INFRARED SPECTRA OF IMPACT PRODUCTS FROM LONAR CRATER: THE EFFECTS OF WEATHERING AND IMPLICATIONS FOR MARS. B. L. Ehlmann[1], J. F. Mustard[1], P. S. Kumar[1,2], [1]Department of Geological Sciences, Box 1846, Brown University, Providence, RI 02912, [2]National Geophysical Research Institute, Hyderabad, India. (bethany_ehlmann@brown.edu)

Introduction: Impact processes have been hypothesized to play a causal role in the creation of regionally extensive spectral units on Mars [e.g. 1, 2], and recent high spatial resolution visible and near infrared data provided by the OMEGA and CRISM instruments show spectral signatures of altered materials in crater walls, central peaks, and ejecta [3-6]. Impact shocking of target materials [2, 7] and impact-induced hydrothermal alteration [e.g. 8] are two mechanisms to induce changes in the crystallinity and mineralogy of target materials. At the ~50 kyr old, 1.8 km diameter Lonar crater, located in central India, both mechanisms appear to have been at work [2, 8]. What has not been investigated is the effect of subsequent weathering.

Lonar impact crater is an excellent Mars analogue in terms of target composition [9] and impact and post-impact modification [10, 11]. Infrared spectral signatures from Lonar crater materials may be similar to those associated with Martian impact craters. Lonar crater rocks experienced widely varying shock pressures [12], and aqueous alteration also varied spatially, particularly as a function of depth, due to gradients in temperature, pressure, and aqueous fluid chemistry. While saponite, celadonite, and carbonate alteration minerals observed in drill cores have been inferred to result from hydrothermal alteration at 130-200°C [8], we focus here on materials with varying degrees of shock which have undergone aqueous alteration at surface ambient temperatures with the idea that these may be the most likely to be exposed on the surface of Mars and detectable from orbit.

Samples and Measurements: Fractured basalt, impact melt rock, and impact glass [13] were collected (Fig. 1):

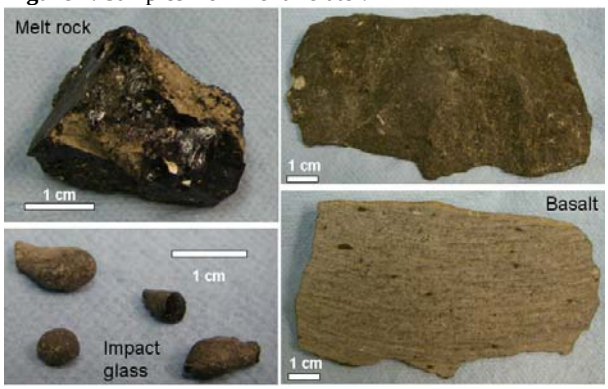
Fractured basalt (Bas): cut and fresh surfaces of fractured, possibly shocked basalt collected ~20 m below the rim on the southeastern wall of Lonar crater with.

Impact melt rock (Melt): mostly aphanitic vitrified sample with apparent flow features and a few included crystalline clasts of basalt. Natural surfaces are rougher and higher albedo, probably due to weathering. Broken surfaces appear dark and unweathered. A brownish rind or cemented coating can be found on part of the sample, collected from ~150 m ESE of the crater rim.

Impact glass (Gl): few mm to cm sized teardrop shaped, tektite-like clasts with weathered exteriors and dark, glassy interiors, collected near the melt rock.

Hand samples were measured with a portable ASD spectrometer with a contact probe attachment and bare fiber optic to obtain spectra from 0.4-2.5 µm (Fig. 3). Sample chips and powders were also prepared from these (Table 1) for measurement with the biconical FTIR instrument in Brown's RELAB facility (Fig. 2).

Figure 1. Samples from Lonar crater.



