SCIENCE INVESTIGATION APPROACH FOR THE PROPOSED 2018 MARS ASTROBIOLOGY EXPLORER - CACHER [MAX-C] ROVER.

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The Mars Astrobiology Explorer-Cacher (MAX-C) is a mission concept for the Mars 2018 launch opportunity, formulated by the MEPAG Mid-Range Rover Science Advisory Group (MRR-SAG). The proposed mission would conduct high-priority in situ science centered on the search for signs of past life or prebiotic chemistry on Mars, and would collect and document a suite of samples for potential return to Earth [1].

MAX-C Science Investigation Approach: Searching for evidence of past martian life requires observations of the macroscopic and microscopic fabrics of sedimentary materials, measurements that enable the reconstruction of the history of mineral formation as an indicator of preservation potential and geochemical environments. It also requires the capability to detect organic molecules with high sensitivity, and ability to determine specific mineral compositions as indicators of oxidized organic materials or coupled redox reactions characteristic of life. This type of information is also critical for selecting relevant samples for addressing the life question through analyses on Earth.

Rationale for 2D Compositional Mapping: The Mars program has previously used arm-mounted instruments to assess sample composition over an area several centimeters in size. However, newer instruments can achieve spatial resolution down to millimeter and micrometer scales. Some instrument approaches can produce data in a 2-D scanning or imaging mode, enabling the spatial co-registration of texture and composition. These spatially resolved compositional measurements would provide vital information for interpreting paleoenvironments and habitability, and particularly for evaluating potential signs of ancient microbial life – key aspects of which may be manifested at millimeter scales and smaller.

As a compelling example of the potential science return from 2-D compositional mapping on Mars, consider Figure 1, which shows an abraded rock surface imaged by the Opportunity Rover. This rock contains ~2% jarosite – a hydrated mineral that implies aqueous conditions sometime during the rock's history. To understand the relevance of hydrated minerals to habitability, we need to know the residence of minerals in relation to small scale geological features such as detrital grains, cements, concretions, laminae, crystals etc (all of which occur in this rock). This is required in order to determine (for example) whether the minerals formed in standing bodies of surface water, or in the subsurface long after the rocks were buried. ***Compositional mapping will provide the necessary observations to resolve these questions.***

MAX-C Recommended Measurement Capabilities: Because MAX-C is intended to have substantially lower cost and lower risk than the 2011 Mars Science Laboratory, we propose that the measurement strategy focus on interrogation of abraded surfaces from a robotic arm rather than onboard processing of rock chips or powders. The rover's interpretive capability should include:

- Remote mineralogical sensing at ~1 mrad/pixel or better, SNR > 100;
- Geomorphological context (optical) imaging at ~0.3 mrad/pixel or better ;
- Abrasion of ~3 cm diameter areas on rocks;
- Measurements of the abraded rock surfaces:
  - Micro-imaging at ~ 30 μm/pixel resolution or better, SNR > 100,
  - Mineralogical mapping with ~ 0.3 mm spatial resolution, SNR > 100,
  - Organic mapping with ~ 0.1 mm spatial sampling ,
  - Elemental chemistry mapping with ~0.1 mm spatial resolution, or if not possible to accommodate, then bulk chemical composition measured on a 1.5 to 2.5-cm diameter spot.

Figure 1. Opportunity Microscopic Imager mosaic of a 4.5 cm diam. abraded rock surface (NASA/JPL-Caltech/USGS).

A number of suitable instruments are either already developed or are under development (currently at Technology Readiness Level 3 or higher) in each of these measurement areas.

Imaging and Remote Mineralogical Sensing: The proposed rover would have a camera and an instrument capable of remotely determining mineral composition (such as a Vis-Near IR imaging spectrometer or a mid-IR spectrometer) mounted on the mast. These instruments would enable rapid surveying of local rocks and outcrops.

Arm-Mounted Micro-imaging: The microtextures of rocks and soils provide essential data for inferring both primary formational processes and secondary (postformational) diagenetic processes. Multispectral microimages could provide contextual information for evaluating the spatial (and implied temporal) relationships between constituent compositional phases characterized by other methods. Microimaging also provides important contextual information for selecting rocks for potential caching or additional analyses with other *in situ* instruments.

