# Proposed Research Plan

## *Perchlorate Salt Effect on Rock Weathering on Mars at Phoenix Landing Site*

***1-2. Research Plan and Study Objectives***

The Phoenix Mission was the first to land in the polar regions on Mars. The mission revealed three surprising results: (1) The surface at the landing site had a very low concentration of large size rocks, (2) The unexpectedly sticky nature of the soil prevented it initially from falling through one of the instrument's screens as planned, (3) Perchlorate salt was found at a high concentration (~1%) in Martian soil. Further study could prove that the three results are related. The scientific results of the Phoenix mission motivate a return to that site with a mission capable of drilling into the ice-cemented ground. To design a mission we must understand the engineering properties of the soil, salt, ice and rock environment.

It is possible that the presence of perchlorate salt (most likely magnesium perchlorate) at a high concentration caused the soil stickiness. Since rocks disintegration due to the presence of salt is known on Earth, perchlorate may also cause rock disintegration on the Martian surface and could explain the absence of large size rocks at the Phoenix site.

NASA's Phoenix Mars Mission returned images that provided strong evidence that the Phoenix landing site is dominated by fine soil and pebble sized rocks (Fig.1, A)[1]. These images are in contrast to NASA's Pathfinder's Mission which returned images showing the Mars surface is characterized by large sized rocks (Fig.1, B)[2]. Both missions utilized instruments to analyze the Martian geology, soil, and rock composition. ***The goals of this project are an excellent match to the goals & objectives of NASA's Planetary Sciences Program. The proposed research is focused on advancement of science by examining the phenomenon of the absence of large size rocks at the Phoenix landing site and perchlorate salt effect on rock disintegration utilizing both data sets returned from Phoenix and Pathfinder missions.***

The results from the Phoenix mission led scientists to believe it is possible that signs of past life may exist in the ground ice below the Martian polar surface. Therefore, drilling in the ice-cemented ground at the Phoenix site in search for signs of life 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. 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.

Perchlorate salt was found at a high concentration (~1%) in the Martian soil during the Phoenix mission and it is known that salt has an effect on rock weathering at Earth's atmospheric pressure and moisture conditions [1]. However, the concept of rock weathering on Mars must be different due to its extreme and harsher environment relative 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 that 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 [2].

**Summary of Science Goals:**

1. **Confirm the hypothesis that perchlorate salt causes stress corrosion causing resulting in rock weathering**
2. **Generate thermal stress model of basalt rock as a function of time using Finite Element Modeling.**
3. Test perchlorate salt phase change/segregated ice effect on basalt rocks under Martian temperature cycle.
4. **Analyze data generated from experiments identifying the cause of rock weathering under Martian environment.**

***3-4. Methodology and Key Elements***

**Major concepts behind rock weathering are salt Weathering, thermal stress and segregated ice. 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) [3]. **Thermal Stress:** Elliot (2008) observed that temperature cycling had a significant effect on the rates of rocks breakdown from all directions with the magnitude varying with moisture level (Fig.2, B) [4][6]. **Segregated Ice:** Fracture of rock samples due to segregated ice growth on Earth rocks has been examined and the results reported show that freezing rocks fractured at lower temperatures than the freezing point of water (0˚C), Freezing and segregated ice growth results in substantial pressure within micro-cracks [5][7].

1. **Stress corrosion:** Magnesium perchlorate is likely to reduce the strength of basalt rocks due to stress cracking. Perchlorate weakens the rock due to high stress concentrations inside the rocks at the tip of a crack, thereby accelerating fracture. Over time, fractures propagate breaking down the rocks to small particles that form soil. An experiment will be conducted to measure the stress-corrosion cracking fracture toughness $K_{Iscc}$ in single edge-notched lava specimens as a function of perchlorate in a vacuum chamber held at the typical temperature ranges experienced on Mars. Bending tests will be conducted to determine the effect of perchlorate on basalt beam specimens with diamond scribed notches.

2. **Thermal stress:** Rock weathering occurs on Mars due to exposure to intense radiation/ temperature differences causing rocks to break down as a result of thermal stress arising from high thermal gradients. Thermal modeling of basalt rocks will be performed to determine temperature gradients as a function of time using finite element analysis (COMSOL).

3. **Phase change/segregated ice:** The extreme temperature cycling on Mars causes freezing-thawing cycles resulting in ice segregation generated in the rock pores. The segregated ice process generates micro-fractures and the cyclic loading imposed on them causes crack propagation over several cycles resulting in rock breakdown. Tests will be conducted on basalt rocks that are saturated in magnesium perchlorate salt solution and exposed to Martian temperature cycles.

