Yellowstone's Supervolcano Gets a Lid

The giant volcano lurking under the state of Wyoming might not have originated from a rising plume of hot rock, as previously thought

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Simmering deep below the geysers and hot springs of the Yellowstone caldera is a dormant supervolcano—a powerful behemoth with the ability to blanket the western U.S. with many centimeters of ash in a matter of hours. What could spark such a powerful eruption? Scientists have long debated over the origins of Yellowstone's supervolcano, with the most widely accepted idea suggesting that it was formed by a mantle plume—a column of hot rocks emerging from our planet's core. But a new simulation shows that the conventional wisdom was wrong. The plume could not have reached the surface because it was blocked by a slab from an ancient tectonic plate.

The simulation results of the model, which is the first to replicate the complex interaction between a mantle plume and a sinking slab, was detailed last month in Geophysical Research Letters. Lijun Liu, a geologist at the University of Illinois at Urbana–Champaign, and his graduate student Tiffany Leonard built the model to replicate both the plate tectonic history of the surface and the geophysical image of Earth's interior. "No one had modeled it this vigorously," says Brandon Schmandt, a geologist at the University of New Mexico who was not involved in the study. Not only did Liu and Leonard create a three-dimensional view of Yellowstone's underbelly, they did so over the past 40 million years in an attempt to re-create the eruptions that have dotted the U.S. from Oregon to Wyoming.

No matter how they tweaked the parameters, Liu and Leonard could not re-create most of the recent eruptions. The reason is simple: "Slabs are the bully," says Eugene Humphreys, a geophysicist at the University of Oregon who was also not involved in the study. "Plumes are just pretty wimpy in comparison."

The slab in question was driven deep into Earth's mantle about 100 million years ago when the Pacific and North American plates began converging. Like a canoe paddle pushing through water, the mantle flows around the sinking slab causing pressure to build toward the front. But 15 million years ago the model shows that the pressure difference became too much to bear and the slab began to tear. The plume below pulsed through the slab, leading to massive outpourings of magma, the pattern and timing of which appear consistent with the Steens–Columbia River flood basalts, which spewed out one million times more molten rock than the 1980 Mount Saint Helens eruption.

But that's where the similarities between the model and geologic surface features end. Despite the gaping hole in the center of the sunken slab, the plume did not continue to rise through it. That is because the mantle is more like honey than water—it's highly viscous. So as the slab continued to sink, it pulled the surrounding mantle down with it, ultimately sealing the hole and blocking the plume from reaching the surface for the next 15 million years. The favored hypothesis cannot explain the string of volcanic eruptions since those first flood basalts, including the formation of Yellowstone's caldera, which happened only 2.1 million years ago. "Ultimately, we need a new explanation for Yellowstone's formation," Liu says.

In other words, the team needs to find an additional heat source. Leonard thinks this could come from the Juan de Fuca Ridge—a jagged volcanic seam where magma oozes up between spreading plates to create a new seafloor—in the Pacific Ocean. Although that's almost 1,600 kilometers away from Yellowstone's hotspot today, the ridge can easily affect the middle of the North American Plate. Because it lies just slightly west of the Cascadia subduction zone, the young seafloor is easily shoveled east beneath the North American

Plate. So it is likely that some event, millions of years ago, spurred a lot of heat within the Juan de Fuca Plate, which was then shoveled underneath the North American Plate and swept along with that string of volcanic eruptions until it eventually helped form Yellowstone's gaping caldera in the Rocky Mountains.

Although scientists will continue to argue over Yellowstone's murky origin, the model makes it clear that slabs are much more important than previously thought. "It's like smoke from a chimney that's getting swept up in some sort of windstorm," Humphreys says. "But it's not this vigorous plume that just blasts through everything."