THE SECONDARY MINERAL FORMING FLUID IN THE NAKHLITES.

S. P. Schwenzer[1] and J. C. Bridges[2] [1]Dept. of Earth Sciences, CEPSAR, The Open University, Milton Keynes MK7 6AA, UK; s.p.schwenzer@open.ac.uk. [2]Space Research Centre, Dept. of Physics & Astronomy, University of Leicester LE1 7RH, UK; j.bridges@le.ac.uk.

Introduction: The nakhlite secondary minerals are mainly a siderite/smectite and serpentine/silicate gel/salt assemblage which varies in composition between the nakhlites [1, 2]. This increasingly accurate understanding of the secondary mineralogy now allows us to model the associated fluid. Fluid modelling also helps test our hypothesis that the alteration occurred in the aftermath of an impact into ice-bearing martian crust [2]. We utilize experience on thermochemical modelling of Martian impact hydrothermal systems [3], with the presence of CO_2 [4] to derive likely formation conditions of the nakhlite alteration assemblage.

Methods: We use CHILLER [5] to model the fluid. Lafayette bulk chemistry [6], olivine [6], mesostasis compositions, and combinations of them are used as dissolving host rock chemistry. The initial fluid is a diluted brine with Fe, Ca and Mg in the 10^{-2} mole/L range, charge balanced by Cl^-. We modelled H_2CO_3 concentrations between $0.1x10^{-4}$ mole/L H_2CO_3 and 5 mole/L. Each analysis has data for water to rock ratios (W/R) between 1 and 100,000. W/R is defined as the amount of rock that completely dissolved in the given amount of initial fluid. Model temperatures (at 10 bar) are 10 and 100 °C.

Results and Conclusions: At both temperatures the nature of the mineral assemblages can be grouped e.g. high W/R, where Fe and Al mainly form minerals such as hematite (at 100 °C) or goethite (at 10 °C), but silicates – such as are seen in the nakhlites – are not formed. At intermediate W/R phyllosilicates like some of those observed [2] are predicted: nontronite, chlorite, talc, serpentine, depending on T and composition of the host rock, occur together with hematite/goethite. At low W/R smectite (nontronite) is not formed from most host rock chemistries, but the assemblages include serpentine, chlorite and other minerals. In the presence of CO_2, carbonates precipitate replacing any oxide and forming Mg-(Ca)-siderite at low W/R. At 10 °C and W/R of 1.5-8 the model carbonate contains ~45% sd, 32% cc, 23% mg, which matches some of the compositions in Nakhla [1]. From our observation of Lafayette with carbonate being precipitated first followed by smectite and serpentine [2], we assume that CO_2 was exhausted by carbonate precipitation and was followed by phyllosilicate. During initial carbonate formation the pH is buffered by the presence of dissolved H_2CO_3. Smectite (nontronite 43%) with serpentine (antigorite 36%) and traces of chlorite plus goethite, apatite, pyrite precipitated in our model from Lafayette bulk rock, W/R ~380 and pH 8. Our results are consistent with the nakhlite mineral assemblages and W/R ratios decreasing from Lafayette to Nakhla and low fluid temperatures

References: [1] Bridges J.C. et al. *Space Science Reviews*, 2001. 96: 365-392 [2] Changela H.G. & Bridges J.C. 2010. MAPS, 45: 1847–1867. [3] Schwenzer S. P. & Kring D.A. 2009. *Geology*, 37: 1091–1094. [4] Schwenzer, S. P. & Kring D.A. 2009. MAPS, 44, A188. [5] Reed M.H. & Spycher N.F. 2006. Users Guide for CHILLER: A Program for Computing Water-Rock Reactions, Boiling, Mixing and Other Reaction Processes in Aqueous-Mineral-Gas systems and Minplot Guide..U. of Oregon. [6] Treiman A.H. 2005. *Chem. Erde.*, 65: 203–270.