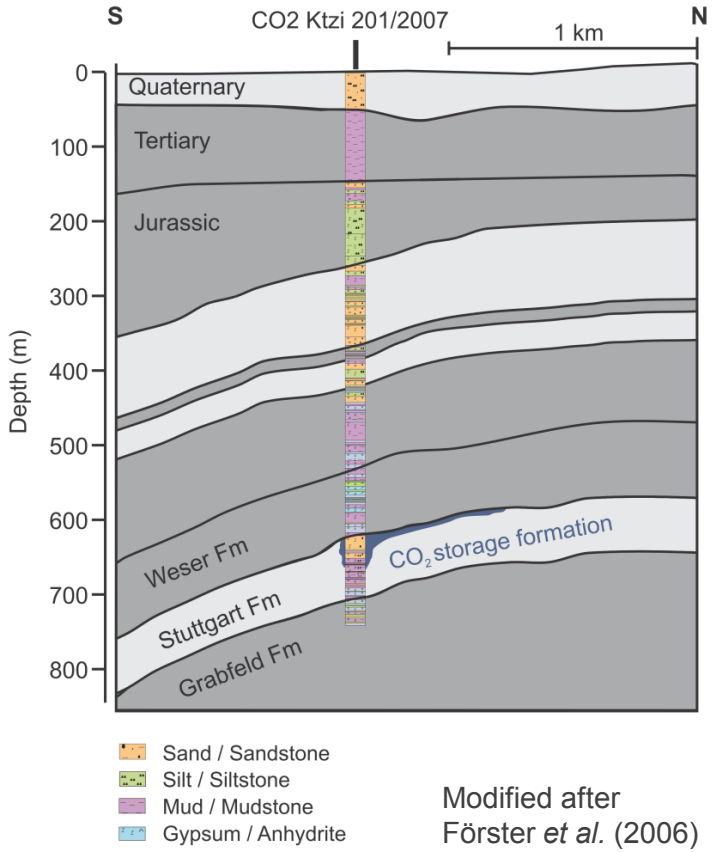
Large-scale DC geoelectric measurements at the CO_2 pilot storage Ketzin

P. Bergmann[1], C. Schmidt-Hattenberger[1], C. Rücker[2], D. Kiessling[1], T. Labitzke[1], Ch. Juhlin[3] & Ketzin Group

[1]GFZ German Centre for Geosciences, Centre for CO_2 Storage, Potsdam, Germany
[2]Technical University Berlin, Department of Applied Geosciences
[3]Uppsala University, Department of Earth Sciences

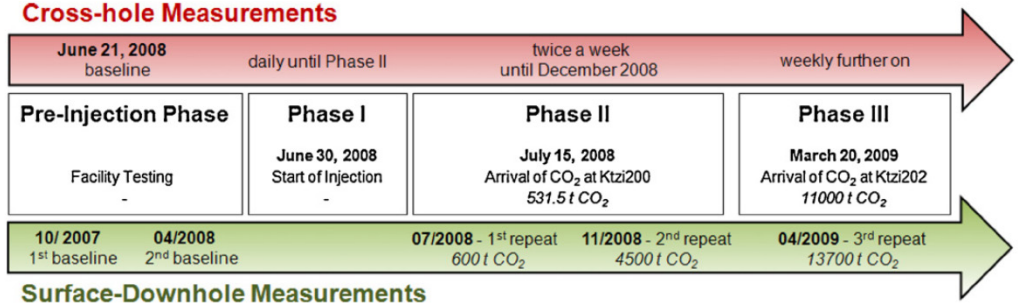
TCCS-6, Trondheim, 14-16 June 2011

Geoelectric Surveying at the Ketzin Site: The Ketzin project



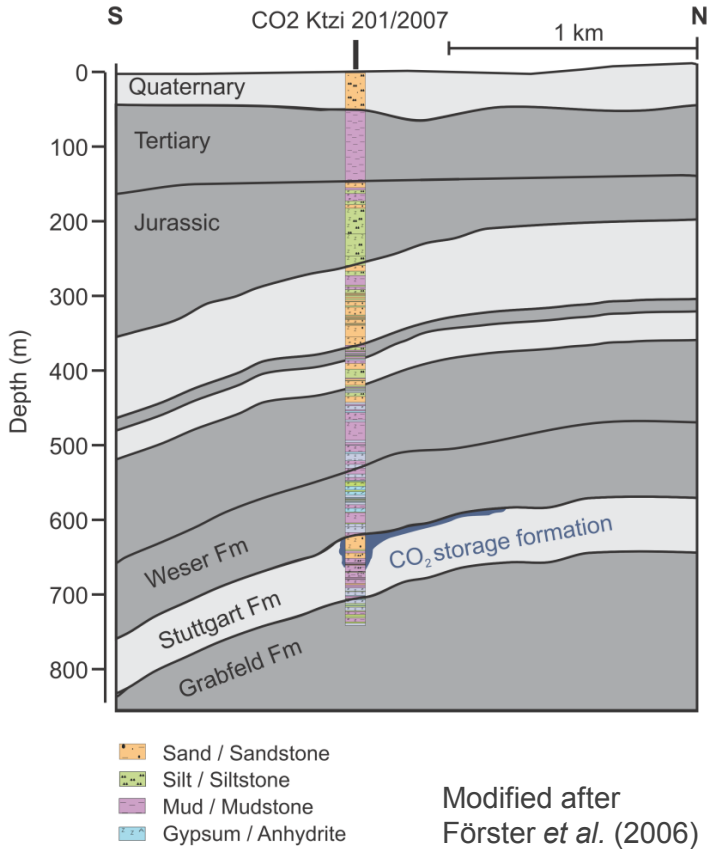
Modified after Förster *et al.* (2006)

The Ketzin pilot project test site



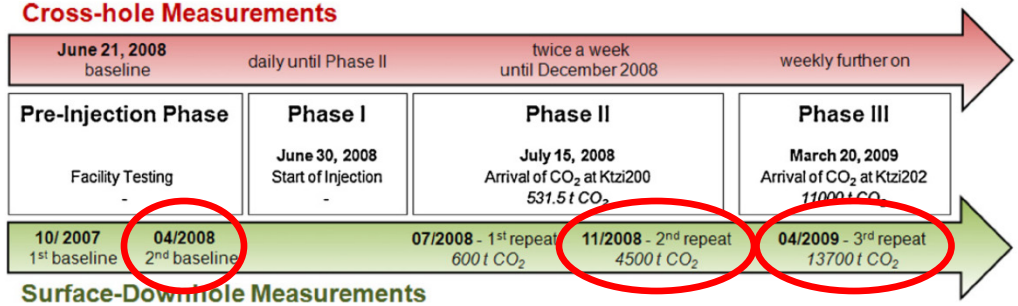
Kiessling *et al.* (2010)

Geoelectric Surveying at the Ketzin Site: The Ketzin project



Modified after Förster *et al.* (2006)

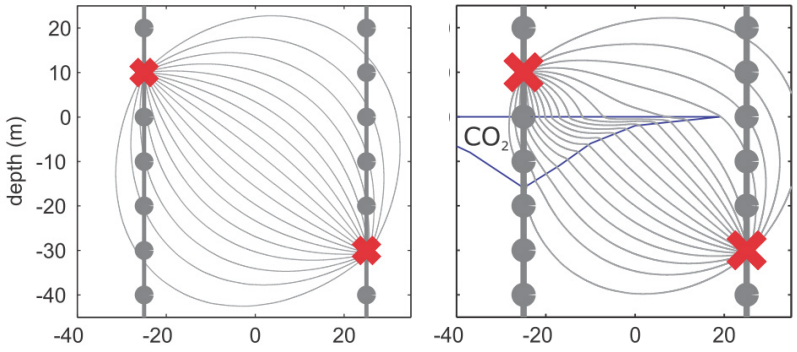
The Ketzin pilot project test site



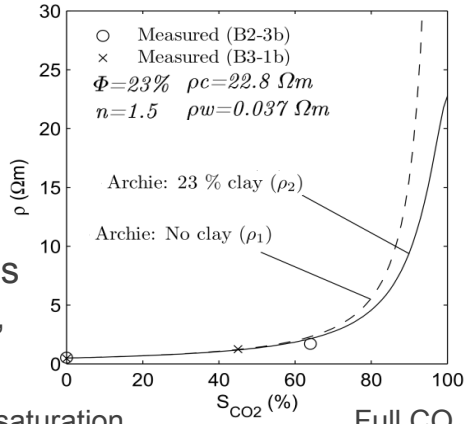
Kiessling *et al.* (2010)

