XEROPHILES ON MARS: POSSIBLE EVOLUTIONARY STRATEGIES USING HYDROGEN PEROXIDE AND PERCHLORATES. Joop M. Houtkooper[1] and Dirk Schulze-Makuch[2], [1]Center for Psychobiology and Behavioral Medicine, Justus-Liebig-University of Giessen, Germany, [2]School of Earth and Environmental Sciences, Washington State University, Pullman, USA, joophoutkooper@gmail.com / dirksm@wsu.edu

Introduction: The Martian surface environment has been characterized as dry, cold and harsh with respect to various forms of radiation. Also, the thin Martian atmosphere does only contain trace amounts of oxygen. If organisms are present, these could be characterized as xerophiles, psychrophiles and anaerobes.

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 [1]. These putative organisms would provide a consistent explanation for the observations by the Viking Biology Experiments. In contrast, it has often been concluded from the results of the Viking Biology Experiments that the Martian surface regolith is in a highly oxidized state, based on the evolution of molecular oxygen upon moisturizing soil samples in the Gas Exchange (GEx) experiment [2, 3].

Perchlorate: The finding of surprisingly large amounts (0.4-0.6 wt%) of perchlorate salts in the Martian arctic soil by the Phoenix lander [4] sheds a new light on these interpretations. First, although perchlorates are known as powerful oxidants, there is no perchlorate known to release oxygen upon moisturizing at the Viking experimental temperature of about 10 deg. C.

H_2O_2-H_2O hypothesis: The H_2O_2-H_2O hypothesis implies that the addition of water vapor at a relatively high temperature could only be withstood by the organisms for a short time, as they perished due to hyperhydration [1]. Thus, the evolution of oxygen in the GEx experiment is explained by the high oxidative content of the organisms. The lack of detected organics by the Viking GCMS could be the result of autooxidation of the organisms as these were gradually heated. Especially heating together with perchlorate salts would result in combustion to CO_2 and H_2O of any organics present.

Antifreeze: An interesting property perchlorate salts share with hydrogen peroxide is their effectiveness as anti-freeze. Whereas the eutectic for H_2O-H_2O_2 freezes at -56 deg C, the water-magnesium perchlorate eutectic is as low as -70 deg C. Therefore, as Mg and Na are prevalent cations in the Martian soil, their perchlorate salts might well be employed as an antifreeze by hypothetical Martian microbes. The reason we still think that H_2O_2 is a more likely choice is the rapid evolution of O_2 in the GEx experiment, at variance with the stability of perchlorate under its experimental conditions, and also because of the fact that H_2O_2 can be produced from only atmospheric constituents.

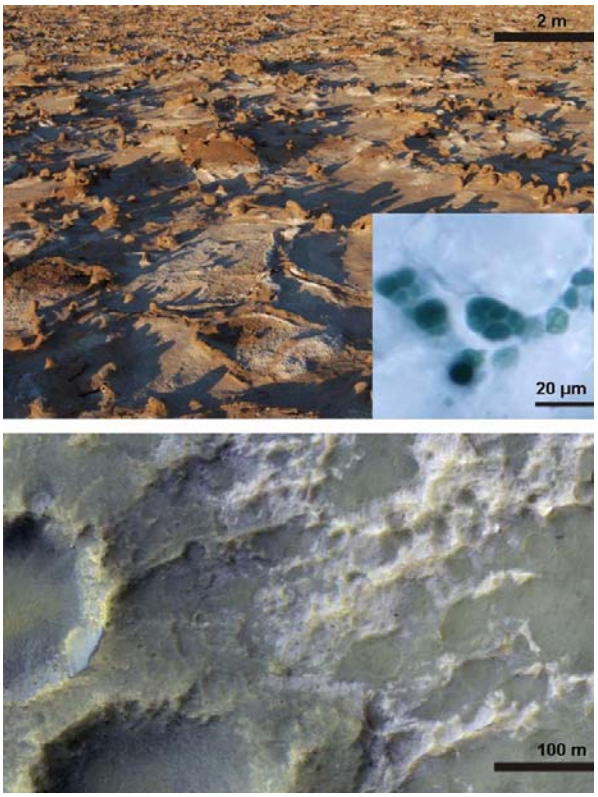

Fig. 1: Top: Halite crusts in the very dry core of the Atacama desert in Chile, which are colonized by cyanobacteria (inset) that live within the rocks and take advantage of the hygroscopic properties of the mineral to obtain liquid water from the atmosphere. Any organisms utilizing a water-hydrogen peroxide or perchlorate solution would be hygroscopic as well and could in principle attract water from the Martian 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.

