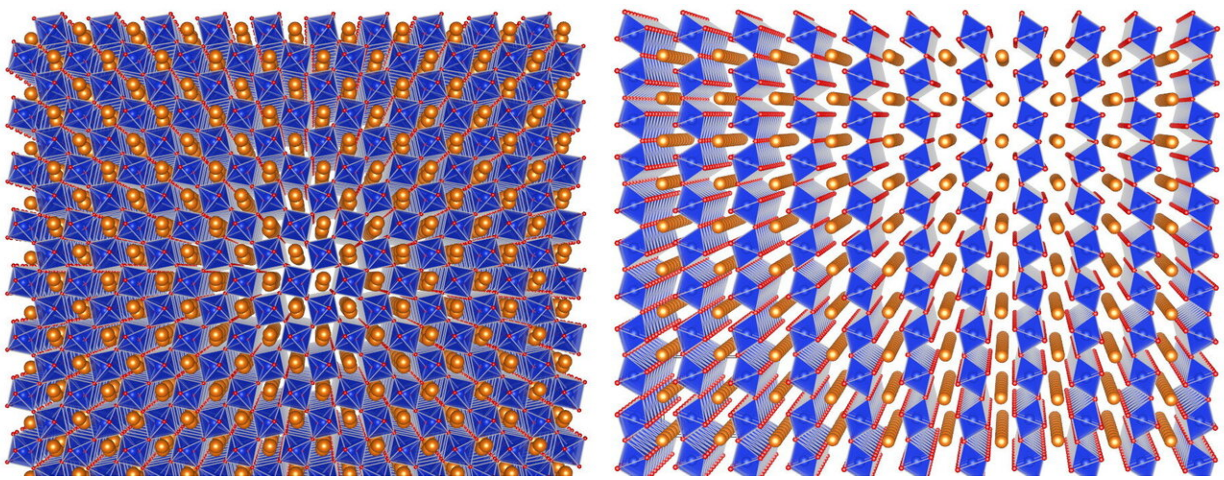
Extreme conditions experiments sharpen view of our planet's interior

December 17 2019

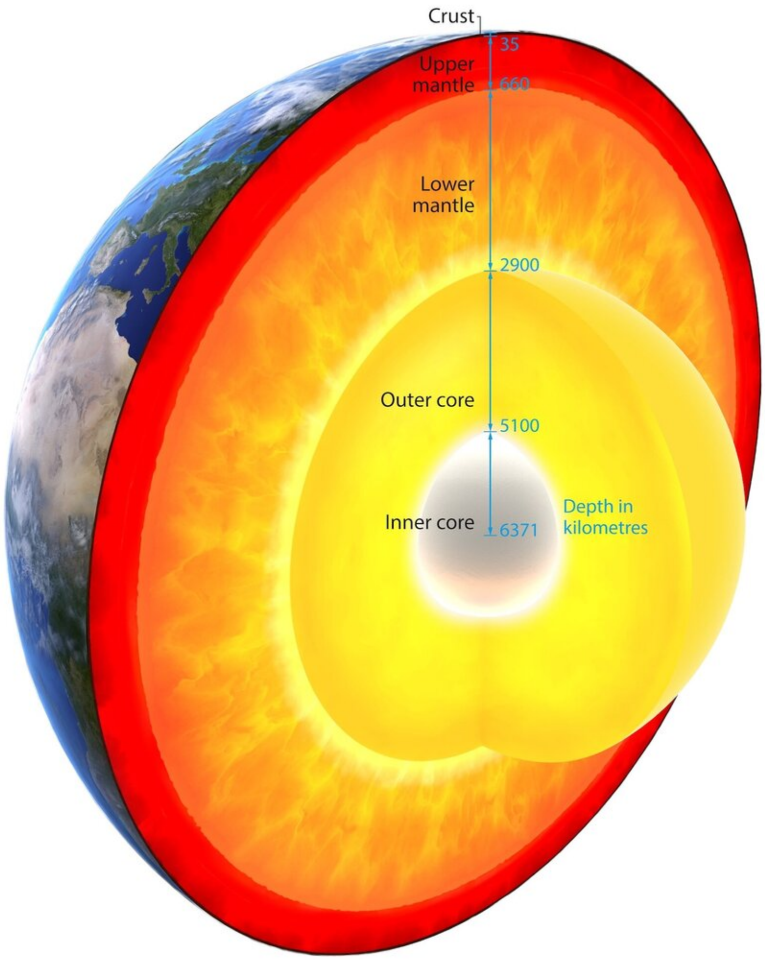


The crystal structures of bridgmanite (left) and post-perovskite (right). Credit: Université de Lille, Sébastien Merkel