Geoelectric Surveying at the Ketzin Site: Method

The principle of time-lapse resistivity measurements

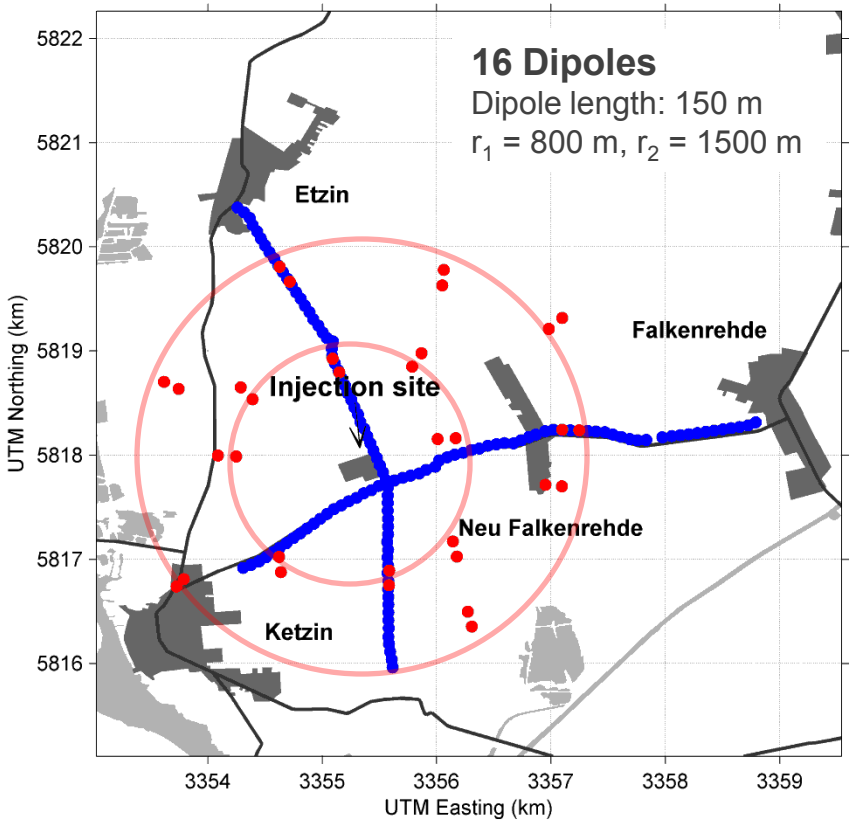


Archie-based fluid substitution model for the Ketzin reservoir (measured values after Kummerow, GFZ)



Full brine saturation

Full CO_2 saturation



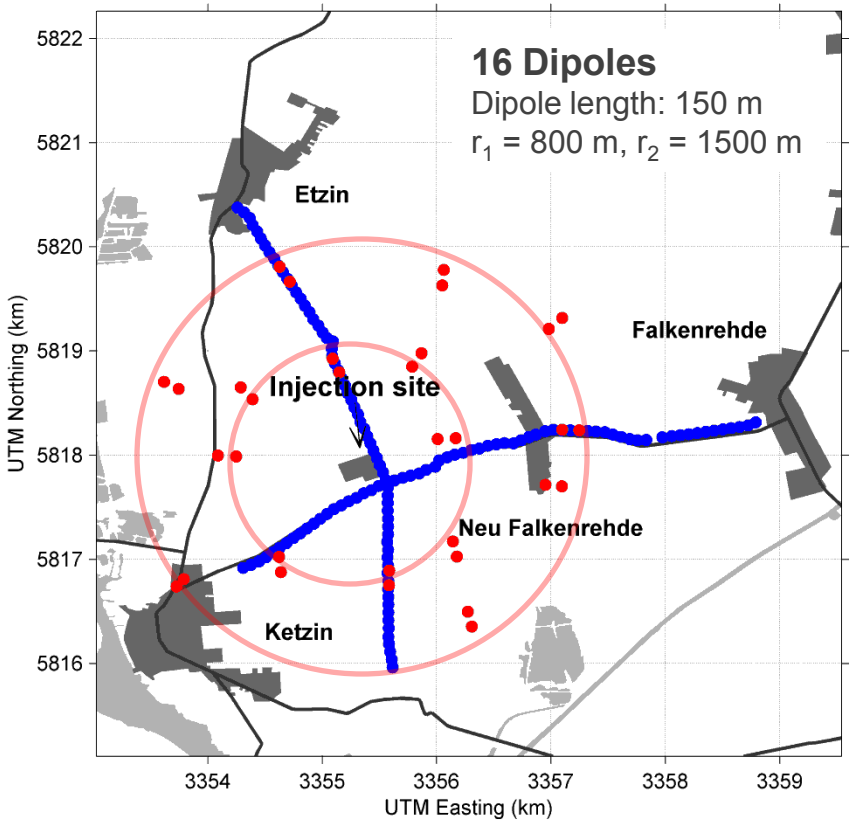
Geoelectric Surveying at the Ketzin Site: Instrumentation

I=4–10 A, U=900–1300 V

Texan-125 (Refraction Tech. Inc., USA), Electric power source TSQ-4 (Scintrex Ltd., Canada), (Property of University of Leipzig)

Well electrode

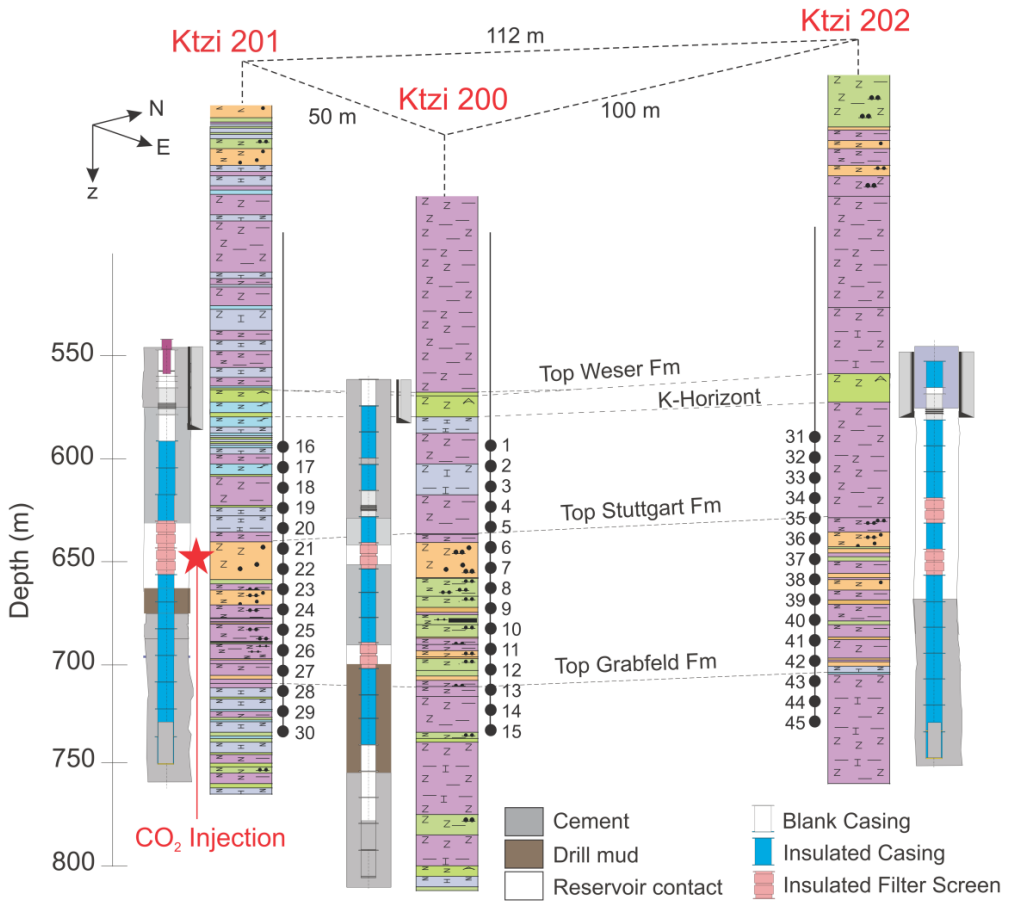
Installation of the well electrodes



Geoelectric Surveying at the Ketzin Site: Instrumentation

VERA
(Vertical Electrical Resistivity Array)

