

U.S. Department of the Interior  
National Park Service  
Natural Resource Stewardship and Science Directorate  
Geologic Resources Division



# Tonto National Monument

## *GRI Ancillary Map Information Document*

Produced to accompany the Geologic Resources Inventory (GRI) Digital Geologic  
Data for Tonto National Monument

tont\_geology.pdf

Version: 12/23/2013

# Geologic Resources Inventory Map Document for Tonto National Monument

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## Geologic Resources Inventory Map Document



# Tonto National Monument, Arizona

## Document to Accompany Digital Geologic-GIS Data

[tont\\_geology.pdf](#)

Version: 12/23/2013

This document has been developed to accompany the digital geologic-GIS data developed by the Geologic Resources Inventory (GRI) program for Tonto National Monument, Arizona (TONT).

Attempts have been made to reproduce all aspects of the original source products, including the geologic units and their descriptions, geologic cross sections, the geologic report, references and all other pertinent images and information contained in the original publication.

National Park Service (NPS) Geologic Resources Inventory (GRI) Program staff have assembled the digital geologic-GIS data that accompanies this document.

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## About the NPS Geologic Resources Inventory Program

### Background

Recognizing the interrelationships between the physical (geology, air, and water) and biological (plants and animals) components of the Earth is vital to understanding, managing, and protecting natural resources. The Geologic Resources Inventory (GRI) helps make this connection by providing information on the role of geology and geologic resource management in parks.

Geologic resources for management consideration include both the processes that act upon the Earth and the features formed as a result of these processes. Geologic processes include: erosion and sedimentation; seismic, volcanic, and geothermal activity; glaciation, rockfalls, landslides, and shoreline change. Geologic features include mountains, canyons, natural arches and bridges, minerals, rocks, fossils, cave and karst systems, beaches, dunes, glaciers, volcanoes, and faults.

The Geologic Resources Inventory aims to raise awareness of geology and the role it plays in the environment, and to provide natural resource managers and staff, park planners, interpreters, researchers, and other NPS personnel with information that can help them make informed management decisions.

The GRI team, working closely with the Colorado State University (CSU) Department of Geosciences and a variety of other partners, provides more than 270 parks with a geologic scoping meeting, digital geologic-GIS map data, and a park-specific geologic report.

### Products

**Scoping Meetings:** These park-specific meetings bring together local geologic experts and park staff to inventory and review available geologic data and discuss geologic resource management issues. A summary document is prepared for each meeting that identifies a plan to provide digital map data for the park.

**Digital Geologic Maps:** Digital geologic maps reproduce all aspects of traditional paper maps, including notes, legend, and cross sections. Bedrock, surficial, and special purpose maps such as coastal or geologic hazard maps may be used by the GRI to create digital Geographic Information Systems (GIS) data and meet park needs. These digital GIS data allow geologic information to be easily viewed and analyzed in conjunction with a wide range of other resource management information data.

For detailed information regarding GIS parameters such as data attribute field definitions, attribute field codes, value definitions, and rules that govern relationships found in the data, refer to the NPS Geology-GIS Data Model document available at: <http://science.nature.nps.gov/im/inventory/geology/GeologyGISDataModel.cfm>

**Geologic Reports:** Park-specific geologic reports identify geologic resource management issues as well as features and processes that are important to park ecosystems. In addition, these reports present a brief geologic history of the park and address specific properties of geologic units present in the park.

For a complete listing of Geologic Resource Inventory products and direct links to the download site visit the GRI publications webpage [http://www.nature.nps.gov/geology/inventory/gre\\_publications.cfm](http://www.nature.nps.gov/geology/inventory/gre_publications.cfm)

GRI geologic-GIS data is also available online at the NPS Data Store Search Application: <http://irma.nps.gov/App/Reference/Search>. To find GRI data for a specific park or parks select the appropriate park (s), enter "GRI" as a Search Text term, and then select the Search Button.

For more information about the Geologic Resources Inventory Program visit the GRI webpage: <http://www.nature.nps.gov/geology/inventory>, or contact:

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The Geologic Resources Inventory (GRI) program is funded by the National Park Service (NPS) Inventory and Monitoring (I&M) Division.

## GRI Digital Geologic Map and Source Map Citations

The GRI digital geologic-GIS map for Tonto National Monument, Arizona (TONT):

### **GRI Digital Geologic Map of Tonto National Monument (*GRI MapCode TONT*)**

Arizona Geological Survey source maps used:

Spencer, J.E., Richard, S.M., Ferguson, C.A., and Gilbert, W.G., 1999, Preliminary Bedrock Geologic Map and Cross Sections of the Windy Hill 7.5' Quadrangle, Gila County, Arizona, Arizona Geological Survey, Open-File Report OFR 99-12, 1:24,000 scale. ([Preliminary Bedrock Geologic Map of the Windy Hill 7.5' Quadrangle](#)). (*GRI Source Map ID 74430*).

Spencer, J.E., and Richard, S.M., 1999, Geologic Map and Report for the Theodore Roosevelt Dam Area, Gila and Maricopa Counties, Arizona, Arizona Geological Survey, Open-File Report OFR 99-06, 1:24,000 scale. ([Geologic Map of the Theodore Roosevelt Dam Area](#)). (*GRI Source Map ID 7493*).

Additional information pertaining to each source map is also presented in the GRI Source Map Information (TONTMAP) table included with the GRI geology-GIS data.

## GRI Digital Surficial Map and Source Map Citations

The GRI digital surficial geologic-GIS map for Tonto National Monument, Arizona (TONT):

### **GRI Digital Surficial Map of Tonto National Monument (*GRI MapCode TSUR*)**

U.S. Bureau of Reclamation source map used:

Anderson, L.W., Piety, L.A., and LaForge, R.C., 1987, Seismotectonic Investigation, Theodore Roosevelt Dam, Salt River Project, Arizona, U.S. Bureau of Reclamation, Seismotectonic Report No. 87-5, 1:48,000 scale. ([Seismotectonic Investigation, Theodore Roosevelt Dam](#)). (GRI Source Map ID 39467).

*Note: This source map was used partially. Only areas overlapping with the quadrangles of interest for Tonto National Monument were captured. Some rock units listed here do not appear in the GIS data.*

Additional information pertaining to the source map is also presented in the GRI Source Map Information (TONTMAP) table included with the GRI geology-GIS data.

## GRI Digital Geologic Map of Tonto National Monument

### Geologic Map Unit List

The geologic units present in the digital geologic-GIS data produced for Tonto National Monument, Arizona (TONT) are listed below. Units are listed with their assigned unit symbol and unit name (e.g., Qya - Young alluvium). Units are listed from youngest to oldest. No description for water is provided. Information about each geologic unit is also presented in the GRI Geologic Unit Information (TONTUNIT) table included with the GRI geology-GIS data.

### Cenozoic Era

#### Quaternary Period

[Qd](#) - Disturbed ground  
[Qya](#) - Young alluvium  
[Qs](#) - Surficial deposits  
[Qtc](#) - Talus and colluvium  
[Qoa](#) - Old alluvium  
[Qr](#) - River gravel  
[Qoal](#) - Older alluvium

#### Tertiary to Quaternary Period

[QTu](#) - Undifferentiated sediments  
[QTls](#) - Landslide deposits  
[QTs](#) - Older alluvium  
[QTsm](#) - Conglomerate, mixed clasts  
[QTsa](#) - Conglomerate, Apache Group clasts  
[QTsg](#) - Poorly sorted sand and gravel deposits  
[QTr](#) - Old major river deposits  
[Tsy](#) - Siltstone, sandstone and sparse conglomerate  
[Tsyc](#) - Conglomerate  
[Tss](#) - Sandstone, pebbly sandstone and siltstone  
[Toc](#) - Older conglomerate  
[TXp](#) - Pegmatite dikes  
[TXm](#) - Mafic dikes  
[Tta](#) - Apache Leap Tuff  
[Ti](#) - Tuff

### Paleozoic Era

#### Carboniferous Period

[Mr](#) - Redwall Limestone

#### Devonian Period

[Dm](#) - Martin Formation, undivided  
[Dmj](#) - Martin Formation, Jerome Member  
[Dms](#) - Martin Formation, sandstone  
[Dmb](#) - Martin Formation, Beckers Butte Member

## Cambrian Period

[Cb](#) - Bolsa Quartzite

## Paleozoic Era and older

[PZYU](#) - Undifferentiated rocks associated with Roundup Hill

## Precambrian Era

[Yd](#) - Diabase

[Yt](#) - Troy Quartzite

[Ym](#) - Mescal Limestone, undivided

[Yma](#) - Mescal Limestone, argillite

[Ymb](#) - Mescal Limestone, basalt

[Ymd](#) - Mescal Limestone, dolomite

[Yds](#) - Dripping Spring Quartzite, undivided

[Ydsu](#) - Dripping Spring Quartzite, upper unit

[Ydsm](#) - Dripping Spring Quartzite, middle unit

[Ydsl](#) - Dripping Spring Quartzite, lower unit

[Ydslb](#) - Dripping Spring Quartzite, Barnes Conglomerate

[Yp](#) - Pioneer Formation, undivided

[Yps](#) - Pioneer Formation, Scanlan conglomerate

[Yg](#) - Coarse-grained porphyritic biotite granite

[Yga](#) - Aplite associated with coarse-grained porphyritic biotite granite

[YXgm](#) - Granite and schist

[Xga3](#) - Granitic rocks of Cottonwood Creek, aplite and aplitic granite

[Xg3](#) - Granitic rocks of Cottonwood Creek, granodiorite

[Xgbc](#) - Granitic rocks of Cottonwood Creek, granitic rocks in Bronco Creek

[Xga2](#) - Granitic rocks in Rock Creek area, aplitic granite

[Xg2](#) - Granitic rocks in Rock Creek area, coarse-grained granite

[Xgmvg](#) - Granitic rocks in Rock Creek area, mixed granite and metavolcanics

[Xg1](#) - Granitic rocks in Mills Canyon area, granite

[Xgd1](#) - Granitic rocks in Mills Canyon area, granodiorite

[Xgb](#) - Granitic rocks in Mills Canyon area, diorite-gabbro phase

[Xb](#) - Buckhorn Creek Crystalline Complex, undivided

[Xbf](#) - Buckhorn Creek Crystalline Complex, felsic unit

[Xbm](#) - Buckhorn Creek Crystalline Complex, mafic unit

[Xhm](#) - Hornblende and mafic intrusive rocks

[Xms](#) - Metasedimentary rocks, undivided

[Xmv](#) - Metavolcanic rocks

## Geologic Map Unit Descriptions

Descriptions of all geologic map units, generally listed from youngest to oldest, are presented below.

## **Qd - Disturbed ground**

Heavily disturbed ground due to agriculture, extensive excavation, or construction of earth dams. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

## **Qya - Young alluvium (Holocene)**

Deposits of sand, silt, pebbles, cobbles, and boulders in the channels of ephemeral and perennial streams, typically coarse and very poorly sorted within mountain areas and on upper piedmonts. Particle size ranges from silt to cobbles or boulders. Deposits are typically composed of sand, silt, and pebbles on lower piedmonts, sand in major drainages, and sand, silt and mud in areas subject to overbank flooding. Within the larger channels distributary and anastomosing channel patterns are common. The deposits are generally well-stratified and lack appreciable soil formation; soils are classified as Torrifluvents or Torriorthents. Most of the channel surfaces are modern in age, but vegetated bars may be several hundred years old. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

## **Qs - Surficial deposits (Quaternary)**

### **Qs - Surficial deposits (Quaternary)**

Undivided alluvium, talus, colluvium, and local active channel deposits. Typically consists of weakly to moderately indurated gravel and sand. Primarily exposed on weathered, slightly to moderately incised alluvial fans and alluvial valley filling deposits that form gentle to moderate slopes adjacent to hills and mountains. Also includes alluvium in recently active channels and some colluvium and talus. (GRI Source Map ID 74430) ([Preliminary Bedrock Geologic Map of Windy Hill 7.5' Quadrangle](#)).

### **Qs - Surficial deposits, undivided (Quaternary)**

Undivided alluvium, talus, colluvium, and local active channel deposits (map units Qoa, Qtc, and, locally, Qyc, undivided). Typically consists of weakly to moderately indurated gravel and sand. Primarily crops out on weathered, slightly to moderately incised alluvial fans and alluvial valley filling deposits that form gentle to moderate slopes adjacent to hills and mountains. Also includes alluvium in recently active channels and some colluvium and talus. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

## **Qtc - Talus and colluvium (Quaternary)**

### **Qtc - Talus and colluvium (Quaternary)**

Weakly to non-indurated deposits mantling hill slopes on bedrock. Typically consists of angular clasts of locally derived rock in a sand and clay matrix, derived by weathering of bedrock and downslope movement of regolith material. Mapped where hill-slope deposits are thick enough to obscure the nature of the underlying bedrock. Non-conformably overlies all older deposits. Locally includes deposits with boulders >1 m diameter. (GRI Source Map ID 74430) ([Preliminary Bedrock Geologic Map of Windy Hill 7.5' Quadrangle](#)).

