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Quantification of rock heterogeneities by structural geological field studies combined with laboratory analyses

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Heterogeneous rock properties in terms of layering and complex infrastructure of fault zones are typical in sedimentary successions. The knowledge of in-situ mechanical rock properties is crucial for a better understanding of processes such as fracturing and fluid transport in fractured reservoirs. To estimate in situ rock properties at different depths it is important to understand how rocks from outcrops differ from rocks at depth, for example due to alteration and removal of the overburden load. We aim at quantifying these properties by performing structural geological field studies in outcrop analogues combined with laboratory analyses of outcrop samples and drill-cores. The field studies focus on 1) fault zone infrastructure and 2) host rock fracture systems in two different study areas with different lithologies, the North German and the Bristol Channel Basin. We analyse quantitatively the dimension, geometry, persistence and connectivity of fracture systems. The field studies are complemented by systematic sampling to obtain the parameters Young's modulus, compressive and tensile strengths and elastic strain energy (also referred to as destruction work) from which we estimate rock and fracture toughnesses.

The results show that in rocks with distinctive layering fractures are often restricted to individual layers, that is, stratabound. The probability of arrest seems to depend on the stiffness contrast between two single layers as well as on the thickness of the softer layer. The results also show that there are clear differences between fault zones in the different lithologies in terms of damage zone thicknesses and fracture system parameters. The results of laboratory analyses show that the mechanical properties vary considerably and for many samples there are clear directional differences. That is, samples taken perpendicular to layering commonly have higher stiffnesses and strengths than those taken parallel to layering.

We combine the results of laboratory analyses and field measurements to specify the mechanical heterogeneities of typical sedimentary rocks and of the mechanical units of fault zones. The results from drill-core sample analyses are then compared with the results from the outcrop samples. Another approach is to analyse how rock mechanical properties correlate with petrographic properties (e.g., mineral content, cementation, fabric) to use this knowledge to extrapolate the data to depth.

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