Geologic Map of Bonita and Rhyolite Canyons, Chiricahua National Monument, Arizona

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Chiricahua National Monument, Cochise County, Arizona

CONTRIBUTED REPORT CR-16-F

December 2016

Arizona Geological Survey

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Arizona Geological Survey

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Manuscript approved for publication in December 2016
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Recommended Citation: Pearthree, K.S. and Youberg, A., 2016, SGeologic Map of Bonita and Rhyolite Canyons, Chiricahua National Monument, Arizona. Arizona Geological Survey Contributed Report, CR-16-F, 9 p., 1 map plate (1:12,000).

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By
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ABSTRACT

The surficial geology of Chiricahua National Monument was mapped around Monument headquarters and the primary visitors' facilities to understand the geologic and geomorphic framework of the area, and to assess some of the geologic hazards that could impact park and visitor facilities. The surficial geology primarily consists of relatively coarse-grained tributary alluvial fans, finer-grained very young alluvial fans, channels and low terraces deposited in the axial valley by Bonita and Rhyolite Creeks, and hillslope colluvium. All surficial deposits are presumed to be Quaternary in age, and most of them are likely of Holocene age, but none have been numerically dated and are therefore mapped by relative age.

INTRODUCTION

The study area covers part of Chiricahua National Monument (CNM) in the Chiricahua Mountain Range in southeastern Arizona (Fig. 1). The surficial geology of the canyon bottoms, tributary deposits and adjacent hillslopes of the area around Monument headquarters and primary visitor facilities was mapped during October 2015 through July 2016. The bedrock geology of the surrounding mountain slopes was compiled from previous mapping by Pallister et al. (1997). The purpose of this study is to map the surficial deposits in Bonita and Rhyolite Canyons in order to understand the geomorphic framework of the area and to get a better idea of the areas that are most likely to experience flooding and debris flows.

The surficial geology primarily consists of relatively coarse-grained tributary alluvial fans, finer-grained very young alluvial fans, channels and low terraces deposited in the axial valley by Bonita and Rhyolite Creeks, and hillslope colluvium. All surficial deposits are presumed to be Quaternary in age, and most of them are likely of Holocene age, but none have been numerically dated and are therefore mapped by relative age. The volcanic bedrock geology was mapped at a 1:24,000 scale as part of an interpretive map and guide to the monument (Pallister et al., 1997).

