

The refractory precursor of Al-rich chondrules in unequilibrated ordinary chondrites: CAI or non-CAI?

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Unlike Al-rich chondrules (ARCs) in carbonaceous chondrites, the genetic relationship of ARCs in ordinary chondrites (OC) to calcium-aluminum-rich inclusions (CAIs) is ambiguous, where ¹⁶O-rich relict minerals and bulk ⁵⁰Ti excess are absent but CAI-like fractionated rare earth element (REE) patterns have been identified [1, 2]. Furthermore, oxygen isotope ratios of OC ARCs define a slope ~0.8 line that does not intersect with CAI region on the primitive chondrule minerals (PCM) line [3]. To further understand the genesis of OC ARCs, we studied one porphyritic and five glassy ARCs from four unequilibrated OCs (3.00-3.05). The porphyritic ARC contains spinel, olivine, plagioclase, and high-Ca pyroxene, in which the former two minerals ($\delta^{17}\text{O} \sim 5\text{‰}$) are more ¹⁶O-enriched than the latter two ($\delta^{17}\text{O} \sim -5\text{‰}$ to -3‰). The order of ¹⁶O-enrichement among these minerals is consistent with their crystallization sequence, indicating gas-melt oxygen isotope exchange during melt crystallization. The five glassy ARCs consist mainly of skeletal or dendritic olivine and/or high-Ca pyroxene embedded in glassy mesostasis. The glassy mesostasis was concentrically zoned in major elements such as MgO and SiO₂, like the Semarkona ARCs described in [4]. Three glassy ARCs show internally oxygen isotope homogeneity, while the other two exhibit co-variations of $\delta^{18}\text{O}$ and $\delta^{17}\text{O}$ by $\sim 1\text{‰}$ and $\sim 4\text{‰}$, respectively. The oxygen isotopes of all ARCs define a line with a slope of ~ 1.0 , which is above and almost parallel to the PCM line (slope: 0.987). Several OC ferromagnesian chondrules (FMCs) are plotted on the regression line but most are below [5]. Within the uncertainty, the regression line passes the oxygen isotope region of CAIs, supporting the formation of ARCs by melting of CAI-like precursors in OC FMC-forming regions [4]. The ¹⁶O-poor ARCs would have experienced a significant mass dependent fractionation during chondrule formation, or they formed from precursors with previously fractionated oxygen isotope ratios [5].

Reference: [1] Ebert, S., and Bischoff A. (2016) *GCA*, 177, 182-204. [2] Ebert, S., et al. (2018) *EPSL*, 498, 257-265. [3] Russell, S. S., et al. (2000) *EPSL*, 184, 57-74. [4] Nagahara, H., et al. (2008) *GCA*, 72, 1442-1465. [5] Kita, N. T., et al. (2010) *GCA*, 74, 6610-6635.

