Geologic Resource Evaluation Scoping Summary
Gila Cliff Dwellings National Monument, New Mexico

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The Geologic Resource Evaluation (GRE) Program provides each of 270 identified natural area National Park System units with a geologic scoping meeting and scoping summary (this report), a digital geologic map, and a geologic resource evaluation report. Geologic scoping meetings generate an evaluation of the adequacy of existing geologic maps for resource management, provide an opportunity for discussion of park-specific geologic management issues, and if possible include a site visit with local experts. The purpose of these meetings is to identify geologic mapping coverage and needs, distinctive geologic processes and features, resource management issues, and potential monitoring and research needs.

Gila Cliff Dwellings National Monument celebrated its 100th anniversary on November 16, 2007, with special events and programs at the monument and nearby Silver City, New Mexico. Serendipitously the National Park Service held a GRE scoping meeting for Gila Cliff Dwellings National Monument two days before this celebration on November 14, 2007. Bruce Heise (Geologic Resources Division) facilitated the discussion of map coverage and geologic processes and features. Jim Ratté (U.S. Geological Survey), who started mapping in the Gila Wilderness area in 1968, presented information about the status of mapping and highlighted the general geologic history of the monument. Participants at the meeting included NPS staff from Gila Cliff Dwellings National Monument, Chamizal National Monument, and the Geologic Resources Division, and cooperators from the U.S. Geological Survey, New Mexico Bureau of Geology and Mineral Resources, and Colorado State University (table 1, p. 10). Scoping included a field trip led by Sonya Berger (Gila Cliff Dwellings National Monument) and Jim Ratté (U.S. Geological Survey) on November 15, 2007.

Park and Geologic Setting

The 216-ha (533-ac) Gila Cliff Dwellings National Monument is surrounded by the 225,823-ha (558,000-ac) Gila Wilderness, which is part of 1.3 million hectares (3.3 million ac) of Gila National Forest. The earliest recorded visit to the cliff dwellings was in 1878 by Henry B. Ailman, an early emigrant to southwestern New Mexico who had become a prosperous co-owner of the Naiad Queen silver mine in Georgetown, now a ghost town about 24 km (15 mi) east of Silver City (Russell 1992). The journals of Adolph Bandelier, the well-known amateur archaeologist of the time, make it clear that many people knew about the cliff dwellings by the time he visited in 1884; completed that same year, the first survey of the township also locates the ruins. Bandelier heard about the site from several informants in the Mimbres Valley and along Sapillo Creek, and also from the settlers around the Gila Hot Springs. Bandelier remarked that the dwellings had been "rifled" by cowboys, prospectors, and curiosity seekers. President Theodore Roosevelt signed the proclamation that recognized the "group of cliff-dwellings known as the Gila Hot Springs Cliff-Houses" as a national monument in 1907. The proclamation noted the dwellings as being "of exceptional scientific and educational interest" and "as the best representative of the Cliff-Dwellers' remains of that region." This proclamation was intended to prevent further damage and vandalism.

Today archaeological preservation, research, and visitor interpretation are the monument's primary missions (Parent 2004). The geologic setting gives shape to the archaeology. In many places, in fact, the surrounding geology and human structures are indistinguishable; for example, at the north end of cave 5, the approximately 20-million-year-old Gila Conglomerate and 700-year-old Mogollon wall meld together (fig. 1).

The geologic setting of Gila Cliff Dwellings National Monument may be separated into four major geologic events, which various processes or rock formations represent: (1) Oligocene (approximately 28 million years ago) volcanism of the Bursum and Gila Cliff Dwellings calderas with emplacement of the Bloodgood

Canyon Tuff and the Bearwallow Mountain Andesite; (2) Basin and Range faulting highlighted by the Gila Hot Springs graben and infilling Gila Conglomerate; (3) erosion of the landscape to present conditions by Pleistocene downcutting of Cliff Dweller Canyon, formation of terraces, and development of the alcoves; and (4) deep circulation of groundwater along faults, resulting in geothermal resources in the vicinity of the national monument. Leopold (1981), Mack (2004), and Chapin et al. (2004) may provide details about the geologic setting for the final GRE report.

