

OVERVIEW OF ATHENA MICROSCOPIC IMAGER RESULTS. K. Herkenhoff¹ (kherkenhoff@usgs.gov), S. Squyres², R. Arvidson³, J. Bell III², N. Cabrol⁴, M. Chapman¹, B. Ehlmann³, B. Franklin⁵, L. Gaddis¹, P. Geissler¹, R. Greeley⁶, J. Grotzinger⁵, J. Johnson¹, B. Jolliff³, L. Keszthelyi¹, A. Knoll⁷, P. Lanagan⁸, E. Lee¹, J. Maki⁵, S. McLennan⁹, D. Ming¹⁰, K. Mullins¹, J. Rice⁶, L. Richter¹¹, M. Sims⁴, L. Soderblom¹, N. Spanovich⁵, R. Springer⁵, R. Sucharski¹, R. Sullivan², C. Weitz¹², and the Athena Science Team, ¹U. S. Geological Survey, Flagstaff, AZ 86001; ²Cornell Univ.; ³Washington Univ.; ⁴NASA Ames Research Center; ⁵Caltech/JPL; ⁶ASU; ⁷Harvard Univ.; ⁸Univ. Arizona; ⁹SUNY, Stony Brook; ¹⁰NASA JSC; ¹¹DLR Institut für Raumsimulation; ¹²PSI.

Introduction: The Athena science payload [1] on the Mars Exploration Rovers (MER) includes the Microscopic Imager (MI). The MI is a fixed-focus camera mounted on the instrument arm. The MI acquires images at a scale of 31 microns/pixel over a broad spectral range (400 - 700 nm). The MI acquires images using only solar or skylight illumination of the target surface. The MI science objectives, instrument design and calibration, operation, and data processing were described by Herkenhoff *et al.* [2]. Initial results of the MI experiment on both MER rovers (“Spirit” and “Opportunity”) have been published previously [3,4]. Highlights of these and more recent results are described below.

Spirit (MER-A) results: As examined by the MI, soil materials at Gusev show texture down to the limit of resolution (~100 microns). Soil surfaces are typically rough at submillimeter scales but are molded to much smoother surfaces under compression by the Mössbauer (MB) contact plate and/or a rover wheel, suggesting the presence of a substantial fraction of particles too small to be resolved. It is unclear whether remolding was accomplished by compression of void space and reorganization of existing particles versus by destruction of weak particles to even smaller sizes. Original soil texture was obliterated by the ~1 N force applied by the MB contact plate. If this was due to crushing of particles, the original particles must have been very weak. These observations are consistent with electrostatic cohesion or minor cementation of dust grains.

Some of the MI images of soil or dusty rocks show linear textures that may have been formed by recent winds. Bedforms at Gusev have coarser particles at their crests and finer grains in the troughs, like aeolian ripples on Earth [5]. Particle-size frequencies of sampled ripple surfaces typically are bimodal, with one mode centered between 1 and 2 mm (coarse sand to very fine granules) and the other below 210 μm (fine to very fine sand).

MI observations of rocks on the Gusev plains that were abraded by the Rock Abrasion Tool (RAT) reveal evidence for thin coatings on the rocks, which may be products of alteration by water. The images show mineral grains, probably phenocrysts, beneath the coatings. These observations are consistent with

the plains rocks being weakly-altered basalts, as indicated by other Spirit observations [6].

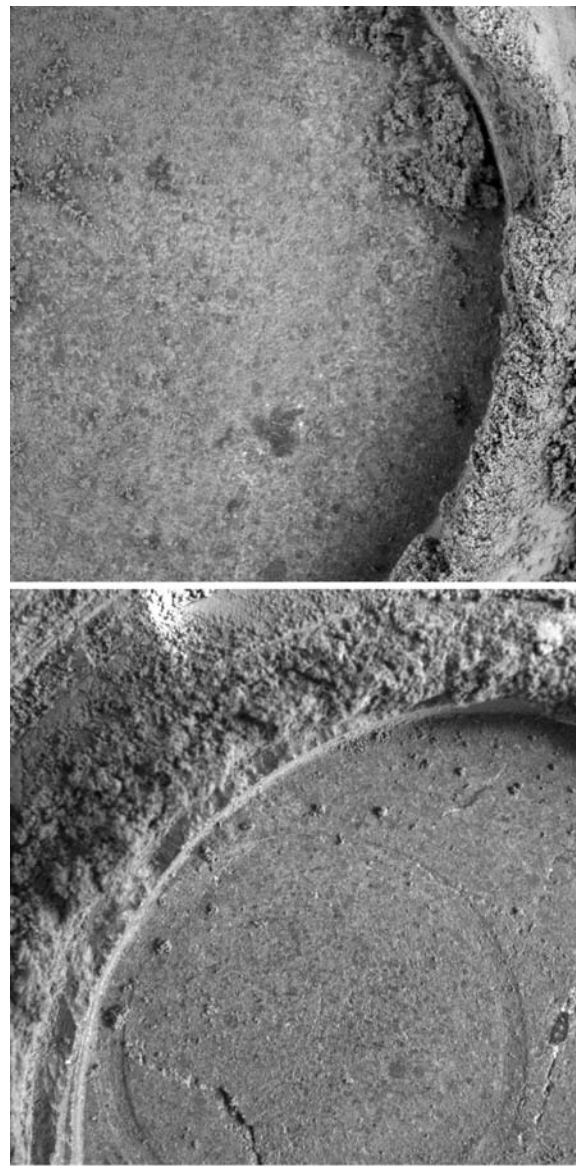


Figure 1. MI images of rock surfaces, taken when target in shadow after RAT grinding. Area shown in each image is 3 cm square. (top) Merge of 5 images of target “Ratchit2” on rock “Ebenezer,” taken on Sol 232. Note poorly sorted texture, with angular to subrounded clasts. (bottom) Radiometrically-calibrated image 2M151759702 of target “Koolik2” on rock “Uchben,” taken on Sol 283. Clasts are generally more rounded than in “Ebenezer.”

