EXPERIMENTAL INVESTIGATION INTO THE EFFECTS OF METEORITIC IMPACTS ON THE SPECTRAL PROPERTIES OF PHYLLOSILICATES ON MARS. 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: Phyllosilicates have been detected on the surface of Mars by both the OMEGA spectrometer onboard Mars Express and by the CRISM spectrometer onboard Mars Reconnaissance Orbiter [1-3]. These minerals have been found in the Noachian terrains on Mars and 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 impact-induced hydrothermal processes [5,7].

This investigation deals with the effects of shock pressures and temperatures on the spectral properties of phyllosilicates and how these pressures and temperatures may be modeled. Investigating shock effects on phyllosilicates will help determine if clays form 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 gun can accelerate a projectile to about 5 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. Twenty shock experiments were conducted (Table 1). Samples' near-infrared (NIR) reflectance spectra were analyzed using a FTIR in the range 1 – 2.5 µm.

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.

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 one nontronite and three montmorillonite samples. 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 = 3.5×10^{-3} ms for nontronite and 10.0×10^{-3} ms for montmorillonite.

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 (Table 2). In all cases, the simulation shows that the pressure and temperature are not uniform in the sample. Figure 1 shows the pressure and temperature gradients for a montmorillonite sample shocked with projectile velocity = 4.49 km s^{-1}, 1.05×10^{-3} ms after impact.

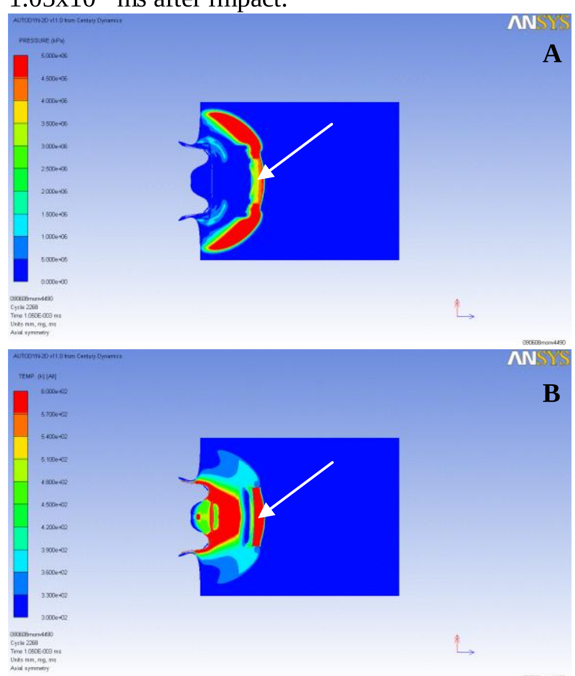

Figure 1: (A) Pressure and (B) temperature gradients in the montmorillonite sample, v = 4.49 km s^{-1}. The white arrows indicate the location of the sample.

Projectile velocity (km s^{-1})	Average Temperature (K)	Peak Temperature (K)	Average Pressure (GPa)	Peak Pressure (GPa)
2.56	352	584	0.40	7.0
3.66	420	926	0.67	11.4
4.49	475	1220	0.74	15.0

Table 2: Maximum and average temperatures and pressures for three montmorillonite samples.

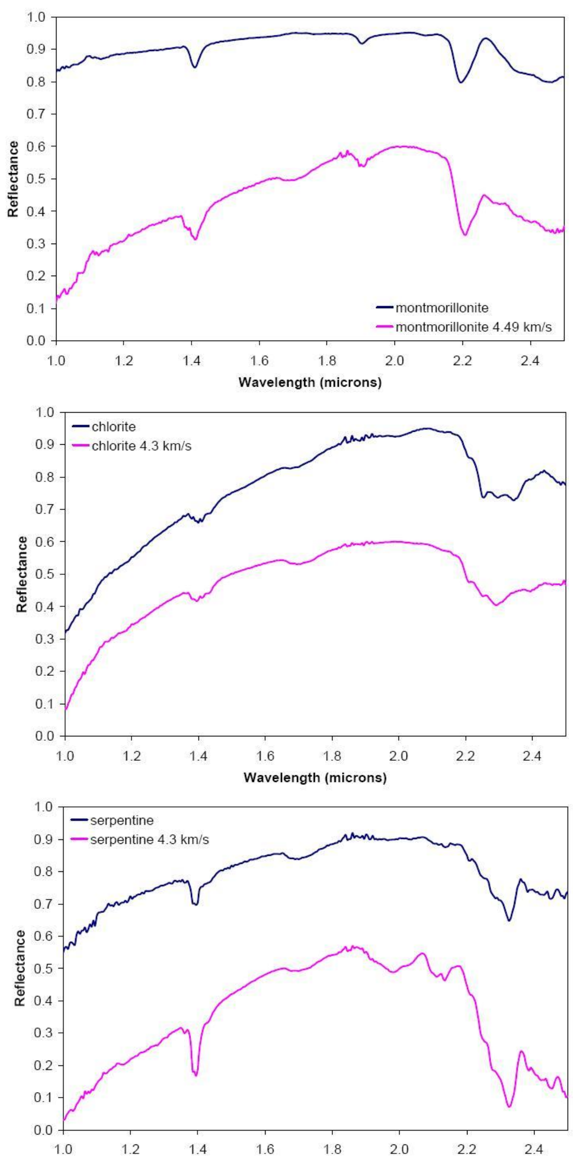

Figure 2: NIR spectra of impacted montmorillonite, chlorite and serpentine compared to untreated samples.

Figure 2 shows the spectra of the untreated samples of montmorillonite, chlorite and serpentine compared to the spectra of impacted samples with highest projectile velocity. The impacted montmorillonite spectrum shows a shoulder feature in the 2.2 μm band and a more positive contiuum slope between 1-2 μm. In the impacted chlorite spectrum, the 2.35 μm band disappears while the 2.26 μm band becomes more shallow and a new band at 2.4 μm forms. In the impacted serpentine spectrum, a new band forms at 2.0 μm and a new doublet forms at 2.12-2.14 μm. The impacted nontronite spectrum shows that 1.9 μm band has deepened and morphed into a shoulder feature. Both the impacted prehnite and kaolinite spectra show no significant change from the untreated spectrum.

Discussion and Conclusions: Even in the highest velocity impacts, we observed no extreme changes in the NIR spectra of our samples. The highest peak temperature reached in the montmorillonite samples was 1220 K (~950^{o}C) which has been shown to significantly alter the mineralogy of montmorillonite and initiate secondary phase formation [10,11]. However, this temperature regime was very localized in the sample so the impacted sample is a mixture of altered and unaltered material. The average temperature in the highest velocity impact was only 475 K (~200^{o}C). This temperature is well below the threshold for significantly altering montmorillonite [10,11]. More analysis, such as X-ray diffraction, is needed to determine the extent of the alteration.

Another factor to consider is that the sample was only heated to these temperatures for times on the order of microseconds whereas the purely heated samples were at high temperatures for hours [10,11]. Time is an important issue when considering thermal alteration of phyllosilicates since a sample will be altered more if heated for longer durations. This would most likely be the case for impacts on the martian surface where the larger impact would leave the subsurface at higher temperatures for much longer timescales (~thousands of years).

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