Sedimentary Basins in the Eastern Desert of Jordan

First Geophysical Investigations and Insights

P. Yogeshwar, B. Tezkan, A. Haroon
Institute of Geophysics and Meteorology, University of Cologne

Abstract

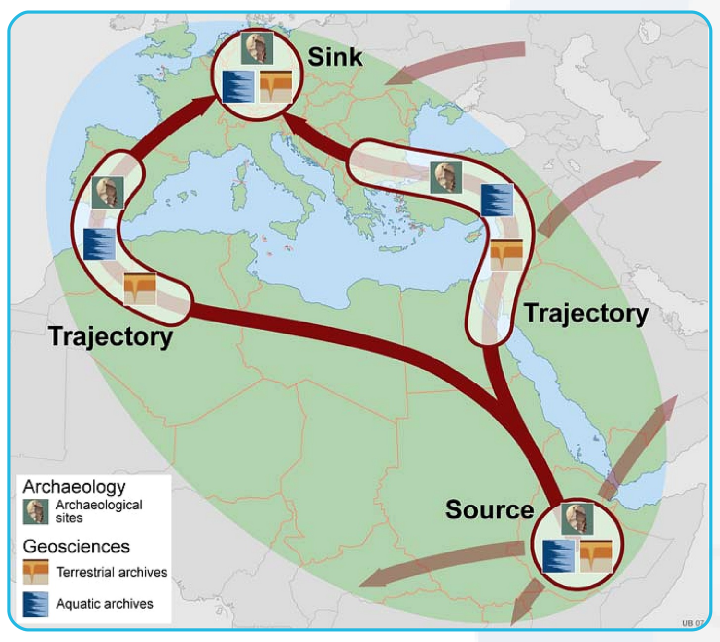

Fig. 1: Study Areas of the CRC 806 "Our Way to Europe".

Fig. 2: Stone artefact.

The Collaborative Research Centre 806 (CRC 806) "Our Way to Europe" concerns the history of mankind. It is designed to capture the complex nature of dispersal of Modern Man from Africa to Western Eurasia, and particularly to Europe. The CRC concentrates on the time span between the dispersal of Modern Man from Africa (190,000 B.P.) and the permanent establishment of Man in Central Europe (40,000 B.P.). The CRC investigates archaeological sites, terrestrial and aquatic archives in the source region of Modern Man, along trajectories of dispersal and in sink areas (Fig. 1).

The Eastern Mediterranean has been the passageway for human migration between Africa, the Middle East, the Balkans and Europe. The Azraq, area around the former oasis Qa' Al Azraq, in the eastern desert of Jordan has been a major spot for prehistoric settlements since the middle Pleistocene. The former shorelines of the Qa' Al Azraq are littered with stone artefacts, which were also found during the field survey (Fig. 2).

Very promising archives for paleoclimatical reconstruction are sediment successions accumulated in dry clay lakes (Playa lakes).
We utilized the Transient Electromagnetic (TEM), the Direct Current Resistivity (DCR) and the Radiomagnetotelluric (RMT) methods to identify the most complete sedimentary sequences inside the mudflat Qa' Al Azraq and to derive suitable borehole locations for the paleoclimatical reconstruction.

