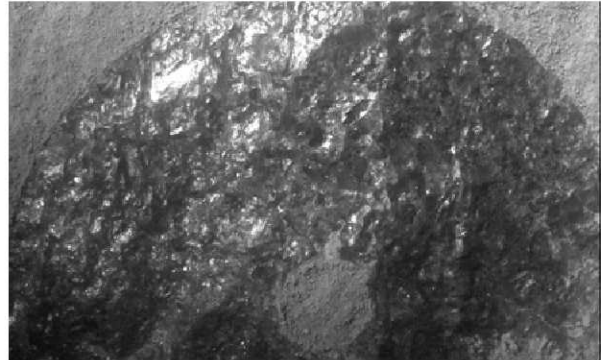


MARQUETTE ISLAND: A DISTINCT MAFIC LITHOLOGY DISCOVERED BY OPPORTUNITY. D. W. Mittlefehldt¹, R. Gellert², K. E. Herkenhoff³, R. V. Morris¹, B. C. Clark⁴, B. A. Cohen⁵, I. Fleischer⁶, B. L. Jolliff⁷, G. Klingelhofer⁶, D. W. Ming¹, R. A. Yingst⁸ and the Athena Science Team, ¹NASA/JSC, Houston, TX USA (david.w.mittlefehldt@nasa.gov), ²Univ. Guelph, Guelph, ON CA, ³USGS, Flagstaff, AZ USA, ⁴SSI, Boulder, CO USA, ⁵NASA/MSFC, Huntsville, AL USA, ⁶Johannes Gutenberg-Univ., Mainz, DE, ⁷Washington Univ., St. Louis, MO USA, ⁸Univ. Wisconsin Green Bay, Green Bay, WI USA.

Introduction: While rolling over the Meridiani Planum sedimentary terrane, the rover Opportunity has occasionally discovered large, >10 cm erratics. Most of these have proven to be meteorites [1], but one - Bounce Rock - is a martian basaltic rock similar in composition to the meteorite EETA79001 lithology B [2]. Presently, Opportunity is intensively investigating an ~30 cm tall rock named Marquette Island that may be a distinct type of martian mafic lithology. We report the results of its continuing investigation using the Microscopic Imager (MI), Mössbauer Spectrometer (MB) and Alpha Particle X-ray Spectrometer (APXS). A companion abstract discusses the results of Panoramic Camera (Pancam) imaging of the rock [3].

Microscopic Imager: The MI has imaged undisturbed and brushed surfaces, but the underlying texture remains obscure. Some undisturbed regions appear to show blocky, mm-sized grains. The brushed surface is hackly and contains numerous glints from regions of a highly reflective surface (Fig. 1). Regions of subdued reflectivity show a dark-light structure with darker material interstitial to brighter equant “grains” of mm size. Thus, Marquette Island may be comprised of what appear to be individual clastic, angular grains embedded in a finer-grained matrix. The larger clast-supported grains are poorly-sorted, with no preferred orientation. There is no evidence for sedimentary structures or layering. The texture is not highly diagnostic of a particular process or origin, but is grossly similar to the target Seminole, imaged by Spirit in Gusev Crater. There are a few instances of what appear to be semi-arcuate structures. This and the fact that several facets are highly reflective, suggest that the parent rock may be a breccia containing glassy shards. However, the high reflectivity may simply be a result of crystal facets sitting at advantageous angles to reflect sunlight into the MI. The semi-arcuate structures are not common, and the rock appears very well-lithified, which would argue against brecciation. Some regions show possible igneous texture, confounding the textural interpretation of Marquette Island.

Figure 1. Part of radiometrically-calibrated MI image IM311956850 of target "Peck Bay", taken by Opportunity on Sol 2070. Subframe is about 3 cm across, with direct sun illumination from upper left. Dust has been removed by RAT brushing, except in circular area at bottom center and upper right and left corners.



Mössbauer Spectrometer: We have acquired over 150 hours of combined MB integration time on two targets on Marquette Island. The major iron-bearing minerals are olivine and pyroxene. Most of the total rock Fe is contained in olivine with $Fe_{Ol}/(Fe_{Ol}+Fe_{Px}) \sim 0.8$ (Fig. 2). A small amount of the total rock Fe is contained in nanophase ferric oxide. A Mössbauer sextet consistent with magnetite, maghemite or hematite has not been detected.

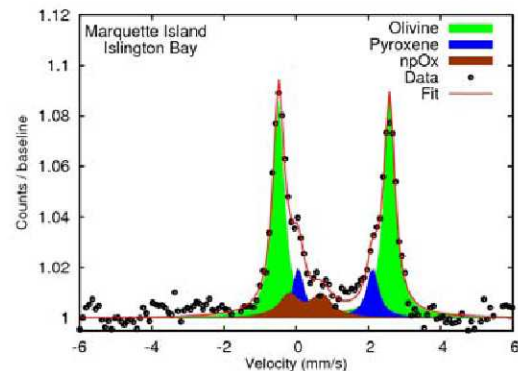


Figure 2. Mössbauer spectrum from the target Islington Bay, dominated by olivine with contributions from pyroxene and nanophase ferric oxide.

