Carbon isotopic composition of haxonite in Aletai (IIIE-an iron).

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Introduction: Earth's core might contain minor amounts of light element, such as C and Si[1]. The $\delta^{13}C$ value of Earth's mantle-derived samples is ~-5‰, which is higher than that of carbonaceous and ordinary chondrites (-5~-25 ‰)[2,3]. It was suggested that C-bearing material (e.g., Fe-carbide) in Earth's core could be a low-$\delta^{13}C$-reservior to balance the bulk carbon[4]. Iron meteorites are the core materials derived from differentiated parent bodies. A study of C-bearing minerals in iron meteorites can provide insights into carbon isotope fractionation during core formation and other related planetary processes. Aletai is an anomalous IIIE iron[5], in which haxonite (~5.3 wt.% C and ~4-6 wt.% Ni) is a major carbon-carrier[6,7]. Haxonite precipitates at relatively low temperature (~300-450 °C) in plessite when C is saturated in metallic Fe-Ni during cooling[7]. Here, we conducted in situ SIMS carbon isotope analysis for haxonite in Aletai (Wuxilike and Akebulake mass), to look into the C isotope fractionation during core formation and compare its genesis with other IIIE irons.

Methods: The carbon isotopic composition of Fe-carbide was determined using a CAMECA IMS-1280 at the Institute of Geology and Geophysics, Chinese Academy of Sciences (IGGCAS). $^{13}C/^{12}C$ ratios were measured on a multi-collection mode. The mass resolution used in the analysis was ~5000, and the spot size was typically 20 µm in diameter. A Cs^{+} primary ion beam was accelerated at 20 kV with an intensity of ~1.8 nA. Each carbon isotope analysis contains 30 s of pre-sputtering and a total counting time of 360 s with 60 cycles. A recommended $\delta^{13}C$ value of 23.5‰ of Disko Fe-carbide standard was used to corrected for the IMF[8]. The reproducibility of standard was better than 0.5‰ (1σ). The internal precision of a single analysis of standard and sample was around 0.4-0.7‰ (2σ).

Results: Multiple carbon isotope measurements were performed in one single Fe-carbide grain each for Wuxilike and Akebulake. The $\delta^{13}C$ results show a weighted mean of -15.8±1.0 ‰ (n=14) and -14.4±1.0 ‰ (n=10) for Wuxilike and Akebulake mass, respectively. This indicates that Aletai Fe-carbide grains are essentially homogeneous in carbon isotopes. Combing the analyses from two masses yields a weighted mean of -15.2±1.2 ‰ (n=24) for Aletai.

Discussion: $\delta^{13}C$ value of Aletai haxonite (-15.2±1.2‰) is significantly lighter than that in Colonia Obrera (IIIE, -1.9±6.4‰)[9]. Assuming that carbon contents of kamacite (3.7-9.7 ppm), taenite (330-364 ppm) and plessite (117-347 ppm) in Aletai are comparable with that in IIIAB irons[7], haxonite (0.1-0.25 vol.%) in Aletai accounts for 43-70 wt.% of the total carbon based on the mass balance calculations. If Aletai has the same bulk C-isotopic compositions as other IIIE irons, taenite in Aletai would have a $\delta^{13}C$ value of -0.63~+12‰. It is therefore expected that the C-isotopic fractionation between taenite and haxonite in Aletai would be up to ~15-27‰. Such a large C-isotopic fractionation has not been reported in IAB irons where cohenite (Fe_3C) extensively grows at ~600 °C (~3-6‰ for taenite-cohenite C-isotopic fractionation[10]). In this regard, it seems the C-isotopic composition of haxonite is unique and more likely represent the characteristics of Aletai's parent body. Further experimental studies on C-isotopic fractionation between taenite and haxonite is required. Alternatively, the differentiation process of iron meteorites may affect the C-isotopic compositions. Aletai and the other IIIE irons have similar primary cooling rates[11], which would not cause the variable C-isotopic compositions of taenite and carbide like those in IAB irons. But the lost of carbon-bearing gas may contribute to the relatively low haxonite $\delta^{13}C$ value in Aletai iron, since the fractionation between CO_2/CH_4 and carbide at 1000 °C can be up to 8-14‰[4]. Overall, the haxonite C-isotopic composition of Aletai provides another line of evidence that Aletai either experienced a different differentiation process or had a unique origin other than that of the other IIIE irons. This concurs with its anomalous geochemical signature.

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