4. 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.

***5-6. Timetable and Milestones***

| | |
|---|---|
| 8/2010 to 12/2010 | Perform stress corrosion test on various known types of ceramics in the presence and absence of perchlorate salt establishing test methodology |
| 1/2011 to 5/2011 | Collect various types of lava rocks and conduct same stress corrosion test in the presence and absence of perchlorate salt. |
| 08/2011 to 12/2011 | Conduct thermal stress analysis on basalt rocks using Finite Element Modeling |
| 1/2012 to 5/2012 | Perform tests examining phase change/segregated ice of perchlorate on basalt rocks |
| 8/2012 to 12/2012 | Detailed comparison to rock weathering on Earth and under Martian environment |
| 01/2013 to 5/2013 | Analysis of collected data of stress corrosion, thermal stress, and phase change/segregated ice and determining the effect of perchlorate salt on Martian rock weathering |
| 8/2013 | Complete analysis and finalize dissertation material |

**Conclusion:**

Studying the three surprising results returned from Mars Phoenix Mission, absence of large size rocks, sticky soil, and high perchlorate salt concentration will help generate a model for the perchlorate salt effect on rock weathering on Mars. Testing stress corrosion, thermal stress, and segregated ice on igneous rocks that emulate Martian rocks in the presence and absence of perchlorate salt will help in achieving the goal of understanding and generating a model for perchlorate effects on rock weathering.

***References:***


[1] Phoenix Mars Mission site, "*NASA Spacecraft Analyzing Martian Soil Data*", August 2008.

[2] McSween, H., Jr., et al., "*Elemental Composition of the Martian Crust*", Science 324, 736 (2009).

[3] Wellman et al, "*Salt Weathering, a Neglected Geological Erosive Agent in Coastal and Arid Environments*", Nature, Vol. 205, March 13, 1965.

[4] Elliot, C., "*Influence of temperature and moisture and moisture availability on physical rock weathering along the Victoria Land coast, Antarctic*" Antarctic Science 20 (1), 61-67 (2008).

[5] Hallet, B., et al, "*Why Do Freezing Rocks Break?*", Science 314, 1092 (2006).

[6] Hall, K., "*The role of thermal stress fatigue in the breakdown of rock in cold regions*", Geomorphology 31, 47-63, (1999).

[7] Murton et al, "*Bedrock Fracture by Ice Segregation in Cold Regions*", Science 314, 1127 (2006).

***Figures***

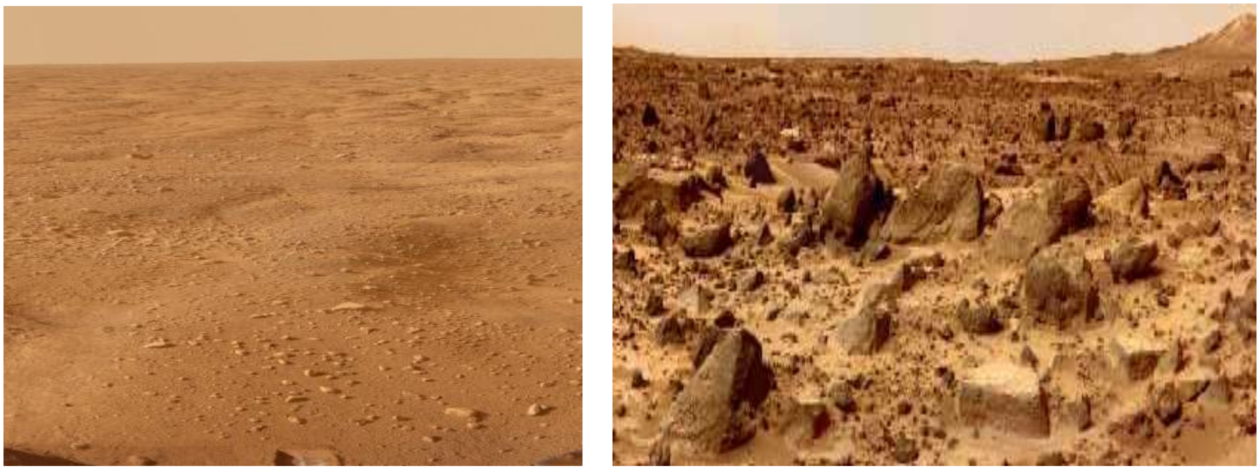

***Figure 1:*** *(A) Phoenix landing site (left) [3] and (B) Pathfinder landing site (right)[4]*

***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)*