EXPERIMENTAL MELTING OF ALLENDE AT IW+1 AT PRESSURES RELEVANT TO THE INTERIORS OF PLANETESIMALS. N. G. Lunning[1], L. E. Waters[1], T. J. McCoy[1], and C. M. Corrigan[1]. [1]Department of Mineral Sciences, National Museum of Natural History, Smithsonian Institution, Washington, DC 20560-0119, USA. lunningn@si.edu

Introduction: Only a few studies investigating igneous processes on planetesimals have been undertaken at pressures relevant to planetesimal interiors [1-2]. Planetesimals, including those thought to have undergone melting and perhaps minimal differentiation, were relatively small (10-1,000 km in diameter [3]) and correspondingly would have had much lower interior pressures (10s of MPa to 100s of MPa) than the contemporary Solar System's rocky planets. Differentiation experiments focused on studying the terrestrial planets are typically conducted at pressures much too high (≥GPa) for planetesimals [e.g., 4]. It is common to study igneous processes related to planetesimals in 1-atm (~0.1 MPa) gas-mixing furnaces. However, elements important to some aspects of planetesimal differentiation can be lost to volatilization (e.g., S or Na) in experiments run at ~0.1 MPa [5].

In this study, we are interested in melting and differentiation of relatively oxidized planetesimals (fO_2=IW+1), which we hypothesize may have had cores dominated by sulfides. We are particularly interested in the potential relationship between body size, which controls the interior pressure, and the retention or volatilization of sulfur.

Jurewicz et al. [6] partially melted Allende ($CV3_{oxA}$ chondrite) to examine planetesimal basalt petrogenesis at fO_2 from IW-1 to IW+2. This work provides hints regarding the effects of sulfur volatilization on spinel-group mineral compositions. [6] noted that there may be an fO_2 influence on spinel-group mineral composition with more Al-rich spinels (i.e. hercynite var. picotite) forming at progressively higher fO_2 conditions. Commensurate with the interest of [6] in basalt formation their gas-mixing furnace experiments were run for ≥72 hours to approach silicate equilibrium: a side effect of this design is that their charges completely lost sulfur to volatilization. We posit compositional changes in spinel group minerals toward more Al-rich compositions may be due to the combination of sulfur volatilization and relatively oxidized melting conditions. When sulfur is lost from chondritic materials it is lost directly from FeNi-sulfides. At IW+1, most of the associated Fe will be oxidized to FeO and may lead to crystallization of Al-rich spinels.

The Al-content of accessory spinel-group minerals has the potential to play an outsized role in differentiation of oxidized planetesimals, because these accessory minerals could influence the distribution of ^{26}Al in these bodies, decay of which is generally thought to be primary heat driving melting on planetesimals [e.g., 3].

Methods: We performed partial melting experiments on homogenized Allende reference powder [7]. The experiments were conducted in a vertically oriented cold-seal apparatus, where the pressure vessel is composed of a Mo-alloy with trace amounts of Hf and C (referred to henceforth as MHC) at the Smithsonian Institution (SI). The pressurizing gas was ultra-high purity Ar-gas. Our experiments, so far, have been run for 24 h at temperatures between 1075-1125°C and pressures of 15 MPa, 50 MPa, and 100 MPa. Our MHC experimental charges use a double Pt-capsule setup (Fig. 1) with a pre-saturated inner Pt-capsule containing the Allende sample powder crimped but not welded at the top. The WWO (IW+1: [8]) buffer pair work by exchange of molecular oxygen between the inner capsule and the atmosphere contained by the welded outer capsule.

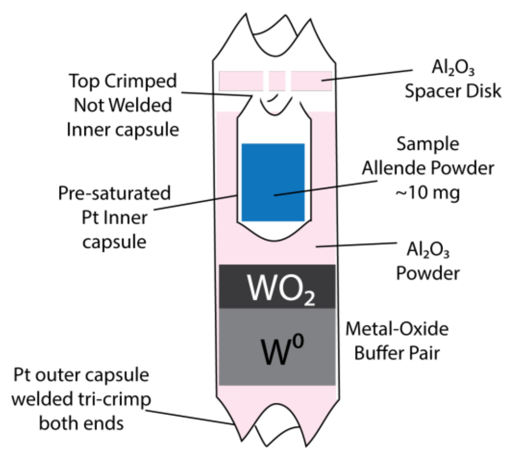

Figure 1: Illustration of experimental double capsule set-up.

High-resolution energy dispersive x-ray (EDS) elemental maps and semi-quantitative phase data were obtained using the FEI Nova NanoSEM 600 at the SI. We collected EDS analyses and maps using a beam current of 13 kV and 2-3 nA.

