

OVERVIEW OF ATHENA MICROSCOPIC IMAGER RESULTS. K. Herkenhoff¹ (kherkenhoff@usgs.gov), S. Squyres², R. Arvidson³, D. Bass⁴, J. Bell III², P. Bertelsen⁵, N. Cabrol⁶, B. Ehlmann³, W. Farrand⁷, L. Gaddis¹, R. Greeley⁸, J. Grotzinger⁹, A. Hayes², S. Hviid¹⁰, J. Johnson¹, B. Jolliff³, K. Kinch¹¹, A. Knoll¹², M. Lemmon¹³, M. Madsen⁵, J. Maki⁴, S. McLennan¹⁴, D. Ming¹⁵, R. Morris¹⁵, J. Rice⁸, L. Richter¹⁶, M. Sims⁶, P. Smith¹⁷, L. Soderblom¹, N. Spanovich¹⁷, R. Sullivan², C. Weitz¹⁸, and the Athena Science Team, ¹U. S. Geological Survey, Flagstaff, AZ 86001; ²Cornell Univ.; ³Washington Univ.; ⁴Caltech/JPL; ⁵Danish Space Research Institute; ⁶NASA Ames Research Center; ⁷SSI; ⁸ASU; ⁹MIT; ¹⁰Max Planck Institute for Aeronomy; ¹¹Aarhus Univ.; ¹²Harvard Univ.; ¹³Texas A&M; ¹⁴SUNY, Stony Brook; ¹⁵NASA JSC; ¹⁶DLR Institut fur Raumsimulation; ¹⁷Univ. Arizona; ¹⁸PSI.

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 an extendable arm, the Instrument Deployment Device (IDD). The MI acquires images at a spatial resolution of 31 microns/pixel over a broad spectral range (400 - 700 nm). The MI uses the same electronics design as the other MER cameras but its optics yield a field of view of 32×32 mm across a 1024×1024 pixel CCD image. 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 remodeling 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 Mössbauer contact plate. If this was due to crushing of particles, the original particles must have been very weak. A few soils preserve a vertically coherent network (100-300 micron scale) of tube-like and honeycomb features. 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].

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 (Fig. 1), 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 poorly sorted, subangular to subrounded clasts of sizes ranging down to the MI resolution limit. 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 climbs higher into the Columbia Hills; examples of recent MI observations will be shown at the conference.

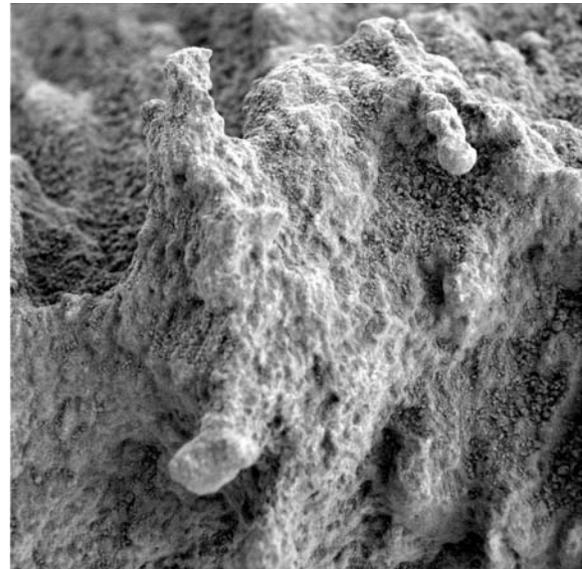


Figure 1. MI image of rock “Pot o’ Gold” taken on Spirit Sol 163 in full shadow. Field of view 3 x 3 cm.

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 in and near Eagle crater, 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]. 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 (Fig. 2). 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. The lower part of the mosaic illustrates several sets of ripple 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. These and more recent images will be shown at the conference.

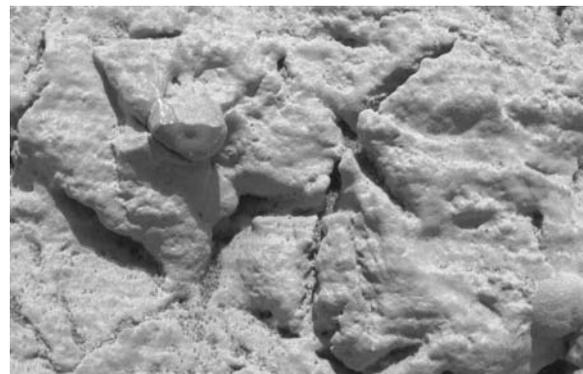


Figure 2. Part of merge of 5 MI images of outcrop feature McKittrick (1M130672440-1M130672724), taken on sol 28. Illumination from top, area shown is 2.8 cm across. Note concentric banding in shaded face of broken spherule upper left of center. Vugs cut across subhorizontal bedding and are partly filled by dark, very fine sand grains.

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) *LPSC XXXVI* (this issue).