

# Organization and Research

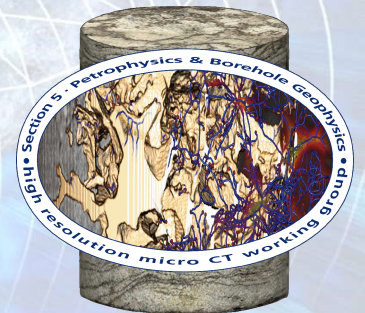


Matthias Halisch

Reinjection Workshop

Szeged, Hungary

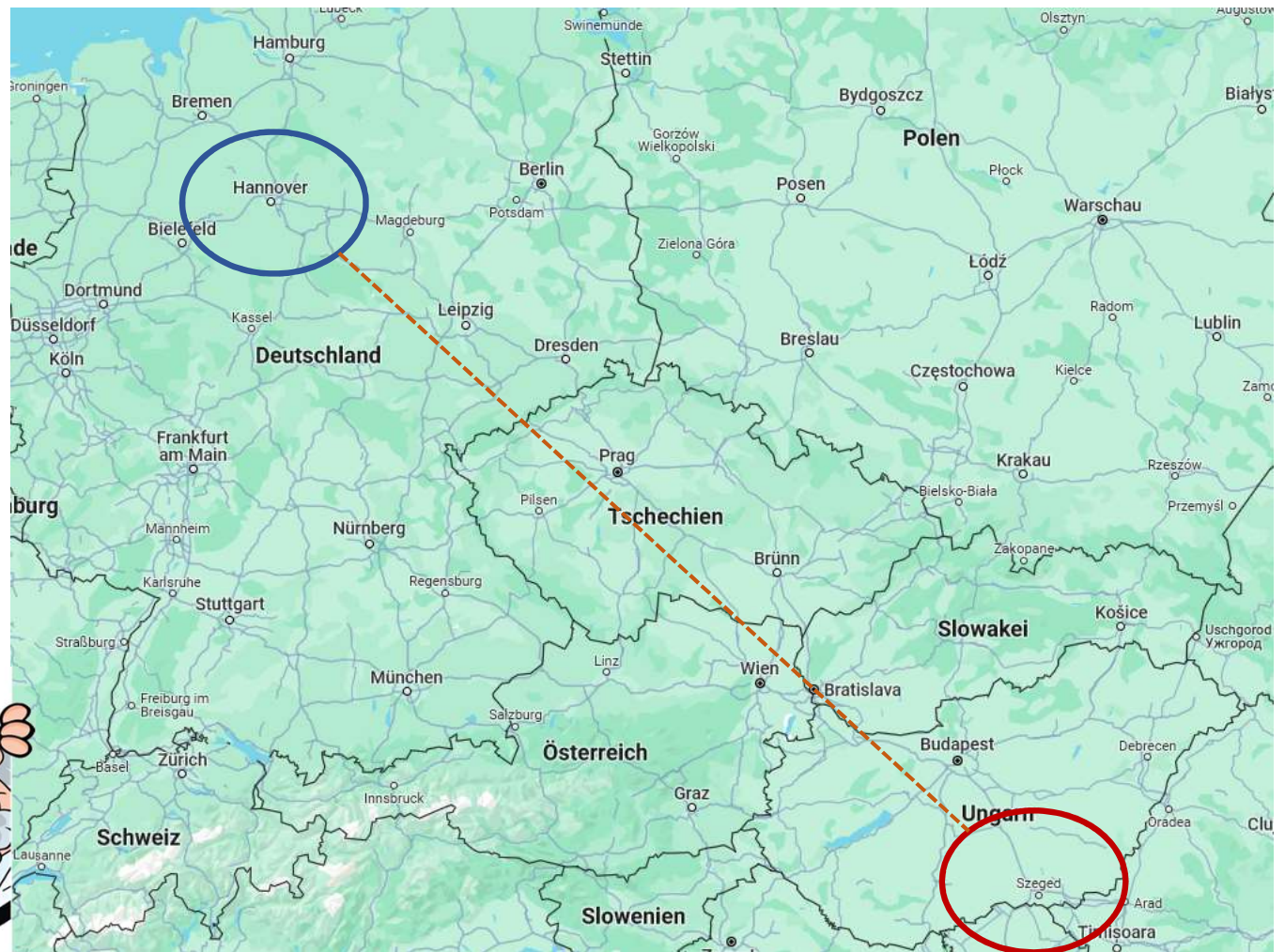
16.04.2024





Where you can find us

[www.leibniz-liag.de](http://www.leibniz-liag.de)







- Independent, non-university research institute based in Hannover
- 75 years of geophysical research experience
- Application of geophysical methods to explore future-oriented topics of societal importance
- Exploration of usable subsurface and development of measuring technologies and evaluation methods
- Independent and knowledge-based counselling for decision makers
- Great expertise in geophysical applications combined with high quality equipment and infrastructure allows for the combination of various methods to address current research topics







## Organizational Plan (decided on April, 11th 2024)



Stand: 07.03.2024



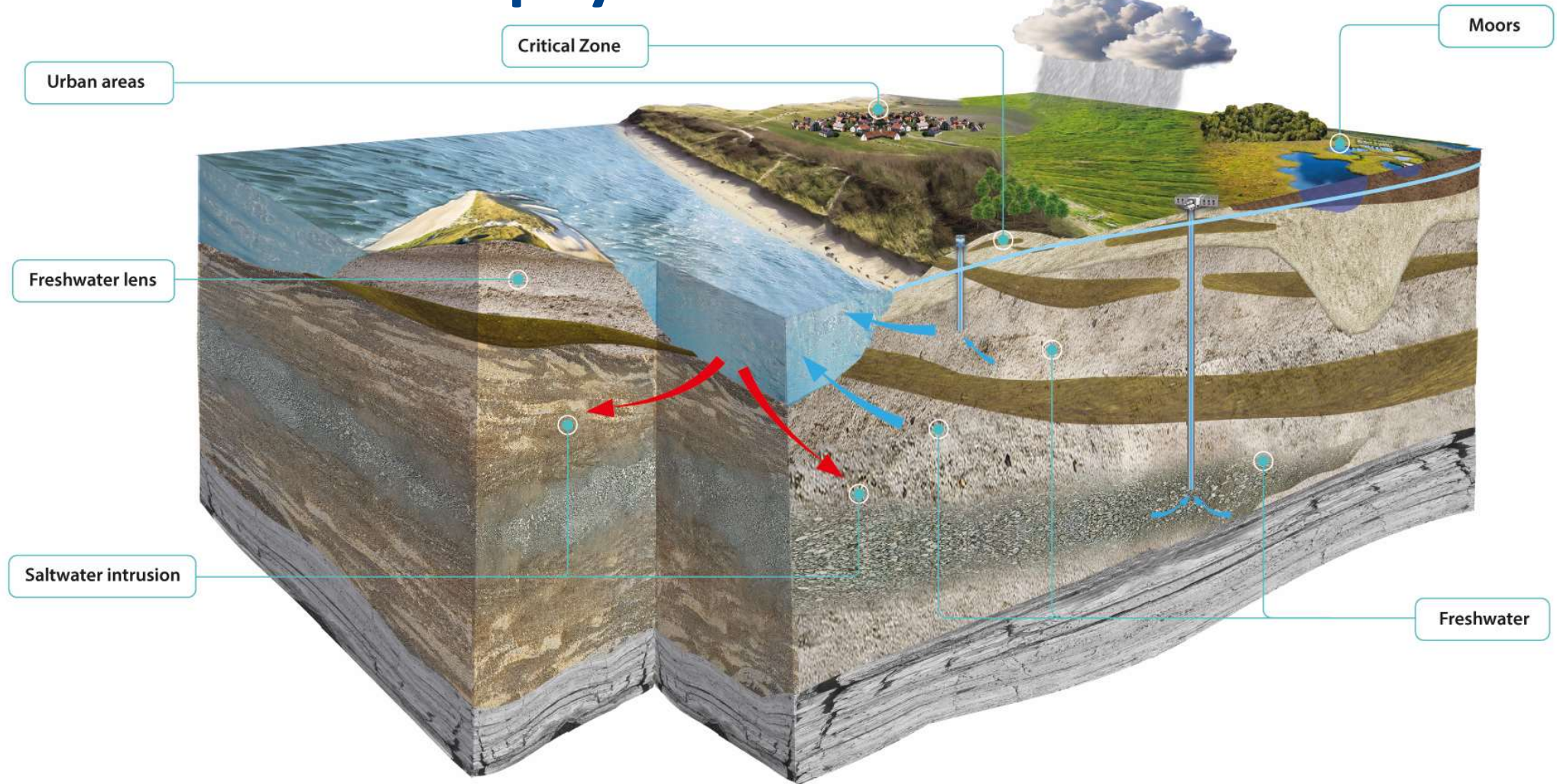


Research Topic Profiles

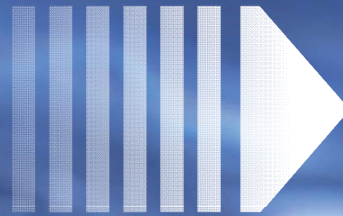
Groundwater-Geophysics  
Geohazards  
Georeservoirs as energy  
storage & energy source



# Groundwater Geophysics







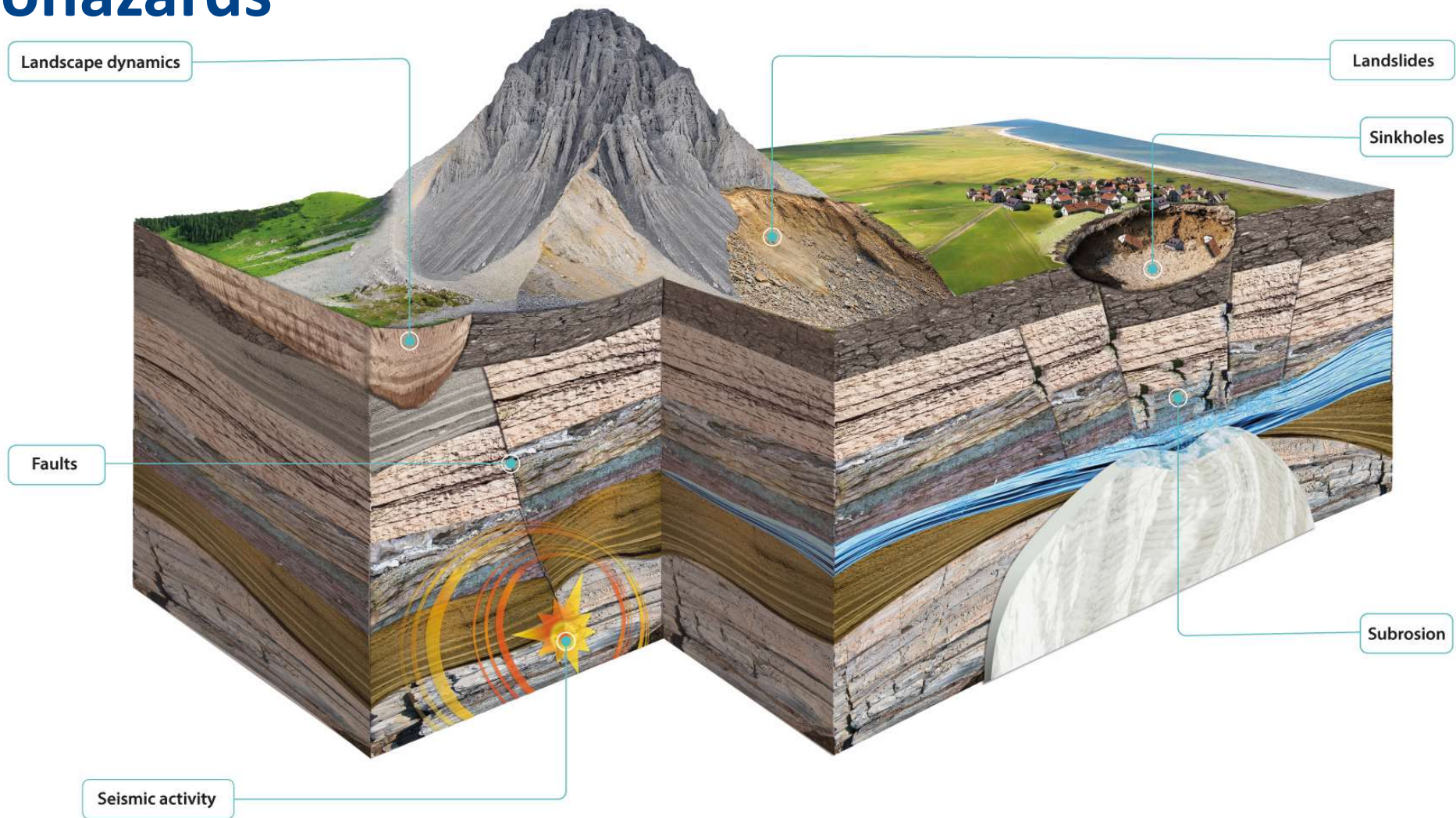
## Groundwater-Geophysics

### Observing and understanding the elixir of life

- Researching coastal aquifers, soils and moors for medium- and long-term predictions with innovative measuring technology
- Determining drinking water resources and their development for sustainable management and groundwater protection
- Early warning of salinization processes using the specially developed monitoring system SAMOS
- Optimizing methods for drone-based measurements as flexible and cost-effective alternative for large scale subsurface investigation



