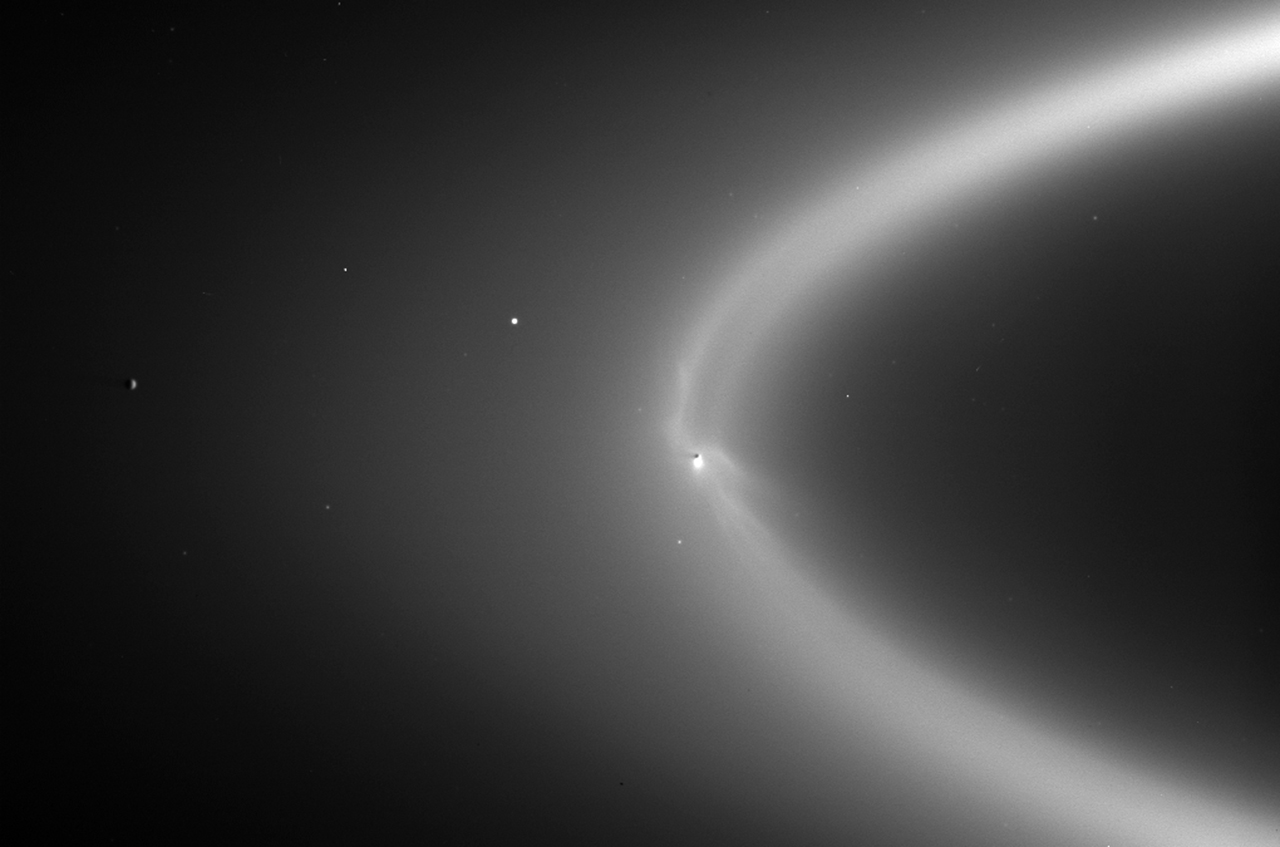


8th Astrobiology Society of Britain – “Beyond the ice line”

***Abstract Booklet***

Newcastle University

25th-26th April 2019

**SCIENTIFIC PROGRAM – MAIN CONFERENCE**

**Location: Armstrong Building (Presentations – Lecture Theatre 2.98, Posters – Room 1.06)**

**Thursday 25th April 2019**

9.00 **ARRIVAL AND REGISTRATION (next to room 1.06 in the corridor space)**

10.00  **LOGISTICS/OPENING REMARKS BY NEWCASTLE UNIVERSITY**

Jon Telling

10.05 **OPENING OF CONFERENCE**

Manish Patel

**Session 1: ExoMars/Mars**

10.15 **MARS SURFACE CAMERAS: PAST, PRESENT, AND FUTURE**

C. Cousins (Invited)

10.45 **MULTISCALE AND MULTISPECTRAL ASSESSMENT OF MINERALOGY WITH THE EXOMARS 2020 ROVER REMOTE SENSING PAYLOAD**

E.J. Allender

11.00 **COMPLEX ORGANICS IN MARTIAN METEORITES**

A. C. O’Brien

11:15 **THE DAILY GRIND: AEOLIAN ABRASION OF SEDIMENTARY ROCKS AS A MECHANISM TO PRODUCE METHANE IN THE MARTIAN ATMOSPHERE**

E. Safi

11.30 **DETERMINATION OF SURVIVABILITY AND BIO-SIGNATURE FORMATION USING LABORATORY SIMULATION EXPERIMENTS**

K. Olsson-Francis

11:45 **POSTERS/LUNCH**

**Session 2: Habitability of Cold and Icy Environments**

13:30 **ICY MOONS – HOW ENCELADUS, EUROPA, AND OTHER ICY WORLDS CHANGED OUR IDEA OF HABITABILITY**

R.S. Taubner (Invited)

14:00 **THE ENERGETIC HABITABILITY OF ENCELADUS MAY BE TENUOUS**

P. M. Higgins

14:15 **FREEZING-INDUCED FRACTIONATION IN SIMULATED ENCELADUS OCEAN BRINES**

M. G. Fox-Powell

14:30 **WET-BASED GLACIATION ON MARS AND ITS ASTROBIOLOGICAL IMPLICATIONS** F. E. G. Butcher

14:45 **CRUSHING AS AN ABIOTIC NUTRIENT AND ENERGY SOURCE IN A SUBGLACIAL LAKE ENVIRONMENT.**

B. Gill Olivas

15:00 **COFFEE**

15:30 **SENSING TECHNOLOGIES FOR MEASURING BIOGEOCHEMICAL ACTIVITY AND RETURNING DATA FROM ICY ENVIRONMENTS**

E. A. Bagshaw

15:45 **THE RED DOTS SEARCH FOR NEARBY EXOPLANETS: IS BARNARD’S STAR B THE CLOSEST EXTRA-SOLAR HABITAT?**

C. Haswell

16:00 **POSTERS**

17:30  **PRE-DINNER TALK – Exploration of Antarctic subglacial lakes**

M. Tranter (Invited)

19:45 **CONFERENCE DINNER – BALTIC (can arrive any time from 19:00)**

**Location: Armstrong Building (Presentations – Lecture Theatre 2.98, Posters – Room 1.06)**

**Fri 26th April 2019**

8.30 **COFFEE**

**Session 3: Methods for in situ and remote sensing of biosignatures and habitability**

9.30 **SUBGLACIAL MOISTNESS ON MARS**

S.J. Conway (Invited)

10.00 **CONSTRAINING THE EFFECTS OF STELLAR FLARES ON EXOPLANET HABITABILITY WITH NGTS**

James A. G. Jackman

10.15 **PYROLYSIS OF FATTY ACIDS IN THE PRESENCE OF IRON OXIDES: IMPLICATIONS FOR LIFE DETECTION MISSIONS TO MARS**

Samuel H. Royle

10:30 **ORGANIC RECORDS OF LIFE ON MARS: THE ROLE OF IRON, BURIAL AND KINETICS** Jonathan S. W. Tan

10:45 **DETECTABILITY OF BIOSIGNATURES IN A LOW-BIOMASS SIMULATION OF MARTIAN SEDIMENTS**

Adam H. Stevens

11:00 **COFFEE**

11:30 **NANO-IMAGING + NANO-CHEMISTRY = UNAMBIGUOUS BIOMARKERS**

J. C. Hood

11:45 **COMBINING MORPHOLOGICAL AND ORGANIC GEOCHEMICAL EVIDENCE FOR THE DETECTION OF FOSSILISED LIFE ON MARS**

Graham Purvis

**Session 4: Applied impact and outreach**

12:00 **EXPANDING WORLDVIEWS: ASTROBIOLOGY, BIG HISTORY, AND THE SOCIAL AND CULTURAL BENEFITS OF THE COSMIC PERSPECTIVE**

I. A. Crawford

12:15 **MISSION TO MARS: DRIVING INTERDISCIPLINARY STEM ENGAGEMENT IN SCHOOLS**

J. Brooke

12:30 **O NA HOKU NO NA KIU O KA LANI: BRIDGING GENOMICS AND CULTURE-BASED SCIENCE EDUCATION THROUGH ASTROBIOLOGY IN HAWAI‘I**

Rebecca Prescott

12:45 **LUNCH AND POSTERS**

**Session 5: Life at the limits**

13:45 **EXCEPTIONAL SERPENTINITE NICKEL CONTENT IN THE UK AND REP. OF IRELAND: POTENTIAL CONSEQUENCES FOR MICROBIAL LIFE**

Eleanor A. Heptinstall

14:00 **WE WILL BIOROCK YOU: EXPERIMENTS ON SPHINGOMONAS DESICCABILIS IN PREPARATION FOR THE INTERNATIONAL SPACE STATION**

Rosa Santomartino

14:15 **HOW DO EXTREMOPHILE BDELLOID ROTIFERS SURVIVE ON LIMITED NUTRIENTS?**

T. McNally

14:30 **TESTING THE POTENTIAL FOR CELL ENTOMBMENT WITHIN LABORATORY-**

**GROWN MARTIAN SALT ANALOGUES**

P. Reekie

14:45 **BACTERIAL ‘TALKING’ IN EXTREME ENVIRONMENTS: A STUDY OF COOPERATIVE BEHAVIOR AMONG MICROBES**

Rebecca Prescott

15:00 **FUNDING OPPORTUNITIES WITH THE UK SPACE AGENCY**

Paul Smith

**NEWCASTLE UNIVERSITY EXTERNAL SPEAKER CODE OF CONDUCT**

**Introduction**

This code of conduct exists to ensure that all speakers taking part in a Newcastle University branded, hosted or run event or activity, on one of the UK or overseas campus or elsewhere, act in accordance with the University’s External Speaker Code of Conduct.

**Context**

Universities operate in a highly complex environment, it is therefore important that any visiting speakers understand the framework and context that governs speaking at a Newcastle University branded event. The University has an obligation to protect Freedom of speech whilst also ensuring that any visiting speaker does not break the law or breach the lawful rights of others. The University has a duty to protect staff, students, members & visitors from hate crimes, harassment, defamation, breach of human rights, unfair treatment, breach of the peace and terrorism whilst they are at a University branded event.

In addition the University must also consider legislation around Health and safety law, public meetings, public processions/assemblies and public order and data-protection which must be considered when allowing an event to go ahead.

