OXYGEN ISOTOPIC COMPOSITIONS OF IGNEOUS CAIs FROM CK3 CHONDRITES. A. N. Krot[1*], K. Nagashima[1], T. L. Dunn[2], M. I. Petaev[3], C. Ma[4]. [1]University of Hawai‘i at Mānoa, USA. *sasha@higp.hawaii.edu, [2]Colby College, Waterville, USA, [3]Harvard University, Cambridge, USA, [4]Caltech, Pasadena, USA.

Introduction: CK (Karoonda-like) carbonaceous chondrites have similar bulk chemical and O-isotope compositions to those of CVs (Vigarano-like), but experienced higher degree of thermal metamorphism (petrologic types 3.7–6 *vs.* 3.1–4) and under higher fO_2 [1–4]. Both groups contain large (cm-sized) igneous CAIs – Compact Type A (CTA), Type B (B), Forsterite-bearing Type B (FoB), and Type C – characterized by similar textures and primary mineralogies [5,6]. However, igneous CAIs in CK3s experienced higher degrees of metasomatic alteration, probably, under higher temperature and fO_2 than those in CV3s: melilite is nearly completely replaced by grossular, Al-diopside, forsteritic olivine, Mg-spinel, plagioclase, clintonite; Al,Ti-diopside is corroded and crosscut by veins of ferroan Al,Ti-diopside, Ti-bearing grossular, rutile, and titanite [6]. Monticellite, wollastonite, sodalite, nepheline, and Na-bearing melilite, commonly observed in the Allende CAIs, are absent in CK3 CAIs; Ca,Na-plagioclase, Cl-apatite and wadalite are observed instead.

Primary minerals in igneous CAIs from the most metamorphosed oxidized CV chondrite Allende (petrologic type >3.6) show significant variations in O-isotope compositions: hibonite, spinel, forsterite, relatively low-Ti Al-diopside (<8 wt% TiO_2), and Ti-rich Al-diopside (>10 wt% TiO_2) inclusions inside spinel have similar ^{16}O-rich compositions (Δ^{17}O ~ –23±2‰); coarse melilite, anorthite, perovskite, and Ti-rich Al-diopside are ^{16}O-depleted to various degrees (Δ^{17}O range from ~ –23 to ~ –3‰) [7–13]. The nature of this O-isotope heterogeneity is controversial: it could have been established during incomplete remelting of CAIs in a nebular gas of variable O-isotope composition [8–12] and/or during aqueous fluid–rock interaction in an asteroidal setting [7,13]. Here we report on O-isotope compositions of coarse primary and secondary minerals in the CTA, B, and FoB CAIs from the NWA 4964 (CK3.8) and NWA 5343 (CK3.7) meteorites and compare them with those from Allende. Oxygen isotopic compositions were measured *in situ* with the UH Cameca ims-2180 SIMS in multicollection mode (FC-EM-FC) using ~1.4 nA primary beam current and 10 µm spot size (for details see [14]). Diopside, San Carlos olivine, Burma spinel, anorthite, and albite were used as standards.

Results: The NWA 4964 CTA CAI consists of grossmanite (18–20 wt% TiO_2, 18–21 wt% Al_2O_3), louisfuchsite [$Ca_2(Mg_4Ti_2)(Al_4Si_2)O_{20}$], spinel, hibonite, gehlenite, perovskite, and secondary minerals [grossular, Al-diopside, clintonite, spinel, forsteritic olivine, anorthitic plagioclase, wadalite, and ilmenite] replacing melilite nearly completely and partially replacing Al,Ti-diopside, spinel, and perovskite. Coarse louisfuchsite grains poikilitically enclose spinel grains often containing exsolutions of perovskite and are surrounded by a symplectitic layer of Al,Ti-diopside, perovskite, and spinel (Fig. 1). Spinel grains inside grossmanite and louisfuchsite and in alteration regions have similar ^{16}O-rich compositions (Δ^{17}O ~ –23‰; Fig. 2a). Louisfuchsite

