**EXPERIMENTAL INVESTIGATION OF THE EFFECT OF METEORITIC IMPACTS ON CLAYS ON MARS.** P. Gavin[1], V. Chevrier[1], K. Ninagawa[2], A. Gucsik[3], S. Hasegawa[2]. [1]Arkansas Center for Space and Planetary Sciences, University of Arkansas, 202 Old Museum Building, Fayetteville, AR 72701, [2]Okayama University of Science, Dept. of Applied Physics, Okayama, Japan, [3]Max Planck Institute for Chemistry, Germany. pgavin@uark.edu

**Introduction:**

Phyllosilicates have been detected on the surface of Mars by both OMEGA/MEx and by CRISM/MRO [1-3]. Phyllosilicates have been found in some of the oldest terrains on Mars and are thought to date back to the Noachian era. These clays have especially been detected in the ejecta and central peaks of small impact craters [4, 5]. The exact processes that occurred to form these clays are still unclear. It has been suggested that clays were formed in the earliest history of Mars through the activity of liquid water on the surface [6]. Other possible mechanisms include formation by the hydrothermal processes caused by meteoritic impacts [5, 7].

This investigation deals with the effects of shock pressures and temperatures on the spectral properties of clays and how these pressures and temperatures may be modeled. Investigating shock effects on phyllosilicates will help us determine if clays formed prior to an impact event, and are thus affected by it, or after by the impact-induced hydrothermal processes. The latter case implies that some clays in craters may not be as old as previously thought [5].

**Methods:**

The shock experiments were carried out using a two-stage light gas gun at the Institute of Astronautical Science, Japan Aerospace Exploration Agency (JAXA) [8, 9]. The light gas gun has a target chamber of 500 mm in diameter by 1000 mm long. The projectile collides with a sample holder in the target chamber under 40 Pa at room temperature. This gas sun can accelerate a projectile to about 4 km $s^{-1}$. The projectiles used were polycarbonate cylinder, 7 mm in diameter and 4.5 mm in height, with a stainless steel head 4 mm in diameter and 1 mm in height. Stainless steel (SUS304) or brass sample holders (100 mm in diameter and 20 mm in height) were placed in the target chamber. Five shock experiments were conducted – two with loose powder with projectile speeds of 2.25 km $s^{-1}$ (montmorillonite sample) and 2.47 km $s^{-1}$ (nontronite sample) and three using sample chunks with projectile speeds of 2.07, 2.15 and 3.27 km $s^{-1}$ (all nontronite samples). Samples were analyzed using X-ray diffraction and near-infrared reflectance spectroscopy using a FTIR Nicolet 6700, in the range 1 – 2.6 µm.

**Estimation of Shock Pressure and Temperature-Autodyn Simulation:**

Shock pressures and temperatures were estimated numerically under experimental conditions using the Autodyn software package (Century Dynamics, Inc.). Simulations have been done only for nontronite samples, but considering the very similar physical properties between nontronite and montmorillonite (both smectites), the results are easily extrapolated to montmorillonite. Porosity of the samples was only considered in the density. Twenty-four gauge points were taken at uniformly placed points throughout each sample. The pressure and temperature were averaged from these twenty-four gauge points from shock wave arrival time on each gauge point up to time t = $3.5 \times 10^{-3}$ ms.

**Results:**

Samples are referred to by their projectile velocity because it is the measured parameter. As expected, both peak and average temperatures and pressures appeared to increase with increasing projectile velocity. In all cases, the simulation shows that the pressure and temperature are not uniform in the sample (P = 0 – 4.5 GPa, Fig. 1). Therefore we extracted for pressure and temperature, a peak value (maximum) and an average value from the measurements at each gauge point (Table 1).

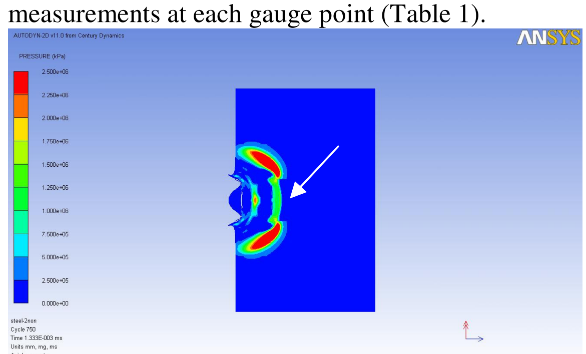


**Figure 1:** A snapshot of the pressure shock wave propagating through a sample of nontronite. Projectile speed for this sample was 2.47 km $s^{-1}$. The sample is located left of center of the blue area (white arrow).

