El Morro

National Park Service
U.S. Department of the Interior

El Morro National Monument

Geology

Geology 101

The geology of Inscription Rock made it possible for travelers to leave their lasting legacy etched into the sandstone. The stone, known as Zuni Sandstone, is a deposit of wind–blown sand of Jurassic age (about 170 million years old). The details of the geology add background to the stories we read from the inscriptions and from the remains of ancient dwellings found here at El Morro.

Why is Inscription Rock so easy to inscribe?

Zuni Sandstone is only held together by clay between the sand grains; it is not cemented at all.

The Zuni Sandstone was never buried so deeply that sand grains were squeezed tightly, fusing the grains together. Instead, below the water table, where the subsurface water chemistry was quite alkaline, some sand grains were dissolved and reprecipitated as a weak cement around the remaining grains. When the alkaline ground water dissolved these grains, it also precipitated a clay mineral called *kaolinite* in the minute spaces between the remaining quartz grains. This clay is the only thing that binds the sandstone together. Scratching on the sand easily dislodges sand grains from the rock.

Although it may be easy to carve, this irreplacable natural and cultural wonder is protected by the National Park Service as it is. It is illegal to carve or write anything on Inscription Rock.

Some of the inscriptions are finely detailed. Does the rock type have something to do with that?

Yes. The sandstone grains are very uniform in size and they are very small. You can imagine that a gravel deposit could not be inscribed so finely.

The Zuni Sandstone has been interpreted as a wind-blown or *eolian* deposit. As is typical of most wind deposits, the sandstone is composed of very fine to fine grains (more than 10 grains fit in a millimeter). That's because wind generally blows away the finest dust, clay and silt particles but cannot transport heavier, coarse–grained sand, pebbles or cobbles. The result is that eolian deposits like the Zuni are well sorted—the grains are all about the same size and are quite small.

The combination of fine, evenly sorted, and weakly cemented grains has created a smooth texture that was well–suited to finely detailed carving.

Why is the Zuni Sandstone believed to be a wind–blown deposit?

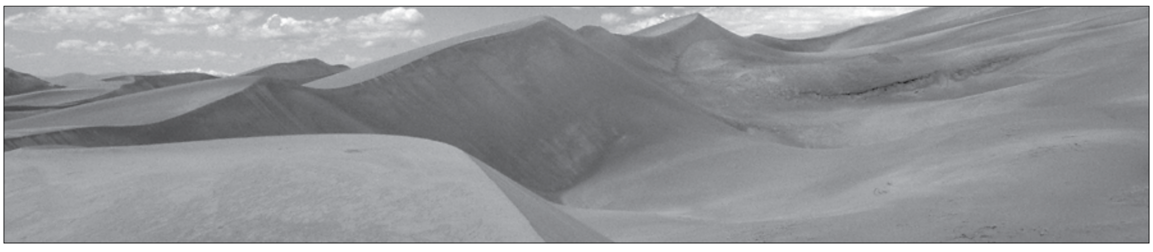
Thick sets of inclined beds, uniform small sand grains, lack of coarse pebbles or fine shale beds and lack of fossils all indicate that the Zuni is a desert sand deposit.

The sweeping bedding planes are known as cross-beds. They are produced as wind (or water) transports sand grains up and over a dune or a ripple. The steep leeward faces of the dunes or ripples are preserved as cross-beds in the final sandstone deposit. The windward or upstream side of the dune, being continually attacked and eroded, is rarely preserved in the final deposit.

Wind–blown dunes tend to be taller than water–laid cross-beds. The El Morro cross-beds are thick like desert dune deposits. By noting the direction of inclination of the cross-beds, you can determine that the ancient wind direction at El Morro was from the northeast.

You may also see that the cross-beds are sandwiched between persistent, relatively flat horizons spaced several meters apart. The flat enclosing surfaces indicate that the tilted beds are cross-beds and have not been tilted by mountain building.

The Zuni Sandstone was deposited in a Sahara like desert, not in a coastal or lakeside dune field. Zuni Sandstone and equivalent sandstones with different names are found throughout the Colorado Plateau.



El Morro is surprisingly vertical. Doesn't erosion tend to crumble cliffs?

The Zuni Sandstone is broken by large vertical fractures called *joints*. When erosion occurs, whole slabs on one side of a joint fall off and the cliff remains vertical.

Joints may have expanded as the Zuni Sandstone was uplifted and confining pressure was removed. The beginnings of the joints may have occurred while the sandstone was buried and squeezed horizontally. The stress may have been related to drift of the North American continental plate or to more local uplift of the Zuni Mountains. Under constant pressure the rock adjusted its shape, relieving the stress by fracturing vertically in two directions. At El Morro the main joints are oriented east-northeast; others are oriented almost north.