# Geohazards







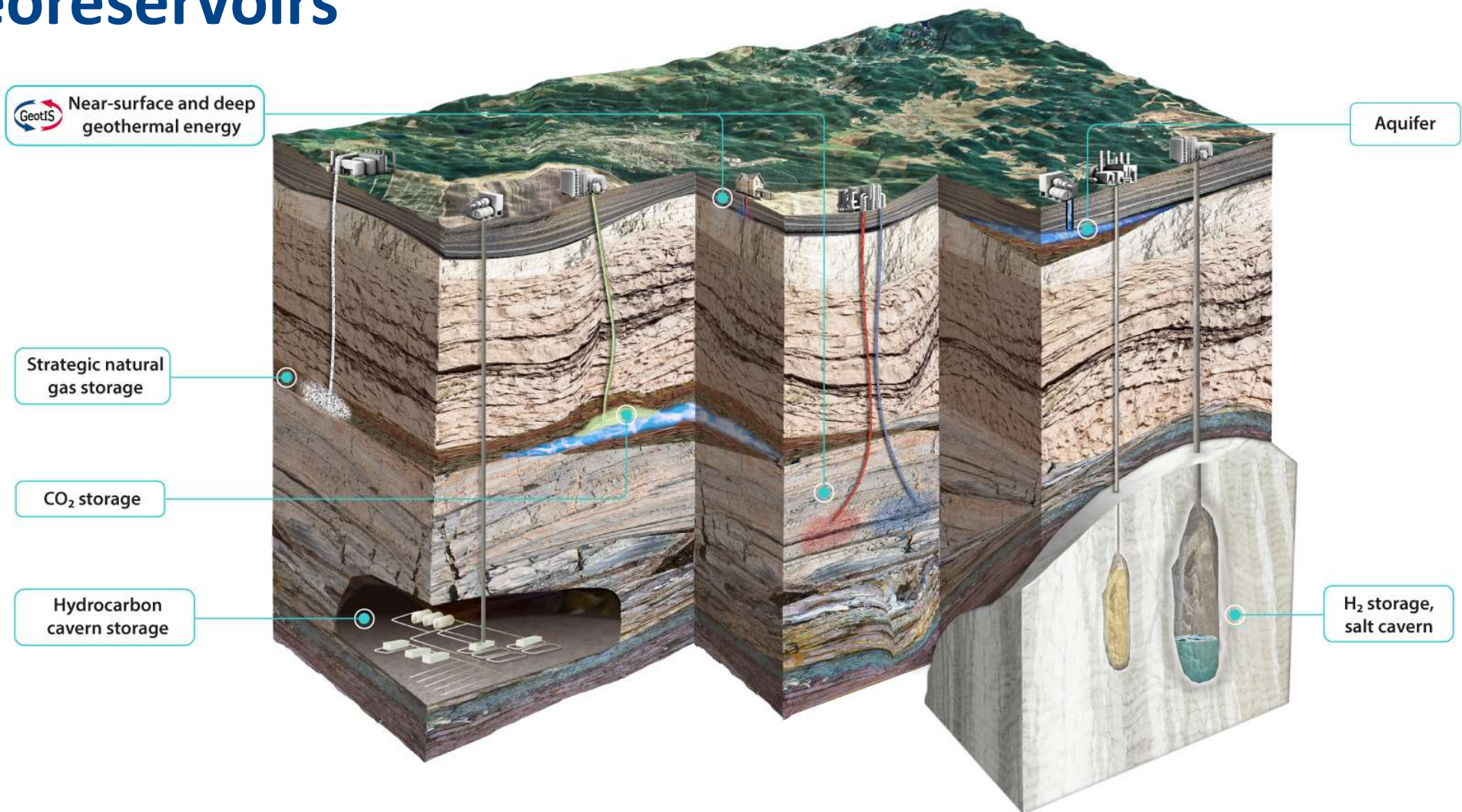
# Geohazards

## When the ground moves

- **Neotectonics:** Detection of recent tectonic activity by characterizing geological faults; investigation of volcanic structures; age determination of paleoearthquakes and their geological record
- **Subrosion:** Identifying vulnerable areas and non-destructive monitoring
- **Modelling of deformation processes**
- **Prediction of climatic influence on geohazards**



# Georeservoirs







# Geothermal energy

## Renewable energy from depth

- Further development of models for reservoir prediction and temperature field
- Simulations for sustainable reservoir operation
- Geothermal knowledge across Germany in our own geothermal information system GeotIS – e.g., Germany-wide temperature maps
- Machine learning in seismic exploration
- Knowledge transfer through development and distribution of e-learning modules
- Recommendations for the national heating strategy for the expansion of geothermal energy





# Georeservoirs

## Energy sources and storage

- Georeservoirs are geological, fractured, porous and permeable rock formations
- They supply energy resources and heat, and are suitable as storage systems (water, hydrogen, natural gas)
- Characterisation and determination of their potential helps secure the energy supply
- Societally-relevant research for the energy supply in Germany – over 75 years of expertise in the field of geophysics





## Sediments on the move

### Learning from the past

- Understanding climate and environmental changes in the past from terrestrial sediments with regard to the future
- Generation of a transregional, consistent picture of climate and landscape development
- Unravelling the secrets of unexplored climate archives such as lake basins, loess or valleys formed by glaciers and refilled with sediments
- Creating knowledge about past and future ice ages
- Reconstructing conditions of human ancestors



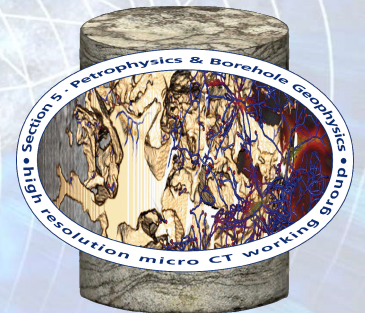
# Quantitative 3D DIA and DRP for understanding fluid flow and clogging processes of the DG Formation

Matthias Halisch

Reinjection Workshop

Szeged, Hungary

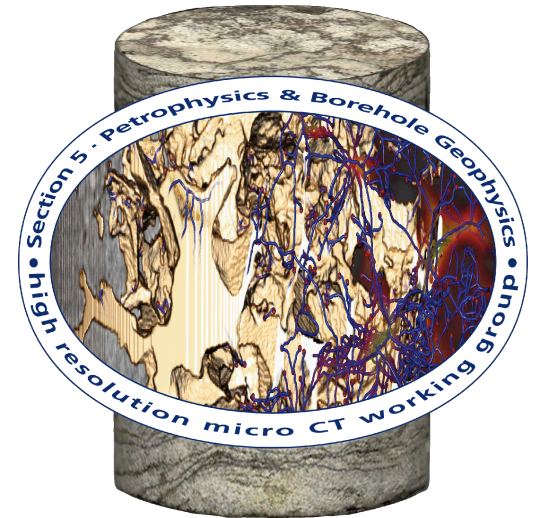
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# Outline

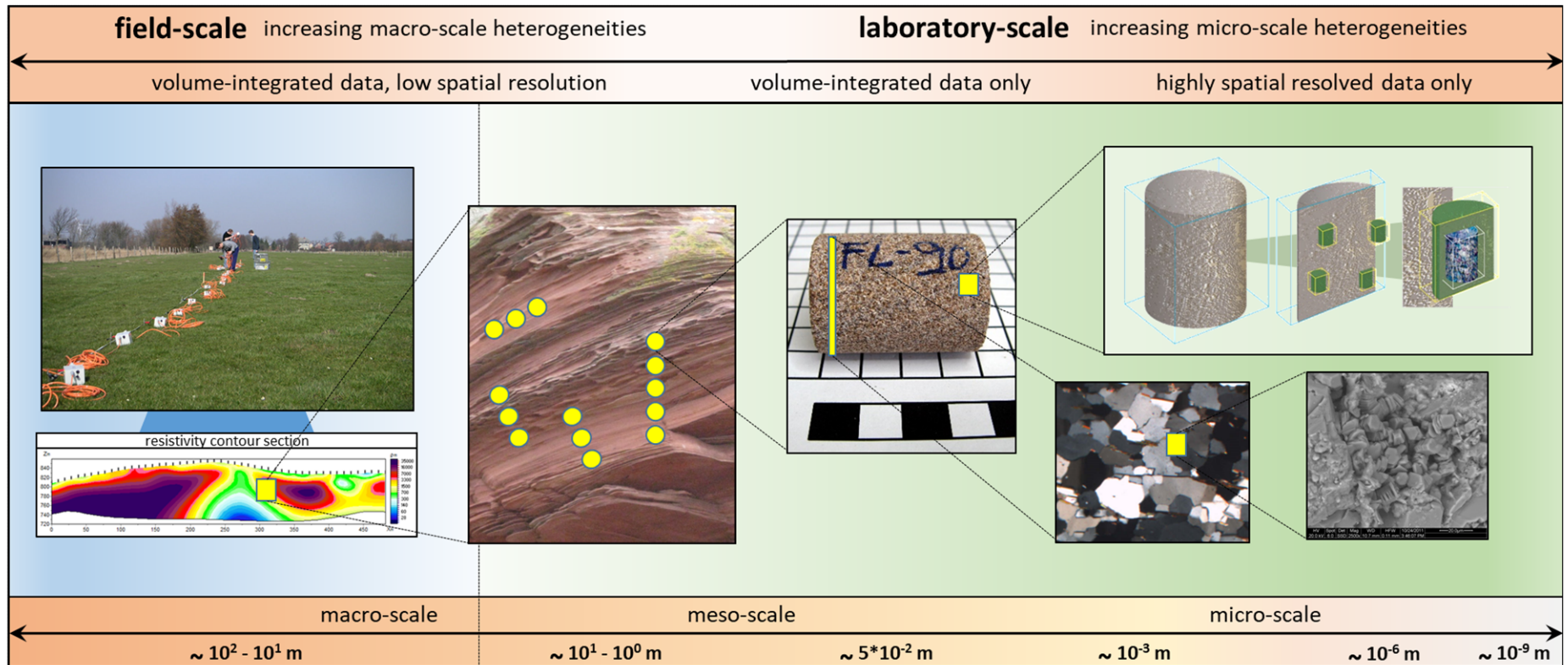
- Motivation
- DIA / DRP concept and workflow @ LIAG
- 3D  $\mu$ -CT imaging
- Digital Image Analysis & Digital Rock Physics
- Clogging of the DG Formation:
  - Results from Image Analysis
  - Results from DRP
- Summary
- Conclusions / Outlook