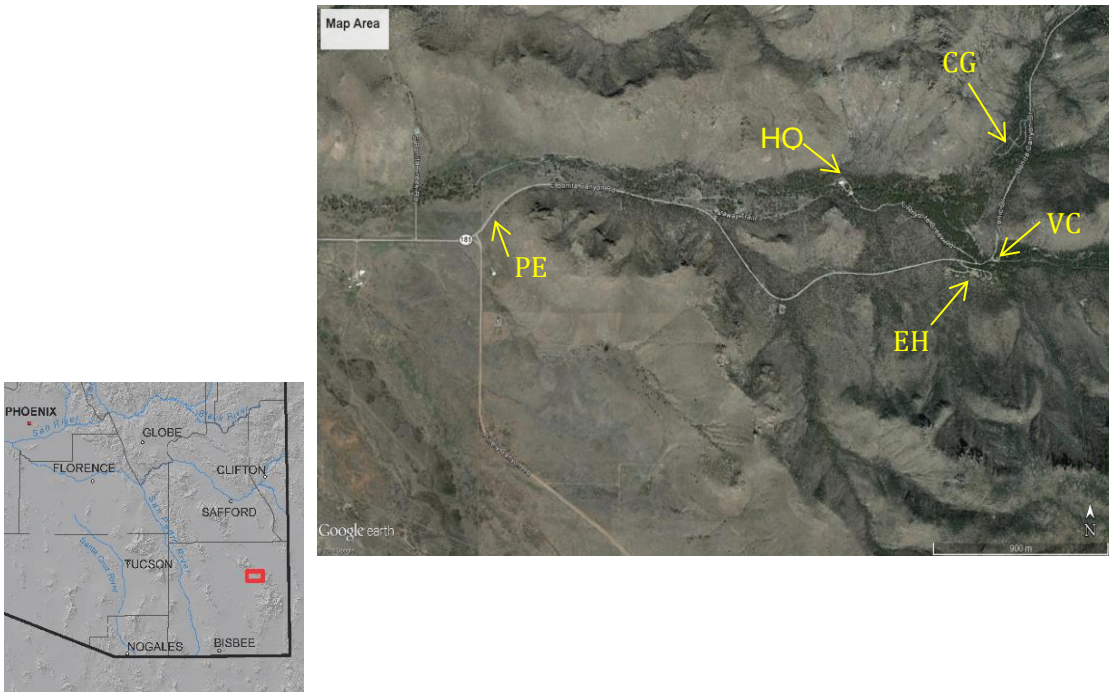

Figure 1. Location of the map area in Arizona and within Chiricahua National Monument. PE- Park Entrance, HQ- Park Headquarters, EH- Employee Housing, VC-Visitors' Center, CG-Campground.

Climate

The Chiricahua Mountains are part of the Madrean Archipelago, a series of "sky island" mountain ranges that have oak and conifer forests at higher elevations, surrounded by grassland and scrubland in the valleys between ranges. Vegetation in the study area consists of mixed conifer, oak brush, pinyon, juniper, ponderosa pine, and grasses (Arechederra-Romero, 2012). Data from the Western Regional Climate Center (2016) show average annual minimum and maximum temperatures are 43.5 and 73.3 degrees Fahrenheit (° F), respectively, the average June temperature is 90.5°F and the average December temperature 30.2°F. The. Average total precipitation is 19.02 inches annually, and on average 10.3 inches of the annual precipitation is snowfall, however snow is not typically persistent (Western Regional Climate Center, 2016). Southeast Arizona receives about half of its total annual precipitation between during the summer monsoon from June to September. Moisture moves north from the Gulf of Mexico and the Gulf of California, generating thunderstorms over the mountains that can cause flooding or start wildfires. The monsoon system is usually strongest in southeastern Arizona and western New Mexico (Climate Assessment for the Southwest University of Arizona, 2016).

METHODOLOGY

Surficial geology mapping was conducted iteratively using remotely sensed data and field observations. Geologic units were differentiated using a detailed digital elevation model (DEM) developed from 0.25-meter resolution LiDAR collected in January 2015 for the National Park Service Southern Arizona Office, and ESRI World Imagery high-resolution aerial imagery. Observations of surface characteristics, topographic relationships between alluvial surfaces, and stratigraphic exposures in the field supplemented and refined the remotely mapped geologic units. (Plate 1) Differences in surface texture evident in the LiDAR DEM, physical characteristics of the alluvial deposits and position in landscape were used to differentiate Quaternary deposits.

The ages of alluvial deposits are relative to each other as no strongly developed soils were observed on any of the surfaces in the valleys of CNM; all geologic units are inferred to be Late Pleistocene or Holocene. Further work with soils or dating could better constrain ages of surfaces. Mapping was compiled in ArcGIS. Bedrock mapping by Pallister et al. (1997) was transferred to this map as accurately as possible. Minor adjustments were made to some bedrock contacts using the superior imagery and topographic data available for this investigation, and contacts between bedrock, alluvium, and colluvium were remapped for this study.

Relative ages of alluvial fans were determined based on position of landscape and roughness of their appearance on the LiDAR DEM. Very poorly sorted debris-flow deposits dominate all of the alluvial fan units (Fig. 2), except the most recent finer grained Qaf unit. Rougher fans with more relict distributary channels are inferred to be younger than older smoother fans. Differences in soils developed in various fan deposits were not obvious in the field, with the exception of Qi, which shows some reddening and is probably the oldest fan in the mapping area. Higher fans that were graded to a higher level of Bonita Creek deposits are older, and generally the younger fans are inset against the older fans.

A **B**

Figure 2. A) Snout of a debris flow deposit consists of large boulders located on alluvial fan unit Qdf2. B) Boulder levees on debris-flow dominated alluvial fan deposit unit Qdf2.

Units associated with the Bonita Creek axial valley deposits were differentiated based on level above the active stream channel, and, although there are boulders present, are more sorted and fine grained than the debris flow deposits. The active channel itself, Qyr3, is dominated by gravel-sized clasts on the streambed, with larger clasts probably deposited during flooding events (Fig. 3). The fan/terrace unit Qrt associated with Rhyolite Creek is easily distinguishable from terraces associated with Bonita Creek by stronger boulder bar and swale topography as well as the alignment of the deposits that could be both flood and debris-flow deposits. Qrt and the terrace associate with Bonita Creek, Qyr1, are the same height above the active channel, suggesting that they are the same age.

