Smart Monitoring – Part C: Data acquisition and geophysical inversion

Smart Monitoring by means of process-based experimental design

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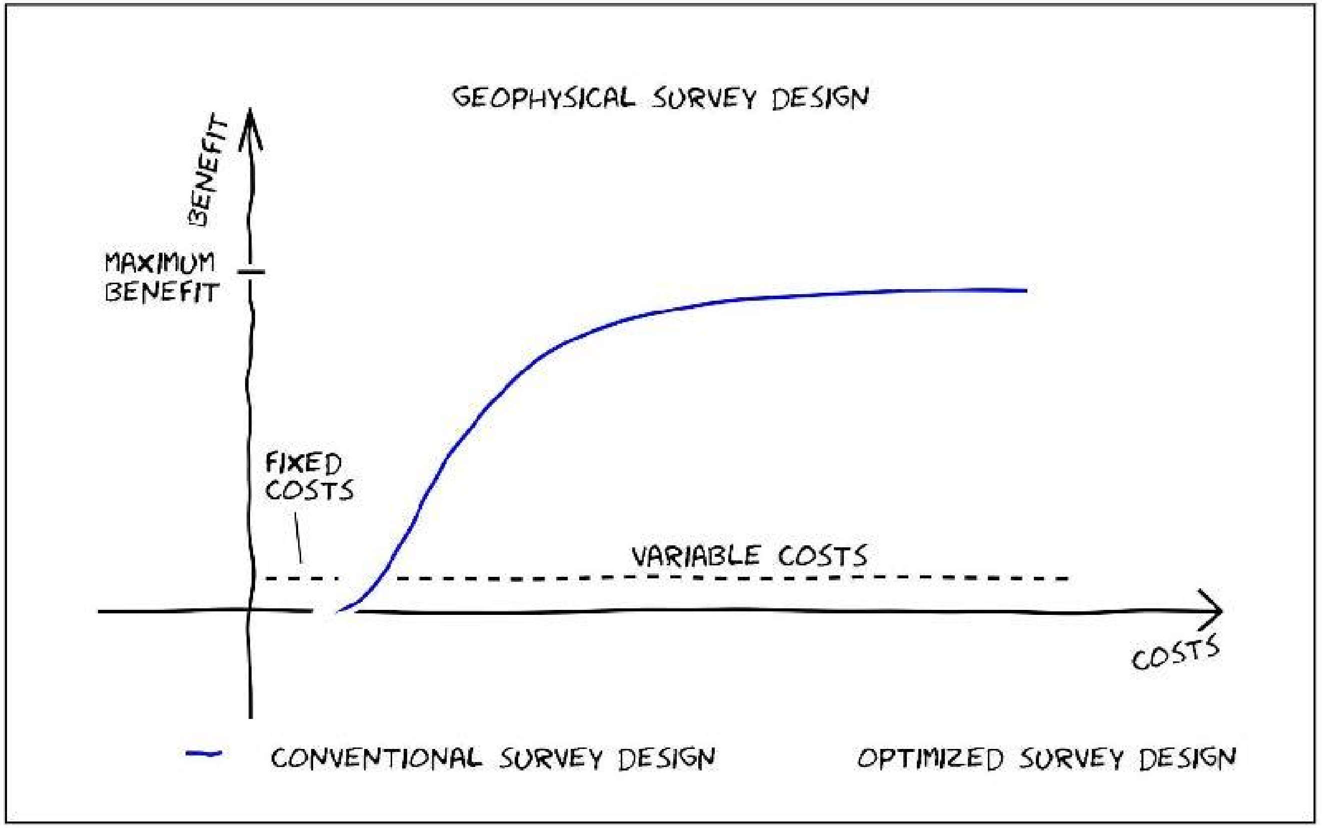
Optimal Experimental Design – Theoretical background