Figure 1. The architecture of the Gila Cliff Dwellings mimics the texture of the underlying Gila Conglomerate. NPS photo/Katie KellerLynn.

With the exception of the geothermal processes, the entire geologic setting of Gila Cliff Dwellings is on display at the parking lot and trail to the cliff dwellings. Jim Ratté's "Road Log: Sapillo Junction to Gila Cliff Dwellings National Monument via NM Highway 15" highlights the steep slopes on the north side of the parking lot near the mouth of Cliff Dweller Canyon. These slopes show the local rock sequence, beginning with the nearly white, 28-million-year-old Bloodgood Canyon rhyolite tuff (an ignimbrite; see "Unique Geologic Resources"), overlain by the dark-colored Bearwallow Mountain Andesite lava flows, and topped by the Gila Conglomerate. Visible across the river from the parking lot, Gila Conglomerate, the rock in which the alcoves formed and the cliff dwellings were built, caps the volcanic sequence. Across the bridge that leads visitors to the cliff dwellings, the light-colored Bloodgood Canyon Tuff runs upstream along the west bank, barely visible at the shoreline. Beneath the cliff dwellings in Cliff Dweller Canyon, the Bearwallow Mountain Andesite thins down to two lava flows, which a few feet of sandstone separate. The contact between the Gila Conglomerate and the underlying Bearwallow Mountain Andesite is well exposed along the return trail from the cliff dwellings, where the bottom of the conglomerate includes loose regolith material derived from older andesite and sand deposited into the cracks of the andesite. The Gila Conglomerate within the cliff dwellings consists of clasts that range from sand-size particles to boulders of primarily Bloodgood Canyon Tuff, but also andesite and other volcanic rocks that eroded from the surrounding mountains. When the sun is right, the sanidine feldspar crystals, characteristic of Bloodgood Canyon Tuff, reflect as blue fragments in the conglomerate (Ratté 2007).

In order to experience the geothermal resources, visitors must hike 0.8 km (0.5 mi) to the Light Feather (Middle Fork) Hot Springs along the Middle Fork Trail in the Gila Wilderness. After the second river crossing, the hot springs are located at the river's edge beneath an unusual rock outcrop of travertine. The travertine ledge indicates a higher river level in the past when this rock was deposited from the spring. The water is scalding 60°C (140°F) when it comes out of the ground, so finding a cooler spot downstream makes soaking more comfortable (Ransom 2006). This is one of three undeveloped hot springs easily accessible from Gila Cliff Dwellings National Monument (see "Geothermal Features and Processes" section).

Geologic Mapping

In addition to being GIS compatible, digital geologic maps produced by the GRE Program reproduce all aspects of paper maps, including notes, legend, and cross sections. The NPS GRE Geology–GIS Geodatabase Data Model incorporates the standards of digital map creation set for the GRE Program. Staff members digitize maps or convert digital data to the GRE digital geologic map model using ESRI ArcMap software. Final digital geologic map products include data in geodatabase, shapefile, and coverage format, layer files, FGDC-compliant metadata, and a Windows HelpFile that captures ancillary map data.

When possible, the GRE Program provides large scale (1:24,000) digital geologic maps for each park's area of interest, which is often composed of the 7.5-minute quadrangles that contain park lands. Maps of this scale (and larger) are useful to resource managers because they capture most geologic features of interest and are accurate to within 12 m (40 ft). The process of selecting maps for management use begins with the identification of existing geologic maps in the vicinity of the park. Scoping session participants then discuss mapping coverage and needs and select appropriate source maps for digitization or conversion.

