Upside-down answer for deep Earth mystery: Clues point to 'density trap' in early mantle

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(PhysOrg.com) -- When Earth was young, it exhaled the atmosphere. During a period of intense volcanic activity, lava carried light elements from the planet's molten interior and released them into the sky. However, some light elements got trapped inside the planet. In this week's issue of *Nature*, a Rice University-based team of scientists is offering a new answer to a longstanding mystery: What caused Earth to hold its last breath?

For some time, scientists have known that a large cache of light elements like helium and argon still reside inside the planet. This has perplexed scientists because such elements tend to escape into the atmosphere during volcanism. However, because these elements are depleted in the Earth's upper mantle, Earth scientists are fairly certain the retained elements lie in a deeper portion of the mantle. Researchers have struggled to explain why some gases would be retained while others would rise and escape into the air. The dominant view has been that the lowermost mantle has been largely isolated from the upper mantle and therefore retains its primordial composition.

In the new study, a team of researchers from Rice, the University of Michigan and the University of California-Berkeley suggests that a particular set of geophysical conditions that existed about 3.5 billion years ago -- when Earth's interior was much warmer -- led to the formation of a "density trap" about 400 kilometers below the planet's surface. In the trap, a precise combination of heat and pressure led to a geophysical rarity, an area where liquids were denser than solids.

Today, liquids generated in the mantle are less dense than solids and therefore rise to the surface to form volcanoes. However, several billion years ago, a hotter mantle permitted deeper melting and generated dense liquids that stalled, crystallized and eventually sank to the bottom of the mantle.

"When something melts, we expect the gas to get out, and for that reason people have suggested that the trapped elements must be in a primordial reservoir that has never melted," said lead author Cin-Ty Lee, associate professor of Earth science at Rice. "That idea's become problematic in recent decades, because there's evidence that suggests all the mantle should have melted at least once. What we are suggesting is a mechanism where things could have melted but where the gas does not escape because the melted material never rises to the surface."

Lee said the rise of less dense, melted material from Earth's interior is the process that created Earth's crust. Suggesting that melted material might sink instead literally turns conventional wisdom on its head. But the "upside-down" model can explain several geochemical and geophysical oddities in addition to the trapped gases, which suggests that it is a plausible hypothesis.

"I hope this generates a lot of interest," Lee said. "There are seismic methods that can be used to test our idea. Even if we turn out to be wrong, the tests that would be needed to falsify our hypothesis would generate a lot of new information."

Provided by Rice University