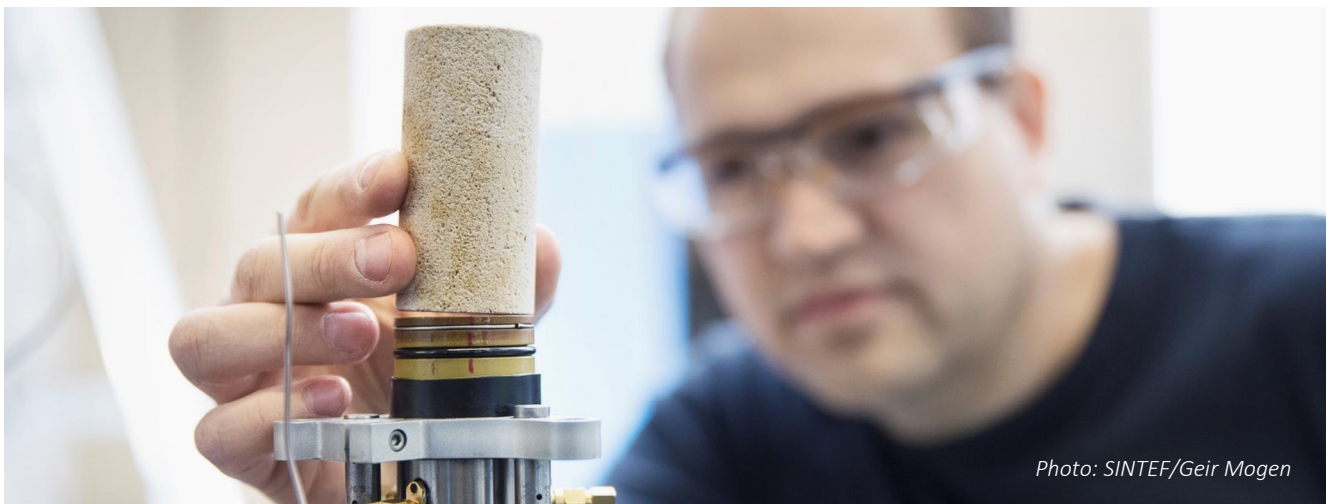


SINTEF Formation Physics Laboratory

- Advanced geomechanical tests

The Formation Physics laboratory is a specialized rock mechanics and rock physics laboratory well equipped for both advanced research- and standard tests.



TESTING RELEVANT FOR OVERBURDEN

Rock Physics

- Overburden characterization for improved seismic resolution
- Characterization of ultrasonic- and mechanical anisotropy
- Dynamic measurement from low (Hz) to ultrasonic frequency

Borehole stability

- Simulated drilling operations in hollow cylinder tests
- Drilling fluid sensitivity
- Specialized tests on small samples (cavings)

Creep

- Triaxial and oedometer creep tests
- Permanent barrier tests with hollow cylinder
- Screening tests on small samples

TESTING RELEVANT FOR RESERVOIR CONDITIONS

Solids production

- Hollow cylinder tests with radial fluid flow (brine/oil/gas)
- Simulation of production conditions

Special stress paths

- Uniaxial strain condition with radial permeability measurement, at reservoir stress conditions
- Thermal effects at injector wells

