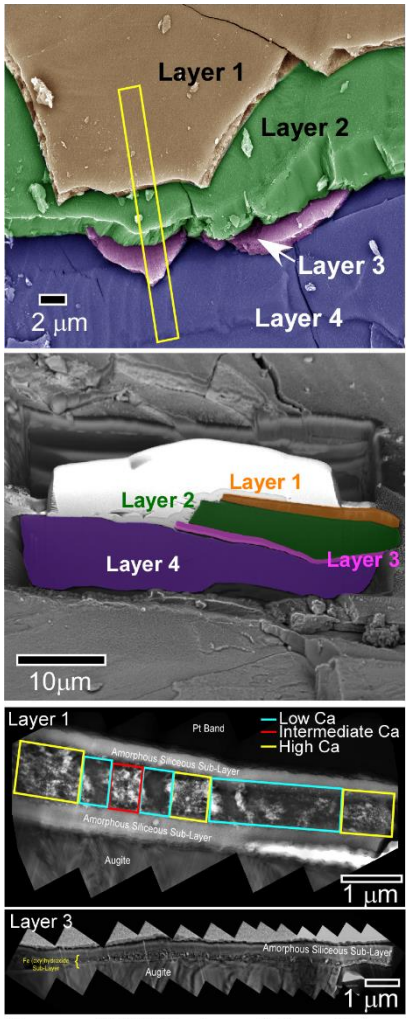
UNUSUAL AQUEOUS DEPPOSITS LOCATED WITHIN THE NAKHLA MARS METEORITE

K. L. Thomas-Keprta[1], S. J. Clemett[1], N. Baskar[2], Z. Rahman[1], E. K. Gibson[3], S. J. Wentworth[1], and D. S. McKay[3]; [1]Jacobs JETS, NASA/JSC, Houston, TX 77058 (kathie.thomas-keprta-1@nasa.gov); [2]Liberty High School, Frisco TX 75035; [3]ARES, NASA/JSC, Houston, TX 77058; [3]Deceased, NASA/JSC, Houston, TX 77058.

Introduction: We report the first identification of two unique, aqueously altered, foliated assemblages on interior fracture surfaces of the martian meteorite Nakhla. The assemblages are of demonstrably martian origin and are consistent with formation from low temperature, CO_2-rich, aqueous brines of variable composition. They appear as micron-thick layers overlying augite and olivine-rich groundmass. The interfaces between adjacent layers are sharply delineated both chemically and structurally with the width of the transition zone in the nanometer range. Although physically these features appear superficially similar to the more traditional, and well documented, 'iddingsite' alteration assemblages present in Nakhla [*e.g.*, 1-3 and references therein], the absence of phyllosilicates indicates they represent a new, distinct and separate type of alteration feature.

Methods: The Nakhla samples used in this work were provided by the British Museum of Natural History. Chips from Nakhla, split 14, were mechanically fractured using stainless steel tools under clean conditions. Fragments with freshly exposed interior fracture surfaces were selected and photo-documented prior to being sputter-coated with Pt (~1 nm) for subsequent characterized using field emission scanning electron microscopy (FESEM) and energy dispersive X-ray spectroscopy (EDX). Based on these observations regions of interest (ROIs) were identified and subsequently extracted by focused ion beam (FIB) microscopy for characterization by field emission scanning transmission electron microscopy (FESTEM) and EDX.

Results and Discussion: Figure 1 (upper view) shows one ROI on a fresh fractured Nakhla surface in which a series of alteration layers, designated 1-4, are apparent. Using FIB micrscopy, a section through these layers was prepared (Fig 1, center view), and then extracted and ion-milled to electron transparency for TEM analysis. TEM images of Layers 1 & 3 are shown in Fig. 1, lower view. Layer 1 is composite of a chemically heterogenous central region sandwiched between two amorphous, Si-rich layers. The central layer is composed of mixture of amorphous phases in which nanophase crystallites (primarily carbonate along with minor Fe-(oxy)hydroxides and salts) are interspersed. Discrete variations in the abundance of Ca, Mg & Mn are observed the longitudinally, *i.e.*, from left to right, at scale lengths of one to several microns. Layer 3, in contrast, is composed of a single amorphous, Si-rich sheet overlain by a layer composed primarily of fine-grain, polycrystalline Fe-(oxy)hydroxides (with a positive identification for ferrihydrite). The absence of discernible phyllosilicates in any of the layers means these alteration assemblages fail to meet the criteria to be described as iddingsite. We suggest formation of these alteration features occured, at least in part, through the process of interface coupled dissolution-reprecipitation, described in detail by Hellmann et al. [4, 5]. In this process silicate alteration occurs within a thin distinct and mobile aqueous surface alteration layer.



Upper: FESEM view of four (false-colored) layers on a freshly fractured chip of Nakhla. Region in box was extracted by FIB microscopy. **Center**: FIB extracted region (upper view; yellow box) showing location of four layers. **Lower**: TEM images of Layers 1 & 3. Layer 1 is composed of three sub-layers, two of which are composed of amorphous silica. These layers sandwich a central layer composed of a mix of carbonate and non-carbonate phases. Layer 3 is composed of an amorphous silica phase bordered by a layer composed of fine-grain Fe-(oxy)hydroxide.

Conclusions: Previous studies of mineral weathering in Nakhla have invoked saturation-precipitation models to explain their observations [*e.g.*, 1, 2]. We suggest these new alteration features provide evidence for a recently proposed reaction mechanism for silicate weathering which proceeds through a coupled interfacial dissolution-reprecipitation mechanism [4, 5].

References: [1] Lee *et al*. (2015) *Geochim. Cosmochim. Acta* 154, 49-65. [2] Changela & Bridges (2011) *Meteorit. Planet. Sci*. 45, 1847-1867. [3] Treiman (2005) Chemie der Erde 65, 203-270. [4] Hellmann *et al*. (2013) *Procedia Earth & Planet. Sci*. 7: 346-349. [5] Hellmann *et al*. (2015) Nature Materials. DOI 10.10.1038/NMAT4172.