

METASOMATIC ALTERATION OF COARSE-GRAINED IGNEOUS CAIs IN CK3 CHONDRITES. A. Krot^{1*}, T. L. Dunn², M. I. Petaev³, K. Nagashima¹ ¹University of Hawai'i, HI 96822, USA. *sasha@higp.hawaii.edu, ²Colby College, Waterville, ME 04901, USA. ³Harvard University, Cambridge, MA 02138, 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]. It has been previously suggested that CKs and CVs originated from the same parent asteroid [e.g., 1,2]. However, the reported differences in bulk Cr-isotope compositions of CKs and CVs appear to contradict this conclusion [5].

CK chondrites is the only group that contains large igneous CAIs, which are texturally and mineralogically similar to those in CVs [6]. If CK and CV chondrites accreted similar components (CAIs, chondrules, and matrix), subsequent fluid-assisted thermal metamorphism under different physicochemical conditions (T, fO_2 , fluid composition) could produce different secondary mineral assemblages [6–9]. We have recently reported on the mineralogy, petrography, and O-isotope compositions of the secondary minerals in the Allende (CV>3.6) igneous CAIs [Compact Type A (CTA), B, forsterite-bearing B (FoB), C] [11]. Here we summarize these results, report on the secondary mineralization in the CTA, B, and FoB CAIs from the NWA 4964 (CK3.8) and NWA 5343 (CK3.7) [12] meteorites, and compare these two datasets.

Igneous CAIs in Allende: Metasomatic alteration of the Allende igneous CAIs affected mainly melilite and to a lesser degree anorthite and resulted in formation of different secondary minerals, which are mainly defined by chemical compositions of the primary melilite replaced. Gehlenitic melilite ($\text{\AA}_{k<35}$) in CTAs and in mantles of B1s is replaced and crosscut by veins of grossular \pm anorthite \pm clintonite \pm spinel. Åkermanitic melilite (\AA_{k45-75}) in cores of B1s is replaced by grossular-monticellite-wollastonite and grossular-monticellite-Al-diopside. Highly åkermanitic melilite (\AA_{k75-87}) in B2s and FoBs is replaced by grossular-monticellite-wollastonite \pm Al-diopside. Type Bs contain minor wadalite/adrianite and Na-melilite. The Na-melilite occurs at contact of altered melilite regions and primary anorthite. Primary and secondary anorthites in the peripheral portions of the Allende CAIs are replaced by nepheline, sodalite, and ferroan (Fa_{20-40}) olivine. There is a zoned distribution of Na- and/or Cl-bearing secondary phases in the Allende CAIs: wadalite/adrianite and Na-melilite occur in Type B1 CAI cores, whereas sodalite and nepheline occur in the CAI peripheries. Many Allende igneous CAIs contain voids and cracks filled by andradite, hedenbergite, wollastonite, \pm sodalite, \pm grossular, \pm monticellite, \pm tilleyite, and \pm calcite. Some secondary minerals can be

replaced, overgrown, and crosscut by newly formed ones. For example, grossular-monticellite-wollastonite assemblages are replaced by Al-diopside and/or crosscut by wollastonite veins. The earlier-formed FeO-poor Al-diopside, grossular, and monticellite are overgrown or crosscut by veins of ferroan grossular, monticellite, and Al-diopside, hedenbergite, and andradite. Secondary grossular and Al-diopside in the Allende CAIs are Ti-free. The CAIs are surrounded by matrix-like rims composed of lath-shaped ferroan olivine and abundant nepheline grains and by a layer of Ca,Fe-rich silicates (salite-hedenbergite pyroxenes, andradite, and wollastonite).

Igneous CAIs in CK3s: *CTA CAI #1* from NWA 4964 (CK3.8) consists of Ti-rich fassaite, spinel, hibonite, perovskite, and secondary minerals replacing melilite and, possibly, fassaite – grossular, Al-diopside, clintonite, Mg-spinel, forsteritic olivine, plagioclase, and wadalite (Figs. 1a–c). Most grossular and Al-diopside grains are chemically-zoned: they contain different contents of FeO, TiO_2 , and Al_2O_3 (Figs. 1b,c). Peripheries of primary fassaite grains are replaced by Al,Ti \pm Fe-diopside, perovskite, and spinel (Fig. 1b). Abundant wadalite occurs in the CAI periphery. The CAI is surrounded by a layer composed of chemically-zoned grossular and diopside grains, and minor andradite and Al-apatite. Chemically similar grains fill also voids inside the CAI.

