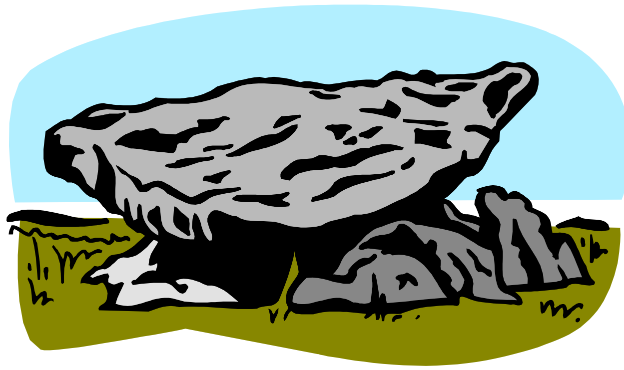


GEOLOGY OF THE GILA CLIFF DWELLINGS

With observations keyed to the sign posts of the

GILA CLIFF DWELLINGS TRAIL GUIDE

Gila Cliff Dwellings National Monument and the surrounding Gila Wilderness are located in the southern Rocky Mountains volcanic province, one of several major volcanic terrains of middle Tertiary age in western North America. This province extends from the southern Rocky Mountains in Colorado to the Sierra Madre Occidental in Mexico. Many episodes of volcanic eruption, faulting, and erosion have alternated through millions of years to form the landscape before you.

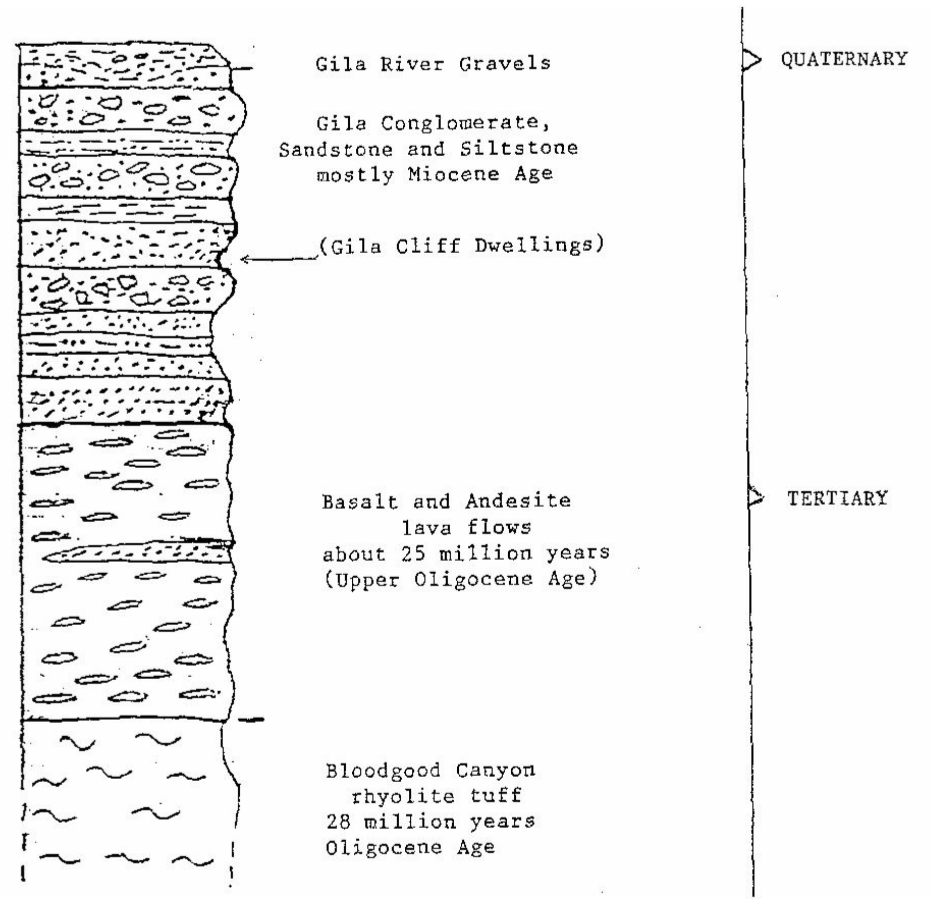
You are standing within, and near the eastern margin, of a large volcanic collapse structure called the Gila Cliff Dwellings caldera. Collapse calderas such as this are formed by the rapid eruption of enormous amounts of pumice and ash which spread for tens of miles across the surrounding area. The removal of such a great volume of magma from a subsurface magma chamber, in a period of only days or weeks, removes support from the chamber roof, causing it to collapse into the magma chamber, in this case leaving a depression or caldera hundreds of feet deep and approximately ten miles across. These events took place about twenty eight million years ago and were followed by more eruptions that filled the caldera so that the depression is no longer present. Faulting and erosion have further modified the land to form the present landscape.

