Why is the Earth's mantle conductive?

December 4 2008

Above: Image of the Masai volcano, Oldoinyo Lengia (mountain of the gods) with, in white, a recent flow of liquid carbonate. Below: Two images of the lava lake, illustrating the very fluid character of this lava with extraordinary electrical properties. © Hannes Mattsson, ETH Zurich,

(PhysOrg.com) -- Researchers from INSU-CNRS (France), working with chemists at a CNRS research unit, have explained that the high conductivity of the Earth's upper mantle is due to molten carbonates. They demonstrated the very high conductivity of this form of carbon.

Appearing in the 28 November issue of *Science*, their work has revealed the high carbon content of the interior of the upper mantle. This composition can be directly linked to the quantity of carbon dioxide produced by 80% of volcanoes. This result is important for quantifying the carbon cycle, which contributes significantly to the greenhouse effect.

Geologists have long claimed that significant amounts of carbon have been present in the Earth's mantle for thousands of years. Up until now, there was very little direct proof of this hypothesis, and samples from the surface of the mantle contained only very small quantities of carbon. Also, for the last thirty years, scientists have been unable to explain the conductivity of the mantle, which is crossed by natural electrical currents at depths of 70 to 350 kms, even though olivine, one of the main mineral components of the upper mantle, is completely isolating.

To explain these phenomena, researchers from the Institut des Sciences de la Terre d'Orléans (ISTO, CNRS / Université de Tours / Université d'Orléans) looked into liquid carbonates, one of the most stable forms of carbon within the mantle, along with graphite and diamond. The Masai volcano is Tanzania is the only place in the world where these carbonates can be observed. Elsewhere, the carbonates are dissolved in basalts and emitted into the atmosphere in gaseous form, as CO2.

Based on lab measurements at CNRS's CEMHTI, the researchers established the high conductivity of molten carbonates. Their conductivity is 1000 times higher than that of basalt, which was previously thought to be the only potential conductor in the mantle. Fabrice Gaillard and his team have shown that the conductivity of the Earth's mantle is a result of the presence of small amounts of molten carbonates between chunks of solid rock.

This work shows that the electrical characteristics of the asthenosphere, the conductive part of the upper mantle, are directly connected to the amount of carbonate in the layer. The work also points to varying carbon distribution according to the regions and depth of the mantle. The researchers calculated that the amount of carbon present as liquid carbonate directly within the asthenosphere is between 0.003 and 0.025%, which seems low but makes it possible to explain the amounts of CO_2 emitted into the atmosphere by 80% of volcanoes(5). This nonetheless represents a reservoir of carbon integrated into the mantle which is higher than that present on the surface of the earth. These results are unmatched in helping to quantify the carbon cycle, which plays a major role in the greenhouse effect. Indeed, the CO_2 emitted by volcanic activity had never before been evaluated at the source (at the level of the mantle).

The presence of molten carbonates in the asthenosphere certainly has major implications on the viscosity of this region of the mantle, which participates in the sliding of tectonic plates, a phenomenon we know little about. The behavior of liquid carbonates in solids and potential effects on viscosity remain to be studied. Everything seems to indicate that the asthenosphere contains only oxidated forms of carbon (carbonates), and not carbon in its reduced solid form (diamond). Diamond formation remains mysterious, but researchers are guessing that diamonds form from liquid carbonates at the base of the lithosphere, below the asthenosphere. Enfin, the electrical measurements of the team on liquid carbonates are of interest to the field of clean energy production, as they can be used as electrolytes in high temperature batteries (eg. lithium carbonate).

This work was funded through a Young Researcher ANR project led by Fabrice Gaillard. He hopes to continue the work on liquid electrolytes through another ANR project and to therefore clarify these new hypotheses.

Reference:

Carbonatite Melts and Electrical Conductivity of the Asthenosphere. F.

Gaillard, M. Malki, G. Iacono-Marziano, M. Pichavant, B. Scaillet. Science. 28 November 2008.

Provided by CNRS