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Liquid-Water Fluid Inclusions in Chondritic Meteorites: Implications for Near-Surface P-T Conditions on Parent Asteroids

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The recent discovery of liquid-water fluid inclusions in the Monahans (Zolensky et al., 1999) and Zag (Zolensky et al., 2000) H chondrite regolith breccias, and in the Ivuna and Orgueil CI1 chondrites (Bodnar and Zolensky, 2000), provides important constraints on the P-T conditions in the near-surface environment of the parent bodies. Based on the size of the vapor bubbles in the inclusions when observed under the microscope at room temperature, the minimum formation temperature of the inclusions is estimated to be less than 100 degrees Celsius. For pure water inclusions, this constrains the pressure to be less than 0.101MPa. However, if the mineralizing solution was a brine with a salinity of 250,000ppm, pressures of only 0.0796MPa are required to stabilize liquid water at 100 degrees Celsius.

Halite mineralization in the Monahans and Zag meteorites occurred in the presence of NaCl-saturated solutions at temperatures below about 100 degrees Celsius, and could have been as low as about 0.01 degrees Celsius. This lower temperature is constrained by the halite-hydrohalite ($NaCl* 2H_2O$) phase boundary. At temperatures below 0.01 degrees Celsius, hydrohalite, rather than halite, is the stable solid phase in equilibrium with an NaCl-saturated solution. At 100 degrees Celsius, the minimum pressure needed to stabilize an NaCl-saturated brine is 0.0754MPa. However, at 0.01 degrees Celsius, a pressure of only about 3×10^{-4}MPa is required for the brine phase to be stable. These minimum pressures would be elevated by the presence of any volatile phases, such as carbon dioxide, nitrogen or sulfur dioxide, in the mineralizing solutions, although no evidence for the presence of gases has been observed in inclusions studied thus far. However, SEM-EDX analysis of opened inclusions in the Zag meteorite has identified sulfur, although the form of the sulfur is unknown at this time.

The $H_2O \pm NaCl$ phase equilibria provide constraints on the possible P-T conditions associated with aqueous alteration of the chondritic meteorites on their parent bodies. The liquid-water inclusions and P-T conditions inferred from the inclusions are consistent with the alteration having occurred in the shallow subsurface of the parent bodies at temperatures ranging from about 0 to <100 degrees Celsius, consistent with temperatures of alteration of types 1 and 2 chondrites reported by Zolensky and McSween (1988). The occurrence of the inclusions in late-forming minerals in the meteorites is consistent with the retrograde nature of the alteration, and suggests that alteration of ordinary chondrites such as the Monahans H5 continued to low temperatures (or was exposed to later, low temperature liquid water on its parent body).

The presence of liquid water inclusions in chondritic meteorites has additional implications concerning the possibility that life has formed and developed elsewhere in the Solar system other than earth. As noted by McKay (1991) *"the search for life in planetary environments can be currently conducted as a search for liquid water habitats - past and present"*. The occurrence of liquid-water inclusions in meteorites confirms the past presence of liquid water on the meteorite parent bodies. Moreover, the P-T conditions inferred for the formation of these inclusions is within the range of temperatures in which life has been observed to exist and thrive on earth. Thus, while life may not have developed on other bodies in the Solar system, at least one of the necessary ingredients (liquid water) was available for this process to occur.

Bodnar RJ & Zolensky ME, . *Geological Society of America, Program and Abstracts*, **32**, A-7, (2000).
McKay CP, *Icarus*, **91**, 93-100, (1991).
Zolensky ME, Bodnar RJ, Bogard DD, Garrison DH, Gibson EK, Nyquist LE, Reese Y, Shih C-Y & Wiesmann H, *Science*, **285**, 1377-1379, (1999).
Zolensky ME, Bodnar RJ, Schwandt C & Yang SV, *In Lunar and Planetary Science XXXI, Abstract #1181*, **31**, 1181, (2000).
Zolensky ME, McSween HY, Jr, . *In Meteorites and the Early Solar System, J. Kerridge and M. Matthews, Eds.* , *University of Arizona Press*, 114-143, (1988).