EXPERIMENTAL INVESTIGATION INTO THE EFFECTS OF METEORITIC IMPACTS ON THE NEAR- AND MID-INFRARED SPECTRA OF MARTIAN PHYLLOSILICATES. P. Gavin[1], V. Chevrier[1], K. Ninagawa[2], A. Gucsik[3], S. Hasegawa[4]. [1.]Arkansas Center for Space and Planetary Sciences, University of Arkansas, Fayetteville, AR, 72701; [2.] Okayama University of Science, Dept. of Applied Physics, Okayama, Japan; [3.]Max Planck Institute for Chemistry, Germany; [4.]Institute of Space and Astronautical Science, Japan Exploration Agency. pgavin@uark.edu

Introduction:

Several types of phyllosilicates have been detected on Mars by both the OMEGA/MEx spectrometer and the CRISM/MRO instrument [1-3]. In addition to deposits found in Noachian terrains, phyllosilicates have also been identified in the ejecta and central peaks of small impact craters [4,5]. The exact formation processes that occurred to form these phyllosilicates is still a topic of debate. Some studies suggest phyllosilicates formed during Mars' earliest history through the activity of liquid water on Mars' surface [6] while others postulate impact-induced hydrothermal systems resulted in phyllosilicate formation [5,7].

Here we investigate the effects of shock pressures and temperatures on the spectral properties of phyllosilicates and how these pressures and temperatures may be modeled. Understanding the effects of shock pressure and temperature on phyllosilicates will help distinguish between clays that formed from the hydrothermal processes resulting after the impact and those that existed pre-impact and were altered by the impact. The former case implies that some phyllosilicates in martian craters may not be as old as previously thought [5].

Methods:

Impact 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 projectile, accelerated up to 5 km s^{-1}, collided with an unvented sample holder in the target chamber under 40 Pa at room temperature. The projectiles were polycarbonate cylinder with a stainless steel head. Stainless steel (SUS304) or brass sample holders were placed in the target chamber. Twenty shock experiments were conducted (Table 1). Samples' near-infrared (NIR, 1-2.5 μm) and mid-infrared (MIR, 5-15 μm) reflectance spectra were analyzed using a FTIR.

Autodyn Simulation:

Shock pressures and temperatures were estimated numerically under experimental conditions using the Autodyn software package (Century Dynamics, Inc.). Simulations were only done for one nontronite and three montmorillonite samples so far. 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 = $3.5x10^{-3}$ ms for nontronite and $10.0x10^{-3}$ ms for montmorillonite.

Sample	**Projectile Velocities (km s^{-1})**			
Chlorite	2.30	3.59	4.3	
Kaolinite	2.23	3.49	4.32	
Serpentine	2.3	3.51	4.3	
Nontronite	2.07	2.15	2.47	3.27
Montmorillonite	2.25	2.56	3.66	4.49
Prehnite	2.32	3.5	4.3	

Table 1*: Impact experiment parameters.*

Results:

Samples are referred to by their projectile velocities because it is the measured parameter. As expected, both average and peak temperatures and pressures increased with increasing projectile velocity. In all cases, the simulation showed that the pressure and temperature were not uniform in the sample. The maximum projectile velocity was 4.49 km s^{-1} (montmorillonite sample) which resulted in a peak temperature of ~950°C and a peak pressure of ~15 GPa but the average temperature and pressure were only ~200°C and 0.74 GPa, respectively [10].

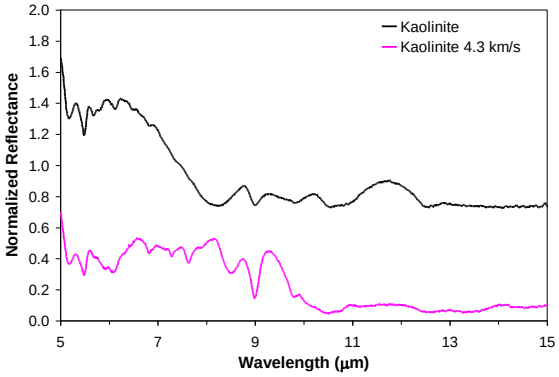

Figure 1: *MIR spectra of untreated and impacted kaolinite.*

Kaolinite: There appeared to be no significant change between the NIR spectra of the untreated kaolinite and the sample impacted with a projectile velocity of 4.3 km s^{-1}. This suggests that the sample did not reach temperatures high enough to significantly alter the sample's mineralogy. In the MIR spectra, although the bands at 5.20, 5.50, 9.02 and 10.6 μm are in both the untreated and impacted spectra, there are significant changes between the two, especially in the 6-8 μm range (Fig. 1). The slope of the spectrum is much flatter in the impacted

sample and new bands have formed at 6.85, 7.31 and 7.65 μm. This suggests there is alteration material present along with unaltered sample, although the alteration material is not evident in the NIR spectrum.

