INDIGENOUS CARBONACEOUS MATTER AND BORON ASSOCIATED WITH HALITE CRYSTALS IN NAKHLA. K. L. Thomas-Keprta[1] (kathie.thomas-keprta-1@nasa.gov), S. J. Clemett[2], D.S. McKay[3], E.K. Gibson[4], and Wentworth S. J.[5]; [1]Barrios – Jacobs JETS Contract, NASA/JSC, Houston, TX 77058; [2]ERC – Jacobs JETS Contract, NASA/JSC, Houston, TX 77058; [3]Deceased, formerly NASA/JSC Houston, TX 77058; [4]NASA/JSC Houston, TX 77058; [5]Hepco – Jacobs JETS Contract, NASA/JSC, Houston, TX 77058.

We report here the observation of indigenous organic matter spatially associated with, and in several cases embedded within, halite crystals located in alteration veins inside the Martian meteorite Nakhla. Furthermore, we have also detected enrichments of boron (*B*) in these halites far in excess of those previously reported in bulk Martian meteorites. Boron in Martian halites has not been detected previously.

Introduction: Secondary minerals in the form of iddingsite alteration phases and evaporites are present as vein fillings along fracture surfaces within the Nakhla meteorite. Their pre-terrestrial origin has been previously established; for example, by their truncation and decrepitation at the fusion crust, indicating formation prior to atmospheric entry, *e.g*. [1]. Consequently the study of secondary minerals in Martian meteorites is of great importance in deciphering the low temperature, aqueous geochemistry of early Mars. It has also slowly become apparent that many Martian meteorites contain organic matter, and in the case of Nakhla, appears to be predominately associated with the secondary alteration phases. We have previously documented that some of this organic matter is present in the form of discrete, well-defined, micron-sized hollow spherical assemblages encapsulated within iddingsite [2].

The proximity of secondary minerals, formed in a low-temperature aqueous environment, with organic matter has implications for astrobiology and the historical habitable potential of the Mars regolith [3].

Procedure and Results: The Nakhla sample used in this study was gratefully received from Dr. Caroline Smith at the British Museum of Natural History. The sample was freshly fractured with resulting chips, ranging up to ~5 mm in diameter, mounted on SEM stubs using double sticky *C* tape. Samples were analyzed at 5, 10, and 15 keV using FESEM-EDX imaging and mapping. Prior to FESEM analysis, a *Pt* surface coating ~1 nm thick was applied to enable imaging and chemical characterization of light elements including *C*. One freshly fractured chip with a layer of iddingsite also contained ~15 euhedral crystallites of *NaCl*. Embedded within two adjoined crystallites, *C*-rich matter was identified (Figs. A, B). The *C*-rich region of interest measured ~2×2 μm and was located near the center of the adjoined crystals (Fig. B). High resolution element maps showed the location of the *C*-rich matter and the composition of the halite crystals which were composed of major *Na* and *Cl* with minor *B* (Fig. C). FESEM-EDX spectra taken at 10 kV and 100 s. showed a peak for *B*, primarily associated with *NaCl* (Fig. D) although one spectrum of the carbonaceous matter appeared to contain *B* (note: Monte Carlo electron trajectory simulation models visualize the interaction volume for a given material). The background spectra showed no evidence of *B*. For comparison, a flat, polished, *C*-coated *BN* standard was analyzed under the same conditions (10 keV, 100 s.; Fig. E). The presence of the *B* peak in the standard indicates this element can be detected using our FESEM-EDX system.

Discussion & Conclusion: We have identified arguably indigenous carbonaceous matter embedded within *B*-rich, *NaCl* crystals spatially associated with an iddingsite vein in the Martian meteorite Nakhla. Both the iddingsite and halite crystals are interpreted to have formed by interaction with low-temperature aqueous fluids that permeated fractures within the Nakhla groundmass while it was in the Martian regolith. The association, and in some cases encapsulation, of carbonaceous matter with the halite suggests that the C-rich matter provided a nucleation site for halite crystallization, as seen in terrestrial evaporite deposits. The presence of wt.% concentrations of *B* in the halite has not been previously observed in Martian meteorites. However, we note that similar *B* abundances have been observed in some terrestrial evaporite salts, *e.g*., teepleite ($Na_2B(OH)_4Cl$) [4].

The presence of *B* in association with organic matter is particularly important because it has been argued that presence of *B* was essential to early development of life on Earth. This is because, in the early "*RNA world*," borate minerals would have provided an inorganic pathway for the synthesis of ribose (a key component in RNA [5, 6]) and other pentoses [6]. The association of *B* and *NaCl* in Nakhla indicates evaporitic environments containing *B* were present on Amazonian Mars. Work is ongoing to identifying the nature of the *B* containing phase and establish the molecular composition of the carbonaceous matter.