### **Qtc - Talus and colluvium (Quaternary)**

Weakly to non-indurated gravel mantling hill slopes on bedrock. Consists of angular clasts of locally derived rock in a sand and clay matrix, derived by weathering of bedrock and downslope movement of regolith material. Mapped where hill slope deposits are thick enough to obscure the nature of the underlying bedrock. Non-conformably overlies all older deposits. (GRI Source Map ID 7493) ([Geologic](#)

[Map of the Theodore Roosevelt Dam Area](#)).

### **Qoa - Old alluvium (Quaternary)**

Cobble and boulder alluvium in topographically high areas on bedrock or forming broad areas deeply incised by drainages. (GRI Source Map ID 74430) ([Preliminary Bedrock Geologic Map of Windy Hill 7.5' Quadrangle](#)).

### **Qr - River gravel (Pleistocene)**

Deposits composed of moderately to well rounded cobbles in a sand matrix. A dark red-brown soil is developed on the surface underlain by this deposit about 1500 feet (450 m) downstream from the point where Buckhorn Canyon enters the Salt River. Desert pavement and rock varnish development is weak to moderate.

Gravels containing well rounded, far-traveled cobbles, probably related to Tonto Creek, are included in this unit in the northern part of the map area. Such gravels are exposed in highway road cuts in the extreme northwestern part of the map area, southeast of the highway maintenance station (sec. 28). The northern exposures are apparently interbedded in old alluvium (Qoa). (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

### **Qoal - Older alluvium (middle and early Pleistocene)**

Weakly to moderately indurated cobble and boulder conglomerate that forms terraces 3-10 m above active channels and flood plains. Surfaces on old alluvium have a well developed red-brown soil. Deposits are generally locally derived. In upper Mills Canyon, old alluvium is weakly indurated cobble-boulder conglomerate with a matrix of coarse, disaggregated granite sand. Boulders are up to 1 m in diameter, and are locally derived. Old alluvium at the south edge of the map area on the northeast side of Bronco Creek is a massive boulder conglomerate.

On the piedmont around Theodore Roosevelt Lake, this unit forms a veneer that blankets terrace surfaces on a pediment cut into older basin fill deposits (Ts and Tss). The reddish color of the old alluvium contrasts with underlying, generally tan to brown color of the older sandstone and conglomerate (Tss and Ts). Exposures of Ts and Tss in the arroyos cutting this unit are probably more abundant than shown. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

### **QTu - Undifferentiated sediments (Tertiary(?) to Quaternary(?))**

No description available. (GRI Source Map ID 74430) ([Preliminary Bedrock Geologic Map of Windy Hill 7.5' Quadrangle](#)).

### **QTls - Landslide deposits (Pliocene to Quaternary)**

Poorly consolidated to unconsolidated, very poorly sorted mud to large boulders, characterized by a hummocky surface littered with boulders. Bedding or foliation in boulders (when present) varies greatly between outcrops. Landslides in Salt River Canyon appear to have failed in middle Dripping Spring

Quartzite (just west of Theodore Roosevelt Dam) or in diabase (Yd) sheets in granitic rocks. Landslides near the southern edge of the map area consist of lower Dripping Spring Quartzite, and probably are due to failure within the Pioneer Formation. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

### **QTs - Older alluvium (Miocene to Quaternary)**

Non-indurated to weakly indurated cobble to boulder conglomerate. Mapped in the piedmont around Theodore Roosevelt Lake where Miocene conglomerate (Ts) is suspected, but is overlain by younger deposits including old alluvium (Qoa) and colluvium (Qtc). Also includes conglomerate deposits on ridge tops of uncertain age that may correlate with Miocene conglomerate (Ts) or old alluvium (Qoa). Old alluvium overlies Ts and Tss conformably or with slight to moderate angular unconformity. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

### **QTsm - Conglomerate, mixed clasts (Miocene to Quaternary)**

Weakly to moderately indurated conglomerate consisting of cobbles to boulders of Paleozoic formations and Apache Group formations. *Note: this lithologic description appears in source data files but does not occur in source GIS data. Correspondence with the map author suggests that this unit was lumped with unit QTs (Older alluvium).* (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

### **QTsa - Conglomerate, Apache Group clasts (Miocene to Quaternary)**

Weakly to moderately indurated conglomerate consisting of cobbles to boulders derived from Apache Group formations. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

### **QTsg - Poorly sorted sand and gravel deposits (Pliocene to Pleistocene)**

#### **Qts - Poorly sorted sand and gravel deposits (Pliocene to Pleistocene)**

Unconsolidated, poorly sorted sand and gravel deposits of uncertain age and stratigraphic position relative to other upper Cenozoic deposits. (GRI Source Map ID 74430) ([Preliminary Bedrock Geologic Map of Windy Hill 7.5' Quadrangle](#)).

### **QTr - Old major river deposits (Pliocene to middle Pleistocene)**

Thin deposits of gravel consisting of sub-rounded to well-rounded pebbles and cobbles of Paleozoic carbonates and quartzites, Apache Group strata, diabase, and Proterozoic granite, metavolcanic rocks, and quartzite. Overlies older units on erosional unconformity. (GRI Source Map ID 74430) ([Preliminary Bedrock Geologic Map of Windy Hill 7.5' Quadrangle](#)).

### **Tsy - Siltstone, sandstone and sparse conglomerate (Pliocene)**

Very light gray, laminated to very thin-bedded, fine to medium-grained, lithic sandstone and siltstone. Interbedded with cobble to boulder conglomerate containing rounded clasts of Apache group and

diabase, especially near basin margins or bedrock exposures. (GRI Source Map ID 74430) ([Preliminary Bedrock Geologic Map of Windy Hill 7.5' Quadrangle](#)).

## **Tsyc - Conglomerate (Pliocene or Miocene)**

### **Tsyc - Conglomerate (Pliocene or Miocene)**

Basin margin facies of map unit Tsy. (GRI Source Map ID 74430) ([Preliminary Bedrock Geologic Map of Windy Hill 7.5' Quadrangle](#)).

### **Tc - Conglomerate - (Pliocene or Miocene)**

Thin, monolithologic deposits on hill slopes consisting of sub-rounded boulders of Pioneer Formation and granite (Xg3) up to 2 m in diameter. Matrix is not exposed, but float suggests that it is sandy. Soil formed on this unit is slightly darker colored and more clay rich than soil formed on granite (Xg3). Appears to be a lag deposit left by erosion of Pioneer formation that previously overlay the granite. This deposit lies at elevations lower than polymict conglomerate of map unit Ts in adjacent hill tops. Unconformably overlies Proterozoic granite. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

## **Tss - Sandstone, pebbly sandstone and siltstone (Miocene)**

Tan, medium to very thin bedded gravelly sandstone, coarse to very fine-grained sandstone, and siltstone. This unit is a distal, fluvial to lacustrine facies of conglomerate of map unit Ts, and grades laterally into conglomerate. Consolidation and lithification are generally poor. The transition between the two units is a zone of interbedded coarse sandstone and pebbly conglomerate. Siltstone consists of very thinbedded, light grayish or reddish brown, fine-grained sandstone and mudstone with a few lenses of cobble conglomerate. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

## **Toc - Older conglomerate (Miocene)**

### **Ts - Conglomerate - (Miocene)**

Typically moderately to poorly bedded and sorted conglomerate. Lithification is variable and generally fairly weak but is commonly sufficient to form steep slopes and small cliffs. This unit underlies several square miles near the western edge of the map area in upper Buckhorn, Vineyard, and Mills canyons. In this area, eastern and stratigraphically lower exposures are generally finer grained and include bedded sandy conglomerate as well as cobble to locally boulder conglomerate, whereas western exposures consist of coarse, massive to poorly bedded conglomerate with clasts locally to 3 meters. Clast compositions also vary, with eastern areas containing a mixed assemblage of rocks of the Apache Group, diabase, lower Paleozoic rocks, and some mafic and felsic granitoids, whereas western exposures are compositionally diverse granitoids, gneiss, and sparse, highly indurated quartzite of presumed early Proterozoic age. North of Buckhorn Spring dominantly sandy conglomerate is overlain by conglomerate along a mappable contact shown on the map as a marker bed (+--+--+). A reworked tuff with sparse fresh biotite is exposed at one location along this contact, but minor faulting or slumping has obscured the original stratigraphic relationship of tuff to conglomerate. Northern exposures contain sparse clasts of Proterozoic felsic metavolcanic rocks.

In the western part of its outcrop in Mills Canyon, the conglomerate consists of angular to subangular boulders of hornblende granodiorite (Xgd1) and mafic dike rock (TXm) in a pinkish tan, very fine-grained muddy matrix. The conglomerate is clast supported. Clasts of metavolcanic rocks (Xv) that are common in the young alluvium along Mills Canyon appear to be absent in this older conglomerate.

At the mouth of Vineyard Canyon, pale tan, sandy fanglomerate, with weakly to moderately defined bedding, contains 5-50 cm, subrounded to subangular clasts of Apache Leap tuff, granitoids, and minor quartzite probably derived from the Apache Group.

East of Peters Mountain conglomerate clasts of porphyritic granite are as large as three meters, and clasts of Barnes (map unit Y dsb) or Scanlan conglomerate (basal conglomerate of the Pioneer Formation) and Early Proterozoic quartzite are as large as two meters. Conglomerate in this area contains fairly little locally derived granite, but contains abundant early Proterozoic quartzite, metamorphic rocks, and porphyritic granite. In lower Cottonwood Canyon and on Two Bar Ridge this unit contains clasts of Apache Leap tuff, granite like that exposed locally, rocks of the Apache Group and associated diabase, and lower Paleozoic clastic and carbonate rocks. The small exposure on the ridge crest above the lower ruin of Tonto National Monument is rubble of Mescal Limestone, Dripping Spring Quartzite, and very sparse basalt of the Apache Group, all resting on Mescal Limestone. This unit overlies Proterozoic granitic and metamorphic rocks on erosional unconformity. In Mills Canyon, the conglomerate appears to be faulted against granitic rocks (map units Xgd1 and Xg1) at low elevations, but overlaps the bounding fault on the ridge crests to depositionally overlie the granitic rocks. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

### **TXp - Pegmatite dikes (Miocene(?) to Early Proterozoic(?))**

No description available. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

### **TXm - Mafic dikes (Miocene to Early Proterozoic)**

Dark gray green, very fine grained to aphyric microdiorite(?). Dikes up to 3 m thick, contacts sheared in some dikes. Aphanitic chilled margins 1-2 cm thick are present at unsheared contacts. Dikes cutting granodiorite (Xgd1) in the canyon north of Mills Canyon are dark gray to black, and locally contain 5% 1-3 mm long plagioclase crystals with a weak trachytic texture. These dikes are nearly concordant to the foliation in the host granite, but their very fine-grained chilled margins do not have cleavage, suggesting that they post-date fabric development in the granite. Intrude granitic rocks of map unit Xgd1 in Mills Canyon area. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

### **Tta - Apache Leap Tuff (early Miocene)**

Weakly welded, moderately to strongly indurated crystal tuff forming one small outcrop southeast of Burnt Corral Canyon. Rocks of this unit contain 2-3% 1-2 mm diameter biotite crystals, 10-15% quartz and feldspar crystals, including sanidine, and sparse fiamme and dark gray aphanitic lithic lapilli. Eutaxitic foliation is quite discordant to lower contact of unit, indication deposition on a slope or some post-depositional rotation of blocks due to failure and down-slope movement on underlying non-welded tuff. Overlies non-welded tuff (Tt) on a sharp contact. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

### **Tt - Tuff (early to middle Miocene)**

Discontinuous lenses of white or light gray nonwelded tuff are exposed at the base of Tertiary conglomerate and sandstone in many areas. Typically the lower part of the exposed tuff contains

abundant blocks of underlying preTertiary rocks, which become less abundant up section. The tuff is well bedded, locally laminated, but generally lacks evidence of reworking. Phenocrysts of biotite, plagioclase and sanidine in variable amounts are invariably present. Lithic fragments of light gray felsite are present in many beds. Tuff nonconformably overlies pre-Tertiary rocks on a surface of significant (10's of m) erosional relief. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

## **Mr - Redwall Limestone (Mississippian)**

### **Mr - Redwall Limestone (Mississippian)**

Gray crystalline limestone, fine-grained to medium grained. Relict crinoid columnals are commonly present, and some limestone beds appear to have been crinoid grainstone. Typically thick bedded, with some medium-bedded intervals. An interval that contains abundant horn-coral fossils is present about 20 m above the base of the unit. Some limestone beds near the base contain sparse spherical quartz grains. In one location about 1m of terra rossa was observed at the Martin-Redwall contact. Otherwise the contact is sharp and unremarkable. Upper contact of Redwall is erosional unconformity overlain by Tertiary sedimentary rocks. (GRI Source Map ID 74430) ([Preliminary Bedrock Geologic Map of Windy Hill 7.5' Quadrangle](#)).

