EFFECT OF IMPACT AND HEATING ON THE SPECTRAL PROPERTIES OF CLAYS ON MARS. P. Gavin[1], V. Chevrier[1], K. Ninagawa[2] [1]W. M. Keck Laboratory for Space Simulations, Arkansas Center for Space and Planetary Sciences, 202 Old Museum Building, University of Arkansas, Fayetteville, AR 72701, [2]Department of Applied Physics, Okayama University of Science, Okayama, Japan. pgavin@uark.edu, vchevrie@uark.edu.

Introduction: The OMEGA spectrometer onboard Mars Express recently detected clays in the Nili Fossae and Mawrth Vallis regions of Mars [1,2]. These observations were then confirmed by the CRISM spectrometer onboard MRO. The outrcops contain mainly Al (montmorillonite), Mg (saponite), and Fe^{3+} (nontronite) [1]. Considering their Noachian age, these outcrops may have been affected by impact shock and volcanism [3]. Indeed some clays were found in the ejecta of craters as well as in terrains surrounded by lava flows.

The previous statement indicates that clays are formed before impact, by interaction between the Noachian atmosphere and primary silicates [4], although other studies suggest that clays could be formed by post-impact hydro-thermalism [5]. Such problems of ancient age, and formation process highlight the importance for studies of metamorphism (impact and thermal) effect on clays.

Previous studies showed that impacted clays undergo various structural and mineralogical transitions making them possibly responsible for the thin layer of red dust on the Martian surface [6-8]. However, in this study we rather focus on the spectral properties of shocked / heated clays to decipher how they were affected during impact.

Table 1: Experimental parameters for nontronite with pictures of secondary products.

Atm	T (^{0}C)	Time (hrs)	Mass loss (wt%)	Picture
Air	630	24	22	
Air	880	6	21	
Air	1130	4	21	
CO_2	475	20	20	
CO_2	725	6	20	
CO_2	875	6	25	
CO_2	975	4	31	

Methods: One-gram samples of nontronite from Cheney Co. WA (Ward's #49E5108) or of montmorillonite from Panther Creek, CO (Ward's #46E0438) were heated in a Lindberg tube furnace at various temperatures ranging from ~400 to ~1100ºC and for 4 to 24 hours. Samples were heated in air and under CO_2 flow to simulate the martian atmosphere.

Nontronite and montmorillonite samples were also impacted using a light gas gun, with a projectile speed of about 2.5 km/s.

Samples' color changes were characterized using a Munsell soil color chart. The nature and composition of neoformed phases was then analyzed using X-ray diffraction and infrared reflectance spectrometry.

Heated Samples: Changes in color are particularly evident in nontronite samples, which transits from yellow-green to various shades of reddish brown (Table 1). This indicates changes in clay structure and mineralogy.

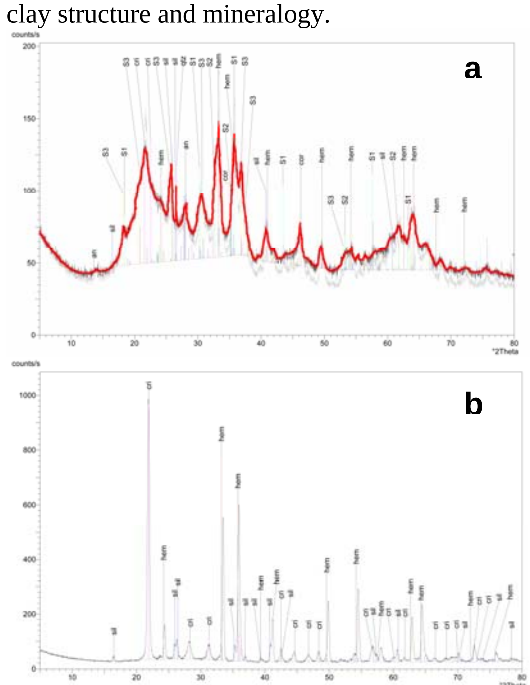

Figure 1: XRD spectra of heated nontronite with positions of reference peaks. a. Red – Air, 880^{0}C, Grey – CO_2, 975^{0}C. b. Air, 1130^{0}C. Abbreviations: an: anorthite; cri: cristoballite; cor: corundum, hem: hematite; qtz: quartz; sil: sillimanite; S1: ferrous spinel; S2: ilmenite; S3: heterosite. S1, S2, and S3 correspond to structures identified but without the right chemistry.

The average mass loss of the samples was 22 $\pm$ 4% most likely due to loss of interlayer water.

XRD results show that the original clay structure is destroyed at temperatures above ~350ºC, with the disappearance of the interlayer peak, confirming the loss of water from the structure. At temperatures above ~800ºC, XRD evidences transformation into a very complex mixture of secondary phases (Fig. 1a). The secondary mineralogy mostly depends on the temperature and the primary clay composition, rather than the nature of the atmosphere. At very high temperature (above 1000ºC) we identify hematite, sillimanite and cristobalite (Fig. 1b) in various proportions according to the original clay composition. Thus montmorillonite does not show any hematite. Several peaks at intermediate temperatures remained unidentified, which suggests the formation of new phases [9].