A B

Figure 3. A) Boulders in bar and swale micro-topography on terrace unit Qyr2. B) Bonita Creek active channel deposit (Qyr3) dominated by silt, sand, and gravel.

Map Units

Surficial Geologic Units

Axial Valley Deposits

Qyr3 **Deposits in active channels, low terraces and bars (Holocene)** - Alluvial deposits located along active drainages including small channels, adjacent low terraces, or floodplain areas. These deposits are composed of unconsolidated sand, gravel, and silt, with some cobbles and boulders.

Qyr2 **Deposits associated with broad valley floors, low terraces, and gravel bars and swales adjacent to active channels (Holocene)** - Alluvial deposits forming terraces and bars located primarily along the flanks of the most active parts of fluvial system drainages. Qyr2 terrace is approximately 0.5-1 meter above the active channel (Qyr3) and is inundated during higher flows. Qyr2 deposits consist of predominantly silt, sand, and gravel, with common to dominant sub-rounded to sub-angular pebbles and cobbles, and are unconsolidated to weakly consolidated sediments with pebble, cobbles, and boulders. These deposits exhibit bar and swale micro-topography.

Qyr1 **Terrace deposits adjacent to active fluvial systems (Holocene)** - Qyr1 deposits typically form high stranded terraces approximately 5-6 meters above the active stream channel (unit Qyr3) typically within the valley bottom along the edges of the canyon adjacent to colluvium (unit Qtc) and alluvial fans (units Qdf3 and Qdf2). Qyr1 consists of predominantly sand and silt, with some pebbles, cobbles and scattered boulders.

Qrt **Rhyolite Creek alluvial fan and terrace deposits (Holocene)** - Expansion terraces located at the mouth of Rhyolite Creek where Rhyolite Creek enters Bonita Canyon. The terraces are located adjacent to, and 5-6 m above, the active stream channel. Deposits are poorly sorted and consist of silt, sand,

gravel, pebbles, cobbles and boulders. These deposits typically exhibit bar and swale topography. Age equivalent to Qyr1 in Bonita Creek axial valley.

Piedmont Deposits

Qaf **Young alluvial fan deposits (Youngest Holocene)** - Fine grained alluvial fan deposits that grade to the active Bonita Creek level. The toes of unit Qaf fans may be inundated during higher flows. These deposits are dominated by alluvial deposits, and have shallower slope angles than debris-flow generated fans Qyd3, Qyd2 and Qyd1.

Qy3 **Young tributary active channel and terrace deposits (Holocene)** - Active channel deposits and terraces near the interface of tributary drainages incised into older fan surfaces. Deposits are poorly sorted and composed of boulders, pebbles, cobbles, sand, and silt. The channel pattern is distributary and terraces may be inundated during higher flows.

Qdf3 **Younger tributary alluvial fan deposits (Holocene)** - Alluvial fans dominated by very poorly sorted debris-flow deposits. Deposits consist of silt, sand, gravel, pebbles, cobbles and boulders, are inset approximately 2 meters into Qdf2 deposits, and grade to creek level at lower limits, indicating alluvial fans units Qdf2 and Qdf1 are older than Qdf3. Possible debris-flow levees are included in these deposits.

Qdf2 **Intermediate tributary alluvial fan deposits (Holocene)** - Very poorly sorted fan deposits, dominated by debris flows, consisting of silt, gravel, sand, pebbles, cobbles, and boulders. These deposits construct moderately eroded relict alluvial fans that are located against canyon walls. Deposits of units Qy3 and Qdf3 are inset approximately 1-4 meters below deposits of unit Qdf2.

Qdf1 **Older tributary alluvial fan deposits (Latest Pleistocene-Earliest Holocene)** - High-standing alluvial fan formed predominately by very poorly sorted debris flow deposits. These deposits are less dissected by active tributaries than units Qdf3, and Qdf2. Slight soil reddening may be present, indicating older deposits than those described above.

Qi **Intermediate alluvial fan and terrace deposits (Late Pleistocene)** - Relict piedmont alluvial fan, rounded broad shape, consisting of sand, gravel, and cobble-sized clasts. Reddened soil is present.

