In this study, hydraulic fracturing is simulated in a controlled laboratory environment to track fracture nucleation (location) and propagation (velocity) in space and time and assess how environmental factors and rock properties influence the fracture process and the developing fracture network. A new technique has been developed, to allow a fluid-rock contact and to generate micro-tensile fractures from the inside of the sample at various pressure conditions (axial pressure + confining pressure). An early Jurassic shale from the Lower Lias, with a very low permeability and a high anisotropy of ~57% (Vp), has been used for this experimental study.

**Figures and Tables**

- **Figure 1:** Sample dimensions and orientation of bedding relative to coring axis.
- **Figure 2:** Elastic wave velocity measured parallel and normal to bedding and velocity anisotropy.
- **Figure 3:** Indirect Tensile Strength measured in the 3 principal fracture directions (tested at ambient pressure conditions).
- **Figure 4:** Fluid pressure and strain during fluid-driven fracturing.
- **Figure 5:** Fluid pressure and seismic activity at time of failure.
- **Figure 6:** Fluid pressure and strain during fluid-driven fracturing experiment (a) Entire experiment (b) Zoom in to time of failure.
- **Figure 7:** Fluid pressure and seismic activity at time of failure.
- **Figure 8:** Fluid pressure and seismic activity at time of failure.
- **Figure 9:** Fluid pressure and seismic activity at time of failure.
- **Figure 10:** Anisotropy ~42%.

**Conclusions**

- Inherent Anisotropy within the rock changes significantly the mechanical properties and behaviour of the rock depending on the orientation relative to the anisotropic feature.
- Fracture propagation trajectories and fracturing fluid pressure are predominantly controlled by the interaction between the anisotropic characteristics of the shale and the stress environment.
- Strength Anisotropy for hydraulic fracturing (~42%, tested at 8MPa confining pressure) is similar to that of indirect tensile strength (~60%, tested at ambient pressure conditions), suggesting similar fracture process and controls. (Difference are within margin if rock variability.)
- Despite the different fracture orientation relative to bedding planes, Short-Transverse and Divider fracture orientation developed planar axial fractures and show a similar seismic activity pattern.
- Fluid pressure drop and radial deformation occur at the same time, but with a time delay to the onset of seismic activity.
- Seismic activity starts ahead of fluid pressure drop and radial deformation with different delay periods depending on the fracture orientation: ~0.18 sec for Short-Transverse (along bedding plane) and ~0.19 sec for Divider (normal to bedding plane). Potential to develop a real-time seismic monitoring system / forecast tool to warn operators and control the fracturing process to avoid uncontrollable fracturing and fracture extent.
- Pressure drop is faster when fractured along bedding planes: ~0.18 sec for Short-Transverse compared to ~0.24 sec for Divider (normal to bedding). Therefore faster fracturing velocity is recorded when fracturing along bedding planes than normal to bedding. This suggests that fracture speed is affected by the tensile strength of the rock and depends on the fracture propagation direction.