DISTINGUISHING MARTIAN "ERRATICS" FROM METEORITES AT MERIDIANI PLANUM USING PANCAM: COMPARING MARQUETTE ISLAND TO MERIDIANI COBBLES. W.H. Farrand[1] , J.R. Johnson[2], J.F. Bell[3], R.A. Yingst[4], and C.M Weitz[4], [1]Space Science Institute, 4750 Walnut St. #205, Boulder, CO 80301, farrand@spacescience.org, [2]U.S. Geol. Survey, Flagstaff, AZ, [3]Cornell University, Ithaca, NY, [4]Planetary Science Institute, Tucson, AZ

Introduction: In the over 2000 sols that Opportunity has been traversing the plains at Meridiani Planum, the rocks encountered have consisted of the in situ layered sulfate rich outcrop [1,2]; cobbles darker in tone but bluer in color than outcrop, at least some of which appear to be meteorites [3,4], several Fe-Ni meteorites [3,5], occasional displaced pieces of the sulfate-rich outcrop, and, until recently, one piece of Martian crust- presumably ejecta from a more distant impact event ("Bounce Rock", Sols 65-69). Bounce Rock's Fe-bearing mineralogy consisted solely of pyroxene [6], but deconvolution of Mini-TES spectra indicated a mineralogic assemblage similar to the SNC meteorite EETA79001 lithology B with a combination of low and high Ca pyroxene and perhaps 30% plagioclase (or its shocked variant maskelynite) [7]. Since examining Bounce Rock, Opportunity has not encountered any other clear example of a displaced "erratic" until the discovery of the rock "Marquette Island." Approximately 30 cm in height and width in its long lateral axis, Marquette Island was also observed to have unique color properties (**Fig. 1**). One face of Marquette Island is clearly dustier than other portions and the contact between the dusty and "clean" face appears very sharp along at least one margin indicating the rock might have fractured on impact.

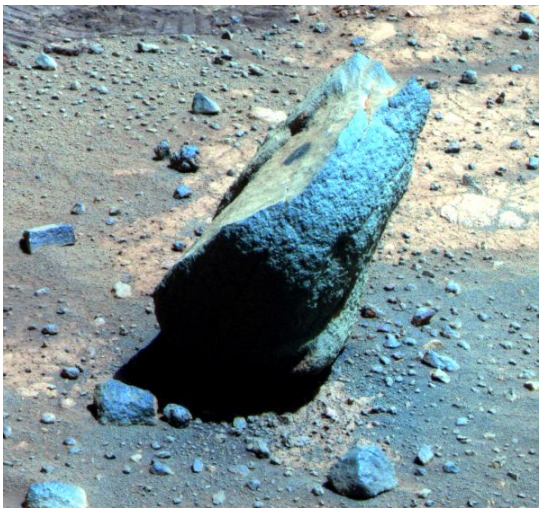

Fig. 1. Sol 2087 P2537 bands L357 composite of Marquette Island. Peck Bay brush spot is visible on left.

Pancam Multispectral Imaging of Marquette Island: Pancam collects 11 spectrally unique channels in the 430 to 1010 nm wavelength range. There are 2 overlapping channels for red or blue stereo for a total of 13 channels devoted to geologic analyses. These 13 filter ("13f") datasets are converted to radiance factor and then to relative reflectance (R*) by dividing radiance factor by the cosine of the solar incidence angle. More details on the Pancam instrument and its calibration are provided in [8,9].

To date, several Pancam 13f sequence views of Marquette Island have been collected from various perspectives. Marquette Island's northwest face was imaged on sol 2057, its southwest face on sol 2059, its southeastern face on sol 2063, and additional work is currently planned on its eastern face. Marquette Island has been subjected to analysis by Opportunity's IDD science instruments [10] and this in situ analysis has also consisted, to date, of the RAT brushing of two spots, Peck Bay and Islington Bay. Additionally, 13f sequences have been collected of these brush spots. The 13f spectra of the Peck Bay brush spots are only subtly different from the windswept, "clean" surfaces of Marquette Island (**Fig. 2**); spectra from both surfaces display a broad absorption feature with a downturn from the 754 nm band. On undisturbed surfaces, there is no upturn in reflectance in the final 1009 nm band, but on the brushed surfaces over smaller clusters of pixels, there can be an upturn in reflectance in the final band. These observations are consistent with the determination by Opportunity's Mössbauer spectrometer that most of the iron in Marquette Island is concentrated in olivine with a smaller amount in pyroxene [10].

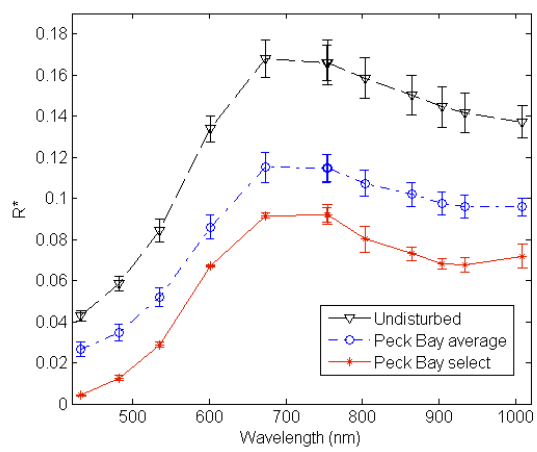

Fig. 2. Pancam 13f spectra of Marquette Island.

