Title: An experimental study of the 4D evolution of relay zones on segmented faults

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Proposal

Faults are widespread geological structures in the subsurface and mostly occur as arrays of fault segments bounding rock volumes referred to as relay zones. It is well known that, after the rapid onset of a segmented fault array, relay zones on it structurally evolve with increasing displacement. This evolution includes a phase in which relay zone deformation can accommodate displacement transfer between the bounding fault segments in a "soft" manner (i.e., through bed rotation and volumetric strains), followed by a phase in which the relay zone fails and the bounding fault segments link. Placing constraints on this relay zone evolution has significant implications for several practical applications dealing with fluid flow in the subsurface (e.g., CO_2 and H_2 storage, geothermal and hydrocarbon exploration, and production): intact relay zones can provide fluid migration pathways across faults that become sealing as the linkage of relay-bounding fault segments occurs and displacement becomes localized on a thoroughgoing fault. The aim of this PhD Project is to explore experimentally this evolutionary scenario of relay zones by using axial deformation rig loading paths on samples of rock analogues.

Research Program

First stage of the research will consist in preparing and testing rock analogue material initially pre-damaged by discontinuities (i.e., fault surfaces) spatially arranged to reproduce a variety of realistic 3D relay zone geometrical templates as derived from other data sources (e.g., field, and seismic reflection data). The material to be selected must hold a linear elastic behaviour at low strain rate and keep visible record of the displacement path during the deformation test. The mechanical experiment will consist of progressively loading this artificially made segmented fault array and in observing and measuring how relay zones evolve with progressive displacement and how linkage of relay-bounding segments triggers and progresses. Experiments will require low strain rate conditions for monitoring through photographic and CT scanning techniques, which will allow observing 3D deformation through time (4D). A final phase will consist in discussing the scalability of the results beyond the rock samples to sedimentary basins and upper crustal scenarios.

Although the PhD Project may slightly vary based on the candidate's scientific propensities and interests, some of the fundamental questions that will be addressed will be, among other possible ones:

how is displacement transfer accommodated and what are the associated displacement gradients? At what strain do relay zones fail? What are the underlying geometrical and mechanical controls on it? How does linkage between relay-bounding faults occur and progress?

Schematic project Schedule/Timeline

The PhD Project will be articulated in successive steps which will include: i) testing analogue elastic materials; ii) perform mechanical experiments; iii) scaling the results; iv) comparing the experimental results with natural fault structures.

Scientific collaborations:

Fault analysis Group, University College Dublin, Ireland
Université Grenoble Alpes, France

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