Laboratory simulation of the microscale stable isotope variability in the ALH 84001 carbonates: Insights into their formation mechanism(s)

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The ALH 84001 (ALH) carbonates display unique chemical and isotopic zonations. They have Ca-Fe-rich cores with $\delta^{18}O_{SMOW}$ and $\delta^{13}C_{VPDB}$ values as low as -10 ‰ and 27 ‰, respectively. In contrast, their rims are Mg-rich, having $\delta^{18}O_{SMOW}$ and $\delta^{13}C_{VPDB}$ as high as 27 ‰ and 64‰, respectively [1,2]. The formative causes of these chemical and isotopic heterogeneities are still controversial (e.g., high temperature, temperature change and low temperature biological/inorganic processes), yet critical for our understanding of the aqueous processes and climate evolution on Mars.

The chemical zonation in ALH has been experimentally mimicked under hydrothermal conditions (150 – 470 °C) [3]. However, our replication of these conditions resulted in an opposite isotopic zontaion to ALH (i.e., higher $\delta^{18}O$ and $\delta^{13}C$ values in Ca-rich carbonates than those values in the Mg-rich carbonates).

Recently, clumped isotope measurements (Δ_{47}) in the ALH carbonates constrained their formation temperature to 18 ± 4 °C [4]. This study suggested that evaporation in a shallow subsurface aquifer (10's of m depth) of a poor communication with Mars atmosphere can explain the striking zonation in ALH. However, such environment would likely be humid enough to cause back oxygen isotope exchange between liquid and vapour, limiting the ^{18}O enrichment in the ALH carbonates. Alternatively, we propose that ALH carbonates formed from a subsurface fluid at/near surface under low relative humidity (≤ 20 %) in gradual isotope exchange with Mars atmosphere. Experiments to test both evaporative scenarios are ongoing and the results will be discussed in the meeting.

[1] Shaheen et al., 2015, PNAS, 112(2), 336–341. [2] Niles et al., 2005, GCA, 69, 2931–2944. [3] Golden et al., 2001, Am. Mineral., 86, 370–375. [4] Halevy et al., 2011, PNAS, 108(41), 16895–16899.