ANALOG STUDIES OF IRON METEORITES FOUND ON MARS — FEATURES, PROCESSES, AND COMPARISONS.
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Introduction: Because their composition and exposure histories are different from those of indigenous Mars rocks, meteorites found on Mars provide complementary insights into chemical and physical surface alteration processes. Spirit, Opportunity, and Curiosity have now discovered 21 confirmed and candidate meteorites at their respective rover landing sites, of which 13 appear to be irons. Surfaces and deep interiors of many have undergone acidic corrosion, aeolian scouring, and oxide production [1-4], but may also show signs of sculpting (regmaglypts, pits, or grooves) by the buffeting effects of atmospheric ablation. Separating ablation (pre-fall) imprints from those of weathering (post-fall) is important to understanding the martian surface exposure history of the rocks because weathering features reflect martian surface processes, while ablation features speak to the freshness of the samples. Knowledge of both are required to estimate weathering intensity and surface residence time of each sample [e.g., 5].

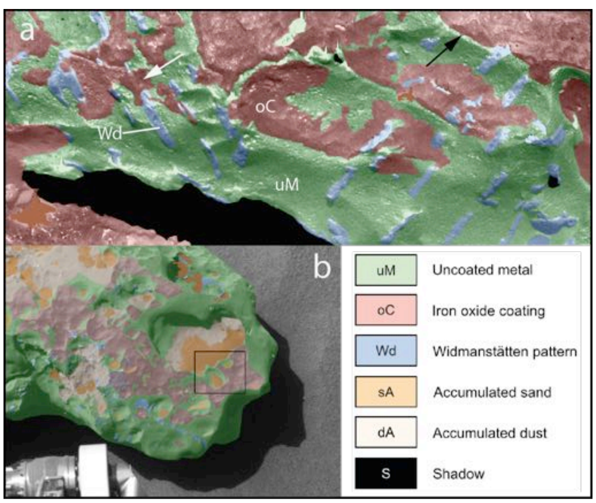

Figure 1. Micro-maps of Opportunity iron meteorites Block Island (a) and Oileán Ruaidh (b). The black box in 1b highlights topographic lows where the agitation of trapped sand grains has removed iron oxide coating. The implication is for a relatively soft, and therefore relatively recent, coating production. Arrows in 1a indicate coating cross-cutting Widmanstätten pattern (white), and margin retreating from hollow rim (black). Maps are created from MI mosaic and Pancam images.

While existing studies sought to compare readily apparent features to common features in known terrestrial examples [1-4], no formal analog study comparing ablation and erosional features of terrestrial meteorites with those on Mars has yet been conducted in depth. The present study is part of an on-going morphometric assessment of possible analog features observed in curated iron meteorites and ventifacted igenous rocks with known atmospheric ablation or weathering histories. Comparisons with features seen in the martian iron meteorite suite are made as information and new ideas become available. This abstract presents a progress report on select findings. Curated iron meteorites were examined at the Center for Meteorite Studies at Arizona State University, and the Smithsonian Institution National Museum of Natural History, Division of Meteorites. Photoreconnaissance of ventifacts was conducted at Garnet Hill, San Gordonio Pass, Mojave Desert, California.

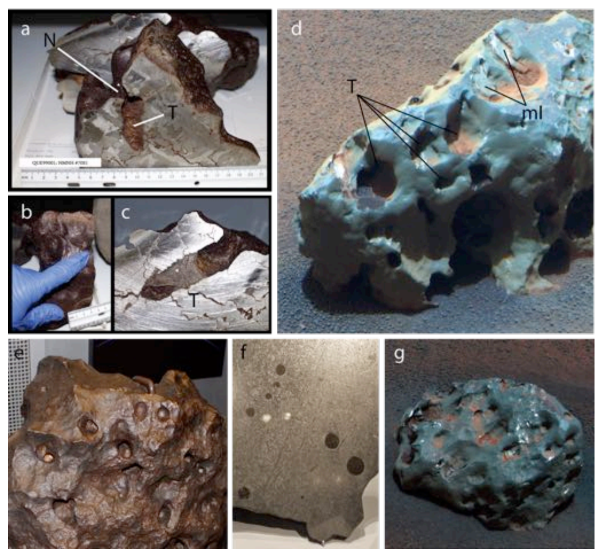

Figure 2. Vug produced by troilite ablation during atmospheric passage (a-c) in QUE99001. Shelter Island (d) exhibits similar nozzle-like features (T), together with differentially eroded inclusive masses (mI). IAB coarse octahedrite Canyon Diablo exterior (e) and interior (f) present troilite nodule distribution. Weathered features share similarities but also significant differences with IAB-complex meteorite Heat Shield Rock (g). NASA/JPL/Pancam/Smithsonian Institution.

Observations: Micro-mapping of meteorite surfaces is a useful tool that can assist understanding of features and their relationships on the rocks (examples in Figure 1). Mapping efforts expand upon the work of [6]. The maps are also used to determine the extent of aeolian modification on the iron surfaces. Grooving, fluting, scalloping, boring, and/or faceting are indicative signs of interaction with wind-blown particles.

