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Porosities and permeability of Paleozoic sandstones derived from Nuclear Magnetic Resonance measurements

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A major obstacle for an increased use of geothermal energy often lies in the high success risk for the development of geothermal reservoirs due to the unknown rock properties. In general, the ranges of porosity and permeability in existing compilations of rock properties are too large to be useful to constrain properties for specific sites. Usually, conservative assumptions are made about these properties, resulting in greater drilling depth and increased exploration cost. In this study, data from direct measurements on thirty-three sandstones from different borehole locations and depths enable to derive statistical values of the desired hydraulic properties for selected sandstones in the German subsurface.

We used Nuclear Magnetic Resonance (NMR) measurements to estimate the porosity and the permeability of sandstones from North Rhine-Westphalia (Germany). Besides NMR standard poro-perm-measurements were performed on the samples to obtain independent data sets for comparison. Porosity was measured by Archimedes principle and pore-size distribution by mercury injection. Also permeability was determined by gas flow measurements taking into account the Klinkenberg effect.

The porosities of the studied samples vary between 0 % and 16 %. NMR yields suitable porosity results whereas the porosities obtain by T_1 relaxation measurements fit better to the Archimedes porosities than the porosities obtained by T_2 relaxation measurements. For porosities up to 10 %, T_2 relaxation measurements overestimate the porosity. Furthermore, we calculate the effective porosity using a cutoff time of 3 ms. This effective porosity agrees much better with Archimedes porosities, particularly for the low porosity samples.

The gas permeability of studied sandstones varies between 10^{-21} m^2 and 2.10^{-17} m^2. A large number of empirical relationships between relaxation times and gas permeability have been published. We have applied several of these relationships to select the appropriate law for Paleozoic sandstones. The results show that the used models yield good correlation between gas- and NMR-permeability (R^2>0.86 for k>10^{-19} m^2).