

## OXYGEN TO CATION RATIOS AS A DESCRIPTOR OF SERPENTINIZATION IN CM CHONDRITE MATRIX

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**Introduction:** The matrices of CM chondrites are expected to be dominated by serpentine ((Mg,Fe)<sub>3</sub>Si<sub>2</sub>O<sub>5</sub>(OH)<sub>4</sub>) that was converted from anhydrous silicates. EMPA data can be plotted on an Si/Mg/Fe ternary plot, a heuristic to identify the mineralogy [1]. In this ternary plot, most matrix material will plot between an Fe-rich serpentine, Mg-rich serpentine, and a mixture of cronstedtite and tochilinite which we call tochilinite/cronstedtite intergrowths (TCI), formally type-II PCP [1,2,3].

The Si/Mg/Fe ternary diagram appears to be less useful to identify the matrix mineralogy. The matrix is usually a non-homogenous mixture of small mineral grains, and the ternary diagram only provides an indication of the mixing of the components rather than a complete identification. It is typically assumed that the matrix becomes homogenized during alteration.

An additional issue in the description of CM chondrite alteration is that the extent of aqueous alteration has been difficult to categorize [1,4,5,6]. Previous work noted a high degree of variability in extent of alteration within a single meteorite [6]. To constrain the distribution of aqueous alteration we studied the O-to-cation ratio of the matrix to provide a spatially resolved indication of aqueous alteration.

**Method/Results:** We analyzed thin sections of Murray, Murchison, Nogoya and Cold Bokkeveld. EMPA of O was done using peak-to-trough evaluation and was calibrated using spinel. We surveyed olivine, pyroxene, chondrule dust rims, and the matrix. Using the EMPA data we calculated the O-to-cation ratios in at%. We made a correction for any S in the analysis by removing an idealized pyrrhotite, Fe<sub>91</sub>S. Analyses of olivine and pyroxene yield the expected O-to-cation ratios of 1.67 and 1.33, respectively. Regions of altered chondrule mesostasis are chemically consistent with cronstedtite, and their ratio (1.8) matches serpentine. We evaluated the O error for olivine and pyroxenes and found the standard deviation to be <1 wt%, and that the error between measured O and stoichiometrically calculated O is ~2 at%.

**Discussion:** The O-to-cation ratios for the dust rims and the matrix vary from 1.2 to 1.8. We expected to see a strong correlation between the indicators of aqueous alteration as suggested by [5] and the O-to-cation ratio approaching 1.8. However, we did not. Even regions that have extensive alteration frequently have ratios between 1.3-1.5. Values below 1.3 must indicate the presence of O-free phases such as metal. We suggest that in many portions of the matrix, much of the anhydrous silicates and metals have not been hydrated. While fayalite quickly alters into cronstedtite [2], forsterite and enstatite are known to resist alteration much longer [1,2]. Further work is needed, specifically TEM and Raman spectroscopy, to determine the mixture of phases in the matrix. Regardless, the matrix cannot be approximated as simply hydrous serpentine with inclusions of troilite (or tochilinite).

**References:** [1] McSween H. 1987. *Geochem et Cosmochem Acta* 43:1761-1765. [2] Tomeoka, K. and Buseck, P. R. 1985. *Geochem et Cosmochem Acta* 49:2149-2163. [3] Zolensky, M. et al. 1993. *Geochem et Cosmochem Acta* 57:3123-3148. [4] Browning, L. B., et al. 1996. *Geochem et Cosmochem Acta* 60:2621-2633. [5] Rubin, A.E. et al. 2007. *Geochem et Cosmochem Acta* 71:2361-2382. [6] Palmer, E. E. 2009. PhD. Dissertation. University of Arizona.