NERC Centre for Doctoral Training in Oil & Gas (2018 start)

Project Title: Granular Rock-Analogue Materials (GRAM) for simulation of multi-scale fault-fracture processes

Host institution: Earth Sciences, Royal Holloway University of London

Supervisor 1: Jürgen Adam

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Additional Supervisor (s):

Project description:

Accurate physical models and predictive tools for the analysis of fault and fracture processes in the Earth crust are critical to many areas of geoscience. The ability to accurately simulate the mechanical properties and deformation behaviour of brittle rocks and the evolution of faults and fractures is essential to properly understand geohazards and applied geoscience problems for the management of natural resources.

The project is fully embedded in the research themes of the Fault Dynamics Research Group and the COMPASS Research Group at the ES department. It will apply innovative integrated physical experiment concept and material science to simulate non-linear fault and fracture processes in brittle crustal fault zones in the FDRG analogue tectonic modelling laboratory.

The core element of the project is the development of new granular "rock-analogue" materials (GRAM) with non-linear elastic-frictional-plastic properties capable to simulate the full range and scales of brittle fault-fracture processes in the Earth crust with scaled analogue experiments from tensile failure at low differential stress to shear failure at high differential stress. Based on GRAM, this project will develop integrated physical experiments and material science concepts to simulate multi-scale fault and fracture processes in fault zones. The advantage of scaled analogue experiments with GRAM is their ability to simulate the evolution of very complex tectonic deformation structures in high-resolution and in 3D over a range of observational scales (structure-fault-fracture).

Specific project aims are:

1. Development of a new granular rock-analogue material (GRAM).
2. Simulation of fault-fracture processes using scaled experiments with GRAM and digital strain monitoring (DIC).
3. Comparative field studies of fault-fracture systems in world-class outcrops of the Eastern Bristol Channel coast.

Project work will include:

(ad. 1) GRAM development

The development of GRAM will require cohesive granular solids capable of shear and tensile fracturing. The design process consists of the adjustment of key material properties of the granular solid (cohesion, shear/compressional/tensile strength, elastic moduli) allowing accurate scaling to the natural fault-fracture processes in fault zones and fault damage zones. Material testing of the granular material samples will be done in the FDRG geomaterial testing lab to analyse the material properties and scaling characteristics relevant for GRAM material design.

(ad. 2) Scaled analogue experiments simulating fault-fracture processes

GRAM materials and high-resolution strain monitoring will be applied in scaled analogue experiments simulating dynamic fault-fracture processes in fault damage zones for fundamental fault types in extensional, contractional and strike-slip fault settings. For each fundamental fault setting, the experiment series includes the design of a standardised deformation rig simulating fault development in an analogue material layer overlying a "basement fault". Each series of basic experiments will test the effect of variable parameters (dip and displacement of basement fault, thickness of cover layer). Experiment analysis includes imaging of the 2D section and 3D surface evolution of analogue fault damage zones, time-series DIC/DVC strain analysis of deformation structures (Figs. 4, 5), and sectioning and 3D digital volume visualisation and interpretation of the damage zone structures of the completed experiment

PhD Proposal: UK Oil and Gas Collaborative Doctoral Training Centre (2014 start)

(ad. 3) Field studies of fault-fracture systems

The project will include structural mapping and kinematic analysis of outcrop analogues of extensional, strike-slip and inverted segmented faults exposed in Jurassic limestones and shales in world-class outcrops of the Mesozoic Bristol Channel Basin on several 100 meter wide wave-cut platforms of the Eastern Bristol Channel coast in Somerset) and Wales. The derived structural and kinematic data sets will be utilised to (1) develop structural and kinematic data sets of natural prototypes directly comparable to the results of the GRAM analogue experiments.

The project will train postgraduate students in essential scientific & technical skills required in an academic research environment and environmental consultancy, civil engineering or resource exploration industry.

CDT Research theme(s): Effective production of unconventional hydrocarbons (Role of natural fracture systems and their stimulation), Exploitation in Challenging Environments (Fractured reservoirs), Environmental Impact and Regulation (Fractures & fluid flow)

Research context: Accurate physical models and predictive tools for the analysis of fault and fracture processes in the Earth crust are critical to many areas of geoscience. The ability to accurately simulate the mechanical properties and deformation behaviour of faults and fractures is essential to understand geohazards such as volcanoes, earthquakes and landslides. Non-academic beneficiaries of improved fault-fracture models are government departments, environmental agencies, consultancies and industry engaged in ground water management geothermal energy, nuclear waste repositories, underground storage of CO2, and resource exploration and extraction of conventional and unconventional hydrocarbon reservoirs, ore-deposits, and rare metals.

Research costs: Tuition fees, living support and RTSG grant

Career routes: Academic research, Energy Industry (E&D), Environment & Government agencies