Earth's mantle: New numerical tool describes rock deformation

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Although solid, the rocks of the Earth's mantle deform very slowly. Professor Patrick Cordier's team at the Materials and Transformation Unit (Université Lille, France) has developed a model that makes it possible, over timescales of several million years, to link the deformation of these rocks with mantle convection, the fundamental driver of plate tectonics. Until now, no experimental method in the laboratory had achieved the real conditions of deformation of mantle rocks. By applying this model to magnesium oxide, a solid present in the Earth's mantle, the scientists were able to show how atomic-scale defects in this mineral could be transmitted on a larger scale and over long periods of time.

Published in the journal *Nature*, these results call into question certain experimental approaches at high pressures and temperatures. They show that only a thin layer in the lowermost mantle can be regarded as a viscous liquid; elsewhere, the mantle behaves like a plastic solid.

The behavior of the Earth's mantle is chaotic on geological timescales. However, it appears relatively static, or indeed motionless, on the scale of a human lifetime (speeds in the mantle are comparable to fingernail growth speed).

To better understand how the deformation affecting rocks and minerals deep inside the Earth impacts mantle convection, a novel numerical approach has been developed by Patrick Cordier's team at the Materials and Transformation Unit.

By integrating theoretical concepts from solid-state physics and material deformation mechanisms, the scientists have been able to describe the behavior of minerals over previously inaccessible timescales and under experimentally unattainable conditions.

The researchers simulated the deformation of magnesium oxide (MgO), a solid naturally present in the lower mantle, under pressure and temperature conditions identical to those in the mantle (around a million times atmospheric pressure and a temperature of several thousand degrees). The researchers were thus able to observe the presence of defects on the atomic scale, called dislocations. For Cordier and his colleagues, such dislocations are the main cause of plastic deformation of the mantle, which is the fundamental driver of the Earth's heat machine (plate tectonics, volcanoes, earthquakes, etc).

From the perspective of geophysics, these results shake up some of the established notions in the field. To model mantle convection (the mechanism that releases the Earth's internal heat), the mantle is usually regarded as behaving like a viscous fluid over long timescales. In this study, the scientists show that only a thin layer in the lowermost mantle actually behaves in this way. Elsewhere in the mantle, the concept of viscosity does not apply, and the rock behaves like a plastic solid.

This new scientific data opens up a new research field in geophysics, linking the dislocation of solids on the atomic scale with fluid flows at the mantle scale.

More information: Modelling the rheology of MgO under Earth's mantle pressure, temperature and strain-rates. Patrick Cordier, Jonathan Amodeo, Philippe Carrez, *Nature*, 12 January 2012

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