THE SEARCH FOR ^{60}Fe IN SECONDARY MAGNETITE AND FAYALITE.

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Introduction: Iron-60 decays to ^{60}Ni with a half-life of 2.6 Myr, making it potentially important for dating events in the first 10-15 Myrs of solar system history. Constraining the ^{60}Fe abundance in the early solar system has proven difficult because of the readily mobile nature of Fe and Ni, particularly in the presence of water [1,2]. Even the most primitive ordinary chondrites, such as Semarkona, are affected by mobilization of Fe and Ni. However, the ubiquitous alteration has produced new phases, such as magnetite and fayalite, that might be amenable to ^{60}Fe-^{60}Ni dating. Here, we explored the potential of secondary minerals to address the ^{60}Fe problem. If the formation of secondary minerals occurred within a few million years after solar system formation, it is plausible the ^{60}Fe signature would be measurable in the form of ^{60}Ni excesses in secondary phases. We investigated fayalite (Fe_2SiO_4) from Kaba (CV3.1) and magnetite (Fe_3O_4) from Kaba and Semarkona (LL3.0).

Methods: SIMS analyses of magnetite and fayalite were conducted using a Cameca ims 1280 ion microprobe in combined multi-collection jump-scanning mode. The Ni isotopes, ^{60}Ni, ^{61}Ni, ^{62}Ni, were measured on the monocollection electron multiplier along with their closest molecular interferences by jump scanning. ^{56}Fe was measured on the L1 Faraday cup in multicollection mode at the same field setting as ^{60}Ni. The mass resolving power for Ni-isotopes was ~4800. The primary ion beam was configured in aperture illumination mode to give a ~10 µm spot. The beam current was 1.9 to 3.4 nA. Each spot was pre-sputtered for 1.5 to 3 minutes to eliminate surface contamination. In-house terrestrial magnetite and synthetic fayalite (Fa_{99}; [3]) standards were used to determine the relative sensitivity factor of Fe and Ni. Excess ^{60}Ni is calculated by linear mass fractionation correction ($\Delta^{60}Ni = \delta^{60}Ni - 2\times\delta^{61}Ni$). The δ^{60}Ni and δ^{61}Ni ratios are fixed to reference values of 7.215 and 0.3136 for ^{60}Ni/^{62}Ni and ^{61}Ni/^{62}Ni, respectively [4].

Results: We were unable to resolve excesses of radiogenic ^{60}Ni in all measured points. Based on the measurement uncertainties, we report one-sided upper limits (95% confidence) on the ^{60}Fe/^{56}Fe ratios.

Semarkona. Semarkona magnetite measurements yielded high Fe/Ni ratios similar to [5], with ^{56}Fe/^{62}Ni ratios up to 2×10^7. At the time of magnetite formation, the initial ^{60}Fe/^{56}Fe, $(^{60}Fe/^{56}Fe)_0$, was $<7.3 \times 10^{-8}$. This is resolvably lower than the $(1.1 \pm 0.4) \times 10^{-7}$ reported for Semarkona magnetite by [5]. It is likely that their result suffered from ratio bias, which we minimize by calculating ratios from total counts rather than the mean of ratios (cf. [6]).

Kaba. Magnetite and fayalite yielded ^{56}Fe/^{62}Ni ratios up to 2.8×10^5 and 6.3×10^5, respectively. Assuming these phases formed simultaneously [7], we regressed all measurements together to yield $(^{60}Fe/^{56}Fe)_0$ of $<8 \times 10^{-8}$.

Discussion: The timing of magnetite formation in Semarkona is not well constrained. ^{53}Mn-^{53}Cr measurements of fayalite in the L3.05 chondrite EET 90161 put fayalite formation at ~2.4 Myr after CV CAIs [8,9]. Assuming a similar time interval for Semarkona would give a solar system initial ratio, $(^{60}Fe/^{56}Fe)_{SS}$, of $<1.4 \times 10^{-7}$.

Fayalite in CV chondrites has three modes of origin. The large, pure fayalite crystals that we measured formed by precipitation from a fluid [10]. The timing of fayalite formation in Asuka 881317 (CV3) was inferred from ^{53}Mn-^{53}Cr dating of the fayalite to be ~4 Myr after CAIs [8]. Applying the 4 Myr time interval to our measured ratio of $<8.0 \times 10^{-8}$ gives an estimated $(^{60}Fe/^{56}Fe)_{SS}$ of $<2.3 \times 10^{-7}$.

Our $(^{60}Fe/^{56}Fe)_{SS}$ upper limits estimated from Semarkona and Kaba are within the range inferred for the early solar system from chondrules from unequilibrated ordinary chondrites (7.2×10^{-8} to 3.8×10^{-7}) [1,11]. Although we have not yet fully evaluated the possibility of Fe-Ni mobility in secondary magnetite and fayalite, we will try to lower the measurement uncertainties to better constrain abundances of ^{60}Fe during aqueous alteration on parent asteroids.

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