Physical properties of Carboniferous and Devonian Rocks drilled in the RWTH-1 borehole

GEOPHYSICA Beratungsgesellschaft mbH

RWTH AACHEN UNIVERSITY

Lydia Dijkshoorn (Applied Geophysics, RWTH Aachen, Lochnerstraße 4-20, 52064 Aachen, Germany; e-mail: l.dijkshoorn@geophysik.rwth-aachen.de
Renate Pechnig (Geophysica Beratungsgesellschaft mbH, Lütticherstraße 32, 52064 Aachen, Germany ; e-mail: r.pechnig@geophysica.de

Cuttings investigations in the RWTH-1 borehole

We present the physical properties of the Carboniferous and Devonian Rocks drilled in the 2500 m deep RWTH-1 borehole. The borehole is located in the center of Aachen, in only few meter distance to the University main building. The geological setting is in front of the Aachen Overthrust , the large southeast dipping fault belt, which separates the Eifel Mountain geology from the northwestern foreland (Fig. 1). The well penetrates carboniferous and devonian formations, which are dominated by series of interlayered sandstones, siltstones and shales. Organic shales and thin coal layers were locally drilled in the upper 1016 m, as part of the Lower Carboniferous deltaic cycles. Carbonates only occurred in the underlying Upper Devonian series between 1016 and 1440 m. The deeper parts of the borehole are dominated by variegated shale and sandstone series, which are of Lower Devonian age (Ribbert 2006).

In total 57 cutting samples were selected at a regular interval every 50 box th ., resulting in a depth interval of 50 m. On the cuttings, matrix density and thermal conductivity were measured (Fig. 2). Density was measured by a helium pycnometer; the thermal conductivity was determined with a line source device on a cuttings-water mixture. Since the rock porosity is very low (< 0.1%), the influence of the pore fluid on the effective thermal conductivity can be neglected.

The density varies from 2.64 g/cm³ and 2.84 g/cm³ with a mean of 2.78 g/cm³. The thermal conductivity (TC) varies between 2.2 W/m/K and 8.9W/m/K (Fig.3). The high values can be explained by a high percentage of quartz. Quartz cemented clean sandstones are frequently observed in the deeper part of hole below 1895 m.

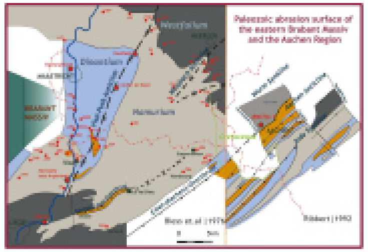
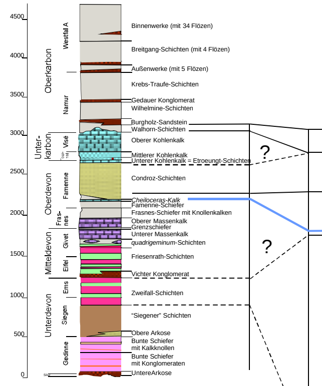


Fig. 1: Geological setting of the RWTH-1 borehole in front of the Aachen Overthrust.



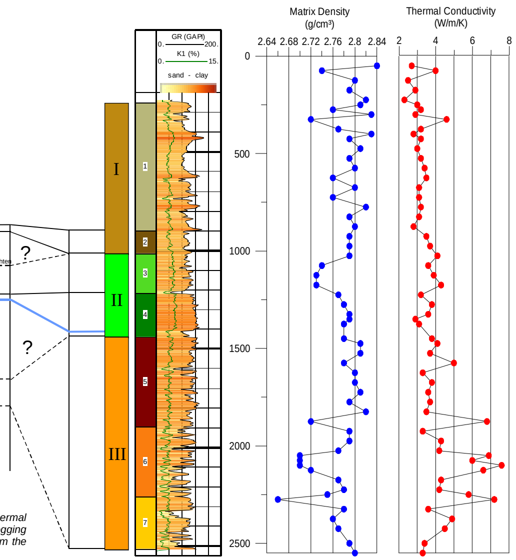


Fig. 2: Cuttings measurements of matrix density and thermal conductivity compared to the borehole zonation (after logging data) and the standard stratigraphic profile known from the Eifelmountains (after Knapp 1980).

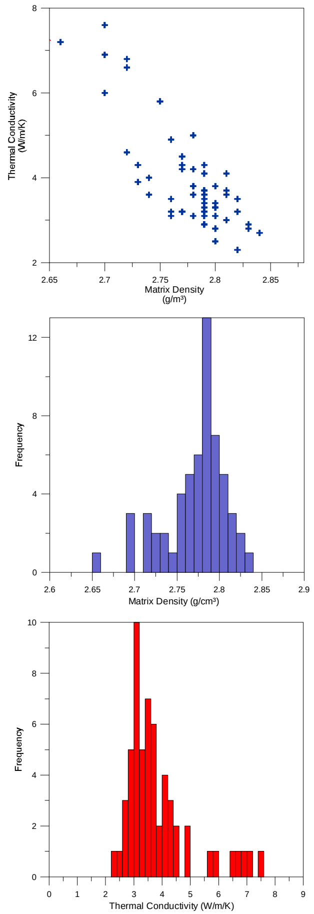


Fig. 3: Cross-plot and histograms of density and thermal conductivity measured on cuttings of the RWTH-1 borehole.