**Conduct**

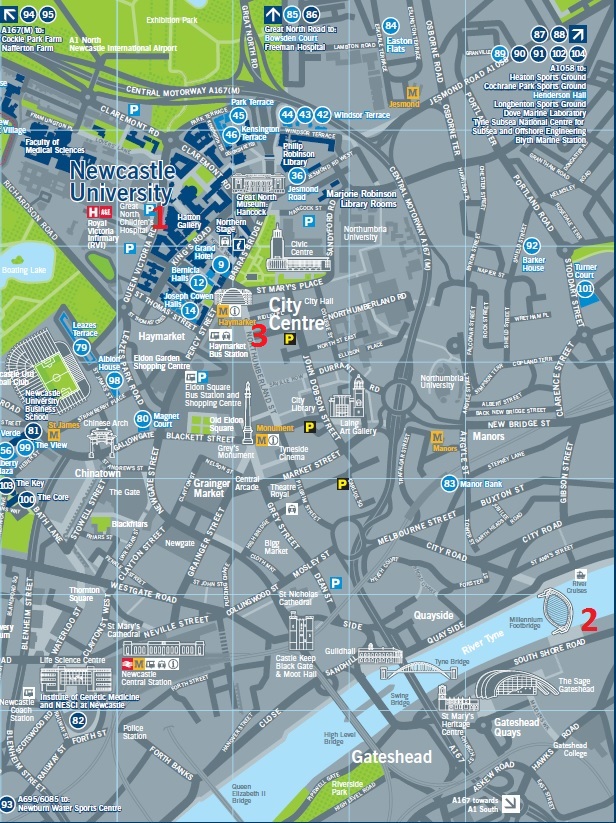
The University expects visiting speakers to act in accordance with the law and not to breach the lawful rights of others.

Set out below are some examples of the University’s expectations. It should be noted that this list is not exhaustive and the University reserves the right to refuse or halt an event at any time if the speaker’s conduct or motives are called into question.

* Speakers must not incite or spread hatred, intolerance, violence or call for the breaking of the law.
* Speakers must be careful not to discriminate against, harass or insult any person or group on the basis of their faith, race, nationality, sex, age, religious beliefs or sexual orientation.
* No speaker should encourage, glorify or promote any acts of terrorism, including any individual, groups or organisations that support such actions.
* Visitors are not permitted to raise or collect funds for any external organisation or cause without express permission of the University.

When visiting the Universities property or campuses Speakers must also

* Comply with the University’s Code of Practice on Freedom of Speech.
* Comply with the University’s policy on External Speakers.
* Comply with the University’s Dignity & Respect Procedure.
* Allow and encourage challenge and debate on opinions and ideas put forward.
* Abide by the University Health & Safety policy.



1. Conference venue, Armstrong building
2. Conference dinner, the Baltic. A yellow bus goes from the Haymarket see link <https://www.newcastlegateshead.com/dbimgs/Quaylink%20Network%20Map(2).pdf>. Alternatively, it is a 30 minute walk at the most.
3. Haymarket



**Addresses**

***Conference Venue:***

Armstrong Building, Newcastle upon Tyne NE1 8QB.

Presentations will take place in **Lecture Theatre 2.98** and posters will be displayed in **room 1.06**.

***Conference Dinner:***

The Baltic, Gateshead Quays, South Shore Road, Gateshead NE8 3BA.

Oral Presentations

Session 1: ExoMars/Mars

8th Astrobiology Society of Britain conference

25th – 26th April 2019

Newcastle University

**(Invited) Mars surface cameras: past, present, and future**

C. Cousins1, M. Gunn2, E. Allender3, and the PanCam Science Team

1 School of Earth and Environmental Sciences, University of St Andrews, UK

2 Department of Physics, Aberystwyth University, UK

Mars has been the focus of robotic space exploration since the 1960s, in which time there have been over 40 missions. Imaging systems have been a core component of all instrument payloads sent to the Martian surface, harnessing a combination of monochrome, color, multispectral, and stereo imagery. These data sets provide the geological context to a mission, which over the decades has included the characterization and spatial mapping of geological units and associated stratigraphy, charting active surface processes such as dust devils and water ice sublimation, and imaging the robotic manipulation of samples via scoops (Viking), drills (Mars Science Laboratory (MSL) Curiosity), and grinders (Mars Exploration Rovers). Through the decades, science context imaging has remained an integral part of increasingly advanced analytical payloads, with continual advances in image analysis techniques. Mars camera design has encompassed major technological shifts, from single photomultiplier tube detectors to megapixel charged‐couple devices, and from multichannel to Bayer filter color imaging. This talk will present the evolution of science context imaging instrumentation resulting from successful surface missions to Mars, and those currently in development for planned future missions, with particular reference to the 2020 ExoMars rover mission and the current focus on the search for microbial biosignatures on Mars.

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Newcastle University

**MULTISCALE AND MULTISPECTRAL ASSESSMENT OF MINERALOGY WITH THE EXOMARS 2020 ROVER REMOTE SENSING PAYLOAD**

E.J. Allender1, C.R. Cousins1, M.D. Gunn2

1 University of St Andrews, School of Earth and Environmental Sciences, Irvine Building, St Andrews, UK, KY16 9AL. (ea63@st-andrews.ac.uk)

2 Aberystwyth University, Department of Physics, Penglais Campus, Aberystwyth, UK, SY23 3BZ.

In 2020, the European Space Agency and Roscosmos will launch the ExoMars rover, with the scientific objective to detect evidence of life within the martian surface via the deployment of a 2 meter drill. The ExoMars Pasteur payload contains several imaging and spectroscopic instruments key to this objective: the Panoramic Camera (PanCam), Infrared Spectrometer for ExoMars (ISEM), and Close-UP Imager (CLUPI). These instruments are able to collect data at a variety of spatial (sub-mm to decimetre) and spectral (3.3 to 120 nm) resolutions across the 440 to 3300 nm wavelength range and collectively will form a picture of the geological and morphological characteristics of the surface terrain surrounding the rover. We deployed emulators of this instrument suite at terrestrial analogue sites that formed in a range of aqueous environments to test their ability to detect and characterise science targets. We find that the emulator suite is able to effectively detect, characterise, and refine the compositions of multiple targets at working distances spanning from 2-18 m. We report on: (i) the detection of hydrothermal alteration minerals including Fe-smectites and gypsum from basaltic substrates, (ii) the detection of late-stage diagenetic gypsum veins embedded in exposures of sedimentary mudstone, (iii) multispectral evidence of grain size differences detected from fossiliferous mudstones, and (iv) approaches to cross-referencing multi-scale and multi-resolution data. These findings aid in the development of data products and analysis toolkits in advance of the ExoMars rover mission, which will in turn facilitate the detection of science targets of astrobiological interest.

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**COMPLEX ORGANICS IN MARTIAN METEORITES**

A. C. O’Brien1, L. J. Hallis2, A. Steele1, L. Daly1 & M. R. Lee1

1School of Geographical and Earth Sciences, University of Glasgow (a.obrien.1@research.gla.ac.uk)

2Geophysical Laboratory, Carnegie Institute of Washington

Small inclusions (< 50 μm) of macromolecular carbon (MMC) have been found in thin section samples from a range of martian meteorites, both in falls and finds. This material consists of polycyclic aromatic hydrocarbons and shows characteristic D (disordered) and G (graphitic) Raman peaks. Current hypotheses for the origin of this material are:

1. It is indigenous to Mars, having been precipitated from the martian mantle,
2. It is exogenous, having been deposited onto the surface by carbonaceous chondrites.

Complex organics have also been found by Curiosity and recent work by Steele et al. (Science Advances, October 2018) has shown that it resembles MMC in martian meteorites. We hope to compare the structure of this meteoritic material to MMC in carbonaceous chondrites to determine whether or not they are possible source of the material. This work will help inform ExoMars mission science, specifically the MOMA (Mars Organic Molecule Analyser) instrument, as well as aid our understanding of the martian carbon cycle.

Carbon-rich regions were detected using confocal Raman spectroscopy at the Carnegie Geophysical Laboratory. Evidence for heterogeneous organic material was found, whereby the G peak centre position varies significantly within individual inclusions. In addition to mature MMC, labile organic material, which matures and forms D and G peaks (ie turns into macromolecular carbon) when the Raman laser was focused on this material for ~45 seconds, was detected.

We then used focused ion beam scanning electron microscopy to extract MMC-rich regions which were then analysed through XANES (X ray analysis near edge structures), a synchrotron technique which allows us to detect individual functional groups.

We are now working on bulk analysis techniques such as metabolomics and GC-MS to gain a greater insight into the structure of martian organics, that also allow detection and characterization of labile material, as well as mature carbon.

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**The daily grind: aeolian abrasion of sedimentary rocks as a mechanism to produce methane in the Martian atmosphere**

E. Safi1, J. Telling1, J. Parnell2, M. Chojnacki3, M. Patel4, J. Realff1, N. J. F. Blamey5, S. Payler6, C. S. Cockell6, L. Davies7, I.M. Boothroyd8, F. Worrall8, J. L. Wadham7

1School of Natural and Environmental Sciences, Newcastle University, NE1 7RU, UK (emmal.safi@newcastle.ac.uk)

2School of Geosciences, University of Aberdeen, AB24 3FX, UK.

3Lunar and Planetary Laboratory, University of Arizona, AZ 85721-0092, US.

4School of Physical Sciences, Open University, MK7 6AA, UK.

5Department of Earth Sciences, University of Western Ontario, ON N6A 3K7, Canada.

6School of Physics and Astronomy, University of Edinburgh, EH9 3FD, UK.

7School of Geographical Sciences, University of Bristol, BS8 1SS, UK.

8Department of Earth Sciences, Durham University, DH1 3LE, UK.

Seasonal changes in methane background levels and methane spikes have been detected in situ a metre above the Martian surface, and larger methane plumes detected via ground based remote sensing, however their origin has not been adequately explained. Proposed methane sources include the UV irradiation of meteoritic-derived organic matter, hydrothermal reactions with olivine, organic breakdown via meteoroid impact, release from gas hydrates, biological production, or the release of methane from fluid inclusions in basalt during aeolian erosion. Here we quantify for the first time the potential importance of aeolian abrasion as a mechanism for releasing trapped methane from within rocks, by coupling estimates of present day surface wind abrasion with the methane contents of a variety of Martian meteorites, analogue terrestrial basalts and analogue terrestrial sedimentary rocks. We demonstrate that the abrasion of basalt under present day Martian rates of aeolian erosion is highly unlikely to produce detectable peaks of methane in the atmosphere. While there is a greater potential for the abrasion of certain sedimentary rocks (evaporites, mudstones) to produce detectable methane spikes, this is only achievable if the abraded rocks have methane contents similar to those of commercial biogenic/thermogenic hydrocarbon deposits on Earth. We therefore conclude that aeolian abrasion is an unlikely source of the methane detected by the Curiosity rover and ground based observations, and that other methane sources are required.

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**Determination of survivability and bio-signature formation using laboratory simulation experiments**

K. Olsson-Francis, M. C. Macey, S.P. Schwenzer, V.K. Pearson and N.K. Ramkissoon

Faculty of Science, Technology, Engineering and Mathematics, The Open University, Walton Hall, Milton Keynes, Buckinghamshire, UK.

There is evidence that water may exist in the sub-surface of Mars in the form of brines [1-4]. The chemistries of these brines will be greatly influenced by the local lithologies [5], which, in turn, would impact microbial growth and bio-signature formation [6]. Determining the potential habitability of the martian sub-surface environment and characterising potential bio-signatures is important for future life detection missions, such as ExoMars.

To evaluate the effect of the sub-surface Mars environment on microbial processes, we have developed a high-pressure flow through environmental simulation chamber. To mimic the chemical environment, simulants were developed based on martian lithologies, e.g., a global composition based on Rocknest [6]. Using thermochemical modelling (CHIM-XPT) the composition of the associated brine chemistries was determined, and defined brines were prepared. For the biotic experiments, a mixed microbial chemolithotrophic community from the Pyefleet mudflats in the Colne estuary (Essex, UK) was used as an analogue community [7]. Batch growth experiments demonstrated that members of the community were able to grow in the Rocknest simulant (1:1 water-to-rock ratio) with 11 μM ammonium acetate (final concertation) and 1 bar H2/CO2 and hence this ratio was used in the simulation experiments.

