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

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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 (ÅkK8–90), anorthite, and low-Ti (~ 2–5 wt% TiO2) fassaite, the melilite and anorthite have 16O-poor compositions (Δ17O ~ −3±2‰), whereas Δ17O of the fassaite is close to the solar value (~ −24±2‰; Fig. 1b). The relatively Ti-rich (~ 10 wt% TiO2) coarse fassaite grains in CG-11 are slightly 16O-depleted (Δ17O up to −16‰). In TS-2, TS-68, and 818-G, coarse melilite and Ti-rich (~ 12–20 wt% TiO2) fassaite grains have 16O-poor compositions (Δ17O range from ~ −10 to −3±2‰; most analyses cluster around −3‰); spinel is 16O-rich (Δ17O ~ −24±2‰); perovskite grains show large variations in Δ17O, from −24 to −3±2‰ (Fig. 1c). Oxygen isotopic compositions of subhedral-to-euhedral Ti-rich (~ 13–17 wt% TiO2) fassaite inclusions in spinel grains are 16O-rich (Δ17O ~ −24±2‰). Fassaite inclusions in spinel grains where both minerals are crosscut by fractures are 16O-depleted (Δ17O ~ −6 to −3±2‰). In 818-G-UR davisite (in wt%: ~12 TiO2, 7–13 Sc2O3, 1–4 ZrO2) has 16O-poor composition (Δ17O ~ −2±2‰), whereas Al-diopside rim (contaminated by davisite) around the inclusion is 16O-enriched (Δ17O < −16‰). On a three-isotope oxygen diagram (Figs. 1b,c), the 16O-poor melilite, anorthite, davisite, and most Ti-rich fassaite in the Allende CAIs studied plot close to or along mass-dependent fractionation line with Δ17O 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 16O-poor reservoir (Δ17O ~ −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 16O-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.