LONG-TERM WATER MANAGEMENT IN THE GERMAN MINING DISTRICT THROUGH THE UNDERSTANDING OF THE SUBSURFACE PERMEABILITES

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ABSTRACT

For the analysis of the dynamic behavior of the subsurface in the German mining district, the Ruhr area, and the long-term water management in this region it is important to get a spatial understanding of the permeabilities of the different geological units and the interaction along fault zones. Based on the exploration wells drilled in the region different digital subsurface models have been built for the Carboniferous overlying Cretaceous. The models included the spatial distribution of lithologies, porosities and permeabilities and an assessment of the permeabilities of the known fault systems. For the first time during mining coal in Germany the results allowed to conclude that the shallower subsurface of the Cretaceous has high probabilities of low permeabilities and sealing faults. However, streaks of higher permeability along fault planes create pathways for a possible migration of mine water. Therefore special attention to the fault systems needs to be paid when mines get abandoned. These results of the subsurface interaction are consequently important for the better design of a long-term water management.

1. INTRODUCTION

The German mining district has a long history of coal mining, during which extensive exploration work was necessary. The drilled exploration wells have mainly evaluated for the Carboniferous coal to get an understanding of the geology and tectonic structure.

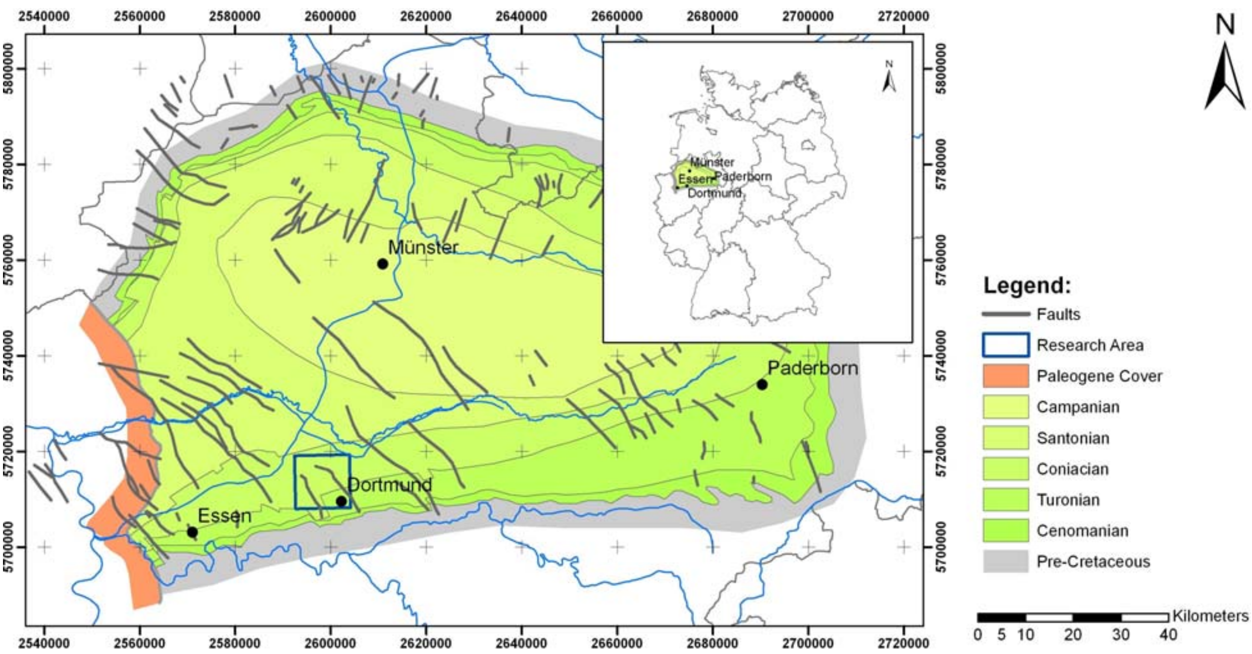
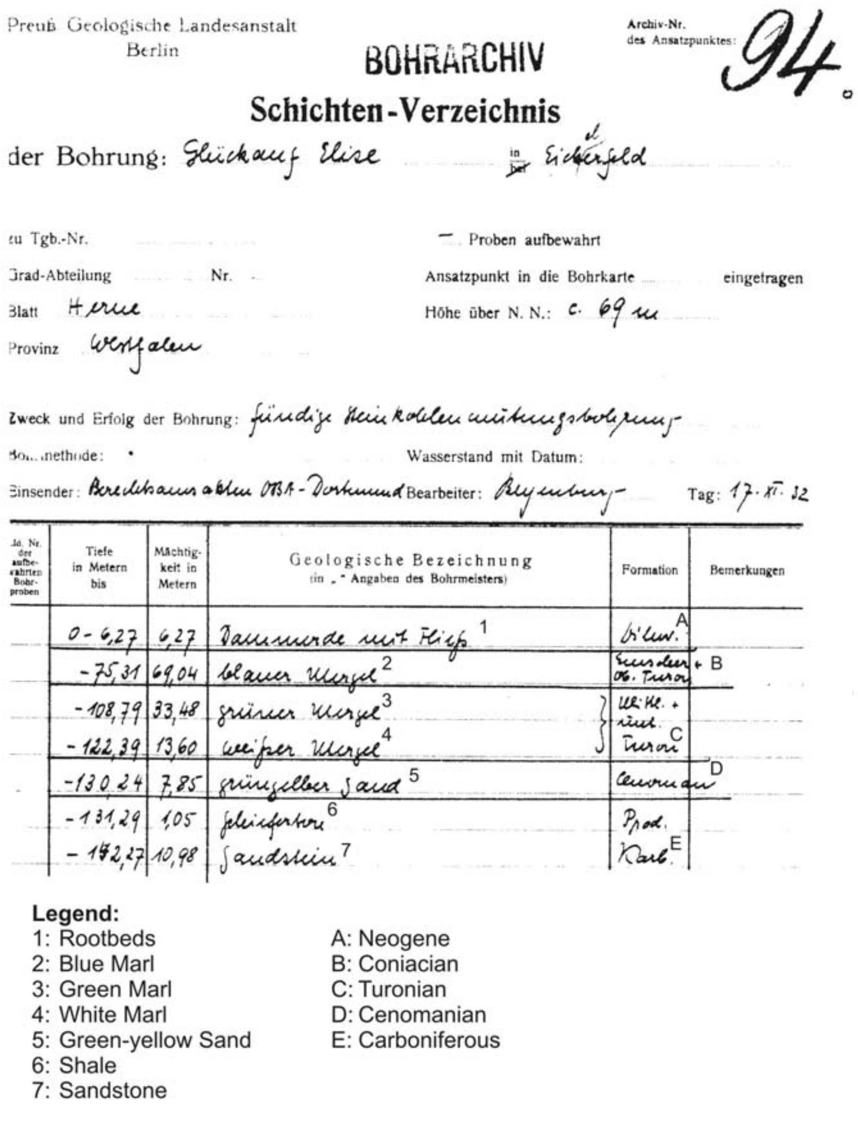


