COMMON PRESENCE OF ^{16}O-RICH MELILITE IN CALCIUM-ALUMINUM-RICH INCLUSIONS FROM THE LEAST METAMORPHOSED CV CARBONACEOUS CHONDRITE KABA.

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Introduction: Oxygen isotopic compositions of individual minerals in most Ca-Al-rich inclusions (CAIs) in CV3 chondrites are characterized by heterogeneous distributions along CCAM (Carbonaceous Chondrite Anhydrous Mineral) line: spinel and pyroxene are ^{16}O-rich (Δ^{17}O $\leq$ -20‰) while anorthite and melilite are typically ^{16}O-depleted (Δ^{17}O > -20‰) [1, 2] with some rare exceptions [e.g., 3-7].

Recently, a correlation between ^{16}O-depletion in melilite in the CO CAIs and petrologic type of the host meteorite has been reported [8, 9]. There is also a correlation between petrologic type of a host meteorite and the degree of alteration resulting in replacement in melilite and anorthite by nepheline, sodalite, andradite, and hedenbergite in the CO CAIs and chondrules [10-12]. Since all CV chondrites experienced fluid-assisted thermal metamorphism [e.g., 13], this process may have been responsible for some of O-isotopic exchange in melilite and anorthite of the CV CAIs. According to the recent classification of the CV chondrites into petrologic subtypes based on Raman spectroscopy of organic matter, Kaba is the least metamorphosed (3.1) while Allende is one of the most metamorphosed (>3.6) CV chondrites [14]. In order to investigate possible effect of fluid-assisted thermal metamorphism on O-isotopic compositions of the CV CAIs, we studied O-isotopic compositions of CAIs from Kaba.

Experimental: Polished thin sections of 4 melilite-rich (Type A) CAIs (HX3-A1, 2-A1, FB-A1, and MP57-A1; Fig. 1) from Kaba were studied by BSE imaging and elemental analyses using JEOL JSM-5900LV with Thermo Electron EDS system. Oxygen isotopic compositions of CAIs were analyzed *in situ* with the UH Cameca ims 1280 ion microprobe. A 2-3 nA focused Cs^+ primary ion beam was rastered over a 25×25 micron area for 120-150 seconds. Then the raster was reduced to 10×10 microns and data were collected for 4sec × 40 cycles. The secondary ion mass spectrometer was operated at -10 keV with a 50 eV energy window. $^{16}O^-$ was measured on a multicollector detector L’2, a Faraday cup with 10^{10} ohm resistor; $^{18}O^-$ was measured on a Faraday collector H1 with 10^{11} ohm resistor, and $^{17}O^-$ was measured with the monocollector electron multiplier. The mass resolving power for $^{16}O^-$ and $^{18}O^-$ was ~2000, and that for $^{17}O^-$ was ~5500 (m/Δm), sufficient to separate interfering $^{16}OH^-$. The normal-incidence electron flood gun was used for charge compensation. All data were corrected for instrumental fractionation using synthetic forsterite and olivine from the Brenham pallasite.

Results and discussion: All 4 analyzed CAIs have melilite-rich core composed of gehlenitic melilite, spinel, ±anorthite, and ±perovskite, surrounded by concentric layers of spinel (+hibonite in 2-A1) and Al-diopside (+forsterite in FB-A1) (Fig. 1). All CAIs, except FB-A1, experienced aqueous alteration to various degrees resulting in formation of phyllosilicates, Na-bearing plagioclase, andradite, and ferrous olivine. Secondary grossular, monticellite, wollastonite, and forsterite, commonly observed in the Allende CAIs, are absent, consistent with the lower degree of thermal metamorphism experienced by Kaba.

