FLASH HEATING A TYPE B CAI COMPOSITION. *Susan V. Maharaj* and *Roger H. Hewins*, Department of Geological Sciences, Rutgers University, New Brunswick, NJ 08903, U.S.A.

Introduction

Ca-Al-rich Inclusions (CAIs) or refractory inclusions are among the first solid bodies that formed during the birth of the solar system and thus provide clues to the processes and conditions that prevailed in the primordial solar nebula [1, 2]. Previous results of crystallization experiments on a Type B CAI composition have shown that some features of CAIs can be reproduced by crystallization from partially molten droplets [3] suggesting possible similarities in history to chondrules. Many characteristics of chondrules are consistent with chondrule formation by transient heating events or in the presence of dust grains in the solar nebula [4]. This study determines the effects on a CAI composition of similar brief heating at high temperature followed by rapid cooling, and dust collisions in some cases. Preliminary results of dynamic crystallization experiments using (1) equilibrium melting (i.e. 3 hr), (2) flash heating (i.e. 1 min) with linear cooling, (3) flash heating with step cooling and (4) equilibrium melting with dust seeding are presented.

Experimental Conditions

Experiments were performed in air on an average Type B coarse-grained CAI composition [5, 6] in a Del-tech vertical muffle-tube furnace. Temperature was monitored 2-3 mm above the sample by a type S thermocouple internal to the sample rod.

Results and Discussion

Experimental results of the conditions under which different melilite textures were observed by [3] have been reproduced with good agreement [7]. When the total time at T_{max} is decreased from 3 hr to 1 min, a significant upward displacement of the subhedral-lattice and lattice-dendritic boundary lines occurs (Fig. 1). Subhedral melilite is produced in flash heated/linear cooled charges at temperatures ~100°C higher and cooling rates of ~100-1000 times faster than in equilibrium melting experiments of [7]. The brief time at T_{max} of flash heated/linear cooled charges permits the formation of subhedral melilite under a wide range of melting temperatures and cooling rates, probably as a result of incomplete melting of the charge [8]. Flash heated/linear cooled samples that experienced slower cooling rates (≤100°C/hr) closely resemble those of equilibrium melting runs cooled at ≤20°C/hr. Melilite (and some pyroxene) under these conditions form coarse-grained subhedral crystals much like those commonly found in natural Type B CAIs. Faster cooling rates of ≅1000°C/hr or greater restrict the time during which melilite may crystallize and thus produce melilite of ~100 μm. Several charges were flash heated for 1 minute and cooled in steps or at non-linear rates (Fig 2). All flash heated/step cooled samples with an initial T_{max} of 1450°C contain subhedral melilite. Pyroxene cooled at 2°C/hr during the final cooling step more closely resembles those of natural Type B CAIs than charges cooled rapidly during the final cooling step. Although flash heated/step cooled runs cooled from 1500°C produce subhedral melilite with cooling rates as high as 3000°C initially (first cooling step) (Fig. 2), melilite and pyroxene require final cooling rates of ~10°C/hr or less in order to grow slowly enough to become coarse-grained subhedrals like those of natural CAIs (Fig. 3). The introduction of the seeding compositions (anorthite, corundum, spinel or the Type B CAI starting material) nucleated melilite in the charges. When the selected seeding composition was puffed into the furnace at T_{max}, dendritic-textured samples resulted from easier nucleation of melilite than in charges run under equilibrium melting conditions (not seeded) which contain 100% glass or mostly glass.

Comparison with Natural CAIs and Chondrules

No plagioclase was observed in experimental runs. Plagioclase nuclei probably remained in the natural CAI liquid but not in the synthetic one, though a simple (i.e. slower) cooling rate explanation is also possible. It is interesting to note that despite the lack of plagioclase, some of the flash heated/step cooled runs contain oscillatory zoned melilite (i.e. normal–reverse–normal zoning from core to rim). [9] suggest that the reversely zoned interval result from the co-precipitation of melilite with pyroxene and the normally zoned rim from the onset of plagioclase crystallization. Our flash heated/step cooled experiments contain both reversely zoned and oscillatory zoned melilite. [10] show that one or more reversals in the direction of melilite zoning may be produced by normal crystallization processes with continuously decreasing temperature. The charges that contain oscillatory zoned melilite were quenched ~600°C lower than the ones that contain reversely zoned melilite. This evidence, along with the lack of plagioclase, suggests that melilite zoning is a function of crystallization under continuously decreasing temperature [10].

Zoning of olivine phenocrysts indicates that porphyritic olivine chondrules cooled at 100° to 1000°C/hr [4]. Final cooling rates that produce spherules similar to natural CAIs, even though not slow enough to produce plagioclase, would probably not make zoned olivine crystals from a chondrule composition. The maximum temperature experienced by chondrules is ~1800°C [11] whereas peak CAI formation temperature appear to be ~1500°C, based on this study. The differences in initial temperature and cooling rate for CAIs and chondrules are most easily explained by different formation mechanisms and/or different environments. This is a conservative conclusion, however, in that CAI starting materials with crystalline plagioclase have yet to be investigated.