The Azraq Basin

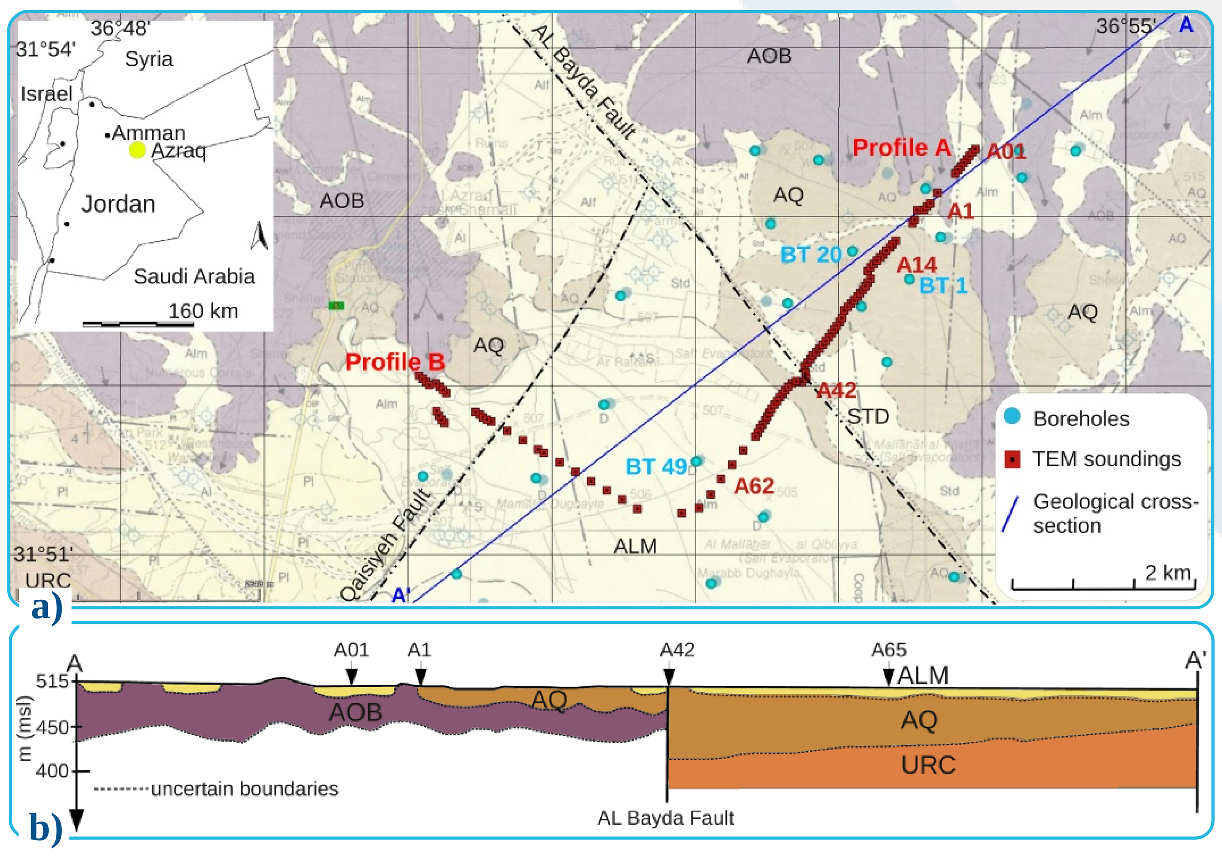

Fig. 3: (a) Geological map of the investigated area. (b) Geological cross-section AA' (Ibrahim, 1996). Stations and boreholes are marked.

The Azraq Basin is a tectonic structural depression. It covers an area of 13,000 km^2. The basin is drained by several Wadis.
Azraq is the main fresh water supplier to Jordan's capital Amman and has immense economic importance due to its huge mineral deposits.

Four geomorphological units are present in the study area (Fig.3):

- **Abed Olivine Phyric Basalt (AOB)**: stems from earliest volcanism, most abundant, forms irregular shaped boulders (Fig. 4(a))
- **Um Rijam Chert Limestone Formation (URC)**: outcrops northeast and southwest
- **Azraq Quaternary Formation (AQ)**: consists of clay, intermixed with various evaporites and fragments of gravel, limestone and basalt. The top is a present erosion and deposition surface, partly covered by alluvial sediments (Fig. 4(b)).
- **Alluvial Mudflat (ALM)**: the basin centre (10x10 km^2) consists of soft, silty hyper-saline clays and various evaporates. The alluvial mudflat is bounded to the north by the **Al Bayda Fault** (Fig. 4(c)).

Fig. 4: The geomorphological formations: (a) Abed Olivine Phyric Basalt (AOB), (b) the Azraq Quaternary Formation (AQ) and (c) the Alluvial Mudflat (ALM). Photos were taken taken during the geophysical survey in March 2011.

Field Survey

Two profiles, 5 and 3 km long (Profile A and B), were investigated in a three week survey in March 2011. from the edge of the basin near the basalt outcrops towards the basin centre, crossing three geological formations: AOB, AQ and ALM. Profile A crosses the Al Bayda Fault at station A42 and profile B crosses the Qaisiyeh Fault (Fig. 3). TEM, DCR and RMT methods were utilized for the geophysical investigation.