Flow through experiments were conducted at a rate of 0.15ml min-1 and at a variety of temperatures and pressures e.g., 25oC/1 bar and 10 oC /100 bar. The chemical evolution of the brine was monitored using ICP-OES and ICP-MS and any alteration of the simulant material was investigated using Raman and SEM analyses. Thermochemical modelling of the brine chemistry was used to identify any unique secondary alteration minerals, which were produced by microbial processes. Cell counts and the concentration of ATP were used to monitor microbial growth; whilst molecular analyses, focusing on the 16S rRNA gene (diversity) and functional genes (e.g., for methanogenesis, denitrification, autotrophy, and sulfur-reduction), were carried out with PMA treated cells (selecting for the active members of the community). Both abiotic and biotic experiments were carried out in parallel.

Here, we present our preliminary findings, which identify plausible microbial metabolisms within martian sub-surface brines and associated secondary alteration minerals that can be used for evidence of life.

**References:** [1] Martín-Torres *et al.* (2015) *Nature*, 8, 357-361 [2] Chavrier and Rivera-Valentine (2012) *Geophys. Res. Lett,* 39, L21202 [3] McEwen *et al.* (2011) *Science*, 333, 740-743 [4] Ojha *et al.* (2015) *Nature Geoscience*, 8, 829-832832 [5] Schwenzer *et al*. (2016) *Meteorit. Planet. Sci,* 51, 2175-2202 [6] Görres *et al.* (2013) *FEMS Microbiol.Ecol.* 85, 227–240**.** [6] Ramkissoon, N.K., et al., 2019. PPS. *In review*. [7]Curtis-Harper, E., et al. Microorganisms. 6, E61. DOI:10.3390/microorganisms6030061.

Session 2: Habitability of cold and icy environments

8th Astrobiology Society of Britain conference

25th – 26th April 2019

Newcastle University

**(Invited) Icy Moons – How Enceladus, Europa, and other Icy Worlds Changed Our Idea of Habitability**

R.-S. Taubner

1 Department of Ecogenomics and Systems Biology, University of Vienna, Austria (ruth-sophie.taubner@univie.ac.at)

For centuries, but especially since Giovanni Schiaparelli detected potential “seas” and “continents” on Mars in 1877, the red planet was the most popular place regarding the search for extraterrestrial life in our Solar System. However, the last two decades, e.g. NASA’s Galileo and Cassini missions showed us that looking for potential life far beyond the classical habitable zone is equally important and promising. The main reason for this rethinking was the detection of the subsurface water reservoirs of Europa, Enceladus, and other icy celestial bodies.

Possible metabolic capacities of life forms in these subsurface water reservoirs must be chemotrophic (independent of products of photosynthesis), and would need to be anaerobic (independent of oxygen). In this talk, I will give an overview about the different environmental conditions on these icy worlds. Further, I will discuss which terrestrial organisms might be able to sustain their metabolism under these conditions. I will give a short introduction into the various experimental and computational efforts and finally, I will focus on the most recent studies on the habitability of especially Enceladus and Europa.

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**The Energetic Habitability of Enceladus may be Tenuous**

P. M. Higgins1, C. S. Cockell1

1 UK Centre for Astrobiology, School of Physics and Astronomy, University of Edinburgh, EH9 3FD (p.m.higgins@ed.ac.uk)

Using the energetic approach to habitability, a new general astrobiological model concept has been developed for assessing the energetic and nutrient availability of poorly characterised environments, to predict their potential biological productivity. The model aims to estimate how much biomass an environment could provide were it exposed to life, and how a microbial community might affect the local chemistry. The model has been used to examine the potential habitability of the Enceladean subsurface ocean using the limited data and models available in the literature for this environment. By iterating through microbial parameters such as maintenance and environmental parameters such as temperature, pressure, pH, and P availability, we predict the final biomass amounts Enceladus’ ocean could sustain across some of its uncertainties and find that it may not be as energetically favourable a candidate for methanogens as previously thought. In the most thermodynamically favourable scenario, pH 8.5, a maximum possible cell density of approximately 104 -105 cells cm-3 and minimum of 0 (e.g. no growth at all) was predicted. Assuming this scenario, and a global temperature of about 273 K, the total biomass in the ocean could reach approximately 1010 kg. This represents a very slim slice of the potential environment, however, and in the majority of cases there is simply not enough energy for the simulated methanogens to grow against realistic maintenance costs. Predictions drop off sharply with pH, for example.

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**FREEZING-INDUCED FRACTIONATION IN SIMULATED ENCELADUS OCEAN BRINES**

M. G. Fox-Powell & Claire R. Cousins

Centre for Exoplanet Science, School of Earth and Environmental Sciences, University of St Andrews, St Andrews, UK (mgfp@st-andrews.ac.uk)

The Saturnian moon Enceladus exhibits large cryovolcanic plumes sourced from a subsurface liquid water reservoir that contain evidence of hydrothermal activity and indigenous organics. Because of these factors, Enceladus has come to be viewed as one of the most promising bodies in the solar system to harbor extraterrestrial life. Particles in the plumes have been observed to contain salts, silica and macromolecular organics. If a microbial biosphere is currently active in the subsurface of Enceladus, it is likely that biomass is also entrained in these particles, and thus accessible to spacecraft. However, our understanding of the mechanisms by which material becomes captured by cryovolcanic processes is rudimentary. Constraints on ocean composition provided by the *Cassini* mission now permit detailed experiments exploring pathways of formation for Enceladus cryo-salts. We investigated freezing-induced mineral fractionation in simulated Enceladus ocean fluids spanning a range of pH estimates, under both flash-freezing (at approx. 80 K) and gradual-freezing (at approx. 240 K) regimes.

We show that mineral phase partitioning occurs at both freezing rates, and that ice crystal templating of cryo-precipitated minerals (including Na-chlorides, carbonates and silica) ensues even when fluids are flash-frozen. Crystal habits and phase partitioning at the sub-10 micron scale are diagnostic of freezing rate, whilst mineral abundances record parent fluid pH. Current models based on equilibrium thermodynamics do not fully predict mineral assemblages, particularly in lower pH fluids, where freezing kinetics control mineral formation. Our results demonstrate that both the composition and physical partitioning of cryogenic salts in ice are key to understanding their origins, thus their potential for hosting biosignatures and probing the habitability of Enceladus’s ocean. In light of these findings, we urge the development of future missions capable of capturing plume particles whole and performing microscopic analysis *in situ*, or, preferably, returning them to Earth.

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**Wet-Based Glaciation on Mars and its Astrobiological Implications**

F. E. G. Butcher1, N. S. Arnold2,M. R. Balme1, C. Gallagher3,4, S. J. Conway5, R. D. Storrar6, S. R. Lewis1, A. Hagermann7

1 School of Physical Sciences, The Open University, UK (frances.butcher@open.ac.uk)

2 Scott Polar Research Institute, University of Cambridge, UK

3 UCD School of Geography, University College Dublin, Ireland

4 UCD Earth Institute, University College Dublin, Ireland

5 CNRS, UMR6122, Laboratoire de Planétologie et Géodynamique, Université de Nantes, France

6 Department of the Natural and Built Environment, Sheffield Hallam University, UK

7 Biological and Environmental Sciences, University of Stirling, UK

The recent discovery of radar evidence for a present-day lake beneath Mars’ south polar ice cap [1] sparked significant interest in the potential astrobiological implications of wet-based glaciation on Mars. In this presentation, we compare the possible drivers of subglacial lake formation beneath Mars’ south polar cap [2] with those of geologically-recent wet-based glaciation in Mars’ mid-latitude regions [e.g., 3–4], and discuss their implications for the habitability and exploration of subglacial environments on Mars. Previously, we identified evidence for at least two occurrences of geologically-recent (110–150 Ma) basal melting of existing glaciers in Mars’ northern mid-latitudes, in the form of eskers associated with those glaciers [3–4]. Eskers are sinuous ridge landforms comprising sediments deposited by glacial meltwater flowing in ice-walled tunnels at the beds of glaciers. We performed numerical modelling experiments simulating heat transfer through glacial ice, which demonstrate that above-average geothermal heat flux, possibly with an additional component of viscous strain heating produced by flow of glacial ice, was required for rare, localised occurrences of wet-based glaciation under extremely cold and hyperarid Amazonian climate conditions [4]. In agreement with our findings, recent modelling experiments found that geothermal heat from subsurface magmatic activity would also be required to explain the existence of a lake beneath Mars south polar cap in the present day [2]. We will compare the relative merits of environments of present-day polar and geologically-recent mid-latitude wet-based glaciation on Mars for habitability and future life-searching missions to Mars.

[1] Orosei, R. et al. 2018. *Science* 361(6401), 490–493

[2] Sori, M. M. and Bramson, A. M. 2019. *Geophys. Res. Lett. 46(3),* 1222–1231

[3] Gallagher, C. and Balme M. R. 2015. *Earth Planet. Sci. Lett. 431*, 96–109

[4] Butcher, F. E. G. et al. 2017. *JGR: Planets 122(12),* 2445–2468.

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**Crushing as an abiotic nutrient and energy source in a subglacial lake environment.**

B. Gill Olivas1, J. Telling2, M. Skidmore3, J. Priscu3, A. Michaud4, M. Tranter1

1 Bristol Glaciology Centre, University of Bristol, Bristol, UK. (b.gillolivas@bristol.ac.uk)

2 School of Natural and Environmental Sciences, Newcastle University, Newcastle upon Tyne, UK.

3 Department of Earth Sciences, Montana State University, Bozeman, MT, United States.

4 Center for Geomicrobiology, Department of Bioscience, Aarhus University, Aarhus C, DK.

Recent clean access to two subglacial lakes, Whillans Subglacial Lake (WSL) and Mercer Subglacial Lake (MSL), has proven unequivocally that microbes live in these environments. However, there is some uncertainty regarding the energy sources which sustain these microbial ecosystems. Sources of energy to these environments are limited to those found in-situ due to the isolated nature of sub-ice sheet environments, where direct access to the atmosphere and in-washed organic matter and oxidising agents does not occur. This study uses sediments from WSL to assess the possible energy contributions from thermo-mechanochemical reactions to this subglacial ecosystem. Samples were crushed under an anoxic N2 atmosphere using a ball mill, and then transferred into serum bottles under anoxic conditions. They were wetted and the headspace gas was subsequently sampled and analysed during a 40 day incubation. Results showed substantial concentrations of hydrogen were produced, as well as some methane production. Both these gases are likely to be significant energy sources to subglacial environments, particularly in WSL, where methanotrophic microbes have been found. Crushing was also shown to increase the concentrations of certain solutes, such as acetate and NH4+, providing these environments with labile sources of both carbon and nitrogen.Further, crushed samples generated significant concentrations of hydrogen peroxide on contact with water, as well as significant amounts of Si radicals, suggesting comminution of these sediments can potentially unlock a wide range of redox species, which in turn may promote a spectrum of REDOX reactions within glacially eroded sediment under ice. We contend that glacial comminution provides a sustainable source of nutrients and energy for these microbiomes.