### **Mr - Redwall Limestone (Mississippian)**

Massive, light gray crystalline limestone. Locally preserved calcarenite (crinoidal grainstone?) texture. Vague bedding partings appear to be slightly silty. Contains scattered horn coral. Stylolites parallel to bedding are common. Base is generally poorly exposed, placed at bottom of first thick limestone bed. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

## **Dm - Martin Formation, undivided (Devonian)**

Stratigraphy of Martin Formations is variable in detail. Teichert (1965) divided the Martin Formation into the lower Beckers Butte Member and the upper Jerome Member, but these divisions were not used because sandstone characteristic of the Beckers Butte Member is present at many levels in the Martin Formation and is not particularly conspicuous at the base. The base is typically a 0.5 m bed of dolomitic sandstone, with prominent brown sandstone laminations that weather in relief. Sand consists of about 99% fine-grained sub-rounded quartz, with a trace of medium- to coarse-grained, well rounded to spherical quartz grains. In some places a thin basal conglomerate is present that contains 1-3 cm diameter, angular clasts of upper Dripping Spring Quartzite or Mescal chert. This basal unit is overlain by 0-5 m of light buff-gray, slightly sandy dolomite or gray, platy-weathering laminated dolomite overlain by a prominent 2-5 m-thick interval of very light gray to white porcelaneous, slightly sandy, thin-bedded dolomite. Where the underlying Mescal Limestone is thickest, the porcelaneous dolomite unit is directly on the unconformity; where more Mescal has been eroded, there is more Martin section beneath the porcelaneous dolomite. Above the porcelaneous dolomite, the stratigraphy was not studied in sufficient detail to discern local variations, but several prominent marker horizons appear to be consistent throughout the area. The next marker horizon is 5-10 m above the porcelaneous dolomite, and is a light gray, vitreous quartzite to friable quartz arenite that contains rare glauconite grains, and 10-20 cm amplitude, trough cross beds. Quartz grains in this unit are up to 2 mm diameter, and the sand is very poorly sorted. Above this is 20-30 m of tan sandy dolomite in thin to medium beds, with marly intervals. Sparse fenestrate bryozoan, crinoid columnals, and brachiopods are present, particularly in the marly intervals. A few very thin brachiopod packstone beds are present. The interbedded marl-dolomite interval is overlain by an upper sandstone unit 10-15 m thick that strongly resembles the quartzite-sandstone unit beneath the marl-dolomite interval. At the base of this upper sandstone, zones of convoluted bedding and dish structure are present in some areas; 1-cm-amplitude herringbone cross-laminated beds are also present in this interval. The top of the Martin Formation consists of 10-15 m of thick, cherty

dolomite beds. Chert forms irregular globs and coalesced nodules, bedding is poorly defined.

Lower contact is erosional unconformity on upper Dripping Spring Quartzite, Mescal Limestone, or diabase. At one location (SW, sec. 6, T. 4 N., R. 13 E), basal sandstone that may correlate with the Beckers Butte member of the Martin Formation consists of poorly sorted, quartz-rich sandstone with local rip-ups of fine grained sandstone up to 10 cm long. Cross beds are 5 to 20 cm thick. Both cross beds and plane beds have opaque-rich layers; opaque mineral is probably magnetite derived from middle Proterozoic diabase. Sandstone is not brown in color as is common in some areas of suspected Cambrian Bolsa Quartzite that contain much iron-rich debris derived from the diabase.

This map unit was locally divided into lower, middle, and upper members (Dm1, Dm2, and Dm3) near the north edge of the map area.

The upper contact with Redwall Limestone is a disconformity. It is placed at the transition from thick beds of cherty dolomite to thick beds of recrystallized limestone. The contact can be difficult to spot from a distance, but on close inspection can generally be located quite closely. (*GRI Source Map ID 74430*) ([Preliminary Bedrock Geologic Map of Windy Hill 7.5' Quadrangle](#)).

## **Dmj - Martin Formation, Jerome Member (Middle to Late Devonian)**

### **Dm3 - Martin Formation, upper member (Middle to Late Devonian)**

This map unit was locally divided into lower, middle, and upper members (Dm1, Dm2, and Dm3) near the north edge of the map area. See [Dm](#) for unit description. (*GRI Source Map ID 74430*) ([Preliminary Bedrock Geologic Map of Windy Hill 7.5' Quadrangle](#)).

### **Dm - Jerome Member, Martin Formation (Middle to Late Devonian)**

Thin to medium bedded, generally light gray dolomite, sandy dolomite, sandstone and shale. Thicker intervals of sandstone north of the Salt River are mapped as unit Dms. Lithology is variable. A good section is exposed in road cuts along the abandoned part of Arizona State Route 88 beneath the SE abutment of the new bridge over the Salt River Canyon (SW sec. 20, T. 4 N., R. 12 E., UTM 485450E 3725550N). The base of the section at the contact with the Beckers Butte Member is disrupted in this section. The lowest beds are medium- to thin bedded porcelaneous, white to light gray dolomicrite (4 m minimum thickness; thicknesses estimated by pacing). These are overlain by about 23 m of thin-bedded, yellowish and greenish gray sandy dolomite(?) with shale partings. Up section, shale becomes more abundant, carbonate beds are sandier and thicker. Tiny green spheres of glauconite(?) are present in the carbonate beds. Above this is an interval of about 30 m of medium-bedded, ledge-forming, laminated sandy dolomite. Small-scale planar troughy cross beds, and some siliceous stringers or chert nodules are present. The next interval is about 9 m of medium-bedded, marly dolomite that weathers to discoid chips and dolomitic, fine-grained, laminated sandstone. Sparse crinoid columnals are present. This is overlain by 15 m of very thin bedded, gray dolomite with interbedded shale. The shale is pinkish to greenish gray, and contains sand-filled tubes (burrows?) about 2 cm in diameter. The top of the section consists of about 28 m of tan orange to gray, slightly sandy dolomite in the lower part that grades up into terra rossa consisting of blocks of dolomite in a red-brown mudstone or siltstone matrix. (*GRI Source Map ID 7493*) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

## **Dms - Martin Formation, sandstone (Middle to Late Devonian)**

### **Dm2 - Martin Formation, middle member (Middle to Late Devonian)**

This map unit was locally divided into lower, middle, and upper members (Dm1, Dm2, and Dm3) near the north edge of the map area. See [Dm](#) for unit description. (*GRI Source Map ID 74430*) ([Preliminary](#)

[Bedrock Geologic Map of Windy Hill 7.5' Quadrangle](#)).

#### **Dms - Sandstone in the Martin Formation (Middle to Late Devonian)**

In the northern part of the map area, progressively more of the middle part of the Martin Formation consists of sandstone, and a predominantly sandstone facies of the Jerome? Member is mapped. A section through much of unit is well exposed in a road cut in NW, sec. 18, T. 4 N., R. 12 E. (UTM 483750E 3727800N), where the unit consists of fine-grained to silty, quartz-rich sandstone, overlain by medium- to coarse-grained quartz-rich sandstone interbedded with calcareous siltstone and silty carbonate. The upper sandstone is moderately cemented and slightly to strongly calcareous, with cross beds 10 to 100 cm thick. Sparse quartzite pebbles are present in one bed. Sandy rocks are typically tan; silty rocks typically have a greenish cast. Lithologically the sandstone is very similar to that in the Beckers Butte Member. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

#### **Dmb - Martin Formation, Beckers Butte Member (Early to Middle Devonian)**

##### **Dm1 - Martin Formation, lower member (Early to Middle Devonian)**

This map unit was locally divided into lower, middle, and upper members (Dm1, Dm2, and Dm3) near the north edge of the map area. See [Dm](#) for unit description. (GRI Source Map ID 74430) ([Preliminary Bedrock Geologic Map of Windy Hill 7.5' Quadrangle](#)).

##### **Dmb - Beckers Butte Member of the Martin Formation (Early to Middle Devonian)**

Light gray to whitish gray, medium- to coarse-grained, arkosic to quartz-rich sandstone, cross bedded and plane bedded, with beds 3-30 cm thick. Planar tabular cross bedding is most common. Some greenish or purplish gray shale partings are present, becoming more abundant up section. Conspicuously poor sorting of this gritty sandstone is distinctive, with sand grains commonly 1-10 mm diameter. This unit also contains local pebbly beds and rare conglomerate with rounded quartzite cobbles up to 15 cm diameter. A few percent of pebbles are black chert. Finer grained sandstone beds in the upper part of the unit contain conspicuous, nearly spherical grains disseminated among smaller, sub-rounded grains (texture inversion). The Beckers Butte Member lacks the hematitic zones that are common in sandstone assigned to the Cambrian Bolsa Quartzite. In the type area of the Beckers Butte Member, 40 miles east of Theodore Roosevelt Dam, shale and impure dolomite at the top of the member contain Early or Middle Devonian psilophyte flora. The Beckers Butte Member pinches out in some areas north of Theodore Roosevelt Dam. Contact on Bolsa Quartzite is exposed at the west end of the road cut on west side of Government Hill. Grit of Beckers Butte Member concordantly overlies finer-grained, better sorted sand assigned to Bolsa. There is no indication of significant erosion or recycling of Bolsa sand or clasts into Beckers Butte Member. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

#### **Cb - Bolsa Quartzite (Middle Cambrian)**

Fine- to coarse-grained quartz arenite and feldspathic quartz arenite. Lower part is typically dark red brown. In thicker sections, grades up into buff to white sandstone with irregular zones of red brown sandstone, mostly along bedding planes. Picturesque Liesegang banding is developed in some outcrops. Small scale planar tabular and troughy cross bedding is abundant. Unit is medium- to thin-bedded. Magnetite-rich laminations are common in some outcrops. Sand grains are typically <1 mm diameter. Middle and upper Bolsa Quartzite consists of fine-grained, medium brown and white sandstone in beds up to 1 m thick, with shaley partings and beds up to 10 cm thick. Cross beds in lower Cottonwood Canyon, form sets 5-10 cm thick. Distinctive, magnetite-rich laminations along the lower part of the cross-bed slip faces flatten and merge downward into a planar, magnetite-rich zone along the

base of the cross bed set. Near the base of the unit in this area, rare beds up to 1 m thick are full of flat rip-up fragments, 1-10 cm long, of underlying Dripping Spring Formation.

This sandstone is preserved in paleovalleys cut into Dripping Spring Quartzite in lower Cottonwood Canyon, cut into the upper part of the Mescal Limestone near Theodore Roosevelt Dam, and into upper, then middle Dripping Spring Quartzite northward from the dam. The erosional unconformity along the sides of a paleovalley are well exposed in road cuts along the Apache Trail near the SE abutment of Theodore Roosevelt Dam. Blocks of Mescal argillite (unit Yma) are present in the Bolsa within about 2-4 m of the contact. Troy(?) sandstone appears to be absent where Bolsa is recognized. Overlain disconformably by Beckers Butte member of Martin formation on a sharp contact. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

### **PZyu - Undifferentiated rocks associated with Roundup Hill (Precambrian(?) to Paleozoic(?))**

No description available. (GRI Source Map ID 74430) ([Preliminary Bedrock Geologic Map of Windy Hill 7.5' Quadrangle](#)).

### **Yd - Diabase (Middle Proterozoic)**

#### **Yd - Diabase (Middle Proterozoic)**

Dark gray, dark greenish gray, and grayish black sills and dikes with typical subophitic, diabasic texture. (GRI Source Map ID 74430) ([Preliminary Bedrock Geologic Map of Windy Hill 7.5' Quadrangle](#)).

