Centre for Doctoral Training (CDT): Geoscience and its Role in the Low Carbon Energy Transition

(2021 start)

Project Title: Induced seismicity in enhanced geothermal systems: testing the limitations of traffic light systems.

Host institution: Durham University
Supervisor 1: Dr Nicola De Paola (Durham University)
Supervisor 2 & 3: Prof. Stefan Nielsen (Durham University); Prof. Jon Gluyas (Durham University)

Project description: *a) Scientific Rationale – Limitations of Current Approaches:* There is general agreement that key controls on induced seismicity are operational parameters, such as the volume of injected fluids, and fault properties, such as stress, structure and rheology.

Traffic Light Systems (TLS) are used to mitigate induced seismicity, whereby fluid injection operations are paused (e.g. orange code) or stopped (e.g. red code) based on the characteristics of the recorded seismicity. For TLS, empirical volume hypotheses imply that the hazard of induced seismicity can be managed prescriptively by simply maintaining the net injection volume below a certain threshold value, so that shaking nuisance or risk of damage can be avoided. However, TLSs present significant limitations, as shown by some recent induced events associated to fluid injection during geothermal energy activities (e.g., 2017 M_w 5.5 in Pohang, South Korea), which lead to larger events than were forecast during injection. We believe that a better understanding of the underlying mechanics of rupture in the specific environment of Enhanced Geothermal Systems is needed (EGS).

b) Overarching Aims of Proposed Research – Addressing the Knowledge Gap: This project will investigate the controls that fault properties exert on the critical transition between self-arrested ruptures, which are contained within the exploited reservoir volume, and large run-away ruptures, able to grow beyond the reservoir. An integrated approach of experimental and geophysical methods will be adopted. Triaxial failure test under in situ confining and pore fluid pressures will be performed on rock types relevant to deep enhanced geothermal systems in the UK (e.g. granite and carbonates). The experimental setup allows failure to initiate on a saw cut portion of the sample – an analogue of a nearby pre-existing fault. Faulting is allowed to either arrest or propagate through an initially intact portion of the sample to simulate a self-arrested or run-away rupture. Rupture models will be performed to evaluate the sensitivity of measured seismic parameters of laboratory earthquakes (e.g., amount of slip, magnitude, stress drop, b-value) with operational parameters (e.g., injected volume, injection rate, pressure) and a range of fault properties (e.g., structure, roughness, rheology). Laboratory-derived earthquakes laws will then be upscaled to field observations of induced events using available microseismic datasets from the well-studied Pohang (2017 M_w 5.5), Basel (2006 M_L 3.4) and Geyser (2005 M_w 4.0) EGS induced seismicity. Valuable comparisons will be made between laboratory, modelling and field dataset results to determine which of the above operational and fault parameters has the largest effect on induced seismicity.

Stated link to CDT theme: This project addresses the issue of managing the hazard of induced seismicity during fluid injections, hence links to the stated CDT Themes: "Geothermal opportunities" and "Safe Subsurface Storage for energy and carbon".

Any Additional Research Costs: Lab experiments, including consumables = £10000; Conference attendance (1 UK and 1 overseas conference)= £3000; High Spec Computing = £2000.

Has access to data been secured? Not applicable.

Career routes: This project trains the student in the expanding career sectors of subsurface energy industries, such as carbon capture storage, geothermal and hydrogen storage. These will make them competitive during the employment process with trusts, regulators, academia or private industry.