

EBSD STUDY OF AMOEBOID OLIVINE AGGREGATES WITH LOW-CA PYROXENES IN THE Y-81020 CO3.0 CHONDRITE. M. Komatsu¹, A. N. Krot², M. Miyamoto³, and K. Keil², ¹The University Museum, University of Tokyo, Japan (mutsumi@um.u-tokyo.ac.jp), ²Hawai'i Institute of Geophysics & Planetology, SOEST, University of Hawai'i at Manoa, USA. ³Department of Earth & Planetary Science, University of Tokyo, Japan.

Introduction: Amoeboid olivine aggregates (AOAs) are irregularly-shaped objects composed of fine-grained forsteritic olivine, minor Fe,Ni-metal, and a refractory component consisting of spinel, Al-diopside, anorthite, \pm melilite. Although among other refractory inclusions, AOAs are mineralogically and chemically most similar to magnesian, olivine-rich (Type I) chondrules, they have lower contents of SiO₂, Cr₂O₃, MnO, and Na₂O, and generally lack low-Ca pyroxene. Recently, Krot et al. [1,2] reported that ~10% of AOAs in primitive carbonaceous chondrites contain low-Ca pyroxene (Fs₁₋₃Wo₁₋₅). It is found in three major textural occurrences: (i) thin (<15 μ m) discontinuous layers around forsterite grains or along forsterite grain boundaries in AOA peripheries; (ii) 5-10- μ m-thick haloes and subhedral grains around Fe,Ni-metal nodules in AOA peripheries, and (iii) shells of variable thickness (up to 70 μ m), commonly with abundant tiny (3-5 μ m) inclusions of Fe,Ni-metal grains, around AOAs. Forsterite grains in AOAs with low-Ca pyroxene have ¹⁶O-rich isotopic compositions ($\Delta^{17}\text{O} < -20\text{‰}$). Low-Ca pyroxenes of the textural occurrences (i) and (ii) are ¹⁶O-rich ($\Delta^{17}\text{O} < -20\text{‰}$), whereas those of (iii) are ¹⁶O-depleted ($\Delta^{17}\text{O} = -6\text{‰}$ to -4‰). Based on these observations, Krot et al. [1,2] concluded that AOAs are aggregates of solar nebular condensates formed in an ¹⁶O-rich gaseous reservoir, in the CAI-forming region(s). Solid or incipiently melted forsterite in some AOAs reacted with gaseous SiO in the same nebular region to form low-Ca pyroxene. Some other AOAs accreted ¹⁶O-poor pyroxene-normative dust and experienced varying degrees of melting, most likely in chondrule-forming region(s). In order to understand the thermal history of AOAs with and without low-Ca pyroxenes, we performed the mineralogical and structural study of AOAs in the CO3.0 carbonaceous chondrite Yamato-81020, one of the most primitive CO chondrites [3], using electron back-scattering diffraction (EBSD) technique which can provide crystallographic information of micron-sized regions on the surface of a polished thin section.

Methods: Polished thin section of Y-81020 was studied in reflected and transmitted light using optical microscopy and mapped in Ca, Al, Mg, Ti and Na Ka X-rays with resolution of 5-10 μ m (1 μ m for individual AOAs) using the JEOL JXA 8900L electron microprobe. Mineral compositions were analyzed using JEOL JX-733 electron microprobe. A NORAN phase ID EBSD system and forescatter detector (VG system Japan Co.) attached to a HITACHI S-4500 scanning electron microscope (SEM) were used to analyze crystallographic

orientation and grain-sizes of AOAs. In SEM, orientation contrast (OC) imaging in backscattered electron (BSE) mode is possible in mounting a solid-state BSE detector underneath the EBSD detector, i.e. in the forward-scattered position [4]. In the resulting image of the contrast is related to the orientation of the grain. By combining the orientation contrast images with EBSD patterns, individual grains were determined.