References

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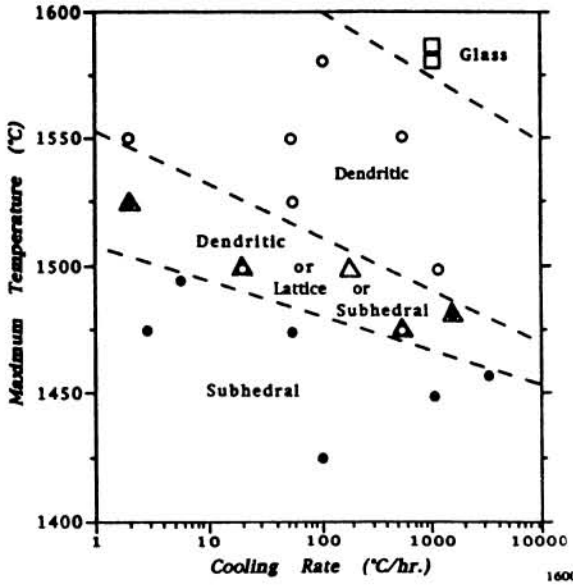

Fig. 1. Melilite habit as a function of maximum temperature and cooling rate in charges flash heated for 1 min.

□ Glass
○ Dendritic
△ Lattice
● Subhedral

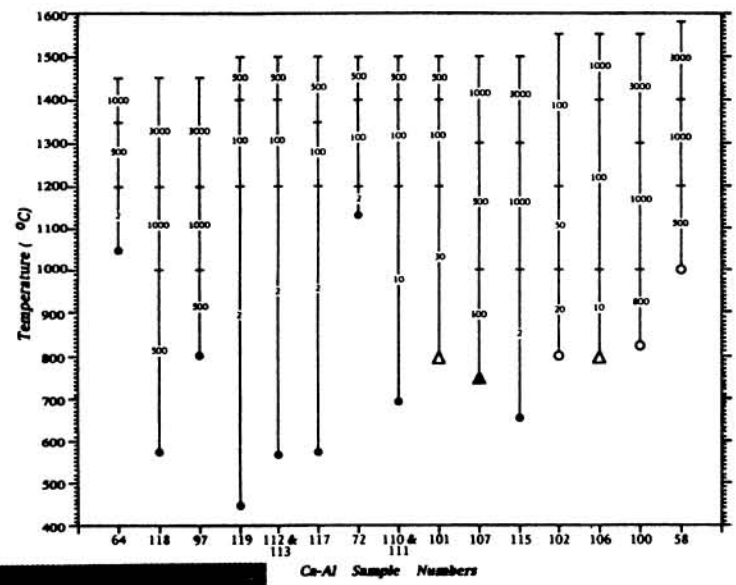

Fig 2. Cooling rates used in flash heated/step cooled runs. Melilite habit is indicated at the bottom of each profile.

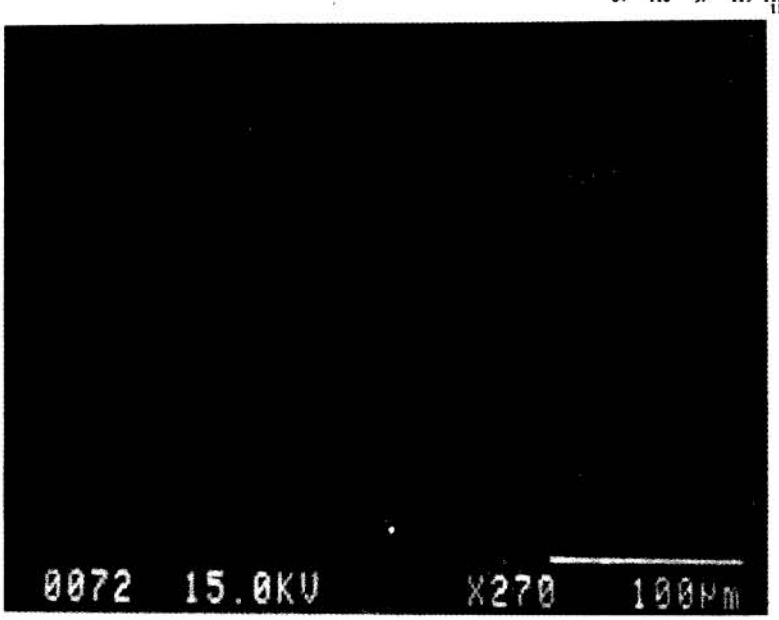

Fig 3. Flash heated/step cooled run Ca-Al-72 (T_{max}=1500°C; 500/100/2°C/hr). Light grey= melt; medium grey=melilite; dark grey=pyroxene; black= spinel.

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