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Physical property characterization of a damage zone in granitic rock – Implications for geothermal reservoir properties

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Geothermal energy offers a viable alternative to mitigate greenhouse gas emitting energy production. A tradeoff between less expensive drilling costs and increased permeability at shallow depths versus increased heat production at deeper depths stipulates the economic energy potential of a given reservoir. From a geological perspective, successful retrieval of geothermal energy from the subsurface requires sufficient knowledge of the structural and stratigraphic relationship of the target formations, which govern the thermal conditions, physical properties, and fluid flow properties of reservoir rocks. In Switzerland, deep basement rocks (∼5 km) with fluid conducting damage zones and enhanced fractured systems stimulated by hydraulic shearing are seen as a potential geothermal reservoir system. Damage zones, both natural and induced, provide permeability enhancement that is especially important for creating fluid conductivity where the matrix permeability is low.

This study concentrates on characterizing the elastic and transport properties entering into a natural damage zone penetrated by a borehole at the Grimsel underground research laboratory. The borehole drilled from a cavern at 480 m below ground surface penetrates approximately 20 m of mostly intact Grimsel granodiorite before entering the first phyllosilicate-rich shear zone (∼0.2 m thick). The borehole intersects a second shear zone at approximately 23.8m. Between the two shear zones the Grimsel granodiorite is heavily fractured. The minimum principle stress magnitude from in-situ measurements decreases along the borehole into the first shear zone. Two mutually perpendicular core samples of Grimsel granodiorite were taken every 0.1 m from 19.5 to 20.1 m to characterize the physical properties and anisotropy changes as a gradient away from the damage zone. Measurements of ultrasonic compressional (Vp) and shear (Vs) velocities at 1 MHz frequency are conducted at room temperature and hydrostatic pressures ranging from room conditions up to 260 MPa. The same cores are used to measure permeability using the transient step method at various confining pressures (up to 20 MPa). The results are contextualized with respect to distance from the shear zone and the physical properties are qualitatively related to the in-situ stress decrease entering the shear zone that is measured in the borehole. The measurements provide a proxy for changing permeability and elastic gradients near shear zones in low matrix permeability geothermal reservoirs.