Oxygen isotopic compositions of individual CAI minerals from Kaba are shown in Fig. 2a. On a three-oxygen-isotope diagram, melilite, spinel, forsterite, and Al-diopside plot along the CCAM line. Spinel, forsterite, and Al-diopside have nearly identical, ^{16}O-rich compositions (-24‰ < Δ^{17}O < -22‰) while O-isotopic compositions of melilite spread continuously from ^{16}O-rich to ^{16}O-poor (up to ~-3‰ in Δ^{17}O). Oxygen isotopic compositions of spinel, forsterite, and pyroxene from Kaba CAIs are similar to those from the majority of the CV CAIs. In contrast, melilite in Kaba is isotopically heterogeneous and systematically richer in ^{16}O. These observations corroborate the suggestion that most CAIs in CV chondrites started from ^{16}O-rich compositions and suffered O-isotopic exchange to various degrees, which preferentially affected melilite. Oxygen isotopic compositions of melilite for each CAI expressed in Δ^{17}O (= δ^{17}O-0.52×δ^{18}O) are shown in Fig. 2b. The CAI 2-A1 is uniformly ^{16}O-rich with Δ^{17}O ~ -23‰. HX3-A1 and MP57-A1 have intermediate O-isotopic compositions with Δ^{17}O ~ -15‰. In contrast, FB-A1 has significant O-isotope heterogeneity in the CAI from ^{16}O-rich (Δ^{17}O ~ -22‰) to ^{16}O-poor (-10‰ < Δ^{17}O < -3‰).

Most melilite grains from Kaba CAIs have ^{16}O-rich compositions except for a few spots from FB-A1, unlike in coarse-grained igneous CAIs (compact Type A, Type B, and Type C) from Allende that have typically uniformly ^{16}O-depleted melilite. The degrees of ^{16}O-depletion of melilite from Kaba CAIs are less or comparable to those in fine-grained, pyroxene-rich [5] and spinel-rich CAIs [7] from the reduced CV chondrite Efremovka (CV3.1-3.4 [14]). These O-isotopic characteristics imply a correlation between ^{16}O-depletion in melilite of the CV CAIs and petrologic type of a host meteorite, similar to the observations in CO CAIs [8, 9].

Based on the existence of ^{16}O-enriched secondary grossular relative to melilite and anorthite replaced by grossular [15,16], it is inferred that at least some of O-

