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# Characterizing fractures and shear zones in crystalline rock using anisotropic seismic inversion and GPR imaging

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Understanding the natural or artificially created hydraulic conductivity of a rock mass is critical for the successful exploitation of enhanced geothermal systems (EGS). The hydraulic response of fractured crystalline rock is largely governed by the spatial organization of permeable fractures. Defining the 3D geometry of these fractures and their connectivity is extremely challenging, because fractures can only be observed directly at their intersections with tunnels or boreholes. In the framework of an in-situ stimulation experiment at the Grimsel Test Site, a detailed rock mass characterization was carried out, combining geological and geophysical methods. While geological observations from tunnel mapping, core- and geophysical borehole-logging are reliable, the obtained data could just be interpolated between tunnels and boreholes. The geophysical surveys, including ground-penetration radar (GPR) imaging and tunnel-tunnel seismic tomography were able to image shear and fracture zones throughout the experimental volume. Clear GPR reflections up to a distance of 30 m from the tunnels allow to define the geometry of tunnel-mapped shear zones in the center of the experimental volume. Anisotropic traveltime inversion of tunnel-tunnel seismic data reveals fracture zones as low velocity zones and ductile shear zones as areas of increased seismic anisotropy. It is thus possible to characterize both type and geometry of shear and fracture zones, which is important for the planned rock stimulation. Combining the GPR and seismic results with the geological information, the geological model could be significantly improved, demonstrating the potential to characterize even subtle geological features in 3D.