

VISIBLE, NEAR-, AND THERMAL INFRARED SPECTROSCOPY OF SHOCKED AND HYDROTHERMALLY ALTERED BASALT FROM LONAR CRATER, INDIA: IMPLICATIONS FOR CURRENT AND FUTURE MARS DATA SETS

S.P. Wright¹, W.H. Farrand², and H.E. Newsom³, S. Misra⁴, and V.L. Narasimham⁴, ¹Department of Geological Sciences, Arizona State University, Tempe, AZ 85287, ²Space Science Institute, Boulder, CO 80301, ³Institute of Meteoritics, Univ. of New Mexico, Albuquerque, NM 87131, ⁴Department of Geology and Geophysics, Indian Institute of Technology, Kharagpur- 721 302, India. Shawn.P.Wright@asu.edu

Introduction: The surface of Mars likely consists of basalt that has been shock metamorphosed by meteorite impact [1,2]. A fraction of the Martian soil may be derived from impact produced glass particles and shocked minerals. Alteration processes have likely been involved in the soil formation process, including palagonitization of the glass and aqueous and hydrothermal alteration of the impact materials [3-5]. Hydrothermal processes may also be partially responsible for the high mobile elements, including S and Cl in the martian fines. Hydrothermal deposits, both impact and volcanic may be important places to look for evidence of life on Mars. These impact related processes would have most important early in Mars history, when the impact rate was highest.

Because impact melts and hydrothermal alteration are a product of the target rocks [1-3], it is necessary to study these materials at a rare terrestrial impact crater that was emplaced into basalt [5,6]. In this study, laboratory visible and near-infrared (VNIR) and thermal infrared (TIR) data of soils, impact melts, and hydrothermally altered basalt from Lonar Crater, India are analyzed in preparation for detecting and sampling similar products with current and future Mars data sets from landers and orbiters. Laboratory spectroscopy of Lonar Crater samples and associated analyses of orbital multispectral images of Lonar Crater may prove useful to the interpretation of VNIR and TIR data from instruments on the surface of or orbiting Mars.

Background: Results from the Thermal Emission Spectrometer (TES) on the Mars Global Surveyor (MGS) indicate that the >99% of the upper 100 μm of low albedo (non-dusty) surfaces are composed of basalt (Surface Type 1) and andesite or weathered basalt (Surface Type 2) [7-9]. The dual interpretation of Surface Type 2 (ST2) is due to the similarity between emittance spectra of glasses and clays in the TIR wavelength regions available for surface information. Due to the igneous nature of the Martian surface, the glass is interpreted to be volcanic glass [7,8]. This study intends to examine the TIR spectra of impact melts and glasses generated from basalt that is analogous to Surface Type 1 (ST1) [7,10] to determine if this provides constraints on the nature of the Martian surface. The possibility of impact-generated rocks on Mars have been noted at the first four landing sites [11-14]. However, shocked rocks and impact glasses have only recently been discussed as contributing to the remote sensing of Mars [2, 15].

Lonar Crater, India: Lonar Crater has a diameter of 1.8 km, an estimated age of ~52 ka, and is one of just two terrestrial impacts (of ~180 known) emplaced in basalt [16,17]. Previous studies have identified Deccan basalt, the target rock of Lonar Crater, to be an excellent Mars analog [5-7,10]. The laboratory TIR spectra of sand-sized particulates of Deccan basalt compares favorably to orbiter spectra of the surface of

Mars that has been interpreted as basalt [7,10]. Further, the geochemistry of Deccan basalts has been shown to be compositionally similar to martian meteorite basalts (shergottites) [5,18,19] containing higher quantities of Fe and lower Al than most terrestrial basalts. As a terrestrial analog, Lonar Crater has been studied regarding hydrothermal alteration [5] and Lonar shocked and unshocked basalt were studied petrographically [20] to compare to lunar basalts [21].

Remote sensing of terrestrial impact sites in arid regions have implications for Mars [22], but remote sensing of Lonar Crater is difficult. Abundant vegetation, urbanization, and a saline lake have obscured the underlying basalt and impact melt sheet of the crater rim, ejecta, and floor. However, there are select pixels where vegetation is absent or low (~5-10%) and soil and rock properties can be collected remotely. These pixels and associated ground-truthing provide ideal locations to assess the accuracy of VNIR and TIR remote sensing of basaltic impactite deposits.

