A workflow to evaluate hydraulic barriers during mine water rebound: A holistic approach

Henning Jasnowski-Peters
Till Genth
Lisa Rose
Sebastian Westermann
Christian Melchers

TH Georg Agricola, University of Applied Sciences
Forschungszentrum Nachbergbau
(Research Center of Post-Mining)

Aim of this research

Technische Hochschule Georg Agricola

- evaluate potential loss of containment issue of mine water during mine water rebound
- generate data to forward model mine water rebound fluid pathways (long term >100 yrs)
- build a static geological model and add petrophysical data in order to build a regional hydrogeological model
- scientific support of drilling & SCAL & calibrate borehole geophysical data (wireline logging)
- specific task: test the heterogeneous facies deposition of the Emscher Formation for its hydraulic conductivity

Project „Deep monitoring wells“

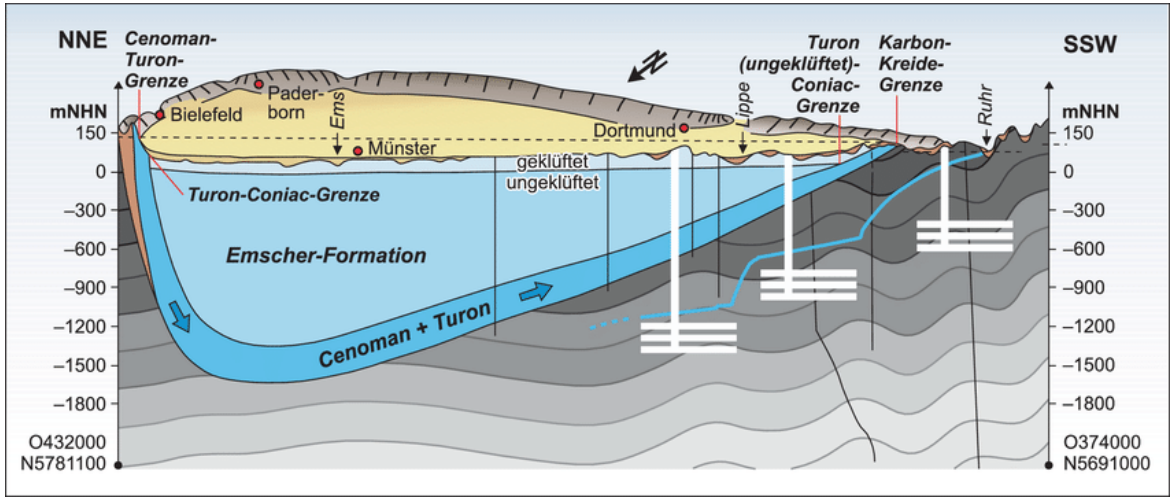
Technische Hochschule Georg Agricola

- scientific drilling support for drilling deep monitoring wells of the operator RAG AG in order to meter, control and forecast hydraulic potentials in the overburden section during rebound
- Specific goals:
  - evaluate and generate permeability and porosity profiles of the Emscher formation („Emscher Marls“) in order to determine the hydraulic conductivity of the formation in various depositional settings
  - detailed quantitative mineralogy, especially clay minerals, due to self healing potential of fissures and fault zones
  - lithofacial changes from West to East (see Wolansky maps)
  - going from 1D well profiles of permeability to 3D depositional model and petrophysical assessment

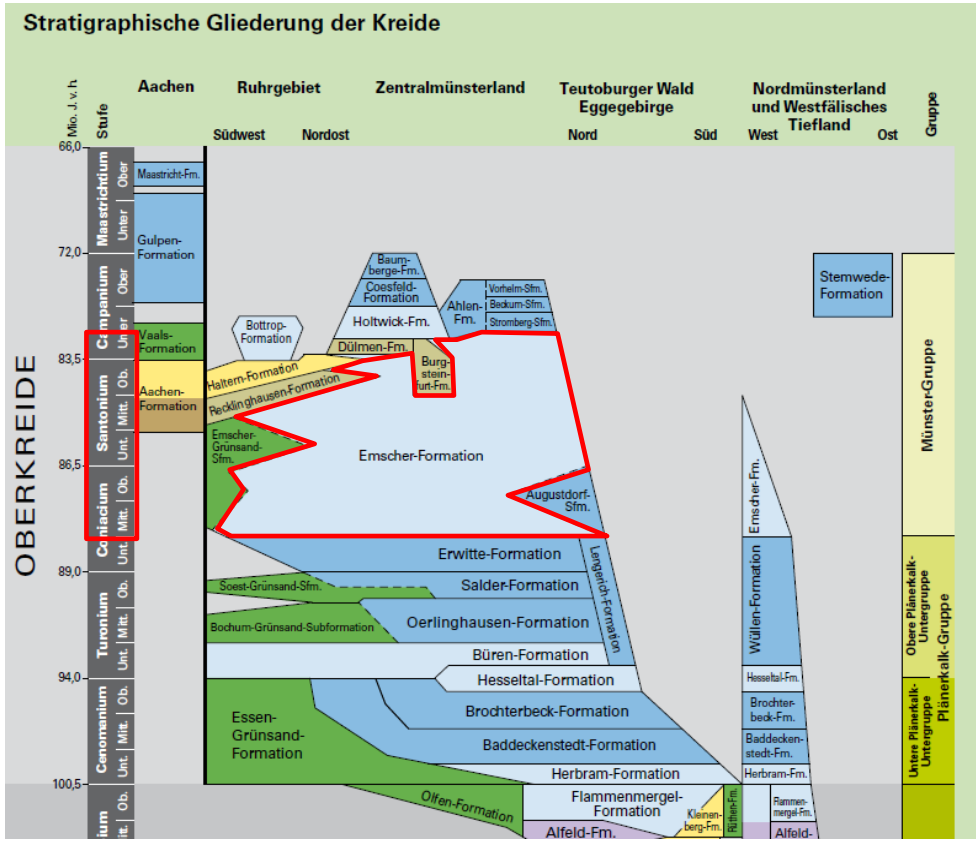
Emscher Formation – fact sheet

Technische Hochschule Georg Agricola

- Emscher Formation (Middle-Coniacium- Lower Campanium), regionally known as „Emscher Marl" after Schlüter 1874
- Lithology: clayish marlstone
  quantitiative petrophysical poroperm unknown
- Regional Aquitard in the Munsterland Basin
- Thickness up to 1000m in the basin centre and up to 1500 m at the northern basin border



