Lithological controls on fracturing in multi-layered sediments: implications for CO₂ storage integrity

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Introduction
Ensuring that reservoir seals remain intact during CO₂ injection and then over a geological timescale, is crucial if CCS is to play an important role in the UK’s carbon mitigation strategy.

Fracturing of the aquifer/caprock during CO₂ sequestration can occur if injection rates are too high or reservoir permeability too low, which may induce leakage. (Martinez et al 2013)

Understanding the propagation characteristics of induced fractures and the conditions that may limit or promote their growth is therefore crucial to ensure site suitability.

This project aims to better understand how fractures propagate through shale multi-layers, that may act as caprocks, through analogue study and DEM fracture modelling.

Field Area
Wick, NE Scotland; Middle Devonian lacustrine sediments deposited in the Orkadian Basin.

Cyclic deposition, due to climate triggered variations in depth and extent of the lake, caused by changes in earth’s orbital parameters (Milankovitch cycles). (Andrews & Trewin 2010)

Deep Lake Facies
Sub-millimetre laminated dark grey sediments, with common thick, en-echelon bitumen filled calcite veins. (scale bar is 10cm)

Shore Zone Facies
Grey, fine to very fine-grained sandstones containing ripples, dewatering structures and small channels (scale bar is 2mm)

Playa Facies
Interbedded grey to dark grey, very fine sand and silt/clay, with common desiccation cracks

Perennial Lake Facies
Very fine-grained grey sandstone and dark grey silt/clay layers with abundant syneresis cracks and rip up clasts at base (pencil is 12cm)

Sedimentary logging

Outcrop scale fractures
Mean fracture orientation (strike/ dip) Blue: 317°/77° Red: 310°/62.5°
Stress orientation: (σ₁ = 32 → 138), (σ₂ = 56 → 298), (σ₃ = 09 → 042)

Scaline fracture location

Scanline fracture logging
A detailed fracture log of 15 scan lines was carried out at the transition between Playa and Shore Zone Facies. Attributes such as orientation, termination, length, spacing and aperture were measured. The E/W fracture set are not captured due to the cliff running parallel to fracture set.

Fracture orientation

Fracture terminations

Fracture intensity

References:
MARTINEZ, M.J., NEWELL, P., BISHOP, J.E., AND TURNER, D.Z. Coupled flow and geomechanics model of jointed caprock, Int J. Gre

Upper Devonian/Carboniferous of the Orkney Islands.


Future work
This work forms part of a larger PhD project funded by the University of Aberdeen. Future work will be carried out on the Marcellus Shale, New York, and Jurassic shales in the French Alps.

SEM/thin section analysis, CT scanning and geochemical analysis will be carried out on samples collected from all field sites to further characterize the lithological/structural controls on fracture attributes. By investigating a range of sites, with different structural conditions, a portfolio of information will be built up that can be used to predict the controls on fracture attributes in shale multi-layers of different compositions and thicknesses.