Coupling heat conductivity and lithofacies of the coal-bearing Upper Carboniferous in the eastern Ruhr Basin, NW Germany

Greve, J.[1, 2], Busch, B.[2], Quandt, D.[2], Knaak, M.[1], Hilgers, C.[2]
[1]Geological Survey of North Rhine-Westfalia, Krefeld, Germany, [2]Karlsruhe Institute of Technology (KIT), Applied Geosciences - Structural Geology & Tectonics, Karlsruhe, Germany

After the closure of coal mining in the northwestern German coalfields the further utilization of mines i.e., for geothermal applications is currently discussed. Recent exploration activities aim for deep geological carbonate horizons in the Rhine-Ruhr area, located at depths relevant for deep geothermal exploitation (cf. [1]). The dismantled Upper Carboniferous coal mines at more than 1000 m depth may also be considered as a potential geothermal reservoir. Thus, determining thermal conductivity including reservoir properties is important to define the geothermal potential of Upper Carboniferous clastics.

In this study, petrophysical properties of three Upper Carboniferous (Westphalian A and B) drill cores were determined in the eastern Ruhr basin including ultrasonic wave velocity (V_P), thermal conductivity, and porosity. We outline how lithofacies, depositional environment and petrophysical data are coupled with thermal conductivity, for deeper process understanding and subsequent potential evaluation.
Cores from three exploration wells in the study area stratigraphically cover the Westphalian A and B, of the coal-bearing Upper Carboniferous. In the Ruhr basin the entire Upper Carboniferous comprises of a 4000 m thick clastic succession of cyclically deposited clay-, silt-, and sandstone of deltaic to fluviatile and lacustrine origin and contains about 250 coal seams ([2], [3]).

Cyclically occurring clastics were categorized into different delta facies by their lithology and sedimentary structures. Thermal conductivities of the Upper Carboniferous samples range between 2.3 and 4.1 W/m/K. In general, most samples are generally tight (mean porosity: 6.4 %) but varies by grain size and facies. Thermal conductivity in sandstones of the delta front ranges from 3.0 to 4.1 W/m/K. The higher values moderately correlate with lower porosities, while e.g., the quartz content or the mineralogical composition seem to impact the heat conductivity. Siltstones of the lower delta plain show lower thermal conductivities from 2.3 to 3.9 W/m/K, while mudstones of the wetlands display the lowest ranging from 2.4 to 3.0 W/m/K.
The p-wave velocity (V_P) was determined on dry core plugs and ranges between 2886 and 5663 m/s. Similar to the thermal conductivity V_P values are highest in sandstones but show the widest spread ranging from 2886 to 5663 m/s. Siltstones and mudstones of the lower delta plain show relatively lower velocities ranging from 4649 to 3060 m/s and 4695 to 3641 m/s, respectively. Comparing the results from porosity measurements with the V_P values a moderate correlation is displayed, as an increase in porosity leads to a decrease in V_P velocities. In following studies petrographic parameters need to be included as limitations occur by simply applying grain size and lithofacies data to understand the subsurface heat distribution and to evaluate the geothermal potential.

References:
[1] Arndt, M., Fritschle, T., Thiel, A., & Salamon, M., (2021), Deep Geothermal Energy potential of Carboniferous carbonate rocks in North-West Europe–History, characterisation, modelling and exploration, Schweizerbart Science Publishers, Zeitschrift der Deutschen Gesellschaft für Geowissenschaften, 205-210
[2] Drozdzewski, G., (1993), The Ruhr coal basin (Germany): structural evolution of an autochthonous foreland basin, International Journal of Coal Geology, 231–250, 23 (1-4)
[3] Suess, M.P., Drozdzewski, G., Schaefer, A., (2007), Sedimentary environment dynamics and the formation of coal in the Pennsylvanian Variscan foreland in the Ruhr Basin (Germany, Western Europe), International Journal of Coal Geology, 267–287, 69 (4)