Geophysical Research Abstracts
Vol. 17, EGU2015-7674, 2015
EGU General Assembly 2015
© Author(s) 2015. CC Attribution 3.0 License.

The architecture and frictional properties of faults in shale

Nicola De Paola, Rosanne Murray, Mark Stillings, Jonathan Imber, and Robert Holdsworth
University of Durham, Rock Mechanics Laboratory, Earth Sciences, Durham, United Kingdom
(nicola.de-paola@durham.ac.uk)

The geometry of brittle fault zones and associated fracture patterns in shale rocks, as well as their frictional properties at reservoir conditions, are still poorly understood. Nevertheless, these factors may control the very low recovery factors (25% for gas and 5% for oil) obtained during fracking operations.

Extensional brittle fault zones (maximum displacement $\leq$ 3 m) cut exhumed oil mature black shales in the Cleveland Basin (UK). Fault cores up to 50 cm wide accommodated most of the displacement, and are defined by a stair-step geometry, controlled by the reactivation of en-echelon, pre-existing joints in the protolith. Cores typically show a poorly developed damage zone, up to 25 cm wide, and sharp contact with the protolith rocks. Their internal architecture is characterised by four distinct fault rock domains: foliated gouges; breccias; hydraulic breccias; and a slip zone up to 20 mm thick, composed of a fine-grained black gouge. Hydraulic breccias are located within dilational jogs with aperture of up to 20 cm, composed of angular clasts of reworked fault and protolith rock, dispersed within a sparry calcite cement.

Velocity-step and slide-hold-slide experiments at sub-seismic slip rates (microns/s) were performed in a rotary shear apparatus under dry, water and brine-saturated conditions, for displacements of up to 46 cm. Both the protolith shale and the slip zone black gouge display shear localization, velocity strengthening behaviour and negative healing rates. Experiments at seismic slip rates (1.3 m/s), performed on the same materials under dry conditions, show that after initial friction values of 0.5-0.55, friction decreases to steady-state values of 0.1-0.15 within the first 10 mm of slip. Contrastingly, water/brine saturated gouge mixtures, exhibit almost instantaneous attainment of very low steady-state sliding friction (0.1).

Our field observations show that brittle fracturing and cataclastic flow are the dominant deformation mechanisms in the fault core of shale faults, where slip localization may lead to the development of a thin slip zone made of very fine-grained gouges. The velocity-strengthening behaviour and negative healing rates observed during our laboratory experiments, suggest that slow, stable sliding faulting should take place within the protolith rocks and slip zone gouges. This behaviour will cause slow fault/fracture propagation, affecting the rate at which new fracture areas are created and, hence, limiting oil and gas production during reservoir stimulation. During slipping events, fluid circulation may be very effective along the fault zone at dilational jogs – where oil and gas production should be facilitated by the creation of large fracture areas – and rather restricted in the adjacent areas of the protolith, due to the lack of a well-developed damage zone and the low permeability of the matrix and slip zone gouge. Finally, our experiments performed at seismic slip rates show that seismic ruptures may still be able to propagate in a very efficient way within the slip zone of fluid-saturated shale faults, due to the attainment of instantaneous weakening.