EVALUATION OF PROGRESSIVE ALTERATION MODELS FOR CM CHONDRITES: INSIGHTS FROM QUANTITATIVE MODAL ANALYSIS BY QEMSCAN®.

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Introduction: CM chondrites exhibit a range of degrees of aqueous alteration, widely interpreted as evidence for progressive hydration on asteroidal parent bodies (e.g. 1,2). This alteration involves the progressive replacement of primary anhydrous phases by secondary alteration products. Several schemes have been proposed as quantitative indicators of the degree of aqueous alteration. [e.g. 1,3]. In practice, most of these classification schemes are difficult to apply because they rely on indicators which are difficult to quantify or are time consuming to measure (e.g. point counting). Other techniques such as XRD [e.g. 4] do provide absolute abundances of mineral phases, but are destructive and do not provide textural context. Here we present quantitative modal abundance data for 10 CM chondrites (9 CM2 and 1 CM1) measured using QEMSCAN® (Quantitative Evaluation of Minerals Using Scanning Electron Microscopy).

Techniques. Automated X-ray mapping of polished thin sections was carried out at a 5 x 5 µm beam stepping interval. X-ray spectra for each pixel were obtained by ultrafast simultaneous X-ray acquisition from 4 Bruker SDD EDS X-ray detectors. Acquisition times range from 2.5-11.5 hours with 1.4-6.5 million pixels per sample. Phase ID is carried out utilizing the unique EDS X-ray spectral mineral libraries, calibrated for individual, boundary and intergrowth phases. For CM chondrites, the modal abundance data will differ from quantitative XRD modal analysis, because we have treated the matrix (with a grain size <5 µm) as though it is one phase with a unique chemical signature.

Results. Our dataset shows a linear negative 1:1 correlation between the abundance of anhydrous silicates (olivine+pyroxene) (25 to 5%) and serpentine (20-40%) consistent with the results of [4] for three CM2 chondrites. The CM1 chondrite, ALH84049, is clearly distinct from the CM2 trend affirming the fact that CM1 chondrites are not simply more heavily altered CM2s. The data also show convincingly that tochilinite/cronstedite (T/C) intergrowths (formerly PCP) decrease in an almost perfect linear correlation with decreasing anhydrous silicate abundance, whereas T/C abundances decrease as serpentine abundance increases.

Discussion: Our study demonstrates that QEMSCAN® is a powerful technique that provides fundamental data for evaluating aqueous alteration processes in CM chondrites. The remarkable negative correlation between serpentine and anhydrous silicate abundances confirms [1] that primary silicate phases in chondrules are replaced by serpentine in a systematic manner during aqueous alteration. Further, they show that T/C intergrowths are clearly consumed as chondrule silicate alteration advances. This is consistent with the hypothesis [1] that cronstedtite decreases in abundance as alteration advances. Our data suggest that tochilinite is also unstable, probably because of the increased availability of Si released from hydration of olivine and pyroxene.

References: [1] Browning, L.B. et al. (1996) *GCA* **60**, 2621. [2] Brearley, A.J. (2006) MESS II. pp. 587; [3] Rubin, A.E. et al. (2007) *GCA* **71**, 2361. [4] Howard, K.T. et al. (2008) *MAPS* **43**, 5160.