# Motivation

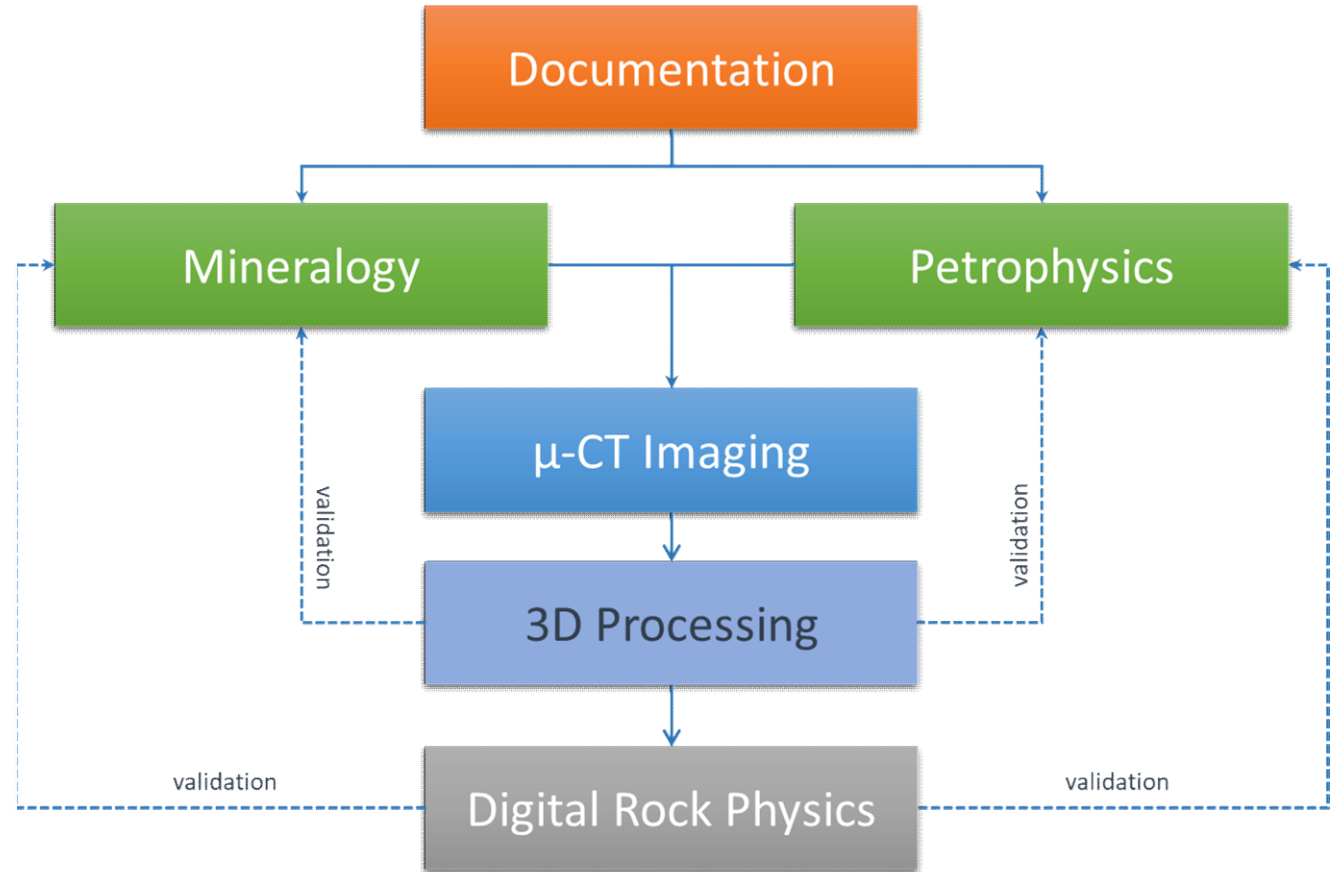
## From application to the micro-scale and vice-versa





# Concept & Workflow

## Integration of 3D image analysis and digital rock physics





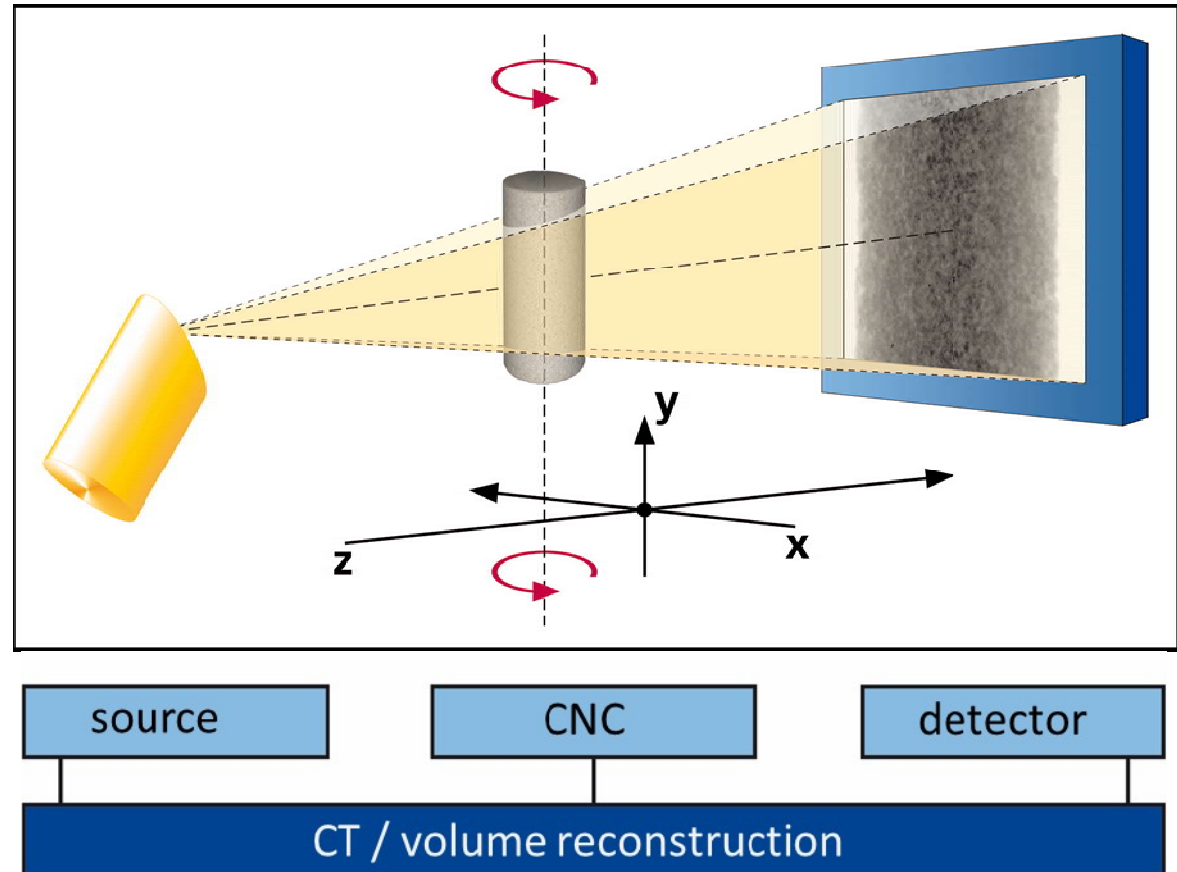
# 3D $\mu$ -Computed Tomography

## Basic principles and demands for high image quality

- Acquisition of 2D pictures, whilst sample rotates 360°
- Rotation steps  $\ll 1^\circ$

### *Typical scan:*

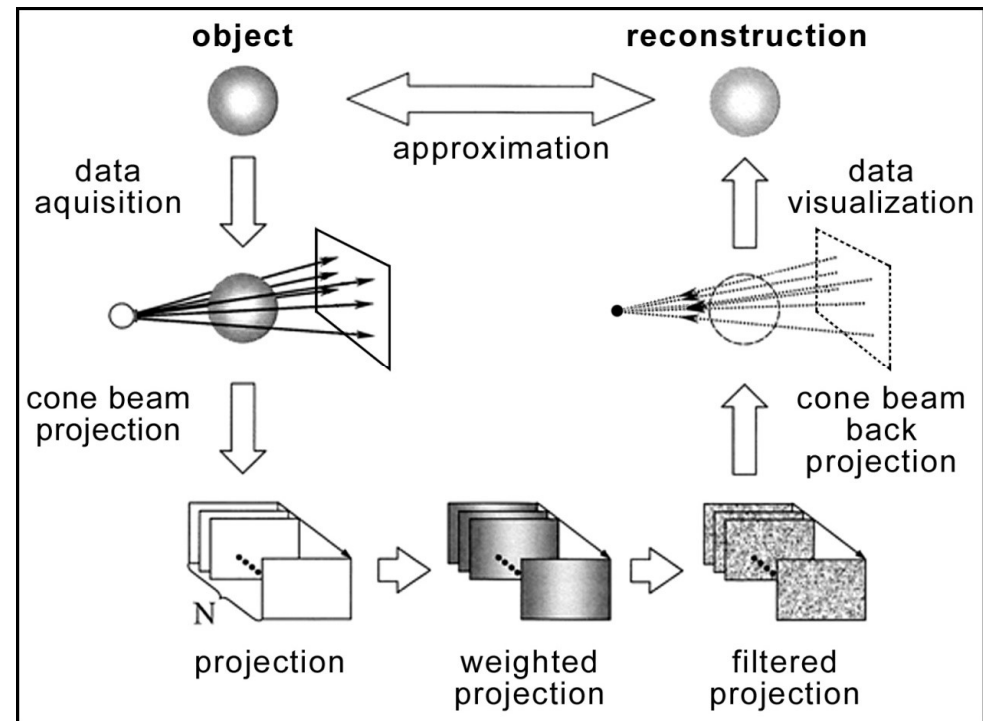
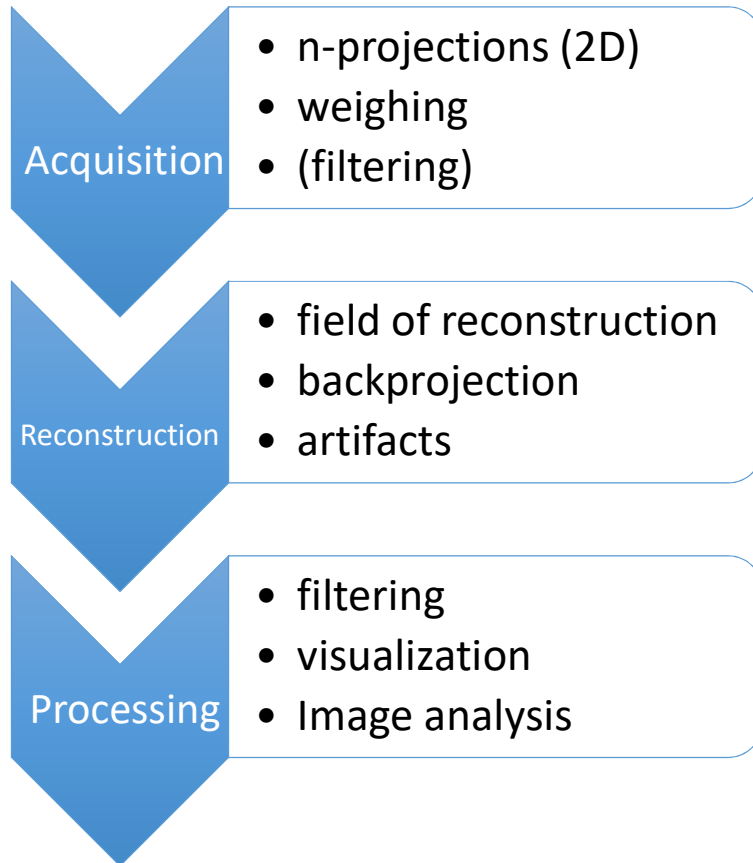
- sample size from few mm to a couple of cm
- 1000-1500 2D pictures for a full 360° turn,
- taking around 1-3h scanning time,
- and ending with 10 -50 Gbyte of raw data)