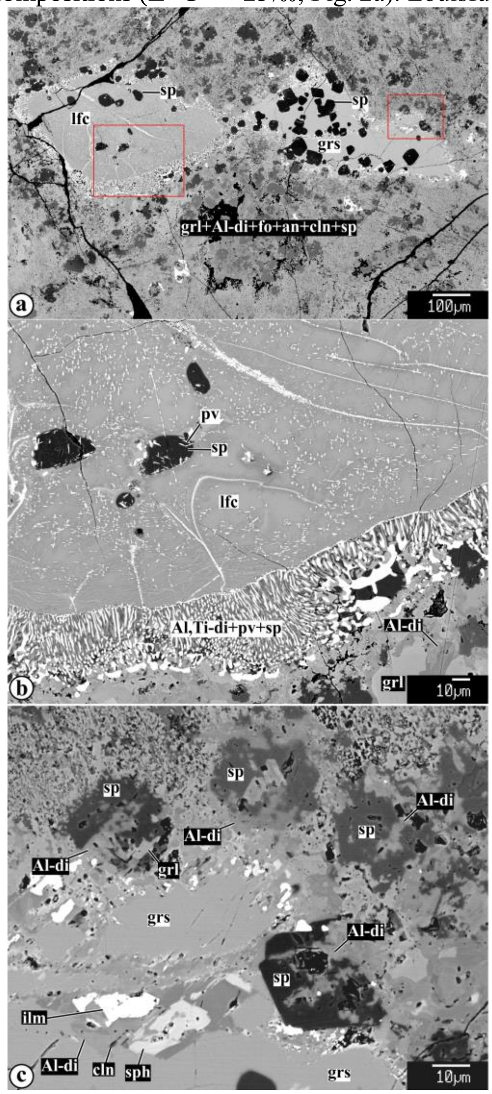

Fig. 1. Backscattered electron images of the NWA 4964 CTA CAI. Coarse louisfuchsite (lfc) and grossmanite (grs) poikilitically enclosing spinel (sp) and are surrounded by a groundmass of closely intergrown secondary grossular (grl), Al-diopside (Al-di), anorthite (an), forsterite (fo), spinel, and clintonite (cln). Grossmanite is replaced by Al-diopside, sphene (sph), ilmenite (ilm), and clintonite (cln). Spinel grains in the groundmass are corroded by grossular and Al-diopside. Regions outlined in “a” are shown in detail in “b, c”.

is slightly ^{16}O-enriched (Δ^{17}O ~ –26‰), whereas grossmanite is significantly ^{16}O-depleted (Δ^{17}O ~ –6‰) compared to spinel. Grossular has similar Δ^{17}O to that of grossmanite, ~ –6‰; secondary olivine is the most ^{16}O-depleted phase analyzed (Δ^{17}O ~ –4‰).

The NWA 5343 Type B CAI consists of Al,Ti-diopside (6–16 wt% TiO_2), spinel, anorthite, and abundant secondary minerals (grossular, Al-diopside, forsteritic olivine, spinel, Na-bearing plagioclase, clintonite, sphene, and ilmenite) replacing mainly melilite and to a smaller degree anorthite and perovskite. Spinel is the most ^{16}O-rich mineral (Δ^{17}O ~–23‰; Fig. 2b). Coarse, 0.5–2.5 mm in size, relatively Ti-poor (6–8 wt% TiO_2) Al-diopside grains poikilitically enclosing spinel grains in the CAI core are slightly ^{16}O-depleted (Δ^{17}O ~ –22 to ~ –20‰). Spinel-free Ti-rich (10–16 wt% TiO_2) Al-diopside grains, 20–50 µm in size, in the CAI mantle are ^{16}O-depleted to various degrees (Δ^{17}O ~ –10 to ~ –3‰). Primary anorthite is ^{16}O-poor (Δ^{17}O ~ –4 to ~ –3‰).