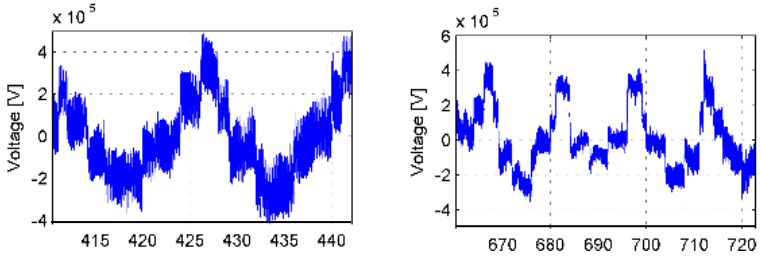
45 permanent electrodes
15 electrodes per well
Electrode spacing: **10 m**
Installation depth: **590 to 735 m**



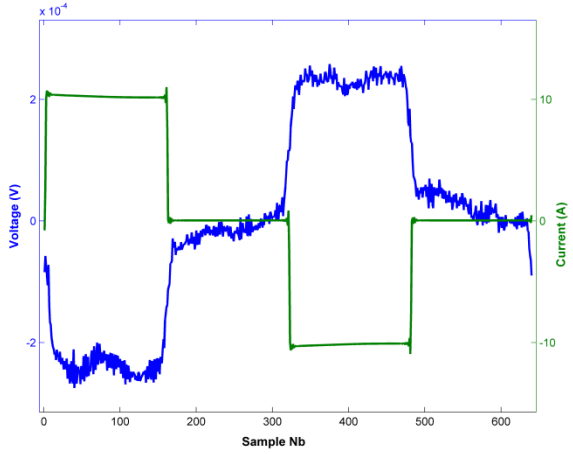
Lithology after Engelmann *et al.* (2010)

Preprocessing: Determination of Resistances

Current step signal: ~20 min/location, period 16 s.
Examples of voltage time series

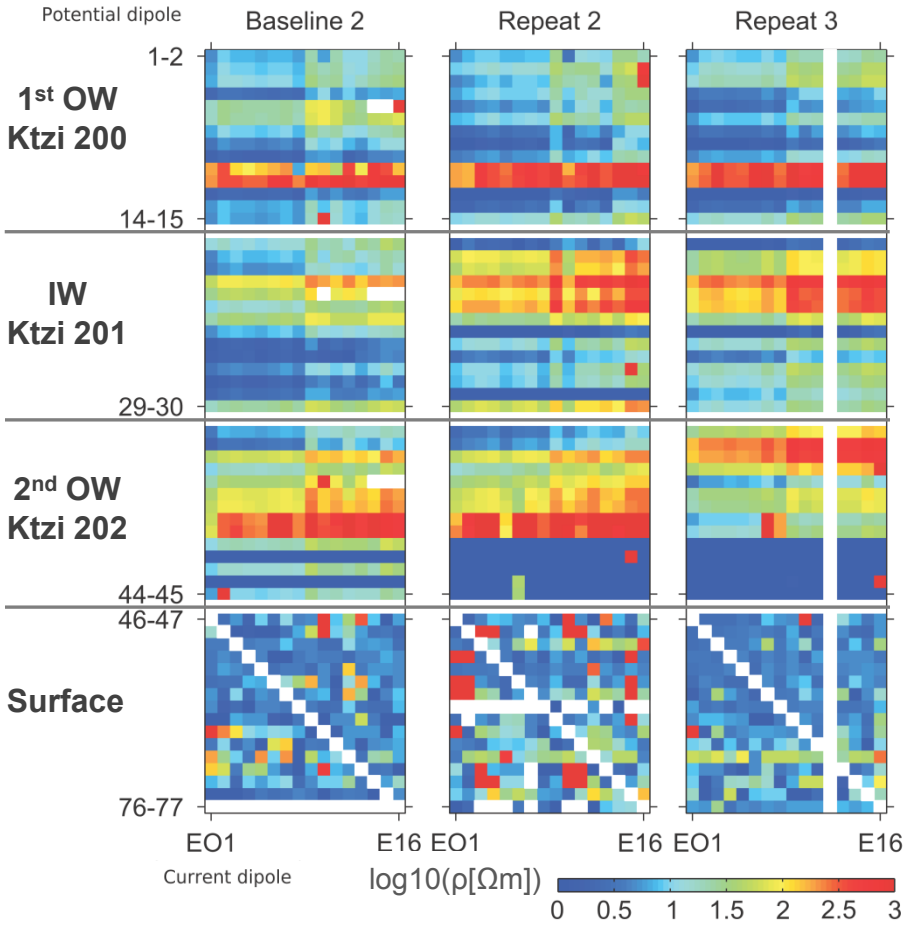


Selective stacking (Storz et al., 2000)



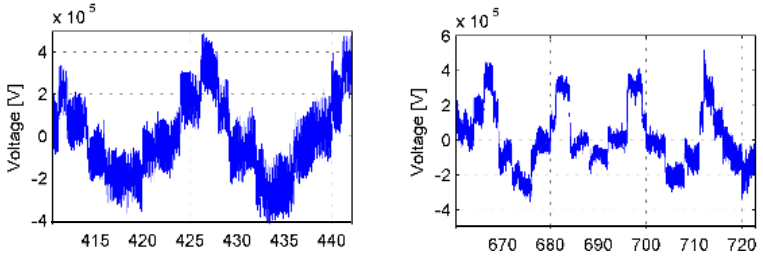
Green=Current
Blue=Voltage

⇨ Resistance & Error

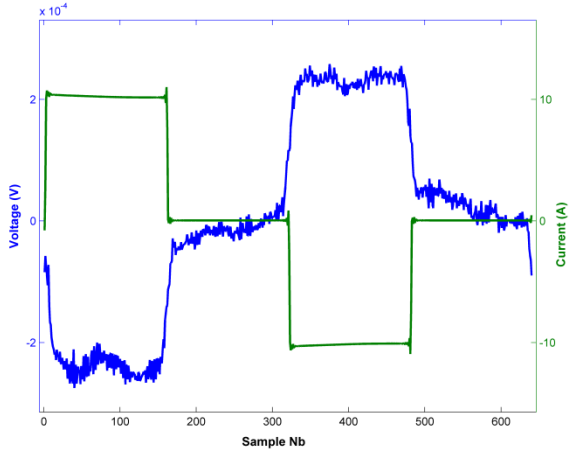


Preprocessing: Determination of Resistances

Current step signal: ~20 min/location, period 16 s.
Examples of voltage time series

