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Quantification of Fractured Carbonate Rock Characteristics Using Structural Geology, from Fault Zone to Microscale

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ABSTRACT

Carbonate reservoirs are of major interest for the petroleum industry since they hold more than 50% of the world's hydrocarbon reserves. Research over the last decades showed that the properties of such reservoirs are often controlled by deformational processes, like faulting and fracturing, which produce the majority of reservoir porosity and permeability. Such reservoirs contain complex internal texture with a lot of heterogeneities that are often difficult to understand in reservoirs not exposed to the surface. Detailed investigation on outcrop analogous can solve this problem, and lead to a better understanding of reservoir permeability. Therefore we investigated carbonate reservoir rocks, from outcrop to nanometer scale, in limestone and dolomite fault zones in the Northern Calcareous Alps, Austria. We selected sinistral strike-slip fault zones that were formed during the Miocene lateral extrusion of the Eastern Alps at shallow crustal depth. These fault zones were selected because they belong to the well-studied Salzach-Ennstal-Mariazell-Puchberg fault system. This helps to understand the link between fault zone formation and deformation process.

Zones of different reservoir properties were distinguished in detailed structural fieldwork, in the fault core and the damage zone. Used techniques include fault rock classification, fracture network characterization, and fracture density analyses. This field based assessment was augmented by porosity and permeability measurements in the laboratory. Additionally, thin-sections have been investigated with optical and Cathodoluminescence microscopy, as well as electron microscopy using backscattered electron imaging.

The results show that by trend fault zones in dolomite lack a distinct, single fault core and masterfault, but instead show multiple branching, minor fault cores that interlock in the 3D geometry of the outcrop. Fault zone formation in dolomite is accompanied and influenced largely by fluid interaction producing large volumes of cemented host rock. In contrast, fault zones in limestone have a well-defined narrow masterfault with cataclastic fault rocks.

Fracture measurements support the fact that intensity and distribution of connected fractures are the controlling factor in terms of fault zone permeability. Measured porosity and permeability data in fractured host rock shows increasing values towards the fault core, with highly fractured rocks next to the fault core (up to 5% fracture porosity) and an increase of permeability towards the fault core (up to about 25 mD measured with a minipermeameter device). Fault rocks in fault cores have an average porosity of 4-5% and an average permeability of 10-20 mD. These values contrast from the protolith with average porosities of 1% and average permeabilities of about 10 mD.

Next to research carried out on reservoir analogues, analyses are performed on core material of narrowly fractured dolomites, originating from producing reservoirs in the Vienna Basin, Austria. These rocks bear similarities to the previously described material. Micro-Computed Tomography (μCT) is used to visualise fracture networks in plug-sized samples, and to quantify and model porosity and permeability. This data is combined with laboratory experiments, 2D microscopy techniques, and 3D Focussed Ion Beam - Scanning Electron Microscopy (FIB-SEM). Especially the latter is powerful for investigating matrix, inter- and intragrain porosity and permeability, existing next to the fracture network. The complete set of information can lead to a better understanding of the microscale characteristics of the investigated reservoir rocks.