Lava provides window on early Earth

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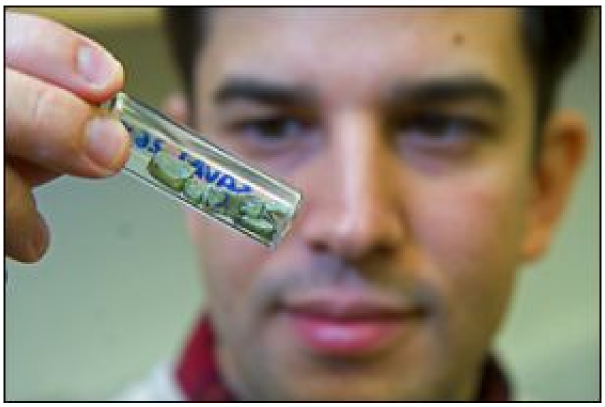

Assistant Professor of Geochemistry Sujoy Mukhopadhyay looks at rock fragments in the lab. Staff photo Jon Chase/Harvard News Office

Researchers at Harvard and the University of Hawaii believe they've resolved a long-standing controversy over the roots of islands — volcanoes in the middle of tectonic plates — showing that the islands' lava provides a window into the early Earth's makeup.

Assistant Professor of Geochemistry Sujoy Mukhopadhyay and Helge Gonnermann at the University of Hawaii ran sophisticated computer models examining changes in gases dissolved in magma as they rise from the mantle through the Earth's crust. The magma emerges as lava, sometimes in spectacular eruptions. As it cools, it can pile up to enormous heights, building ocean islands such as Hawaii's Mauna Kea, the world's largest mountain measured from its base to its summit.

The controversy revolves around how one interprets apparently conflicting evidence presented by the helium in the magma of oceanic islands versus that in mid-ocean ridges — the long undersea mountain chains that run along the sea floor where tectonic plates spread apart and new oceanic crust is created.

One measure — the ratio of two different types of helium called isotopes — indicates that the lava making up oceanic islands is in part derived from the Earth's mantle and has been unchanged since the formation of the Earth.

The second measure, however — the magma's low concentration of helium — seems to indicate that the part of the mantle that melts to produce the oceanic island has been previously melted, which would let helium gas escape. This would indicate that the lavas making up oceanic islands like Hawaii have been recycled, going through a process of melting and solidifying and melting again, like lavas that erupt in the mid-ocean ridges.

In a report in the Oct. 25 issue of the journal Nature, Gonnermann and Mukhopadhyay explain that the low concentration of helium in island magma doesn't have to mean that it has been recycled. The two showed that helium would be lost from the island magma as it moved to the surface for the first time and as the enormous pressure it was under decreased. As the pressure declines, gases such as helium and carbon dioxide dissolved in the magma form bubbles, much like bubbles in a soda bottle when the top is popped.

The presence of a larger amount of carbon dioxide in the ocean island lavas compared with mid-ocean ridge lavas is key, Mukhopadhyay said, because it forms bubbles and provides a place for helium gas to cross into from the liquid magma. Once the magma reaches the Earth's surface, the carbon dioxide and helium are lost to the air or water where it emerges.

Mukhopadhyay said that these results have far-reaching effects in the understanding of how the Earth's geology works. Dominant theories hold that a slow circulation within the mantle — the layer between the crust and the core — coupled with the movement of the continental plates bringing material to the surface and back down again, have recycled the entire Earth over billions of years, leaving no material from the primordial Earth to be studied.

If the oceanic island lava is a remnant of the primordial Earth, however, it will require rethinking those theories to allow parts of the Earth to remain in their original state.

"We're showing that the geochemical data from ocean islands are indeed consistent with parts of the mantle not having melted over Earth history, and now we have to come up with scenarios or models of mantle convection that leave certain parts of the mantle untouched," Mukhopadhyay said.

Gonnermann said there may be a layer hidden somewhere in the lower mantle that is out of the main circulation or there may be pockets of primordial material scattered throughout.

"The challenge is to understand how this can be," said Gonnermann, who began the work in 2005 as Daly Postdoctoral Fellow at Harvard's Department of Earth and Planetary Sciences.

Mukhopadhyay said noble gases such as helium are powerful tools to understand degassing of volatiles over long periods of time because they are inert. Unlike carbon dioxide and water, which are also present in the mantle's rocks, helium doesn't interact with plants, animals, bacteria, and other biological entities, so scientists can be assured that its presence, absence, or the state it's in is a result of geological, not biological, processes.

Using helium and other nonreactive noble gases as tools, Mukhopadhyay said he'd like to continue looking back in time, examining the longstanding question of how the release of gases from the Earth's rocks influenced the makeup of the early atmosphere.

"We're hoping that by using our degassing model and measurements of noble gases in mantle-derived rocks, we'll be able to look back at the first few hundred million years of Earth's history," Mukhopadhyay said.

Source: Harvard University

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