EFFECTS OF SIMULATED MARTIAN IMPACT HEATING ON REFLECTANCE SPECTRA OF VARIOUS MARS-RELEVANT MINERALS G. M. Berard[1] , E. A. Cloutis[1], and P. Mann[1]. [1]University of Winnipeg, Dept. of Geography, 515 Portage Ave., Winnipeg, MB, Canada, R3B 2E9, berard-g@webmail.uwinnipeg.ca.

Introduction: Asteroidal impacts are among the most widespread processes affecting the surface of Mars [1]. The minerals in shocked materials are sometimes altered by the impact itself, including the release of volatiles such as adsorbed and structural H_2O [2, 3], but mineral alteration can continue to occur after the initial impact due to heating and generation of hydrothermal systems [4,5]. In larger craters, impact-heated hydrothermal systems can have lifetimes of millions of years [4,5]. A wide variety of alteration minerals have been detected on Mars, mostly in Noachian terrains, including phyllosilicates, carbonates, sulfates, and hydrous silica [4], some of which or all of which can be the result of impact-associated processes.

The shock of an impact at a planetary surface is not thermodynamically reversible and therefore waste heat is produced upon decompression which leads to a thermal anomaly of elevated temperatures in the central part of an impact structure of approximately 100°C to 300°C [5, 6]. This heated system, which sometimes includes a hydrothermal component if there is near-surface water, can persist for tens of thousands to hundreds of thousands of years depending on the diameter of the crater and the presence or absence of circulating water [5], [6].

An understanding of the spectral characteristics of minerals altered or formed by such a thermal excursion from impact cratering events is applicable to Mars. Remote sensing instruments including the Compact Reconnaissance Spectrometer for Mars (CRISM) and *Observatoire pour la Mineralogie, l'Eau, les Glaces et l'Activité* (OMEGA) could potentially detect such heat-altered surface minerals in Martian impact craters if they exhibit unique spectral properties. The dehydration of minerals caused by elevated temperatures could result in a reduction in band depth of certain spectral features indicative of adsorbed and structural H_2O and OH^- in the VNIR wavelengths. Possible spectral changes include the ~1.45 μm absorption (OH^- stretch overtone), the ~1.91 μm and ~1.95 μm absorptions (OH^- stretch and H_2O bend combination), and the ~3.0 μm absorption (H_2O stretches and first order overtone of the H_2O bend) [7].

The effects of temperatures similar to those generated by impact-heating (100-300°C); [5], [6], in addition to the presence of a CO_2 atmosphere on a variety of minerals previously identified on Mars, were analyzed in this study using reflectance spectroscopy. A study by Cloutis *et al*. (2008) [8] used reflectance spectroscopy to determine the structural changes in the same suite of minerals after exposure to low atmospheric pressures and high concentrations of CO_2, in an attempt to replicate ambient Mars surface conditions. Spectral changes in the same suite of minerals after exposure to high temperatures and CO_2 were examined and compared to the results of [8] in order to determine whether spectral features of minerals on Mars could be uniquely attributable to impact heating alteration versus exposure to Martian surface conditions.

Methods: The 47 minerals included in this study include a variety of phyllosilicates, sulphates, carbonates, hydroxides, zeolites, and organics known to occur on Mars. Samples were ground by hand in an alumina mortar and pestle, then dry-sieved to a grain size of <45 μm. Fine-grained (<45 μm) samples were used in the majority of cases in order to mimic the fine grain size of windblown dust found on the uppermost Martian surface [9]. Fine-grained samples also maximize the surface area to volume ratio so as to increase the kinetics of any reactions [8]. After sieving, samples were placed in 10-hole, 40 mm diameter aluminum sample disks. Each of the 10 holes was 8 mm in diameter and 6 mm deep.

