DOI: 10.26345/EGRSE-001-17-201X

INITIAL GEOPHYSICAL SURVEYING OF ARCHAEOLOGICAL SITES IN ARMENIA

PILOTNÍ GEOFYZIKÁLNÍ PRŮZKUM ARCHEOLOGICKÝCH OBJEKTŮ V ARMÉNII

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Abstract

Within the Apostolus expedition the geophysical measurements were carried out at four archaeological sites in Armenia. These measurements aimed, together with the methods of field archaeology, to gathering information about hidden archaeological features at the sites. At each site particular areas of interest were chosen. These areas were subsequently covered with detailed geophysical survey. The areas of interest were chosen according to the needs of the Archaeological Institute of the Academy of Science of the Czech Republic employees (in cooperation with the experts of the Institute of Archaeology and Ethnography of the National Academy of Sciences of Armenia). The Apostolus project aimed mostly to cognizance of selected archaeological sites, which were concentrated into the Armavir region (gubernia). The Armavir region lies on the southwestern Armenian borders with Turkey. The main task at the sites was evaluating thickness of the historical sediments and describing overall archaeological features situation.

Abstrakt

V rámci expedice Apostolus, se na čtyřech vybraných archeologických lokalitách uskutečnila geofyzikální měření, která měla za cíl, společně s metodami klasické archeologie, zlepšení znalostí o skrytých archeologických prvcích na jednotlivých lokalitách. Na všech lokalitách byly vybrány zájmové plochy, které byly následně pokryty detailním geofyzikálním měřením. Zájmové plochy byly vybrány podle potřeb pracovníků expedice Archeologického ústavu AV ČR a ve spolupráci s odbornými pracovníky Ústavu archeologie a etnografie Národní akademie věd Republiky Arménie. Projekt Apostolus se zaměřil především na poznání vybraných archeologických lokalit, které byly soustředěny do provincie (gubernie) Armavir. Provincie Armavir se nachází na jihozápadní hranici Arménie s Tureckem. Na proměřovaných lokalitách bylo základním úkolem zjistit mocnost archeologických uloženin, event. možný charakter archeologických situací.

Keywords

archaeology, Armenia, DEMP, magnetometry, geophysics

Klíčová slova

archeologie, Arménie, DEMP, magnetometrie, geofyzika

1 Introduction

The Apostolus project aimed mostly to cognizance of selected archaeological sites, which were concentrated into the Armavir region (gubernia). The Armavir region lies in Armenia on the southwestern border with Turkey. It lies on the northern side of the Araks river valley (it forms the border line between either countries). In the north, the Armavir region turns into the foothills of the Armenian highest mountain – Aragats. The Araks river valley was widely peopled since the prehistoric times with remarkable centres in the Chalcolithic period (approximately 5000 – 3000 BC). The valley´s importance remains in the Bronze Age, during the Urartu Empire, Hellenistic period and in the Early Middle Ages. With this in mind we made preliminary sites selection, aimed to more important centres of Nor Armavir, Argishtichinili and Metsamor. Consequently, four archaeological sites were chosen - Ghanjyan Blur, Argishtichinili, Lernamerdz and Agvesi Grer (see map in fig. 1). The main task at the sites was evaluating thickness of the historical sediments and describing overall archaeological features situation.

Using geophysical methods in the fields of archaeology is relatively well described. The priority goes to those methods, which use fast and easy field procedures and are not too expensive. The first choice is usually the magnetometry as described in the ALMUTARI, M. (2015) or BRION, C. (2012). Very often the method of ground penetrating radar (GPR) is being used; see BERSENEVA, N., A. (2016) for instance. Regarding the direct current (DC) physical fields we can find especially the method of the resistivity tomography (ERT), based on the mutielectrode geoelectrical instruments controlled via computer programs - OYEYEMI, K., D. (2015) or EKINCI, Y., L. (2007). To economically more demanding methods the micro-gravimetric survey belongs – hand in hand with its slower working tempo its frequency of use is smaller. Specific issues can be solved via seismic but one has to realize that the resolution of the seismic methods (with respect to the wavelength of the waves) starts minimally at first decimetres. Anyway, seismic methods are being used in the fields of archaeology, as proved in the RUBIN, S. (2014) for example.

