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Experiments on crushed rocks as a tool for understanding electrical conductivity

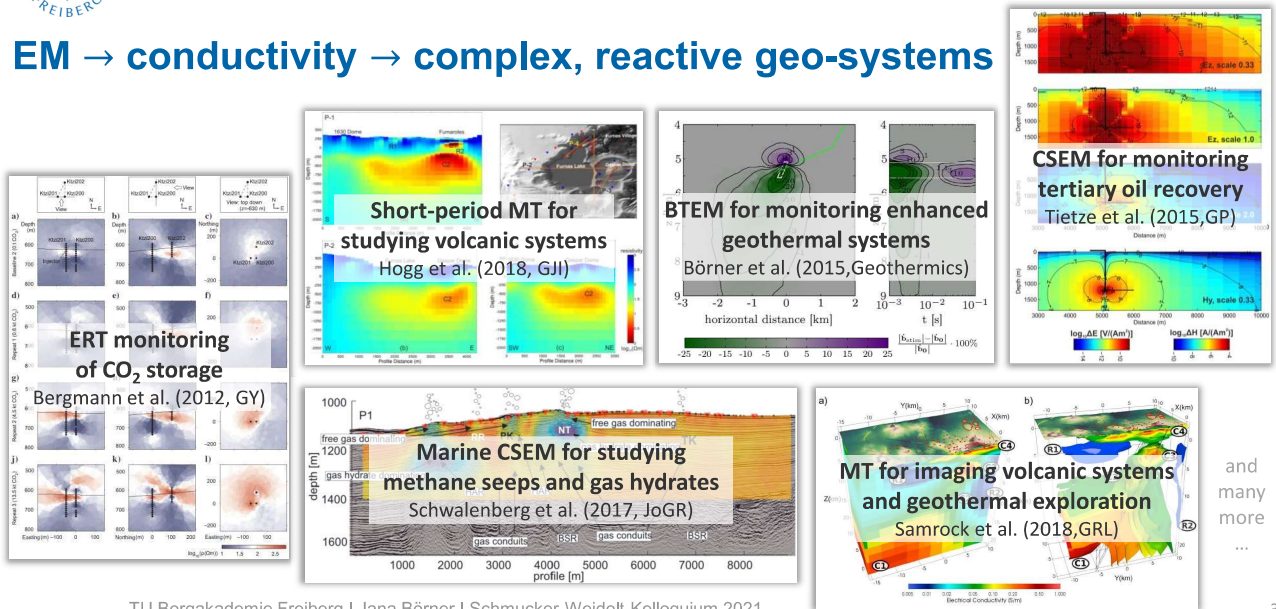
Overview

- Why?** – Motivation
- How?** – Methodology
- How exactly?** – Implementation
- Does it work?** – Results
- What next?** – Outlook



