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Extracting porosity and modelling permeability from μCT and FIB-SEM data of fractured dolomites from a hydrocarbon reservoir

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Currently oil and gas in the Vienna Basin are produced partly from the Upper Triassic Hauptdolomit formation. Various drill-cores were retrieved from densely fractured dolomites from depths between 3000 and 5300 m. Porosity and permeability assessment in specimen from such fractured rocks proves to be difficult by common laboratory methods, and also 2D sample analysis alone is insufficient to this end. In our study, X-ray micro-Computed Tomography (μCT) is used to visualise the inside of core samples of fractured Hauptdolomit. The biggest advantage of μCT is that it provides a 3D view of the fractures and other porosity, without destroying the sample. Core sample descriptions, 2D thin section analysis and standard laboratory measurements are used for extended analysis and cross-calibration of the results. In addition, 3D porosity visualisations at the micro- to nano-scale are obtained from Focussed Ion Beam - Scanning Electron Microscopy (FIB-SEM) on thin sections.

The narrow fractures encountered in the Hauptdolomit samples require sufficient resolution μCT scans (i.e. better than ca. 25 μm). Full 10 cm diameter cores of sample prove to be too thick and dense, so that the fracture network cannot be recorded properly. 3 cm sized plugs on the other hand do provide workable results. After obtaining good datasets, the fractures need to be segmented (separated) from the full dataset for further analysis. A large amount of different segmentation routines is available from literature, but very little are applicable for segmenting narrow fractures, especially not in geological literature. Our current best results stem from applying the so-called “Frangi filter” used in segmentation routines in the medical sciences for segmenting blood vessels. After this segmentation, the fracture patterns can be extracted, and quantitative analysis of the bulk porosity and porosity distribution, fracture aperture and length can be performed. The data obtained by FIB-SEM is treated in a similar way as the μCT data, but different segmentation routines apply. The microporosity in the samples is variable for different domains in the sample, where intra- and intergrain as well as matrix porosity are compared.

Both datasets of microporosity and macroporosity in the fracture network serve as an input for various permeability models. We attempt different approaches for calculating the permeability, e.g. by finite element models solving the Navier-Stokes equations, or by Lattice Boltzmann modelling. Testing of variable grid resolution and numerical sample volume is performed to identify representative volume providing consistent permeability values from the different modelling techniques.

Eventually, all mentioned data sets are integrated to provide an as complete as possible overview of the fractures and the petrophysical properties of the rocks, from μm to dm scale.