New picture of Earth's lower mantle

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Laboratory measurements of a high-pressure mineral believed to exist deep within the Earth show that the mineral may not, as geophysicists hoped, have the right properties to explain a mysterious layer lying just above the planet’s core.

A team of scientists, led by Sébastien Merkel, of the University of California, Berkeley, made the first laboratory study of the deformation properties of a high-pressure silicate mineral named post-perovskite. The work appears in the June 22 issue of the scientific journal *Science*.

The team included Allen McNamara of Arizona State University's School of Earth and Space Exploration, part of the College of Liberal Arts and Sciences. McNamara, a geophysicist, modeled the stresses the mineral would typically undergo as convection currents deep in Earth's mantle cause it to rise and sink. Also on the team were Atsushi Kubo and Thomas S. Duffy, Princeton University; Sergio Speziale, Lowell Miyagi and Hans-Rudolf Wenk, University of California, Berkeley; and Yue Meng, HPCAT, Carnegie Institution of Washington, Argonne, Ill.

"This the first time the deformation properties of this mineral have been studied at lower mantle temperatures and pressures," says McNamara. "The goal was to observe where the weak planes are in its crystal structure and how they are oriented." The results of the combined laboratory tests and computer models, he says, show that post-perovskite doesn't fit what is known about conditions in the lowermost mantle.

Earth's mantle is a layer that extends from the bottom of the crust, about

25 miles down, to the planet's core, 1,800 miles deep. Scientists divide the mantle into two layers separated by a wide transition zone centered around a depth of about 300 miles. The lower mantle lies below that zone.

Most of Earth's lower mantle is made of a magnesium silicate mineral called perovskite. In 2004, earth scientists discovered that under the conditions of the lower mantle, perovskite can change into a high-pressure form, which they dubbed post-perovskite. Since its discovery, post-perovskite has been geophysicists' favorite candidate to explain the composition of a mysterious layer that forms the bottom of Earth's lower mantle.

Known to earth scientists as D" (dee-double-prime), this layer averages 120 miles thick and lies directly above Earth's core. D" was named in 1949 by seismologist Keith Bullen, who found the layer from the way earthquake waves travel through the planet's interior. But the nature of D" has eluded scientists since Bullen's discovery.

"Our team found," says McNamara, "that while post-perovskite has some properties that fit what's known about D", our laboratory measurements and computer models show that post-perovskite doesn't fit one particular essential property." That property is seismic anisotropy, he says, referring to the fact that earthquake waves passing through D" become distorted in a characteristic way.

McNamara explains, "Down in the D" layer, the horizontal part of earthquake waves travel faster than the vertical parts. But in our laboratory measurements and models, post-perovskite produces an opposite effect on the waves."

He adds, "This appears to be a basic contradiction."

McNamara notes that the laboratory measurements, made by team members at Princeton University, were extremely difficult. They involved crushing tiny samples of perovskite on a diamond anvil until they changed into post-perovskite. Then the scientists shot X-rays through the samples to identify the mineral crystals' internal structure.

This information was used by other team members at the University of California, Berkeley, to model how these crystals would deform as the mantle flows. The deformation results let the scientists predict how the crystals would affect seismic waves passing through them.

McNamara's work modeled the slow churn of the mantle, in which convection currents in the rock rise and fall about as fast as fingernails grow, roughly an inch a year. He calculated stresses, pressures and temperatures to draw a detailed picture of where post-perovskite would be found. This let him profile the structure of the D" layer.

"All these computations have been in two dimensions," he says. "Our next step is to go to 3-D modeling."

Does their work rule out post-perovskite to explain the D" layer" "Not completely," says McNamara. "We've begun to study this newly found mineral in the laboratory, but the work isn't yet over."

He adds, "It's possible that post-perovskite does exist in the lowermost mantle, and another mineral is causing the seismic anisotropy we see there."

Source: Arizona State University