Results and discussion: AOA #1 is a compact object, 450×450 μ m in size, composed of nearly pure forsterite (Fo_{99.5-99.9}), Fe,Ni-metal nodules, and a refractory component. EBSD study shows that forsterite grains range in size from 2 to 20 μ m (Fig. 1b). Forsterite grains are overgrown by porous Al-diopside (4-20 wt% Al₂O₃), which is 2-10 μ m in width and 2-5 μ m in length; it also forms discontinuous layers (< 1 μ m) around Fe,Ni-nodules. FeO-free spinel (< 5 μ m) is enclosed within fine-grained (2-10 μ m) anorthite (Fig. 2).

AOA #2 is an irregularly shaped object, 300×400 μ m in size, consisting of forsterite (Fa_{99.5-100}), Fe,Ni-metal, and a refractory component. The outer portion of the AOA is replaced by low-Ca pyroxene (Fs_{0.5-2.5}Wo_{2.9-9.7}) (Fig. 3a). The AOA probably belongs to the first textural type (i) of low-Ca pyroxene in AOA [1,2]. Fe,Ni-metal nodules are preferentially concentrated in low-Ca pyroxene. Occasionally, low-Ca pyroxene encloses fine-grained high-Ca pyroxenes (relict Al-diopside?) that are too fine-grained for microprobe analysis. EBSD study shows that individual low-Ca pyroxenes in this region are much smaller (< 1 μ m) than those in other regions (2-10 μ m; Fig. 3b).

Our study shows that there are no compositional and size differences between AOAs with (AOA #1) and without (AOA #2) low-Ca pyroxene. Krot et al. [1] concluded that some of the AOAs with low-Ca pyroxene experienced melting to a small degree. The presence of rounded Fe,Ni-metal nodules in low-Ca pyroxene of AOA #2 is consistent with this conclusion. We infer that AOAs with low-Ca pyroxene may provide a link between AOAs and Type I chondrules. We note, however, that although low-Ca pyroxenes in AOA #2 are chemically similar to those in Type I chondrules, they are much finer-grained than in chondrules (50-200 μ m) and probably formed by gas-solid condensation.

References: [1] Krot et al. (2004) *GCA*, 68, 1923-1041. [2] Krot et al. (2004) *Chem. Erde*, 64, 185-239. [3] Chizmadia et al. (2002) *MAPS*, 37, 1781-1796. [4] Prior et al. (1996) *Mineral. Mag.*, 60, 859-869.

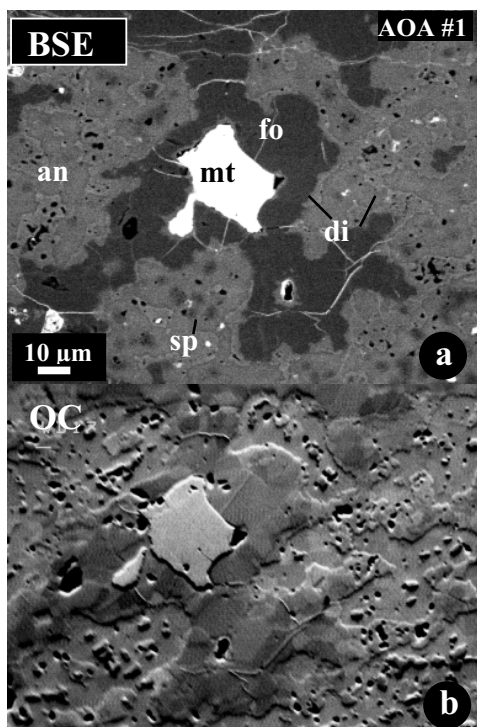


Fig. 1. Backscatterd Electron (BSE) image (a) and orientation contrast (OC) image (b) of AOA#1. (a) AOA#1 consists of forsterite (fo), Al-diopside (di), spinel (sp), anorthite (an), and FeNi-metal (mt). (b) In the OC image, individual mineral grains with different crystallographic orientation have different contrast.

