**CLOSURE TEMPERATURES OF THE SHORT-LIVED DECAY SYSTEMS, Be-B IN MELILITE AND Al-Mg IN ANORTHITE: IMPLICATIONS FOR THE CHRONOLOGY OF CAIs AND EARLY SOLAR SYSTEM EVENTS.**

M. Ito[1, 2] and J. Ganguly[1], [1]RI Centre, University of Tokyo (motoo@ric.u-tokyo.ac.jp), [2]Dept. of Geosciences, University of Arizona (ganguly@geo.arizona.edu)

**Introduction:** Sugiura *et al.* [1] noted that the Al-Mg system in anorthite in the calcium-aluminum-rich inclusions (CAIs) in CV chondrites were disturbed while the Be-B system in the melilites in the same inclusions were undisturbed. This observation led to the suggestion that Be-B system in melilite may be useful for the chronology of high temperature events in the early solar system. To explain the above observation and evaluate the effectiveness of the two decay systems for the determination of high temperature chronology, we have determined the diffusion kinetics of the Be-B system in melilites and used these data, along with the diffusion data of Mg in anorthite [2] to calculate the closure temperatures ($T_C$) of the decay systems as function of peak temperature, grain size and cooling rate.

**Experimental:** Gehlenite crystals, which were synthesized by the Czochralski method [3], were cut normal to the *c-axis*, and polished on one side to mirror finish by a combination of mechanical and chemical polishing [4]. The polished sections were thermally pre-annealed for 24 hours at 900˚C to obtain an equilibrium or near equilibrium defect concentration for the condition of the diffusion experiments, which were carried out at 1 bar, 850-1100˚C. For each experiment, a thin layer consisting of a mixture of B and Be was deposited on the polished crystal surface by thermal evaporation of a mixture of $B_2O_3$ and BeO under a high vacuum condition. The crystal was then sealed in silica tube and annealed for 10 min to 4 days, depending on the temperature, in a vertical tube furnace.

The experimental diffusion profiles of B and Be in the quenched gehlenite crystals were analyzed (as $^{11}B$ and $^{9}Be$, respectively) by depth profiling in an ion probe (Cameca, ims-3f SIMS) using a primary beam of mass filtered $^{16}O^-$, as described in [3]. The crater depths were measured by a surface profilometer that was calibrated against known standards.

**Results:** A typical diffusion profile of $^{11}B$ parallel to the *c-axis* of gehlenite, and a model fit to the data, are shown in Fig. 1. We solved for both D and the surface concentration, which could not be measured directly, by interfacing the solution to the diffusion equation with an optimization program [5].

Fig. 2 shows an Arrhenian plot of the measured diffusion data of B and Be in gehlenite parallel to the c-axis. These data yield the relation D(B)//c-axis = $2.03 \times 10^3 \cdot \exp(-Q(B)/RT)$ and D(Be)//c-axis = $6.24 \times 10^5 \cdot \exp(-Q(Be)/RT$ $cm^2/s$, where the activation energy Q(B) = 420 ± 22 and Q(Be) = 459 ± 18 kJ/mol. Also shown for comparison in Fig. 2 are the Mg diffusion data in anorthite, as determined by LaTourette and Wasserburg [2].

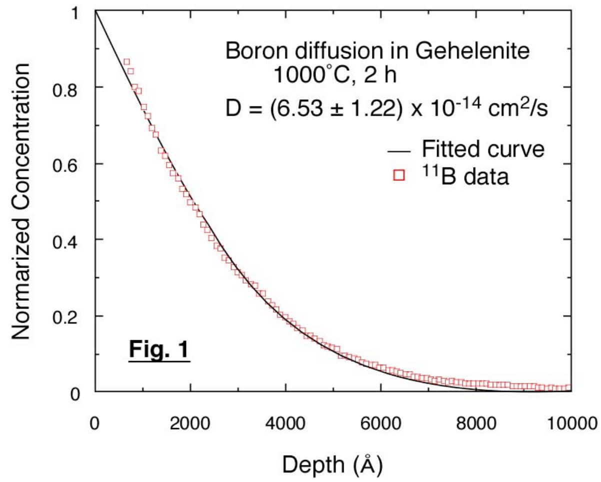


Fig. 1. Typical depth profile of $^{11}B$ diffusion parallel to the c-axis in gehlenite, and model fit according to the appropriate solution of the diffusion equation.

