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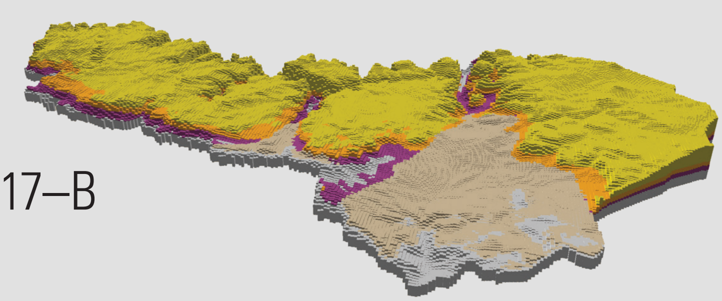
Geology and Hydrology of the Truxton Basin and Hualapai Plateau, Northwestern Arizona

Chapter B of
Geophysical Surveys, Hydrogeologic Characterization, and Groundwater Flow Model for the Truxton Basin and Hualapai Plateau, Northwestern Arizona



Scientific Investigations Report 2020–5017–B

U.S. Department of the Interior
U.S. Geological Survey

Cover Background. Map of the surface geology and geologic structure of the Truxton basin, Music Mountains, and Hualapai Plateau, northwestern Arizona. Faults modified from Arizona Bureau of Geology and Mineral Technology (1988), Beard and Lucchitta (1993), Richard and others (2000), and Billingsley and others (2006).

Cover Inset. Three-dimensional perspective of the Truxton Basin Hydrologic Model viewing the Truxton basin and surrounding area from the south.

Geology and Hydrology of the Truxton Basin and Hualapai Plateau, Northwestern Arizona

By Jon P. Mason, Donald J. Bills, and Jamie P. Macy

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U.S. Department of the Interior
DAVID BERNHARDT, Secretary

U.S. Geological Survey
James F. Reilly II, Director

U.S. Geological Survey, Reston, Virginia: 2020

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Contents

Figures

Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	0.003785	cubic meter (m^3)
acre-foot (acre-ft)	1,233	cubic meter (m^3)
acre-foot (acre-ft)	0.001233	cubic hectometer (hm^3)
	Flow rate	
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year (m^3/yr)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as

$$°F = (1.8 \times °C) + 32.$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as

$$°C = (°F - 32) / 1.8.$$

Datum

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29) and North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Elevation, as used in this report, refers to distance above the vertical datum.

Abbreviations

AEM	airborne electromagnetic
ft	feet

Geology and Hydrology of the Truxton Basin and Hualapai Plateau, Northwestern Arizona

By Jon P. Mason, Donald J. Bills, and Jamie P. Macy

Abstract

The geology of northwestern Arizona is prominently displayed on the canyon and cliff walls that compose the high-desert landscape of the Hualapai Plateau and that border the Truxton basin. The Truxton basin is a small topographic basin filled with Quaternary and Tertiary deposits and volcanic rock (about 1,600 feet thick near Truxton, Arizona) that overlie Proterozoic crystalline metamorphic rocks in the west or Cambrian sedimentary rocks in the east. The Hualapai Plateau is a large block of Paleozoic-age sedimentary rocks that are dissected by many deep canyons. Most surface-water drainages in the Truxton basin and Hualapai Plateau are ephemeral and flow only in response to significant precipitation events, but a few drainages have perennial reaches that are supported by groundwater discharge from springs. Saturated basin-fill sediments in the Truxton basin compose the Truxton aquifer, which is currently used as a water supply for the community of Peach Springs, Arizona, and supplies a small number of livestock and domestic wells. Usable groundwater on the Hualapai Plateau is in either perched water-bearing zones close to land surface or in the Muav Limestone aquifer at depths of greater than 2,000 feet below land surface. To date, only two test wells have been drilled through the Muav Limestone on the Hualapai Plateau, and neither of those wells encountered water in the limestone, indicating the unit is not saturated in all areas of the plateau.

Introduction

The main purpose of this report is to describe groundwater availability in the Truxton aquifer and the hydrogeologic framework supporting that assessment. However, this chapter describes the geology and hydrology of both the Truxton basin and Hualapai Plateau on and adjacent to the Hualapai Indian Reservation (fig. 1 of Mason, Knight, and others, 2020). A discussion of the geology and hydrology of the Hualapai Plateau is included in this chapter for two reasons. First, the Truxton basin and Hualapai Plateau are connected hydrologically. Second, additional information in the form of an airborne electromagnetic (AEM) survey was collected from the Hualapai Plateau, but was not completed in time to be included in the previous report in this series (Mason, Macy, and others, 2020) describing the hydrogeologic characterization of the Hualapai Plateau. Results of the AEM for both the Truxton basin and Hualapai Plateau are presented in Ball and others (2020) of this volume.

The Truxton basin is a relatively small, 75-square mile topographic depression located at the northern edge of the Transition Zone, a geologic province in central Arizona that is transitional between the mostly flat-lying or mildly dipping layered sedimentary rocks of the Colorado Plateau to the northeast and the heavily faulted, folded, and eroded Basin and Range Province to the west and south (Fenneman, 1931). The Transition Zone shares characteristics of both physiographic provinces. The Truxton basin has an average elevation of 4,300 feet (ft; Twenter, 1962).

