MINERALOGY, PETROGRAPHY, OXYGEN- AND ALUMINUM-MAGNESIUM ISOTOPE SYSTEMATICS OF IGNEOUS CAIs FROM CK3 CHONDRITES.

A. N. Krot[1*], K. Nagashima[1], [2]T. L. Dunn, [3]M. I. Petaev, and [4]C. Ma. [1]Univ. Hawai‘i at Mānoa, USA. *sasha@higp.hawaii.edu, [2]Colby College, USA, [3]Harvard Univ., USA, [4]California Institute of Technology, USA.

Introduction: CK (Karoonda type) and CV (Vigarano type) chondrites have similar bulk chemical and O-isotope compositions, but the former experienced higher degree of fluid-assisted thermal metamorphism (metasomatism) under higher temperature (petrologic types 3.7−6 *vs.* 3.1−4) and fO_2 (FMQ+3 to FMQ+5 *vs.* ~IM) [1−3]. Both groups contain large (cm-sized) igneous CAIs, Compact Type A (CTA), Type B (B), and Forsterite-bearing Type B (FoB) which could have recorded physico-chemical conditions of the metasomatic alteration [4−6]. The higher temperature, fO_2, and degree of metasomatic alteration experienced by CKs could have affected O- and Al-Mg isotope systematics of their igneous CAIs. Here we report on the mineralogy, O-isotope compositions of primary and secondary minerals and Al-Mg isotope systematics of primary minerals in the CTA, B, and FoB CAIs from the NWA 4964 (CK3.8) and NWA 5343 (CK3.7) measured *in situ* with the UH Cameca ims-1280 [for details see 7,8].

Results: The NWA CTA CAI consists of grossmanite (18−20 wt% TiO_2), louisfuchsite, spinel, hibonite, melilite ($Åk_{1–2}$), perovskite, and secondary minerals (grossular, Al-diopside, clintonite, spinel, Mg-olivine, Ca-plagioclase, wadalite, and ilmenite) replacing melilite, grossmanite, spinel, and perovskite. On $\delta^{17}O$ *vs.* $\delta^{18}O$ diagram, primary minerals plot along ~ slope-1 line. Spinel, hibonite, louisfuchsite, and a grossmanite inclusion in spinel have $\Delta^{17}O$ of ~ −24±2‰ (2SD), whereas coarse grossmanite poikilitically enclosing spinel and gehlenite enclosing hibonite are similarly ^{16}O-depleted ($\Delta^{17}O$ ~ −6 to −4‰). Secondary grossular, Al-diopside, olivine, and Ca-plagioclase plot along mass-dependent fractionation line with $\Delta^{17}O$ of −3.9±1.8‰; $\delta^{18}O$ range from ~ −6 to +4‰. Hibonite, grossmanite, and spinel define an internal Al-Mg isochron with $(^{26}Al/^{27}Al)_0$ of $(5.01\pm0.24)\times10^{-5}$. Melilite has high $^{27}Al/^{24}Mg$ ratio (100−700), barely resolvable $^{26}Mg^*$, and does not belong to the isochron indicating postcrystallization disturbance.

The NWA 5343 Type B CAI consists of fassaite (6−16 wt% TiO_2), spinel, anorthite, and secondary minerals (grossular, Al-diopside, forsteritic olivine, spinel, Na-bearing plagioclase, clintonite, titanite, and ilmenite) replacing melilite, anorthite, and perovskite. On $\delta^{17}O$ *vs.* $\delta^{18}O$ diagram, primary minerals plot along ~slope-1 line. Spinel is ^{16}O-rich ($\Delta^{17}O$ = −23±0.3‰). Coarse, 0.5–2.5 mm in size, fassaite grains (6–8 wt% TiO_2) poikilitically enclosing spinel grains in the CAI core are similarly ^{16}O-rich ($\Delta^{17}O$ = −21±1.3‰), whereas spinel-free Ti-rich (10−16 wt% TiO_2) fassaites, 20–50 µm in size, in the CAI mantle are ^{16}O-depleted to various degrees ($\Delta^{17}O$ ~ −10 to ~ −3‰). On $\delta^{17}O$ *vs.* $\delta^{18}O$ diagram, primary anorthite and secondary grossular, Al-diopside, olivine, and Ca,Na-plagioclase plot along mass-dependent fractionation line with $\Delta^{17}O$ of −3.5±1.8‰; $\delta^{18}O$ range from ~ −6 to +3‰. Fassaite and spinel grains define an internal Al-Mg isochron with $(^{26}Al/^{27}Al)_0$ of $(5.59\pm2.8)\times10^{-5}$; large uncertainty of the isochron is probably due to a small range of $^{27}Al/^{24}Mg$ ratios (1.4–2.9).

The NWA 5343 FoB CAI has a core-mantle structure. The core is composed of forsterite, spinel, fassaite (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 ($Fa_{\sim35}$) and Ca,Na-plagioclase of variable composition ($An_{90–99}Ab_{1–8}$ and $An_{13–19}Ab_{79–85}$) probably replacing melilite. On a three-isotope diagram, primary minerals plot along ~slope-1 line. Spinel and forsterite are similarly ^{16}O-rich ($\Delta^{17}O$ = −23±0.7‰); fassaite shows large variations in $\Delta^{17}O$ (from −23 to −3‰) which correlate with TiO_2. On $\delta^{17}O$ *vs.* $\delta^{18}O$ diagram, secondary ferroan olivine and Ca,Na-plagioclases have a small range of $\delta^{18}O$ (from ~ −1 to ~+3‰) and on plot along mass-dependent fractionation line with $\Delta^{17}O$ of −2.7±1.1‰. Aluminum and Mg-isotope data of spinel, forsterite, and fassaite define an internal isochron with $(^{26}Al/^{27}Al)_0$ of $(4.56\pm0.66)\times10^{-5}$.

Conclusions: Similarly to igneous CAIs from Allende (CV>3.6), igneous CAIs from CK3.7−3.8 chondrites studied have ~ the canonical $(^{26}Al/^{27}Al)_0$ and heterogeneous $\Delta^{17}O$: spinel, forsterite, and low-Ti Al-diopside (<8 wt% TiO_2) are ^{16}O-rich ($\Delta^{17}O$ ~ −23±2‰), whereas anorthite and high-Ti pyroxenes (8–18 wt% TiO_2) are ^{16}O-depleted to various degrees ($\Delta^{17}O$ up to ~ −3‰). The $\Delta^{17}O$ values of the most ^{16}O-depleted minerals overlap with those of secondary minerals produced by metasomatic alteration on the CK parent asteroid. We conclude that CK and CV CAIs belong to the same generation of refractory inclusions [8] which experienced metasomatic alteration to various degrees on their parent asteroid(s). The alteration of CK3 and CV3 CAIs affected to O- and Al-Mg isotope systematics of some of their primary minerals (anorthite, melilite, and high-Ti pyroxene).

References: [1] Wasson J. et al. (2013) *GCA* 108:45. [2] Greenwood R. et al. (2010) *GCA* 74:1684. [3] Righter K. & Neff K. (2007) *Polar Sci.* 1:25. [4] Chaumard N. et al. (2014) *MAPS* 49:419. [5] Krot A. (2021) *PEPS* 8:61. [6] Krot A. et al. (2022) *LPSC* 53:#1299. [7] MacPherson et al. (2021) *MAPS* 55:2519. [8] MacPherson G. et al. (2023) *MAPS* 58:135. [9] Schollenberger Q. et al. (2018) *GCA* 228:62.