HALITE, SULFATE, AND CLAY ASSEMBLAGES IN THE NAKHLA MARTIAN METEORITE.

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Introduction: Secondary mineral assemblages are commonly observed in nakhlites. They include carbonates, sulfates, clays, amorphous silicates, and halite in different settings and combinations [1–6]. Since water is a prerequisite for their formation, the study of these minerals should help us to determine when, how long, and how much liquid water was present beneath ancient Mars.

However, the findings are usually ambiguous and a complex, multistage history seems to be typical than exceptional. That water once percolated through the nakhlite rocks in a preterrestrial environment is beyond doubt [7,8]: Sulfate and low T silicate assemblages are likely the result of aqueous alteration and precipitation. How much water is required to account for this post-igneous mineralization, and moreover, if one single evaporation event might be responsible for all observed secondary mineral assemblages, is still in dispute. The solutes (alkali metals, halogens, S, and CO_2) may have been leached from bedrock or atmospherically processed as has been shown for S [9].

With these issues in mind, we started the examination of different secondary mineral assemblages, each to be comprehensively analyzed by multiple microchemical techniques. While initial studies focused on carbonate-silicate assemblages in Lafayette [2,3] and an anhydrite-bearing assemblage in Nakhla [4], here we report our first results for halite-clay assemblages in Nakhla veinlets. In addition, the mineral chemistry of clays associated with halite is compared to those found in association with anhydrite.

Methods: Two polished thin sections of Nakhla meteorite were examined: 38LNH-3 (prepared as a typical polished thin section) and 38-LNH-4 (prepared by a H_2O-free method at NMNH to conserve soluble salts). A combined backscattered electron (BSE) and energy dispersive spectroscopy (EDS) reconnaissance inspection identified several halite and sulfate-bearing locations. These areas were further analyzed using electron microprobe (WDS), EDS, and time-of-flight secondary ion mass spectrometry (ToF-SIMS). The latter two techniques, EDS and ToF-SIMS, both acquired and stored the full spectrum information for each pixel, allowing full retrospective analysis of regions of interest. While the X-ray analytical techniques ensure proper identification and major element composition on a µm-scale, ToF-SIMS allows for minor and trace element analysis down to ~300 nm spatial resolution. However, due to complications associated with SIMS appropriate standards are required to obtain quantitative results, and currently we are restricted to silicate analysis.

Results: Two of the newly discovered halite occurrences are situated dominantly within olivine veinlets. In both cases clay-like/amorphous silicates (Figs. 1 and 2) are associated with the halite. This is the first report of this assemblage in nakhlite meteorites. The previously reported anhydrite occurrence also features clays rimming the adjacent pyroxene host [4] (Fig 3). Figure 4 shows a comparison of the major, minor, and trace element composition of clays from these two assemblages determined by ToF-SIMS. The light alkali metals (Li, Na, K), Al, and some transition metals (Sc, Ti, V, Cr) show the largest variability, whereas other elements (Mg, Si, Mn, Fe, Rb, Sr, Ba) are remarkably similar.

Discussion: The minor and trace element composition of clays examined here could be explained by mixing dissolved local bulk chemistry with percolating fluids. The abundance of elements that show large variability in clays seem to be strongly affected by neighboring phases (on the scale of 10s of µm), e.g. feldspar, apatite, anhydrite, and halite. The surprising lack of variability in Rb concentration, on the other side, might be a heritage from the pervading fluid. This is supported by the fact that Rb is only observed in clay and other alteration phases within the examined regions. The origin of the Li may be traced to mesotasis feldspar, though the concentration in clay is significantly greater.

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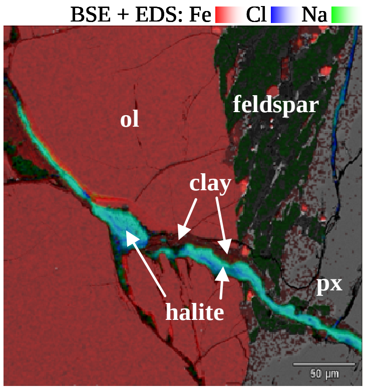

