WATER CONCENTRATION AND OXYGEN ISOTOPES IN NOMINALLY ANHYDROUS MINERALS FROM CM2 MURCHISON CHONDRITE.

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Introduction: Low-level water measurements in nominally anhydrous minerals (NAMs) like olivine and pyroxene are fundamental in understanding the ambient P-T conditions during their formation and volatile inventories in the early solar system. Many recent studies have attempted in situ measurements of water concentration in NAMs using SIMS (e.g. [1-5]). However, the reported range of ~8 to ~10000 ppm is highly variable and still debated. Here, we report water concentration and oxygen isotope composition ($\delta^{18}O$ normalised to SMOW) in olivines and pyroxenes from the CM2 Murchison chondrite using a new grain mounting method.

Methodology: Multiple small (~0.5 cm) chips of Murchison were crushed, and olivine and pyroxene grains were isolated before mounting in Bi-Sn alloy, a mounting method developed for analysing trace amounts of water. Following anhydrous polishing and cleaning, they were analysed using the Sensitive High Resolution Ion Micro Probe Stable Isotope (SHRIMP SI) at RSES, Australian National University. A Cs^+ primary ion source and an electron gun were used to sputter ~25 µm spots in the NAMs and simultaneously acquire $^{16}O^-$, $^{16}O^1H^-$ and $^{18}O^-$ secondary ions.

Raw $^{16}O^1H^-/^{16}O^-$ ratios were converted to water concentration in ppm using three standards: Suprasil Glass (SiO_2; ≤ 1 ppm water), San Carlos Olivine (SCO; 15±2 ppm), Russian Cr-diopside (100±10 ppm) [6]. All the standards were mounted and polished along with the Murchison NAMs on the same section to ensure similar treatment for the standards and the unknowns. A polynomial regression fit was used to calibrate the unknown water concentrations (linear fit R^2=0.99). SCO was used as the reference for $\delta^{18}O$ measurements.

Results: 30 olivine and 3 pyroxene anhedral to subhedral grains ranging from ~50 to ~350 µm on their longest axis were analysed. Out of 30 olivines, 16 appear to be from Type I chondrules as evident from their Mg# ≥99 and 14 olivines are from Type II chondrules (Mg# ~55-85). The pyroxenes are diopsides ($CaMgSi_2O_6$).

Water concentration (ppm) and $\delta^{18}O$ (‰) ratios in the NAMs are shown in Figure 1. One to five spots (median = 3) were analysed per grain depending on the grain size. Type I olivines show 1.3 to 8.5 ppm water (median = 3.6 ppm). Type II olivines show 9.7 to 20.6 ppm water (median = 14.3 ppm). Pyroxenes show water content between 90 and 120 ppm. 10% uncertainty is considered for all water measurements as in [6], however, the maximum analytical uncertainty (2σ) in our measurements is ~8%.

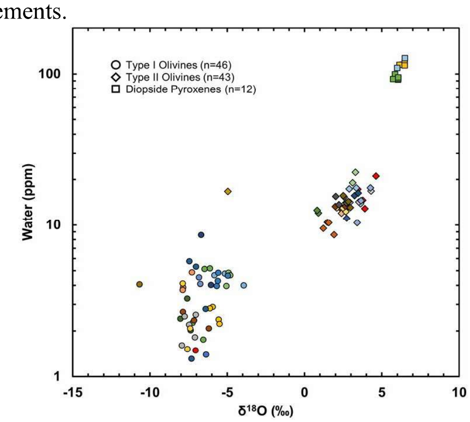

Figure 1: Water concentration and $\delta^{18}O$ in all analysed spots in olivine and pyroxene grains from CM2 Murchison. Different colours represent individual analyses from different grains. Individual $\delta^{18}O$ errors typically range from 0.1‰ to 0.4‰ (2σ).

$\delta^{18}O$ compositions for olivines are consistent with the values reported previously from Murchison [7] and range from -10.8±0.3‰ to -4.0±0.2‰ for Type I olivines and 0.8±0.4‰ to 4.6±0.2‰ for Type II olivines. Isotope compositions for olivines were corrected for matrix bias using procedures followed by [8]. $\delta^{18}O$ in pyroxenes show a heavier composition of 5.7±0.2‰ to 6.5±0.2‰ (all errors are 2σ). However, they have not been corrected for any additional matrix effects yet.

Discussion and Conclusions: Water concentration in olivines and pyroxenes are consistent in the grains analysed and are significantly lower than previously reported values from meteorites. The primary reason seems to be the sample preparation and mounting techniques employed in different studies as shown in [9]. The observed $\delta^{18}O$ and Mg# bimodality in olivines is reflected in their water content as well with forsterites (Mg# >99) showing markedly lower water content than fayalites (Mg# <90). However, there is no apparent correlation between the Mg#, $\delta^{18}O$ and water content within Type II olivines despite the considerable range in Mg#. Thus, it appears that the two chondrule types sampled different isotopic reservoirs with the Type II olivines forming in an oxidizing, more water-bearing environment resulting in their heavier isotopic ratios and higher water concentrations as supported by [10].

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