The Multispectral Microscopic Imager (MMI) and the Mars Microbeam Raman Spectrometer (MMRS): An Integrated Payload for the In-Situ Exploration of Past and Present Habitable Environments on Mars.

J. I. Nuñez[1], J. D. Farmer[1], R. G. Sellar[2] S. Douglas[2], K. S. Manatt[2], M. D. Fries[2], A. L. Lane[2], Alian Wang[3], and D. L. Blaney[2], [1]School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85287, USA (jorge.nunez@asu.edu). [2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA. [3]Department of Earth and Planetary Sciences and McDonnell Center for Space Sciences, Washington University, St. Luis, MO 63130, USA.

Introduction: An immediate objective of the Mars Program is the discovery of past or present habitable environments on Mars that could have supported microbial life and provided conditions favorable for the capture and preservation of biosignatures. In the analysis of aqueously-formed sedimentary rocks, spatially-integrated microscale *texture with mineralogy* provides essential data for inferring both primary depositional environments and secondary (post-depositional) diagenetic processes. Such integrated data sets are regarded as essential for accurate *in-situ* assessments of paleoenvironments, past habitability, and the potential for a fossil biosignature record.

Combining microscopic imaging with spectroscopic methods (VIS-SWIR reflectance and laser Raman spectroscopy), provides a powerful approach for obtaining definitive mineralogy within context, i.e., with the information about volatiles, ices, and organic matter in rocks, soils, and ices; all in the context of microstructure. This approach provides observations at spatial scales (62.5 μm) appropriate for microbial life and is required for realistic assessments of habitability [1], [2]. In addition, certain classes of meso-to-microscale biosignatures (e.g., biosedimentary structures and microfabrics, biominerals, or associated organic remains) can provide direct *in-situ* evidence for the presence of biosignatures under field conditions [1], [3].

Payload: The Multispectral Microscopic Imager (MMI), similar to a geologist's handlens, generates multispectral, microscale, reflectance images of geological samples, in which each pixel consists of a VIS-SWIR spectrum ranging from 463 nm to 1750 nm [4], [5]. This spectral range enables the discrimination of a wide variety of rock-forming minerals, especially Fe-bearing phases, within a microtextural framework.

The Mars Microbeam Raman Spectrometer (MMRS) is capable of identifying inorganic mineral species as well as chemical bonding between important biogenic elements, particularly H-O, H-N, H-C, N-O, C-O, C-N, and P-O bonds [6]. The MMI and MMRS will be combined such that the Raman laser spot will lie inside the MMI field-of-view.

Co-registered MMI and MMRS datasets provide crucial mineralogical, and contextual information: 1) for the in-situ analysis of rocks and soils to support hypothesis-driven, field-based exploration; and 2) to guide sub-sampling of geologic materials for further analysis using analytical instruments onboard a rover, or in selecting samples for potential return to Earth.

Investigation of Samples: In our intial studies, we have combined data collected separately by the MMI and MMRS from a set of geological samples comprising a wide range of astrobiologically-relevant analog environments, to demonstrate the microtextural and mineralogical capabilities of the integrated payload and its potential to identify microscale habitable environments and detect fossilized biosignatures.

Figure 1 shows true-color (1A) and false-color images (1B) obtained with the MMI, a color map (1C) based on spectral end-members (1D), and laser Raman spectra (1E) of spots of interest (boxes 1-2). The integrated datasets enables both definitive identification of minerals present and imaging of their spatial interrelationships at the microscale. Our interpretation of this data is that the sample is a fine-grained, flow-banded, silicic volcanic breccia that has been cemented by clays, hematite, and calcite. Angular clast shapes and poor size-sorting of clasts indicate minimal transport. This, along with the uniformity of clast compositions (monolithologic), suggest deposition at or near the volcanic source as an auto-brecciated lava flow or possibly pyroclastic (airfall) that accumulated near a explosive vent. Cement compositions indicate the presence of alkaline, oxidizing fluids during early diagenesis. Fluid compositions evolved during diagenesis, with clays (also a major clast alteration phase) and hematite (iron oxide) being deposited first and calcite (calcium carbonate) being deposited last.

Figure 2 shows true-color (2A) and false-color (2B) images obtained with the MMI as well as Raman spectra (2C) of particular spots of interest of a Miocene-aged siliceous sinter from the Coromandel Peninsula, New Zealand. The MMI images demonstrate the palisade fabrics are preserved despite the sample having undergone extensive overprinting of primary textures by early diagenetic cementation of the originally porous sinter framework and recrystallization of opaline silica to quartz. Raman spectra confirm the recrystallization to quartz (by a Raman peak centered around 464 cm^{-1}) and the presence of fossilized organic carbon (cyanobacterial sheaths) by Raman peaks centered around 1350 cm^{-1} and 1603 cm^{-1}.

Conclusion: An integrated payload of the MMI and MMRS will provide crucial *in-situ* mineralogical and microtextural information for properly identifying rocks and soils, interpreting the paleoenvironmental conditions they represent, assessing the potential for past or present habitability, and constraints for assessing the biogenicity of any putative fossil remains.

References: [1] Farmer J. D. and Des Marais D. J. (1999) *JGR, 104,* 26,977-26,995. [2] Farmer J. D. (2000) *Palaeobiology II,* Eds. D. Briggs and P. Crowther, Blackwell Science Publishers, Oxford. [3] Cady S. L. and Farmer J. D. (1996) *Hydrothermal Ecosystems on Earth (and Mars?)*, Eds. G. Bock and J. Goode, pp. 150-173. John Wiley, New York. [4] Sellar R. G. et al. (2007) *Seventh Internat. Conf. on Mars,* Abstract #3017. [5] Nuñez J. I. et al. (2009) *40th LPSC*, Abstract #1830. [6] Wang A. et al. (2003) *JGR*, 108, 5005.

