Analyzing Two-Dimensional Effects in Central Loop Transient Electromagnetic Data

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Abstract

Thick sedimentary sequences are deposited in the central area of the Azraq basin/Jordan consisting mostly of hyper-saline clay and various evaporates. These sediment successions form the 10 km × 10 km Azraq mudflat and are promising archives for a palaeoclimatical reconstruction within the Collaborative Research Centre 806 (CRC-806) entitled "Our Way to Europe" [1]. We utilized the central loop Transient Electromagnetic (TEM) method to identify the subsurface resistivity structure along two 7 km and 5 km long transects and, furthermore, to provide a basis for future drilling activities within the CRC-806 [5, 6].
The subsurface resistivity structure varies from around 50 Ωm on the basalt formation to around 0.3 Ωm inside the alluvial mudflat. Therefore, a 1D interpretation may not be adequate. Here we present the calculation of a semi-synthetic TEM Tipper to quantify a probable 2D effect. Although the horizontal component of the magnetic field was not measured in the field, it is possible to use the TEM Tipper to investigate if the derived subsurface model generates a 2D effect, which is e.g. larger than the data error-floor.

Survey area and TEM setup

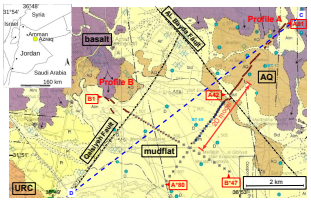

Fig. 1 : Geological map of the survey area in the central part of the Azraq area, Jordan [4].

A total of 150 TEM soundings were recorded with an inter-station distance of generally 50 m up to a maximum distance of 200 m and a transmitter loop size of either 50^2 m^2 or 100^2 m^2. The investigated profiles cross four geological formations (cf. Fig. 1 & 2(a)):

- AQ: Quaternary sediments.
- AOB: Basalt.
- ALM: (alluvial) mudflat sediments with hyper-saline shallow groundwater.
- URC: Chert limestone formation. Base layer below mudflat sediments.

Quasi 2D resistivity-depth sections

The 1D models along both profiles are stitched together as quasi 2D sections (cf. Fig. 2(b,c)). The derived resistivity depth section along profile A is in excellent agreement with the corresponding geological cross-section and the depth to uncertain geological boundaries (dashed lines in Fig. 2(a)) are well detected. Moreover the transition zone from fresh to saline groundwater is identified along both profiles resulting in a resistivity decrease from moderate to extremely low values. Around sounding A42 the Al Bayda Fault is expected. The resistivity structure exhibits maximal lateral variation in that zone. Therefore, the 1D interpretation may be inadequate and lead to miss-interpretations.

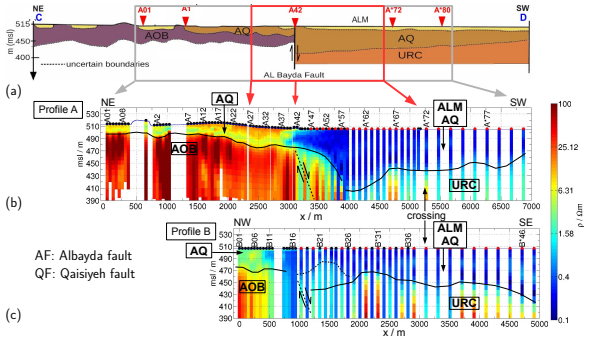

Fig. 2 : (a) Geological cross-section [4], which is representative for profile A. Quasi 2D resistivity-depth sections for (b) profile A and (c) profile B derived from the 1D Occam R1 models. The profile locations are shown on the map in Fig. 1.

Conclusions

- The 1D inversion results are consistent and in good agreement with the geology.
- Considering the derived 2D model, the semi-synthetic TEM-Tipper approach indicates that 8 soundings exhibit a 2D effect. Moreover, the zone where the 2D effect is maximal correlates partly with larger data residuals.
- The presented approach can be used to analyze if a 2D interpretation is required.
- The U_x-response is very sensitive to sensor placement and, therefore, difficult to measure.