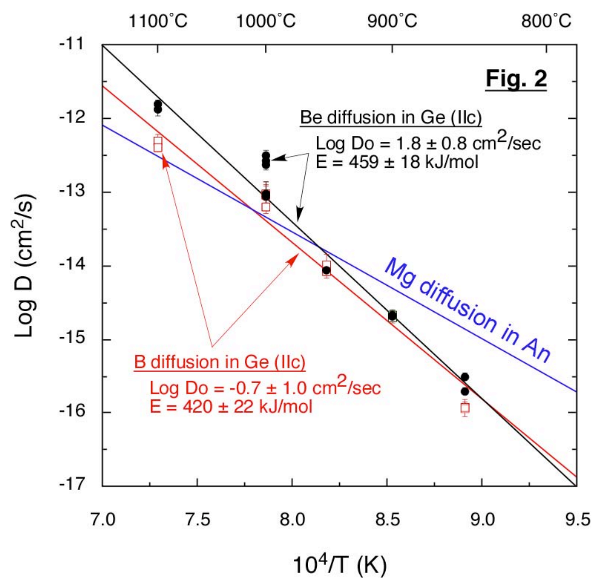


Fig.2. Summary of B and Be diffusion coefficient in gehlenite together with Mg diffusion in anorthite [2]. The error bars represent ±1s.

**Closure Temperatures and Implications:** Fig. 3 (a) shows the calculation of $T_C$ for the Be-B system in melilite and Mg-Al system in anorthite as function of grain size and cooling rate (CR) for T(peak) = 650˚C, according to the modification of Dodson formulation [6] by Ganguly and Tirone [7] (The latter permits calculation of $T_C$ for slowly diffusing species that could not be treated by the Dodson formulation in its standard form). The peak temperature was constrained on the basis of the observation that ~ 50 % anorthite grains in CAIs retained $^{26}$Mg excess and that the CAI-hosting planetesimals were heated by the decay of $^{26}$Al [2]. The diffusion coefficient was corrected for the presence of åkermenite component (~20 mol%) in the melilites in CAIs according to the data on the compositional effect found for the K diffusion in melilites [3]. Anorthite was treated as a plane sheet while melilite, which crystallizes in the hexagonal system, was treated as a cylinder.

From Fig. 3a, we find that $T_C$ for Be-B system in melilite is ~ 50 to 20˚C higher than that of Al-Mg system in anorthite for CR = 10-100˚C/Myr, when both have grain size of 100 µm (half-width for anorthite and radius for melilite). The grain size of melilite and anorthite that were used in the Be-B and Mg-Al chronological studies of CV chondrites were 100-500 and 20-100 µm, respectively [1]. Thus, the difference between the $T_C$ -s of the two decay systems in these bodies was much larger than that indicated above. For T(peak) = 650˚C, $T_C$ for meliltes of the above range of grain size is ~ 635-650˚C. Thus, these calculations explain why the Be-B system in the melilites in CAIs in CV chondrites were undisturbed while the Mg-Al system in anorthites were disturbed [1, 8].

