Investigation of deep mineral deposits in Germany: Inversion results of CSEM data in frequency and time domain

W. Mörbe[1], P. Yogeshwar[1], B. Tezkan[1]*

[1] Institute of Geophysics and Meteorology, University of Cologne (UoC)
* Contact: moerbe@geo.uni-koeln.de, www.geomet.uni-koeln.de

DESMEX
University of Cologne
Bundesministerium für Bildung und Forschung

Abstract

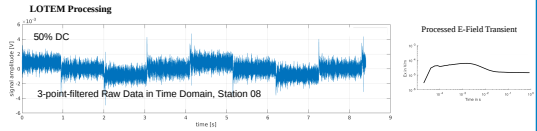
The objective of the BMBF funded DESMEX (Deep Electromagnetic Soundings for Mineral Exploration) project is the development of an electromagnetic exploration system which can be used for the exploration of mineral resources for depths up to 1000 m. In order to obtain a high data coverage as well as a high resolution, airborne and ground based methods are combined. In the framework of DESMEX, the University of Cologne performed ground based (long offset) transient-electromagnetic (LOTEM) measurements in an old mining area in eastern Thuringia, Germany. Within the LOTEM validation study, an independent multi-dimensional resistivity model of the survey area will be derived, which serves as a reference model for the semi-airborne concept and will eventually be integrated in a final mineral deposition model. Here, we will give an overview over the large scale field survey and present an interpretation of the dataset in frequency and time domain.

DESMEX Survey Thuringia September 2017

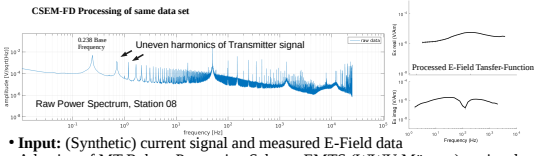
LOTEM Survey (UoC) September 2017
Aim:
- Denser station spacing on top of conductivity anomaly
- Extension of the profile 2016 to the South
  → Acquisition of E-Field data at 40 ground based receiver stations for 3 broad-side Tx locations

Squid/Coil measurements (IPHT Jena):
- Acquisition of (x,y,z) B-Field data for varying transmitter positions along a ~ 3km long profile

Time Domain vs Frequency Domain CSEM Processing



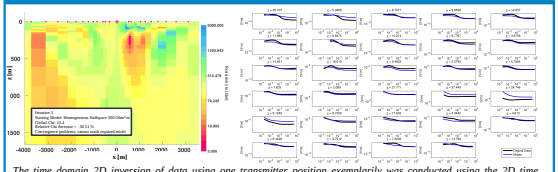
Input: Measured E-Field data, systemresponse (convolution with modelled data)
- Onset picking, data analysis + filtering (in time domain) [1]
- Cluster analysis, stacking, application of time-variable Hanning window



- **Input:** (Synthetic) current signal and measured E-Field data
- Adaption of MT Robust Processing Scheme EMTS (WWU Münster) to signal frequencies of transmitter

(LOTEM) GGT 30-ZONGE Transmitter: clean signal between ~1 Hz and up to 10 kHz (Depending on Offsets):
→ **Suitable for TD & FD Evaluation and deep EM exploration!**

2D Inversion in Time Domain

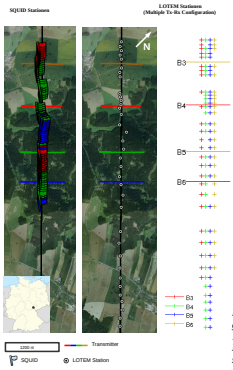


The time domain 2D inversion of data using one transmitter position exemplarily was conducted using the 2D time domain code SINV [4]. The good conducting structure at profile meter ~1000 can be geologically related to Black shale and corresponds with other results, e.g. high current DC measurements carried out in the area by LIAG 2015/2016 (not published). The datafit of the E-Field transients is not yet satisfying (right panel). The inversion exhibit convergence problems, which will need further analyzation in synthetic modelling studies. For further evaluation of the multi-dimensional subsurface and as a comparison, a multi-dimensional inversion of the dataset in frequency domain will be carried out.