Motivation – Methodology – Implementation – Results – Outlook

EM → conductivity → complex, reactive geo-systems



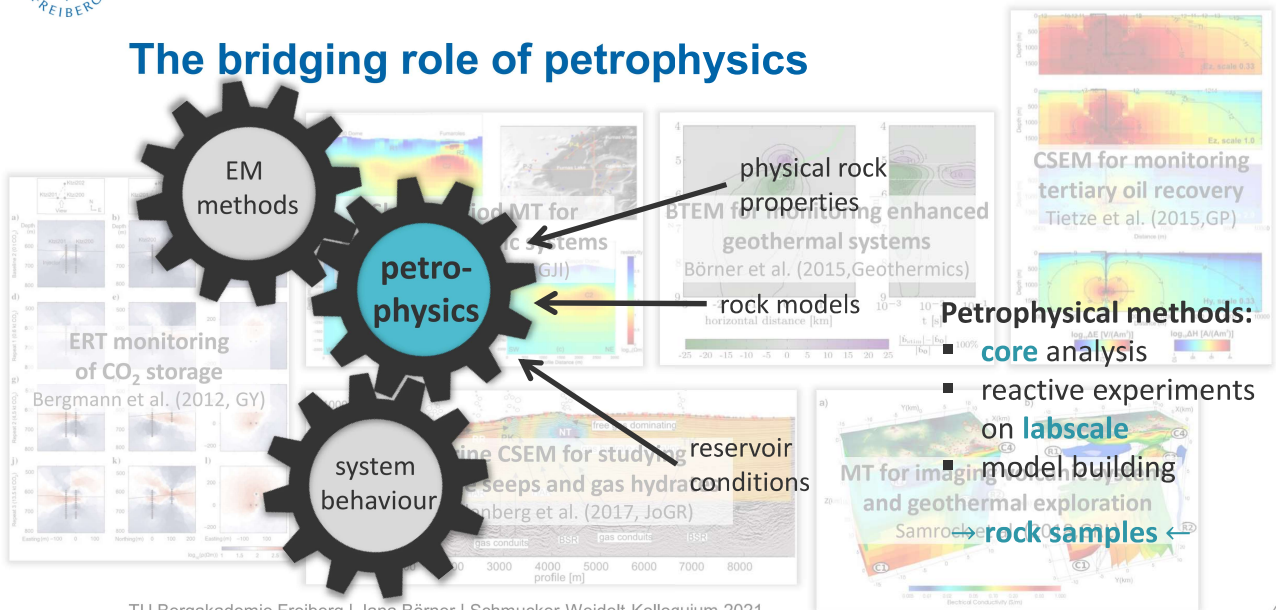
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Motivation – Methodology – Implementation – Results – Outlook

The bridging role of petrophysics



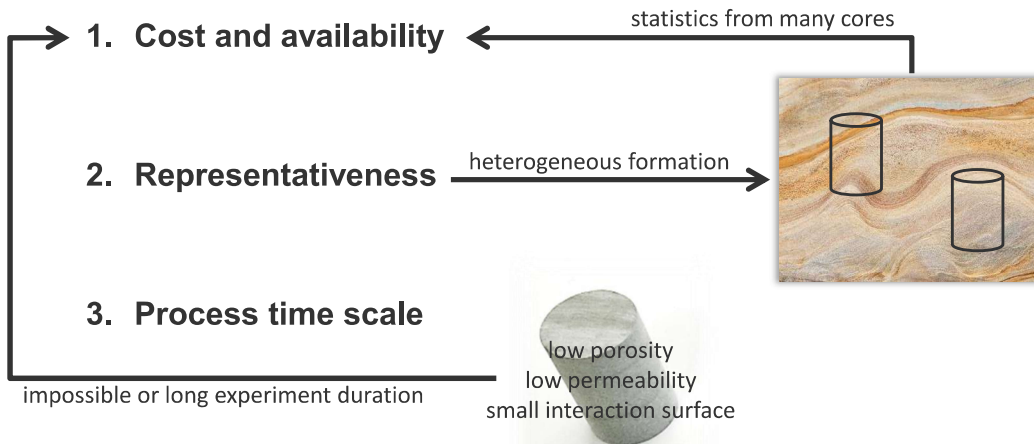
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Motivation – Methodology – Implementation – Results – Outlook

The trouble with rock samples



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Motivation – Methodology – Implementation – Results – Outlook

The trouble with rock samples

1. **Cost and availability**

2. **Representativeness**

3. **Process time scale**



Solution:

- Take what is available.
→ **drill cuttings**
- Condition the sample according to your needs.
→ **crushing**



