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Influence of fault zones on fracture systems in sedimentary geothermal reservoir rocks in the North German Basin

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In the North German Basin many sedimentary rocks have low matrix porosities so that the increase of permeability due to fault zones can be exceedingly high. For different lithologies, such as sandstones and limestones, however, fault zones have dissimilar effects on the fracture systems therein. That is, the deformation of sandstone in a fault zone differs from that in limestone so that the changes of the fracture systems because of the fault zone development are others. Understanding this opposing behaviour is important to better assess the development and propagation of faults. This allows better evaluation and permeability estimates of potential fault-related geothermal reservoirs in sedimentary rocks of the North German Basin.

Fault zones commonly consist of two mechanical units: the fault core and the damage zone. The fault core is composed of brecciated material and usually has a small permeability, when the fault is not active (slipping). In contrast, in the damage zone, the mechanically stressed area, the fracture density normally increases and therefore the permeability is higher than in the host rock.

Here we present results of structural geological field studies on the geometry and architecture of 51 outcrop-scale fault zones of various types in sedimentary rocks of the North German Basin. We measured their orientations and displacements, the thicknesses of their fault cores and damage zones, as well as the fracture densities and geometric parameters of the fracture systems therein. Our field studies show that in sandstones and limestones especially the damage zones are built-up differently. Particularly in limestones, fractures associated with fault zone development are numerous so that the fracture densities in the damage zones are high. In sandstones the effects of the fault zones on the fracture systems are much lower. Therefore we discuss the fault-zone caused changes in the damage zones of fracture densities, orientations, openings and lengths compared with the host-rock fracture systems separately for sandstones and limestones. We further analyse variations in fault-core and damage-zone width for different orientations of the fault zones and the fault displacements. The data indicate that fault zones have greater effects on the fracture systems in limestones than in sandstones. This is manifest in a larger increase of the fracture densities, fracture openings as well as the fracture lengths in limestone damage zones. The damage zone widths compared with the displacements are also higher than in sandstones. For limestones it seems that there is also a relation between the fault damage zone width and the orientation of the fault zone associated to regional fault structures. Small faults with parallel orientation to the major regional fault system appear to develop wider damage zones than those with a high angle to the major fault system.

The results indicate that the positive effects of fault zones on fracture permeability are more pronounced in limestones than in sandstones. Our results, however, do not yet allow general and final statements on the geothermal potential of fault-associated geothermal reservoirs in limestones or sandstones. Nonetheless structural geological field studies of fault zones in outcrop analogues help to improve our knowledge of fault-zone evolution and structure. To improve permeability estimates of a fault-associated geothermal reservoir in a specific stratigraphy and lithology it is necessary to perform further field studies in outcrop analogues of the geothermal reservoir rocks in question.