CENTA Project Proposal Form – 2024 entry

Project Title	The strains of dating: Rb/Sr to the rescue?
University (where student will register)	The Open University
Which institution will the student be based at?	The Open University
Theme (Max. 2 selections)	Climate & Environmental Sustainability ☐ Organisms & Ecosystems ☐ Dynamic Earth ☒
Key words	Geochronology, shear zones, method development, LA-ICP-MS
Supervisory team (including institution & email address	**PI:** Dr Barbara Kunz (OU) barbara.kunz@open.ac.uk **Co-I:** Prof. Clare Warren (OU) clare.warren@open.ac.uk Dr Tom Argles (OU) tom.argles@open.ac.uk Prof. Craig Storey (Portsmouth) craig.storey@port.ac.uk Dr Nick Roberts (BGS) nirob@bgs.ac.uk
Is the PhD suitable for part time study?	Yes ☒ This is a requirement of NERC

Project Highlights:

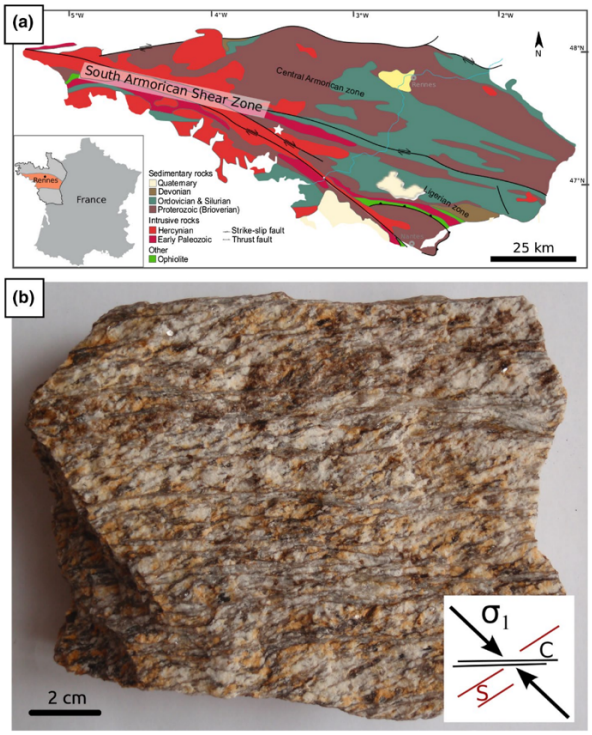
- Fieldwork in the North and South Armorican Shear Zone, Brittany (France)
- Training in cutting-edge geochronology techniques and technique development
- Developing novel "age-to-stage" geochemical tools

Overview:

Ductile shear zones accommodate vast amounts of strain in the crust and are a focus for fluids, magmas and elemental transfer. The rates and timescales of shear zone deformation, and the timing of associated fluid, magma flow or mineralisation events, are critical for constraining large-scale tectonic processes, the rheological behaviour of the lithosphere and the formation of economically important resources through geological time [e.g. 1]. As micas deform and recrystallise during shearing, the geochronological information that they record may be modified or completely re-set.

Following recent analytical advances, micas can now be dated *in-situ* by Rb-Sr LA-ICP-QQQ-MS analysis [e.g. 2], with trace element datasets gathered from the same ablation spot. Micas incorporate trace elements that allow processes such as deformation, fluid infiltration and/or changes in pressure and temperature to be 'fingerprinted', and when linked to their geochronolgoical record, provide rich data about their history. However, there are still challenges to be overcome with the precision and accuracy of *in-situ* Rb-Sr geochronology techniques such as finding and validating community agreed reference materials, determining crystallographic effects on data quality, and choice of analytical parameters and their influence on fractionation and matrix effects.

The aim of this project is to ***develop a new framework for confidently linking mica age to geological process within shear zones.*** Part of this project will involve helping to develop Rb-Sr LA-ICP-QQQ-MS geochronology at the Open University (OU), and developing a framework for linking geochronological data to other petrographic and geochemical datasets collected at the University of Portsmouth (UoP).



This project will make use of an outstanding natural laboratory for shear zone evolution, the South Armorican Shear Zones in Brittany, France [3,4], Figure 1. This shear zone and its northern counterpart separate two major terranes in the Armorican Massif and was active during the Variscan orogeny, about 300-400 Ma ago. The structures are well exposed, and cut through a number of different granite plutons, with variable degrees of deformation and fluid infiltration that could affect how, when and why micas in the shear zone record (differences in) geological time. Furthermore, parts of the shear zones and local granites are mineralised [5], making this region an important case study for investigating the role and timing of element-laden fluids through the shear zone with respect to the timing of shearing.

Figure 1: ***(a)*** *Geological map of the Armorican domain in Brittany, France, with location of South Armorican Shear Zone and sample location (white star).* ***(b)*** *Sample of orthogneiss with S–C fabric. Figure and caption from [3].*

[ALT TEXT: Figure 1a shows a geological map of the Armorican domain in Brittany, northwest France. The South Armorican Shear Zone cuts through the centre of the domain, running roughly east-southeast to west-southwest. (b) shows a 10x10 cm sample of pale brown orthogneiss with roughly horizontal S-C fabrics. It was collected from a region south of the shear zone, in roughly the centre of the map shown in (a).]

Methodology:

Fieldwork to collect carefully-characterised samples will be carried out in Brittany, France, concentrating on locations that show different levels of protolith shearing.

