Small-scale Reservoir Stimulation Experiments in the Deep Underground Laboratory at the Grimsel Test Site

SCCER DUG Lab Team: Valentín Gischig, Joseph Doetsch, Mohammadreza Jalali, Claudio Madonna, Florian Ammann
Swiss Competence Center for Energy Research - Supply of Energy (SCCER-SOE), ETH Zurich, Switzerland.

Abstract

As a response to the Swiss government decision of banning out nuclear power by 2034, research and development in GeоЕnergy has become a major topic in the Swiss energy research. As part of the work-package one of the newly-founded Swiss Competence Centre for Energy Research - Supply of Energy (SCCER-SOE), we are currently planning a small-scale stimulation experiment in the Grimsel Test Site (GTS) - the rock laboratory dedicated to research on natural resource deposits and run by NAGRA. The granite rock mass at the GTS has similar characteristics to those expected at potential enhanced geothermal system (EGS) sites in the deep underground (ca. 4-6 km) of the Swiss Plateau, and thus can act as a proxy for potential future EGS sites.

The objectives of the experiment are to explore:
1) the interaction of hydro-fractures with the natural fracture system;
2) permeability and connectivity enhancement resulting from hydro-fracturing and hydro-fracturing;
3) stress and pressure changes associated with stimulation and different stimulation procedures.
4) induced seismicity characteristics during different stimulation procedures.

The GTS rock laboratory provides favourable conditions for such an experiment, because low fracture density and the wealth of information available from previous experiments allow construction of a near-deterministic rock mass model. Hence, the small scale and clear

Research Goals

Obtain a detailed understanding of processes associated with hydraulic stimulation of a natural fault
- Permeability and hydraulic connectivity before and after stimulation
- Changes of rock mass characteristics due to stimulation
- Stress field and stress changes around a stimulated fault
- Spatial and temporal evolution and scaling of induced seismicity
- Evolution of fault dilation and pressure distribution during injection
- Heat exchanger properties before and after stimulation

Develop and test novel characterization and monitoring methods
- Hydraulic characterization: hydraulic tomography based on heat tracer and acoustic tracer tests
- 3D dilatancy and pressure monitoring in the injection interval (SIMFIP probe)
- High resolution strain and stress monitoring
- Multi-scale and multi-sensor-type seismic monitoring
- Geophysical-imaging: new methods for 3D joint inversion and borehole reflection processing

Create a test and benchmark data set for new numerical methods for reservoir simulation
- Constrast physical concepts for fast THM coupling
- Test bed for near-real-time reservoir simulators
- Test case for near-real-time seismic hazard assessment tools (advance/adaptive traffic light system)

Demonstration project for a fault stimulation at low seismic hazard

Pre-experiment investigations (Phase 1): Geological model, stress field characterization

Currently available stress field estimates:
- Slip tendency analysis
- Fault reactivation pressure is lower if a incide towards SW
- Fault reactivation pressure is lower if a incide towards SW
- Fault reactivation pressure is lower if a incide towards SW
- Fault reactivation pressure is lower if a incide towards SW

Goal:
- Measure 'far-field' stress (20 - 30 m away from faults)
- Systematic stress changes associated with faults
- Estimating shear stress at a target faults.

A combination of:
- Overcoring with USBM probes
- Overcoring with CSIRO-HI probes
- Hydro-fracturing (HF)
- Hydraulic test of pre-existing fractures (HTPF, if possible)

Seismic monitoring with fault-scale network:
- Test and optimize instruments and network geometry
- In-situ calibration of fiber-optic sensors
- Derive orientation of hydro-fractures for orientation of injection

Faults:

Goals:

- Measure hydraulic conductivity before stimulation
- Measure 'far-field' stress (20 - 30 m away from faults)
- Systematic stress changes associated with faults
- Estimating shear stress at a target faults.

A combination of:
- Overcoring with USBM probes
- Overcoring with CSIRO-HI probes
- Hydro-fracturing (HF)
- Hydraulic test of pre-existing fractures (HTPF, if possible)

Seismic monitoring with fault-scale network:
- Test and optimize instruments and network geometry
- In-situ calibration of fiber-optic sensors
- Derive orientation of hydro-fractures for orientation of injection

Results will guide final design of stimulation experiment

Input for pre-experimental seismic hazard and risk study.

Stimulation experiment (Phase 2)

Instrumentation:
- Two injection boreholes (SIMFIP® probe)
- Tiltmeters
- Axial strain (Fibre-optic systems, FBG, DSS)
- Stress cells CSIRO-HI
- Geophysical-imaging boreholes (GPR, activeseisms)
- Passive seismic sensors (piezo-sensors, accelerometers)
- Temperature sensors (Thermistors in placed intervols, DTS®)
- Pressure sensors in permanently installable hydraulic packers

Workflow

Pre-stimulation phase:
- Installation multi-scale seismic network:
  - Regional scale (Grund surface)
  - Rocklab scale (Tunnel*excavation boreholes)
- Drilling of boreholes
- Installation of permanent monitoring components (grouted components):
  - Stress cells
  - Fiber-optic systems
  - Reservoir scale seismic network
  - Permanent hydraulic packers

Characterization of stimulated reservoirs:
- In-situ calibration
- Stress gauges
- Pressure gauges

Stimulation phase:
- Circulation experiments:
  - Reservoir response to fluid temperatures
  - Reservoir response to fluid temperatures
  - Solvent tracer test

- Characterize stimulated reservoirs:
  - Reservoir response to fluid temperatures
  - In-situ calibration

- Repeat with different stimulation protocols

References