The core of the FoB CAI from NWA 5343 is composed of forsterite, spinel, Al,Ti-diopside (2–10 wt% TiO_2), anorthite, and minor secondary Fe,Al-diopside and anorthite. The CAI mantle is forsterite-free and consists of closely intergrown lath-shaped ferroan olivine ($Fa_{\sim 35}$) and Ca,Na-plagioclase of variable composition ($An_{90-99}Ab_{1-8}$ and $An_{13-19}Ab_{79-85}$) most likely replacing melilite. Spinel and forsterite are similarly ^{16}O-rich (Δ^{17}O ~ –23‰). In contrast to uniformly ^{16}O-rich Al,Ti-diopside in the Allende FoB CAIs [15], Al,Ti-diopside in NWA 5343 FoB CAI shows large variations in Δ^{17}O (from –23 to –3‰); Δ^{17}O correlates with TiO_2 content. Secondary fayalitic olivine, albitic and anorthitic plagioclase have ^{16}O-poor compositions (Δ^{17}O ~ –4 to –2‰; Fig. 2c).

Discussion: Similarly to igneous CAIs from Allende (CV>3.6), igneous CAIs from CK3.7–3.8s studied have heterogeneous Δ^{17}O: spinel, forsterite, and low-Ti Al-diopside (<8 wt% TiO_2) are ^{16}O-rich (Δ^{17}O ~ –23±2‰), whereas anorthite and high-Ti pyroxenes (8–18 wt% TiO_2) are ^{16}O-depleted to various degrees (Δ^{17}O up to ~ –3‰). Like in the Allende CAIs, the ^{16}O-depletion in pyroxenes correlates with TiO_2 content [7,16]. The Δ^{17}O values of the most ^{16}O-depleted compositions overlap with Δ^{17}O of secondary minerals produced by metasomatic alteration on the CK parent asteroid. The Δ^{17}O of the secondary minerals in CK3 CAIs are similar to that of magnetite in the anomalous CK3 chondrite Watson 003 [17] and most likely correspond to Δ^{17}O of the metasomatic fluid. These observations suggest that Ti-rich pyroxenes and anorthite in CK3 CAIs experienced O-isotope exchange with an aqueous fluid.

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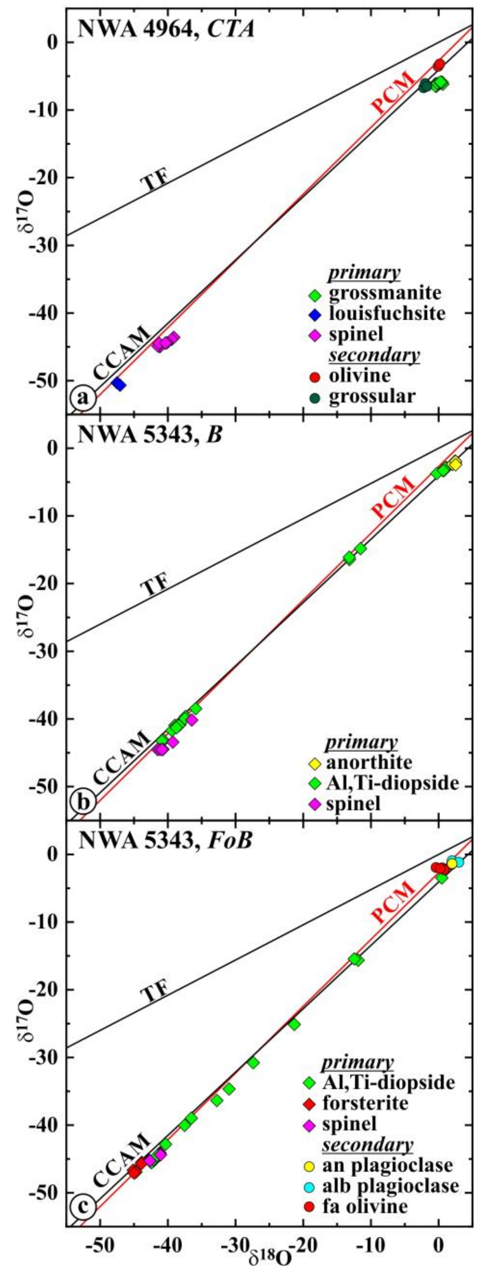

Fig. 2. Three-isotope oxygen diagrams of primary and secondary minerals in igneous CAIs from NWA 4964 (CK3.8) and NWA 5343 (CK3.7).