#### **Yd - Diabase (Middle Proterozoic)**

Dark gray, dark greenish gray, and grayish black sills and dikes with typical sub-ophitic, diabasic texture. Consists of 35-45% 1-3mm plagioclase lathes in black groundmass of pyroxene(?); accessory magnetite(?) is common. Locally crude layering is defined by variation in ratio of plagioclase to groundmass and in size of plagioclase crystals. Major sills intrude granitic rocks 200-400 feet (60-120 m) below the base of the Pioneer Formation, and in the upper part of the Pioneer Formation. Diabase intrudes Proterozoic granitoid and Apache Group. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

### **Yt - Troy Quartzite (Middle Proterozoic)**

Red brown thin to medium bedded sandstone. Poorly sorted sand; fine to very coarse grained, mostly fine- to medium-grained. Grain sized within individual beds is less variable than grain-size variations between beds (contrasting with generally more uniform grain size in Bolsa, and wide within-bed variations in Beckers Butte sandstone). Shale partings are common. Planar tabular cross bedding is present but not ubiquitous. Bedding partings are more sharply defined and planar than in Bolsa or Troy sandstones. Contact with underlying upper Mescal argillite unit south of Theodore Roosevelt Dam is erosional. Chert from argillite unit (Yma) occurs as clasts in basal part of sandstone. On ridges in the southeastern part of the map area, overlies basalt (Yb), and clasts of basalt are present in the basal part of the sandstone. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

**Ym - Mescal Limestone, undivided (Middle Proterozoic)**

Incomplete section preserved beneath erosion surface at base of Martin Formation. At base is 1-2 m thick bed of red brown to orange, variably silicified, calcareous quartz arenite that overlies the 0.5 m vitreous quartzite marker used as the top of the Dripping Spring Quartzite. The vitreous quartzite forms prominent float even on slopes with very poor exposure. This is overlain by about 10 m of nonresistant orange to brown marl, argillite, calcareous or dolomitic fine-grained sandstone, and possible sedimentary (solution collapse?) breccia. This interval is non-resistant and typically forms a slope. Gray chert fragments are common in the float. Above this are cherty dolomite beds. These are 0.5 to 1.5 m thick, with rough, irregular weathering, and gray to tan color; chert nodules form irregular globs. At the upper contact this rock becomes darker colored in some are., probably due to pre-Martin weathering. Conformably overlies Dripping Spring Quartzite. Overlain by Martin Formation on erosional unconformity. (GRI Source Map ID 74430) ([Preliminary Bedrock Geologic Map of Windy Hill 7.5' Quadrangle](#)).

**Yma - Mescal Limestone, argillite (Middle Proterozoic)**

Interbedded chert and massive, very fine-grained sandstone or argillite, with minor shale and medium grained sandstone. Characterized by medium- to thin-bedding, and medium to dark gray color; becomes reddish at top of unit. Chert beds are the most resistant and tend to form the only outcrops. Only present in a small area immediately south of Theodore Roosevelt Dam, and as very thin remnants between Beckers Butte Member of the Martin Formation and basalt (Yb) north of the dam. Disconformably(?) overlies basalt (Yb). (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

**Ymb - Mescal Limestone, basalt (Middle Proterozoic)****Yb - Basalt (Middle Proterozoic)**

Exposed only in the southwestern corner of the map area. Description modified from Spencer and Richard (1999) is as follows: Dark gray to black basalt lava flows and flow breccias that are part of the Apache Group. (GRI Source Map ID 74430) ([Preliminary Bedrock Geologic Map of Windy Hill 7.5' Quadrangle](#)).

**Yb - Mescal Limestone, basalt (Middle Proterozoic)**

Dark gray to black, massive, aphyric basalt lava. Locally contains vesicular or fragmental zones. Conformably(?) overlies stromatolite unit in upper Mescal Limestone. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

**Ymd - Mescal Limestone, dolomite (Middle Proterozoic)****Ym - Mescal Limestone, dolomite (Middle Proterozoic)**

Brown to reddish tan dolomite with blobs, stringers, and laminations of protruding silica. Dolomite weathers in some areas to reveal faint to moderately well developed, 1-2 mm laminations. Locally, protruding siliceous laminations, 2-5 mm thick, define cross bedding in beds 10 cm thick. Basal red-brown, non-resistant beds consists of poorly sorted quartz sand in argillaceous or dolomitic matrix. Breccia zones commonly present in the lower part are possibly related to dissolution of evaporite minerals. These consist of angular chert and dolomite fragments in a dolomite matrix that is lithologically identical to many of the clasts. Basal beds are overlain by a lower member (informal division) of thin to thick bedded dolomite or limestone, with variable amounts of chert as bedding parallel stringers, and calcareous shale partings. Dolomite is tan, limestone light gray to white. These strata are ordinarily 150-

200 feet thick, and form most of the formation. A middle member of massive dolomite or limestone with structural features attributed to the growth of algal colonies during deposition is present in well preserved sections (50-100 feet thick). The upper member of chert, feldspathic siltstone, and thin limestone (Unit Yma) is rarely preserved, and is mapped separately where present. Mescal Limestone beneath the lens of Bolsa quartzite on the south side of Inspiration Point is silicified, varicolored, breccia that may be the product of pre-Bolsa karst.

One mile northeast of Pinyon Mountain the following 4-part division was recognized, from base to top: (1) mottled, silty, tan to brown dolomite, about 5 m thick, (2) siliceous dolomite with abundant, protruding, 1-5 cm thick stringers of brown silica separated by recess-forming, yellowish tan dolomite. This unit is about 30 m thick. (3) Twenty meters of interbedded, silica-stringer-rich dolomite and massive, reddish tan dolomite without siliceous stringers. (4) Ten meters of massive, reddish tan dolomite that locally contains 10-30 cm thick beds of massive to laminated, aphanitic, pale gray to grayish white, indurated and conchoidally fracturing, siliceous rock that could be air-fall tuff (more likely) or very finegrained siltstone (less likely).

Overlain gradationally by argillite unit (Yma) on south side of Theodore Roosevelt Dam. Otherwise overlain disconformably by sandstone of Troy, Bolsa, or Martin Formation. Pinches out about one mile north of Vineyard Mountain due to pre-Martin erosion. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

## **Yds - Dripping Spring Quartzite, undivided (Middle Proterozoic)**

### **Yds - Dripping Spring Quartzite, undivided (Middle Proterozoic)**

No unit description available. (GRI Source Map ID 74430) ([Preliminary Bedrock Geologic Map of Windy Hill 7.5' Quadrangle](#)).

### **Yds - Dripping Spring Quartzite, undivided (Middle Proterozoic)**

Formal unit defined by Ransome 1919. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

## **Ydsu - Dripping Spring Quartzite, upper unit (Middle Proterozoic)**

### **Ydsu - Upper unit (Middle Proterozoic)**

Thin- to very thin-bedded, very fine to fine-grained quartzite or feldspathic quartzite. Weathered surfaces are gray, brown or orangish gray. A 0.5-m-thick, white, vitreous, quartzite marker bed is mapped as the top of the unit. Lower contact with lower Dripping Spring Quartzite is mapped in only one location, and is very poorly exposed. Float mapping indicates that some shale and white, laminated, very fine-grained sandstone is present in the lower part of this unit. This would correlate with strata mapped as middle Dripping Spring Quartzite in the Theodore Roosevelt Dam quadrangle (Spencer and Richard, 1999), but has not been differentiated on this map. Upper contact with Mescal 'Limestone' is concordant, apparently conformable, and marked by a white, vitreous quartzite marker bed. Lower contact placed at top of medium-bedded quartzite of tower Dripping Spring Quartzite. (GRI Source Map ID 74430) ([Preliminary Bedrock Geologic Map of Windy Hill 7.5' Quadrangle](#)).

### **Ydsu - Dripping Spring Quartzite, upper unit (Middle Proterozoic)**

Slope-forming very fine to fine grained sandstone with interbedded shale, grading up to thin-bedded finegrained sandstone. Light gray to pink on fresh surfaces, weathers dark brown or shades of orange and red because of iron-staining along fractures. The upper unit contains little interbedded shale or siltstone except as thin partings on bedding planes. Stylolites are common in fine-grained quartzite of

this unit. The upper part commonly forms a cliff. One to several white, vitreous quartzite beds are typically present at the top of this unit. Top is base of orange and red, poorly sorted calcareous or dolomitic sandstone at base of Mescal Formation. Several thin vitreous quartzite beds commonly present at top of this unit. (*GRI Source Map ID 7493*) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

## **Ydsm - Dripping Spring Quartzite, middle unit (Middle Proterozoic)**

### **Ydsm - Middle unit (Middle Proterozoic)**

Exposed only in the southwestern corner of the map area. Description modified from Spencer and Richard (1999) is as follows: Maroonish brown to light gray siltstone to shale and very fine grained, silty sandstone that forms gentle slopes or, most commonly, is buried by talus and colluvium. Scattered quartzite beds form subtle to prominent ledges. (*GRI Source Map ID 74430*) ([Preliminary Bedrock Geologic Map of Windy Hill 7.5' Quadrangle](#)).

### **Ydsm - Dripping Springs Quartzite, middle unit (Middle Proterozoic)**

Maroonish brown to light gray siltstone to shale and very fine grained, silty sandstone that forms gentle slopes or, most commonly, is buried by talus and colluvium. Scattered quartzite beds form subtle to prominent ledges. Unit locally contain sparse to abundant, 2-20 mm, pale reddish-tan spots known as "reduction spots" that apparently formed where oxidation and maroon to red color development were prevented by the reducing environment around a pyrite grain (now gone) at the center of the reduction spot. Fine grained, plane bedded and low-angle cross-bedded sandstone locally form resistant, amalgamated beds 20-100 cm thick within more abundant siltstone and silty, very fine grained sandstone. Cross beds are typically 10-30 cm thick. Sand contains progressively less K-feldspar up section. Estimated K-feldspar content ranges from 10-20% near base to 2% for an almost vitreous bed near top. An interval of light gray fissile shale is present, but rarely exposed, near the middle of the unit. Slopes on this unit are littered with thin, varicolored rock fragments bounded by planar bedding surfaces. The upper contact is placed at the base of a prominent gray, vitreous quartzite bed (probably correlates with gray sandstone of Granger and Raup [1964]) in the Salt River Canyon area. southward, this bed disappears or is not prominent, and the upper contact is placed at the base of steep slopes or cliffs formed by the upper unit. (*GRI Source Map ID 7493*) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

## **Ydsl - Dripping Spring Quartzite, lower unit (Middle Proterozoic)**

### **Ydsl - Lower unit (Middle Proterozoic)**

Medium- to thick bedded, light tan or orange quartzite, feldspathic quartzite and arkose. Basal Barnes conglomerate contains moderately well rounded cobbles and pebbles of chert and quartzite, but the depositional base of the unit is intruded by diabase and the depositional contact at the base of the Barnes conglomerate is not exposed. Upper contact with upper Dripping Spring Quartzite placed at top of resistant, medium-bedded quartzite. (*GRI Source Map ID 74430*) ([Preliminary Bedrock Geologic Map of Windy Hill 7.5' Quadrangle](#)).

### **Ydsl - Dripping Spring Quartzite, lower unit (Middle Proterozoic)**

Orangish gray, indurated, medium- to coarse-grained, medium- to thick-bedded, sandstone or quartzite that weathers into angular blocks and forms bold outcrops and steep slopes and cliffs. Estimated 15-25% K-feldspar grains impart orangish color. In some areas, abundant, troughy low-angle cross bedding is visible. Bedding parallel burrows(?) and mud cracks are common in the uppenmost part. A conspicuous ledge of white, vitreous quartzite is present at the top of the member (as mapped) on Vineyard Mountain; this marker disappears to the north due to pre-Martin Erosion, and thins and

becomes inconspicuous south of the Salt River. The basal Barnes Conglomerate member ranges from 0-5 m thick, and varies from a clast-supported pebble to cobble conglomerate to a sandstone with rare well rounded pebbles. Clasts are subrounded to well rounded, and include conspicuous white vein quartz, red jasper, and less conspicuous quartzite.

At one location, approximately 3/4 mile north-northwest of the headquarters of Tonto National Monument, sandstone of this unit rests depositionally on medium to coarse grained, pink to orange, equigranular granite (Xg3), which helps account for the high abundance of pink to red K-feldspar in the sandstone. Contact with underlying Pioneer Formation is easily identified when the Barnes Conglomerate is well developed; where the conglomerate is absent, the contact is placed at the base of thick bedded cream or pink-colored medium to coarse-grained quartzite. The upper contact is placed at the break in slope where quartzite beds become thinner and less resistant. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

### **Yds1b - Dripping Spring Quartzite, Barnes Conglomerate (Middle Proterozoic)**

#### **Ydsb - Dripping Spring Quartzite, Barnes conglomerate (Middle Proterozoic)**

The Barnes Conglomerate member ranges from 0-5 m thick, and varies from a clast-supported pebble to cobble conglomerate to a sandstone with rare well rounded pebbles. Clasts are subrounded to well rounded, and include conspicuous white vein quartz, red jasper, and less conspicuous quartzite. Present only at the base of the Dripping Spring Quartzite. This unit is mapped separately at Deer Hill where it forms screens within diabase. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

### **Yp - Pioneer Formation, undivided (Middle Proterozoic)**

#### **Yp - Pioneer Formation (Middle Proterozoic)**

Exposed only in the southwestern corner of the map area. Description modified from Spencer and Richard (1999) is as follows: Maroon, maroonish gray, tan, and brown psammite, silty psammite, and sandy phyllite, commonly with a basal conglomerate. (GRI Source Map ID 74430) ([Preliminary Bedrock Geologic Map of Windy Hill 7.5' Quadrangle](#)).