Fig. 1 Four chosen sites on the map (Aygeshat site is not documented in this paper)

2 The Methods

With respect to relatively short stay in Armenia the quickness of the field works was the crucial parameter, i.e. possibility of covering selected areas in detail and reasonable amount of time, together with high quality data demands. Therefore, two geophysical methods were chosen – magnetometry and dipole electromagnetic profiling (or DEMP, conductometry or slingram).

Magnetic survey is one of a number of methods used in archaeological geophysics. Magnetic surveys record spatial variation in the Earth's magnetic field. In archaeology, magnetic surveys are used to detect and map archaeological artefacts and features. Magnetometers used in geophysical survey may use a single sensor to measure the total magnetic field strength, or may use two (sometimes more) spatially separated sensors to measure the gradient of the magnetic field (the difference between the sensors). In most archaeological applications, the latter (gradiometer) configuration is preferred because it provides better resolution of small, near-surface phenomena. Magnetometers may also use a variety of different sensor types. Proton precession magnetometers have largely been superseded by faster and more sensitive fluxgate and cesium instruments. Every kind of material has unique magnetic properties, even those that we do not think of as being "magnetic". Different materials below the ground can cause local disturbances in the Earth’s magnetic field that are detectable with sensitive magnetometers. The chief limitation of magnetometer survey is that subtle features of interest may be obscured by highly magnetic geologic or modern materials. During our measurements we used the PMG-1 instrument by the SatisGeo manufacturer with one pair of the probes one meter apart.

Among the electromagnetic methods, the DEMP method belongs to the ones using an active source of the alternate current. It also belongs to so called inductive methods, i.e. the EM signal spreads as an all-directional field without any physical transmitters (electrodes etc.). The principle is usually based on using two or more couples of the coils – the first is the transmitting one and the other ones work as receivers. The EM field spreads through the geological environment and interacts with it. Resulting signal (based on so called eddy currents) is furtherly evaluated and interpreted. The depth of investigation of such measurements is based both on the coils separation (direct relation) and on the frequencies (thousands to tens of thousands kHz) of the transmitter. The main parameter influencing the measurements is the electrical resistivity of the environment and the magnetic induction too. Therefore, the DEMP method is widely used when expecting any changes in the electrical resistivity of the environment, typically fractured (electrically conductive) tectonic zones, mapping of the dykes homogeneity or mapping of the archaeological objects with different resistivity values. One also has to keep in mind that in case of the EM measurements of the electrical resistivity the instruments do not directly measure the resistivity value as expected according to the Ohm´s law, but some unit-less value that is furtherly recalculated to the resistivity according to the instruments in situ calibration. We used the CMD – MiniExplorer instrument by GF Instruments with three pairs of coils, i.e. three theoretical calibrated depths of investigation 0.5, 1 and 1.8 meters.

3 Case Studies

At all four sites (Ghanjyan Blur, Argishtichinili, Lernamerdz and Agvesi Grer) particular areas of interest were chosen. These areas were consequently covered by detailed geophysical measurements in the regular orthogonal 1x1m network. Measured data were displayed

mostly in the form of 2D isolines maps of apparent resistivities or magnetic field´s gradients. In some cases we were forced to filter the DEMP data as the geological environment at the sites mostly consists of high resistive volcanic rocks, which may cause collapse of the instrument´s calibration for the recalculation to the resistivity. Therefore, in case of the DEMP measurements, we mostly display the deepest level of measurements (approximately 1.8 meters) as this one was the less affected one by this "noise".

