PRECISION SUBSAMPLING SYSTEM FOR MARS (AND BEYOND).

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Introduction: The ability to analyze heterogeneous rock samples at fine spatial scales would represent a powerful addition to our planetary *in situ* analytical toolbox. This is particularly true for Mars, where the signatures of past environments and, potentially, habitability are preserved in chemical and morphological variations across sedimentary layers and among mineral phases in a given rock specimen. On Earth, microbial life often associates with surfaces at the interface of chemical nutrients, and ultimately retains sub-mm to mm-scale layer confinement in fossilization. On Mars, and possibly other bodies, trace chemical markers (elemental, organic/molecular, isotopic, chiral, etc.) and fine-scale morphological markers (e.g., microfossils) may be too subtle, degraded, or ambiguous to be detected, using miniaturized instrumentation, without some concentration or isolation. This is because (i) instrument *sensitivity* may not be high enough to detect trace markers in bulk averages; and (ii) instrument *selectivity* may not be sufficient to distinguish such markers from interfering/counteracting signals from the bulk. Moreover from a fundamental chemostratigraphic perspective there would be a great benefit to assessing specific chemical and stable isotopic gradients, over mm-to-cm scales and beyond, with higher precision than currently possible *in situ*.

We are developing a precision subsampling system (PSS) that addresses this need while remaining relatively flexible to a variety of instruments that may take advantage of the capability on future missions. The PSS is relevant to a number of lander/rover missions as well as Mars Sample Return. Our plan is to develop a specific PSS prototype and fully test it under Mars ambient conditions, on a variety of natural analog rocks and rock drill cores, using a set of complementary flight-compatible measurement techniques.

PSS Description and Characterization: We are taking a “secondary sampling” approach to the baseline design of the PSS. That is, it is assumed that a primary sample has been acquired by means of a coring drill, grasping tool, or scoop, that can be delivered to a holding station on a lander/rover, where precisely selected secondary samples (masses in the range of tens of μg to tens of mg) are obtained. This approach permits us to focus on subsystem development and testing with instruments, without the additional complexity of primary sampling (working directly with Mars surface) for which there are several existing technologies. For example, one PSS configuration assumes a drill core, such as produced by the Honeybee MiniCorer [1], positioned as shown in Fig. 1 enabling us to subsample any depth by lateral motion of a fine-scale drilling device. The PSS can also be used on hand-samples, with abraded or intact weathered surfaces. The subsample is passively collected on a tape-type collection and transport device (CTD) allowing it to be further analyzed under ambient and vacuum conditions, and optionally archived (with possible use for sample return).

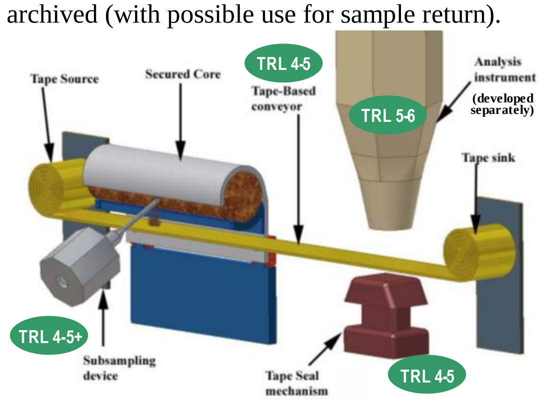

Fig. 1 Nominal spatial arrangement of the PSS applied to an 8 mm diameter core. Current technology readiness level (TRL) of key subsystems is indicated.

The core may be inspected with micro-imagers, spectrophotometers, laser excitation, etc. (not shown in Fig. 1), which can be used to select points for subsampling. Subsampling would be appropriate for measurements requiring separation of the selected material from the bulk, further chemical extraction, and/or analysis under vacuum conditions. Therefore three activities are involved in the PSS:

1. Precision subsampling. The most direct approach here uses a small rock grinding device with a robust universal bur or set of exchangeable burs. We have conducted numerous tests of various grinding tools (Fig. 2) over parameters including speed, rock hardness, grinder lifetime, powdering efficiency, and fines spatial scatter. On balance, the cut-off type wheel approach with a polycrystalline diamond grinding edge provided for the most effective subsampling [2].