Core-Log integration of physical properties

Cores samples were available for three sections (1392-1515 m, 2128-2143 m, 2536-2544 m) covering a total length of 150 m. On the cores, the following physical properties were measured by a multi-sensor core logger: gamma density, magnetic susceptibility and p-wave velocity.

Vp-data were used for comparing core with logging data. After the correction of a 1.2 m depth shift (log deeper core) and the use of a sliding window average on the core data, in-situ and laboratory data comes to an excellent fit (Fig. 4). The data fits best in the carbonate bearing section down to 1440 m and in the deepest part of core section 1. Between 1460 and 1490 m slight off-sets can be observed, which might be attributed to bedding anisotropies. Effects of a Vp lowering by pressure relief are not observed for the RWTH-1 cores.

Core and log data were compared with the petrographic core descriptions (Österreich 2005). In some cases petrophysical property variation follows the optical subdivision. This is valid for the carbonate bearing rocks and the thin sandstone interlayers. The separation made petrographically for the shales and siltstone can not be constrained by the petrophysical data. This is, because petrographical separation is guided by optical markers, such as colour and bedding changes, attributes which can, but must not have a petrophysical correspondence.

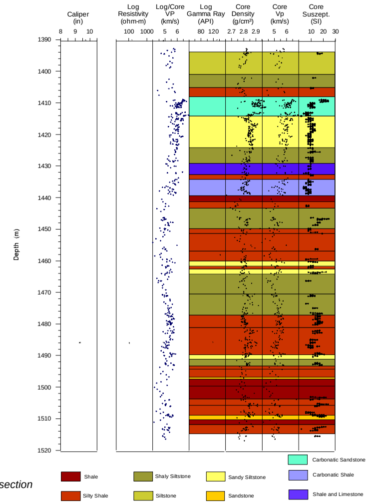


Fig. 4: Petrophysical core and log data of the first core section compared with the petrographic core description.

Continuous thermal property profiles of the formation

The core measurements have a good fit with the associated logging measurements of the borehole wall. Using the logging measurements, the borehole could be divided in 7 zones. These zones correspond with the stratigraphic subdivision of the borehole (Fig. 2).

Due to the paleoenvironment and post-sedimentary processes, the relation between the natural gamma activity and the relative clay volume differ between these zones. Using the natural gamma-ray log for each different zone, it was possible to calibrate the gamma-ray with the thermal conductivity measured on cores und cuttings. The zone identification made it possible to derive a continuous thermal conductivity profile over the entire borehole depth (Speer 2005).

Furthermore a continuous radiogenetic heat production profile was calculated over the borehole depth, derived from the spectral gamma log (Bücker & Rybach 1996).

The thermal properties are used for a design calculation of the (SuperC) borehole heat exchanger and for prognostic 3D modelling of heat flow and temperature in a larger region.

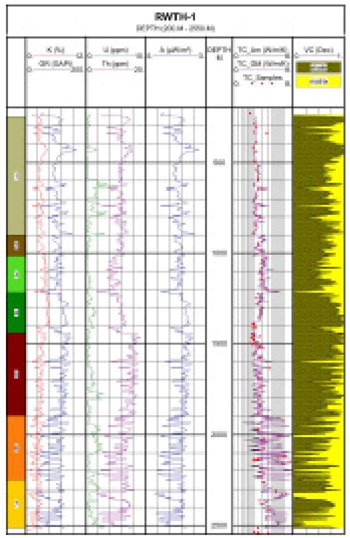


***Fig.6:** Displayed are continuous thermal properties curves, calulated from logging data. TC-Am: Arithmetic mean - thermal conductivity profile; TC-Gm: Geometric mean - thermal conductivity profile; A: Heat production profile; VC: Volume of clay - displayed is the clay content and the quartz/carbonate rockmatrix.*

References

Bücker, C. & L. Rybach (1996): A simple method to determine heat production from gamma-ray logs. Marine andPetroleum Geology13,373-377

Knapp, G. (1980): Erläuterungen zur Geologischen Karte der nördlichen Eifel 1:10000. – 155 S., Geologischer DienstNordrhein-Westfalen, Krefeld.

Ribbert, K.H. (2006): Die Bohrung RWTH-1- Regionalstratigraphische Einordnung und Deutung. Interner Bericht, Geologischer DienstNRW,Krefeld.

Österreich, B., (2005): Petrographische Beschreibung der RWTH-1 Kernsektionen. Interner Bericht, geologischer DienstNRW,Krefeld.

Speer, S., (2005): Design calculations for optimising a deep borehole heat exchanger, Diplomarbeit, Angewandte Geophysik,RWTHAachen.