EFFECT OF RESIDENCE TIME AT MAXIMUM TEMPERATURE ON THE TEXTURE AND PHASE COMPOSITIONS OF A TYPE B Ca-Al-RICH INCLUSION ANALOG; Julie M. Paque, SETI Institute, NASA-Ames Research Center, M. S. 245-3, Moffett Field, CA 94035-1000.

Interpretation of the various models for the formation of Ca-Al-rich inclusions (CAIs) within the context of experimental studies is highly dependent on the parameters selected for the experiments. The majority of the experiments of [1] were performed with a time at maximum temperature (t_{res}) of 3 hr. Based on these experiments [1] concluded that the maximum temperature (T_{max}) for the formation of CAIs was near the isothermal crystallization temperature of melilite (~1400°C for an "average Type B" CAI composition) with a cooling rate less than tens of degrees per hour. However, many of the models for the formation of chondrules and CAIs imply that t_{res} was brief ("flash heating"). To test the effect of t_{res} on resulting texture and chemistry a series of experiments with t_{res}=0 min to 18.5 hr were performed. A decrease in t_{res}, with T_{max} and cooling rate constant, resulted in textures more consistent with those found in CAIs. Based on textures only this result expands the range of T_{max} and cooling rate (CR) that can duplicate the characteristics of Allende Ca-Al-rich inclusions, similar to the preliminary results reported by [2]. However, the experiments with shorter t_{res} do not reproduce the mineralogy and crystallization sequence (particularly with respect to anorthite) inferred from natural CAIs, nor the mineral compositions.

Experiments. A series of runs with maximum temperatures (T_{max}) of 1420 and 1450°C and cooling rates of 50 and 200°C/hr were performed at one atmosphere in air, varying only the residence time at T_{max} (t_{res}) from 0 min to 990 min (18.5 hr). The average Type B CAI starting material composition and experimental protocol are the same as [1]. Spinel (SP), melilite (MEL), and a Ti-fassaite pyroxene (TPX) were produced in all experiments. Glass (GL) was present to the quench temperature (987-1100°C) in most experiments. A fine grained intergrowth of MEL+TPX+anorthite (AN)±UNK [3] formed in a subset of the experiments.

Textures. Melilite textures ranging from dendritic to euhedral are produced in cooling experiments (Figure 1), with only the euhedral texture found in natural CAIs. Definition of melilite textures is somewhat subjective, in that there is a continual gradation from one texture form to another. The progression from dendritic→lattice→skeletal→ euhedral melilite is a reflection of the available nucleation sites in the sample. As t_{res} is decreased the number of nuclei available in the sample would be expected to increase (the shorter time at maximum temperature allows more nuclei to be retained) and the euhedral texture would be more likely. The experimental results are consistent with this hypothesis (Figure 2). A decrease in t_{res} at faster cooling rate produces euhedral MEL.

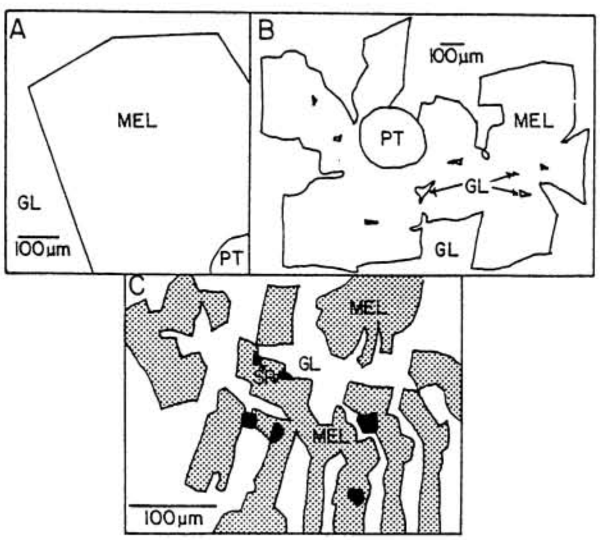

Figure 1. Melilite textural types produced in controlled cooling experiments. **A**. euhedral. **B**. skeletal. **C**. lattice. An example of dendritic melilite can be found in Fig. 3 of [1].

