

## Archaeogeophysics in Georgia – New Results, New Prospects

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### Abstract

*The basics of archaeogeophysics is a difference in physical properties (electrical conductivity, dielectric constant, magnetic susceptibility) of a buried archaeological object and surrounding geological media: as a result the physical field measured on the surface creates anomaly. Modern precise devices and special computer programs allow fast and accurate location of buried archaeological object and determination of its size and burial depth. A short review of archaeogeophysical research in Georgia is given. Fundamentals of main archaeogeophysical methods: georadar, magnetic and electrical prospecting are set forth. The results of archaeogeophysical investigations in areas of Shiraki (georadar) and Armaztsikhe-Bagineti (electrical prospecting) are analyzed,*

### 1. Introduction

Geophysical methods have intensively been used in archaeology during the recent years. The first tests were carried out in 1946 and they are increasingly popular nowadays (Clark, 1996; Gaffney and Gater, 2003; Witten, 2006; Schmidt, 2001). Among them most frequently are used georadar, electric resistance and magnetic methods and more rarely – the methods of natural electric fields, microgravimetry, radiometry, thermal infrared and acoustics or seismicity.

“Archaeogeophysics” or “archaeogeophysical exploration” is based upon contrast of physical properties between component materials of an archaeological monument and its surroundings. If a structure with certain physical properties (electric resistance, magnetism) is covered with a layer of soil with different properties, this causes changes in the measured field of day surface, i.e. a geophysical anomaly. Processing of an anomalous field by means of specific software enables to determine precisely the location of a monument covered with soil, the depth of its location, its size and other details.

As a rule, archeological monuments are strogly localized, i.e. their horizontal and vertical measures are limited. Besides, localization depth of any archaeological monument rarely exceeds 5 meters. Therefore, one of the demands of archaeogeophysical exploration is detail approach to field data, which means that the distance between observation points must be short and observation network should be dense.

The last years’ achievements in geophysical instrumentation and data processing substantially increased exploratory potential of so called “emergency archaeology”, while in areas of big industrial objects it is necessary to map buried cultural heritage monuments localized in a short time and without damaging the environment.

The above statements do not at all contravene purely archaeological methods. Sooner or later archaeologists will reach their goal. We would just like to note that by means of archaeogeophysics archaeologists are able to study the area under exploration more quickly, with less expenditure and

more thoroughly. Importance of archaeogeophysical exploration for such a historical heritage country as Georgia is evident.

## **2. Archaeogeophysical explorations in Georgia**

The territory of Georgia is known for the world civilization since the ancient times. It is proved by the existence of old Greek myths about Prometheus and the Argonauts. Consequently, it is natural that there are numerous archaeological monuments of different periods in our country. Many of them are covered with Quaternary sediments and it is very difficult and quite expensive to discover them without the help of geophysical methods.

In Georgia archaeogeophysical explorations began in 1964-1968 on the territory of ancient town Bichvinta (Tsitsishvili, Tabagua, Khvitia, 1968). The exploration was carried out in different ways by electric, magnetic, gravimetric and radiometric methods, which enabled its completion with satisfactory results: the location of the ancient buried walls was determined on the basis of the discovery of clear geophysical anomalies.

Since then similar explorations have been carried out for many objects (Tsitsishvili, Tabagua, Khvitia, 1968; Tsitsishvili, Tabagua, 1975; Chanturishvili, Jakhutashvili, Kutelia, 1993): for the ancient city of Vani, the surroundings of Tbilisi, the old irrigation system of Tetrtskaro, Bichvinta (1983), the David-Garedja complex, Monastery of Bagrat, the Queen's Palace in Atskuri (1991), a former town in Kakheti (1985-88), the monastery in Ninotsminda (1997-98), the territory of Armaztsikhe-Bagineti (2000-2001).

Since M. Nodia Institute of Geophysics has obtained new up-to-date equipments like GEORADAR ZOND 12, electrical prospecting station SARIS and magnetometer GEOMETRICS, its potential for archaeogeophysical prospecting has greatly increased. The GEORADAR method is especially efficient for its high precision, detailing and reliability as well as for short time, needed for measurements and interpretations.

