Geophysical Research Abstracts
Vol. 21, EGU2019-4569-1, 2019
EGU General Assembly 2019

Inducing shear slip in an underground laboratory: Workflow to constrain the full stress tensor demonstrated by application to the Bedretto Underground Laboratory

Ankush Singh (1), Xiaodong Ma (2), and Mark Zoback (1)

(1) Stanford University, School of Earth Sciences, Geophysics, Stanford, United States (ankushs@stanford.edu), (2) ETH, Zurich, Switzerland (xiaodong.ma@sccer-soe.ethz.ch)

Accurate characterization of the full in-situ stress tensor is necessary for deep underground experiments aiming to better understand shear stimulation. The relative magnitudes of the three principal stresses play an important role in site selection, experimental design and interpretation of monitoring data. The vertical stress (S_v) and minimum horizontal stress (S_{hmin}) can be constrained by characterizing the overburden and direct mini-frac measurements in vertical boreholes. The maximum horizontal stress (S_{Hmax}) is often more challenging to constrain due to lack of reliable direct measurement techniques. In this study, we demonstrate a general, integrated workflow to accurately constrain S_{Hmax} magnitudes in these settings by creating injection induced tensile fractures along deviated wellbores and show its proposed application to the experiments at the Bedretto Underground Laboratory.

Initial estimates of S_V and S_{hmin} for the Bedretto testbed were done by estimating the weight of granitic overburden and assuming a normal faulting frictional equilibrium. Since pore pressure around the excavations is likely to be depleted, we consider pore pressure realizations ranging from hydrostatic (10 MPa at 1 km depth) to severely depleted (2 MPa at 1 km depth). Using these input parameters, we have created forward models to compute injection pressures required to induce open-hole tensile fractures along all possible wellbore orientations using the Kirsch equations. These forward models are created for different realizations of S_{Hmax} as a function of S_V ranging from $0.8 \times S_v$ to $1.2 \times S_v$. Each model realization corresponds to a combination of S_{Hmax} and pore pressure with the other inputs remaining fixed. Based on these models we have identified *discriminant orientations*: well-bore orientations in which the failure observations are most dependent on S_{Hmax}, subject to the operational constraint of wellbore dip greater than 45 degrees. From the current models, we recommend two deviated wellbores both dipping at around 45-60 degrees and oriented along the S_{hmin} and S_{Hmax} azimuths. The modelling is an iterative process and will be updated once S_{hmin} measurements from a vertical well hydro-frac are available. Additionally, we plan to use absence and presence of borehole breakouts and knowledge of rock strength parameters to add further constraints on S_{Hmax}. The advantage with using tensile fractures instead of borehole breakouts is that they are nearly independent of lithology, as the range of tensile strength for rocks is very limited compared to compressive strength.

The presence of underground tunnels results causes stress perturbations in their immediate vicinity. We will present a finite element model for the induced thermal and poroelastic stresses caused by the presence of the hollow space to estimate the minimum distance from the tunnel wall that is required to adequately sample the far field stresses.

Finally, we demonstrate the impact of correctly determining the S_{Hmax} magnitude on the design of a shear stimulation experiment. We analyzed the shear slip potential for fractures of various orientations under different S_{Hmax} conditions. The results clearly show that depending on the objective of the experiment, knowledge of S_{Hmax} is required for site selection and experimental design.