THERMAL INFRARED SPECTROSCOPY OF BASALT FROM LONAR CRATER, INDIA: IMPLICATIONS FOR THE REMOTE SENSING OF IMPACT CRATERS ON MARS

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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 processes, including palagonitization of the glass and aqueous and hydrothermal alteration of the impact materials [3-5]. Locating shocked materials [1,2], impact melts [3], and potential hydrothermal alteration [4,5] would prove that impact and post-impact processes have contributed to the Martian surface.

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 thermal infrared (TIR) data of impact melts, impact glasses, 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 may prove useful to the interpretation of 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 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]. Whereas it is unikely for all occurences of ST2 to contain impact glass [6], 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 interpretations of ST2.

The possibility of impact-generated rocks on Mars have been noted at the first four landing sites, which occurred on impacted flood plains (Viking 1, Pathfinder, Spirit) and Mie Crater ejecta (Viking 2) [11-14]. Further, the possible role of shocked glass in the martain soil has been predicted [15-16] and it has recently been suggested that these materials contribute to the remote sensing of Mars [2, 17]. Estimates on the occurrence and amount of impact glass have been predicted and compared to ST2 regions [2] and shocked calcic plagioclase feldspar has been detected at significant (13%-16%) abundances in 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) emplaced into basalt [18,19]. 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] (Figure 1). Further, the geochemistry of Deccan basalts has been shown to be compositionally similar to martian meteorite basalts (shergottites) [5,20-21] containing higher quantities of Fe and lower Al than most terrestrial basalts. All shergottites contain maskelynite and other shock features [20-24] that influence TIR spectra [22-24].

As a terrestrial analog, Lonar Crater has been studied regarding hydrothermal alteration [5] and Lonar shocked and unshocked basalt were studied petrographically [25] to compare to lunar basalts [26]. In the earlier studies, it was found that naturally-shocked Lonar basalt had different petrographic properties than experimentally-shocked Deccan basalt [25], 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 [25].

Remote sensing of terrestrial impact sites in arid regions have implications for Mars [27], 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. Detailed fieldwork and sample collection will take the place of remote sensing analyses.

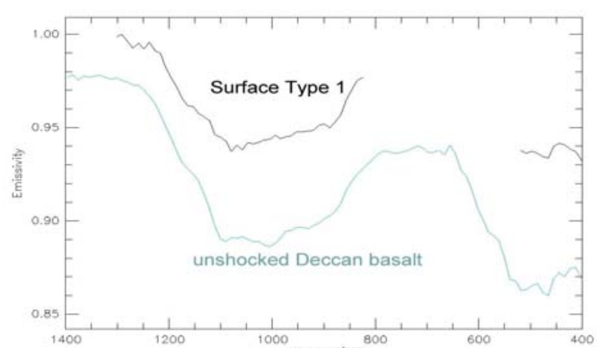

Figure 1

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 [28], albitite [29], orthopyroxenite [28], and basalt [30]. 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 [28] and measured [29]. For this work, impact melts from Lonar Crater were acquired, but their specific shock pressures are unknown. However, because the target rock has been suggested to be analogous to Mars ST1 basalt [7, 10] and the noted petrographic differences between natural shock and experimental shock [25], sample emission spectra of Lonar Crater basalts and impact melts were acquired.

Thermal Emission Spectra: TIR spectra of various impact melts and drill cores from Lonar Crater were acquired using the Nicolet 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. 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 1). TIR spectra of local impact melts and glasses from Lonar Crater are shown as Figure 2. Similar to most glasses and clays, the spectra of the Lonar glasses and melts have an absorption feature in the ~1200 to ~960 cm^{-1} region with an emissivity minimum at ~1060 cm^{-1}. Where ST2, which also shares this absorption feature, is deconvolved with mineral spectral libraries, Si glass and/or Si-K glass (from [31]) or clays [9] are usually chosen by deconvolution algorithms to acount for this absorption feature. The objective of this and future studies of Lonar impactites is to explore the possibility that impact glasses and melts on the surface of Mars contribute to remote TIR spectra that is interpreted as volcanic glass or clay weathering products. Multiple interpretations of the nature of ST2 have been suggested [32], and 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 (maskelynite) (from [28]) 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 [6,17]. Further, understanding the effects of shock on the TIR spectrum might prove useful for locating the source region(s) of the shocked martian meteorite basalts [24].

Conclusions and Future Work: TIR spectra exhibit spectral changes where basalt has been shocked. This agrees with the previous studies that quantified these bands [28-30]. Future studies will continue to analyze materials 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 [5,6,28-30] and may provide insight into the interpretation of TIR data of impact craters on Mars.

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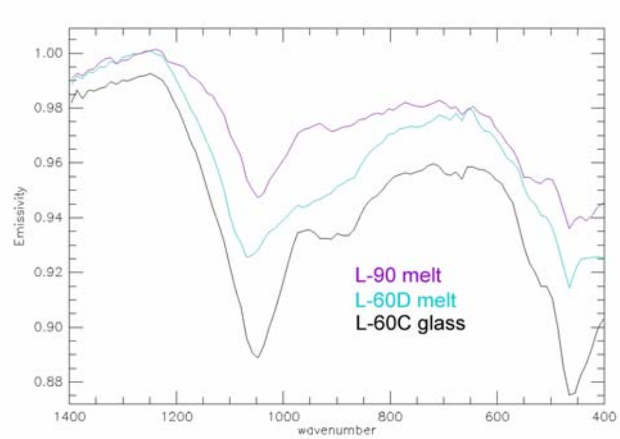

Figure 2