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Like a molten pancake: A new model for shield volcano eruption

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There are some large shield volcanoes in the world's oceans where the lava is usually not ejected from the crater in violent explosions, but flows slowly out of the ground from long fissures. In the recent eruption of the

Sierra Negra volcano in the Galapagos Islands, which lie just under a thousand kilometers off South America in the Pacific Ocean, one of these fissures was fed through a curved pathway in June 2018. This 15 kilometer-long pathway, including the kink, was created by the interaction of three different forces in the subsurface, Timothy Davis and Eleonora Rivalta from the GFZ German Research Centre for Geosciences in Potsdam, together with Marco Bagnardi and Paul Lundgren from NASA's Jet Propulsion Laboratory in Pasadena, now explain based on computer models in the journal *Geophysical Research Letters*.

Even before the eruption, the geoscientists in California had seen in radar satellite data that the surface of the flank of the 1140-meter-high Sierra Negra volcano had bulged to a height of about two meters: this bulge, about five kilometers wide, stretched from the crater rim about ten kilometers in a west-northwest direction and turned at a right angle to the north-northeast near the coast. Timothy Davis and his team then found out what this structure and its perplexing bend were all about with the help of computer models.

Driving Force 1: Hotspot beneath the Galapagos Islands

As with many other volcanoes in the middle of the world's oceans, a "hotspot" is hidden beneath the Galapagos Islands. For at least 20 million years, hot rock has been rising slowly from deep within the Earth's interior, like a solid, but difficult-to-form plasticine. Like a blowtorch, this hotspot, up to 200 kilometers wide, melts its way through the solid crust of the Earth. This hot magma is a little lighter than the solid rock around it, so it keeps rising until it collects in a large cavity about two kilometers below the crater of the Sierra Negra volcano. "With a diameter of around six kilometers and a thickness of no more than one kilometer, this magma chamber resembles an oversized pancake of molten rock," Timothy Davis describes this structure.

Driving Force 2: The weight of the volcano rock

In the almost 13 years since the last eruption in October 2005, more and more magma has flowed into the chamber from below. There, the pressure rose and lifted the crater floor up to 5.20 meters. However, the enormous force of the gathering magma masses sought another way out. Deep underground, the viscous rock slowly crawled in a west-northwest direction. Another force plays an important role here: the enormous weight of the volcano's rock masses presses from above on the magma flow that is just forming. As the shield volcano becomes flatter and flatter towards the outside, the pressure there also decreases. As the molten rock is pressed in the direction with lower pressure, it slowly swells outwards in a magma flow that is four kilometers wide but only about two meters high.

Driving Force 3: Buoyancy

Near the coastline, the flattening shield volcano presses ever more weakly on the now almost ten-kilometer-long magma corridor deep below the surface. There, a third force gains the upper hand. The magma is much lighter than the rock around the passage and was previously only prevented from swelling by the overlying weight of the shield volcano. Near the coastline, however, this buoyancy becomes stronger than the pressure of the rock from above. On top of that, the magma slope there tilts about ten degrees into the depths. Together, these forces change the direction in which the viscous rock is pressed and the magma slope bends towards the north-northeast.

The rock cracks, the volcano erupts

Still, the magma swelling under the crater continues to increase the pressure until the upward-pressing molten mass begins to crack the rock around the magma passage. At no more than walking speed, this magma-filled crack (dyke) is traveling deep underground towards the coastline. "The magma rising from the crack reaches the surface after a few days and continues to flow there as lava, which solidifies after some time," Timothy Davis explains the subsequent course of the volcanic eruption.

Important prerequisite for prediction and hazard minimization

For the first time, the geophysicist was able to simulate such a tortuous magma propagation pathway feeding an eruption and determine the forces that control this. Timothy Davis and Eleonora Rivalta, together with their colleagues in California, have thus laid important foundations for research into such fissure eruptions. And they have taken a decisive step towards predicting such eruptions and thus reducing the dangers they pose.

More information: Timothy Davis et al, Extreme Curvature of Shallow Magma Pathways Controlled by Competing Stresses: Insights From the 2018 Sierra Negra Eruption, *Geophysical Research Letters* (2021). DOI: 10.1029/2021GL093038

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