Spectroscopy of shocked minerals: The composition of impact melt depends upon the composition of the target rock [1]. Previous studies have shown that experimental shock alters the TIR spectra of anorthosite [23], albitite [24], orthopyroxenite [23], and basalt [25] and the VNIR spectra of plagioclase feldspar [27]. The effects of increasing experimental shock pressures (17–57 GPa) on the TIR spectra of recovered chips and powders were quantified where compared to the TIR spectra of the original, unshocked sample. The implications for the deconvolution and interpretation of TIR data of Mars were noted [23] and measured [24].

VNIR Reflectance Spectra: Figure 1 shows three rock spectra and Figure 2 shows three soil spectra from Lonar Crater. The L-75 sample spectrum shows a “standard” basalt with a strong 1 μm absorption attributable to clinopyroxene and a weaker broad 2 μm absorption. The L-60G spectrum is of a moderately shocked basalt. Its overall reflectance is higher and while it still displays the 1 μm pyroxene band, it also displays evidence of some hydration (weak 1.4 and 1.9 μm bands) and a broad absorption centered at 2.25 μm which is tentatively assigned to a Si-OH absorption. The L-60C sample spectrum is of a melt and is very low in albedo with virtually no spectral character in the VNIR, agreeing with previous work [26]. The three soil spectra in Figure 2 also have a 1 μm pyroxene band, display deeper water bands (increased hydration) and have weak cation-OH bands in the 2.2 to 2.3 μm region. The L-83 soil has a stronger 2.3 μm absorption consistent with a Mg-OH absorption from a mineral such as saponite. The L-91 soil has a stronger 2.2 μm absorption consistent with an Al-OH absorption from a mineral such as illite or montmorillonite.

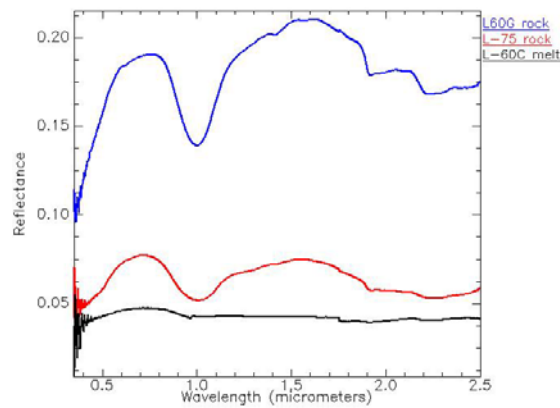


Figure 1

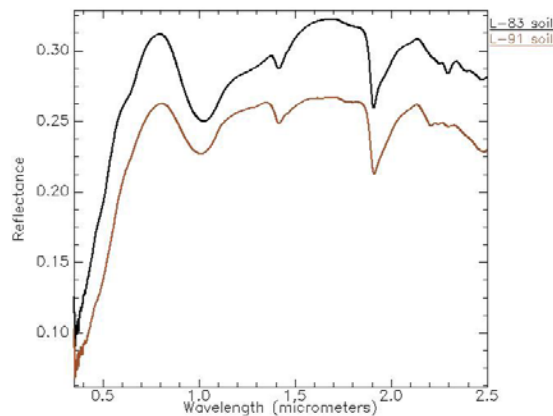


Figure 2

Thermal Emission Spectra: TIR spectra of the unshocked drill cores are flood basalts that have identical spectra to earlier TIR spectra of Deccan basalts compared to ST1 [7,10] (Figure 3). TIR spectra of impact melts and glasses are shown in Figure 4. The spectra of the Lonar glass and shocked melt are similar to that of ST2 from ~ 1200 to 960 cm^{-1} . Most glasses have a “V-shaped” absorption in this spectral region. However, it should be noted that the center of the Lonar glass absorption feature is located at or near ~ 1060 cm^{-1} , and this is identical to that of ST2. This suggests that basaltic impact glass might be a component of certain ST2 pixels. The amount of impact melt and distribution of impact glass ejecta on Mars have been estimated [3,2]. Deconvolutions of the Lonar impact glass and TES ST2 with shocked plagioclase feldspar (from [24]) included in the spectral library have detected this end-member at high abundances, which suggests that shocked calcic plagioclase feldspars should be included into spectral libraries used to deconvolve TIR data of Mars [6, 15].

