OVERVIEW

The Pinnacles

of Chiricahua National Monument

Introduction

The Chiricahua Mountains were part of the traditional homeland of the Chiricahua Band of the Apache Indian Nation. The Apaches called the area that is now within the Chiricahua National Monument (NM) "The Land of Standing-Up Rocks" because of the numerous rock pinnacles, columns, and balanced rocks. The maze of rock columns and passageways provided a stronghold for the Apaches during conflicts with the U.S. military during the nineteenth century. Protection of the picturesque rock pinnacles was the purpose for establishing the monument in 1924. The Chiricahua Mountain Range is an inactive volcanic range 40 miles (64 kilometers) long by 20 miles (32 kilometers) wide. The rock pinnacles, columns, and balanced rocks were eroded from layers of ash deposited by the eruption of the Turkey Creek Volcano 27 million years ago. The volcanic deposits were largely shaped by freezing, thawing, and running water during the last Ice Age, when the climate was wetter and cooler than it is now. Some of the pinnacles rise hundreds of feet in the air, and many are balanced on a small base. Many of the rock formations were named by the Civilian Conservation Corps in the 1930s, and names include the Totem Pole, Big Balanced Rock, Duck on a Rock, Sea Captain, Organ Pipe Formation, and Mushroom Rock.

Where they occur, various terms are given to similar rock formations including "pinnacles," "spires," "columns," and "hoodoos." Use of the terms varies, but in general pinnacles (the same as spires) are columns of rock that have a uniform thickness and taper towards the top. The term "hoodoo" is often reserved for columns that are more fantastic in form; they tend to have a variable thickness that may be described as "totem-pole-shaped." In this Overview, the terms "pinnacle" and "hoodoo" are used interchangably.

Pinnacles occur mainly in dry, hot areas. They protrude from the bottom of arid basins and "broken" lands. In the U.S., pinnacles and hoodoos are most common in the High Plateaus region of the Colorado Plateau and in the Badlands regions of the Northern Great Plains. Although scattered throughout these areas, they are most abundant in the northern section of

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Pinnacles (or hoodoos) at Chiricahua National Monument (NM)

Bryce Canyon National Park (NP) in Utah. The rock formations and other natural features at the 11,985-acre Chiricahua NM can be observed along portions of the 8-mile paved scenic drive and 18 miles of day-use hiking trails. The formations occur primarily in the walls of Bonita, Echo, Rhyolite, and Sarah Deming Canyons.

Chiricahua NM Geologic Setting

The Chiricahua Mountain Range is one of the many "sky island" ranges that occur in southern Arizona. The "islands" rise above the surrounding desert grasslands— in this case to over nine thousand feet. Pallister et al. (1993) describes the geologic history and ancient physical environment of Chiricahua NM and its surroundings, including the oldest rock in the area, Pinal Schist (a metamorphic rock that formed about 1.7 billion years ago during the Precambrian Era). The oldest rocks within the monument are late Paleozoic, Permian limestones about 280 million years old; they are exposed in fault blocks in the northeast corner of the monument. Although Paleozoic and Mesozoic sedimentary rocks are exposed at the monument, the Cenozoic volcanic rocks dominate the landscape and are the focus of this overview. Rocks of this age also exist in other parts of Arizona, but the volcanic rocks that formed from the eruption of the Turkey Creek volcano are found only in the Chiricahua Mountains and its immediate vicinity (National Park Service [NPS] 2009).

The Turkey Creek Caldera and Formation of the Pinnacles

Information in this section is from Pallister et al. (1993).