Simulating the conditions 2,700 kilometers deep underground, scientists have studied an important transformation of the most abundant mineral on Earth, bridgmanite. The results from the Extreme Conditions Beamline at DESY's X-ray light source PETRA III reveal how bridgmanite turns into a structure known as post-perovskite, a transformation that affects the dynamics of Earth's lower mantle, including the spreading of seismic waves. The analysis can provide an explanation for a range of peculiar seismic observations, as the team headed by Sébastien Merkel from the Université de Lille in France report in the Journal *Nature Communications*.

Bridgmanite is a magnesian-iron mineral ((Mg,Fe)SiO_3) with a crystal structure that is not stable under ambient conditions. It forms about 660 kilometers below the surface of the Earth, and microcrystalline grains found as inclusions in meteorites are the only samples ever recovered on the surface. "In order to study bridgmanite under the conditions of the lower mantle, we had to produce the mineral first," explains Merkel. To do so, the scientists compressed tiny amounts of iron-magnesium-silicon-oxide in a diamond anvil cell (DAC), a device that can squeeze samples with high pressure between two small diamond anvils.

The freshly made bridgmanite was then put under even higher pressure of 1.2 megabar (about 1.1 million times the pressure on the surface) corresponding to the lowest layer of Earth's mantle, just above the core. Here, seismic waves are reflected while they are traveling through Earth's interior, and the way they are reflected depends on the characteristics of the material they encounter. "Seismic waves sometimes behave funny in that region," says Merkel. "Sometimes you see strong reflections, and sometimes you don't see anything at all."



The inner structure of the Earth. The investigations simulated condition as in the lower mantle. Credit: DESY, Franziska Lorenz & Jochen Stuhrmann

Scientists have long suspected that a structural change within bridgmanite is an important part of the explanation. "We have known for 15 years that bridgmanite transforms to a different crystal structure called post-perovskite under these conditions, but what we didn't know was, how fast it does that," explains Merkel. Post-perovskite consists of the same chemical elements as bridgmanite, but has a different crystal structure, leading to different characteristics.

At DESY's Extreme Conditions Beamline (P02.2) the scientists could now investigate the dynamics of the transformation. It turned out that it happens in about 10 to 10,000 seconds, depending on pressure and temperature. This includes the timescale of the frequency of seismic waves. "This means that seismic waves can trigger the transformation, and in turn it can amplify the seismic signal," emphasizes Merkel. "This observation explains why you sometimes see strong reflections and sometimes you don't. And it might also explain other anomalies."

The mantle-core boundary at about 2,900 kilometers below the surface is not as sharp as a mirror surface. Instead in a region roughly 200 kilometers above the core, known as the D" layer, large slabs of different material with different structures move about. "You can think of it as a second set of plate tectonics down there," explains Merkel. Also, in a boundary layer of about 100 kilometers thickness, bridgmanite and post-perovskite can co-exist, complicating the analysis of seismic signals. The more details scientists know about the physical characteristics of the material at the boundary, the better the analysis they can do. This helps not only to investigate the boundary region itself, but also many other regions inside the Earth, as seismic waves probe all layers on their way. "The better we know the material characteristics at the core-mantle boundary, the sharper is our view of the Earth's interior," says Merkel.

More information: Christopher Langrand et al. Kinetics and detectability of the bridgmanite to post-perovskite transformation in the Earth's D″ layer, *Nature Communications* (2019). DOI: 10.1038/s41467-019-13482-x

Provided by Deutsches Elektronen-Synchrotron