ANALYSES OF AN ATYPICAL TYPE A REFRACTORY INCLUSION FROM ALLENDE: THE EYE OF HORUS.

M. K. Allen[1], H. C. Connolly, Jr.[2,3,4]; S. R. Dunn[1]; J. R. Beckett[5]; D. H. Hill[4]. [1]Dept. of Geology, Mt Holyoke College, South Hadley, MA, 01075, USA (allen22m@mtholyoke.edu); [2]Dept. Physical Sciences, Kingsborough Community College of CUNY Brooklyn, NY 11235, (hconnolly@kbcc.cuny.edu); and Earth and Environmental Sciences, The Graduate Center of CUNY, 365 5th Ave., New York, NY 110024; [3]Dept Earth and Planetary Sciences, AMNH, New York, NY 10024, USA; [4]LPL, University of Arizona, Tucson, AZ 85721; [5]Div. Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125.

Introduction: Calcium-Aluminum-rich Inclusions (CAI's) are found within all chondrites and provide the most compelling data for constraining the age of the solar system at ~4.5 Gy [1.2]. The also are the first rocks to form in the Solar System and their phase or their precursors (in the case of igneous CAIs) are predicted to be the first condensation from a gas of solar or enhanced solar composition. Thus, they provide powerful constrains on the evolution of primitive planetary materials in the Solar System and the environments in which they formed. Of key signficance to constraining the condensation process is the investigation of non-igneous CAIs, whose minerals are hypothesized to be either direct condensates, evaporative residues, or the final products of reactions between condensed solids and nebular gases [3]. To further contrain the condensation of primitive planetary materials and the enviroment in which they formed, we report our preliminary data on an investigation of an atypical type A CAI from Allende that we have named the "Eye of Horus", with emphases on the primary mineralogy and the major and minor element abundances.

Analytical Technique: A thin section of a sample of Allende (CV3) chondrite containing a 9 mm refractory inclusion was made (Fig. 1). The similarity of the inclusion to an eye, with a pupil and iris, inspired the name. We designated 5 regions within the eye for analyses (Fig. 2): Region 1- center of the pupil, Region 2- mid point between center and rim of the pupil, Region 3- pupil rim, Region 4- inner iris, and Region 5- rim of the iris (eye lid). One of our goals is to compare the phases within the pupil to the outer region or rim of the object. Petrographic and SEM image analyses were performed at the AMNH and at Mt. Holyoke. EMPA and x-ray mapes (Fig. 3) were performed on the CAMECA SX-100 at the AMNH and CAMECA SX-50 at the University of Massachusetts-Amherst.

Figure 1: A XPL image of a sample of Allende containing The Eye of Horus (arrow). Section is 15mm across.

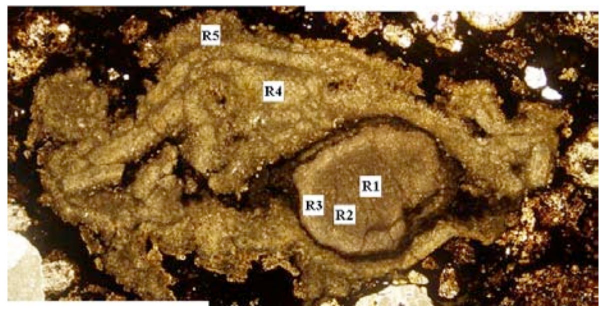

Figure 2. A PPL image of The Eye of Horus showing the regions we investigated. FOV = 10 mm.

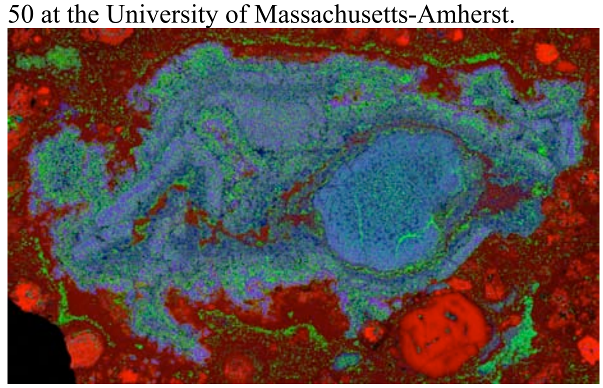

Figure 3. RGB X-ray map of the Eye of Horus, Si = red, Ca = green, Al = blue. FOV = 11 mm.

Results: The Eye of Horus is a type A, compound inclusion with a distinct circular (possibly spherical) central portion (the pupil) surrounded by an irregularly shaped portion (the iris). All parts are extremely fine grained (generally ≤ 20µm) and anhedral. It is composed calcium-rich, aluminium-rich oxides and silcates, with a primary mineral presence of spinel, melilite, anorthite and clinopyroxene, with minor perovskite, all of which appear in different abundance in the regions studied. The pupil consists of spinel rimmed by anorthite which is partially rimmed by clinopyroxene. Melilite is abundant in the central part of the pupil.