The Music Mountains form the southwestern rim of the Hualapai Plateau. They are topographically higher than but geologically part of the Hualapai Plateau. Twenter (1962) described the Hualapai Plateau as “a large block of sedimentary rocks dissected by many deep canyons.” The plateau is part of the southwestern Colorado Plateau and extends from the mouth of the Grand Canyon east to Aubrey Valley and the Juniper Mountains, south of the Colorado River (Trapp and Reynolds, 1995) (fig. 1 of Mason, Knight, and others, 2020). The highest part of the Hualapai Plateau is over 6,700 ft in the Music Mountains at the plateau’s southwestern margin. The central part of the plateau has an average elevation of about 5,000 ft (Twenter, 1962). No major faults separate the Hualapai Plateau from the Truxton basin. Removal of the Paleozoic section from the Truxton basin by erosion is the primary reason for the difference in elevation between the two physiographic features. The physiography of the study area is described in greater detail in Bills and Macy (2016).

Geology

The Truxton basin and Hualapai Plateau were likely very similar geologically prior to the Laramide uplift. Erosion during and after regional uplift removed Mesozoic deposits from the entire area and further removed Paleozoic deposits from most of the Truxton basin. Tertiary volcanism affected both areas, whereas Tertiary and Quaternary sedimentation further changed the Truxton basin.

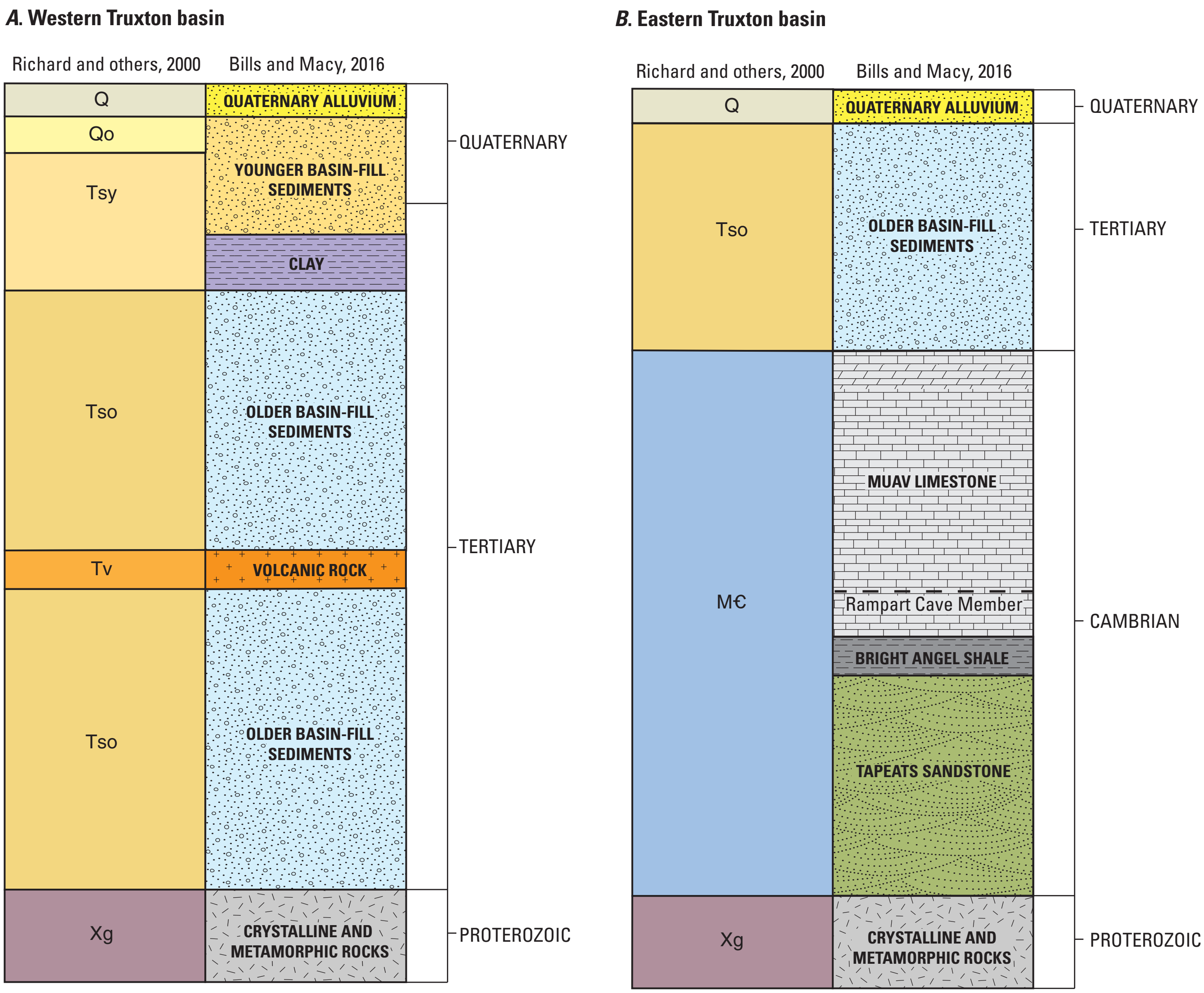


Figure 1. Diagrams showing the generalized stratigraphic section for western Truxton basin (*A*) and eastern Truxton basin (*B*) near the town of Peach Springs, Arizona. Geologic units from Bills and Macy (2016), and stratigraphy of Richard and others (2000) interpreted from the contacts of their map units. Dashed line delineating the Rampart Cave Member is not an interpretation of Bills and Macy (2016) but is shown here to mark the relative position of this hydrologically important part of the Muav Limestone.