Fig. 3b shows the calculation of $T_C$ for the two systems for T(peak) = 1200˚C. We find that both systems will be substantially disturbed unless the cooling following a high temperature event was very rapid. Also, for CR > $2x10^{5}$˚C/Myr ($2.3x10^{-5}$˚C/hour), Al-Mg system in anorthite has a higher $T_C$ than that of Be-B system in melilite when both minerals have the same grain size. This reversal of the relative $T_C$ values is due to the intersection of logD vs. 1/T curves of the two systems (Fig. 2). However, since melilite grains usually seem to be much larger than anorthite grains in the CAIs, the Be-B system might be somewhat more robust than the Al-Mg system for the purpose of dating high temperature events in the early solar system if it is done with proper consideration for the effect of grain size, as illustrated in Fig. 3b.

**References:** [1] Sugiura *et al.*, (2001) *MAPS* **36**, 1397-1408. [2] LaTourrette and Wasserburg (1998) *EPSL* **158**, 91-108. [3] Ito and Ganguly (2004) *MAPS in press*. [4] Ganguly *et al.*, (1998) *Contrib. Mineral Petrol.* **131**, 171. [5] James and Roos (1975) *Comp. Phys. Comm.* **10**, 343-367. [6] Dodson (1973) *Contrib. Mineral Petrol.* **40**, 259-274. [7] Ganguly and Tirone (1999) *EPSL* **170**, 131-140. [8] McKeegan et al., (2001) *LPSC* **32**, CD-ROM#2175.

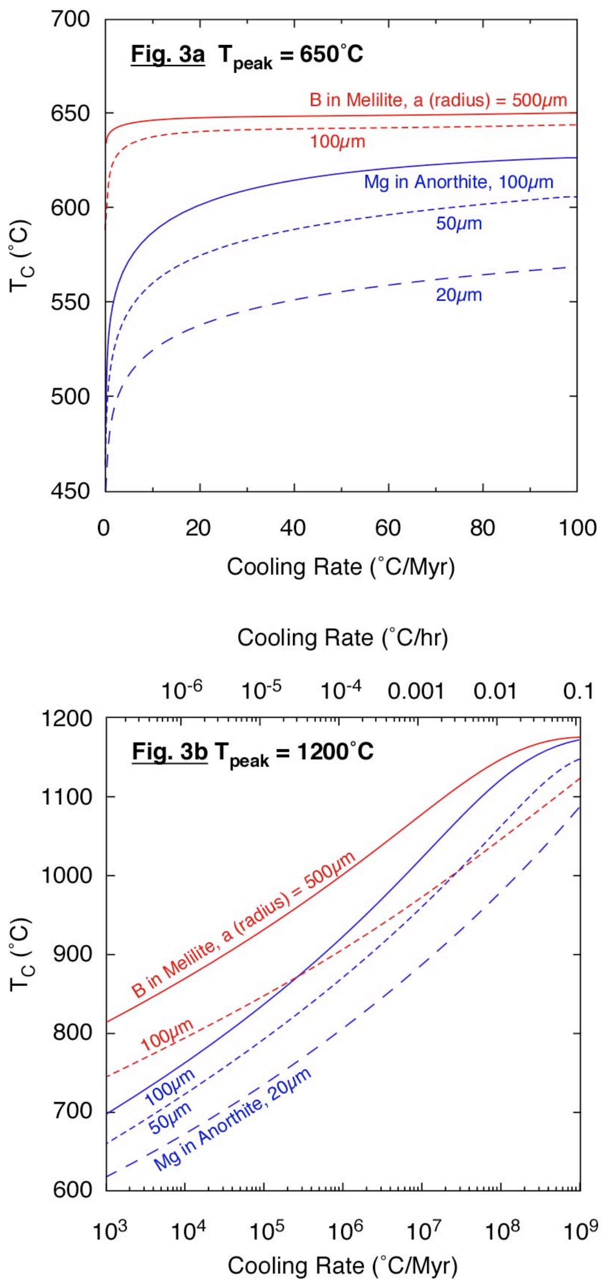


Fig. 3. Closure temperature, $T_C$, of Be-B system in melilite and Mg-Al system in anorthite as function of cooling rate and grain size for T(peak) of (a) 650˚C and (b) 1200˚C.