Results and Discussion: It is useful to compare and contrast our preliminary results with the results from the ~0.1 MPa experiments of [6]. There are aspects of our experimental results that we expect to be similar to [6] because they should be neither directly nor indirectly pressure sensitive (because of element volatility differences between 0.1 MPa and 15 MPa). Comparison between these two experiments will provide an initial validation that our experimental design is working We cannot make exact comparisons with the results of [6] because they only conducted one experiment at an fO_2 of IW+1 and that experiment was conducted at 1200°C. At an fO_2 of IW+2, [6] conducted experiments across a broader temperature range (1130-1325°C). However, comparing the IW+I at 1200°C and IW+2 at 1140-1200°C results of [6] still provides useful context with which to consider our results.

Volatilization insensitive features. We expect the olivine and glass compositions (excluding elements affected by volatilization) to be very similar between our experimental charges and those of [6]. Olivine in our 1125°C IW+1 charges (Fig. 2) is Fo_{63-70} while in the results of [6] olivine is Fo_{65} in the IW+I at 1200°C charge and Fo_{62} in the IW+2 charges between 1140-1200°C. The glass in our 1125°C IW+1 charges have Ca/Al ratios 0.93-1.16 while in the results of [6] the glass has Ca/Al ratio of 1.14 in the IW+I at 1200°C charge and Ca/Al ratios of 1.20-1.36 in the IW+2 charges between 1140-1200°C. The olivine major element compositions and glass Ca/Al ratios are broadly consistent with that of [6] at IW+I and 1200°C.

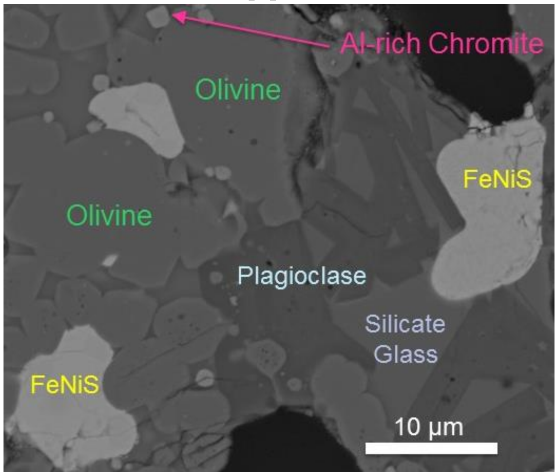

Figure 2: Backscatter electron image of 15 MPa 1125°C IW+1 experimental charge.

Volatilization sensitive features. Features that are notably different in our experimental charges from those of [6] include the presence of FeNiS globules, spinel-group mineral compositions are less Al-rich, and plagioclase is more Na-rich (Fig. 2). These differences were generally expected and are part of the reasons for conducting our experiments at moderate pressures (15-100 MPa).

The presence of FeNiS globules is one indicator of S-retention, and that Fe is sequestered in these globules when sulfur is retained. The spinel group minerals in our 1125°C IW+1 charges can be best classified as Al-rich chromite rather than hercynite; they have Cr#={100*Cr/(Cr+Al)}=55-59 while the hercynites (var. picotite) in [6]'s IW+1 and IW+2 charges have Cr#=22 and 14, respectively. The presence of FeNiS globules with less Al-rich spinel-group minerals in our experiments conducted ≥15 MPa supports our hypothesis that sulfur volatilization increased the activity of FeO in the ~0.1 MPa experiments conducted at fO_2 > IW of [6], and fed crystallization of picotite.

The plagioclase that crystallized in our experiments (15-100 MPa) is more Na-rich than all plagioclase reported in the experimental charges of [6], regardless of fO_2 (IW-1 to IW+2). All plagioclase formed in the work of [6] is anorthite (An_{92-99}). In contrast, the plagioclase formed in our experiments is labradorite (An_{60-67}). This difference can be explained by devolatilization of Na during the long duration gas-mixing furnace experiments of [6], as has been demonstrated in other experimental studies partially melting chondrites [5,9].

Conclusions: Our preliminary results demonstrate that oxidized differentiated planetesimals would have contained cores formed from immiscible FeNiS liquids, represented by FeNiS globules in our experiments. The composition of spinel-group minerals that form in partially melted Allende material is strongly influenced by retention or volatilization of sulfur, with Al-rich chromite forming when sulfur is retained and picotite forming when sulfur is lost.

Future Work: By the time of the meeting, we plan to conduct additional experiments at 1150-1200°C IW+1 at 15 MPa, 50 MPa, and 100 MPa for 24-60 h. In the coming months, we plan to conduct high resolution quantitative compositional analyses of our experimental charges using a field emission source electron microprobe, currently being installed and tested at SI. High resolution quantitative analyses will enable us to study potential influences of varying planetesimals size on differentiation processes sensitive to volatilization.

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