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Hydraulic stimulation of transversely isotropic rock

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Rock mass fabric, associated anisotropy in mechanical properties, and pre-existing fractures are some of the prevalent factors affecting generation and propagation of hydraulic fractures. A suite of stimulation experiments were performed in the research mine Reiche Zeche, Freiberg, Germany, where silver veins were exploited in the past that penetrate a strongly foliated gneiss that also contains damage zones as well as joints. Accompanying laboratory experiments on gneiss samples prepared in different orientations relative to the foliation revealed substantial anisotropy in mechanical properties. Fracture toughness of the gneiss is significant and increases from about 1 to about 3 MPa $m^{0.5}$ for a change in direction of fracture propagation from along to across the foliation. Hydraulic fracturing experiments on cylindrical samples with an injection hole of 3 mm diameter yield an anisotropic hydraulic tensile strength exceeding 10 MPa. Furthermore, fracturing seemed to be controlled by strength anisotropy rather than stress anisotropy for stresses representative of the conditions at the mine, i.e., the induced hydraulic fractures occurred along foliation planes even in cases where substantially different principal stresses were applied.

Ten stimulation tests were performed in the injection well at the mine drilled with a diameter of 76 mm, an azimuth of NE, and a dip of $\sim$15° resulting in an average angle to the foliation of about 20 to 25°. The pressure record of each stimulation exhibited a distinct breakdown pressure corresponding to hydraulic tensile strengths of up to more than 10 MPa, i.e., similar values to the ones deduced from the laboratory experiments. The fracture traces identified from impression packer tests and borehole logs (before and after stimulation) agree well and revealed considerable variety in orientation. The majority of traces is subparallel to the borehole axis, but their dips vary between 20 and 80° with a number of them showing *en echelon* character. Shut-in and jacking pressures are consistent with a strike-slip regime, but the variability of fracture orientation might indicate a significant variability in the orientation and magnitude of local stresses. The observations are currently analysed in the light of fracture-initiation criteria for inclined boreholes penetrating an isotropic or a transversely isotropic medium.