DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING

University of Strathclyde Engineering

Fully Funded PhD Studentship

The structure, mechanics & flow properties of faults in coal & shale-bearing rocks

University of Strathclyde Department of Civil and Environmental Engineering and British Geological Survey

There is a clear gap in understanding of the properties of faults cutting shale and coal-bearing rocks. A review by the research group found only limited numbers of published papers documenting permeability data from faults cutting shale-rich sequences. Uncertainty in the mechanical and fluid flow properties of faults in shale and coal presents a risk for unconventional oil and gas, exploitation of shallow mine workings for geothermal energy and minewater drainage prediction. For shale gas and coal bed methane it is particularly important to predict the risk of fluids migrating along faults and the risk of fault reactivation during hydraulic fracturing and/or wastewater disposal. The issue of up-fault leakage, possibly facilitated by seismic activity, has been repeatedly raised at several planning hearings, for instance at Airth (CBM) and Lancashire (Shale Gas), and by the House of Commons Environmental Audit Committee (2015). Improving the understanding of the mechanical and hydraulic properties of these structures will aid informed decision-making of the risks posed by faults for leakage and seismicity, and if extraction goes ahead, inform safe and sustainable usage of natural resources.

Our literature study of fault permeability and mechanical properties in shale and coal-rich sequences highlighted the paucity of data, and has outlined key research gaps. The main concern raised by the public can be phrased as: How likely is it that a fault in an unconventional gas field could leak, either due to the fault rock properties, or because a fault was induced to slip thereby changing the flow properties? To make predictions about the behaviour of faults at depth the following questions must be addressed:

- What are the main processes governing fault development in these rock types?
- Which processes tend to enhance or reduce fault zone permeability and/or strength?
- What data should operators collect to quantify risk to groundwater a) in advance of drilling, b) at the appraisal stage and c) during production?
- What measures could an operator take, based on these data to reduce the risk of fault-related flow and seismicity?

The aim of the PhD is to produce a database on the mechanical and hydrological properties of faults in shale and coal-rich rocks to inform risk-based predictions of their properties at depth. Faults in such lithologies are often very poorly exposed due to the ease of weathering of resulting fault rocks. Therefore in addition to examining well-exposed faults in shale and coal identified in the pilot project in the UK and overseas, the study will take advantage of exposures in abandoned coal mines where shale-rich units are interbedded with coals. There are 2 key large abandoned open-cast mines in Scotland that we have access to through the

British Geological Survey (BGS) and the Scottish Mines Restoration Trust (SMRT), with the possibility of future access to other sites across the Central Belt of Scotland. The student will conduct detailed mapping of faults in these mines, will examine cores (from BGS and industry collaborators) and mining records such as coal mine excavation models and water ingress data (from the Coal Authority and SMRT). The student will also liaise with industry collaborators to source pertinent data from boreholes, wireline logs and formation tests.

Field studies will constrain what key parameters control the fault architecture (for instance: thickness of host rock layering, mechanical properties of the layers - e.g. clay content and/or coal grade). New lab data will be collected of the mechanical properties and permeability of samples of faulted shales collected from the field. For many faults the permeability changes over time (e.g. Caine and Forster 1999); for example fault reactivation can increase the permeability of the fault zone by fracturing and the development of slip surfaces. Subsequent cementation and/or stress dependent closure of the fractures reduces the permeability and affects the mechanical properties of the fault zone. Detailed field and microscope studies will unpick this temporal evolution of the fault zones' properties, and constrain the processes that have controlled the temporal evolution of fault properties.

We are looking for a numerate geoscientist or engineer to join the faults and fluid flow research group in the department of Civil and Environmental Engineering. This group currently has 3 post-docs and 10 PhD students working on applications including unconventional gas, geothermal energy and radioactive waste disposal. The student will also join a rapidly growing group of researchers examining all aspects of the geological and environmental engineering of unconventional gas, including emissions, seismicity, public health and wastewater treatment.

The scholarship covers home/EU tuition fees, a stipend of £12,000 for three years (36 months). For further information, please contact: Prof Zoe Shipton (zoe.shipton@strath.ac.uk), Department of Civil and Environmental Engineering, University of Strathclyde, James Weir Building, Glasgow G1 1XJ

Applications should be submitted using the online application form available at: http://www.strath.ac.uk/prospectus/postgraduateapplications/. In the "source of funding" section of the application, please state that you wish to be considered for the above studentship. Applications will be considered upon receipt. While there is no closing date, the post will be filled as soon as a suitable applicant is found, so early application is advised. The successful applicant must start the project, at the latest, by the end of December 2015.