TEM

- NT-20 transmitter, GDP-32 receiver (Zonge, 2002). We measured Nano-Tem (NT) and Zero-Tem (ZT) mode
- 102 stations, station distance 50 m
- Tx=50x50 m^2; Rx=10x10 m^2
- Rx-time: 1.9 µs to 19 ms

DCR

- ABEM SAS 4000 (Abem, 2002), Wenner Long+Short configuration
- Interelectrode spacing: 5 m
- 3.1 km of DCR along profile A (A01 to A50 in Fig. 3(a))
- Longest Roll-on was 1700 m, several short arrays

RMT

- RMT-F device from the University of Cologne
- 6 to 8 frequencies, 18 kHz to 1 MHz, only TE-mode data available
- 118 stations along profile A between A1 and A42
- 10 m station distance

TEM Data

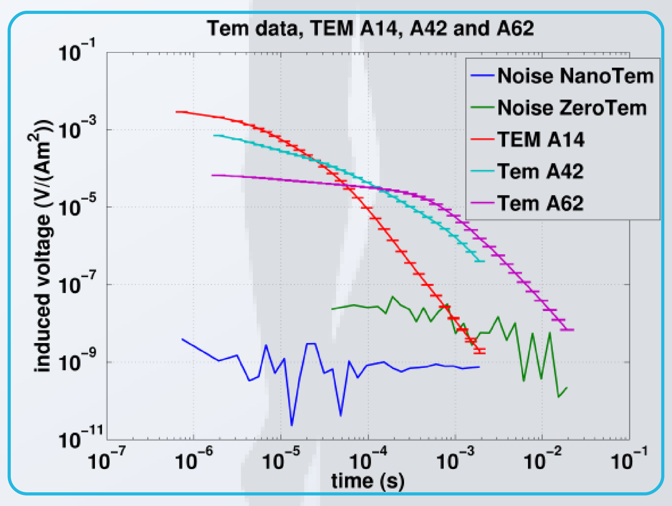

Fig. 5: TEM data for Station A14, A42 and A62 and Noise level.

As the subsurface is very conductive, the data recorded on the alluvial mudflat indicates a very low dynamic range, in comparison to the data obtained north of the Al Bayda Fault.
The signal amplitude for the transients recorded on the alluvial mudflat increases the noise level up to t=1.9 ms.

Correlation with Borehole Data

The geoelectrical models were correlated with ground truthing data (Fig. 6(d)). 1D Marquardt and Occam (first and second order roughness) inversion models were calculated (Fig. 6). Equivalent models define a confidence range for the resistivity and thickness of each resolved layer (Scholl, 2005).
According to the boreholes (Fig. 6(d)) and the results for station A14 (Fig. 6 (a,b,c)) the porous basalt exhibits a resistivity of approximately 40 Ωm. The top 10 m is a clay layer apparently intermixed with fragments of limestone, gravel and various evaporates. The 3 Ωm layer below corresponds to soft clay.
TEM station A62 exhibits a nearly homogenous resistivity of 0.2 Ωm, which corresponds with hyper-saline clay, which are present in the alluvial mudflat.

