WHAT DO CHEMICAL TRENDS IN IRON METEORITES TELL US ABOUT THE BULK COMPOSITION AND EVOLUTION OF ASTEROIDAL CORES?

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Introduction: As samples of the central metallic cores of asteroid-sized parent bodies, iron meteorites provide a unique opportunity to investigate the formation and evolution of asteroidal cores. Studies of the cooling rates of iron meteorites provide information about the sizes and thermal histories of the parent asteroids, including intriguing insights into the early impact and bombardment history of the bodies [e.g. 1-2]. Studies of the chemical trends in iron meteorites yield complementary insights into the crystallization history and the bulk compositions of asteroidal cores.

In the last decade, a number of studies have provided iron meteorite measurements for a large number of trace elements in multiple magmatic iron meteorite groups [3-8]. Also in the last decade, studies have yielded experimentally determined partition coefficients in metallic systems for a large number of trace elements [9, 10]. This has enabled new crystallization models to simultaneously model more trace elements than previously possible. As each magmatic iron meteorite group generally represents samples from a different asteroidal core, modeling the chemical trends in multiple iron meteorite groups can allow comparisons between the crystallization histories and the bulk compositions of these different cores. How was the core crystallization process the same on different asteroids? How was it different? How do the bulk core compositions vary between asteroids? These are the questions we address with our multi-element crystallization modeling work.

Model: The overall modeling approach is similar to that employed by [11]. The liquid crystallizes to a solid in small, discrete steps. The S and P contents of the liquid have a significant effect on the partitioning behaviors, which are parameterized as a function of the liquid's S and P contents based on experimentally determined partitioning values [e.g. 9, 10]. Sulfur is effectively excluded from the solid, resulting in an increasing S content of the liquid as crystallization proceeds; some P partitions in the crystallizing solid, but P is also enriched in the liquid as crystallization progresses. Crystallization modeling includes Fe, Ni, S, and P along with the following trace elements that exhibit siderophile behavior in the Fe-S system: Au, As, Co, Ga, Ge, Ir, Pt, Sb, and W.

In the model, the initial bulk composition of the metallic core is allowed to vary and is determined after achieving a good match to the iron meteorite chemical trends. In addition to the simple fractional crystallization of the metallic core, the model considers the chemical effects of both liquid immiscibility in the Fe-Ni-S-P system [12] and the existence of trapped melt [3]. We have applied the model to the IVB [5], IIIAB [3], IID [6], and IIG [8] iron meteorite groups, with preliminary model runs also for the IVA [4] and IIAB [7] groups.

Results and Implications: Our initial results suggest a diversity of S contents for the bulk core compositions of the different parent asteroids. The chemical trends in the IVB group are fit well by a S-free core, while the IIIAB core likely encountered liquid immiscibility and trapped significant melt during the crystallization process. The IID trends suggest a P-bearing and S-poor bulk composition, consistent with its formation after a S-rich metal had already segregated in the parent asteroid [6]. The bulk composition of the IVB core shows a strong volatility depletion trend, while the IIIAB and IID bulk core compositions are, within an order of magnitude, chondritic for all trace elements modeled. In contrast, the IIG bulk composition is not consistent with a parent asteroid chondritic composition. The IIG irons have the highest P contents of any iron meteorites, and their non-chondritic element ratios may be due to the proposed scenario of being related to the larger IIAB group as a late-stage crystallizing component of the parent core [8]. Modeling the IIAB and IIG groups together will provide further insight.

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