## **3. GEORADAR**

The georadiolocation or GEORADAR method (Neal, 2004; Witten, 2006) has become very popular in archaeogeophysical explorations during the last years. This method, like the usual radar method, uses the radiation of high frequency electromagnetic waves and their property of reflecting from objects with different properties; the difference is that in the case of georadar method the radiation is directed to the Earth's crust. Both the radar and GEORADAR methods enable to determine the distance of reflect surface by means of measuring the travel time of a direct and reflected ray: travel time divided by wave velocity makes distance. The difference between these two methods is that a radar ray directed to the atmosphere spreads over a quite long distance; while due to high conductivity of the Earth's composite rocks the geo-radar radiation is strongly absorbed and in optimal cases it propagates down to several dozen meters into depth. As georadar ray is reflected from objects with different dielectric properties, by this method structures are distinguished according to a dielectric constant.

The georadar method gives possibility not only to cut expenses but also use funds more effectively as scanning a soil by georadar method enables to explore more area of the desirable territory in considerably little span of time.

If an explored object is placed in 10-20 m depth from the surface there is no alternative to the GEORADAR method in the contemporary archaeology.

Aerophotography and visual signs do not enable archaeology to determine in detail depth/location of objects that lack adequate features: e.g. graves and traces of settlements underneath soil, remains of foundations (Odilavadze, Chelidze, 2010).

Soil scanning by means of georadar method makes it possible to discover even objects with different density (as dielectric conductivity depends on porosity). Subjects discovered by GEORADAR can be a geological formation, void, a stone coffin, a crypt, a wine-jar etc. In certain cases it is possible to process and interpret obtained results in real time in field conditions. When scanning a soil in order to investigate barrows it is quite possible to reveal such structural elements as debris layer, central constructions, stone cover, etc. It is also possible to explore soil-filled graves (i.e. filled and covered with different dielectric materials) by GEORADAR despite there are no distinguishable signs on the surface.

GEORADAR enables to obtain information about bedrock underneath the surface. According to contrast range of dielectric conductivity of layers we distinguish a soil type (clay, clay soil, sand soil, rocky soil), its structure (consolidates soil and destructed one, i.e. cultural layer), soil condition (dry, humid or saturated by water) and segments with different physical properties, among them different kinds of archaeological objects (walls, basements, graves, voids, different size objects).

Soil scanning by GEORADAR results in determining the depth, section of soil and cultural layers. This method enables to map their borders as well. It completes and enriches information for classical method of archaeological stratigraphy.

A section obtained by GEORADAR, unlike the classical stratigraphy method of archaeology, is constructed in a shorter time as it is presented on a PC screen immediately during profiling. The advantage of georadar stratigraphy compared to the classical one is that in this case the environment of the investigated object is not damaged after carrying out works on it. It is important also for archaeologists as an investigated object remains undamaged as well.

The conducted works and obtained experience makes possible to distinguish four main trends of GEORADAR investigations in archaeology. Each of them is significant as they can solve relevant archaeological tasks, the final main instrument of which is excavations.

The first one out of the above mentioned trends in archaeology is geological survey of future exploration area. Large profiles (1-2 km) are constructed by GEORADAR on a probable archaeological excavations territory. GEORADAR exploration makes it possible to make a general geological image, observe possible geological evolution of a relief and determine borders of the cultural layer, buried fields, buried riverbeds, etc. Analysis of a geological survey image obtained by GEORADAR investigation assists in planning of archaeological excavations works as it is able to precisely determine borders of locations of ancient towns and settlements.

The second trend of GEORADAR investigation in archaeology is detailed GEORADAR survey (georadar stratigraphy) of a cultural layer in order to verify location of a soil for processing (for excavations). It enables to reveal locations of foundations of certain constructions.

The third trend of georadiolocation investigation in archaeology is search, discovery and in certain cases identification of medium sized (of meter order) archaeological objects without processing the soil. Archaeological objects have radio image that is characteristic for them. This makes possible to define the object (size, shape, features) without destruction the integrity of the soil.