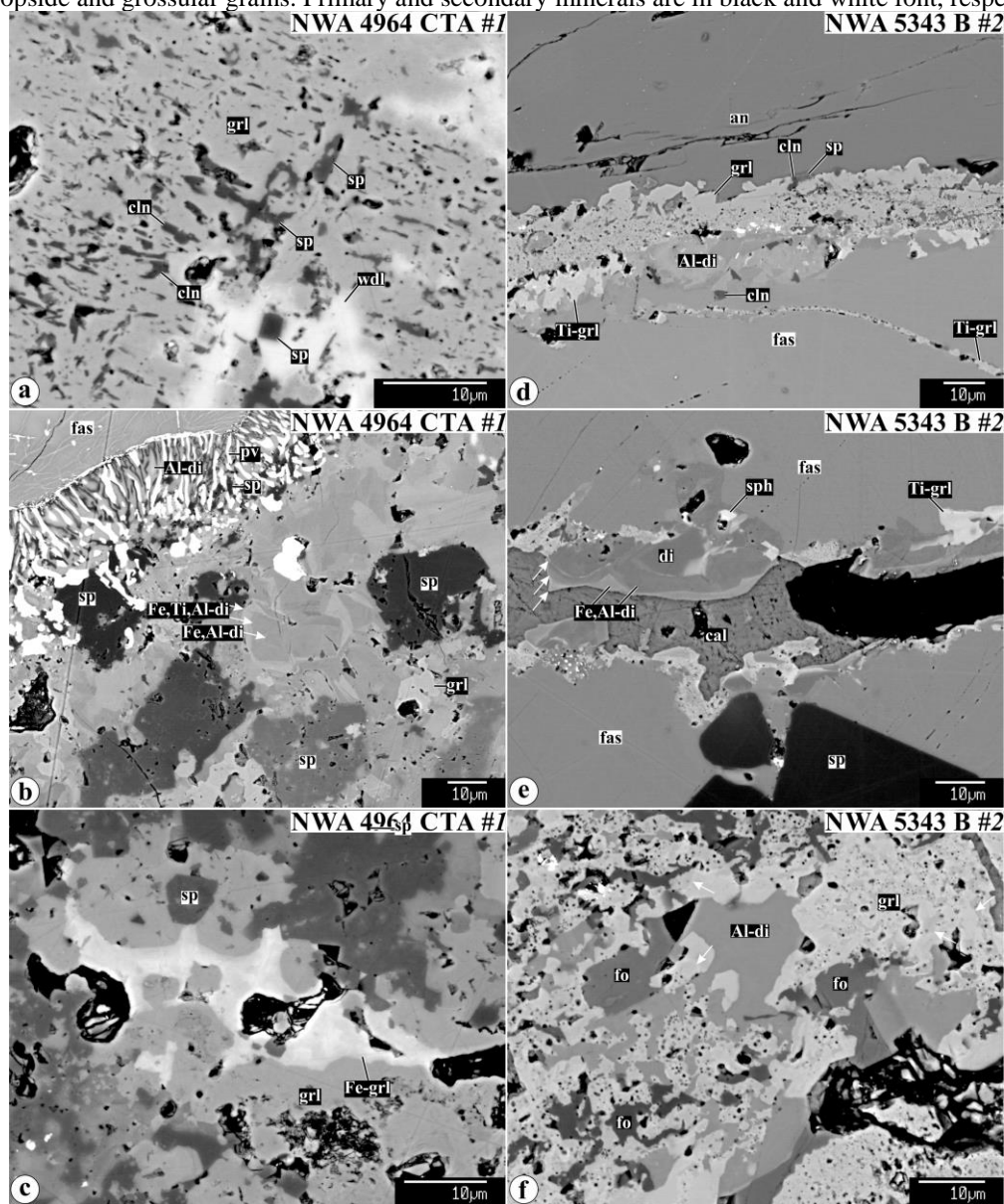
Type B CAI #2 from NWA 5343 (CK3.7) consists of fassaite, spinel, anorthite, and secondary minerals replacing melilite and, possibly, fassaite – grossular, Al-diopside, forsteritic olivine, Mg-spinel, Na-plagioclase, clintonite, and sphene. Coarse Al-diopside and grossular grains are often chemically-zoned they contain different contents of FeO, TiO_2 , and Al_2O_3 (Figs. 1d,e). (Figs. 1d,e). The CAI is surrounded by a layer of ferroan diopside and minor Cl-apatite.

FoB CAI #3 from NWA 5343 consists of forsterite, spinel, Al,Ti-diopside, and secondary Fe,Al-diopside and plagioclase most likely replacing melilite. The CAI mantle is forsterite-free and consists of closely intergrown lath-shaped ferroan olivine and plagioclase of variable composition; anorthitic plagioclase is replaced and overgrown by albitic plagioclase.

Discussion: Igneous CAIs in CK3s experienced higher degree and more advanced metasomatic alteration in the presence of an aqueous fluid than those in Allende. Primary melilite and, possibly, fassaite is completely replaced by grossular, Al-diopside, forsteritic olivine, Mg-spinel, plagioclase, clintonite, and sphene; monticellite and wollastonite are absent. Grossular and Al-diopside contain variable abundances of FeO, Al_2O_3 ,

and TiO_2 ; they are often oscillatory-zoned, possibly reflecting chemical evolution of the aqueous fluid. Nepheline, sodalite, and Na-rich melilite are absent; Ca,Na-plagioclase, Cl-apatite, and wadalite are observed instead. Coarse-grained secondary minerals in CK3s are suitable for *in situ* measurements by SIMS and could potentially provide important constraints on O-isotope composition of the CK aqueous fluid. Wadalite and Cl-apatite have a potential for ^{36}Cl - ^{36}S isotope study. This work as well as thermodynamic analysis of the secondary mineral assemblages in CK CAIs are in progress.

Fig. 1. Backscattered electron images of secondary minerals in the CTA CAI #1 (a–c) and Type B CAI #2 (d–f) from NWA 4964 (CK3.8) and NWA 5343 (CK3.7). Mineral abbreviations: an:anorthite; cal:calcite; cln:clintonite; di:diopside; fas:fassaite; fo:forsteritic olivine; grl:grossular; pl:Ca,Na-plagioclase; sp:spinel; sph:sphene; wdl:wadalite. Arrows in “b, e, f” indicate chemically distinct zones (having different contents of FeO , Al_2O_3 , and TiO_2) in diopside and grossular grains. Primary and secondary minerals are in black and white font, respectively. 10 μm scale bars are shown in each panel.



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