The role of shear zones in Northwest Scotland for Precambrian crustal assembly and evolution

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Research theme(s):	• Geodesy, Tectonics, Volcanology and related hazards • Planetary Evolution and Materials
Eligible courses for this project:	• DPhil in Earth Sciences • Environmental Research (NERC DTP)

Overview

The geological mechanisms of continent formation and growth on Earth have changed significantly through time, with a global subduction-driven (mobile lid) regime having replaced a stagnant-lid tectonic regime sometime during the Mesoarchean (Fig. 1). This critical geodynamic transition, marking the onset of plate tectonics, paved the way for the rearrangement and juxtaposition of discrete continental fragments and island arc systems that became caught up in the supercontinent cycle.

The Lewisian Complex, northwest Scotland, is dominated by Archean tonalite–trondhjemite–granodiorite (TTG) orthogneiss, with subordinate metasedimentary and meta-volcanic supracrustal sequences (Mason, 2016). These units were variably reworked and retrogressed during Paleoproterozoic assembly of the supercontinent Nuna. These Scourian (c. 2.75–2.5 Ga) and Laxfordian (c. 1.9–1.65 Ga) metamorphic and deformational events have been documented throughout the Assynt terrane and Outer Hebrides, and can be directly correlated with equivalent tectonometamorphic episodes in Greenland and northern Canada (Whitehouse and Bridgwater, 2001). Yet, despite decades of study, fundamental questions remain within the community concerning the assembly and geological evolution of the Lewisian Complex. In particular, major tectonic boundaries provide a structural framework for correlating crustal fragments between the mainland and Outer Hebrides, with prominent crustal-scale ductile shear zones thought to represent the loci of amalgamation of separate crustal blocks with distinct geological histories (e.g. Goodenough et al., 2010). However, it is unclear whether these deformation zones record large-scale horizontal motion and welding of continental masses and/or island arc complexes previously separated by an ocean of indeterminate size, such as occurs at the terminal stages of the Wilson Cycle (e.g. Park and Tarney, 1987), or alternatively they record the effects of intracontinental deformation that post-date major episodes of assembly. Understanding the sequence of events that led to the current configuration of the Lewisian Complex has wider implications for palaeotectonic reconstructions of supercontinent formation during Earth's middle age.

This project will involve fieldwork, structural mapping, and sample collection from several localities within the Lewisian Complex, both on the mainland and on the outer islands, including deformed units belonging to Paleoproterozoic shear zones. Strategic sampling will allow competing hypotheses of terrane accretion in the region to be tested. Detailed petrological and microstructural observations will be obtained at a range of scales across the Complex in order to construct a model for pre-, syn-, and post-shear terrain growth. This research will complement ongoing research by the supervisory team focused on the geological processes responsible for the growth and long-term stabilization of Archean terrains, and provide new insight into secular changes in metamorphism and tectonics throughout geological time.

Methodology

Fieldwork will involve geological mapping, structural analysis, and collection of a variety of sheared and unsheared metamorphic and magmatic rocks from across the Lewisian Complex, northwest Scotland. Subsequent laboratory work will involve bulk-rock and mineral chemical analysis, with these data used to perform thermobarometry and petrological modelling. Isotope geochronology will be used to constrain the absolute ages and rates of metamorphism and deformation.

A student working on this project will gain experience in the following tools and techniques:

- Field work, structural mapping and identification of minerals in the field
- Optical microscopy
- X-ray fluorescence (XRF) analysis
- Scanning-electron microscopy (SEM)
- Electron probe micro-analysis (EPMA)
- Laser ablation inductively coupled mass spectrometry (LA-ICP-MS)
- Petrological modelling using the Theriak-Domino software package

Timeline

Year 1: Doctoral training courses, literature review, fieldwork planning, fieldwork and sample collection, sample characterisation, and laboratory training.

Years 2 and 3: Microanalytical work (XRF, SEM, EPMA), isotope geochronology (LA-ICP-MS), and petrological modelling. Data compilation and interpretation. Presentation of results at domestic and international conferences.

Year 4: Data integration, thesis completion, write papers for submission and publication in scientific journals.

Training & Skills

The successful student will join the Hard Rock Group at the University of Oxford, UK, which has a long-standing history of research excellence in metamorphism, tectonics, and investigation into early-Earth geodynamics. Current members of the group are conducting research on critical metals in crustally derived magmas, developing machine learning algorithms to improve mineral prospectivity analysis, and performing petrological modelling of the formation of early planetary crusts.

The successful applicant will have the opportunity to interact with faculty at external institutions and industry partners at annual career fairs. The student will be trained how to plan and conduct a field campaign, how to prepare and characterise geological thin sections, and perform petrological and geochemical analyses of igneous and metamorphic rocks. This will include hands-on work with SEM, EPMA, and LA-ICP-MS equipment in leading laboratories across the UK. Training will also be provided on how to conduct geochemical and petrological modelling, for use in performing thermobarometry and interpreting the geodynamic evolution of discrete lithological units. The student will also be mentored on how to prepare scientific results for presentation at international conferences and how to write papers for publication in high-profile, international journals.

References & Further Reading

Feisel, Y., et al., 2018. New constraints on granulite facies metamorphism and melt production in the Lewisian Complex, northwest Scotland. *J. Metamorph. Geol.*, 36, 799-819.

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Further Information

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