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Integrating Geology and Petrophysics into Numerical Models – A Step towards the Digitalization of Rocks

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Abstract

Detailed petrographic analyses as well as petrophysical measurements are well established standard methods used for reservoir characterization by the E&P industry. Advances in computational power over the last decade combined with the ongoing challenge of digitalization present new opportunities regarding fluid flow through porous siliciclastic sandstones. Based on a case study from a northern German Rotliegend gas reservoir (depth >5000 m), we introduce a workflow that calibrates numerical flow simulations with geologic lab data.

X-ray micro computed tomography (µCT) images of samples representing the reservoir heterogeneity were used to reconstruct the 3D geometry of the studied sandstones. The digitized rock was integrated with mineralogical data relevant for reservoir quality like mineral content (Morad et al. 2000, Taylor et al. 2010) and clay coating coverages (Ajdukiewicz et al. 2010, Busch et al. 2017). Petrophysical measurements of porosity (He pycnometry) and permeabilities were conducted and integrated. Permeability was measured under constant (1.2 MPa) and elevated confining pressures (2-50 MPa), as well as at room temperature and elevated temperatures (140° C).

Petrographic analyses highlight primary and secondary porosities and the importance of chemical compaction by quartz grain dissolution. The impact on grain coating clay minerals on cementation and compaction was assessed. Illite, present on grain surfaces can inhibit syntaxial cementation, where present at the grain–IGV interface. Where illitic grain coatings are present at grain-grain contacts it enhances the chemical compaction by enhancing quartz dissolution. Petrophysically derived porosities range from 0.6-14.5% with permeabilities ranging from 0.01-781mD. Rock types, defined on characteristics from thin section analyses show characteristic decreases in reservoir quality at confining pressures from 2 to 50 MPa, ranging in permeability reductions from below 1 order of magnitude to three orders of magnitude.

First results are three-dimensional permeability tensors from digitized rocks that are in agreement with the measured permeabilities of our reservoir samples. The 2-phase flow models use the different wetting properties of different mineral species derived from 3D µCT analyses. The modeling of gas flow through a water saturated porous rock shows the migration of the gas phase along high-perm streaks.

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