Arm-Mounted Mineralogical Mapping: Mineralogical mapping of abraded rock surfaces would provide powerful new insights into the origins and alteration history of martian materials beyond those that can be achieved by point or bulk measurements. Mineralogical mapping from a robotic arm could potentially be performed by various small, low power instruments including a scanned conventional Raman spectrometer at green or red wavelengths, a scanned time-gated Raman spectrometer, or a visible-near-IR imaging spectrometer.

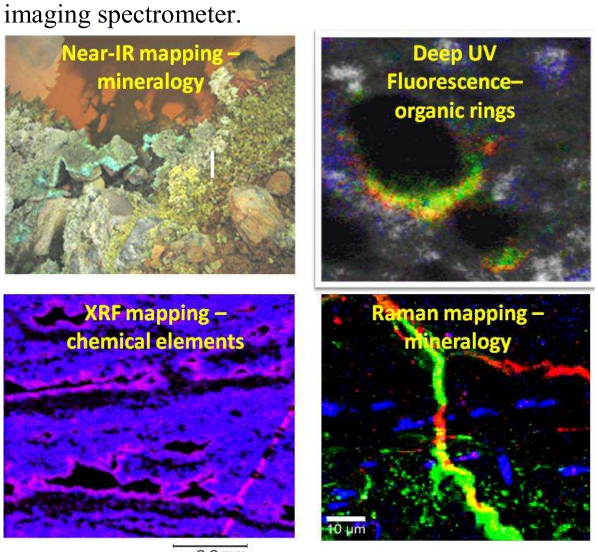

Figure 2. Micro-mapping measurements such as these could be used to relate mineralogy / chemisty / elemental composition / organics to textures, fabrics, and small scale structures. Spatial and spectral resolutions shown above may not represent those achievable on MAX-C (NASA/JPL-Caltech).

Arm-Mounted Organic Mapping. State-of-the-art measurements can map the presence of organic compounds at trace (parts-per-billion) levels in abraded rock surfaces. For example, UV Fluorescence imaging provides high sensitivity to fluorescent organic compounds, and can discriminate between fluorescent aromatic rings and fluorescent minerals when excitation < 260 nm is employed. Another emerging technique, deep UV Resonance Raman spectroscopy, is well suited to *in situ* detection of many astrobiologically relevant molecular bonds, including C-H, CN, C=O, C=C, NH_x, NO_x, SO_x, PO_x, ClO_4, water and OH (with sub-parts-per-million sensitivity). Other instrument approaches that can potentially map the distribution of organic compounds on abraded rock surfaces include conventional Raman spectroscopy (though less sensitive to organics), and *in situ* fluorescent derivatization methods coupled to diode illumination and microimaging.

Arm-Mounted Elemental Chemistry mapping: A new measurement approach that may be suitable for implementation on the MAX-C rover is chemical mapping (for instance, by scanning a focused X-ray beam across an abraded rock surface, or scanning a laser-induced breakdown spectrometer), which can show the spatial distribution of chemical elements in rocks at scales of tens to hundreds of microns. These hand-lens scale maps can be overlaid to reveal covariations between elements, and relationships between chemical composition and visible features. If chemical mapping were not achievable with mission resources, analyses averaged over an area a few cm in diameter can be achieved with instruments such as the APXS that have flight heritage and low data volume.

Need for Focused Investment in Instrument Development for MAX-C: During the next two years, significant instrument funding through NASA's MIDP, PIDDP, and similar programs would need to be made available to the community to ensure an adequate pool of instruments matured to about TRL-5 or greater by the 2012-2013 timeframe that can credibly be proposed for the MAX-C payload. Instrument competitions should include specific measurement needs related to MAX-C science goals.

References: [1] MEPAG MRR-SAG (2009) Mars Astrobiology Explorer-Cacher: A potential rover mission for 2018. http://mepag.jpl.nasa.gov/reports/index.html

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