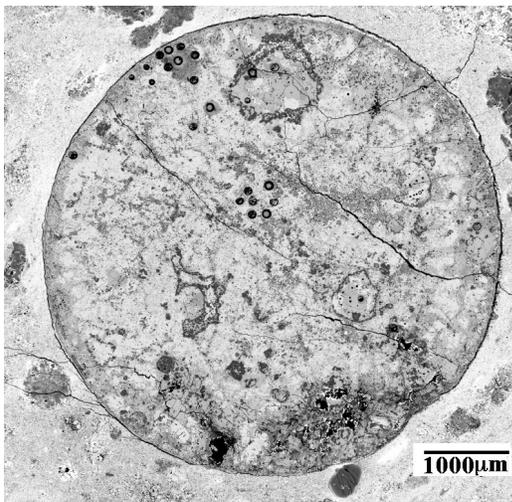


**DIFFUSION WITHIN THE CAI BOCCE BALL 1: THE REDISTRIBUTION OF  $^{26}\text{Mg}^*$  CORRELATED WITH VARIATIONS IN  $\text{Al}/\text{Mg}$  WITHIN A TYPE B2 INCLUSION FROM ALLENDE.** H. C. Connolly Jr.<sup>1,2,3</sup>, G. R. Huss<sup>4</sup>, A. Shahar<sup>5</sup>, K. Nagashima<sup>4</sup>, E. D. Young<sup>6</sup>, D. S. Ebel<sup>2</sup>, M. K. Weisberg<sup>1,2</sup>, J. R. Beckett<sup>7</sup>, J. M. Paque<sup>7</sup>, C. Ma<sup>7</sup>, G. R. Rossman<sup>7</sup>. <sup>1</sup>Dept. Physical Sciences, Kingsborough Community College of CUNY, Brooklyn NY 11235 & Dept. Earth & Environmental Sciences, The Graduate Center of CUNY, 365 5<sup>th</sup> Ave., New York, New York, USA (chondrule@haroldconnolly.com); <sup>2</sup>Dept. Earth & Planetary Sciences, AMNH, New York, NY 10024 USA; <sup>3</sup>LPL, University of Arizona, Tucson, AZ 85721, USA, chondrule@haroldconnolly.com; <sup>4</sup>Hawai'i Institute of Geophysics & Planetology, University of Hawai'i at Mānoa, Honolulu, HI 96822 USA; <sup>5</sup>Geophysical Laboratory, Carnegie Institution of Washington, Washington, DC 20015 USA; <sup>6</sup>Dept. of Earth & Space Science, UCLA, Los Angeles, CA 90095 USA, <sup>7</sup>Division of Geological and Planetary Science, California Institute of Technology, Pasadena, CA 91125 USA.

**Introduction:** In 2006 we reported on the petrology of Bocce Ball 1 (BB 1), a type B2 CAI from Allende (Fig. 1). The original motivations behind our investigation were (1) to constrain the



**Figure 1. BEI of Allende Bocce Ball 1.**

geologic history of an inclusion that is essentially nearly spherical in shape and (2) determine the abundance of initial  $^{26}\text{Al}$  in the inclusion. We reported our results by LA-MC-ICPMS technique at LPSC in 2006. As part of our ongoing investigation to determine the veracity of the isotopic data collected on LA-MC-ICPMS, we re-analyzed the  $^{26}\text{Al}$ - $^{26}\text{Mg}$  systematics of BB 1 using the 1280 ion microprobe at the University of Hawai'i. Our results and interpretations are presented below.

