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Solving the Bermuda Mystery: an Island that Tells a Story of a New Way to Form Volcanoes

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Solving the Bermuda mystery: an island that tells a story of a new way to form volcanoes

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ABSTRACT

Bermuda's explosive past has changed how geologists think about the processes that make volcanoes. The chemical composition of the lavas analyzed in this study indicate that Bermuda 'tapped' a geologically young, volatile rich layer in the mantle, unlike anything previously known.

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Volcanoes are responsible for creating most of Earth's crust by transporting molten rock from deep within the Earth to the surface. Volcanoes are typically present at active plate boundaries, where two tectonic plates either converge or diverge. At convergent plate boundaries, one plate is forced under the other during a process called subduction. As temperature and pressure increase due to increased depth of the tectonic plate (a.k.a. the slab), volatile elements such as H_2O and CO_2 are released. The release of water reduces the melting point of surrounding rocks creating magma that will rise to the surface. At divergent plate boundaries, volcanoes are the result of the decompression of the rocks due to the separation of tectonic plates. Volcanoes can also be found away from active plate boundaries, termed intraplate volcanoes, and traditional melting mechanisms associated with plate tectonics cannot explain this type of magmatism. The classic model to explain intraplate volcanism is the "hotspot" model, also known as the mantle plume model. A mantle plume is the buoyant upwelling of hot material that originates from deep within the Earth, potentially at the core-mantle boundary (a lava lamp is a great analogy!). The mantle plume itself is stationary, so as a tectonic plate moves over the plume, a chain of volcanoes will appear, as seen with the Hawaiian Islands and associated Emperor Seamounts (submarine volcanoes).

However, not all intraplate volcanoes are the result of the mantle plume model. Hence, geologists need to explore other explanations for why and how intraplate volcanoes erupt. Bermuda is such a location: its volcanic past has been known since the 1930s, and geologists had previously assumed that Bermuda is the result of a mantle plume. But the first order observations do not add up: 1) there are no seamounts to make up the chain of volcanoes characteristic of a mantle plume, and 2) the predicted location of the "hotspot" should be southeast of Bermuda; however, there is no sign of magmatism there. Due to the inaccessibility of sampling Bermuda's volcanic root, the mystery of how Bermuda formed has remained unanswered for several decades.

To answer questions about Bermuda's enigmatic volcanic past, we investigated a rock core that was drilled on Bermuda in the 1970s and had since been collecting dust in Halifax, Canada. This core recovered over 700 meters of the volcanic rocks that make up the island of Bermuda. We sampled and processed a subset of this core.

We found that Bermuda is composed of two different types of volcanic rock, which alternate along with the depth of the core. One of these types of rocks is particularly interesting because it needs special conditions to form: these rocks are depleted in SiO_2, which is one of the classic building-blocks for volcanic rocks. Depletion in SiO_2 is likely the result of increased CO_2. In addition to needing high concentrations of CO_2 to make Bermuda, we found that H_2O concentrations of magma were also higher than average. Together these results indicate that Bermuda's volcanic origins must come from a region of the deep Earth that is rich with volatile elements.

The unique component that we discovered about Bermuda is the isotopic signature of these volatile rich rocks. In particular, the isotopic footprint was unlike anything ever before recorded in oceanic intraplate volcanoes! We found that this isotopic signature can only be explained by having Bermuda's magmas originate from a geologically young reservoir in the mantle.

The geochemistry tells us that we need a young, volatile-rich source to produce Bermuda, but where is that source, and how is it sampled? The "where?" can be explained by the supercontinent Pangea, which formed ~330 million years ago with the subduction of slabs into the mantle. Studies have shown that these slabs are rich in volatile elements and can be stored in the mantle transition zone (a region defined by a change in the physical behavior of the mantle, between 410 and 660 km depth). Geophysics helps explain the "how?" as we used present-day thermal conditions of the mantle beneath Bermuda and modeled what the mantle conditions could have been when Bermuda was an active volcano. Our models show thermal upwelling occurred as a convecting cell that reached transition zone depths. We are thus the first to describe a new mechanism to produce volcanoes: where Bermuda sampled the transition zone due to mantle convection. Not only did our study find a new way to create volcanoes, but it also shows that there is still much to learn about the internal workings of the Earth!