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Demonstration of soft stimulation treatments of geothermal reservoirs

Lessons learnt: Hydraulic Stimulation treatments

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WP 5 Key points and tasks

Key points of WP5 « Demonstration cyclic hydraulic and multi stage treatments »

Demonstration of soft stimulation in Pohang (Korea) and Geldinganes (Iceland)
Application of conventional as well as advanced seismic traffic light systems
Mitigation measures by application of cyclic soft stimulation and zonal isolation of well intervals (multi-stage stimulation)

Task 5.1 Lab testing of individual completion elements required to segment EGS reservoir section

Task 5.2 Fibre-Optics

Preparatory work for Task 5.5

Task 5.3 Proof of concept of cyclic treatment by laboratory hydraulic fracturing under X-ray CT environment

Task 5.4 Demonstration at the sites in Pohang and Geldinganes

Task 5.5 Demonstration at the underground laboratory in Bedretto

Substitute of the Haute-Sorne site

Lessons learnt from laboratory tests

Poster of Cheng et al. (China University of Petroleum, Beijing)

- Frequency dependence of cyclic shear friction showed that high frequency normal force stimulates the shear slip with a lower frictional coefficient of granite fractures
- High frequency shear friction promotes jumping shear and fatigue failure to create finer powders that lubricate the shear slip

Results from KICT laboratory experiments (not shown at the Poster session)

- Cyclic hydraulic fracturing (CHF) generally reduces the Breakdown Pressure by ~ 20% compared with continuous injection.
- Maximum amplitude of acoustic emission during CHF is reduced by an average of 13.7 dB.
- CT observations show that CHF tends to produce more complex and branched fractures
- The average values of maximum aperture of hydraulic fractures and injectivity are smaller for CHF samples than those for conventional HF samples.

Lessons learnt from field tests in Pohang

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Poster of Park et al. (Seoul National University)

First stimulation in PX-2:

- Stimulation mechanism can be interpreted as prevailing hydraulic jacking, or a transition from hydraulic fracture extension to dominant hydraulic jacking

- Maximum flow rate: 46.8 L/s
- Maximum wellhead pressure: 89.2 MPa.
- Total injected volume:1970 m^3
- Largest seismic event: ML 1.7

First stimulation in PX-1:

- Stimulation mechanism can be interpreted as a combination of shear dilation and hydraulic jacking

- Maximum flow rate: 18.0 L/s
- Maximum wellhead pressure: 27.7 MPa
- Total injected volume: 3907 m^3
- Largest seismic event: ML 2.2

Hydro-mechanical simulation results

- Early pressure histories in both wells were successfully modeled by the coupled hydro-mechanical processes.
- PX-2 model captured the distinct pressure response around 67 MPa in Stages I and II
- PX-1 model reproduced breakdown pressure at 16 MPa in Stage I

Pohang (cont'd)

Poster by Farkas et al. (GFZ)

- Modelling second PX-1 stimulation.
- Demonstration of cyclic soft stimulation.

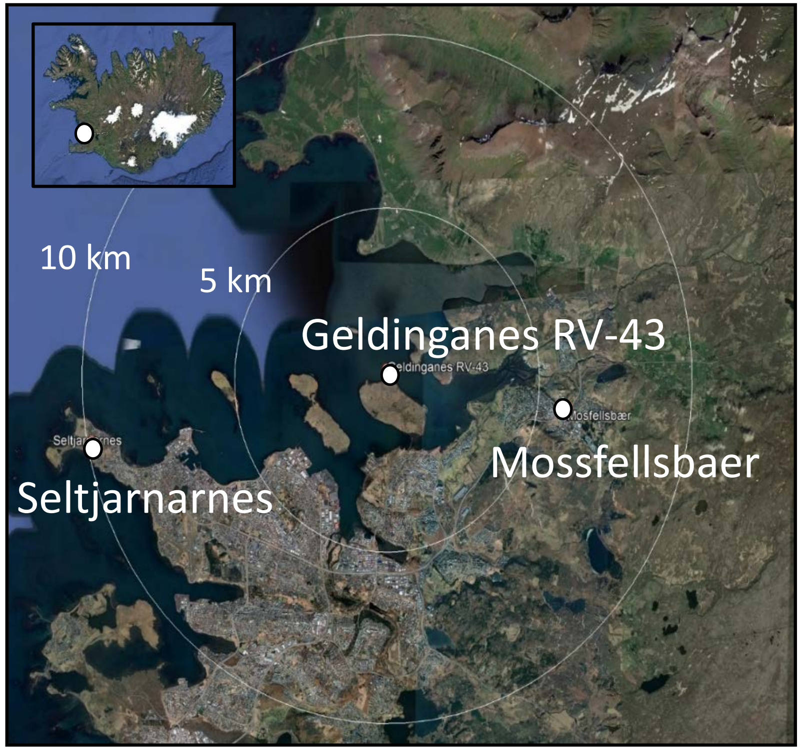
- Maximum flow rate: 10 L/s
- Maximum wellhead pressure: 23 MPa
- Total injected volume: 1756 m^3
- Largest seismic event: Mw 1.9

- History match by partitioning the treatment into separate periods.
- The hydraulic aperture evolution is typical of hydraulic fracturing. Plane P1 is favorably oriented for hydro-shearing with permanent increase in aperture.
- Permeability increases through opening of plane P1.
- Extent of direct pore pressure difference of >0.01 MPa is approx. 180 m in the direction of the shortest possible distance to the plane P2 along plane P1 (half way to P2).

Lessons learnt from field test at Geldinganes, Iceland

- **Zonal isolation with open hole packers and borehole integrity problems is challenging in "old" wells.**
- **Injectivity and productivity of well RV-43 is pressure dependent and was improved**
- **Workflows for seismic risk analysis and –management demonstrated (quantitative risk assessment, real-time monitoring, TLS, ATLS, cyclic injection)**
- **New wells should be drilled towards NNW to intersect these fracture systems**

→ Hydraulic stimulation can be an efficient and safe method for productivity improvement of geothermal wells in Reykjavik



St1 Deep Heat Project: Hydraulic stimulation at 5-6 km depth in crystalline rock, hydraulic properties and lessons learnt

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- two deep wells extending to 6.2 - 6.4 km depth, located in Espoo, southern Finland
- Production of hot fluid at about 100° C to be re-injected at 50° C
- In 2018 about 18,000 m^3 of fresh (tap) water was injected into OTN-3 in five 100-200 m long stimulation stages
- Hydraulic conductivity increased to about 10^{-8} m/s - 10^{-7} m/s at well head pressures of 70- 90 MPa
- low-pressure conductivity appears to be of the order of $5{\cdot}10^{-11}$ m/s
- Pressure connection between both wells confirmed

Lessons learnt from Bedretto Underground Laboratory for Geoenergies (preliminary results)

Main outcomes from test stimulation January/February 2020:

- Monitoring system worked well
- Natural fractures are not conductive, first hydrofracturing treatment necessary.
- Injectivity increased during test stimulation in February 2020

Results from hydraulic testing in September and October 2020

- Cross-borehole connection was observed.
- This cross-borehole connection is not homogeneous all along the borehole length but it is concentrated in very specific segments.
- The most efficient connection between ST2 & CB1 is most likely along a fault zone around 288m MD.
- The two main structural sets are 1) NE-SE to EW and 2) N-S

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Liability claim

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