UNVEILING THE MYSTERIES OF MARS WITH A MINIATURIZED VARIABLE PRESSURE SCANNING ELECTRON MICROSCOPE (MVP-SEM).

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Introduction: Development of a miniaturized scanning electron microscope that will utilize the martian atmosphere to dissipate charge during analysis continues. This instrument is expected to be used on a future rover or lander to answer fundamental Mars science questions. To identify the most important questions, a survey was taken at the 47th Lunar and Planetary Science Conference (LPSC). From the gathered information initial topics were identified for a SEM on the martian surface. These priorities are identified and discussed below. Additionally, a concept of operations is provided with the goal of maximizing the science obtained with the minimum amount of communication with the instrument.

Survey Results: A Survey Monkey link was provided in a 2016 LPSC abstract [1], as well as bulletin boards at the conference venue. Conference attendees were also asked in person about their priorities for a SEM on Mars. The following items were identified:

- Martian dust. According to B. Ehlmann [2], "the martian dust has proven to be illusive to characterize". Its small size, colloquially less than 10 microns in size [e.g., 3], makes it difficult to characterize by means other than SEMs. As the dust has not been sufficiently characterized, its origin is still up for debate. The MVP-SEM will be capable of imaging to a resolution of 50 nm or better and obtain Energy Dispersive Spectroscopy (EDS) results. The MVP-SEM imaging capability will also allow for quantification of the grain size and shape of the dust grains, as well as degree of aggregation, which has implications on the mixing of dust with ice.
- Chlorine distribution. Perchlorates are thought to be ubiquitous on the surface of Mars [4]. Chlorine can also be found in apatite [e.g., 5] as well as Gusev soil samples, up to approximately 1 weight percent [6]. While chlorine appears to be readily located on the surface of Mars, its distribution is variable [7]; the MVP-SEM can assist in the identification of phases that may be responsible for such concentrations (e.g., chloride salts) and provide ground truth for remote sensing.
- Phyllosilicates, specifically Al and Fe-Mg phyllosilicates and phyllosilicate microfabrics. The types of clays present at specific locations provide a basis from which the evolution of the region can be determined [e.g., 8, 9]. The MVP-SEM will have the ability to determine the type of clay present and characterize its size and shape for an analysis of the clay's history, as well as the history of the area under study. A SEM can also assist in determining the mechanism(s) responsible for microfabric formation. A summary of microfabrics and formation mechanisms can be found in [10].
- Spatial relationship between phases. Numerous instruments that have operated on Mars focused on the bulk chemistry of samples. Mineralogy is often inferred from spectra, and amorphous phases often appear in analyses. The MVP-SEM will provide detailed mineralogical and textural analysis, including any flow banding observable in amorphous samples.
- Fluid depositional processes. A couple of examples of this include the Allan Hills 84001 carbonates [11, 12, 13] and the veins at Garden City, lower Mount Sharp, as observed by Curiosity [14]. Examining the minerals formed in sequence from the outside of the vein to the middle allows derivation of the evolution of fluid chemistry over time. The sequence of deposition can be determined using the SEM, and the evolution of the fluid chemistry can be deduced.
- Small particles. Texture is a difficult characteristic to determine for particles ~50 nm and below. This cannot be determined using alpha particle X-ray spectroscopy [15]. Depending on the final resolution of the MVP-SEM (goal 50 nm resolution), texture can be determined for these small particles.
- Alteration products: texture and composition. The extent of dissolution, oxidation, precipitation, other alteration and weathering in individual grains can be determined using the MVP-SEM. The SEM can also test Thermal Emission Spectroscopy results that indicate mechanical weathering is the dominant process on the martian surface [16].
- General petrology data. The MVP-SEM will determine the general petrology of the area with imaging and EDS. Small phases, such as those observed in melt pockets can indicate the formation history of the area.
- Organic material, biological activity, and other potential biosignatures. The MVP-SEM will look for chemical and morphological biosignatures as

they are currently defined (i.e., terrestrial examples). The instrument can also be used to study the environment of formation surrounding suspect biosignatures, to assist in determining if the suspect biosignatures could truly represent life. Knowing with a high degree of certainty that a chemical or morphological feature is truly a biosignature existing on another planet is one of the difficulties inherent in astrobiology. When combined with the environment of formation information determined with the MVP-SEM, identification is expected to be certain. Minerals such as greigite, green rust (fougerite), and clays will be studied in detail with the MVP-SEM for evidence of biological activity.