#### **Yp - Pioneer Formation (Middle Proterozoic)**

Formal unit defined by Ransome [1919]. The basal Scanlan Conglomerate is overlain by maroon, maroonish gray, tan, and brown sandstone and silty sandstone with about 10 m of maroon siltstone and very fine grained sandstone within the upper half. Sandstone is generally medium to thick bedded, poorly sorted, and feldspathic. Includes reddish brown, fine-grained sandstone with silty layers where the rock has parted to reveal polygonal mudcracks, and locally contains conspicuous red K-feldspar grains presumably derived from underlying granite. Sandstone generally thins and fines up section, and dark red-brown shale partings are common, but no intervals of shale has been observed in the section. Upper beds of the Pioneer Shale are thin-bedded siltstone.

Fine-grained sandstone and siltstone commonly contains sparse to abundant, 2-20 mm, pale reddish-tan spots known as "reduction spots" that apparently formed where oxidation and maroon to red color development were prevented by the reducing environment around a pyrite grain (now gone) at the center of the reduction spot.

Scanlan Conglomerate Member is poorly sorted, massive to poorly bedded, clast-supported conglomerate with subrounded to rounded quartzite cobbles up to 30 cm diameter. Thickness varies from approximately 12 meters west of Vineyard Mountain (south of peak 5559) to zero in lower

Cottonwood Canyon. Scanlan conglomerate overlays Proterozoic granite on a sharp unconformity with very little local relief. Upper contact with Dripping Spring Quartzite is placed at base of Barnes conglomerate where that can be identified. Upper beds of Pioneer are thin-bedded siltstone; where Barnes is absent, contact is placed at base of massive, relatively well sorted feldspathic Dripping Spring Quartzite. A thick diabase sill intrudes near the contact between Pioneer and Dripping Spring, obscuring the contact in many places. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

## **Yps - Pioneer Formation, Scanlan conglomerate (Middle Proterozoic)**

### **Yp - Pioneer Formation (Middle Proterozoic)**

Formal unit defined by Ransome [1919]. The basal Scanlan Conglomerate is overlain by maroon, maroonish gray, tan, and brown sandstone and silty sandstone with about 10 m of maroon siltstone and very fine grained sandstone within the upper half. Sandstone is generally medium to thick bedded, poorly sorted, and feldspathic. Includes reddish brown, fine-grained sandstone with silty layers where the rock has parted to reveal polygonal mudcracks, and locally contains conspicuous red Kfeldspar grains presumably derived from underlying granite. Sandstone generally thins and fines up section, and dark red-brown shale partings are common, but no intervals of shale has been observed in the section. Upper beds of the Pioneer Shale are thin-bedded siltstone.

Fine-grained sandstone and siltstone commonly contains sparse to abundant, 2-20 mm, pale reddish-tan spots known as "reduction spots" that apparently formed where oxidation and maroon to red color development were prevented by the reducing environment around a pyrite grain (now gone) at the center of the reduction spot.

Scanlan Conglomerate Member is poorly sorted, massive to poorly bedded, clast-supported conglomerate with subrounded to rounded quartzite cobbles up to 30 cm diameter. Thickness varies from approximately 12 meters west of Vineyard Mountain (south of peak 5559) to zero in lower Cottonwood Canyon. Scanlan conglomerate overlays Proterozoic granite on a sharp unconformity with very little local relief. Upper contact with Dripping Spring Quartzite is placed at base of Barnes conglomerate where that can be identified. Upper beds of Pioneer are thin-bedded siltstone; where Barnes is absent, contact is placed at base of massive, relatively well sorted feldspathic Dripping Spring Quartzite. A thick diabase sill intrudes near the contact between Pioneer and Dripping Spring, obscuring the contact in many places. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

## **Yg - Coarse-grained porphyritic biotite granite (Middle Proterozoic)**

### **Yg - Coarse-grained, porphyritic biotite granite (Middle Proterozoic)**

Exposed only in the southwestern corner of the map area. Description modified from Spencer and Richard (1999) is as follows: Coarse-grained biotite granite with sparse, 5-15 cm mafic enclaves. K-feldspar phenocrysts up to 4 cm diameter poikilitically enclose sparse, 1-2 mm plagioclase and biotite. The granite consists of 15-25% K-feldspar, both as phenocrysts and 1-6 mm diameter anhedral grains, 5-10% biotite in 1-3 mm-diameter flakes, 25-30% quartz in aggregates of 1-2 mm-diameter grains that are up to 6 mm in diameter, and 35-45% plagioclase in subhedral grains 2-5 mm in diameter. (GRI Source Map ID 74430) ([Preliminary Bedrock Geologic Map of Windy Hill 7.5' Quadrangle](#)).

### **Yg - Coarse-grained porphyritic biotite granite (Middle Proterozoic)**

Coarse-grained biotite granite with sparse, 5-15 cm mafic enclaves. K-feldspar phenocrysts up to 4 cm diameter poikilitically enclose sparse, 1-2 mm plagioclase and biotite. The granite consists of 15-25%

Kfeldspar, both as phenocrysts and 1-6 mm diameter anhedral grains, 5-10% biotite in 1-3 mm diameter flakes, 25-30% quartz in aggregates of 1-2 mm-diameter grains that are up to 6 mm in diameter, and 35-45% plagioclase in subhedral grains 2-5 mm in diameter. Granite contains fine-grained, resistant, dike-like zones that grade into equigranular to weakly porphyritic granite locally containing conspicuous 8-10 mm quartz phenocrysts. Forms grassy slopes and very poor exposures in small outcrop area at north end of Pinyon Mountain. Rock is more distinctly porphyritic than Early Proterozoic granitoid in the map area, and is completely non-foliated. This granite is overlain depositionally by Pioneer Formation. The contact with Xg3 north of Pinyon Mountain is not exposed; a zone of mixed metasedimentary rocks (Xms) and granite (Xg3? or Yg?) crops out along the contact. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

### **Yga - Aplite associated with course-grained porphyritic biotite granite (Middle Proterozoic)**

Fine-grained aplite forming irregular masses within map unit Yg. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

### **YXgm - Granite and schist (Middle and Early Proterozoic)**

Fine-grained granite, containing abundant magnetite and muscovite, mixed with muscovite schist, and quartzite and quartz-feldspar-mica gneiss, forming one small outcrop at the southern edge of the map. Interpreted as border zone to coarse grained, porphyritic biotite granite of map unit Yg or to aplite and aplitic granite of map unit Xga3. Contacts with other pre-Apache Group units are not exposed. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

### **Xga3 - Granitic rocks of Cottonwood Creek, aplite and aplitic granite (Early Proterozoic)**

Mixed medium- to coarse-grained granite similar to Xg3, fine-grained granite, and aplite to aplite porphyry. Aplitic granite is more resistant to weathering and tends to form most of the float, whereas the coarser-grained granite decomposes to grus. It is thus difficult to estimate the relative abundance of the two rock types. The aplite porphyry contains about 50% phenocrysts up to 8 mm diameter. The groundmass is a very fine-grained aggregate of equant, anhedral quartz and feldspar, with 1- 2% recrystallized biotite. Phenocrysts include 20-25% plagioclase, 45-55% quartz, and 25- 30% K-feldspar. Some of the aplite has a weak foliation due to alignment of biotite in the groundmass. Contact with granite (Xg3) is gradational. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

### **Xg3 - Granitic rocks of Cottonwood Creek, granodiorite (Early Proterozoic)**

Granitoid consisting primarily of granodiorite and less common quartz diorite to granite. Granitic rocks of this unit are typically medium- to coarse-grained with seriate texture. Along the Salt River Canyon, the unit consists mostly of medium-grained, seriate granodiorite containing: 15-20% mafic minerals, mostly biotite with some hornblende, forming clots up to 4 mm diameter; 40-45% plagioclase in subhedral to anhedral grains 2-8 mm in diameter; 10-20% K-feldspar in equant, subhedral to anhedral grains 2-10 mm in diameter; 20-30% quartz in equant, anhedral grains up to 6 mm diameter (See point count data). In the Two Bar Ridge area this unit is pale orangish tan, medium- to coarse-grained, equigranular biotite

granite. In the area south of Burnt Corral Canyon the rock appears to be alkali granite with 25-35% quartz up to 1 cm diameter, 60-70% Kfeldspar up to 2 cm in diameter, 3-7% biotite in 2-4 mm diameter recrystallized clots, and 10-20% plagioclase; no samples of this rock were stained and point counted. Discrete contacts between lithologically distinct granitoids were not observed in the field. Feldspars are stained pink throughout much of the unit, making distinction of plagioclase and K-feldspar difficult, and rock classified as alkali granite in the field is likely to be granodiorite. Near the base of the Apache group, the granite is dark red-brown, biotite is chloritized, and the cores of some feldspar are replaced by opaque minerals. This red zone is interpreted to result from pre-Apache Group weathering. Aplite and fine-grained granite dikes are abundant near the contact with the Buckhorn Creek Complex, and are apparently identical with the non-foliated granite dike component of that unit. To the southeast, aplite again becomes more abundant and unit grades into aplitic granite unit (Xga3). (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

### **Xgbc - Granitic rocks of Cottonwood Creek, granitic rocks in Bronco Creek (Early Proterozoic)**

In the far southwestern corner of the Theodore Roosevelt Dam 7.5' Quadrangle, this unit consists of medium to coarse grained, biotite + hornblende granite with roughly equal amounts of quartz, plagioclase, and K-feldspar and about 10% mafic minerals. Fine grained, pale orange leucogranite dikes are abundant and typically form ridge crests. Together with the leucogranite dikes, this granite resembles the granitic rocks of Cottonwood Creek and is tentatively correlated with them. This unit appears to intrude the Buckhorn Creek Complex. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

### **Xga2 - Granitic rocks in Rock Creek area, aplitic granite (Early Proterozoic)**

Pinkish colored aplitic granite and granodiorite, consists of 60-70% anhedral feldspar (mostly K-feldspar?), and 30-40% anhedral quartz. Grain size and texture is variable. Fine to medium-grained (up to about 5 mm average grain size), generally homogranular, but in some places has 3-10 mm diameter quartz and feldspar phenocrysts in a fine-grained (1mm) groundmass. Much of the exposed rock along lower Rock Creek is slightly silicified, with ubiquitous quartz veinlets, and weathers to angular blocks, forming bold cliffs. Contact into coarse grained granite is gradational to abrupt. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

### **Xg2 - Granitic rocks in Rock Creek area, coarse-grained granite (Early Proterozoic)**

Homogranular to seriate granite, consists of 50-60% subhedral to anhedral feldspar, up to 1.5 cm diameter, 25-35% anhedral, equant quartz grains up to 7 mm diameter, and 2-4% biotite. Pinkish color makes distinction of feldspars difficult. In areas where the plagioclase is bleached white (sericite or clay), and can be distinguished from K-feldspar, it forms grains up to 6 mm diameter composing 10-35% of the rock. Biotite is recrystallized to clots of very-fine grained biotite. Much of eastern part of outcrop is weakly silicified and pinkish due to iron staining. Thin bull quartz veins are common in this area, and the rock is penetratively microfractured with chlorite, epidote, and hematite along the fractures. Contact with metavolcanic rocks to south is a zone of mixed hornfelsed metavolcanic rock and texturally variable granitoid. Rocks in the vicinity of the contact are silicified and iron stained. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

### **Xgmv - Granitic rocks in Rock Creek area, mixed granite and metavolcanics (Early Proterozoic)**

Mixed Xg2 and hornfelsed metavolcanic rocks in border zone of Xg2. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

### **Xg1 - Granitic rocks in Mills Canyon area, granite (Early Proterozoic)**

Ranges from biotite granodiorite to granite. Biotite granodiorite phase consists of 7-10% 1-3 mm biotite flakes in clots; 45-55% 3-7 mm anhedral to subhedral white plagioclase; 25-30% 2-5 mm anhedral colorless quartz and 10-15% K-feldspar in subhedral, pinkish crystals, carlsbad twins commonly visible. Sphene was not observed. The granite phase is coarse grained, with 25-35% quartz, 30-40% subhedral plagioclase, 30-40% subhedral K-feldspar, 3-5% 1-3 mm biotite flakes. Granite and biotite granodiorite are intermingled and gradationally mixed on a decimeter scale; contacts both sharp and gradational. Granite in the Mills Canyon area is generally coarser grained, and contains more quartz and fewer mafic enclaves than the granodiorite (Xgd1). Hornblende is absent in the granite unit. This unit includes two small exposures of alkalic granite 1/4 mile southwest of trailhead north of upper Buckhorn Canyon. This rock contains abundant 5-15 mm diameter blocky K-feldspar and 10% biotite(?) altered to chlorite + epidote.