During scoping, participants recommended that GRE staff digitize the eastern half of *Reconnaissance Geologic Map of the Gila Wilderness Study Area, southwestern New Mexico* (Ratté and Gaskill 1975). This map, published at a scale of 1:62,500, will provide immediate data and a regional, geologic picture in a digital format for management use. The U.S. Geological Survey anticipates revising this map at 1:100,000 scale (Jim Ratté, U.S. Geological Survey, written communication, March 3, 2008). Ultimately park managers would like the day-use area (i.e., area around the visitor center, the cliff dwellings, trails, and hot springs) captured in detail at 1:24,000 scale (or larger). Jim Ratté is currently working on more detailed geologic mapping to be published at 1:24,000 for the two quadrangles of interest for Gila Cliff Dwellings National Monument: Little Turkey Park and Gila Hot Springs. The cliff dwellings are situated on the Little Turkey Park quadrangle, and the TJ unit is located on the Gila Hot Springs quadrangle. Jim Ratté needs to compile his field data for Gila Hot Springs and the northeastern portion of Little Turkey Park. He anticipates completing this work by June 2008. Dave Love (New Mexico Bureau of Geology and Mineral Resources) mentioned the possibility of the bureau publishing Jim Ratté's finished work.

Geologic Resource Management Issues, Features, and Processes

The scoping session for Gila Cliff Dwellings National Monument provided the opportunity to develop a list of geologic features and processes and associated management issues, which will be further explained in the final GRE report. During the meeting, participants identified the most significant issues as fluvial processes and cave (alcove) features and processes. These will be discussed first, followed alphabetically by other features and processes at the national monument.

Fluvial Features and Processes

The Gila Wilderness protects the upper Gila River watershed in which Gila Cliff Dwellings National Monument is situated. This is the longest undammed stretch of river in the contiguous 48 states and the last undeveloped river in New Mexico. Three forks of the Gila River converge in the valley near the national monument and ultimately flow to the Colorado River. The West Fork joins the Middle Fork and East Fork southeast of Cliff Dweller Canyon and from there the Gila River cuts through the Diablo and Pinos Altos ranges before reaching the broad grasslands of the Gila River valley toward the Arizona state line (Parent 2004). The West Fork of the Gila River provides 0.9 km (0.6 mi) of riparian habitat in the northeastern portion of the monument. At most times of the year, Cliff Dweller creek, a perennial spring-fed creek in the monument, disappears into layers of gravel that line the streambed. A small spring at the head of Cliff Dweller Canyon ensures a constant flow of water that reaches the West Fork of the Gila River at the monument's eastern boundary. The spring and creek in Cliff Dweller Canyon sustain an oasis of walnut, oak, grapes, and pine in the canyon.

During summer monsoons and resulting flash floods, both the West Fork of the Gila River and Cliff Dweller creek fill their channels. Winter storms also increase streamflow (Sonya Berger, Gila Cliff Dwellings National Monument, personal communication, December 12, 2007). Flood waters occasionally wash out the trail, which runs along the creek bed in Cliff Dweller Canyon. Though rare, big floods have historically washed out foot bridges. Floods also leave their mark as scour depressions and deposited debris. The West Fork of the Gila River has a much larger watershed (4,200 km^2 [1,620 mi^2]) than Cliff Dweller creek, resulting in greater floods.

