Project Proposal Form – 2022 entry

Project Title	**OU3 - Ice microenvironments and biogeochemistry within seasonal glacier-associated ice deposits on Svalbard, Arctic Norway**
University (where student will register)	The Open University
Which institution will the student be based at?	As above
If other	Student will have visiting PhD status at the University Centre in Svalbard (UNIS)
Theme (Max. 2 selections)	Climate & Environmental Sustainability ☒ Organisms & Ecosystems ☒ Dynamic Earth ☐
Key words	
Supervisory team (including institution & email address	**PI:** Mark Fox-Powell (Open University; mark.fox-powell@open.ac.uk) **Co-I:** Susanne Schwenzer (Open University; susanne.schwenzer@open.ac.uk) Charlotte Spencer-Jones (Open University; charlotte.spencer-jones@open.ac.uk) **External collaborators:** Andy Hodson (University Centre in Svalbard; Andrew.Hodson@unis.no) James Bradley (Queen Mary, University of London; james.bradley@qmul.ac.uk)
Is the project co-designed by a student?	Yes ☐ No ☒
Is the PhD suitable for part time study?	Yes ☒ This is a requirement of NERC

Project Highlights:

- Conduct High Arctic fieldwork to investigate the composition of seasonal glacier-adjacent ice deposits originating from sub-glacial drainage
- Become an expert in analytical and computational methods for studying sub-zero-Celsius biogeochemical processes within ice
- Contribute to developing a fundamental understanding of ice geochemistry applicable to many environments on Earth and elsewhere in the Solar System

Overview:

The High Arctic cryosphere is experiencing some of the most rapid and pronounced effects of climatic warming. Understanding how High Arctic glaciers interact with their surrounding environments over seasonal timescales is critical to forecasting future climate-driven changes in these regions. This project will investigate biogeochemical processes within seasonal ice deposits

(termed 'naledi') in Svalbard, Arctic Norway. Naledi form by re-freezing of upwelling subglacial drainage, which is rich in inorganic and organic compounds sourced from the subglacial environment. This material becomes incorporated into the ice deposits, influencing its export from glaciers on annual timescales.

The successful candidate will visit and sample a range of chemically distinct naledi in Svalbard. Using analytical inorganic and organic geochemistry alongside state-of-the-art computational models of sub-zero aqueous chemistry, the student will: (1) quantify the abundance of redox-active inorganic elements and organic compounds, and how these vary across the ice deposits; (2) investigate the bio-availability of these compounds by modelling the formation of "cryogenic" mineral precipitates and liquid brine microenvironments within the ice matrix; and (3) explore the potential for naledi to host active biological processes, and thus contribute to the recycling and mobilisation of subglacially-derived compounds. Sample sets taken in the field will capture compositional gradients across the naledi, meaning that chemical fractionation during freezing, and its role in defining biogeochemical processes, can be reconstructed.

Through this project, the student will apply approaches developed for other solute-rich ice (such as sea ice) to wholly novel chemical and hydrological regimes. They will contribute to a new emerging fundamental understanding of ice geochemistry and habitability applicable to many environments on Earth and on other planetary bodies (such as Mars and icy moons of Jupiter).

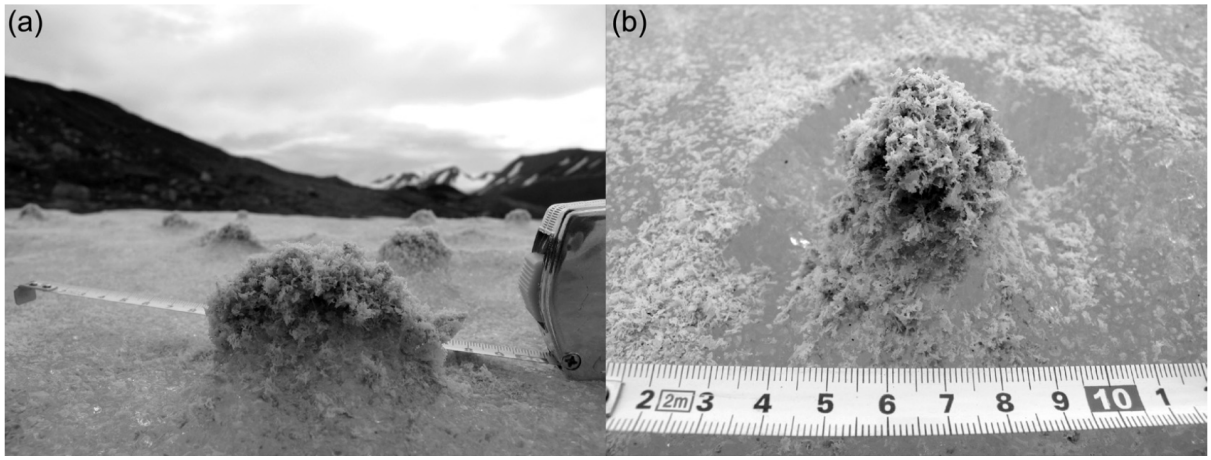

Figure 1: Examples of cryogenic calcium carbonate minerals on the surface of a glacier-derived naled at Austre Grønfjordbreen, Svalbard. Reproduced from Yde et al. (2012).

Alt. text: Photos showing several clumps of white minerals protruding from ice.

