Perchlorate Effect on Rock Weathering on Mars at Phoenix Landing Site

Keywords: Phoenix, salt weathering, rock weathering, stress corrosion, thermal stress, segregated ice

Relevance

Surprising evidence from a spacecraft flying in orbit around Mars suggests that the planet was once much like Earth is today-with a hot dynamo at its core, intense magnetism in its crust and possibly massive continental plates adrift on its surface [1]. In the effort to understand more about our own planet, it is often necessary to study another planet that is at a different development stage than ours. Mars and Earth share many similarities - hard crust, dense cores and same materials composition [2]. To better understand our planet, one of the best comparative laboratories exists is planet-Mars. The study of Mars provides Earth scientists invaluable information as they examine the processes of climate change, geophysics, and the potential for life beyond our own planet. Mars took the center stage as a primary planet where life may have existed in the past when the recent Phoenix Mars Mission revealed indisputable evidence of water and perchlorate existence in Martian soil. Presence of water strengthen the possibility of past life existence on Mars since it is one of the major sources for life, and it was reinforced by the presence of Perchlorate since it can be used as an oxidizer to derive energy organisms [3].

The results from the Phoenix mission led scientists to believe it is possible that primitive life exists below the Martian surface. Therefore, drilling in Martian soil in search for organisms is the next logical step. Drilling on Mars is a major engineering challenge since Martian soil surprised Phoenix mission scientists with unexpected soil characteristics that nearly prevented the mission from being completed. Unexpectedly sticky soil initially prevented it from falling through one of the instrument's screens as planned. Further understanding of Martian soil mechanics is needed to better prepare engineers for proper drilling device design and methodology. Since soil is generated from rock disintegration (weathering), the most logical step toward drilling is to understand rock weathering on Mars in the presence of perchlorate salt. Understanding rock weathering will also help in the process of determining future suitable landing sites and navigation of the Martian surface.

Background

NASA's Phoenix Mars Mission returned images that provided strong evidence of Phoenix landing site is dominated by fine soil and pebble size rocks (Fig.1, A)[3]. This images contrasted by NASA's Pathfinder's Mission returned images showing Mars surface is highly populated by large size rocks (Fig.1, B)[4]. Both missions utilized instruments to analyze the Martian geology, soil, and rock composition. **The proposed research is focused on advancement of science by studying the phenomenon of the absence of large size rocks at the Phoenix landing site and perchlorate effect on rock disintegration utilizing both data sets returned from Phoenix and Pathfinder's missions.**

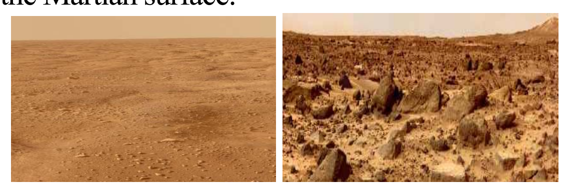

Figure 1: *(A) Phoenix landing site (left) [3] and (B) Pathfinder landing site (right)[4]*

Perchlorate salt was found at a high concentration (~1%) in the Martian soil during Phoenix mission and it is known that salt has an effect on rock weathering at Earth atmospheric pressure and moisture condition [3]. However, the concept of rock weathering on Mars must be different due to its extreme and harsh environment in comparison to Earth. Further studies are needed to determine whether or not perchlorate salt has an effect on rock weathering, which would explain the absence of large size rocks at the Phoenix landing site. The results Pathfinder returned for the Martian rock composition together with Martian meteorites received on Earth suggests that Martian rocks are igneous rocks. **This research focuses on igneous rocks (basalt) because they are most abundant and well characterized.** Moreover, their petrographic characteristics are consistent with Martian near-surface rocks [4].

Major concepts behind rock weathering: Salt Weathering: is the fragmentation of rocks due to salt crystallization in a restricted range of environments. Relatively hard rocks can be completely broken down into their component particles by soaking them in a salt solution and allowing the salt to crystallize in the rock pores (Fig.2, A) [5]. **Thermal Stress:** Elliot (2008) observed that the temperature cycle had a significant effect on the rates of rocks breakdown from all directions but the magnitude varied with moisture level (Fig.2, B) [6][8]. **Segregated Ice:** Fracture of rock samples due to the segregated ice growth was examined and the results reported showed that freezing rocks fractured at lower temperatures than water freezing point (0˚C), which are necessary for substantial pressure within micro-cracks to develop as segregated ice grows [7][9].

Figure 2: *(A) Intact frost-sensitive cobbles are reduced to fans of rock slivers over decades [5] (left) (B) Rock fracture due to: Thermal Stress [8] (right)*

Methods

First hypothesis - Stress corrosion: Magnesium Perchlorate salt is likely to reduce the strength of basalt rocks due to stress cracking. Perchlorate weakens high stress concentrations inside the rocks at the tip of a crack accelerating fracture. Over time, fracture propagates breaking down rocks to its original particles, soil. An experiment will be conducted to measure single edge-notched lava specimen's fracture toughness (K_{ICC}) in the presence and absence of perchlorate in a vacuum chamber held at temperature range experienced on Mars. Bending tests will be conducted to determine the effect of perchlorate on basalt specimens. **Second - Thermal Stress:** rock weathering occurs on Mars due to the exposure to intense radiation/temperature difference causing rocks to break down as a result of thermal stress. Thermal modeling of basalt rocks will be performed to determine temperature gradient as a function of time using Finite Element Modeling. **Third - Phase Change/Segregated Ice:** extreme temperature cycling on Mars causes freezing-thawing result in ice segregation generated in the rock porosity. Segregated ice process generates micro-fractures and the cyclic loading imposed on them results in crack propagation over several cycles and rocks breakdown turning into soil. Tests will be conducted on basalt rocks that are saturated in Perchlorate salt solution and exposed to Martian temperature cycle.

Results

Recent investigations on rock weathering have shown that salt crystallization, thermal stress and segregated ice growth have an influence on rock breakdown within Earth atmospheric condition. **I hypothesize** that rocks on Mars will exhibit lower fracture toughness and an increase in rate of fatigue crack growth upon perchlorate salt crystallization inside rock pores. Intense radiation due to Martian thin atmosphere and extreme temperature cycle (-30 to -100˚C) will cause the rock to exhibit high thermal stress fatigue rate. I also predict that due to perchlorate low eutectic freezing point ~ (-70˚C) thawing-freezing process will take place at much lower temperature than water freezing point. As a result, segregated ice will grow developing substantial pressure within micro-cracks causing rock breakdown.

My mechanical engineering background and my previous research experience working with Dr. Chris McKay, Mars expert at NASA, on similar research equipped me with the skill set needed. The proposed research is well suited for completion in Professor Dharan or Professor Pruitt's labs at UC Berkeley. I am experienced and well accustomed to testing equipment and specimens' preparation. Alternatively, the research could also be carried out in Professor Bernett's lab at Stanford University.

Statement of Originality: NASA's missions brought the attention to rock weathering on Mars. I devised and wrote this research plan, no similar research has been conducted to the best of my knowledge.

References: [1] Mitchell, D., *Berkeley SSL* (1999) [2] ESA, *Mars Express* (2006) [3] *Phoenix Mars Mission*, (2008) [4] McSween, H., et al., *Science* (2009) [5] Wellman et al, (1965) [6] Elliot, C., Antarctic *Sci.*(2008) [7] Hallet, B., et al, (2006) [8] Hall, K., *Geomorph.*(1999) [9] Murton et al, *Science* (2006).