Preservation of biosignatures in the Martian subsurface: should future missions target meteorite impact sites?

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Project background – Of all of the planetary bodies in our solar system, excluding Earth, Mars is arguably the best candidate for finding evidence for life. The presence of seasonal liquid water and enigmatic methane emissions have both been suggested to indicate that Mars could be habitable. Alternatively, it has been proposed that more favourable conditions early in the geological history of Mars could have supported organic life which is now dormant or extinct. However, analysis of the Martian surface has not, so far, conclusively detected organic signatures which could be indicators of past or present life. Due to the largely unfavourable surface environment of Mars, it has been suggested that such evidence, if present, may remain hidden deep in the Martian subsurface. Although drilling deep into the Martian surface remains technologically challenging, large impacts on Mars could provide a ready solution to problem of sampling the subsurface. During impact events, significant volumes of material are uncovered, providing a window into the subsurface. It has also been suggested that hydrothermal processes immediately following impacts could provide conditions favourable for life. However, recent preliminary work on the effects of extreme pressures and temperatures during impact events has cast doubt on the survivability of some organic compounds, and suggests that key signatures of life may be fundamentally altered. If we are to effectively search for evidence of life on Mars and accurately interpret data from future missions, we need to fully understand the effect which impacts will have on these biosignatures. In this project you will conduct high pressure-temperature (HPT) experiments and detailed organic chemical analysis to determine preservation of organic signatures during Martian impact events. Results will be used to (1) identify the effects of impacts on key organic and isotopic

Top left: ESA ExoMars rover which will drill 2 meters into the Martian surface to search for biosignatures. Bottom left: Melas Dorsa impact crater showing flow of ejecta material on the Martian surface due to melting of subsurface ice. Impact sites allow sampling of larger volumes of material from deeper in the Martian surface (photos: ESA). Bottom right: Pyrolysis products in 4 types of organic material before and after subjection to HPT conditions of impact events¹.
signatures in the Martian subsurface and inform future missions on the search for extra-terrestrial life, and (2) determine the effects of sustained, large impacts on preservation of key organic precursors for life on the early Earth.

**Key research questions** – (1) Determine the HPT stability of key types of organic material and investigate the kinetics their breakdown during impact events; (2) Investigate the effects of different matrices (i.e. different surface material) on biosignature survivability; (3) Assess how direct sampling of impact ejected material in future missions to Mars can be meaningfully interpreted: (4) Assess survivability of organic precursors to life during heavy bombardment on the early Earth.

**Methodology** – You will perform HPT experiments at Edinburgh using well-characterised types of organic material (months 1-18), and organic material mixed with various inorganic substrates (months 12-30). Experiments will be conducted over a range of conditions expected in impact basins. Run products will be characterised by scanning electron microscopy and X-ray microtomography at Edinburgh (ongoing, months 3-30), and detailed organic analysis by pyrolysis at the Dept. Earth Sciences, Imperial (one 2 week visit during each year of study). Additional in-situ and detailed tomographic analysis will be performed at international synchrotron facilities, following application for beam time (years 2 onwards, subject to application for beamtime).

**Training** - A comprehensive programme will be provided comprising both specialist scientific training and generic transferable and professional skills. Specific training will include use of HPT experimental equipment and microanalysis using scanning electron microscopy and X-ray microtomography. You will also have the opportunity to network and present your research at local and international conferences and be a member of the cross-disciplinary Edinburgh Centre for Science at Extreme Conditions (CSEC). Training on the pyrolysis unit at Imperial will provide an introduction to analytic geochemistry skills and access to experts in the field.

**Requirements**
The student should have a good first degree in an area of Earth Science or physical sciences and should have good numeracy skills. Experience in analytical techniques, sample synthesis, organic chemistry and general lab skills would be advantageous.

**Further reading**

**Project summary** – You will determine the effects of impact events on survivability of biosignatures on Mars. Data will inform future Mars missions and determine the effect of impacts on emergence of life on Earth.