The contact station and parking lot for the Cliff Dwellings Trail is on a floodplain. In the past 40 years, flood waters have reached the parking lot twice. All other major facilities and the TJ site are above the present floodplain on the terraces of the West Fork of the Gila River. The terraces may reflect fluctuating river levels and canyon carving related to a wetter climate during the Pleistocene Epoch (1.8 million–11,500 years ago). Post-meeting correspondence among, Sonya Berger, Jim Ratté, and Katie KellerLynn discussed a possible six levels of terraces, as documented in the New Mexico Geological Society's *Guidebook of Southwestern New Mexico II* (Fitzsimmons and Lochman-Balk 1965). However, three main terrace levels are in the vicinity of Gila Cliff Dwellings National Monument: (1) the highest and oldest (Qt-1) where the fire-training center and main TJ ruins are located, (2) intermediate terrace (Qt-2) where the residence area is located, and (3) the lowest and youngest terrace (Qt-3) where the visitor center is located. Other possible terrace remnants such as at the level of the horse barn and on the south side of the river (e.g., below the State of New Mexico wildlife barn) are likely within the present floodplain (Jim Ratté, U.S. Geological Survey, e-mail communication, December 14, 2007). Work by J. A. Sandor and others may also provide information about the terraces (e.g., Sandor et al. 1986a, b, and c).

Connell et al. (2005) is a source of information about the development of rivers in New Mexico and may provide information specific to Cliff Dweller Canyon. Leopoldt (1981) may also provide specific information about Cliff Dweller Canyon. Work by Hawley et al. (2000) may provide the "start date" of canyon cutting in the Gila River watershed. Although the USDA Forest Service guide, "Geology of the Gila Cliff Dwellings," makes an attempt at quantifying the rate of downcutting based on the rate of the Grand Canyon of the Colorado River—that is, Cliff Dweller Canyon is at most 0.6 m (2 ft) deeper now than when the caves were occupied in the late 1200s (USDA Forest Service 2003)—long-distance comparisons and calculations can be spurious. Study of the Holocene floodplain in the monument would result in a more accurate interpretation of late-Holocene stability and downcutting.

Cave (Alcove) Features and Processes

In 1885 Army Lieutenant G. H. Sands described the cliff dwellings as "quite a long row of houses … set like a nest in the face of the wall." The dwellings are located in alcoves 55 m (180 ft) above the floor of Cliff Dweller Canyon. They are the reason Gila Cliff Dwellings National Monument was designated as part of the National Park System and are the only representative sites in the system of the major southwestern culture known as the Mogollon. Not all of the seven caves contain artifacts.

According to Ratté (1999), the alcoves were probably excavated by a combination of stream action and spring sapping. As discussed during the GRE field trip, exfoliation and rockfall also play a role in alcove formation. Where multiple cracks have formed concentric to the cave openings, for example, exfoliation is one of the major processes contributing to continued enlargement of the caves. As the stream in Cliff Dweller Canyon cut down through the Gila Conglomerate, it may have encountered a relatively soft layer and cut laterally through it, initiating alcove formation. In some places, for instance in the canyon of the Middle Fork, alcove formation occurred at the contact between the Bearwallow Mountain Andesite and the Gila Conglomerate (Jim Ratte, U.S. Geological Survey, written communication, March 3, 2008). A modern analog for alcove formation occurs near the bridge along the trail in Cliff Dweller Canyon. At this point the creek impinges on the rock and undercuts it at a bend in the creek. Water also seeps through the rock and weakens the natural cement in the conglomerate. With time and gravity, spalling and rockfall occur, allowing this alcove to increase in size. Perhaps this alcove will eventually reach the size of the alcoves where the Mogollon built their cliff dwellings, which extend back 30 m (100 ft) and are as wide as 45 m (150 ft).

Though a natural process, continued erosion in the alcoves is a safety concern and a management concern with respect to the protection of cultural resources. Rockfall and spalling inside the alcoves have the potential to impact cultural resources via exfoliation (and loss) of rock art (i.e., pictographs) or falling rocks onto structures. Relatively thin but large-diameter rocks (as large as 1.8 m [6 ft]) have fallen inside the alcoves during and since Mogollon occupation. Generally speaking, however, the 700-year-old soot on the walls indicates that the interiors have achieved a semblance of stability.