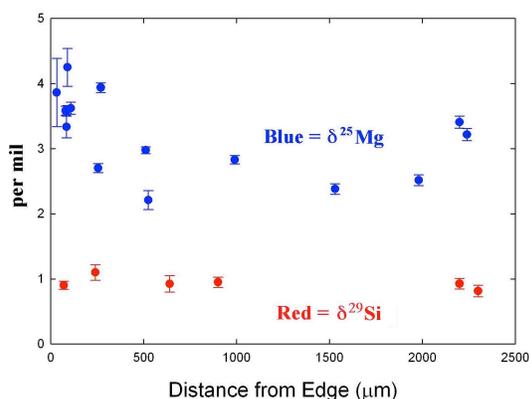
**Analytical Technique:** A large, essentially spherical type B2 CAI (AMNH AL4947-1-CA1, affectionately named Bocce Ball 1) was recovered from Allende. **Petrography:** Analyses and imaging were performed with a Cameca SX50 at the LPL. Major and minor element concentrations for silicates were determined at 15 kV and 40 nA (2nA for Na). For spinels (*sensu stricto*  $\text{MgAl}_2\text{O}_4$ ) concentrations were determined at 15 kV and 40 nA for major

elements and 15 kV and 100 nA for minor elements (Si, Ca, Ti, Cr, Mn, Fe, V) with 120 sec counting (peak and background). All appropriate interference corrections were applied following [1]. **Isotopes:**  $^{26}\text{Al}$ - $^{26}\text{Mg}$  systematics were analyzed by two different *in situ* techniques. LA-MC-ICPMS analyses were performed with a ThermoFinnigan Neptune at UCLA and following the methods of [2]. SIMS analyses were performed with the Cameca IMS 1280 at the University of Hawai'i at Mānoa following the techniques of [3]. For consistency the same data reduction techniques were used for both data sets.

**Results:** We will limit our discussions to the isotopic data since the overall petrographic and petrologic characterization of BB 1 was reported by [1]. **LA-MC-ICPMS:** The  $^{26}\text{Al}$ - $^{26}\text{Mg}$  systematics, which were presented in 2006 [1], with an initial  $^{27}\text{Al}/^{26}\text{Al}$  for this object of  $5.35 \pm 0.09 \times 10^{-5}$  ( $\pm 1.09$   $2\sigma$ ), consistent with what is known as canonical, although we do note that the best-fit line is anchored by a single anorthite grain. Most anorthites in BB 1 are too small to analyze with the LA-MC-ICPMS.

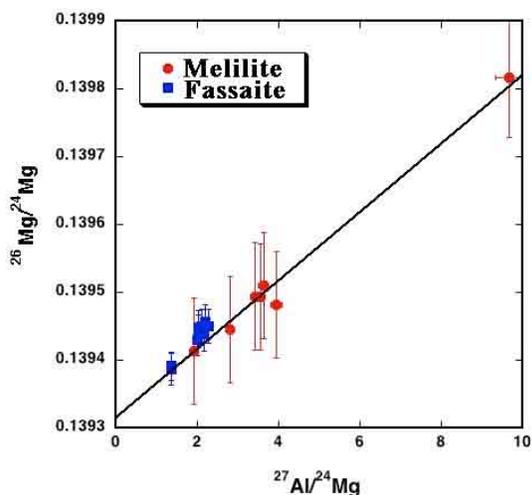
$^{25}\text{Mg}$  and  $^{29}\text{Si}$  collected on the UCLA LA-MC-ICPMS from core to edge of BB 1 show a slight increase in  $^{25}\text{Mg}$  at the edge and an essentially flat  $^{29}\text{Si}$  following a similar traverse across the object (Fig. 2). These data were not reported in detail by [1].

**SIMS Data:** The data collected on melilites and fassaites from the center of BB1 by SIMS technique essentially match, within error, data collected by LA-MC-ICPMS technique at UCLA, although we note that there is less spread in  $^{26}\text{Mg}/^{24}\text{Mg}$  overall (Fig. 3). When possible, SIMS analyses were performed on grains next to the areas analyzed by LA-MC-ICPMS. The best-fit line includes anorthite grains from the center of the inclusion. Data for anorthite grains near the edge of the inclusion, however, show large variations in their  $^{26}\text{Mg}^*$  abundance and their  $\text{Al}/\text{Mg}$  ratio. Petrographically, the grains appear to be similar to those in the center, but we will be investigating but we will be investigating them in greater detail to look



**Figure 2. Stable isotope composition from BB1 from traverses from core to edge indicating evaporative mass fractionation. Y axis = ‰**  
for possible chemical or textural signatures of secondary processes.

