3D imaging of electrical conductivity structures in the Eastern Cheb Basin across the Hartoušov mofettes

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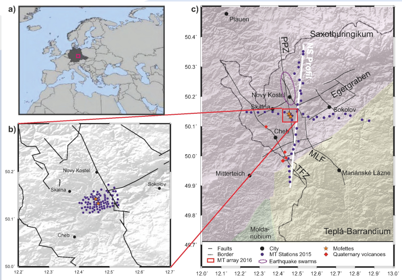
Background:

The Hartoušov mofettes field (Czech Republic) is one of the most prominent CO_2 degassing centres in Europe, which is located in a shallow Neogene intracontinental basin (the Cheb basin).
The region is also characterized by the NNW-SSO running Mariánské Lázne Fault (MLF), the partially parallel Tachov Fault Zone (TFZ), and the N-S oriented Počátky-Plesná Zone (PPZ).
The massive degassing of CO_2 in the Cheb Basin, especially in the Mofette fields of Bublák and Hartoušov, originats from great depths. These mantle/lower crustal derived fluids might use fault zones for their ascent.

Figure 1:
a) Overview map of the Study area (red rectangle). Germany and the Czech Republic are marked in dark colours.
b) Detailed view of the stations of the Magnetotelluric (MT) array measured in 2016.
c) Simplified tectonic map of the West Bohemian Massif with the distribution of the MT stations of 2015. Black lines: Fault zones with the NO-SW running Eger Graben and the Mariánské-Lázně (MLF) and Tachov Fault Zone (TFZ) as well as the Plesná Poátky Zone (PPZ). The moffets and the Mt-array of 2016 are at the crossing point of the 2015 profiles.



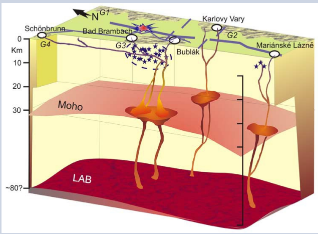
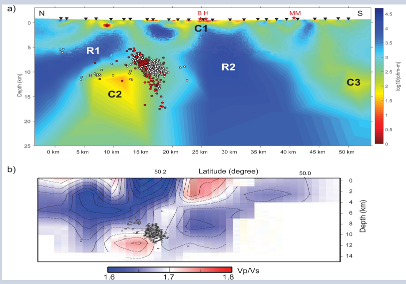


Figure 2:
Cartoon illustrating the geodynamic model in the Eger Rift region (Bräuer et al.,2008).
The model assumes that magma from the Earth's mantle forms larger reservoirs at Moho depth. From there it ascends towards the surface and might trigger earthquake swarms and feed mofettes and springs.

The MT measurements in 2015 (Fig. 1) resulted in a 2D image of the electrical conductivity along a N-S profile across the Eger Rift (Muñoz et al., 2018). It reveals a conductive channel similar to the one obtained from the Vp/Vs studies by Mousavi et al. (2015) that extend from the lower crust to the surface forming a pathway for fluids up to the region of the mofettes.

Figure 3: Comparison of (a) the 2D MT model (Muñoz et al., 2018) and (b) a cross section of Vp/Vs tomography from (Mousavi et al., 2015).
Our current study area is in the vicinity of the mofettes (red stars B-H).



Field Experiment:

A dense grid of MT stations was measured in February-March 2016 in the region where the two profiles cross and the mofettes are located. This grid has an approximate size of 5 ×10 km² and includes 97 stations with an average site spacing of 500 m.
At all stations horizontal components of the electric field and all components of the magnetic field were measured in the frequency range of 10 kHz–0.001 Hz. We used the S.P.A.M. Mk IV magnetotelluric system, Metronix induction coils and unpolarisable Ag/AgCl electrodes from the Geophysical Instrument Pool Potsdam (GIPP).
The recording time at each station was approximately three days.

