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A Perchlorate Strategy for Extreme Xerophilic Life on Mars?

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Abstract

The near-surface environment of Mars is a challenging environment for microorganisms to survive. Yet, resources such as perchlorates and hydrogen peroxide-water mixtures are available that could provide supportive tools for putative Martian life. Here, we focus on the useful properties of perchlorates such as hygroscopicity and the suppression of the freezing point of water, and point to perchlorate reducing microbes on Earth, some of which are related to magnetotactic bacteria, as analogs for possible near-surface Martian life.

1. Introduction

The Martian surface environment can be characterized as dry, cold, and harsh with respect to various forms of radiation. We previously suggested the presence of microbial organisms on Mars that use a mixture of hydrogen peroxide and water as an intracellular solvent as an adaptation to the harsh Martian surface environment [5]. While the hydrogen-peroxide water hypothesis for life on Mars would explain the Viking Biology Experiments best (e.g., especially in regard to the release of oxygen upon moisturizing in the GEx experiment), perchlorate solutions have similar properties as a hydrogen peroxide-water solution. Thus, they could also be employed by putative Martian microorganisms, particularly in the subarctic plains where perchlorates were recently detected by the Phoenix Mission.

2. Perchlorates on Mars and Earth

The Wet Chemistry Laboratory (WCL) of the Phoenix Lander found surprisingly large amounts (0.4-0.6wt%) of perchlorate salts in the Martian arctic soil [4]. Perchlorates are powerful oxidizers, but also have other interesting properties. These include antifreeze properties; for example, the water-magnesium perchlorate eutectic is as low as -70^{o}C. Perchlorates are also hygroscopic, thus these compounds could aid putative Martian microbes to directly scavenge liquid water from the atmosphere. Xerophilic organisms on Earth such as the yeast-like fungus *Trichosporonoides nigrescens*, which can grow at water activities at least as low as 0.75 may provide a suitable analog. Perchlorate salts have been detected on Earth in hyperarid soils (Fig. 1). For example, the soils of the Atacama desert contain 0.03-0.6wt% perchlorate [2]. The diurnal temperature cycle on the Martian surface at the Phoenix landing site is concomitant with a water saturation cycle in the local atmosphere. At low temperatures shortly before and after sunrise, the moisture level is close to saturation (ground fogs were observed by Phoenix). This means that any perchlorate would attract water. The clumpiness of the soil, which posed a technical hurdle to get proper samples into the Phoenix's TEGA instrument, and the drops of liquid water observed on Phoenix's landing struts [7] could be a direct result of the perchlorates.

3. Perchlorate Bacteria on Earth

Perchlorate-reducing bacteria generally grow by the complete oxidation of organic carbon or various alternative inorganic electron donors (H_2, H_2S or Fe^{2+}) coupled to the reduction of perchlorate in anoxic environments. The microbial perchlorate reduction of *Dechloromonas aromatica* has more recently been likened to rocket-fueled metabolism [1]. Most perchlorate bacteria are α- or β-proteobacteria. Members of both the *Dechloromonas* and *Azospira* genera are ubiquitous and have been identified and isolated from nearly all environments that have been screened, including pristine and contaminated field samples, and even in soil and lake samples collected from Antarctica. A third group — the *Dechlorospirillum* species — is closely related to the magnetotactic *Magnetospirillum* species, a subgroup of the Proteobacteria. The *Magnetospirillum* genus has been described on the basis of its ability to form magnetosomes — an intracellular form of magnetite

— when grown microaerophilically on iron-based media, which confers a unique magnetotactic characteristic on these microorganisms. A link (highly speculative at present) may exist to the magnetites and magnetic chains discovered in Martian meteorite ALH84001 [3]. Could the magnetic chains discovered in ALH84001 possible be the product of Martian microbes that use a perchlorate metabolism?