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References:
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Analyzing 2D effects in synthetic TEM data

Although the 1D interpretation of TEM field data has proven its feasibility in various case studies, data may be 2D affected for certain subsurface situations. The 1D inversion of such data can lead to significant miss-interpretations (cf. Fig. 4).
In order to quantify if a certain model generates a 2D effect in TEM data, we calculate a TEM-Tipper from the ratio of the horizontal and vertical induced voltage components: $T_U = U_x/U_z$ (cf. Fig. 3(c,d)). As a cross-check for the TEM-Tipper approach we compare it to the relative difference calculation between the 2D model and a 1D background model response: R-diff $= \frac{U_{ind}^{2D} - U_{ind}^{1D}}{U_{ind}^{2D}} \times 100$ (cf. Fig. 3(b), [2]). Both approaches yield comparable results and allow to quantify which soundings and transient times are influenced by a 2D effect. The maximum 2D response is directly on the contact zone. The TEM-tipper approach is convenient, as it does not require to construct a 1D background model, which is rather complicated for realistic 2D models.

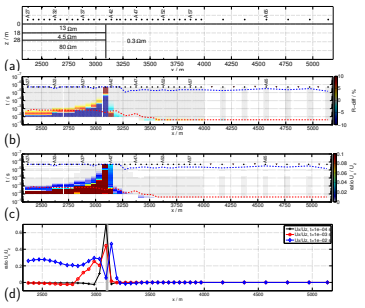

Fig. 3 : (a) 2D model with vertical contact zone at sounding A41. (b) Relative difference calculated from the 2D response and 1D background model response. (c) Tem tipper $T_U = U_x/U_z$. (d) T_U for three distinct time points.

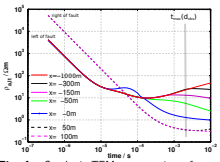

Fig. 4 : Synthetic TEM $\rho_{a,U}$ transients for several distances from vertical contact zone.

Analyzing 2D effects in TEM field data

The application of the above presented TEM-Tipper approach to the field data is straight forward. Herewith it is possible to quantify which soundings and transient times are 2D affected, although only U_z was measured in the field. We conclude the following:

- Good global fitting for 2D model with $\chi = 1.47$ (cf. Fig. 3(a)).
- Larger residuals partly between sounding A34 and A59. This zone correlates with the lateral conductivity change (cf. Fig. 3(a) and (b)).
- Significant 2D effect between sounding A35 and A42 (cf. Fig. 3(c) and (d)). In that zone also larger residuals are present. At sounding A37 the 2D effect is maximal and occurs earliest.
- U_x response strongly depends on Rx-location and is difficult to measure (cf. Fig. 6).

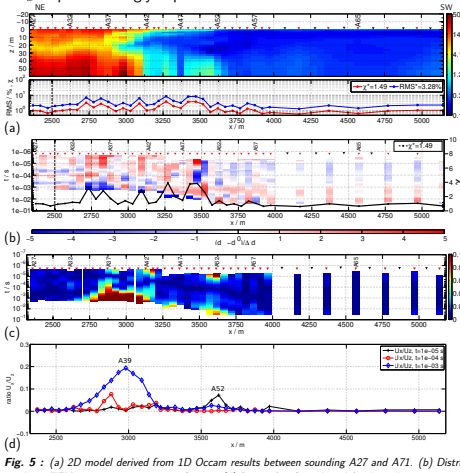

Fig. 5 : (a) 2D model derived from 1D Occam results between sounding A27 and A71. (b) Distribution of residuals. (c) Semi synthetic TEM-tipper $T_U = U_{x,synthetic}/U_{z,obs}$. (d) Ratio of U_x/U_z plotted for three distinct time points along the profile line.

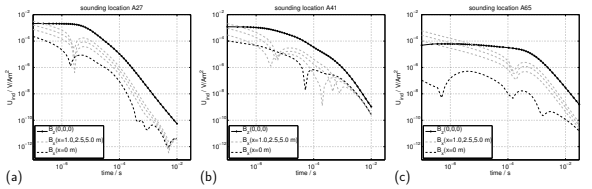

Fig. 6 : Synthetic induced voltage response U_z and U_x for sounding locations A27, A41 and A65. Additionally U_x is plotted as gray dashed lines for 1.0, 2.5 and 5.0 m offset to the center of the transmitter.

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