Oriented thin sections and polished thick sections will be made at the OU for further analysis. Careful petrographic observation and major element geochemical analyses at the OU's Electron Microscopy Suite will identify different mica generations. Electron backscatter diffraction (EBSD) analysis at the UoP will support the characterisation of deformation histories. LA-LIBS analysis (UoP) will provide further characterisation of light mica components such as Li, OH and F. Rb/Sr geochronology and petrochronology (collecting other trace elements simultaneously) analytical procedures will be developed in conjunction with the supervision and laboratory teams at the OU and BGS. The ages of different mica generations and chemical zones will be compared with the petrological and geochemical datasets to develop a new framework for age interpretation.

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. In the first year, students will be trained as a single cohort on environmental science, research methods and core skills. Throughout the PhD, training will progress from core skills sets to master classes specific to CENTA research themes

The successful candidate will receive specific scientific training in safe fieldwork planning, first aid, rock preparation, lab safety, data collection using a variety of cutting-edge geochemical instruments, data processing and interpretation using a variety of chemical and statistical plotting methods.

The School of Environment, Earth and Ecosystem Sciences at the OU has a thriving postgraduate community. Additionally, our students can gain excellent skills in science communication by contributing to outreach activities at local schools, science festivals or to CENTA or OU social media communications. The OU is a centre of excellence for public engagement with research. The student will also be enrolled in the 2024 BGS University Funding Initiative (BUFI) cohort, where a wide range of BGS- and externally-led training is available.

Partners and collaboration (including CASE):

The student will receive both training and external supervision at Portsmouth University and the BGS. This will include regular visits to both places as well as virtual meetings with supervisors. Furthermore, the student will be able to incorporate additional laboratory analyses at the BGS' isotope laboratories, where they will be able to interact and work with internationally renowned scientists and have access to specialist instrumentation and analytical expertise. The BGS has recently installed the latest mass spectrometry technology, for which this project will be able to assist with method and application development.

Possible timeline:

Year 1: Initial induction, literature review. Regional context field trip to Brittany in April with the University of Portsmouth (10 days) and further sampling fieldwork in Brittany, France (5 days). Sample preparation, method development at the OU and initial data collection at the OU & Portsmouth.

Year 2: Initial interpretation of data set. Second field season (1 week). Continued method development and data collection; Presentation at national conference. Work placement (2 weeks).

Year 3: Final interpretation of data set. Preparation of papers. Presentation at an international conference. Writing and submission of thesis

Further reading:

1. Papapavlou, K., Darling, J.R., Storey, C.D., Lightfoot, P.A., Moser, D.E & Lasalle, S. (2017), Dating shear zones with plastically deformed titanite: New insights into the orogenic evolution of the Sudbury impact structure (Ontario, Canada). *Precambrian Research 291*, 220-235.
2. Olierook, H.K., Rankenburg, K., Ulrich, S., Kirkland, C.L., Evans, N.J., Brown, S., McInnes, B.I., Prent, A., Gillespie, J., McDonald, B. and Darragh, M., 2020. Resolving multiple geological events using in situ Rb–Sr geochronology: implications for metallogenesis at Tropicana, Western Australia. *Geochronology*, *2*(2), pp.283-303.
3. Bukovská, Z., Wirth, R. and Morales, L.F., 2015. Pressure solution in rocks: focused ion beam/transmission electron microscopy study on orthogneiss from South Armorican Shear Zone, France. *Contributions to Mineralogy and Petrology*, *170*(3), 31.
4. Tartese, R., Boulvais, P., Poujol, M., Chevalier, T., Paquette, J.L., Ireland, T.R. and Deloule, E., 2012. Mylonites of the South Armorican Shear Zone: insights for crustal-scale fluid flow and water–rock interaction processes. *Journal of Geodynamics*, *56*, 86-107.
5. Ballouard, C., Poujol, M., Boulvais, P., Mercadier, J., Tartese, R., Venneman, T., Deloule, E., Jolivet, M., Kéré, I., Cathelineau, M. and Cuney, M., 2017. Magmatic and hydrothermal behavior of uranium in syntectonic leucogranites: The uranium mineralization associated with the Hercynian Guérande granite (Armorican Massif, France). *Ore Geology Reviews*, *80*, 309-331.

Further details:

The student will join a strong team of geochemists at the OU and UoP working together to develop in-situ laser ablation Rb-Sr petrochronology techniques.

Students should have a strong background in hard rock geology, with experience in petrographical and geochemical techniques and enthusiasm for fieldwork. Experience of making detailed observations during fieldwork and of thin sections, and a strong interest in (micro)structural and/or metamorphic petrology and geochemistry are highly desirable.

The successful student will join a well-established team researching Dynamic Earth processes at the Open University and Crustal Evolution at Portsmouth University:

https://www.open.ac.uk/stem/environment-earth-ecosystem-sciences/research/dynamic-earth

https://www.port.ac.uk/research/research-areas/areas-of-expertise/crustal-evolution

Both the OU and Portsmouth have the necessary cutting-edge lab facilities to conduct this research:

https://www.open.ac.uk/stem/environment-earth-ecosystem-sciences/research/analytical-facilities/earth-science-laboratories

https://www.port.ac.uk/about-us/our-facilities/lab-and-testing-facilities/mass-spectrometry-and-laser-ablation-laboratory

Please contact **Barbara Kunz, barbara.kunz@open.ac.uk** for further information.