OttenJann et al. 2022



Geological Survey NRW, 2018

Pre-work

- Wolansky (1964) – hydrological characterisitcs of the overburden section

- Changes of groundwater reservoir within the formation – going from fractured aquifer to tight aquitard

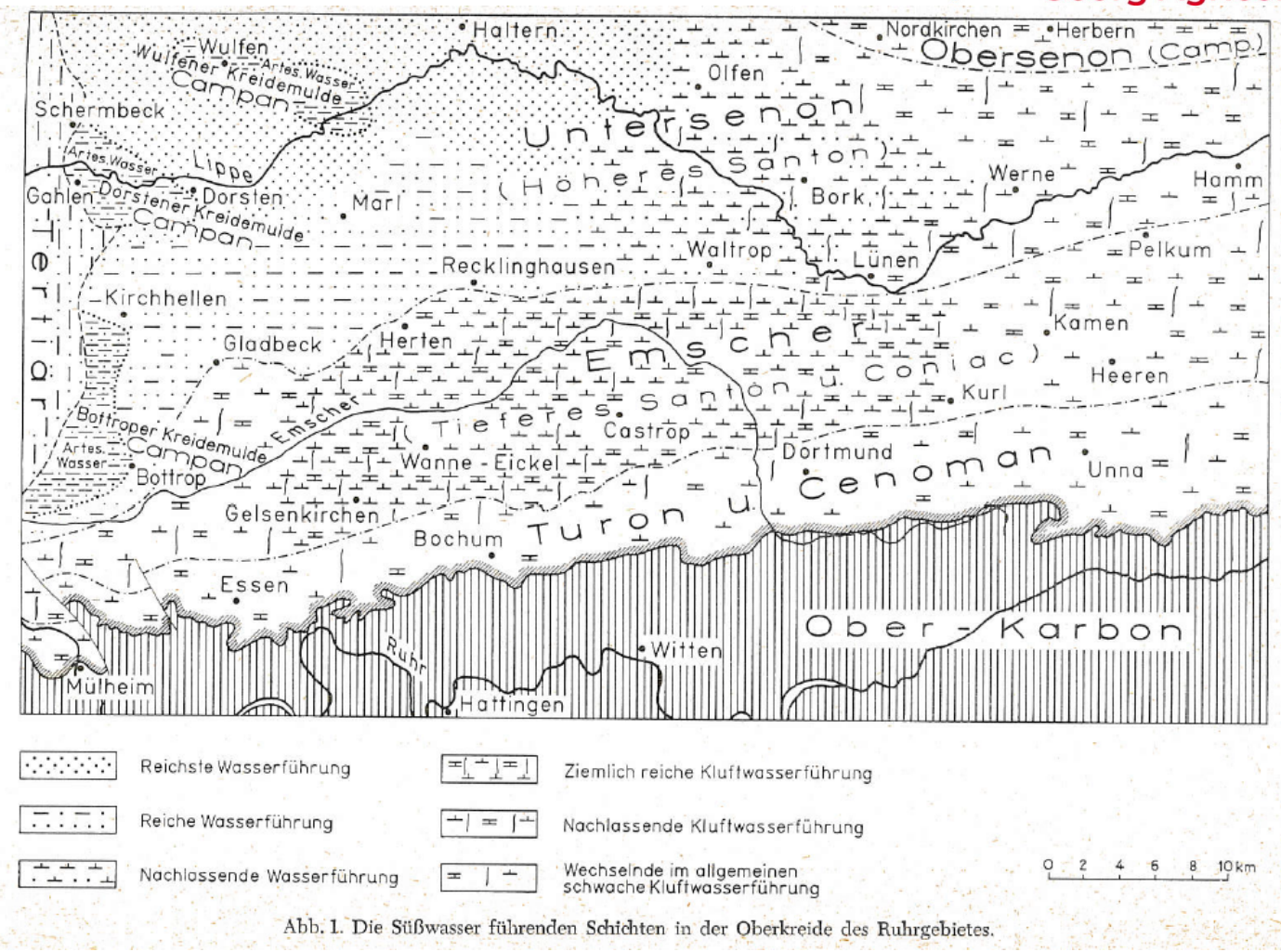
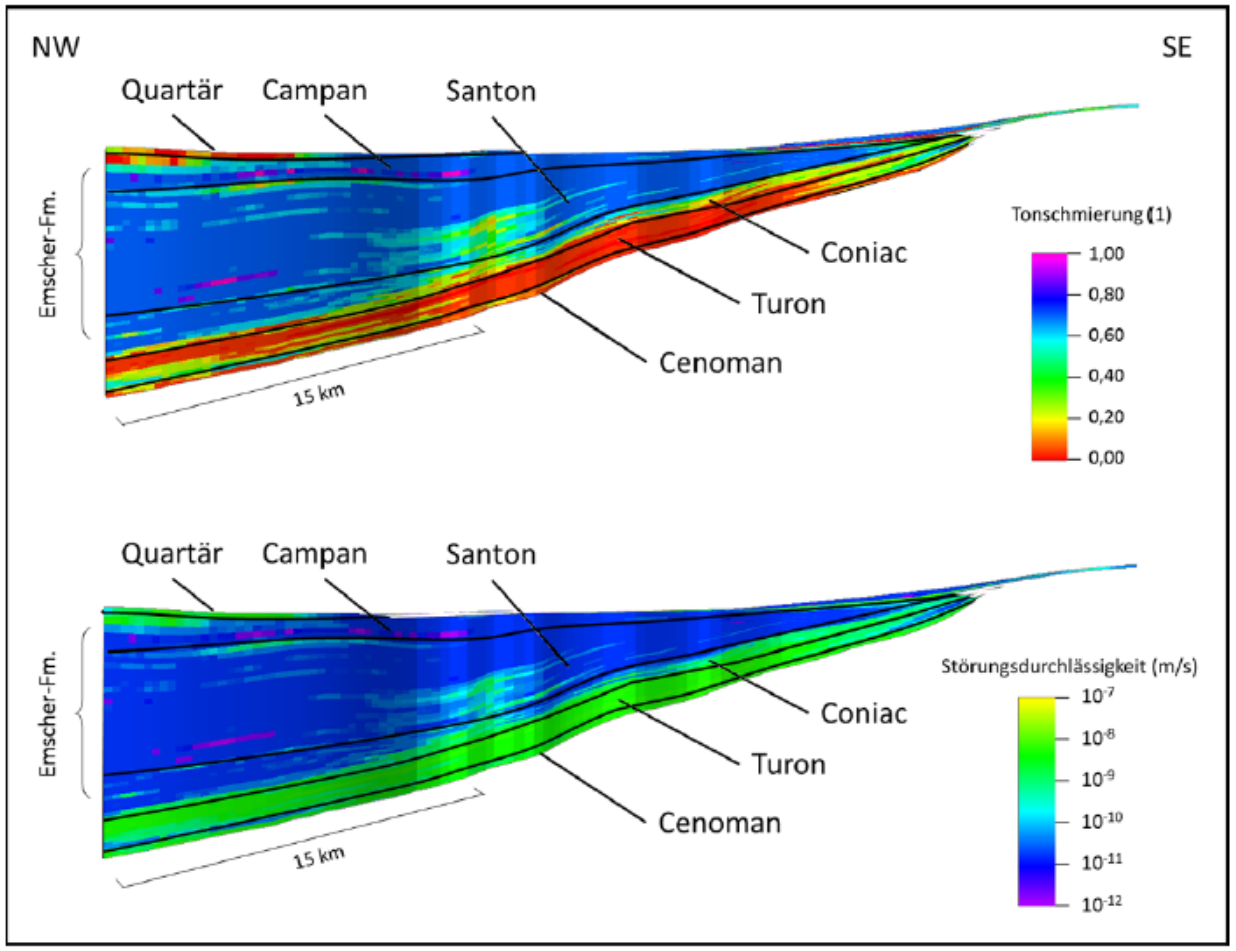


