

Imaging the connectivity of partial melts in three dimensions

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The 3-D distribution of basaltic melt around crystals of olivine (as an analogue of peridotite) is difficult to determine by conventional X-ray tomography due to the small difference in density between the two phases. Another approach is to image the surface of a sample as a function of polishing depth (serial sectioning), however, this is laborious and time consuming. Our approach was to use X-ray fluorescence tomography to image the 3-D distribution of an incompatible element that partitions almost exclusively into the melt. We chose to use niobium since it occurs exclusively as Nb(V) under upper mantle conditions, is highly incompatible, and has a high energy fluorescence X-ray, which allows a relatively large volume of sample to be studied. The sample comprised synthetic olivine (Fo90) and synthetic basalt (2.5 %) with 0.7 wt% niobium, and was equilibrated at 1350 °C and 1 GPa for 14 days. Niobium K-alpha X-ray fluorescence maps (~250 x 350 micron) were recorded for 200 different angular orientations as the sample was rotated around the vertical axis. Each map represents the 2-D projection of all the niobium in the thickness of the sample. The fluorescence data were reconstructed to give the 3-D distribution of niobium, which corresponds to the distribution of melt. In addition to the expected melt pockets at grain corners and melt channels along grain edges, melt sheets corresponding to wetted two-grain boundaries were observed. Sheets smaller than the size of the analysis spot (2-3 micron) can be imaged if there is sufficient niobium for fluorescence to be detected. A melt distribution that includes wetted two-grain boundaries has a lower permeability, would be more visible seismically than the expected tubule geometry, and can explain the significant drop in seismic velocity observed in the oceanic upper mantle.