The fourth trend of GEORADAR investigation in archaeology is more detailed subsurface survey and search for relatively small sized (dozen cm) archaeological objects. According to the thumb rule GEORADAR is able to identify objects with size of the order of one tenth of bedding depth (for example the objects with size of 10 cm buried on the depth 1 m). Generally, discovery of relatively small buried objects by GEORADAR depends on several factors. One of them is frequency: high frequency is needed to find small sized objects. At the same time the propagation depth of such frequencies is small. Revealing objects located relatively deeper require lower frequencies. As a rule, archaeological monuments are situated in 1-5 m depth. Consequently, the central frequency is to be 100-1000 MHz. Discoverability of objects also depends on distance  $d$  between observation points: results are good if separation of the observation points is less than the one fourth of the wave length in

the soil, more precisely, when  $d$  is less than approximately  $[75/f(\epsilon)^{1/2}]$  where  $f$  is a frequency in MHz and  $\epsilon$  is a dielectric relativity constant of the embedding media. For detailed investigation the 1/5 of this value is recommended.

Below are the preliminary results of the 2011 Shiraki joint archaeological and archaeogeophysical expedition. The interperpendicular radiograms of barrows (not excavated) that were obtained by georadar method show the depth in meters on the  $y$ -axis and the distance in meters along the profile—on the  $x$ -axis. This preliminary study proves that the georadar method enables to vividly distinguish the borders of the barrow, its inner structure, zones of possible voids and water intrusion (fig. 1-4). Unfortunately, the black-and-white versions of the diagrams presented here have less resolution; the colour diagrams are more informative.

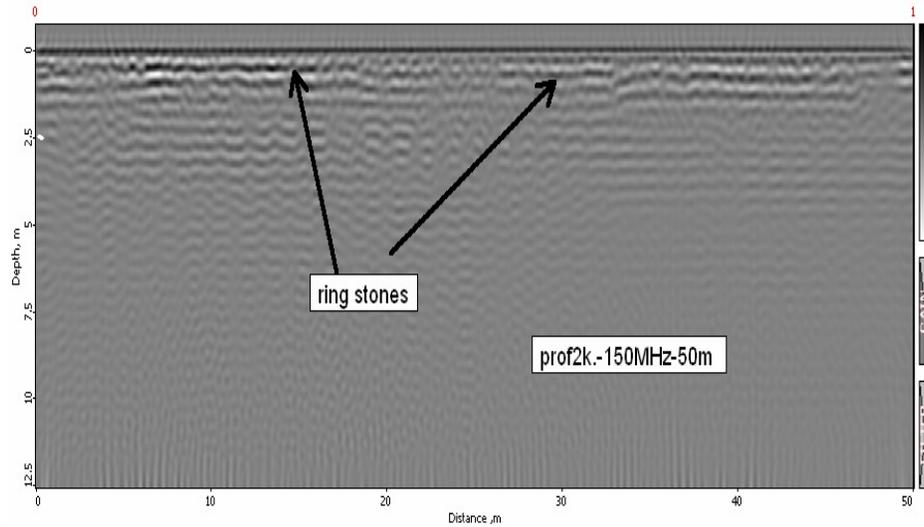


Figure 1. The diagram shows large stones of a barrow (probably) placed in circular shape (in the section). The radar signal distribution depth – 10 m shown in the figures 1-6: on the  $y$ -axis – depth in meters, on the  $x$ -axis – the distance in meters along the profile.

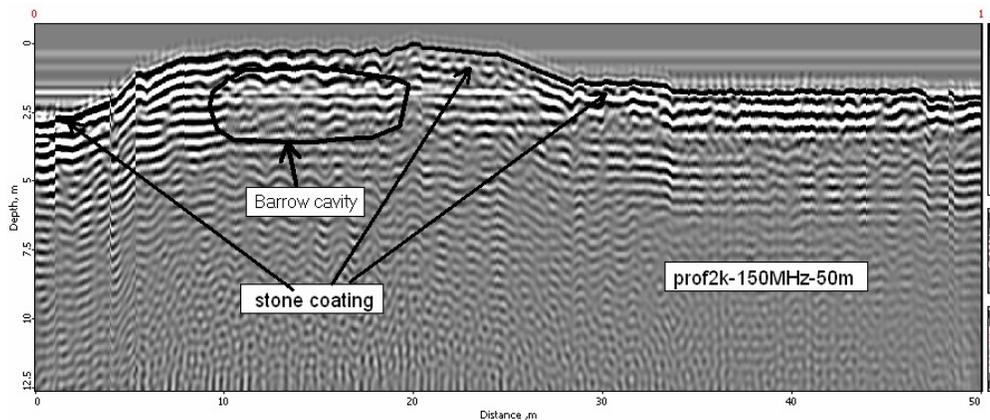


Figure 2. The same radiogram with corrections in the relief. The wide arrow shows the location of the probable cavity (contoured). The long arrows distinguish locations (coverage) of the large stones.

