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Fault zone architecture and fracture systems in sedimentary rocks of the North German Basin

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It is well known that fault zone architecture varies much for different lithologies, for example, for sandstones and limestones, which both are typical sedimentary rocks. Understanding this differing behaviour is important to better assess the development and propagation of faults. This leads to a better evaluation and estimation of the permeability in potential fault-associated fluid reservoirs such as of petroleum, gas, geothermal, and groundwater.

Here we present results of structural geological field studies on the geometry and architecture of 51 m-scale fault zones of different types in Mesozoic sedimentary rocks of the North German Basin. The field studies were performed predominantly in 1) limestone/marl-stratifications (Upper Cretaceous, Upper Jurassic and Middle Triassic) and 2) sandstone/claystone-stratifications (Lower Cretaceous and Lower Triassic). We measured the fault-zone 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. We also analysed the effects of rock heterogeneities, particularly stiffness variations between layers (mechanical layering) on the propagation of natural fractures and fault zones.

From the data we determined the structural indices of the fault zones (ratio of damage zone and fault zone width). By their nature structural indices can obtain values from 0 to 1; the values having implications for fault zone permeability. An ideal value of 0 would mean that a fault damage zone is absent. An index of 1 would imply that there is practically no fault core and the fault zone permeability is entirely controlled by the fractures within the damage zone. Our measurements show that damage zones in limestones are commonly thicker than those in sandstones, and fracture densities therein are higher. The directions of predominant joint strike correspond to the orientations of the fault zones in most cases. Particularly in limestones this effect is very clear. In the host rock, both in limestone-marl- as well as in sandstone-claystone-stratifications, mechanical layering has great effects on fracture propagation. Already thin layers (mm- to cm-scale) of low stiffness – here marl or claystone – seem to suffice to change the local stress field so that it arrests many joints, leading to stratabound fractures. In the damage zones the effects of layering on fracture propagation are considerably lower. Therefore the number of fractures that are non-stratabound and connect several layers is raised so that an increase of the fracture-related permeability is probable.

Putting all these information together we see that fracture systems in limestones are much more affected by fault zones than in sandstones. In terms of fault-related fluid reservoirs our data suggest that the increase of reservoir permeability due to fault zones is much larger in limestone/marl- than in sandstone/claystone-stratifications.