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Supporting Information for

In Situ Continuous Monitoring of Borehole Displacements induced by a Stimulated Hydrofracture Growth

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Contents of this file:

Additional Supporting Information (Files uploaded separately)

- Location_of_seismic_events.csv (time, location)
- Simfip_data.csv (time, flowrate, fluid pressure, normal displacement, shear displacement)

SIMFIP instrument

The SIMFIP has been used for several research experiments in mine-based environments (Guglielmi et al., 2015). Since 2017, further engineering of the SIMFIP increased the pressure conditions under which the SIMFIP can operate to 40 MPa. We report here the first application of this instrument to a hydrofracture monitoring in a deep stress field environment. The SIMFIP has a 0.2 m long and 0.1 m diameter pre-calibrated aluminum cage that is connected to two 0.25 m long elements that allow clamping both ends of the cage to the borehole wall (Fig. 1b). The raw data recorded by this instrument consist of 6 strain measurements performed with optical fiber Bragg gratings (FBG) that are mechanically clamped on the 6 wings of the deforming cage.

Figure S1. SIMFIP probe before deployment in borehole E1-I from the Sanford Underground Facility gallery 1478m depth.

Numerical Model Setting

The 3DEC code [Itasca Consulting Group Inc., 2013] is employed to represent a pre-defined 159°/40° oriented fracture by a vertical contact plane in an elastic medium (20 × 20 × 20 m, Fig. S2). Before injection, this plane is treated as intact rock (table S1). The principal stresses measured in situ at the depth of the experiment ($\sigma1 = 41.8$ MPa, $\sigma2 = 34$ MPa, $\sigma3 = 21$ MPa) are applied to the six boundaries of the model, and a 80 kPa/m horizontal stress gradient is set to calculate the thermomechanical stress perturbation caused by the nearby drift excavation (Fu et al., 2018). Our model allows for fluid flow only through the ruptured (either in shear or tension) parts of the predefined plane. The injection is applied in a local point source in the middle of the plane (E1-I in Fig. S2), and pressure increases in a few sub-contacts (i.e., triangular mesh elements) that are represented in an initially 0.6 m radius ruptured circular patch (Fig. S2). Outside of this circular patch, which is considered representative of the fracture initiated in step 1, sub-contacts must rupture for the hydrofracture to propagate. When a plane element is ruptured, fluid flow is calculated using the modified cubic law (Witherspoon et al., 1980), where the hydraulic aperture is dependent on the fracture deformation to account for the stress-dependent fracture hydraulic conductivity (Detournay, 1980).

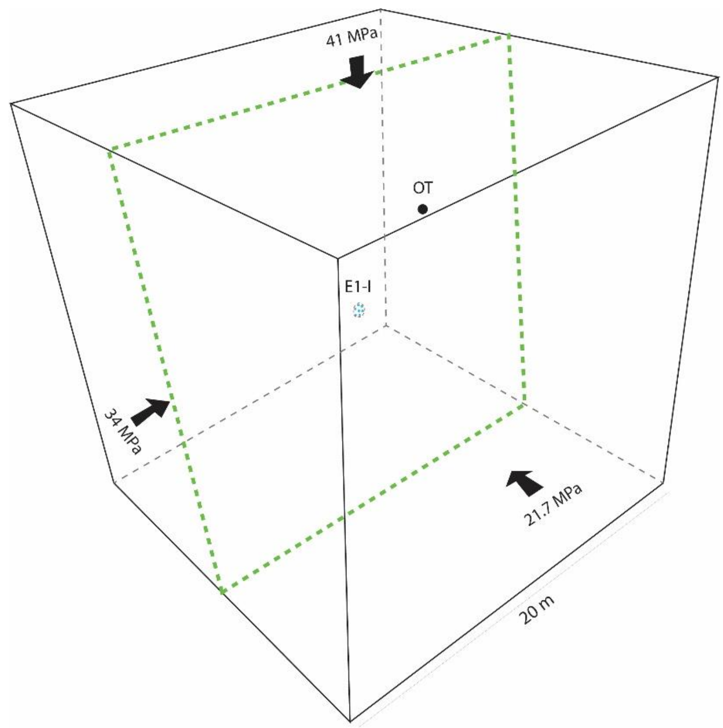

Figure S2. (a) Numerical Model setting. The green dashed line pre-figures the direction of propagation of the hydraulic fracture as it was deduced from the orientation of the field borehole displacements and induced seismicity. Injection is initiated at E1-I in a zone of this fictive plane that has been previously broken to figure the initial fracturing during stimulation step 1. That zone is about 1 meter diameter (green circles patch at E1-I).

Table S1. Model hydromechanical parameters for the hydraulic fracture and the intact rock.

Parameter	**Value**	**Units**
Bulk modulus of rock *(K)*	48.5	GPa
Shear modulus of rock *(G)*	24.5	GPa
Rock density (ρ_r)	2764	kg/m^3
Fracture elastic stiffness (k_n, k_s)	100, 43	GPa/m
Fracture cohesion/tensile strength	3/3	MPa
Fracture friction coefficient (μ_o)	0.72	(-)
Initial hydraulic aperture (b_{ho})	10	µm
Dilation angle (ψ)	12	Degree
Fluid Bulk modulus (K_w)	2	GPa
Fluid density (ρ_f)	1000	kg/m^3
Fluid viscosity (μ_f)	0.001	Pa.s
Stress (*Sh/SH/Sv*)	21.7/34/41.8	(MPa)