Mars Sample Return – How Should it be Organised Into Science Objectives?

International Mars Sample Return and Objectives Team (iMOST) and Caroline Smith[1]
[1]*Department of Earth Sciences, The Natural History Museum, London, SW7 5BD, UK. C.L.Smith@nhm.ac.uk*

The analysis in Earth laboratories of samples that could be returned from Mars is of extremely high interest to the international Mars exploration community. IMEWG (the International Mars Exploration Working Group) is currently exploring options to involve the international community in the planning for returned sample science, including the analysis of the returned samples. The Mars 2020 sample-caching rover mission is an essential component of a potential Mars Sample Return campaign, so its existence constitutes a critical opportunity - the prospects for MSR are more real now than they have ever been. The Mars 2020 samples, if returned, would provide the basis for performing a variety of Earth-based experiments including ones related to the search for the signs of life.

PROPOSED MARS SCIENCE OBJECTIVES

Seven objectives have been defined for MSR, traceable to published priorities established over more than two decades by Planetary Science Decadal Surveys in the USA and other international studies [e.g. 1, 2]. For each, their importance to science or engineering is described, critical measurements that would address the objectives are specified, and the kinds of samples that would be most likely to carry key information are identified.

1. Interpret in detail the primary geologic processes that formed and modified the ancient (pre-Amazonian) geologic record.

The objective seeks to investigate the geologic environment represented at a high-priority landing site (whichever site might be selected). All the sites are of ancient (Noachian or Hesperian) age. The intent is to provide definitive geologic context for samples and details that relate to past biologic processes. This objective is divided into sub-objectives that would apply at different landing sites.

1.1 Understand the essential attributes of a martian sedimentary system. The intent is to understand the preserved martian sedimentary record. Most important samples: A suite of sedimentary rocks that span the range of variation. Scientific importance: Basic inputs into the history of water, climate change, and the possibility of life.

1.2 Understand an ancient martian hydrothermal system through study of its mineralization products. The intent is to evaluate at least one potentially life-bearing 'habitable' environment via samples. Most important samples: A suite of rocks formed and/or altered by hydrothermal fluids. Scientific importance: A possibly habitable geochemical environment with high preservation potential.

1.3 Understand the rocks and minerals representative of a deep subsurface groundwater environment. The intent is to definitively evaluate the role of water in the subsurface. Most important samples: Suites of rocks/veins representing water/rock interaction in the subsurface. Scientific importance: May be the longest-lived habitable environments and key to the hydrologic cycle.

1.4 Understand ancient water/rock interactions at the martian surface, or more broadly, atmosphere/rock interactions, and how they have changed with time. The intent is to constrain the time-variable factors necessary to preserve records of microbial life. Most important samples: Regolith, paleosols, and evaporites. Scientific importance: Subaerial near-surface processes could support and preserve microbial life.

1.5 Understand the essential attributes of a martian igneous system. The intent is to provide definitive characterization of igneous rocks on Mars. Most important samples: Diverse suites of ancient igneous rocks. Scientific importance: Thermochemical record of the planet and nature of the interior.

2. Assess and interpret the biological potential of Mars.

The objective seeks to inform our efforts to understand the nature and extent of martian habitability, the conditions and processes that supported or challenged life, the timescales, and how different environments might have influenced the preservation of biosignatures and created non-biological 'mimics'. This objective also has three sub-objectives.

2.1 Assess and characterize carbon, including possible organic and pre-biotic chemistry. Most important samples: All samples collected as part of Objective 1. Scientific importance: Any biologic molecular scaffolding on Mars would likely be carbon-based.

2.2 Assay for the presence of biosignatures of past life at sites that hosted habitable environments and could have preserved any biosignatures. Most important samples: All samples collected as part of Objective 1. Scientific importance: Provides the means of discovering ancient life.

2.3 Assess the possibility that any life forms detected are still alive, or were recently alive. Most important samples: All samples collected as part of Objective 1. Scientific importance: Planetary protection, and arguably the most important scientific discovery possible.

3. Determine the evolutionary timeline of Mars, including calibrating the crater chronology time scale.

This objective seeks to provide a radioisotope-based time scale for major events, including magmatic, tectonic, fluvial, and impact events, and the formation of major sedimentary deposits and geomorphological features.

Most important samples: Ancient igneous rocks that bound critical stratigraphic intervals or correlate with crater-dated surfaces. Scientific importance: Quantification of martian geologic history.

4. Constrain the inventory of martian volatiles as a function of geologic time, and determine the ways in which these volatiles have interacted with Mars as a geologic system.

Comprising the atmosphere and hydrosphere, volatiles play major roles in martian geologic and possibly biologic evolution. The objective seeks to recognize and quantify these roles.

Most important samples: Current atmospheric gas, ancient atmospheric gas trapped in older rocks, and minerals that equilibrated with the ancient atmosphere. Scientific importance: Key to understanding climate and environmental evolution.

5. Reconstruct the history of Mars as a planet, elucidating those processes that have affected the origin and modification of the crust, mantle and core.

The objective seeks to quantify processes that have shaped the planet's crust and underlying structure, including planetary differentiation, core segregation and state of the magnetic dynamo, and cratering.

Most important samples: Igneous, potentially magnetized rocks (both igneous and sedimentary) and impact-generated samples. Scientific importance: Elucidates fundamental processes for comparative planetology.

6. Understand and quantify the potential martian environmental hazards to future human exploration.

The objective seeks to define and mitigate an array of health risks related to the martian environment associated with the potential future human exploration of Mars.

Most important samples: Fine-grained dust and regolith samples. Scientific/engineering importance: Key input to planetary protection planning.

7. Evaluate the type and distribution of in-situ resources to support potential future Mars exploration.

The objective seeks to quantify the potential for obtaining martian resources, including use of martian materials as a source of water for human consumption, fuel production, building fabrication, and agriculture.

Most important samples: Regolith. Scientific/engineering importance: Facilitating long-term human presence on Mars.

References

[1] National Research Council (2003) New Frontiers in the Solar System: An Integrated Exploration Strategy. [2] MEPAG E2E-iSAG (2011) Planning for Mars Returned Sample Science.