References – Acknowledgements

[1] Hanstein, T. (1996), Digitale optimalfilter für Lotem Daten, in Protokoll über das 16. Kolloquium Elektromagnetische Tiefenforschung, edited by K. Baur and A. Junge, Deutsche Geophysikalische Gesellschaft.
[2] 1D Frequency inversion code provided by M. Becken
[3] 1D Time domain Code EMUplus UoC
[4] Martin, R., Development and application of 2D and 3D transient electromagnetic inverse solutions based on adjoint Green functions: UoC
Acknowledgement:
We would like to thank the field team of the DESMEX Survey 2016 & 2017 from Cologne and LIAG (R. Rochlitz), and IPHT Jena (R.Stolz) for providing the SQUID System. Michael Becken for providing the MT Robust processing scheme and the 1D FD inversion scheme. Furthermore, we would like to thank the Geophysical Instrument Pool Potsdam (GIPP) for the provision of the SPAM Mk IV System. DESMEX is funded by the Federal Ministry of Education and Research

DESMEX Survey Thuringia 2016

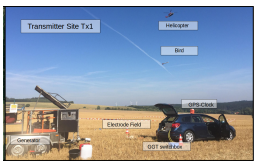


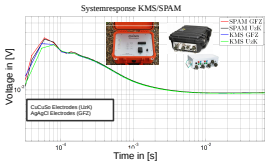
Main LOTEM Survey (UoC):
- Acquisition of E-Field data at up to 35 ground based receiver stations for 4 broad-side Tx locations
- Multiple offsets for every station due to variable transmitter position
- 115 E-Field datasets, 30 dHz/dt-Field datasets
- Profile ~ 7 km

Squid/Coil measurements (IPHT Jena):
- Acquisition of (x,y,z) B-Field data for varying Transmitter positions
- Profile ~ 4 km, every ~ 50 m one station

Objective of the LOTEM Survey: Derivation of an independent multi-dimensional resistivity model for semi-airborne concept

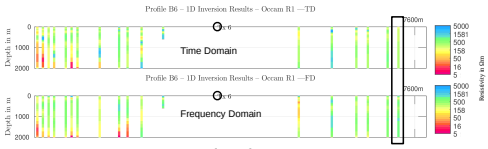
Bottom Left: Typical setup of a (semi-airborne) transmitter site. The source consists of a grounded electrical dipole. Tx currents ranging between 10-30 A with dipole length of ~ 1000 m, using a 50 % duty cycle. Bottom Right: Recorded E-Field data of the Dataloggers (KMS-820 and SPAM Mk-4) and different electrodes used in the survey. Both systems deliver a similar response.



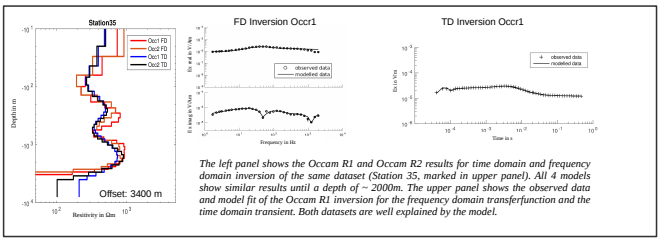


1D Inversion in Frequency and Time Domain

Inversion results of transmitter position Tx6 in frequency and time domain of SPAM Mk 4 data



In the upper panel the inversion results of 1D frequency domain inversion [2] and 1D time domain inversion [3] are illustrated in colorcode. The 1D Occam R1 inversion results for transmitter location Tx6 (black circle) are plotted under the corresponding receiver position. An errorfloor of 3 % was added to both datasets. The average Chi of both inversion schemes lies below a value of 2. The overall structures of the inversion results are similar for the given depth of investigation of ~ 2000 m, which encourages a further interpretation in frequency domain.



The left panel shows the Occam R1 and Occam R2 results for time domain and frequency domain inversion of the same dataset (Station 35, marked in upper panel). All 4 models show similar results until a depth of ~ 2000m. The upper panel shows the observed data and model fit of the Occam R1 inversion for the frequency domain transferfunction and the time domain transient. Both datasets are well explained by the model.

Conclusion and Outlook

LOTEM Survey 2016 & 2017:
Over 180 E-Field datasets were recorded during the DESMEX LOTEM Survey in 2016 and 2017. Additional information about the magnetic field was acquired by SQUID measurements conducted by IPHT.

Processing and 1D inversion results in frequency and time domain:
It was shown, that the LOTEM dataset can be evaluated in time domain and frequency domain. Both methods deliver similar results. Transients can be fitted between 10^{-5} s and 1 s, Transfer functions between 1 Hz and up to 10 kHz.

Outlook:
In order to explain all data and to derive a more realistic subsurface validation model, a multi-dimensional inversion of the dataset will be conducted. First 2D inversion results in time domain show already the expected good conducting black shale anomaly, but the code has still problems reaching convergence. Therefore, in a next step an inversion of the LOTEM dataset in frequency domain will be conducted.