Contacts with granodiorite of Mills Canyon are gradational and sharp. Gradational mixed contact with Buckhorn Creek Complex is interpreted to be intrusive. Overlain nonconformably by Tertiary conglomerate of map unit Ts. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

### **Xgd1 - Granitic rocks in Mills Canyon area, granodiorite (Early Proterozoic)**

This unit includes diorite or gabbro, tonalite, and granodiorite, with gradational contacts between the various phases. The predominant rock is hornblende-biotite granodiorite, medium- to coarse-grained, consisting of 15-25% hornblende and biotite; hornblende crystals are up to 1 cm long, biotite is in 1-3mm diameter flakes; 45-60% plagioclase in 2-15 mm equant to slightly elongate subhedral grains; 15-25% quartz in 2-10 mm equant grains, interstitial to other minerals and frequently as 1 cm equant 'quartz-eyes'; conspicuous 1-3 mm brown sphene is a common accessory. Typically slightly finer-grained than granite unit (Xg1), and distinguished by ubiquitous presence of hornblende. Weathers to form grussy slopes and rounded granite boulders. Mafic enclaves are common. Flattened enclaves and aligned hornblende crystals define a gneissoid foliation in most of the rock. Mylonite zones up to 20 m thick are present. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

### **Xgb - Granitic rocks in Mills Canyon area, diorite-gabbro phase (Early Proterozoic)**

Is medium grained and equigranular, consisting of 50-60% plagioclase and 40-50% hornblende or pyroxene, both in subhedral grains 2-7 mm in diameter. Small bodies of this more mafic rock, 10-100 m in long dimension, are scattered in the granodiorite. Intrudes metamorphic rocks and foliated to gneissic granitoid. Contacts with granite unit (Xg1) are both gradational and sharp, and the two units are interpreted to be co-magmatic. At sharp contacts, a gneissic zone 1-2 m thick separates the granite and granodiorite. Relationship to Buckhorn Complex is uncertain. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

**Xb - Buckhorn Creek Crystalline Complex, undivided (Early Proterozoic)**

No description available. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

**Xbf - Buckhorn Creek Crystalline Complex, felsic unit (Early Proterozoic)**

Part of Buckhorn Creek complex in which granite and gneissic granitic rocks are the predominant host rock for late granitic dikes. The contact with the mafic unit of the Buckhorn Creek Complex is gradational. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

**Xbm - Buckhorn Creek Crystalline Complex, mafic unit (Early Proterozoic)**

Part of Buckhorn Creek crystalline complex in which the predominant host rock for granitic dikes is mafic gneiss and gabbro gradational contact in felsic unit of Buckhorn Creek Crystalline Complex. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

**Xhm - Hornblendite and mafic intrusive rocks (Early Proterozoic)**

Heterogeneous, with large variations in ratio of mafic to felsic minerals, but generally medium-grained.

In the upper Buckhorn Canyon area this unit contains clots of hornblende up to 10 mm diameter and medium to fine grained, chalky white plagioclase, with rare hornblende(?) crystals up to 3 cm with poikilitically enclosed feldspar. A mafic dike in granodiorite (map unit Xgd1) adjacent to hornblende diorite may be related to the diorite, suggesting that the diorite is younger than the granodiorite.

Two dike-like bodies of diorite near Burnt Corral campground on the east side of Apache Lake contain 50 to 95% hornblende and are completely unfoliated, with much variation in mafic/ felsic ratio.

About two miles southeast of Peters Mountain this unit consists of hornblendite that is intruded by a dike of granite, probably of map unit Xgd1. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

**Xms - Metasedimentary rocks, undivided (Early Proterozoic)**

Generally quartz-rich metasedimentary rocks. On the south flank of Vineyard Mountain, consists of quartz+sericite and quartz+sericite+feldspar schist, with steep foliation defined by sericite orientation and flattened quartz. Feldspar is generally altered to micaceous minerals (clays?) and is stained with iron oxides. These outcrops resemble Pinal Schist.

Outcrops in the Cottonwood Creek drainage consist of thin bedded, light tan-colored, sericitic arkose grit and sandstone that do not appear significantly deformed. Conglomeratic beds in this unit contain pebbles of quartz. These southern outcrops may be younger than the metasedimentary rocks on Vineyard Mountain. In Cottonwood Creek, intruded by granite (Xg3) and overlain in angular unconformity by Pioneer Shale. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

### **Xmv - Metavolcanic rocks (Early Proterozoic)**

Felsic to intermediate-composition metavolcanic rocks form a northeast-trending outcrop belt between Mills Canyon and Rock Creek. These rocks separate the granitic rocks in Mills Canyon from the granitic rocks in Rock Creek. The unit consists mostly of light gray felsic tuff(?) that contains common 1-2 mm diameter quartz and feldspar crystals in a microcrystalline, granular groundmass of quartz and feldspar. The rock has a foliation defined by composition or texture variations in the groundmass that define discontinuous lamina. This foliation could be related to a primary eutaxitic foliation, but the rock parts on the foliation planes, revealing aligned chlorite in the foliation, and suggesting that the foliation is a tectonically induced cleavage.

Near the northern boundary of the unit several different tuff units can be recognized, but were not mapped separately. These included the light gray crystal-rich variety described above, a red-brown crystal poor tuff that contains only feldspar crystals, a gray crystal rich tuff that does not contain quartz crystals, and a gray, crystal-rich lithic tuff that contains crystals up to 6 mm diameter and lithic fragments of dense gray felsite.

Intruded by granitic rocks in Rock Creek on the north through a complex mixed zone of hornfelsed volcanic rocks and texturally variable granitoid. Southeastern boundary is poorly exposed high strain zone juxtaposing tectonite derived from the metavolcanic rocks with granodiorite of Mills Canyon. (GRI Source Map ID 7493) ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

## GRI Digital Surficial Map of Tonto National Monument

### Surficial Map Unit List

The surficial geologic units present in the digital geologic-GIS data produced for Tonto National Monument, Arizona (TONT) are listed below. Units are listed with their assigned unit symbol and unit name (e.g., Qa - Floodplain deposits). Units are listed from youngest to oldest. No description for water is provided. Information about each geologic unit is also presented in the GRI Geologic Unit Information (TSURUNIT) table included with the GRI geology-GIS data.

### Cenozoic Era

#### Quaternary Period

[Qa](#) - Floodplain deposits

[Qls](#) - Landslide deposits

[Qt](#) - Terrace deposits

[Qp](#) - Pediment deposits

[Qf](#) - Alluvial fan deposits

[Qg](#) - Gravel deposits

#### Tertiary Period

[Tbf](#) - Basin fill

[Tv](#) - Volcanic rock

### Paleozoic to Precambrian Eras

[br](#) - Pre-Tertiary rock

### Surficial Map Unit Descriptions

Descriptions of all surficial geologic map units, generally listed from youngest to oldest, are presented below.

#### Qa - Floodplain deposits (Holocene)

Sandy boulder and cobble gravel, poorly to moderately sorted; clasts rounded and well rounded, generally unvegetated deposits in channels along present drainages. Shown only for Tonto Creek, Salt River, and their larger tributaries. (GRI Source Map ID 39467) ([Seismotectonic Investigation, Theodore Roosevelt Dam](#)).

#### Qls - Landslide deposits (Holocene and upper Pleistocene?)

Deposits with hummocky topography and visible headscarps formed through mass-movement processes. Often deposits involved are gravel over clay-rich mudstone facies of the Tertiary basin fill (Tbf). Only large landslide deposits are delineated. (GRI Source Map ID 39467) ([Seismotectonic Investigation, Theodore Roosevelt Dam](#)).

### **Qt - Terrace deposits (Pleistocene to upper Pleistocene?)**

Sandy boulder and cobble gravel to cobble and pebble gravel, moderately sorted; clasts rounded and well rounded, clast lithology is mixed including granite, quartzite, volcanic rocks, limestone, dolomite, sandstone, and conglomerate. Form terraces 3 m to about 153 m above Tonto Creek, Salt River, or their larger tributaries (e.g., Pinto Creek, Campaign Creek, Slate Creek). Higher terraces (t6 and higher) commonly covered by fine-grained deposits (loess?) 2 to 5 cm thick, terraces locally covered by alluvial fan deposits or colluvium. Numbers delineate terrace deposits t2 to t12, older to younger, based chiefly on height above the modern drainage and on degree of soil development (text). No terrace deposits correlative with deposit p1 have been recognized and so no t1 deposits are shown on map. Gravel thickness 2m to >20m. *Note: See SRC\_SYM field in GIS data for unit numbering. (GRI Source Map ID 39467) ([Seismotectonic Investigation, Theodore Roosevelt Dam](#)).*

### **Qp - Pediment deposits (Pleistocene to upper Pleistocene?)**

Sandy boulder and cobble gravel, moderately sorted, clasts well rounded to subrounded, commonly bedded, clast lithology is variable and reflects the bedrock in the local drainage (e.g., mixed lithology similar to l deposits to nearly 100% granite or quartzite). Form pediments about 20 m to 183 m above Tonto Creek, Salt River, or their larger tributaries, Higher pediments (p6 and higher) covered by fine-grained deposits (loess?) 2 to 25 cm thick. Lower pediments locally include areas of modern alluvium. Pediment surfaces slope into the basin. Numbered pediment deposits grade into or project into similarly numbered terrace deposits and are inferred to correlate with them. Gravel thickness 3 to 10 m. *Note: See SRC\_SYM field in GIS data for unit numbering. (GRI Source Map ID 39467) ([Seismotectonic Investigation, Theodore Roosevelt Dam](#)).*

### **Qf - Alluvial fan deposits (Pleistocene to upper Pleistocene?)**

Cobble and pebble gravel, moderately to poorly sorted, clasts subrounded and subangular, generally bedded; discontinuous gravel beds interfinger with sandy beds and lenses, clast lithology variable and reflects local bedrock. Surfaces of the alluvial fan deposits have relatively steep slopes into the basin and exhibit fan morphology. Lower fans include areas of modern alluvium, especially near the range fronts. Numbered alluvial fan deposits grade into or project into similarly numbered terrace deposits and are inferred to be correlative. Gravel thickness 2 m or greater. *Note: See SRC\_SYM field in GIS data for unit numbering. (GRI Source Map ID 39467) ([Seismotectonic Investigation, Theodore Roosevelt Dam](#)).*

### **Qg - Gravel deposits (Pleistocene?)**

Boulder and cobble gravel, clasts rounded and subrounded. Gravel preserved as unconsolidated deposits on rounded hills with relatively steep slopes along the east side of the Mazatzal Mountains and along the west side of Tonto Basin. Age and genesis not known. (GRI Source Map ID 39467) ([Seismotectonic Investigation, Theodore Roosevelt Dam](#)). *Note: this unit does not appear in the GIS data.*

### **Tbf - Basin fill (Pliocene and Miocene)**

Texture varies from gravel-rich facies to mudstone facies. K-Ar dates on dacite suggest the base of the basin fill has an age of less than 19 Ma. Correlation with similar basin-fill deposits in central and

southern Arizona suggests the top of Tbf has an age of 3 to 5 Ma. (GRI Source Map ID 39467) ([Seismotectonic Investigation, Theodore Roosevelt Dam](#)).

### **Tv - Volcanic Rock (Miocene and Oligocene?)**

Includes dacite and basalt, probably correlative with Apache Leap Tuff to the southeast. (GRI Source Map ID 39467) ([Seismotectonic Investigation, Theodore Roosevelt Dam](#)). *Note: this unit does not appear in the GIS data.*

### **br - Pre-Tertiary rock (Precambrian to Paleozoic)**

Locally includes Tertiary volcanic rock. (GRI Source Map ID 39467) ([Seismotectonic Investigation, Theodore Roosevelt Dam](#)).

