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Astrobiological implications for Perchlorates on Mars

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Astrobiology is the study of the past, current and future potential for life in the Universe and has been fascinated with the possibility of life on Mars since the late 1800s. Because of the potential for life on Mars it is vital to understand the role perchlorates may play in that potential.

In 1976, Viking, the first landed mission to Mars conducted a variety of chemical and mineralogical analyses, but at the centre of its mission were the life detection experiments. The experiment packages were designed to detect microbial metabolism of soil microbes. Among them were the Gas Exchange Experiment (GEx), and the Labelled Release Experiment (LR). In each of the experiments, samples of Martian soil were incubated in chambers with either a mixture of complex organic compounds (GEx), H_2O vapour (GEx humid mode) or ^{14}C labelled simple organics (LR). Changes in the gaseous composition of the chamber were used as an indication of potential biological activity. To discriminate between biological activity and non-biological activity samples were collected and heated prior to testing. The assumption was that heating should stop biological reactions and some non-biological reactions, but most non-biological reactions would proceed. The results obtained from all of the life detection experiments were similar for both Viking lander sites. The results suggested that there may have been biological activity in the soil, but additional testing indicated that the results from all of the experiments were due to an abiotic reaction caused by an unknown oxidant in the regolith.

Viking also made the important discovery that the Marian regolith contained an unusual amount of chlorine, and was virtually the same at two widely separated landing sites. The concentration of chlorine found at both landing sites was far higher than in typical terrestrial soils or the lunar regolith. Measurements made on subsequent missions exhibited the same high chlorine concentrations at multiple sites over the Marian surface. For years it was thought that the chlorine was in the form of chloride salts as it occurs on the Earth. However, the analyses conducted during the Phoenix mission in 2008 determined that a significant portion of the chlorine in the regolith was in the form of perchlorate (ClO_4^-). The questions arose, 'Could perchlorate have played a role in the Viking life detection experiments, and if so what role?'. It was unclear if perchlorate played a role in the results of these experiments because perchlorate alone cannot explain the Viking biology experiments due to the fact that at low temperatures perchlorate is not reactive. Subsequently, it was found that ionizing radiation similar to that on Mars decomposes perchlorate and forms hypochlorite (ClO^-), and other lower oxidation state oxychlorine species as well as produces O_2 that remains trapped in the salt crystal. The release of trapped O_2 from radiation-damaged perchlorate salts and the oxidation of the added organic compounds by ClO^- with the organic compounds that were added to the Martian soils can explain the results of the Viking GEx and the LR life detection experiments.

The origin and mechanism of production of the high perchlorate concentration in the Martian regolith is unclear. The origin of natural perchlorate on Earth also remains a subject of speculation. It has been proposed that perchlorate could be formed by the photochemical oxidation of volatile sea-salt chlorine by ozone in the troposphere or at the soil surface. This mechanism, however, has not been validated.

In this issue, we present four articles that explore the origin, longevity and reactivity of the perchlorates in the Martian regolith, as well implications for life on Mars. The papers are based on talks that were presented during December 2014 at a workshop that was held at NASA Ames Research Center, Moffett Field, CA, USA, entitled 'Perchlorates on Mars: implications for human exploration and astrobiology'. Clark and Kounaves review the data from the Curiosity rover and the Phoenix lander and make the case that these data strongly suggest that perchlorate is widespread across the Martian surface. Additionally, Sutter *et al.* explain that the Mars Science Laboratory's Sample Analysis Instrument indicated the presence of oxychlorine phases in Gale Crater, but the Chemistry and Mineralogy (CheMin) X-ray diffractometer did not detect any oxychlorine phases. These data suggest that the oxychlorine in Gale Crater may be poorly crystalline, or that the individual oxychlorine phases are in concentrations that are each below the 1 wt% detection limit of CheMin. These data indicate that although perchlorates may be ubiquitous in the Martian regolith its concentration varies across the planet.

It has been known for years that the naturally occurring perchlorates at the low concentrations found in places such as the Atacama Desert were not inhibitory, but could be respired in place of nitrate by a variety of denitrifying organisms. But the question 'Would the high concentration of perchlorates in the Martian regolith prevent life from evolving on Mars? Remained. The results of the studies by Matsubara *et al.* using organisms isolated from Big Soda Lake in Nevada, USA, a hypersaline alkaline lake, and Al Soudi *et al*. using isolates from the Great Salt Plains of Oklahoma (NaCl-rich) and Hot Lake in Washington ($MgSO_4$-rich) indicate that organisms from different environments could grow in the perchlorate levels found on Mars. Their data strongly suggests that the perchlorates in the Martian regolith would not prevent life from evolving on Mars, and leads us one step closer to understanding the environment on Mars and its implications for life.