Climate Change

"A climate disrupted by human activities poses such sweeping threats to the scenery, natural and cultural resources, and wildlife of the West's national parks that it dwarfs all previous risks to these American treasures," so states the July 2006 report, "Losing Ground: Western National Parks Endangered by Climate Disruption" (Saunders et al. 2006). The authors contend that "a disrupted climate is the single greatest threat to ever face western national parks." Because of the potential disruption that climate change could cause to park resources, including geologic features and processes, the GRE Program has begun to include a discussion of the effects of climate change to park resources during scoping meetings. Participants at the scoping meeting for Gila Cliff Dwellings National Monument identified the following as possible outcomes of climate changes at the monument: (1) changes in flooding cycles, (2) increase in the number and intensity of monsoons, and (3) increase in the number and intensity of forest fires.

Cultural Resources Related to Geology

The connection between the Mogollon culture and geology at Gila Cliff Dwellings National Monument is undeniable and often indistinguishable. From the vantage point across the canyon, as shown on the front of the park brochure, the dwellings blend with the natural cave openings. Even at closer perspectives, visitors to the alcoves may find it difficult to distinguish where bedrock ends and architecture begins. Moreover, as if from the same color palette, the soot on the ceilings of the caves resembles the blackened watermarks on the cliff fronts, where running water has deposited thin coating of iron and manganese oxides dissolved out of the rocks and re-precipitated from solution as the water ran down the cliffs (Ratté 1999). The soot serves as an informal geologic dating method for determining rockfall events pre- or post-occupation 700 years ago. Though the caves do not show signs of onsite quarrying, the Mogollon used stone, clay, and calcium carbonate for mortar and building materials, and volcanic rocks for tools. They fashioned native rock as grinding stones and "cupules." One particularly interesting alteration, primarily in Caves 4 and 5, is the coating of uric acid, the same composition as kidney stones, on large, flat rocks; these surfaces may have been used during the tanning of hides (Sonya Burger, Gila Cliff Dwellings National Monument, personal communication during scoping, November 15, 2007). Park staff would find research conducted about various geologic materials (e.g., sources of clay and mortar) helpful in management and interpretation. Work by J. A.

Sandor and others provides information about the agricultural impacts and nutrient depletion of the soils 700 years after occupation (e.g., Sandor et al. 1986a, b, and c).

Geothermal Features and Processes

The Gila National Forest is known for its hot springs, with several within hiking distance of the visitor center. A few of the most popular are Jordan, Light Feather (Middle Fork), and Melanie (Gila River) hot springs (http://www.nps.gov/gicl/naturescience/hotsprings.htm). Light Feather is about a 20-minute walk and two river crossings away from the Gila Visitors Center along Trail 157. It is situated in a steep canyon and flows from the base of a hill into the Middle Fork of the Gila River. A travertine ledge sits 9–12 m (30–40 ft) above the present spring. This travertine could be dated using techniques developed at the University of New Mexico, Earth and Planetary Science Department; this would help determine when the canyon was cut (Dave Love, New Mexico Bureau of Mines and Geology, written communication, May 12, 2008). Jordan Hot Springs is about 10 km (6 mi) from the visitor center via Little Bear Canyon and 13 km (8 mi) via the Middle Fork route. The hot-spring pool is about 6 m (20 ft) in diameter, about 0.9 m (3 ft) deep, and has a water temperature of about 34°C (94°F). This is a very popular hot spring and many people use it (http://www.nps.gov/gicl/naturescience/hotsprings.htm). The 2.4-km (1.5-mi) trek to Melanie Hot Springs starts near Grapevine Campground. The trail makes six river crossings then hikers should veer left near the seventh and continue downstream for approximately 0.2 km (0.1 mi). According to a Gila Wilderness information sheet, "warm water cascades over the rock and collects in a very shallow pool at the base of the reddish cliffs" (Ransom 2006).

