

SIZE INFLUENCES CORE COMPOSITION OF OXIDIZED PLANETESIMALS

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Introduction: No previous studies have experimentally investigated planetesimal core compositions at the pressures expected for differentiated planetesimals (diameters of 200-1000 km [1] and interior pressures of roughly 15-400 MPa), although a few other experimental studies have looked at other aspects of planetesimal differentiation at these pressures [2,3]. Pressure is an important consideration when volatile elements may play a significant role; as we hypothesized should be the case with sulfur and formation of FeNiS core-forming liquids during differentiation at oxygen fugacities (fO_2) above the iron-wüstite buffer (IW).

In this study, we conducted partial melting experiments on homogenized Allende (CV3 chondrite) reference powder [4] at pressures calculated for the interiors of planetesimals based on their sizes. These experiments draw upon the findings from the 1-atm (~0.1 MPa) Allende partial melting experiments of Jurewicz et al. [4,5], but are focused on the compositions of FeNiS liquids and co-forming spinel-group minerals as relatively dense phases that could contribute to the cores of differentiated planetesimals.

Methods: Our experiments were conducted in a vertically oriented cold-seal apparatus equipped with an in situ electromagnetic rapid quench system at the Smithsonian Institution (SI). Its pressure vessel is composed of a Mo-alloy with minor amounts of Hf and C. Argon is used as our pressurizing gas. Our experiments are buffered at $fO_2 = IW+1$ by WWO [6], run for 24 h at temperatures between 1075-1200°C, and at pressures of 15 MPa, 50 MPa, and 100 MPa. The experimental charges are run in double Pt-capsules, which by design means any sulfur that volatilizes will effectively be lost from the partially melted Allende material. Compositional data presented in this abstract are energy dispersive x-ray (EDS) analyses collected with the FEI Nova NanoSEM 600 at the SI. Quantitative EDS with standards was used to determine FeNiS globule compositions.

Results and Discussion: In our experiments, the average FeNiS globule compositions have ~31 wt. % S, consistent with the globules being monosulfide solid solution precursors. The ratio of Ni:Fe varies across the pressure steps with higher proportions of Fe at higher pressures. For the pressure series at 1200°C, FeNiS globules have average compositions with 33 wt. % Ni and 37 wt. % Fe for the 15 MPa experiment, 22 wt. % Ni and 44 wt. % Fe for the 50 MPa experiment, and 19 wt. % Ni and 48 wt. % Fe for the 100 MPa experiment. Alternatively, expressed as Ni:Fe ratios in order of ascending pressure about 1:1, 1:2, and 2:5. This increase in proportion of Fe without a change in percentage of S across the pressure series likely corresponds to a greater volume of S retained at higher pressures, and by extension a greater volume of FeNiS liquids forming at higher pressures.

Many other aspects of the charges from this experimental suite follow expected geochemical trends. For instance, olivine compositions in the higher temperature experiments are more Mg-rich (~Fo₇₀) and more Fe-rich in the lower temperature experiments (~Fo₅₇). A small pressure depression of olivine solid solutions is observed across the pressure series for each temperature step, with more Fe-rich olivine at higher pressures for a given temperature.

The spinel-group minerals are a notable exception. Across the temperature series, the spinel-group mineral are more Al-rich as temperature increases, spanning the compositional boundary between Al-rich chromite and the picotite variant of hercynite. Contrary to a pressure depression of solid solution, the spinel-group minerals are more Al-rich at 100 MPa than at 15 MPa for each temperature. This includes the temperature step (1200°C) at which plagioclase is not present (i.e., above the liquidus for plagioclase) across the entire pressure series. Higher Al-concentrations in spinel-group minerals at higher pressures are the opposite of what is expected for a pressure depression of solid solution. These preliminary findings suggest that spinel phase chemistry is sensitive to pressure between 15-100 MPa. In the basalt (eucrite) petrogenesis experiments of Bartels and Grove [2], spinel-group minerals are more Al-rich at 100 MPa than at 0.1 MPa for shared bulk compositions and at similar temperatures. With appropriate constraints, spinel-group mineral chemistries may have potential for geobarometry of planetesimals.

Conclusion: The size of oxidized planetesimals would—based on varying interior pressure—exert a strong influence on the core composition of these bodies, with larger oxidized planetesimals forming more Fe-rich and larger FeNiS-cores than geochemically similar smaller bodies. Between 15-100 MPa, pressure may also influence the composition of spinel-group mineral phase chemistry, and thus these accessory minerals may provide a means for determining the pressures, and by extension the depths, at which various achondrites formed in their parent planetesimals.

References: [1] Elkins-Tanton L. T. et al. 2012 *Annu. Rev. Earth. Planet. Sci.* 40: 113 [2] Bartels K. S. and Grove T. L. (1991) *Proc. LPSC* 21: 351 [3] Singletary S. and Grove T. L. (2006) *Geochim. Cosmochim. Acta* 70: 1291-1308 [4] Jurewicz A. J. G. et al. 1991 *Science* 252: 695 [5] Jurewicz A. J. G. et al. 1993 *Geochim. Cosmochim. Acta* 57: 2123 [6] Shofner G. A. et al. 2016 *Am. Mineral.* 101: 211