Conclusions and Future Work: Both the VNIR and TIR spectra exhibit spectral changes where the Deccan basalt has been shocked. This agrees with the previous studies that quantified these bands [23-26]. Future studies will continue to analyze materials from Lonar Crater and remote sensing and field work will constrain the exact locations of these materials within the rim and ejecta blanket. These studies will complement previous works [5,6,23-26] and may provide insight into the interpretation of VNIR and TIR data of Mars.

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References: [1] Bouska and Bell (1993), *JGR*, 98(E10), 18719-18725. [2] Schultz and Mustard (2004) *JGR*, 109, E01001, doi:10.1029/2002JE002025. [3] Newsom (1980), *Icarus*, 44, 207-216. [4] Newsom (2004), *Space Technology and Appl. Int. Forum 2004*, 931-937. [5] Hagerty and Newsom (2003) *MaPS*, 38, 365-381. [6] Wright *et al.* (2004) *LPSC XXXV*, #1495. [7] Bandfield *et al.* (2000) *Science*, 287, 1626-1630. [8] Hamilton *et al.* (2001) *JGR*, 106, 14733-14746. [9] Wyatt and McSween (2002) *Nature*, 417, 263-266. [10] Christensen *et al.* (2000) *JGR*, 105(E4), 9609-9621. [11] Mutch *et al.* (1977) *JGR*, 82, 4452-4467. [12] Moore *et al.* (1979) *JGR*, 84, 8365-8377. [13] McSween *et al.* (1999) *JGR*, 104(E4), 8679-8715. [14] Grant *et al.* (2004) *Science*, in press. [15] Staid *et al.* (2004) *LPSC XXXV*, #1778. [16] Fredriksson *et al.* (1973) *Science*, 180, 862-864. [17] Fudali *et al.* (1980) *The Moon and Planets*, 23, 493-515. [18] McSween (1994) *MaPS*, 29, 757-779. [19] McSween (2002) *MaPS*, 37, 7-25. [20] Kieffer *et al.* (1976) *7th LPSC*, 1391-1412. [21] Schall and Hörz (1977) *8th LPSC*, 1697-1729. [22] Ramsey (2002), *JGR*, 107(E8), doi 10.1029/2001JE001827. [23] Johnson *et al.* (2002) *JGR*, 107 (E10), doi:10.1029/2001JE001517. [24] Johnson *et al.* (2003) *Amer. Min.*, 88, 1575-1582. [25] Johnson and Hörz (2003) *AGU Fall*, P21B-0053. [26] Johnson and Hörz (2003) *JGR*, 108(E11), doi:10.1029/2003JE002127.

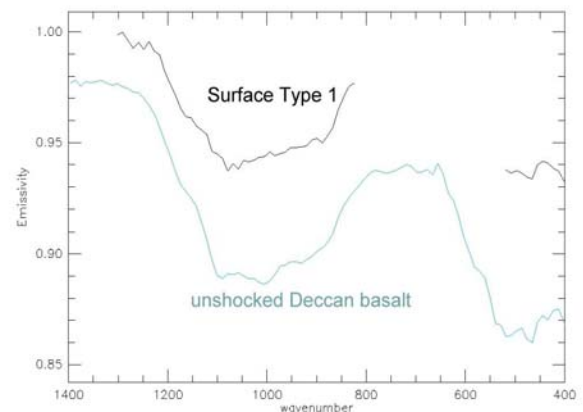


Figure 3

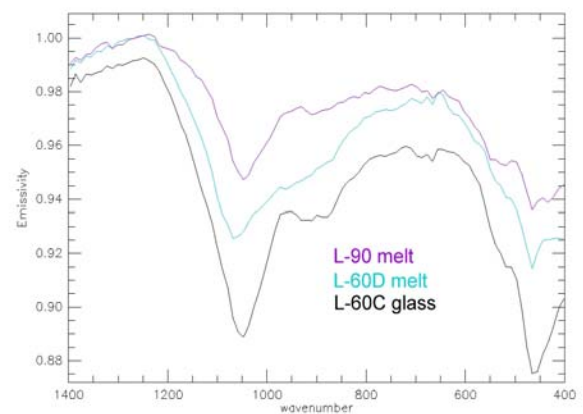


Figure 4