Many rocks in the Columbia Hills have different textures than the rocks on the plains. The rock "Pot o' Gold" appears to contain nodules in a less-resistant matrix, but the composition of the nodules cannot be determined from MI observations. This rock has probably been eroded by a combination of chemical weathering and aeolian abrasion. Higher in the Columbia Hills, MI observations of RAT holes show a variety of textures, with clasts of sizes ranging down to the MI resolution limit (Fig. 1). These images, along with observations by the other Athena instruments, suggest that these rocks are altered volcanoclastics or impact ejecta. The investigation of these rocks continues as Spirit explores the Columbia Hills; examples of recent MI observations will be shown at the conference.

Opportunity (MER-B) results: MI observations of soil-like materials within Eagle crater and on the surrounding plains have been used to assess cohesion and cementation of very fine-grained (<125 μm) material, based upon soil morphology after disturbances caused by the rover wheels and by the MB contact plate. Granules on the surface typically are pressed into the underlying very fine sand by MB contact; cohesion between grains is indicated where this results in very short, near-vertical walls in the surrounding soil. Some MI observations of soils disturbed by the MB contact plate show apparent fractures, suggesting that cementation of surface particles has formed a crust. The thickness of this crust is estimated to be at least 1 mm (the penetration depth of the MB contact plate) based upon images taken after the surface was disrupted. Plausibly, and consistent with APXS spectra of soil-like deposits at the Meridiani site, the cementation is caused by precipitation of various salts (e.g., Cl^- and SO_4^- -bearing) that bridge soil particles. Salts in the dust (unresolved by the MI) may dissolve and migrate into voids between soil particles in thin films of water adsorbed onto soil particles. Thin liquid films may occur in soils when the spin axis obliquity and atmospheric relative humidity are high enough to cause precipitation or condensation of water. During warming events, salts may precipitate on soil particles as thin liquid films evaporate, weakly cementing the upper soil surface.

In the investigation of sedimentary rocks exposed at Meridiani Planum, the MI has provided key data that help to integrate observations made by Pancam with chemical analyses made by APXS, MB, and Mini-TES [7]. MI images indicate that outcrop rocks have four principal components: (i) moderately rounded medium to coarse (0.2 to 1 mm) sand grains (probably reworked heterogeneous evaporites—mixtures of sulfates and very fine-grained siliciclastic material) that form mm-scale laminations; (ii) fine grained and coarser crystalline textures of subsequently precipitated cements and areas of

recrystallization; (iii) centimeter-size vugs that record the early diagenetic growth and subsequent dissolution of crystals similar to sulfate crystals in terrestrial evaporites, and (iv) mostly 3-5 mm spherules distributed throughout the outcrops. MI images document spatial relationships among these constituents, recording a complex history of deposition and diagenesis [8]. In places, fine-grained evaporite muds appear to have been ripped up, transported and redeposited. Sandy laminae have been cemented, probably by sulfate minerals, during earliest diagenesis. The large vugs cut across bedding, indicating that the minerals that once filled them also formed diagenetically within the sediments. Where present, the vugs are found to continue into the rock for at least as deep as the Rock Abrasion Tool was able to grind (~ 5 mm) and commonly are seen to increase in size with increasing abrasion depth. Accordingly, they are interpreted to represent an intrinsic feature of the outcrops. Vugs exhibit prismatic to discoidal geometry, characteristically with maximum width (1-2 mm) near their midpoints and tapering toward their ends. This morphology is consistent with precipitation of certain evaporite minerals within the rock matrix, either displacing or replacing the matrix grains during growth. Vug geometry is most consistent with a monoclinic precursor mineral. Subsequently, these minerals were either dissolved by percolating fluid or abraded by wind activity to produce the vugs.

MI images and mosaics provide evidence for the presence of small-scale cross bedding with festoon geometry at Meridiani Planum. An MI mosaic of part of the outcrop target called Last Chance shows festoon cross-lamination. Another MI mosaic of a rock called Upper Dells reveals abundant small-scale discordant laminae and truncations, including ripple cross laminae. In a manner similar to Last Chance, this rock preserves evidence for festoon ripple cross-lamination, in a view that is largely transverse to current paleoflow. The MI images confirm two key features that lead to the interpretation of water having flowed at times across the surface at the landing site: centimeter-scale cross-stratification and festoon geometry of cross-lamination. Opportunity has discovered further evidence for festoon cross-lamination near Erebus crater, and MI images of these features are planned. These and other recent images will be shown at the conference.

References: [1] Squyres, S. W. *et al.* (2003) *JGR*, 108, 8062. [2] Herkenhoff, K. E. *et al.* (2003) *JGR*, 108, 8065. [3] Herkenhoff, K. E. *et al.* (2004) *Science* 305, 824. [4] Herkenhoff, K. E. *et al.* (2004) *Science* 306, 1727. [5] Greeley, R. *et al.* (2004) *Science* 305, 810. [6] McSween, H. Y. *et al.* (2004) *Science* 305, 842. [7] Squyres, S. W. *et al.* (2004) *Science* 306, 1709. [8] McLennan, S. M. *et al.* (2005) *EPSL* 240, 95.