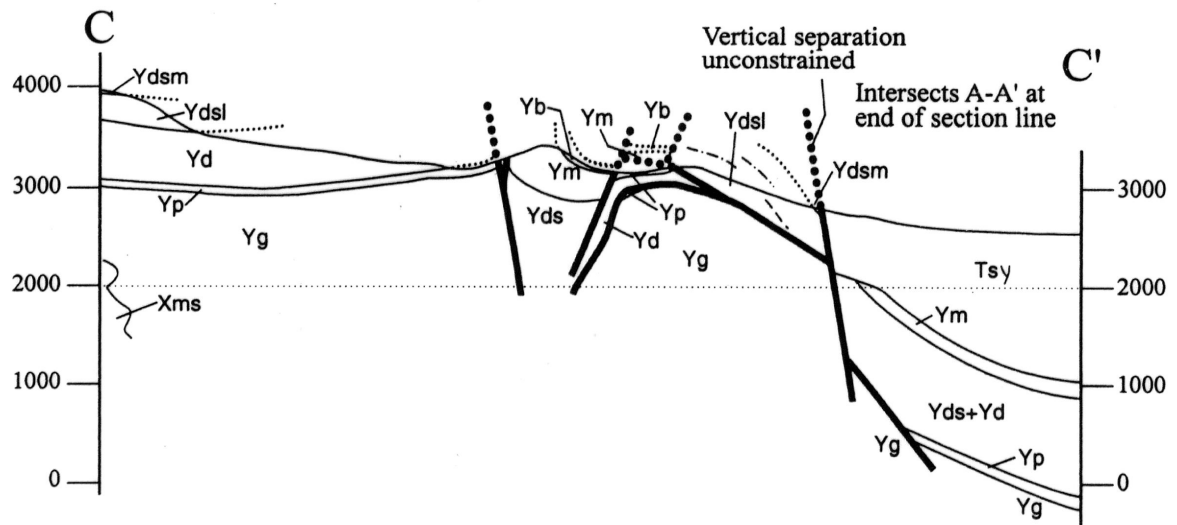
The geologic cross sections present in the GRI digital geologic-GIS data produced for Tonto National Monument, Arizona (TONT) are presented below. Note that some cross section abbreviations (e.g., A - A') may have been changed from their source map abbreviation in the GRI data so that each cross section abbreviation in the GRI data is unique. Cross section graphics were scanned at a high resolution and can be viewed in more detail by zooming in (if viewing the digital format of this document).

Dip of bedding in Ym is discordant with trace of contact, indicating abundant minor faulting

Intersects A-A' at end of line

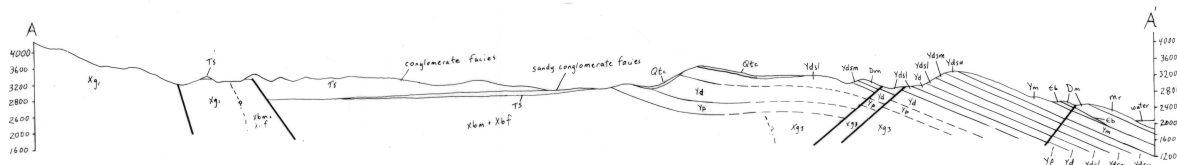
2013 NPS Geologic Resources Inventory Program

### Cross Section C-C'



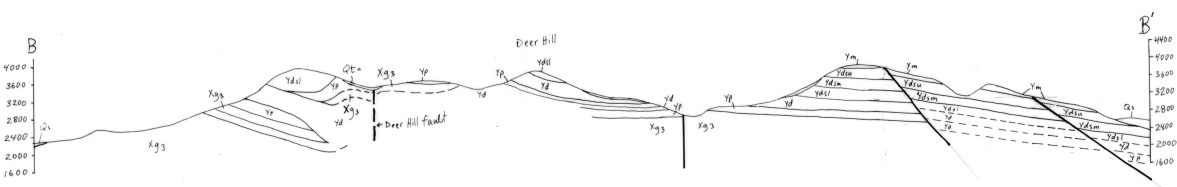
Extracted from: ([Preliminary Bedrock Geologic Map of Windy Hill 7.5' Quadrangle](#)).

### Cross Section D-D'



Extracted from: ([Geologic Map of the Theodore Roosevelt Dam Area](#)). Cross section A-A' on source map.

### Cross Section E-E'



Extracted from: ([Geologic Map of the Theodore Roosevelt Dam Area](#)). Cross section B-B' on source map.

## GRI Source Map Information

### Preliminary Bedrock Geologic Map of the Windy Hill 7.5' Quadrangle

Spencer, J.E., Richard, S.M., Ferguson, C.A., and Gilbert, W.G., 1999, Preliminary Bedrock Geologic Map and Cross Sections of the Windy Hill 7.5' Quadrangle, Gila County, Arizona, Arizona Geological Survey, Open-File Report OFR 99-12, 1:24,000 scale. (*GRI Source Map ID 74430*).

### OFR 99-12 Introduction

The Windy Hill 7 1/2' Quadrangle is located in the southeastern part of Tonto Basin and includes bedrock on both sides of the basin. Bedrock geology is dominated by the middle Proterozoic Apache Group, the middle Proterozoic diabase that commonly intrudes it (e.g. Bergquist et al., 1981; Wrucke, 1989), and by overlying lower Paleozoic sandstone and carbonate rocks. Tertiary conglomerate and sandstone are deposited on the bedrock and are not greatly tilted-or faulted. Upper Cenozoic sedimentary units and geomorphic surfaces were not mapped in most areas for this study because they have been mapped previously (Anderson et al., 1987). Bedrock in the southwestern corner of the quadrangle was mapped earlier by Spencer and Richard (1999) and their mapping is only partially represented in this report.

Extracted from: ([Preliminary Bedrock Geologic Map of Windy Hill 7.5' Quadrangle](#)).

### OFR 99-12 Cross Section Information

Cross Section of the Windy Hill Quadrangle (by S.M. Richard)

Cross section A-A' is contiguous northward with cross section A-A' of Bergquist et al. (1981). Apache Group strata in the southern Sierra Ancha (southwest of the Armer Mountain fault [Bergquist et al., 1981]) are horizontal to very gently southeast-dipping. At the edge of the range, which is the north end of our cross section A-A', the dip increases to about 15° to the southwest. This southwest dip characterizes strata southward along the section line to Windy Hill on the south side of Theodore Roosevelt Lake. Numerous faults cut the section, primarily with down to the northeast separation. The slip on these faults is not well constrained. Based on the outcrop trace of the faults and rare exposures, faults appear to dip steeply to vertical. The strike of the faults is oblique to the strike of bedding in Apache group and lower Paleozoic strata. This geometry suggests that the faults may be strongly oblique slip, or normal faults that cut previously tilted strata.

The U.S. Forest Service Windy Hill water test well is located about 4000' south of Windy Hill. This well penetrated about 1640' of basin fill, about 45' of carbonate rock (either Martin Formation or dolomite of the Mescal "Limestone"), 35' of sandstone that could be lower Martin Formation or Bolsa Quartzite, 130' of probable Dripping Spring Quartzite, and bottomed in diabase (Richard, 1999). The dip of the penetrated strata is unknown, but extrapolation of the top of the Dripping Spring Quartzite from its projected position beneath Windy Hill requires either a down to the southeast fault between Windy Hill and the well, or that the southwestward dip of the strata increases towards the well. On Windy Hill itself, the dips decrease southwestward and up section; thus a fault has been interpreted between Windy Hill and the well.

Before discussing the southern end of section A-A', it is necessary to study sections B-B' and C-C'. Apache Group and Paleozoic strata at the northeast end of Two Bar Ridge (southwestern corner of Windy Hill quadrangle) dip gently to moderately in an easterly direction, and a series of mostly

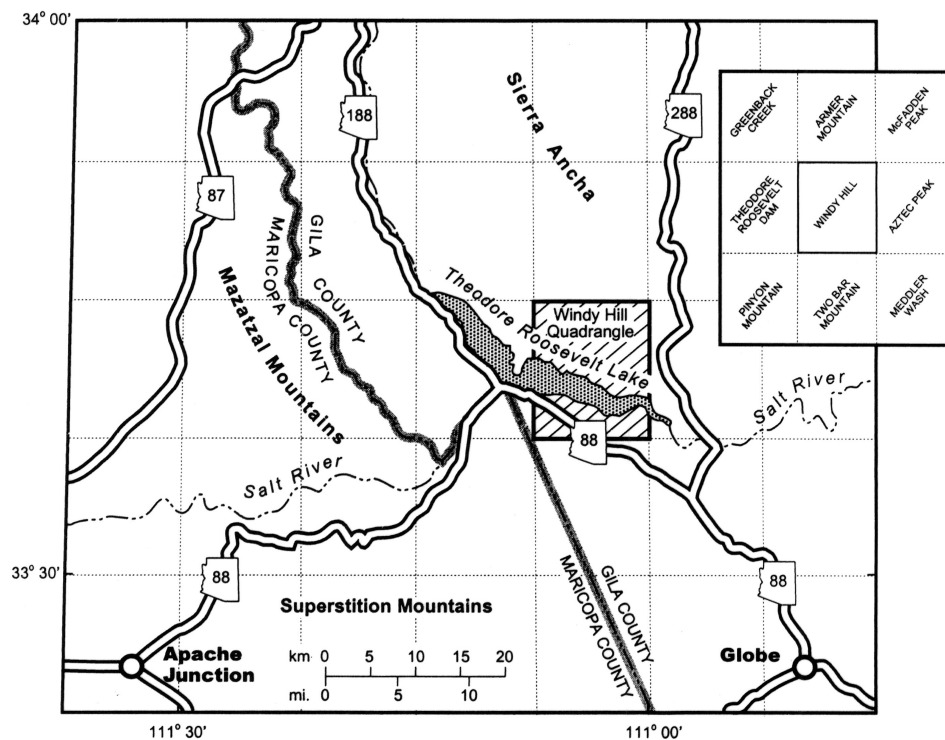
northwest-trending faults with down-to-the-northeast separation cut strata in this area (Spencer and Richard, 1999). Section B-B' includes the northeastern end of section B-B' from Spencer and Richard (1999), and extends this section northeastward to meet section A-A' of this report at a point 1200 feet south of the USFS Windy Hill water test well. A range-front fault with a separation of about 2000 feet is inferred in this section to displace the top of the Dripping Spring Quartzite down to an elevation comparable to its elevation in the Windy Hill test well.

Section C-C' is drawn to highlight the structural complexity at the northern end of a major north-trending fault that cuts the eastern side of Two Bar Ridge (Spencer and Richard, 1999). This fault has been mapped southward for about 6 km, where it is overlapped by Tertiary conglomerate of uncertain exact age (Peterson and links, 1983). The fault juxtaposes Proterozoic Ruin(?) granite against rocks of the Apache Group with a down-to-the-west separation. At its northern tip, the fault intersects, and is apparently truncated by a northwest-trending fault that has down-to-the-northeast separation. Highly faulted Mescal Limestone and overlying Proterozoic basalt are continuous around the intersection of these two faults (Spencer and Richard, 1999). The north-trending fault is apparently dragged to the southeast (right-lateral sense) along the northwest-trending fault. The complex pattern of faulting in Apache Group strata in the southwest corner is interpreted as an intersection zone between coeval northerly-trending faults that bound the eastern side of Two Bar Ridge, and northwest-trending faults that form the southwest margin of the Tonto Basin to the northwest. Alternating movement on faults with different orientation, and large displacement changes over short distances, may be due to slip transfer between the fault systems. Extrapolation of this structure into the subsurface beneath the basin fill not feasible, so the northeastern part of section C-C' has been interpreted as a simple northeast-dipping homocline, continuing the dip of strata at the edge of the range with offset by a range-bounding normal fault. Normal separation on the range-bounding normal fault is not constrained by data. The existence of Martin Formation and Redwall Limestone in the subsurface here is purely speculative.

The southern end of section A-A' is shown as a broad synform between the southwest-dipping strata between Windy Hill and the Sierra Ancha and the easterly-dipping strata of Two Bar Ridge. The geometry of the structure beneath the basin is poorly constrained, but any geometric interpretation must explain the reversal of regional dip between Two Bar Ridge and Windy Hill. Plausible interpretations of this structure include the following: (1) it may be a synform related to formation of the Tonto Basin in Miocene time, (2) the east-tilted strata of Two Bar Ridge may be a southern continuation of the east-tilted Mazatzal Mountains, with both in the hanging wall of a late Cenozoic, west-dipping, moderate to low-angle normal fault (Ferguson et al, 1998), (3) the structure may represent a Laramide monocline modified by Tertiary normal faults that have tilted the strata to the southwest. The east-tilted strata along Two Bar Ridge and north of Theodore Roosevelt Dam (Spencer and Richard, 1999) would have been the more steeply east-tilted eastern side of a Laramide 'Mazatzal uplift' that was a source for the Eocene Mogollon Rim Formation (Potochnik, 1989; Potochnik and Faulds, 1998). Southwestward tilting in Miocene time would have decreased the dip of these strata after tilting related to monocline formation. At present there are insufficient data to rule out any of these hypotheses.

Extracted from: ([Preliminary Bedrock Geologic Map of Windy Hill 7.5' Quadrangle](#)).

## OFR 99-12 Location Map



Extracted from: ([Preliminary Bedrock Geologic Map of Windy Hill 7.5' Quadrangle](#)).

