CRYSTALLIZATION EXPERIMENTS ON A RANGE OF CA-AL-RICH INCLUSION COMPOSITIONS.

J.M. Paige and E. Stolper, Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125

Introduction. Previous experiments on an average Type B Ca-Al-rich inclusion composition have suggested that the observed textures and mineral chemistries of unaltered Type B inclusions are the result of slow cooling from a partially molten state (1). In order to extend our results to a wider range of coarse-grained inclusions, we have conducted crystallization experiments on four additional compositions. The starting material compositions (Table 1) were chosen to correspond to a typical Type B1 melilitite-rich inclusion; a typical Type B2 pyroxene-rich inclusion; a plagioclase-pyroxene-rich inclusion (Type B1 (2) or Type C (3)); and a hibonite-bearing inclusion. The compositions are shown in projection on Figure 1, along with relevant phase boundaries (4).

Equilibrium crystallization sequences. The equilibrium crystallization sequences are shown in Figure 2 along with that of an average Type B composition (CAI, (4)). The early appearance of spinel for all of the compositions we have studied is consistent with petrographic study of natural CAIs (4).

The nearly simultaneous onset of spinel and melilitite crystallization in experiments on the model Type B1 composition is consistent with the petrography of these inclusions (5). The low temperature of perovskite crystallization for our Type B1 composition contrasts with earlier results (6) but this probably reflects the difference in TiO₂ contents of the compositions studied. The earliest formed melilitites for the Type B1 composition were ~Ak8, ranging to ~Ak30 at low temperatures. This compares with a composition of ~Ak22 for the earliest formed melilitites in the less melilitite-rich average Type B composition studied by (4). The compositions of melilitites from natural inclusions are consistent with those predicted on the basis of these equilibrium crystallization data.

The hibonite-bearing composition (ES) did not crystallize hibonite or corundum, although they might have been expected from the phase diagram. A similar result was obtained by (6). This could be due to nucleation problems for these phases (e.g., (8)) or to uncertainties in the available phase diagram (4).

Controlled cooling experiments. Preliminary controlled cooling experiments on the Type B1 melilitite-rich composition (#98) have been conducted in order to determine if the conclusions drawn from experiments on an average Type B composition (1) can be extended to more melilitite-rich Type B inclusions. Samples were quenched at different temperatures during the cooling sequences in order to determine the crystallization sequences and to observe the development of textures. Samples were held at maximum temperature (T_max) for 3 hrs before beginning the cooling sequence. Cooling rates ranged from 0.5 to 1000°C/h. The variation in crystallization sequences with T_max and cooling rate were similar to those found for the average Type B composition (1).

Experiments with T_max near or above the liquidus produced dendritic or feathery melilitites at all cooling rates studied. The absence in natural Type B1 melilitites of textures similar to the distinctive melilitites produced under these experimental conditions suggests that CAIs cooled from a partially molten state. This extends our conclusions based on previous experiments on an average Type B composition (1).

For T_max=1500°C (near the equilibrium crystallization temperature of melilitite) large (mm-sized) euhedral melilitites were produced in controlled cooling rate experiments on composition #98. These melilitites displayed reversely-zoned rims on normally-zoned cores in those samples in which pyroxene crystallized. This is similar to a feature that we found in the CAI composition (9), and that is present in several natural CAIs. Spinel, pyroxene, and an unidentified phase (see below) were included in these experimentally produced melilitites. A basal section of an experimentally grown melilitite suggests that the pyroxene and the unidentified phase form from late liquids infiltrating the melilitite crystals, perhaps along cracks. The liquid reacts with the previously formed melilitite, resulting in a rim of higher akermanite content surrounding the pyroxene inclusion. In this feature, an increase in the akermanite content of melilitite surrounding pyroxene inclusions, was noted by (10) but interpreted to be a result of melilitite replacing pyroxene during metamorphism. Our experiments show that the same result can be produced by simple crystallization from a liquid, providing an alternate explanation for this petrographic feature.

Perovskite was not found in any of the controlled cooling experiments on the Type B1.
CRYSTALLIZATION OF CAIs

Paque, J.M. and Stolper, E.

composition (#98), although it is present in equilibrium experiments and is found as inclusions in mullite and pyroxene in some CAIs (7). Some perovskites in natural CAIs may thus be unmelted relics enclosed within mullite and pyroxene.

Unidentified phase. An unidentified phase was found in controlled cooling experiments for both the average Type B (CAI) and mullite-rich (#98) compositions. In composition #98 it is present as euhedral inclusions (<100µm) in mullite but in the CAI composition it is part of a complex intergrowth with spinel, anorthite, pyroxene, and mullite. An average of 12 analyses is given in Table 2 along with an analysis of an "unidentified silicate phase" from a Ca-Al-rich inclusion in Essebi, a CM2 carbonaceous chondrite (11), which may be the same phase. The phase has a stoichiometry of R₂O₃, with an inverse correlation between TiO₂ and SiO₂ and between TiO₂ and Al₂O₃, suggesting the possibility of tetrahedrally coordinated Ti. An attempt to synthesize a larger amount of this phase is being carried out in order to further characterize its properties.