

THE MARS SUBSURFACE EXPLORER. L. W. Beegle¹, J. Guerrero², S. Douglas¹, R. Kidd¹, A. L. Lane¹, M. Pelletier¹, S. Feldman¹, G. S. Mungas¹, D. Blake³, R. Dissly⁴, J. H. Waite⁵, D. T. Young⁶, H. Sun⁷ S. Wells⁷ and the MSE Team, ¹Jet Propulsion Laboratory 4800 Oak Grove Dr. Pasadena Ca 91109, ²Swales Aerospace, 404 North Halstead Street, Pasadena, CA 91107, ³NASA Ames Research Center, Moffett Field, CA, ⁴Ball Aerospace & Technologies Corp. 1600 Commerce St. Boulder, CO 80301, ⁵Southwest Research Institute, San Antonio, TX, ⁷Desert Research Institute, 755 East Flamingo Road, Las Vegas, NV 89119

Introduction: We have developed a terrestrial field campaign to explore two subsurface biological habitats under the Mojave Desert. This field campaign will not only help us understand terrestrial desert biology, but also will develop methodologies and strategies for future Mars missions that seek to explore the Martian subsurface.

We have proposed to the ASTEP program to integrate a suite of field demonstrated instruments with a 20 m subsurface drill as a coherent unit, the Mars Subsurface Explorer. The Swales Modular Planetary Drill System (MPDS) requires no drilling fluid, which allows aseptic sampling, can penetrate lithic ground up to 20 meters of depth, and utilizes less than 100 W throughout the entire depth. The drill has been developed through the Mars Technology Program and demonstrated in field testing to a depth of 10 meters in Arizona, December 2002.

The MPDS returns a continuous core throughout the drilling depth, so a complete 20 meter long sample will be acquired. Once returned to the surface the cores will be imaged by the CHAMP microscopic imager [1] for texture and structure and by the Mars Microbeam Laser Raman Spectrometer for relevant chemistry and mineralogy [2]. Results are then used to select strata for further analysis to determine the presence of microorganisms, the fines will be analyzed by the CheMin X-Ray Fluorescence/Diffraction spectrometer [3] and the PICASSO GCxGC. The material that is not analyzed by the XRD and GCxGC will be returned to the laboratory for further analysis. All of these field instruments have been developed under MIDP, ASTID, PIDD and internal R&D funds, and have been at least partially demonstrated in the field.

Follow on laboratory investigations will include A) extraction of DNA followed by PCR amplification of small subunit (SSU) rRNA genes to identify microbes present, B) HPLC/Mass spectrometer system to identify major groups of organic biomarkers, C) microstratigraphy of textures and elemental composition in vertical profiles on a micrometer to mm scale, D) presence or absence of morphological elemental characteristics of organic sample fractions and E) the presence of minor mineral fractions not detectable by other methods (e.g., XRD) to understand geological history of the sample.

Rationale: Speculation of life in Mars is based on evidence that Mars had copious amounts of liquid wa-

ter on its surface early in its planetary history. However, this liquid water quickly disappeared and Mars became a desert. In 1976 the Viking lander explored the surface of Mars and found a surface that was virtually devoid of organic material [5]. While Viking might have missed some organic material thought to exist on the surface [6, 7], the general consensus is that the surface is sterilized by strong oxidizing species and/or cosmic radiation that destroys all organic material [8, 9]. If life ever existed on Mars, it may have regenerated into a protected subsurface environment.

In 2009 the Mars Science Laboratory (MSL) mission will search for evidence of the habitability of the near surface, and inside of rocks. This includes looking for organic material in the upper ~0.5 m of the subsurface [9]. If MSL, like Viking, fails to identify organic material, exploring the subsurface would become a priority; however the depth of the oxidized soil, below which a future drill needs to reach, is not presently known. Mars currently experiences planet-wide dust storms and has experienced impacting events and volcanism. Mixing as a result of such events would create a sterile layer that varies in depth across the planet and hence would require a drilling platform that can reach well below any possible sterile layer depth.

Terrestrial Martian Analogue Sites: Terrestrial regions with limited precipitation, and hence reduced active biota, are some of the best Martian analogs, be they the Antarctica dry valleys, regions within the Atacama Desert or in the Mojave Desert. The Mojave Desert/Death Valley area is considered a Mars analogue site by the Terrestrial Analogues Panel of the NSF-sponsored decadal survey. This region has received a great deal of attention due to its accessibility and variety of landforms and processes relevant to Mars study.

The identified field sites include an evaporate lake bed located within Death Valley National Park. This site is located ~20 meters above sea level so it is well above the water table. Here, we will look at the depth profile of microorganisms and how they have weathered the mineralogy developed as the lake bed evaporated.

