ELEMENTAL SIGNATURES OF NEBULAR AND ALTERATION PROCESSES IN CV, CO, and CR CAIs.

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Introduction: Calcium-, aluminum-rich inclusions (CAIs) generally display the chemical and mineralogical compositions thermodynamically-predicted for the earliest, high-temperature condensates in a solar nebular gas [1, 2]. Trace element patterns in CAIs and their constituent minerals are the result of not only these initial formation conditions, but also the result of later events including post-accretionary melting and, in some cases, secondary aqueous alteration within the host parent body [3].

We have quantified 46 trace elements (by increasing putative volatility: Hf, Lu, Zr, Y, Er, Th, Ho, Tm, Dy, Tb, Gd, U, Nd, Pr, Sm, La, Ce, Ta, Ca, Nb, V, Yb, Eu, Sr, Ba, W, Ni, Mo, Pt, Co, As, Cu, Sb, Ge, Sn, Ga, Rb, Cs, Se, Te, Pb, Zn, In, Bi, Tl, Cd) by the LA-ICPMS method of [4] and 10 major and minor elements (by increasing z: Na, Mg, Al, Si, K, Ca, Ti, Mn, Cr , Fe) by EMPA in 92 CAIs from $CV3_{ox}$, $CV3_{red}$, CO, and CR chondrites. With our 80µm-120µm LA-ICPMS spot size, we have collected either CAI bulk compositional data or compositions of individual melilite, fassaite, and (secondary) anorthite in them.

With our CAI-element database, we will address two issues: First, are there identifiable chemical signatures of secondary alteration and can these be rationally decoupled from primary nebular signatures predicted for moderately volatile elemental concentrations? Second, are there correlations between REE pattern, a known indicator of early thermal history [2], and other moderately volatile and refractory lithophilic trace elements?

Chemical Signatures of CAI Alteration: Siderophile and chalcophile elemental abundances in our CAIs are commonly 2-100× higher than might be expected for pure primary nebular condensates [5]. Examples include the trace elements As, Cu, Sb, Ge, Sn, In, Bi, Tl, and Cd; which can be mobilized in aqueous solutions under suitable redox conditions. These trace elements, predicted to condense with Fe alloys or into FeS, were likely transported into CAIs during the aqueous processes known to have affected many CAIs. We will discuss results of investigations of relationships between degree of host-chondrite alteration and contents of the above elements.

Refractory Lithophile Contents: REE abundances in our CAIs range from slightly below 5× CI to greater than 100× CI and contain representatives of Group I, II, III, and V REE patterns [6]. In addition to the REE, we have quantified refractory lithophile trace elements that can be difficult to comprehensively analyze with other microprobe techniques. We will discuss observed and calculated relationships among refractory lithophiles based on volatility, thermal history, and mineral chemistry.

References: [1] Grossman L. (1980) *Ann. Rev. Earth Planet. Sci.* 8:559-608. [2] Boynton W. V. (1989) In: *Geochem. Mineral. of REE*, Ribbe P. H. ed. [3] Krot A. N. et al. *Meteoritics* 30:748-775. [4] Jochum K. P. et al. (in press) In: *High Resolution ICPMS*, Douthitt, C. B. ed. [5] Lodders K. (2003) *APJ* 591:1220-1247. [6] Mason B. and Martin P. M. (1977) *Smith. Contrib. Earth Sci.* 19:84-95.