Serpentine: Figure 2 shows the NIR spectra of untreated serpentine and serpentine impacted with a projectile velocity of 4.3 km s^{-1}. The overall spectrum of the impacted sample is very similar to that of the untreated sample. However, there are new bands that have formed at 2.0 μm and a doublet at 2.12-2.14 μm. The MIR spectra of the two samples are quite different (Fig. 3). The bands at 5.60, 6.15, and 8.36 μm have disappeared while new bands appear at 9.28, 11.3, and 13.4 μm. These differences in the NIR and MIR spectra are evidence of secondary phases forming due to the high temperatures and high pressures reached during the impact.

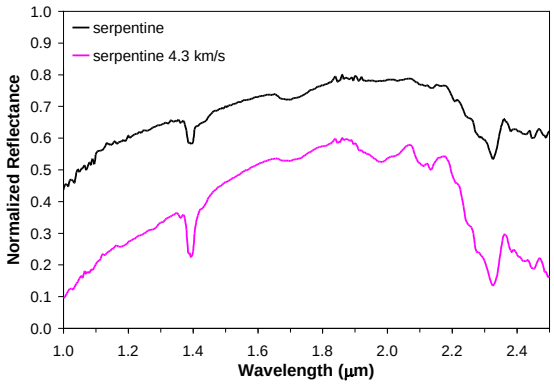

Figure 2: *NIR spectra of untreated and impacted serpentine.*

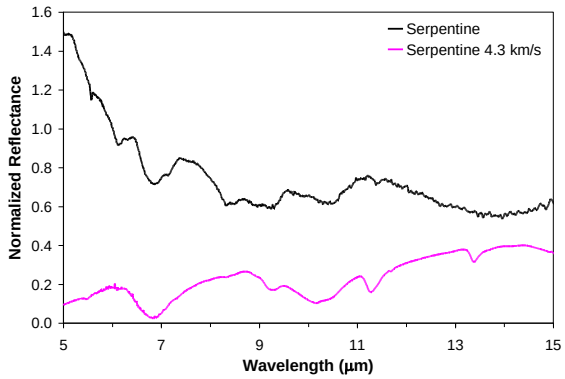

Figure 3: *MIR spectra of untreated and impacted serpentine.*

Prehnite: There seemed to be no significant change in the NIR spectra between the untreated prehnite and the sample impacted with a projectile velocity of 4.3 km s^{-1}. The only apparent change was the slope of the impacted spectrum became more negative at wavelengths above ~2.2 μm. However, the MIR spectra of the two samples are very different (Fig. 4). In the impacted spectrum, all bands in the 5-8 μm range have disappeared and two new bands have formed at 12.1 and 12.9 μm. This suggests there is unaltered material mixed with alteration products that resulted from the impact.

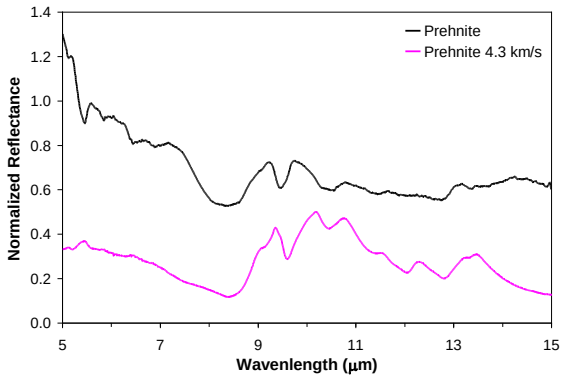

Figure 4: *MIR spectra of untreated and impacted prehnite.*

Discussion and Conclusions:

NIR spectra of even the highest velocity impacts showed no significant change. Only the impacted serpentine samples showed evidence of alteration by the new bands forming at 2.0 μm and a doublet at 2.12-2.14 μm.

Because our experiments used unvented sample chambers, we were able to isolate the effects of shock pressure on the samples. Thus we can conclude that the major changes observed in the MIR spectra are mostly due to the shock pressure in the sample. From our simulations, we found that the highest peak pressure was ~15 GPa but this peak pressure was very localized, resulting in a mixture of unaltered and altered material. This altered material had a strong signal in the MIR spectra of the impacted samples. The presence of new bands in this region indicates the presence of secondary phases as results of the impact pressure, although most bands of the original sample were still present also. This supports the idea that our impacted samples are mixtures of altered and unaltered material.

Clearly, more work in the MIR region is needed in order to identify any secondary phases formed as a result of meteoritic impacts. While minor changes may be detectable in the NIR range, categorization of alteration products can only be done by studying these minerals' MIR spectra.

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References: [1] Poulet, F., et al., (2005) *Nature* 481, 623-627. [2] Bishop, J., et al., (2008) *Science* 321, 830-833. [3] Mustard, J., et al., (2007) *JGR* 112(E08S03). [4] Mangold, N., et al., (2005) *JGR* 112. [5] Fairen, A., et al., (2010) *PNAS* doi: 10.1073/pnas.1002889107. [6] Chevrier, V., et al., (2007) *Nature* 448, 60-63. [7] Naumov, M., (2005) *Geofluids* 5, 165-184. [8] Crozier, W., and Hume, W., (1957) *J. Appl. Phys.* 292. [9] Mieno, T., and Hasegawa, S., (2008) *Appl. Phys. Exp.1* 0607006. [10] Gavin, P., et al., (2010) *LPSC XLI*, abs. #1890.