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Electrical conductivity of carbonatite-bearing peridotite

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Electrical impedance measurements were performed on two types of partial-molten samples with basaltic and carbonatitic melts in a Kawai-type multi-anvil apparatus in order to investigate melt fraction-conductivity relationships and melt distribution of the partial molten mantle peridotite under high pressure. The silicate samples were composed of San Carlos olivine with various amounts of mid-ocean ridge basalt (MORB), and the carbonate samples were a mixture of San Carlos olivine with various amounts of carbonatite. High pressure experiments on the silicate and carbonate systems were performed up to 1600 K at 1.5 GPa and up to at least 1650 K at 3 GPa, respectively. The sample conductivity increased with increasing melt fraction. Carbonatite-bearing samples show approximately one order of magnitude higher conductivity than basalt-bearing ones at the similar melt fraction. A linear relationship between log conductivity and log melt fraction can be expressed well by Archie's law with parameters C (pre-exponential factor) = 0.68 and 0.97, n (exponent) = 0.87 and 1.13 for silicate and carbonate systems, respectively. Comparison of the electrical conductivity data with theoretical predictions for melt distribution indicates that the model assuming that the grain boundary is completely wetted by melt is the most preferable melt geometry. The gradual change of conductivity with melt fraction suggests no permeability jump due to melt percolation at a certain melt fraction. The melt fraction of the partial molten region in the asthenosphere can be estimated to be 1~3 % and ~0.3 % for basaltic melt and carbonatite melt, respectively.
We demonstrated that a small amount of carbonatite in olivine aggregates can largely enhance the bulk conductivity of the upper mantle rocks. The deep electrical conductivity profile, obtained from analysis of data from a submarine cable extending from Hawaii to North America, showed a conductivity peak of 10-1 S/m at the depth range of 200~250 km. Such a conductive anomaly can be explained by a presence of very small amount of carbonatite melt.

Keywords: electrical conductivity, carbonatite, peridotite, connectivity, upper mantle, permeability