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Long-period tilt-induced accelerations associated with hydraulic fracturing

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In 2015, several small scale hydrofracture experiments have been performed in situ from a horizontal borehole in a mine gallery in granitic rock. The hydrofracture experiments were monitored by a bundle of different near field sensors covering a broad range of frequencies (see Zang et al., Geophys. J. Int. (2017) 208, 790–813, doi: 10.1093/gji/ggw430).

We installed broad band sensors in the gallery close to the fracture experiments, and observed clear long period transients on the horizontal components, with timing and polarity correlated with the opening and closing of the fractures. We interpret the broadband signals as tilt-induced excursions. The broadband signals have been measured independent whether high frequency acoustic emission have been observed or not during the individual fracture experiments. They are thus an independent measure of the success of a hydrofracture experiment and the parameter of the newly formed cracks.

In this study we show that most tilt-induced long-period signals can be modeled by a rectangular crack with constant opening in an elastic full space, as first order approximation. From theoretical forward modeling, we proof that the tilt has a higher sensitivity to resolve the strike of the fracture than the displacement field. With this model, we retrieve the strike of the fractures from the tilt observed at a single sensor. The results indicate that the strike angles of the hydrofractures change systematically with the distance to the gallery wall, indicating a rotation of the principal stresses close to the free surface of the gallery. The rotation trend is similar to the one observed in previous hydrofracture experiments in mines.

We compare the strength of the modeled tensile cracks, i.e. opening times crack area, with the volume of the injected fluid, and discuss the general resolving power of tilt signals for source parameter fractures. The temporal evolution of the opening and closure of the fractures is discussed.