THE EXTENT OF AQUEOUS ALTERATION WITHIN THE JBILET WINSELWAN CM2 CHONDRITE

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Introduction: The detailed study of alteration of chondrules within meteorites is often overlooked, yet these analyses can significantly improve our understanding the nature of aqueous alteration in the early solar system. Aqueous alteration is generally considered to have occurred uniformly across the CM parent asteroid [e.g. 1, 2, 6]. However, we have identified large differences in the degrees of alteration of individual chondrule clasts from the newly classified Jbilet Winselwan CM2 chondrite. These findings support the hypothesis that aqueous alteration may have been more complex than previously thought, and suggest that alteration may have taken place in un-compacted precursor bodies [7].

Typically, chondrites that show the most extensive aqueous alteration contain chondrule pseudomorphs, absence in olivine and pyroxene, and contain little metallic FeNi and sulfides. In addition, altered matrix surrounding chondrules typically consists of mixtures and intergrowths of phyllosilicates (cronstedtite-chryotile-greenalite solid solutions) and tochilinite material containing up to 9 wt.% H_2O, commonly termed PCPs (Poorly Characterized Phases). Consequently, PCP chemical ratios, such as FeO/S and FeO/SiO_2, are often used to assess the extent of chondrite aqueous alteration [e.g. 1-3]. We have employed EMP and LA-ICP-MS techniques to thoroughly assess the role and extent of aqueous alteration on the CM2 Jbilet Winselwan chondrite. It is thereby demonstrated that aqueous alteration is highly variable between individual chondrules, from within a single CM chondrite.

Results: The Jbilet Winselwan chondrite from the Western Sahara is a new CM2 chondrite, classified as of August, 2013 [5]. The sample displays both Type I and II chondrules within a fine-grained matrix of PCP. Olivines and pyroxenes within the chondrules have a limited range in Mg# of 99 to 97. Within the matrix, however, olivine compositions extend to much lower Fo contents, from 90 to 44. Rare kamacite, with up to 6.4% Ni, in addition to calcite, are also present at modally <1%. Due to the fine-grained nature of the PCPs, bulk-PCP analyses were determined by LA-ICP-MS. Resulting values plot within the serpentine field in Si-Mg-Fe ternary plots (Fig. 1). This is consistent with XRD analyses [5], which display a strong 0.7 nm peak for serpentine. However, a weak, broad peak was also observed [5], consistent with minor amounts of tochilinite. Bulk major and trace-elements contents were determined for the PCPs by LA-ICP-MS using 32-64 µm spot sizes. The PCPs have broadly flat REE profiles with moderate to small Eu anomalies (Fig. 2;