Abb. 1. Die Süßwasser führenden Schichten in der Oberkreide des Ruhrgebietes.

Pre work II

- Coldewey & Wesche (2017) – „Hydrogeological and petrophysical properties of the Emscher-Formation“



Coldewey & Wesche 2017

The Workflow

- Target: Emscher Formation
  - facies and depth correlation
- Lab work
  - quantitative clay mineralogy using XRD-Rietveld
  - density and porosimetry
  - air permeametry
- Field data
  - borehole geophysics
  - hydraulic packer tests

Technische Hochschule Georg Agricola

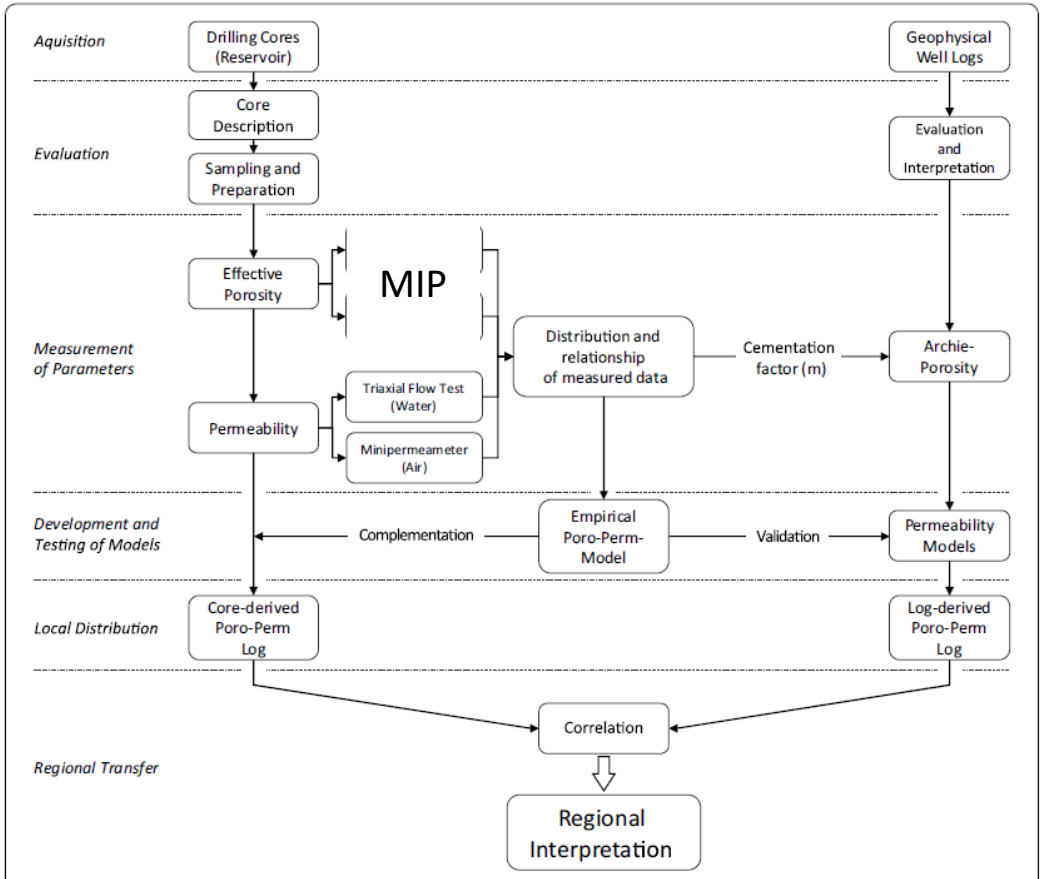
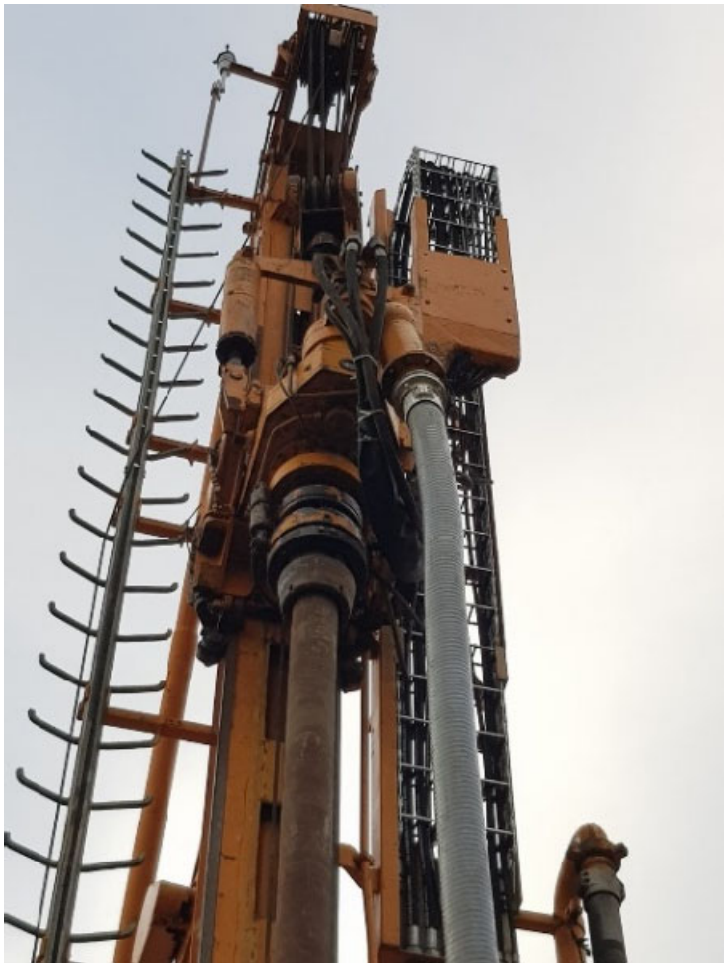