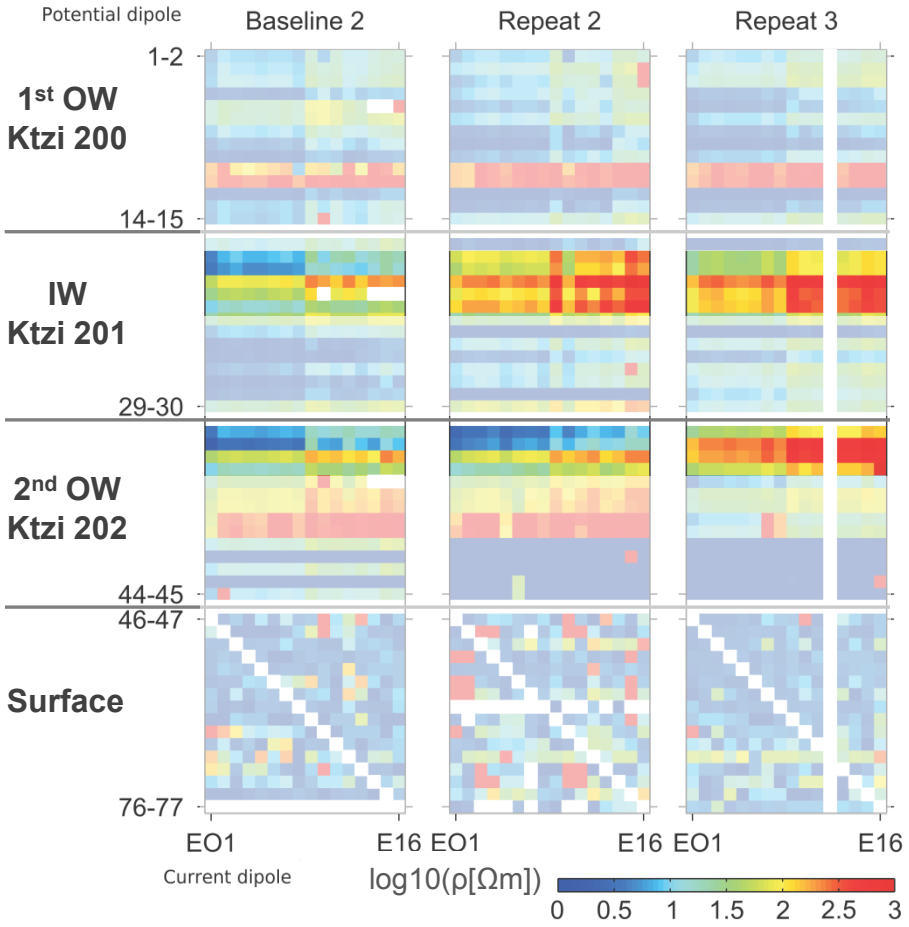


Selective stacking (Storz et al., 2000)

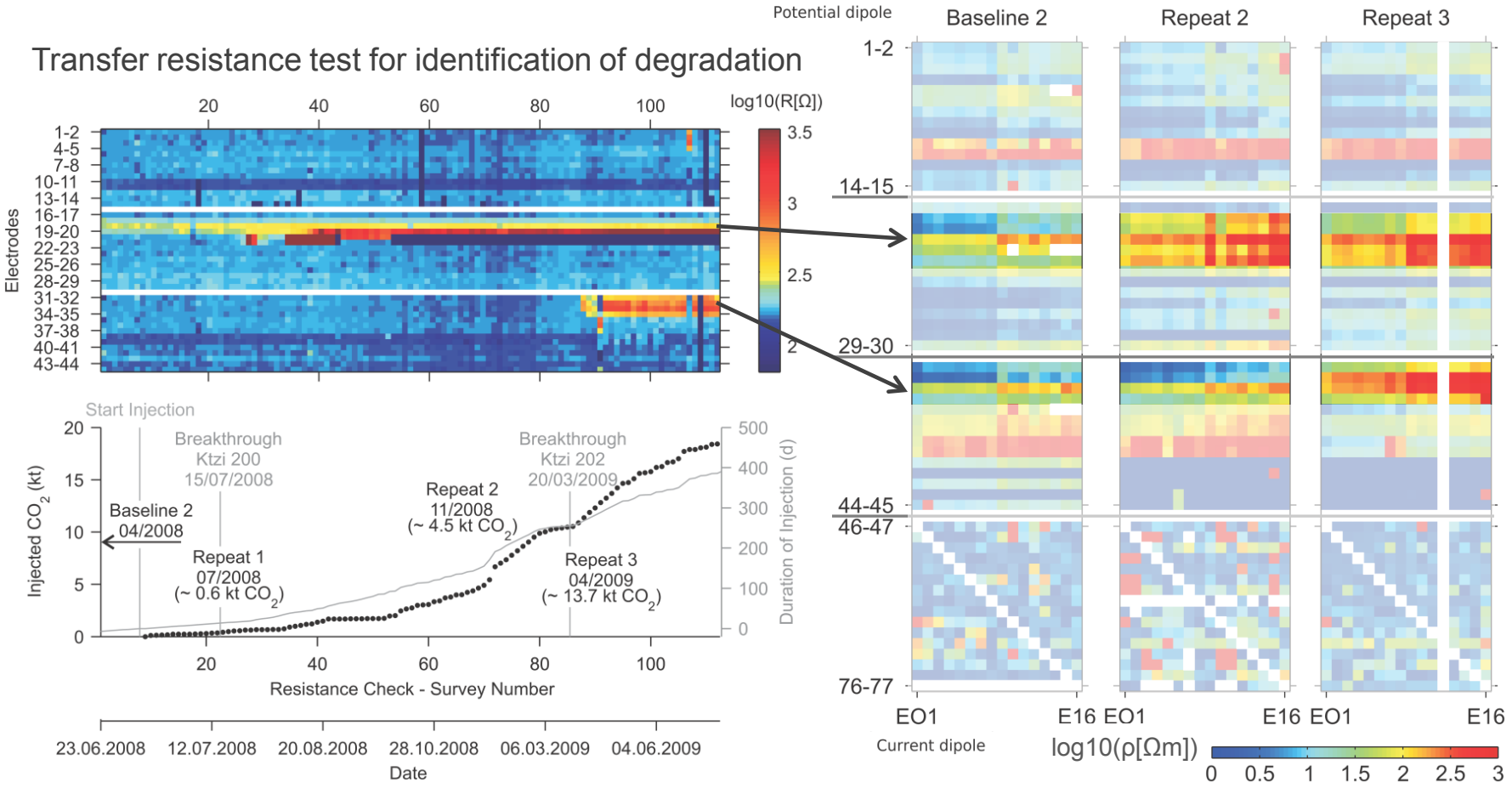


Green=Current
Blue=Voltage

⇨ Resistance & Error



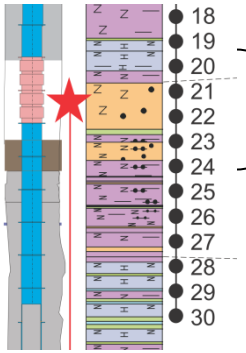
Preprocessing: Comparison with Electrode Tests

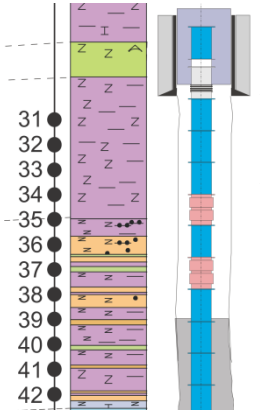


Preprocessing: Time-lapse Features in the Field Data

Comparison of field data with well completion and lithology

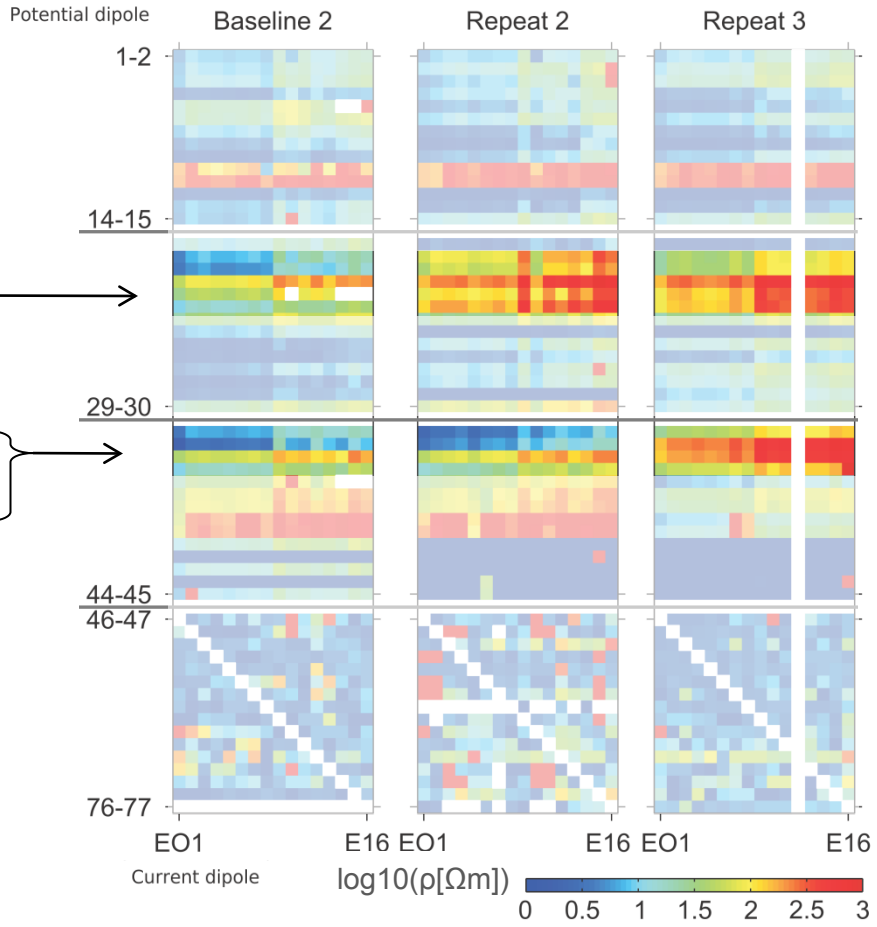
Injection well (Ktzi 201)