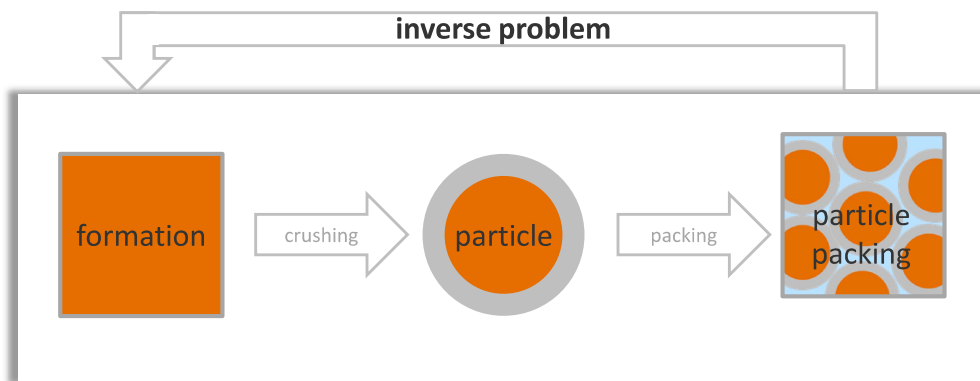
→ **Need for a methodology to reconstruct undisturbed rock properties from measurements on crushed samples.**

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Relation between formation and particle packing



→ **Crushing & packing adds unknowns and ambiguities to the inverse problem.**

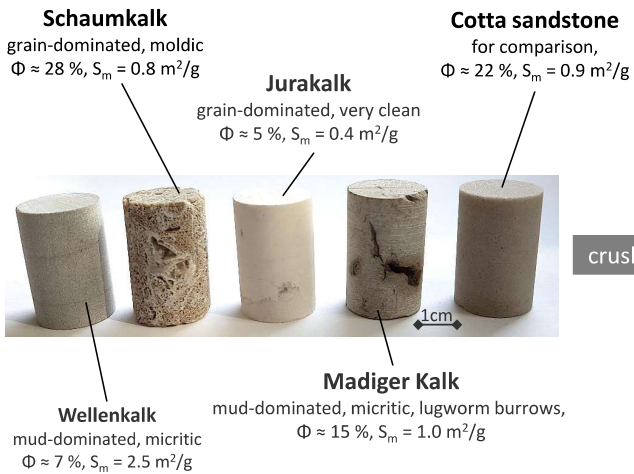


Combination of lab and computational methods

- **Tweaking inverse problem**
 - parameterization
 - multiple data types
 - multiple particle size fractions
 - extensive lab measurements
 - **common inversion**



Investigated rocks



crushing

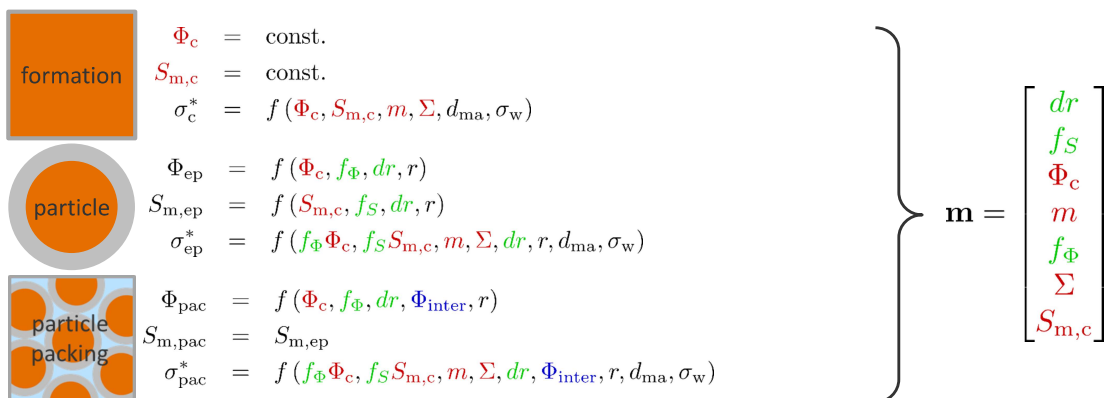
$d_{obs} =$

4 data types:

$d_{\sigma',1}$	electrical conductivity $\sigma^* = \sigma' + i\sigma''$ ▪ multiple particle sizes
\vdots	
$d_{\sigma',q}$	
$d_{\sigma'',1}$	
\vdots	
$d_{\sigma'',q}$	▪ 23 – 30 entries for each rock $\sim III$
$d_{S,1}$	
\vdots	
$d_{S,n}$	porosity Φ
$d_{\Phi,1}$	
\vdots	
$d_{\Phi,j}$	



Petrophysical model for crushed rock



→ Minimum set of electrical, pore space and reservoir quality parameters link data types.