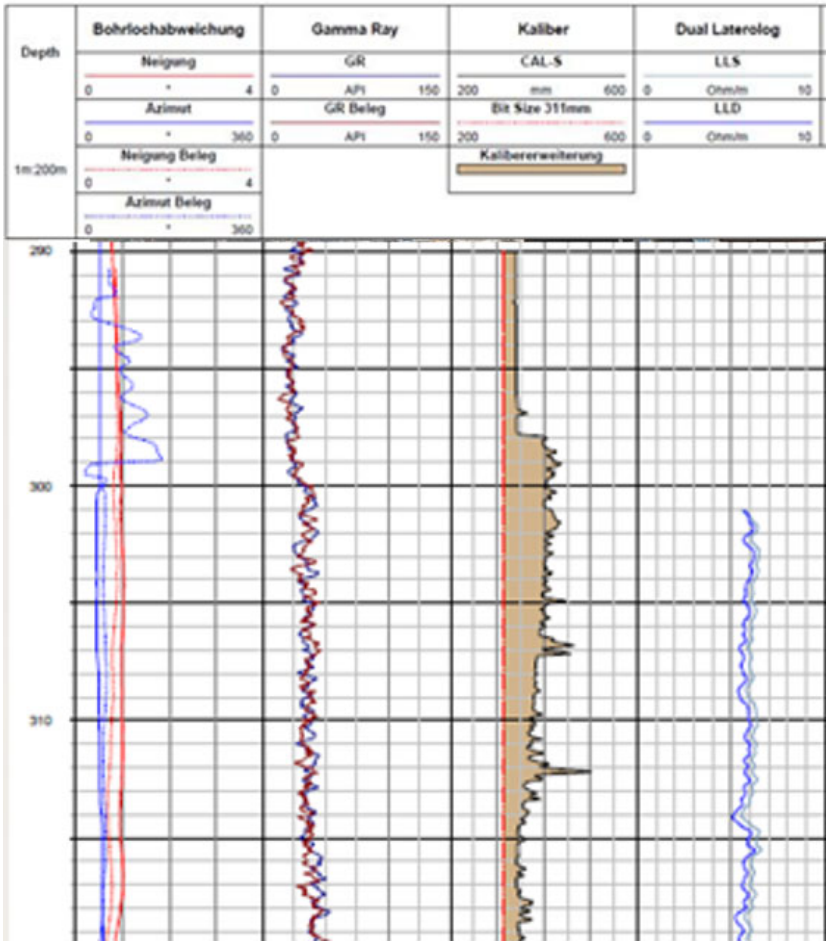
Fig. 2 Workflow for determination of hydraulic parameters from drilling cores and downhole logs

