

IN SITU INVESTIGATION OF IRON METEORITES AT MERIDIANI PLANUM, MARS. I. Fleischer¹, G. Klingelhöfer¹, C. Schröder², D. W. Mittlefehldt³, R. V. Morris³, M. Golombek⁴, J. W. Ashley⁵. ¹Johannes Gutenberg-Universität, Staudinger Weg 9, 55128 Mainz, Germany (fleischi@uni-mainz.de), ²Center for Applied Geosciences, Eberhard Karls University, Sigwartstr. 10 72076 Tübingen, Germany. ³NASA Johnson Space Center, Houston, Texas. ⁴Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California. ⁵School of Earth and Space Exploration, Arizona State University, Tempe, Arizona.

Introduction: The Mars Exploration Rover Opportunity has encountered four iron meteorites at its landing site in Meridiani Planum. The first one, informally named “Heat Shield Rock”, measuring ~30 by 15 cm, was encountered in January 2005 [1, 2] and officially recognized as the first iron meteorite on the martian surface with the name “Meridiani Planum” after the location of its find [3]. We will refer to it as “Heat Shield Rock” to avoid confusion with the site. Between July and October 2009, separated ~10 km from Heat Shield Rock, three other iron meteorite fragments were encountered, informally named “Block Island” (~60 cm across), “Shelter Island” (~50 by 20 cm), and “Mackinac Island” (~30 cm across). Heat Shield Rock and Block Island, the two specimens investigated in detail, are shown in Figure 1. Here, we focus on the meteorites’ chemistry and mineralogy. An overview in the mission context is given in [4]; other abstracts discuss their morphology [5], photometric properties [6], and their provenance [7].



Figure 1: Heat Shield Rock (left, ~30 cm across; Sol 346, sequence P2591, filters 257) and Block Island (right, ~60 cm across; Sol 1961, Sequence P2537, filters 257).

Chemical composition and classification: The elemental compositions have been determined by APXS for Heat Shield Rock, Block Island and Shelter Island. Based on their Ni, Ge, and Ga contents, all three are consistent with an IAB iron meteorite classification. The compositions of the three meteorites are nearly identical, and well within the range of compositions found for the IAB Canyon Diablo iron on Earth [8-11]. The IAB iron meteorite group shows a wide range in compositions [7], and they account for ~1% of all meteorite falls on Earth. It is thus likely that the three investigated specimens are fragments from the same meteorite rather than separate falls. Mackinac Island was not investigated with either the APXS or

the MB instruments. It is therefore unknown whether it has a composition similar to the other three iron meteorites.

Mineralogy: Mössbauer spectra were obtained on two of the meteorite specimens. On Heat Shield Rock, one spot was investigated before and after brushing the surface; the two spectra are practically identical [1,2]. Four spots were measured on Block Island, two spots each were located close to each other and measured from the same rover position. Figure 2a shows Mössbauer spectra obtained on Heat Shield Rock and the two Block Island targets “New Shoreham” and “Siah’s Swamp 2” in comparison. The Heat Shield Rock spectrum is much better resolved than the two Block Island spectra because more than 5 half lives of the Mössbauer source have passed between the measurements. All spectra are dominated by a Mössbauer sextet corresponding to metallic iron-nickel phases. Two separate sextets can be resolved, most likely corresponding to kamacite (α -(Fe,Ni)) and taenite (γ -(Ni,Fe)). Heat Shield Rock spectra show additional minor amounts of schreibersite ((Fe,Ni)₃P) and ferric oxides (figure 2b; [1]). Block Island spectra show some diversity. The spectra from the adjacent spots “Siah’s Swamp” and “Siah’s Swamp 2” are very similar to the Heat Shield Rock spectrum, with larger fractions of ferric oxide for Siah’s Swamp 2 (~27% subspectral area compared to less than 10% for Siah’s Swamp and Heat Shield Rock). Siah’s Swamp 2 was selected in particular because it had the most amount of the purple coating in the field of view of the MB instrument. The spectrum from the spot “New Shoreham” is more complex, with indications for the presence of Mössbauer sextets corresponding to cohenite ((Fe,Ni,Co)₃C) and schreibersite (~16% each). The spectrum from the adjacent spot “Clayhead Swamp” shows indications for cohenite (~12%) and ferric oxide (~27%), as shown in figure 2c.

Physical and chemical weathering: Iron meteorites on the martian surface are susceptible to the presence of trace amounts of water and halogens. Therefore, they may be regarded as valuable probes to assess weathering conditions on the martian surface [12].