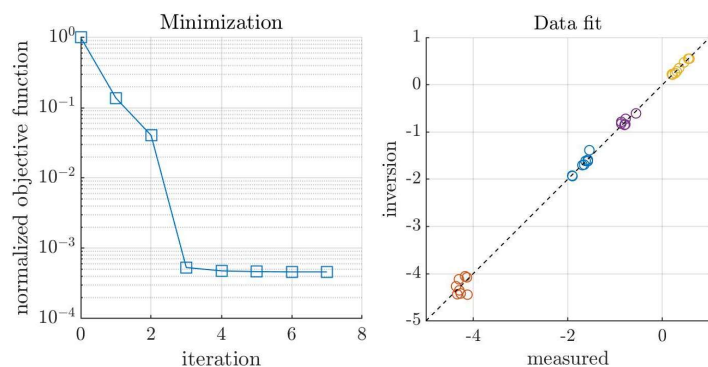
Inverse problem

- utilization of transformed model parameters
 - log
 - range
- damped least-squares objective function
- data weighting matrix
 - data errors
 - weighting of data types
- Gauss-Newton scheme for minimization
- recalculation of Jacobian in each iteration



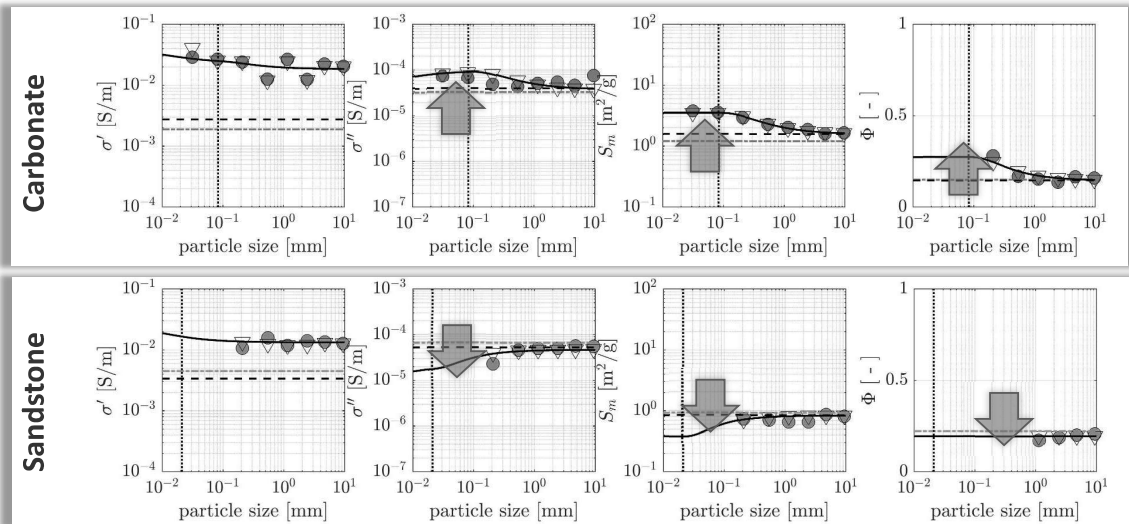
Minimization process

- few iterations required
- good fit for all data types
- few seconds on a standard PC





● measured ▽ fit from inversion
 - - - formation (measured)
 - - - formation (inversion result)



→ Robust retrieval of formation properties is successful, if particle interior is representative.

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Conclusions

- Rock models for complex geo-systems help interpreting EM results
- Availability and/or time scale suggest working with crushed rock material
- Methodology for retrieving formation properties
 - sample conditioning
 - multi-method laboratory measurements
 - common inversion
- Successful retrieval for very different rocks
 - electrical conductivity
 - porosity
 - internal surface area

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Thank you for your attention.

