Frictional strength improvement of fractures in granitic geothermal reservoirs by chelating agent–driven selective mineral dissolution

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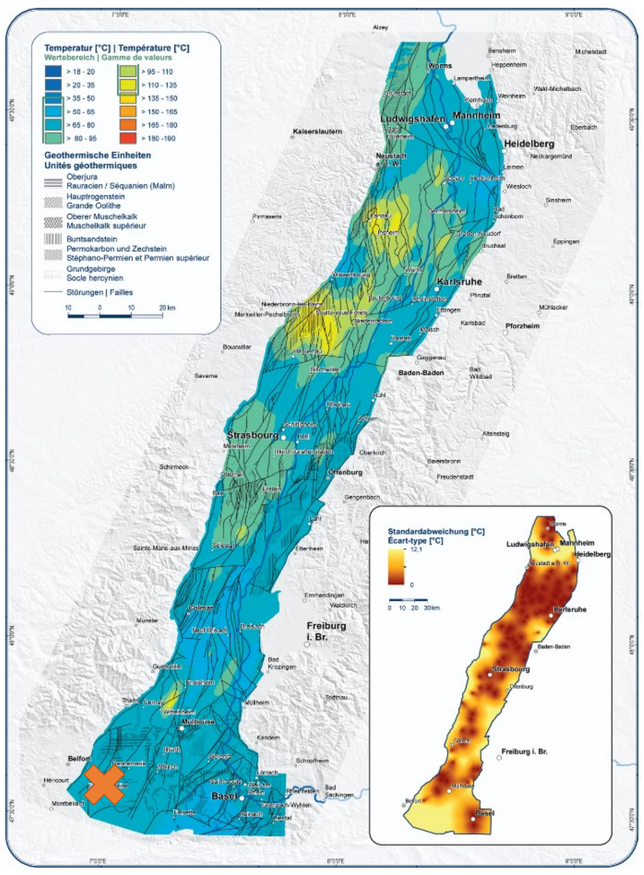


Temperature and Distribution of geothermal potential below 1500 mm (GeORG-Projektteam, 2013)

Objectives

- Improvement of stimulation methods in EGS in granitoids
- Sustainable fracture permeability
- Mitigate seismic events

Methods

- Hydraulic & Chemical stimulation
- Laboratory testing
  - Batch experiments
  - Shear-slip experiments

Achievement

Environmentally friendly stimulation applicable in granitic geothermal reservoirs:

Mitigation of risk of induced seismicity

Sample Material

Granite with general geothermal project context

Malsburg Granite from Malsburg-Marzell, Southern Black Forest

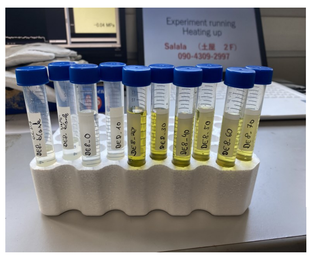
Minerals:
Qtz, Pl, Kfs, Bt, Cal

Fracture permeability:
1.53E-16 m² to 3.38E-18 m²

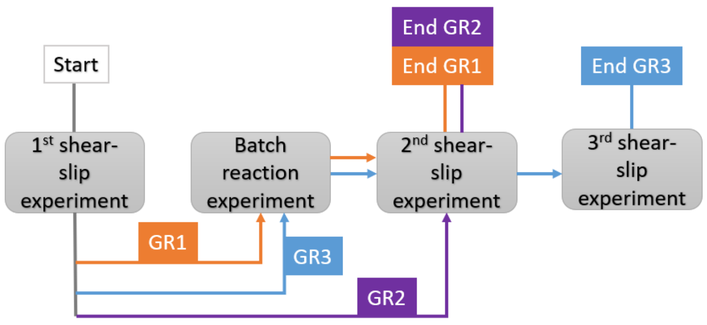
Fluid

Environmentally friendly chelating-agent:
L-glutamic acid, N,N-diacetric acid, tetrasodium salt ($C_9H_9NO_8Na_4$) (**GLDA**)

Injection Fluid: 20 wt.% GLDA acidified to pH 4 with HNO_3

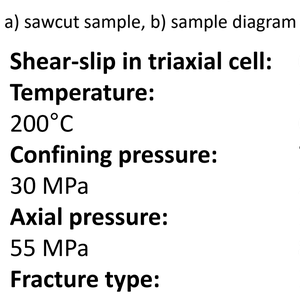


Experimental Design



Experimental set up for the Shear-slip experimental series

Experimental set up



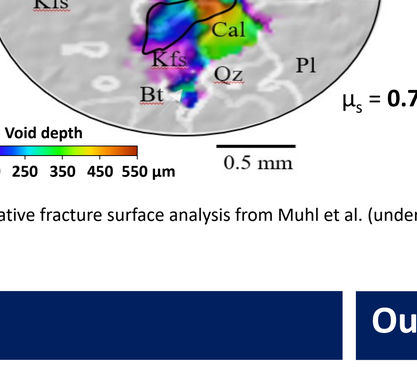
LVDT : Linear variable differential transducer
PT : Pressure transducer
TC : Thermocouple

a) sawcut sample, b) sample diagram and c) design of shear-slip experiment from Muhl et al. (under review)

Shear-slip in triaxial cell:	**Chemical alteration in autoclave:**
Temperature:	**Fluid:**
200°C	GLDA of 20 wt.%, pH4
Confining pressure:	**Temperature:**
30 MPa	200°C
Axial pressure:	**Duration:**
55 MPa	8 hours
Fracture type:	**Effluent sampling:**
sawcut	Every 2 hours

