Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.33928

Diverse chondrule formation regions constrained by chemical and isotopic compositions of aluminum-rich chondrules

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The isotopic composition of chondrites provides information about formation, migration, and accretion processes of materials in the early Solar System. In particular, the isotopic compositions of chondrules, ubiquitous components of chondrites, provide a valuable record of the isotopic evolution of solids from presolar dust to the planetary accretion. Among various types of chondrules, Al-rich chondrules (ARCs) have intermediate isotopic and chemical compositions between calcium-aluminum-rich inclusions (CAIs) and ferromagnesian chondrules (FMCs) [1,2], providing insights into material mixing between the inner and outer protoplanetary disk at a heliocentric distance.

This study performed analyses of the abundances of 54 elements and multi-elemental isotopic compositions of Ca-Ti-Cr-Sr on fourteen ARC samples extracted from four Vigarano-type chondrites (CVs). The elemental abundance shows enrichments in refractory elements and depletions in volatile elements, together with the Group-II rare-earth-element patterns, which are generally observed in fine-grained CAIs (FG-CAIs). These features suggest that CV ARCs received contributions from multiple CAI types, including FG-CAIs, in addition to non-carbonaceous chondrite (NC) and Ivuna-type chondrite (CI) components typically found in FMCs. The mass-bias corrected μ^{48}Ca, μ^{50}Ti, μ^{54}Cr, and μ^{84}Sr values (10^6 times relative deviation from standard materials) range from +39 ± 69 to +944 ± 31 ppm (2SE), from +34 ± 17 to +1053 ± 23 ppm (2SE), from −12 ± 35 to +121 ± 36 ppm (2SE), and from −13 ± 42 to +133 ± 45 ppm (2SD), respectively. The Ca and Ti isotopic compositions of the ARCs indicate the contribution from FG-CAIs, while the incorporation of NC components is evident from the Cr isotopic composition. These results demonstrate that CV ARCs contain various types of refractory materials currently observed in CVs. Unlike ARCs from ordinary chondrites (OCs), which lack CAI signatures [3], CV ARCs are considered to have formed within the accretion region of carbonaceous chondrite parent bodies. The substantial contribution of NC components observed in ARCs and FMCs in CVs suggests that NC, CI, and CAI components coexisted within the CV parent body accretion region.

[1] MacPherson & Huss (2005) *GCA.* 69, 3099. [2] Zhang et al. (2020) *GCA.* 272, 198. [3] Ebert et al. (2018) *EPSL.* 498, 257.