Differences between Marquette Island, Bounce Rock and Cobbles:

Multispectral Differences: Marquette Island was originally distinguished in Opportunity's navigation camera or Navcam imagery on the basis of its size and vertical orientation. Closer examination revealed the bimodal color character shown in **Fig. 1** between its dustier and cleaner face. The clean face was darker in tone and bluer than standard Meridiani outcrop. But in what other ways is it similar or different in terms of its multispectral character from the smaller Meridiani cobbles and the one other analyzed Martian erratic, Bounce Rock?

The depth of a subtle absorption at 535 nm has been used [11] as a proxy for the degree of oxidation of rocks examined by Spirit in Gusev crater. Likewise, at Meridiani Planum it can be used to distinguish "blue" cobbles from dislodged pieces of oxidized, sulfate-rich Meridiani outcrop. Generally, materials with 535 nm band depth values greater than 0.2 are considered likely to be outcrop, though especially dusty cobbles could also have high values in this parameter. The cleaner surfaces of Marquette Island have 535 nm band depth values lower than 0.2. However, when compared with other spectral parameters, Marquette Island plots amidst Meridiani cobbles, whereas Bounce Rock is distinct from those cobbles. **Fig. 3** shows a plot of 754 to 864 nm slope vs. 803/904 nm ratio. A set of Bounce Rock measurements from undisturbed and abraded surfaces has higher 803/904 nm ratio values than any other IDD-examined cobbles . However, as noted above, measurements of undisturbed nominally "clean" surfaces and RAT-brushed surfaces of Marquette Island plot amidst the cobbles. Closer examination of the cobbles plotted shows that Marquette Island plots below (lower 803/904 nm ratio) a group of cobbles identified by [4] as the "Arkansas group" (which the APXS has indicated as being relatively low in Ni and which potentially has a basaltic component). This group generally exhibits higher 803/904 nm ratio and lower 754 to 864 nm slope than the more populous "Barberton" group of cobbles [3,4] which are relatively high in Ni and have been shown to contain kamacite and/or troilite and thus are believed to be small meteorite, likely mesosiderites. Such trends are backed up by plots of other near infrared (NIR) spectral parameter values such as the 754 to 1009 nm slope and 904 nm band depth.

Textural Differences: More difficult to quantify are textural differences between these objects. However, applying a co-occurrence based texture filter [e.g., 12] to single band images show smoother surfaces for cobbles than for Marquette Island or Bounce Rock.

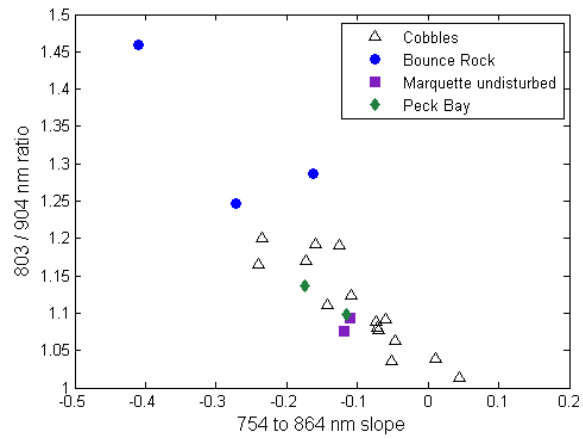

Fig. 3. Spectral parameter plot comparing Marquette Island (Peck Bay is the brush spot on Marquette Island), Bounce Rock and a set of cobbles.

Microscopic Imager (MI) images indicate a moderately rough textured matrix with indications of mm-sized grains. Heterogeneity of Pancam spectral signatures from the Peck Bay brush spot indicate these grains could be mineral phenocrysts.

Conclusions: While a definitive identification of a seemingly out-of-place rock encountered by a rover requires in situ examination, examination of multispectral reflectance can provide an initial assessment of whether it is similar to other such rocks observed to date. Multispectral data can also provide an estimate of whether it is dominated by olivine or by pyroxene, although even relatively small fractions of pyroxene can produce an out of scale spectral response [13]. Textural information can also provide additional qualtitative information to use in distinguishing rougher textured from smoother textured rocks.

References: [1] Squyres S.W., et al. (2004) *Science, 306,* 1709–1714. [2] Clark B.C. et al. (2005) *EPSL., 240,* 73-94. [3] Schröder C. et al. (2008) *JGR, 113,* 2007JE002990. [4] Fleischer I. (2010) paper in prep. *JGR-Planets*. [5] Johnson J.R. et al. this conference. [6] Klingelhöfer G. et al. (2004) *Science, 306,* 1740-1745. [7] Christensen, P.R. et al. (2004) *Science, 306,* 1733-1739. [8] Bell J.F., et al. (2003) *JGR,108,* 2003JE002070. [9] Bell J.F. et al. (2006) *JGR,111,* 2005JE002444. [10] Mittlefehldt D.W. et al. This conference. [11] Farrand W.H. et al. (2006) JGR, 111, 2005JE002495. [12] Anys H.A. et al. (1994) Proc. 1st Int. Airb. Rem. Sens. Conf., vol. 3, 231-245. [13] Sunshine J.M. and C.M. Pieters (1993) JGR, 98, 9075-9087