Bohnsack, 2020

Drilling operations

Technische Hochschule Georg Agricola

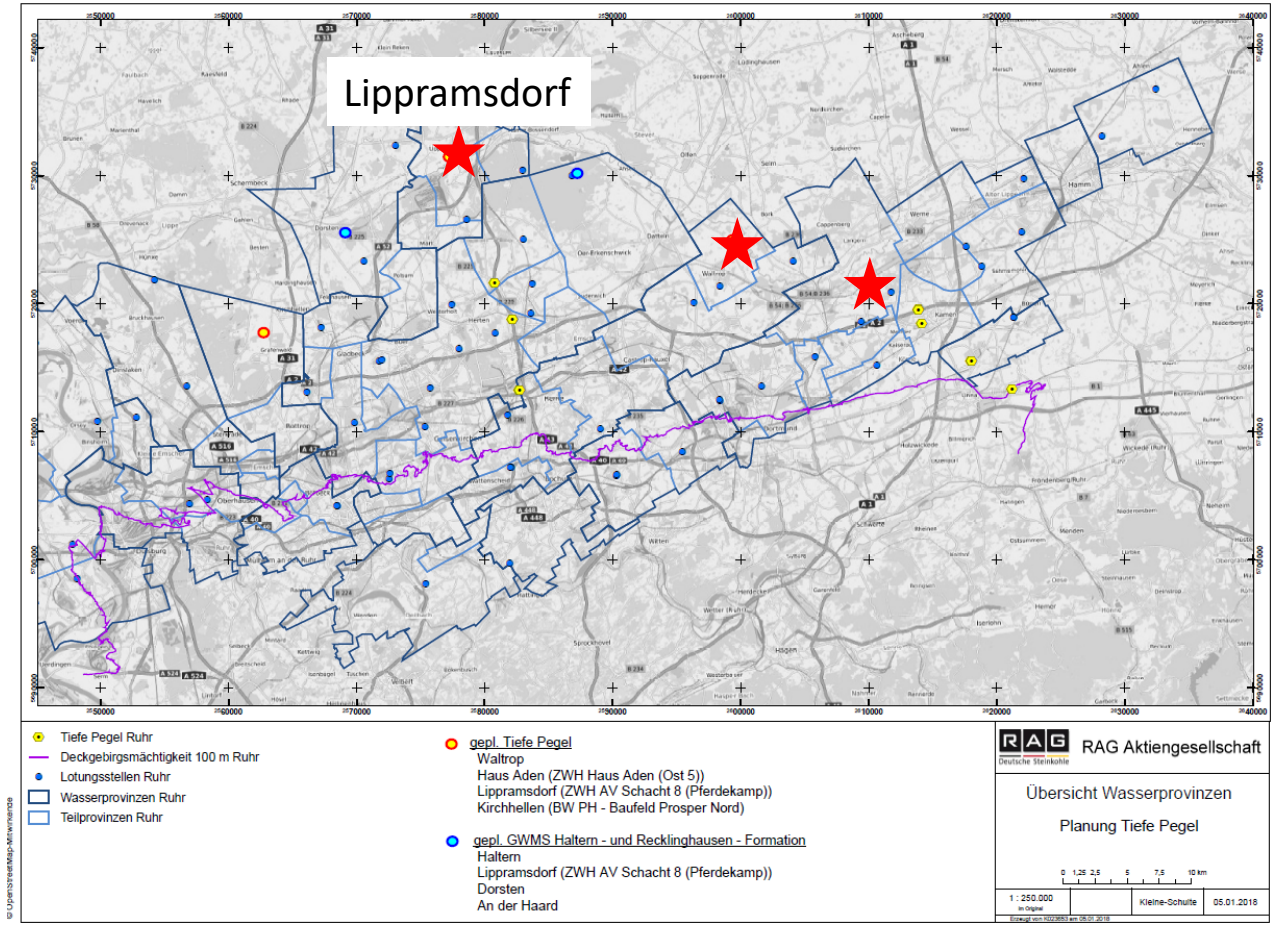




Deep monitoring well sites „Tiefe Pegel“

Technische Hochschule Georg Agricola

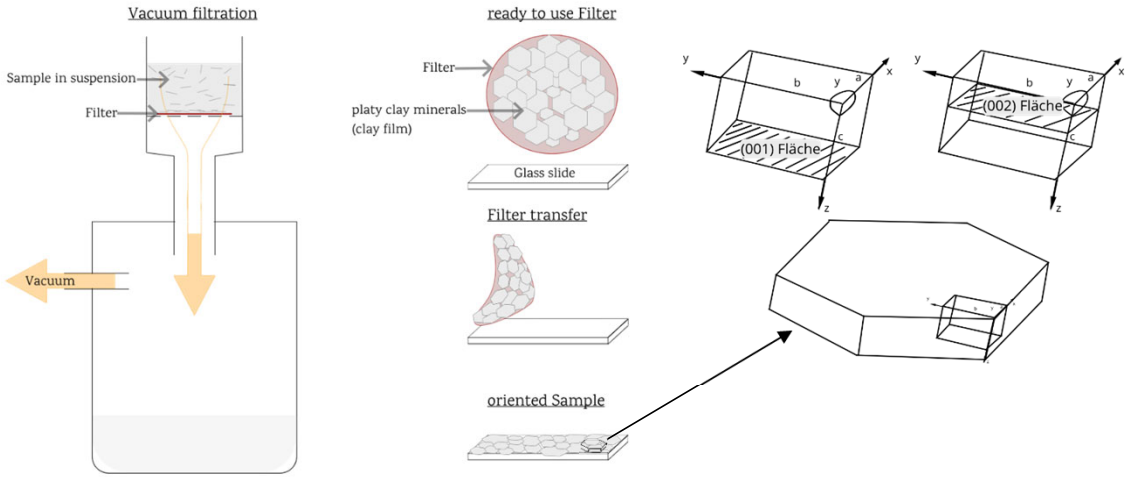
- Drilling sites
  - Waltrop
  - **Lippramsdorf**
  - HA-Ost 5
  - at least three more to be determined…

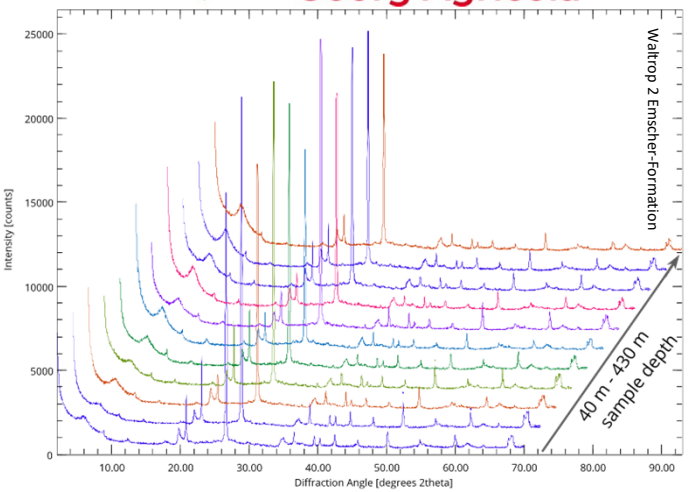


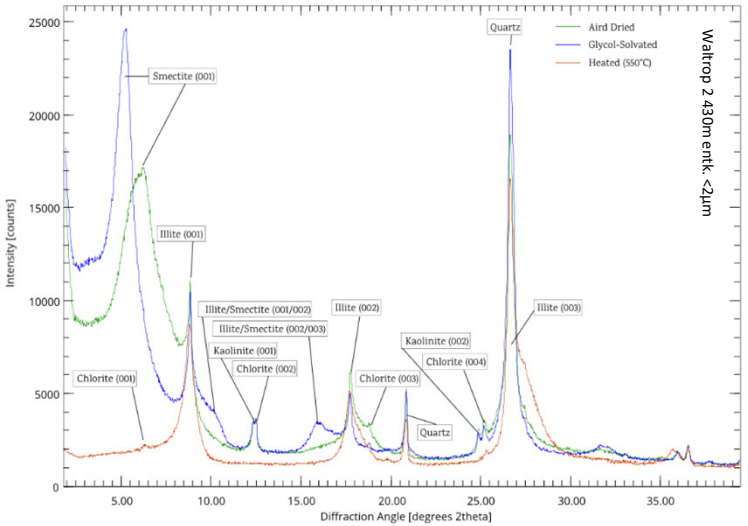
XRD-Rietveld quantification

- Using open-source software program („Profex“)
  - for „bulk“- and decarbonated „random powder“-samples