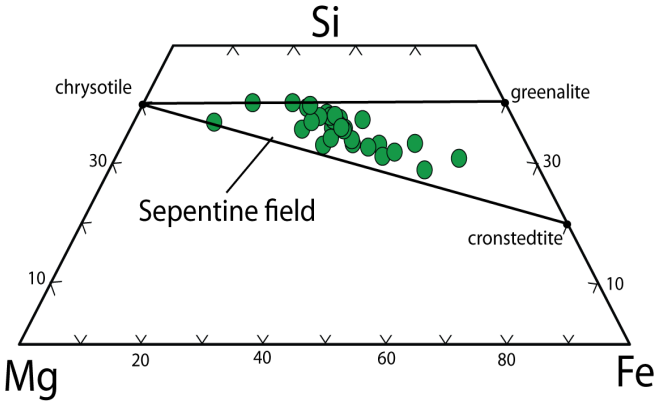

Figure 1. Si-Mg-Fe ternary plot for all PCP analyses deterimed by LA-ICP-MS

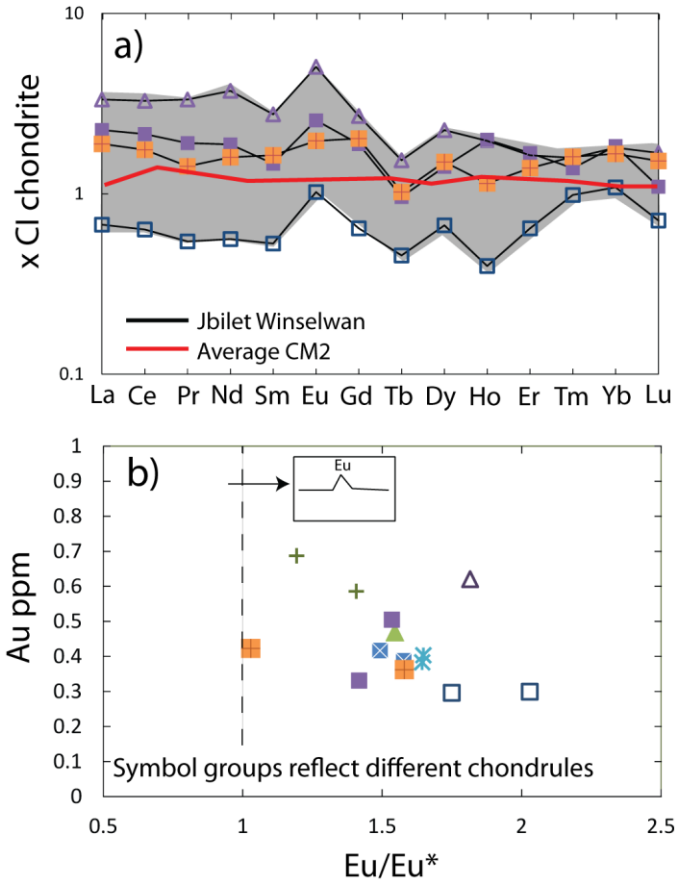

Figure 2. a) REE profiles of PCP and average bulk-rock CM2 chondrite (from [9]); b) Au ppm vs. Eu anomalies for PCP. Symbol groups reflect different chondrules. Gray field represents total REE variation.

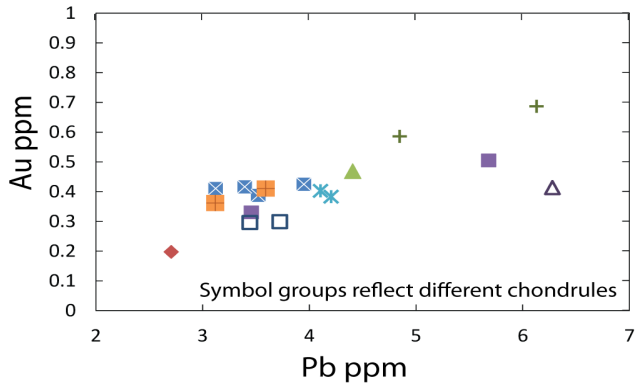

Figure 3. Plot of Au vs. Pb. Symbol groups reflect different chondrules.

Eu/Eu* = 1.02-2.01), potentially reflecting fine-grained plagioclase within the PCP phases. Enrichment in mobile element6, such as Rb, Au, and Pb, are also observed (up to 8 x CI) and show good correlations with each other (Fig. 3). Oxygen isotope analysis for this meteorite have a reported mean $\Delta^{17}O$ of -4.05 ‰ and a mean $\delta^{18}O$ of 4.83 ‰, plotting along the chondrite fractionation line [5].

Discussion: Recently, Rubin et al. [3] proposed a scheme to classify the extent of aqueous alteration based on a combination of PCP chemistry, modal metal, and sulfide abundances. Differing degrees of alteration, based on these parameters, were subsequently divided into a number of petrological sub-types ranging from 2.8 (limited alteration) to 2.0 (pervasive alteration). Our analyses from individual chondrites from Jbilet Winselwan show a range of alteration from 2.0-2.3, corresponding to moderate to pervasive alteration (Fig. 4). Europium anomalies correlate well with alteration sub-types, illustrating that the breakdown of plagioclase also occurs during aqueous alteration. In addition, there are good correlations with alteration sub-type and mobile element concentrations. However, the identification of variable degrees of alteration in the

