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ridge, shear waves were slower than they were underneath older Atlantic seafloor, implying a hotter MTZ. These characteristics are typically found at hot spots, not ridges.

"For the first time, we have evidence of higher temperatures in the mantle transition zone [at the Mid-Atlantic Ridge]," said Agius. From that, the researchers inferred that material in the lower mantle is rising to the upper mantle. Instead of gravity, upwelling could be driving seafloor spreading.

This experiment is the first time scientists have obtained seismic data directly from the ridge, as opposed to data from land stations, which provide a hazier view of Earth's inner mechanics at the ridge. "It introduces new evidence for the whole study of plate tectonics," said Agius.

> **"It introduces new evidence for the whole study of plate tectonics."**

"This finding in itself, that there could be regions in our mantle where there's vertical material transport that are not…[sites of] active upwelling and downwelling like slabs and plumes, is intriguing," said Elvira Mulyukova, an associate research scientist who studies geodynamics at Yale University who was not involved in the research.

Houser, like the Southampton team, uses seismic data to map Earth's mantle. She said that the data from this new study align with her own models so far.

But Mulyukova wants stronger evidence and measurements of more geophysical properties at the ridge. The authors interpreted their observations as evidence of vertical material transfer in the mantle, but there are other possibilities. Agius and his colleagues agree that studying other properties in this area would give a more holistic view.

If proven to be true, this team's findings could change the understanding of major aspects of Earth's history. "This would have an implication for the thermal history of the planet, the geochemical history of the planet [and] the geodynamo," Agius said.

By **Jackie Rocheleau** (@JackieRocheleau), Science Writer

Superlasers Shed Light on Super-Earth Mantles

The way planetary materials behave under pressure influences planets' interior structure. Credit: iStock.com/Rost-9D

Of the more than 4,300 planets discovered outside our solar system, super-Earths—rocky planets up to twice as large and up to 5 times as massive as Earth—are among the most common. What they're made of, how they form, and what their interior structure and dynamics look like are still relatively unclear.

> **"Laboratory experiments…tell you something about the interior structure of planets so far away and which we can't even look at directly."**

To get a grasp on the inner workings of super-Earths, recent experiments put iron oxide under the pressures expected within the mantles of these rocky exoplanets. The experiments showed that this common planetary material likely takes a different shape in those planets' mantles than it does in Earth's.

Working with one of the most powerful lasers in the world allowed researchers to conduct "laboratory experiments that tell you something about the interior structure of planets so far away and which we can't even look at directly," said Federica Coppari, a planetary materials scientist at Lawrence Livermore National Laboratory in Livermore, Calif.

Coppari said that many planetary scientists begin studying super-Earths with simplified models of Earth's interior and proceed to scale them up to approximate super-Earth sizes, pressures, and temperatures. This approach is a good starting point, she said, but it doesn't account for how properties of mantle materials might change. In recent years, experimentalists have begun to explore how common planetary materials behave at the pressures and temperatures inside super-Earths to build a picture of the structure and dynamics inside those planets.

Coppari and her team sought to learn how one of the dominant minerals in Earth's mantle, ferropericlase, might behave in a super-Earth's mantle. They used the Omega Laser Facility in Rochester, N.Y., to compress iron oxide, a component of ferropericlase, to pressures 3–5 times those at Earth's core-mantle boundary. Just a few nanoseconds of compression were needed to reach super-Earth mantle pressure (roughly 350–665 gigapascals).

Researchers found that at those pressures, iron oxide reached a density more than twice that of another end-member component of mantle material, magnesium oxide, and underwent a phase transition at a far lower pressure. Inside Earth's mantle, these two minerals have the same structural phase and mix together in ways that are well understood. However, the fact that the material properties of iron oxide and magnesium oxide diverge at high pressures means that super-Earth mantles could layer, mix, and flow in entirely foreign ways.

"Not only are the atoms more tightly packed, this new material phase [of iron oxide] is associated with a dramatic drop in viscosity…[which] plays an important role in the convecting motions inside the mantle," Coppari said. "The rheology of a large extrasolar planet might be completely different than that of the Earth…and it's related to the different material properties at more extreme conditions expected inside exoplanets." The researchers published these results in *Nature Geoscience* (bit.ly/interior-exoplanet).

The lower viscosity "would affect how the mantle flows over time," said Rebecca Fischer, "with implications for heat transport, thermal evolution, and even magnetic field generation and surface tectonics, which may be important processes to creating a habitable planet.… I think this is a very impactful study that significantly advances our understanding of a mineral likely to be abundant in exoplanet mantles." Fischer, who was not involved with this research, is an experimental planetary scientist at Harvard University in Cambridge, Mass.

"These are impressive experiments with significant technological advances to investigate material structure and behavior under conditions of a super-Earth interior," said Yingwei Fei, an experimental planetary scientist at the Carnegie Institution for Science in Washington, D.C., who was not involved with this research. "It provides new opportunities for determining not only density but also phase transition at conditions relevant to a super-Earth mantle…[and] raises an important question about stratification caused by phase transition and its potential role in mantle dynamics."

High-pressure experiments help build a more complete geophysical picture of planets larger than Earth, Coppari said. These tests explore materials common in Earth's mantle, but the composition of exoplanet mantles is completely unknown. Future work will continue to study the high-pressure behavior of individual mineral components of Earth's mantle and also test different planetary mixtures to find ones that could exist in super-Earths. All of these experiments help refine models of planetary interiors that, in turn, help predict which materials would be useful to test.

"From the experimental side, it is a good approach to start with compositionally simple end-members, but important components of rocky planets, and build the database necessary for modeling the complex real systems," Fei said. "We are still at the early stage to paint a detailed picture of the interior. It will require an interdisciplinary approach to advance our understanding."

By **Kimberly M. S. Cartier** (@AstroKimCartier), Staff Write

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