Spectral properties also strongly evolve, according to the heating temperature (Fig. 2). There seems to be no difference in the samples heated in air and those heated in CO_2, in accordance with XRD results. Evolution is mostly characterized by rapid loss of the 3 μm water band, in accordance with mass loss and XRD observations. At higher temperatures, the 1.9 μm hydration and the 2.3-2.3 μm metal-OH band disappear [2]. However, it does not seem that secondary phases present significant absorption bands in the 1.0 – 2.6 region investigated for clays by OMEGA.

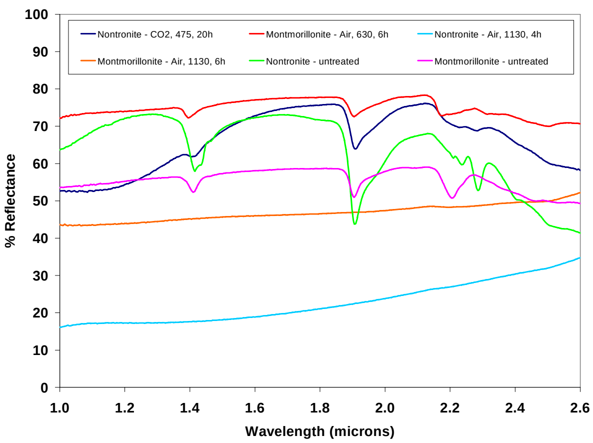

Figure 2: NIR reflectance spectra of several heated nontronite and montmorillonite samples compared to the untreated sample of each.

Impacted samples: XRD results of nontronite and montmorillonite samples do not show any significant change compared to untreated samples. No secondary phase or significant shift in any peak was observed. The interfoliar peak remained intact, suggesting that even interlayer water is globally unaffected. NIR observations of both clays show similar results (Fig. 3). The signature bands of each mineral are still prominent as well as the hydration band at 1.9 and 3.0 μm, indicating that impact alone did not affect the structure of the clays.

Discussion and Conclusions: Two conclusions can be drawn from our results: (1) impact alone does not affect the clays and (2) heating is mainly affecting clays. Clays are even altered at relatively low temperatures (~350ºC), and rapidly loose their water while changing in color (nontronite). At higher temperatures, complex mineralogical transitions occur. However, the NIR spectra of the mixtures do not appear to be very characteristic, enhancing the necessity for other spectral regions to be used (VIS and MIR).

Small impacts do not release large amounts of energy and thus are not expected to affect the clays. This could explain the presence of fresh clays in ejecta of small craters. If large amounts of heat are released during larger events, then significant transformations are expected to occur, leading to obviously altered clays and/or secondary phases. Signals of "reddened" clays (having lost their interlayer water but keeping a global clay crystalline structure) are of special interest.

Further studies include the search for typical spectral signatures impacted clays, especially high-temperature phases like cristobalite or sillimanite, and comparison of our spectra with OMEGA and CRISM spectra in the regions affected by impact or thermal metamorphism.

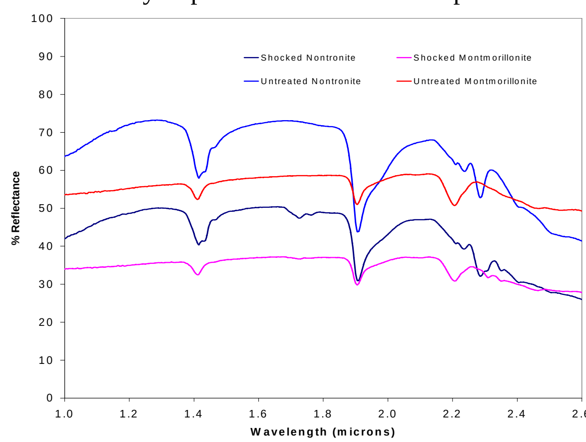

Figure 3: NIR reflectance spectrum of shocked nontronite and shocked montmorillonite compared to the untreated sample of each.

References: [1] Bibring J.-P. et al. (2005) *Science* 307, 1576-1581. [2] Poulet F. et al. (2005) *Nature* 481, 623-627. [3] Gavin P. et al. (2007) *LPSC* XXXVIII, #2295. [4] Chevrier V. et al. (2007) *Nature* 448, 60-63. [5] Naumov M. V. (2005) *Geofluids* 5, 165-184. [6] Boslough M. B. et al. (1986) *J. Geophys. Res.* 91, E207-E214. [7] Hviid S. F. et al. (1994) *hyperfine Interactions* 91, 529-533. [8] Weldon R. J. et al. (1982) *J. Geophys. Res.* 97, 10102-10114. [9] Chevrier V. et al. (2007) *LPSC* XXXIX, This meeting.