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Content

3-D Resistivity Inversion Study in an Important Roman Military Center in Turkey

Study area

The archaeological site of ancient Satala (modern village of Sadak, province Gümüshane, NE Turkey) was situated on the crossing of two singularly important routes in North-East Asia Minor: one was the only major natural East-West route in the North of Asia Minor leading from Ankyra via Nicopolis and Satala into Northern Armenia, and onward to the countries of the Caucasus as well as into northern Persia. The second route running roughly along the Eastern frontier of the Roman Empire connected the Black Sea harbour of Trapezus and other major military centers such as the legionary fortresses at Melitene, Samosata and Zeugma with Northern Syria and its capital Antioch (Fig.1). Satala is one of the last great military centers in the Roman East available for archaeological and historical investigations. Thus, Satala offers the rare opportunity to find a good number of answers to the many open questions concerning the military history of the Roman Empire, as well as the ancient history of Anatolia and the Near East in general. (Hartmann *et al.* 2004, The Mavors Institute – http://www.mavors.org/).

Figure.1: The satellite image of Eastern Anatolia, Caucasus and Arabian region, and The Roman Legions in Anatolia (from Mavors Institute)

Figure 2: The general view of geophysical study area

In this study, we carried out the 3-D resistivity surveys, which were performed by single channel resistivity equipment that has an apparatus fitting to collect the 2-D multi-electrode resistivity data. Thus, 3-D data were obtained from a number of combined 2D data sets according to the Wenner array. 3D Resistivity surveys were carried out in the eastern part of the investigation area, which contains very regular and high magnetic anomalies (Fig.2 and 3). During this resistivity survey, data were collected from separate 18 grids, and the measuring direction was selected as N-S. Resistivity measuring was performed by the Wenner configuration in array spacing with 1, 2, 3, 5 and 7m, and measuring interval was 1m. The distance between the profiles was also chosen as 2m. Resistivity data were obtained from different investigation levels to obtain the 3D apparent resistivity distribution, and our main target was to show extensions of the anomalies in depth and to determine the true resistivity values in the investigation area. Thus, data were processed by 3-D robust inversion technique using by RES3DINV software. Appropriate results were obtained after three iterations. Percentage ABS errors did not exceed the value of 3.87%-4.75%.

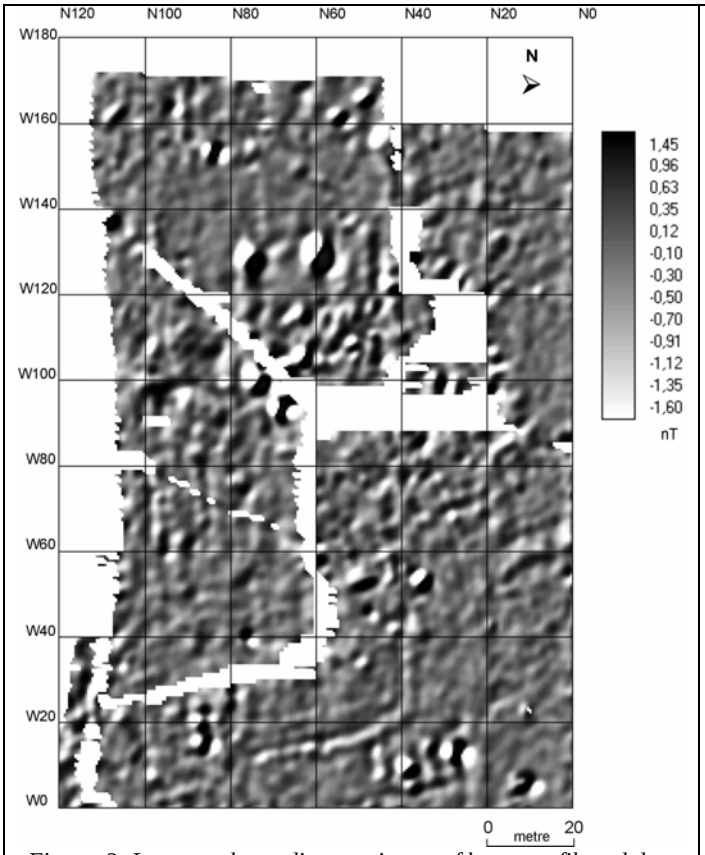

Figure. 3: Large-scale gradiometer image of low-pass filtered data (5x5) after relief processing sun direction: 45°, scaling: 1.5)

