THERMAL EMISSION SPECTRA OF IMPACT GLASS AND SHOCKED DECCAN BASALT FROM LONAR CRATER, INDIA AND IMPLICATIONS FOR REMOTE SENSING OF MARS.

S. P. Wright[1], J. R. Johnson[2], and P. R. Christensen[1], [1]Department of Geological Sciences, Arizona State University, Tempe, AZ 85287, [2]United States Geological Survey, Flagstaff, AZ. Shawn.P.Wright@asu.edu, jrjohnson@usgs.gov

Introduction: It has been shown that impact shock alters specific absorptions of the thermal infrared (TIR) spectra of plagioclase feldspars and, to a lesser extent, orthopyroxene [1-3]. This is due to the depolymerization of the silica tetrahedra with increasing pressure. In those studies, igneous lithologies were experimentally shocked to various degrees and the implications for the deconvolution and interpretation of TIR data from Mars were noted. In this study, laboratory sample emission spectra of localized Deccan basalts and impact glasses are analyzed in preparation for field work, sample collection, and further analyses at their source region – Lonar Crater, India. Thermal emission spectra of Lonar samples may prove useful to the interpretation of TIR data from instruments on the surface of or orbiting Mars.

Background: Analyses of global TIR data from the Mars Global Surveyor (MGS) Thermal Emission Spectrometer (TES) has yielded the identification and interpretation of two surface spectral end-members [4]. Surface Type 1 (ST1) is widely accepted to be basalt, whereas Surface Type 2 (ST2) is disputed to be either andesite [4, 5] or weathered basalt [6]. Other potential interpretations of ST2 include oxidized basalt [7, 8], palagonite [9], secondary zeolite [10], or silica coatings [11]. Recent work has argued for the dual interpretation of ST2 [12] that is a function of the geologic landscape of the region under study. The object of this study is not to argue for a specific interpretation of the nature of ST2, but rather to examine the TIR spectra of impact glass generated from the impact shock of flood basalt to determine if these data provide constraints on the nature of ST2.

The possibility of impact-generated rocks on Mars have been noted at the first four landing sites, which occurred on flood plains (Viking 1, Pathfinder), Mie Crater ejecta (Viking 2), and a potential lake bed (Spirit) [13-16]. However, shocked rocks and impact glasses have only recently been discussed as contributing to the TIR remote sensing of Mars [1-3, 17]. Estimates on the occurrence and amount of impact glass have been predicted and compared to ST2 regions [17].

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) that is emplaced in basalt [18,19]. Previous studies have identified Deccan basalt, the target rock of Lonar Crater, to be an excellent Mars analogue. 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 [4, 20]. Further, the geochemistry of Deccan basalts has been shown to be compositionally similar to martian meteorite basalts (Shergottites) [21-23] concerning higher quantities of Fe and lower Al than most terrestrial basalts.

As an analog for Mars, Lonar Crater has been studied in detail regarding the potential hydrothermal alteration [23] and Lonar shocked and unshocked basalt were studied petrographically [24] to compare to lunar basalts [25]. In the earlier studies, it was found that higher degrees of shock metamorphism resulted in increased modal percentages of SiO_2 [24,25], as determined by X-ray fluorescence. This could have implications for APXS findings at the Pathfinder landing site [15]. Further, naturally-shocked Lonar basalt had different petrographic properties than experimentally-shocked Deccan basalt [24], and this may affect the TIR spectra. The difference is attributed to the difference in the duration of the shock wave, which reaches 1 sec in nature as opposed to 1 μsec in laboratory experiments. The surface of Mars likely consists of local amounts of shocked basalt, as SNC meteorites used for acquisition of thermal infrared spectra have been shown to contain maskelynite and impact glasses that are indicative of shock metamorphism [26, 27].

TIR remote sensing of select terrestrial impact craters such as Meteor Crater, Arizona has applications to Mars [28, 29], but TIR remote sensing of Lonar is not useful. Abundant vegetation, urbanization, and a saline lake have obscured the underlying basalt of the crater rim, ejecta, and floor. As a result, TIR studies of Lonar Crater will focus on detailed field work and laboratory spectra of Lonar samples. The application of laboratory data of impact-related materials to the remote sensing of Mars is the long-term goal of the previous studies [1-3, 30, 31] and this one.

