

EVIDENCE FOR HIGHLY ^{16}O -RICH CHONDRULE PRECURSORS

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Introduction: Agglomeratic olivine (AO) chondrules were sintered at peak temperatures $<1200^\circ\text{C}$ [1] and therefore retain abundant chondrule-precursor silicates [1–3], including chondrule fragments [2,3]. Type I (FeO-poor) and type II (FeO-rich) chondrules in the Renazzo-like carbonaceous (CR) chondrites have distinct chemical and O-isotopic compositions [e.g., 4–9], indicating that related chondrule fragments in AO chondrules can be identified. It has been proposed that AO chondrules either (1) consist primarily of chondrule precursor materials and minor, rare fragments of earlier formed chondrules [2] or (2) consist primarily of type I and type II chondrule fragments, and represent a stage of chondrule recycling [3]. We studied the chemical and O-isotopic compositions of AO chondrules in the CR chondrites to determine the origin of their silicate precursors.

Samples and Analytical Procedures: A total of eight AO chondrules were identified from CR chondrites; one in Elephant Moraine 92048, one in Graves Nunataks 95229 [6], five in Gao-Guenie (b), and one in Pecora Escarpment 91082. Chemical and O-isotope compositions of AO chondrules were studied with the Smithsonian Institution JEOL 8900 Superprobe electron probe microanalyzer (EPMA) and the University of Arizona Cameca SX-100 EPMA, and the University of Hawai'i Cameca ims-1280 ion microprobe, respectively (details see [7]).

Results: Four of the eight AO chondrules contain porphyritic textures identical to type II chondrules, while the other four are solely AO chondrules (mean diameters range 0.05 to 1.73 mm). The AO chondrules contain normally zoned FeO-poor ($\text{Fa}_{0.8-9.6}$) and FeO-rich olivine ($\text{Fa}_{10.9-54.5}$) grains. The chemical compositions of FeO-rich olivine in AO chondrules are typically indistinguishable from that in type II chondrules. The chemical compositions of FeO-poor olivine in AO chondrules are similar to, but do not have the same compositional range as, type I chondrule olivine; they often have lower abundances of MnO, CaO, and Cr_2O_3 . The O-isotope compositions of olivines in the AO chondrules measured with a $\sim 1\ \mu\text{m}$ beam range in $\Delta^{17}\text{O}$ from -25.4 ± 2.2 to $0.2 \pm 2.0\ \text{‰}$ (2σ), and are internally heterogeneous in $\Delta^{17}\text{O}$. O-isotope analyses of fine-grained AO material are either (1) similar to type I chondrules (e.g., $\Delta^{17}\text{O} = -6.8 \pm 0.6\ \text{‰}$ [6]), (2) type II chondrules (e.g., $\Delta^{17}\text{O} = -0.7 \pm 2.1\ \text{‰}$), or (3) highly ^{16}O -rich (e.g., $\Delta^{17}\text{O} = -25.4 \pm 2.0\ \text{‰}$). The ^{16}O -rich compositions are mostly observed in FeO-poor olivine cores. O-isotope analyses of type II chondrule material are consistent with that of type II chondrules.

Discussion: The chemical and O-isotope compositions of FeO-poor and FeO-rich olivine within AO chondrules indicate multiple sources, including but not limited to type I and type II chondrules. The O-isotope compositions of olivine in AO material ($\Delta^{17}\text{O} = -25.4 \pm 2.2$ to $-0.5 \pm 2.1\ \text{‰}$) overlap with but are sometimes more ^{16}O -rich than type I ($\Delta^{17}\text{O} = -6.9 \pm 2.0$ to $0.1 \pm 1.1\ \text{‰}$ [6–8]) or type II ($\Delta^{17}\text{O} = -1.8 \pm 0.5$ to $1.4 \pm 0.6\ \text{‰}$ [6–8]) chondrule phenocrysts. This ^{16}O -rich olivine (e.g., $\Delta^{17}\text{O} < -20\ \text{‰}$) is inconsistent with an origin from type I or type II chondrules, but is similar to that of amoeboid olivine aggregates (AOAs) in CR chondrites ($\Delta^{17}\text{O} \sim -24\ \text{‰}$; [10]); such ^{16}O -rich relict olivine grains have also been observed in type I and II porphyritic chondrules [e.g., 11–13]. We conclude that the O-isotope compositions of some olivine in AO chondrules are most consistent with, and indicate a relationship to, AOAs. This is similar to the AOA origin for ^{16}O -rich olivines in FeO-rich igneous rims around type I chondrules in CR chondrites (i.e., $\Delta^{17}\text{O} \sim -24\ \text{‰}$ [14,15]). Therefore, at least in the CR chondrites, AO chondrules may contain but are not solely composed of recycled type I and type II chondrules. Instead, AO chondrules also contain chondrule-precursor silicates related to AOAs. This may also suggest that the assumed anhydrous precursor compositions of type I and type II chondrules [e.g., 6,9] are too ^{16}O -poor, and should be revised to more AOA-like ^{16}O -rich compositions.

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