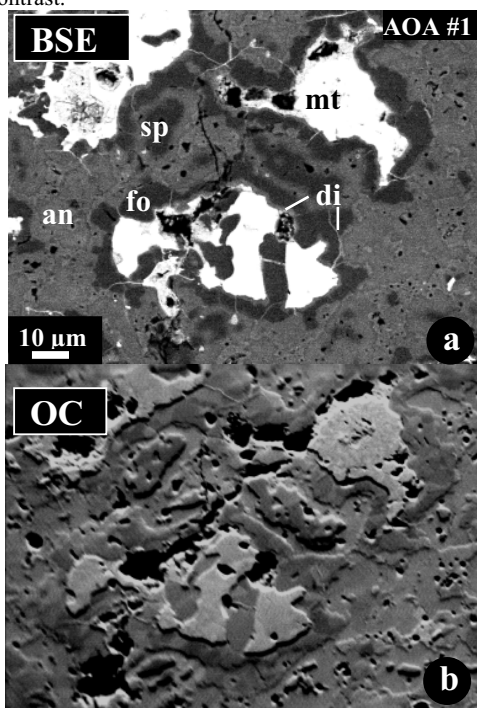


Fig.2. BSE image (a) and OC image (b) of AOA#1.

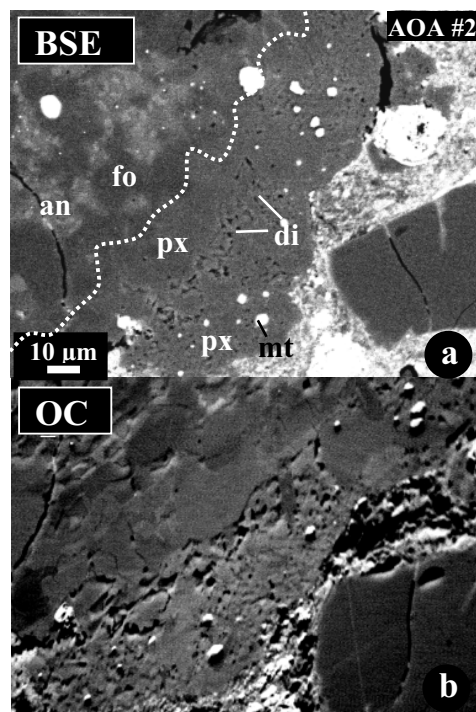


Fig. 3. BSE image (a) and OC image (b) of AOA#2.

(a) Olivine in the outer portion of the AOA is replaced by low-Ca pyroxene (px). (b) Fine-grained low-Ca pyroxenes enclose tiny FeNi-metals and high-Ca pyroxenes.

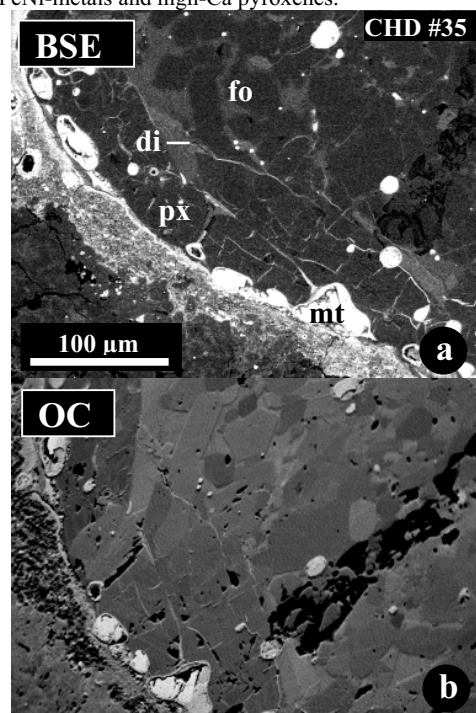


Fig.4. BSE image (a) and OC image (b) of chondrule #35 from Y-81020. Low Ca pyroxene grains (px) are coarser than those in AOAs.