

Petroleum Geoscience: Rock Mechanics

CSIRO's rock mechanics laboratory undertakes research and testing for exploration, development and production scenarios in the oil and gas industry as well as for geological storage of carbon dioxide.

The CSIRO rock mechanics laboratory, located at the Australian Resources Research Centre in Perth, is one of the leading geomechanics and rock physics laboratories in the world.

Our specialised laboratory is equipped to measure the mechanical and ultrasonic properties of rocks under in-situ conditions of stress, pore pressure and temperature to provide essential data for modelling and prediction of mine safety, wellbore stability, trap integrity and sand production.

Laboratory testing is the only direct way to determine the mechanical properties of rocks.

Accurate analysis of rock mechanical properties can improve exploration, drilling and reservoir management and assist the industry to maximise production and recovery. It may also help to optimise well siting, and minimise down-time and reservoir loss.

Expertise

The rock mechanics team has extensive experience in experimental geomechanics and rock physics. Further expertise includes geology, petrology, petrophysics, physics and materials science. Much of the team's work is multi-disciplinary and closely linked with CSIRO's petrophysics laboratory.

The experimental work also informs further expertise in geomechanical, dynamic elastic and petrophysical modelling. Our unique combination of capability allows us to conduct targeted experimental and theoretical research that directly addresses industry challenges.



CSIRO's new HPT-Triax Cell is equipped with 20 channels for active ultrasonic and passive micro-seismic monitoring, and can reach pressures up to 150 MPa and temperatures up to 200°C.

Facilities

CSIRO has developed a range of high pressure and high temperature triaxial cells for testing and to understand rock-fluid interaction and deformation under in-situ stress conditions, including:

1.3 Autonomous Triaxial Cells

The Autonomous Triaxial Cells (ATCs) at CSIRO are equipped with multiple single pin feed-throughs, allowing for the direct instrumentation of the rock specimen being subjected to in-situ conditions. The equipment loading capacity is as follows:

- ♦ cylindrical rock specimen: interchangeable sizes, normally $\varnothing = 38$ millimetres (mm) and $L = 80$ mm or $\varnothing = 25$ millimetres (mm) and $L = 50$ mm
- ♦ confining pressure: up to 70 mega pascals (MPa)
- ♦ pore pressure: up to 70 MPa
- ♦ axial Stress: up to 400 MPa (for $\varnothing = 38$ mm)
- ♦ temperature: up to 100 °C.

On a single rock specimen, this allows monitoring of compressive strength parameters such as peak and residual loads, Young's modulus and Poisson's ration and failure envelopes. They may also provide Sample Compressibility Calculations and Peak Collapse Pressure data.

Some of our ATCs have the added capacity of ultrasonic signalling systems for the simultaneous measurement of both static and dynamic rock properties.

The results of these tests provide industry with valuable information about the calibration and referencing of dynamic tools to more common static measurements and the determination of material anisotropy through off-axis ultrasonic measurement relative to axial measurement.

CSIRO has also developed mechanisms whereby the ultrasonic sensors are in direct contact with the rock specimen face thereby eliminating offsets and signal dampening introduced with some other systems.

We build ATC systems to custom specifications for various clients.



2. High Frequency Acoustic Measurements

The Acoustic Emissions Triaxial Cells at CSIRO are equipped with multiple single pin and up to 20 coaxial feed-throughs, allowing for the direct instrumentation of the rock specimen that is subjected to in situ conditions. The equipment loading capacity is as follows:

- ◆ cylindrical rock specimen: $\varnothing = 38$ millimetres (mm) and $L = 80$ mm
- ◆ confining pressure: up to 150 mega pascals (MPa)
- ◆ top pore pressure: up to 100 MPa
- ◆ bottom pore pressure: up to 100 MPa (independent from the top)
- ◆ axial Stress: up to 700 MPa (for $\varnothing = 38$ mm)
- ◆ temperature: up to 200 °C.

On a single rock specimen, this allows monitoring of:

- ◆ strains in axial, radial or inclined directions using strain gages attached to the lateral surface of the specimen
- ◆ P- and S-wave velocities along many propagation paths to assess rock properties' (i) sensitivity to stresses and temperatures; and (ii) anisotropy (active seismic monitoring)
- ◆ micro-seismic activity (passive seismic monitoring) using the same set of ultrasonic transducers
- ◆ water or gas permeability along the specimen's axis.

These laboratory measurements are of fundamental importance for the interpretation of field-scale geophysical data in exploration and production.

They can be applied to:

- ◆ sub-surface seismic monitoring of oil and gas reservoirs or overburden
- ◆ geological storage of carbon dioxide or radioactive waste
- ◆ geothermal production as well as for production in tight gas and shale gas environments.

The laboratory measurements are also used to inform and validate rock physics models developed by the CSIRO geophysics team.



3. Low Frequency acoustic measurements

Our rock mechanics laboratory has specialised capability to conduct low frequency acoustic measurements.