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**Sensing technologies for measuring biogeochemical activity and returning data from icy environments**

E. A. Bagshaw1, J. L. Wadham2, M. Prior-Jones1, S. Burrow2, M. Tranter2, A. Beaton3, J. Hawkings2, 4, N. Karlsson5, L. B. Lok6

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Icy environments on Earth host active microbial populations in zones that have periodic access to liquid meltwater. Detection and quantification of this biological activity is a significant biogeochemical and technological challenge, since meltwaters are characterized by inaccessibility, low concentrations, low temperatures and freeze-thaw cycles. Commercially-available and bespoke sensing technologies can perform effectively with suitable adaptations, and the chemical signature of microbial activity may be detected even in sub-zero conditions. The next challenge is to return the captured biogeochemical data from remote icy habitats. In cases where meltwater is sealed beneath an icy cap, a sub-ice sensor that can return data through the ice without requiring a physical connection is advantageous. In this talk, chemical sensors that perform effectively in extreme cold climates will be reviewed, and a sub-ice ‘Cryoegg’ sensor that can wirelessly return data from subglacial environments will be introduced. Field tests in Greenland and Antarctica demonstrate how these technologies could be utilized to explore icy extra-terrestrial bodies.

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**The Red Dots Search for nearby exoplanets: Is Barnard’s Star b the closest extra-solar habitat?**

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Within 10 parsecs of the Sun there are 283 known, intrinisically dim M dwarfs, and 95 known (brighter) stars of all other types. M dwarf stars preferentially host low mass planets. The Red Dots collaboration is conducting a comprehensive search for planets orbiting the very closest M dwarf stars using the radial velocity technique, which measures the orbital Doppler shift in the starlight. The Red Dots 2016 discovery of Proxima b orbiting our nearest stellar neighbour was followed in November 2018 with the discovery of Barnard’s Star b. The latter is a cold super-Earth planet, with a minimum mass 3.2 Earth Masses in a 233 day orbit around the nearest single star to the Sun. Because M dwarf stars are much less luminous than the Sun, this planet orbits near the snow-line of the star where water and other molecules form ices. In the absence of an atmosphere the temperature of Barnard’s Star b would be -150° C, so it is unlikely to host liquid water on its surface. This temperature is similar to that of Jupiter’s moon Europa, the sub-surface ocean of which may be a potential habitat for life. Barnard’s Star b may offer similar niches. Red Dots’ search for planets orbiting our nearest stellar neighbours continues. This contribution will give an overview of our nearest exoplanetary neighbours, the prospects for exoplanetary astrobiology, and will offer a preliminary overview of the exoplanetary habitat content of the Galaxy.

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**(Invited) Ellsworth, WISSARD and SALSA – Exploration of antarctic Subglacial Lakes**

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The subglacial lakes beneath Antarctica are host to diverse microbial communities, and may hold valuable paleo-climatic records. This talk covers three fieldwork seasons with the NERC SLE (Subglacial Lake Ellsworth) Project, the NSF WISSARD (Whillans Ice Stream) project, and conclude with the successful recovery of water, sediment and a host of organisms from Mercer Subglacial Lake with the SALSA Project. The importance of experienced drillers and field teams, road-tested equipment and a spectrum of sampling equipment, from simple to complex designs and intents, with be stressed. These projects are expensive to set up and run, and it is sensible to minimise expectations so that the maximum science can be achieved from the likely minimal return of sample. The field and project teams should also be chosen with care, so that friction associated with the competing demands of individual projects and ambitions is minimised when participants are tired (and cold), during periods of compromised hole access which are almost a routine part of these types of projects.

What is beyond doubt is that a variety of microorganisms thrive in the deep, dark and cold nether-regions of ice sheet beds, and that icy environments on other heavenly bodies should be targets in the search for extra-terrestrial life.

Session 3: Methods for in situ and remote sensing of biosignatures and habitability

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**(Invited) Sub-Glacial Moistness on Mars**

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The mid-latitudes of Mars are host to a wide variety of ice-related landforms, including those that resemble debris covered glaciers on Earth – collectively known as Viscous Flow Features (VFF). It is widely accepted that these glaciers are perennially frozen to their beds and never melt – so called “cold based glaciers”. Using detailed topographic analysis we have found evidence that sometime in the last 0.5-10 Ma there was a widespread melting event that allowed some of these glaciers to move like wet-based glaciers on Earth. Our evidence comes in the form of increased erosion of the bedrock exposed in crater walls. This increase in erosion is only observed where moraine-like ridges and “pasted-on terrain” (which we interpret as icy till) are also present. We hypothesise that small amounts of liquid water near the beds of these glaciers allowed them to erode their beds and also deform the subglacial sediments to form moraines. With current data it is not possible to estimate the duration of the “moist” event, but we have been able to estimate that the moist conditions prevailed somewhere between 0.5 and 10 Ma. Although we only made measurements on a handful of geographically isolated examples the same configuration of landforms occurs across the mid-latitudes leading us to conclude that this event was a near-global climate triggered phenomenon, possibly assisted by volcanic gas emissions. Similar events could have occurred earlier in Mars’ history, and work is underway to investigate this possibility.

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**CONSTRAINING THE EFFECTS OF STELLAR FLARES ON EXOPLANET HABITABILITY WITH NGTS**

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Stellar flares are explosive phenomena which can subject exoplanets to intense levels of UV and X-ray irradiation, along with showers of charged particles. High energy flares can degrade atmospheric ozone, alter atmospheric spectra and possibly cause biological damage to surface organisms. This may be a critical issue for planets around M dwarfs (e.g. TRAPPIST 1, Proxima Cen b), which reside at close proximity to the host star. However, flares may also be required to kick start prebiotic chemistry in these systems, due to the lack of quiescent UV irradiation from these host stars. Understanding the exact balance of these effects requires a detailed understanding of the occurrence rates and maximum energies of stellar flares in M and L star systems. We present stellar flares detected with the Next Generation Transit Survey (NGTS), identifying hundreds of flare events from the reddest stars. In this talk we will show how we have used the 13 second cadence, full frame image NGTS observations to measure the occurrence rates of both individual stars and bulk samples of stars as a function of age. Along with this we will also report how the maximum flare energy changes down to stars equivalent to TRAPPIST-1, along with reporting the first detection of a flare from a star below 2000K (L2.5 spectral type). Finally, we will detail how these results can be used to inform future studies of exoplanet habitability.

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**PYROLYSIS OF FATTY ACIDS IN THE PRESENCE OF IRON OXIDES: IMPLICATIONS FOR LIFE DETECTION MISSIONS TO MARS**

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The continuing search for life on Mars by current (Mars Sample Laboratory/Curiosity) and imminent (ExoMars) missions depends on the positive detection of biologically relevant organic molecules in Martian surface and near surface sediments. Iron oxides are ubiquitous in the Martian regolith and are known to be associated with both the deposition and preservation of organic matter in terrestrial environments. In aqueous environments on Earth, almost a quarter of organic carbon in sediments have been found to be directly bound to reactive iron phases and this association promotes preservation of organic carbon over geological timescales; the ‘rusty sink’ effect. Many of these terrestrial, iron-rich settings are analogous to environments present on ancient Mars, hence, iron-oxide rich sediments are considered to be potential targets for future life-detection missions. Current protocols (also planned for use on ExoMars) use thermal extraction processes to transfer organic matter to gas chromatograph/mass spectrometry detectors and so it is necessary to explore how iron oxide – organic matter mixtures evolve during this process. We have thermally decomposed iron oxides simultaneously with octadecenoic acid and analysed the products via pyrolysis-Gas Chromatography – Mass Spectrometry. We found that the thermally driven dehydration, reduction and recrystallization of iron oxides had transformative effects on adsorbed fatty acids. Overall detectability of products was greatly reduced, there was a decreased molecular diversity, decreased number of double bonds and increased aromatisation. The severity of this effect increased through haematite, goethite, ferrihydrite as reduction potential of the iron oxide, and free radical formation, increased. When selecting life detection targets on Mars, localities with decreased ferrihydrite abundance must therefore be targeted and it can be expected that fatty acids, or similar biomarker molecules, having been subjected to enhanced polymerisation, aromatization and breakdown will appear, to thermal decomposition analysis methods, similar to mature hydrocarbons.

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**Organic records of life on Mars: The role of iron, burial and kinetics**

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Past life on Mars would have left behind fossilized microbial organic remains – these biosignatures must have survived over three billion years in Martian rocks, and must have been shielded from the deleterious effects of the harsh radiation flux at the Martian surface [1,2]. One mechanism that promotes such preservation is burial, which raises questions about how organic biomarkers are influenced by the post-burial effects of diagenesis over long timescales. Kinetic modelling presents an opportunity by which a wide variety of geochemical data can be interpreted and extrapolated over geological time.

Hydrous pyrolysis is a well-known laboratory technique conventionally used to artificially mature organic matter-rich samples in the laboratory and to simulate the effects of diagenesis on biomarkers, alongside any promoted organic-mineral reactions [3,4]. This study investigated the kinetics of organic degradation in an acidic, iron- and sulfur-rich stream, a good geochemical analogue for the late Noachian and early Hesperian Mars [5].

Natural mixtures of acidic sulfur stream sediments and their associated microbial populations and remains were subjected to hydrous pyrolysis. The experiments and subsequent kinetic modelling indicated that low carbon contents, high water-to-rock ratios, and the presence of clay minerals combine to provide unfavourable conditions for organic preservation over the billions of years necessary to produce present day organic records of late Noachian and early Hesperian life on Mars. Paradoxically, these conditions are markers of habitable environments favoured by microbial communities.

These results suggest that targeting deposits that reflect habitable conditions without considering the effects of geological storage over billions of years would be a dangerous approach; conditions necessary for both the production of biomass and the long-term preservation of Martian organic matter must be present for successful life detection.

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**Detectability of biosignatures in a low-biomass simulation of martian sediments**

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Some of the most promising potential sampling sites for astrobiology are the numerous sedimentary areas on Mars such as those explored by the Mars Science Laboratory (MSL). As sedimentary systems are known to preserve biosignatures well on Earth, the remains of martian sedimentary systems are an attractive target for exploration (Hays et al., 2017). However, we found that the low biomass capable of being sustained a simulated martian sedimentary environment presents challenges for the detection of biosignatures.

We used the Y-Mars analogue (Stevens et al., 2018), which simulates a martian mudstone, to investigate the detectability of biosignatures in martian sedimentary environments. The material was inoculated with a relevant microbial community and cultured over several months. We also prepared abiotic controls and samples with a single known species (Bacillus subtilis). We pressed the different types of samples into pellets and then used a variety of biosignature detection techniques to test what was detectable in our samples.

No biological signatures were apparent in bulk mass-spectrometric analysis in either carbon, nitrogen or sulfur abundance, or in the isotopic fractionation of carbon or sulfur in the samples. Higher resolution Laser-ablation Ionisation Mass Spectrometry (LIMS) was able to measure a consistent signature at micrometer scales in biological samples but not abiotic controls. Raman maps of inoculated samples showed consistent micrometer scale structures with high response of particular Raman peaks in biologically relevant areas of their spectra, suggesting imaging of individual cells. Similar maps were recovered using FTIR spectroscopy.

The analogue material contains a number of minerals that can obscure or interfere with biological signatures. Plagioclase has a number of Raman peaks close to Bacillus subtilis, making those peaks ambiguous. In mixed, unknown communities, it is difficult to identify known peaks to look for, meaning any putative biological feature is also ambiguous.

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**Nano-Imaging + Nano-Chemistry = Unambiguous Biomarkers**

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Detecting and identifying complex organic molecules in samples is an important problem in astrobiology, particularly in determining if extra-terrestrial samples contain biosignatures indicative of life.

We present a suite of analytical instrumentation available at Newcastle University which has been combined to provide insight into a range of biological and geological samples. This includes results from a Zeiss ORION NanoFab Helium Ion Microscope (HIM) fitted with a magnetic sector analyser to allow nanoscale chemical information to be gathered using secondary ion mass spectrometry (SIMS) correlatively with secondary electron images [1]. The HIM can achieve lateral resolution of better than 0.5nm when imaging with helium, while SIMS data can be gathered with resolution as low as 10nm, representing the highest spatial resolution SIMS instrument in the UK, and one of only three such instruments in the world.