## OFR 99-12 Map Legend

### Map Symbols

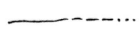
 Drill hole

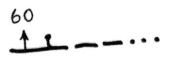
### UNIT IDENTIFICATION

 Leader connecting areas of identical map unit

 Barnes Conglomerate at base of Dripping Spring Quartzite

**CONTACTS** (dashed where approximately located, dotted where concealed)

 Intrusive or depositional contact

 High-angle fault, showing dip, ball on downthrown side

**ATTITUDES** (orientation of planar and linear features)

**Bedding:**

 Upright

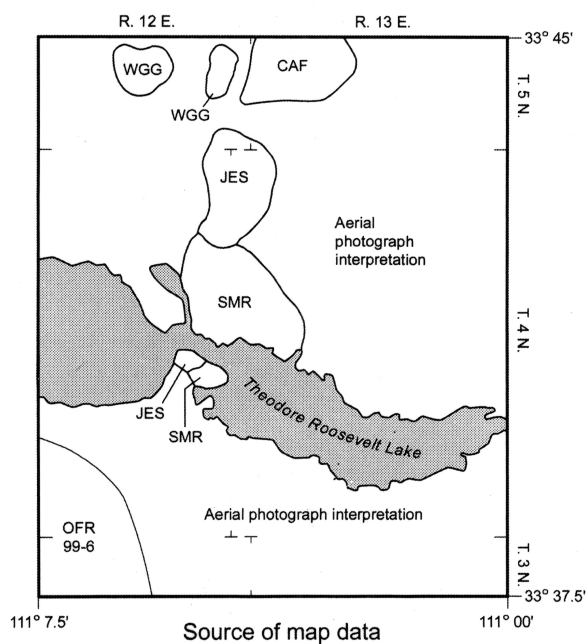
 Horizontal

 Approximate (upright)

 Apparent dip

Extracted from: ([Preliminary Bedrock Geologic Map of Windy Hill 7.5' Quadrangle](#)).

## OFR 99-12 Sources of Map Data



Extracted from: ([Preliminary Bedrock Geologic Map of Windy Hill 7.5' Quadrangle](#)).

## OFR 99-12 References

Anderson, L.W., Piety, L.A., and LaForge, R.C., 1987, *Seismotectonic investigation, Theodore Roosevelt Dam, Salt River Project, Arizona: Bureau of Reclamation Seismotectonic Report 87-5, scale 1:48,000.*

Bergquist, JR., Shride, A.F., and Wrucke, C.T., 1981, *Geologic map of the Sierra Ancha Wilderness and Salome Study Area, Gila County, Arizona: U.S. Geological Survey Miscellaneous Field Studies Map MF-1 162-A, scale 1:48,000.*

Ferguson, C. A., Skotnicki, S. J., and Gilbert, W. G., 1998, *Geologic map of the Tonto Basin 7.5' quadrangle, Gila and Maricopa counties, Arizona: Tucson, Arizona Geological Survey Open-File report 98-16, 15 pages 2 sheets, 1:24000.*

Peterson, D. W., and links, L.E., 1983, *Mineral resource potential of the Superstition Wilderness and Contiguous Roadless Area, Maricopa, Pinal, and Gila Counties, Arizona: U.S. Geological Survey Open-file Report 83-885, 34 p., scale 1:48,000.*

Potochnik, Andre R., 1989, *Depositional style and tectonic implications of the Mogollon Rim Formation (Eocene), east-central Arizona Southeastern Colorado Plateau: New Mexico Geological Society Guidebook, 40. Field Conference, p. 107-118.*

Potochnik, A. R., and Faulds, J. E., 1998, *A tale of two rivers: mid-Tertiary structural inversion and drainage reversal across the southern boundary of the Colorado Plateau, in Duebendorfer, E. M., ed, Geologic Excursions in Northern and Central Arizona, Field Trip Guidebook for Geological Society of America Rocky Mountain Section meeting, Flagstaff, AZ: Flagstaff, Northern Arizona University, p. 149-174.*

Richard, S. M., 1999, *Subsurface information from three wells in the Tonto Basin, Gila County, Arizona: Tucson, Arizona Geological Survey Open-File Report 99-07, 9 pages.*

Spencer, J.E, and Richard, S.M., 1999, *Geologic map and report for the Theodore Roosevelt Dam area, Gila and Maricopa Counties, Arizona: Arizona Geological Survey Open-File Report 99-6, scale 1:24,000, 28 p.*

Teichert, C., 1965, *Devonian rocks and paleogeography of central Arizona: U.S. Geological Survey Professional Paper 464, 181 p., 11 sheets, scale 1:500,000.*

Wrucke, C.T., 1989, *The middle Proterozoic Apache Group, Troy Quartzite, and associated diabase of Arizona, in Jenney, J.P., and Reynolds, S.J., eds., Geologic Evolution of Arizona: Arizona Geological Society, Digest 17, p. 239-258.*

Extracted from: ([Preliminary Bedrock Geologic Map of Windy Hill 7.5' Quadrangle](#)).

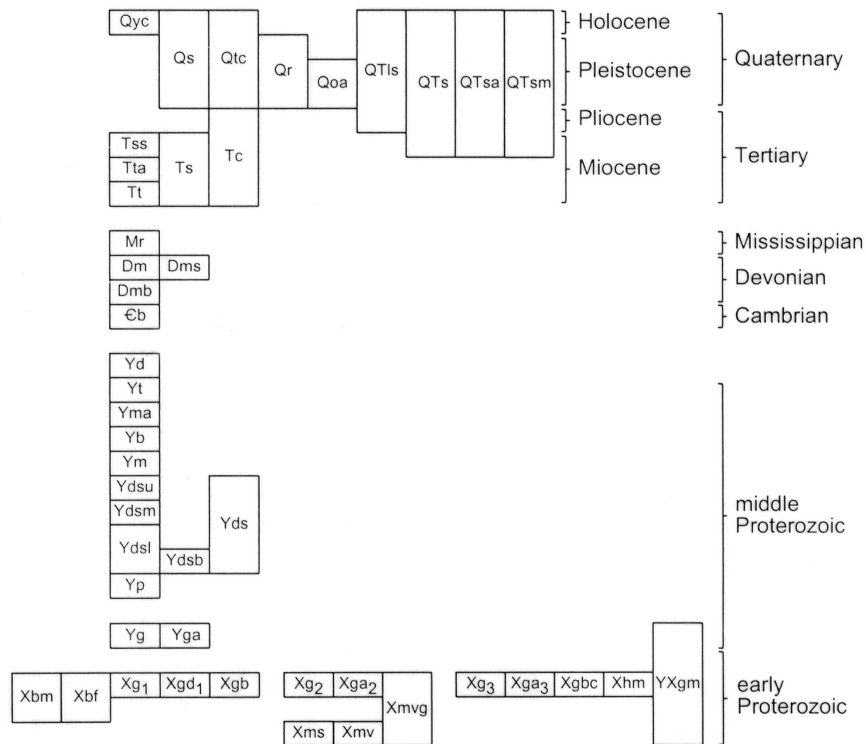
## Geologic Map of the Theodore Roosevelt Dam Area

Spencer, J.E., and Richard, S.M., 1999, *Geologic Map and Report for the Theodore Roosevelt Dam Area, Gila and Maricopa Counties, Arizona, Arizona Geological Survey, Open-File Report OFR 99-06, 1:24,000 scale. (OFR 99-06). (GRI Source Map ID 7493).*

## OFR 99-06 Correlation of Map Units

## CORRELATION OF MAP UNITS

(dike unit TXm not shown)

Extracted from: ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

## OFR 99-06 Map Legend

### Map Symbols

#### UNIT IDENTIFICATION

-  Leader connecting areas of identical map unit
-  Scanlon Conglomerate at base of Pioneer Formation or Barnes Conglomerate at base of Dripping Spring Quartzite

#### CONTACTS (dashed where approximately located, dotted where concealed)

-  Intrusive or depositional contact
-  High-angle fault, showing dip, ball on downthrown side
-  Gradational or obscure contact associated with Buckhorn Crystalline Complex

#### ATTITUDES (orientation of planar and linear features)

##### Bedding:

-  Upright
-  Horizontal
-  Overturned
-  Approximate (upright)
-  Apparent dip

##### Joints and cleavage:

-  Joint
-  Upright disjunct (spaced) cleavage
-  Vertical disjunct (spaced) cleavage

##### Foliation:

-  Weakly developed shape fabric
-  Moderately developed shape fabric
-  Strongly developed shape fabric
-  Mylonitic fabric
-  Eutaxitic foliation in volcanic rocks, flow foliation in intrusive rocks
-  Eutaxitic foliation with parallel tectonic fabric overprint
-  Compositional banding
-  Vertical compositional banding
-  Contorted compositional banding
-  Vertical generic foliation

##### Lineation associated with foliation:

-  Mylonitic
-  Shape

#### DIKES AND VEINS

-  Mafic dike
-  Pegmatite dike
-  Quartz vein

#### STRUCTURES

-  Anticline axis
-  Shear zone
-  Shattered rock
-  Brecciated rock (shattered and mixed)

#### MISCELLANEOUS

-  Sample location (also MS)
-  Contact determined from physiography

Extracted from: ([Geologic Map of the Theodore Roosevelt Dam Area](#)).

## Seismotectonic Investigation, Theodore Roosevelt Dam

Anderson, L.W., Piety, L.A., and LaForge, R.C., 1987, Seismotectonic Investigation, Theodore Roosevelt Dam, Salt River Project, Arizona, U.S. Bureau of Reclamation, Seismotectonic Report No. 87-5, 1:48,000 scale. (GRI Source Map ID 39467).

## Seismotectonic Report No. 87-5 Correlation of Map Units

| CORRELATION OF MAP UNITS |                    |                     |                   |                       |                 |                    |                     |      |
|--------------------------|--------------------|---------------------|-------------------|-----------------------|-----------------|--------------------|---------------------|------|
| Age                      |                    | Mainstream Alluvium | Pediment Alluvium | Alluvial fan Deposits | Gravel Deposits | Landslide Deposits | Basin-fill Deposits | Rock |
| QUATERNARY               | Holocene           | a                   |                   |                       |                 |                    |                     |      |
|                          | Upper Pleistocene  | t12                 |                   | f12                   |                 | ls                 |                     |      |
|                          |                    | t11                 | p11               | f11                   |                 |                    |                     |      |
|                          | ---??---           | t10                 |                   |                       |                 |                    |                     |      |
|                          |                    | t9                  | p9                | f9?                   |                 | ??                 |                     |      |
|                          | Middle Pleistocene | t8                  | p8                | f8                    |                 |                    |                     |      |
|                          |                    | t7                  | p7                | f7                    |                 |                    |                     |      |
|                          |                    | t6                  | p6                | f6                    |                 |                    |                     |      |
|                          |                    | t5                  | p5                | f5                    |                 |                    |                     |      |
|                          | ---??---           | t4                  | p4                | f4                    |                 |                    |                     |      |
| TERTIARY                 | Lower Pleistocene  | t3                  | p3                | f3                    |                 |                    |                     |      |
|                          |                    | t2                  | p2                |                       | ??              |                    |                     |      |
|                          |                    |                     | p1                |                       |                 |                    |                     |      |
|                          |                    | ??                  | ??                |                       | g               |                    | Tbf                 |      |
|                          |                    |                     |                   |                       | ??              |                    |                     |      |
| TERTIARY                 | Pliocene           |                     |                   |                       |                 |                    |                     |      |
|                          | Miocene            |                     |                   |                       |                 |                    | ??                  | Tv   |
|                          | Oligocene          |                     |                   |                       |                 |                    |                     | ??   |
| Paleozoic to Precambrian |                    |                     |                   |                       |                 |                    |                     | br   |

Extracted from: ([Seismotectonic Investigation, Theodore Roosevelt Dam](#)).

## GRI Digital Data Credits

This document was developed and completed by James Winter (Colorado State University) for the NPS Geologic Resources Division (GRD) Geologic Resources Inventory(GRI) Program. Quality control of this document by Derek Witt and James Chappell (Colorado State University).

The information in this document was compiled from GRI source maps, and intended to accompany the digital geologic-GIS maps and other digital data for Tonto National Monument, Arizona (TONT) developed by Rachel Yoder, Kari Lanphier, Derek Witt and James Chappell (Colorado State University). See the [GRI Digital Geologic Map and Source Map Citations](#) and the [GRI Digital Surficial Map and Source Map Citations](#) sections of this document for all sources used by the GRI in the completion of this document and related GRI digital geologic-GIS maps.

GRI finalization by Jim Chappell (Colorado State University).

GRI program coordination and scoping provided by Bruce Heise and Tim Connors (NPS GRD, Lakewood, Colorado).