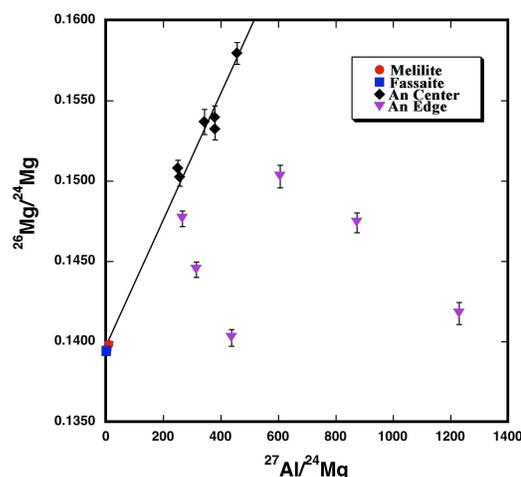
Very little variation in  $\delta^{25}\text{Mg}$  exists within anorthite grains based on spatial location of either center or edge, although the precision from SIMS measurement is not favorable to addressing this issue definitively.



**Figure 3. Data collected with the 1280 SIMS in Hawai'i on from grains near the center of BB 1. The best-fit regression line corresponds to an initial  $^{27}\text{Al}/^{26}\text{Al} = 5.11 \pm 0.09 \times 10^{-5}$ ; data from anorthite grains are not plotted.**

**Discussion:** Within error, data from two techniques on BB 1, previously reported as having an initial  $^{26}\text{Al}$  value of canonical, agree within error. Although all melilite and fassaite grains near the

inclusion edge appear to have undisturbed  $^{26}\text{Mg}^*$  excesses, anorthite grains near the edge of the inclusion are disturbed. These variations are



**Figure 4. Data collected with the 1280 SIMS on all grains. An = anorthite. Line =  $^{27}\text{Al}/^{26}\text{Al} = 5.11 \times 10^{-5}$ .**

correlated with Al/Mg ratios. We propose two hypotheses to explain our results: (1) A solid-state, diffusion-controlled process (both elemental and self-diffusion), post-crystallization, either in a pre- or post-accretion environment. This process post-dated all melting events and produced the observed fractionation of  $\delta^{25}\text{Mg}$ . (2) The near edge anorthites record remelting or, more likely, partial remelting of the outer 10's of  $\mu\text{m}$  after the decay of significant  $^{26}\text{Al}$  followed by recrystallization of melilite, fassaite, and anorthite. In this scenario, the anorthite recorded local variations in Al/Mg abundances of the melt as well. At least one anorthite near the edge may have experienced some fractionation of  $\delta^{25}\text{Mg}$ , potentially supporting hypothesis (2). We hypothesize that the anti-correlation of  $\text{Mg}^*$  with Al/Mg could potentially be recording more than one remelting event occurring after continued decay of  $^{26}\text{Al}$ .

**Conclusions:** We have shown that  $^{26}\text{Al}$ - $^{26}\text{Mg}$  systematics analyzed by two different techniques on a third inclusion agree within error. Our data from anorthite grains suggest either post-crystallization diffusion or partial remelting of the inclusion during continued decay of  $^{26}\text{Al}$ .

**References:** [1] Connolly. et al (2006) *LPSC*. [2] Young et al., (2005) *Science* **308**, 223. [3] Makide et al. (2009) *GCA* 5018. [4] Shahar and Young (2007) *EPSL*, 257 and references therein. This research funded by NASA grants NNX09AB86G to HCCJr, NNX08AG58G to GRH, NNX07AJ01G to EDY.