The geologic materials that you see at the mouth of Cliff Dweller Canyon include three bedrock formations plus the floodplain sediments that are being deposited today along the West Fork of the Gila River. Each year, seasonal floods deposit sand and gravel over the banks of the river and occasionally large floods uproot trees and destroy bridges. Meanwhile, the river continues its main work of wearing away the hillsides and mountains and transporting the eroded rock debris downstream and eventually to the ocean.

- **Parking Lot**

The white outcrops in the lower cliff on the north side of the parking lot are called Bloodgood Canyon Tuff, (BCT), named for the Bloodgood Canyon, which is on the other side of the ridge at the head of Cliff Dweller Canyon. The BCT is 28 million years old and is the formation that erupted and filled the Gila Cliff Dwellings caldera after it collapsed. Only the upper 50 feet or less of the tuff is seen at the parking lot, but holes drilled downstream near Doc Campbell's Post, during exploration for hot, geothermal water, have shown that the tuff is about 600 feet thick. Upstream along the West Fork of the Gila River, where the tuff outcrops rise higher and higher above the surface, it forms cliffs up to 1100 feet high and the bottom of the tuff still is not visible.

The Bloodgood Canyon Tuff was produced by a special kind of extremely explosive volcanic eruption during which a huge column of pumice and ash collapsed, the pyroclastic materials piled up at the base of the eruption column, and then rushed out over the surrounding countryside at speeds up to 100 km or 60 m per hour. The pumice and ash formed a sheet up to hundreds of feet thick, which thins away from the eruptive vent or vents. Such ash-flow sheets, or ignimbrites, make up very low profile dome-shaped volcanoes, which with their typically collapsed caldera vent areas, are very different from the classical, high, symmetrical, cone-shaped volcano.



Tuffs, such as the BCT, are also described by geologists and volcanologists as ash-flow tuffs, pyroclastic flows, ignimbrites, and welded tuffs to distinguish them from the somewhat less catastrophic tuffs formed as fallout from ash clouds that are dispersed in the upper atmosphere. Pyroclastic flows, or ash-flow tuffs, are a mixture of hot pumice and ash particles enclosed in a cloud of fiery hot gases, which not only increases their mobility, but also saves much of the original heat of the eruption, which results in welding together of the pyroclastic fragments after they are deposited, if the temperature has remained above about 600-750 degrees Centigrade. Depending upon the temperature, and the pressure of overlying material, welding can be quite varied throughout a deposit, and there can be a complete range from non-welded tuff to completely welded tuff. The BCT at the north side of the parking lot is moderately welded, as determined from the partially flattened pumice fragments that give the tuff a weakly layered or foliated appearance. This rock contains rounded, glassy crystal of quartz and rectangular glassy to dull white crystals of feldspar of the variety called sanidine. The crystals are mainly less than 1/10th of an inch (2-3 mm) across. When the sun reflects of these rocks, some of the sanidine crystals show a satiny sheen or even a blue color if the light is just right, and this gives rise to the name “moonstone.” Therefore, the BCT is commonly referred to as “moonstone tuff.” However, not all “moonstone” tuff is BCT.

Quartz and feldspar crystals and rare black biotite (mica) crystals make up only about 10-15% of the tuff – the rest consists of microscopic shards of glass and more or less flattened chunks of white pumice generally less that an inch or two (1-3 cm) long. The total rock is called rhyolite, which is a volcanic rock that contains more than about 70% silica (quartz is made of silica). Rhyolite is commonly a light colored rock because it contains very little iron or other constituents that form dark minerals. Exceptions are obsidians, which are glassy rhyolites that contain iron-bearing minerals that are so widely distributed throughout the glass that it has dark, even dense black, colors.

BCT is not visible along the trail in Cliff Dweller Canyon, but keep your eyes peeled for tiny blue moonstones in the gravel along the trail. If you were to shine a flashlight on the river bottom at night you might see blue flashes from the moonstones.

Above the BCT at the parking lot, dark gray to reddish-brown basaltic to andesitic lava flows about 100 feet thick are in turn overlain by light-brown, bedded sedimentary rocks consisting of sandstone and conglomerate, commonly referred to as Gila Conglomerate. This is composed of grains, pebbles and boulders that have been eroded from the surrounding volcanic mountains and then transported and deposited by streams. The Gila Conglomerate is described as a volcaniclastic deposit because the sedimentary materials have all come from the erosion of volcanic rocks.

Looking at the cliffs on the south side of the river at the mouth of Cliff Dweller Canyon, you will see the same sequence of Gila Conglomerate overlying the basaltic lava flows. However, the BCT is out of sight below the river level, but can be seen on the south side of the river a short distance upstream.

Keep this rock sequence in mind as you follow the trail to the cliff dwellings. The lower part of the trail is in the basaltic lava flows. We do not have a chemical analysis of the flows here, which is why we hedge on their composition, but we know that similar flows in this area range from andesite to basalt, which contain only about 50-58% silica, in contrast to the 75% silica in the BCT, which we call a rhyolite. Also, unlike rhyolite, the andesitic flows contain an abundance of dark, iron-bearing minerals.