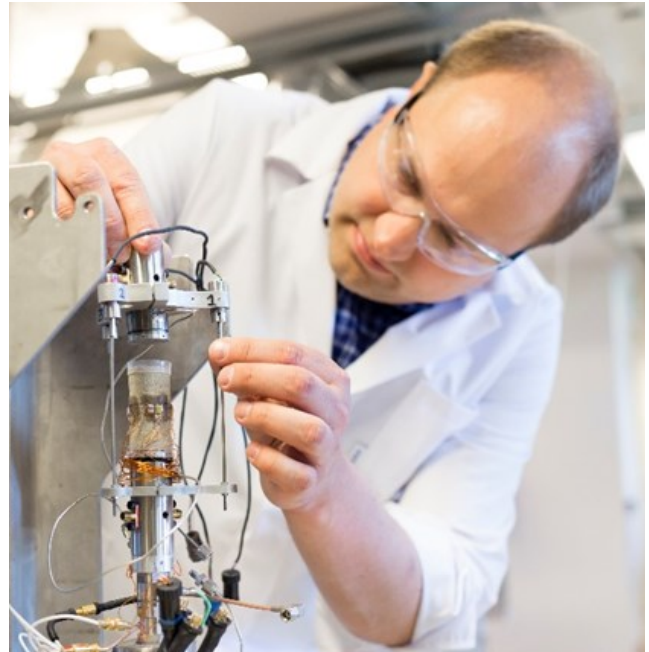
Uniaxial loadframes (10 kN, 50 kN and 300 kN)

Our flexible and versatile test systems can easily be tailored for a variety of configurations. We build on 25 years of experience designing, operating and interpreting results.

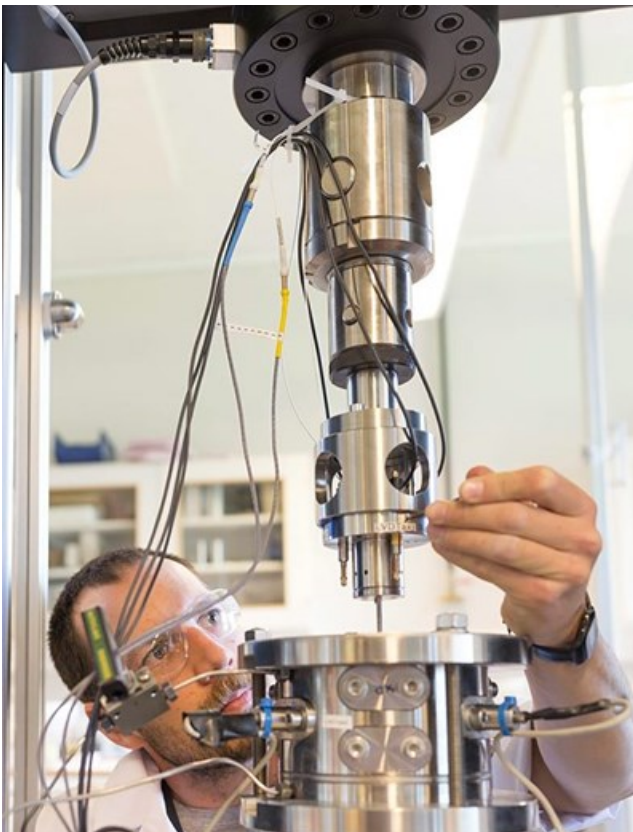
- Uniaxial compressive or tensile tests
- Small sample triaxial compression tests
- Fracture characterization
- Low frequency setup
- 300 °C temperature chamber (on 50 kN frame)

