"What a conflict of fire and water!" - Interactions between volcanism and the Colorado River

Ryan Crow, Karl Karlstrom, William McIntosh, Lisa Peters, and Laura Crossey

Floating through the Lava Falls area it is easy to picture, as Powell did, "…a river of molten rock running down into a river of melted snow." While basalt clinging to the canyon walls, lava frozen in descent, provides a dramatic and very visual record of the lava dams that must have formed there, many questions about the area's most recent volcanic history remain incompletely answered: When did these eruptions occur? What was the structure and extent of the different lava dams? How did the dams fail?

View of Vulcan's Throne (cinder cone), lava cascades, and horizontal flow remnants at the canyon's bottom near Lava Falls rapid. The photo was taken from a cinder cone fragment on the south rim.

While the erosive Colorado River removed much of the lava dams soon after their formation, a number of volcanic features remain, offering important clues into the area's past. High on the rim and in some cases down in the Canyon, cinder cones record the locations of volcanic vents and the source of lava flows. Dikes, plugs, and sills remain as the crystallized plumbing of those vents. Lava cascades show us where lava flows poured into the Canyon from the rim. Horizontal flow remnants at the Canyon's bottom are the remains of dissected lava flows that traveled downstream, confined to the river corridor.

An important first step in unraveling the area's volcanic history is the correlation of these features which allows us to reconstruct the structure and extent of the lava dams and relate them to specific lava cascades and vents. In order to do this we have mapped the Canyon's volcanic features in three-dimensions, dated them using a naturally-occurring radioactive "clock" (Ar-Ar dating), and "fingerprinted" them using their geochemistry.

Through our work, we have identified key episodes in the area's volcanic history. The oldest known volcanic features in the Lower Gorge are approximately 600,000 to 500,000 years old, which is significantly younger than the 1-2 million year ages previously reported using the older K-Ar dating method. Most of the eruptions during this episode occurred in the Lava Falls area. Lava poured into the Grand Canyon from both rims and erupted inside the Canyon at places like Vulcan's Anvil. These lava flows were some of the most voluminous to reach the Grand Canyon and traveled at least 130 km (80 miles) downriver, choking the canyon with lava and cinders. While early workers thought that the most far-traveled flow, which they called Black Ledge, was a separate flow, we suggest that they are actually parts of some of the same flow which emanated from Vulcan's Anvil and left large remnants immediately above Lava Falls rapid on river right. Almost all of the basalt in Prospect Canyon dates from this same oldest period of volcanism as well.

Around 300,000 years ago volcanism started again with eruptions concentrated in Whitmore Wash. Multiple flows traveled down that side canyon, filling it and partially filling the Grand Canyon.

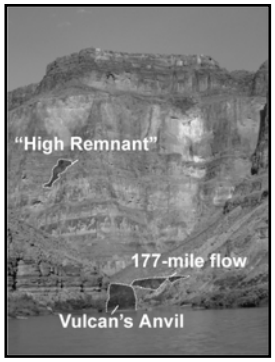
Approximately 200,000 and 100,000 years ago, the youngest known lavas entered the Canyon from the north rim. Cinder Cones between Vulcan's Throne and Whitmore Wash erupted, sending lavas cascading into the Canyon at multiple locations. These youngest flows have been called "Gray Ledge." Devil's Ramp, at river mile 184.5, is likely an example of one of these young cascades.

Many, starting with Powell, have wondered how long these lava dams would have lasted. Would it have take tens of thousands or just a few years for the Colorado River to cut through them? Recently Cassandra Fenton and others have found outburst flood deposits on top of some basalt remnants indicating that some lava dams failed catastrophically. However, at downstream locations, like Spencer Canyon (RM 246), basalt remnants have potholes, filled with typical Colorado River gravels, cut into their top. This indicates that the downstream parts of some lava dams were stable enough for the Colorado River to establish itself on top of them. Field mapping also indicates that the upstream parts of lava dams were likely much less stable than the far-traveled parts. Upstream parts of lava dams show evidence that they were weakened as they were quenched by Colorado River water. In some cases, volcanic debris from erupting cinder cones was incorporated into the upstream portions

of lava dams which would have further weakened those areas. Dams may have failed in multiple stages, with early catastrophic failure of the unstable upstream parts of dams and more gradual removal of the more stable downstream parts.

River Log of Interesting Young Volcanic Features

River Mile 176.9 on the left - "High Remnant"
Look hard - about 300 meters above river level is a basalt remnant that rests on volcanic cinders. We climbed up there to get a sample and dated it at approximately 610,000 years old. Since it's upstream from all the major cinder cones and lava cascades, it must be the remains of a lava flow that traveled upstream when the Canyon was half choked with cinders and lava.



River Mile 177.3 on the left - "177-mile flow"
Tens of meters above river level on the left is a basalt remnant that flowed upstream from an unknown source. If you walk along the base of the flow you can find large pillow-like structures on top of Colorado River gravel and sand. These formed when hot lava was cooled quickly by river water or wet river sand. The remnant is approximately 350,000 years old. The age of the flow and the height of the gravels yield an incision rate of 145 meters per million years – that is equivalent to the thickness of a sheet of paper each year.

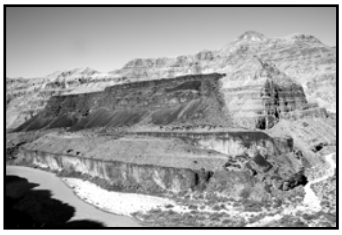
River Mile 178 - Vulcan's Anvil
Most agree that Vulcan's Anvil is a volcanic plug, the plumbing of an ancient volcano. New Argon-Argon dating indicates that it is about 600,000 years old. Its chemistry is similar to the similarly-aged, far-traveled Black Ledge remnants that flowed 130 km downstream. We think the flows at Granite Park and across from Spencer Canyon may have originated here.

River Mile 179 on the right - Toroweap Fault
The Toroweap fault cuts young basalt flows and gravels showing that this fault has been active in the recent geologic past. It has also affected Grand Canyon incision. Above Toroweap fault, incision rates are about 162 meters per million years; downstream of the fault, incision rates are about 66 meters per million years. The fault is lowering the downstream block about 100 meters per million years, accounting for the difference in incision rates.

River Mile 187.6 on the right - Whitmore flow stack

Over fifty thin flows filled the paleo-Whitmore Wash diverting flow to its present downstream location. The top flows, which are approximately 200,000 years old, covered the lower ones which may be up to 300,000 years old. Since these flows effectively filled the side canyon to its brim, we also think (as did Kenneth Hamblin) that it filled the main canyon and created the Whitmore dam.

River Mile 188.2 on the right - Youngest known intra-canyon flow



Immediately in and downstream of Whitmore Wash are three separate flows which have been inset into each other. Recent dating efforts show that the middle flow is the oldest, at about 610,000 years old. The topmost flows, which resemble those of the Whitmore flow stack, are about 320,000 years old. The lowest flow is one of the youngest known flows in Grand Canyon. It is approximately 100,000 years old and was inset into the eroded remains of the older flows after the Canyon had been carved a little deeper.