Comparison to Previous Work: This project has a different approach from previous studies [1-3, 31]. In those works, 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 lithologies examined include albitite [2], anorthosite [1], orthopyroxenite [1], and basalt [3]. Visible and near infrared spectra of the plagioclase feldspars (from [1,2]) were also analyzed [30]. The implications for the deconvolution of TIR data were noted [1] and measured [2, 31]. For this work, four samples from Lonar Crater were acquired, but their specific locations and natural shock pressures are unknown. However, because the target rock has been suggested to be analogous to Mars ST1 basalt [4, 20] and the noted petrographic differences between natural shock and experimental shock [24], emissivity spectra of various surfaces of each sample were acquired.

Sample Emission Spectra: Spectra of four samples from Lonar Crater were acquired using the Nexus 670 TIR spectrometer at Arizona State University. TIR data were acquired from 2000 – 200 cm^{-1} (5 – 50 μm) with 4 cm^{-1} spectral resolution. The emissivity data was resampled to a spectral resolution of 10.58 cm^{-1} and compared to selected TES spectral regions (73 bands from 1301 – 825 cm^{-1}, 508 – 232 cm^{-1}). Three of the samples are flood basalts and have identical spectra to earlier TIR spectra of Deccan basalts that are comparable to ST1 [4, 20]. These are not shown here. Four TIR spectra of the fourth sample, an impact glass, are shown in Figure 1 and compared to TES ST1 and ST2 spectra (from [4]). The spectra of the Lonar glass is similar to that of ST2 from ~1200 to 960 cm^{-1}. This is not unusual, as most glasses have the "V-shaped" absorption in this spectral region. However, it should be noted that the center of the Lonar glass absorption feature is located at ~1055 cm^{-1}, and this is identical to that of ST2. At lower wavenumbers (400 – 232 cm^{-1}), the spectra of the Lonar glasses exhibits absorptions due to water vapor, so this region is excluded from the plots. Future spectral acquisitions will attempt to remove this hinderance from the TIR spectrometer. The purpose of this study and the figure is not to suggest that ST2 is composed entirely of basaltic impact glass. It is unlikely that a TES pixel, with 3 km spatial resolution, would precisely match a laboratory sample emission spectra. Rather, this comparison suggests that basaltic impact glass might be a component of certain ST2 pixels. Multiple interpretations of the nature of ST2 have been suggested [12], and the distribution of impact glass ejecta on Mars has recently been estimated [17]. Finally, recent deconvolutions of ST2 spectra with shocked plagioclase feldspar (from [1,2]) included in the spectral library have detected this end-member at high abundances, which suggests that shocked plagioclase feldspars should be included into spectral libraries used to deconvolve TIR data from Mars [31].

Conclusions: The objective of this study is to collect and report on the sample emission spectra of basaltic impact glasses and evaluate these as a possible interpretation of TIR spectra of Mars. A secondary objective is to introduce Lonar Crater, India, a terrestrial crater in Deccan Traps flood basalt, as a viable analog for martian impact craters with respect to target rock composition and the production and composition of impact glasses. Future studies will include the analyses of impact glasses, impact melts, and shocked basalt from Lonar Crater and field work will constrain the exact locations of these materials within the rim and ejecta blanket. These studies will complement previous works [1-3, 31] and may provide insight into the interpretation of TIR data of Mars.

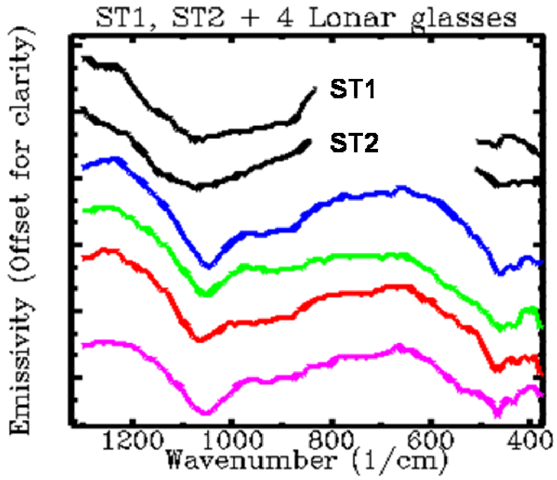

Figure 1. MGS TES spectra of the martian surface is shown with 4 sample emission spectra of impact glass from Lonar Crater

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