CHARACTERIZATION OF ROCK TYPES AT MERIDIANI PLANUM, MARS USING MER 13-FILTER PANCAM SPECTRA. D. L. Nuding[1] and B. A. Cohen[2], [1]University of Alabama in Huntsville, 320 Sparkman Dr. Hunstville AL 35805 (nudingd@uah.edu), [2]NASA Marshall Space Flight Center, VP62, 320 Sparkman Dr. Huntsville AL 35805 (Barbara.A.Cohen@nasa.gov).

Introduction: The Mars Exploration Rover Opportunity has traversed more than 13 km across Meridiani Planum, finding evidence of ancient aqueous environments that, in the past, may have been suitable for life. Meridiani bedrock along the rover traverse is a mixture in composition and bulk mineralogy between a sulfate-rich sedimentary rock and hematite spherules ("blueberries") [1]. On top of the bedrock, numerous loose rocks exist. These rocks consist of both local bedrock and "cobbles" of foreign origin. The cobbles provide a window into lithologic diversity and a chance to understand other types of martian rocks and meteorites.

For example, several cobbles are interpreted as probable meteorites (e.g., Santa Catarina, Heat Shield, Barberton) [2]. Other rocks that have compositions different from the average bedrock (e.g., Jin, Bounce) may not be meteorites, but instead may be derived from locations deeper than the present surface and delivered to the current site as ejecta.

Due to limitations dictated by mission operations, it is likely that not every interesting cobble was recognized or characterized. However, 13-filter (13F) Pancam images of specific targets and landscape scenes that contain cobbles were frequently collected. Therefore, we have been able to create a database of archived 13F cobble spectra throughout the entire traverse and gather statistical information on the types of rocks that populate the Meridiani plains.

In the summer of 2007, Opportunity experienced a global dust storm which coated the Mini-TES mirrors. Although work is ongoing to recover the Mini-TES capabilities, the team is now relying on Pancam as its primary remote sensing tool. Therefore, this study was also an attempt to establish a method to expand upon those of Mini-TES to remotely identify rocks of interest to make efficient use of the rover's current resources.

Methodology: Pancam is a multiband, stereoscopic, panoramic imager that covers the visible and near infrared wavelengths (432-1009 nm) [3]. In this study, we are interested in developing the ability to distinguish groups of cobbles and understand their location along Opportunity's traverse, including association with craters. It should be noted that for this study we did not use 13F spectra to determine mineralogy or composition of the cobbles, but instead used the spectra solely for grouping purposes.

To create a database of cobble spectra, we extracted individual spectra from more than 200 rocks using Pancam 13F images. We initially identified images of interest (IOI) that contained a clear view of cobbles, bedrock, and crater blocks with limited dust cover and surfaces that appeared homogeneous. The IOI were imported into MERTools, a science analysis program created by the Pancam team, to generate spectra from hand-picked selection areas. The selection areas varied in number of pixels for each feature but each corresponded to a homogeneous and relatively dust-free area. The measured reflectance values at each wavelength were converted into relative reflectance levels (R*) using Pancam calibrations. R* minimizes the spectral effects of atmospheric dust and lighting that could alter the reflectance spectra [3].

We defined several mathematical parameters for each 13F spectrum, following [4-6]. These include: blue slope between 432 nm and 601 nm (albedo); red slope between 754 nm and 1009 nm, 535 nm band depth, 903 nm band depth, 803/904 nm ratio, and 934/1009 nm ratio (indicators of the generic type or crystallinity of ferric minerals); maximum reflectance value in each spectrum; and the sol used to pinpoint the location of cobbles along the traverse.

Each derived spectrum has an associated uncertainty due to variation in pixels in the selection area. An in depth analysis of the cobble Jin was performed to understand the uncertainty associated with the method. Jin is a cobble found within Victoria Crater. Though Opportunity never conducted an IDD campaign on Jin, it collected multiple 13F images over 282 sols, at different times of day and from different angles. We analyzed eight images of Jin, collecting spectra of 18 selection areas including shadowed, dusty, normal, and large, heterogeneous areas. We then used the variation among these spectra to create a standard method error that we applied to every cobble, convolving it with the measurement error for each cobble. In general, the method uncertainty was ~2x greater than the measurement uncertainty.

Analysis: Each parameter was graphed versus every other parameter to look for trends and relationships. Most parameters regularly produced scatter plots with no clear correlations. However, interpretable relationships were observed between the blue slope and the 934/1009 nm ratio (Figure 1) and the following discussion is based on this representation of the data.