Truxton Basin

In this report the term Truxton basin is used to refer to the topographic depression that is bordered by the Music Mountains, Grand Wash Cliffs, Cottonwood Mountains and the Hualapai Plateau (fig. 1, of Mason, Knights, and others, 2020). On most maps of the area this feature is referred to as Truxton valley, an informally named valley that surrounds the town of Truxton, Ariz., that makes up most of the surface drainage area for Truxton Wash. We use the term basin because we are primarily interested in the saturated sediments and volcanic rocks contained within the subsurface topographic depression and not the surficial features. At one time the Truxton basin was probably a closed basin when surface drainage was blocked by lava flows at the western end of the area. This blockage would have promoted the deposition of thick sedimentary units in the basin including lacustrine deposits (Twenter, 1962).

The base of the Truxton basin is delineated by Proterozoic crystalline and metamorphic rock (fig. 1). Although these rocks are known to produce small quantities of water in some instances, they are generally not considered an aquifer in the area. The bulk of geologic units above the Proterozoic consist of Tertiary and Quaternary basin-fill deposits with some Cambrian rock units present on the east end of the basin (figs. 1, 2, and 3).

The younger basin-fill sediments depicted in figures 1*A* and 2, are generally a sequence of Quaternary age unconsolidated to semiconsolidated sand, gravel, clay, and silt that are

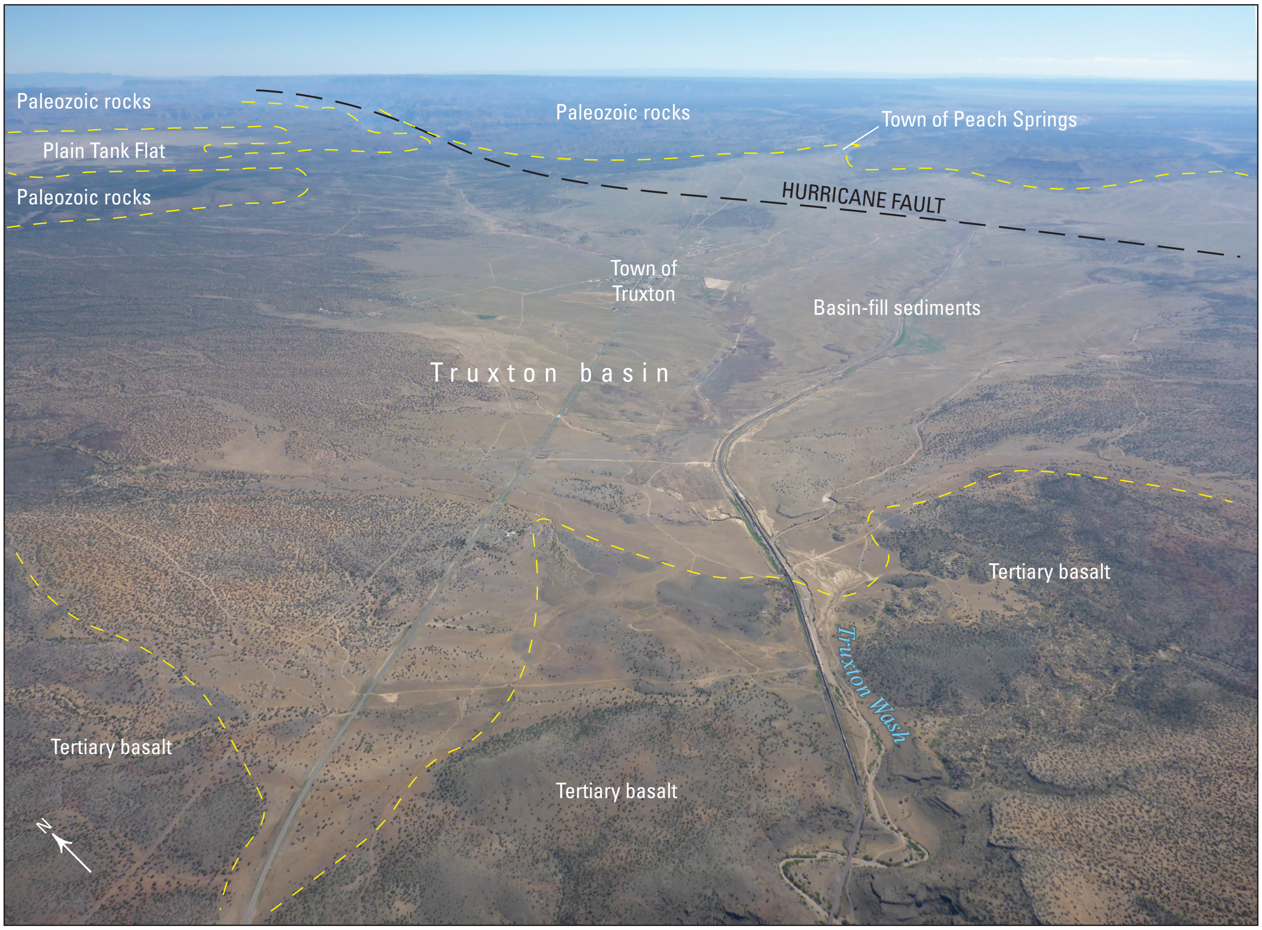


Figure 2. Aerial photograph of the Truxton basin, Arizona (view to northeast). Yellow dashed lines are approximate boundaries between labeled geologic features and units. U.S. Geological Survey photograph by Jon Mason, July 2015.

