Fracture Propagation During Fluid Injection Experiments and Indentation in Shale

Mike Chandler[1], Julian Mecklenburgh[1], Ernest H. Rutter[1], Anne-Laure Fauchille[2], Rochelle Taylor[1], and Peter D. Lee[2]

[1]School of Earth and Environmental Science, University of Manchester, Manchester, United Kingdom.
[2]Manchester X-Ray Imaging Facility, University of Manchester, Manchester, United Kingdom.

ABSTRACT

The use of hydraulic fracturing to recover shale-gas has focused attention upon the fundamental fracture properties of gas-bearing shales. Fracture propagation trajectories in these materials depend on the interaction between the anisotropic mechanical properties of the shale and the anisotropic in-situ stress field. However, there is a general paucity of available experimental data on their anisotropic mechanical, physical and fluid-flow properties, especially at elevated confining pressures. Here we report the results of laboratory-scale fluid injection experiments, for Whitby mudstone and Mancos shale (an interbedded silt and mudstone), as well as Pennant sandstone (a tight sandstone with permeability similar to shales), which is used an isotropic baseline and tight-gas sandstone analogue. Our injection experiments involved the pressurisation of a blind-ending central hole in an initially dry cylindrical sample. Pressurisation was conducted under constant volume-rate control, using silicone oils of various viscosities. The dependence of breakdown pressure on confining pressure was seen to be dependent on the rock strength, with the significantly stronger Pennant sandstone exhibiting much lower confining-pressure dependence of breakdown pressure than the weaker shales. Fracture initiation is observable through a small drop in injection pressure and accompanying burst of acoustic noise. A rapid and uncontrolled complete breakdown then follows if injection is continued. If injection is ceased after fracture initiation, this breakdown is less rapid, but is still uncontrolled. A simplified 2-dimensional model for explaining these observations is presented in terms of the stress intensities at the tip of a pressurised crack, and the more complex crack-propagation pathways throughout the heterogeneous shale materials are investigated through x-ray imaging during small-scale indentation experiments. Additionally, we present a suite of supporting mechanical, flow and elastic measurements. Mechanical experiments include standard triaxial tests, pressure-dependent permeability experiments and fracture toughness determined using the double-torsion test. Elastic characterisation was determined through ultrasonic velocities determined using a cross-correlation method.