The Totem Pole

There have been various periods of volcanic activity over time. In the Chiricahua Mountains, most of the volcanic activity occurred between 35 and 25 million years ago. At about 27 million years ago, the giant Turkey Creek volcano, just south of the monument, erupted, blowing out more than 100 cubic miles (400 cubic kilometers) of magma and burying an area of at least 1,200 square miles (3,100 square kilometers) in a thick blanket of ash and pumice. The eruption was 1,000 times the size of the Mount St. Helens eruption in 1980 and five to ten times larger than the explosion of Krakatoa in 1883. The eruption produced a large circular depression that was 12 miles (19 kilometers) in diameter and at least 5,000 feet (1,500 meters) deep above the magma chamber. After erupting, the Turkey Creek caldera would have looked similar to Crater Lake caldera in Crater Lake NP (in Oregon), but the Turkey Creek caldera would have been twice as large. Erupted ash and pumice partially filled the depression. The caldera is not recognizable today. Similar eruptions in the San Juan Mountains of Colorado and in Yellowstone NP were even bigger, each releasing more than 500 cubic miles (2,000 cubic kilometers) of magma.

Magma from the Turkey Creek volcano contained a high proportion (~77%) of silica. Rock with this composition is known as rhyolite. The eruption released, into the atmosphere and across the land, boiling clouds of ash, pumice, rock fragments, and gas. As gas was released from the clouds, their density increased and they flowed down from the volcano; they collected in valleys and formed thick deposits of ash and pumice. Because the deposit was thick, and the shards of volcanic glass and pumice fragments were extremely hot, they fused together and compacted to form a rock called welded tuff. The monument area, which had formerly been a valley, was filled with about 1600 feet (490 meters) of this material. The deposit is named Rhyolite Canyon Tuff and is extremely well preserved in Rhyolite Canyon. The thick tuff layer has also become the dramatic cliffs and outcroppings framing Bonita Canyon. The tuff is primarily composed of pumice, ash, rock fragments, and crystals of feldspar and quartz. The pumice is recognizable as the prominent white streaks (flame) in the rock. Horizontal white bands in the cliffs mark areas of successive pyroclastic flow deposits. Three eruptions occurred in rapid succession.

The pinnacles and columns are erosional features. As the welded tuff layer cooled and contracted, it formed cracks or joints. [Similar columnar joints are known in other welded tuff layers, such as in the rhyolite tuff cliffs at Bandelier NM and adjacent to the Gila Cliff Dwellings NM]. Water seeped into the cracks, and the erosional process began. Over time, other factors contributed—the wedging action of freezing water, running water, and erosion by the wind. These processes carved the tuff into a maze of narrow canyons separated by angular ridges lined with pinnacles. The welded tuff and its joints are about 27 million years old, but the columns and

Pinnacles with a wedged, fallen rock

Pinnacles at Massai Point

pinnacles are thought to be less than three million years old (based on an estimated erosion rate of about two-thirds of an inch of downcutting per 1,000 years). Chemical and physical weathering processes continue to shape the landscape.

The extreme western and southern parts of the monument contain Tertiary, pre-Turkey Creek caldera tuff pyroclastic and lava flows. These flows underlie the Rhyolite Canyon Tuff deposits.

Other Geologic Features

The geologic features at Chiricahua NM were formed by the processes of weathering, volcanic activity, and faulting. The pinnacles, columns, and balanced rocks are a result of the differential weathering processes of the Rhyolite Canyon Tuff. Other exceptional geologic features arose from volcanic events that impacted the southeastern Arizona area and from regional tectonics associated with the western margin of North America (NPS 2009). Below is a sampling of the geologic features (and processes) at the monument, many of which occur in relation to the pinnacles and columns; for a thorough discussion, see the references at the end of the Overview. The summary descriptions below are based primarily on Bezy (2001).

