

“RELICT” FASSAITE IN TYPE B1 CAI'S: PRODUCTS OF LATE-STAGE LIQUIDS?;
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Several lines of evidence suggest that some of the fassaite (Ti-, Al-rich clinopyroxene) in once-molten Type B1 Ca-, Al-rich inclusions in the Allende meteorite occurs as relict grains which predate the melting of their host inclusions. We are attempting to identify such grains because they could provide valuable chemical and isotopic data bearing upon condensation in the solar nebula. Kuehner *et al.* [1] described several fassaite grains in Allende inclusion TS23F1 which appeared to be relict, based on petrographic criteria (see below) and on trace element signatures different from those of unambiguously subliquidus fassaite grains. Here, we report the results of a search for relict fassaite grains in Allende Type B1 inclusion TS34F1 in which we used petrographic, electron probe and ion probe techniques.

Experiments show that the order of crystallization in slow cooling of Type B1 compositions is spinel, melilite, anorthite and fassaite, a sequence which produces “normal” chemical zoning (Al-rich cores to Mg-rich rims) in the melilite. With faster cooling, fassaite crystallizes before anorthite, increasing the Al/Mg ratio of the residual liquid and causing a reversal in the zoning of the coprecipitating melilite [2]. This provides a marker horizon for the incoming of fassaite in inclusions with this feature, such as TS23F1 [1] and TS34F1. We would therefore not expect to find fassaite in the normally zoned cores of melilite with reversely zoned rims, in melilite that is more aluminous (gehlenitic) than that at the point of reversal, or in mantle melilite, which is thought to be the first part of the inclusion to crystallize. Fassaite is found in these locations in TS34F1, however, and based on the petrographic evidence, these are potentially relict grains, and were selected for electron and ion probe analysis.

In the relatively spinel-free mantle of TS34F1, fassaite occurs as rounded, isolated grains up to 50 μm across, enclosed by melilite that is typically Åk_{20-30} . In the spinel-rich interiors of TS34F1 and TS23F1, the potential relict fassaite occurs as rims <10 μm wide on spinel, as meniscus-like infillings between adjacent spinel crystals, and as isolated grains ~ 100 μm across partially or completely enclosing spinel, all enclosed by melilite that is mostly Åk_{30-40} . We also analyzed anhedral, “ragged” fassaite enclosed by Åk_{50-55} melilite at the late-forming end of a large zoned crystal, just inside its reversely zoned edge. “Relict” fassaite in mantle melilite is characterized by high TiO_2 (2-6 wt %), Ti_2O_3 (5-12 %), and Sc_2O_3 (0.2-1 %) relative to the “relict” fassaite in the interior of the inclusion. Interior “relict” fassaite more closely approximates the major element compositions of the relict grains identified in TS23F1, although those in the present study have slightly higher $\text{TiO}_2^{\text{tot}}$ and lower MgO contents.

Major and trace element abundances in the potential relict fassaite and in subliquidus fassaite were determined by ion probe. We use Sc as a fractionation index, because it strongly partitions into fassaite and its abundance in fassaite decreases with continued crystallization [3]. On a plot of La vs. Sc (Fig. 1), the data for both subliquidus and “relict” fassaite form a single linear trend, indicating a common source. “Relict” fassaite in the mantle melilite plots at the high-Sc end of the trend. C1 chondrite-normalized REE abundances (Fig. 2) exhibit flat patterns except for slight LREE depletions and negative Eu and Yb anomalies. There is complete overlap between interior “relict” and subliquidus fassaite. “Relict” fassaite in the mantle has lower REE abundances outside the range of the other fassaite. The fact that all the patterns are nearly parallel to each other and have Yb anomalies of the same magnitude is additional evidence for a common parent. We observe a much wider range of compositions than [1] because we analyzed more grains and a greater variety of them, including points along a traverse across a large, 1 mm zoned fassaite crystal, and fassaite which petrographically appears to have crystallized after anorthite. The relict grains of [1], with La at $\sim 100 \times \text{C1}$, fall within our observed

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range. In TS34F1, the "ragged" fassaite mentioned above, late subliquidus fassaite that occurs as "fingers" between anorthite crystals, and the extreme rims of large zoned crystals have the highest REE and Th abundances.