Fig. 2 shows the near-infrared reflectance spectra taken of each of the impacted samples compared to an untreated sample. Even in the sample impacted at 3.27 km $s^{-1}$, which reached a peak temperature of 800 K, all three nontronite bands are still visible, although they have decreased in intensity. The temperatures reached in each of the impacted samples were not high enough to significantly alter these samples. In order to alter clays, temperatures would have to reach at least 900 K [10, 11]. At this point, the signature bands of nontronite disappear completely signifying the destruction of the nontronite structure. This

| Projectile velocity (km $s^{-1}$) | Average Pressure (GPa) | Peak Pressure (GPa) | Average Temperature (K) | Peak Temperature (K) |
|---|---|---|---|---|
| 2.07 | 1.0 | 5.4 | 355 | 495 |
| 2.15 | 1.1 | 6.4 | 347 | 495 |
| 2.47 | 0.9 | 4.5 | 424 | 597 |
| 3.27 | 1.6 | 17.5 | 412 | 799 |

**Table 1:** Peak pressures and temperatures for the impacted samples of nontronite.

shows that temperature is the major factor in altering clays, not pressure.

This information was confirmed by the XRD spectra taken of one of the impacted samples of nontronite (Fig. 3). The large 001 peak is still intact as well as many of the other signature peaks of nontronite. This shows that the overall structure of nontronite has not been completely destroyed. The fact that the 001 peak has slightly decreased in intensity is still evidence of alteration, probably through amorphization of the sample, but not to the extent of nontronite that has undergone pure thermal treatment [10, 11].

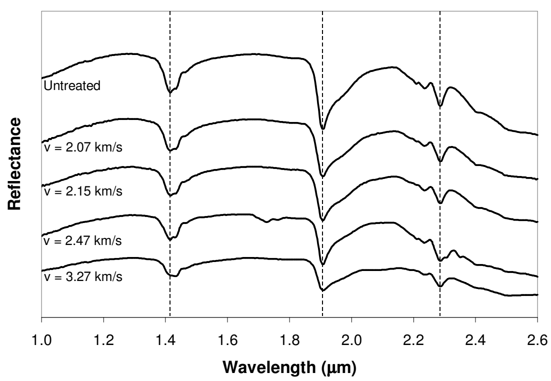


**Figure 2:** Near-infrared reflectance spectra of samples of impacted nontronite at various projectile velocities. Spectra are offset for clarity.

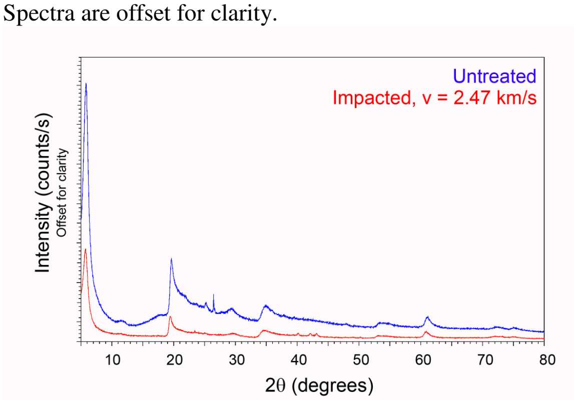


**Figure 3:** XRD spectra of impacted nontronite (red) compared to an untreated sample (blue).

**Discussion:**

Even at the highest impact velocities we do not observe extremely significant changes in the spectral and XRD properties of smectites. The highest peak temperature reached by the impact experiments was 800 K. According to our previous thermal treatment experiments [10, 11], this temperature does not completely destroy nontronite, and thus does not significantly alter its properties, as determined by the samples' XRD and NIR spectra. At temperatures below 800 K, the only evidence for alteration is a slight decrease in band depth in the NIR spectra, especially of the 1.4 and 2.3 µm bands, as we observe on the spectra of impacted samples.

Moreover, the peak temperature was in a very concentrated part of the sample, not over the entire sample (Fig. 1). When considering the average temperature measured in the sample, the highest average temperature was only 425 K, which is well below the threshold temperature for altering clays. In fact, in the NIR spectra of a sample heated to 670 K, the three signature nontronite bands are still intact and easily visible [10, 11].

A third factor to consider is the fact that the impacted samples were only heated for times on the order of milliseconds where as the purely heated samples were heated for hours. Time is an important factor in that a sample will be altered more if heated for longer periods of time. This would most likely be the case in a natural impact on the surface of Mars where the larger scale of the impact would leave the ground at a hotter temperature for longer time.

**Conclusions:**

We can conclude from our experiments that small impacts have limited, but still visible, effects on clays. This can help in determining whether clays that are found in association with impact craters were formed pre- or post-impact.

**References:**

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