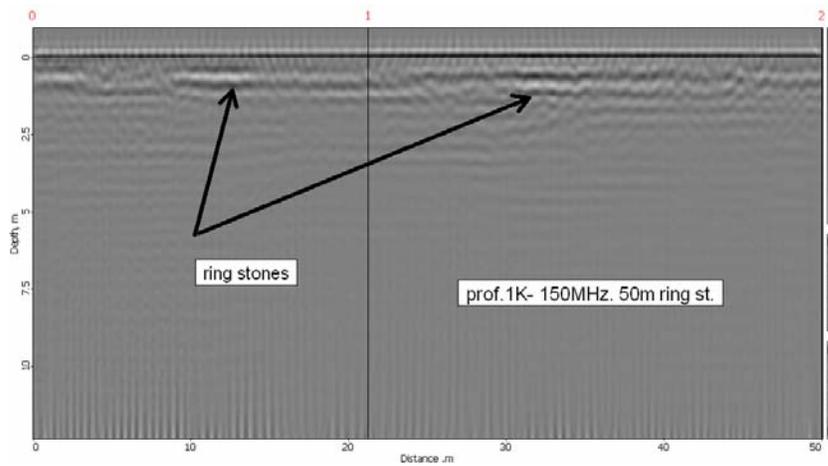


Figure 3. Radiogram constructed on the perpendicular profile of the radiogram in the figure 1-2. The arrows show the barrow stones situated in a circular shape.

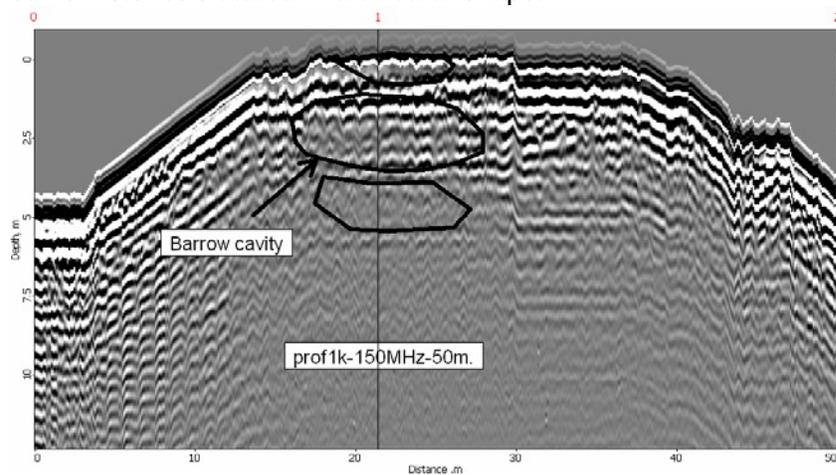


Figure 4. The same radiogram as in the fig. 3 after corrections in the relief. The arrows show and the lines contour the (probable) cavities in the barrow.

Figures 5-6 present Radiograms constructed for the former town in Shiraki. A section of 10 m depth was determined; water intrusion zones and (probably) pavement stones are distinguished.

