THE PETROGRAPHY AND GEOCHEMISTRY OF AN ALLENDE TYPE B CAI: V DEPLETION, RELICT REGIONS AND REMELTING? H. C. Connolly Jr.[1,2], D. S. Ebel[2], M. K. Weisberg[1,2], J. R. Beckett[3] and J. M. Paque[3]. [1]Dept. of Physical Science, Kingsborough College and the Graduate School of CUNY, Brooklyn, NY 11235 (hconnolly@kingsborough.edu); [2]Dept. of Earth and Planetary Sciences, American Museum of Natural History, New York, New York 10024; [3]Division of Geological and Planetary Science, California Institute of Technology, Pasadena, CA 91125.

Introduction: We have begun a systematic comparative investigation of, arguably, the first igneous rocks formed in the Solar System [1], type B CAIs. One of our goals is to compare the petrography and geochemistry of these inclusions within and among CV3 meteorites to better constrain (1) their formation conditions and (2) the origin and evolution of CAI compositions. Herein we report preliminary results of a petrographic investigation of a spherical type B CAI from Allende.

Analytical Technique: A large portion of a type B CAI, AMNH AL4947-1-CA1, was recovered from Allende, a section of which is shown in Fig. 1. The object is essentially spherical and we have affectionately named this sample Bocce Ball 1. Analyses and imaging were performed with a Cameca SX100 at the AMNH. Major and minor element concentrations for silicates were determined at 15 kV and 40 nA (2nA for Na). For spinels (*sensu stricto* $MgAl_2O_4$,) 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 [2].

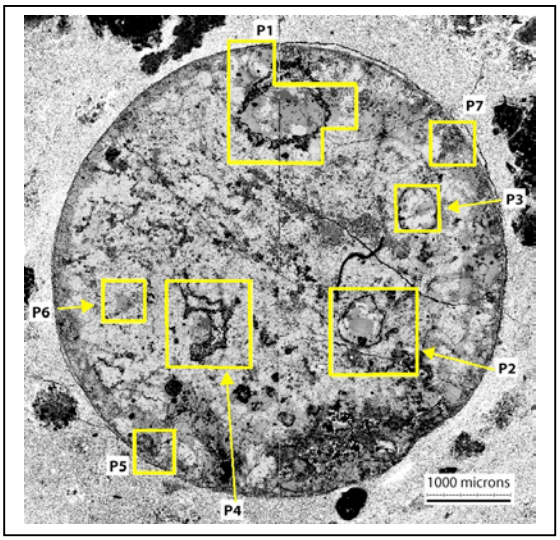

Fig 1. BSE image of a thin section of Allende AMNH Al4947-1-CA1, Bocce Ball 1. Areas outlined in yellow enclose regions mapped at higher resolution, many lined with spinels.

Petrography: The inclusion closely approximates a sphere (circle in TS) with a diameter of 6 mm. Texturally, the object contains regions (Fig. 2) of coarse crystals, many enclosed by spinels, all set in

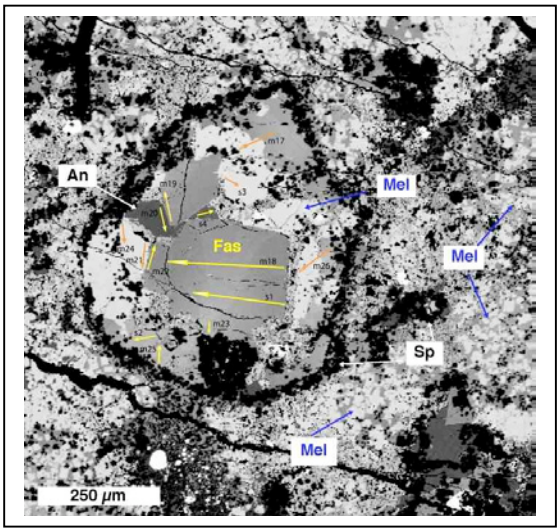

Fig 2. BSE image of region P2. Sp = spinel; Mel = melilites; Fas = Fassaite; An = Anorthite. Scale bar ~ 250 µm.

a fine-grained matrix. The coarse regions are composed of subhedral melilite, euhedral to subhedral fassaite (many with strong chemical zoning), minor subhedral anorthite, spinel (from sub-µm up to ~ 30µm in size) and porous areas of alteration phases that appear to be replacing melilite. Outside of the coarse regions the inclusion is a mixture of fassaite of undetermined size and form with abundant, euhedral to anhedral melilites averaging ~ 20 x 40 µm, found as clusters and chadacrysts within fassaite. Porous areas enriched in alteration phases are observed. To date we have yet to observe perovskite. Additional work is needed to carefully document the observed opaque phase. A thin Wark-Lovering rim of varying thickness up to ~20 µm is present around the object. The object has an internal rim of varying thickness that initially appears to be a Si-enrichment zone based on X-ray mapping. Petrographic characteristics imply that the inclusion is a type B2 CAI.