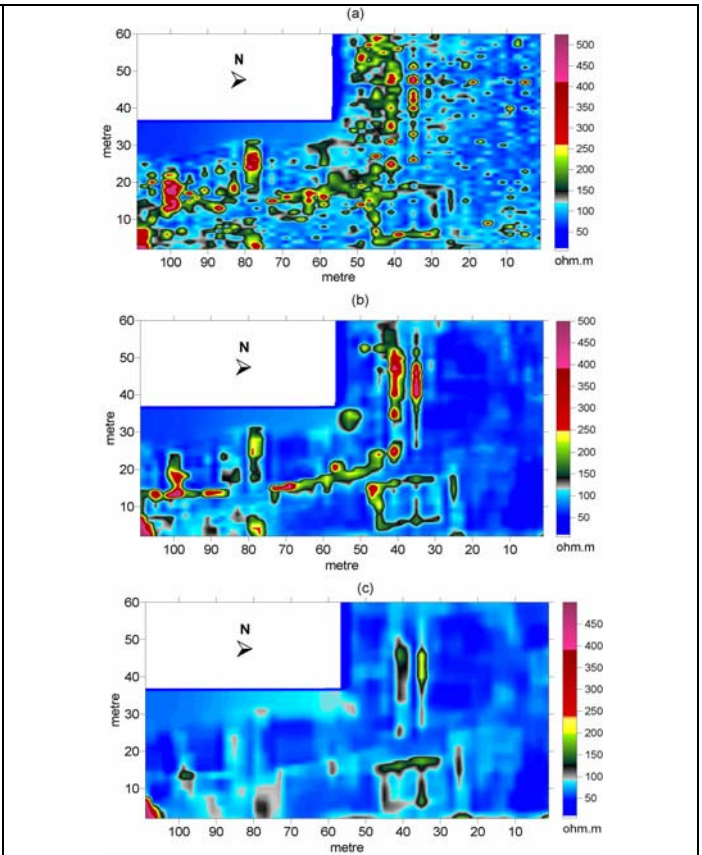

Figure.4: Large-scale inverted resistivity images obtained from (a) 0.25m, (b) 0.79m and (c) 1.41m depths

The 3D resistivity inversion results obtained from robust method of the all profiles running N-S direction are presented as image for first three depth levels (Fig.4). These images were obtained from 0.25, 0.76 and 1.41 m depth below the surface. The archaeological structures with high resistivity are clearly observed in the depth of 0.25 m (Fig.4a). Same structures appeared more definitive in the depth of 0.76m (Fig.4b). In the depth of 1.41m, the effects of these structures are gradually disappeared, and other structures with same directions are shown evidently (Fig.4c). After the robust inversion, we obtained six different resistivity depth levels (0.25, 0.79, 1.41, 2.12, 2.93 and 3.87m depths from the surface). In addition, to increase the quality of image representations that it means the enhancement the quality of picture in image processing, the calculated data were processed by low-pass filter and sun relief projection. All inverted resistivity values were combined by using the volumetric representation software. As can be seen from the bottom figure, the burial archaeological structures are clearly observed in the slice obtained from the 0.9m (Drahor *et al.*, 2004).

Results

The successful applications showed that 3-D resistivity inversion method is very reliable to determine the burial structures very near to the surface such as archaeological context. This interpretation technique is also very effective method to determine the depths and extends of the burial structures in 3-D. Thus, it can be mentioned that the method is also very useful to obtain the burial architectural plan for the archaeologists. In addition, the geophysical results processed by 3D resistivity inversion method in Satala in 2004 research period can be summarized as follows:

Results indicate that there are significant archaeological features in the eastern part of the area. In general, structures are very close to surface (0.5 - 1 m), but some of them extended to deeper places (2 - 2.5m) in the investigation area. Structures detected by resistivity method are verified with the anomalies in magnetic gradiometer images. According to this result, resistivity and magnetic anomalies in some parts of the field are very similar to each other, and there is a good correlation between resistivity and magnetic results. This means that each method successfully defines burial archaeological features in the survey field. In addition, the electrical resistivity inversion results exposed the depths and original cases of buried archaeological structures.

Acknowledgement

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References

Drahor, M.G, Berge, M. A. and Kurtulmus, T.Ö. 2004. The final report on large-scale geophysical studies in the Satala (Legio XV Apollinaris) in 2004. DEÜ, CNSGAP, Report No: 04-03.

Hartmann, M., Speidel, M.A., and Drahor, M. G. 2004. Satala Project 2005-2008. Mavors Institute.

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Journal *Archaeological Prospection*

Issue 12-1 of the journal Archaeological Prospection is out. As you will be aware ISAP members receive a generous discount on this journal – see http://www.archprospection.org/ for details. The issue starts with an Editorial by the new editors (Chris Gaffney and Larry Conyers) and contains papers from five different countries.

- Geophysical Investigations at the Ancient Royal site of Rathcroghan, Co Roscommon, Ireland (K Barton & J Fenwick)
- GPR and Geo-electrical simulations of the Floridablanca archaeological site data (M de la Vega *et al.*)
- Geophysical Survey at King Lobengula's Palace, Ko Bulawayo, Zimbabwe (C Gaffney *et al.*)
- Magnetic Survey at the submerged archaeological site of Baia, Naples, Southern Italy (A Rapolla & V Paoletti)
- Gradiometer survey for detecting the ancient remains distributed at the northeast of the Zoser Pyramid, Saqqara, Egypt (H Odah *et al.*)

Magnetic susceptibility survey at King Lobengula's Palace. (C Gaffney et al.*)*

Chris Gaffney, ISAP Vice-Chairman

Games and Entertainments (and a bit of advertisement)

We are all grateful for the phenomenal growth in computer power over the last two decades. Power which allows us to perform magical feats with our data, from almost instant downloads (almost…) to real time rotation of 3D GPR data (very pretty, whatever it actually means).

