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Germanium isotopes reveal dual origin of volatile element depletion among magmatic iron meteorites

ELIAS WÖLFER, FRIDOLIN SPITZER, JAN L HELLMANN, CHRISTOPH BURKHARDT AND THORSTEN KLEINE

Max Planck Institute for Solar System Research

Variations in the abundances of moderately volatile elements (MVEs) in planetesimals and planets provide key insights into the processes that shaped their chemical compositions, yet the origin of these variations remains poorly constrained [e.g., 1–4]. Magmatic iron meteorites represent samples of the metallic cores of the earliest planetesimals in the solar system and are among the most strongly volatile element-depleted samples, as demonstrated by their low abundances of the MVE germanium (Ge) [5]. To investigate the nature of the process(es) determining an iron meteorite's MVE budget, we studied the elemental and mass-dependent Ge isotope systematics of a comprehensive set of 50 magmatic iron meteorites from all major groups, including the most extremely MVE-depleted IVA and IVB irons. We find that magmatic iron meteorites display a similar range of Ge isotope fractionations compared to chondrites [6], despite being characterized by much larger Ge depletions. Specifically, the strongly depleted IVA and IVB irons have lighter Ge isotope compositions than the CI chondrites, while there rarely are iron groups with heavier compositions. These observations indicate that the MVE depletions among the irons cannot simply result from degassing of CI-like starting materials. Instead, we infer that the elemental and mass-dependent Ge isotope fractionations among iron meteorites record the combined effects of primary volatile element depletion in the solar nebula (i.e., as recorded in chondrites [6]) and subsequent evaporative loss, most plausibly associated with collisionally exposed molten cores. Interestingly, the most pronounced volatile element depletions occurred in iron meteorite parent bodies that formed from precursor materials already depleted in volatiles, indicating that the initial volatile element inventory of an iron meteorite parent body, potentially by influencing core melting temperatures, plays a fundamental role in governing its subsequent evolution.

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