# 3D $\mu$ -Computed Tomography

## Basic principles and demands for high image quality



Source: BUZUG (2005) Basic Principles of Micro Computed Tomography



# 3D $\mu$ -Computed Tomography

## Basic principles and demands for high image quality

LIAG's  $\mu$ -CT system

nanotom M from  
Baker Hughes Waygate Technologies

tube:

nanofocus < 1.0  $\mu\text{m}$  spot size

max. voltage 180 kV

max. Target power max. 20 W

detector:

Flat panel, 12 Megapixel

24 Megapixel virtual detector

manipulator:

5 axis stepper motors

granite-based





# 3D $\mu$ -Computed Tomography

## Basic principles and demands for high image quality

### Advantages of nanofocus technique

#### Magnification

Geom.: 4x

Total: 20x

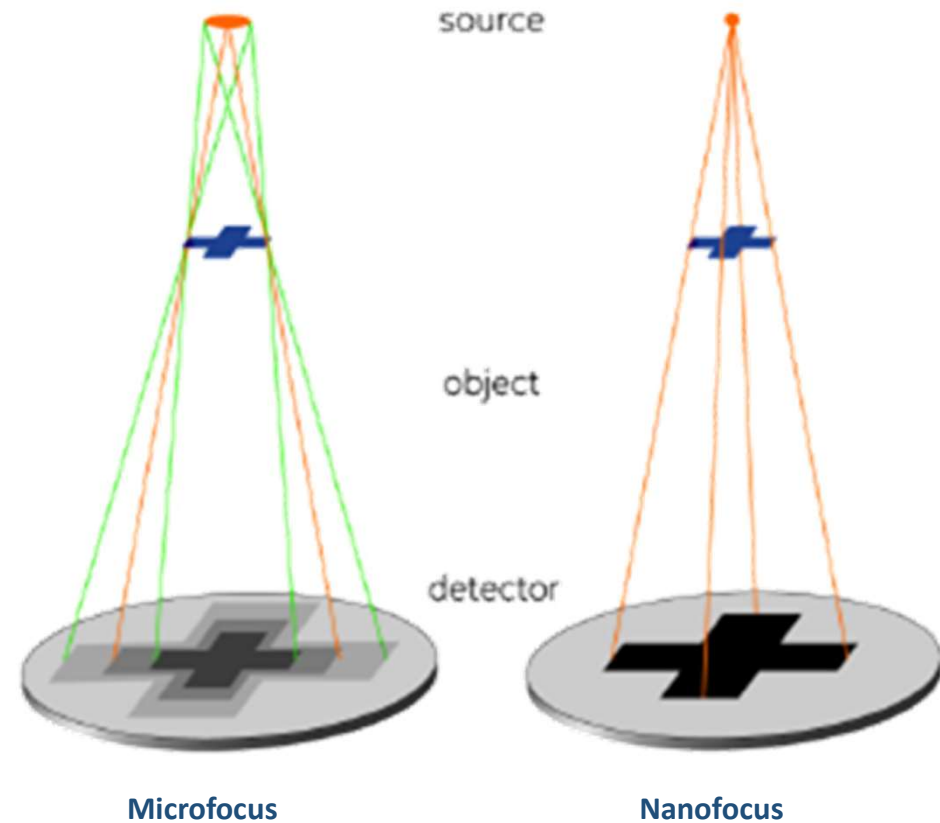
#### Focal spot

Microfocus:  $F = 3\ \mu\text{m}$

Nanofocus:  $F = 0.5\ \mu\text{m}$

Resolution limit =  $F$

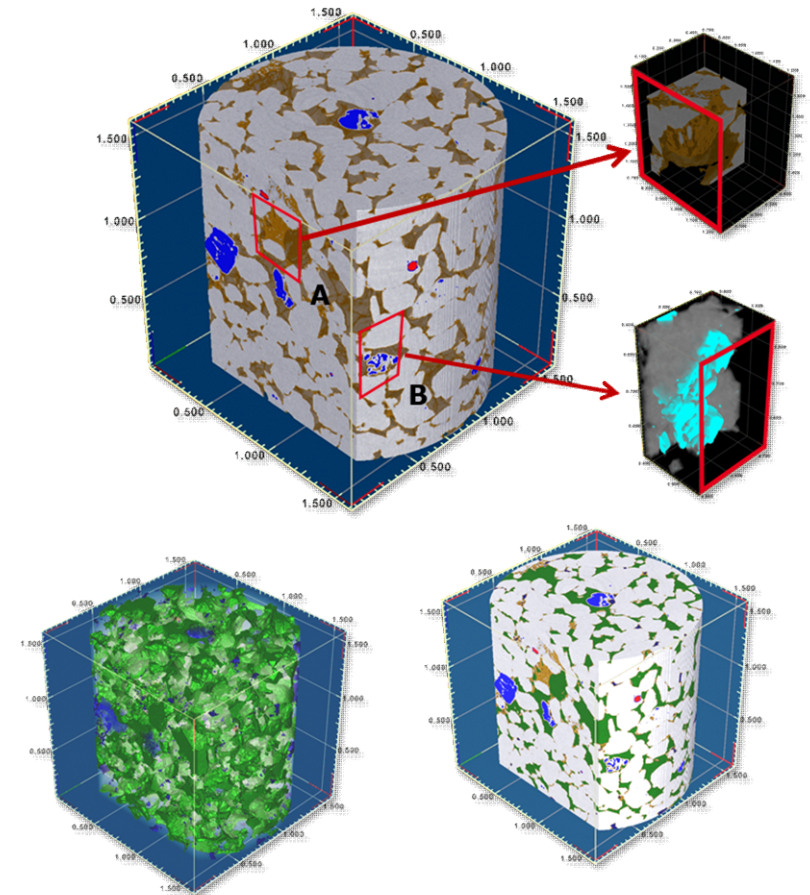
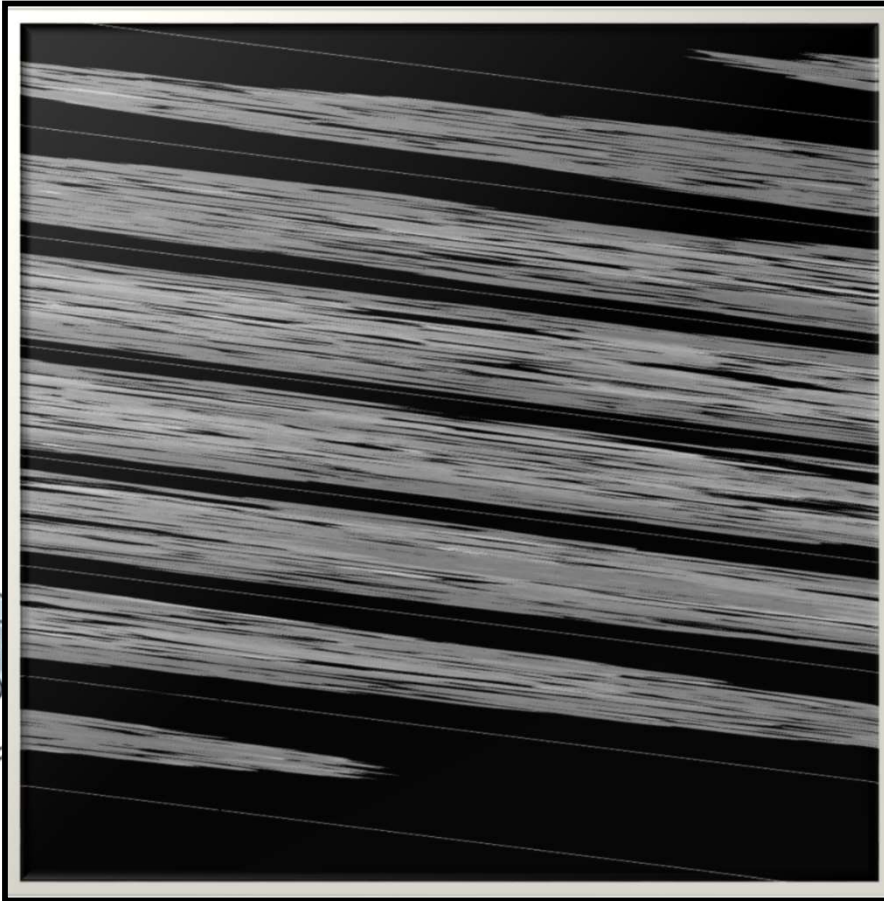
Qualitative detail detectability approx.  $1/3\ F$





# 3D $\mu$ -Computed Tomography

Image analysis starts with decent images!





# Digital Image Analysis (DIA)

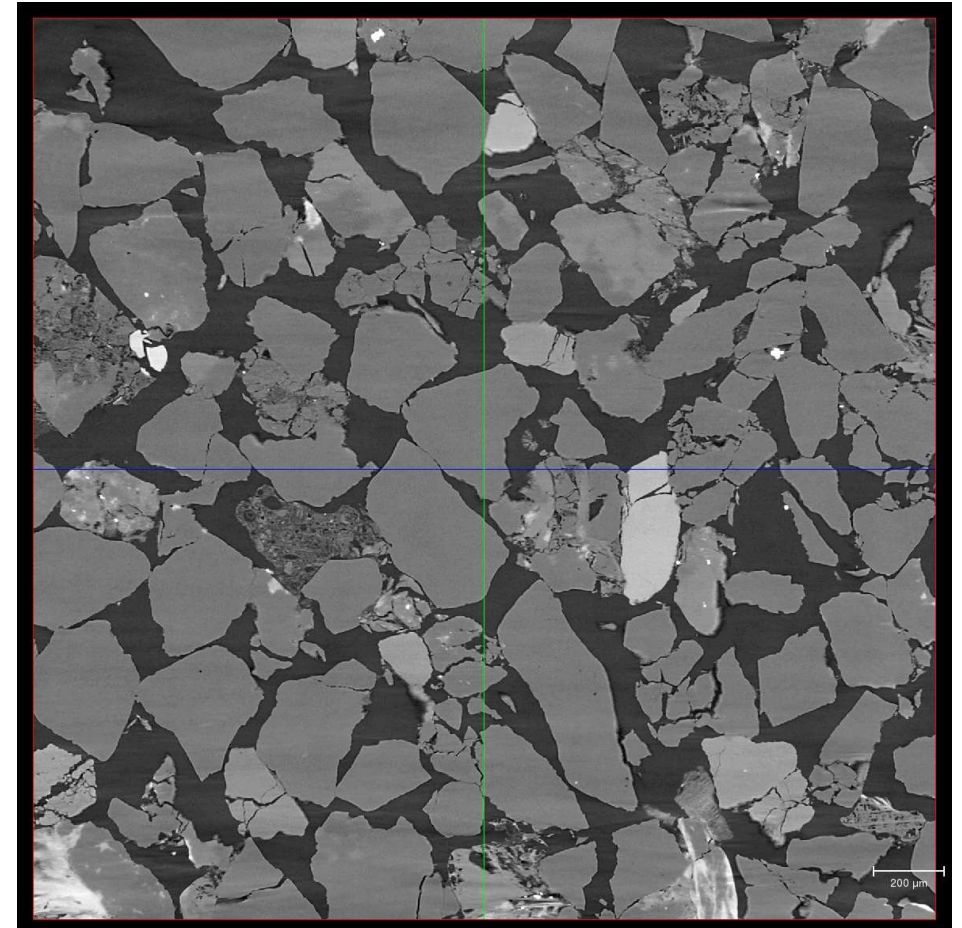
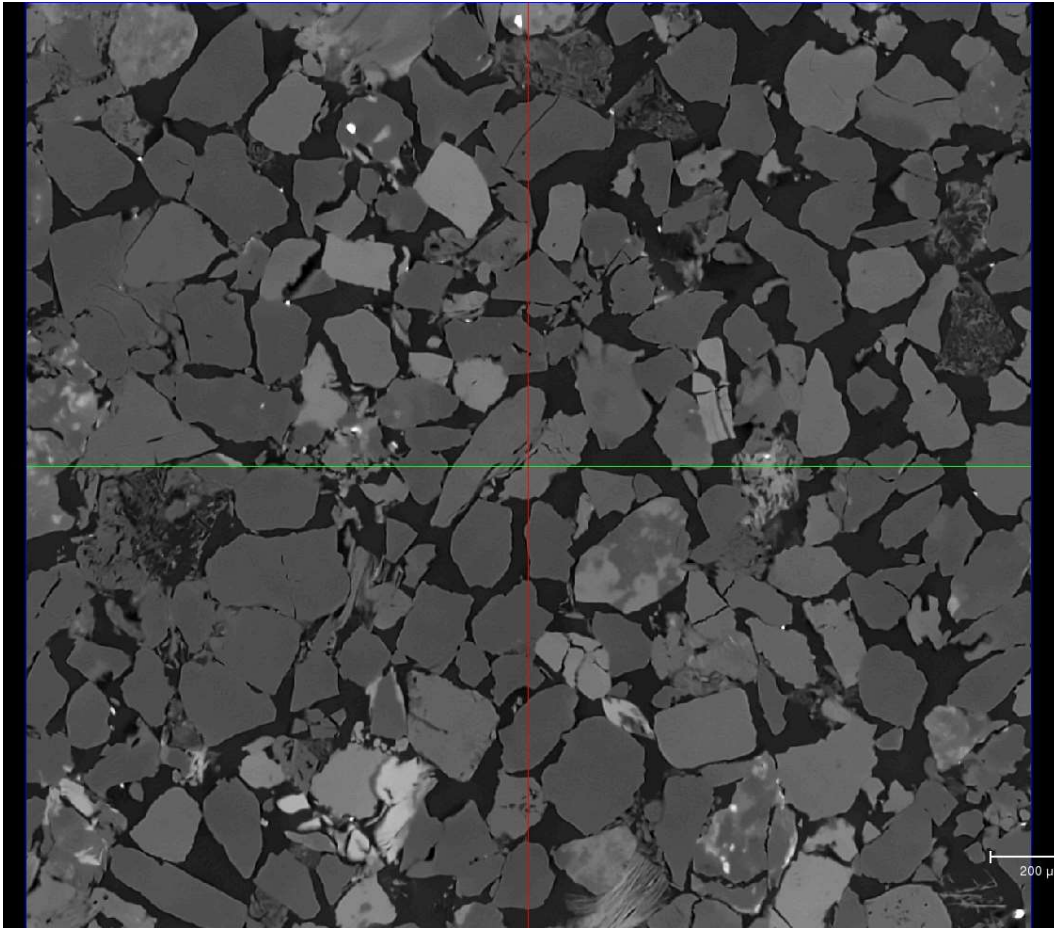
## Basic processing workflow





