THERMAL EMISSION SPECTROSCOPY OF IRON METEORITES ON EARTH AND MARS – A LABORATORY EVALUATION OF MERIDIANI PLANUM (HEAT SHIELD ROCK).
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Introduction: The discovery of a meteorite on the surface of any planet presents an opportunity to probe the environmental conditions on that world over a time interval likely to be far greater than typical mission operations. In the case of Mars, meteorites may exhibit signs of physical and/or chemical weathering, help to constrain atmospheric conditions during their time of arrival, or provide insights into possible variabilities in meteoroid sampling between Mars-space and Earth-space. The chemical alteration of meteoritic iron to iron oxyhydroxide minerals, in particular, could serve as a useful index to water exposure at the location of the specimen. Meteorites therefore should play a role in the "follow-the-water" strategy of astrobiologic planetary exploration.

At least five rocks confirmed or suspected of having a meteoritic origin have been identified by the Mars Exploration Rover (MER) science team over the course of its four-year-plus mission [1]. Three of these appear to be irons, based on their high reflectivity in the thermal infrared (TIR). Of these, Meridiani Planum (MP; formerly Heat Shield Rock) was examined with the full compliment of instruments on Opportunity's instrument arm (IDD). The meteorite appears to exhibit minimal signs of alteration. However if MP had ever been exposed to water and oxidized as a result, these coatings could have been removed by wind abrasion, but might still be present within its recessed cavities.

A regmaglypt interpretation for the cavities [e.g. 1] implies that they have been present within the surface of the meteorite since its fall, and would have been available to trap any alteration products that might have formed. These cavities also appear to be common sinks for greater than average dust accumulation (Figure 1). Because the effects of extant alteration products may be subtle, and could yet be present beyond the range of IDD instruments but within the field of view of the Miniature Thermal Emission Spectrometer (Mini-TES), we are interested in determining the effects of dust on oxide coatings in the TIR, with an iron meteorite as a substrate.

Background: As in the visible portion of the electromagnetic spectrum, metals are highly reflective in the infrared with significantly reduced thermal emissivities [e.g. 1]. Iron meteorites stand out in this way against the background of indigenous rocks by reflecting downwelling atmospheric sky radiance. Any departure from graybody behavior (the case for an ideal metal) is therefore indicative of 1) the surrounding environment, 2) the morphology of the metal surface, and/or 3) coatings upon the surface. Our work follows on that presented in [2], and is part of a broader program to parameterize TIR spectra for iron meteorites in general with respect to the effects of possible blackbody cavities, dust coatings, and iron oxides. This program is required to finalize our interpretation of Mini-TES spectra for all iron meteorite candidates on Mars.

Figure 1. MP (left) and 10 kg Canyon Diablo sample (right). Note comparable sizes, deeply set cavities, and the heterogeneous dust layer on MP. Could the less wind-abraded portions of MP be harboring dust-coated oxyhydroxides? MP image; NASA/JPL/Pancam.

Martian dust is a problem for all remote sensing because of its ability to obscure underlying surfaces both in the TIR and visible light [e.g. 3]. The extent to which variable dust thicknesses could mask spectral features of an underlying oxide or oxyhydroxide coating on a metal surface are unknown and thus the focus of this study. While MP does not appear to have extensive oxide coatings [1], the possibility exists for these to be obscured by dust within the cavities.

Using the Nexus 670 FTIR interferometric spectrometer at ASU's Mars Space Flight Facility, TIR spectra were collected of a MP analog with Martian dust analog loading in incremental stages to monitor the thermal effects of these subtle differences in a controlled environment. This abstract reports on the effects of dust coatings on an oxidized portion of the Canyon Diablo sample. A parallel phase is underway to characterize this problem for less thermally straightforward bare metal surfaces.

Methods: A 10,195 g sample of the Canyon Diablo meteorite was obtained through the Center for Meteorite Studies at ASU. The sample was selected for its size, oxide coatings, and deep cavities, characteristics that are comparable to those of MP (Figure 1). The sample also has a smooth undersurface for comparison with the cavitied surface, which forms another complimentary phase of this study. The oxide and oxyhydroxide coating has been determined to consist primarily of goethite and maghemite [4].

The Canyon Diablo sample is a IAB coarse octahedrite, implying a possible genetic link to MP, classified as a IAB complex iron [5]. That the two specimens could share a common parent body is an interesting and unusual consideration for our planetary study.

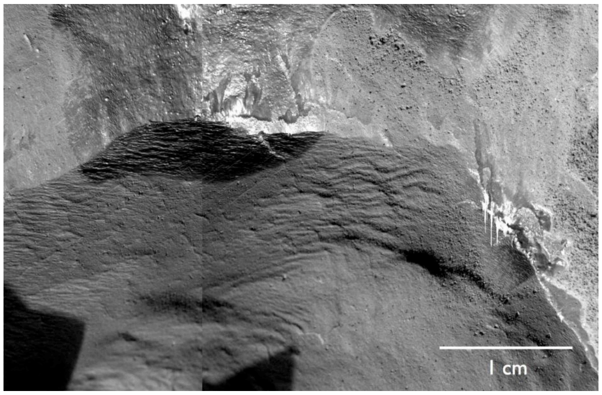

Figure 2. Dust coatings are evident in this Microscopic Imager mosaic of MP. The Rock Abrasion Tool-brushed region can be seen at the upper left-central portion of the image; NASA/JPL/MI.