Composition: *Spinels* 85 useful analyses of spinel were obtained from various petrographic settings. In Fig 3., V vs. Ti is plotted along with data

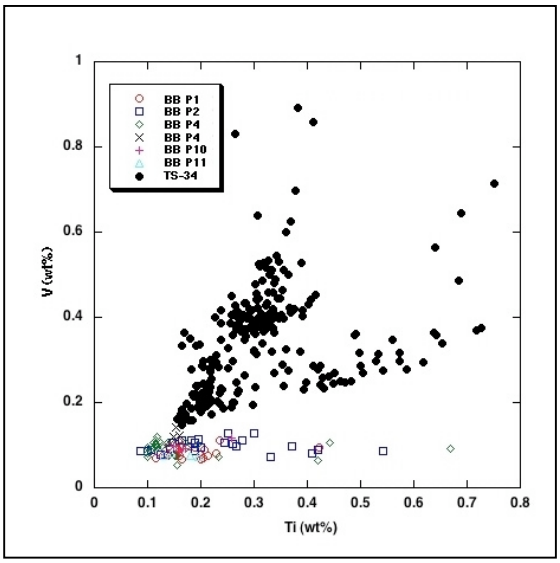

Fig 3. V vs Ti (wt%) diagram for spinels from Bocce Ball 1 (BB with regions labeled as P) and TS-34 [3]. Error bars are ~ the size of the symbols and not shown.

from [3] for the type B1 TS-34. As with spinels analyzed from type B1 [2,3], spinels from Bocce Ball 1 show a range of Ti concentrations from ~0.1 to 0.7 wt% but, V = 0.8-0.14 wt% shows minimal scatter, in sharp contrast to B1s. No systematic differences in spinel composition based either on their associated host phase composition or locations within the CAI were observed. *Fassites* We concentrated on fassite in the coarse regions. Fig 4 is a composite X-ray map of region P2 showing what may be sector

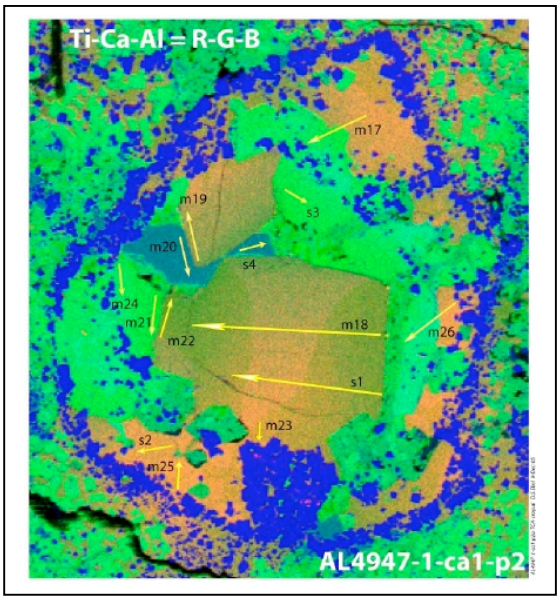

Fig 4. X-ray map of regions P2. Field of view ~ 0.5mm. Note possible sector zoning of large fassaite in the center of the image. R= Red, G= Green, B = Blue

zoning within the fassaites. Line profiles of the fassaite across sectors (Fig. 5) show differences in the concentrations of Ti and Al in the core vs. rim;

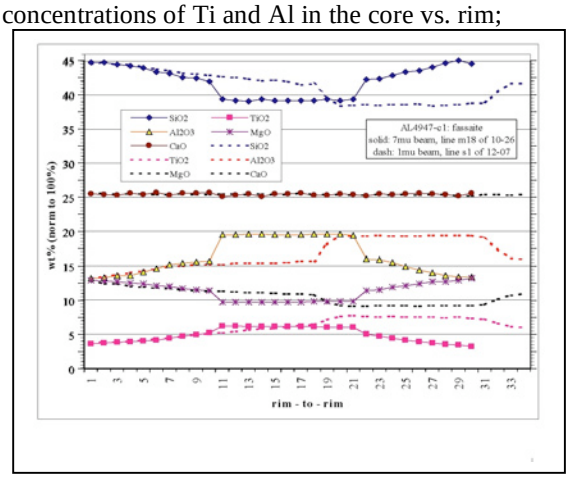

Fig 5. EMP analyses profiles across the large fassaite shown in P2. Note the sharp boundary from core to edge.

essentially flat in the core with a sharp boundary, then decreasing towards the rim. Maximum TiO_2 values up to ~10 wt% are observed in this P2 region, which is similar to peak values observed in other coarse-grained regions. Interestingly, V within **all analyzed** fassaites is below detection limit. *Melilites* Region P2 contains melilites with ~Ak5 to rims ~ Ak63, similar to melilite in other coarse regions. Melilite in or near alteration areas has higher Na contents, up to ~0.25 wt%. Reconnaissance of small melilites outside of coarse regions shows ~Ak40 and up to 1.6 wt% Na.

Petrogenesis: Based on the overall petrography and geochemistry, it is clear that the formation conditions for this object were complex. We propose the following questions for continued investigation: (1) Why was V depleted in the liquid from which spinel and fassaite grew? (2) Is the lack of correlation between V and Ti in spinel reflecting different formation histories of B1 and B2 CAIs? (3) Are the coarse-grained regions relict? (4) What conditions are needed to form the abundant, small euhedral melilites (representing a high nucleation density)? (5) Does the high Ak and Na content of these small melilites reflect their formation by remelting after a period of alteration where Na was introduced or was Na introducted post-formation? (5) Why is the object such a well-defined sphere? (6) Did Bocce Ball 1 experience significant evaporation while liquid?

References: [1] Amelin Y. et al (2002) *Science, 297.* [2] Connolly H. C. Jr and Burnett D. S. (1999) *M&PS., 34* [3] Connolly H. C. Jr. et al (2003) *M&PS 38.* NAG5-12855 (DSE); NAG5-11546 (MKW).