3.1 Ghanjyan Blur site

Ghanjyan Blur site consists of the stone objects relics (shapes of medieval houses or prehistoric graves) covered by remarkably thick overlying sediments. The goal of the measurements here was to map out archaeological features and possibly guess on the thickness of the sediments. Together with geophysical measurements a detailed sketch and sherd analysis of the site was carried out. We proved existing larger archaeological objects and detected right-angled structures (probably walls). The future of this site is in danger because of a growing landfill nearby. Results in the form of the magnetic gradient, together with a photograph from the site, can be seen in the fig.2.

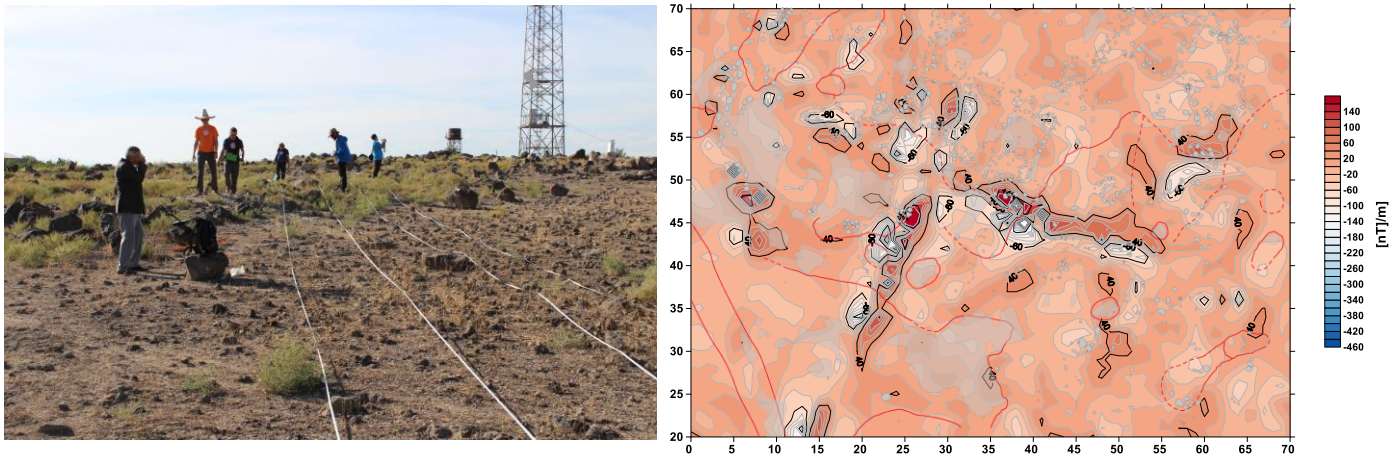

Fig. 2 Ghanjyan Blur site – field situation and the 2D isolines map of magnetic gradient.

3.2 Argishtichinili site

The Argishtichinili hillfort site has been widely surveyed in the past, particularly its acropolis with the built-up areas of the Bronze Age to the modern times. We aimed to the western foreland that was untouched by any previous research. Considering the size and flat shape of the foreland one might have guessed that this area was used in the imilar way as the eastern part. In the fig. 3 we show the results of the DEMP measurements from the lowest calibrated depth of 1.8 meters. One can clearly distinguish regular high-resistive bodies that probably equals to old buried walls of this part of the hillfort´s foreland. It is important to mention that due to calibration-like approach for