A dust deposition chamber was employed to coat the meteorite uniformly using the air-fall method of [3]. Aluminum witness sample discs were placed within the chamber to measure dust thickness on a uniform substrate. Palagonitic dust from the summit region of Mauna Kea Volcano, Hawaii, was used as an analog for Mars dust [6]. Dust was applied in increments to a maximum thickness deemed sufficient to obscure radiance of the underlying substrate as demonstrated in [3]. Dust thickness was measured after each application using a micrometer focuser and averaged over five locations. Irregularities in sample morphology on a meteorite of this size can effect positioning repeatability in the sample chamber. Special care was therefore taken to minimize positional shifting between the collection of spectra.

Results: Figure 4 shows the dust thicknesses on aluminum disc witness samples in stages from 0 to ~364 microns. The corresponding spectra are presented in Figure 5. The strong absorption band at ~275 cm^{-1} is present to varying intensities for all but the thickest dust loading, while more subtle features, such as the weak absorption at ~800 cm^{-1}, become indiscernible with even the lightest dusting. As dust thickness increases, all features diminish until they are no longer discnerable, and are replaced by the features of the dust itself. Minor variability in the spectra may reflect both increasing dust thickness, the irregular morphology of the specimen, and or localized clumping of the dust. The thicknesses required to mask spectral signatures of the underlying substrate at all wavelengths is consistent with the findings of [5]. Our results imply that either 1) no significant alteration products are present within the Mini-TES fields of view on MP, or that 2) the dust layers coating the cavity interiors are likely to be greater than ~360 microns in thickness.

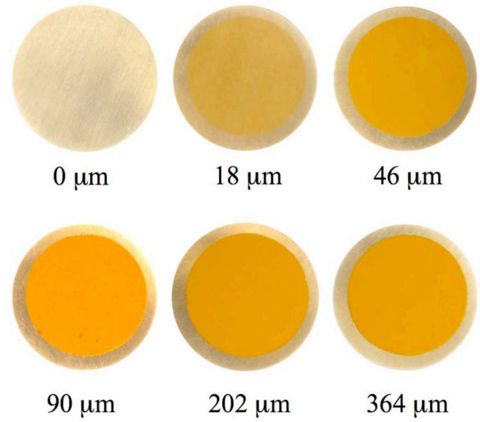

Figure 4. Dust thickness is measured using an aluminum disc adjacent to the specimen in the airfall chamber. The rate of opacity development in visible light is similar to that of the infrared.

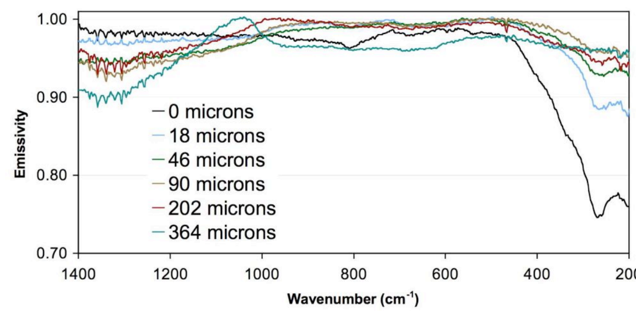

Figure 5. TIR spectra of oxidized surface with incremental dust loading. Strong absorption features are not completely masked until after 364 microns of dust are appllied.

Summary: TIR analyses of a MP analog specimen show evidence that Maritan dust can mask subtle spectral features beginning at ~18 microns, and strong absorption features above ~360 microns on an oxidized meteorite substrate. Regmaglypt cavities on MP could contain relict secondary alteration products that are now obscured by dust. As no obvious spectral indications of secondary products are present in Mini-TES spectra of MP, an estimate of dust thickness within the regmaglypts would help resolve this question. In addition to serving as a remote sensing tool for identification purposes, spectra collected using the Mini-TES instruments can provide information on the emission and reflectivity behavior of iron meteorite surfaces in the ambient infrared environment of Mars. The MER search for meteorites using Mini-TES remains on-going.

References: [1] Schröder C. et al. *JGR* (in press). [2] Ashley J.W. et al. (2007) *LPSC* XXXVIII, abstract #2264. [3] Graff T.G. (2003) Master's Thesis, ASU. [4] Buddhue J.D. (1957) *The Oxidation and Weathering of Meteorites*. [5] Connolly H.C. Jr. et al. (2006) Meteoritical Bulletin 90. [6] Morris R.V. et al. (2001b) *JGR*, 106, 5057-5083.