

**TOPOMETRIC ANALYSIS OF IRON METEORITE SURFACES AND THEIR OXIDE COATINGS USING MICROSCOPIC IMAGER DIGITAL ELEVATION MODELS AT MERIDIANI PLANUM MARS – SUPPORT FOR RECENT EQUATORIAL MINERAL-WATER INTERACTION AND PERSISTANT PALEOWIND DIRECTION.** J. W. Ashley<sup>1</sup>, K. E. Herkenhoff<sup>2</sup>, C. Schröder<sup>3</sup>, M. P. Golombek<sup>1</sup>, A. G. Curtis<sup>1</sup>, J. R. Johnson<sup>4</sup>, B. C. Clark<sup>5</sup> and the Athena Science Team. <sup>1</sup>Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109; [james.w.ashley@jpl.nasa.gov](mailto:james.w.ashley@jpl.nasa.gov), <sup>2</sup>USGS Astrogeology Science Center, Flagstaff, AZ; <sup>3</sup>Biological and Environmental Sciences, University of Stirling, Stirling FK9 4LA, UK; <sup>4</sup>John Hopkins University Applied Physics Laboratory, 11100 John Hopkins Road, MP3-E169, Laurel, MD; <sup>5</sup>Space Science

**Introduction:** Weathered iron, stony iron and probable chondritic meteorites found on Mars by the *Spirit*, *Opportunity*, *Curiosity*, and *Perseverance* rovers are climate-sensitive, opportunistic samples whose study complement science objectives for these missions. Of the 56 confirmed and candidate meteorites found as both serendipitous finds and formal science campaign targets [1-7], eight are irons at Meridiani Planum. Working titles Heat Shield Rock, Block Island, Shelter Island, and Mackinac Island have been augmented to Meridiani Planum (MP) 001, 006, 007, and 008, respectively, after formal recognition as meteorites by the Meteoritical Society Meteorite Nomenclature Committee [8]. However, original titles may be used in lieu of official designations on occasion to avoid confusion in discussion.

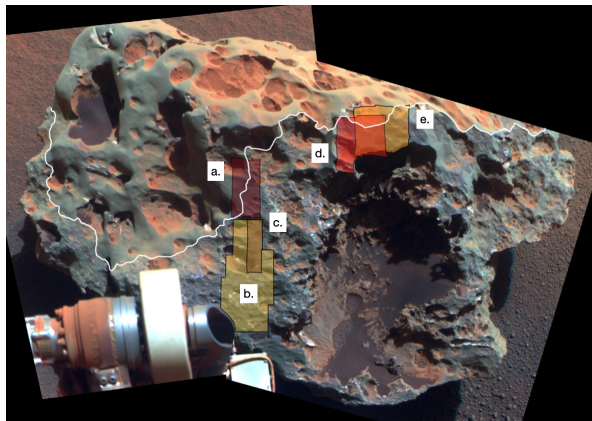


Figure 1. MP006 (Block Island) MER MI footprint map using Pancam color mosaic. Continuous white line identifies surface dichotomy boundary. Mosaics: (a) Spring House Ice Pond; (b) New Shoreham; (c) Middle Pond; (d) Siah's Swamp; (e) Siah's Swamp 2. NASA/JPL/Cornell.

We focus here on iron meteorite surface topographies and their oxide coatings to address Amazonian chemical and physical weathering processes near the martian equator. A total of five Microscopic Imager (MI) mosaic Digital Elevation Models (MicroDEMs) and their respective orthorectified images were requested from the USGS Astrogeology Science Center for the study of IAB complex irons MP001 (Heat Shield Rock) and MP006 (Block Island) pursuant to their follow-up study after [5].

**Methods:** MicroDEMs were created using MI stereo pairs to assess surface topography on a sub-millimeter

scale. Since the MI camera is monoscopic, the MicroDEM is generated using stereo by taking two images of a target, separated by a horizontal offset. With stereo imaging, the location of each pixel in 3D space can be found with 0.03-mm precision [9]. The 3D data are then projected onto a defined vector, representing the normal of a surface plane. The projected data makes up the MicroDEM, displaying the height of each pixel relative to the defined surface plane. Geospatial data were evaluated using QGIS. Spatial ortho and MicroDEMs are 0.03 and 0.09 mm/px, respectively.