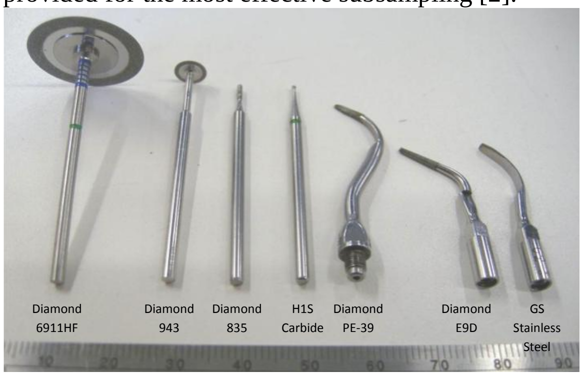

Fig. 2 Tested subsampling burs ranged from grinding wheels (at left), to dental mills (center), to sonic/ultrasonic scalers (at right).

2. Collection and transport. The CTD (Fig. 3) was inspired by the use of a similar approach in a terrestrial aerosol collection time-of-flight mass spectrometer (TOF-MS) [3]. The tape supports entrapment of fine particulates on a substrate for laser desorption, which can be done *in vacuo* with the tape serving as a demountable vacuum sealing gasket. With appropriate material selection, surface treatment, and electrostatic design, the tape-based system can efficiently and passively collect a thin, localized layer of subsample. In this approach each of potentially hundreds of subsamples occupies a pristine section of tape (a few mm in diameter). A separate CTD task is focusing on capture and analysis of subsampling-induced volatiles.

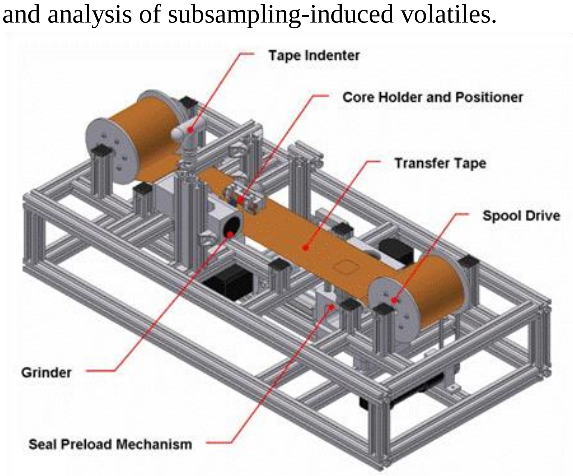

Fig. 3 Preliminary design of CTD prototype for testing at Mars ambient (installed in low-pressure environmental chamber).

3. Ambient and lab analyses. Individual subsamples are analyzed under ambient or vacuum conditions as desired, nominally in a given sequence. As an example, a microscope combined with point spectrometers using ultraviolet fluorescence and infrared reflectance could be used to determine the presence of organic compounds which could then be thoroughly studied with various forms of mass spectrometry possibly including laser sampling and/or microfluidic-based chemical preparation and extraction steps.

Preliminary Tests: Selected subsamples obtained under reproducible conditions were further subject to evolved gas analysis to detect chemical differences. The Pilbara sample in Fig. 4 was cut from a dolomitic drill core from Hamersley Province in Western Australia. It displays finely laminated dolomite (lighter material) and kerogenous shale (darker material) with some mild faulting evident. It is known to contain extractable hydrocarbons including bacterial biomarkers [4]. Several-mg aliquots of light and dark layer subsamples were analyzed with the pyrolysis-based quadrupole mass spectrometer breadboard of the Sample Analysis at Mars (SAM) suite on the Mars Science Laboratory. Preliminary analysis suggested that distinct evolved gas signatures associated with layer mineralogies and organics were detectable at these mg masses.

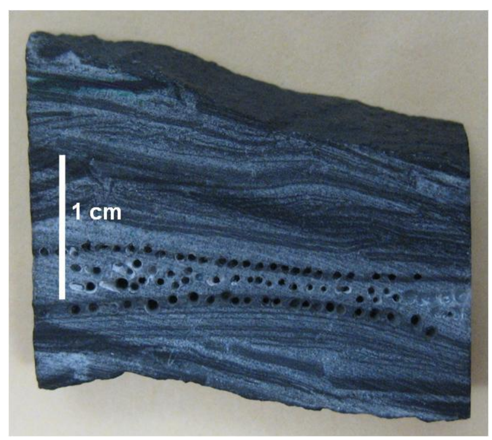

Fig. 4 Laminated Pilbara core sample with individual subsampling pits at scale and locating precision as expected for a Mars PSS.

References: [1] Myrick T. M. et al. (2000) *Proc. Concepts Appr. Mars Exploration, 6105*. [2] Brinckerhoff W. B. et al. (2009) *Proc. Earth and Space 2010*, submitted. [3] Anderson C. W. and Carlson M. A. (1999) *JHU/APL Tech. Digest, 20*, 352-362. [4] Eigenbrode J. et al. (2008) *EPSL, 273*, 323-331.

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