Time of Flight SIMS (ToF-SIMS) has the advantage of parallel detection of all secondary ions in a single measurement, with little damage done to the sample, making the technique particularly suitable for analysis of small astrobiological samples. Results are shown from our Ionoptika J105 SIMS instrument, on which an Ar gas cluster ion beam (GCIB) has been used to detect high molecular-weight organic material in tardigrade samples (*Hypsibius dujardini*), and telluric basalts which serve as an analog for extra-terrestrial geological samples [2].

Work will also be presented on improving mass resolution in SIMS, with the aim of being able to unambiguously identify specific surface chemistry through the coupling of an orbital ion trap mass analyser with SIMS [3].

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**COMBINING MORPHOLOGICAL AND ORGANIC GEOCHEMICAL EVIDENCE FOR THE DETECTION OF FOSSILISED LIFE ON MARS**

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The procedures for detecting fossils on Mars can be derived from the methods that are already used in telluric paleobiology (Cady *et al*., 2003). In this approach, regions that are geologically conducive to the formation of fossils, are visually located, and then these sites can be inspected for morphological features that have sizes, shapes and distribution that might imply fossilised biology (Cady and Noffke, 2009; Westall *et al*., 2015). Morphological evidence of microfossils on its own, is not a completely reliable biosignature (García Ruiz *et al*., 2002). However, evidence of biological activity may be implanted within the molecular and isotopic composition of organic compounds. This can also serve as a biosignature (Summons *et al*., 2008) and combining both morphological with organo-geochemical evidence could strengthen any argument that a given geological feature could be associated of biological activity.

As a proof of concept, the distribution of the organic material that is associated with distinctive microtubules in the glassy volcaniclastic shards within tuff, which have been suggested to be putative ichnofossils (Banergee and Muehlenbachs, 2003), were analysed by us, using the Ionoptika J105 time of flight secondary ion mass spectrometer (ToF-SIMS), to detect and map the distribution of the higher molecular weight organic materials that are of interest as molecular biosignatures, in the tuff sample. This indicated that nitrogenous organic material occurred in regions of the sample that were rich in microtubule textures and in the surrounding microfractures (Sano *et al*., 2016). These results demonstrated that that the J105 ToF-SIMS combined with XPS and GC/MS analysis is able to match geomorphological features with their organic and inorganic composition at the µm scale, which may be a useful approach for the identification of fossilised life on Mars.

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Session 4: Applied impact and outreach

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**Expanding Worldviews: Astrobiology, Big History, and the Social and Cultural Benefits of the Cosmic Perspective**

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Astrobiology is usually defined as the study of the origin, evolution, distribution, and future of life in the universe. It is inherently interdisciplinary, integrating results from multiple fields of knowledge, and in this respect has strong synergies with the emerging discipline of 'big history'. I will argue that astrobiology and big history are both acting to widen human perspectives in intellectually and socially beneficial directions. These include:

1. Breaking down artificial barriers between scientific disciplines after a long period of intense specialisation, thereby helping to produce a generation of better educated and more broad-minded scientists;
2. Helping (at least partially) to break down barriers between the sciences and the humanities;
3. Enhancing public awareness of cosmic and evolutionary perspectives.

From the point of view of wider society, raising awareness of cosmic and evolutionary perspectives is by far the most important of these benefits. I will argue that, once grasped, these perspectives imply two important socio-political corollaries:

* That maintaining the continued habitability of the Earth is essential, not just for the sake of our own species, or indeed other extant species, but because (unless or until astrobiology itself teaches us otherwise) it may be that the entire future of life in the universe will depend upon it;
* That, as a single intelligent technological species that has become dominant on a small planet of possibly unique importance to the future of life in the universe, humanity has a responsibility to develop international social and political institutions appropriate to managing the cosmic situation in which we find ourselves.

It is important to note that the social and intellectual consequences and implications of astrobiology and big history are already, and will increasingly prove to be, beneficial to society even if extraterrestrial life is never discovered!

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**MISSION TO MARS: DRIVING INTERDISCIPLINARY STEM ENGAGEMENT IN SCHOOLS**

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Space exploration is an ideal conduit for enhancing STEM education, as it incorporates aspects of a wide range of subjects and provides an excellent demonstration of the importance of cross-disciplinary approaches in the real world. Furthermore, the involved nature of planning and executing a (mock) mission is a useful platform to encourage teamwork while allowing individuals to focus on personal skill development.

Here we present the Mission to Mars! Education package, developed by GeoBus (an Earth Science Education project run by the School of Earth and Environmental Sciences at the University of St Andrews) as part of a UK Space Agency education and outreach grant, that provides a series of learning resources suitable for delivery in schools and at public outreach events . Thus far, the resources have been delivered to over 2,600 individuals in a range of settings (including science festivals, workshops in schools, teacher CPD events and prison learning centres).

The learning resources have been specifically developed in order to support practitioners in delivering materials, in order to facilitate knowledge transfer from research to education. Experiments and materials used are designed to be readily obtainable at minimal cost, and lesson plans and descriptions are freely available through the GeoBus website. The resources are also modular and easily adaptable for use in range of settings and we aim to demonstrate ways in which they can be developed and incorporated in to education, communication and outreach events and activities by anyone interested in doing do.

1 Cousins, C., & Brooke, J. (2018). Mars rovers drive STEM teaching in schools. Astronomy & Geophysics, 59(1), 1.34-1.35.

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**O NA HOKU NO NA KIU O KA LANI: BRIDGING GENOMICS AND CULTURE-BASED SCIENCE EDUCATION THROUGH ASTROBIOLOGY IN HAWAI‘I**

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Culture-based science education provides a framework that integrates diverse educational strategies. The goal is to develop the potential of every student (**haumāna**), through the mutual exchange of cultural and academic knowledge (content – **a`o**), including cultural values. Knowledge becomes meaningful by placing it in a context with which the student identiﬁes (context - **honua**), including family, community, island, and other cultural aspects. Using this framework, we are developing teacher training programs and classroom exercises that bridge genomics, astrobiology, and Hawaiian culture- based science education. We hope to improve interest in STEM professions among groups underrepresented in STEM, help provide a cultural identity in public school science education, and provide teachers the support and training needed to teach genomics and bioinformatics. Astrobiology, a subject that is easily linked with Hawaiian culture, provides an intriguing pladorm for students, teachers, and parents to discuss both traditional and modern understandings of biology and the Universe. Thus far, we have framed this program around microbes from Hawaiian lava caves on the island of Hawai’i, an environment thought to be similar to lava caves on Mars. This provides an opportunity to discuss these sacred sites in Hawaiian culture, as well as related information we have learned through modern technology about microbes that live in these caves. We have hosted two teacher training workshops, which provide hands-on training that genomics and bioinformatics using the EDGE pladorm*.* EDGE is a free and user-friendly pladorm for a variety of bioinformatic pipelines that can utilize Illumina and Nanopore data. Through funding and expertise provided by ‘Iolani school, we are developing an outreach education training program (ʻĀina-Informatics) that provides teachers with all the necessary tools to examine and discuss the microbiology and cultural value of Hawaiian lava caves, and why these unique environments are relevant to astrobiology.

Session 5: Life at the limits

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**EXCEPTIONAL SERPENTINITE NICKEL CONTENT IN THE UK AND REP. OF IRELAND: POTENTIAL CONSEQUENCES FOR MICROBIAL LIFE**

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Nickel-bearing compounds, particularly sulphurous compounds such as millerite (NiS), are important sources of sulphur for microbial redox processes. Serpentinites typically have anomalous nickel contents of over 1-2 orders of magnitude greater than the crustal average of ~75 ppm. This study will consider if the nickel-bearing Dooros serpentinites, Co. Galway has an exceptional nickel content compared to other serpentinites in Scotland and the Rep. of Ireland, with an association with the Dalradian super group and the Grampian event. This will allow consideration of the potential consequences of a nickel anomaly on microbial life, where nickel toxicity is reduced in magnesium-rich, alkaline and high hydrostatic pressure environments, potentially greatly suiting mid ocean ridge or subduction ridge microbial environments. We examine the serpentinite mineralogy through ESD and EBSD scanning electron microscopy, LA-ICP-MS and whole rock analysis. This will allow us to characterise the Dooros geochemistry and nickel-bearing minerals in greater detail to understand what this indicates about the serpentinite paragenesis. Nickel sulphide occurs sporadically as small euhedral <100µm crystals and within larger 100-400µm euhedral to subhedral crystal aggregates with iron oxide or nickeline (NiAs). The Dooros serpentinite has nickel contents comparable to the Portsoy serpentinite, NE Scotland and to a lesser extent the Balmaha serpentinite in Central Scotland. The Dooros serpentinite nickel content established by whole rock analysis is typically in line with serpentinites with nickel-rich dunite parent rocks, including the potentially related Dawros ultramafic intrusion. Comparable nickel and sulphur contents in nickel tolerant microbial environments at upper mantle/sea floor contacts indicates that while the Dooros serpentinite nickel content is above the crustal mean, it does not appear to be toxic for a nickel tolerant, deep sea biosphere. Indications of serpentinites supporting less vegetation and very low nickel contents required for the inhibition of microbial growth indicates far lower subsurface biosphere nickel tolerance.

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**WE WILL BIOROCK YOU: EXPERIMENTS ON SPHINGOMONAS DESICCABILIS IN PREPARATION FOR THE INTERNATIONAL SPACE STATION**

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The BioRock experiment has the aim to study biofilm formation and bioleaching on the International Space Station (ISS) to advance our understanding of microbial behavior and the use of microbes in applications such as biomining and waste recycling in space.

Microgravity has been demonstrated to induce several morphologic and phenotypic changes in bacterial cultures. Experiments conducted on the ISS showed that microgravity had an effect on biofilm formation and altered biofilm architecture.

In this work we describe the results of the experiments on the bacterium *Sphingomonas* *desiccabilis* in preparation for the ESA BioRock experiment (ILSRA-2009-0952). This project has the aimto investigate how bacteria interact with basalt rock in microgravity, simulated Mars (0.38 g) and Earth (1 g) gravities. The experiment will be performed on the ISS in 2019 and will take advantage of the BMR hardware (Kayser Italia), specifically designed for this purpose. Two main features of bacterial growth will be assessed: biofilm formation and bioleaching.

Biofilms are an intricate matrix of biopolymers produced by bacterial cells after attachment to several surfaces (biotic or abiotic). During the BioRock experiment, biofilm formed by the bacteria on a basalt rock surface after the flight will be analyzed by several microscopic techniques. The results obtained from our tests at 1 g showed interesting features of biofilm formation on basalt slides, with a preference for formation around the edges of rock’s cavities.

Moreover, data from ICP-MS showed leaching of metals from the basaltic rock by *S. desiccabilis*, and in particular some rare earth metals.

The BioRock experiment will give important information regarding the changing occurring on bacterial bioleaching capacity and biofilm formation in different gravities.

Moreover, the preliminary analysis in preparation to the flight could provide useful data on what will be the main features we expect to be modified when gravity changes.

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**How do extremophile bdelloid rotifers survive on limited nutrients?**

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Bdelloid rotifers are microscopic animals able to withstand extremes of freezing, arid, anoxic and radioactive conditions. They can survive without water or nutrients in a desiccated state for up to nine years. They are also extremely resistant to starvation and pilot studies into the limits of their tolerance suggest laboratory cultures of rotifers can thrive and even reproduce in the absence of added organic nutrients in a minimal ionic solution. How they can do this is currently a mystery. A clue to this puzzle is the fact that they are unable to grow or reproduce in media that is completely free of bacteria. This suggests a bdelloid rotifer’s associated microbial community may be able to use inorganic ions to generate energy, fix carbon or both, producing the biochemical complexity to support animal life.

