MECA Microscopy, the Next Generation. M. H. Hecht[1], A. Aubrey[1], G. Sellar[1], S. Kounaves[2], N. Chaniotakis[2], W.T. Pike[3], U. Staufer[4], [1]Jet Propulsion Laboratory, California Institute of Technology, M/S 306-431, Pasadena, CA 91109 (email: mhecht@jpl.nasa.gov), [2]Tufts University, Medford, MA, [3]Imperial College, London, [4]Technical University Delft, the Netherlands.

Introduction: During the summer of 2008, the Microscopy, Electrochemistry, and Conductivity Analyzer (MECA) operated on the Northern Plains of Mars as part of the Phoenix mission. From $L_S = 76°$ to 147°, Phoenix characterized the local terrain and atmosphere, and analyzed soil excavated by a robotic arm [1]. MECA combined three experiments in a single instrument suite (Fig. 1): The Microscope Station (MS); the Wet Chemistry Laboratory (WCL); and the Thermal and Electrical Conductivity Probe (TECP). While MECA was fully successful within the context of Phoenix, and is for the most part generalizable to non-polar terrains, it was designed for a fixed lander and constrained by consumables. Subsequent development has been aimed at extending those technologies to long-lived rover missions.

The MS [2] combined an Atomic Force Microscope (AFM) and an optical microscope (OM) to observe soil particles ranging from micron to millimeter size, and is the only instrument to have resolved individual sand, silt, and clay grains on Mars. The OM acquired thousands of 256x512 monochromatic frames, corresponding to 1 mm wide, 2 mm tall sections of prepared, 3-mm round sample substrates that captured films of excavated particles up to 200 µm thick. The optical system blur circle was smaller than the 4µ per pixel image granularity, producing images 10x finer than previous or currently planned Mars microscopes.

AFMs produce 3-D images (or, more properly, topograms), by rastering a fine tip across the sample under force-feedback control. A number of high quality AFM topograms were acquired during the mission, typically with 16µm square frames, x-y resolution of approximately 0.1 µm and vertical resolution of ~0.01 µm. The MECA AFM was contributed by a Swiss consortium led by the University of Neuchatel.

A typical OM image is shown in Fig 1. From a mass perspective, the dominant particle type was found *not* to be the ubiquitous red dust, but small, brown or glassy sand-sized particles subrounded by saltation[3]. The red dust, commonly called nanophase iron oxide, was relatively coarse and deficient in clay-sized particles, indicative of formation in a non-aqueous environment [4]. The AFM allowed the particle size distribution to be extended to clay-sized particles and offered unmistakable evidence of platy, angular particles reminiscent of phyllosilicates [5].

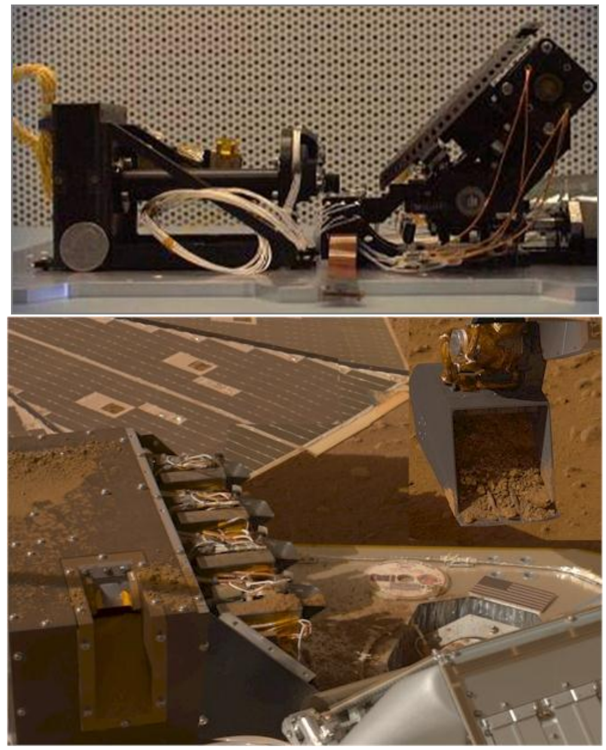

Fig. 1: Top: The MECA microscopy station. The sample wheel is on the right, the OM on the left, and the AFM is the small box between the two. Bottom: The MECA enclosure on Mars. On the right are the Wet Chemistry (WCL) cells. In the foreground is the soil inlet for the microscopes.