- Samples as texture slides
  - decarbonated 2 µm fraction
  - measurements: air dry, glycolated, heated up to 550°C







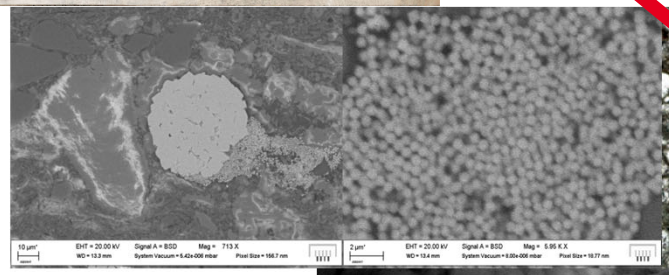
SCAL – special core analysis

- Lithostratigraphy
- Sedimentology
- Marlstone to clayish marlstone, intercalated marly carbonate layers
- Carbonate fraction: chalk-type bioclastics (*Coccolithophorida*)
- framboidal pyrite often present (AMD!)

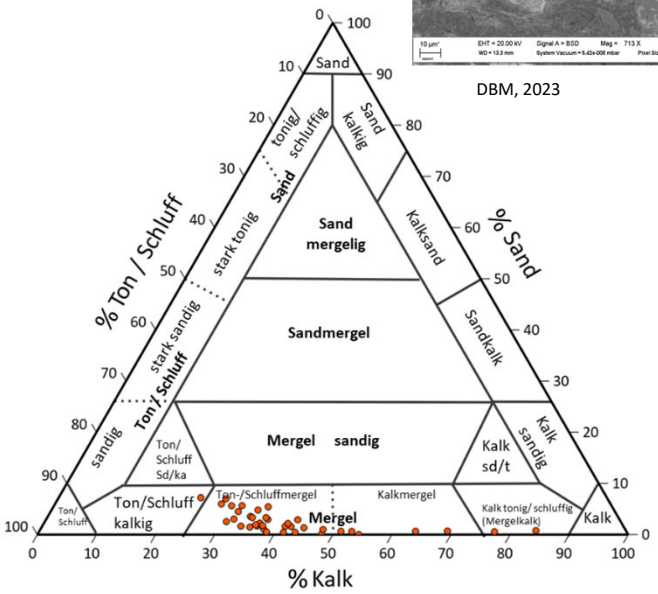
Technische Hochschule Georg Agricola

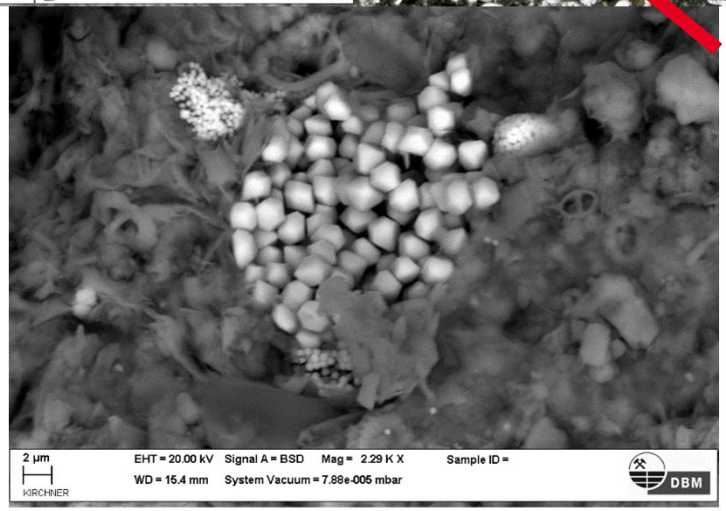
GD NRW, 2019

Upscaling



DBM, 2023

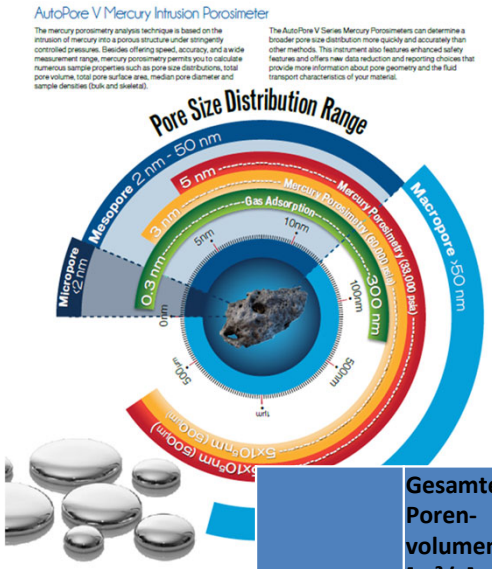




DBM, 2021

Pyknometry/ Porosimetry

- **Equipment:**
  - Pyknometer AccuPyc II 1345 (He/N2)
  - Hg– Porosimeter Autopore V9600
  - Gas-Permeameter UltraPerm 610 + Hassler Cell
  - Permeabilität measured and calculated using pore throat determination from porosimetry (Katz-Thompson Verfahren)
- **Emscher Formation results**
  - mean pore diameter **0,03124 µm**
  - mean porosity **14,7439 %**