Figure 1. Geological map including simplified fault system of the Cretaceous basin of Münster. Rectangle indicates the research area (after Hilden, 1999 and Kaever, 1980).

In the southern Ruhr area the coal pinches out at the surface and to the north the Carboniferous rocks are deeply buried under 1200 m of Mesozoic layers (Figure 1). Initial a static model, based on 4,000 wells for the Cretaceous basin in southwest Münsterland and the Ruhr areas was created in cooperation with different partners (Rudolph, 2006). Emphasis in this research was on the lithological and stratigraphical settings, as well as the tectonic and structural analysis, of these well logs in order to build a fine-scaled digital subsurface model. Based on this model the methane generation and accumulation conditions in the Münsterland area were investigated (Melchers, 2009). A possible correlation between the locations of methane emissions at the surface, the tectonic subsurface structures, as well as the increased permeabilities of the cretaceous layers and the deeper carboniferous units were appraised.

2. MODELLING

The results of these initial models were used to build a more detailed model in the area of the city of Dortmund (Figure 1). In a first modeling step it was important to standardize the quality of the very heterogeneous datasets, because wells have been drilled in the research area for nearly 200 years (Figure 2).


Preuß. Geologische Landesanstalt Berlin

BOHRARCHIV

Archiv-Nr. des Ansatzpunktes: 94.

Schichten-Verzeichnis

der Bohrung: Glückauf Elise

zu Tgb.-Nr.

Grad-Abteilung Nr.