But we also know that this growth has been made possible and cheap by the parallel growth in computer games. The demands of square-eyed teenagers for ever more convincing bloodbaths has propelled vast computer memories and sophisticated 3D graphic engines from the universities and spy agencies to the desktop in every geeks bedroom. I recently heard it said that there is more processing power in the average mouse than in the computers to which the first commercial mice were connected.

Now I can reveal a vice in which all who delight or profit from the earth sciences can indulge – really good landscape models for flight simulators.

There was a time when we used to write little bits of code for our HP calculators (100 program steps and the memory of an amoeba) and enjoy the thrill of guiding a simulated moon lander down to the lunar surface. It all seemed so sophisticated at the time. Now a company called Visual Flight has released real air-photo scenery for the whole of England and Wales, and parts of the US, which is sufficiently clear to be of some use to the fieldworker.

When used with various flight simulators the scenery, and associated terrain model, is able to show very considerable detail. The imagery is smoothed and gives a picture with a pixel size sufficiently small to see roads, hedges, houses and the details of crops within fields. When it is

combined with the terrain mesh, of 15m horizontal resolution and better than 10cm vertical precision, it provides a very realistic picture of the landscape.

This allows me to have almost instant access to good photography of any part of England and Wales. In five minutes I can assess the topography, land-use and, to a lesser extent, such useful matters of drainage and access to sites. Combined with other mapping (on paper only, since the makers have not yet seen fit to simulate the drift geology or soils) this can be revealing.

The pixel size means that you can only see the most obvious archaeological remains in the photography. Thus the giant hill figures cut into the English chalk are visible but the average Medieval or Iron Age village is not. I can just make out the line of a Roman road cutting through the hills near my home but only because it is linear and because I knew it was there. Thus the photography won't really help us to map unknown archaeological remains - in Britain at least.

The program allows you to open both vertical and oblique photographic windows from a range of flying heights.

Perhaps most surprising is the cost. Those who have been used to paying thousands of pounds for commercial terrain models and photo coverage are likely to be surprised that the flight simulator, air-photography and terrain model of the whole country can be bought for less than £100. My only regret is that the data, having been obtained through the British Millennium Mapping campaign, does not yet cover other countries, but I hope that it may be just a matter of time.

You can get more details from Visual Flight at http://www.visualflight.co.uk/, where you can also see examples of typical imagery. I can imagine a market for a combat-enabled version which will allow the user to make spectacular attacks on particularly unresponsive sites.

David Jordan, 14 February 2005

Conferences

Symposium on the Application of Geophysics to Engineering and Environmental Problems (SAGEEP), 2-6 April 2006, Seattle, Washington, USA

Special Session SS-04: (Oral and Poster): Geophysics in Archaeology

Urbanization and land development both in industrialized and in developing countries are continuously threatening known and yet to be discovered cultural heritage resources. In addition, environmental awareness and regulations designed to protect existing resources make it increasingly difficult for archaeology to rely on destructive excavation as the main investigation approach. These are two of the factors that make geophysics an increasingly important component of archaeological investigations. We are inviting oral or poster presentations of case studies and innovative approaches in the use of geophysics in archaeology and historical heritage management.

- Session Co-Chairs:
    - Jean-Michel Maillol, Department of Geology and Geophysics, University of Calgary, 2500 University Dr. NW, Calgary, Alberta, Canada, T2N 1N4 (403)-220-8393, maillol@ucalgary.ca
    - Julie Aitken, Department of Geology and Geophysics, University of Calgary, jaitken@ucalgary.ca
- Deadline for abstract submission: 19 September 2005
- Web: http://www.eegs.org/sageep/

AARG 2005, 18-21 September 2005, Leuven, Belgium

Dept. Archaeology and Art History, University of Leuven (K.U. Leuven), Leuven, Belgium

Address for conference correspondence: Toby Driver, Chairman, AARG, Royal Commission on the Ancient and Historical Monuments of Wales, Crown Building, Plas Crug, Aberystwyth, Ceredigion. SY23 1NJ, UK., Tel + (0) 1970 621207, Email: toby.driver@rcahmw.org.uk

Provisional sessions:

Monday September 19th. Conference Day 1

- Interpreting the Roman landscapes of Europe from the air
- Aerial archaeology projects: issues, aspirations and results
- Informal evening session for short presentations of work and results

Tuesday September 20th. Conference Day 2

- Aerial archaeology on the edge: lakes, coasts, islands and mountains
- Wartime and military landscapes: archives, survey and remote sensing
- Managing archaeology in agricultural landscapes

For details please visit the Aerial Archaeology Research Group website: http://aarg.univie.ac.at/

Notes

Turkey

Turkey is very rich in archaeological settlements. Thus, many geophysical surveys have been carried out over the years at several archaeological sites in Turkey. Very interesting geophysical results have been obtained each and every year. As a consequence last year a Center of Near Surface Geophysics and Archaeological Prospection has been established at the Dokuz Eylül University in Ýzmir, Turkey. This Center aims to improve near surface geophysics and archaeological prospection studies in Turkey.

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