ATOMIC PROBE TOMOGRAPHY OF OLIVINE AND CLINOPYROXENE GRAIN AND PHASE BOUNDARIES IN DEFORMED WEHLRLE. J. T. Cukjati1* S. W. Parman1, R. F. Cooper1, and N. Zhao1, Department of Earth, Environmental and Planetary Sciences, Brown University, Providence, RI (*joseph_cukjati@brown.edu)

Introduction: The structure and mineralogy of the modern lunar mantle is attributed to crystallization of a magma ocean followed by its gravity-driven overturn [1]. Constraining the physical and chemical properties of olivine (ol) and pyroxene (px) mixtures is important to understanding mantle evolution, including the distribution of heat-producing elements stored along grain boundaries (or other extended defects) [2], and the dynamics of overturn and convection. Experiments on natural, terrestrial analogues demonstrate that grain boundary sliding along ol-px phase boundaries is faster than sliding along ol-ol grain boundaries [3,4], and that olivine deformed via diffusion creep is weaker when grain boundaries contain impurities [5].

Methods: Here, we use atom probe tomography (APT) to measure the chemistry of ol-ol, ol-clinopyroxene (cpx), and cpx-cpx grain boundaries from a fine-grained, experimentally-deformed wehlrite. Ol-ol and ol-cpx tips were analyzed in a LEAP4000HR (Harvard University). The cpx-cpx tip was analyzed in a LEAP5000 (University of Alabama). Chemical profiles of compatible and incompatible elements are used to estimate the chemical widths of grain and phase boundaries.

Results: What we determine for the chemical width of grain and phase boundaries depends on the element that is analyzed/scrutinized. Elements enriched on ol-ol grain boundaries include Na, Al, P, Cl, K, Ca, and Ni. Enrichment on cpx-cpx grain boundaries is observed very weakly for Al and Ca. The width of Ol-cpx phase boundaries are estimated from distributions of incompatible (Cl) and compatible elements (Na, Mg, Al, Si, Ca, and Fe). The average chemical width for ol-ol is 3.3 nm while the average chemical width for ol-cpx is 4.6 nm. Our results for ol-ol grain boundary widths are consistent with prior results [5]. For chemical profiles observable in both ol-cpx and ol-ol, the ol-cpx boundary widths are approximately 40% greater than those observed in ol-ol.

Conclusions: These results complement rheological experiments, and imply that the chemistry of grain and phase boundaries could affect/impact strain localization as observed in nature (e.g. in lithospheric shear zones) [3]. The chemical widths of grain and phase boundaries is uniquely measurable by APT; the results facilitate an improved understanding of mantle rheology as well as of the storage and transport of incompatible elements.


Figure 1: Slices from APT reconstructions of olivine-olivine and olivine-diopside (cpx) samples containing grain boundaries. Each dot represents an atom. Segregation of Al, Ca, Na, Cl occurs to the olivine-olivine grain boundary. Segregation of Cl occurs to the olivine-diopside boundary.