By probing the microbial communities associated with *A. ricciae*, the laboratory model for bdelloid rotifers, we will characterise that microbial community and its metabolites with metabarcoding, reverse genetics techniques, NMR and SEM imaging. This will be done with an eye towards useful or novel biomolecules that could provide an understanding on how metabolism can operate elsewhere in the solar system where freezing, arid, anoxic and radioactive conditions are the norm.

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**TESTING THE POTENTIAL FOR CELL ENTOMBMENT WITHIN LABORATORY-GROWN MARTIAN SALT ANALOGUES**

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On Earth, microorganism cells can get entombed within solid salt species during crystal growth, and can therefore be protected from biodegradation for hundreds of millions of years, due to a preservation mode analogous to insects trapped in amber. Various salt species in both solid and liquid state have been identified on the surface of Mars, and so it is essential for us to investigate different salts for their potential to preserve biological cells. For this study, a series of qualitative laboratory experiments have been carried out with the main aim of determining which salt species are favorable for entombing cells within mineral fluid inclusions during crystal growth. Salt species with desirable properties should therefore be prime targets for investigating habitability on Mars, both past and present-day. We have desiccated supersaturated cell-containing hydrous brines, individually composed of NaCl, MgSO4, Mg(ClO4)2, FeSO4, CaSO4, with prokaryotic cells that are halophilic belonging to genera *Chroococcidiopsis*, *Marinococcus* and *Halobacterium*. Our experiments involved desiccation from evaporation under both Earth and Mars-like surface pressures. Our results have demonstrated that NaCl has an extraordinary potential for entombing large numbers of cells during crystal growth, far greater than any other mineral contender, while also providing long-term visual access for observation and analysis by light-microscopy. We have also observed the entombment of cells within MgSO4 during exposure to 6 mbar pressure and -40°C temperature, owing to a phenomenon that sees MgSO4 crust formation, and so is capable of protecting underlying brine and cells from low-pressure instability. We therefore propose that we concentrate our efforts for detecting and investigating Martian NaCl and MgSO4, as they may lead us to extraterrestrial life.

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**BACTERIAL ‘TALKING’ IN EXTREME ENVIRONMENTS: A STUDY OF COOPERATIVE BEHAVIOUR AMONG MICROBES**

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Quorum sensing (QS) is a type of microbial intercellular signaling and is a central communication mechanism found in Bacteria and Archaea that coordinates activities among microbes through community-level gene expression and regulation. It is common in structured microbial communities that colonize surfaces, like biofilms and microbial mats, and evolved early in microbial life on Earth. However, QS has not been investigated in extreme environments in detail nor in an astrobiological context. The best studied form of QS uses *N*-acyl homoserine lactones (AHLs) as the molecule of communication, with genes that produce AHLs (*Lux*I homologs), and AHL receptor proteins that are transcriptional regulators (*Lux*R homologs). Using bioinformatic tools, we are determining 1) the presence of QS genes, and 2) if differences exist in QS systems between particular types of extreme environments. This study is a first step to understanding the importance of cooperative behavior to survival in extreme environments, particularly over geological time spans. To date, we have detected putative *Lux*I and *Lux*R homolog gene/protein families responsible for the production and detection of AHL signaling molecules and transcriptional regulation of QS-controlled genes. In all of the extreme environment samples investigated, the highest number of putative *Lux*I/R genes were from Hawaiian lava caves (50 *Lux*I, 921 *Lux*R), and fewest *Lux*I/R genes in Boulby Salt Mine (2 *Lux*I, 7 *Lux*R), a subsurface hypersaline community dominated by Archaea. These include putative *Lux*R solos, genes that have no corresponding *Lux*I gene near them in the genome, but which are capable of binding with AHL molecules to regulate transcription. Our results suggest that QS is common in many extreme environments, but not all, and may be a sign of differences in the evolutionary history of microorganisms on Earth, or in our current knowledge of these systems.

Poster presentations

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**P.01 THE SEARCH FOR GASEOUS BIOSIGNATURES IN SULPHATE-RICH LAKES AND ITS APPLICATION FOR MARS EXPLORATION**

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The NOMAD instrument (a UV/visible/IR spectrometer on board the ExoMars Trace Gas Orbiter mission Mars) is seeking the presence of atmospheric trace gases (e.g. methane, ethane) at concentrations of up to parts per trillion. Methane-to-ethane ratios over 1000 indicated biogenic gas production, whereas ratios of less than 50 suggests a thermogenic source. Water is a requisite for life on Mars and growing evidence shows that brines could have existed or still exist. The compositions of Martian brines have been inferred from the observations of evaporitic deposits, dominated by magnesium sulphate, both for past and present sub-surface aqueous environments on Mars. However, whereas our knowledge of life within chloride brines is extensive, comparatively there have been few studies in sulphate brines. To address these issues, we will use a combination of *in situ* analogue site study (sulphate-rich lakes in the interior of British Columbia) and laboratory simulations. Cultivation-independent analysis of the bacterial community in lake sediments showed that they were dominated by halophiles (*Alkalibacterium*, *Salengetibacter*), a high abundance of sulphate-reducing bacteria (*Desulfofustis*, *Desulforomonas*, *Dethiobacter*), and sulphur-oxidisng bacteria (*Halothiobacillus*, *Sulfurovum*), indicating the central role ofsulphur cycling in the lakes. Enrichment cultures amended with CO2 + H2, acetate, or trimethylamine led to accumulation of methane in the headspace after 60 days. Our results demonstrate that life can thrive in highly concentrated brines, similar to the ones expected in Mars in sulphate-evaporitic deposits. Positive enrichment cultures transferred into simulated Martian brines being conducted by parallel experiments by collaborators (Ramkissoon) will be monitored for VOC production, microbial diversity and functionality. Combining the characterisation of VOCs will be used to compare with the data obtained from the NOMAD instrument on the ExoMars Trace Gas Orbiter mission to elucidate the potential origin of any relevant detected trace gases and can inform future exploration missions.

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**P.02 Microbial Nitrogen Cycling in the Atacama Desert as a Mars-Analogue Environment**

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The Atacama Desert located at northern Chile is a harsh terrestrial environment analogous to Mars in multiple physicochemical aspects, such as its hyperaridity, a similar landscape, lack of water weathering, high UV radiation, an organic C-depleted condition, and a large reservoir of oxidants. Since nitrate minerals are abundant on Mars and nitrogen is one of the essential elements to all known organisms, biosignatures that affect N stable isotope fractionations are potential targets for life detection on Mars. Three purposes of my study are 1) to apply molecular biology to identify the composition of microbial consortia inhabiting a gradient from the hyperarid core to the transition zones in the Atacama Desert, 2) to determine N cycling-related genes and proteins of each microbial member, and 3) to utilize N stable isotope geochemical analyses to determine the biosignatures imprinted on associated N cycling processes, which can be used to predict life traces on Mars. Soils of 7 sites at an aridity gradient in the Atacama Desert (21°S to 29°S) were sampled. The heterogeneity of soils based on the composition of salts is the highest in the intermediate sites, and gradually decrease to the driest and most humid sides. As expected, there is a general increasing trend in organic level and microbial abundance from the hyperarid to the transition zones. δ13C and δ15N of soil organic matters are significantly higher in the transition zone than the hyperarid core, implying more biological activities. Compared to culturable heterotrophic microbes from transition zones, those from hyperarid areas responded more positively to the additions of water and carbon sources (carbonate, acetate, and L-lactate), but in a similar pattern to nitrogen sources (nitrate and ammonium). These findings imply that even under a low moisture and organic carbon environment, such as Mars, there is sufficient nitrogen sources to grow lives.

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**P.03 Characterizing the diurnal cycle of the Chilean Altiplano and the preservation potential of silica sinters**

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High altitude soils provide one of the closest representations to Martian conditions that occur naturally on Earth. This study conducted in the Sairecabur range sought to determine how closely the diurnal temperature and water cycle represented possible Martian conditions. The Sairecabur volcano in Antofagasta, Chile provided a suitable sample site that provides conditions that more closely approximate those of Mars than other potential Martian analogues, most notably the UV radiation environment (Cabrol, et al., 2014; Cockell, et al., 2000), sub-zero atmospheric temperatures accompanied by solar heating of the surface (Fischer, et al., 2016), and reduced atmospheric density due to high altitude (4000-6000m above sea level).

This study also sought to determine whether precipitated deposits of hydrothermal origin could provide data sufficient to encourage targeting such a location for future mars missions. Hydrothermal vents could provide the necessary mineral surfaces, thermal gradient and possible sources of organic molecules from the earth’s crust to form the first proto-cells. Analysed silica sinters returned 3 potential sources of biosignatures; actively viable bacteria that were able to be cultured; visual evidence of microbial encrustation in the form of filamentous or coccal bacteria; and organic biomarkers in the form of n-alkanes, fatty acids and other organic compounds.

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**P.04 THE EXOMARS-LIKE FIELD TRIALS (EXOFIT): PANCAM EMULATOR MULTISPECTRAL OBSERVATIONS**

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ExoFiT is the latest installment of martian surface simulation missions, designed to test the response of the ExoMars2020 suite in an analogue Mars location and inform the processing pipeline for ExoMars2020. The two 10 sol campaigns, first in Southern Spain and second in the Atacama desert, consisted of a field team and near-fully instrumented rover platform to carry out mission-like operations following tactical plans from the Rover Control Centre (RCC), in Oxford. The RCC received no contextual information on the site out with the scope of Mars orbital data, using only the data returned from instrumentation to constrain the surrounding environment, plan mission goals and create tactical plans within the time frame of a Martian surface mission. The PanCam emulator, AUPE, was invaluable in providing contextual colour and stereo images for navigation and target acquisition as well as high resolution textural information of the target and 440nm to 100nm multispectral information. The 12 geological filters chosen for ExoMars PanCam are designed to identify mineralogical signals from the most Astrobiologically relevant minerals and other indicators of the presence of water. During the Trials minerals like hematite and potential Fe3+ absorption features could be inferred from the PanCam multispectral data, however to fully characterize a target comparison with other context instruments, like the Infrared Spectrometer for ExoMars (ISEM) and textural information from the high-resolution camera (HRC), is necessary.

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**P.05 MEASURING THE VARIATION AND DISTRIBUTION OF OZONE IN THE MARTIAN ATMOSPHERE**

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In this project, ozone will be retrieved and mapped in the Martian atmosphere using nadir and occultation UV observations from the NOMAD instrument. The aim is to further understand the vertical, temporal and spatial distribution of ozone and how this affects or is affected by other atmospheric species including water vapour, water ice clouds, and photochemical radicals.

Ozone is a trace gas in the Martian atmosphere, and it can be used to infer water vapour through its anticorrelation and, under certain conditions, track global meridional circulation patterns.

It can be used to derive concentrations of trace gases through its photochemical reactions which are otherwise difficult to measure, such as and radicals [2]. These species are short lived and highly reactive, including to any potential organic species, biological or otherwise. Furthermore, they are responsible for the stability of carbon dioxide, the primary component of the atmosphere [3].

Investigating the distribution of ozone, therefore, can help determine the photochemistry of these radicals and their formation and destruction.