Water activity: What could be another role of perchlorates in addition to allow liquidity at lower temperatures? Some terrestrial microorganisms and plants living in extremely arid conditions could serve as analogs (Fig. 1). Martian organisms may employ perchlorate salts to scavenge water from the atmosphere. Both H_2O_2-H_2O mixtures and concentrated solutions of perchlorate salts have very low water activity (down to

approximately 0.5 at the respecttive eutectics). The presence of perchlorate salts on their surface would enable organisms to pump water into their cells at relatively modest energy cost.

Discussion: Xerophilic organisms are often also halophilic, some of them occurring in hypersaline solutions [8]. Whereas terran organisms evolved a number of organic (e.g. glycerol) and ionic (KCl) solutes to obtain osmotic balance with the environment, the adaptation to H_2O_2 as a solute, which is compatible with the cell content, would for Martian organisms enable growth at very low water activity, as in concentrated perchlorate solutions.

The detection of perchlorates by the Wet Chemistry Laboratory (WCL) was realized by using an "ion-specific" electrode for different anions, apart from ClO_4^-, also for NO_3^-. However, the presence of a significant concentration of ClO_4^- overwhelms the response for NO_3^-, so that the biologically significant nitrate anion could not be detected [5].

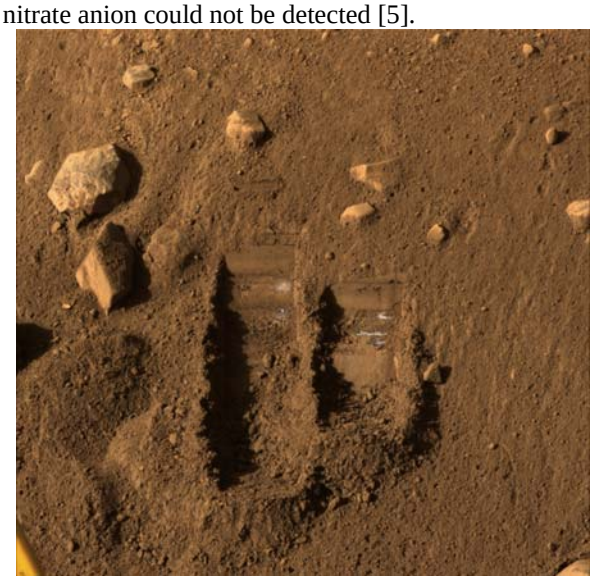

Fig.2: NASA's Phoenix Lander's Surface Stereo Imager took this image on Sol 14 (8 June 2008). It shows two trenches dug by Phoenix's Robotic Arm. Soil from the right trench, informally called "Baby Bear", was delivered to Phoenix's Thermal and Evolved-Gas Analyzer, or TEGA, on Sol 12 (6 June 2008). The following several sols included repeated attempts to shake the screen over TEGA's oven number 4 to get fine soil particles through the screen and into the oven for analysis. When analyzed, a sample from "Baby Bear" showed an oxygen release consistent with perchlorate on Sol 25 (20 June 2008).

Perchlorate salts have also been detected on Earth in hyperarid soils. For instance, Ericksen found that the soils of the Atacama desert contain 0.03-0.6 wt% perchlorate [6].

The diurnal temperature cycle on the Martian surface 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 the Phoenix lander). This means any Mg-perchlorate would attract water. The clumpiness of the soil, which posed such a problem for getting a proper sample into the TEGA instrument of Phoenix (Fig. 2), as well as what seemed drops of liquid water on one of Phoenix' struts (Fig. 3), support that notion.

The presence of perchlorates was primarily detected by the Wet Chemistry Laboratory MECA package on board the Phoenix Lander [5], but it was confirmed by the Thermal and Evolved-Gas Analyzer (TEGA).

The presence of perchlorates at a level of about 0.5% is surprising, because there is no straightforward chemical production mechanism for these compounds to account for the measured concentrations. The production of perchlorates by putative organisms is therefore an alternative possibility - this could be a case of organisms modifying their environment to serve their needs.

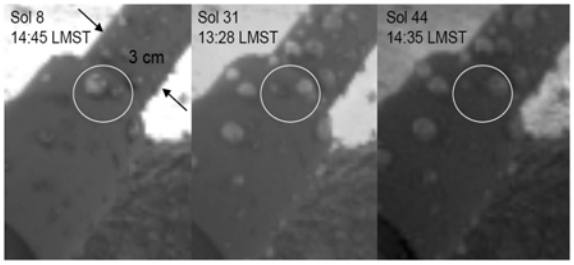

Fig.3: Robot Arm Camera images of a strut on Sols 8, 31 and 44. The two spheroids enclosed by the circle appear to merge with each other. The resulting spheroid moves to the right, which is downslope. For a more in detail discussion of this finding, see Renno et al. [7].

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