

ALLENDE 5241: ANATOMY OF A FREMDLINGE-RICH CAI A. El Goresy, J.T. Armstrong and G.J. Wasserburg, The Lunatic Asylum, Div. Geol. & Planet. Sci., Calif. Inst. of Tech., Pasadena, CA 91125

A Ca-, Al-rich inclusion, USNM #5241, from the Allende meteorite was selected for the present investigations because: 1) It contains large complex Fremdlinge enriched in V-bearing magnetite, spinels and CaWO_4 (scheelite) along with a molybdate and apatite as well as Pt metals [1]. 2) It reveals complex textures which cannot be easily reconciled with any of the present models for the single stage formation of CAIs.

Allende 5241 is a type B CAI composed of a spinel-fassaite-melilite core surrounded by a melilite mantle. The thin section available for this study (graciously loaned to us by B. Mason) appears to encompass approximately 1/4 of the inclusion. It appears that the original inclusion was roughly spherical and approximately 1.2 cm in diameter. Patches of grossular, monticellite-bearing alteration are found throughout the core and mantle of the inclusion.

The core is a texturally heterogeneous mixture of spinel-rich (~50% by volume), medium-grained, polycrystalline melilite and fassaite encompassing elongated regions of coarse-grained melilite, fassaite, and minor anorthite that are islands totally free of spinel. The spinel-free areas of the core are surrounded by dense rims of coarse idiomorphic spinel crystals. The rimming of these "islands" by spinels may bear some similarities to spinel framboids [2] or "palisades" [3], however in the islands the textural relationship is distinctly different. The spinel morphology in the core changes gradually from the densely-packed large idiomorphic crystals found at the boundaries of the islands to smaller, non-touching euhedral grains frequently ordered in curly, convoluted chains and vortices.

Both fassaite and melilite in the core show evidence of chemical zonation; however, the nature of this zonation is distinctly different in the islands and spinel-rich areas. In the islands, every fassaite displays concentric zonation and the melilites show a narrow range (Ak 50-60) of inverse zonation from Ak-rich core to Ge-rich rim. In the spinel-rich areas, fassaite is polycrystalline and asymmetrically zoned and the melilite exhibits a wide range of zoning, often by dramatic amounts over small areas. Some of the fassaite in the spinel-rich areas occur as small rounded blebs, often adjacent to spinel, surrounded by melilite similar to those described in [4]; such occurrences are not found in the islands. The fassaite in the center of the islands is more oxidized than in the surrounding fassaite. In one of the largest islands, the fassaite was found to be zoned in Ti^{3+} ranging from $\text{Ti}^{3+}/\text{Ti} \approx 0.4$ at the center to ~ 0.7 at the rim. The surrounding fassaite in spinel-rich areas is quite reduced with Ti^{3+}/Ti ranging from 0.8-0.9. Often the boundary of the spinel-free "islands" marks the termination of the crystals which are present inside. When fassaite or melilite appears to continue across the spinel rims of these islands, many of the crystals do not maintain optical continuity.

Numerous Fremdlinge (several hundred) ranging in size from a few μm to $> 150 \mu\text{m}$ are found in the spinel-rich fassaite and pyroxene portions of the core of the inclusion. A number of these Fremdlinge occur in rounded embayments at the edge of spinel crystals indicating that they pre-existed the spinels. No Fremdlinge were found in any of the spinel-free islands. All of the Fremdlinge studied in this inclusion are separated from their melilite or fassaite hosts by V-rich fassaite rims. When included in fassaite, the V content drops abruptly from several % in the V-rich fassaite rim to $\sim 0.2\%$ in the fassaite host. Such rimming of Fremdlinge

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appears to be a common feature which we have observed in other CAI.

The core is surrounded by a 0.5 to 1.5 mm band of melilite crystals aligned perpendicularly to the rim. These melilites are zoned with akermanite-rich portions near the core and gehlenite-rich near the rim. Spinel morphologies in the core and the melilite mantle are markedly dissimilar. Spinel crystals in the core are idiomorphic. In the melilite mantle the spinel grains are much smaller and are rounded.

Discussion: The spinel-free "island" areas of the core do not appear to have formed simultaneously with the spinel-rich areas. The sharp termination of large crystals at the spinel boundaries, the distinctive fO_2 indicated by the Ti^{3+}/Ti in the fassaite, and the absence of any included Fremdlinge suggest that the coarse grain islands crystallized before the spinel-rich areas. If this was the result of a single crystallization sequence from a homogeneous liquid, the required chaotic sequence would involve melilite and fassaite crystallizing both before and after a stage of spinel crystallization, and under considerably differing fO_2 . A plausible alternative is that the islands were pre-existing clasts which were cemented in a refractory liquid that crystallized under reducing conditions to form the medium-grained assemblage found in the core. In any event, such a chaotic crystallization sequence is difficult to explain by a simple mechanism of single stage equilibrium condensation from a solar gas or distillation of pre-existing material. Likewise, the Fremdlinge also present strong evidence for incorporation as preexisting solids into the inclusion. The existence of V-rich fassaite rims around Fremdlinge contained both in V-free melilite and V-poor fassaite and the rounded, indented surfaces of spinels found in contact with rimmed Fremdlinge suggest that both the Fremdlinge and their V-rich rims pre-existed the crystallization of the spinel-rich portions of the core. The apparent lack of any significant diffusion of V from the V-rich fassaite rim to the surrounding host fassaite and the disequilibrium in the included Fremdlinge may provide constraints regarding the cooling history of CAI.

Thus, textural relationships and mineral chemistries suggest that Allende 5241 may be an agglomerate whose multistage formational history involved capture of silicate clasts and pre-existing oxidized Fremdlinge in a refractory liquid, followed by crystallization under low fO_2 , partial resorption of some phases, and lower temperature alteration. This inclusion as well as other Allende CAI studied provide strong evidence that Fremdlinge are indeed "foreigners" and suggest that some of the refractory oxidized silicates and oxides may be as well.

Ref.: [1] Armstrong et al., this vol.(1984); [2] Proc. 10th LPSC, 833 (1979); [3] GCA 46, 2596 (1982); [4] GCA 47, 707 (1983)