Other Deposits

d **Disturbed ground (Holocene)** - Roads, buildings, and other areas of excavation and burial where original geologic characteristics are obscure or invisible.

Qtc **Colluvium and talus (Holocene and Pleistocene)** - Poorly sorted, angular to subangular, weakly to massively bedded, locally derived hillslope deposits.

QTls **Landslide deposits (Quaternary or Tertiary)** – Deposits formed by gravity sliding or flowage. Cuspate breakaway scarps exposed at heads of some deposits. Degree of erosion and alteration, as well as proximity to Tertiary faults and to margin of Turkey Creek caldera suggest a Tertiary age for some deposits. From Pallister et al. (1997).

Bedrock Geologic Units (all unit descriptions are taken directly from Pallister et al., 1997)

Trcm **Turkey Creek Caldera outflow facies, middle member (Oligocene)** - Voluminous, gray, densely welded, pumiceous ash-flow tuff. Prominent vertical columns (hoodoos) produced by erosion along joint planes in this member. Jointing attributed primarily to contraction related cooling (Hall, 1993). Internally homogeneous; however, slight variation in welding and weathering profile suggest member formed from multiple ash flows that were erupted in rapid succession and cooled together. Base locally marked by a 0-3-foot-thick section that consists of pumiceous ash-flow, ash-cloud, and surge deposits that were welded as a result of emplacement of the overlying main body of the middle member. The middle member overlies the white, poorly welded, top of the lower member. Thickness 1,050 feet at Sugarloaf Mountain where top exposed.

Trcl **Turkey Creek Caldera outflow facies, lower member (Oligocene)** - Pumiceous and locally lithophysal ash-flow tuff and related ash-cloud deposit. Consists of red-brown densely welded middle zone. Middle zone grades upward into white, pumice-bearing, poorly welded ash-cloud deposit. Thickness 0-600 feet; forms a wedge that thickens to south and east.

Tjj **Jesse James Canyon Tuff (Oligocene)** - Light-gray or pinkish-gray, typically lithic poor, moderatly crystal poor (about 10 percent crystals), biotite-bearing quartz-sanidine rhyolite ash-flow tuff from undetermined source (76-77 weight-percent SiO2). Similar to middle and lower members of Rhyolite Canyon Tuff (Trcm, Trcl); however, distinquished by presence of trace amounts of bronze biotite and sphene, typically smaller and less abundant phenocrysts of sanidine and quartz, higher ratio of sanidine to quartz (3:1 or greater). less-evolved chemistry, and stratigraphic position. Forms a simple cooling unit; poorly welded upper zone grades downward into densely welded, eutaxitic lower zone; basal vitrophyre exposed locally. Thickness about 790 feet near Jesse James Canyon; thins to north, northwest, and northeast. Lithic-rich pyroclastic flow found locally at tope of Jesse James Canyon Tuff. Overlain by about 5 feet of white, crystal poor, biotite-bearing ash where present.

Tfpe **Pyroclastic flow deposits of Erickson Ridge (Oligocene)** - Light-gray to orange block-and-ash flow, ash-fall and surge deposits, and ash-rich lahars interbedded with rhyolite of Erickson Ridge (Tfre). Partly equivalent to Faraway Ranch Formation member 6 of Fernandez and Enlows (1966). Locally includes reworded sedimemtary deposits. Thickness 0-200 ft. Trend of bedding- varies widely as a result of steep near-vent topography.

Tfre **Faraway Ranch Formation: Rhyolite of Erickson Ridge (Oligocene)** - Light-gray or red-brown (devitified) to black (glassy) biotite rhyolite (averages 73 weight-percent SiO2). Contains phenocrysts of plagioclase (3-7 percent) and biotite (1-2 percent). Accessory or trace sphene forms euhedral phenocrysts. Forms small lava domes and lobate flow-layered lava flows that have black glassy carapace breccias. Equivalent to Faraway Ranch Formation member 7 of Fernandez and Enlows (1966). Thickness variable; as much as 500 feet thick near Faraway Ranch.

