OXYGEN ISOTOPIC COMPOSITIONS OF FAYALITE IN THE KABA CV3 CARBONACEOUS CHONDRITE.

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INTRODUCTION

The Fe-rich olivine end-member, fayalite (Fa_{100}), occurs in the matrix, chondrules, CAIs, silicate aggregates, and dark inclusions in the oxidized Kaba and Mokoia CV3 chondrites, where it is associated with magnetite and troilite. To help constrain the origin of the fayalite, we measured O-isotope compositions of fayalite (Fa_{98-100}) from two petrographic settings of the Kaba meteorite using the ion probe at ASU.

ANALYTICAL METHODS AND SAMPLES

The O-isotope analyses were performed with the ASU Cameca ims-6f ion microprobe. The Cs^+ primary ion beam was focused in aperture-illumination mode to produce a ~20 µm spot. The secondary column was operated at -9 kV with a mass resolving power of 5500 and a 75 eV energy window. The normal-incidence electron flood gun was used for charge compensation. Negative ^{16}O ions were measured on the faraday cup and $^{17,18}O^-$ were measured on the electron multiplier. Synthetic forsterite (Fa_0), Rockport fayalite ($Fa_{\sim 100}$), and San Carlos olivine (Fa_{11}) were used as standards. We did not have a suitable magnetite standard. The 2σ error ellipses on the figures consider the counting statistical uncertainties, the uncertainty in the correction for the relative yields of the faraday cup and electron multiplier, and the variability of the instrumental mass fractionation. The calculation explicitly takes into account the correlated components in the errors for instrumental mass fractionation and yield correction. In this data set the uncertainty in instrumental mass fractionation dominates the errors.

Fayalites from two petrographic settings were identified for study in a thin section of Kaba prepared from ASU materials. One type consists of large (up to 600 µm long) laths of fayalite embedded in the matrix, where they radiate from a core of magnetite and troilite. The boundaries between fayalite laths and their adjacent matrix, as well as between fayalite and their enclosed troilite-magnetite cores, are well defined and sharp, without detectable diffusion zones in the fayalite at 1 µm scale. The second type of fayalite was found in two porphyritic olivine chondrules consisting mainly of forsterite grains and mesostasis. Fayalite-magnetite-troilite nodules that occur either within or at the surfaces of the chondrules clearly replaced the primary metal grains in chondrules. These chondrules have fayalite in direct contact with forsterite, which is a strikingly disequilibrated assemblage. Electron probe analyses show these grains are quite homogeneous end-member fayalite containing minor MnO (from 0.14 to 0.57 wt %) and NiO (from 0.08 to 0.15 wt %).

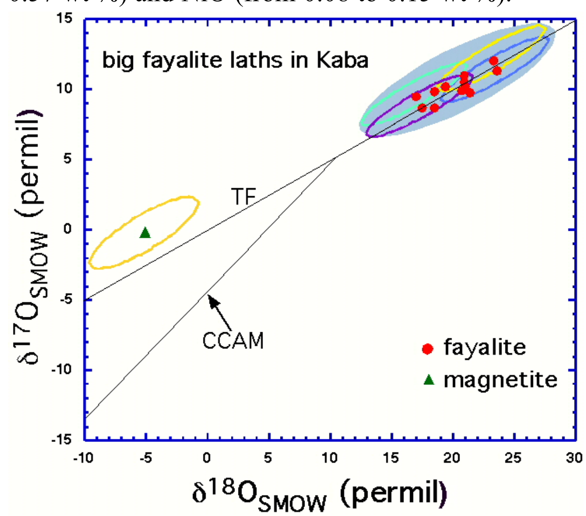

Fig.1. O-isotope compositions of large (up to 600 µm long) laths of fayalite radiating from a core of magnetite and troilite in Kaba CV3 meteorite

RESULTS

The O-isotope compositions for big fayalite laths are plotted in a $\delta^{17}O$ vs. $\delta^{18}O$ diagram (Fig. 1). We did not plot all error ellipses. Instead, we chose the lightest and heaviest data points to illustrate the uncertainties. These error ellipses overlap in the middle of the distribution. Thus, we are justified in arguing that all of these data reflect a single composition that can be approximated by the mean of the data and the standard deviation (i.e., $\delta^{18}O = 19.7 \pm 5.0$ ‰; $\delta^{17}O = 9.9 \pm 2.9$ ‰). Our value does not match the O-isotope compositions of Kaba fayalites reported by Choi et al. ($\delta^{18}O = 10.0 \pm 7.5$ ‰; $\delta^{17}O = 5.2 \pm 2.3$ ‰ [1]). However, this value matches well their Mokoia fayalite data ($\delta^{18}O = 20.7 \pm 1.0$ ‰; $\delta^{17}O = 10.9 \pm 2.1$ ‰). The chondrule fayalites have a mean composition of $\delta^{18}O = 16.6 \pm 4.3$ ‰; $\delta^{17}O = 8.8 \pm 3.1$ ‰ (Fig. 2), which is between our Kaba and Choi et al.'s [1] Mokoia fayalite data.