- Data processing can compensate for missing or inadequate data only to a certain extent
- Survey optimization aims at **optimizing the information content** of (geo)physical data sets
- **Limit amount of data** without (drastically) reducing their information content



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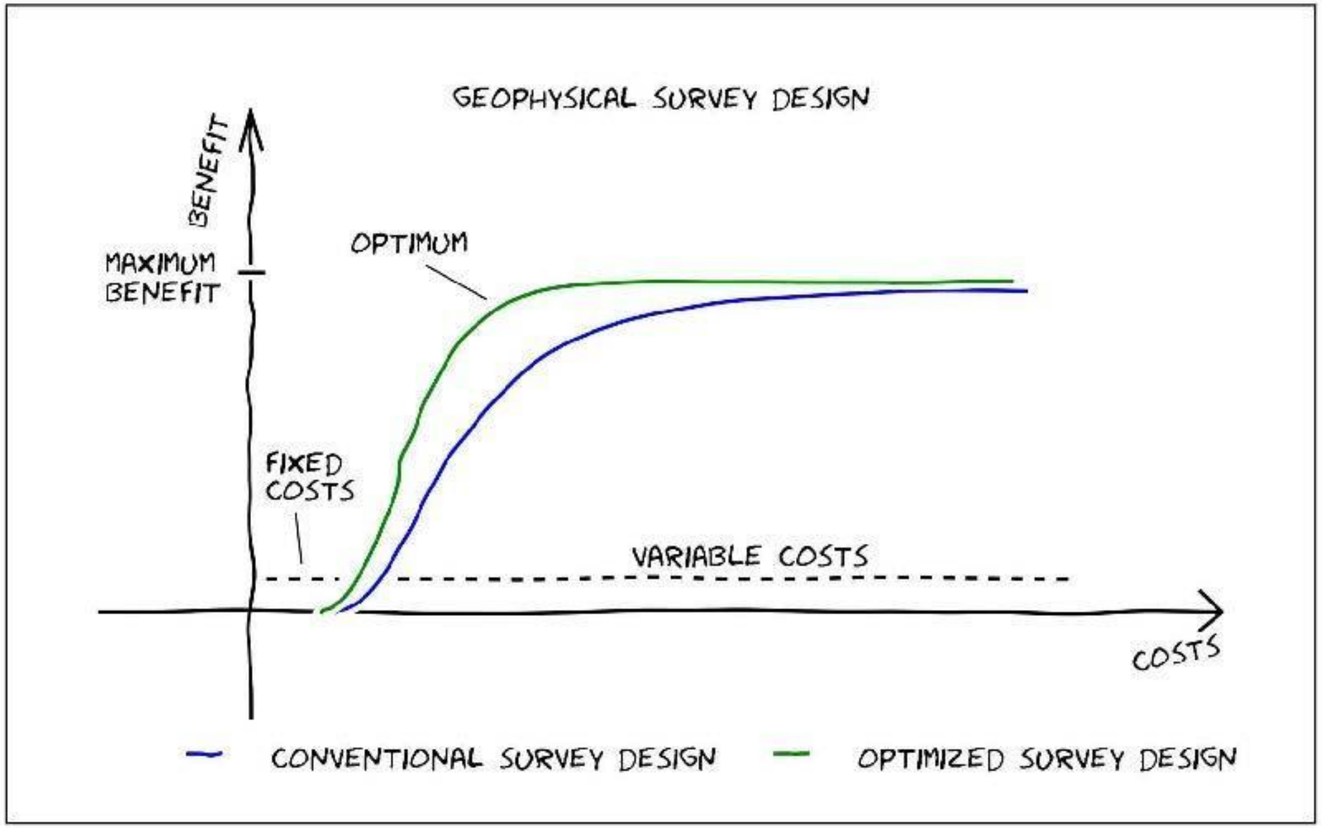

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Optimal Experimental Design – Methodology

Examples for optimization of geophysical survey designs:

- Compare-R method for geoelectrical measurements
- Seismic OED with Full Waveform Inversion
- Multi-methodological Bayesian survey optimization