NOMAD (Nadir and Occultation for Mars Discovery) is an instrument aboard the ExoMars Trace

Gas Orbiter. It reached Mars in 2016 and entered science mapping orbit in March 2018 [4, 5]. One of its primary objectives includes mapping trace gases in the atmosphere such as ozone and species. It aims to retrieve transient, temporal and spatial data from the ultraviolet region using the UVIS spectrometer. These retrievals, coupled with a GCM, will then be used to study Mars’ climate to better understand its diurnal, seasonal and potentially interannual variations.

This will allow us to find out how ozone is influenced and further develop our understanding of the processes such as the water cycle and photochemistry in the Martian climate.

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**P.06 Simulating martian subsurface temperature and pressure ranges for growing methanogens**

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Methane has been detected in the martian atmosphere by a number of instruments [1-3] in trace amounts. Whilst the sources of the methane are unknown, it is generally agreed that potential sources such as volcanism [4], meteoritic infall [5] and degradation of surface organics [6] are unlikely to explain observed variations in methane concentration. Instead, serpentinisation and microbial methanogenesis, both of which are subsurface processes, are thought to be the most likely source of atmospheric methane [7]. Most methane detected in Earth's atmosphere is produced by methanogens [8, 9] and potentially similar processes might be occurring in the subsurface of Mars.

An energy source (molecular hydrogen) [10], an electron acceptor and carbon source (carbon dioxide) [11] and water [12] are thought to be present in the subsurface of Mars, making microbial methanogenesis plausible. In order to study the potential for microbial methanogenesis in the martian subsurface environment, it is necessary to simulate it within a laboratory environment. If methanogens are present in the subsurface, due to limitations placed on transport mechanisms such as diffusion (too slow) [13] and advection (driven by pressure gradients over short distances) [7], methanogens proposed to explain the link to atmospheric observations would need to be in the near-surface subsurface (between ~10 to ~500 m). The martian subsurface lithostatic pressure range extends from 1 bar to up to approximately 60 bar at those depths [14], although the pressure of the subsurface environment will dependent on whether it is connected to the surface environment or not [15]. The temperature range could extend from 160 K to 350 K (-110 to 80°C) [14]. Therefore, apparatus used to simulate the martian subsurface environment to a depth of 500 m must be compatible with these pressure and temperature ranges, simultaneously. Such a system is described here, which not only simulates the temperature and pressure ranges, but also allows for gas headspace aliquots to be sampled without interfering with the experiment, allowing for continuous measurements over long time periods.

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**P.07 The impact of coupled aeolian abrasion – UV irradiation on the transformation of organic matter and detectability by the ExoMars 2020 MOMA instrument (ABRADE)**

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Erosional rates throughout the Amazonian eon are estimated to be 2 - 5 orders of magnitude less than Noachian Mars and the slowest rates of continental erosion on earth (Golombek *et al.*, 2006); this suggests Mars has been cold and arid, precluding water from taking an active role in erosion and leaving aeolian processes to dominate. Sand transport by wind is evidenced by modern aeolian bedforms, ranging from centimetres to tens of meters (Balme *et al.*, 2018). Sand particles greater than ~ 10 µm, too large to be suspended as aerosols, are transported by saltation which can lead to their fracturing. The fracturing of silicate minerals results in the mechanical cleaving of covalent bonds and the generation of reactive mineral surfaces. Reactive oxygen species (ROS) such as H2O2 and •OH can form at these surfaces and modify the Martian regolith accordingly (Bak *et al.*, 2017).

A critically understudied aspect of Martian surface chemistry is the role of aeolian abrasion in the transformation of organic molecules within sediment/surface outcrops. The quantitative role of aeolian abrasion relative to UV-irradiation in oxidizing organic molecules, and the effects on organic molecules of varying molecular weights and functional groups, has yet to be quantified.

ABRADE will simulate the effects of saltation on a range of analogue materials and under a variety of Martian conditions. Organic molecules targeted by the ExoMars 2020 Mars Organic Molecule Analyser (MOMA) (carboxylic acids, amino acids, nucleobases, amines, alcohols, fatty acids, lipids, polyaromatic compounds) will be introduced and changes in abundance and speciation will be determined before and after simulation. Data will a) quantify the role of mineralogy and temperature on Martian regolith reactivity, b) constrain the potential survivability/detectability of organic molecules in Martian sediment, and c) aid interpretation of MOMA data.

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**P.08 HYDROLOGICAL HISTORY OF A COMPLEX LAKE AND VALLEY SYSTEM IN WESTERN ARABIA TERRA, MARS.**

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The Arabia Terra region of Mars hosts diverse landforms indicative of ancient hydrological processes, and the presence of liquid water bodies on Mars is crucial to identifying and characterizing the locations, and potential conditions for past habitability. However, there is little consensus on the timing, duration or interaction of hydrological processes, and their detailed study is often limited by the resolution of topographic data. This study focuses on a small area in western Arabia Terra of middle Noachian age, and utilizes high resolution digital terrain models (DTMs) to reconstruct the past hydrological system. The goal of this work is to reveal the interplay and relative timing of hydrological process in the broader region which includes the ExoMars rover landing site.

Fluvial valleys were observed across the study area as apparently unconnected segments with seven distinct basins identified between segments. Palaeolake extents inferred from outlet valley elevations were found to link the majority of discontinuous channel segments into connected valley and palaeolake chains with bank spillover elevations interpreted as representing earlier maximum palaeolake extents, and valley base and outlet start elevations representing progressively later post-incision extents with smaller and lower surfaces.

The detailed study of this area’s topography and geomorphology serve to reconstruct the hydrological setting of the area, and reveal two valley and lake systems that were likely fed by ground water and only drained in periodic, high discharge events. However, it is also indicated that smaller, residual lakes existed after drainage had ceased. The Oxia Planum landing site of the ExoMars rover is situated on the crustal dichotomy to the SSW and at a similar elevation to the study area. Therefore the hydrological processes active within the study area are of relevance to the landing site, and suggest similar conditions for habitability.

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**P.09 Active sulfur and carbon cycling in deep Greenland groundwaters**

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The deep terrestrial subsurface harbours most of the microbial diversity on Earth, and a significant proportion of the planet’s biomass. Understanding how life operates in these extreme environments can help guide the search for life on other planetary bodies. However, most studies to date have catalogued diversity of deep biosphere microbial communities, rather than surveyed function and activity. As a result, we are left with a phylogenetic tree of deep biosphere life with little appreciation of how its foliage operates.

Here, we apply metagenomics and metatranscriptomics to probe microbial life in cold groundwater collected from two deep boreholes (191 m and 645 m deep) in the western region of Greenland. We present evidence for active carbon and sulfur cycling amongst diverse communities, dominated by Firmicutes and Proteobacteria. We also show evidence for active ‘rare biosphere’ microorganisms likely participating in carbon and sulfur cycling, and explore genomic evidence for cold adaptations and viral associations. These active microbial communities appear to be self-sustaining, with evidence of cryptic sulfur and carbon cycles, and are distinct from surface communities.

This work sheds light on deep cold subsurface communities that reside in environments analogous to those in the subsurface of other planetary bodies, especially ice moons of Jupiter and Saturn.

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**P.10 AN INVESTIGATION OF HYPERVELOCITY IMPACT CRATERS FROM SALT CRYSTALS ONTO ALUMINIUM FOIL**

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Cryovolcanism is prevalent on several of the solar system’s bodies, especially on the icy moons of Jupiter and Saturn. Enceladus shows many of the signs of cryovolcanism, has a very active south polar region which regularly ejects materials (including water ice) from its surface. The ejection of such material indicates the presence of a sub-surface liquid water ocean. Previous Enceladus encounter, have shown that this ocean contains large number of salts which are also ejected. Environments like those thought to be found on Enceladus provide one of the most likely locations for extra-terrestrial life to develop, as similar locations on Earth have been found to be abundant in life. As such Enceladus provides one of the most likely locations in our solar system for the discovery of life.

Here we present an investigation into a method of analysing the evaporate material which could be collected via impact by a flyby or orbiter mission passing through the plumes of material. We recreated this collection method using the two stage light gas gun (LGG) at the University of Kent for a number of salts; NaCl, NaHCO3 (which have been detected in Enceladus’ plumes) and MgSO4.H2­O and MgSO4 (both found on many rocky bodies). The LGG shots were carried out at a range of speeds (0.3 - 7.0 kms-1) and grain size (75-90 µm) currently thought to be characteristic of a flyby encounter at Enceladus.

The resulting impact craters and residues were analysed using optical and scanning electron microscopy techniques and Raman spectrometry. It was found that the resultant crater morphologies show significant dependence on the speed of the impact. In addition, the state and proportion of residue inside of the craters also show velocity dependence. We aim to present the results of the shot program and the findings of the subsequent analysis.

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**P.11 LASER ABLATION FOR BROADBAND ROTATIONAL SPECTROSCOPY**

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Laser ablation is a powerful tool used in Chirped Pulse Fourier Transform Microwave (CP-FTMW) Spectroscopy to bring non-volatile and high melting point solids into the gas phase for spectroscopic interrogation. Ablation of organic molecules (e.g. imidazole) mixed with a metal binder (Cu, Ag, Mg) can generate a number of interesting fragments, reaction products and formation of transient and exotic species. The rotational spectra of the precursor, fragments and reaction products are all observed simultaneously with CP-FTMW. The majority of molecules that have been detected in space have been verified by their laboratory finger-print rotational spectra. Fragments generated by laser ablation, particularly nitriles, have also been detected in the Interstellar Medium (IM) and they are thought to be precursors for complex molecules such as Polyaromatic Hydrocarbons (PAHs). The CP-FTMW spectrometer at Newcastle University operating between 2.0 and 18.5 allows to record rotational spectra over large bandwidths offering high frequency precession and resolution. Such an instrument could be used to generate finger-print spectra that can be used to elucidate astronomical observations.

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**P.12 THE EFFECT OF MARS RELEVANT SALTS ON CHYMOTRYPSIN CATALYTIC ACTIVITY**

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This study investigated the effect of Mars relevant salts on the enzymatic activity of chymotrypsin. When the Phoenix Mars Lander detected perchlorate salts in the northern plains of Mars it had important implications for the presence of liquid water on Mars due to the reduced eutectic point of aqueous perchlorate solutions. Whilst being beneficial for liquid water, perchlorate salts are also known to be harmful to life and its processes. The salts investigated were magnesium perchlorate (Mg(ClO4)2), calcium perchlorate (Ca(ClO4)2), sodium perchlorate (NaClO4), magnesium sulphate (MgSO4) and magnesium chloride (MgCl2). Mg(ClO4)2, Ca(ClO4)2 and NaClO4 were found to induce a dose dependent reduction in chymotrypsin’s enzymatic activity whereas MgCl2 and MgSO4 had no discernable effect on enzymatic effect. A previous study concluded that the Hofmeister effect is responsible for the observed changes in enzyme activity, especially increases in such activity, as no conformational changes in the protein structure were observed. In contrast to these results, our study shows that the reduction in enzyme activity by both magnesium and calcium perchlorate is caused by almost complete protein unfolding as shown by circular dichroism spectra in the near UV range. These results may have implications for the habitability of Martian perchlorate brines. While microorganisms may exclude harmful salts from their cytoplasm, extracellular digestive reactions in high perchlorate concentrations may be significantly affected due to protein unfolding. The extent of this effect is almost certainly protein dependent and as shown from the range of perchlorates used it is also dependent on the cation species and the dissolved concentration of the perchlorate anion.

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**P.13 Modelling the Rock-Water Interface on Enceladus**

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Modelling the potential reactions occurring at the rock-water interface within Enceladus is crucial for establishing that environment’s habitability.

