METAL-SILICATE PARITIONING OF SI AND S IN HIGHLY REDUCING CONDITONS: IMPLICATIONS FOR THE EVOLUTIONS OF MERCURY. V. J. Hillgren[1] and Y. Fei[1], [1]Geophysical Laboratory, Carnegie Institution of Washington, 5251 Broad Branch Rd. NW, Washington, D. C. 20015, vhillgren@ciw.edu

Introduction: Mercury has long stood out among the terrestrial planets because of its anomalously large metallic core, and recent measurements from the MESSENGER spacecraft have shown that Mercury is truly a unique and fascinating world. For example, gravity measurements have indicated that the core is even larger than previously believed and suggest that there maybe a dense FeS layer, termed the anticrust, at the base of the mantle [1]. Furthermore, measurements of the surface composition show that the FeO content of the surface is low, however still on the order of a few wt. % and that the S content is strikingly high, up to 4 wt. % [2]. All of these characteristics—the large core, the anticrust, the low FeO and high surface S—are related to core formation and evolution on Mercury.

The low surface FeO suggests that core formation occurred under very reducing conditions, and Si along with S may have been incorporated into the core. There is a well documented miscibility gap in the Fe-Si-S system that closes with pressure [3,4]. This miscibility gap was invoked by Smith *et al.* [2] as an origin for the dense FeS layer that they proposed may reside at the bottom of the mantle.

On the other hand, early metal-silicate partitioning work showed that when conditions are reducing enough that the metal contains significant Si, the S partitions into the mantle instead of the core [5]. This suggests that Si and S would be mutually exclusive in a core, and thus liquid immiscibility could not be responsible for the anticrust, but it would provide an explanation for the high S content of the mantle. Other data at higher pressures (25 GPa) and extremely reducing conditions (19 wt. % Si in the metal), suggests S would enter the core, but also low density sulfides such MgS would form that would presumably remain in the mantle also leading to higher than expected S [6]. However, it is not clear if these relationships would hold under the much lower pressures (approx. 6 GPa) of Mercury's core formation. Recent work at atmospheric pressure, however, showed both high S contents in the mantle and an immiscible core can be achieved, but not a high enough FeO content of the mantle [7].

We wished to further explore the mutual partitioning of Si and S between metal and silicate under reducing conditions at pressures that may be more relevant to core formation in Mercury.

Experimental: We prepared two sets of starting materials. The first set was based on a reduced Bencubbinite-like composition where all the Fe was added as metal or FeS and a portion of the Si was also added in reduced form. This composition had low bulk S (total FeS of 0.48 wt. %). Two other materials were made by adding approximately 1.5 and 3 wt. % FeS to this basic composition. The Bencubbinite-like composition was chosen because they have been suggested as possible precursor materials for Mercury based on their high metal to silicate ratio [for example, 8]. The second set of materials consisted of an oxide mix in roughly chondritic proportions (38 wt. % MgO, 53 wt. % SiO_2, 3.8 wt. % Al_2O_3, 2.8 wt. % CaO, 2.0 wt. % Na_2O, 0.26 wt. % K_2O, 0.22 wt. % TiO_2) mixed with a metallic component composed of Fe-metal with 20 wt. % Si and either 5, 10 or 15 wt. % S.

Runs were conducted at 2 GPa in the piston cylinder apparatus. For each material set a run was conducted at 1600°C and one at 1800°C. The experiments were conducted in MgO capsules. Run duration were either 60 or 120 minutes. Samples were recovered and sectioned horizontally opposed to longitudinally and polished. Each consisted of several horizontal sections. Samples were then examined JEOL 6500F Field Emission SEM outfitted with an Oxford X-Max 80 mm^2 Si Drift Detector combined with the Aztec software package.

Results: The samples turned out to be very complex, and not all phases are present in each horizontal section. All sections have not been analyzed yet, so the data presented here is preliminary.

Bencubbinite Runs. Only portions of the 1800°C runs have been examined to date. In all three runs there was a single metallic phase that contained 6 to 7 wt. % Si, and depending on which starting composition 0.3 to 2.5 wt. % S. The FeO contents of the silicate were less than 1 wt. % and the S content of the silicate was a few tenths of a weight percent. These compositions at these presents and temperatures could not product the compositions observed on Mercury's surface. Figure 1 shows an example of the run products.