- Diagenetic features such as concretions/nodules to study the precipitation process. Determining the cause of nucleation, by organic or inorganic means, would require an instrument such as the SEM.

Concept of Operations: The MVP-SEM must operate as autonomously as possible. Thus, a detailed concept of operations must be developed. A preliminary concept of operations has been prepared, and refinements are being made by the MVP-SEM Science Team. The MVP-SEM Science Team is composed of numerous scientists with expertise in different fields, ranging from astrobiology to petrology and remote sensing. Because of their areas of expertise, they are adept at defining a wide range of features of interest. Features of interest must be clearly characterized and resolvable to be included in the automation software.

The initial checkout of the SEM will involve a systems diagnostic routine. The results of this test will be relayed to Earth and will indicate the health of the instrument after landing. Following diagnostics, calibration of the imaging and EDS system will be completed. The imaging calibration will confirm performance of the instrument. The EDS system will analyze synthetic mineral and other phase standards sent with the instrument to identify any component of the martian atmosphere in the EDS signal; this will be calculated out if necessary. Standards being considered include: hematite, magnetite, anorthositic feldspar, olivine, jarosite, gypsum, montmorillonite, pyroxene, basaltic glass, and Teflon.

Sample operations will start with a low magnification, high resolution image and element map that will be relayed to Earth. The instrument will autonomously identify features of interest within the sample, prioritize those features for analysis, and investigate each feature as the instrument is able (time and data constraints are expected to come into play). The type of analysis to be completed (e.g., imaging, point or mapping EDS), as well as the data to be returned and logged will be defined in the software for each feature of interest. During this autonomous operation, the Science Team, and any other interested party with an instrument onboard that could analyze samples post-SEM analysis, will assess the data downlinked and identify any other features of interest not chosen by the feature recognition software. Once the sample is sufficiently examined, it will be ejected.

Future Work: The MVP-SEM Science Team will refine the concept of operations based on previous mission experiences and new tactical planning timeframes. The Science Team will define features of interest for the automation software and test the software as it develops. The entire MVP-SEM team will continue to develop the instrument and optimize its capabilities. Once the instrument reaches a technology readiness level of 5-6, it will be proposed for a Mars rover or lander mission.

Conclusions: This instrument has the potential to greatly impact our knowledge of Mars and its evolution. Small features can lead to large discoveries!

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References: [1] Edmunson et al. (2016) *LPS XLVII*, Abstract #2301. [2] B. Ehlmann, LPSC talk, 3/21/16. [3] Bell et al. (2000) *J. Geophys. Res.*, 105, 1721-1755. [4] Hecht et al. (2009) *Science*, 325, 64-67. [5] Filiberto and Treiman (2009) *Geology*, 37, 1087-1090. [6] Gellert et al. (2006) *J. Geophys. Res. Planets*, 111, doi: 10.1029/2005JE002555. [7] Keller et al. (2006) *J. Geophys. Res.*, 111, doi: 10.1029/2006JE002679. [8] Ehlmann et al. (2011) Nature, 479, 53-60. [9] Agar et al. (1989) *Geology*, 17, 901-904. [10] Merriman (2005) *Eur. J. Mineral.*, 17, 7-20. [11] A. Treiman http://www.lpi.usra.edu/publications/slidesets/marslife/slide_22.html. [12] McKay et al. (1996) *Science*, 273, 924-930. [13] Harvey and McSween (1996) *Nature*, 382, 49-51. [14] http://www.jpl.nasa.gov/news/news.php?feature=4536. [15] T. Pike, Phoenix mission scientist, personal communication 3/24/16. [16] Christensen et al. (2001) *J. Geophys. Res.*, 106 (E10), 23823-23871.