Blatt Herne

Provinz Westfalen

– Proben aufbewahrt

Ansatzpunkt in die Bohrkarte eingetragen

Höhe über N. N.: c. 69 m

Zweck und Erfolg der Bohrung:

Bohrmethode:

Wasserstand mit Datum:

Einsender:

Bearbeiter:

Tag: 17. XI. 32

Lfd. Nr. der aufbewahrten Bohrproben	Tiefe in Metern bis	Mächtigkeit in Metern	Geologische Bezeichnung (in „" Angaben des Bohrmeisters)	Formation	Bemerkungen
	0 - 6,27	6,27	Dammerde mit Flies 1	Diluv. A	
	- 75,31	69,04	blauer Mergel 2	Emscher Ob. Turon + B	
	- 108,79	33,48	grüner Mergel 3	Ut. Kr. + Mittl. Turon	
	- 122,39	13,60	weißer Mergel 4	Turon C	
	- 130,24	7,85	grüngelber Sand 5	Cenoman D	
	- 131,29	1,05	Schieferton 6	Prod.	
	- 142,27	10,98	Sandstein 7	Karb. E	

Legend:

1: Rootbeds
2: Blue Marl
3: Green Marl
4: White Marl
5: Green-yellow Sand
6: Shale
7: Sandstone

A: Neogene
B: Coniacian
C: Turonian
D: Cenomanian
E: Carboniferous

Figure 2. Well log of the borehole Glückauf Elise drilled in 1932.

The lithological log of the borehole Glückauf Elise shows in a very clear way that the old lithological description varies from a modern interpretation. In the next step the highly developed software Petrel (Schlumberger) and modern workflows of the oil industry were used to improve the existing expertise in the mining industry and to build a new static subsurface model populated with the available subsurface data and properties. The simulated model shows the spatial distribution of:

- the lithology and the facies,
- the petrophysical parameters (e.g. porosities and permeabilities) and
- the fault sealing (Shale smearing and fault permeabilities).

To cover the uncertainty of the different model attributes every property was modeled with a range (Low Case (LC), Base Case (BC) and High Case (HC)) (Figure 3). The usage of distributions, rather than using single values, enabled a better understanding of the sensitivities to certain petrophysical properties.

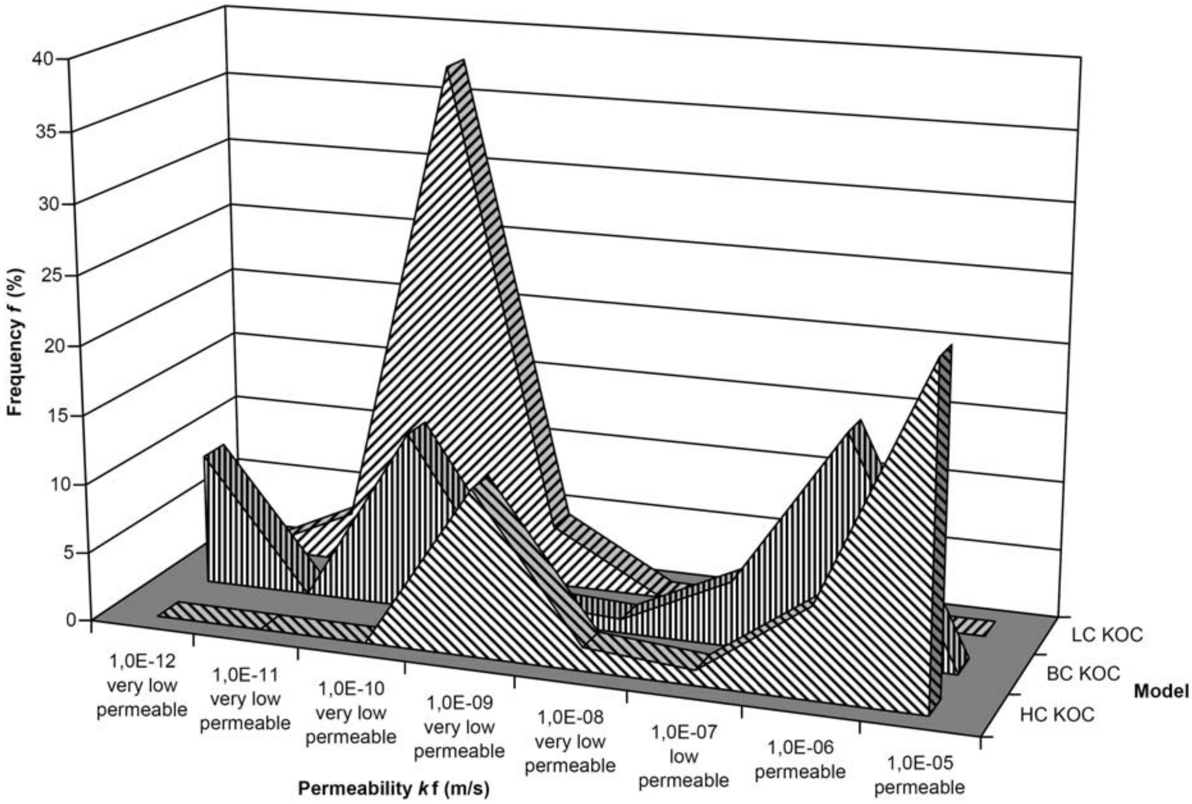


Figure 3. Permeability distribution for the Coniacian for the LC- BC- and HC-models.