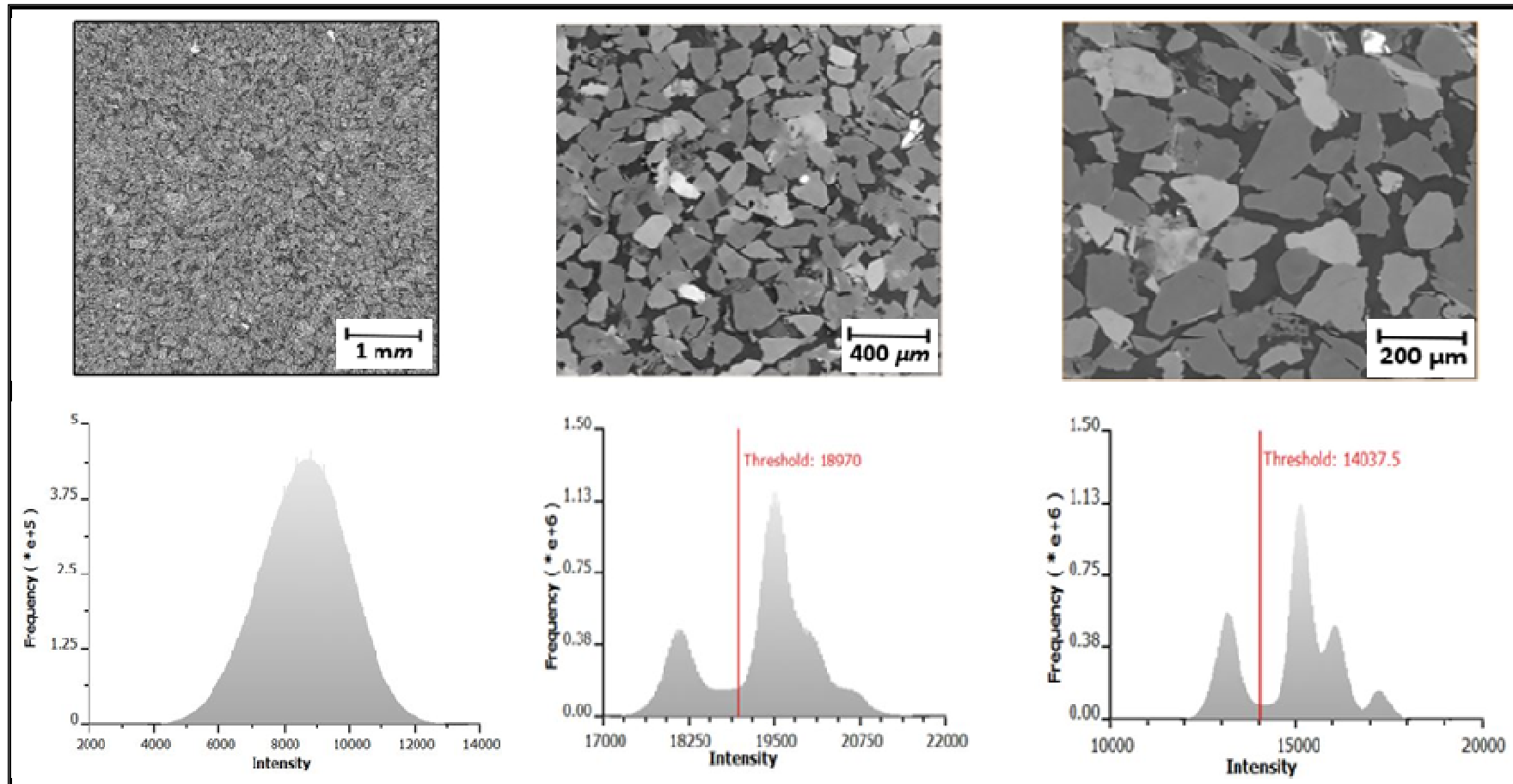
# Digital Image Analysis (DIA)

Investigated samples: H38, H78, H93



# Digital Image Analysis

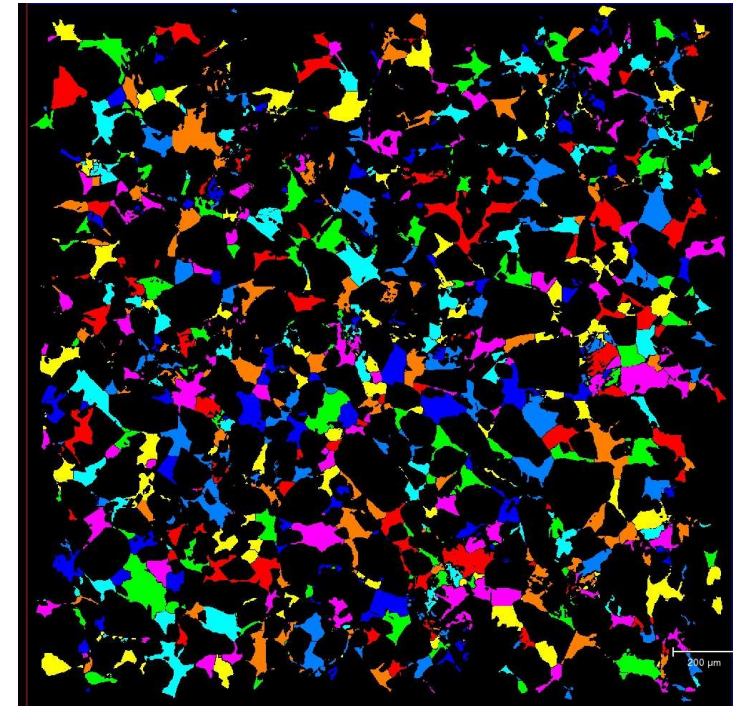
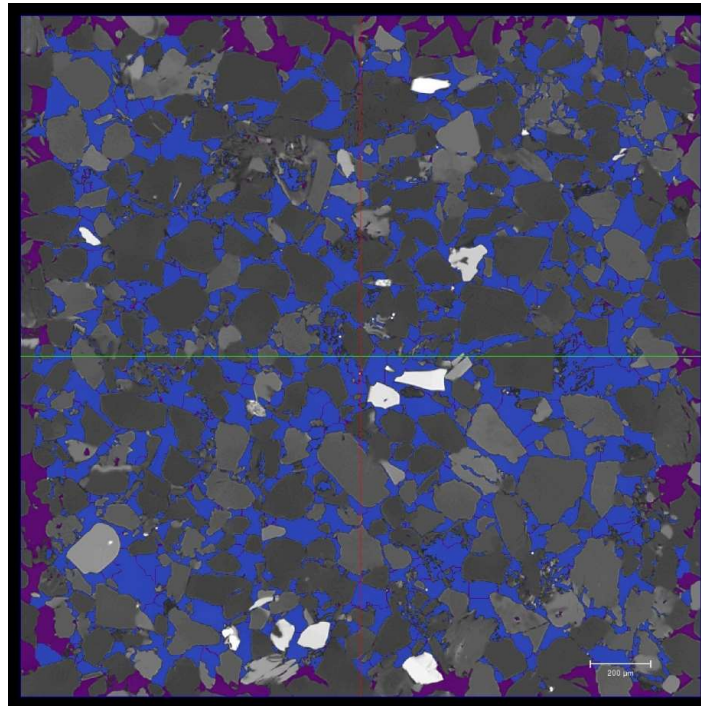
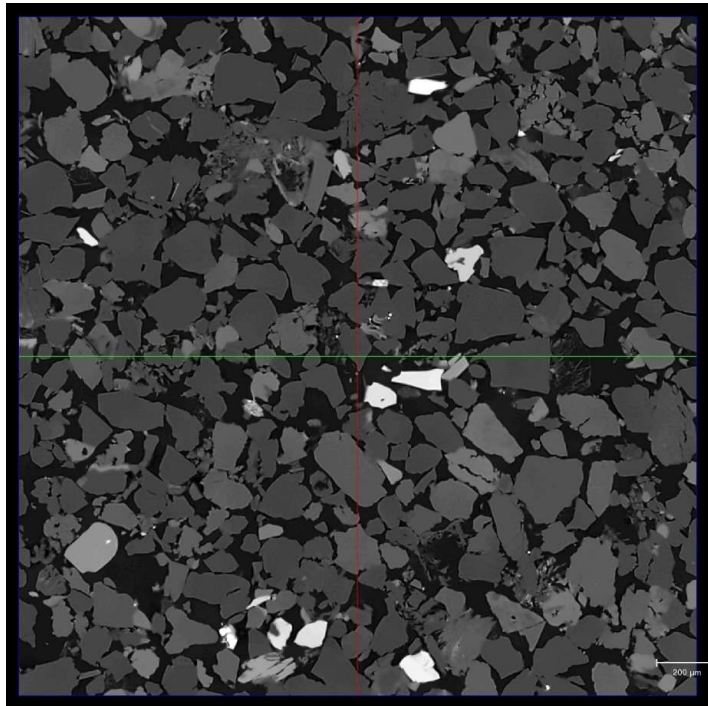
## Choosing the correct scale & threshold