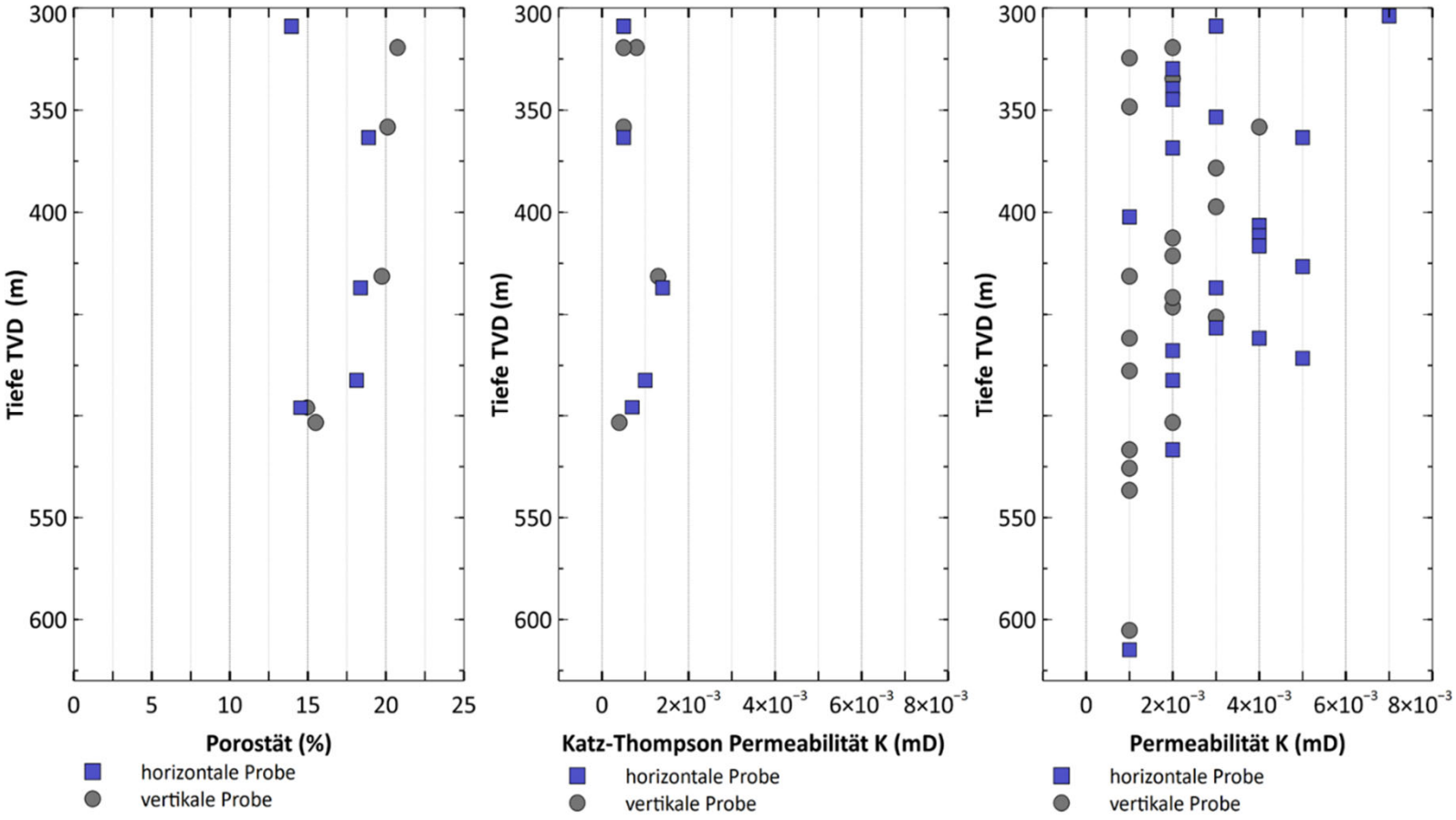
Technische Hochschule Georg Agricola

	Gesamtes Poren-volumen [m²/g]	Mittlerer Porendurch-messer [µm]	Durchschnitt Porendurch-messer [µm]	Gesamt Dichte [g/mL]	Skelett-dichte [g/mL]	Porosität [%]
EM h1	9,951	0,03475	0,02582	2,2900	2,6850	14,7094
EM h2	10,658	0,02954	0,02326	2,2740	2,6471	14,0959
EM h3	10,145	0,03322	0,02570	2,2735	2,6690	14,8192
EM v1	10,581	0,03544	0,02677	2,2369	2,6579	15,8393
EM v2	12,310	0,02800	0,02128	2,2497	2,6385	14,7360
EM v3	11,475	0,02646	0,02175	2,2858	2,6660	14,2636
Sst v1	0,147	28,10055	3,19340	2,0061	2,6233	23,5259
Sst v2	0,310	26,49321	1,35345	2,0846	2,6680	21,8660
Sst h1	0,269	27,70771	1,64421	2,0318	2,6207	22,4717

Results – porosimetry & air permeametry

Technische Hochschule Georg Agricola

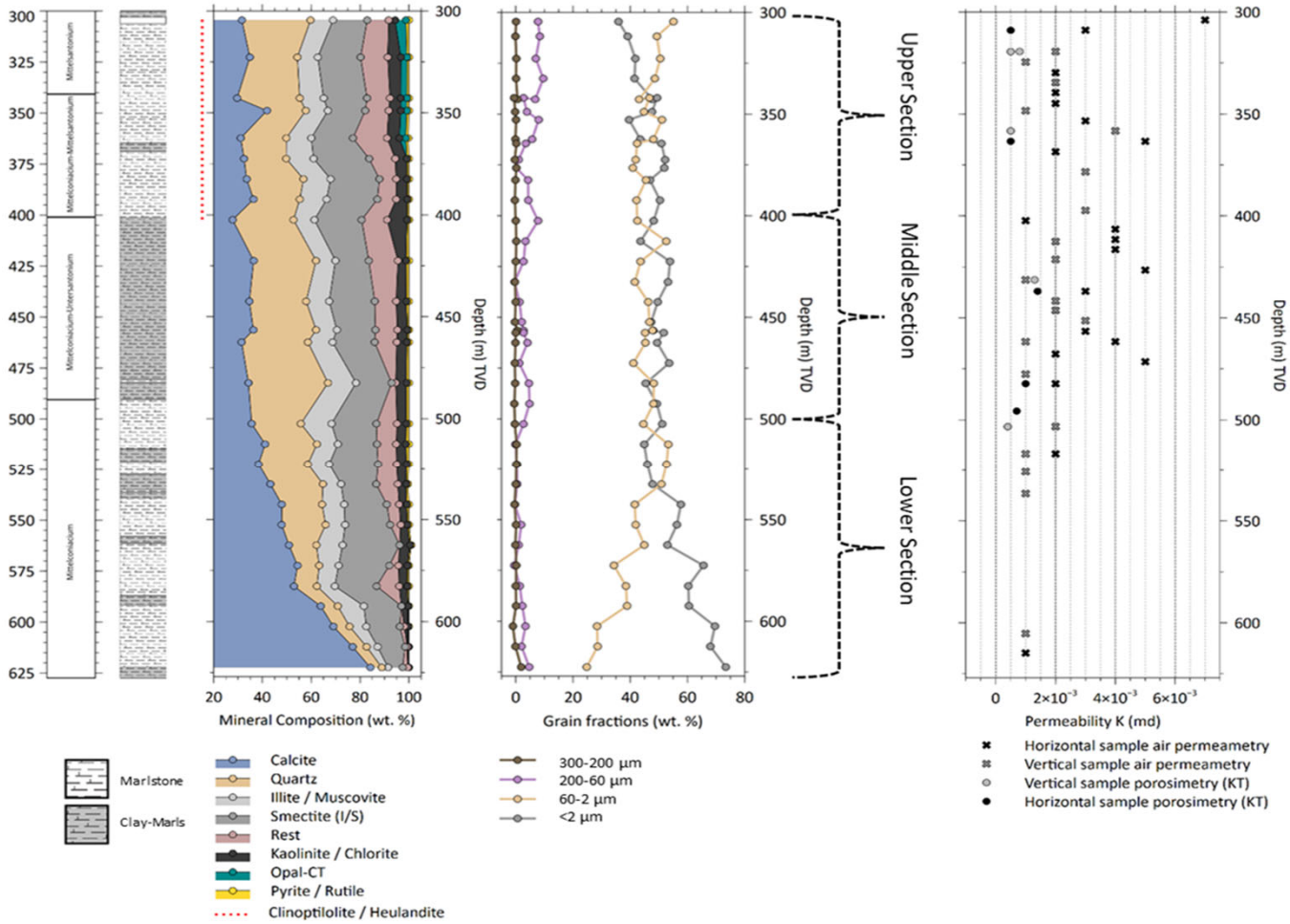
- low permeability ranging from 1×10^{-3} mD to 8×10^{-3} mD
- porosity: 15-21%