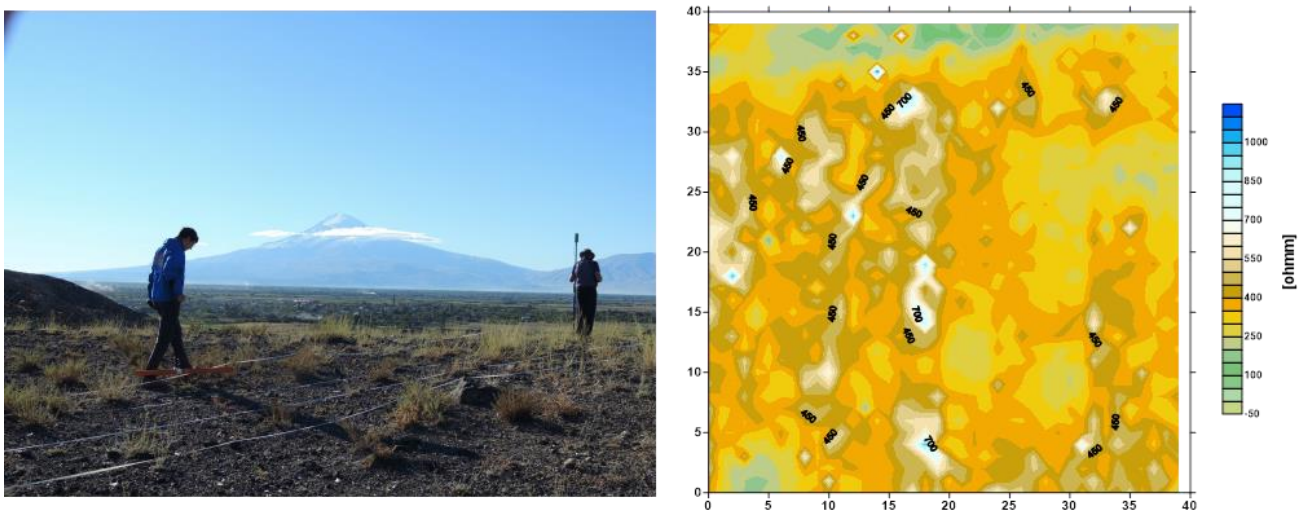

Fig.3 The Argishtichinili hillfort site – field situation and result of the DEMP measurements – calibrated depth of 1.8 m.

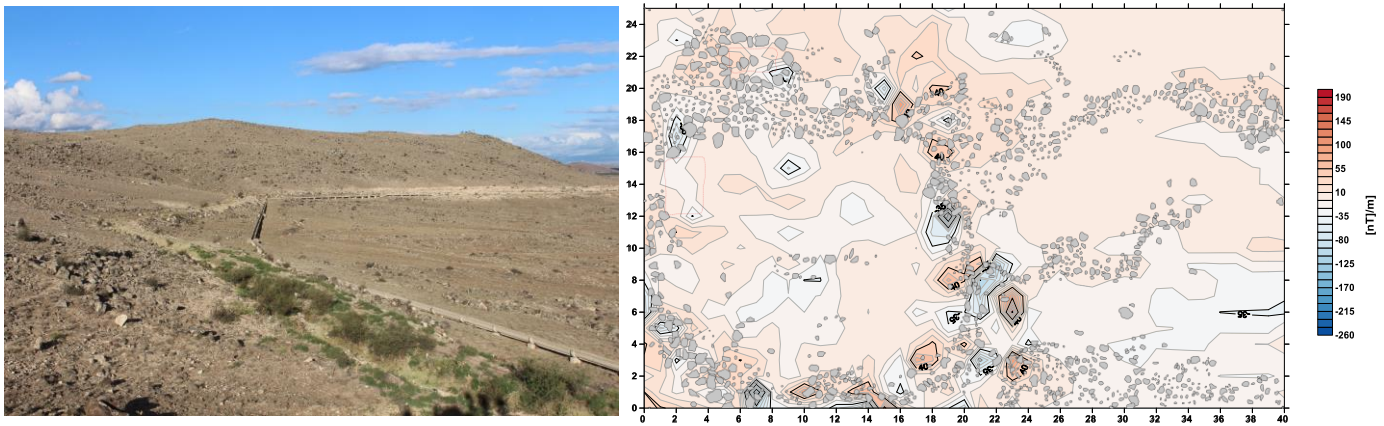

Fig.4 Depiction of magnetic gradients registered at the Lernamerdz archaeological locality.

the recalculation to the resistivity the absolute values here are not correct (they are always lower than in case of DC measurements). In this case we look more at the relative differences in the values.

