Bots in Rocks: Intelligent Rock Deformation for Fault Rock Petrophysical Properties
Heriot-Watt University, Institute of Petroleum Engineering

Supervisory Team

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Key Words Nano/Micro sensors; faults; fault zones; geomechanics; rock mechanics; rock deformation; experiment; petrophysical properties

Overview

Physical and petrophysical properties of fault rocks are a crucial element in predicting fault rock sealing and leaking capabilities. They can be generated in the rock mechanics laboratory (fig. 1) but in spite of many excellent fault zone laboratory studies it is still not possible to derive direct, within sample, data from these experiments. This project will use a new nano-sensors, developed at Heriot-Watt, in a experimental rock deformation programme to create and characterise fluid-filled rock deformation.

Figure 1. Example of natural fault, its laboratory-deformed equivalent, a different lab-deformed example and a geomechanical simulation of a fault zone showing permanent strain

The project will deliver for the first time: a. fluid flow (two phase) through porous rocks (deformed and undeformed) to measure pressure, flux and fluid phase interface location with time; and b. deformation state (displacement, strain and derivatives) of lab-deformed natural and artificial rocks. The latter adds real, within-sample, data to a suite of long-lived on-going studies of rock deformation from X-Ray and Ultrasonic tomography (XRT and UT), Acoustic Emissions (AE) and Digital Image Correlation (DIC) of deformed rock evolution all the way to Environmental Scanning Electron Microscope (ESEM) and thin section deformed rock studies. It also capitalises on recent experimental work on shear and compaction bands (Charalampidou et al 2011, 2013; fig. 2).

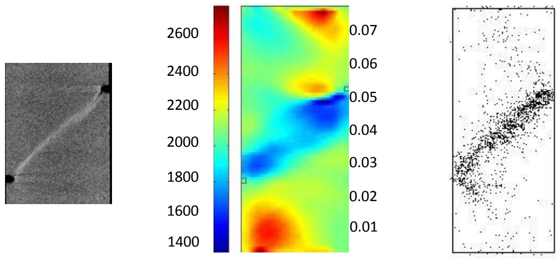

Figure 2. Experimental results for deformed sandstone. XRT and UT show density (and hence porosity) and velocity changes. AE shows location of micro-events as shear zone develops.

Together the fluid flow and microstructure evolution will provide a step change in our understanding of petrophysical property prediction of deforming rocks in the subsurface.

The PhD is suitable for a competent structural geologist with a flair for laboratory work, or for a geomechanicist with a geological (rock) or civil engineering (granular materials) background. Sensor expertise is not required: knowledge in signals, sensors and systems will be provided by Dr Flynn's team.

Methodology

The student will be involved in designing the laboratory experiments using the nano-sensors (bots) developed at Heriot-Watt in an existing ETP-Maersk-Energy Academy funded project.

The project has two topics, fluid movement though the rock pore network and rock deformation.

Rock Deformation: Starting with a thorough investigation of existing experimental methods such as XRT, UT, DIC and AE, the student will design a series of experiments on artificial rocks containing bots that provide within-sample data on e.g. force and displacement. Design includes choice of artificial rock grains and cement and location of bots. The next step is design of the rock mechanics experiments which could include parallel use of previous laboratory techniques such as XRT. After suitable training the student will perform the experiments (supervised) and process the results.

Fluid Flow: This section provides the first actual measurement of fluid movement through a rock pore network. After a similarly thorough study of flow through porous networks and starting with a natural undeformed porous rock, the student will design a series of experiments using bots in a single or multiple (water and oil) fluids that is injected through the rock. Measurements couldl include fluid pressure or position of the oil-water interface with time. The student will perform the experiments and process the results, drawing comparisons to simulated flow and to flow through pore network models.

There is a potential to combine both techniques to investigate flow through deforming rocks.

Timeline

Year 1: training academy courses (10 weeks), literature review of both rock deformation experiment principles and techniques and pore network flow theory and modelling. Familiarisation with nano-sensors; design of experiments with observation of similar experiments if possible; rock mechanics laboratory training and performance of first experiments.

Years 2 and 3: training academy courses (5 weeks per year); main suit of rock mechanics and flow experiments and integration of new data into existing conceptual models. Comparison with natural examples. Paper prepared for publication.

Year 4: Potential fluid and deformation experiments, complete comparison with natural examples; thesis completion; papers prepared for publication.

Training & Skills

As part of a CDT cohort, you will receive 20 weeks bespoke, residential training of broad relevance to the oil and gas industry: 10 weeks in Year 1 and 5 weeks each in Years 2 and 3. Instructors will be both from expert academics from across the CDT and also experienced oil and gas industry professionals.

The supervisory team has expertise in structural geology, sensors, geomechanics and rock mechanics.

You will be expected to present posters and talks at conferences, and to participate in discussions involving the wider research group. You will benefit from the opportunity to associate with the ALERT Geomaterials alliance (http://alertgeomaterials.eu/).
There will also be the opportunity to engage with MIcroSystemsCentre (MISEC)
(https://www.misec.hw.ac.uk/members) and the CDT in Embedded Intelligence, and associated industrial sponsors.

Heriot-Watt actively encourages applications from women and all minorities and provides ongoing active support for all staff and students.
www.hw.ac.uk/athenaswan

References & Further Reading

Charalampidou, E-M, Hall, S.A., Stanchits, S., Viggiani, G., and Lewis, H., 2013. Shear-enhanced compaction band identification at the laboratory scale using acoustic and full field methods. International Journal of Rock Mechanics and Mining Sciences

Charalampidou, E-M,, Hall, S.A., Stanchits, S., Lewis, H. and Viggiani. G. 2011 Characterization of shear and compaction bands in a porous sandstone deformed under triaxial compression. Tectonophysics, vol. 503, issues 1-2, p. 8-17. Available online 29 September 2010

Lewis, H. Hall, S. H, and Couples, G.D. 2009. Geomechanical simulation to predict open subsurface fractures. Geophysical Prospecting, v.57, p. 289-295.

Further Information

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