Results – Clay mineralogy & permeability

Technische Hochschule Georg Agricola

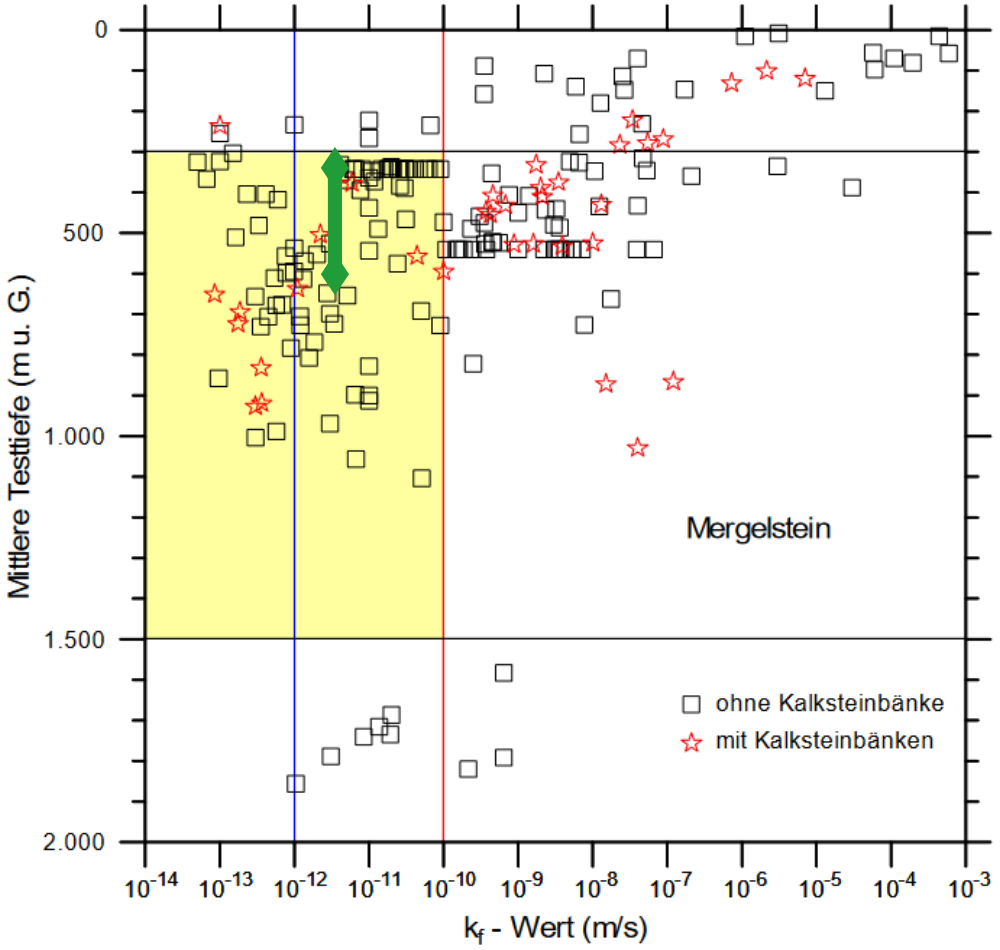
- complete mineralogical profile including detailed clay mineralogy for the entire cored section of the Emscher Fm. at site Lippramsdorf



Classification of marlstones

Technische Hochschule Georg Agricola

- nuclear waste repository related marlstone screening in Germany
- yellow bracket means: "suitable as repository"
- pure marlstones vs. marlstones with intercalated carbonate layers
- Emscher Fm. Is part of a suitable hydraulic conductivity value range for hydraulic barriers



Conclusions

Technische Hochschule Georg Agricola

- The workflow applied resulted in quantitative clay mineralogy and poroperm data to be used in hydrogeological modeling and borehole geophysics calibration
- especially the two-way independent permeability assessment delivers a robust QC of the data
- the first continuous depth profile of quantitative plug-based poroperm data for the Emscher Marl has been obtained
- vertical and horizontal hydraulic conductivity of $k_f = 6{,}77 \times 10^{-12}$ m/s - $7{,}4 \times 10^{-13}$ m/s

Technische Hochschule Georg Agricola

Thank you for your attention and Glückauf!

Acknowledgments:

We thank RAG AG for permission, sampling and data support,
And the „Forum Bergbau und Wasser" is cordially thanked for financing this research.

Forum Bergbau Wasser

RAG