Optimal Experimental Design – Methodology

“Compare-R” method:

- Uses **resolution matrix** of linearized Gauss-Newton solution for ERT problem; defined as:

$$R = (G^T G + C)^{-1} \, G^T G$$

- Iterative optimization starts from a **set of base measurements** -> calculation of **change in resolution matrix** for each possible new measurement:

$$\Delta R_b = \frac{z}{1+(g*z)}\left(g^T - y^T\right) \qquad \text{where} \qquad z = \left(G_b^T g_b + C\right)^{-1} g, \qquad y = \left(G_b^T G_b\right) z$$

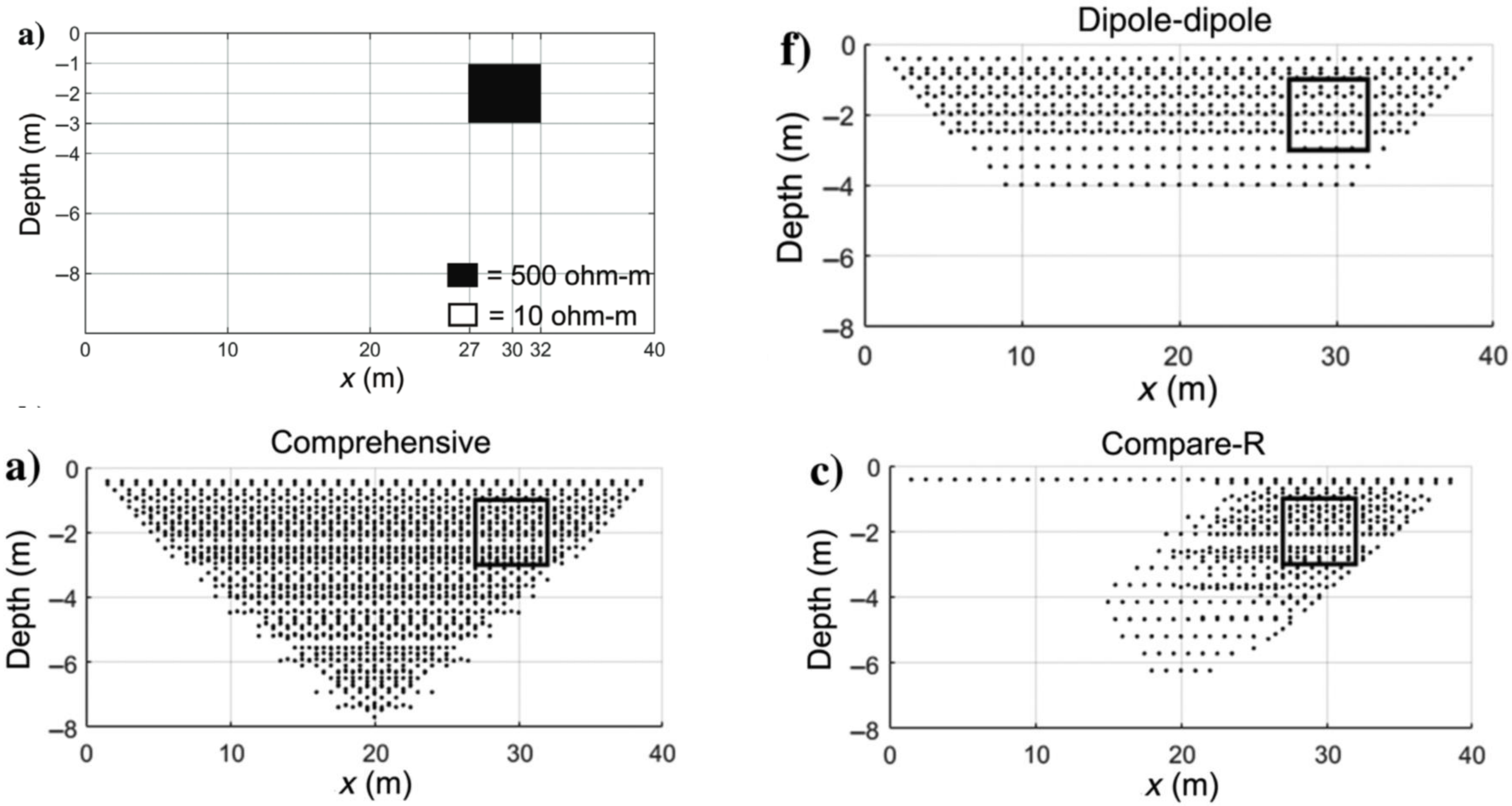
- All **additional measurements are ranked** according to improvement of resolution matrix:

$$F_{CR} = \frac{1}{m} \sum_{j=1}^{m} \frac{w_{t,j} \, \Delta R_{b,j}}{R_{c,j}}$$

- Depending on chosen step size, **n measurements** with greatest benefit are **added to base set**

Optimal Experimental Design – Methodology

“Compare-R” method:



Optimal Experimental Design – Methodology

Examples for optimization of geophysical survey designs:

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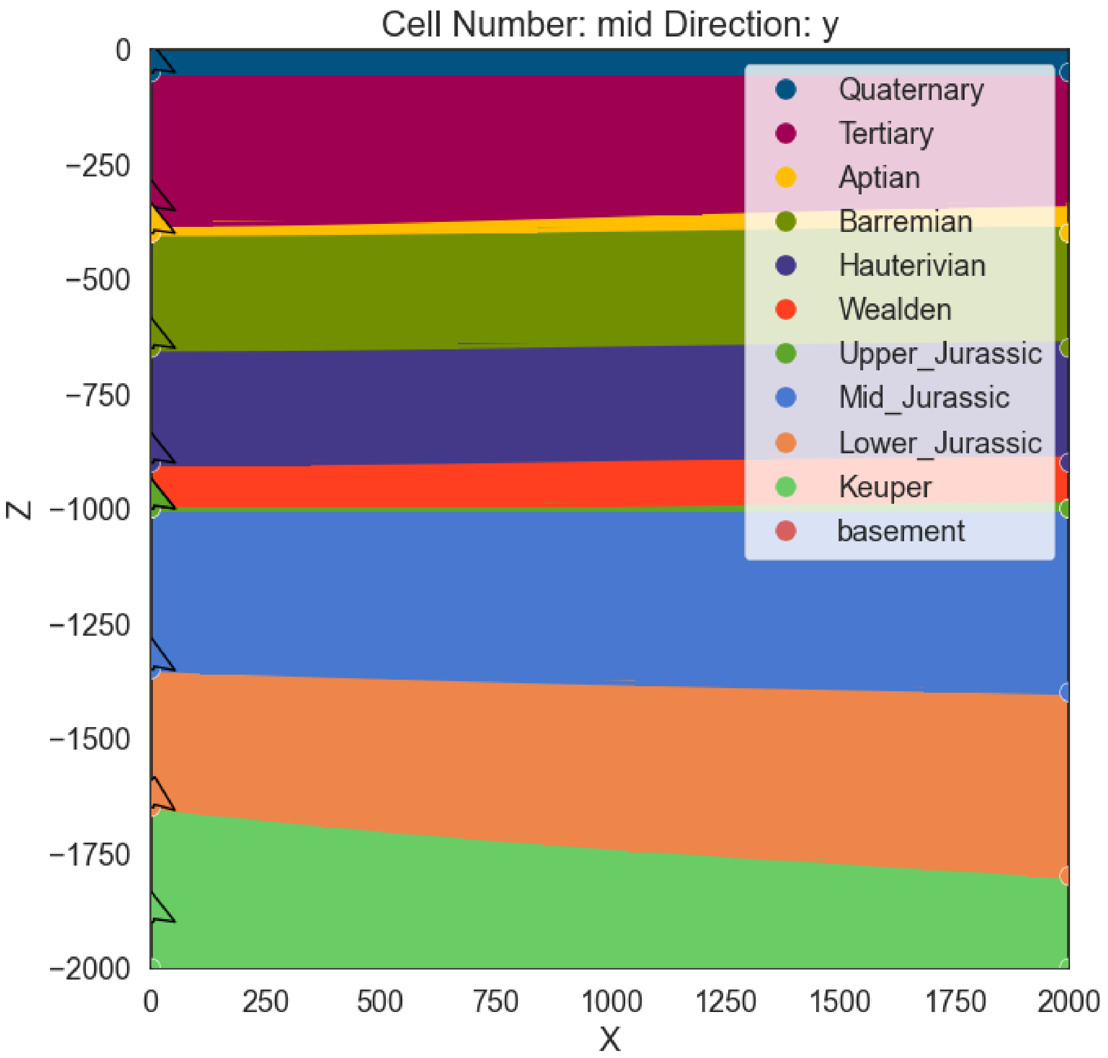
However, existing OED approaches are **neither process-based nor applicable to joint inversions**.

