METAL IN AMOEBOID OLIVINE AGGREGATES (AOA) ACROSS CHONDRITE GROUPS

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Introduction: The earliest solids formed in the solar system are refractory inclusions, primarily AOAs and CAIs [1, 2]. While both contributed to chondrule formation [3, 4], the habit and composition of metal grains in AOAs and CAIs differ greatly. In CAIs, refractory metal nuggets (RMNs) are common and likely nucleation sites (Han, pers. comm.). In AOAs, discrete, large FeNi metal grains surrounded by forsteritic olivine are often found toward the outer portions relative to the CAI-like, olivine-coated nodules. A range of textural forms links nodular CAIs to AOAs. We have mapped hundreds of chondrite thin and thick sections using x-ray element emission intensity mapping in electron beam instruments. We find a wide diversity in AOA textures but many similarities. We are able in some samples to track the sizes and shapes of AOAs into 3D computed tomography (CT) volumes from exposed 2D surfaces.

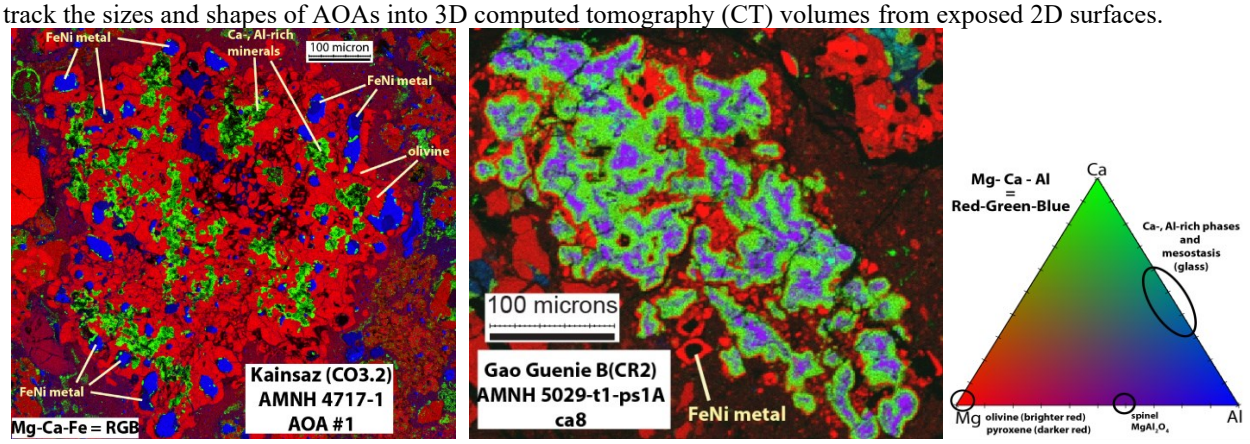
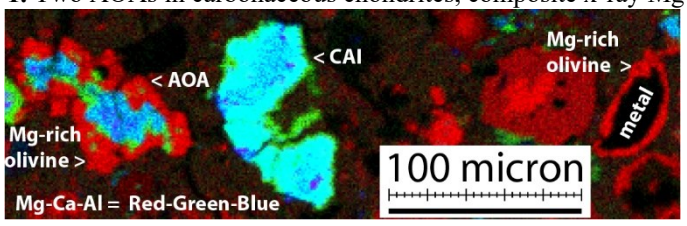


Figure 1. Two AOAs in carbonaceous chondrites, composite x-ray Mg-Ca-Fe and Mg-Ca-Al (right) mosaic images.

2L:



2R:

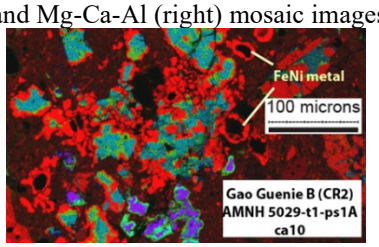


Figure 2. 2L: Nodules of Mg-olivine-coated materials in Acfer 094 (C2 ungrouped; left, IfP Münster PL 93022) [5] and **2R:** an intermediate object in Gao Guenie (b) (CR2, right), both Mg-Ca-Al RGB images (see triangle, Fig. 1)

Methods: Methods and element maps including AOAs are described in and available as online supplements to [5]. Acfer 094 was found to have highly primitive, apparently independent metal/olivine and CAI/olivine nodules (Fig. 2L), and also more complex aggregates of such nodules like those in Fig. 1. Olivine is often Mn-metasomatized [7]. Intermediate objects with olivine-coated CAI-like and metal nodules loosely attached are also found (Fig. 2R).

Results: AOAs are common across the carbonaceous chondrite groups and rarely found in ordinary chondrites. Many AOAs are associated with a few or many metal-cored nodules with forsteritic rims, always on their outer margins [e.g., 1, their Fig. 19]. Metal is more Co-, Ni-rich than metal in chondrule rims, consistent with higher temperatures of equilibration of AOA metal with vapor of solar composition. Results are consistent with [1, conclusion #6].

Conclusions: The principle of superposition supports an interpretation that the common appearance of olivine surrounding CAI-like material and metal grains in AOAs is due to condensation at total pressure $>10^{-3.5}$ bar [6, Plate 1] and low dust/gas enrichments [7]. Further high-resolution study of these metal-cored nodules is warranted [8].

References: [1] Krot et al., (2004) *Chemie de Erde* 64:185-239. [2] Weisberg M. K. et al. (2004) *Meteoritics & Planetary Science* 39:1741-1753. [3] Marrocchi Y. et al. (2019) *Geochimica Cosmochimica Acta* 247:121-141. [4] Krot A. N. et al. (2006) *Astrophysical J.* 639:1227-1237. [5] Ebel D. S. et al. (2016) *Geochimica Cosmochimica Acta* 172:322-356. [6] Ebel D. S. (2006) In *Meteorites and the Early Solar System II*, U AZ, p. 253-277. [7] Ebel D. S. et al. (2012) *Meteoritics & Planetary Science* 47:585-593. [8] Alpert S. P., et al. (2022) This conference, #6391.

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