Using CHIM-XPT [1], used previously to model martian water-rock interactions [2, 3], we will present the results of thermochemical modelling of reactions at the Enceladus rock-water interface over a temperature range of 273-373 K [4]. These temperatures were chosen assuming that the concentration of salt and ammonia is insufficient to have an effect on the freezing/melting point of water. The pressure range invoked is that suggested by Hsu et al., of 10-80 bar [4]. This will allow us to better constrain the pressure to be used for future simulation experiments using the results of the thermochemical modelling as crucial inputs.

The modelling will focus on the interaction of the ‘initial’ ocean chemistry with the defined silicate simulant [5] – mimicking the interaction of the sub-surface ocean with the silicate interior.

We are using two different initial compositions for the subsurface ocean:

1. A dilute sodium chloride solution, based upon the assumption that the subsurface ocean originated as almost pure water [6].
2. A melted cometary ice fluid (the composition of 67P) [7], based on the assumption that the ice had a cometary origin.

The modelling will lead to a theoretical ‘modern’ ocean composition, which can be compared to the composition of the plumes analysed by Cassini [8, 9]. Since these plumes are expected to originate from the sub-surface ocean, it can be considered that the plume composition reflects that of the ocean [10].

The modelled ‘modern’ ocean composition will be presented. This work will be used in the future as an input for further modelling experiments and laboratory simulation experiments of the rock-water interface.

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**P.14 LIQUID WATER LIFETIME IN MARTIAN ANALOGUE ENVIRONMENTS**

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The presence of water is one of the foremost considerations for determining the habitability of an environment. The lifetime of liquid water in such an environment would impact the ability of potential microorganisms to colonize and reproduce. This investigation aims to use computer and physical simulation techniques to determine the effect of capillary pressure in Martian rock analogue environments on the lifetime of liquid water.

Capillary pressure occurs within very thin tubes due to a combination of intermolecular forces between the fluids in the tube and the walls of the tube. This pressure opposes the transport of fluid within the tube thus inhibiting the evaporation of liquid water into the surrounding environment and extending the liquid water lifetime.

The computer simulation, based on molecular kinetics, predicts the mass loss rate of water due to evaporation. It considers the effects of capillary force, humidity and the presence of salts (NaCl and MgSO4) in the solution. The simulation predicted that liquid water lifetime can increase by up to a factor of 50 due to capillary force.

An ongoing physical simulation in a low-pressure chamber measures the mass loss rates of free water and water within capillary tubes at primordial Martian surface pressures. This simulation aims to determine the veracity of, and potentially improve the predictive model, thus deepening our understanding of the habitability of Martian and other terrestrial environments.

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**P.15 IDENTIFYING THE MECHANISMS OF THE MARS-RELEVANT NITRATE-DEPENDENT Fe2+ OXIDATION METABOLISM**

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Establishing the potential habitability of Noachian Mars (4.1-3.7 Ga) requires consideration of key environmental parameters, for example: pH and redox environments, available electron acceptors and donors, carbon inventory and oxygen fugacity. These factors may have combined to produce localised environments that were anoxic, largely reducing, circumneutral and rich in inorganic electron donors and oxidants such as nitrates and perchlorates (Grotzinger et al., 2015). These conditions could have allowed microbial life based upon chemolithotrophic metabolisms, such as nitrate-dependent Fe2+ oxidation (NDFO), to thrive (Price et al., 2018).

We have previously tested the capability of some NDFO strains, such as *Acidovorax sp.* strain BoFeN1, to grow in simulated environments using a Mars-relevant Fe2+ source (olivine) and a variety of martian brines. The compositions of the brines were based on *in situ* (“Rocknest”, “Paso Robles” and “Haematite”) and meteorite (“Shergottite”) geochemical data (Ramkissoon et al., 2018).

We are now investigating the biochemical mechanisms of NDFO *via* genome analyses and a series of experiments that use the denitrifier *Salmonella enterica* serovar Typhimurium strain SL1344 and a Δ*narGHIJ* knockout mutant. This will measure the contribution of the Nar respiratory nitrate reductase enzyme to the oxidation of Fe2+ in NDFOs. The contribution of nitrite accumulation to NDFO organisms through abiotic chemical reactions is being assessed under the same conditions.

The apparent adaptability of selected strains to Mars-relevant Fe2+ sources and brines supports the plausibility of NDFO in the martian past, and these experiments will shed light on the underlying mechanisms of NDFO and the extent to which they contribute energy for metabolism. From this, we can draw more robust conclusions as to the viability of this metabolism as a driver of microbial life on Noachian Mars.

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**P.16 SIMULATING THE MARTIAN CHEMICAL ENVIRONMENT**

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The detection of alteration minerals on the martian surface [1,2] and contemporary Recurring Slope Lineae (RSL) [3,4] suggests fluids, either as liquid water or a brine, may have existed on the surface of Mars. Water is a crucial component for life, and the detection of fluids, past or present, suggests habitable environments could exist on Mars. *In situ* geochemical analysis has shown variations in the geology and chemistry of the martian surface, which would influence the chemistry of these fluids [5,6]. The chemistries of these fluids and preciptatiating secondary alteration minerals could potentially be used as a diagnostic tool to identify the primary chemistry of initial fluids and silicate compositions. In addition, analogue fluids could be utilised in laboratory experiments that aim to identify potentially habitable martian environments.

To determine the potential habitability of the martian chemical environment, regolith simulants were developed to mimic four key environments: 1) a basaltic shergottite [7], representative of magmatic, unaltered martian bedrock; 2) Rocknest at Gale crater [8,9], representing a globally average martian regolith composition; 3) Paso Robles at Columbia Hills ([10] a sulfur-rich soil), and 4) Haematite Slope at Meridiani Planum ([11] an iron-rich regolith).

Thermochemical modelling [12,13] was conducted using the geochemistries of these simulants to determine associated fluids chemistries and secondary mineral assemblages. These fluid chemistries were produced and used in combination with the simulants to mimic martian chemical environments in the laboratory. To these environments, a microbial analogue community will be added. These experiments will help in our understanding of whether life can survive under Mars-like conditions and if it would exert any influence on the precipitation of minerals. We will present the results from these thermochemical models.

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**P.17 EXTRATERRESTRIAL RECALCITRANT ORGANICS AS A MICROBIAL ENERGY AND CARBON SOURCE**

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Recalcitrant, complex organic molecules are abundant in the Interstellar Medium (ISM). Multiple stable molecules, such as high molecular weight polycyclic aromatic hydrocarbons (HMW PAHs) and fullerenes, are formed in the ISM in high concentrations. Abiotically, these molecules are known to be respectively electron donors and acceptors (Waajen, 2018). It is currently unknown whether these extraterrestrially produced molecules can be used by microorganisms as an energy and carbon source, or whether these molecules rather have a negative impact on microbial growth. A first set of experiments shows no inhibition of bacterial growth of Bacillus subtilis by fullerenes. Future experiments will focus on the potential use of fullerenes as an energy and carbon source, as well as the inhibition or enhancement of HMW PAHs to microbial growth. Next to the tests of single compounds, early Earth analogs will be used to test growth inhibition or enhancement of a heterogeneous mixture of recalcitrant organics. The incorporation of these organics into the microbial biomass will be tested as well. This research is important for the understanding of biological breakdown of recalcitrant organic matter, and the potential usage of these molecules by early life on early Earth, when this material was present in significant abundances. Other industrial applications include the breakdown of toxic PAHs present in polluted environments on Earth.

A.C. Waajen (2018). *The accessibility of polycyclic aromatic hydrocarbons and C60* *fullerenes to life.*

Unpublished MSc report, Master Microbiology, Radboud University, the Netherlands.

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**P.18 CARBON-CONTAINING MOLECULES PROBED BY BROADBAND MICROWAVE SPECTROSCOPY**

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Laser vaporisation of solid starting material is employed to generate and study a wide range of gas phase, carbon-containing molecules. These are stabilised and cooled within a supersonically-expanding pulse of gas prior to interrogation by microwave spectroscopy.1 Broadband microwave spectroscopy now permits the *rapid* acquisition of laboratory microwave spectra which assist and facilitate the identification of new molecules in interstellar and circumstellar environments. Microwave spectra of a series of carbon-containing molecules, of possible relevance in circumstellar/interstellar chemistry, will be presented. Laser vaporisation of imidazole yields a wide variety of carbon-containing molecules such as HC7N generated through fragmentation and further reactions. Finally, results from a study of a complex formed between isocyanic acid and urea will be described.

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**P.19 Do Large Sand Dunes Migrate On Mars? Dune Movement, Valles Marineris, Mars.**

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Aeolian processes are the main agent for moving material on present day Mars and aeolian bedforms can be used to analyse changing wind speeds. In this study, we have measured the rate of ripple migration on the stoss side of some of the largest dunes on Mars over a 7 year time period and tracked the movement of dune crests. The study site in southern Coprates Chasma, Valles Marineris, is a large dune field covering 111 km2. This dune field is interesting for two main reasons. First, a potential source region for the dune field is located ~35 km west of the dune field , which could offer an insight into source to sink systems and possibly erosion rates on Mars. Second, the dune field contains dunes with mean heights of ~100 m, with the largest dunes reaching heights of ~250 m, thus offering the chance to test whether such large aeolian bedforms are active under the current atmospheric conditions.

Ripple migration rates have been measured, using sub-pixel correlation of images from the High Resolution Imaging Science Experiment Camera (HiRISE; 25cm/pixel [1]) with the Co-registration of Optically Sensed Images and Correlation (COSI-Corr) software package [2]. Dune crest migration has been measured by manual mapping of dune crests using Arc Map.

COSI-Corr has been successfully used with HiRISE imagery to show the displacement of ripples along the stoss side of dunes at Coprates Chasma. The large sand fluxes in the area suggest there are fast wind speeds, likely to be due to the local wind regime in the valley, providing details about the local climate and atmospheric conditions. This method could be applied to bedform monitoring at future landing sites, providing an independent method of estimating wind speeds and sand fluxes, which could then be used to assess their relative safety.

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**Methane exports, microbial assemblages, and geochemical energy sources of a Greenland subglacial catchment**

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The cold, isolated, and often oligotrophic nature of subglacial systems arguably makes them excellent analogues to potential refugia for life on other icy and cold worlds such as Mars, or habitats on the Jovian and Saturnian moons Europa and Enceladus. The past two decades have indeed demonstrated how subglacial environments (on Earth) are not devoid of life, that the bed of glaciers and larger ice masses harbour active microbial communities. But large uncertainties remain surrounding how widespread subglacial biota are beneath the ice and what lifestyle allows for sustained microbial activity over extended glaciation periods.

Here, we present results from a large subglacial catchment of the Greenland Ice Sheet (GrIS) on the methanogenic footprint of the catchment, the make-up of the microbial communities beneath the ice, as well as the influence of bedrock comminution in fuelling such subglacial microbial communities. High-resolution sensor measurements of bulk runoff hydrochemistry, as well as stable-isotope and molecular analyses, revealed the production of several tonnes of microbial methane from beneath the GrIS. Molecular analyses further hinted that chemolithotrophy centred on both iron and methane cycling likely plays a key role in sustaining subglacial microbial populations beneath the ice. Laboratory incubations indicated that crushing of bedrock material liberate bioavailable energy (e.g. H2), nutrients (NO3- and PO43-) and also organic carbon (acetate and formate) to indigenous subglacial populations indicating that bedrock comminution by moving ice masses likely act as a microbial fuel to subglacial ecosystems independent of photosynthates. All in all, results arguably represent one of the strongest lines of evidence to date of the widespread presence of an active microbiome beneath terrestrial ice masses and inform on how life can be sustained in these isolated environments on Earth, and potentially elsewhere.