

**UV-VIS-NIR REFLECTANCE SPECTRA OF SHOCKED CARBONATES FROM THE HAUGHTON IMPACT STRUCTURE, DEVON ISLAND, CANADA: 0.35 – 2.5  $\mu\text{m}$ ; IMPLICATIONS FOR CARBONATE IDENTIFICATION ON MARS.** M. A. Craig<sup>1</sup>, G. R. Osinski<sup>1</sup>, R. L. Flemming<sup>1</sup> and E. A. Cloutis<sup>2</sup>, <sup>1</sup>University of Western Ontario, Department of Earth Sciences, 1151 Richmond St., London, Ontario, N6A 5B7, (mcraig44@uwo.ca); <sup>2</sup>University of Winnipeg, 515 Portage Ave., Winnipeg, Manitoba, R3B 2E9.

**Introduction:** The identification of carbonates on Mars has remained tentative until very recently [e.g., 1–4, 5, 6]. Given that carbonates are present at or near the surface of Mars and appear to be stable in the present Martian atmosphere, it begs the question, why have we only just found them [7]? Is it because they are simply being masked by overlying material or are there other factors that may be intervening to “hide” the carbonates? To this end, we have conducted a preliminary look at the possible spectral effects of hyper-velocity impact-induced shock metamorphism and melting in carbonates from the Haughton impact structure on Devon Island, in the Canadian High Arctic to see if shock processes produce systematic changes in carbonate UV-Vis-NIR spectra.

**Experimental Procedure:** A suite of various carbonate samples from Haughton were gently crushed with an alumina mortar and pestle and dry sieved by hand to produce <45 and 45–90  $\mu\text{m}$  powdered splits. Absolute reflectance spectra were collected with the Analytical Spectral Devices (ASD) FieldSpec Pro HR spectrophotometer at the University of Winnipeg Planetary Spectroscopy Facility (PSF), from 0.35–2.5  $\mu\text{m}$  at phase angles of  $i30^\circ$ ,  $e0^\circ$  using a PSF built 50 watt Quartz-Tungsten-Halogen collimated light source for illumination. Spectra were acquired relative to Spectralon<sup>®</sup> and corrected for minor irregularities in Spectralon's<sup>®</sup> absolute reflectance in the 2–2.5  $\mu\text{m}$  range. Spectral calibration was monitored via periodic measurement of a Holmium Oxide doped Spectralon<sup>®</sup> reflectance standard. The field-of-view (FOV) of the spectrometer was ~ 5 mm.

The ASD instrument has a fixed spectral resolution between 2 – 7 nm and the spectra are interpolated to 1 nm resolution internally by the spectrometer prior to output. Each spectrum shown is the sum of 1000 spectra to increase the signal-to-noise ratio. Spectral measurements were performed at a constant geometry and as a single set such that overall reflectance is a useful metric within the sample set. The spectra were corrected in post-processing for breaks that occur at the 1.0 and 1.83  $\mu\text{m}$  junctions of the three detectors used by the ASD instrument and FOV is given as approximate as the fibre-optic bundle which feeds the spectrometer has a random distribution of fibres at the pick-up end.

Each of the samples was loaded into aluminium sample cups for spectral measurement with sample

well diameters of 10 mm, and depths of 3, 5 or 9 mm. In each instance, samples were loaded into cups with the deepest wells that the available sample volume could fill. Sample loading was performed by lightly tamping the powders into the wells then “cutting” across the top surface with a glass slide.

**Results:** Results are presented in Figures 1 through 5. Spectra of <45  $\mu\text{m}$  splits of a selection of the collected spectra are presented here. The analyzed samples include three carbonate standards, confirmed to be pure samples of dolomite, calcite and aragonite via XRD, and a sequence of Haughton samples: Haughton reference carbonate HMP01-051 (representative of the outlying unaltered in situ carbonate), and three samples of largely similar composition representing increasing levels of shock metamorphism: HMP06-093, HMP99-097A and HMP99-052. HMP06-093 is a black shatter cone, HMP99-097A is a moderately shocked sample of oolitic limestone and HMP99-052 is a highly shocked sample of oolitic limestone.

Band minima for the ~2.33  $\mu\text{m}$  C-O related stretching overtone characteristic of calcite, its polymorph aragonite and dolomite as well as band minima for the Haughton samples were computed with GFit<sup>®</sup> using a 12<sup>th</sup> degree polynomial [7]. Figures 1 and 2 (with spectra normalized to 1 at 2.15  $\mu\text{m}$ ) focus on the ~2.33  $\mu\text{m}$  C-O absorption feature and calculated band minima are as follows: **Dolomite:** 2317 nm; **Calcite:** 2337 nm; **Aragonite:** 2314 nm; **HMP01-051:** 2323 nm; **HMP06-093:** 2337 nm; **HMP99-097A:** 2331 nm; and **HMP99-052:** 2213 nm. Figures 3 and 4 are of the same samples, in the same order, shown in absolute reflectance and Figure 5 (also normalized to 1 at 2.15  $\mu\text{m}$ ) compares the moderately shocked and compositionally very similar to unaltered carbonate from inside the crater (**HMP99-097A** oolitic limestone) with a similar oolitic limestone (**HMP99-052**) that is highly shocked and evidences other products of shock/melt in its spectrum such as silica glass.

**Discussion:** In Figures 1 and 3, HMP01-051 most resembles aragonite with minor calcite as do the samples evidencing low levels of shock in Figures 2 and 4, HMP06-093 and HMP99-097A. Highly shocked HMP99-052, however, differs significantly from the others, as do other highly shocked samples not shown here, with its ~2.33  $\mu\text{m}$  C-O absorption band shifted from an initial 2323 nm, in its moderately shocked

counterpart HMP99-097A, to 2213 nm. It also evidences significant loss of band depth in the ~2.33 and ~2.53  $\mu\text{m}$  C-O stretching related overtone and fundamental bands (Figure 5) along with a bluing of the overall spectral slope and a loss of albedo (Figure 4) [7].

**Conclusion:** It is clear from the spectrum of HMP99-052 (and other samples not shown) that high levels of shock metamorphism and even melting induced by hypervelocity impact significantly affect the reflectance spectra of shocked carbonates. When attempting to identify carbonate deposits on Mars, it is important to remember that a large percentage would likely be shocked to varying degrees and altered; in sample HMP99-052, the reflectance spectrum in the 0.35–2.5  $\mu\text{m}$  range is so altered as to be unidentifiable as carbonate. Without the suite of carbonates from Haughton, HMP99-052, could not be spectrally identified as carbonate if it were a lone sample collected without sister materials that provide it with context. Thus, identification of carbonates on Mars referencing laboratory spectra of pure carbonate samples requires that they be unaltered by impacts and not be masked by overlying material. Our goal is to carry out a systematic study of the effects of shock on the spectral properties of impacts and to provide a library that may aid in the identification of more carbonates on Mars by the community. This work will also aid in the identification of shock effects in carbonates in general, which is of high interest to terrestrial cratering studies.

**References:** [1] Blaney D. L. and McCord T. B. (1989) *JGR*, 94, 10159-10166. [2] Pollack J. B. et al. (1990) *JGR*, 95, 14595-14627. [3] Calvin W. M. et al. 91994) *JGR*, 99, 14659-14675. [4] Hamilton V. E. et al. (2005) *JGR*, 110, E12006. [5] Ehlmann B. L. et al. (2008) *Science*, 322, 1828-1832. [6] Kerr R. A. (2008) *Science*, 322, 32. [7] Cloutis E. A. et al. (2008) *Icarus*, 195, 140-168.

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