- Slot canyons – Slot-like canyons are often 40 times deeper than they are wide. They have been cut into the rhyolite along the joints that also form the pinnacles and columns.
- Natural bridge – There is a natural bridge with a 30-foot (9-meter) span of welded tuff that can be seen from the overlook at the end of the Natural Bridge Trail (off of the Bonita Canyon scenic drive; NPS 2009). The trail crosses the Middle Member of the Rhyolite Canyon Tuff. The natural bridge was probably formed when flowing water eroded weaker rock beneath the bridge.
- Tafoni – Tafoni are pits or cavities in rock walls and pinnacles formed by weathering. They occur along zones of weakness in the bedrock in various climates and types of rock. The openings may reach up to several yards in diameter.
- Desert or rock varnish – Rock varnish may develop on the surface of pinnacles and columns and is a thin coating of clay minerals (from dust in the atmosphere) stained by high concentrations of iron and manganese oxides. Varnish appears as dark areas (brown and black blotches) on the buff-colored columns.
- Solution pans – These are dish-shaped depressions in rock that form by chemical and physical weathering processes. They may be up to 3 feet (1 meter) across and 4 inches (10 centimeters) deep and can hold rainwater or snowmelt. They occur in flat areas, including the level tops of pinnacles.
- Horizonal ribs – Ribs are common surface features on the rock pinnacles that develop because thin layers of ash and fiamme (from pumice) more readily erode (leaving the ribs). The ribs and depressions range from ½ to 4 inches (~1-10 centimeters) wide and up to 8 inches (20 centimeters) long.
- Talus cones – Talus cones are steep, triangular-shaped piles of rock rubble that fell from the bedrock outcrops higher up the slope. Talus cones are a result of weathering and rock movement due to gravity. The cones in the Chiricahua Mountains were produced during the Ice Age (1.6 million to 10,000 years ago) and show little evidence of recent rockfall; they are somewhat stabilized by vegetation. These features are best seen on the Hailstone segment of the Echo Canyon Loop.
- Dacite caprock – This dark-colored type of rock is the youngest in the monument and occurs on the top of Sugarloaf Mountain. Once molten, the dacite flowed as lava down a valley from higher slopes to the south. Upon cooling, the flow solidified. The flow eroded away, except in this area. Sugarloaf Mountain and its dacite caprock now form a mesa where a valley once existed (an example of topographic reversal).

- Spherulites – These structures are marble-sized and spheroidal in shape, and they formed as the volcanic ash sheet cooled. The radial growth of needle-shaped, secondary crystals of quartz and feldspar from a common center produced their shape. They were once thought to be volcanic hailstones, but this is not the case. Spherulites can be seen along the Echo Canyon Loop.

Status and Management

As previously discussed, Chiricahua NM was created nearly one hundred years ago to protect the pinnacles, columns, and balanced rocks. The tall, slender pinnacles and balanced rocks might appear susceptible to collapse, but they are actually quite stable. Studies have shown that the pinnacles could withstand 12-13 times their weight in stress before they would collapse (Bezy 2001). An engineering analysis found that the columns are within their mechanical failure limits for static load (Hall 1996). Furthermore, columns that support balanced rocks above V-shaped incuts were shown to have more stability than columns that do not have necks. It is said that even the Totem Pole (shown on p.2; height 187 feet [57 meters]) could be suspended upside-down without breaking. The columns are more likely to be brought down by dynamic failure (involving seismic shaking by a lateral force) than by gravity. Although earthquakes produce lateral forces, relatively little damage was done by the Pitaycachi earthquake in 1887. The epicenter of this earthquake was approximately 75 miles (120 kilometers) south-southeast of the monument, and it shook all of southeastern Arizona.

A recent study of maintenance activities (road maintenance, use of heavy equipment) at the monument used seismometers to monitor the vibrations produced. The study did not find that road maintenance affected the pinnacles or other rock structures, but it indicated that climbing on the rocks promoted rockfall (NPS 2009). The previously-existing ban on rock climbing was supported by the study.

Landslides are a threat along Sugarloaf Mountain Trail (NPS 2009). At the contact of the Upper and Middle Members of the Rhyolite Canyon Tuff on Sugarloaf Mountain is an ash-rich, white-to-light gray layer that is soft and more easily eroded than the overlying layers of welded tuff. During wet years, the white ash layer becomes wet from water moving along joints. The ash layer becomes weakened and slumps, and the overlying cliff becomes unstable and collapses (Bezy 2001). Blocks in the overlying cliffs then break loose and travel down the slopes of the mountain.

