Taking Earth's Inner Temperature

WHY THE MANTLE MAY BE HOTTER THAN WE THOUGHT

by Véronique LaCapra

Woods Hole Oceanographic Institution wasn't an obvious fit for Emily Sarafian.

"I always felt a little out of place here, because I don't study the ocean, really," said Sarafian, a recent graduate student of the MIT-WHOI Joint Program.

At WHOI, Sarafian studied geology—specifically, Earth's mantle, the mostly solid part of our planet's interior that lies between its superheated core and its outer crust. One good place to do that is under the seafloor, at mid-ocean ridges.

"At mid-ocean ridges, the tectonic plates that form the seafloor gradually spread apart," said Sarafian. "Rock from the upper mantle slowly rises to fill the void between the plates, melting as the pressure decreases, then cooling and re-solidifying to form new crust along the ocean bottom."

To better understand how that process works, Sarafian needed to know the temperature at which rising mantle rock starts to melt. But how do you take the temperature of the planet, thousands of feet below the ocean surface and tens of miles below the ocean floor?

It's not possible to do directly, so geologists have to estimate it through laboratory experiments. Sarafian used a piston-cylinder apparatus: a massive, old-school, intimidating-looking machine that combines electrical current, heavy metal plates, and stacks of powerful pistons to simulate the high pressures and temperatures found deep inside the Earth: more than 200,000 pounds per square inch and 2,500° F—hot enough to melt rock.

Sarafian created a synthetic mantle rock to test in the machine. Then, following standard methods of experimental petrology, she dried it in an oven to remove water that would contaminate her results.

"Water—or more specifically, the hydrogen in it—changes the reaction," said Glenn Gaetani, a WHOI petrologist and Sarafian's advisor. "The more water in rock, the lower its melting point."

The problem is that water in the air gets into the powders used to create mantle samples. "So, whether you added water or not, there's water in your experiment," Sarafian said.

To get around that problem, Sarafian added a mantle mineral called olivine in spheres about 300 micrometers in diameter—the size of fine sand grains. But they were large enough for Sarafian to use a technique called secondary ion mass spectrometry to determine the water content of her samples before she put them in the piston-cylinder apparatus to determine the temperatures and depths at which rock begins to melt.

Her results, published in March 2017 in the journal *Science*, surprised her: They indicated that mantle rock must be melting at a *shallower* depth under the seafloor than previously thought.

To verify her experimental results, Sarafian worked with WHOI geophysicist Rob Evans, who specializes in magnetotellurics—a technique to analyze the electrical conductivity of rocks. Molten rock conducts electricity much more than solid rock, so magnetotelluric data can reveal where melting is occurring in the mantle.

Sarafian examined a 2013 magnetotelluric analysis of a mid-ocean ridge by researchers at the Scripps Institution of Oceanography. It showed that mantle rock was actually melting much *deeper* beneath the seafloor than her experiments suggested.

Sarafian knew that both the experimental petrology and the magnetotelluric results had to be correct. Reconciling them led to her startling conclusion: "The oceanic upper mantle must be about 110° F hotter than current estimates," said Sarafian.

That may not sound like a lot compared with typical molten mantle temperatures of more than 2,500° F. But Sarafian and Gaetani say it is significant. For one thing, a hotter mantle would make rocks more fluid. That, in turn, would help explain how rigid tectonic plates move and how ocean basins form.

"The thing that is remarkable about Emily and made her the perfect person to do this study is that, because of her two very disparate scientific interests in experimental petrology and magnetotellurics, she was able to put these different results together and say, 'They're telling us the mantle's hotter than we thought.' Working separately, Rob (Evans) and I wouldn't have been able to do that," Gaetani said. "That's all her."

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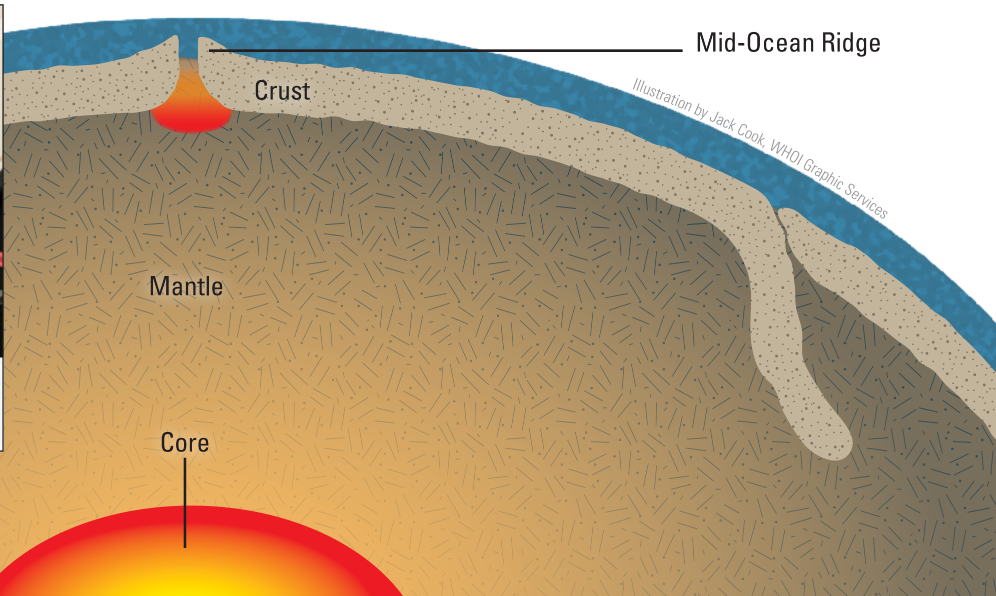
Véronique LaCapra, WHOI

Emily Sarafian used an apparatus that simulates what happens to rock under the high pressures and temperatures in Earth's mantle.



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