Methodology:

The student will work initially with source fluid (glacial seep) samples taken on a field expedition in Summer 2021 and conduct their own field sampling campaign to collect ice samples from across ice deposits in Spring 2023. The following methods will be used:

1. Arctic fieldwork, involving field sampling of ices for inorganic and organic analyses.
2. Laboratory handling and preparation of ice samples.

3. Analytical geochemistry, including ion chromatography, inductively-coupled plasma optical emission spectroscopy, and gas chromatography-mass spectrometry to quantify soluble ions and organic carbon compounds in ice and seep samples.
4. Geochemical modelling using Pitzer ion interaction models specifically parameterized for temperatures below 0 °C (including the code FREZCHEM, and the programme PHREEQC), to investigate mineral formation and geochemical processes within ices.

Training and skills:

Students will be awarded CENTA2 Training Credits (CTCs) for participation in CENTA2-provided and 'free choice' external training. One CTC equates to 1⁄2 day session and students must accrue 100 CTCs across the three years of their PhD.

The student will receive training in the clean handling of field samples, analytical and computational geochemistry, and in polar cryosphere biogeochemistry. An iterative cycle of analysis and model construction will provide training in sample prioritisation and hypothesis testing. Fieldwork will provide training in logistics, planning and sampling skills. The student will gain experience managing international collaborative work and will benefit from training in scientific writing, grant proposal writing, time management, presentation skills, and networking.

Partners and collaboration (including CASE):

This project will be in partnership with the University Centre in Svalbard (UNIS) via collaboration with Prof. Andy Hodson. Andy is an expert in glacier-associated hydrological and biological processes and is conducting long-term monitoring of naledi icings at multiple locations on Svalbard. The student will have External PhD student status at UNIS, and there is the potential for an extended stay on Svalbard (funding permitting). The project will also benefit from collaboration with Dr James Bradley (Queen Mary, University of London). James is an expert in bioenergetics modelling, and in particular microbial dynamics and biogeochemical cycling in icy environments.

COVID-19 Resilience of the Project:

Samples of glacial seep fluids are already in hand at the Open University, meaning that fluid analyses and predictive modelling of ice deposit composition can proceed immediately. If field sampling of ice deposits cannot occur, Project Partner Andy Hodson can send ice samples to the Open University. Should analytical work also become impossible, the project's emphasis will shift towards the modelling component, using data from the literature alongside fluid transport calculations to generate predictions that can be tested once analytical work becomes possible again. Modelling work does not require the use of specialist computing facilities and can be conducted remotely.

Possible timeline:

Year 1: Literature review and familiarisation with ice biogeochemistry, cryogenic mineral formation. Initial analyses of seep samples. Planning and conducting field campaign (spring 2023). Report writing and beginning analysis of ice samples.

Year 2: Detailed analysis of organic and inorganic compounds within ice samples. Familiarisation with model codes and initial modelling of ice deposit formation. Present results at national conference and begin preparing manuscript for publication.

Year 3: Detailed modelling of liquid brine microenvironments and cryogenic mineral formation. Predictions of intra-ice biogeochemical processes. Prepare second manuscript for publication. Present results at a major international conference. Write up and submit thesis.

Further reading:

Irvine-Fynn, T.D., Hodson, A.J., Moorman, B.J., Vatne, G. and Hubbard, A.L. (2011). Polythermal glacier hydrology: a review. *Reviews of Geophysics*, 49 (4)

Stachnik, L., Yde, J. C., Kondracka, M., Ignatiuk, D. and Grzesik, M. (2015) 'Glacier naled evolution and relation to the subglacial drainage system based on water chemistry and GPR surveys (Werenskioldbreen, SW Svalbard)', *Annals of Glaciology*, 57 (72), pp. 19-30.

Yde, J. C., Hodson, A. J., Solovjanova, I., Steffensen, J. P., Nørnberg, P., Heinemeir, J. and Olsen, J. (2012) 'Chemical and isotopic characteristics of a glacier-derived naled in front of Austre Grønfjordbreen, Svalbard', *Polar Research*, 31, 17628, DOI: 10.3402/polar.v31i0.17628

Vancoppenolle, M., Madec, G., Thomas, M., and McDougall, T. J. (2019). 'Thermodynamics of sea ice phase composition revisited, *Journal of Geophysical Research: Oceans,* 124, 615–634.

Toner, J. D., Catling, D. C. and Sletten, R. S. (2017). 'The geochemistry of Don Juan Pond: Evidence for a deep groundwater flow system in Wright Valley, Antarctica.' *Earth and Planetary Science Letters* 474, 190–197

Further details:

The successful candidate will join AstrobiologyOU, a vibrant, multi-disciplinary group of researchers investigating the scientific, technical, and ethical challenges associated with understanding the limits of life on Earth and beyond.

Please contact **Mark Fox-Powell, Mark.Fox-Powell@open.ac.uk** for further information.

Applications should include:

- an academic CV containing contact details of three academic references
- a CENTA application form, downloadable from: CENTA application
- and an Open University application form, downloadable from: Home OU application form (if you are resident in the UK) or an Overseas OU application form (if you are an international applicant).

Applications must be sent to **STEM-EEES-PHD@open.ac.uk by Friday 7th January 2022 (12 pm, noon)**