USING LASER INDUCED BREAKDOWN SPECTROSCOPY (LIBS) TO ASSESS GEOLOGIC SAMPLES ASSOCIATED WITH A TERRESTRIAL IMPACT STRUCTURE AS AN ANALOGUE FOR FUTURE PLANETARY EXPLORATIONS. Z. E. Gallegos[1], N. L. Lanza[1], H. E. Newsom[1], A. M. Ollila[1], P. L. King[1,2], G. R. Osinski[2], S. M. Clegg[3], R. C. Wiens[3], D. T. Vaniman[3], S. D. Humphries[3], R. E. McInroy[3], P. Lee[4,5,6], [1]Institute of Meteoritics, MSC03 2050, [1]Univ. of New Mexico, Albuquerque, NM 87131, U.S.A. (newsom@unm.edu), [2]Univ. of Western Ontario, Canada, [3]Los Alamos National Laboratory, Los Alamos, NM. U.S.A., [4]Mars Institute, [5]SETI Institute, [6]NASA Ames Research Center, Moffett Field, CA 94035, U.S.A.

Fig. 1. A panoramic view of the field site near Trinity Lake at Haughton Crater, Devon Island, Canada, (image H. Newsom). Distance from the image foreground to the base of the ridge at the center is ~ 9 m.

Introduction: This study aims to evaluate our ability to determine the diversity of geologic materials at a complex impact structure field site using instruments from the Mars Science Laboratory (MSL) payload. Specifically we use imagery and analytical tools, including laser induced breakdown spectroscopy (LIBS), to evaluate the deposits. Deposits on this scale cannot be measured using remote sensing satellites, but can be accessed by in situ rover instruments. The small spot size of LIBS (< $1mm^2$) ideally assesses the nature of the deposits because the individual samples are very heterogeneous. The MSL LIBS instrument will offer quick, localized analysis of materials from a distance of 1.5m to 7 m [1] from the rover. Our samples offer an interesting test in this respect because they are very heterogeneous as a result of impact and alteration processes. LIBS will be an integral part of the MSL's mission, so its analytical potential in a geologic respect must be fully assessed.

Haughton Crater: Haughton Crater is an impact structure located at 75°22'N, 89°41'W, which lies within the Canadian Arctic on Devon Island, Nunavut territory. Devon Island consists mainly of Paleozoic carbonate/sulfate sediments overlying gneissitic basement. The crater, roughly 23km in diameter, is the result of a meteorite impact about 39 million years ago (Late Eocene). With a highly seasonal availability of liquid water as well as a quasi-lack of vegetation to induce weathering, the geologic record of the impact, and the associated deposits have been well preserved by the polar desert environment of the Arctic. Because of this desolate environment, Haughton Crater is used as an analogue site for Moon and Mars studies by NASA and the Canadian Space Agency [2,3].

Field site: This study focuses on an area, ~ 10m x 10m, located at the northeast edge of the crater near a site called Trinity Lake (**Fig. 1**). The data from this study may also be used for future remote field tests [4].

Samples: All 13 samples are all sedimentary carbonate/sulfate materials but vary quite dramatically in appearance as a result of several processes including hydrothermal alteration (**Fig. 2**), impact brecciation (**Fig. 3**), and biologic (epilithic/endolithic) colonization (**Fig. 4**).

Fig. 2. TLH-9, impact breccia of carbonate clasts cemented with iron oxides and coated with a white precipitate mineral.

Mars Science Lab instrument suite: The MSL contains a suite of imaging and analytical instruments that are being simulated with this study. The MastCam consists of two cameras, one medium angle and one narrow angle. Each camera will produce color and multispectral images and will also provide stereoscopic data. The arm mounted MAHLI will acquire full color images down to hand lens scale. The CheMin instrument will provide mineral structural information via X-ray diffraction and limited chemical information with X-ray fluorescence. The APXS provides chemical data and a Peltier cooling allows for analysis of samples during the day. The ChemCam instrument consists of a LIBS device and a remote micro-imager (RMI). LIBS uses a pulsed laser to create a plasma on the surface of the target, which in turn emits light with emission lines at wavelengths characteristic of the constituent species. The RMI will provide high-resolution black and white context images and will be able to confirm locations of the laser pits.

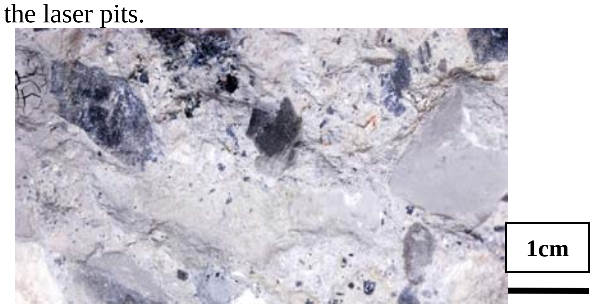

Fig. 3. TLD, a breccia consisting of clasts of the Paleozoic carbonates, with some sulfates and crushed matrix.