The surfaces of Heat Shield Rock and Block Island are smooth, with pits interpreted as regmaglypts that have formed by ablation during the descent through the atmosphere. Apart from a large weathered pit on the surface of Block Island, both meteorites appear

fresh with a low degree of alteration. This pit, however, may be an indication of an aqueous interaction [5]. The other two meteorites, Shelter Island and Mackinac Island, appear more eroded, with large hollows indicating cavernous weathering, which may be from aqueous weathering and/or from atmospheric ablation effects. Hematite spherules are residing in some of the pits. Because they are too large to saltate they indicate ripple migration across the meteorites and thus at least partial burial, which may have enhanced chemical weathering.

On both Heat Shield Rock and Block Island, false color Pancam images revealed the presence of a thin coating that of distinct color compared to uncoated surface portions [2, 6]. The coating is most likely related to the ferric doublet detected in Mössbauer spectra from both meteorites (figure 2). The ferric doublet can be attributed to iron oxides or oxyhydroxides that are in a paramagnetic state over the measured temperature range (e.g., nanocrystalline hematite (α -Fe₂O₃), maghemite (γ -Fe₂O₃), goethite (α -FeOOH), akaganeite (β -FeO(OH, Cl)) and/or lepidocrocite (γ -FeOOH)). Heat Shield Rock spectra show evidence for an additional Mössbauer sextet with broad lines, likely corresponding to a mixture of hematite, maghemite and potentially magnetite (Fe₃O₄) [1]. Block Island spectra show fractions of ferric oxide comparable to Heat Shield Rock for Siah's Swamp and New Shoreham, and significantly larger for Siah's Swamp 2 and Clayhead Swamp. This indicates a more weathered state for Block Island than for Heat Shield Rock, consistent with the presence of the weathered surface pit. The statistics of Block Island spectra do not allow the detection of a potential sextet stemming from iron oxides.

Conclusions: Three of the four iron meteorites encountered by the MER Opportunity have very similar elemental composition, the composition of the fourth is unknown. Mössbauer spectra obtained on "Heat Shield Rock" and "Block Island" are dominated by iron-nickel phases, with contributions from schreibersite and/or cohenite. A low degree of chemical weathering is indicated by the presence of iron oxides or oxyhydroxides. Weathering is also indicated by a coating detected on both meteorites and a large weathered pit on Block Island. Based on the amounts of ferric oxide detected in Mössbauer spectra, Block Island appears to be more weathered than Heat Shield Rock.

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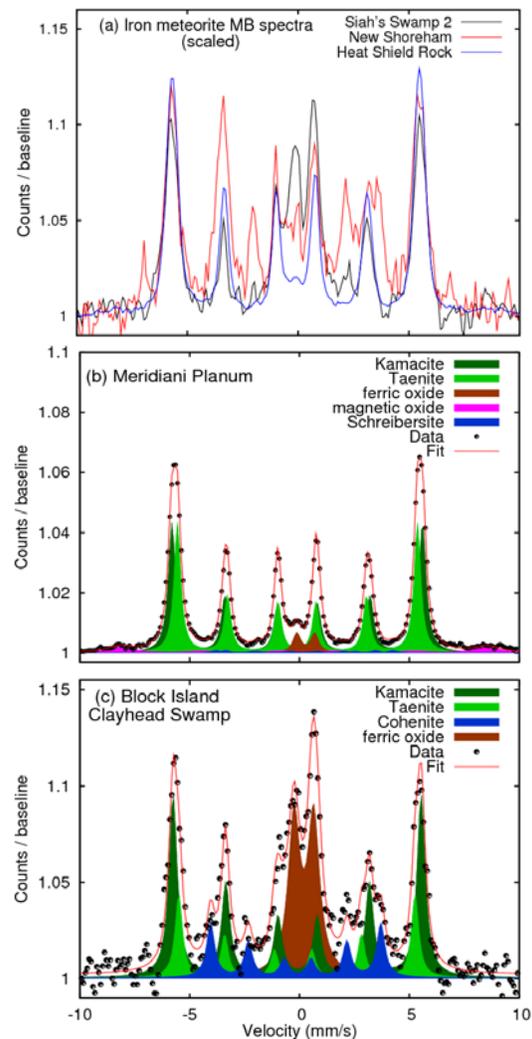


Figure 2: (a) Mössbauer spectra obtained on Heat Shield Rock and two spots on Block Island. Fits reveal the presence of kamacite, taenite, schreibersite or cohenite and different amounts of iron oxides for (b) Meridiani Planum (Heat Shield Rock) and (c) Block Island.