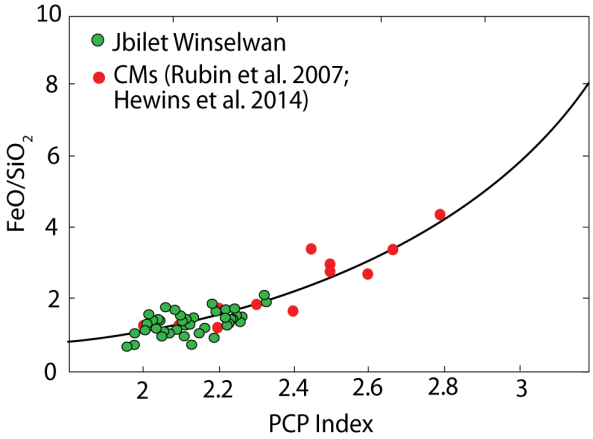

Figure 4. The PCP index for CM chondrites [3,8] and Jbilet Winselwan based on the PCP FeO/SiO_2 value.

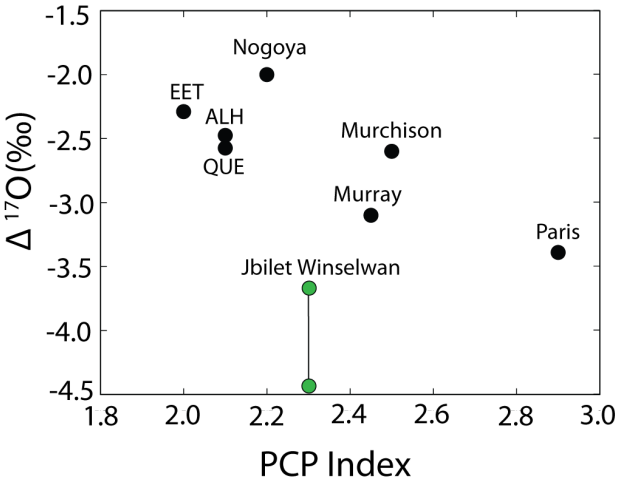

Figure 5. Plot of $\Delta^{17}O$ vs. PCP index for CM chondrites. Data are from [3,5,8]

individual chondrule clasts analyzed, supports our supposition that aqueous alteration may have occurred prior to the incorporation of the chondrules into the parent body. Alternatively, alteration may have taken place in the un-compacted precursor bodies, where chondrules were able to mix [7]. Additionally, it is interesting to note that $\Delta^{17}O$ values reported for this sample display much lower values then expected for reported correlations of alteration sub-type vs. $\Delta^{17}O$ (Fig. 5), indicating that *oxygen-isotope variations may not entirely reflect alteration processes.*

Summary: The highly variable degrees of aqueous alteration observed between individual chondrule clasts has important implications for the nature of aqueous alteration in the early solar system. With the aid of *in-situ* analytical techniques, allowing the detailed study of individual chondrule clasts, *it is clear that aqueous alteration within CM chondrites is more complex than the uniform process that has been previously described* [e.g. 4, 7].

References: [1] McSween H. Y. (1979) GCA, 43, 1059–1078. [2] Browning L. F. et al. (2000) Meteoritics & Planet. Sci., 35, 1015-1023. [3] Rubin A. E. et al. (2007) GCA, 71, 2361-2382. [4] Lindgren P. et al. (2013) Meteoritics & Planet. Sci., 48, 1074-1090. [5] Aoudjehane et al. (2014) Meteoritical Bull 102, 48, (http://www.lpi.usra.edu/meteor/metbull.php?code=57788). [6] Trigo-Rodriguez J. M. et al. (2006) GCA, 70, 1271-1290. [7] Metzler K. (2004) Meteoritics & Planet. Sci., 39, 1307-1319. [8] Hewins et al. (2014) GCA, 124, 190-222. [9] Lodders K. and Fegley B. (1998) The Planetary Scientist's Companion, Oxford Press, 371 pp.