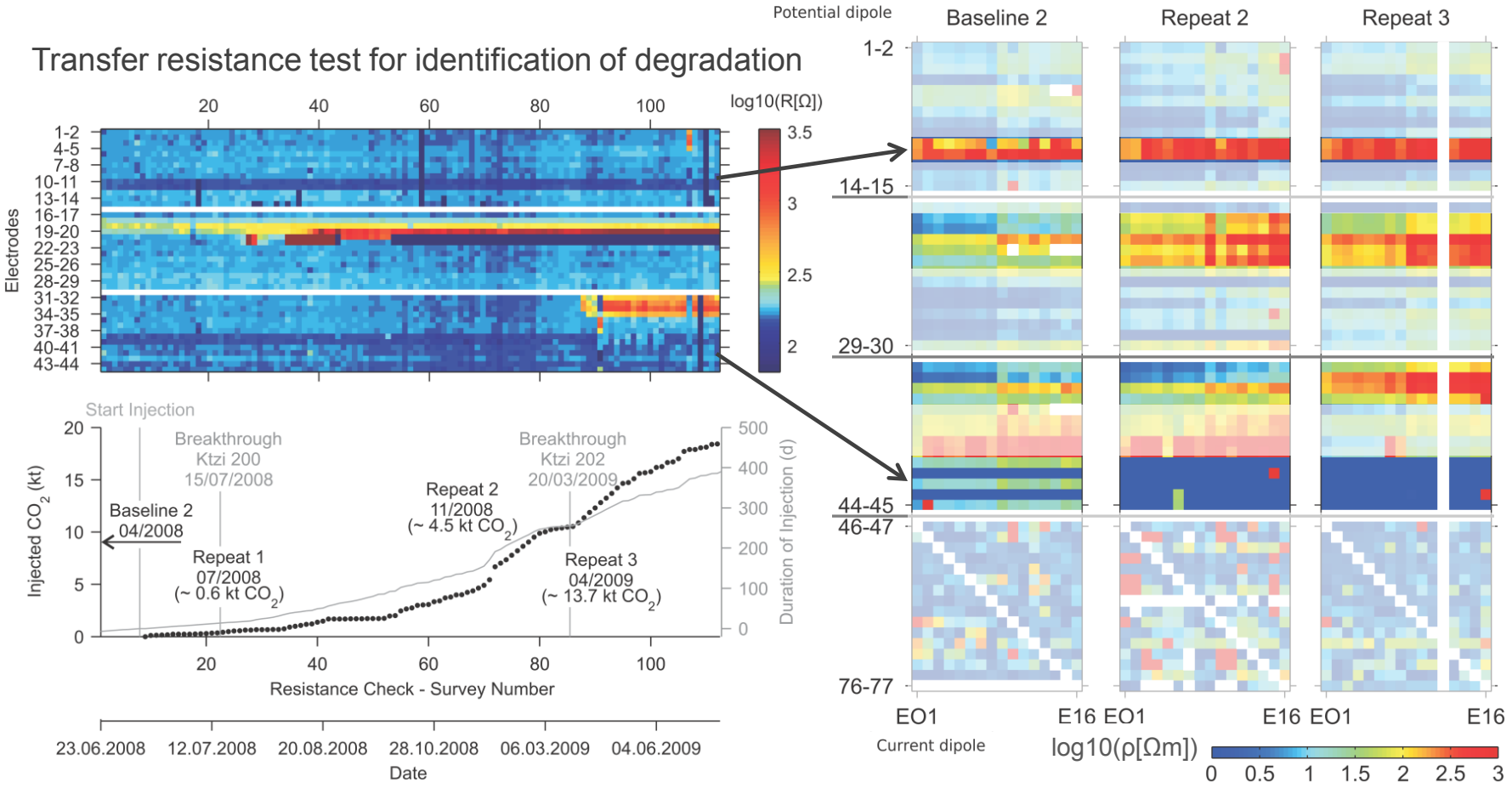


2nd observation well (Ktzi 202)

An increase in resistivity is observable for Ktzi 201 and Ktzi 202 (cement-free completion in the upper part of the array).



Preprocessing: Comparison with Electrode Tests



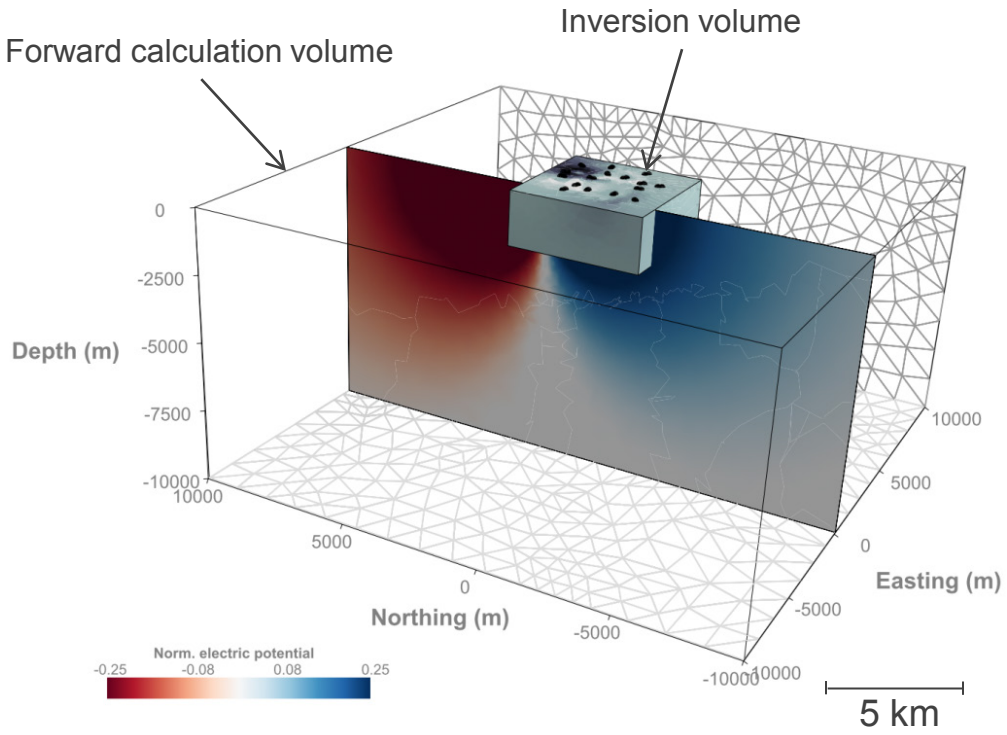
Time-lapse Inversion

Boundless Electrical
Resistivity Tomography (BERT)
- 3D Surface-downhole geometries
- Variant cell sizes
- Time-lapse capabilities
- Open source (www.resistivity.net)