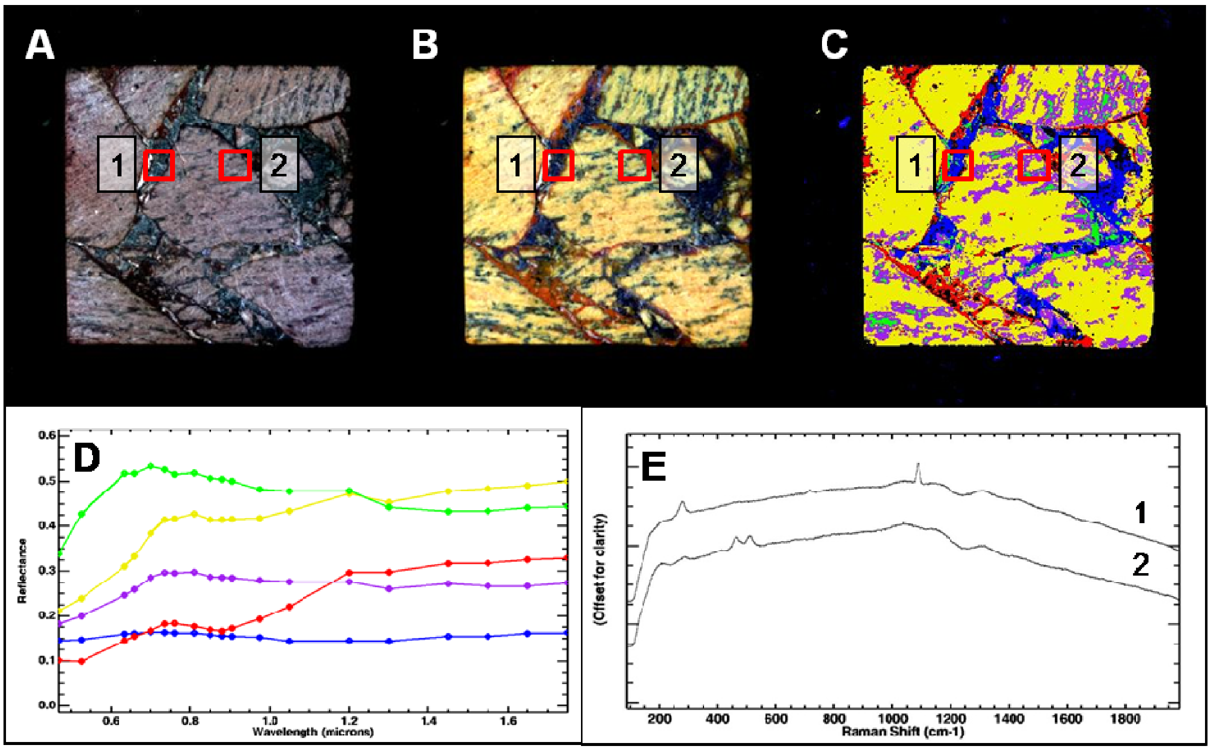

Figure 1. Multispectral images obtained with the MMI and spectra of a volcanic breccia with clays, calcite and hematite cements. MMI subframe field of view: 25 mm x 25 mm (62.5 µm/pixel). Images A & B are 2% histogram stretched for clarity. Figure 1A: Natural-color image (R = 641 nm; G = 522 nm; B = 463 nm). Figure 1B: False-color image (R = 1430 nm; G = 970 nm; B = 522 nm). Figure 1C: Color mineral map based on spectral end-members (figure 1D). Figure 1E: Raman spectra of spots of interest (boxes 1-2).

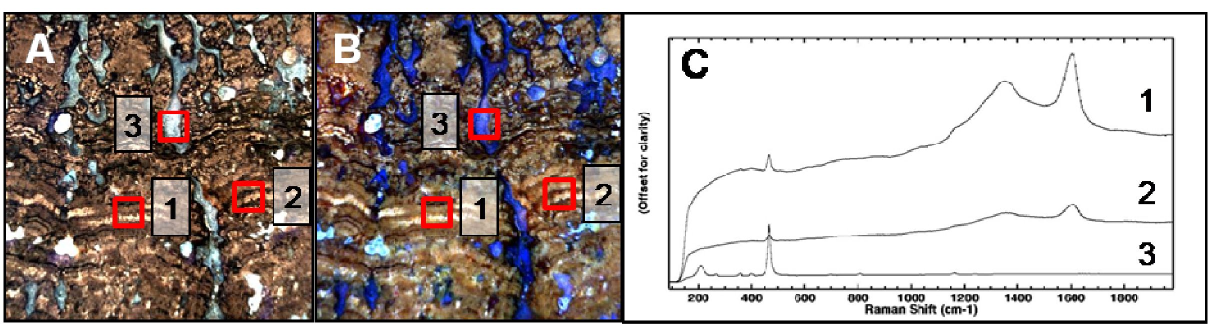

Figure 2. Multispectral images obtained with the MMI and corresponding Raman spectra of a Miocene-aged siliceous sinter from the Coromandel Peninsula, New Zealand. MMI subframe field of view: 25 mm x 25 mm (62.5 µm/pixel). Images A & B are 2% histogram stretched for clarity. Figure 1A: Natural-color image (R = 641 nm; G = 522 nm; B = 463 nm). Figure 1B: False-color image (R = 1430 nm; G = 970 nm; B = 522 nm). Figure 1C: Raman spectra of spots of interest (boxes 1-3).