The basaltic or andesitic lava flows here have not been dated. We do know that they are younger than the 28 million year old BCT. A good date on the lava flows would give us a maximum age of the lower part of the Gila Conglomerate. However, similar lava flows in this same position in the rock sequence nearby are about 25-26 million years old, so these flows are probably about the same age.

- **Between Marker 1 and Marker 2**

Here you can see a number of features characteristic of basaltic and andesitic lava flows such as vesicles and amygdules (pronounced am-ig-dules). Vesicles are small holes present in the lava flows. They are formed when gases that were dissolved in the lava tried to escape under the low pressure conditions at the surface. Gas tends to rise toward the surface of a lava flow, is concentrated there, and the vesicles show where one flow stopped and another began. Vesicles that are filled with minerals crystallized from the gaseous solutions that were trapped in the vesicles are called amygdules. Calcite, quartz, and zeolites are the mineral most commonly present in amygdules. Some of the zeolites present in amygdules here can be recognized by their radiating crystal form.

- **Marker 4**

Look on the right side of the trail for evidence of more than one lava flow where the Gila Conglomerate overlies one flow and separates it from another flow that pinches out within the conglomerate.

- **Marker 5**

Erosion by Cliff Dweller Creek has started to form small caves along the contact between hard lava beneath and softer conglomerate above. However, the larger caves above, where the cliff dwellings were built, were eroded above the contact between the conglomerate and the harder lava flows.

- **Beyond Marker 5**

Watch for moonstones sparkling in the gravel along the trail. All the moonstone-bearing BCT is below at the river level. So where do the moonstones come from? The answer is found by looking at the Gila Conglomerate in the boulders beside the trail between Marker 6 and Marker 7 and in the cliffs above. It contains some pebbles and boulders of dark basalt, but most of the conglomerate consists of large and small pieces of the Bloodgood Canyon "moonstone" Tuff. This tells geologists that the land that was being eroded by the streams that deposited the Gila Conglomerate was covered mainly by BCT. In other words, the source of the conglomerate was right in this area.

- **In front of Cave 1**

Here is a good place to look over the canyon and think about some of the other geological questions which are commonly asked, such as:

When was Cliff Dweller Canyon formed and how long before the dwellings were built were the caves formed?

How much deeper is Cliff Dweller Canyon now than when the cliff dwellers lived here?

If we make the assumption that the caves began to form when the canyon was only as deep as the level at the bottom of the caves (following the suggestion that the caves were started by lateral cutting of the stream into the side of the canyon as at Marker 5), then we know that the canyon has been cut about 175 feet deeper since then. To answer the question then of when were the caves formed, we need to know the average rate of down cutting or erosion. If we had a date on the age of the basaltic flows at the base of the conglomerate and another dated lava flow or ash bed higher in the conglomerate, we could calculate an average rate of down cutting in Cliff Dweller Canyon. Lacking that information, we have to use an average rate of down cutting from somewhere else, such as the Grand Canyon of the Colorado River, where it is known that it has taken about 10 million years to excavate the canyon to a depth of about 1800 meters or 5670 feet. Doing a little arithmetic shows that this is an average rate of down cutting of about 0.2 mm or 0.0008 inches per year. At this rate it probable took 266,700 years to deepen the canyon from the level of the caves to the present level. This means that the caves began forming sometime in the late Pleistocene Period and the canyon is probably only a few inches to a foot or two deeper now than when the caves were occupied 700 years ago in the late 1200's. Once started by stream action, the caves continued to be enlarged by weathering processes, as continues today. Exfoliation, which is one of the major processes contributing to continued enlargement of the caves, can be seen clearly where multiple cracks have formed concentric to the openings.

- **Down trail**

From the cliff dwellings, the trail continues back to the parking lot by an upper route that provides good view and additional geologic features along the contact between the top of the lava flows and the overlying Gila Conglomerate adjacent to the trail. As you descend the steps beyond Cave 6 there are good exposures of the basaltic lava showing the concentration of vesicles and amygdules at the top of the flow. Also visible is the contact zone where sandstone was deposited directly on top of and mixed with angular blocks of basaltic rubble derived by weathering of the upper part of the flow. In some places you can see where the sand filtered down into cracks below the surface of the flow.

Note the irregular bedding and mixture of course and fine materials in the conglomerate, which is characteristic of deposits formed by streams exiting the mountains and depositing their sediment loads in fans.

- **Marker 18**

This is a good viewpoint from which to see across the valley of the West Fork of the Gila River and see the rocks in the two small, conical hills near the parking lot. Both hills are capped by Gila Conglomerate, which overlays dark, basaltic flows that make up most of the two hills. A thin, white stripe of BCT can be seen at the base of the hills. Look for a fault line that runs behind the hills. Look past the hills and you will see only Gila Conglomerate to their right. This means that, whereas you can see the bottom of the Gila Conglomerate on top of the two small hills, behind them the bottom of the conglomerate has dropped down below ground level. Starting at the Scorpion Campground, at the east end of the hill on the right, the fault follows along behind the other two hills.