Fracture compliance estimation in crystalline rock masses from fullwaveform sonic data

Zhou, Zhenya[1]; Caspari, Eva[2]; Barbosa, Nicolás D.[1]; Greenwood, Andrew[2]; Holliger, Klaus[1]

1 Institute of Earth Sciences, University of Lausanne, Geopolis UNIL-Mouline, CH-1015 Lausanne, Switzerland; 2 Chair of Applied Geophysics, Montanuniversität Leoben, A-8700 Leoben, Austria.

The presence of fractures, which create fluid pathways and zones of weakness in their embedding background rock mass, is ubiquitous throughout the Earth's upper crust. Correspondingly, there is interest not only in the detection, but also, in the quantitative characterization of mechanical and hydraulic fracture properties for a wide range of applications throughout the geo-, environmental and engineering sciences. An important mechanical property is the compliance of fractures, as it quantifies the opening or closing of a fracture in response to pressure changes, which play a role for hydraulic stimulation experiments and induced seismicity. Seismic borehole methods, especially full-waveform sonic (FWS) data, have indicated their potential to infer the compliance of individual macroscopic fractures under in situ conditions. So far this has been achieved for a specific acquisition set-up of static FWS measurements which are characterized by a very high data quality. In this study we evaluate the potential to estimate fracture compliances from standard, production type FWS data in a crystalline rock mass. To test the robustness of fracture compliance estimation from production type data with respect to the data quality and other factors of influence e.g., heterogeneity of the background rock mass we perform a set of numerical simulations. The impact of different signal-to-noise ratios, i.e. data quality, on fracture compliance estimates is then evaluated by contaminating the synthetic FWS data sets with scaled noise traces extracted from standard, production-type field data. These FWS field data sets were acquired before and after a mini-frac hydraulic stimulation campaign in a granitic rock mass. In a next step we estimate from the field data compliances of natural and small man-mad fractures created by the stimulation. The estimates are sufficiently robust for the natural fractures, and are still feasible for generally much smaller man-made fractures. This in turn may shed some light on the differences between these two fracture types.