

HIGH PRIORITY SAMPLES TO CHARACTERIZE THE HABITABILITY OF GROUNDWATERS AND SEARCH FOR ROCK-HOSTED LIFE ON MARS WITH SAMPLE RETURN. iMOST Team (B.L. Ehlmann¹, L. E. Mayhew, J. F. Mustard, F. Altieri, Y. Amelin, E. Ammannito, M. Anand, D. W. Beaty, L. G. Benning, J. L. Bishop, L. E. Borg, D. Boucher, J. R. Brucato, H. Busemann, K. A. Campbell, B. L. Carrier, A. D. Czaja, V. Debaille, D. J. Des Marais, M. Dixon, B. L. Ehlmann, J. D. Farmer, D. C. Fernandez-Remolar, J. Fogarty, D. P. Glavin, Y. S. Goreva, M. M. Grady, L. J. Hallis, A. D. Harrington, E. M. Hausrath, C. D. K. Herd, B. Horgan, M. Humayun, T. Kleine, J. Kleinhenz, N. Mangold, R. Mackelprang, F. M. McCubbin, J. T. McCoy, S. M. McLennan, H. Y. McSween, D. E. Moser, F. Moynier, P. B. Niles, G. G. Ori, F. Raulin, P. Rettberg, M. A. Rucker, N. Schmitz, E. Sefton-Nash, M. A. Sephton, R. Shaheen, D. L. Shuster, S. Siljeström, C. L. Smith, J. A. Spry, A. Steele, T. D. Swindle, I. L. ten Kate, N. J. Tosca, T. Usui, M. J. Van Kranendonk, M. Wadhwa, B. P. Weiss, S. C. Werner, F. Westall, R. M. Wheeler, J. Zipfel, M. P. Zorzano) ¹California Institute of Technology (ehlmann@caltech.edu).

Introduction: Objective 1.1 of the iMOST sample return objectives is to establish the geologic context, interpret the potential habitability, and evaluate the potential for biosignature preservation in samples from an environment hypothesized to have had elevated potential for Martian life [1]. Here, we describe the strategies required to understand the geologic context and habitability of Martian groundwater aquifers and to search for evidence of life in the Martian subsurface using samples.

Why samples recording groundwaters are important: Radiation, cold temperatures, low water activity, and atmospheric pressure were challenging to life over most of Mars history, including time-equivalent periods on Earth [2,3]. Mineralogic evidence from the Opportunity and Curiosity landed missions [4,5], from orbit [6], and thermophysical modeling suggest ancient groundwaters on Mars that may even persist to the present [7]. Because the terrestrial subsurface is inhabited [8-9], similar mafic and ultramafic igneous and sedimentary aquifers on Mars should be interrogated to understand their geologic characteristics, habitability, and search for rock-hosted life.

Key investigations: To interrogate samples from groundwater-altered rocks, the rover will first search for features indicative of groundwater flow. A non-exhaustive list includes: mineralized fractures or ridges, diagenetic concretions, zones with color change indicating leaching and/or cements. Key phases include Fe and Mn oxides, phyllosilicates, silica, sulfates, carbonates, and other salts. Samples should be selected to:

Determine the physical-chemical conditions of water-rock interaction and assess habitability. Key water properties can be derived by identification of mineral assemblages and include temperature, pH, Eh, aH₂O, and ion activities as indicated by mineral phases.

Determine the source of fluids. Mineral phases and H, C, S, O and metal isotopes can be used to understand the relative contributions from different fluid sources (atmospheric, groundwater, magmatic).

Determine the time-evolution of the groundwater system and chemical reactions. Petrological relationships (overgrowths, cross-cutting relationships) can be used to time-order the formation and dissolution of phases, thereby understanding changes in groundwater properties due to changing sources or fluid evolution.

Characterize organics to evaluate sources. Organics, if present, may be observed in situ with SHERLOC fluorescence. Detailed characterization of location and structure at nanometer-scale will inform endogenous abiotic, biotic, vs. meteoritic origin.

Evaluate evidence for biosignatures: Initial signatures are likely chemical/mineralogic as the products of life tend to be more volumetrically significant than life itself. Nanometer-scale investigations will investigate isotopic signatures of phases and mineral-organic associations.

Samples: Samples from groundwater aquifers with evidence for redox interfaces (because redox disequilibria drives metabolism), lithologic interfaces (because permeability focuses fluid flow), and sites of mineralization (which indicate active chemistry and the potential for entrapment of cells/organisms) are specifically sought. A non-exhaustive, unprioritized list of high-priority samples includes rocks with (1) organics associated with mineralized fractures or voids, (2) Fe oxide or Fe sulfide precipitates (e.g., framboids), (3) Fe or Mn redox fronts, (4) fractures, vugs, vesicles, or pore space filled with precipitated minerals (carbonates, silica, sulfates, clays, oxides), (5) zones enriched in minerals formed by leaching or in situ transformation, (6) textures suggestive of microtubules possibly present at smaller spatial scales.

References: [1] Beaty et al., 2nd International Mars Sample Return Conference, Abstract #6089. [2] Fassett et al., 2011, *Icarus* [3] Onstott & Ehlmann, 3rd M2020 Landing Site Workshop [4] McLennan et al., 2005, *EPSL*; [5] Grotzinger et al., 2015, *Science* [6] Ehlmann et al., 2011, *Nature* [7] Grimm et al., 2017, *JGR* [8] Shrenk et al., 2013, *Rev. Min Geochem* [9] Onstott et al., 2009, *Microbe*