IDDINGSITE IN THE NAKHLA METEORITE: TEM STUDY OF MINERALOGY AND TEXTURE OF PRE-TERRESTRIAL (MARTIAN?) ALTERATIONS.

Allan H. Treiman and James L. Gooding, SN21, NASA/JSC, Houston TX 77058.

Rusty-colored veinlets and patches in the Nakhla meteorite, identified as "iddingsite" [1], are pre-terrestrial [2]. The rusty material is iddingsite (smectites + hematite + ferrihydrite); like terrestrial iddingsites, it probably formed during low-temperature interaction of olivine and water.

Fragments of rusty material with host olivine were removed from thin sections of Nakhla (USNM-426, Smithsonian Institution) with a tungsten needle. Fragments were embedded in epoxy, microtomed to 100 nanometers thickness and mounted on Cu grids. Phase identifications were by Analytical EM/EDX 'standardless' chemical analyses (for silicates), electron diffraction (hematite and ferrihydrite), and lattice fringe imaging [2].

The rusty material contains hematite, ferrihydrite, iron saponite, and a distinct "iron-bearing smectite"; the name iddingsite is consistent with this mineral assemblage [3,4]. Some serpentine is also present. The amorphous material found by [5] may be ferrihydrite or a smectite, which appear poorly crystalline in electron diffraction. Hematite and ferrihydrite (two-ring) were identified by composition and by electron diffraction.

Chemical analyses identified as iron saponite have little Al and normalize to 4 Si+Al and 3 Fe+Mn+Mg per 11 O; alkali content is variable. Interlayer spacings are 11-13 nm [2]. Areas identified as "iron-bearing smectite" are similar to iron saponite in CTEM imagery; their analyses show little Al, atomic (Fe+Mg+Mn)/(Si+Al) = 0.5, and variable alkali contents. They may represent a dioctahedral smectite. Analyses identified as serpentine have little Al and approximate, and average to, atomic (Fe+Mg+Mn)/(Si+Al) = 1.5. Individual analyses have this ratio significantly larger or smaller than 1.5.

Many analyses contain excess Ca, Na, K, S, P, and Cl, suggesting admixture of other phases. For a few analyses, the admixed phases can be tentatively identified as K-sulfate (jarosite?), Ca-sulfate [2], or KCl; other analysis contain equimolar K and Na, suggesting admixture of a stoichiometric mixed-alkali phase.

Textural relations suggest that the olivine altered in three stages: serpentine first; then smectites; and then hematite + ferrihydrite. Serpentine is found adjacent to olivine and as isolated patches in the iddingsite; it was probably the earliest alteration, as it normally forms at higher temperature and lower redox state than iddingsite. Two assemblages occur in the iddingsite. The smectites occur intermixed in patches and veins (down to 100 nm width) cutting olivine and possibly serpentine, as larger patches, and as coatings on mineral fragments [2]. The smectites are cross-cut by patches and veinlets, down to 40 nm width, of intergrown ferrihydrite and hematite (average grainsize 20 nm). Areas of pure ferrihydrite are present, but their paragenetic position is unknown.

This iddingsite in Nakhla is nearly identical to some formed on Earth [6], suggesting similar conditions of formation on the SNC parent planet. To permit formation of iddingsite, Nakhla must have been penetrated by oxidizing water at temperatures of weathering or of deuteric alteration, 50-150°C [4].

Assistance from K. Thomas, R. Barrett and L. Keller is gratefully acknowledged.

[1] Bunch and Reid (1970) Meteoritics 10, 303. [2] Gooding et al. (1991) Meteoritics 26, in press. [3] Deer et al. (1966) Intro. to Rock-Forming Minerals; Longman Gp. [4] Delvigne et al. (1979) Pedologie XXIX, 247. [5] Ashworth and Hutchinson (1975) Nature 256, 714. [6] Banfield et al. (1990) Contrib. Min. Petrol. 106, 110.