# Project 1.6: Seal geomechanics and potential for $CO_2$ leakage

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## 1. Abstract

This project aims to address the question: under what geological circumstances are faults (and fractures) in mudstone seal rocks likely to impact on bulk permeability and the flow of $CO_2$ through these rocks and are there other geomechanical processes that might result in loss of containment? This project consists of three distinct work packages:

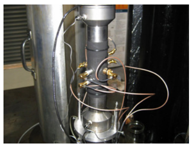
1)Develop detailed geomechanical models of the Iona and Otway storage facilities, with the aim of understanding the effects of gas injection and withdrawal on reservoir and seal integrity, as well as fault stability. The physical and poro-elastic properties of the various units will be determined using sonic logs, calibrated to rock mechanical measurements. The final stage of the modelling will involve fully coupled simulation using finite element modeling techniques.

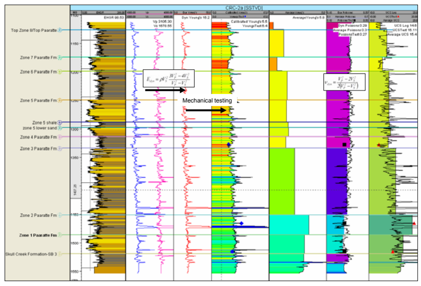
2)Mapping of the potential development and reactivation of fractures and faults within the intraplate Rosedale fault system in the Gippsland Basin, Australia. This study will involve the creation of a static geological model of the fault zone and the stratigraphy it intersects, SGR modelling and characterisation of the associated fracture network.

3)A number of different mudstones from around the world will be examined, both at the large basin scale and at the hand specimen and microscopic scale, through field work, mercury injection capillary pressure, petrography and image logs. It is hoped that the findings will allow some type of constitutive relationship to be developed that describes the transmissive behavior of faults under different conditions.

## 2. Geomechanical Modelling: Otway

Sonic logs have been used in conjunction with rock mechanical tests to yield a continuous record of static Young's modulus, Poisson's ratio and unconfined compressive strength (UCS) through the Paaratte Formation. These parameters are cornerstones of the static geomechanical model for both the reservoir and encapsulating formations. The Paaratte formation and overlying lithologies have been broken down into zones possessing specific physical parameters. These values will be fed into the dynamic geomechanical simulation, which will be used to assess how in situ stress and strain evolve during $CO_2$ injection and provide an estimation of surface ground movement.






*4 multi stage triaxial tests on Paaratte Fm specimens were used to calibrate CRC-2 sonic logs for static mechanical properties. The Paaratte Fm and overburden were broken down into discrete zones of variable Young's modulus, Poisson's ratio and UCS.*

## 3. Geomechanical Modelling: Iona

Geomechanical modelling of the Iona structure is at an advanced stage. The reservoir, overburden, underburden and sideburdens have been assigned key rock mechanical properties such as Poisson's ratio and Young's modulus and the model is ready to be coupled to an Eclipse flow model provided by TRUenergy. Modelling work is expected to be complete by mid-March.

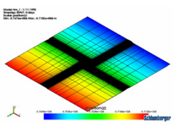
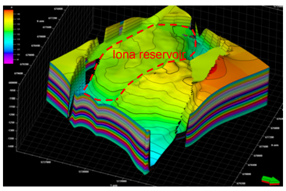


*Image showing the sideburden gridding of the Iona structure using Visage geomechanical software. The reservoir is located at the intersection of the two high density grid lines. Careful attention to the sideburden is necessary so that edge effects are eliminated in the dynamic simulation.*

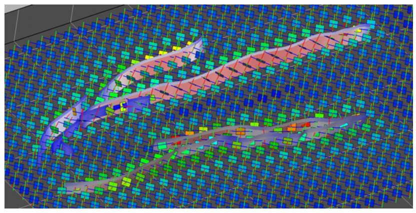


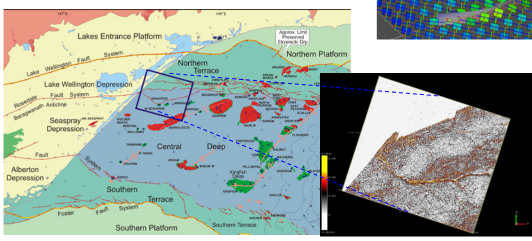

*3D model of the Iona gas storage facility showing the vertical Eclipse gridding that will be used in the dynamic geomechanical model. Mechanical properties for each layer have been calculated using sonic logs. The surface shown is the top of the Waarre C Formation.*