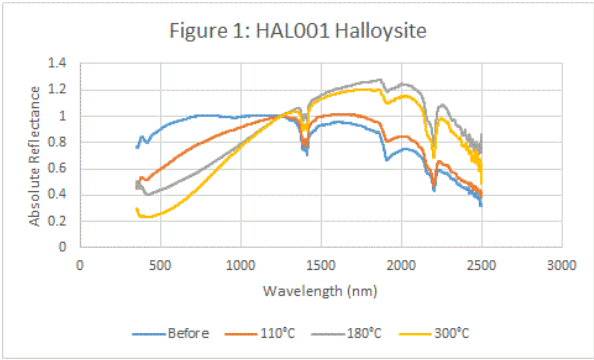
A bifurcated cable attached to a 150 watt light source was used to collect reflectance spectra using an Analytical Spectral Devices (ASD) Spectrophotometer (350-2500 nm). One thousand measurements were averaged per sample, with an incident angle of 0° and an emission angle of 0°. Before spectral analysis, reflectance spectra were corrected for jumps where detectors switch over at 1000 and 1830 nm, using Microsoft Excel, and all spectra were then normalized to 1250 nm.

Reflectance spectra of the unaltered samples were obtained through a 10 mm- thick sapphire window, using an ASD spectrometer equipped with a bifurcated cable, and again without the window. The reflectance spectra of the samples were measured relative to Spectralon. The sapphire window was used because it was used in the original experiments in [8] and it provides <1% absorbance between 0.2 and ~6 μm and the lower-wavelength limit corresponds very closely to the lower transmission limit of the Martian atmosphere [8, 11, 12, 13]. The sample disks were then heated in an oven at 110°C, 180°C, and 300°C. These temperatures

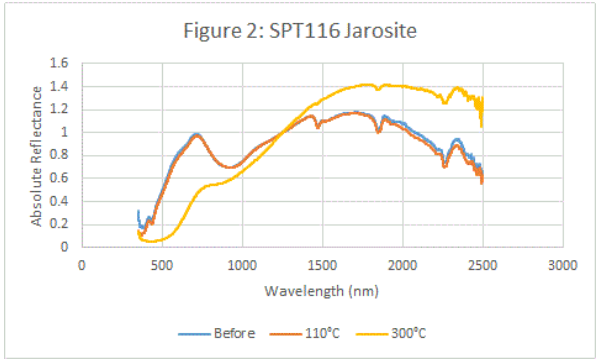
were chosen as they are representative of the range of temperatures that would be found for an extended period of time at an impact site on Mars [5]. Samples were kept at each temperature interval for one week. CO_2 gas was allowed to flow continuously into the oven to create atmospheric conditions similar to those found on Mars and to prevent oxidation of the samples due to terrestrial atmospheric oxygen.

After one week of exposure to each designated temperature and CO_2, reflectance spectra of the samples were obtained once again using the ASD spectrometer, both with and without the sapphire window.

Results and Discussion: Some mineral spectra changed significantly due to increased temperatures and exposure to a CO_2 atmosphere, while others were less affected. Cloutis et al. [8] found that when phyllosilicates were exposed to martian surface conditions, the reflectance spectra showed measurable losses of interlayer H_2O. This was also observed in the present study, as H_2O absorption bands located at 1450 and 1950 nm saw reductions in band depth with increased temperatures (eg. halloysite; Fig.1). This implies that these absorption bands may be shallower in areas affected by thermal, versus areas of Mars minimally affected by impacts (and ambient terrestrial conditions).



Under the experimental conditions used by Cloutis et al. [8], OH-bearing sulfates (eg. alunite, jarosite) showed no measurable change in spectral properties under Mars surface conditions. Similarly, no major changes were observed in the alunite spectra with increases in temperature and exposure to a CO_2-rich atmosphere; however, major changes were observed in the jarosite spectra (Fig.2). Most notably, the band depth of the broad absorption feature due to Fe^{3+} at ~900 nm became broader and shallower between 110°C and 300°C. We hypothesize that this may be due to the reduction of iron to Fe^{2+} by the CO_2 in the oven. Heating at ambient pressure appears to change the depth of the ~900 nm absorption while low pressure alone does not.



Many martian minerals exhibit spectral changes when exposed to increased temperatures representative of those potentially encountered at impact sites when compared to spectra measured under ambient Martian or terrestrial conditions. Understanding these spectral changes could allow for identification of surface exposures on Mars that have been affected by impact events.

Future work: Our analysis of the reflectance spectra is ongoing, and all major absorption bands are being examined for changes in depth and position, and we are also quantifying changes in spectra slope that may be attributable to changes in iron oxidation state in most cases.

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