Results

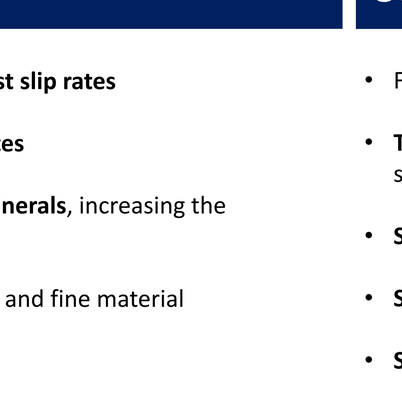
1st shear-slip



1st Shear-slip: rapid slip, intermediate to fast slip velocity = smooth surface

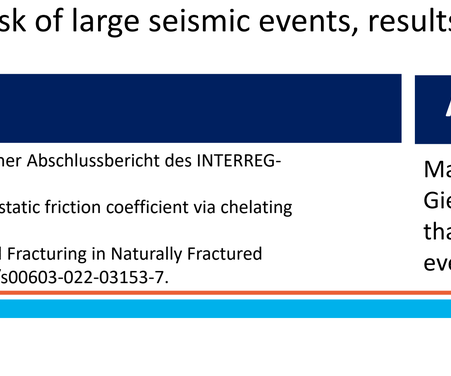
μ_s = **0.5** ± 0.05

Chemical alteration



Chemical alteration: surface roughening, dissolution of weak minerals (Bt, Cal)

2nd shear-slip

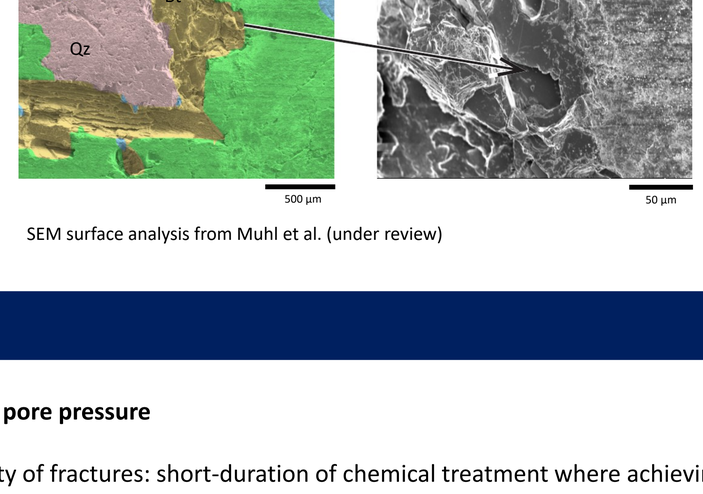


2nd Shear-slip and 3rd Shear-slip: slower slip, intermediate slip velocity, interlocking of asperities, precursory signals, fine material in voids

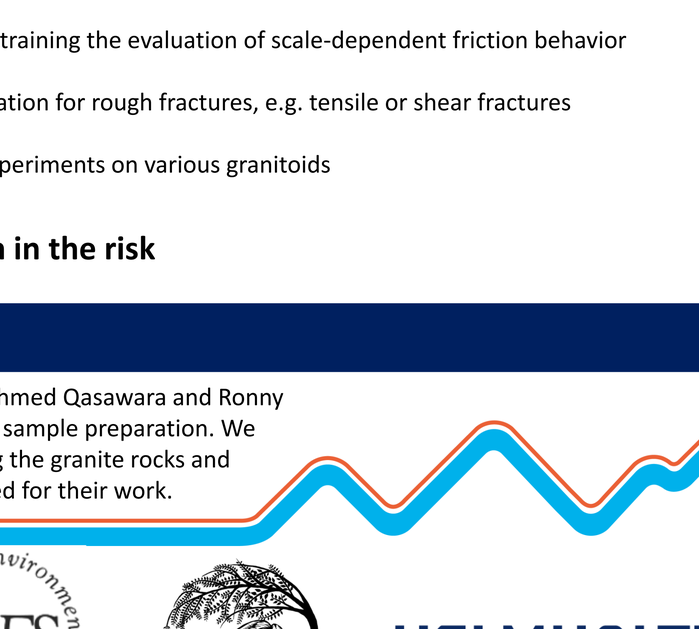
μ_s = **0.7** ± 0.05

Qualitative fracture surface analysis from Muhl et al. (under review)

Chemical treatment in Batch experiment over 8 h duration



Surface degradation after 2nd shear-slip



SEM surface analysis from Muhl et al. (under review)

Discussion

- μ_s of unreacted sawcut **0.5** ± 0.05 exhibiting faster dynamic slip with **intermediate to fast slip rates**
- reacted sawcut μ_s of **0.7** ± 0.05 exhibiting slower dynamic slip with **intermediate slip rates**
- Static friction coefficient (μ_s) increased due to the **removal of low friction coefficient minerals**, increasing the shear resistance
- **Dissolution induced-voids** results in rim spalling due to friction lead to increase of voids and fine material deposition in the voids

Outlook and Conclusion

- Fluid injection experiment with **varying pore pressure**
- **Time dependent effects** on sustainability of fractures: short-duration of chemical treatment where achieving sufficient permeability enhancement
- **Sample size** is comparatively small, constraining the evaluation of scale-dependent friction behavior
- **Smooth** sawcut fractures lack representation for rough fractures, e.g. tensile or shear fractures
- **Statistical improvements** by multiple experiments on various granitoids

No increase in the risk of large seismic events, results suggest a potential **reduction in the risk**

References

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- Pramudyo, E., Goto, R., Sakaguchi, K., Nakamura, K., Watanabe, N. (2023): CO2 Injection-Induced Shearing and Fracturing in Naturally Fractured Conventional and Superhot Geothermal Environments. Rock Mech Rock Eng 56 (3), 1663–1677. DOI: 10.1007/s00603-022-03153-7.

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