CENTA

Natural Environment Research Council

Project Proposal Form – 2022 entry

Project Title	**OU10 - After the dust has settled - The post-impact hydrothermal system at Rochechouart impact crater and implications for Early Earth**
University (where student will register)	The Open University
Which institution will the student be based at?	As above
If other	
Theme (Max. 2 selections)	Climate & Environmental Sustainability ☐ Organisms & Ecosystems ☐ Dynamic Earth ☒
Key words	
Supervisory team (including institution & email address	**PI:** Susanne P. Schwenzer (The Open University; susanne.schwenzer@open.ac.uk) **Co-I:** Julia Semprich (The Open University; julia.semprich@open.ac.uk) Karen Olsson-Francis (The Open University; karen.olsson-francis@open.ac.uk) **Project partner:** Philippe Lambert, Centre for International Research on Impacts and on Rochechouart, lambertbdx@numericable.fr (France)
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:

- Becoming an independent user of cutting edge and industry standard analytical, laboratory and modelling methods
- Investigating fluid-rock interactions and element mobility
- Understanding processes on Early Earth – with potential application to other celestial bodies

Overview

Large hypervelocity impacts that cause craters in the Earth's crust are catastrophically destructive and therefore have implications for mass extinction events. However, the heat distributed by these impacts and subsequent melting and fluid release may also have provided new habitats for microbial life on Earth, especially in its very early history. The main barrier to testing this in nature is that plate tectonics has erased these early environments and our knowledge is derived from models that have little ground truth.

This project will investigate the Rochechouart impact crater, a young crater that was not eradicated by plate tectonic processes to quantify the following key processes: (1) the dissipation of heat derived from the hypervelocity impact; (2) the generation of a hydrothermal system, with heat from the impact and ground- and surface-waters in the immediate environment and; (3) the mobility of elements and potential habitability within the shattered rocks. Among the population of preserved impact structures on Earth, Rochechouart provides a complete sequence of impactites including impact melt rocks and direct access to both the deposits and the underlying target rocks through a set of drill cores. This will allow the determination of the temperature evolution and fluid availability in a terrestrial crater, which can then be used in models to simulate impact-induced hydrothermal systems in the oldest preserved rocks (Archean; 4-2.5 Ga). Further, the temperature profiles and fluid geochemistry can be implemented into simulation experiments to test implications for the survival of microbial life. By investigating the temperature, volatile, fluid-flow and associated bio-geochemical history of the Rochechouart impact crater and extrapolating the obtained data to Early Earth impact structures, this project aims to improve the understanding of the significance of impact craters to life for Early Earth.

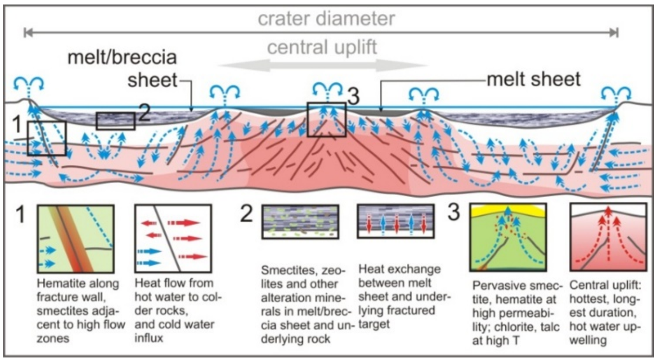

Figure 1: Qualitative assessment of the impact heat distribution, water flux and alteration minerals for a crater in basaltic target lithology. The goal of this project is to quantify this qualitative picture of impact-aftermath to assess the contribution of such craters to habitability on Early Earth.

Alt text: Cross section of an impact crater, with rim, moat and central uplift at the top, and moat partially filled with ejecta.

Methodology:

1. Optical microscopy and electron microprobe analysis will be used to study the alteration mineralogy and geochemistry in the different crater regions.
2. Thermochemical and phase equilibria modelling using industry standard and research software (Geochemist workbench, CHIM-XPT, Perple_X) will be employed to understand the alteration parameters that cannot be measured such as fluid temperature and chemistry.
3. The new data and models will be combined to test and refine existing hydrothermal models, particularly those for Early Earth impact craters using relevant parameters such as rock compositions and temperature estimates

Laboratory simulation experiments will aim to quantify the concentrations of elements acting as nutrients in the hydrothermal fluid and the environmental conditions for microbial life

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 be trained in optical microscopy, electron microprobe and petrologic, laboratory, and modelling methods, to the level of independent user. In addition, field work will provide planning and sampling skills. With the international and interdisciplinary nature of the project, teamwork and collaboration are an essential aspect of the work. Special emphasis will be on the oral and written communications skills, ranging from e-mail and phone negotiations, e.g., in the planning of the field work, to conference presentations, report writing and publication in peer reviewed papers.

Partners and collaboration:

This project will be in collaboration with Dr Philippe Lambert. He is the initiator and head of Centre for International Research on Impacts and on Rochechouart (CIRIR) created in 2016. He has overseen the first campaign of scientific drillings at Rochechouart funded by the National Reserve and he is in charge of the coordination of the scientific valorisation of the cores, which are available to the project and to the scientific community at large since 2018.

COVID-19 Resilience of the Project:

In the case of restricted travel and the postponement or cancellation of field work, samples will be shipped to the UK by the collaborator. Current arrangements at the OU allow for data acquisition and experimental work but likely over a longer time than normal due to limited access and training for students. Should analytical and experimental work become impossible, the project can shift focus to the modelling components using data from the literature, which can then be modified once laboratory work is feasible again. Most of the modelling software does not require high-end computers and can be used remotely.

Possible timeline:

Year 1: Oct to March: Literature work, familiarising with mineralogy, petrology, geochemistry of impactites (with P. Lambert), familiarising with cooling and thermochemical modelling, and initial models based on estimated temperature values and rock compositions from the literature, preparation of the field trip; March-July: field trip, sampling of cores, sample preparation; petrologic characterization. July to October: Project report writing, summarizing petrological data in writing, preparation for more detailed geochemical work.

Year 2: Detailed petrological and geochemical work, understanding the cooling history from data obtained from the rock samples studied. Phase equilibria and thermochemical modelling to understand fluid conditions and extrapolation of models to Early Earth conditions. Prepare a conference presentation and publication.

Year 3: Laboratory simulation experiments to test implications of analytical and modelled results on microbial life in an Early Earth environment. Prepare a second conference presentation and initial publication. Write up and submit thesis.

Further reading:

Osinski, G. R., et al. (2013) 'Impact-generated hydrothermal systems on Earth and Mars', Icarus, 224, pp. 347–363.

Kelley, S. P. and Spray, J. G. (1997) 'A late Triassic age for the Rochechouart impact structure, France', Meteoritics and Planetary Science, 32, pp. 629–636.

Kelley, S. P. (2007) 'The geochronology of large igneous provinces, terrestrial impact craters, and their relationship to mass extinctions on Earth', Journal of the geological Society, London, 164 pp. 923–936.

Lambert, P. (2010) 'Target and impact deposits at Rochechouart impact structure, France', GSA Special Papers, 465, pp. 509-541.

Further details:

Students should have a strong background in Earth sciences and enthusiasm for laboratory work and data analysis. Experience of thermochemical modelling is desirable. The student will join a well-established team researching into fluid rock-interaction and geo-microbiology on Earth, Mars, and icy moons (https://www.open.ac.uk/research-groups/astrobiology/).

Please contact Dr. Susanne P. Schwenzer (susanne.schwenzer@open.ac.uk) or Dr. Julia Semprich (julia.semprich@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)**