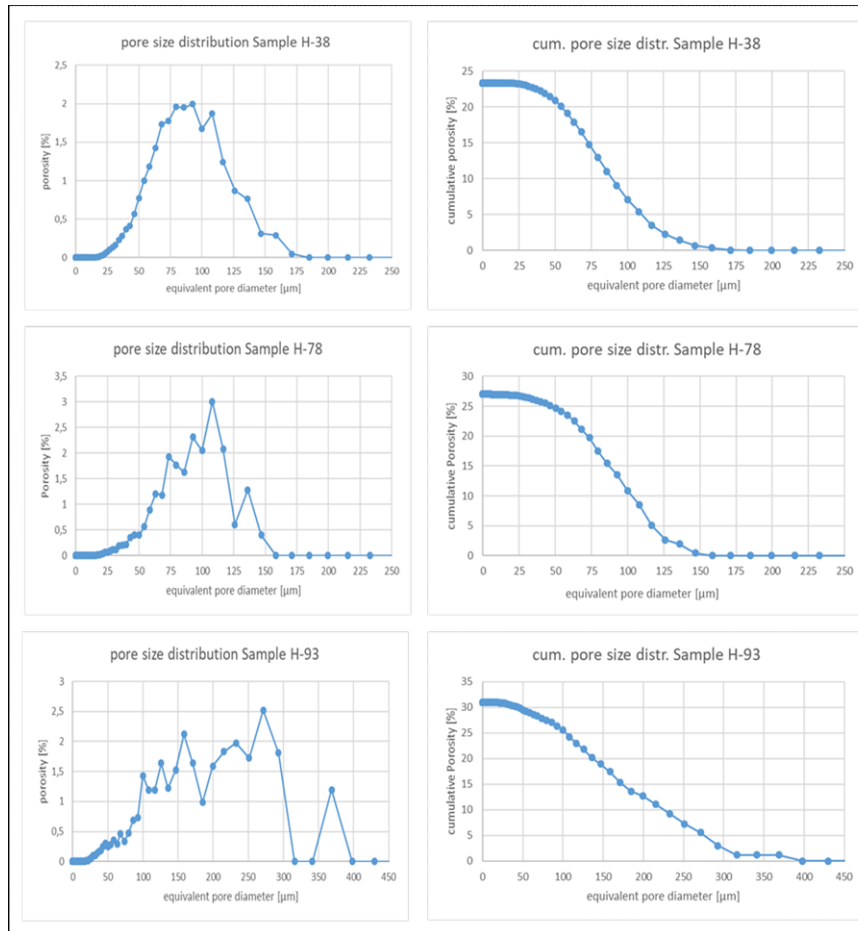
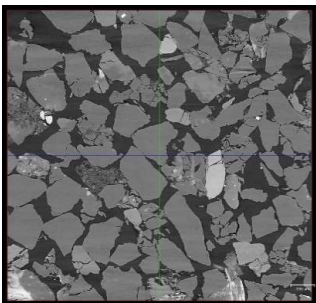
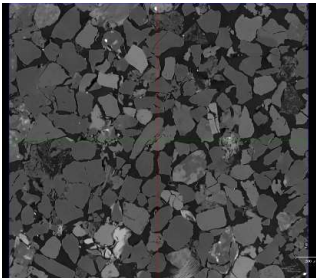
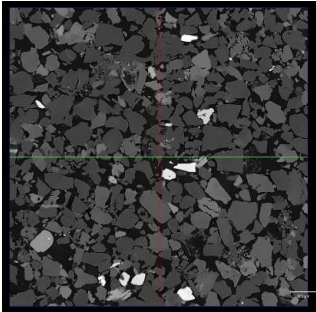
# Digital Image Analysis

Good segmentation = good numbers!



# Digital Image Analysis (DIA)

## Pore space quantification for samples H38, H78 & H93

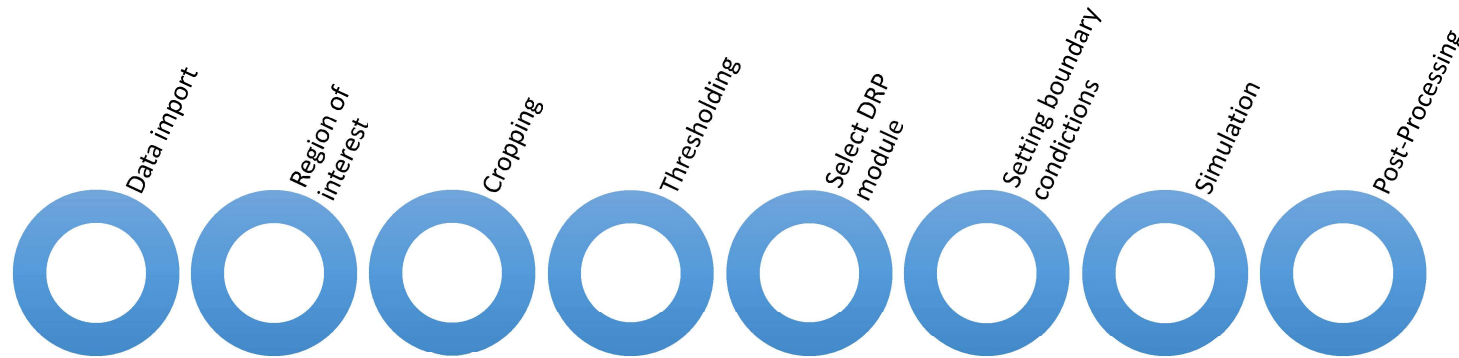


- **H38**
  - Avg. pore diameter: ~ 80 μm
  - Effective porosity: ~ 24 %
- **H78**
  - Avg. pore diameter: ~ 100 μm
  - Effective porosity: ~ 27 %
- **H93**
  - Avg. pore diameter: ~ 150 - 250 μm
  - Effective porosity: ~ 31 %



# Digital Rock Physics (DRP)

## Basic workflow & capabilities



- 1-phase fluid flow
- 2-phase fluid flow
- Capillary pressure (digital MICP)
- Elastic rock properties
- Electrical rock properties
- Digital porometry / NMR
- Filtration \*

\* currently not at LIAG

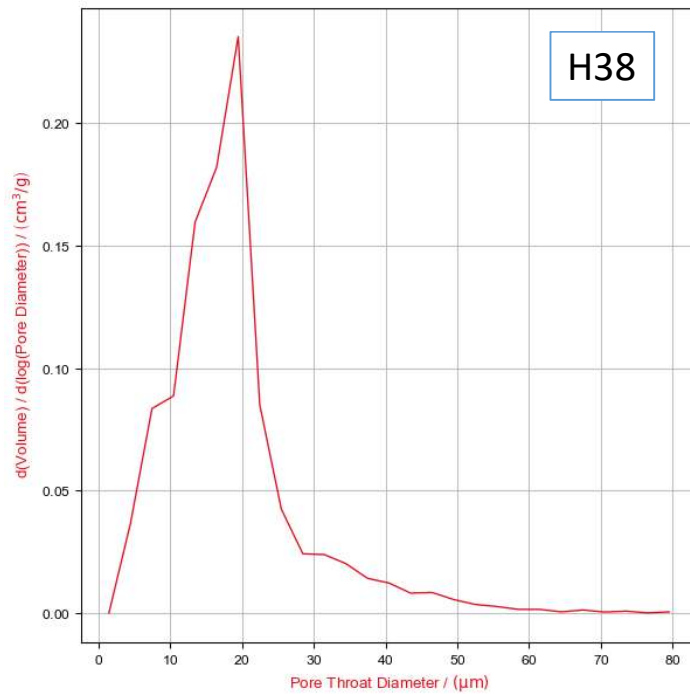
**GEO**DICT  
The Digital Material Laboratory



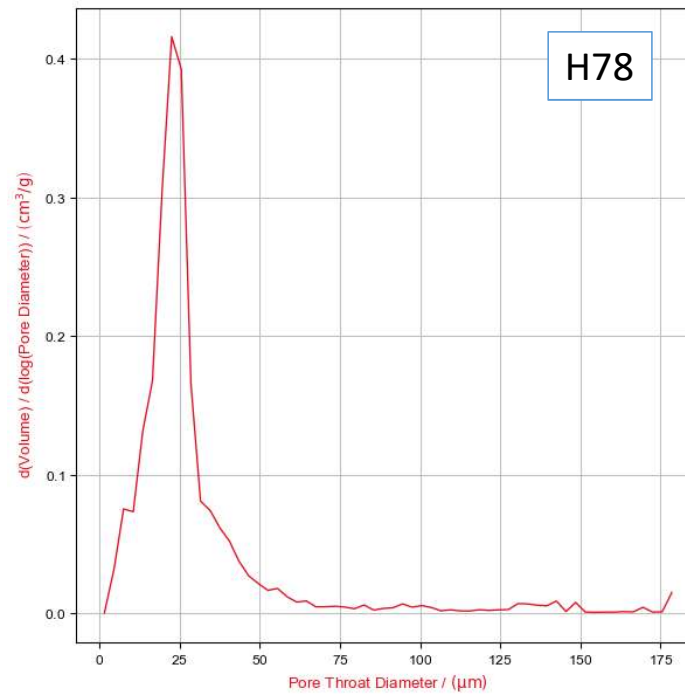
**MATH**  
2 MARKET

# Digital Rock Physics (DRP)

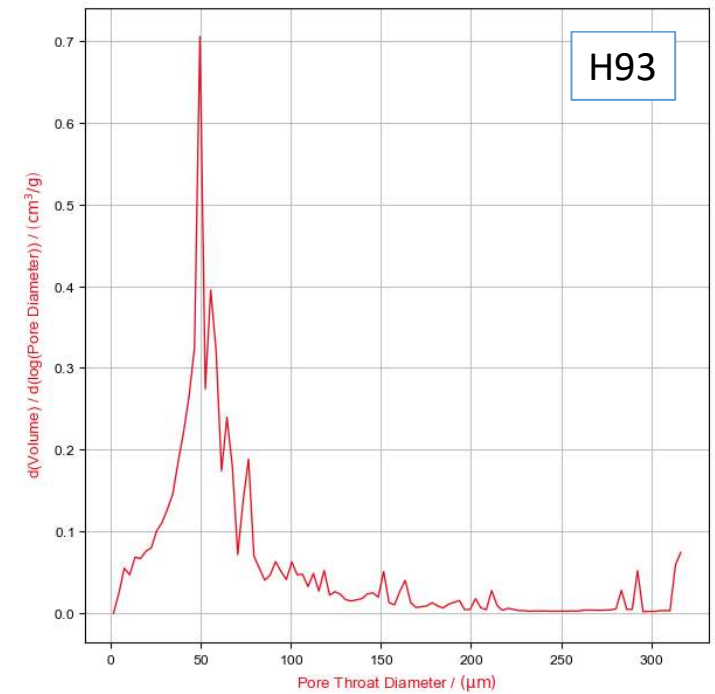
## Results from MICP & 1-phase fluid flow simulations