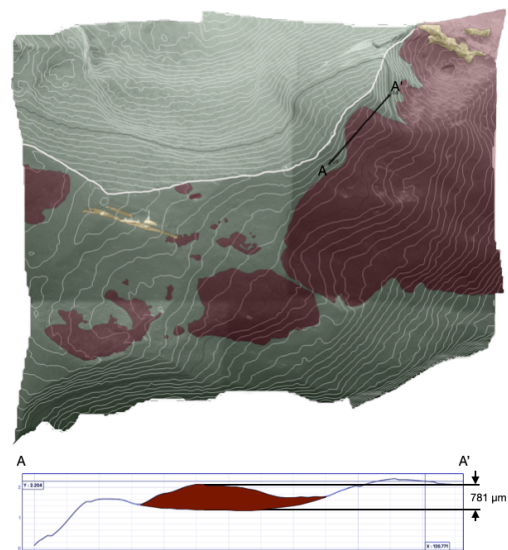


Figure 2. Siah's Swamp 2 MicroDEM with feature map and orthorectified base image. Topographic profile A-A' measures tongue of residual oxide coating within negative relief scallop. Bare metal green, iron oxide coating burgundy, lamellar taenite gold, white line is dichotomy boundary; width is 6.77 cm, contour interval 0.5 mm. NASA/JPL/Cornell/USGS.

**Results:** The coatings found regularly on these meteorites have been characterized in [1] as a mineralogically ambiguous iron oxide (possibly an oxyhydroxide). While interpreted as chemical alteration products after iron-nickel-water interactions, coatings with similar spectral attributes have been detected on indigenous rocks at Jezero crater [10]. Suspected in [5], MicroDEM measurements confirm coatings to be in a crosscutting relationship to taenite lamellae exposed by post-fall abrasion; and therefore not a fusion crust but a product of post-fall exposure processes. The coating is found

consistently in local hollows and sloping surfaces up to the crests of hollows on Heat Shield Rock and Block Island. Assuming these occurrences to be in wind shadow where surface crests represent protection from abrasion, both meteorites would indicate abrading winds from generally southerly directions across their 10 km separation. These directions are not necessarily consistent with recent wind streak orientations [11] or the most recent aeolian bedform migration directions [12].

For Heat Shield Rock, 1) the RAT-brushed zone of the surface (representing the only brushed area for the Meridiani iron suite) reveals a number of separate unique features in the ortho mosaic. Among these are 1) surface pitting not seen where dust-covered, even where optically thin; and 2) examples of subtle mottling, polishing, sculpting and other structural attributes not seen where dust covers coatings. Some of these features may represent multiple coating deposit episodes. Most examples of coating fall on the opposite slope of an amphitheatre-shaped hollow (see Figure 3 A-A'). Flutings of the coating have a linearity similarly consistent with abrasion from a ~N-S direction. The edge of this hollow is shown to have a sharp break in slope (see Figure 3 B-B').

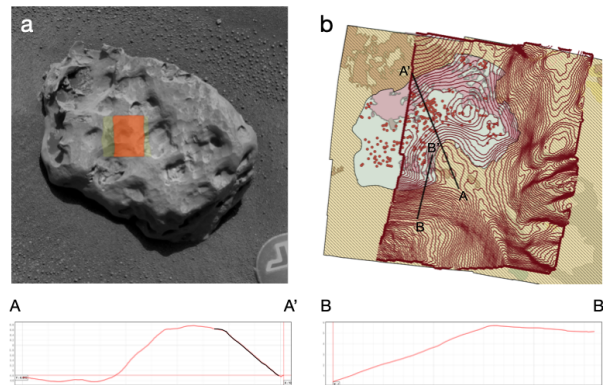


Figure 3. a) MP001 footprint localization map; feature map yellow, MicroDEM footprint red. b) feature map showing RAT-brushed zone with MicroDEM overlay identifies amphitheatre structure with coating on the opposite slope (A-A'; black). The 8.53 cm<sup>2</sup> brushed area also shows extensive pitting (red spots) not visible where even optically thin dust occurs on any of the 8 specimens. The pitting is likely to be a further result of mineral-water interaction, now exposed where the coating has been removed. NASA/JPL/Pancam/Cornell/USGS.

