Lena Muhl | GFZ Helmholtz-Zentrum für Geoforschung

# UNLOCKING SUBSURFACE POTENTIAL: ENHANCED GRANITOID PERMEABILITY & FRACTURE BEHAVIOR VIA CHEMICAL STIMULATION BY CHELATING AGENTS

*Autoren: Lena Muhl[1,2,3,] Luis Salalá[1], Eko Pramudyo[1*], Jiajie Wang[1], Guido Blöcher[2,4], Ingo Sass[2,3], and Noriaki Watanabe[1]*

1 *Department of Environmental Studies for Advanced Society, Graduate School of Environmental Studies, Tohoku University, Sendai 980-8579, Japan.*

2 *GFZ Helmholtz Centre for Geosciences, Section 4.3: Geoenergy, Telegrafenberg, 14473, Potsdam, Germany.*

3 *Department of Geothermal Science and Technology, Institute of Applied Geosciences, Technical University of Darmstadt, Schnittspahnstraße 9, 64287 Darmstadt, Germany.*

4 *Department of Engineering Geology, Technical University of Berlin, 10587 Berlin, Germany*

Chemical stimulation is often proposed as a complement to hydraulic stimulation to enhance fracture permeability. Previous studies have shown that conventional acids (e.g., HF and HCl) may be less efficient at dissolving minerals far from the injection point. In addition, HCl-based stimulation has been reported to reduce the friction coefficient of granite fractures, increasing the potential for slip and induced seismicity. Recent advancements in environmentally friendly chelating agent-based chemical stimulation with N,N-bis(carboxymethyl)-L-glutamic acid tetrasodium salt (GLDA-Na4) enabled controlled mineral dissolution under acidic conditions. This research investigates the impact GLDA-Na4 on the frictional behavior and permeability of fractured German granitoids under representative high-temperature (150-200 °C) and high-pressure (15-55 MPa) geothermal reservoir conditions in the Upper Rhine Graben.

Laboratory experiments on artificially created fractures in cylindrical core samples included X-ray computed tomography (XCT) prior and after the experiment, as well as effluent analysis by inductively coupled plasma atomic emission spectroscopy (ICP-OES). The results demonstrate that GLDA-Na4 treatment induces selective mineral dissolution of Ca- and Fe-bearing minerals, such as biotite, hornblende and calcite. First, results presented permeability improvement, accompanied by a wormhole formation due to dissolution of a mineral vein identified by XCT. Moreover, biotite dissolution was observed which led to void formation and therefore wider fluid paths. It can be assumed that the combination of a fracture filled with Ca-bearing minerals and biotite being dissolved is a reason for the permeability enhancement. Second, experimental results demonstrated that the reactivity of the injected solution can be regulated by adjusting the pH, from 4 to 2, to achieve effective permeability enhancement at 150 °C and 55 MPa confining pressure.

Remarkable permeability enhancement was achieved by injecting a chelating agent solution into rocks with a shear fracture, improving connectivity through selective mineral dissolution and removal of fragmented minerals. This study provides evidence that fracture permeability can be remarkably improved under various pressure and temperature conditions. Third, frictional properties of saw-cut granites under initial conditions of 55 MPa axial stress and 30 MPa confining pressure at 150 °C before and after the chemical treatment revealed a static friction coefficient increase from 0.48 ± 0.03 to 0.62 ± 0.01, accompanied by a reduction in shear slip velocity, suggesting a reduced propensity for large seismic events. The treatment created a network of voids and asperities on the saw-cut surface leading to increased resistance to shear motion. These findings suggest optimized chemical stimulation protocols can modulate reservoir frictional response and improve flow characteristics, contributing to safer, more sustainable Enhanced Geothermal System (EGS) development. This work provides important insights for auditing stimulation designs and assessing the potential for induced seismicity and reservoir performance in high-pressure geothermal projects.