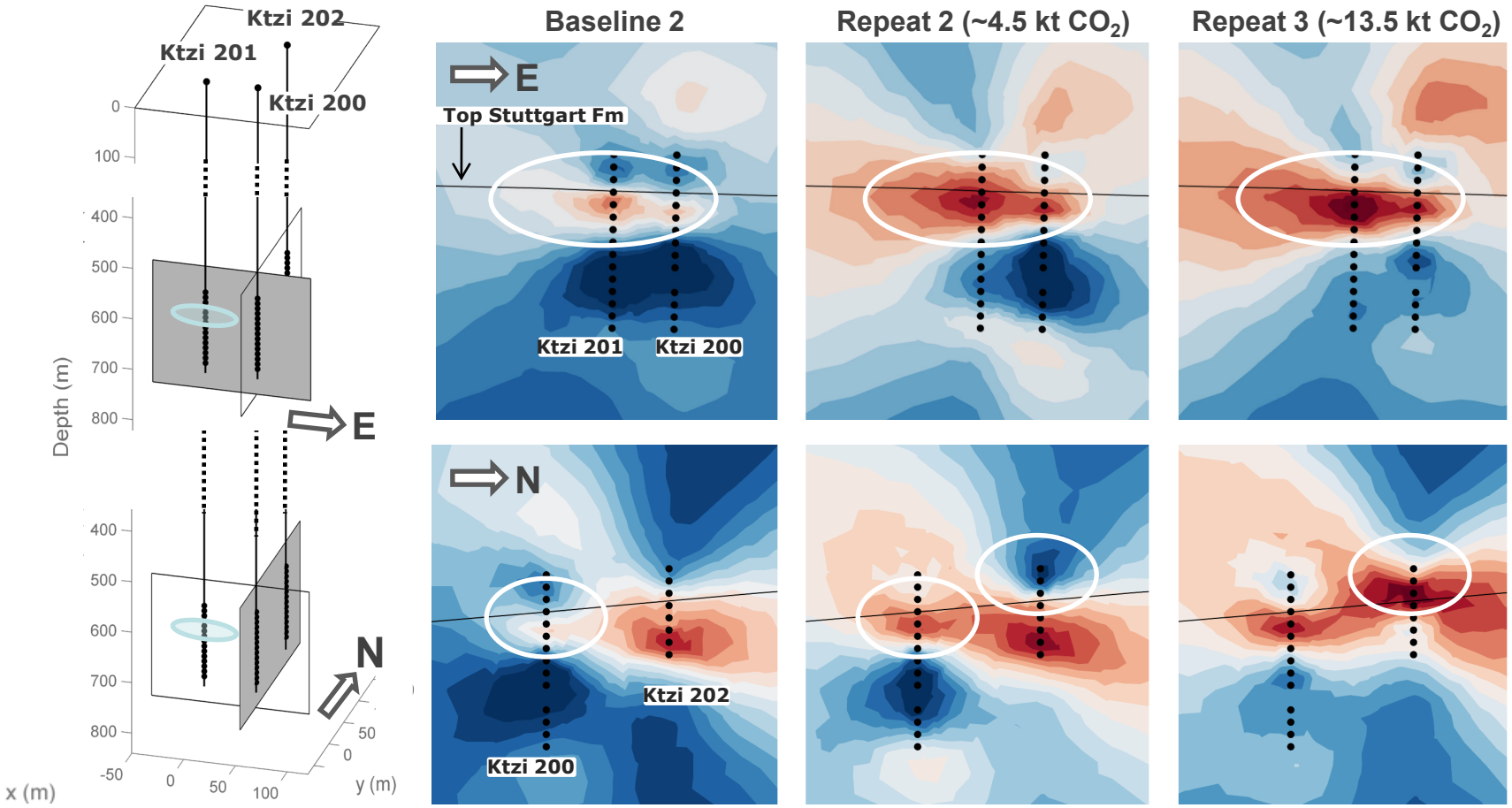
Forward calculation (Rücker et al.,2006):
FE (tetrahedral)

Inversion (Günther et al., 2006):
Conjugate gradient, Least-squares

Inversion domain for the Ketzin datasets



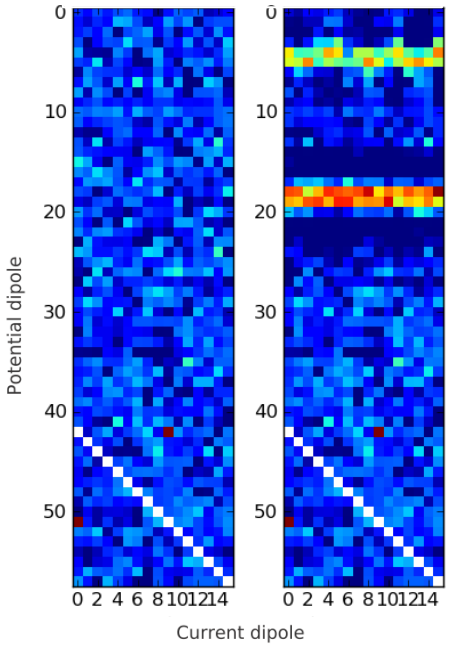
Time-lapse Inversion images the Expansion of a resistive Signature



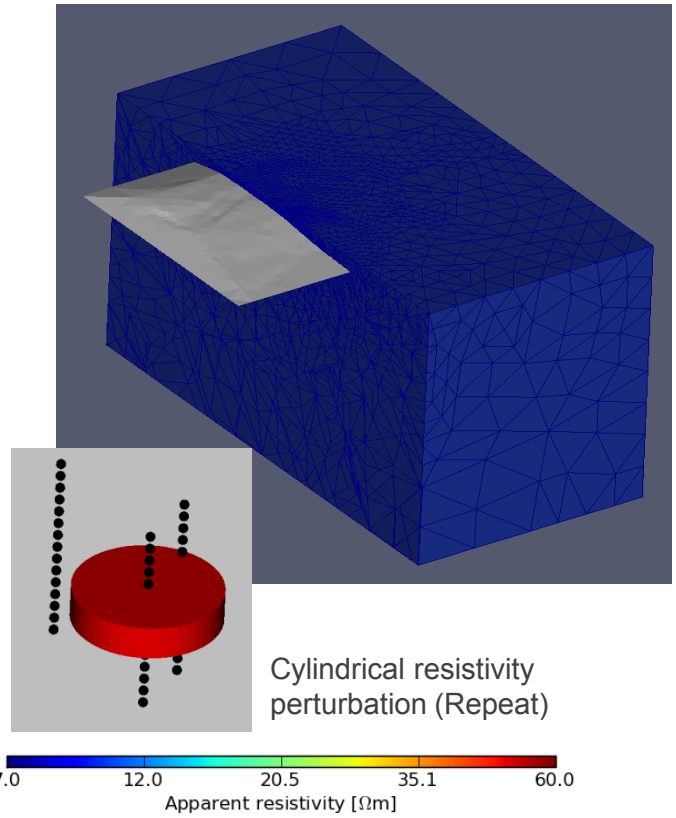
Geoelectric Modelling to investigate Plausibility and Imaging Characteristics