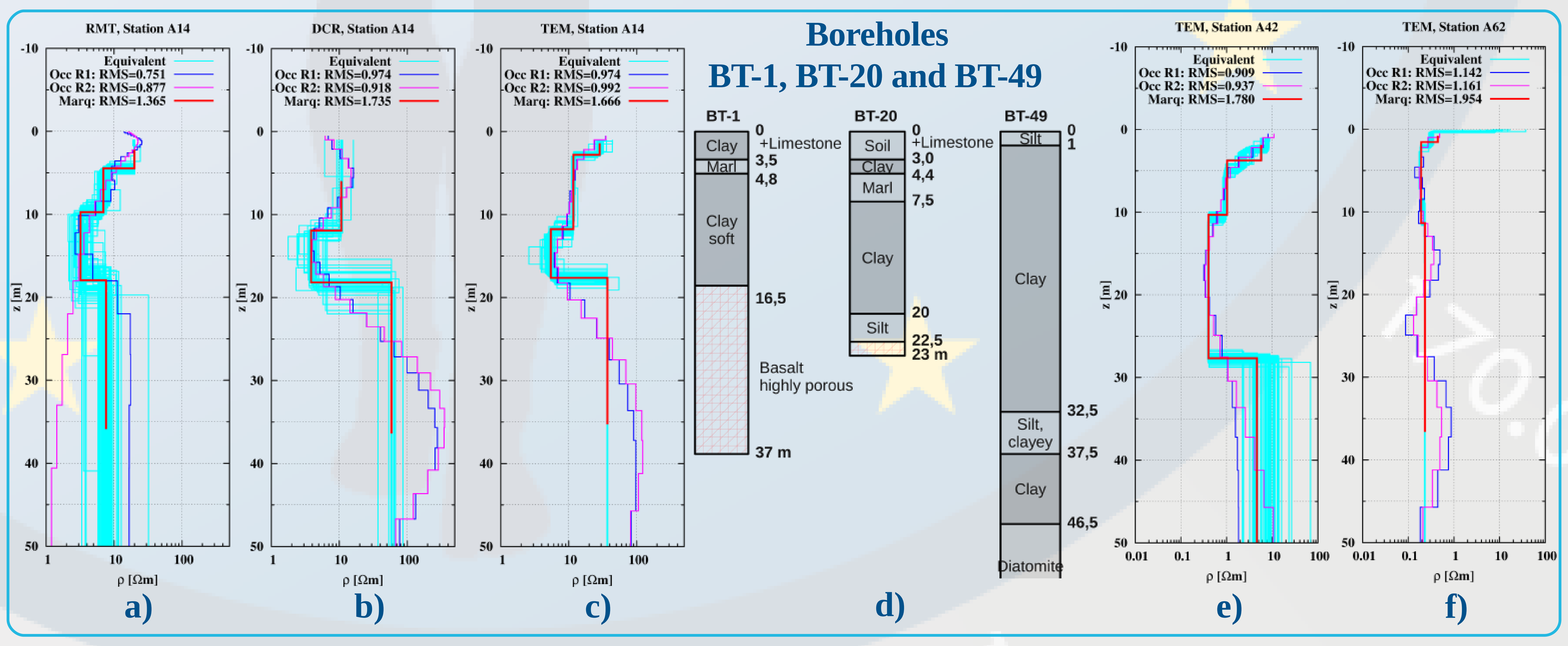

Fig. 6: (a,b,c) 1D RMT, DCR and TEM inversion models for station A14 and (d) corresponding boreholes BT-1 and BT-20. TEM station A62 (f) correllates with BT-49 (d).