Results and Discussion: FTIR basalt spectra have absorptions at 1.0 and 2.0 µm, typical of pyroxene and glass spectra show characteristic absorption features at somewhat shorter wavelengths. FTIR spectra show minimal evidence of alteration, and imply initial impact-produced materials are extremely dry. At 3 and 6 µm, fundamental absorptions due to H_2O are completely absent in the melt rock chip (Melt_fresh) and only a weak 3 µm feature, perhaps due to absorbed water, is present in the interior of the impact glass (Gl_int; Fig. 2). The weathered surfaces of these along with all basalt samples show significant absorptions near 3.0 and 6.0 µm along with subtle 1.9 µm bands, indicative of H_2O and occasionally 2.3 µm bands indicative of Fe/Mg smectite clays.

Using the fiber optic to investigate different toned surfaces of the cut and natural basalt surfaces shows considerable heterogeneity at the mm-scale of the fiber optic and much more evidence for aqueous alteration (Fig. 3a). Both surfaces contain a relatively unaltered component where mafic bands are still present. Other portions are considerably more altered showing deep 1.9 µm bands from structural H_2O and 1.4 µm bands due to OH. Ferric absorptions are found at 0.52 and

0.63 µm as well as absorptions at 2.3 and 2.2 µm characteristic of Fe/Mg- and Al- smectites.

Systematic changes in the spectral shape of melt rock glasses appear to occur with enhanced weathering (Fig. 3b). The absorption at 1.9 µm deepens and sharpens; the absorption at ~1.4 shifts longward from 1.38 to 1.41 µm; the absorption at ~2.2 µm becomes sharper. The glass bands seen in Fig. 2 disappear as the ferric slope strengthens and the continuum begins to slope downward from l.0 to 2.5 µm. The brownish coating/rind spectra resembles that of palagonite with a sharp L-shaped absorption at 2.20 µm.

Table 1. FTIR sample descriptions

Name	Description
Gl_nat	chip of natural impact glass surface
Gl_int	chip of impact glass interior, broken in lab
Melt_brown	chip of impact melt rock surface, from brown material
Melt_fresh	chip of impact melt rock surface, from vitrified interior, broken in lab
Melt_45-75	45-75 µm particle size separate of impact melt rock vitrified interior
Bas_weath	chip of natural fractured basalt surface
Bas_cut	chip of cut fractured basalt surface
Bas_45-75	45-75 µm particle size separate of basalt

Implications and Future Work: Lonar crater alteration minerals appear comparable to those found associated with Martian craters, e.g. 2.3 µm bands probably due to Fe/Mg-OH in smectite and broad 2.2 um features characteristic of weathered glasses [4, 5, 14]. A somewhat puzzling observation is that evidence of alteration is more apparent at larger spatial scales of measurement. Nevertheless, FTIR spectra convincingly show melt rock and glass samples are initially very dry and weathering post-impact creates water and hydroxyl absorption features in spectra. Sampling a larger suite of Lonar glassy materials may allow tracking the sequence of changes in spectral properties as a function of weathering extent. Collected spectra are representative of the combined, time-integrated effects of shock and aqueous alteration and by combining spectral and petrologic data, information on the relationship between these two processes can be obtained.

References: [1] Mustard, J.F. and Schultz, P.H., *JGR* 109, E01001. [2] Wright, S.P. et al. (2004*) 2nd Conf. on Early Mars*, Abs. #8067. [3] Poulet, F. et al. *Nature* 438, 623-627 (2005). [4] Swayze, G.A. et al., 2007, *7th Mars Conf.* Abs. #3384. [5] Ehlmann, B.L. et al., this conf., [6] Mustard, J.F. et al., submitted, *Nature*.[7] Johnson, J.R et al. (2007) *Am. Min.* 92, 1148-1157. [8] Hagerty, J.J. and Newsom, H.E. (2003) *Meteoritics & Planet. Sci* 38, 365-381. [9] Bandfield, J.L. (2000). [10] Fudali, R.F. et al. (1980) *Moon & Planets* 23, 493-515. [11] Kumar, S. (2005) *JGR* 110, B12402. [12] Kieffer, S.W. et al. (1976) *Proc. Lunar Sci. Conf.*, 1391-1412. [13] Son, T. and Koeberl, C. (2007) *GFF* 129, 161-176. [14] Milliken, et al., this conf. [15] Bishop, J.L. et al. (1998), *Meteor. & Plan. Sci*., 699-707.