$D_{\text{dom}} = 19 \mu\text{m}$



$D_{\text{dom}} = 23.5 \mu\text{m}$



$D_{\text{dom}} = 50 \mu\text{m}$



# Digital Rock Physics (DRP)

Results from MICP & 1-phase fluid flow simulations



H38

$k_{kl} = 60 \text{ mD}$   
 $A = 1.43$



H78

$k_{kl} = 240 \text{ mD}$   
 $A = 1.08$

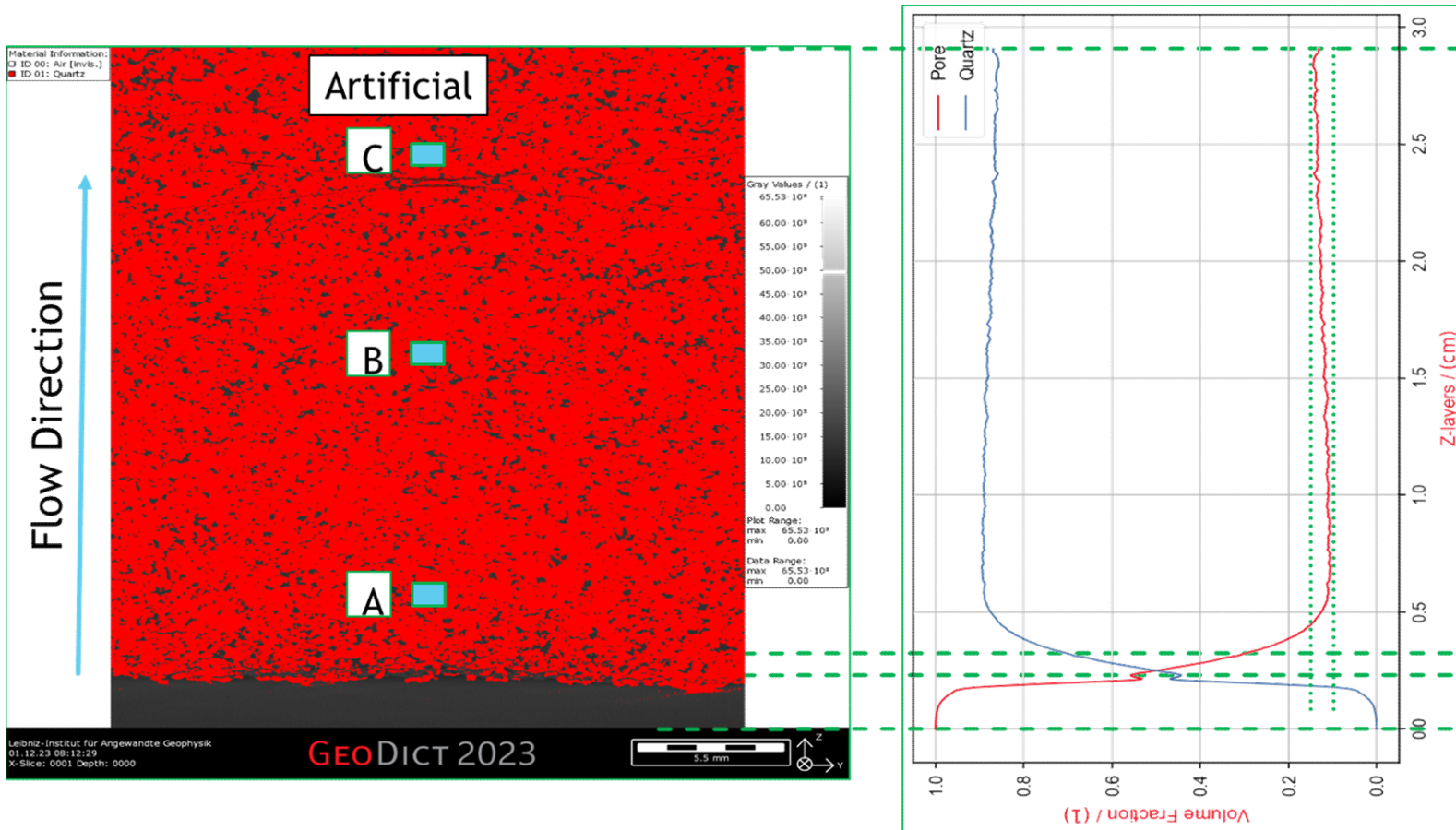


H93

$k_{kl} = 390 \text{ mD}$   
 $A = 1.05$

# Clogging Quantification

## Linking laboratory experiments and simulations

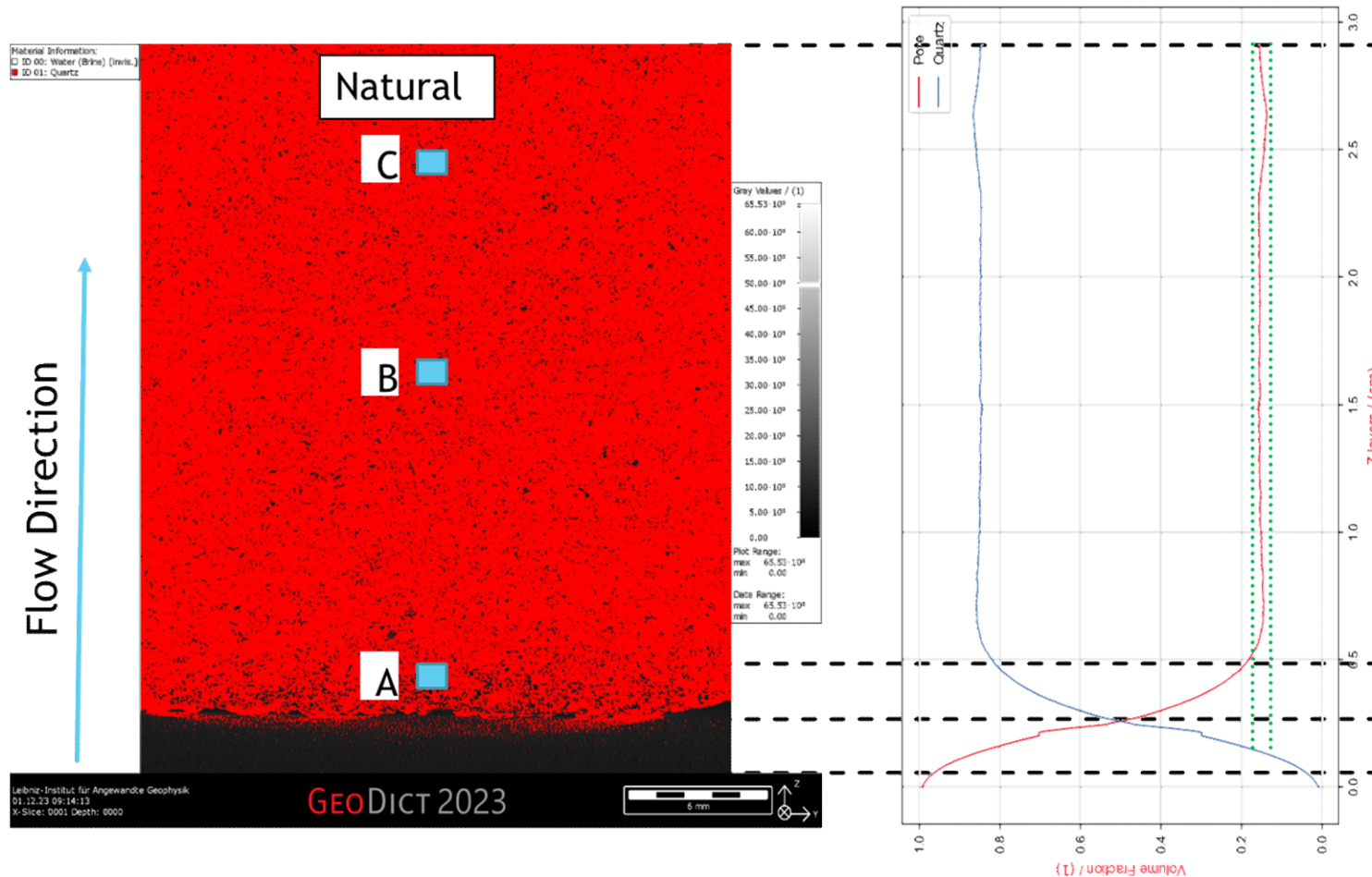


- distinct porosity increase from inflow towards outflow
- approx. +50%
- deep infiltration (entire core length)



# Clogging Quantification

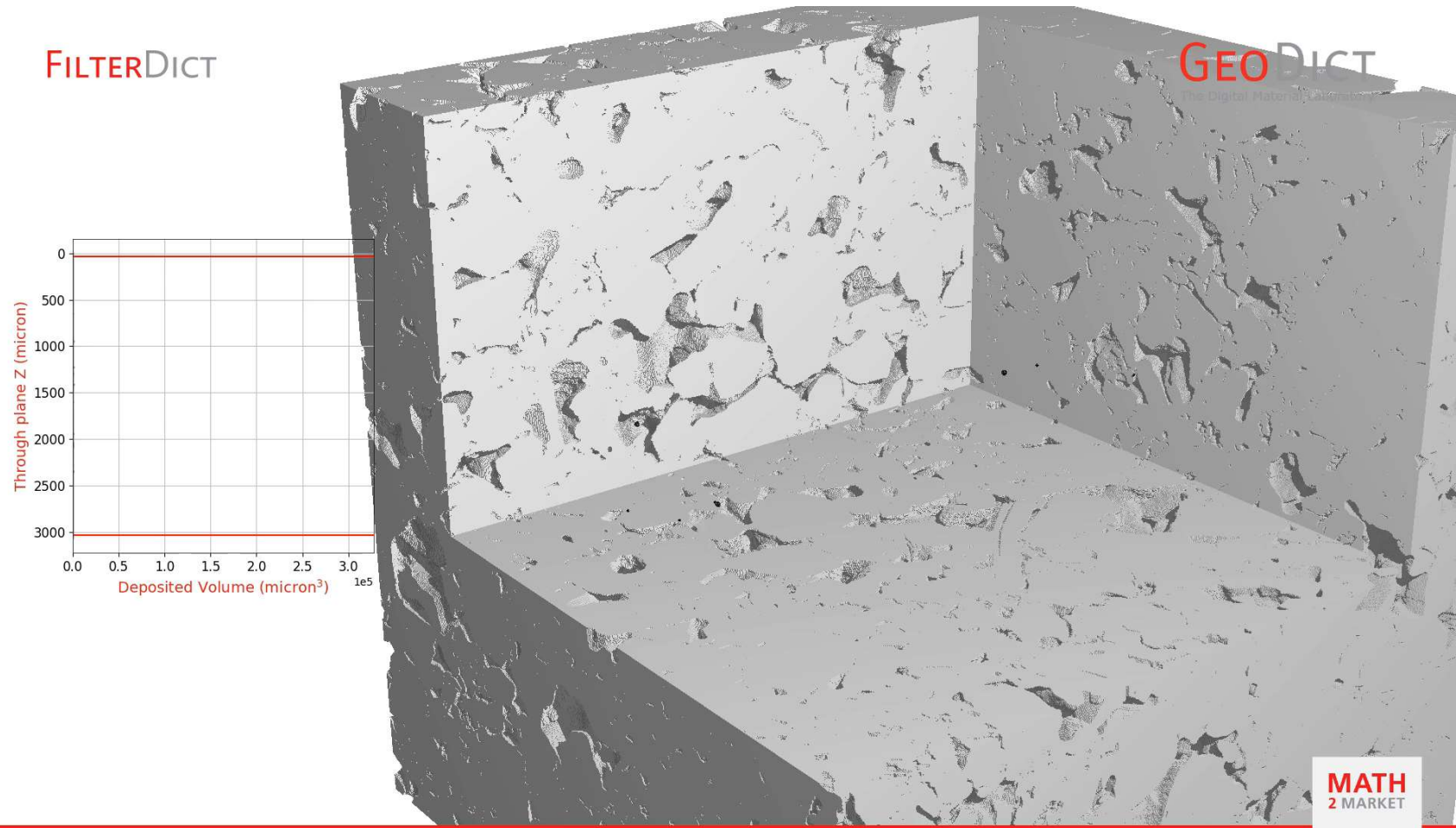
## Linking laboratory experiments and simulations



- only little porosity increase from inflow towards outflow
- approx. +10-15%
- shallow infiltration (first couple of mm at the inflow region)

