ON THE NATURE OF OXYGEN ISOTOPE HETEROGENEITY OF IGNEOUS CALCIUM-ALUMINUM-RICH INCLUSIONS IN CV (VIGARANO-TYPE) CARBONACEOUS CHONDRITES

Alexander N. Krot[1], Kazuhide Nagashima[1], and Glenn J. MacPherson[2]. [1]Hawai'i Institute of Geophysics and Planetology, SOEST, University of Hawai'i at Mānoa, Honolulu, HI 96822, USA, sasha@higp.hawaii.edu. [2]Dept. Mineral Sciences, Museum of Natural History, Smithsonian Institution, Washington DC, 20560, USA.

Introduction: To understand the nature of oxygen isotopic heterogeneity in coarse-grained igneous Ca,Al-rich inclusions (CAIs) from CV (Vigarano-type) carbonaceous chondrites and test the hypotheses that this heterogeneity was established either (1) during igneous crystallization in a gaseous reservoir with variable oxygen isotopic composition [e.g., 1−4] or (2) during aqueous fluid−mineral interaction on the CV parent asteroid [e.g., 5−9], we studied the mineralogy, petrology, and O-isotope compositions of the Type B1 (*CG-11*), Compact Type A (CTA: *TS-2*, *TS-68*, and *818-G*), and davisite-rich (*818-G-UR*) CAIs from the Allende CV3.6 chondrite.

Results: In ***CG-11***, in the eutectic melt regions composed of the co-crystallizing melilite ($Åk_{65–70}$), anorthite, and low-Ti (~ 2−5 wt% TiO_2) fassaite, the melilite and anorthite have ^{16}O-poor compositions ($\Delta^{17}O$ ~ −3±2‰), whereas $\Delta^{17}O$ of the fassaite is close to the solar value (~ −24±2‰; Fig. 1b). The relatively Ti-rich (~ 10 wt% TiO_2) coarse fassaite grains in *CG-11* are slightly ^{16}O-depleted ($\Delta^{17}O$ up to −16‰). In ***TS-2***, ***TS-68***, and ***818-G***, coarse melilite and Ti-rich (~ 12−20 wt% TiO_2) fassaite grains have ^{16}O-poor compositions ($\Delta^{17}O$ range from ~ −10 to ~ −3±2‰; most analyses cluster around −3‰); spinel is ^{16}O-rich ($\Delta^{17}O$ ~ −24±2‰); perovskite grains show large variations in $\Delta^{17}O$, from −24 to −3±2‰ (Fig. 1c). Oxygen isotopic compositions of subhedral-to-euhedral Ti-rich (~ 13−17 wt% TiO_2) fassaite inclusions in spinel grains are ^{16}O-rich ($\Delta^{17}O$ ~ −24±2‰). Fassaite inclusions in spinel grains where both minerals are crosscut by fractures are ^{16}O-depleted ($\Delta^{17}O$ ~ −6 to −3±2‰). In ***818-G-UR***, davisite (in wt%: ~12 TiO_2, 7−13 Sc_2O_3, 1−4 ZrO_2) has ^{16}O-poor composition ($\Delta^{17}O$ ~ −2±2‰), whereas Al-diopside rim (contaminated by davisite) around the inclusion is ^{16}O-enriched ($\Delta^{17}O$ < −16‰). On a three-isotope oxygen diagram (Figs. 1b,c), the ^{16}O-poor melilite, anorthite, davisite, and most Ti-rich fassaites in the Allende CAIs studied plot close to or along mass-dependent fractionation line with $\Delta^{17}O$ of ~ −3±2‰, defined by the metasomatically-formed secondary minerals in the Allende coarse-grained igneous CAIs (Fig. 1a), to the right from the PCM line.

Conclusions: We conclude that coarse-grained igneous CAIs in Allende experienced postcrystallization O-isotope exchange with the external ^{16}O-poor reservoir ($\Delta^{17}O$ ~ −3±2‰). The exchange appears to be mineralogically, not petrologically controlled: i.e., variations in O-isotope compositions of minerals within individual CAIs are inconsistent with their inferred crystallization sequence. This mineralogically-controlled exchange most likely resulted from aqueous fluid−rock interaction on the CV chondrite asteroid and affected O-isotope compositions of melilite, anorthite, Ti-rich fassaite, perovskite, and davisite. Hibonite, spinel, Al-diopside, low-Ti fassaite, and Ti-rich fassaite inclusions in spinel grains preserved their original ^{16}O-rich compositions established during igneous crystallization of the CAIs. Experimental studies of oxygen self-diffusion in CAI minerals under the conditions of metasomatic alteration of CV chondrites are required to test this conclusion.

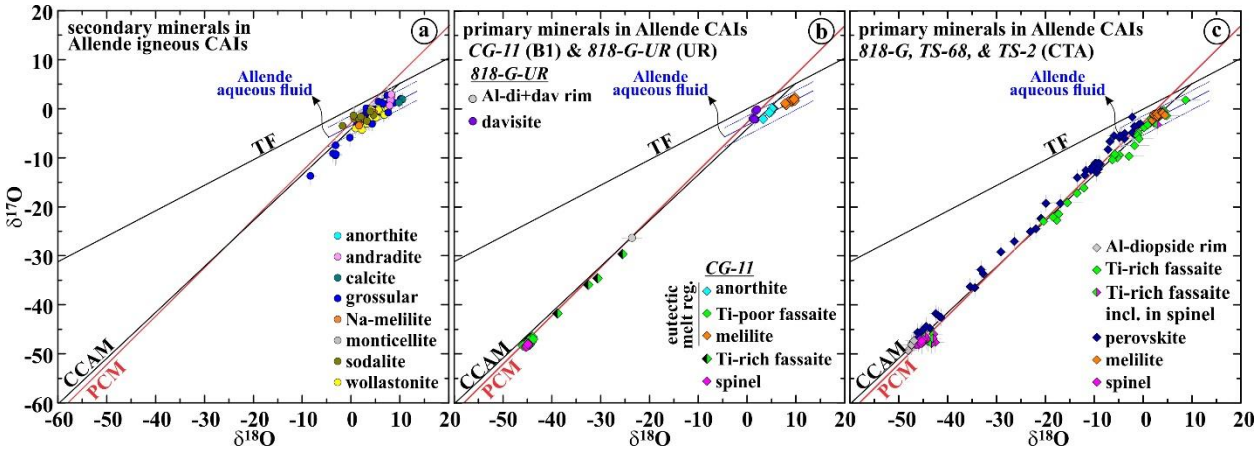

Fig. 1. Three-isotope oxygen diagrams of individual minerals in the Allende CAIs studied. CCAM = Carbonaceous Chondrite Anhydrous Mineral line; PCM = Primitive Chondrule Mineral line; TF = Terrestrial Fractionation line.

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