The permeability is defined in this paper as the ability of rocks and sediments to conduct (ground)-water (Hölting and Coldewey, 2008) (Equation 1).

$$k_f = \frac{\dot{V}}{A \cdot i} \tag{1}$$

with:

k_f = Permeability (Durchlässigkeitsbeiwert) (m/s)

$\dot{V}$ = Flowrate (m^3/s)

A = Cross - section (m^2)

i = Gradient (−)

The simulation of the petrophysical parameters and the fault analysis for the Cretaceous subsurface structures in the Ruhr area produced new results, which are important for the understanding of the shallower subsurface permeabilities. For the different stratigraphic units mostly multimodal permeability distributions with wide ranges exist. The Figure 3 shows as an example of the multimodal permeability distribution for the Coniacian ("Emschermergel"), a main geological unit in the research area. To get a better understanding of the distributions, the assessment of the fault permeability was needed (Figure 4). The combination of the general permeability analyses shows that juxtaposed cells along the fault planes are locally permeable (Figure 3).

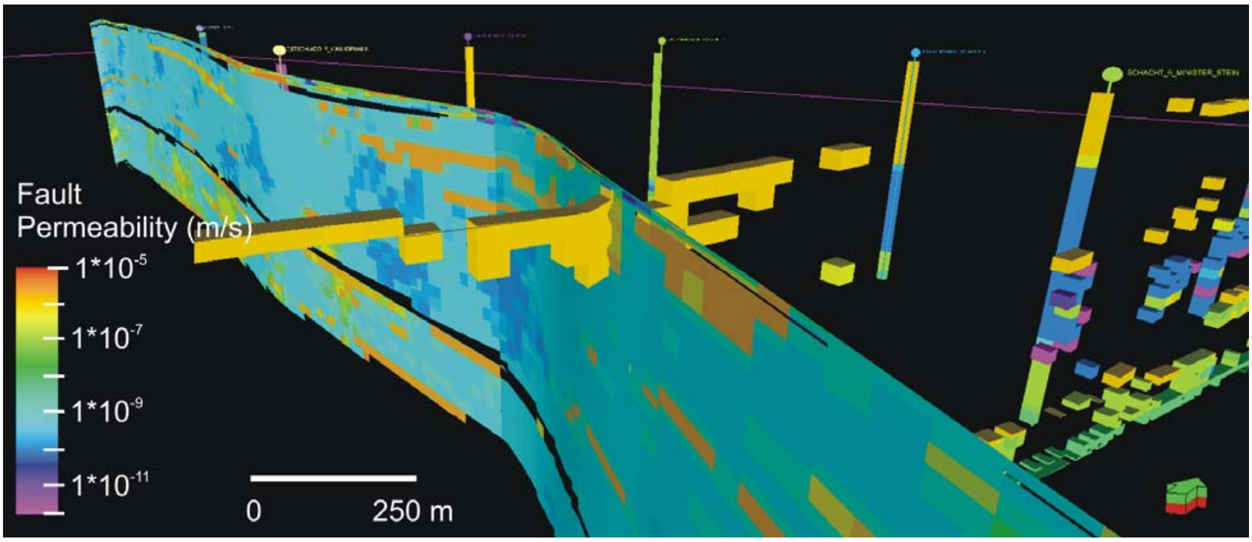


Figure 4. Filtered high permeability cells juxtaposed along the fault plane.
Fault permeabilites are displayed on the fault plane.

3. RESULTS

In summary, this model enables the first spatial analysis, on regional and local scales, of possible pathways for groundwater migration along faults and permeability changes in the different geological units. In general very low permeabilities with $k_f < 1*10^{-9}$ m/s exist with high permeabilities streaks of $k_f > 1*10^{-6}$. The faults are not areas of generally enhanced permeability with low permeabilities of $k_f \sim 1*10^{-9}$ m/s. But areas with increased permeability streaks exist, which are potential pathways for the migration of liquids (Figure 4). Because the structural setting of the Carboniferous and the Cretaceous layers is known and reproduced, this model could be used for a long-term water management to predict on a larger scale the possible rise of the mine water after the abandonment of all mine activities in the Ruhr area. This work simulates for the first time on a more regional basis the permeability distributions in the Cretaceous and differs therefore from the more localized research of the past (Coldewey and Löhnert, 1997). It helps to identify regions where during the flooding of a mine increased permeabilities could lead to a quicker mine water rise and supports consequently the long-term water management of a whole region.

4. REFERENCING

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