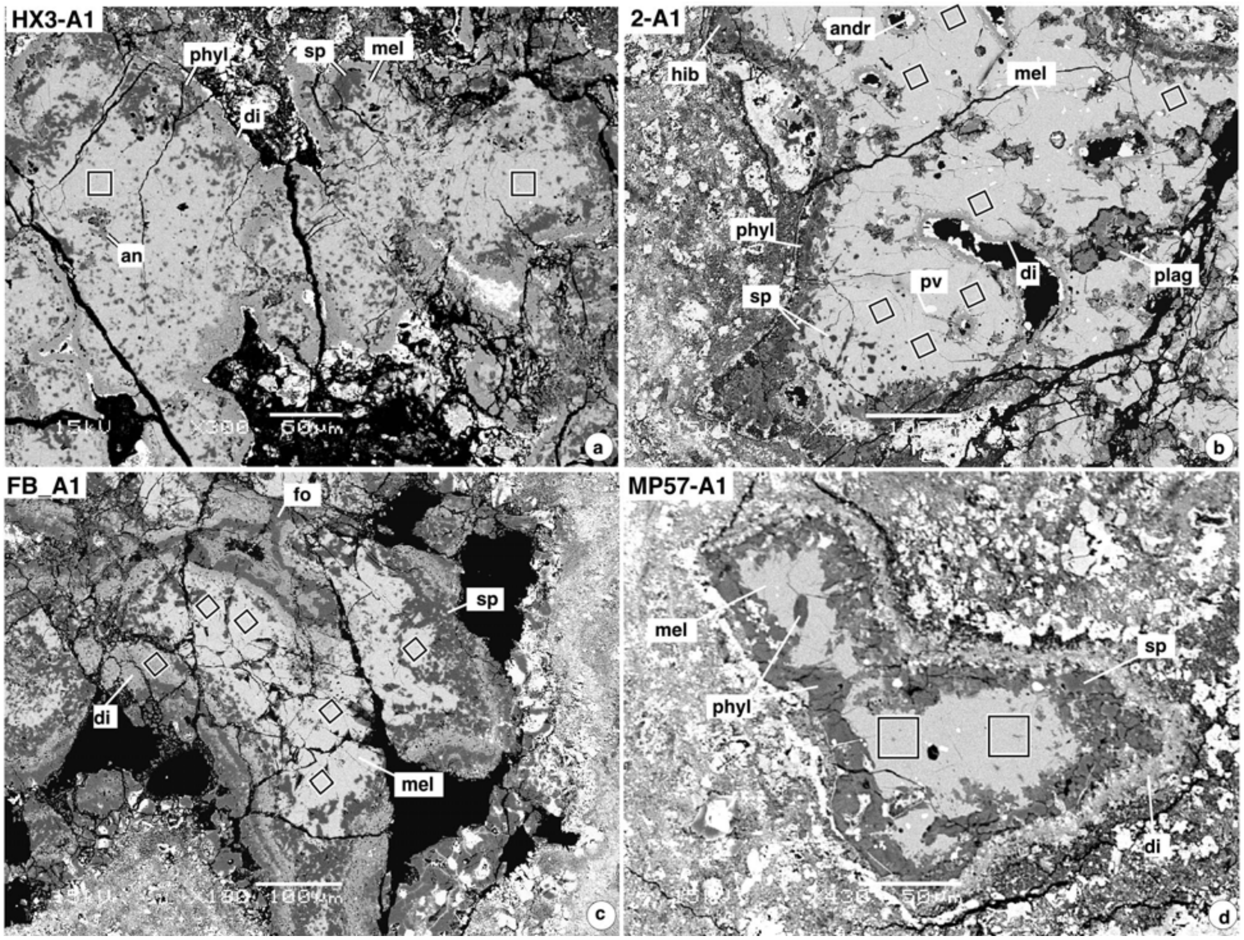

Fig. 1. Backscattered electron images of melilite-rich (Type A) CAIs from the CV3.1 carbonaceous chondrite Kaba. an = anorthite; andr = andradite; di = Al,Ti-diopside; fo = forsterite; hib = hibonite; mel = melilite; phyl = phyllosilicate; plag = plagioclase; pv = perovskite; sp = spinel. Outlined rectangle regions show sputtered regions during oxygen isotope measurements.

isotopic exchange of melilite and anorthite in the Allende CAIs continued after formation of grossular without melting being involved [16]. These observations and the common presence of ^{16}O-rich melilite in Kaba (CV3.1) suggest fluid-assisted thermal metamorphism was probably responsible for at least some of O-isotope exchange in CV CAIs. Laboratory experiments simulating isotopic exchange between melilite, grossular, and high-temperature water vapor are required to test this hypothesis.

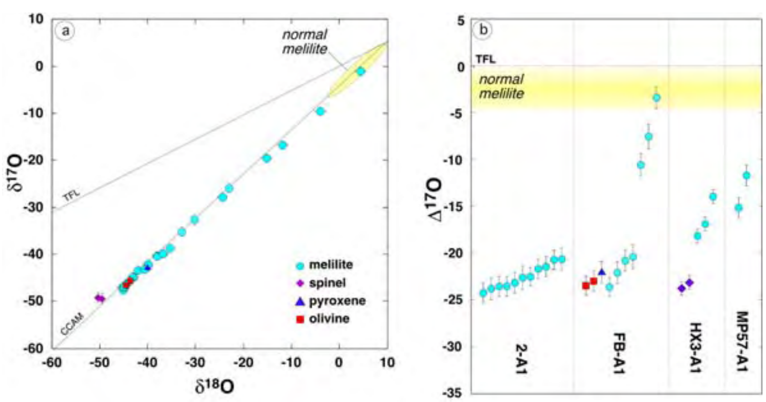

Fig. 2. Oxygen isotopic compositions of the melilite-rich (Type A) CAIs from Kaba (CV3.1). Errors are 2σ. Shaded fields outline typical O-isotopic compositions of melilite from the Allende CAIs [1, 2]. TFL = terrestrial fractionation line.

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