Kuehner *et al.* [1] suggested that the high REE and Th abundances of the fassaite grains which they studied could not be attained by crystal/liquid fractionation and concluded that they were relict fassaite grains. Our results strongly suggest, as do preliminary modelling calculations, that crystallization from a liquid can produce the observed compositions, with approximately the last 0.5 per cent of the liquid crystallizing fassaite with REE at $300 \times C_1$ and >3 ppm Th.

Several questions remain unanswered, however. If the fassaite grains which are petrographically "out of place" are not relicts, how did they form? If they represent trapped, early liquids or injected, late liquids, why are they not associated with anorthite, which crystallized elsewhere in the inclusion? In many cases, the host melilite immediately adjacent to the fassaite is enriched in MgO. These Åk-enriched halos may represent melilite crystallized from trapped liquids that continued to fractionate. Finally, based on their high Sc and low REE concentrations, fassaite grains in the melilite mantle may have been the first fassaite to form. A problem with interpreting these grains as products of trapped, early liquids, which would be consistent with their location, host melilite composition and possibly their Åk-enriched halos, is that their Sc contents (3000-6000 ppm; Fig. 1) are so high that, even with a $D > 4$ [3], they require parent liquids which have undergone extensive ($>85\%$) prior crystallization of Sc-free melilite and spinel. Resolution of these problems will greatly improve our understanding of the crystallization histories of Type B1 CAI's.

REFERENCES: [1] Kuehner, S.M. *et al.* (1989) *GRL* 16, 775-778. [2] MacPherson, G.J. *et al.* (1984) *J. Geol.* 92, 289-305. [3] Simon, S.B. and Grossman, L. (1990) *LPS XXI*, this volume.

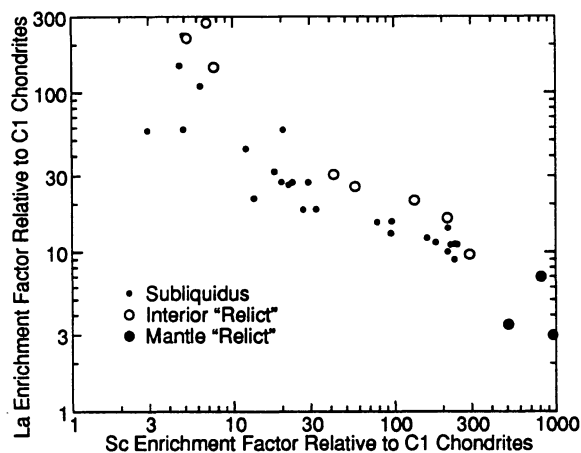


Fig. 1. Chondrite-normalized La vs. Sc in fassaite.

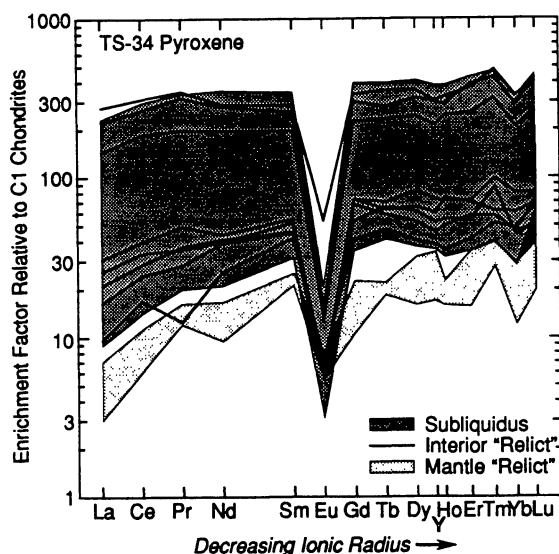


Fig. 2. Chondrite-normalized REE abundances in fassaite.