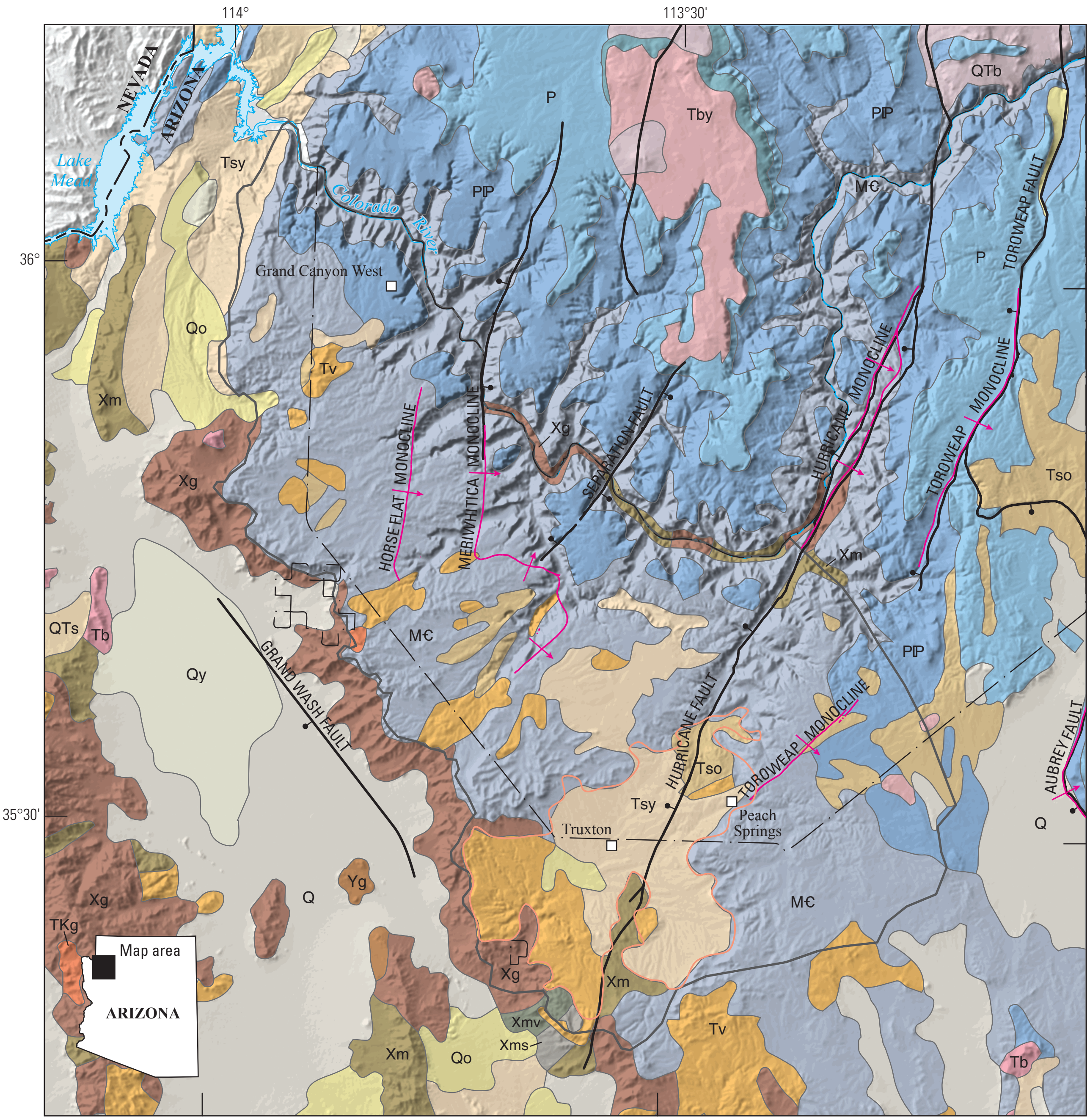
tan, light brown, to reddish-brown. Below those sediments in the western part of the basin, a clay layer is often found that consists of brown to reddish-brown clay and sandy and silty clay also of Quaternary age (fig. 1*A*). These younger basin-fill sediments are typically dry except near the bottom of the sediments as found in a few wells (Bills and Macy, 2016).

Below the younger basin-fill sediments are interbeds of volcanic material that are typically described in well cuttings as cinders, tuff, or basalt. These rocks are consistent with the middle to lower Miocene volcanic rocks of the Hualapai Plateau described by Billingsley and others (2006). The volcanic rocks predate the younger basin-fill sediments found in boreholes and can be interbedded with the upper parts of older basin-fill sediments and lacustrine deposits deeper in the subsurface (fig. 1*A*). The volcanic rocks found in wells are typically fully saturated, although drillers report they yield little to no water (Bills and Macy, 2016).

The older basin-fill sediments shown in figures 1 and 2 consist of a sequence of partly consolidated to consolidated, reddish-brown to brown gravel and sand with differing amounts of clay. Descriptions in drillers' logs are consistent with the older basin-fill sediments described as filling basins and paleochannels from the Late Cretaceous to the middle to late Miocene (Twenter, 1962; Billingsley and others, 2006). These rock units are almost always fully saturated and represent the main part of the Truxton aquifer (Bills and Macy, 2016).

