The Habitability of Mars

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Project summary
This project will investigate the geochemistry of Martian environments with an emphasis on brine and mudstone environments. The purpose of the project is to study habitability of different Martian environments.

Project rationale
We now know that many environments on Mars hosted pH neutral environments in basaltic sediments and that these environments were likely habitable. This project will focus on investigating the limits of life in different Martian environments with a special focus on briny environments and effects of brine on habitability. We have previously shown that sulfate salts on Mars can create high ionic strength that can limit life even when the water activity is clement for life. Although sulfate salts are found on Earth, they are more prevalent on Mars as the planet went through a phase when acid rock weathering, caused by low water-rock ratios, generated these salts. These findings show that the geological history of a planet can influence the extremes that limit life in different environments and that Mars, although similar to Earth, generated very different conditions for habitability on account of its different geological history.

The scientific motivation of this work is to understand better how the specific geochemical conditions generated on Mars in its past history influenced its habitability and which of those conditions might define limits to life different to Earth. In particular, we want to explore the effects of different salts and brines on habitability, focusing on those salts that are common on Mars, but might influence habitability on Earth, such as sulfates and perchlorates. In examining the growth and death of cells in different Mars environments we will also study whether the cells merely die or are physically disrupted, in the latter case this would destroy their potential for preservation. Thus, this work will also allow us to ascertain the potential for biomarker preservation in these environments. Our work will have direct implications for understanding the geochemical limits to life in extreme environments on Earth.

This interdisciplinary PhD proposal will link the extensive and pre-existing expertise in the habitability and geochemistry of Martian environments with our microbiology expertise. This doctoral project will address key questions in geosciences:

1) How do different salts define the growth space for microorganisms?
2) How do salts prevalent on early and present-day Mars define habitability with respect to the limits of life and how have those conditions changed over time?
3) How do these limits for life compare to conditions in extreme briny environments on Earth and what can we learn about how changing geochemical conditions in aqueous environments on Earth change the limits for life?
4) What is the preservation potential of microorganisms in Martian salt environments?

Aims and Methodology
Aims: The aims are to understand how different ions limit life and thus how geochemical factors define the limits to life.

Analytical approach:
The approaches to be taken are:
1) Microbial enrichments will be used to obtain microorganisms that will grow in different brines with different salt concentrations and to varying levels of concentration. These enrichments will be obtained in aerobic and anaerobic conditions.
2) Microorganisms will be isolated from the most extreme brines and purified through to single isolates. The organisms will be used to investigate tolerance to extremes of water activity, ionic strength, pH and other extremes relevant to brines. The response of organisms
to multiple extremes will also be investigated to ascertain which physical and geochemical stressors limit life most in different brines and in brines with different concentrations of salts. The preservation of cells (i.e., whether they are merely made non-viable or physically disrupted) will be examined. The organisms will be identified using 16S rDNA sequencing.

3) The data above will be used to obtain ‘maps’ of habitability to understand how different geochemical conditions in past aqueous environments on Mars may have limited habitability.

4) The data above will be linked to known Earth environments to understand how different aqueous environments on Earth, particularly briny environments, may limit life and what those physical and geochemical limits are caused by.

**Timeline:**

**Year 1:** Literature review. Carry out studies of survival of organisms in extreme brines of varying salt concentrations using enrichments.

**Year 2:** Isolate microbes from extreme brines and study the effects of single and multiple limits on growth. Compare these limits to known environments on Earth to understand how stresses in extreme terrestrial brines limit life.

**Year 3:** Investigate preservation potential in different brines and the fate of microorganisms in different extreme salinities.

**Year 4:** Completion and further papers.

**Research Training**

We are seeking a microbiologist with proven interest and experience in the laboratory. A comprehensive training programme will be provided comprising both specialist scientific training and generic transferable and professional skills. The student will receive training in microbiology (aerobic and anaerobic culturing), molecular biology, sterile sample collection. The project offers an extremely exciting opportunity to learn interdisciplinary field and laboratory techniques. These skills are highly transferable to many career choices. Leaving the PhD with microbiology and geology methods expertise would particularly lend itself to an earth scientist seeking to pursue research.

**Further reading/ references**


Fox-Powell MG, Hallsworth JE, Cousins, CR Cockell CS. 2016. Ionic strength is a barrier to the habitability of Mars. Astrobiology 16, 427-442.
