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Study hints that ancient Earth made its own water—geologically

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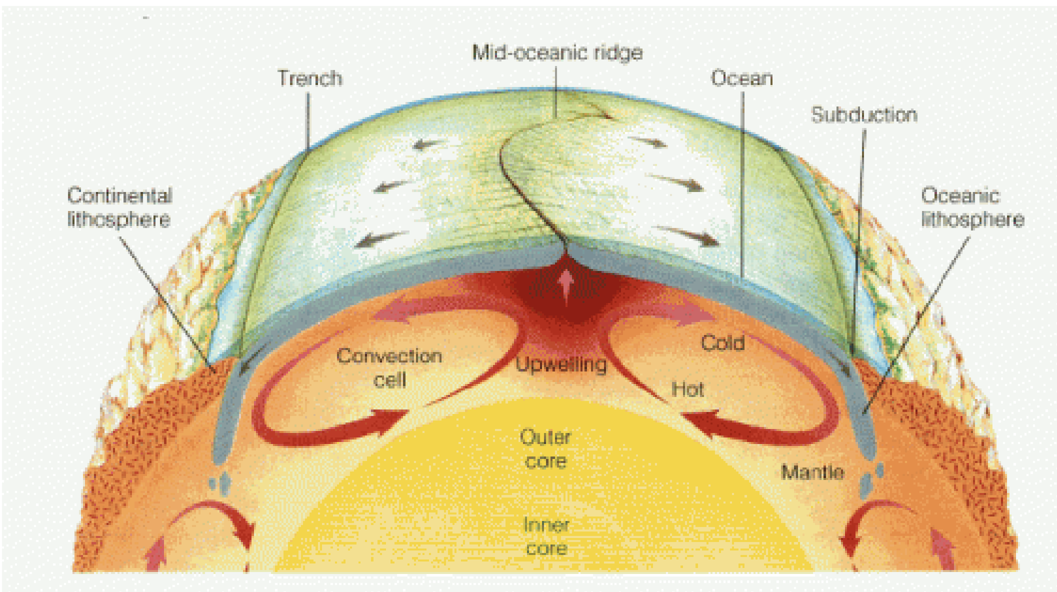

This plate tectonics diagram from the Byrd Polar and Climate Research Center shows how mantle circulation delivers new rock to the crust via mid-ocean ridges. New research suggests that mantle circulation also delivers water to the oceans.

A new study is helping to answer a longstanding question that has recently moved to the forefront of earth science: Did our planet make its own water through geologic processes, or did water come to us via icy comets from the far reaches of the solar system?

The answer is likely "both," according to researchers at The Ohio State

University— and the same amount of water that currently fills the Pacific Ocean could be buried deep inside the planet right now.

At the American Geophysical Union (AGU) meeting on Wednesday, Dec. 17, they report the discovery of a previously unknown geochemical pathway by which the Earth can sequester water in its interior for billions of years and still release small amounts to the surface via plate tectonics, feeding our oceans from within.

In trying to understand the formation of the early Earth, some researchers have suggested that the planet was dry and inhospitable to life until icy comets pelted the earth and deposited water on the surface.

Wendy Panero, associate professor of earth sciences at Ohio State, and doctoral student Jeff Pigott are pursuing a different hypothesis: that Earth was formed with entire oceans of water in its interior, and has been continuously supplying water to the surface via plate tectonics ever since.

Researchers have long accepted that the mantle contains some water, but how much water is a mystery. And, if some geological mechanism has been supplying water to the surface all this time, wouldn't the mantle have run out of water by now?

Because there's no way to directly study deep mantle rocks, Panero and Pigott are probing the question with high-pressure physics experiments and computer calculations.

"When we look into the origins of water on Earth, what we're really asking is, why are we so different than all the other planets?" Panero said. "In this solar system, Earth is unique because we have liquid water on the surface. We're also the only planet with active plate tectonics. Maybe this water in the mantle is key to plate tectonics, and that's part of what makes Earth habitable."

Central to the study is the idea that rocks that appear dry to the human eye can actually contain water—in the form of hydrogen atoms trapped inside natural voids and crystal defects. Oxygen is plentiful in minerals, so when a mineral contains some hydrogen, certain chemical reactions can free the hydrogen to bond with the oxygen and make water.

Stray atoms of hydrogen could make up only a tiny fraction of mantle rock, the researchers explained. Given that the mantle is more than 80 percent of the planet's total volume, however, those stray atoms add up to a lot of potential water.

In a lab at Ohio State, the researchers compress different minerals that are common to the mantle and subject them to high pressures and temperatures using a diamond anvil cell—a device that squeezes a tiny sample of material between two diamonds and heats it with a laser—to simulate conditions in the deep Earth. They examine how the minerals' crystal structures change as they are compressed, and use that information to gauge the minerals' relative capacities for storing hydrogen. Then, they extend their experimental results using computer calculations to uncover the geochemical processes that would enable these minerals to rise through the mantle to the surface—a necessary condition for water to escape into the oceans.

In a paper now submitted to a peer-reviewed academic journal, they reported their recent tests of the mineral bridgmanite, a high-pressure form of olivine. While bridgmanite is the most abundant mineral in the lower mantle, they found that it contains too little hydrogen to play an important role in Earth's water supply.

Another research group recently found that ringwoodite, another form of olivine, does contain enough hydrogen to make it a good candidate for deep-earth water storage. So Panero and Pigott focused their study on the depth where ringwoodite is found—a place 325-500 miles below the surface that researchers call the "transition zone"—as the most likely region that can hold a planet's worth of water. From there, the same convection of mantle rock that produces plate tectonics could carry the water to the surface.

One problem: If all the water in ringwoodite is continually drained to the surface via plate tectonics, how could the planet hold any in reserve?

For the research presented at AGU, Panero and Pigott performed new computer calculations of the geochemistry in the lowest portion of the mantle, some 500 miles deep and more. There, another mineral, garnet, emerged as a likely water-carrier—a go-between that could deliver some of the water from ringwoodite down into the otherwise dry lower mantle.

If this scenario is accurate, the Earth may today hold half as much water in its depths as is currently flowing in oceans on the surface, Panero said—an amount that would approximately equal the volume of the Pacific Ocean. This water is continuously cycled through the transition zone as a result of plate tectonics.

"One way to look at this research is that we're putting constraints on the amount of water that could be down there," Pigott added.

Panero called the complex relationship between plate tectonics and surface water "one of the great mysteries in the geosciences." But this new study supports researchers' growing suspicion that mantle convection somehow regulates the amount of water in the oceans. It also vastly expands the timeline for Earth's water cycle.

"If all of the Earth's water is on the surface, that gives us one interpretation of the water cycle, where we can think of water cycling from oceans into the atmosphere and into the groundwater over millions of years," she said. "But if mantle circulation is also part of the water cycle, the total cycle time for our planet's water has to be billions of years."

Provided by The Ohio State University