

SPECTROSCOPIC OBSERVATIONS OF SUBRESOLVED TARGETS: APPLICATIONS TO THE MER MINI-TES AND RAT EXPERIMENTS. S. M. Ciccolella¹ and J. E. Moersch¹, ¹Department of Geological Sciences, University of Tennessee, Knoxville, TN 37996.

Introduction: In January, 2004, the twin Mars Exploration Rovers (MER) [1] will begin their exploration of the Martian surface. Among the payload of instruments carried by each rover is the Miniature Thermal Emission Spectrometer (Mini-TES) and the Rock Abrasion Tool (RAT). One challenge in exploring the mineralogy of Mars via remote sensing is the presence of dust that pervasively mantles many areas of the planet's surface. The Mini-TES aperture is located on the rover's Pancam Mast Assembly (PMA), and the RAT is mounted on the rover's Instrument Deployment Device arm. The purpose of the RAT is to remove thin weathering surfaces and/or dust on rock samples to reveal their interiors for analysis by other instruments on the rover, including Mini-TES. The minimum field of view for Mini-TES is 6.35 cm, defined by the diameter of the mirror used in the rover's PMA Cassegrain telescope. The area abraded by the RAT, however, is only 4.5 cm in diameter, meaning that freshly exposed surfaces are subresolved, filling ~50% of the Mini-TES field of view. As a result, each spectrum obtained by Mini-TES will represent a combination of the "RAT-hole" (exposed surface) target and the surrounding background of weathered or coated surface. Here we investigate different techniques for determining the spectrum of a target that incompletely fills the spectrometer's field of view.

Methods: An Analytical Spectral Devices FieldSpec Pro JR portable field spectrometer that operates in the visible/near infrared (.35–2.5 μ m) was used to collect spectra. This spectrometer was selected because the instrument can be fitted with a telescopic foreoptic. The foreoptic can, in turn, be mounted to a computer-controlled pan/tilt platform on an adjustable tripod to simulate Mini-TES observations from the MER PMA. Although the Mini-TES operates in the thermal infrared (5–29 μ m) and the FieldSpec Pro JR operates in the Vis/NIR (.35–2.5 μ m), the techniques investigated here would be applied essentially identically to data from either spectral region.

Samples were prepared by applying four coats of iron oxide paint to each of three identical natural carbonate tiles (A, B, and C). These paint and tile compositions were chosen because they have distinctly different spectra. The iron oxide paint simulates a weathered surface or coating, and the tile is a proxy for the rock interior composition. A Dremel tool

fitted with a grinding stone was used to remove material from tile A to create a simulated RAT hole with a diameter of approximately 1.4–1.5cm. No modifications were made to tile B, which represents the pre-RATed Mars rock. The entire iron oxide layer was removed from tile C to expose the underlying carbonate surface using the same method as was used to create the RAT hole in tile A.

The spectrometer was set up outside under natural sunlight with the tripod apparatus. Spectra were acquired of the RATed tile centered on the RAT hole (tile A), the unRATed tile (tile B), and the carbonate tile (tile C), all at a range of 1m. At this distance, the field of view for the spectrometer is greater than the diameter of the RAT hole, as will be the case for MER.

Two different approaches can be used to obtain the subresolved spectrum of the freshly-exposed material in our simulated RAT hole. The "temporal method" makes use of spectral observations before and after the target is RATed. The "superresolution method" derives the spectrum of the subresolved target using spectra collected in a grid pattern at a spatial interval smaller than the spectrometer's field of view [2]. Here we present results from our experiments in testing the temporal method.

The temporal method operates under the principle that spectra are additive [3]. The spectrum of a rock containing n components can be modeled by a linear combination of the spectra of the n components. During the MER mission, the Mini-TES will sometimes have the opportunity to obtain spectra of rocks both before and after RAT operations. Using the assumption of linear mixing:

$$R_{\text{after}} = aR_{\text{before}} + bR_{\text{target}} \quad (1)$$

where R_{after} is the spectrum of the RATed tile, R_{before} is the spectrum of the painted (unRATed) tile, R_{target} is the spectrum of the subresolved material freshly exposed in the RAT hole, and a and b represent weighting factors for the two spectral components. The equation above is constrained by the relation $a + b = 1$. Solving (1) for R_{target} , the desired spectrum of the freshly exposed material seen in the RAT, hole gives:

$$R_{\text{target}} = (R_{\text{after}} - aR_{\text{before}}) / b \quad (2)$$

The weighting factors a and b are determined by convolving the area that each spectral component occupies with the point spread function (PSF) of the

spectrometer/foreoptic combination. Because the PSF is peaked at the center of the spectrometer's field of view, R_{target} contributes more to R_{after} than its area alone would imply. The spectrometer/foreoptic PSF was estimated by taking two scans of spectra at 1.75 mrad (0.1°) intervals, oriented 90° from each other, across a point source. The weighting factor a , which is the ratio of the portion of the PSF occupied by the RAT hole to the total PSF, was determined to be .31. Similarly, b is the ratio of the remaining region to the total PSF, or .69.