Synthetic vs. real data

Synthetic data (noisified):
Baseline Repeat

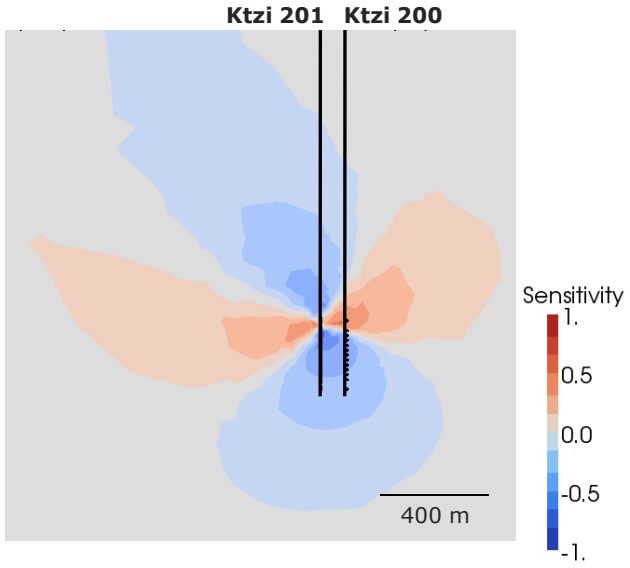


Geologic Formation boundary (Top Sinemurian) incorporated in the baseline model

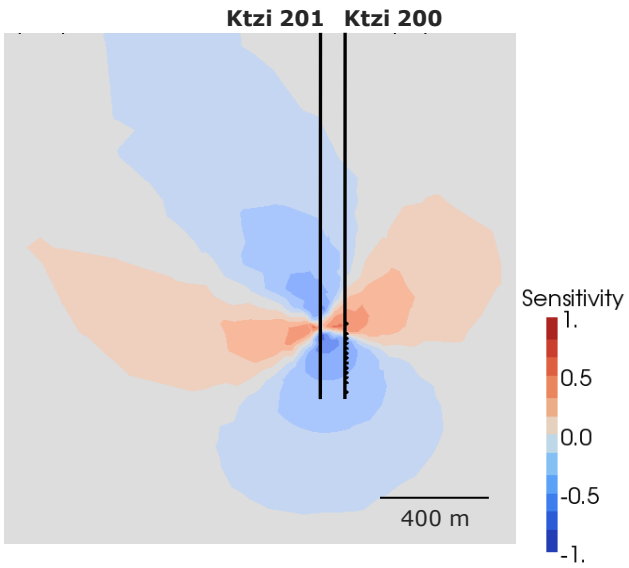


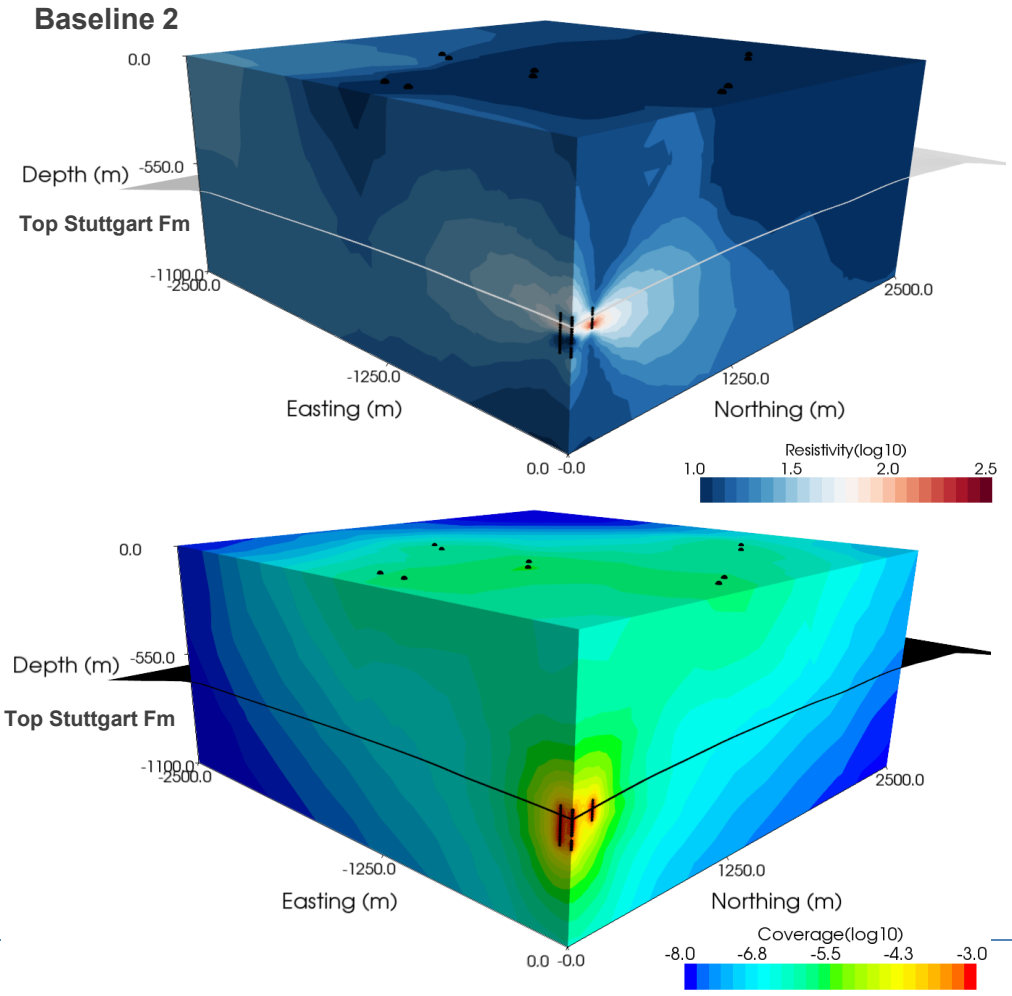
Sensitivity analysis

Sensitivity pattern (normalized) for a Dipole-Dipole measurement in the Ketzin SD-ERT setup



