

CHROMIUM ISOTOPIC COMPOSITIONS OF AMOEBOID OLIVINE AGGREGATES FROM CV3 CHONDRITES: IMPLICATIONS FOR EARLY SOLAR SYSTEM ISOTOPIC RESERVOIRS

Z. A. Torrano¹, C. M. O'D. Alexander¹, R.W. Carlson¹, and E. S. Bullock¹ ¹Earth and Planets Laboratory, Carnegie Institution for Science, Washington, DC, 20015, USA (ztorrano@carnegiescience.edu)

Introduction: Amoeboid olivine aggregates (AOAs) are the most common type of refractory inclusions in CM, CR, CV, CO, and CH carbonaceous chondrites and consist of forsterite, metal, and Ca-Al-rich inclusions (CAIs) [1, 2]. Thermodynamic calculations and O isotope measurements suggest that AOAs formed in a similar region to CAIs [2, 3] and may represent an intermediate stage between the formation of CAIs and chondrules [4]. The Cr isotopic compositions of bulk meteorites, chondrules, and CAIs have proven instrumental in assessing the spatial and temporal relationships between early-formed solids in the Solar System [e.g., 5–9]. Existing Cr isotope data for AOAs, however, is restricted to a single sample [10] to our knowledge, limiting our understanding of the diversity within the AOA Cr isotopic reservoir, the relationship between AOAs and other meteorite constituents, and the formation of early Solar System isotopic reservoirs. In this study, we analyzed the mass-independent Cr isotopic compositions of eight AOAs from four CV3 chondrites (Allende, Northwest Africa (NWA) 3118, NWA 12675, and NWA 12180).

Methods: AOAs were identified and first analyzed using a JEOL JXA-8530F EPMA for compositional mapping and spot analyses via wavelength dispersive X-ray spectrometry (WDS). AOAs were extracted from meteorite slabs using a New Wave Research MicroMill, digested on a hot plate in a mixture of pure HF and HNO₃, and then digested in Parr digestion vessels in a 2:1 mixture of HF and HNO₃ at 190 °C for 4 days. Elemental abundances were measured using a Thermo Scientific iCAP Q ICPMS. Cr was purified from the samples in a three-column procedure [11]. Cr isotopic compositions were measured using a Thermo Scientific Triton XT TIMS and are reported relative to the NIST SRM 979 Cr isotopic standard with the data corrected for instrumental mass fractionation using an exponential mass fractionation law and a ⁵⁰Cr/⁵²Cr ratio of 0.051859 [12].

Results: The AOAs studied here are variable in shape from round to oblong and measure from ~3–15 mm along their long axes. They primarily consist of forsterite (Fa₅₋₂₀), and some contain CAIs up to 1 mm in size. All AOAs studied here exhibit unfractionated rare-earth element (REE) patterns (~1–10 x CI). The range of ε⁵⁴Cr compositions (3.39 ± 0.28 to 7.73 ± 0.40) is nearly identical to the range reported for CAIs, while the ε⁵³Cr compositions (–0.02 ± 0.10 to 0.73 ± 0.20) are more positive than those reported for CAIs [5, 13–15].

Discussion: The bulk compositions and mineralogies of these AOAs are consistent with previous interpretations of formation as aggregates of solar nebular condensates [e.g., 2, 4]. The ε⁵⁴Cr compositions suggest that AOAs and CAIs formed in a common isotopic reservoir, which is consistent with O isotope analyses of AOAs [3]. The more positive ε⁵³Cr values of the AOAs compared to CAIs could be indicative of cosmogenic effects, nucleosynthetic mixing, or a difference in formation time. Previous Cr, Ti, and O isotope data suggest that AOA-like material was present in carbonaceous chondrite (CC) chondrule precursors [e.g., 8, 9, 16, 17], although open system exchange of O and Si during melting may be necessary to fully explain such a scenario [e.g., 4, 8]. The CAI-like isotopic composition and less refractory chemical composition of AOAs [18] also suggests that these objects may play a significant role in the range of compositions observed for the various CC meteorite groups in ε⁵⁰Ti vs. ε⁵⁴Cr isotope space [9] because mixing lines between NC and AOA/CAI isotopic compositions would have distinct shapes depending on whether an AOA or CAI chemical composition is used. Although a single previous Cr isotopic measurement of an AOA and the assumption of CAI-like isotopic compositions have been used in previous models, the new data reported here provide additional constraints on the AOA isotopic reservoir and provide a clearer understanding of the range of Cr isotopic compositions that should be considered for mixing models.

References: [1] Grossman L. and Steele I. M. (1976) *Geochimica et Cosmochimica Acta* 40, 149–155. [2] Krot A. N. et al. (2004) *Chemie der Erde* 64, 185–239. [3] Hiyagon H. and Hashimoto A. (1999) *Science* 283, 828–831. [4] Ruzicka A. et al. (2012) *Geochimica et Cosmochimica Acta* 79, 79–105. [5] Birck J. -L and Allègre C. J. (1984) *Geophysical Research Letters* 11, 943–946. [6] Trinquier A. et al. (2007) *The Astrophysical Journal* 655, 1179–1185. [7] Warren P. H. (2011) *Earth and Planetary Science Letters* 311, 93–100. [8] Schneider J. M. et al. (2020) *Earth and Planetary Science Letters* 551, 116585. [9] Williams C. D. et al. (2020) *Proceedings of the National Academy of Sciences* 117, 23426–23435. [10] Larsen K. K. et al. (2011) *The Astrophysical Journal* 735, L37. [11] Torrano Z. A. et al. (2021) *Geochimica et Cosmochimica Acta*, 301, 70–90. [12] Shields W. R. et al. (1966) *Journal of Research of the National Bureau of Standards* 70A, 193–197. [13] Birck J. L. and Lugmair G. W. (1988) *Earth and Planetary Science Letters* 90, 131–143. [14] Papanastassiou D. A. (1986) *The Astrophysical Journal* 308, 27–30. [15] Loss et al. (1994) *The Astrophysical Journal* 436, L193–L196. [16] Olsen M. B. et al. (2016) *Geochimica et Cosmochimica Acta* 191, 118–138. [17] Zhu K. et al. (2019) *The Astrophysical Journal* 873, 82. [18] Sugiura N. et al. (2009) *Meteoritics and Planetary Science* 44, 559–572.