SIDERITE IN THE NAKHLITE METEORITES: EARLY FORMED PRECIPITATES FROM A HYDROTHERMAL BRINE.

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Introduction: The nakhlite martian meteorites contain fracture-filling deposits, including siderite, ferric saponite and serpentine, amorphous silicate gel and evaporite salts [1-4]. In a recent model this assemblage was considered the result of CO_2-rich fluids originating from shallow, ice-bearing rocks, partially dissolving the nakhlites [2], and depositing carbonates at temperatures of up to 150-200°. The heat source may have been an impact and this can also have initiated the brittle fractures which are sometimes filled with the secondary phases. Carbonate was followed, and partially replaced, by crystalline ferric saponite and then rapidly cooled silicate gel of similar composition as the temperature dropped and the fluid became progressively more oxidising [3]. In contrast [5] suggested that the Fe-Mg secondary silicate in Lafayette formed first, and then veins widened by dissolution-precipitation of the walls replacing them with siderite through carbonation of the olivine. In order to test and develop our model, we have made a study of Fe-rich carbonates in the nakhlites, combining new data on Nakhla and Lafayette polished sections using SEM, EPMA, with that from previous work [1-4].

Results: We have found martian (sideritic) carbonates in polished sections and grain mounts of Lafayette [BM1959,755], Nakhla [BM1911,369], and Governador Valadares [BM1975,M16] but not in Y 000593/749, MIL 03346, NWA 817, NWA 998 and NWA 5790. Carbonate is present on the walls of olivine fractures partially dissolved and replaced by phyllosilicate. However, carbonate is also present within the mesostasis of Nakhla and GV. The measured chemical compositions vary between the different nakhlites, with Lafayette having notably Ca-rich compositions compared to the other two. Siderite located within nakhlite olivine fractures has a CaO content of <19.3 wt%, but the olivines in the nakhlites have negligible CaO contents. Similarly, olivines in Lafayette have a MgO content of ≲14 wt%, whereas our analysis of carbonates in those olivine fractures show <1 wt% $MgCO_3$ equivalent. In summary, carbonate associated with Lafayette olivine is Cc18-31Sd37-73Rh7-35%; GV olivine Mg15-16Cc3Sd80.0Rh2.0%; GV mesostasis Mg13-16Cc5.0-6.0Sd78-79Rh1-2%; Nakhla olivine Mg6-23Cc1.5-2.5Sd73-82Rh2.1-11.0%. Carbonate in Nakhla mesostasis Mg6-32Cc0-4Sd62-82Rh0-14% has a near identical compositional range to siderite associated with Nakhla olivine.

Discussion and Conclusions: The compositional ranges of nakhlite siderite strongly suggest that their chemical compositions are not solely dependent on adjacent minerals and cannot be an isochemical replacement of olivine. Rather, we suggest the siderite-bearing secondary assemblage formed from fluids resulting from dissolution of a nakhlite mixture e.g. approximately 70% ol, 20% bulk, 10% mesostasis [3]. As the fluid migrated through the nakhlite pile the composition of the precipitated carbonate changed, becoming less Ca-rich. However, after Nakhla, the fluid exhausted its HCO_3^- content [1,2].

References: [1] Hicks L.J. et al. 2014, *GCA*, 136, 194-210. [2] Changela H.G. and Bridges J.C. 2011, *MAPS*, 45, 1847-1867. [3] Bridges J.C. and Grady M.M. 2000, *EPSL*, 176, 267-279. [4] Bridges J.C. and Schwenzer, S.P. 2012, *EPSL*, 359-360, 117-123. [5] Lee M.R. et al. 2015, *GCA*, 154, 49-65.