The next generation: MECA traveled with 69 substrates, grouped into sets of 6 types of substrates that were exposed simultaneously. Based on these findings, one or two types of substrates would be sufficient for each sample, and it is possible to re-use substrates if proper care is taken to sparsely populate them with particles. In this respect, the MS could be used immediately on a rover mission with a sample delivery mechanism.

We have focused, therefore, on improvements that would extend the capability of the instrument to particle-by-particle mineral identification. At the simplest level, a different selections of LED wavelengths would allow more sophisticated multispectral imaging [6].

A further extension to the OM has been investigated that utilizes engineered substrates with polarized back illumination and chemical stains to reveal properties such as pH and ion concentrations (Fig 2). The proposed chemical microscope (CM) focuses through a transparent platform to the surface of an array of gel-based substrates containing fluorescent cation- or anion-selective dyes and other indicators. Stained particles are then imaged at high resolution from the back of the platform, and the particle color indicates properties such as pH (Fig. 1-2) or specific ion content. Such films are commonly configured as optical fiber caps for ion selective optrodes (ISO), which are typically used for remote chemical sensing. Other "smart substrates" could be invisioned, such as fluorescamine-impregnated gels tol test for the presence of primary amines, or freshly-deposited metal films to reveal oxidation potential.The fluorescence detection scheme will be similar to that used for the OM [2], where the sample could be illuminated by a trio of 375 nm UV LEDs fitted with blocking filters to remove visible light. A UV filter in the imager blocked reflected UV light such that only fluorescence was detected.

Enhancements to the AFM have not been explored, but could include tips for magnetic imaging.

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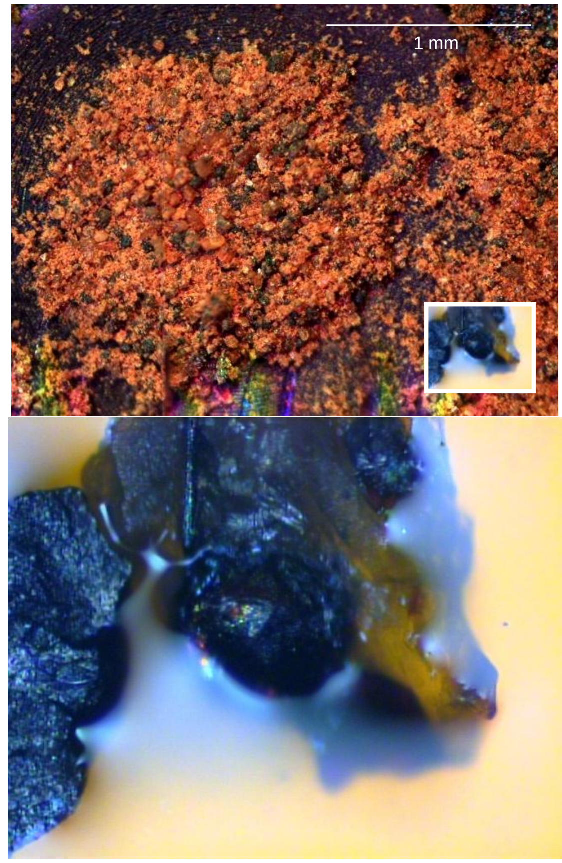

Fig. 2. Top: MECA OM micrograph showing several particle types (photo JPL/NASA). Inset: Lab image (same scale) of particles in contact with a pH indicator dispersed in a hydrogel (blue is basic). Bottom: Inset enlarged.