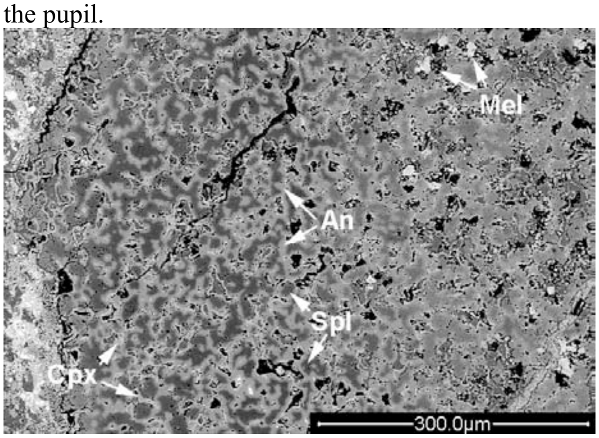

Figure 4. Backscattered electron image of pupil center (upper right) to rim (left) showing spinel rimmed by anorthite with thin rims of clinopyroxene. Spinel becomes darker (less Fe) rimward. Melilite grains are disseminated in the central part of the pupil.

Pupil: The pupil of the eye (Fig. 4) contains a sequence of spinel (~0.34 – 0.9 wt% TiO_2; ~0.02 – 0.08 wt% V_2O_3; ~0.36 – 0.86 wt% Cr_2O_3; 1.73 – 8.72 wt% FeO), anorthite ($An_{99.5}$), and clinopyroxene (0.36 – 2.89 wt% TiO_2). Melilite grains (Ak_2) are disseminated throughout the center comprising ~10% of the modal abundance, and rapidly decrease outward becoming absent in the pupil rim (Region 3). Clinopyroxene at the center of the pupil is exceedingly fine grained (≤5 µm), however it becomes more abundant and coarser toward the pupil rim and in the iris (Regions 4 & 5). Spinel in the pupil is relatively Fe-rich in the center (~8.7 wt% FeO) becoming more Fe-poor toward the pupil rim (~1.7 wt% FeO). Secondary nepheline is found throughout Region1.

Iris: The inner iris and rim contain the assemblage spinel (~0.04 – 0.34 wt% TiO_2; ~0.03 – 0.22 wt% V_2O_3; ~0.07 – 0.30 wt% Cr_2O_3; 1.29 – 3.81 wt% FeO), anorthite ($An_{\geq 99}$) and clinopyroxene (~0.08 – 4.7 wt% TiO_2). The rim (Region 5) also contains small (~5-15 µm) perovskite grains ($Pv_{92\text{-}97}$), which are not found in the pupil or inner iris. Secondary hedenburgite ($Di_1Hd_{94}CaTs_5$) overgrowths occur on clinopyroxene ($Di_{80}Hd_1CaTs_{19}$) in the outer rim.

Discusion: The pupil and iris of this compound inclusion have similar mineral assemblages, mostly spinel-anorthite-clinopyroxene. The pupil interior also contains melilite and the outer iris rim also contains perovskite.

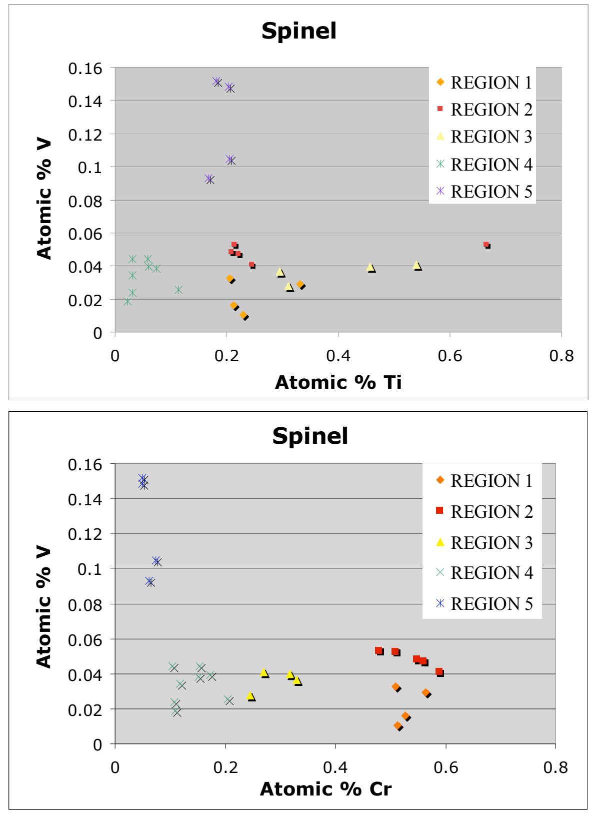

Figure 5. Spinel minor element abundances in different regions of the inclusion.

The spinel in the iris (regions 4 & 5) has similar Mg, Al and Cr compositions as the spinel in the pupil rim (region 3), however spinel in the pupil interior (regions 1 and 2) has less Mg (more Fe) and higher Cr (Fig. 5). Spinel in the pupil rim (region) 3 is enriched in Ti compared to spinel in all other regions. There is also notable vanadium enrichment in spinel toward the iris rim (region 5).

The major unresolved questions, which we need to collect additional data to constrain are: (1) How did this apparently compound object inclusion form?: (2) Why is it compound?: (3) What was the environmental conditions during formation?: and (4) What is the extend of secondary processing experienced?

References: [1] Amelin Y. et al., (2002) *Science* 297. [2] MacPherson et al., (2003) in *Treatise on Geochemistry* pp.201-246. [3] Ebel D. (2006) *MESS II* p. 253 and references therein. This research was supported by NASA OSS Grant # NNX09AB86G, (HCCJr PI) and REU Grant #AST 0851362 CUNY-AMNH. Acknowledgement: We wish to dedicate this abstract to D. Wark, who recovered this CAI from Allende in the 1980s and never investigated it.