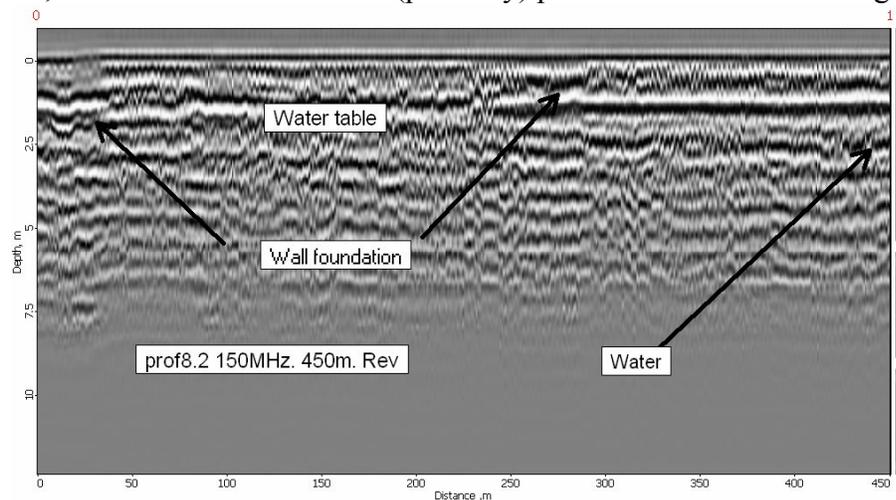
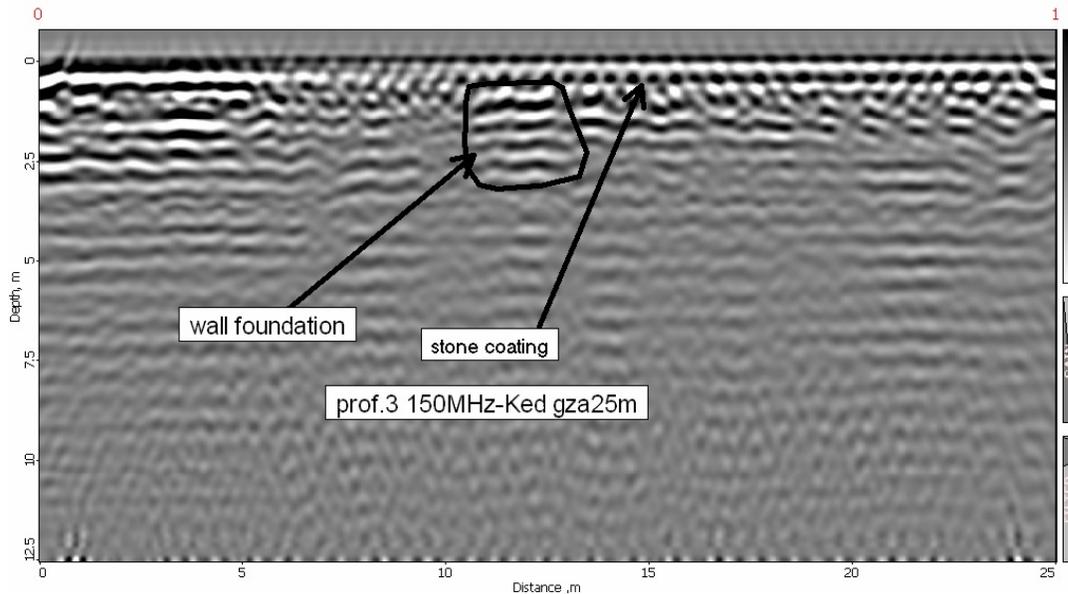


Figure 5. Georadar section of the 450 m length plot of the former town in Shiraki. Georadar layers were distinguished: the first layer is situated in 1-1.5 m and the second layer – in 2-1.5 m depths.

Along the section the ground water level in 1-1.5 m depth (black line) and the water intrusion area at the end of the radiogram were distinguished. The places indicated by the arrows near the surface (probably) are remains of the foundation.



*Figure 6.* The radiogram (length – 25m) shows objects, possibly stones used for covering the road (approximately 3—35 cm size), regularly situated near the subsurface (0.8-1 m depth). It is supposed that the road crosses the remains of some old foundation.

The works were carried out by means of certified GEORADAR “ZOND-12” with supporting 2GHz, 150MHz and 75MHz antennas possessed by Institute of Geophysics. The results were processed by certified software PRIZM-2.5.

#### 4. The archaeomagnetic method

The magnetic method, as a quick and high resolution method, is often used in archaeology. Nowadays it is one of the main methods in archaeological search. It is used for revealing objects with magnetic properties different from the environment such as covered metal (iron) segments, stone walls and foundations, kilns and stoves. Institute of Geophysics has a modern magnetometer GEOMETRICS G-856, which can be successfully used in archaeological survey (Fig. 7).



