CHARACTERIZING EARLY SOLAR SYSTEM FLUIDS ON THE ALLENDE (CV3) PARENT BODY: NANOSIMS STUDY OF PHOSPHATE VOLATILE CONTENTS.

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Introduction: Much of our knowledge about the early Solar System comes from the study of CV3 meteorites, in particular Allende. Hydrothermal alteration is recognized as an important, ubiquitous process within these rocks (e.g. [1]). Nevertheless, we know little regarding the nature of these fluids. Volatile-element abundances in phosphates from carbonaceous chondrites could constrain relative fugacities of H_2O, HF and HCl in the fluid present during metasomatism in primitive planetesimals.

Petrography: We analyzed phosphate grains (diameter~3-5 μm) found in sulfide assemblages associated with chondrules [2]. Coexisting minerals include troilite, pentlandite, and olivine (~Fa_{40}); phosphates are commonly associated with void space. Their textures are consistent with altered metal or sulfide and occur both entirely within a chondrule and adjacent to matrix.

Methods and Results: The NanoSIMS 50-L at Caltech was used to measure the halogen contents of phosphates in Allende. Due to the small size of these grains and their association with void space, images were captured and later processed to quantify volatile abundances in domains free of contaminants or voids. A Cs+ primary beam (FC0 = 5−10 nA) imaged areas ~8 μm x ~8 μm for the following anions: $^{16}OH^-$, $^{18}O^-$, $^{19}F^-$, $^{31}P^-$, and $^{35}Cl^-$.

Two distinct phosphate minerals were identified by volatile contents. The first, merrillite ($Ca_3(PO_4)_2$), contains no discernible volatiles above background values. The second has apatite stoichiometry containing 1.2–1.4 wt % H_2O, 6,000–10,000 ppm F, and 900–-3,000 ppm Cl ($X_{H20} \approx 0.7$, $X_F \approx 0.25$, $X_{Cl} \approx 0.05$, where X is the fractional occupancy of the −1 anion site). These minerals are often found together in the same assemblage.

Discussion: The volatile composition of apatite, combined with experimental data, constrains the metamorphic fluids that last interacted with these minerals. Following [3], we estimate $f(HCl)/f(H_2O) \approx 10^{-5}$ and $f(HF)/f(H_2O) \approx 10^{-6}$–$10^{-9}$ for assumed temperatures of 300−550ºC. Thus, throughout the range of hypothesized metamorphic conditions on the Allende parent body, this fluid is not strongly acidic and has sufficiently low halogen contents to form hydroxylapatite [4].

Alteration of CAIs into phases such as nepheline and sodalite argues for a Na-Cl-rich fluid. Andradite-hedenbergite nodules within matrix also suggest a Ca-Fe-Na-rich fluid where Si, Mg, Mn, and S are soluble [1]. Applying these constraints for $f(H_2O)$, $f(HF)$ and $f(HCl)$, we can begin to better understand the conditions accompanying alteration and its capacity for mass transport. The presence of OH-rich apatite thus provides new insight into hydrothermal systems present in the early Solar System.

References: [1] Krot A. N. et al. 2007. *Geochimica et Cosmochimica Acta* 71:4342-4364. [2] Rubin A. E. and Grossman J. N. 1985. *Meteoritics* 20(3):479-489. [3] Korzhinskiy M. A. 1981. *Geochemistry International* 18(3):44-60. [4] Zhu C. and Sverjensky D. A. 1991. *Geochimica et Cosmochimica Acta* 55:1837-1858.