Much of the erosion at El Morro is probably related to the freezing and thawing of water that has seeped into the joints. Freezing water expands 10 percent, exerting pressure on the joints. Plant roots seek water in the joints and as they grow they exert their own pressure on the joint walls. A block that is sufficiently weakened may fall during an earthquake or even during a strong wind storm.

When one side of a joint does fall, the collapse leaves behind the vertical opposite side of the joint. The spire of rock in the box canyon was probably bounded by joints. The spire has been left as the outer joint walls fell away.

How did that box canyon form inside the mesa?

Although some rainwater drains off the edge of the cliff to fill the pool, most drainage is down the gentle backside of the cliff. This runoff is eroding the box canyon.

El Morro is a flat–topped mesa, gently tilted about 3° to the southwest. Because of the tilt, it is called a cuesta. Due to much greater surface area tilted south west, the majority of runoff flows that direction. Initially, a weak area to the southwest on the cuesta eroded into an indentation. Continued runoff focused on that indentation and has caused the canyon to enlarge back into the cuesta. The box canyon is still eroding and enlarging headward, toward the cliff edge. In the geologic future it will break through to leave standing two fins of rock.

At the head of the box canyon, the most recently developed part, the southwest orientation is composed of segments of east-west mini-canyons that are controlled by the direction of the main joints.

Why is there a pool here in this arid land?

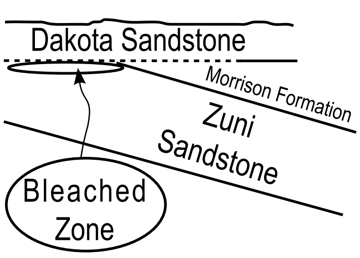
The pool catches and holds rainfall and snow melt from the bluff top. It is naturally sealed and the alcove is shaded and cool, reducing evaporation.

The original pool was likely a basin hollowed out by cascading water from above. The lip of the hollow basin formed a natural dam. Clay from the sandstone filtered out of the standing water and lined the pool, effectively sealing it against leakage through the porous bedrock.

Whether or not the pool is fed by a spring is the subject of current research. The water chemistry suggests the pool water is just rainwater and runoff, but the constancy of the water level could indicate that it is also fed by a spring connected to ground water.

The ruins atop El Morro indicate that there must have been sufficient water to sustain the residents of the pueblo for a time. If you lived here then, wouldn't you have enlarged the pool with a small dam? The Puebloans may have. In fact, the first caretaker of the Monument found the remains of an old dam when he deepened and dammed the pool in the 1920s. When a large rock fall destroyed that dam in 1942, a new dam was constructed and now encloses the pool.

What is the very white rock on top of the bluff?



The bleached zone is part of the Zuni Sandstone that was deeply weathered before the uppermost sediments now found on the mesa were deposited.

The sediments on top of El Morro are pebbly Cretaceous Dakota Sandstone. In this area the Dakota usually lies above Jurassic Morrison Formation, but not here. Because the Morrison is missing, there must be an unconformity at the top of the Zuni. An unconformity means that there was a period of time (perhaps 50 million years) during which there was active erosion and weathering.

The weathering process especially attacked green clay minerals and feldspar, altering them to white kaolinite clay. In addition, iron was dissolved and percolated down to be redeposited as the dark crusts and the bands of color (Liesegang banding) parallel to joints lower down in the Zuni Sandstone.

Both the removal of iron and alteration of the green clay produced the white bleached zone. This zone is now being weathered a second time. Below the bleached zone the sandstone retains some chlorite clay that gives the rock a light yellowish-green cast.

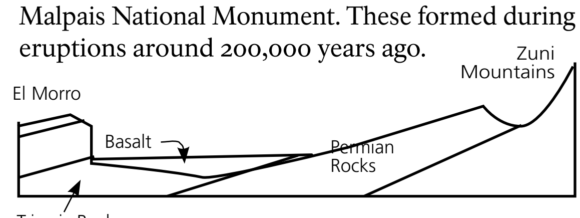
What am I seeing in the view from the top of the mesa?

The dark hills to the north are the granite–cored Zuni Mountains. The valley just below El Morro is underlain by soft Triassic Chinle Shale, but was recently buried under basalt flows from volcanoes to the east.

The formation of the Zuni Mountains includes more than one period of uplift. They were high and above sea level until they were buried by sediments in Permian time. Mesozoic rocks accumulated over the Permian limestone. After deposition of Cretaceous rocks (including the Dakota Sandstone at the top of El Morro) the Zuni Mountains were elevated again. Erosion related to that uplift has produced the valley north of El Morro and the exposure of the Zuni Sandstone cliffs.

Volcanic eruptions about 100,000 years ago spread a veneer of basalt over the El Morro valley floor. If you would like to see some basalt up close, stop at the pullouts along the park entrance road; basalt was used to construct the walls.

In the distance to the east you can see cinder cones found in the Chain of the Craters area of El Malpais National Monument. These formed during eruptions around 200,000 years ago.



Geologic cross section

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