**INSIGHTS INTO THE FORMATION OF TYPE B2 REFRACTORY INCLUSIONS.** S. B. Simon[1] and L. Grossman[1,2], [1]Dept. of the Geophysical Sci., 5734 S. Ellis Ave., [2]Enrico Fermi Inst., The Univ. of Chicago, Chicago, IL 60637. (sbs8@midway.uchicago.edu)

Introduction. The petrology of Type B Ca-, Al-rich refractory inclusions is generally thought to be well understood, but actually most of this knowledge is based on studies of Type B1 inclusions (having melilite-rich mantles) and experiments on analogs of B1 bulk compositons. Type B2 inclusions (no mantles) tend to have relatively SiO_2-rich compositions compared to those of B1s [1], and inferences about the formation of CAIs that are based on studies of Type B1 compositions should not be routinely extended to Type B2s. Documentation of fundamental petrologic differences between Types B1 and B2, and determination of which ones can be attributed to bulk composition differences and which depend upon the presence/absence of a melilite mantle will improve our understanding of the formation of both suites. Some basic questions we are addressing in this study are: 1) What are the zoning patterns and ranges of compositions of melilite in Type B2 inclusions? 2) Are these patterns and ranges related in some systematic way to inclusion bulk composition? 3) Does melilite in Type B2s undergo late zoning reversals, like that in Type B1s [2]? 4) How is melilite in Type B2 inclusions zoned with respect to Na, and do Na contents in Type B2 melilite imply that a mantle is necessary for Na retention?
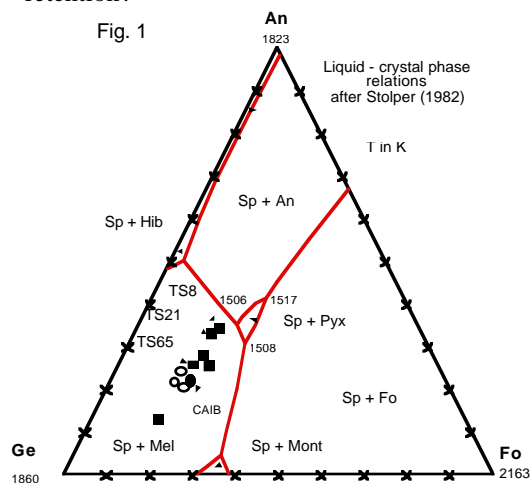
Fig. 1

Results. In Fig. 1, $CaO-MgO-Al_2O_3-SiO_2$-normalized bulk compositions of CAIs determined using the modal recombination and correction (to solar CaO/Al_2O_3) methods of [3] are projected from spinel onto the gehlenite (Ge)-anorthite (An)-forsterite (Fo) plane. Compositions of Type B1s (open circles) plot near and to the Ge-rich side of CAIB (solid circle), an estimate of the average bulk composition of Type B1

inclusions [1]. One unusual B2 is relatively melilite-rich, but most B2s (squares) plot between CAIB and the Mel-An cotectic. Given the range of inclusion bulk compositions, we might expect melilite abundances, composition ranges and zoning patterns to vary among Type B2s. They should have less melilite, and it should be less gehlenitic, than B1s.

Each of the six B2 and three B1 corrected bulk compositions plotted in Fig. 1 can be represented as an assemblage of the four primary phases melilite, fassaite, anorthite and spinel. In Fig. 2, the phase abundances (wt %) and the average Åk contents (mole %) are plotted as a function of the ratio of the bulk An and Ge components. The results show that as the An/Ge ratio increases (i.e., as bulk compositions approach the Mel-An cotectic in Fig. 1), anorthite contents increase, melilite decreases and its average Åk content increases, from ~28 – 37 mole % in B1s to ~40 – 45% in B2s. Spinel contents decrease slightly, and fassaite stays at about 25 – 30 wt %, reflecting the nearly uniform TiO_2 contents of 1.8 – 2.0 wt %.

We studied in detail three Allende Type B2 inclusions, TS8, TS21 and TS65, whose bulk compositions span most of the range of typical Type B2s (Fig. 1). TS65 has a Type B1-like bulk composition while TS21 and TS8 are both CaO-poor and SiO_2-rich relative to Type B1 compositions. In TS65, melilite ranges from $Åk_{12}$ to $Åk_{66}$. In TS21, melilite ranges from $Åk_8$ to $Åk_{76}$. In TS8, melilite ranges from $Åk_{12}$ to $Åk_{69}$. Each inclusion contains gehlenitic melilite that is probably relict. Both TS65 and TS21 contain large (500-1000 µm) melilite grains that poikilitically enclose fassaite and anorthite. In addition, TS65 contains short (200-300 µm), stubby laths. The melilite in TS21 is mostly anhedral. In TS8, much of the melilite occurs as short laths ~200 µm long. In contrast, in Type B1 CAIs, subhedral laths and blocky crystals >1 mm long are common. The generally lower melilite abundances and higher Åk contents observed in B2s are consistent with the higher An/Ge ratios of their bulk compositions compared to B1s. The smaller melilite grain sizes in TS8, and the enclosing of late phases by melilite in TS21, are consistent with relatively late formation of a higher proportion of the melilite, which is expected on the basis of the bulk compositions of these inclusions.

