Journey to the Centre of a Continental Fault (Ref IAP2-18-96)

Durham University, Department of Earth Sciences
In partnership with the British Geological Survey (BGS)

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Key Words
Continental fault zones, fault rocks, geochronology, fracture attributes, mineralization.

Overview

Location of the Glendoe Hydroelectric scheme and view of exposed basement rocks in the tunnel walls.

Continental strike slip faults typically cut vertically through the Earth's crust and thus are rarely intersected by boreholes or imaged clearly using geophysical techniques. They are often modelled as relatively simple, predictable features and the incomplete nature of most surface exposures means that there is limited understanding of the extent, nature and complexity of the mineralogy, rock textures and history of movement preserved within the fault core and associated damage zones.

The Glendoe Hydroelectric Scheme in the Central Highlands of Scotland required construction of a shallowly dipping hydrotunnel over 6 km long, cutting through the crystalline basement rocks. This resulted in a complete sub-surface traverse across the entire damage zone and core of the Conagleann Fault which cuts amphibolite facies Dalradian rocks and forms part of the Great Glen-Sron Lairig fault system. The project will have access to a unique collection of pristine rock cores, together with recently acquired photographic, televiewer and engineering logs to advance our understanding of the geology, fault rocks, fracture networks and associated mineralization related to one of the largest strike-slip fault networks in NW Europe.

BGS 3D view of geological field logs and modelled faults across main tunnel and by-pass tunnels.

The project will study the surface and subsurface expression of the Conagleann Fault. A range of materials are available for the research including 2.1 km of 10cm to 6cm diameter core from both surface and subsurface boreholes in varying orientations from vertical to inclined to horizontal that encompass the full extent of the fault zone. Other data include full pre-sampling photography, blasting logs, photos and
descriptions, scans and field data all captured during the investigation into the major tunnel collapse at the Glendoe Hydroelectric Scheme.

The research will lead to the following outcomes:

- A new fault movement and mineralization history for a major UK strike-slip fault zone at an unprecedented level of detail.
- An improved understanding of controls of lithology and pre-existing fabric on fault style, fault rock development and mechanical strength.
- A new methodology linking fault zone geometry and kinematic evolution as seen in sub-surface cores to previously collected field observations made at the surface and in the tunnel walls.
- The development of a uniquely well-constrained predictive model for fault development (core vs damage zone) in metamorphic basement rocks.
- An improved understanding of the fracture attributes and topology (orientation, intensity, aperture, connectivity) in continental strike-slip faults with applications to reservoir modelling and seismic imaging of fractured basement rocks (CCS, geothermal, groundwater, hydrocarbons).

Methodology

Fieldwork: The BGS have a detailed working knowledge of the surface geology of the Conagleann Fault. During an initial period of fieldwork on the surface, the student will visit all known key exposures in road and river sections in order to understand the geological setting of the fault zone and its associated metamorphic host rocks.

Geological characterisation and scanning: the student will receive training to carry out detailed logging of selected cores under the supervision of Dr Martin Gillespie at BGS Keyworth and study all existing geological logs of the tunnel walls and, using a GIS digital platform, will integrate these with re-orientated borehole core, existing BGS photographs and regional scale 3D fault models. In addition, selected cores will be scanned using the new BGS Core Scanning Facility at Keyworth that allows high-definition optical, near-infrared (NIR), ultraviolet (UV) and X-radiographic images to be taken. Using the cores, they will develop a methodology and criteria to log core and damage zones and associated fault rock suites in a range of host rock lithologies (quartzite, psammite, semi-pelite, pelite). The nature, orientation and intensity of both ductile and brittle deformation fabrics will be recorded, together with any associated kinematic indicators and associated mineralization (silicates, carbonates, base metal sulphides).

Tunnel wall fault zone exposure and core

BGS surface field map and fault rock exposure

Fracture attribute and topology analysis: The tunnel wall images, logs and cores allow a multiscale quantitative analysis of fracture attributes and connectivity. These include 1D and 2D analysis of fracture intensity, aperture/thickness and connectivity and how these vary across the fault core and damage zones and in different host rock lithologies.

Microstructural analysis: The student will study fault rock (mylonites, phyllonite, cataclasite, gouge) and silicate-carbonate-sulphide mineral vein assemblages formed during strike-slip fault movements under mid-to-upper crustal conditions. Optical & SEM studies of the selected fault rock and mineralization samples will elucidate the relative timing relationships between the
different types and how these may be influenced by host rock lithology. Kinematic indicators will be documented and SEM-EBSD analyses (to be carried out under the supervision of Dr Eddie Dempsey at the University of Hull) will be carried out on selected deformed quartz vein samples in order to further constrain movement history and deformation conditions. In addition, the associations between changes in fault rock mineralogy & textures will be studied in order to assess likely pressure-temperature conditions and fluid-related alteration sequences that occurred during deformation, especially those related to phyllosilicate enrichment. The results will be used to test the hypothesis that deformation processes lead to the development of weak, phyllosilicate-rich fault rocks in the upper crust.

Geochronology: following full geological and microstructural characterization, the student will carry out dating of carefully selected representative samples of base metal sulphides (using rhenium-osmium geochronology at Durham) and carbonates (using uranium-lead geochronology at BGS Keyworth). These data will be used to constrain the absolute timing of fault movements. This will allow a better understanding of how long-lived the fault zone is and how its movements may be related to the known reactivation histories of other Late Caledonian fault zones in nearby onshore and offshore regions (e.g. the Inner Moray Firth Basin).

Timeline

Year 1: training courses, literature review, fieldwork, core scanning and logging, fault rock and mineral vein sampling, GIS platform construction, data processing and analysis.

Years 2 and 3: training courses, detailed logging and sampling for geochronology, data processing, U-Pb & Re-Os geochronology, thin section analysis of fault rocks (optical, SEM, EBSD).

Year 3.5: Data integration, thesis completion, papers for international journals

Training & Skills

The student will become part of the Structural Research Group at Durham, an established research unit of 15 academic, postdoctoral and postgraduate structural geologists. The project will also overlap with a NERC-funded Oil and Gas CDT PhD project (started in 2017) studying Devonian and younger tectonics and basin development in the nearby Inner Moray Firth Basin.

Training will be provided in structural geology including data logging of core, integration, manipulation and analysis of multiple datasets using a GIS platform. Laboratory-based training will include optical and scanning electron microscopy, EBSD and training in sample preparation and analysis using rhenium-osmium (at Durham) and uranium-lead carbonate geochronology (at Keyworth). The student will be expected to present posters and talks at conferences and will spend time away from Durham at the BGS and Hull.

You will also become part of the IAPETUS DTP which offers a multidisciplinary package of training focused around meeting the specific needs and requirements of each of our students who benefit from the combined strengths and expertise that is available across our partner organisations.

References & Further Reading


Further Information

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