To the Lifeboats:
Fluid inclusions as the last habitable environments on Mars

Supervisory team: *Dr. Michael C. Macey (Open University), Dr. Vic Pearson (Open University), Prof. Terry McGenity (University of Essex)*

Project Highlights:

- Investigate the preservation of life and its biosignatures in fluid inclusions under Mars-like conditions, informing the search for life on Mars.
- Develop a unique skillset in microbiology, advanced spectroscopy, and Mars simulations.
- Explore the physiological and genomic impacts of extreme conditions on life and its biosignatures, providing insights into the limits of habitability and the evolution of life in extreme environments on Earth.
- Guaranteed funding from the UK Space Agency.

Overview:

The search for life in the Solar System is dependent on detecting and identifying reliable signatures formed by life (extinct or current), known as biosignatures. The surface of Mars today is arid and bombarded by radiation. However, there is extensive evidence that Early Mars (four billion years ago) was water rich. As time progressed, the atmosphere of Mars was lost, resulting in low-pressure conditions that drove these waters to become hypersaline, desiccated, and then eventually cease to exist. This evaporation of waters led to the formation of specific minerals (evaporite minerals) that have been detected by numerous Mars missions and that, in terrestrial environments, can capture and preserve biological material. This project would advance the search for life, by defining the potential for these evaporite minerals to have captured and preserved signs of life on Mars.

Key questions are: Did the potential for the capture of biological material vary across the surface of Mars, depending on the local chemical environment? Could minerals formed in these martian chemical environments have preserved, modified, or destroyed biosignatures? Could potential martian life have adapted to these increasingly extreme environments, and could this have influenced their preservation? Can biosignatures in these minerals be detected today?

This project will answer these questions with a combination of Mars simulation experiments, experimental evolution, and analytical geochemistry. The student will generate analogue martian fluids of varied chemistries and evaporate these, simulating the martian surface during its transition, to form Mars-relevant evaporite minerals. This will allow them to examine the impacts of martian chemistries on the preservation of biosignatures, and how this may have varied across Mars. The student will leverage cutting-edge genomic techniques to perform long-term evolution experiments and assess if it is possible for microbial life to adapt to martian environments and the consequences on biosignature formation. For biosignature detection and analysis, the student will use techniques used by current Mars missions plus ultra-sensitive techniques.

Evaluating the potential for evaporite minerals to preserve life and its biosignatures under martian chemistries is vital for informing the search for life and interpreting data from past, current and future missions to Mars (e.g., the ESA ExoMars Rosalind Franklin rover)..

Figure 1. The salt flats of Kachchh in northern India – an extreme and hypersaline environment.

Alternate text – a photograph showing salt flats in Kachchh, India. Wide, flat landscape covered with a layer of white salt. The terrain stretches to the horizon under a cloudy sky.

Methodology:
This studentship will employ a three-pronged approach: 1) Conducting controlled laboratory experiments to simulate martian aqueous environments, using varied fluid chemistries and physical conditions; 2) Performing parallel experiments with salt-adapted microorganisms to assess their survival, adaptation through experimental evolution, and biosignature preservation within fluid inclusions within generated minerals; and 3) Utilizing mission-relevant and advanced analytical techniques, including microscopy and spectroscopy (Raman, FTIR, NIR), to characterize the formation of fluid inclusions, entrapped biological material, and the impact of Mars-relevant destructive processes.

Training and skills:
The student will be trained in specific, laboratory-based techniques in molecular biology (DNA extraction, PCR, library preparation, stable isotope probing and DNA sequencing), analytical geochemistry (e.g., Raman Spectroscopy, FTIR, NIR) and culture-based microbiology *via* one-on-one training by members of the research team. Short placements with the external supervisor will enable access to laboratory facilities and training in further laboratory techniques. The student will also be trained in computer-based techniques, including bioinformatic analysis of sequencing data. The student will be embedded within the established support and monitoring framework of AstrobiologyOU, the School of Environment, Earth and Ecosystems Sciences and the wider Open University, involving fortnightly update meetings, progress reports, and an upgrade process in the first year, in additional to regular supervision meetings and access to independent academic mentors. They will also benefit from additional skills development opportunities offered by AstrobiologyOU and wider faculty/university (e.g., communication skills, time management, academic writing).

Possible timeline:

Year 1: Perform a literature review and initial evaporation experiments (with and without microbes) to generate baseline data on the formation of fluid inclusions and the physiologies of the strains.

Year 2: Establish and monitor the evolution experiments. Present results at a national conference. Prepare and submit a manuscript on the genome sequencing results.

Year 3: Perform destructive experiments with generated evaporative minerals. Write and submit thesis. Present data at an international conference.

Further reading:

Macey, M.C.; Ramkissoon, N.K.; Cogliati, S.; Toubes-Rodrigo, M.; Stephens, B.P.; Kucukkilic-Stephens, E.; Schwenzer, S.P.; Pearson, V.K.; Preston, L.J.; Olsson-Francis, K. Habitability and Biosignature Formation in Simulated Martian Aqueous Environments. *Astrobiology* **2023**, *23*, 51-2973-51–2973, doi:10.5860/choice.51-2973.

Westall, F., Loizeau, D., Foucher, F., Bost, N., Betrand, M., Vago, J., & Kminek, G. (2013). Habitability on Mars from a Microbial Point of View. *Astrobiology*, 13(9), 887–897.

Macey, M.C.; Fox-Powell, M.; Ramkissoon, N.K.; Stephens, B.P.; Barton, T.; Schwenzer, S.P.; Pearson, V.K.; Cousins, C.R.; Olsson-Francis, K. The Identification of Sulfide Oxidation as a Potential Metabolism Driving Primary Production on Late Noachian Mars. *Sci Rep* **2020**, *10*, 10941, doi:10.1038/s41598-020-67815-8.

Olsson-Francis, K., Ramkissoon, N. K., Macey, M., Pearson, V. K., Schwenzer, S. P. and Johnson, D. N. (2020) Simulating microbial processes in extraterrestrial, aqueous environments. *Journal of Microbiological Methods*, 172, 105883.

Further details:

Students should have a strong background in microbiology and an interest in geochemistry/mineralogy/planetary science. The successful student will join the well-established AstrobiologyOU research group (more details will be found here) and a vibrant postgraduate community at The Open University and will be based in the School of Environment, Earth and Ecosystems Sciences. For more information please refer to: PHD STUDENTSHIPS | School of Environment, Earth and Ecosystem Sciences | School of Environment, Earth and Ecosystem Sciences (open.ac.uk)

Please contact Michael Macey (Michael.Macey@open.ac.uk) for further information.

Applications should include:

- a cover letter outlining their motivation for doing a PhD, why this specific project is of interest and how their skills (technical and transferable) match those required of this project,
- an academic CV containing contact details of three academic referees,
- an OU application form, downloadable from: https://www.open.ac.uk/students/research/system/files/documents/application-formuk.docx

Applications should be sent to **STEM-EEES-PHD@open.ac.uk by 12pm (noon) on the 10th April 2025.** Interviews will be held on the **18th April 2025**.