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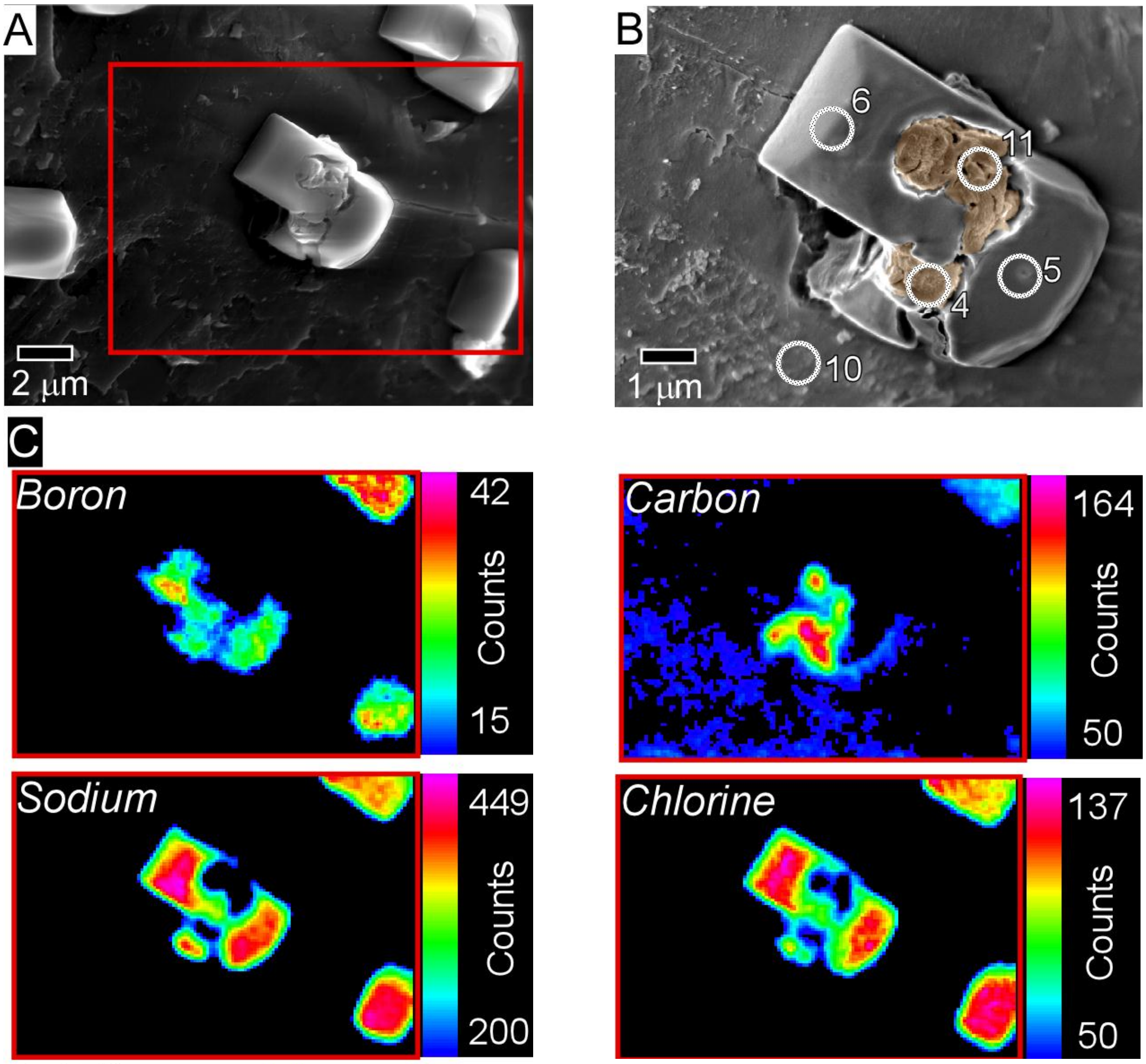

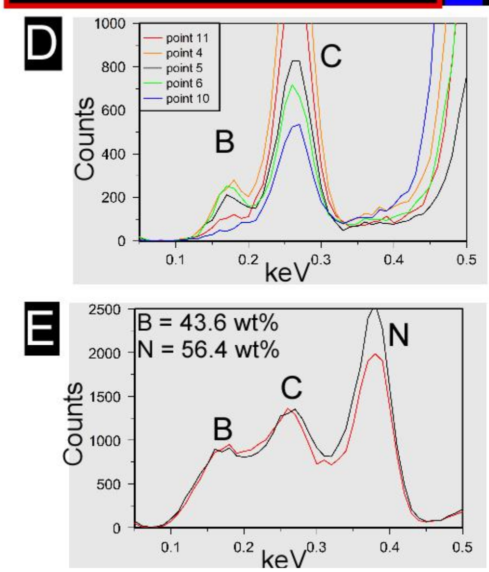

Fig. A. FESEM scanning electron image of *NaCl* crystals on a freshly fractured Nakhla chip surface. Carbonaceous matter is embedded within two adjoined crystals in the center of the view. The red box highlights the region mapped by EDX (see Fig. C). **Fig. B**. FESEM image taken at 3 keV of *C*-rich matter (false-colored orange) encased by *NaCl* crystals. EDX spectra for the designated spot analyses are shown in Fig. D. **Fig. C**. High resolution FESEM maps of *B*, *C*, *Na* and *Cl* acquired at 10 keV. *C*-rich matter is located near the center of the adjoined *NaCl* crystals. A crystal in the upper right corner of the *C* map also appears to contain carbonaceous matter. Heterogeneously distributed *B* is associated with the *NaCl* crystals. **Fig. D**. EDX spectra (10 keV, 100 s., up to 0.5 keV) of spot analyses shown in Fig. B. Background lacks detectable *B*. Significant enrichments of *B* are present in the *NaCl* crystals. **Fig. E**. EDX spectra (10 keV, 100 s., up to 0.5 keV) of a *C*-coated *BN* standard.