We quantified trends related to shadow and dust in our parameters by sampling a variety of areas on a single rock (Jin). Figure 1 presents all of the cobbles in our database, including known meteorites. We also include, for comparison, the range of variability in bedrock using areas of interest from [5]. The bedrock analysis showed the variation in hematite, allowing a hematite trend to be defined.

Most of the cobbles follow a roughly linear trend, where cobbles with higher blue slope also exhibit a more positive 934/1009 ratio. We interpret this trend as relating to the amount of dust and/or coating on the rocks, which increases the albedo and obscures the 934 nm absorption band. The dust and coatings on the rocks, coupled with the fairly large uncertainties in the measurements, appear to mask smaller differences that might distinguish particular cobbles from one another.

However, several cobbles lie off this trend, having a flat blue slope and a 934/1009 nm ratio <1. Initially, it was thought that this trend was caused by shadows in the selection areas. However, we confirmed that multiple cobbles not in shadow also have this characteristic. The majority of these unusual cobbles are from sol 50-51, when Opportunity was near Eagle Crater. In general, the spectral characteristics of these rocks are very similar to each other including positive red slope values, a low albedo, and muted bands. We speculate that these cobbles form a group, possibly derived from a rock that formed Eagle Crater.

Figure 2 shows a cobble from sol 50 that appears to have regmaglypts, commonly found on iron meteorites. However, other iron meteorites found along the two rovers' traverses (e.g., Heat Shield [2], Allan Hills and Zhong Shan in Gusev Crater) do not have a 934/1009 nm ratio <1. Instead, they follow the linear trend as seen in Figure 1, which suggests that they too have variable amounts of dust and/or coatings. The cobble in Figure 2 does not appear to be very dusty and its spectrum is roughly similar to the brushed but coated spectrum of Heat Shield [2].

There are several other cobbles that have a 934/1009 nm ratio that is <1 that are still under investigation. We plan to compare them to the cobbles from the sol 50-51 group and correlate all of the cobbles in this group with geographic position along the traverse.

Conclusions: Pancam 13F reflectance spectra can reveal differences between cobbles. However, many factors influence 13F spectra, particularly the dust, coatings, lighting/viewing geometries, and shadows that are present in nearly all real rock spectra. These effects make it difficult for simple methods to discriminate between cobbles from afar. We found that the blue slope and 934/1009 nm parameters allow us to examine some trends and identify an interesting type of cobble. This cobble group has a constant blue slope and 934/1009 nm ratio <1 that did not follow the general linear relationship between the two parameters. The cobbles that make up this trend may be related to Heat Shield rock and/or Eagle Crater itself.

References: [1] Squyres, S. W. and Knoll, A. H. (2005), *EPSL, 240,* 1-10. [2] Schroeder C. et al (2008) *JGR*, *113,* E06S22. [3] Bell, J. F. et al. (2006), *JGR, 111,* E02S03. [4] Farrand, W. H. et al (2008) *JGR, 113,* E12S38. [5] Farrand, W. H. et al. (2007), *JGR, 112,* E06S02. [6] Thompson, S. D. et al. (2006), *LPSC XXXVII*, Abstract #1938.

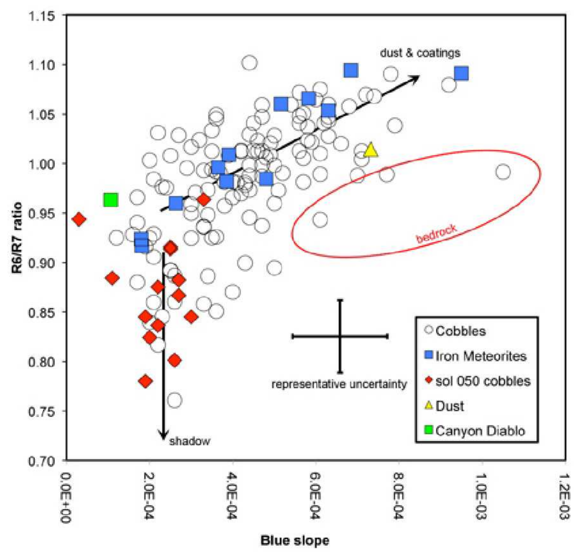

Figure 1. 904nm/1009nm ratio versus blue slope for all the cobbles in the database (n=160). The trend lines related to shadowing, dust, and coating are indicated by arrows. The representative uncertainty for each cobble (cross) takes into account both measurement and method uncertainty. For reference, bedrock and iron meteorites (Heat Shield, Canyon Diablo [2], Allan Hills, and Zhong Shan) are also shown.

Figure 2. False-color (L245) image of one of the unusual cobbles (~2 cm) in the sol 50-51 group.