People have developed thermal wells in the area, for example, Doc Campbell's Trading Post and RV Campground. Doc Campbell's supplies domestic hot water and heating for a number of residences and other facilities (Ratté 2007). The natural hot water emerges from springs that are related to faults that bound the Gila Hot Springs graben (Ratté 2007). In 2002, the Oregon Institute of Technology prepared a report about the Gila Hot Springs, including geology and hydrogeology, and geothermal use (i.e., Witcher and Land 2002).

Park managers are interested in heating park facilities with heat pumps. Superintendent Steve Riley (Gila Cliff Dwellings National Monument) is working on a feasibility study, which he hopes will get funded. A research question related to the development of heat pumps is whether development would affect the amount and temperature of the water used for recreational bathing in the national forest.

Hillslope Processes

In addition to the spalling and rockfall that occurs as part of alcove formation, the mesa cliffs and canyon walls are susceptible to rockfall. Scoping participants observed two potential rockfall hazards along the Cliff Dwellings Trail near Caves 2 and 6. The potential hazards are large, jointed rocks along the cliff face where topple could be possible. Participants thought that the Cave-6 site looked potentially more hazardous than the Cave-2 site. Bruce Heise will discuss these hazards with Deanna Greco at the Geologic Resources Division; park staff is encouraged to submit a request for technical assistance to the division.

Jim Ratté (U.S. Geological Survey) keeps a notebook of information about Gila Cliff Dwellings National Monument. An entry on October 12, 2000, states: "Learned that a rock of small but dangerous size fell from cliffs close to a visitor prompting Doug Ballou, Monument Manager, to seek help in assessing rock fall hazard. As a result, Edwin L. Harp of USGS in Denver made a visit to the site and wrote a report dated August 25, (I assume that was 2001), recommending a scaling operation to remove some of the loose rock. His report cites exfoliation slabs as the main source of rock falls, probably small but could be deadly." Jim Ratté doesn't recall whether the scaling was ever done, but if so, it should be in the records at the monument. Furthermore, if the GRE Program needs a copy of Harp's report, and Steve Riley cannot find one, Jim may be able to provide a copy (Jim Ratté, e-mail communication, June 6, 2008).

Gila Cliff Dwellings: An Administrative History documents background information about rockfall hazards in the national monument. Chapter 6 highlights the various stages of stabilization projects in the monument's history. In 1985 Bruce Wachter, a contract geologist, examined the deterioration of bedrock in and around the caves (Wachter 1985). In 1989 the National Park Service addressed the identified rockfall hazards by removing benches along the trail and loose rock above the trail in hazardous areas (*Gila Cliff Dwellings: An Administrative History*, chapter 6, endnote 23).

Mass-wasting processes at the monument also include minor debris flows associated with flash floods: as water pours off the mesas during monsoon storms, waterfalls form, transporting water and debris onto trails. Additionally trail erosion and access up Cliff Dweller Canyon may increase sedimentation in the creek.

Paleontological Resources

In this volcanic setting, fossils are rare. However, unstudied pack rat middens occur in the alcoves, which may provide paleontological information for the past 20,000 years. Scoping participants suggested Ken Cole at the Colorado Plateau Cooperative Ecosystems Study Unit (CESU) in Flagstaff, Arizona, as a potential resource and possible investigator. Holmgren et al. (2003) may also be useful (Dave Love, New Mexico Bureau of Geology and Mineral Resources, written communication, May 12, 2008).

Seismicity

The Hot Springs graben and the "flaring" of faults around the caldera are related to Basin and Range faulting. Earthquakes have not been significant enough to cause offset in the Quaternary (1.8 million years ago to present time), but quakes of magnitude 2 or 3 on the Richter scale are fairly regular in the area; for instance, in 2007 two quakes estimated at magnitude 2.9 were felt in the national monument (Jim Ratté, U.S. Geological Survey, written communication, March 3, 2008). The most-significant recent activity was during the 1930s when a series of magnitude 5.5 quakes occurred and became known as the "Mogollon Mountain Swarm" (Taggart and Baldwin 1982).

