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Electrical conductivity of olivine and new implications for electrical anomalies in the asthenospheric mantle

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The asthenospheric mantle is often assumed to be conductive, in particular beneath the oceans, and the conductive zones are spatially independent of the overlying plate ages (Evans et al., 2005; Baba et al., 2013). The origin of the electrical anomalies has long been debated. Many candidates have been invoked to explain the high conductivity, including partial melts and structural water in olivine, the most abundant mineral in the upper mantle. All available models assume a very low conductivity (<0.01 S/m) of dry olivine at shallow mantle conditions. This assumption is based mainly on conductivity experiments conducted at reduced conditions (e.g., buffered by Mo-MoO_2, MMO). However, the shallow mantle is in general relatively oxidized, with redox state close to the Ni-NiO buffer (NNO, ~4 log units more oxidized than MMO and being close to the quartz-fayalite-magnetite (QFM buffer). On the other hand, the conductivity of dry olivine is sensitive to redox state. Consequently, the conductivity of olivine needs to be re-characterized.

We have experimentally measured the conductivity of dry and wet olivine at well-controlled mantle conditions. Starting samples were gem-quality dry olivine single crystals, and water-bearing samples were pre-prepared. The data show that the conductivity of olivine is significantly enhanced by water only at relatively low temperature (e.g., <700 °C), and at higher temperature (>1000 °C), the enhancement is insignificant for a water content <200 ppm H_2O which is possible in the shallow mantle. In particular, the conductivity of dry olivine is strikingly high at 1000-1350 °C and oxidized conditions in the shallow mantle (Liu et al., 2021), e.g., 0.01-0.1 S/m which is comparable to the geophysically-resolved values of conductive zones at the corresponding depths. The high conductivity of dry olivine itself must be taken into account for any models attempted to explain the electrical anomalies in the shallow mantle.

References:

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