CHARACTERIZATION OF RESIDUAL BIOSIGNATURES IN MARS ANALOG ENVIRONMENTS TOWARDS DETERMINATION OF EXTREMOPHILIC MICROBIAL LIFE IN A PLAUSIBLE SAMPLE RETURN MISSION

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Abstract: Anoxic, reducing environments coupled with hydrothermal and hot spring deposits on Earth have been cited as prime analog locations for astrobiological exploration of Mars and elsewhere in the Solar System. The presence of preserved microscopic physical biomarkers supports a strategy of searching for evidence of life in hot spring deposits on Mars.

With recent data [1] three craters have been found to exhibit compelling spectral features that indicate the presence of hydrated minerals, two of which may have evidence for postimpact hydrothermal systems. Another multidisciplinary approach involving various remote sensing instruments was used to investigate Apollinaris Mons, a prominent volcano on Mars, as well as the surrounding plains for signs of prolonged hydrologic and volcanic, and possibly hydrothermal activity. The findings point [1] to a site of extensive volcanic and hydrologic activity with possibly a period of magma–water interaction and hydrothermal activity.

For my PhD thesis, I studied a natural asphalt lake, Pitch Lake for its relevance to planetary research. The morphological characterizations of the pyrite (especially framboidal pyrite: Fig. 1) in this lake have revealed that they are possibly biogenic in nature and may form as a result of metabolism of nanobacteria (Fig. 2). I have also used a new model to describe the origins of this lake from an asphalt volcano. The evidence of which was confirmed with geochemical analysis of the minerals and with morphological and phylogenetic analysis of thermophiles in the lake.

It is speculated that nanobacteria of the asphalt community, through either, induced biomineralization or controlled biomineralization produce iron sulfide minerals. Induced biomineralization, the formation of framboidal pyrite as a metabolic by- product is dependent on factors, such as, the environmental conditions. H_2S produced by microbial cells, exogenously reacts with Fe, in solution, forming either iron mono sulfides ($H_2S + Fe^{2+} = FeS + H_2$) or iron disulfides ($2H_2S + Fe^{2+} = FeS_2 + 2H_2$). Sulfate reduction, anaerobic degradation of sulfur-rich organic components and iron respiration are some of the physiological activities associated with induced biomineralization of iron sulfides [2,3,4] .

In controlled biomineralization, the microbial cells determine mineral composition. Energetics may have given rise to biogenic pyrite during the early stages of life's evolution, in what it is known as the "iron sulfide world" hypothesis [5,6]. It has been hypothesized that pyrite's exergonic formation, coupled with ATP production, generated sufficient reducing power to be coupled directly with NADP reduction.

Therefore, studying isotopic variants of pyrite like biomarkers, which are adapted to the biogeochemical makeup of the hydrothermal environment, aimed at life detection mission to other planets, is of vital importance.

A study should be designed, which aims to utilize models of chemosynthetic productivity and transport in hydrothermal deposits, followed by sampling and subsequent analysis of the selected sites to determine biological and mineralogical components, which can be elucidated as biogeochemical markers. Data from the field site will be used to refine a remote sensing technique for these environments and in-situ analysis and extrapolate the work to other hydrothermal communities, the Martian surface and subsurface.

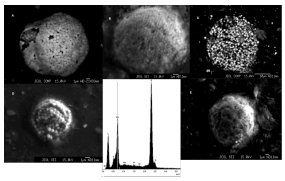

Figure 1: SEM images of Framboidal pyrite

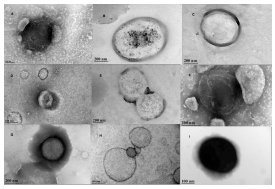

Figure 2: Nanobacteria under TEM

References: [1] Turner, S. M., Bridges, J. C., Grebby, S., & Ehlmann, B. L. (2016). Hydrothermal activity recorded in post Noachian-aged impact craters on Mars. *Journal of Geophysical Research: Planets*, *121*(4), 608-625. [2] Cammack, R. *Adv. Inorg. Chem*. 1992; 38, 281-322. [3] Conover, R.C., et al. *Biol. Chem*. 1990; 265, 853 –8541. [4] Drobner, E., et al. *Nature*. 1990; 346, 742-744. [5] Russell, M.J., et al. *Mol. Evol*. 1994; 39, 231-243. [6] Russell MJ, Hall AJ. "Pyrite and the origin of life." *Nature* 344 (1990): 387–387.