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MARS ANALOG RESEARCH AND TECHNOLOGY EXPERIMENT (MARTE): A SIMULATED MARS DRILLING MISSION TO SEARCH FOR SUBSURFACE LIFE AT THE RIO TINTO, SPAIN

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Introduction and Background: The MARTE (Mars Astrobiology Research and Technology Experiment) project was selected by the new NASA ASTEP program, which supports field experiments having an equal emphasis on Astrobiology science and technology development relevant to future Astrobiology missions. MARTE will search for a hypothesized subsurface anaerobic chemoautotrophic biosphere in the region of the Tinto River in southwestern Spain while also demonstrating technology needed to search for a subsurface biosphere on Mars. The experiment is informed by the strategy for searching for life on Mars.

Most familiar life forms on Earth live in the surface biosphere where liquid water, sunlight, and the essential chemical elements for life are abundant. However, such environments are not found on Mars or anywhere else in the solar system. On Mars, the surface environmental conditions of pressure and temperature prevent formation of liquid water. Furthermore, conditions at the Martian surface are unfavorable to life due to intense ultraviolet radiation and strong oxidizing compounds that destroy organic compounds. However, subsurface liquid water on Mars has been predicted on theoretical grounds [1]. The recent discovery of near surface ground ice by the Mars Odyssey mission [2], and the abundant evidence for recent Gulley features observed by the Mars Global Surveyor mission [3] strengthen the case for subsurface liquid water on Mars. Thus, implementing the Mars program strategy of "following the water" to search for life points to drilling to the depth of liquid water with instrumentation to detect in situ organisms and biomarker compounds.

Searching for life in the subsurface of another planet will require drilling, sample extraction and handling, and new technologies to find and identify biomarker compounds and search for living organisms. Unlike rover missions, with a relatively rich history of field testing and flight heritage, none of these technologies has been demonstrated in an automated system or been the subject of a mission or field mission simulation. However, the science definition team for the 2009 Mars Exploration Program Smart Lander mission has called for drilling as a key objective of the next Mars mission. Thus, there is a critical and immediate need for technology maturation for drilling that can be accomplished with a field mission simulation.

The subsurface biosphere on Earth is relatively unexplored but constitutes the largest portion of the biosphere. In most environments where subsurface life has been found it utilizes buried byproducts of surface life, and so these are not relevant analogue systems for exploring for life off Earth. Even the deep sea hydrothermal vents, often cited as analogs for life on Europa, rely on oxygen produced at the surface to oxidize hydrogen sulfide emanating from the vents. Subsurface life on other worlds must utilize chemical energy as a basis for primary production. Examples of such life on Earth are rare. The only purely anaerobic chemoautotropic subsurface life found on Earth to date derives chemical energy by reacting hydrogen, produced in the weathering of basalt, with carbon dioxide to produce methane. Such systems were originally discovered in the Columbia River basalt [4,5] and have subsequently been found in a wide variety of other environments.[6,7, 8] represents the only subsurface life systems found to date that exist solely on geochemical energy sources. While such an environment could exist on Mars, it is important to explore for other subsurface chemical systems which might support life in the terrestrial subsurface. This is the Scientific Objective of MARTE.

Experiment Description: MARTE will take place near the source waters of the Rio Tinto, a river in Southwestern Spain. The river is sourced in the Iberian Pyrite belt, one of the largest deposits of sulfide minerals in the world (Figure 1). Similar mineral concentrations could plausibly be found on Mars as they are associated with hydrothermalism and basaltic volcanism. The river system and associated ponds are an acidic extreme environment produced and maintained by microorganisms that metabolize sulfide minerals and produce sulfuric acid as a byproduct. The low pH of the river causes high concentrations of metal ions in the water (Table 1). The high concentration of dissolved iron in the water is responsible for its characteristic color, similar to red wine, and the name "Rio Tinto". The river is hypothesized to be a surface manifestation of an underground biochemical reactor. If so, the system is of great Astrobiological interest as an example of life sustained and controlled by inorganic compounds operating underground in anoxic conditions. Laboratory observations suggest some organisms found in the Tinto river system such as *At. ferrooxidans* can grow anaerobically and autotrophically using reduced sulfur compounds or H_2 as electron donors and ferric iron as electron acceptors [9,10, 11]. However, no example of an anoxic ecosystem supported by sulfur or sulfide-oxidizing metabolism is known. We hypothesize that such a system exists in the subsurface of the Rio Tinto area. If found, it would represent an previously undescribed subsurface life system.

Table 1. Comparison of physicochemical parameters of the Tinto River with a normal river from the same geographical area. Concentrations in mg/L (adapted from [12]).

Quantity	pH	Fe	Zn	Cu	K	SO_4^{2-}	NO_3^-
Tinto (mean)	2.3	2261.0	225.0	109.0	7.4	10110.0	9.33
Normal River	7.8	12.1	0.97	0.07	6.6	312.5	0.83

Figure 1a. Location of the Rio Tinto in Spain.