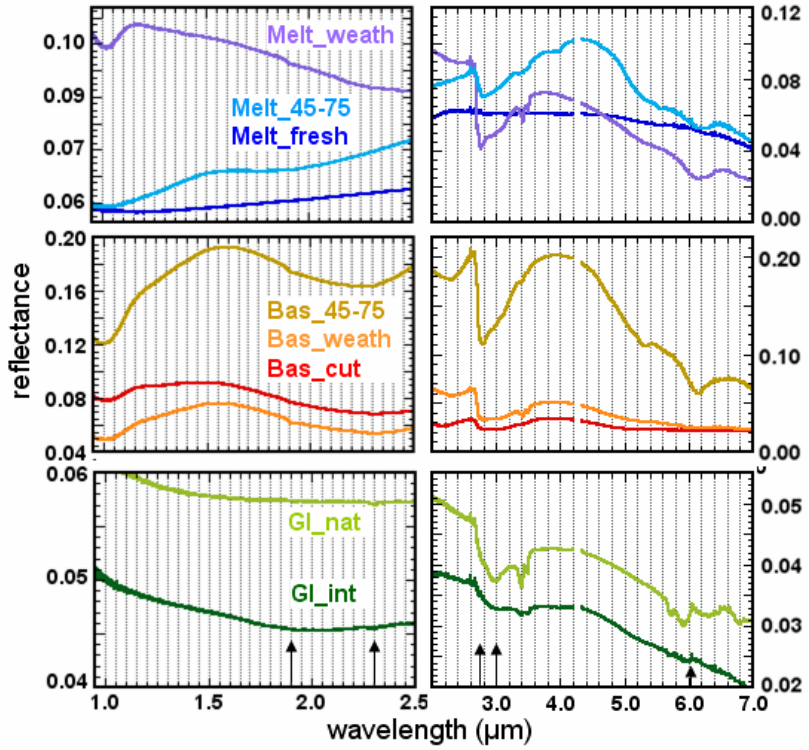


Figure 2. FTIR spectra of materials in Table 1. Arrows indicate absorptions discussed in the text. The feature at 3.4 um is possibly due to contamination as discussed in [15].

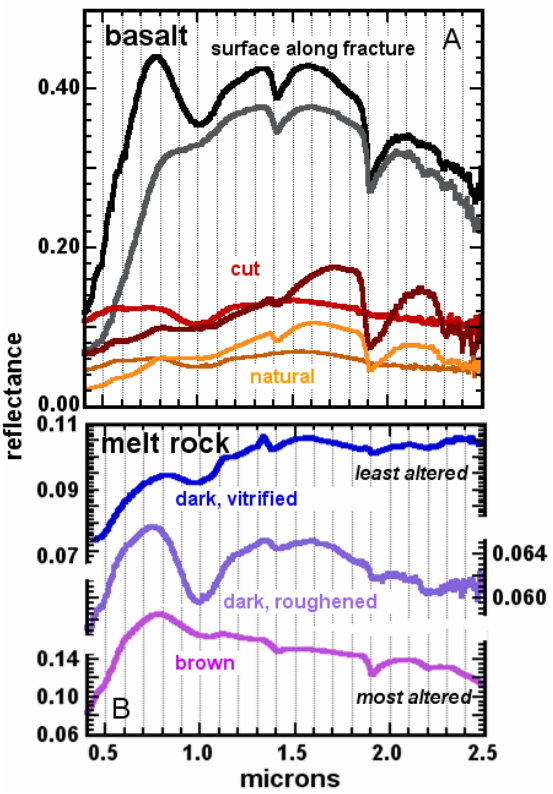


Figure 3. ASD spectra (A) of spots on the basalt surfaces with the fiber optic (B) on the impact melt rock with the contact probe