Goldschmidt 2025 Abstract
https://doi.org/10.7185/gold2025.30197

Petrology and rare earth element compositions of Calcium-Aluminium-rich-Inclusions in CV3-red Chondrite NWA 12590

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Calcium-Aluminium-rich Inclusions (CAIs) (4.567 Ga [1]), commonly found in carbonaceous chondrites are the oldest dated solids in the solar system. Their mineralogical, chemical and isotopic compositions provide unique insights into various events and processes such as condensation, evaporation, melting and transportation of solids that occurred during the early stages of the solar system prior to asteroid and planetary differentiation.

Here we present petrological and chemical investigations using SEM, EPMA and LA-ICP-MS techniques on a new suite of CAIs from CV3-red NWA 12590. Of the CAIs investigated, the fine-grained (FG) examples consist primarily of spinel, Al-diopside, anorthite, hibonite and ilmenite, whereas the coarse-grained (CG) examples consist primarily of melilite, spinel, fassaite, anorthite and perovskite. Both FG and CG CAIs show various degrees of secondary mineralisation such as the formation of nepheline, sodalite and apatite, but all CAIs show significantly less alteration when compared with Allende CAIs, consistent with the reduced sub-group of CV3's [2].

LA-ICP-MS results show that CG CAIs have broadly flat CI-chondrite normalised REE abundances whereas most FG inclusions belong to the group II REE pattern. However, a subset of the FG CAIs that are especially enriched in spinel and hibonite yield a group III pattern. Given that spinel and hibonite are assumed to be primary condensates in FG CAIs, the group III pattern may have been produced by condensation of the more refractory REEs before temperatures were low enough for the more volatile REEs (Eu and Yb) to condense. Alternatively, the pattern could have been produced by distillation and/or solar outburst heating events whereby Eu and Yb were evaporated, although this is hard to reconcile with the accompanying FG texture.

SEM imaging of laser ablation pits in the CAIs indicate that incongruent ablation relating to mineralogical properties occurs when such highly heterogenous samples are ablated. This likely creates biases in the elements analysed and is a cautionary lesson for future LA-ICP-MS investigations.

[1] Connelly, J.N., Bizzarro, M., Krot, A.N., et al. (2012), *SciAdv* 338, 651-655

[2] Krot, A.N., MacPherson, G.J., Ulyanov, A.A., & Petaev, M.I. (2004), *MAPS* 39, 1517-1553