Most of the iron meteorites found on Mars have deep pits ranging in size from <1 to ~10 cm in diameter. Some appear to have been enlarged, undercut, or otherwise modified. Curated IAB iron meteorites show many examples of similar features, most associated with troilite nodules, which tend to weather preferentially with respect to the surrounding iron groundmass (Figure 2e). Troilite nodules may also acidify in the presence of water and further contribute to the hollowing process by corrosion of the surrounding metal groundmass [7]. Future morphometric analysis will involve measuring the spatial distribution of hollows for quantitative statistical comparisons.

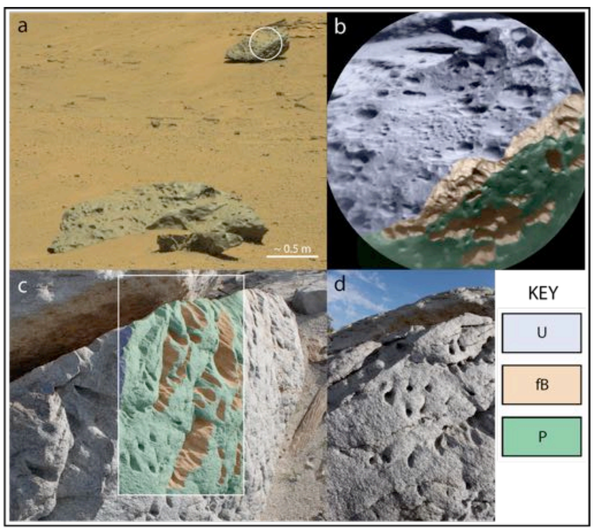

Figure 3. 3a shows Lebanon A and B (large and small iron meteorites in foreground), together with Littleton (background) in Gale crater. White circle in 3a shows ChemCam Remote Microscopic Imager area which has been color-mapped in 3b to highlight three surface types, an upper or side surface (heavily scalloped on Littleton and marked U, tangential flutings and face-on cavities that coalesce to become deep excavations (fB); and a sub-planar surface (perpendicular to borehole orientation in the terrestrial case, P). A possible analog to these surfaces can be found in ventifacted igneous rocks at San Gordiono Pass, California; example in 3c (angled view), and 3d (face on view). Boreholes penetrate deeply into the rock mass and indicate paleowind direction. Image credits: NASA/JPL/Mastcam/ ChemCam RMI.

The Opportunity iron Shelter Island exhibits mineral inclusions or kamacite plates exposed by differential weathering on its uppermost surface (Fig. 1d; mI). These features are adjacent to similarly appearing pits, four of which have funnel-shaped cross sections, including a cavity at the base in each case. Nozzle-shaped depressions breaching vugs and partially excavating troilite nodules during atmospheric ablation can be seen in the cross section saw cut of Antarctic iron meteorite QUE99001 [8], which presents an alternative interpretation of the Shelter Island funnels (Figure 2a-c).

Gale crater iron meteorites Lebanon and Littleton exhibit flutings and scallops with oriented symmetry potentially useful as paleowind direction indicators (Fig. 3). Clean-edged, elliptical to round cavities of varying diameter, and often occurring independently of local topography, can also be observed. On Littleton these latter features have a character that resembles several features seen among the terrestrial Garnet Hill ventifacts where rock faces present changing aspects with respect to the prevailing wind direction. These igneous rocks have a variety of wind-abraded surfaces ranging from surficial polishing to deep incision from late Pleistocene and Holocene sand grain saltation [e.g., 9]. Of interest to this study are numerous cicular to teardrop shaped, ~1-3cm diameter cavities that penetrate deeply into the rock mass with variable spacing between the holes. The production of these 'boreholes' may be related to a venturi-like acceleration of sand grains as they find purchase in the rock mass, but a full explanation of the mechanism is unknown. Their orientation within the rockmass is, however, clearly related to wind direction. Cavernous excavations result where these boreholes coalesce, and can be characterized in some cases by two mappable texture types (Figure 3c; fB and P) that can also be mapped on Littleton ChemCam RMI frames (Figure 3b). Though the iron meteorites and igneous analogs are of different petrologies and mineralogies, both rock types are massive, homogeneous and unfractured, which may conceivably account for these apparent similarities.

References: [1] Schröder C. et al. (2008) *J. Geophys. Res*., 113, E06S22. [2] Schröder C. et al. (2010) *J. Geophys. Res*., 115, E00F09. [3] Ashley J. W. et al. (2011) *J. Geophys. Res*., 116, E00F20. [4] Fleischer I. et al. (2011) *Met. Planet. Sci.*, 46, 1, 21-34. [5] Schröder C. (2015) *LPSC XLVI*. [6] Ashley J. W. (2012) *GSA* abs. #P23C-194. [7] Buchwald V. F. (1975) *Handbook of Iron Meteorites*, 1418 pp. [8] McCoy at el., (2000) *Antarctic Newsletter.* 3, 2. [9] Griffiths P. G. et al. (2009) *Aeolian Res*., 1, 1-2, pp. 63-73.