Objectives:

- High resolution image of the electrical conductivity of the area surrounding the Bublák and Hartoušov mofettes
- Investigation of possible correlations between CO_2 degassing, fluids, aquifers, fault zones and swarm activity in the Cheb basin
- The assessment of the seismic hazards and mechanism of fluid-induced earthquake swarms
- Investigation of the geothermal potential of the Cheb Basin

Conclusion:

-The extremely noisy MT data could be improved (except Hz) effectively through the application of remote-reference technique, Mahalanobis distance criterion, and Short Time average/Long Time average filter.
-The low frequency data (< 1 Hz) will be improved by applying Wiener filter which removes spikes and steps in the electromagnetic time series (Kappler, 2012 ; Kütter & Weckmann, 2015).
- Both 2D and 3D inversion results display similar structures, such as a near-surface anomaly beneath Bublák and Hartoušov mofettes and a deep-reaching channel (north and east of 3D Model).

Data Processing:

The study area is heavily populated with power plants and, therefore severely affected by electromagnetic noise, which deteriorates the quality of the MT data.
The data were processed using the EMERALD software package (Ritter et al., 1998; Weckmann et al., 2005; Ritter et al., 2015a).
We observed spikes and steps in the time series, were removed using a Short Time Average/Long Time average filter (STA/LTA) (Fig 4a; Kuetter & Weckmann 2015).
A notch filter (Kanasewich, 1981; Hanstein et al.,1986) is used to remove the noise from power lines and railways.
Two new processing criteria after Platz & Weckmann (2019). The Mahalanobis distance criterion removes data points that scatter around the desired MT distribution and reject data cluster originating from noise sources. In addition, we eliminated data points caused by a strongly polarised magnetic signal with the magnetic polarisation direction criterion (Figure 4b; Platz & Weckmann, 2019).
We used the permanent Reference Station in Wittstock (Germany), about 350 km from the study area, for processing (Figure 4b).

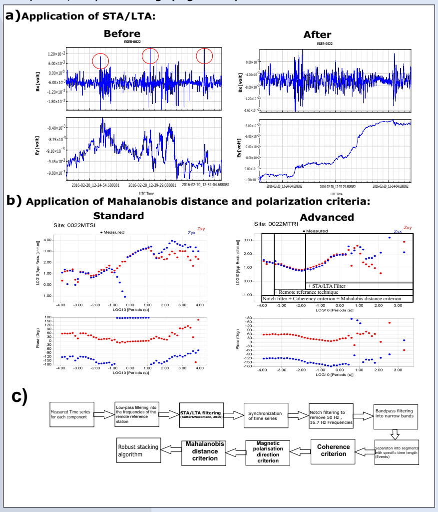
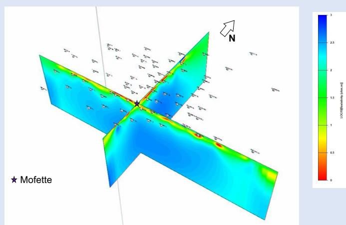


Figure 4: Data Processing
a) The improvement of the time series after applying the STA/LTA filter and a notch filter with B_x and E_y.
b) Comparison between standard single site and advanced magnetotelluric impedance tensor elements. Notch filter (Hanstein et al.,1986) + Coherency criterion (Weckmann, 2015) + Mahalobis distance criterion &magnetic polarisation criterion (Platz & Weckmann 2019)+ Remote referance technique (Krings,2007; Ritter et al., 2015) + STA/LTA Filter (Kuetter & Weckmann, 2015)
c)The Sequence of processing steps

Figure 5:
2D model sections taken from the first 3D model of the MT data. A near-surface anomaly at 500 m depth seem to be spatially related to the Bublák & Hartoušov mofette fields.

3D Inversion:

With the improved data quality, we are able to start with 3D inversion of the array data. We can use data in the period range from 0.0001 s to 10s.



Model grid:
Background resistivity : 100 Ωm ,
X - Direction: 100 cells x 70 m , 22 of padding cells, increasing factor 1.3
Y - Direction: 135 cells x 70 m , 22 of padding cells, increasing factor 1.3
Z - Direction: 59 layers , first layer thickness is 20 m , increasing factor 1.15, max. depth 508 km
Data Error:
Zxy: 5% of |Zxy|, Zyx: 5% of |Zyx|, Zxx and Zyy : 40% of √|Zxy*Zxy|
Smoothing parameters: 0.2 in all directions

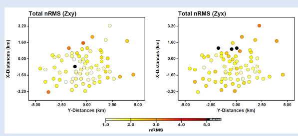


Figure 6:
Distribution of RMS data misfit of each site. Starting RMS was 20.8, final RMS after 113 iterations 2.03.

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