kaibab Formation. Forms slope. Locally thickens to as much as 25 m in paleovalleys and thins to less then 5 m thick

TRmt **Timpoweap Member**--Light-gray conglomerate and sandstone. Composed of subangular to rounded pebbles and cobbles of gray and dark-gray limestone, white and brown chert, and rounded quartzite in matrix of gray to brown, coarse-grained, low-angle cross-bedded calcareous sandstone, gravel, and minor siltstone derived from Kaibab Formation. Source for dark-gray limestone and quartzite may be Paleozoic rocks west of quadrangle. Forms cliff. Fills Triassic paleovalleys as much as 70 m deep and 1,800 m wide eroded into Kaibab Formation (fig. 2). Rocks of Timpoweap occupy major paleovalley considered an eastern extension of Sullivan Valley (fig. 2; Billingsley, 1994) that may join with another paleovalley leading in from the southwest near top of Hurricane Cliffs, southeast quarter of quadrangle. A significant but smaller paleovalley is located in northeast corner of quadrangle (fig. 2). Imbrication of pebbles in conglomerate shows an eastward paleoflow. Thickness ranges from 10 to 70 m

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

Pkh **Harrisburg Member**--Consists of an upper, middle, and lower part. Upper part is eroded from this map area. Middle part consists mainly of two cliff-forming marker limestone beds. Top marker bed consists of gray, thin-bedded, cherty limestone; weathers dark brown or black and commonly forms bedrock surface of this quadrangle. Bottom marker bed consists of light-gray, thin-bedded, sandy limestone. Middle part unconformably truncates lower part. Lower part consists of slope-forming, light-gray, fine- to medium-grained, gypsiferous siltstone, sandstone; medium-grained, thin-bedded gray limestone; and gray massive bedded gypsum. Solution of gypsum in lower part has locally caused limestone beds of middle part to slump or bend into local drainages. Gradational and arbitrary contact between siltstone slope of Harrisburg Member and limestone cliff of Fossil Mountain Member. Harrisburg, in general, forms slope with middle limestone cliff. Maximum thickness about 75 m

Pkf **Fossil Mountain Member**--Light-gray, fine- to medium-grained, thin-bedded, fossiliferous, sandy, cherty limestone. Chert weathers black. Contact with Woods Ranch Member of Toroweap Formation marked by solution and channel erosion with relief as much as 5 m; contact generalized on map because of extensive talus and minor landslide cover. Forms cliff. About 105 m thick

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

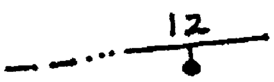
Ptw **Woods Ranch Member**--Gray gypsiferous siltstone and pale-red silty sandstone interbedded with medium-bedded, white, laminated gypsum. Beds are locally distorted due to gypsum solution. Gradational and arbitrary contact between slope-forming Woods Ranch Member and cliff-forming Brady Canyon Member. Thickness varies from 12 to 50 m due to solution of gypsum

Ptb **Brady Canyon Member**--Gray, fetid, medium-bedded, fine- to coarse-grained, fossiliferous limestone; weathers dark-dray. Includes thin-bedded dolomite in upper and lower part. Limestone beds average about 0.5 m thick. Includes chert lenses and nodules but these are 50% less abundant than in Fossil Mountain Member of Kaibab. Gradational and arbitrary contact between cliff-forming limestone of Brady Canyon Member and slope-forming siltstone and gypsum of Seligman Member of Toroweap; commonly covered because of minor slump or talus debris. Forms cliff. Approximately 75 m thick

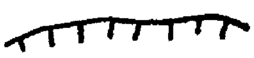
Pts **Seligman Member**--Consists of an gray, interbedded, thin-bedded dolomite and gypsiferous sandstone in upper part; gray to red, thin-bedded, interbedded siltstone, sandstone, and gray gypsum in middle part; and brown, purple, and yellow, fine- to medium-grained, thin-bedded, low- to high-angle cross-bedded and planar-bedded sandstone in lower part. Unconformable, sharp planar contact with underlying sandstone of Hermit Formation having local relief as much as 1 m. Forms slope with ledges. Thickness ranges from about 50 to 60 m

Ph **Hermit Formation (Lower Permian)**--Light-red, yellow, and white, fine-grained, thin- to medium-bedded sandstone and siltstone. Includes upper ledge-forming, red, yellow, and white sandstone beds separated by beds of red, slope-forming, siltstone and silty sandstone. Red sandstone beds in upper part commonly contain yellow-bleached spots, or are entirely bleached yellow or white. Sandstone beds gradually thicken northward. Lower part of unit not exposed due to cover of alluvial deposits. Thickness 75 m


Contact--Dashed where approximately located

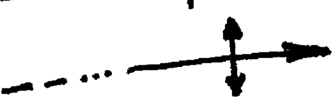


Fault--Dashed where inferred or approximately located; dotted where concealed; bar and ball on downthrown side. Number is estimated displacement in meters. Number with plus denotes minimum estimated displacement


