CHLORIDE AND SULFATE MINERALS IN THE NAKHLA METEORITE.

S. J. Wentworth[1] and J. L. Gooding[2], [1]Lockheed/EMSCO, 2400 NASA Rd. 1, Houston, TX 77058. [2]SN2/Planetary Materials Branch, NASA/Johnson Space Center, Houston, TX 77058.

Introduction. SNC meteorites (shergottites, nakhlites, and chassignites) are thought to be from Mars, with the strongest evidence for Martian origin occurring in Antarctic shergottite, EETA79001 [1,2]. Recent work [3,4] has shown that secondary minerals in EETA79001, including calcite, gypsum, and secondary aluminosilicates, may be of Martian origin. Positive identification of volatile-bearing minerals produced in the Martian regolith would be of key importance in understanding Martian near-surface processes. Nakhla is a good candidate for additional secondary-mineral studies because its carbon isotopic composition includes an unusual "carbonate" component [5] that is similar to the Martian (?) calcite in EETA79001 [6]. In addition, Nakhla (an observed fall) is not extensively weathered, although a previous petrologic study [7] reported the presence of "iddingsite" (a mixed-phase silicate alteration product) of undetermined origin along fractures in olivine.

Samples and Methods. Untreated, ~ 50-mg bulk chips of Nakhla (BMNH-1911-369 provided by A. Graham, British Museum of Natural History) were studied by scanning electron microscopy (SEM) and energy-dispersive X-ray spectrometry (EDS), including light element EDS for carbon, using the same techniques applied to shergottite EETA79001 [3,4]. BMNH samples included an exterior, fusion-crusted chip and an interior chip from > 2-cm depth. In addition, Nakhla powder (individual grains of 50-200 μm size), remaining from carbon isotopic work [5] (supplied by I. Wright and M. Grady, Open University), was studied by the same SEM/EDS methods.

Results. Both interior and exterior BMNH samples contain common halite and traces of Ca-sulfate (crystal system as yet unidentified). Halite occurs as euhedral crystals (Fig. 1) in interstices and as massive fracture fillings; it is also present on the fusion crust surface, mostly in vugs and fractures but also on smooth portions of the fusion crust (Fig. 2). Ca-sulfate, which occurs as isolated, irregular grains (Fig. 3), is also found along interior fractures. On the fusion crust, Ca-sulfate has been identified in vugs along with halite and possible secondary aluminosilicates (which have not yet been closely examined). A trace of another secondary mineral, consisting of Mg and S (probably Mg-sulfate) also occurs in the exterior chip, in a fracture ~ 100 μm below the fusion crust surface; this phase appears to be highly desiccated.

The focus of study for the Open University powder is to identify a carrier for the "carbonate" carbon analyzed by [5]. Preliminary work has not yet identified the carbon-bearing phase(s) in the OU powder or the BMNH chips. Traces of halite have been identified in the OU powder, however.

Discussion. Secondary salts are surprisingly abundant in Nakhla. Halite, at least, was ubiquitous in all samples we studied. Halite is almost certainly the carrier of the bulk Cl that was found by high-temperature evolved gas analysis of the BMNH samples [8]. The SO_2 and H_2O evolved from Nakhla [8] are attributable to the Ca-sulfate. The evolved-gas molecular ratio of $SO_2/H_2O = 1.6$ [8] suggests that the sulfate-mineral carrier is a mixture of bassanite and gypsum rather than anhydrite. We cannot yet exclude the possibility that the salts were indigenous phases that were remobilized as surface efflorescences after arrival of the meteorite on Earth. The propensity of evidence, though, points toward terrestrial origin for the halite, Ca-sulfate, and Mg-sulfate. The presence of terrestrial salts in Nakhla does not rule out the possibility that pre-terrestrial alteration products are present, however, and work will continue to identify carbonates and characterize the "iddingsite."

REFERENCES: [1] Bogard D. D. and Johnson P. (1983) *Science, 221*, p. 651-654. [2] Becker R. H. and Pepin R. O. (1984) *Earth Planet. Sci. Lett., 69*, p. 225-242; [3] Gooding J. L. and Muenow D. W. (1986) *Geochim. Cosmochim. Acta, 50*, p. 1049-1059; [4] Gooding J. L. et al. (1988) *Geochim. Cosmochim. Acta* (submitted); [5] Carr R. H. et al. (1985) *Nature, 314*, p. 248-250. [6] Wright I. P. et al. (1988) *Geochim. Cosmochim. Acta* (submitted). [7] Bunch T. E. and Reid A. M. (1970) *Meteoritics, 10*, p. 303-315. [8] Gooding J. L. et al. (1987) Program for 50th Meeting of the Meteoritical Society, Newcastle Upon Tyne, p. 69, and ms. in prep.

Figure 1. Halite crystals (arrows) in the interior of Nakhla.
Figure 2. Halite and Ca-sulfate (arrow) on Nakhla fusion crust.
Figure 3. Ca-sulfate (arrow) in the interior of Nakhla.