

**FORMATION OF THE MELILITE MANTLE OF THE TYPE B1 CAIs: EXPERIMENTAL SIMULATIONS.** R. A. Mendybaev<sup>1</sup>, F. M. Richter<sup>1</sup>, and A. M. Davis<sup>1,2</sup>, <sup>1</sup>Department of the Geophysical Sciences, <sup>2</sup>Enrico Fermi Institute, The University of Chicago, Chicago, IL 60637 (ramendyb@uchicago.edu).

**Introduction:** Type B Ca-Al-rich inclusions (CAIs) in carbonaceous chondrites represent the oldest materials known to have formed in the solar system, most likely by condensation from a gas of solar composition followed by reheating to ~1400°C and slow cooling at <50°C hr<sup>-1</sup> [1]. This reheating resulted in the igneous textures of Type B CAIs, the fractional loss of the moderately volatile elements Mg and Si, and the heavy isotope enrichment of the residual Mg and Si.

Texturally, Type B CAIs are classified into those characterized by a relatively uniform distribution of melilite (Type B2), and those mineralogically zoned with a relatively thick outer melilite mantle (Type B1). The coarse-grained igneous texture of the B2s has been reproduced experimentally by cooling partially molten (spinel + melt) droplets of a Type B-like composition from about 1400°C at rates of 1 to 50°C hr<sup>-1</sup> [2]. To the best of our knowledge, zoned textures similar to that of the B1s have not been reproduced by experiment. Richter et al. [3] suggested that the presence of melilite mantles in B1s and their absence in B2s is caused by differences in the evaporation rates of Mg and Si relative to their diffusion rates in the melt. If the evaporation rate is slow compared to the diffusion rate, the droplets would remain chemically homogeneous and there would be no distinction as to where melilite crystallizes, thus making textures like that of the B2s. If however, evaporation is fast compared to diffusion, the outer parts of the molten droplets would be more depleted in Mg and Si, which as we will show, will favor melilite crystallizing there, thus making B1 textures.

Here we discuss the results of a new series of evaporation and crystallization experiments of Type B CAI-like compositions, which depending on the conditions can produce textures very much like those of Type B2 and B1 CAIs.

**Experimental:** The experiments were conducted in a gas-mixing Deltech vertical tube furnace with air or hydrogen flowing at 950cm<sup>3</sup> min<sup>-1</sup>. As starting materials, we used three compositions with approximately solar Ca/Al ratios, but variable Mg and Si contents: the Type B composition used by [2] (CAIB—30.4 wt% CaO, 9.6% MgO; 28.6% Al<sub>2</sub>O<sub>3</sub>, 31.4%SiO<sub>2</sub>); a composition close to □ from [4] (DT1—25.3% CaO, 13.9% MgO, 29.7% Al<sub>2</sub>O<sub>3</sub>, 31.0% SiO<sub>2</sub>), and a composition intermediate between CAIB and DT1 (DT2—26.2 % CaO, 12.8% MgO, 30.5% Al<sub>2</sub>O<sub>3</sub>, 30.5% SiO<sub>2</sub>). The experimental samples were made by partially melting powders loaded onto Ir or Pt loops 2.5 mm in diameter.

Experiments run in air were used to determine the crystallization temperature of melilite at fixed composition. Experiments exposing the DT1 starting composition to flowing H<sub>2</sub> at a fixed temperature of 1350° or 1380°C were used to explore Mg and Si loss under isothermal conditions. Cooling experiments in air and in H<sub>2</sub> were also run with composition DT1 cooled from 1380°C to 1280° or 1250°C at controlled rates of 5°C hr<sup>-1</sup> and 10°C hr<sup>-1</sup>. Run products from all experiments were examined by scanning electron microscopy and analyzed by energy-dispersive x-ray microanalysis.

**Results and discussion:** The red dotted line in Fig.1 connects the experimentally determined initial crystallization temperature of melilite: 1405°C for CAIB, which is the same as reported in [2], 1390°C for DT2, and 1315°C for DT1. The only mineral observed at temperatures above the red line was spinel, which crystallizes at T>1550°C. Fig. 1 shows that the crystallization temperature of melilite decreases with increasing MgO content of the melt. This has important implications for how melilite crystallization might be produced in a natural system. As show in Fig. 1, melilite can crystallize during isothermal evaporation, isochemical cooling, or combinations of evaporation and cooling.