At the far eastern end of the Truxton basin, Cambrian age Tapeats Sandstone, Bright Angel Shale, and Muav Limestone are present above the Proterozoic crystalline and metamorphic rock (fig. 1*B*). These strata are known as the Tonto Group and are discussed in more detail in the following section.

The Hurricane Fault runs northeast to southwest across the eastern end of the Truxton basin (fig. 3). In the basin, the fault offset has created a greater thickness of older and younger basin-fill sediments to the west of the fault. The fault is not mapped in the southern part of the Truxton basin where no detailed geologic maps are available, and no obvious surface expression of the fault occurs. However, Beard and Lucchitta (1993) indicated the fault terminates in the Cottonwood Mountains south of the basin, and airborne electromagnetic surveys and gravity surveys done as part of this study also indicate the fault continues through the Truxton basin.



Base from 2012 U.S. Geological Survey 100-meter digital data
Universal Transverse Mercator, Zone 12 North
North American Datum of 1983

0 10 20 MILES
0 10 20 KILOMETERS

EXPLANATION

Geologic map units from Richard and others, 2000

Q	Quaternary surficial deposits, undivided
QTb	Holocene to middle Pliocene basaltic rocks
Qy	Holocene surficial deposits
Qo	Early Pleistocene to late Pliocene surficial deposits
QTs	Early Pleistocene to late Miocene basin deposts
Tsy	Pliocene to middle Miocene deposits
Tby	Pliocene to late Miocene basaltic rocks
Tb	Late to middle Miocene basaltic rocks
Tv	Middle Miocene to Oligocene volcanic rocks
Tso	Oligocene to Paleocene? sedimentary rocks
TKg	Early Tertiary to Late Cretaceous granitic rocks
P	Permian sedimentary rocks
PIP	Permian to Pennsylvanian sedimentary rocks
MЄ	Mississippian, Devonian, and Cambrian sedimentary rocks
Yg	Middle Proterozoic granitic rocks
Xg	Early Proterozoic granitic rocks
Xms	Early Proterozoic metasedimentary rocks
Xmv	Early Proterozoic metavolcanic rocks
Xm	Early Proterozoic metamorphic rocks

- **Regional fault**—Includes approximately located, concealed, or inferred faults. Bar and ball on downthrown block
- **Regional monocline**
- **Groundwater model extent**
- **Truxton basin**
- **Hualapai Indian Reservation**

Figure 3. Map of the surface geology and geologic structure of the Truxton basin, Music Mountains, and Hualapai Plateau, northwestern Arizona. Faults modified from Arizona Bureau of Geology and Mineral Technology (1988), Beard and Lucchitta (1993), Richard and others (2000), and Billingsley and others (2006).

Music Mountains and Hualapai Plateau

The Music Mountains form the southwestern rim of the Hualapai Plateau. They are topographically higher than the plateau but geologically part of it, and they will be discussed together here. The geologic map of the Peach Springs 30’ X 60’ quadrangle by Billingsley and others (2006) is the most recent and complete geologic map available for the Hualapai Plateau and is the primary reference in this section (fig. 4). The northwest corner of the plateau was mapped as part of the Mount Trumbull 30’ X 60’ quadrangle done by Billingsley and Wellmeyer (2003). Figure 3 shows the geology of the entire study area. No recent detailed geologic maps are available for the southern part of the Truxton basin, so figure 3 uses more generalized geology from Richard and others (2000). This map allows the entire study area to be shown on one geologic map (fig. 3).

The basement rock of the plateau is similar to the Proterozoic crystalline and metamorphic rocks that underlie the Truxton basin. Above the basement rock lies the Tonto Group, a Cambrian transgressive sequence defined by Noble (1922) and modified by McKee and Resser (1945).

The Tonto Group includes in ascending order, the Tapeats Sandstone, Bright Angel Shale, and Muav Limestone (figs. 4 and 5). According to Billingsley and others (2006), the Tapeats Sandstone ranges in thickness from 0 to 200 ft and consists of medium- to coarse-grained sandstone, conglomerate, and shale that unconformably overlies Proterozoic basement rock. The conformably overlying Bright Angel Shale is described as siltstone and shale with thin beds of sandstone and dolomite, which has a thickness ranging from 300 to 350 ft (figs. 4 and 5). The Muav Limestone conformably overlies the Bright Angel Shale and comprises numerous members throughout the Grand Canyon region. Billingsley and others (2006) described the Muav Limestone as containing limestone, dolomite, and calcareous mudstone and having a thickness ranging from 1,200 to 1,400 ft (figs. 4 and 5).

The Devonian Temple Butte Formation unconformably overlies the Muav Limestone on the Hualapai Plateau (figs. 4 and 5). The formation is 400 to 460 ft thick in the Peach Springs quadrangle and consists of mudstone, sandstone, dolomite, and conglomerate-filled channels eroded into the underlying Cambrian strata (Billingsley and others, 2006).

The Mississippian Redwall Limestone occurs at or near the surface on much of the Hualapai Plateau. It lies unconformably over the Temple Butte Formation and has many members as defined by McKee (1963), and McKee and Gutschick (1969) (figs. 4 and 5). The Redwall Limestone is several hundred feet thick and consists of limestone, fossiliferous limestone, oolitic limestone, dolomite, fossiliferous dolomite, and chert beds (Billingsley and others, 2006).