The two measurements for magnetite within chondrules fall within errors of the TF line (Fig. 2). However, magnetite from the core of the assemblage with large fayalite laths appears to lie slightly above the TF line (Fig. 1). Although all three points lie to the left of fayalite, these data have limited significance because we did not measure a proper magnetite standard.

We also measured forsterite grains adjacent to and often in direct contact with fayalite and magnetite. The O-isotope compositions of chondrule forsterites lie within errors of the CCAM line, with $\Delta^{17}O$ values ranging from -6.0 to -2.4 ‰, similar to the data of [1] ($\Delta^{17}O$ = -9 to -3 ‰).

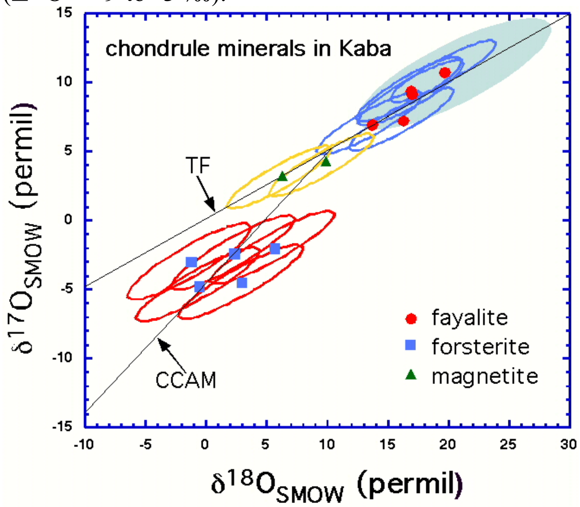

Fig.2 O-isotope compositions of small fayalite grains, coexisting forsterite and magnetite grains from two porphyritic olivine chondrules in the Kaba meteorite.

DISCUSSION

All of the fayalite grains that we measured fall within errors of the TF line, and we find no difference in $\Delta^{17}O$ between the big fayalite laths and the chondrule fayalites. Two of three magnetite grains, both from within chondrules, also fall within errors of the TF line. These data indicate that the big fayalite laths, the chondrule fayalites, and the chondrule magnetites all formed from the same O reservoir. Magnetite in the core of the assemblage with large fayalite laths seems to lie above the TF line (Fig. 1). If so, then this implies that a more ^{16}O-depleted O reservoir was involved in the formation of this magnetite. The forsterite grains are clearly more ^{16}O-rich than the other phases measured and represent a distinct O reservoir from that which gave rise to the fayalites.

As discussed above, Mokoia fayalite [1] is very similar in composition to the big fayalite laths we measured from Kaba, but our Kaba fayalite data seem to differ significantly from the Kaba data collected by [1]. Part of the answer can be found in the occurrences of the fayalite. The Mokoia fayalite grains chosen by [1] for O measurement are big subhedral laths, which are petrographically similar to the big fayalite laths we measured in Kaba. These fayalites have similar O compositions. In contrast, the Kaba fayalite grains measured by [1] are small and appear to come mostly from within chondrules, similar to our Kaba chondrule fayalites. Although our data are more ^{18}O-rich than those from [1], both sets lie to the left of the big fayalite laths. This suggests that the big laths and chondrule fayalites may have formed either at different times during evolution of the parent reservoir, or that the O was subjected to different processes. Perhaps diffusion of O into the chondrule to form fayalite and magnetite caused the O to fractionate favoring the lighter isotopes.

To date we have learned the following about fayalite in Kaba (and Mokoia): 1) Mn-Cr data for fayalites in Kaba [2] and Mokoia [3] show that all fayalites, regardless of petrologic setting, formed with essentially the same $(^{53}Mn/^{55}Mn)_0$, which implies that they formed ~9.7 Ma after the formation of CAIs [2]. This is approximately the same time as that inferred for the carbonates measured in Orgueil and Ivuna (CIs) [7, 8]. 2) The O-isotope data [1, this study] indicate that fayalites in all petrographic settings formed from the same O reservoir. This reservoir was distinct from that which gave rise to anhydrous phases such as forsterite. 3) The O data also suggest some type of reservoir evolution between the time that the large fayalite laths formed and the chondrule metal was replaced by fayalite. The direction of this evolution is not clear since we do not know the composition of the O reservoir *a priori*. Taken together, these data seem to point to a parent body setting for the production of magnetite. However, nothing in our data permits us to identify the specific mechanism by which fayalite formed.

REFERENCES

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