The second site is located within the Mojave national preserve. The Cima lava formation is ~6 meters in height and sits on what was desert pavement when the lava event occurred (Figure 1). The event thermally altered and sealed off the pavement (and any microor-

ganisms) from the atmosphere. If anaerobic or autotrophic life survived the initial lava event it may still be

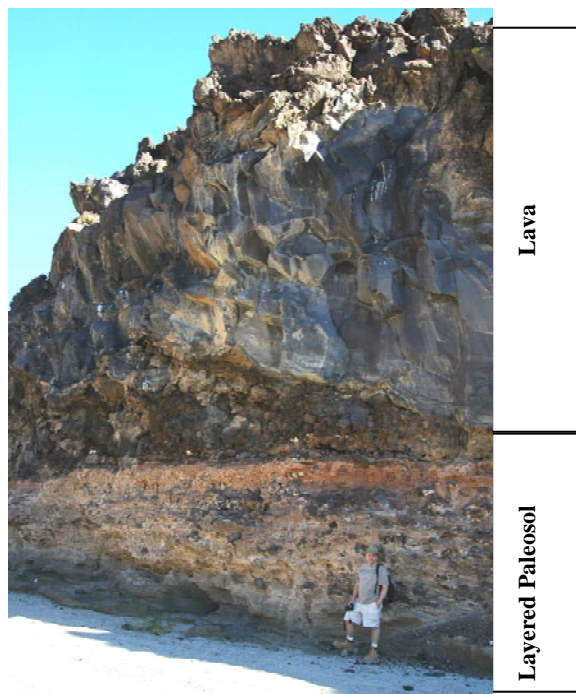


Figure 1 Images of the Cima lava formation showing lava formation and underlying stratigraphy.

biologically active. We will look for chemical and mineralogical evidence of biology including evidence of photo-autotrophic bacteria that did not survive the lava eruption or died due to lack of available resources.

These sites resemble geological features that have been identified on Mars. Understanding the biological

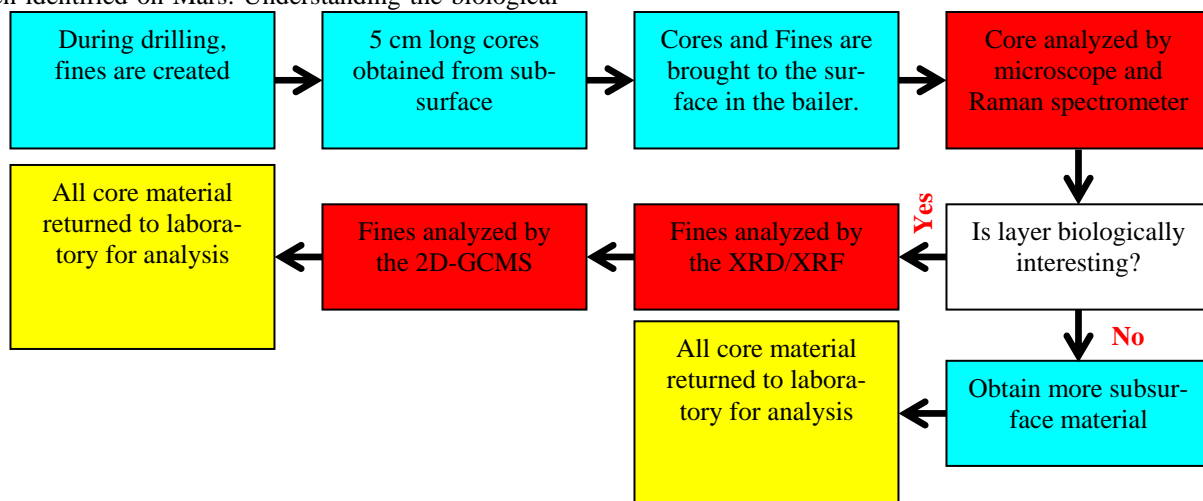


Figure 2 The basic operation scenario for the field investigations. Elements in **BLUE**, will be preformed by a 20 meter drill that has been developed under the Mars Technology Program by Swales Aerospace. Elements in **RED** will be analyzed by automated instruments *in-situ*. Finally, in **yellow** are laboratory investigations.

habitats at both sites will help us understand desert biology as well as potential Martian biology, including where it could be and how to look for it.

Objectives of this work:

The **objectives** of this investigation will be to:

1. *Study subsurface biological environment in sites that are potential Martian analogs.*
2. *Develop in situ technologies for sample analysis.*
3. *Develop a methodology that can be utilized by a future mars mission.* Our effort will take high TRL instruments and further automate them into a coherent unit capable of fully autonomous operations.
4. *Explore and characterize autonomous dry-drilling and subsurface sample analysis that will likely be incorporated into future drilling missions [10].*

To our knowledge this work will attempt to perform the first end-to-end automated core retrieval and in-situ sample analysis.

References: [1]Mungas, G., et al. 2005 *IEEE Aerospace Conference*.abstract 1510. [2] Wang, A., et al., (2003) *JGR* **108**(E1). [3] Sarrazin, P., et al., (2005) *Powder Diffraction*. **20**(2) 128. [4] Biemann, K., et al., (1976) *Science*. **194**(4260) 72. [5] Navarro-Gonzalez, R., et al., (2003) *Science*. **302**(5647) 1018. [6] Benner, S.A., et al., (2000) *PNAS*. **97**(6) 2425. [7]Klein, H.P., N.H. Horowitz, and K. Biemann, *Mars*, University of Arizona Press: Tucson. p. 1221. [8] Pavlov, A.K., et al. (2002) *Planet and Space Sci.* **50**(7-8) 669. [9] Heninger, R., *Mars Science Laboratory Mission 2009 Proposal Information Package*. 2004. [10] Miller, S.L., et al. *Space 2004 Conference and Exhibit*. 2004.