TEM & DCR Sections for Profile A

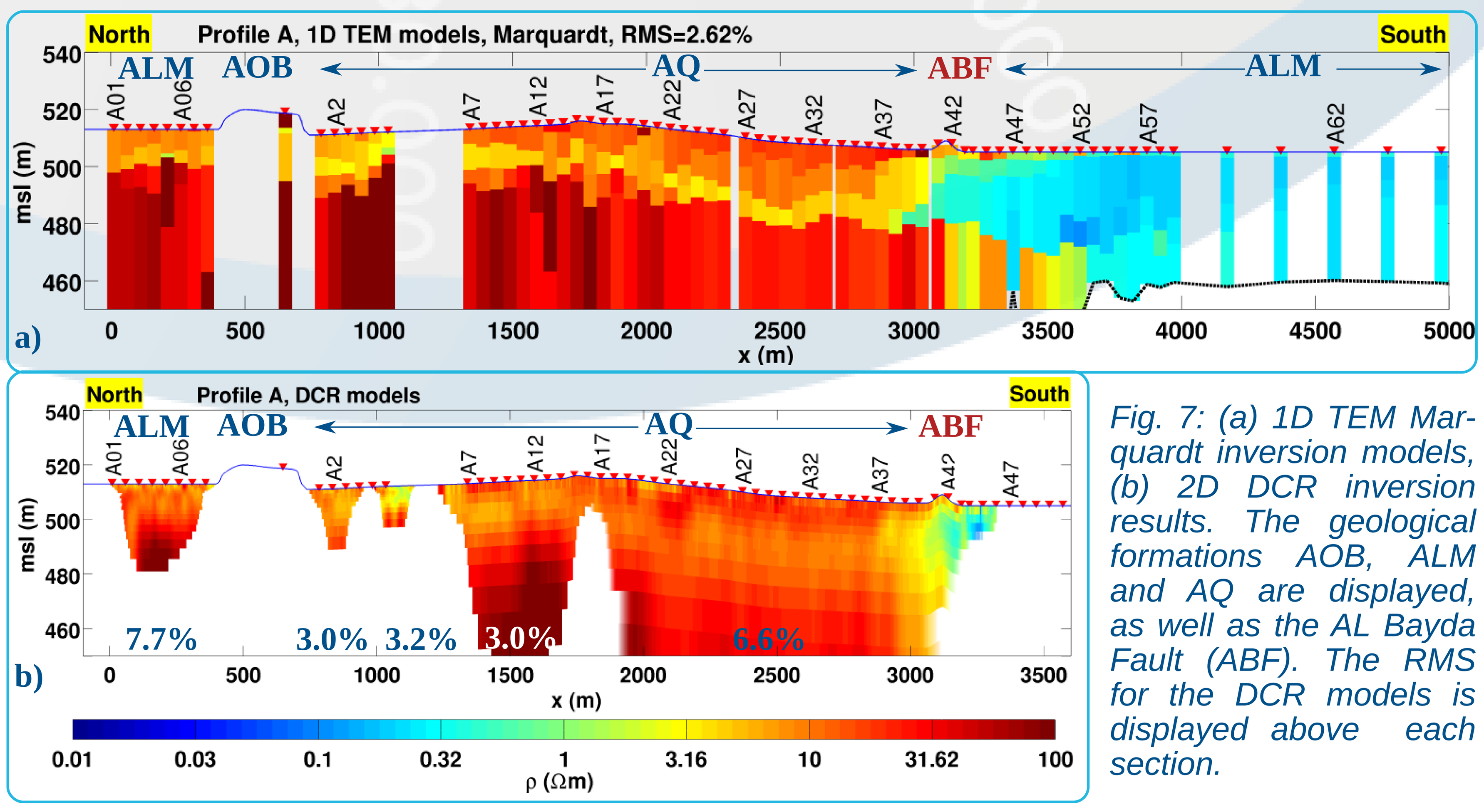

Fig. 7: (a) 1D TEM Marquardt inversion models, (b) 2D DCR inversion results. The geological formations AOB, ALM and AQ are displayed, as well as the AL Bayda Fault (ABF). The RMS for the DCR models is displayed above each section.

- The 1D TEM Marquardt models are stitched together and presented as a 2D section (Fig. 7(a)). North of station A42 the top of the basalt stream is clearly detected in a depth of 14 m to 35 m. Above, the AQ-formation is present. The 3 Ωm layer might correspond to soft clay.
- A resistivity contrast inside the mudflat is slightly visible in approximately 20 m depth and could be the ALM-AQ interface (Fig. 3(b)). The data is fitted well with a mean *RMS* of 2.62%. The starting model was a 10 Ωm halfspace with 4 layers.
- The DCR sections (Fig. 7(b)) support the TEM result. DCR measurements were not possible on the alluvial mudflat. The 2D DCR inversions were performed using DC2DINVRES (Günther, 2002).

Conclusions & Outlook

- Three geomorphological units are detected clearly: AOB, AQ and ALM. The boundaries of the basalt stream, which were uncertain from the geological map, are determined by the geoelectrical results. The base of the alluvial mudflat and the URC formation beneath was not resolved, due to the low depth of investigation.
- Suitable borehole locations for paleoclimatical reconstruction can be found on the alluvial mudflat. However, the results have to be analysed in detail to determine the ALM-AQ interface (Fig. 3(b)).
- A 2D interpretation (Forward modelling and inversion) is the next objective.

Acknowledgement

The project is funded by the DFG. We gratefully thank the Natural Resources Authority, Jordan, and especially Tahsin Talat for great support in the field work, the tough organization and for the hospitality.

References

ABEM, Terrameter SAS 4000 / SAS 1000 Instruction Manual, ABEM Atlas Copco., printed matter no. 93109 Auflage, 2004
Günther, T., Inversion Methods and Resolution Analysis for the 2D/3D Reconstruction of Resistivity Structures from DC Measurements, Dissertation, Technische Universität Bergakademie Freiberg, 2004
Ibrahim, K. M, The regional geology of Al Azraq area. Bulletin 36, Geological Mapping Division, Natural Resources Authority, Jordan, 1996
Zonge, GDP-32 II Multifunction Receiver Operation Manual, Zonge Engineering and Research Organization, 2002
Scholl, C., The influence of multidimensional structures on the interpretation of LOTEM data with one 1dimensional models and the application to data from Israel, Dissertation, IGM-Cologne, 2005

Deutsche Forschungsgemeinschaft