- Apply OED to **process-based inversions** in context of repository monitoring
- Utilize **multiple (geo)physical input datasets** in one OED approach

Reference scenarios

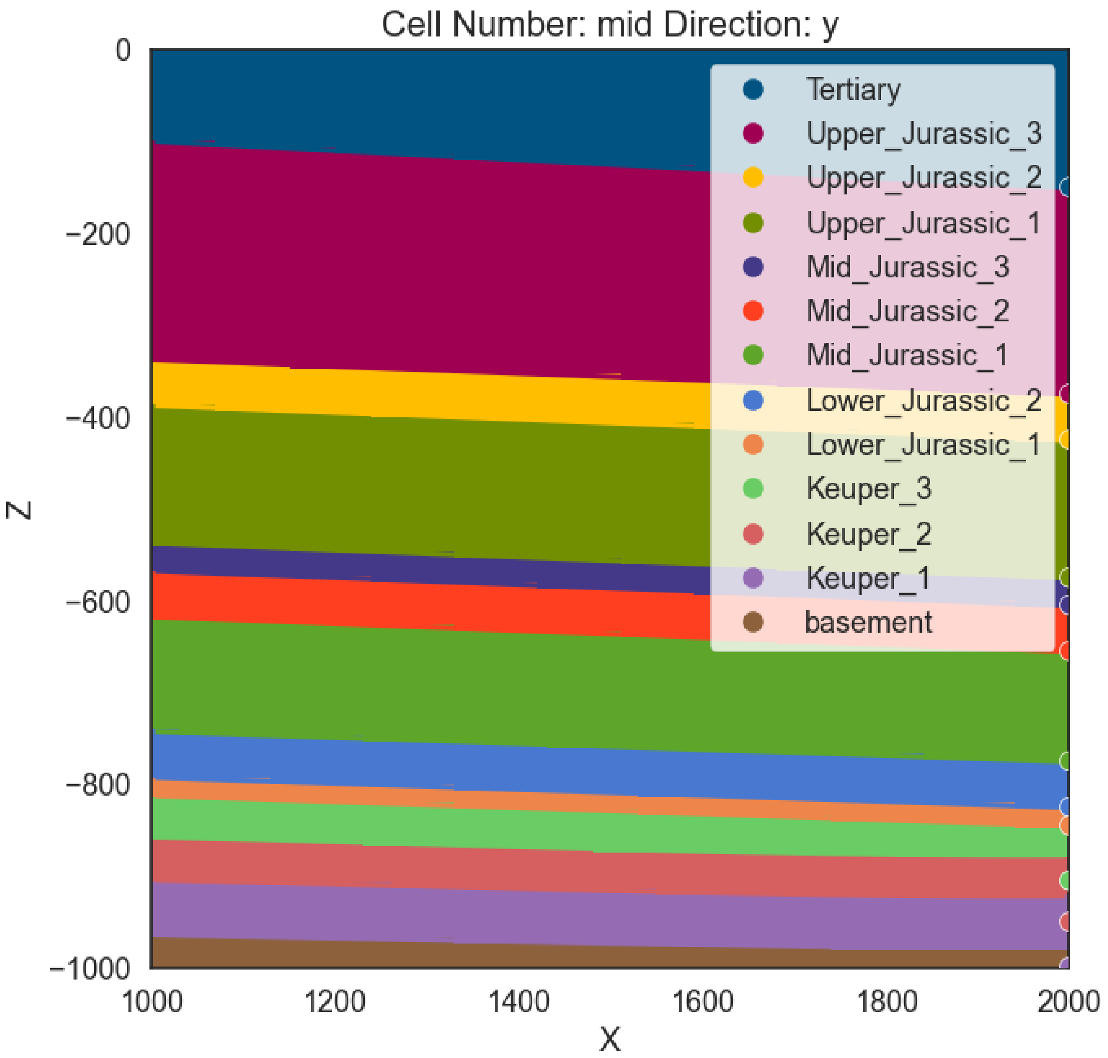
Geological scenario claystone 1:

- Claystones of Barremian and Hauterivian age (cretaceous)
- Depth of host rocks: 500 bis 850 m below ground level
- Underlying: Formations of Jurassic and Triassic
- Overlying: Upper Cretaceous and Cenozoic units
- Model represents geologic conditions of Northern Germany (according to Reinhold et al., 2013)



Geological scenario claystone 2:

- Second model represents Opalinus clay formation in Southern Germany (Mid_Jurassic_1)
- Depth of host rock formation: 600-800 m below surface
- Underlying: Jurassic and Keuper
- Overlying: Upper Jurassic, Tertiary
- Karstification of limestone layers
- Model represents geologic conditions of Swabian Alb and comparable regions



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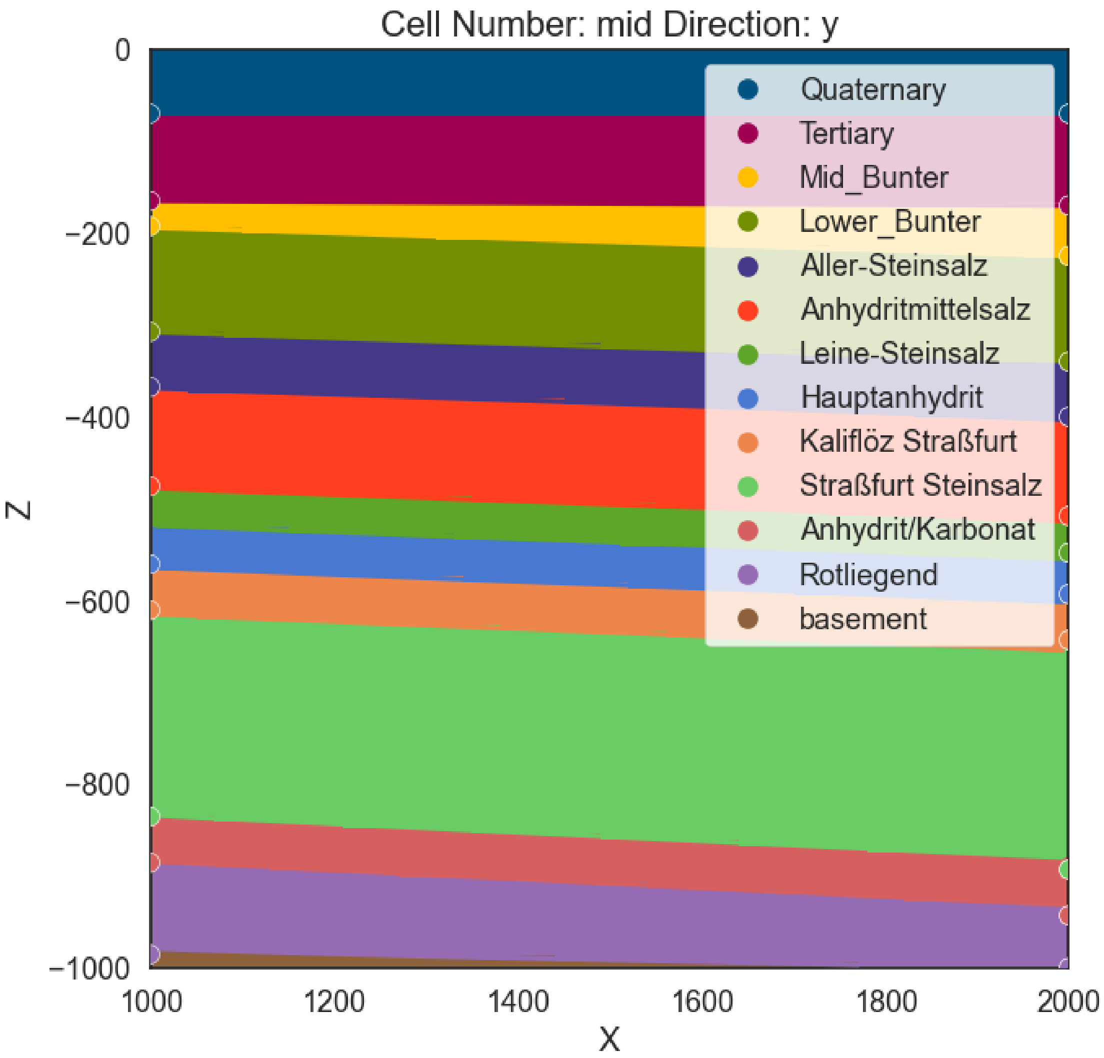
Reference scenarios

Geological scenario stratiform rock salt:

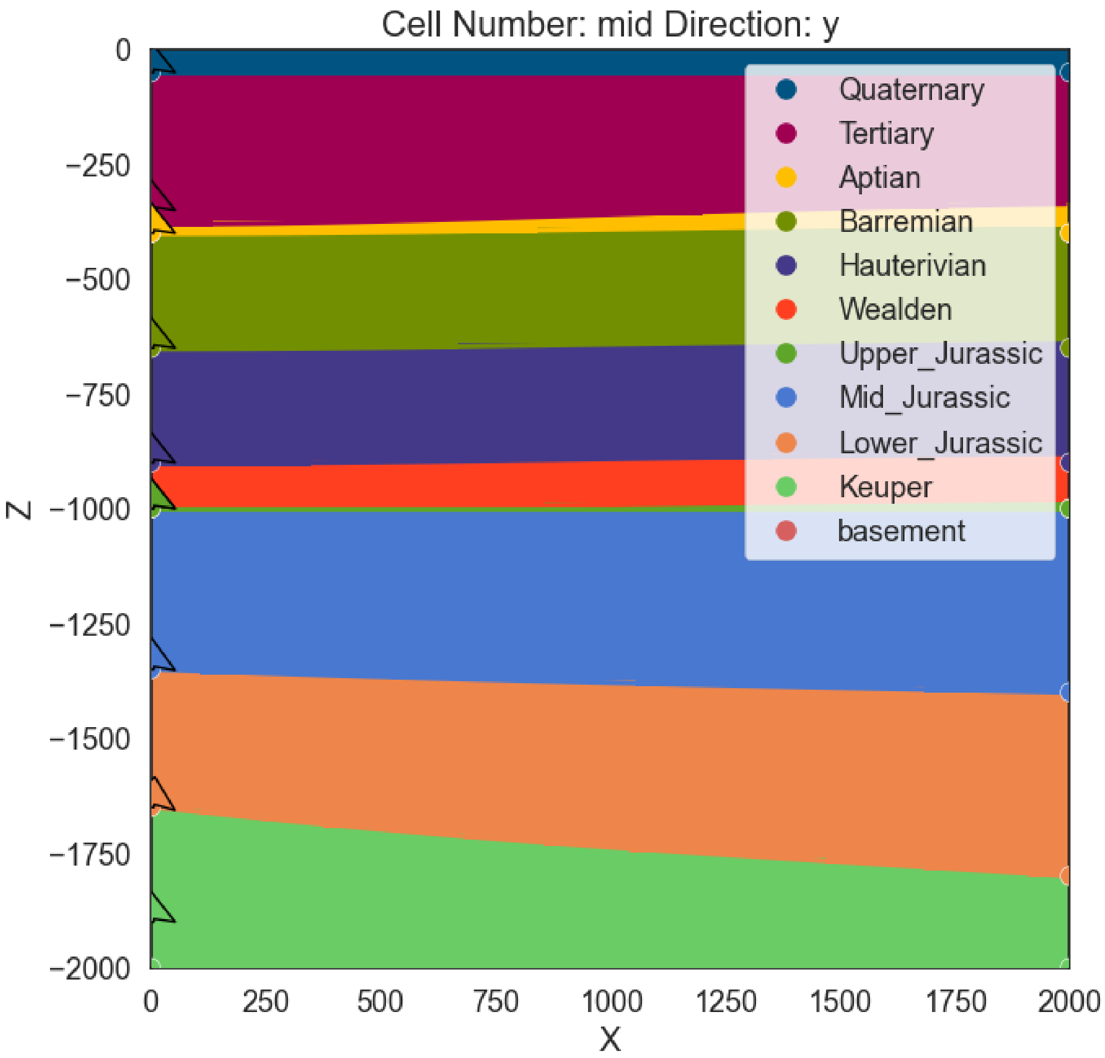
- Model focuses on rock salt of the Zechstein (in particular: Straßfurt formation)
- Depth of the host rock: 600-850 m below surface
- Underlying: Zechstein anhydrite and Keuper
- Overlying: younger Zechstein succession, Bunter, Cenozioc sedimentary rocks
- Model information are taken from the KOSINA project (BGR, 2017)



Reference scenarios

Geological scenario granite:

- Crystalline Model in Granite
- Depth of the host rock: < 900 m below surface
- Underlying: -
- Overlying: Triassic sediments
- Model represents geology of the mitteldeutsche Kristallinschwelle



Reference scenarios

Physical model parameters:

- Stored as **YAML-files**, containing most relevant **physical properties** of formations in reference models:

- Density
- (Effective) porosity
- Permeability
- Heat capacity
- Heat conductivity
- Seismic velocities
- Specific electrical resistivity
- Diffusivity

Reference scenarios

Synthetic models are based on Europe-wide studies:

- **Claystone**: Mont Terri URL (Switzerland), ANDRA URL (France), ANSICHT (Germany)
- **Rock salt**: German salt structures (Gorleben, Asse)
- **Crystalline**: Äspo URL (Sweden), TURVA (Finland)

However, do the synthetic models represent scenarios that are **close enough to real geological conditions**?

- Further research on **more realistic 3D structures** (in cooperation with GeoBlocks)
  - **Plutonites** of the Erzgebirge
  - **Salt domes** of central and northern Germany

Smart monitoring – next steps

Optimal Experimental Design:

- Apply **“Compare-R” method** to reference cases as **process-based inversion** and survey optimization technique

- Simulate **time-lapse inversions** using OED

- Implement **seismic** forward simulations and inversions on reference models

- Work on **OED for joint inversion approaches**

Reference scenarios:

- Implement **more realistic 3D reference scenarios** for crystalline and (non-stratiform) saline host rocks

Vielen Dank
für Ihre Aufmerksamkeit

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