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Thermal Properties of paleozoic rocks from the Rhenish Massif

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Large areas of Germany and neighbouring countries are formed by paleozoic rock formations. Beside large outcrops such as the mountain chains of the Rhenish Massif, paleozoic rocks also dominate the subsurface as forming the Northern Germany basement. Still, reliable data sets on thermal properties are rare. To improve this situation, paleozoic rocks samples from outcrops and drillings of North-Rhine Westfalia were investigated.

We studied about 230 core samples and obtained information on thermal conductivity, density, porosity and Vp-velocity of the rocks in dry and saturated conditions. In addition, about 50 core plugs were taken for measurements of heat capacity, and P-T-dependent thermal conductivity and thermal diffusivity. Chemical and mineralogical analyses were performed on almost 100 samples. Thus, a unique data set was created, which enables to connect thermal properties to rock porosity and to mineralogical and chemical rock composition. Data analysis revealed the mineralogical composition as the most prominent factor for effective thermal conductivity. This is especially the case for the Carboniferous and Devonian sandstones with quartz contents varying from 35 to 95%. Rock porosity in paleozoic rocks is usually low and it's impact on thermal properties not as significant as the rock mineralogy. Thus, the geometric mixing law is applicable only for rocks, if the mineralogical composition is known.

In a similar way, mineralogy affects the temperature and pressure dependence of thermal properties. The strong mineralogical variation of the sandstones leads to non-uniform P-T trends of thermal properties. Only claystones and carbonates show more consistent dependency trends. This allows the definition of rock type specific P-T-correction values.

In a following step, the results from the discrete core measurements were combined with continuous bore-hole geophysical data. Based on the laboratory data, petrophysical models were built up. This allows deriving continuous profiles of rock porosity and volumes of shale, sandstone, coal and carbonates for the different drillings. By this information, the geometric mixing law could be applied to calculate continuous thermal conductivity profiles. These profiles give information on the vertical and lateral heterogeneity of thermal properties and were used to derive statistically proven value ranges for entire stratigraphic units. These values can serve as input parameters for geothermal models and can help to reduce the uncertainty of numerical simulations.