Found! Hidden Ocean Locked Up Deep in Earth's Mantle

By Joseph Castro, Live Science Contributor | June 12, 2014 02:00pm ET

Earth's surface oceans are quite apparent, even from satellite images of our blue marble, but now scientists have found oceans' worth of water are hidden deep in Earth's mantle, locked up in a mineral called ringwoodite.

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Deep within the Earth's rocky mantle lies oceans' worth of water locked up in a type of mineral called ringwoodite, new research shows.

The results of the study will help scientists understand Earth's water cycle, and how plate tectonics moves water between the surface of the planet and interior reservoirs, researchers say.

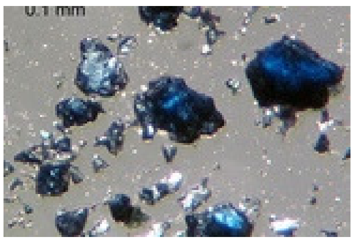
The Earth's mantle is the hot, rocky layer between the planet's core and crust. Scientists have long suspected that the mantle's so-called transition zone, which sits between the upper and lower mantle layers 255 to 410 miles (410 to 660 kilometers) below Earth's surface, could contain water trapped in rare minerals. However, direct evidence for this water has been lacking, until now. [See Images of Water-Rich Ringwoodite and Earth's Layers]

To see if the transition zone really is a deep reservoir for water, researchers conducted experiments on water-rich ringwoodite, analyzed seismic waves travelling through the mantle beneath the United States, and studied numerical models. They discovered that downward-flowing mantle material is melting as it crosses the boundary between the transition zone and the lower mantle layer.

"If we are seeing this melting, then there has to be this water in the transition zone," said Brandon Schmandt, a seismologist at the University of New Mexico and co-author of the new study published today (June 12) in the journal Science. "The transition zone can hold a lot of water, and could potentially have the same amount of H_2O [water] as all the world's oceans." (Melting is a way of getting rid of water, which is unstable under conditions in Earth's lower mantle, the researchers said.)

A water-rich mineral

Ringwoodite is a rare type of mineral that forms from olivine under very high pressures and temperatures, such as those present in the mantle's transition zone. Laboratory studies have shown that the mineral can contain water, which isn't present as liquid, ice or vapor; instead, it is trapped in the ringwoodite's molecular structure as hydroxide ions (bonded oxygen and hydrogen atoms).



Fragments of the blue-colored mineral ringwoodite synthesized in the laboratory.

Credit: Steve Jacobsen / Northwestern University

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In March, another research group discovered an unusual diamond from the mantle that encased hydrous ringwoodite. Though the find suggested the transition zone could contain a lot of water, it was the first and only ringwoodite specimen from the mantle scientists have ever analyzed (all other samples were produced in the lab or found in meteorites), and may not be representative of other mantle ringwoodite. [Shine On: Photos of Dazzling Mineral Specimens]

"Right now, we're one-for-one, because that ringwoodite had some H_2O in it, but we didn't know if it was normal," Schmandt told Live Science. So Schmandt and geophysicist Steven Jacobsen of Northwestern University in Illinois set out to observationally test if other mantle ringwoodite also contains water.

The researchers knew the crystal structure of ringwoodite allows the transition zone to hold water, but that structure changes if the material moves across the boundary to the lower mantle (due to increasing pressures and temperatures). Because the structure of minerals in the lower mantle can't trap water the way ringwoodite can, Schmandt and Jacobsen reasoned the rocks would melt as they flowed from the transition zone to the lower mantle. "Melting is just a mechanism of getting rid of the water," Schmandt said.

To test this hypothesis, Jacobsen and his colleagues conducted lab experiments to simulate what would happen to transition zoneringwoodite as it travels deeper into the Earth. They synthesized hydrous ringwoodite and recreated the temperatures and pressures it would experience in the transition zone by heating it with lasers and compressing it between hard, anvil-like diamonds.

Using their setup, they then slowly increased the temperature and pressure to mimic the conditions in the lower mantle. The ringwoodite transformed into another mineral called silicate perovskite, and transmission electron microscopy showed that the mineral contained silicate melt around single crystals of perovskite.

"What that tells us is if there is similarly hydrated ringwoodite in the transition zone that's dragged down, we would expect it to produce melt," Schmandt said. "Because melt changes how seismic waves propagate, that's a target I can hunt for [with seismometers]."

Finding the melt

Using the Earthscope USArray, a network of portable seismometers across the United States, Schmandt analyzed seismic waves as they passed from the transition zone to the lower mantle. He found the waves slowed as they crossed into the lower mantle, suggesting that melt was present in the boundary. Importantly, the decrease in seismic velocity didn't happen everywhere — models showed the wave velocity decreased only where material was flowing downward from the transition zone to the lower mantle, as the researchers predicted. [Infographic: Earth's Tallest Mountain to Its Deepest Ocean Trench]

The melt produced in the boundary likely then flows back upward, returning to minerals that can hold the water, Schmandt said, adding that this mechanism allows the transition zone to be a stable water reservoir.

"[The study] provides critical experimental support for the important role that the transition zone plays in controlling the melting behavior and flux of hydrogen in the deep Earth," Graham Pearson, a mantle geochemist at the University of Alberta, who wasn't involved in the work, told Live Science in an email.

Anna Kelbert, a geophysicist at Oregon State University who also wasn’t involved in the study, notes that scientists have previously used numerous approaches to look for evidence of Earth's interior water reservoir, but this is the first time researchers have searched for clues of the reservoir by focusing on the potential water-induced melting at the bottom of the transition zone. "It provides an important multidisciplinary perspective on this problem," Kelbert said. "It has important implications on our understanding of the behavior of subducting slabs deep in the mantle, and on our understanding of [the] overall water budget/distribution in the Earth."

Schmandt hopes to now analyze seismic data from other areas across the globe and see how common mantle melting is. This would allow researchers to see if there's something special about the subduction history of the mantle beneath North America, or how the Earth's plates have shifted beneath one another over time.

The new findings will also help scientists better understand Earth's water cycle. "The surface water we have now came from degassing of molten rock. It came from the original rock ingredients of Earth," Schmandt said. "How much water is still inside the Earth today relative to the surface?"

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