The uppermost Paleozoic units found on the Hualapai Plateau are members of the Supai Group as defined by McKee (1982). These units include the Watahomigi, Manakacha, and Wescogame Formations. They were deposited unconformably over the Redwall Limestone and range from the Lower Pennsylvanian to Upper Pennsylvanian (figs. 4 and 5).

No Paleozoic rocks are above the Supai Group on the Hualapai Plateau, and the only Mesozoic unit present is an Upper Cretaceous quartz monzonite intrusion near the western margin of the plateau (fig. 4). Tertiary deposits on the plateau

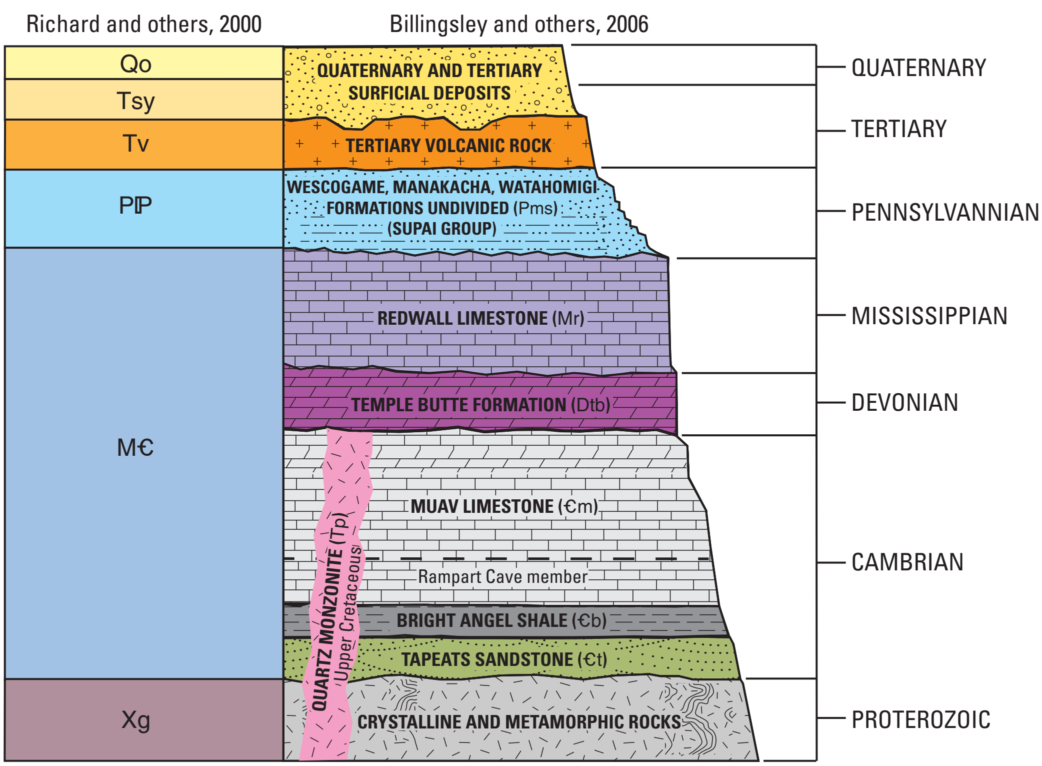


Figure 4. Diagram showing the generalized stratigraphic section of the Hualapai Plateau, northwestern Arizona. Stratigraphy of Richard and others (2000) and Billingsley and others (2006) interpreted from the contacts of their map units. Discrete surficial units from Billingsley and others (2006) have been combined into a single unit called Quaternary and Tertiary surficial deposits. Dashed line delineating the Rampart Cave Member is not an interpretation of Billingsley and others (2006) but is shown here to mark the relative position of this hydrologically important part of the Muav Limestone.

