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Understanding iron meteorites and early Solar System metallic cores of asteroid parent bodies

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Abstract

Iron meteorites provide unique opportunities to investigate the central metallic cores of asteroid-sized bodies in the early Solar System. This work investigates the chemical variability present in asteroidal cores as represented in our iron meteorite collections, with implications for the parent bodies.

1. Introduction

Recent work [1] has identified isotopic signatures in iron meteorites that suggest that they formed in two distinct reservoirs in the early Solar System: one with similarities to carbonaceous chondrites (CC-type) and the other with similarities to other meteorites (NC-type, non-carbonaceous). The two reservoirs have been proposed to be separated by Jupiter, thus representing inner and outer Solar System formation regions [1]. An important follow-on question to this observation is whether there are chemical differences between asteroidal cores that formed in the inner and outer Solar System. This work explores this question through using iron meteorite measurements and experimental partitioning data to understand the chemical compositions of asteroidal cores in the early Solar System.

2. Iron meteorite trends revealed on a Co vs. Ni diagram

A Co vs. Ni diagram can provide a framework to understand iron meteorite compositions. As shown in Fig.1, many iron meteorite groups plot roughly along a trend consistent with the Ni/Co CI ratio. For irons along the CI Ni/Co line, higher absolute concentrations of Co and Ni may be produced by more oxidized core formation conditions on the parent asteroidal body. As a body becomes more oxidized, the amount of FeO rather than Fe increases, resulting in less Fe in the metallic core; consequently, the core concentrations of Ni and Co are higher, as Ni and Co continue to partition dominantly into the core. As seen on Fig. 1, the large majority of CC-type irons have higher Co and Ni values, suggesting more oxidized parent bodies than the NC-type irons, and hence more oxidized parent bodies in the outer Solar System than the inner Solar System.

Additionally, in this work, it is postulated that irons with low Ni/Co ratios may be due to the formation of schreibersite in these irons, which are avoided during the analysis of the metal of the irons [2]. Schreibersite can have a substantial amount of Ni [3], resulting in lower Ni/Co ratios in the remaining metal phase. It is also postulated that irons with high Ni/Co ratios may be due to the formation of troilite. Slight differences in the solid metal-liquid metal partitioning values for Ni and Co [4] result in the formation of troilite at the Fe-Ni-S cotectic producing enrichments in Ni in the metal while the Co concentration in the metal is relatively constant.

3. Iron meteorite experiments to determine bulk core compositions

To determine the bulk composition of an asteroidal core as sampled by iron meteorites, it is necessary to model the fractional crystallization trends of each iron meteorite group. The S content of the asteroidal core can have a large effect on the partitioning behavior of elements and was recently parameterized in [4]. Using these parameterizations, the bulk core compositions for the IIAB, IIIAB, IVB, IVA, and IID iron meteorite groups were modeled [5] and are discussed briefly in the conclusions below.

Summary and Conclusions

Overall, there is strong evidence that the majority of CC-type irons sampled more oxidized parent bodies than NC-type irons, based on the separation observed on a Co vs. Ni diagram. This suggests that the parent asteroids of iron meteorites in the outer Solar System were more oxidized than the parent asteroids that formed iron meteorites in the inner Solar System.

Modeling of the bulk compositions of iron meteorite parent bodies cores shows largely chondritic bulk compositions, with varying levels of volatility depletions that are not correlated with classification as NC or CC-type. The modeled bulk compositions also show evidence for enrichment in refractory siderophile elements in some cores of both NC and CC-types.

Acknowledgements

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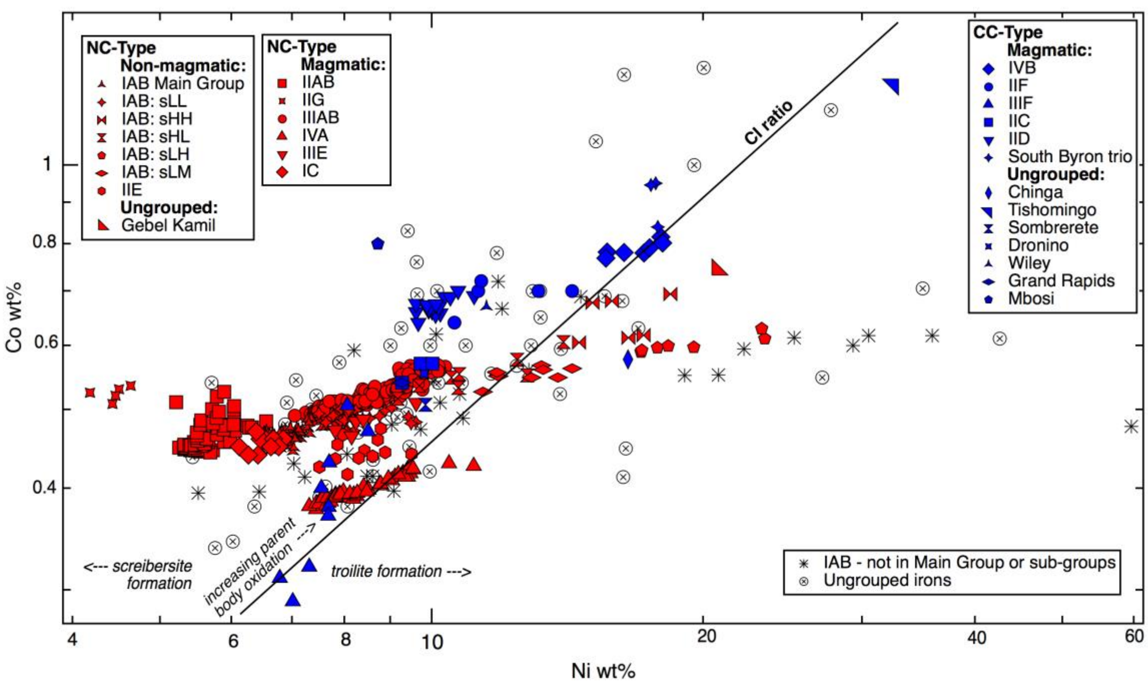

Figure 1: Co vs. Ni diagram provides a framework to evaluate processes that have influenced the chemistry of iron meteorites. Iron meteorite data from numerous studies, largely from the UCLA Wasson group, as listed in [6]. NC and CC classifications from: [1], [7–11]. IIG shown as NC based on association with the IIAB parent body [12].