Unique Geologic Resources

Unique geologic resources include natural features mentioned in a unit's enabling legislation, features of widespread geologic importance, geologic resources of interest to visitors, and geologic features worthy of interpretation. The GRE Program also considers type localities and age dates as unique geologic resources. At Gila Cliff Dwellings National Monument, unique features include the following:

- The contact between the Gila Conglomerate and Bear Mountain Andesite
- The spring and associated perennial stream in Cliff Dweller Canyon
- The cave system, i.e., the size and number of caves (alcoves) within the Gila Conglomerate
- The number (possibly six) of river terraces in such a small area (at confluence of West Fork and Middle Fork) and in such a small canyon
- Volcanic features such as ignimbrites (e.g., Bloodgood Canyon Tuff). Ignimbrites are rock formed by the widespread emplacement of ash flows and swiftly flowing nuées ardentes.
- Sandstone dikes in the Wall Lake Dacite (see Ratté 2007)
- Basin and Range grabens (e.g., Hot Springs graben)
- Paleo-liquefaction (transformation of loosely packed sediment into a more tightly packed fluid mass as a result of sudden shocking) recorded in the rock record, possibly a result of Basin and Range faulting in the sediments above the lava flows; clasts may be large, including blocks of Bloodgood Canyon Tuff (up to 33 cm [13 in] in diameter) (see Ratté 2007)

Each of these unique resources will be highlighted in the final GRE report, along with others identified during research of the scientific literature pertaining to Gila Cliff Dwellings National Monument.

Volcanic Features and Processes

Gila Cliff Dwellings National Monument is located in one of the world's great volcanic provinces (Ratté 1997). In the Gila region, the volcanic rocks are part of the mid-Tertiary Mogollon-Datil volcanic field, which covers several thousand square miles in southwestern New Mexico and southeastern Arizona. The entire province extends from northern Mexico to Colorado. Lava has erupted as recently as 11,000 years ago in the vicinity of the national monument (e.g., southeast of Deming) (Parent 2004). The present landscape is largely a result of erosion and faulting of the original volcanoes and deposition of the eroded material by streams in local sedimentary basins.

Two collapse calderas formed in this area 28 million years ago: the Gila Cliff Dwellings and Bursum calderas. The Gila Cliff Dwellings caldera is about 24 km (15 mi) in diameter with its center estimated about 5–6 km (3–4 mi) west of the mouth of Cliff Dweller Canyon and its buried eastern margin somewhere near the Gila Hot Springs and Doc Campbell's Trading Post, 5–6 km (3–4 mi) down river. It probably collapsed in response to the eruption of one of the widespread welded tuffs in the area. The Gila Cliff Dwellings caldera is thought to be filled with 305 m (1,000 ft) or more of Bloodgood Canyon Tuff, which was erupted from and caused the collapse of the slightly younger—but also dated as 28-million-year-old—Bursum caldera.

The Bursum caldera formed at almost the same time as the Gila Cliff Dwellings caldera. It is nearly 40 km (25 mi) across and covers the western half of the Gila Wilderness. This huge caldera intersects and overlaps the western margin of the Gila Cliff Dwellings caldera at Hells Hole, about 16 km (10 mi) up the West Fork of the Gila River from the mouth of Cliff Dweller Canyon. It formed by collapse after the eruption of the Bloodgood Canyon Tuff. The sanidine crystals used to date the tuff "flash" blue in the sun and are better known to the public by its common name "moonstone."

The dark-colored lava flows of the Bearwallow Mountain Andesite contain vesicles that are often lined with zeolites. Tiny green pyroxene crystals in the uppermost flow, the Wall Lake Latite, distinguish it from the underlying Bearwallow Mountain Andesite. Scoping participants observed the Wall Lake Latite exposed on the hillside above Geronimo's birthplace. In this location, faulting has offset it. This locale may also be a unique cultural site; ancestors of Geronimo believe the legendary leader was born here.

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