Figure 1. *Halite and clay bearing vein in Nakhla 38LNH-4 #48.*

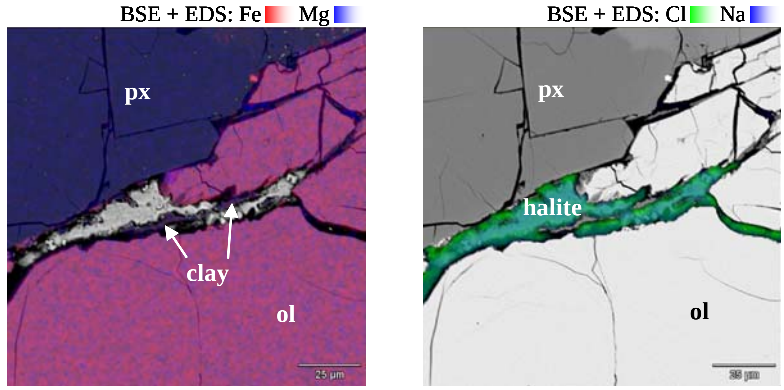

Figure 2. *Halite and clay bearing vein in Nakhla 38LNH-4 #101*

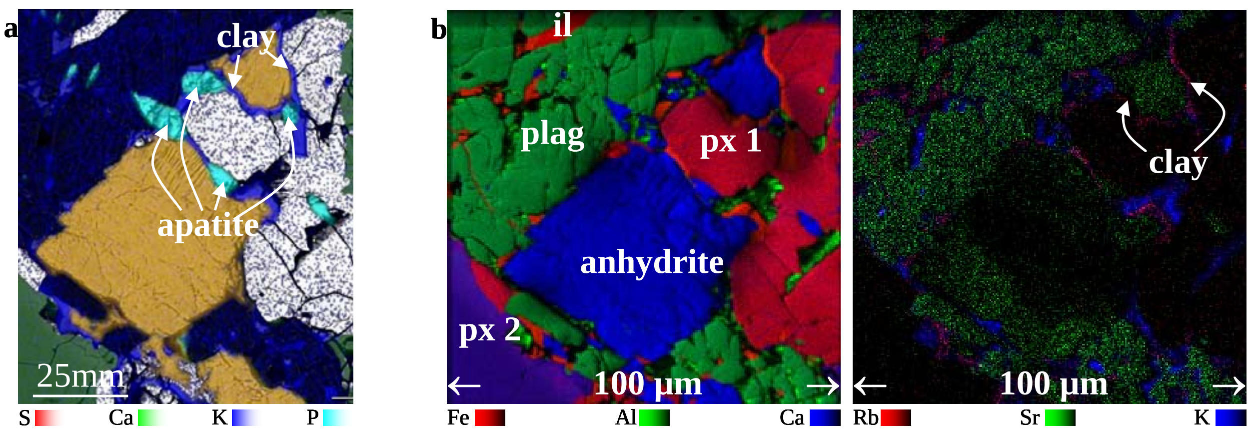

Figure 3. *Anhydrite-apatite assemblage in Nakhla 38LNH-3. (a) BSE and EDS composite images, (b) ToF-SIMS secondary ion composite images.*

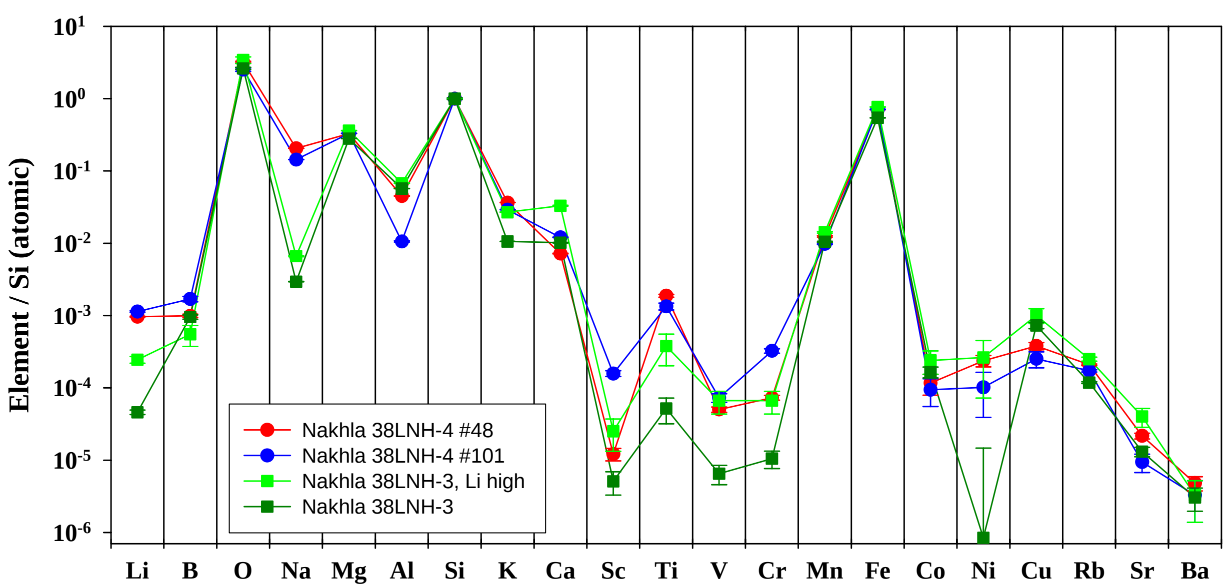

Figure 4. *Element abundances in Nakhla secondary mineral assemblage clays relative to Si.*