For Block Island, 1) An oxide coating thickness of 781  $\mu\text{m}$  was determined within a scallop using a Bezier curve inferred for the lower surface from side slopes and the cosine of the measured surface slope. The value represents an approximate minimum thickness as it occurs within a tapered zone on the scallop, and corresponds to a 258 to 157  $\mu\text{m}$  thickness of altered metal assuming a kamacite to goethite, or kamacite to hematite alteration product, respectively [13].

In [5] we identified a continuous contact on Block Island that separates two surface types; one rough with

patchy coating, and other smooth and coating-free. Tracing this contact onto the three-dimensional Block Island geometric model surface in [5] permits an examination of the dichotomy with respect to possible genetic causes. Manipulation of the model can position this line along the crest of the rock without adjusting the orientation of its basal plane (parallel to the martian surface) (Figure 4). While we originally suspected the line to represent a partial burial history for Block Island, the dichotomy boundary now appears more consistent with a sustained erosive surface wind direction and not burial as the cause of the anomaly. Dichotomy surface type topographies are characterized using the Spring House Ice Pond, Siah's Swamp and Siah's Swamp 2 MicroDEMs.

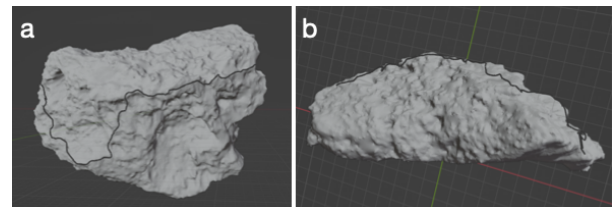


Figure 4. MP006 3D model from [5] with surface type dichotomy contact plotted in 3D space (black line). a) plan view; b) shows a reorientation that presents the contact at the crest of the rock along nearly all of its length, favoring sustained southerly wind abrasion in the current orientation as probable cause for the anomaly. NASA/JPL.

Based on the ubiquity of samples, we can reliably anticipate exogenic materials to be encountered during routine *Curiosity*, *Perseverance* and future (e.g., *ExoMars Rosalind Franklin*) rover terrain navigation. Additional science applications of exogenic materials found on Mars as planetary research tools are presented in [14].

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**References:** [1] Schröder C., et al. (2008) *J. Geophys. Res.* 113 E06S22. [2] Ashley J. W., et al. (2009) *LPSC XL, abs. #2468*. [3] Schröder C., et al. (2010) *J. Geophys. Res.* 115 E00F09. [4] Fleischer I., et al. (2010) *J. Geophys. Res.* 115 E00F05. [5] Ashley J. W., et al. (2011) *JGR* 116, E00F09. [6] Meslin P.-Y., et al. (2019) *LPSC L, abs. #3179*. [7] Wellington D. F., et al. (2019) *LPSC L, abs. #3058*. [8] Gattacceca J., et al. (2021) *Meteoritical Bulletin* no. 109. [9] Herkenhoff et al. (2019) *J. Geophys. Res.* 124, 528-584. [10] Garczynski, B., et al., *this conference*. [11] Sullivan R., et al. (2005) *Nature* 436, 3641. [12] Golombek M. P., et al. (2010) *J. Geophys. Res.* 115 E00F08. [13] Ashley J. W. (1995) MS thesis, 266 pp. [14] Ashley et al., Vol. 53, Issue 4 *Planetary/Astrobiology Decadal Survey* #183.