APPLICATIONS

- Index property characterization
- Strength, stiffness
- Fracture toughness



Sample mounting in the low frequency setup



Uniaxial loadframe of 300 kN instrumented for formation reinforcement testing

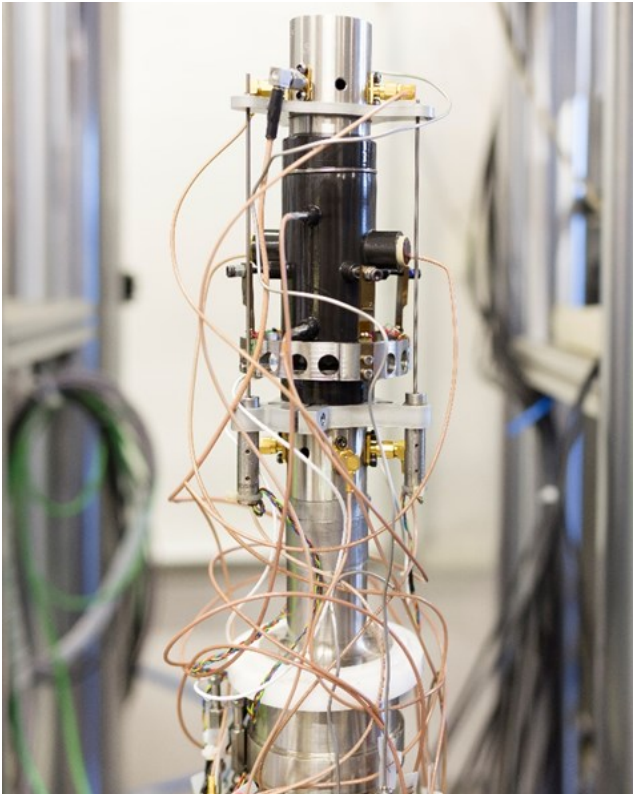
LOW FREQUENCY MEASUREMENTS

Fitted in a pressure vessel with full static and dynamic test configuration

- Confining and pore pressure up to 70 MPa
- Axial and radial static deformation (lvdt's and cantilever)
- Internal static loadcell
- Axial P- and S-wave ultrasonic measurements
- Piezo actuator (Hz – kHz range)
- 3 nm- 60 mm deformation
- Dynamic quartz loadcell
- Direct measurements of dynamic axial– and radial strain

Triaxial loadframes (250 kN and 2.7 MN)

Our flexible testing setups allow us to study the mechanical and dynamic response at in-situ conditions.



Sample prepared for anisotropic ultrasonic velocity test.

APPLICATIONS

- Ultrasonic anisotropy linked with static anisotropy simulating stress paths in reservoir overburden for improved 4D resolution
- Strength anisotropy characterization for borehole stability
- Hydraulic fracture propagation and location through acoustic emission
- Reservoir pore volume compressibility due to production
- Reservoir response to fluid injection and thermal gradient

TRIAXIAL TESTS

- Compression or extension testing
- Currently configured with 220 kN load cells
- 65 MPa and 140 MPa confining and pore pressure capacity
- 7 channel ultrasonic transmission / 20 ch. AE
- 200 °C max. temperature (175 °C long term)
- Standard sample diameters
 - 15 mm
 - 25.4 mm
 - 38.1 mm
 - 50.8 mm
- True triaxial setup for 70 mm cubes
- MTS Flextest control system



Samples from shale and chalk tested for tensile strength.

Hydrostatic pressure vessels

Unique capabilities for hollow cylinder test in terms of size, functionalities and flow conditions; both for reservoir and overburden conditions. New True Triaxial system arriving late 2016, expanding our existing hollow cylinder test capabilities with larger size and true triaxial conditions.

- Up to 200 mm diameter samples and 200 mm length
- 100 MPa confining pressure capacity
- Max. temperature 100 °C
- Flowrate up to 4 l/min @40 MPa (brine/oil)
- Radial gas flow (compressed air) @1MPa
- Hollow cylinder for formation damage tests



SINTEF research scientists observing shale samples after P&A testing

SHALE TESTING FOR P&A

- Screening tests for creep characterization
- Sensitivity response in shale to pressure and temperature
- Response to changes in surface chemistry
- Measurement of thermally induced plastic deformation with hollow-cylinder samples
- Quantification of zonal isolation through direct permeability measurements



Post-test photograph of sandstone hollow cylinder sample

HOLLOW CYLINDER TEST WITH RADIAL FLUID FLOW

Able to measure solids production during failure

- Sample size (OD) up to 200 mm
- Separate setup for 100 mm and 132 mm (OD) for field cores
- 20 mm diameter center hole
- Strain sensor in borehole to detect local failure
- Continuous monitoring and measurement of produced solids

Photo: Thor Nielsen /SINTEF