Tim **Intermediate and Mafic Lava Flows (Oligocene)** - Interfingering lava flows, flow breccia, and near-source pyroclastic rocks that are part of a regional assemblage of intermediate and mafic rocks that underlie most rhyolitic rocks in the Chiricahua Mountains (du Bray and others, in press). In the National Monument, consists of red to brown, hornblende- and biotite-bearing plagioclase porphyritic dacite that locally overlies sedimentary rocks of Bonita Park and dark- gray aphanitic to glassy, clinopyroxene-bearing andesite and basalt. Thickness greater than 400 feet locally, base not exposed in map area.

Tbp **Sedimentary rocks of Bonita Park (Oligocene)** - Rocks that predate the Faraway Ranch Formation. Red-weathering, poorly sorted, clast-supported conglomerate, and interbedded volcaniclastic arenite, siltstone, and claystone; contains gypsum veinlets near Bonita Park. Graded beds and channel deposits common. Extensively altered to clay minerals and hematite. Initially interpreted as lakebed deposits by Waller (1952). Poor sorting, hematitic alteration, and channel bedding more consistent with alluvial-fan deposition (Hall, 1993). Red clay-rick soil suggests that Quaternary-Tertiary colluvium and landslide deposits, mapped in Bonita Park and west of Whitetail Pass, are underlain by sedimentary rocks of Bonita Park. Interbedded between andesitic and rhyolitic lavas of Faraway Ranch Formation about one quarter of a mile west of map boundary, north of Arizona Highway 181. Thickness less than 160 feet.

GEOLOGIC/GEOMORPHIC FRAMEWORK

The Chiricahua Mountain Range is part of the Basin and Range Province. The majority of the mountain range bedrock was formed when the Turkey Creek Caldera erupted 26.9 million years ago (Pallister et al., 1997). Basin and Range extension began about 20 million years ago increasing erosion through Bonita Canyon and into the Sulphur Springs Valley, located between the Chiricahau Mountains and the Dragoon Mountains to the west (Pallister et al., 1997). Downcutting has continued to remove the rhyolite bedrock, and deposit it in Bonita Canyon and Sulphur Springs Valley. Currently, most of the material transported by Bonita Creek out of the canyon is dominated by gravel-sized and smaller clasts.

Geologic Hazards

Flooding

Due to the flashy nature of the watersheds that feed into Bonita Canyon, risks from flooding to park infrastructure are high, especially during monsoon season. Impacts from the 2011 Horseshoe 2 Fire to vegetation and soil resulted in temporarily increased runoff, greatly reducing the size of the storm needed to generate flooding in Bonita Creek and increasing the frequency of flooding. This threatened the campground, which is located on a low terrace adjacent to the active stream channel (unit Qyr1), and the park headquarters, which is located within a meander bed that contains overflow from the active channel during flooding (unit Qyr2). Vegetation on the low terrace adjacent to the axial active channel shows signs of recent flooding, including flattened grass and vegetation debris stranded against trees. Flash flooding in tributaries could impact the road and, particularly, the visitor's center located in what was previously the channel of Madrone Creek before it was artificially diverted around the building. Rhyolite Creek also regularly floods near the visitor's center, requiring a semi-permanent sand bag wall behind the structure.

Figure 4. Vegetation flattened by flooding, located on axial valley terrace Qyr2, which is 0.5-1 meter above the active stream channel.

Debris Flow/Wildfire

Most of the alluvial fans in Bonita Canyon consist of course, very poorly sorted debris-flow deposits with large boulders that can be 2 meters on the longest (c-)axis. The Visitor's Center and employee housing are constructed on alluvial fan debris-flow deposits, although there is no evidence for a recent debris flow. There are a number of tributary streams that run through the area so flooding may pose a bigger threat to the housing buildings. There were no significant debris flows documented in the Monument after the Horseshoe 2 Fire, but there were many within the adjacent forests. The extensive amount of paleo-debris flow deposits present in Bonita Canyon indicates that there have been many debris flows earlier in the Holocene, which may correlate to an increased rate of extensive burn or may be a climate-change signal in the latest Pleistocene to early Holocene. More research dating the debris flows could

help illuminate this relationship. With the uncertainty of a changing climate, it is possible that the number of large wildfires could increase and, potentially, increase the number of debris flows in the Monument.

ACKNOWLEDGEMENTS

The National Park Service Geoscientists-in-the-Parks Program and the Geological Society of America GeoCorps program funded this mapping project, and the Arizona Geological Survey provided logistical support. We also thank Phil Pearthree for providing field assistance and guidance on this project.

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