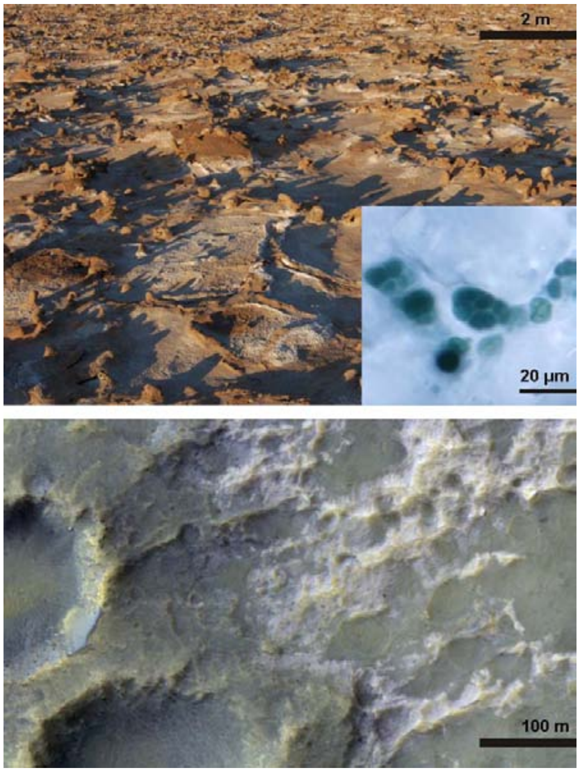

Figure 1: Top: Halite crusts in the very dry core of the Atacama desert in Chile, which are colonized by cyanobacteria (inset) that live within the rocks and take advantage of the hygroscopic properties of the mineral to obtain liquid water from the atmosphere. Bottom: Chloride-bearing deposits on Mars (bright) which could have similar properties as the salt crusts in the Atacama desert and could provide a habitable niche for well-adapted microorganisms. Top picture and inset are courtesy of Jacek Wierzchos from the Institute of Natural Resources, CSIC, Spain. Bottom picture is credit to NASA/JPL/University of Arizona.

4. Extreme Xerophiles on Mars?

Xerophilic organisms are often also halophilic, some of them thriving in hypersaline solutions, conditions which would be expected on Mars, at temperatures well below the freezing point of pure water. Xerophilic adaptations would allow microbes to grow at very low water activities. Even *E. coli* cells are able to generate up to 70 % of their intracellular water during metabolism rather than from extracellular sources [6]. The antifreeze and hygroscopicity properties would make perchlorate and H_2O_2-water solutions ideal adaptation tools for life in the Martian cold desert. Adaptation to highly oxidizing compounds would also convey adaptation advantages to deal with high radiation doses on the Martian surface. Evolution on Earth favored (salt) water as an internal solvent, but in dry and cold conditions a mixture of water with hydrogen peroxide as intracellular solvent and/or an adaptation to perchlorate-water mixtures would be much more favorable. A lesson learned from evolution of life on Earth is that microorganisms use the resources of their environment optimally, and we expect that to be the case for Mars as well.

References

[1] Coates, J.D., and Achenbach, L.A.: Microbial perchlorate reduction: rocket fuelled metabolism, Nature Reviews Microbiology, Vol. 2, p. 569-580, 2004.

[2] Ericksen, G.E.: Geology and origin of the Chilean nitrate deposits. U.S.G.S. Prof. Paper 1188, 37 p, 1981.

[3] Friedmann, E.A., Wierzchos, J., Ascaso, C., and Winklhofer, M.: Chains of magnetite crystals in the meteorite ALH84001: evidence of biological origin, PNAS (USA), Vol. 98, p. 2176-2181, 2001.

[4] Hecht, M.H., and 13 co-authors.: Detection of perchlorate and the soluble chemistry of Martian soil at the Phoenix lander site, Science, Vol. 325, p. 64-67, 2009.

[5] Houtkooper, J.M., and Schulze-Makuch, D.: A possible biogenic origin for hydrogen peroxide on Mars: the Viking results reinterpreted, Int. J. Astrobiology, Vol. 6, p. 147-152, 2007.

[6] Kreuzer-Martin, H.W., Ehleringer, J.R., Hegg, E.L., and Hayes, J.M.: Oxygen isotopes indicate most intracellular water in log-phase *Escherichia coli* is derived from metabolism, PNAS (USA), Vol. 102, p. 17337-17341, 2005.

[7] Renno, N.O. and 20 co-authors.: Physical and thermodynamical evidence for liquid water on Mars? Lunar and Planetary Science Conference XL, abstract # 1440, 2009.