Material Set Two. In all the 1600°C runs, we have so far only observed only a single metal phase with 14 to 17 wt. % Si and only a few tenths of a weight percent S. the liquids contained only approximately 0.5 wt. % Fe and similar amounts of S. There is clearly a missing S-rich phase which is presumably in sections that have not been analyzed yet.

The 1800°C runs have a metallic phase with 17 to 19 wt. % Si and only approximately 0.5 wt. % S. the silicate liquids however contain up to 5 wt. % S and 0.8 to 0.9 wt. % Fe. Also in these runs was an Mg-Fe-S-O phase of uncertain stoichiometry surrounded by enstatite (figure 2).

The higher temperature runs have significantly more S in the silicate than the lower temperature runs. Although the higher temperature runs have a few wt. % more Si in the metal, this result would suggest that temperature is the main influence on how much S is in the silicate melt. Interestingly, the higher temperature runs also have close to 1 wt. % Fe in the silicate liquid. Thus, perhaps S and Fe contents of the silicate portion of Mercury are the result of high temperature differentiation under reducing conditions.

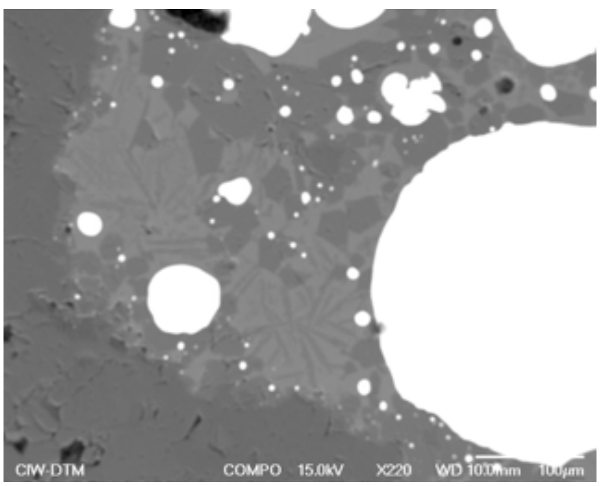

Figure 1. A Backscatter electron image of an 1800°C run with a Bencubbinite starting composition. The bright white is a single metal phase, the dark crystals are olivine, and a dendritic silicate liquid is also present.

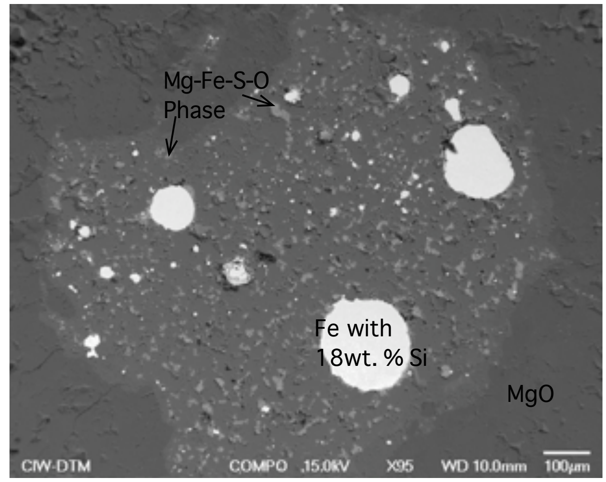

Figure 2.

References:

[1] Smith et al. (2012) *Science, 336,* 214-217. [2] Nittler *et al.* (2011) *Science., 333,* 1847-1850. [3] Morad and Katsura (2010) *Geochim. Cosmochim Acta, 74,* 3659-3667. [4] Sanloup and Fei (2004) *PEPI,* 147, 57-65. [5] Kilburn and Wood (1997) *EPSL, 152,* 139-148. [6]Seibert *et al.* (2004) *PEPI, 143,* 433-443. [7] Chabot *et al.* (2012) *MAPS, 47,* A96. [8] Brown and Elkins-Tanton (2009) *EPSL, 286,* 446-455.