We conducted electron probe traverses across 9 to 19 melilite grains in each of the inclusions we studied. In contrast with B1s, in Type B2s, few melilite grains are radially oriented at inclusion rims. Without such a reference point we must assume that most grains grew

concentrically from their cores to their rims. A wide variety of zoning patterns was found in each inclusion. No single pattern is dominant. Unzoned, normally-zoned (MgO, or Åk component increases away from crystal core), and reversely-zoned grains are present in each inclusion. Some grains, especially in TS21, appear to have homogeneous or normally-zoned cores enclosed in relatively thick reversely-zoned rims (Fig. 3). Most grains we analyzed have at least one normally-zoned rim, and many are asymmetrically zoned, reaching much higher Åk contents at one rim than on the opposite one. Other grains are monotonically zoned from one rim to the other. Most of the grains, regardless of zoning type, exhibit oscillations in Åk contents from rim to rim. The amplitudes range from ~2 mole %, also commonly seen in B1 melilite, to ~10 mole %.

Despite the wide variety of zoning patterns, Na_2O contents are generally correlated with Åk contents within most grains, especially in TS8 and TS65, where most melilite with Åk contents <40 mole % has Na_2O contents <0.1 wt % and melilite with >40 mole % Åk has 0.1-0.3 wt % Na_2O. In TS21, most melilite has >40 mole % Åk and Na_2O contents range from below detection to 0.46 wt %. The analyses exhibit a great deal of overlap with analyses of melilite from Type B1 inclusions. While it might be expected that Na would be lost by evaporation from molten CAIs, previous work [4] has shown that its distribution in melilite in Type B1 CAIs is consistent with partitioning during fractional crystallization. Our results suggest that this occurred in B2s as well and thus, that a melilite mantle is not necessary for retention of Na_2O during crystallization of Type B CAIs.

Discussion. The suggestion that zoning of melilite in Type B2 inclusions could be understood in terms of crystal-liquid phase equilibria of their bulk compositions was made long ago [2] but had not been explored until now. These preliminary results support that suggestion. Upon crystallization of liquids with compositions typical of B2s, melilite should begin crystallizing later than in B1s, leading to at least some of the contrasts between B1s and B2s that we have observed. The wide variety of melilite zoning patterns within individual B2 inclusions suggests crystallization from relatively late, isolated melt pockets rather than the early, relatively homogeneous melts from which B1 mantles crystallized. Asymmetrical zoning probably reflects sheltering of one grain edge against a previously crystallized phase, also more likely for a relatively late phase. Zoning reversals found in late (~Åk60) melilite in B1s have been attributed to incoming of fassaite, which drives up the Al/Mg ratio of the residual liquid [2]. The grains in TS21 with small, normally-zoned cores and fairly thick reversely-zoned

rims can be explained by crystallization of a relatively small amount of melilite prior to fassaite crystallization and a more extended interval of melilite and fassaite cocrystallization than occurred in typical B1s. This is consistent with the bulk composition of TS21, which plots near the Mel-An cotectic (Fig. 1).

Fig. 2

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Fig. 3   TS21 MELILITE
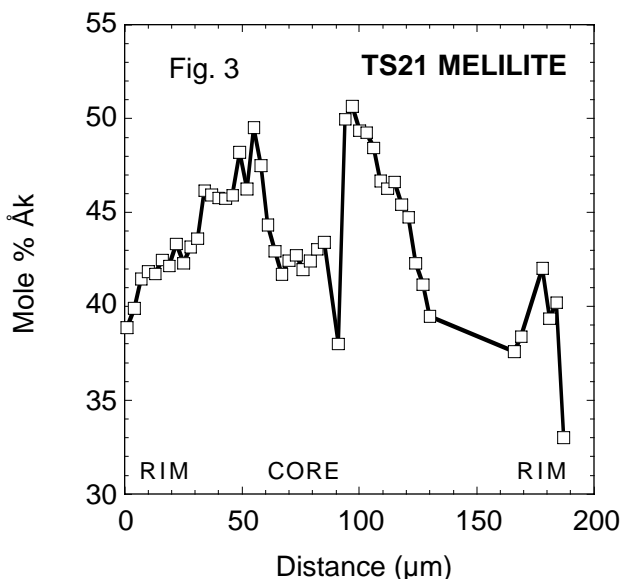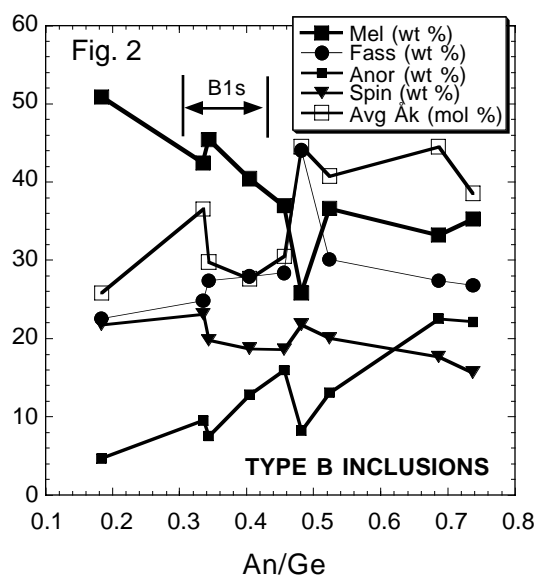
References. [1] Stolper E. *GCA* **46,** 2159. [2] MacPherson G. et al. (1984) *J. Geol.* **92,** 289 [3] Simon S. et al. (2002) *LPS XXXIII,* abstract #1620. [4] Beckett J. et al. (2000) *GCA* **64,** 2519.