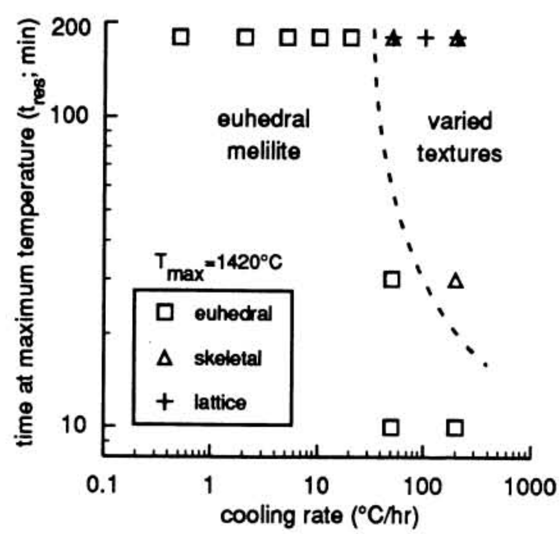

Figure 2. Melilite textures as a function of cooling rate for T_{max}=1420°C.

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TPX texture also varies systematically with t_{res}, with euhedral TPX prevalent when t_{res} is ≤30 min and dendritic TPX at longer t_{res} for T_{max}=1420°C. For T_{max}=1450°C euhedral TPX formed only when t_{res} was 0 min, dendritic TPX was present from t_{res}=10-180 min. TPX did not form in any of the experiments with t_{res}=18.5 hr, suggesting that t_{res} may also be a significant factor in TPX nucleation.

Crystallization sequence. The majority of Type B inclusions from Allende contain anorthite, either as euhedral crystals or anhedral grains interstitial to MEL and TPX. The only anorthite produced in the experiments done as part of this study formed as part of an intergrowth with MEL, TPX, and UNK (Figure 3). This intergrowth texture has not been found in any natural CAI, although it would probably be more susceptible to alteration due to the fine grained nature of the material. Anorthite was not found in any experiments from T_{max}=1450°C, CR=200°C/hr with t_{res}≥30 min, however anorthite as part of the intergrowth was produced at t_{res}=0 and 10 min. The glassy nature of the starting material may be a contributing factor in the inability of anorthite to nucleate. Further experiments are planned to address this important question.

Chemistry. All MEL, including dendritic MEL, have increasing åkermanite (Åk) content from core to rim ("normally zoned"). In some samples a rim of reversely zoned MEL is found overlaying the core of normally zoned MEL and is believed to be due to the precipitation of TPX in the absence of AN [4]. The range of Åk within a sample correlates with the MEL texture, with dendritic and lattice textures showing a more restricted range in composition than skeletal or euhedral. TPX composition is also correlated with the crystallization of AN [1]. TPX that formed as part of the intergrowth have higher Ti and lower Al than TPX formed prior to the crystallization of AN. This is a result of the depletion of Al by anorthite crystallization. TPX from CAIs have compositions similar to TPX that formed as part of the intergrowth. With the exception of TPX formed as part of the intergrowth, all TPX from these experiments have lower TiO_2 (≤6 wt. %) and higher Al_2O_3 (19-30 wt. %) than TPX from CAIs similar in bulk composition to the starting material used in the experiments (TiO_2=3-20 wt. %; Al_2O_3=15-20 wt. %).

Conclusions. A shorter residence time at T_{max} allows the reproduction of textures common to Ca-Al-rich inclusions at higher T_{max} and/or more rapid cooling rates. However, anorthite crystallization (except as part of an intergrowth) and Ti-fassaitic pyroxene chemistry are not reproduced under these conditions. Therefore, the earlier conclusion of [1] that CAIs cooled on the order of tens of degrees per hour from temperatures near the isothermal crystallization temperature of melilite remains valid. Additional experiments with shorter t_{res} at higher T_{max} and slower cooling rates are planned to determine if the range of T_{max} can be extended, even if cooling rate must remain slow to reproduce the chemistry.

References. [1] Stolper E. M. and Paque J. P. (1986) *GCA* 50, 1785. [2] Maharaj S. J. and Hewins R. H. (1994) *LPSC XXV*, 825. [3] Paque J. P. et al. *Meteoritics* 29,673. [4] MacPherson et al. (1984) *J. Geol.* 92, 289.

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Figure 3. An intergrowth consisting of anorthite, Ti-fassaitic pyroxene, and melilite crystallized between larger grains of melilite and pyroxene. Run conditions: T_{max}=1420°C, cooling rate=200°C/hr, t_{res}=30 min.

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