Results: Figure 1 shows spectra of the painted tile A (R_{before}) and tile B (R_{after}), which is painted but with a RAT hole exposing the underlying carbonate composition of the tile. These spectra are analogous to the types of measurements that would be available to Mini-TES on Mars before and after RATING a coated rock. Applying equation (2) with the PSF-derived weighting factors discussed above yields the derived spectrum of the material in the RAT hole (R_{target} in Figure 2). This derived spectrum compares well to the measured spectrum of the unpainted tile C ($R_{\text{carbonate}}$ in Figure 2). The slight variations between the derived and measured spectra in Figure 2 may be the result of a quasi-circular RAT hole. The diameter of the RATED area on tile B varies from 1.4–1.5 cm in diameter. Also, the Field Spec Pro JR has three detectors covering different wavelength regions, each with its own PSF. The average PSF was used in our

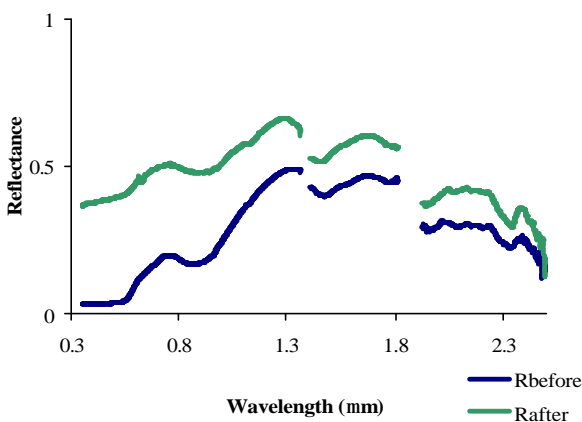


Figure 1: Spectra of two painted tiles: one with no RAT hole (R_{before}), and with a RAT hole (R_{after}). Both spectra show the influence of the iron oxide paint in the absorption near $1 \mu\text{m}$. The carbonate absorption feature at $2.3 \mu\text{m}$ from the tile substrate is strongest in the post-RATING spectrum (R_{after}).

calculations, but deviations from this average would lead to under- or over-correction for the non-RATED portion of the spectrum as a function of wavelength.

Discussion: Given the spectrum of an unRATED rock and the spectrum of the same rock after RATING, the spectrum of fresh material revealed in the RAT hole can be reasonably determined using knowledge of the RAT hole size and the PSF of the spectrometer. These results are encouraging for use of this technique during MER operations; however, additional factors not considered in this preliminary experiment may be important for MER. For example, the incomplete removal of grindings from the RAT hole could add a third spectral component and confound the technique. To address this possibility, we will obtain samples of natural coated rocks and take spectra of them before and after being RATED (in various orientations) by a more flight-like MER RAT tool. We will also use the previously-described superresolution technique with our measured PSF and a maximum likelihood inversion algorithm to attempt to “image” the center of the RAT hole and extract its spectrum with minimal contamination from unRATED surrounding areas and grindings.

References: [1] Squyres, S.W. (2002) *GSA abstr.*, 35, Abstract #P21C-02. [2] Moersch, J.E. et al. (2000), *LPS XXXI*, Abstract #1839. [3] Ramsey and Christensen (1998) *JGR*, 103, 577-596.

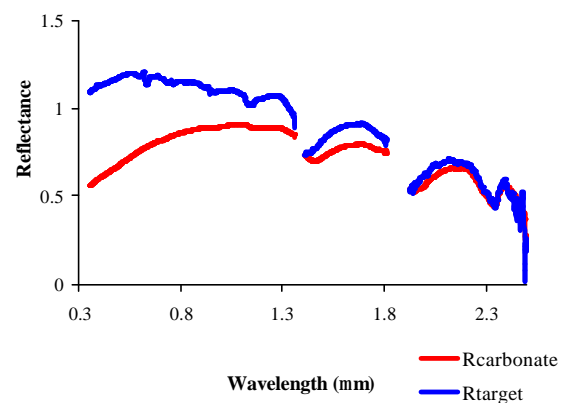


Figure 2: R_{target} , the derived spectrum of the RAT hole, closely matches the measured spectrum of the unpainted carbonate tile ($R_{\text{carbonate}}$). The spectrum of iron oxide paint surrounding the RAT hole has been successfully removed.