Landslide detachment--Headwall scarp of landslide, hachures point in direction of slide

Folds--Showing trace of axial plane and direction of plunge; dashed where approximately located; dotted where concealed


syncline


Anticline


Monocline


Dome

Strike and dip of beds--Showing dip where known


Inclined


Approximate--Estimated from aerial photographs


Implied--Interpreted from aerial photographs, amount of dip not determined


Strike of vertical and near-vertical joints--Interpreted from aerial photographs

Collapse structure--Circular collapses, strata dipping inward toward central point. May reflect collapse of deep-seated breccia pipe that originated in Redwall Limestone. Qurried where uncertain


Sinkholes--Steep-walled or enclosed depression or cave


Flow direction of basalt

REFERENCES CITED

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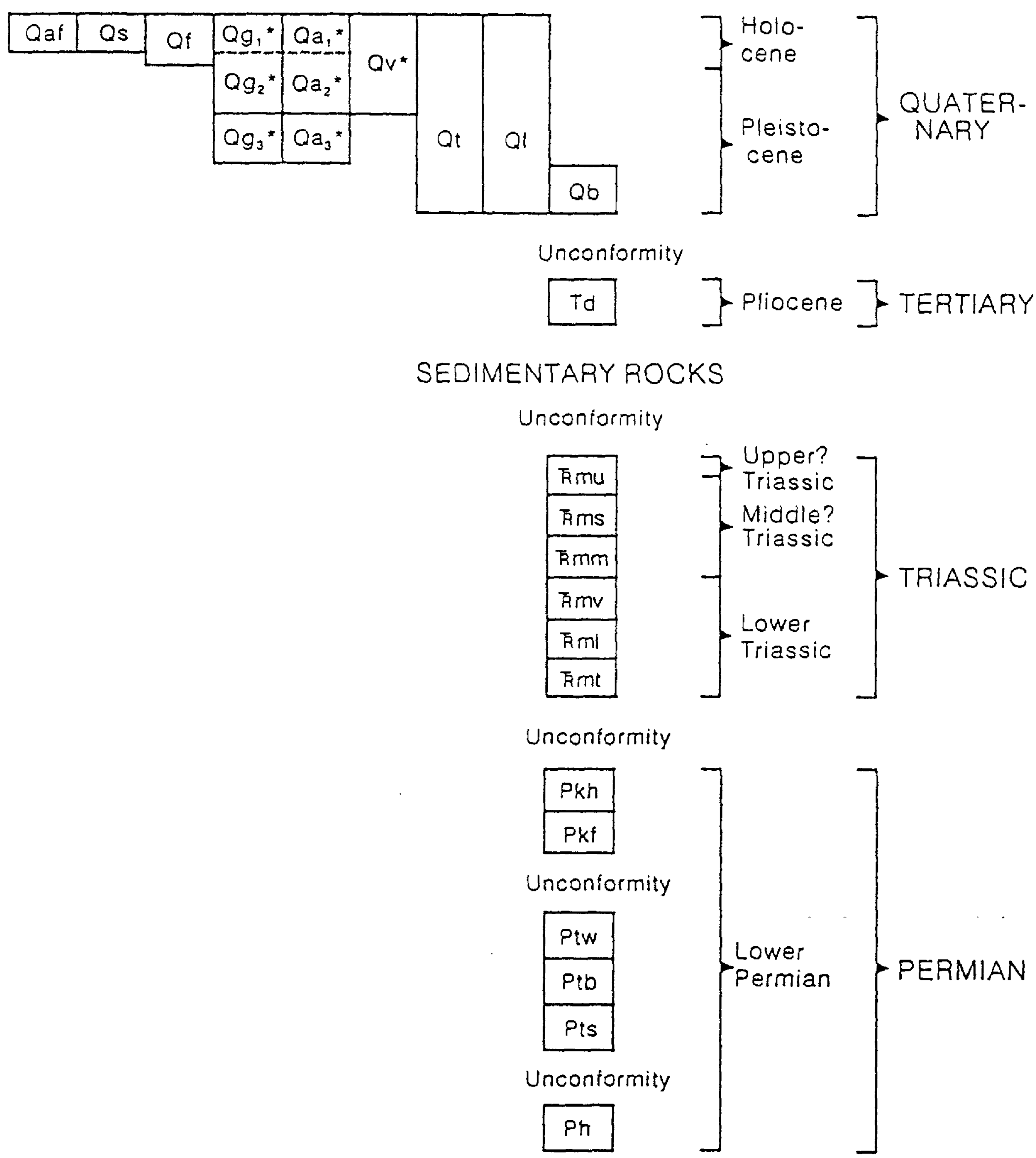
CORRELATION OF MAP UNITS

SURFICIAL DEPOSITS AND IGNEOUS ROCKS



* See description of map units for exact unit age assignment