Traditional laboratory measurement tools interpret core samples at ultrasonic frequencies, but data acquired in the field is measured at low (seismic and sonic) frequencies. Because these measurements are generally frequency-dependent, laboratory data processed at ultrasonic frequencies is often less useful for field interpretation.

State-of-the-art equipment at the Rock Physics Laboratory allows accurate measurements of elasticity properties of rock in a broad frequency range (seismic to ultrasonic frequencies) at reservoir conditions.

The equipment capacity can measure seismic frequencies up to:

- ◆ Axial Pressure: up to 150 MPa
- ◆ Confining Pressure: up to 70 MPa
- ◆ Fluid pore pressure: up to 20 MPa
- ◆ Frequency range : 0.01 Hz – 400 Hz
- ◆ Recorded periodical strain: 10⁻⁸ - 10⁻⁶

Such core analysis helps energy companies to maximise recovery from oil and gas reservoirs by directly enabling quantitative measurement of reservoir properties, crucial for reservoir characterisation.



Additional equipment at the Rock Mechanics Laboratory includes:

- ♦ High pressure cell (300 MPa)
- ♦ Medium pressure cell (35 MPa)
- ♦ Hoek cell (70 MPa, 100C)
- ♦ Terratek cell (70 MPa)
- ♦ Sand production rig (70 MPa)
- ♦ HPHT cell (150 MPa, 200C)
- ♦ Velocity-resistivity rig (35 MPa)
- ♦ Low frequency rig (70 MPa, 0.1-400Hz.)

Six of these rigs have ultrasonic capability with both P- and S- wave transducers, of which three have the capability of simultaneous measurement in different orientations. One ATC and the HPHT rig have 16 and 20 channel active/passive acoustic emission systems. The low frequency rig allows measurement of elastic properties at seismic frequencies under low periodical strain.

The rock mechanics team can conduct a number of tests, including:

- ♦ Confined and unconfined compressive strength
- ♦ Thick walled cylinder collapse strength
- ♦ Tensile strength
- ♦ Friction angle and cohesions
- ♦ Poisson's ratio
- ♦ Young modulus
- ♦ Bulk and pore compressibilities / stiffnesses
- ♦ Uniaxial compactions
- ♦ P- and S-wave velocity
- ♦ Attenuation
- ♦ Anisotropy

Applying the capability

The rock mechanics laboratory provides key support to strategic research projects on shale behaviour, top seal integrity and the geological storage of carbon dioxide.

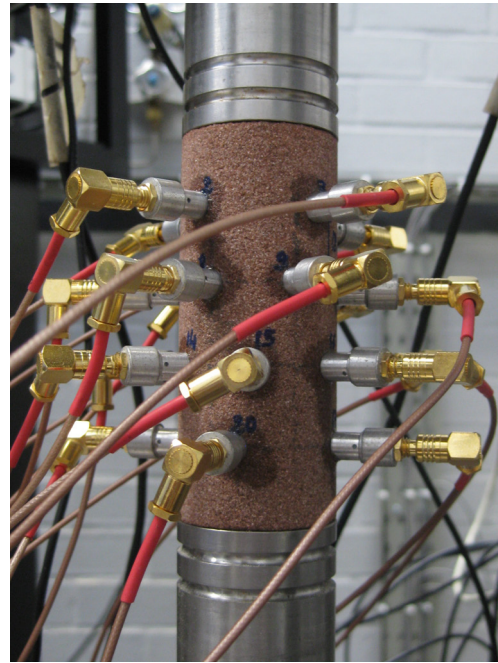
CSIRO's rock mechanics capability was used extensively in the recently concluded and highly successful Integrated Predictive Evaluation of Traps and Seals (IPETS) project.

Our specialised facilities are now used by CSIRO's Shale Research Centre (SHARC), which conducts experimental and theoretical research on shale properties and problems.

It is being applied to investigate links between geomechanical, petrophysical and rock physics properties of shales.

Technical service projects are undertaken in collaboration with oil and gas companies for projects related to wellbore stability, reservoir compaction, 4D seismic interpretation, CO₂ storage and hydraulic fracture stimulation.

CSIRO's custom built rock testing equipment has been sold to industry and research organisation around the world.



Setting up the high pressure triaxial cell to measure rock strength

Getting involved

We have worked with national and international petroleum and mining companies, State and Federal Government agencies, Cooperative Research Centres and international universities.

For further information about rock mechanics testing and services, please contact:

Dr Jeremie Dautriat
Rock Mechanics Laboratory Supervisor

p +61 8 6436 8842

e jeremie.dautriat@csiro.au

For further information about rock mechanics and rock physics research, please contact:

Dr David Dewhurst
Senior Researcher

p +61 8 6436 8750

e david.dewhurst@csiro.au

CONTACT US

t 1300 363 400

+61 3 9545 2176

e enquiries@csiro.au

w www.csiro.au

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