## 4. Understanding the Rosedale Fault System

A study of the Rosedale Fault system in the Gippsland Basin has been undertaken, at various scales, so that fault and fracture patterns can be better understood in terms of connectivity and potential for reactivation; both factors which can contribute to gas migration and potential leakage through low permeability lithologies.

*Fault stability mapping of the large faults within the Gippsland basin has been conducted using Poly 3D software (right). Blue axes represent maximum horizontal stress direction, red are minimum horizontal and green are vertical. The model assumes a reverse faulting regime. The portion of the Rosedale fault coloured in red is more susceptible to reactivation therefore suggesting that the onshore portion of the fault should be relatively stable in a CO2 injection scenario.*



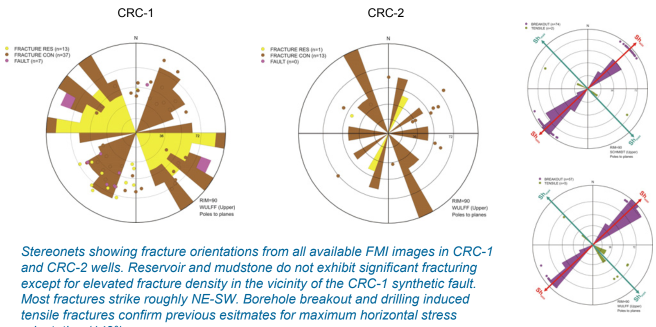



*Example of seismic attribute analysis that has been conducted on the Rosedale Fault system. This example shows a time slice taken at 1250 ms, which is approximately the top of the Latrobe Fm.The Most-positive Curvature attribute allows faults and fractures to be mapped in three dimensions, which would not be possible using conventional seismic interpretation techniques.*

## 5. Fault/fracture Distributions and Fluid Flow

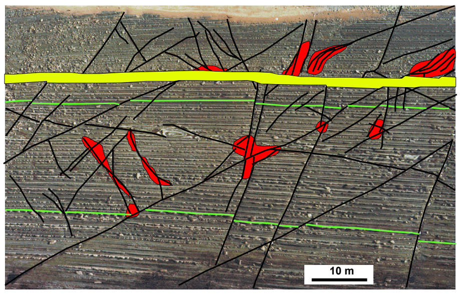
This project seeks to understand and characterize fault and fracture distribution in a number of different mudstones in varying geological environments. The main goal is to develop some predictive ability relating to connectivity of faults and fractures so that some estimation can be made regarding the risk of $CO_2$ leakage through caprocks in various environments. We will accomplish our goal by studying faults and fractures over a wide range of scales, from the hand specimen to the basin scale.

### FMI Logging at the Otway Project




*Stereonets showing fracture orientations from all available FMI images in CRC-1 and CRC-2 wells. Reservoir and mudstone do not exhibit significant fracturing except for elevated fracture density in the vicinity of the CRC-1 synthetic fault. Most fractures strike roughly NE-SW. Borehole breakout and drilling induced tensile fractures confirm previous esitmates for maximum horizontal stress orientation (142°).*

### Mapping Fracture Systems in New Zealand Mudstones




*Faults (black lines) exposed in map view within a turbidite sequence from Whakataki, New Zealand. Mudstone beds are darker grey (two selected beds shown by green lines). Larger faults typically pass through thinner (<1 m) mudstone beds, however, several faults terminate in a thick mudstone-dominated stratigraphic interval shown by the yellow polygon. Red polygons mark zones of intense fracturing (mainly near fault intersections and faults) that could locally enhance fluid flow. Fracturing occurs both within mudstone beds.*

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