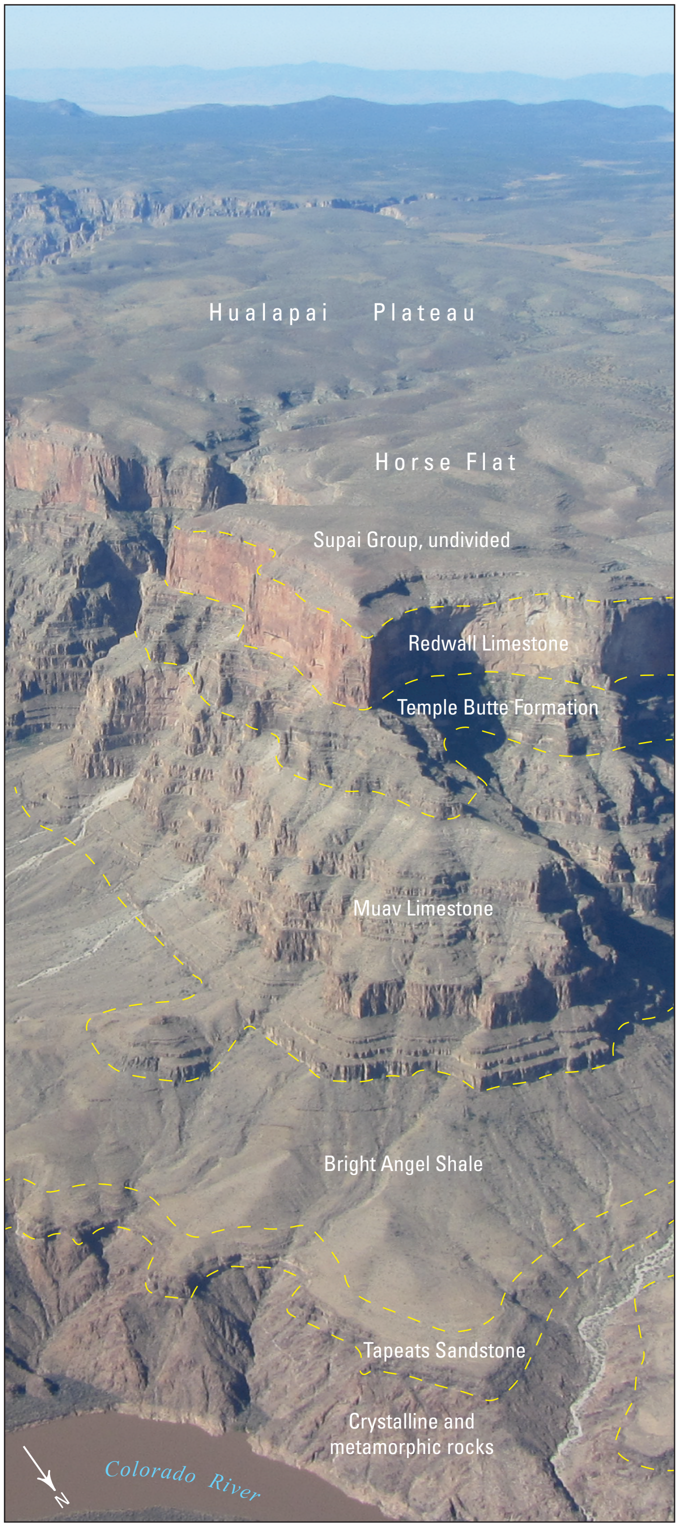


Figure 5. Aerial photograph of northern edge of Hualapai Plateau between Horse Flat and Quartermaster Canyons, looking south. Yellow lines are approximate contacts between rock units exposed in the Grand Canyon. U.S. Geological Survey photograph by Jon Mason, July 2016.

consist mainly of andesite and basalt lava flows and sedimentary gravel deposits. The lava flows occur somewhat sporadically across the plateau, but they are generally larger and more common in the Music Mountains along the southwest edge of the plateau (fig. 3). The gravel deposits, which are Tertiary through Quaternary in age, occur mainly in stream valleys and across much of Plain Tank Flat. Quaternary deposits on the plateau consist of stream channel, valley fill, travertine, landslide, and alluvial fan deposits (Billingsley and others, 2006). For the purpose of this study, all of the Tertiary and Quaternary sedimentary deposits of Billingsley and others (2006) have been combined into a single stratigraphic unit called ‘Quaternary and Tertiary surficial deposits’ (fig. 4). Figure 5 is an aerial photograph of the northern edge of the Hualapai Plateau between Horse Flat and Quartermaster Canyons.The Proterozoic and Paleozoic rock units described in this section are labeled in the photograph.

Hydrology

Comprehensive hydrogeological studies of the field area were conducted by Bills and Macy (2016) and Mason, Macy, and others (2020), and a brief summary of their findings will be presented here. A number of earlier studies provide additional insight into the hydrology of the study area (Twenter, 1962; Devlin, 1976; Boyer, 1977; Boyer and others, 1978; Remick, 1981; Young, 1966, 1987, 1999, 2007; Hualapai Department of Natural Resources, 2010, 2015; Hualapai Water Resources Program, 1999, 2004, 2009; Natural Resources Consulting Engineers, 2011).

Surface Water

Most surface-water drainages in the study area are ephemeral, flowing only in response to significant precipitation events, but a few drainages have perennial reaches that are supported by groundwater discharge from springs. Truxton Wash is the principal drainage of the Truxton basin. The wash often flows for a short reach at the west end of the basin, where it has eroded a channel through the basin sediments into impermeable granitic basement rocks below. The U.S. Geological Survey has operated a streamflow-gaging station (09404343) in this reach for the Hualapai Tribe since 1993. Flow in this reach has been less consistent in recent years. Principal drainages of the Hualapai Plateau are Peach Springs Canyon, which also drains part of the Truxton basin; Spencer creek, an informally named perennial stream within Spencer Canyon that drains the Spencer, Milkweed and Meriwhitica Canyons; Lost Creek, which drains Clay Tank Canyon; Reference Point Creek, which drains Horse Flat Canyon; and Quartermaster Canyon (fig. 1 of Mason, Knight, and others 2020).

Both Spencer creek and Peach Springs Wash have perennial reaches with substantial flow. The majority of perennial flow in Spencer creek originates in springs issuing from the Rampart Cave Member of the Muav Limestone. Lesser amounts of flow come from sediments and (or) volcanic rocks in the upper parts of Milkweed and West Water Canyons. Groundwater discharge to upper Peach Springs Wash is derived from older sediments and lakebed deposits of the Truxton aquifer and the Muav Limestone and Bright Angel Shale (Billingsley and others, 2006; Bills and Macy, 2016). Perennial flow comes into the lower reach of Peach Springs Wash from Diamond Creek which flows out of the Coconino Plateau. Numerous other springs issuing from the Rampart Cave Member of the Muav Limestone support relatively short reaches of perennial flow in many other canyons of the Hualapai Plateau.

