New insight into the temperature of deep Earth

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Clouds over Australia are shown. Credit: NASA

Scientists from the Magma and Volcanoes Laboratory (CNRS) and the European Synchrotron, the ESRF, have recreated the extreme conditions 600 to 2900 km below the Earth's surface to investigate the melting of basalt in the oceanic tectonic plates. They exposed microscopic pieces of rock to these extreme pressures and temperatures while simultaneously studying their structure with the ESRF's extremely powerful X-ray beam.

The results show that basalt produced on the ocean floor has a melting temperature lower than the peridotite which forms the Earth's mantle. Near the core-mantle boundary, where the temperature rises rapidly, the melting basalt produces liquids rich in silica (SiO_2), which react rapidly with the mantle and indicate a speedy dissolution of the basalt back into the depths of the Earth. These experiments provide a new explanation for seismic anomalies at the base of the mantle while fixing its temperature in the region of 4000 K.

The results are published in *Science* on the 23 May 2014.

The Earth is an active planet. The heat it contains is capable of inducing the mantle convection responsible for plate tectonics. This energy comes from the heat accumulated during the formation of our planet, the latent heat of crystallization of the inner core, and radioactive decay. The temperatures inside the Earth, however, are not well known.

Convection causes hot material to rise to the surface of the Earth and cold material to sink towards the core. Thus, when the ascending mantle begins to melt at the base of the oceanic ridges, the basalt flows along the surface to form what we call the oceanic crust. "Over the course of millennia the crust will then undergo subduction, its greater density causing it to sink into the mantle. This is why the Earth's continents are known to be several billion years old, while the oldest oceanic crust only dates back 165 million years" said Mohamed Mezouar, scientist at the ESRF.

The temperature at the core-mantle boundary (also known as the D" region) is thought to increase by more than 1000 degrees over a few hundred kilometers, which is significant compared to the temperature gradient across the rest of the mantle. Previous authors have suggested that this temperature rise could cause the partial melting of the mantle, but this hypothesis leaves a number of geophysical observations unexplained. Firstly, the anomalies in the propagation speed of seismic waves do not match those expected for a partial melting of the mantle, and secondly, the melting mantle should lead to the production of liquid pockets in the lowermost mantle, a phenomenon which has never been observed.

The team led by Professor Denis Andrault from the Université Blaise Pascal decided instead to study the melting point of basalt at high depths, and found that it was significantly lower than that of the mantle. The melting of sub-oceanic basalt piles could therefore be responsible for the previously unexplained seismic anomalies. The researchers also showed that the melting basalt generates a liquid rich in SiO2. As the mantle itself contains large quantities of MgO, the interaction of these liquids with the mantle is expected to produce a rapid reaction leading to the formation of the solid MgSiO3 perovskite. This would explain why no liquid pockets have been detected by seismologists in the deep mantle: any streams of liquid should rapidly re-solidify.

If it is indeed the basalt and not the mantle whose melting in the D"-region is responsible for the observed seismic anomalies, then the temperature at the core-mantle boundary must be between 3800 and 4150 Kelvin, between the melting points of basalt and the Earth's mantle. If this hypothesis is correct, this would be the most accurate determination of the temperature at the core-mantle boundary available today.

"It could solve a long time controversy about the peculiar role of the core-mantle boundary in the dynamical properties of the Earth mantle, said Professor Denis Andrault. "We know now that the cycle of crust formation at the mid-ocean ridges and crust dissolution in the lowermost mantle may have occured since plate tectonics were active on our planet", he added.

More information: "Melting of subducted basalt at the core-mantle boundary," by D. Andrault et al. *Science*: www.sciencemag.org/lookup/doi/ … 1126/science.1250466

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