Alpha Particle X-ray Spectrometer: We have done APXS measurements on two brushed spots on Marquette Island. Some dust remained in the APXS field of view (Fig. 1) and we do not have a contamination-free composition yet. Nevertheless, Marquette Island is compositionally distinct from all other materials analyzed by Opportunity (Fig. 3). Among the major elements, Marquette Island has higher Mg/Si, Al/Si and lower Ca/Si than the basalt Bounce Rock. The high-Ni cobbles, probable silicate-rich meteorites

possibly similar to mesosiderites [1], have Si-normalized ratios of Mg, Cr and Ni far above, and Al and Ca lower than, those of Marquette Island. The low-Ni cobbles are of uncertain origin, but their compositions are markedly different from that of Marquette Island. However, these small cobbles do not fill the APXS field of view and thus their compositions are compromised by their soil substrate to varying degrees.

The closest compositional match to Marquette Island among materials studied by the MER mission are Adirondack Class basalts from Gusev Crater (Fig. 3), but there are important differences – higher Mg/Si, Al/Si and lower Ca/Si in the former. Martian meteorites do not match Marquette Island in composition. Martian meteorites with similar Mg/Si have Al/Si that are much lower and Ca/Si that are much higher.

While the composition of Marquette Island is similar to Adirondack Class rocks (Fig. 3) and basaltic soils at both landing sites, there is a clear distinction in the Pu x-ray scatter peaks of Marquette Island compared to other basaltic samples. These peaks are sensitive to the overall composition of the sample at greater depth, including x-ray-invisible light elements such as H, O and C. Therefore it might be that either Marquette Island includes significant amounts of “unseen” light elements, or that the rock has a significantly different composition at greater depth with a higher light element content.

Discussion: Marquette Island is very distinct from the high-Ni cobbles such as Barberton that are probable silicate-rich meteorites, possibly similar to mesosiderites [1]. Because of the low Ni/Si and lack of kamacite or troilite, we do not consider a meteoritic origin for Marquette Island to be likely.

Marquette Island is mafic in composition. Current MI images do not allow for confident textural interpretation; igneous and clastic textures remain possibilities. Our working hypothesis is that Marquette Island is a distinct martian mafic lithology with compositional similarities to Adirondack Class basalts of Gusev Crater. The MB spectra show that the Fe mineralogy is dominated by olivine with subordinate pyroxene. Pancam spectra on some regions of the brushed surface show no upturn in relative reflectance at the longest wavelength, consistent with the presence of olivine [3]. A normative mineralogy calculated for low Fe^{3+} is consistent with the MB Fe mineralogy. Although generally similar to Adirondack Class basalts, there are nonetheless important differences in composition. The low Ca/Si in Marquette Island results in ~2 wt% normative diopside, compared to 14-16 wt% for brushed Adirondack Class basalts. The excess in light ele-

ments suggests that Marquette Island may be an altered rock, and thus not a true mafic igneous lithology.

Bounce Rock is interpreted as being a mafic igneous ejecta block deposited on Meridiani Planum [2]. Marquette Island probably is also crater ejecta, possibly from the same crater. However, the compositions of Bounce Rock and Marquette Island are not simply related by igneous fractionation. Bounce Rock is an olivine-poor, pyroxene-rich basalt with lower Mg/(Mg+Fe), Mg/Si, Cr/Si and Ni/Si, and higher Ca/Si suggesting that it could be a more fractionated member of a common magma series. However, the higher Al/Si of Marquette Island is inconsistent with this scenario. Thus, if these two mafic erratics were ejecta from the same crater, they appear to represent unrelated rock series.

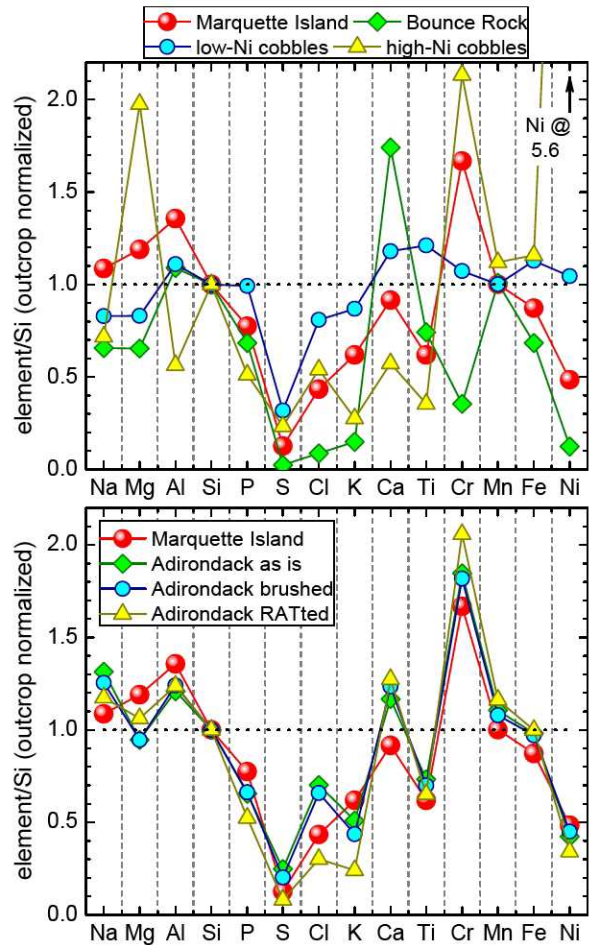


Figure 3. Element/Si ratios for Marquette Island compared to other rocks from Meridiani Planum (upper) and Gusev Crater Adirondack Class basalts (lower). Element ratios are normalized to an average brushed Meridiani outcrop composition.

References: [1] Schröder C. *et al.* (2008) *JGR*, 113, doi:10.1029/2007JE002990. [2] Squyres S. W. *et al.* (2004) *Science*, 306, 1698. [3] Farrand W. H. *et al.* (2010) This conference.