Atom probe tomography of phase and grain boundaries in experimentally-deformed wehrlite

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Olivine-olivine (ol-ol) and olivine-clinopyroxene (ol-cpx) grain boundaries in an experimentally deformed wehrlite were characterized by atom probe tomography (APT). Concentrations of slow-diffusing and olivine-incompatible cations present in cpx (e.g. Ca and Al) may control diffusion-acommodated grain boundary sliding and thus affect mantle rheology[1]. To study this effect, a fine-grained wehrlite sample was deformed at 1.5GPa and 1100ºC with a $2*10^{-5}$/s strain rate. The wehrite mixture has a lower effective viscosity than either olivine or clinopyroxene end-member.

Grain boundaries were extracted and formed into APT tips using a focused ion beam (FIB). The tips were analyzed in a reflectron-equipped LEAP4000HR (Harvard University) at 1% detection rate, 5pJ laser energy and 100kHz pulse rate. Total ion counts per tip are between 50 and 100 million.

Regions of grain boundary segregation for the ol-ol and ol-cpx tips are estimated from incompatible element concentration profiles. The ol-ol segregation region is observed for Al, K, Ca, Cl, Na, and Ni, and apparent segregation width depends on the incompatible element. Al and K produce segregation layers between 4.3nm and 4.4nm wide. Ca, Cl, Na, and Ni all produce segregation layers from 3.2nm to 3.8nm. The ol-cpx segregation is only observed for Cl and is estimated to be 3.9nm wide. These estimates are consistent with prior estimates of grain boundary segregation by atom probe tomography on ol-ol and opx-opx samples[2].

Mg and Si have symmetrical compositional profiles from ol to cpx. However, Ca and Al concentration profiles have a chemical inflection point approximately 1nm within the cpx. Assuming grain-scale equilibrium, the profiles suggest either nanoscale disequilibrium within the cpx near the phase boundary or a bimodal transport mechanism specifically for slow-diffusing olivine-incompatible oxides. Determining the nature of phase boundary chemistry and structure allows for modeling of mantle rheology and diffusive transport (or storage) of incompable elements along grain boundaries.

[1] Sundberg, M., and R. F. Cooper (2008), *J. Geophys. Res.*, **113**, B12208. [2] Bachav, M., et al., (2015), *Microsc. Microanal.,* **21 (Suppl 3)**.