EEES Project Proposal Form – 2021 entry

Project Title	**OU24 - After the dust has settled: The post-impact hydrothermal system at Rochechouart impact crater and implications for Early Earth**
Key words	Impact crater, hydrothermal alteration, habitability
Supervisory team (including email address	**PI:** Susanne P. Schwenzer (susanne.schwenzer@open.ac.uk) **Co-I:** Julia Semprich (julia.semprich@open.ac.uk) Karen Olsson-Francis (karen.olsson-francis@open.ac.uk) **Collaborator:** Simon P. Kelley, University of Edinburgh (simon.kelley@ed.ac.uk) **Project partner:** Philippe Lambert, Centre for International Research on Impacts and on Rochechouart, (lambertbdx@numericable.fr)
Is the PhD suitable for part time study?	Yes ☒ No ☐

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 (including 1 high quality image or figure):

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.

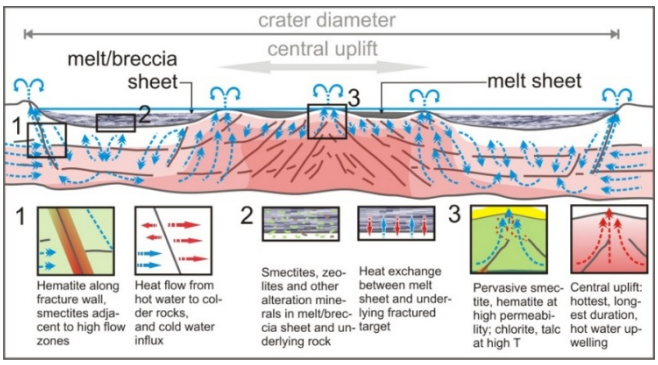

Figure 1: Qualitative assessment of the impact heat distribution, water flux and alteration minerals for a crater in basaltic target lithology. The goal of this project is to quantify this qualitative picture of impact-aftermath to assess the contribution of such craters to habitability on Early Earth.

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.
4. 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:

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 oversees the coordination of the scientific valorisation of the cores, which are available to the project and to the scientific community at large since 2018.

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, modelling and data analysis. Experience in modelling approaches is desirable.

If you're not sure whether your academic background is suitable, please contact one of the supervision team or Olivia Acquah at STEM-EEES-PhD@open.ac.uk. We'd be happy to hear from you.

The successful student will join well-established teams researching fluid-rock interaction and geo-microbiology on Earth, Mars, and icy moons at the Open University (https://www.open.ac.uk/research-groups/astrobiology/).

Applications should include:

- A covering letter that includes:
    - Your motivation to study for a PhD in general
    - Your interest in this project in particular
    - The project-specific skills, aptitude and experience you bring to the project
- an academic CV containing contact details of three references, one of whom should be able to comment on your academic abilities.
- and an Open University application form.
    - If you are British, please use the Home form
    - If you are not British, please use the International form

Applications should be sent to **STEM-EEES-PHD@open.ac.uk** **by 12 noon on Monday 1st March 2021.**