Effectively imaged Volume assessed from cumulated Sensitivities

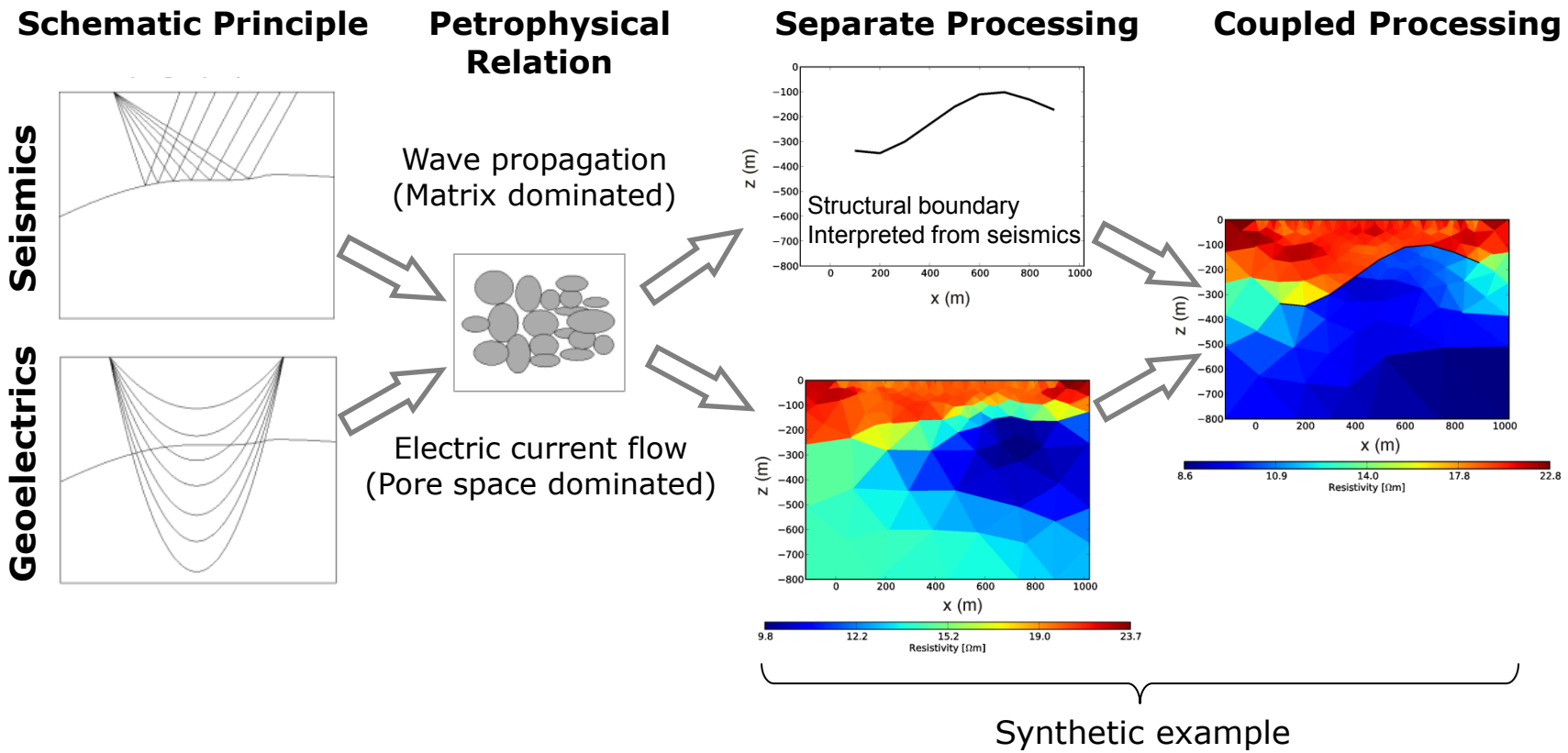




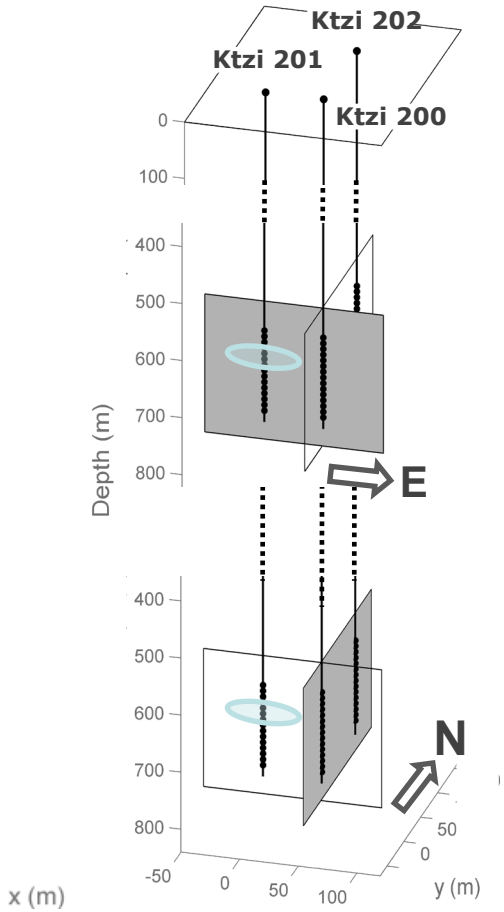
Current activities:

- Constrained Inversion using structural a priori information (->seismics)
- Interpretation based on petrophysical models and other monitoring observations

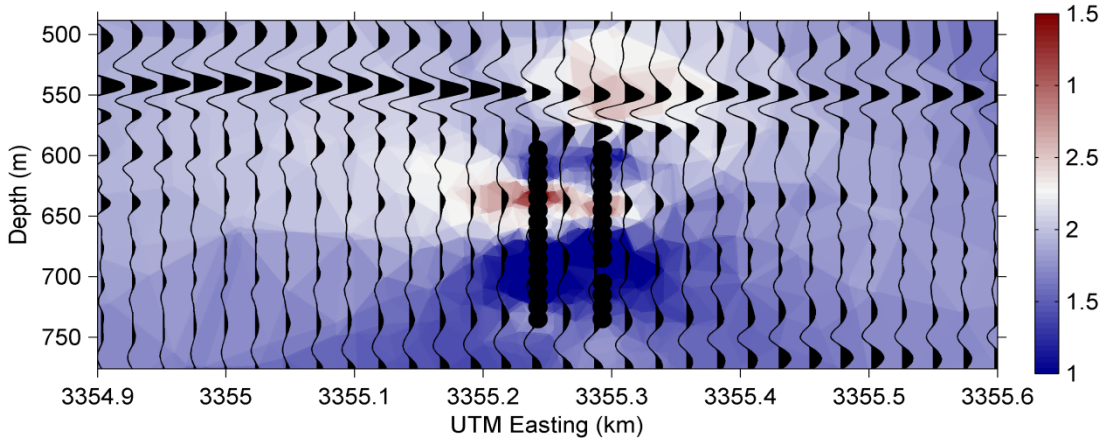
Outlook: Constrained Inversion of Seismics and Geoelectrics

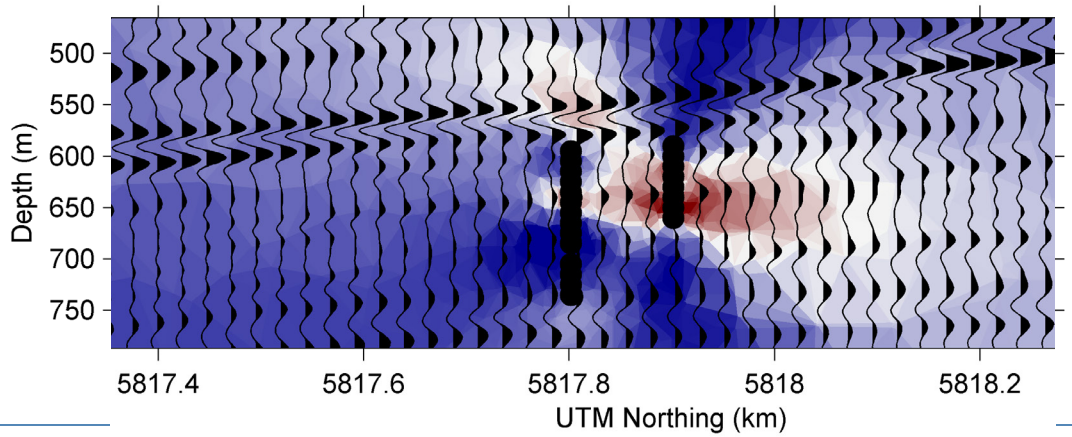


Outlook: Combined Interpretation with time-lapse Seismics



Resistivity inversions (Baseline 2) and seismic sections (3D Baseline).





Summary & Conclusion

- Geoelectric Surveying at the Ketzin site (Large-scale, SD)
- Field data show a resistivity increase
- Importance of electrode QC
- Inversion and Modelling
- Time-lapse results image the expansion of a resistive signature

Summary & Conclusion

- Geoelectric Surveying at the Ketzin site (Large-scale, SD)
- Field data show a resistivity increase
- Importance of electrode QC
- Inversion and Modelling
- Time-lapse results image the expansion of a resistive signature

⇨ Geoelectric measurements allow for imaging of injected CO_2 at the Ketzin site

Engelmann *et al.*, 2008. Eignungsnachweis für die Speicherung geringer Mengen CO2 am Standort Ketzin—CO2SINK. UGS GmbH.
Förster *et al.*, 2006. Baseline characterization of the CO2SINK geological storage site at Ketzin, Germany. Environmental Geosciences 13 (3), 145–161.
Günther et al., 2006. Three-dimensional modelling and inversion of dc resistivity data incorporating topography—II. Inversion. GJI 166, 506–517.
Kiessling *et al.*, 2010. Geoelectrical methods for monitoring geological CO2 storage: first results from cross-hole and surface-downhole measurements from the CO2SINK test site at Ketzin (Germany). IJGGC (2010).
Rücker et al. 2006. Three-dimensional modelling and inversion of dc resistivity data incorporating topography—I. Modelling. GJI 166, 495–505.
Storz et al., 2000. Electrical resistivity tomography to investigate geological structures of the earth's upper crust, Geophysical Prospecting, 2000, 48, 455-471

Summary & Conclusion

Acknowledgements:

COSMOS

GEOTECHNOLOGIEN

Federal Ministry of Education and Research

Federal Ministry of Economics and Technology

GeoEn

⇨ Geoelectric measurements allow for imaging of injected CO_2 at the Ketzin site

Engelmann *et al.*, 2008. Eignungsnachweis für die Speicherung geringer Mengen CO2 am Standort Ketzin—CO2SINK. UGS GmbH.
Förster *et al.*, 2006. Baseline characterization of the CO2SINK geological storage site at Ketzin, Germany. Environmental Geosciences 13 (3), 145–161.
Günther et al., 2006. Three-dimensional modelling and inversion of dc resistivity data incorporating topography—II. Inversion. GJI 166, 506–517.
Kiessling *et al.*, 2010. Geoelectrical methods for monitoring geological CO2 storage: first results from cross-hole and surface-downhole measurements from the CO2SINK test site at Ketzin (Germany). IJGGC (2010).
Rücker et al. 2006. Three-dimensional modelling and inversion of dc resistivity data incorporating topography—I. Modelling. GJI 166, 495–505.
Storz et al., 2000. Electrical resistivity tomography to investigate geological structures of the earth's upper crust, Geophysical Prospecting, 2000, 48, 455-471