# Clogging Quantification

Linking laboratory experiments and simulations

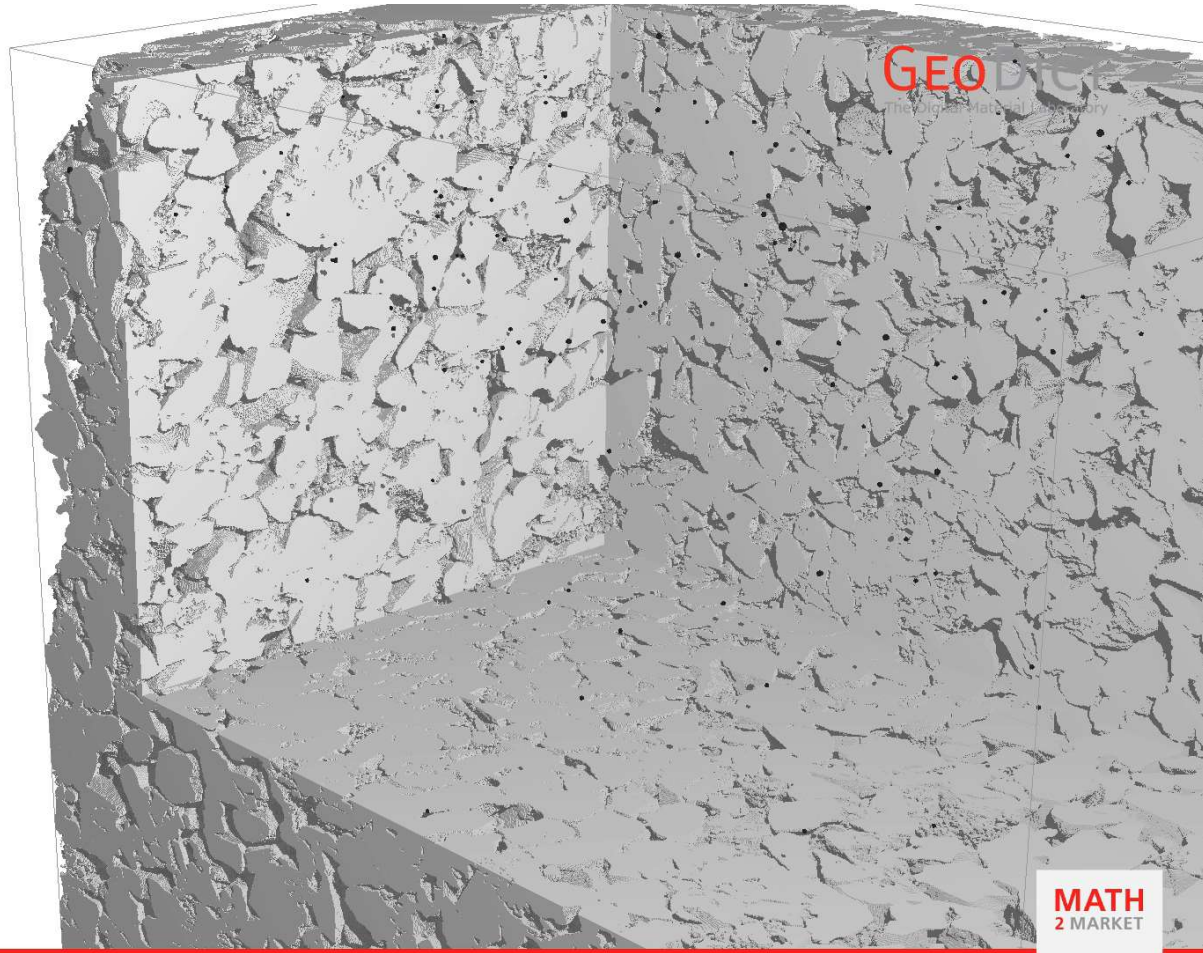
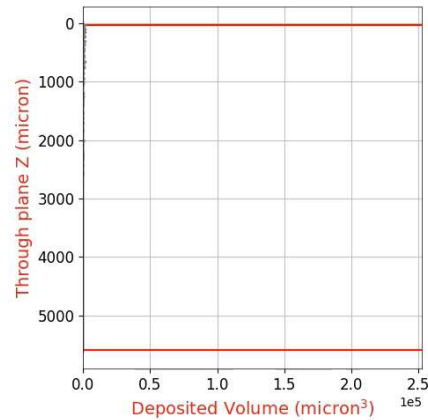




# Clogging Quantification

Linking laboratory experiments and simulations

FILTERDICT



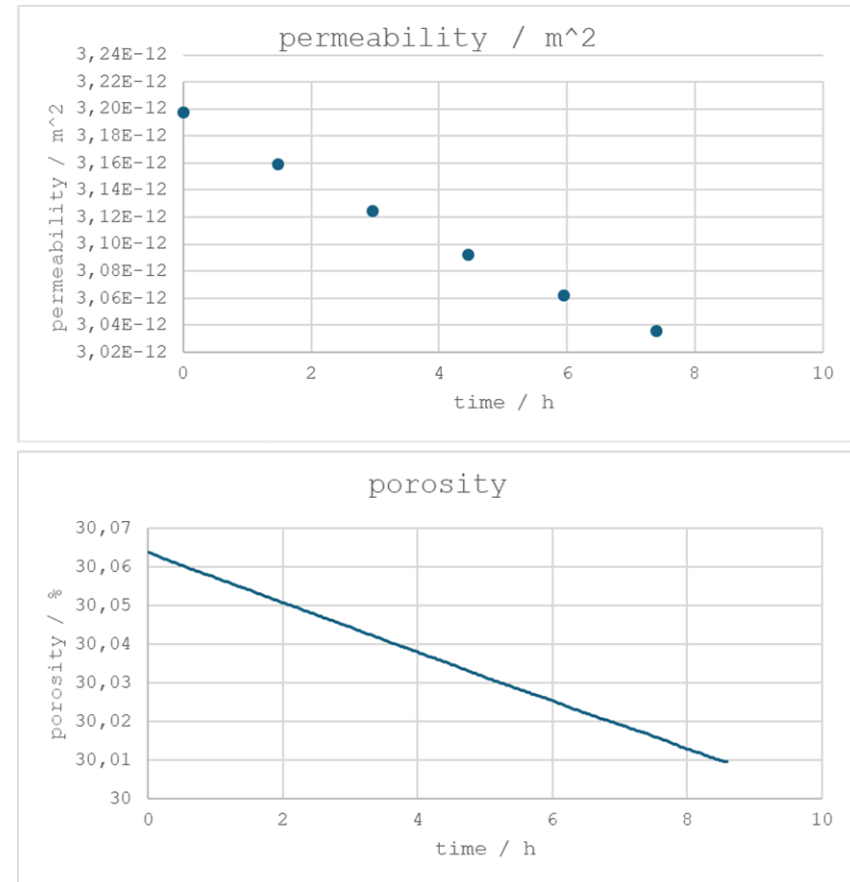
# Clogging Quantification

## Linking laboratory experiments and simulations

### Main observations between simulations

#### *Artificial Sample*

- deep infiltration
- main clogging deeper inside the sample
- very locally distributed
- assuming secondary flow paths
- only minor decrease in porosity and permeability





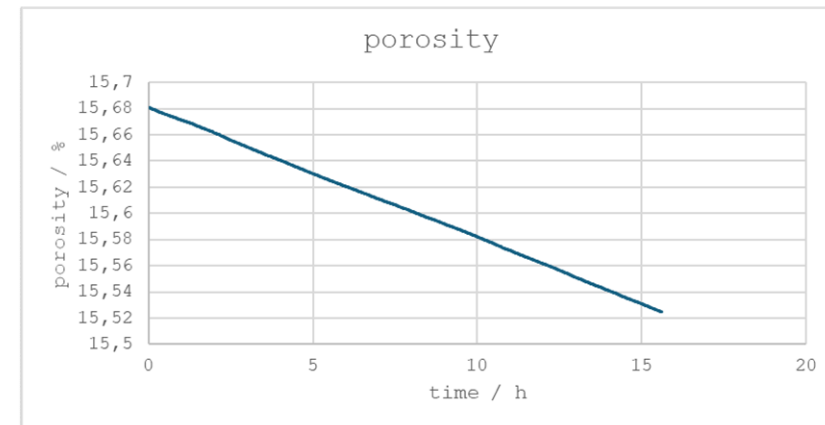
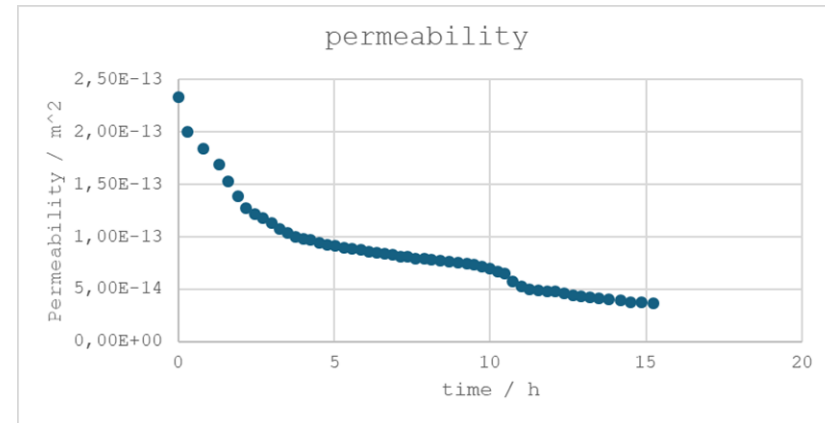
# Clogging Quantification

## Linking laboratory experiments and simulations

### Main observations between simulations

#### *Natural Sample*

- shallow infiltration
- clogging literally everywhere
- clogging very homogeneously distributed
- main flow paths
- large impact upon permeability
- less impact upon porosity

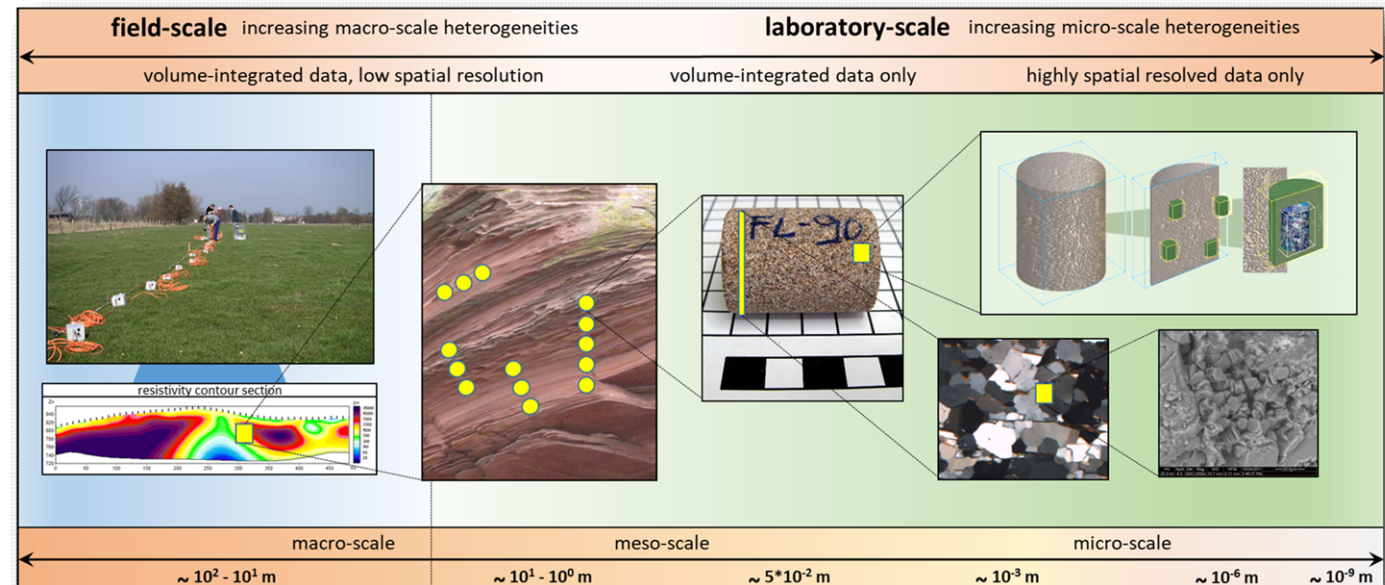


# Summary

- DG samples feature pronounced heterogeneity
  - pore morphology & topology
  - grain morphology & topology
  - on a variety of scales (mm to m)
- 3D DIA is able to catch the complexity of the rock system
  - qualitatively &
  - quantitatively
- DRP allows for systematic analysis using „digital twins“
  - revealing clogging locations and
  - affiliated structures causing / initiating clogging
  - leading to an overall greatly increased understanding and new approaches



# Conclusions



Köszönöm a figyelmet!  
Any questions?

