Goldschmidt 2022 Abstract
https://doi.org/10.46427/gold2022.12497

A Multi-spectroscopic Study of Electrical Conduction in Xenoliths

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Electrical measurements are one of few methods for exploring the physical and chemical state of the Earth's interior. The interpretation of electrical data from the field requires laboratory measurements on natural or analogous rock samples performed at relevant temperatures and pressures. To that end, experiments in large-volume presses (LVPs) are particularly important because (1) sample volumes are sufficient (>1 mm^3) to characterize the chemical, physical, and textural properties of polycrystalline aggregates; and (2) pressure and temperature are very well controlled.

Despite decades of electrical measurements in LVPs, questions persist regarding conduction mechanisms and laboratory-based models for mantle minerals and rocks. Uncertainty originates from the sensitivity of conductivity to minute amounts of volatiles (particularly H, C) within the crystal lattice or along grain boundaries. Electrical conduction in polycrystalline materials is also sensitive to the onset of melting, or redox conditions. To characterize these influences and gain a fundamental understanding, electrical measurements must be accompanied by other probes, e.g., infrared spectroscopy to quantify hydrogen.

Here, we investigate the electrical properties of two natural xenoliths, a dunite and a pyroxenite. Our approach is two-fold; first, in-situ impedance spectroscopy is performed under a wide range of temperatures and at a pressure of 2 GPa. Second, we deploy multiple ex-situ spectroscopic techniques for analyses of the starting materials and retrieved samples. These techniques include infrared reflectance, UV-Vis-NIR reflectance, Raman scattering, and electron paramagnetic resonance spectroscopy. We explore new analytical approaches with Raman spectroscopy in particular, to quantify graphitic carbon in rock samples for the first time, and to probe the extent of melting. Additional insights result from a comprehensive analysis of the in-situ impedance spectra over a large span of frequencies. Our study not only illuminates the mechanisms of electrical conduction in xenoliths, but also exemplifies an approach that would be useful for other geomaterials.