Fig. 4 TLH-1, a massive carbonate showing epilithic/endolithic colonization. LIBS laser pits shown by arrows.

Methods: The samples and field images were collected from the field site on an expedition to the crater in the summer of 2008. Field images were obtained by using a zoom lens to simulate the cameras of the MastCam and assembled into panoramic views (**Fig.1)**. The samples were gathered primarily for slow motion field tests for the ChemCam/MSL project. The samples were imaged in the laboratory using a macro-lens to simulate the MAHLI and RMI cameras. The samples were analyzed using LIBS at Los Alamos National Laboratory in the fall of 2009. There, samples are placed in a Mars chamber that maintains ~6 mbar CO_2, and LIBS analyses are done through a quartz window. The laser is a Spectra-Physics Indi Nd:YAG laser operating at 1064 nm, a repetition rate of 10 Hz, and an energy of 17 mJ/pulse was used. Samples were measured at a stand-off distance of 7m. An example of a LIBS spectrum from sample TLH-1 (**Fig. 4**) is inset in **Fig. 6**. A multivariate analysis (MVA) method was used with a set of training standards to analyze and classify the LIBS data, including principal component analysis (PCA). PCA is a measure of spectral similarity; rocks with similar compositions will plot together in PCA space [1]. The samples were compared against one another using the PCA method (**Fig. 5**). The resulting Ca, Mg, and Si abundances were plotted on a ternary diagram from Osinski et al. [3] (**Fig. 6**). The range of our sample compositions lies within the range of the previously plotted Haughton materials.

Conclusions: LIBS is an effective means for discerning the chemical variations in complex impact deposits based on the results achieved in this study.

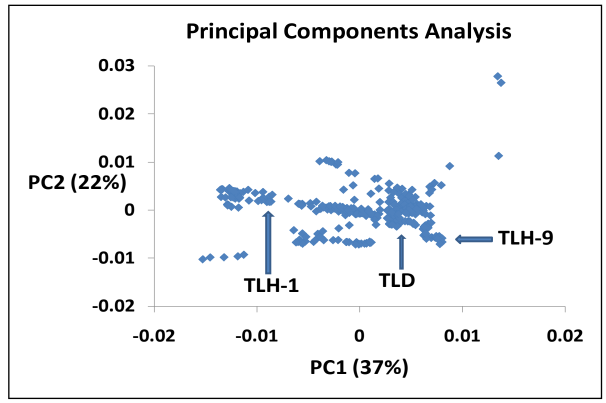

Fig. 5. Principle components analysis graph of samples shown in Figs 2-4, demonstrating the ability of LIBS to distinguish the diversity of materials at this site.

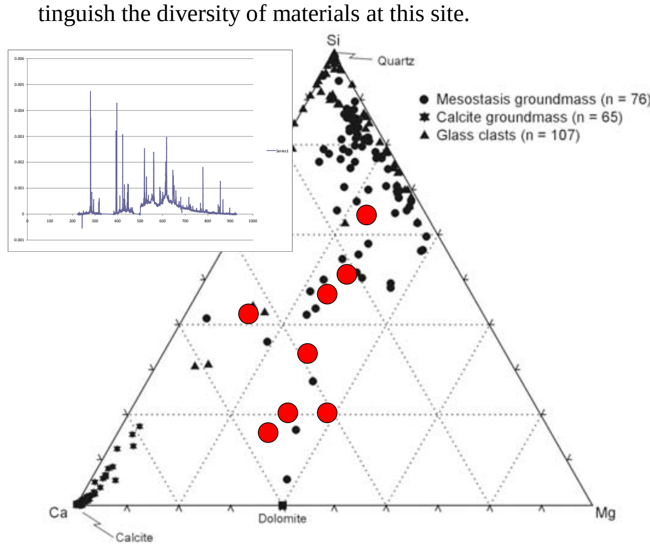

Fig. 6. Ternary diagram [3] showing the range of compositions in Haughton Crater samples. Red represents this study's samples. Inset – spectra of sample TLH-1 (Fig. 4).

References: [1] Lanza N.L. et al (2009) *Calibrating the ChemCam LIBS instrument for the Martian environment*, [2] Lee, P. & G. Osinski 2005. MAPS 40 : 1755-1758. [3] Osinski G. R., et al. (2005) *MAPS* 40:12:1759–1776, [4] Newsom H.E. (2009) LPSC abstract #1446.

Acknowledgements: Supported by NASA MMAMA grant *NNX08AR87G* (HEN), NASA PGG grant NNX 08AL74G (HEN), and NASA/JPL/Los Alamos National Lab/MSL/ChemCam (RCW, P.I., HEN, Co-I), and the NM Space Grant Consortium (Z. E. Gallegos).