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Rock formations at Chiricahua NM

Another area of concern for the geologic resources of the park is mineral/rock collecting (NPS 2009). Collecting and gold panning of rocks, minerals, and paleontological specimens is generally prohibited in all units of the National Park System (36 C.F.R. § 2.1(a) and § 2.5(a)). However, visitors have been known to collect samples of galena and sphalerite (lead-zinc minerals) and spherulites along trails. The extent of illegal collecting is unclear.

Literature Cited

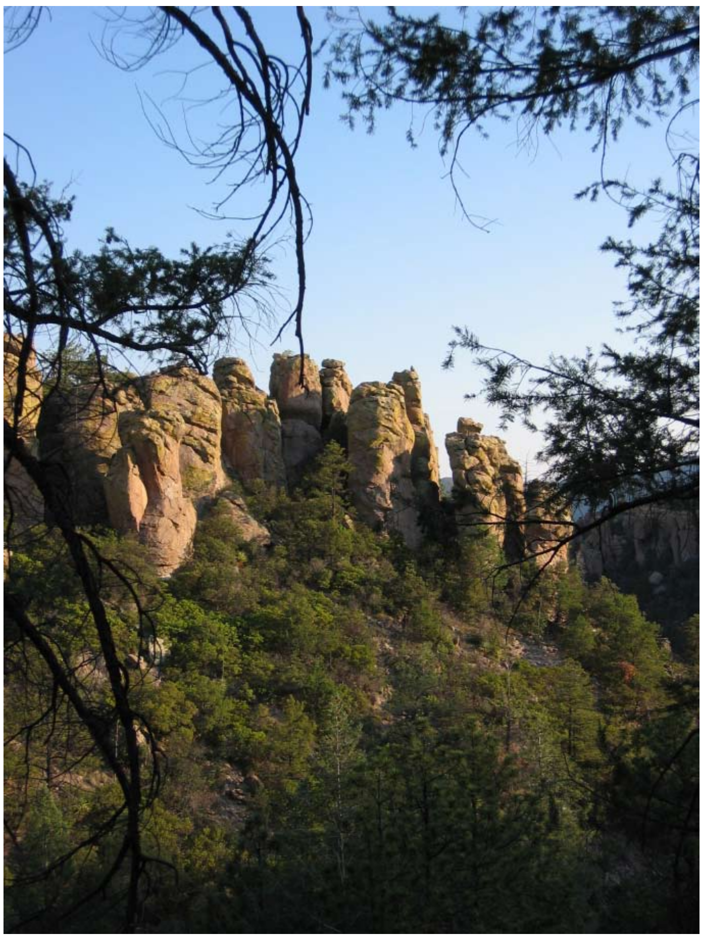
Bezy, J. 2001. Rocks in the Chiricahua National Monument and the Fort Bowie National Historic Site. Arizona Geological Survey, Down-to-Earth 11.

Hall, D.B. 1996. Modeling failure of natural rock columns. Geomorphology 15:123-134, as cited in NPS 2009.

National Park Service (NPS). 2009. Chiricahua National Monument Geologic Resources Inventory Report. Natural Resource Report NPS/NRPC/GRD/NRR—2009/081. Geologic Resources Division, Natural Resource Program Center, Denver, Colorado.

Pallister, J., E. du Bray, and D. Hall. 1993. Geology of Chiricahua National Monument, a review for the non-specialist. Open-File Report 93-617. U.S. Geological Survey.

Pallister, J., E. du Bray, and D. Hall. 1997. Guide to the volcanic geology of Chiricahua National Monument and vicinity, Cochise County, Arizona. Pamphlet to accompany Miscellaneous Investigations Series Map I-2541. U.S Geological Survey.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Pinnacles at Echo Canyon