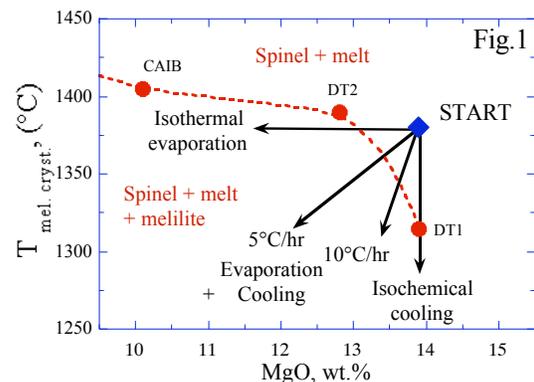


Fig. 2 shows false-color backscattered electron images of DT1 exposed to H<sub>2</sub> at 1380°C and cooled to 1250°C at 10°C hr<sup>-1</sup> (DT1-4L, Fig. 2a) and to 1280°C at 5° hr<sup>-1</sup> (DT1-4O, Fig. 2b). Melilite is shown in blue, spinel in black, and quenched glass in green. The texture of DT1-4L with large (up to ~400 μm) euhedral melilite grains is similar to that of natural Type B2 inclusions. Similar textures were produced in experiments where melts were cooled at 10°C hr<sup>-1</sup> in air. The more slowly cooled sample DT1-4O clearly shows a continuous melilite mantle, which is the distinguishing feature of the natural Type B1 inclusions [5]. However, in contrast to natural B1s, DT1-4O has no melilite grains

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in its interior, which is probably the result of the sample having been quenched at too high temperature. No melilite mantles were found in experiments conducted in air.

Run products from our isothermal experiments at 1380°C in H<sub>2</sub> usually have incomplete melilite mantles. These melilite crystals, unlike those of natural Type B CAIs, are reversely zoned with the Åk content decreasing towards the outside of the crystals (see Fig. 3a). Fig. 3b and 3c are typical composition profiles of melilite from DT1-4L and DT1-4O. Melilites from these samples are normally zoned. The zoning of melilite grains from DT1-4L is characterized by relatively high Åk content varying from ~Åk<sub>40</sub> in the center of grains to ~Åk<sub>55</sub> at the edges. Melilite from DT1-4O is less åkermanitic with composition varying from ~Åk<sub>20</sub> in the center to ~Åk<sub>40</sub> in the outer parts of the grains. These melilite compositions are close to the values reported in the literature for typical Type B1 (from Åk<sub>20</sub> to Åk<sub>35</sub> for mantle melilite) and Type B2 (>Åk<sub>45</sub>) inclusions [5].

The observed dependence of melilite zoning on cooling rate agrees with experimental results of [2] and calculations by [4].

The remarkable similarities in the texture and chemical composition of melilites in our experiments and natural Type B CAIs suggest that both Type B1 and B2 CAIs could form from partially melted CAI precursors of similar composition. The major factor controlling the texture and melilite composition in our experiments is the cooling rate. Relatively fast cooling (~10°C hr<sup>-1</sup>) resulted in the formation of Type B2 CAIs-like objects, while slow cooling in hydrogen, with more evaporation of Mg during melilite crystallization, produces Type B1-like objects.

**References:** [1] Grossman L. et al. (2000) *GCA* **64**, 2879. [2] Stolper E. and Paque J. M. (1986) *GCA* **50**, 1785. [3] Richter F. M. et al. (2002) *LPS XXXIII*, Abstract # 1901. [4] Grossman L. et al. (2002) *GCA* **66**, 145. [5] Wark D. A. and Lovering J. F. (1982) *GCA* **46**, 2581.

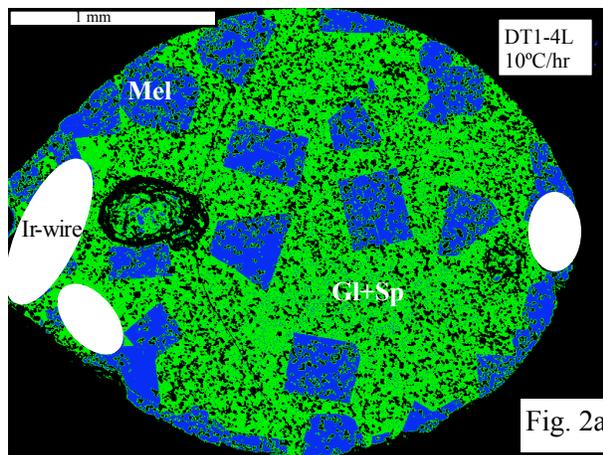


Fig. 2a

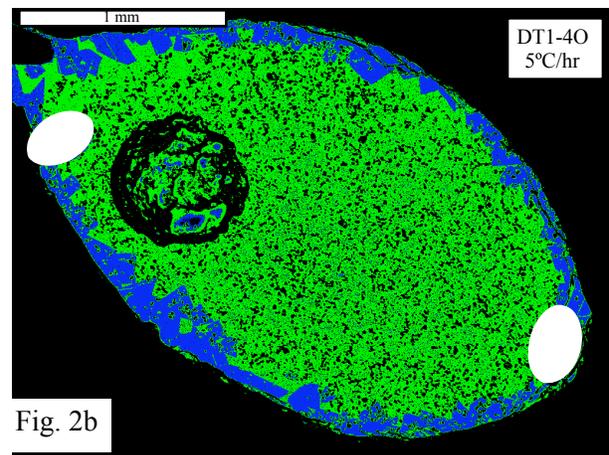


Fig. 2b