3.3 Lernamerdz site

The site is placed on the sloping terrain and the nearby foot of the Aragats Mountain. Previous surface survey has detected frequent occurrence of the stone structures (right-angled, oval and spherical) and proved that this area was settled since prehistory. The goal of the geophysics here was checking on the similar spherical structures in depth and their eventual shapes description. The correlation of the surface archaeological methods (mainly sketches) with geophysics was more or less good in here. Especially magnetometry showed some linear structures with reasonable connection to the surface bodies, fig. 4.

3.4 Agvesi Grer site

The goal of our measurements at this polycultural site was checking on the borders of the site that is being continuously destroyed by human activities. This prehistoric site (Bronze Age) is placed on the elevated "tel locality" (artificial mound formed from the accumulated remains of people living on the same site) and its lower placed parts could be covered by accumulated sediments. The survey proved that the site is continuously being spatially reduced due to increasing space of the agricultural fields around. Geophysical

measurements showed that the western end of the site corresponds with the current surface boundary. Results of the DEMP measurements are demonstrated in the fig. 5, western side is documented by low resistivities around 50 ohmmeters.

4 Conclusions

Overall results of the DEMP and magnetometry showed that either of these methods are viable for quick archaeological survey and bring valuable results even in non-favourable conditions of highly resistive volcanic rocks. As we did not need to concentrate on the absolute values of the apparent resistivity, the DEMP method proved to be sufficient in mapping buried structures by relative differences in measured values. Due to sensitivity to resistive sources of noise we mostly worked with the lowest calibrated depth of 1.8 m, which was less noised. The DEMP method was a fast and reliable method for checking on the buried objects closer to the surface. Magnetometry was giving us interesting results in case of the gradient measurements as we did not have the second magnetometer for observing variations of the Earth magnetic field (necessary for working with the total magnetic field´s component). Compering to the DEMP results the magnetometry described deeper structures at the sites and was not that sensitive to the noise sources. In the future we would like to do quantitative (modelling) interpretation of several magnetic anomalies. It would be interesting to uncover some of the geophysical anomalies. In fact, this might be dangerous for the sites as the protection of them in Armenia is at low level - the sites are being destroyed and robbed out often by locals. We believe that the Apostolus project may illuminate some of the future archaeological sites and will help in their future protection.

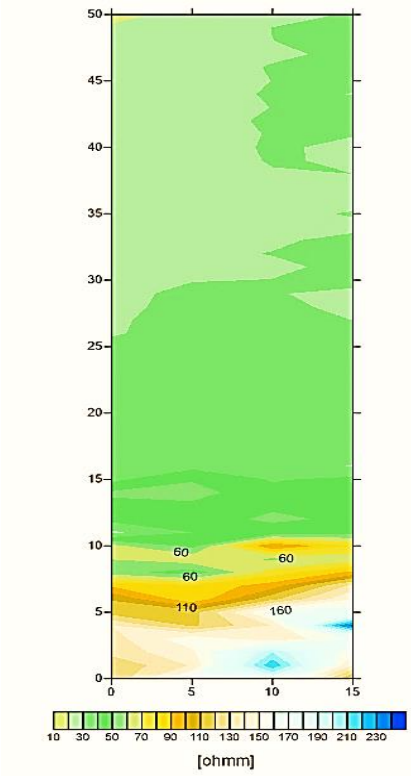

Fig.5 The Agvesi Grer site - DEMP measurement

Acknowledgements

We would like to express our thanks to the Chironium Ltd. Company for the financial support of the Apostolus project. We also thank to our colleagues from the Institute of Archaeology in Prague for reasonable cooperation, technical advising and selflessness.

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