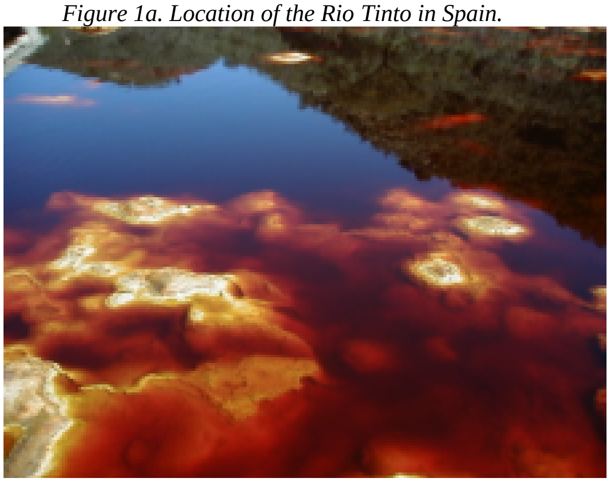

Figure 1b. Red mineral-rich waters of the Rio Tinto.

The MARTE project has three primary objectives: (1) Search for and characterize subsurface life, along with the physical and chemical properties and sustaining energy sources of its environment; (2) Perform a high fidelity operational simulation of a Mars drilling mission to characterize the subsurface and search for subsurface life; (3) Demonstrate the drilling, sample handling and instrument technologies relevant to searching for life on Mars.

MARTE will perform a simulation of a Mars drilling mission to search for life, while also characterizing the biology in the subsurface at the Rio Tinto. The mission simulation will employ a drilling system under development in a collaboration between NASA's Johnson Space Center and Baker-Hughes Corp. for future use on Mars. The drill produces a continuous segmented core and fine cuttings from the bore hole. Individual core segments can be cut from a few centimeters to almost a meter in length, and 2.5 cm in diameter (nominal one inch). The system is based around an electrically-powered coring head/ down hole assembly suspended from a cable. The drill system brings drill cores and cuttings to the surface, and operates on low power without the use of drilling fluids. A remotely operated Core and Sample Handling facility will extract cores from the drill and pass them to a suite of instruments on the surface. An additional instrument suite will be used to inspect the borehole *in situ*. The surface instrument suite will include the Signs of Life Detector (SOLID), an instrument under development for future Mars mission application. The SOLID is a portable automated instrument that uses DNA and protein microarray technologies to detect microorganisms as well as their metabolic products. The aim is to detect any kind of biochemical compound (nucleic acids, proteins, polysaccharides, etc) using microarrays printed with DNA, antibodies or any other protein or molecule able to recognize and bind specifically to them.

A Mars drilling mission simulation will be performed that includes interpretation of drill mission results by a remote science team in a blind test. This simulated drill mission will be accompanied by additional "ground truth" operations utilizing more conventional methods for drilling, sample handling, and laboratory analysis to capture information not fully available through the mission simulation.

The mission simulation and ground truth will lead to important lessons learned for the future exploration for life on Mars. Science teams in the simulation and ground truth efforts will document their findings and publish results. Remote science results will be compared with ground truth to determine consistency and completeness and to derive "lessons learned". Scientists from the Mars and Astrobiology community and students will be involved in the mission simulation and ground truth data analysis. After publication, data and core archives will be made available for subsequent study by the Astrobiology and subsurface science communities.

In summary, the MARTE project achieves exploration of a new, uncharacterized underground ecosystem of key relevance to Astrobiology and the search for life on Mars, while also developing and demonstrating technology needed in the next phase of Mars exploration.

References:

[1] Clifford, S.M. and Parker, T. (2001) *Icarus*, 154,40-71. [2] Boynton, W. *et al.* (2002), *Science* 297, 81-85. [3] Malin, M. and Edgett, K. (2000) *Science* 288, 2330-2334. [4] Stevens, T.O. and McKinle, J.P. (1995). *Science* 270, 450-454. [5] Stevens, T.O. and McKinle, J.P. (2000). *Environ. Sci. Technol.* 34, 826-831.[6] Pedersen, K. (2001). In: Subsurface Microbiology and Biogeochemistry, pp.97-139. Wiley-Liss, New York. [7] Takai, K., *et al*. (2001). *Appl. Environ. Microbiol.* 67, 5750-5760. [8] Chapelle, F. *et al.* (2002). *Nature* 415, 312-315. [9] Brock, T., and Gustafson, J. (1976). *Appl. Environ. Microbiol.* 32, 567-571. [10] Pronk, J. *et al.* (1992). *Appl. Environ. Microbiol*. 58, 2227-2230. [11] Ohmura, N. *et al.* (2002). *J. Bact.* 184, 2081-2087. [12] López-Archilla, A.I. et al. (2001) *Microb. Ecol.* 41, 20-35.

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