Groundwater

The Truxton basin is recognized as part of an old drainage and paleocanyon system eroded into the surface of Proterozoic and Paleozoic rocks. The Proterozoic and Paleozoic rocks that underlie the Truxton basin generally dip 1–3° from the southwest to the northeast and east. This erosional surface was created during regional Laramide uplift of the southwest Colorado Plateau margin from the Late Cretaceous to Paleogene (Young, 1966, 1987).

Older basin-fill sediments of the Truxton basin make up the largest part of the Truxton aquifer. These sediments are a poorly sorted mix of medium- to coarser-grained material (medium to coarse sand, silt, gravel, and cobbles), with low to moderate amounts of clay (fig. 1). The younger basin-fill sediments exposed at the land surface in the Truxton basin are mostly unsaturated but at least moderately permeable, and some coarser-grained sediments near the base of the younger basin-fill sediments are water bearing in the parts of the basin (Bills and Macy, 2016). The offset along the Hurricane Fault, which bisects the Truxton basin, has created a greater thickness of older and younger basin-fill sediments to the west of the fault (figs. 1 and 2). Well logs from near the community of Peach Springs, Ariz., and Truxton Wash, indicate that the older and younger basin-fill sediments are dry in this area, and groundwater is found in the underlying Muav Limestone (Bills and Macy, 2016).

Usable groundwater on the Hualapai Plateau is in either perched water-bearing zones close to land surface or in the Muav Limestone aquifer at depths of greater than 2,000 ft below land surface. Although the Redwall Limestone and Temple Butte Formation are often considered to function along with the Muav Limestone as an aquifer system in northern Arizona (Cooley, 1976), both the Redwall Limestone and Temple Butte Formation appear to be dry on the plateau and are not considered aquifers in this area (Mason, Macy, and others, 2020). Perched water-bearing zones on the plateau are in paleochannel-fill sediments, volcanic rocks and recent channel alluvium (Twenter, 1962). Groundwater in the Muav Limestone aquifer is found near the bottom of the geologic unit in the Rampart Cave Member of the Muav Limestone (Mason, Macy, and others, 2020). The Muav Limestone aquifer is incised by deep canyons on the plateau and truncated by the Colorado River, which results in discharge from the aquifer as springs in plateau canyons and along the Colorado River in the Grand Canyon.

Although water flows out of the base of the Muav Limestone from numerous springs in canyons dissecting the Hualapai Plateau, the unit is not saturated in all areas of the plateau. Test wells drilled on the plateau through the Muav Limestone found the limestone to be dry (Mason, Macy, and others, 2020). These test wells found limited groundwater with marginal water quality under artesian pressure below the Muav Limestone in the Bright Angel Shale and Tapeats Sandstone (Mason, Macy, and others, 2020).

Summary

This chapter focused on the geology and hydrology of the Truxton basin and Hualapai Plateau on and adjacent to the Hualapai Indian Reservation in northwestern Arizona. Most surface-water drainages in the study area are ephemeral in nature, flowing only seasonally or in response to significant precipitation events, but a few drainages have perennial reaches that are supported by groundwater discharge from springs. Truxton Wash often flows for a short reach at the west end of the basin, where it has eroded a channel through the basin sediments and into the impermeable granitic basement rocks below. Both Spencer creek and Peach Springs Wash have perennial reaches with substantial flow. The majority of perennial flow in Spencer creek originates in springs issuing from the Rampart Cave Member of the Muav Limestone. Groundwater discharge to upper Peach Springs Wash is derived from older sediments and lakebed deposits of the Truxton aquifer and the Muav Limestone and Bright Angel Shale (Billingsley and others, 2006; Bills and Macy, 2016). Perennial flow comes into the lower reach of Peach Springs Wash from Diamond Creek, which flows out of the Coconino Plateau. Numerous other springs issuing from the Rampart Cave Member of the Muav Limestone flow for a short distance in many other canyons of the Hualapai Plateau.

At one time, the Truxton basin was probably a closed basin where surface drainage was blocked by lava flows at the western end of the basin. This blockage would have promoted the deposition of thick sedimentary units in the basin including lacustrine deposits (Twenter, 1962). Older basin-fill sediments (Tertiary) in the Truxton basin consist of a sequence of partly consolidated to consolidated, reddish-brown to brown gravel and sand with varying amounts of clay. These rock units are almost always fully saturated and represent the main part of the Truxton aquifer (Bills and Macy, 2016). At the far eastern end of the Truxton basin, Cambrian age Tapeats Sandstone, Bright Angel Shale, and Muav Limestone are present above the Proterozoic crystalline and metamorphic rock.

The Hualapai Plateau is a large block of Paleozoic age sedimentary rocks dissected by many deep canyons. Usable groundwater on the Hualapai Plateau is in either perched water-bearing zones close to land surface or in the Muav Limestone aquifer at depths greater than 2,000 ft below land surface. Although water flows out of the base of the Muav Limestone from numerous springs in canyons dissecting the Hualapai Plateau, the unit is not saturated in all areas of the plateau. Test wells drilled on the plateau through the Muav Limestone found the limestone to be dry (Mason, Macy, and others, 2020). These test wells found limited groundwater under artesian pressure below the Muav Limestone in the Bright Angel Shale and Tapeats Sandstone (Mason, Macy, and others, 2020).

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