*Figure 7.* Magnetometer GEOMETRICS G-856

Below (Fig.8) are the results obtained by surveying an ancient kiln in Germany. The red colour indicates anomalous areas corresponding to the locations of the kilns.

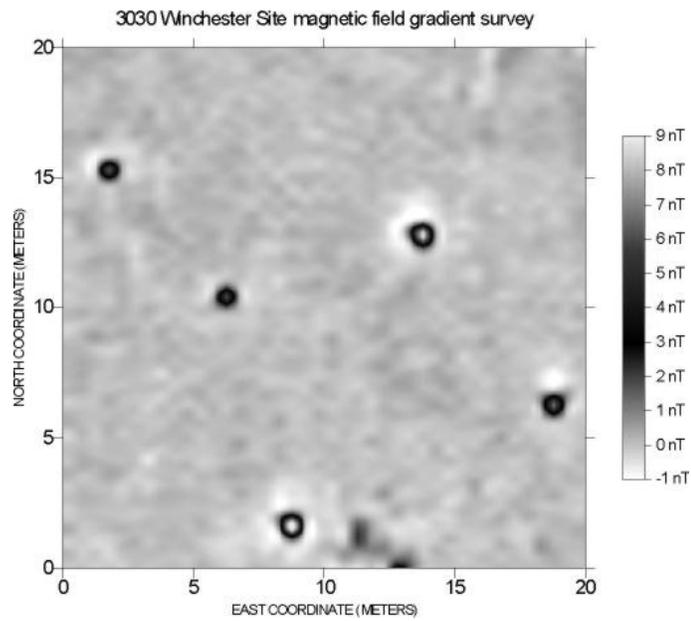


Figure 8. Ancient kilns (dark rings) surveyed by magnetic method (Germany).

Institute of Geophysics carried out field magnetic survey at Shiraki plain, where Google map reveals buried archaeological monument (Fig. 9).



Fig.9. Map of the test area Shiraki 1

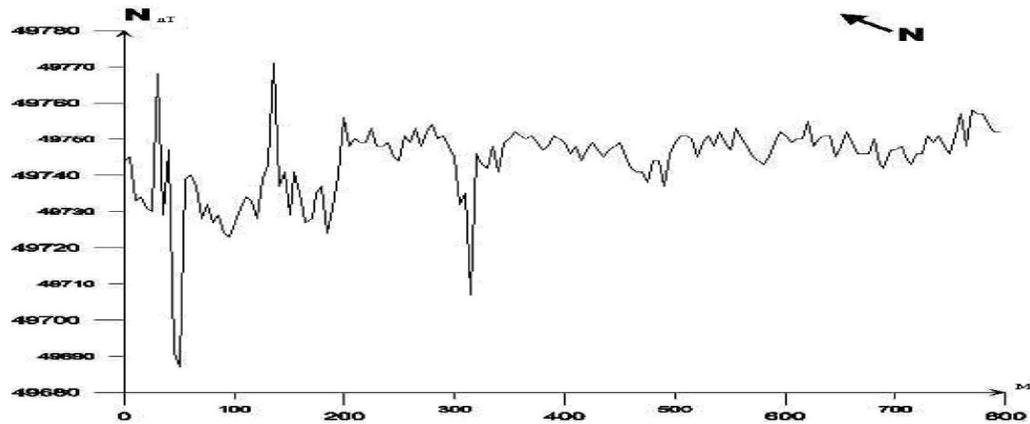


Fig. 10. Magnetic field profile 1 (test area Shiraki1)

The T-component of the geomagnetic field was mapped using proton magnetometer G-856 (precision 0.1 nT). Two parallel profiles were done along highway; the first one on the distance 15-20 m and the second one on the distance 30-40 m from the highway. The magnetic field along profiles is presented on the Figs. 10, 11). The relatively low mean field and significant localized anomalies at the left section of the first profile are absent on the parallel profile, which is separated by only 10-15 m), though the mean values of the field are close for both profiles. Comparison of profiles allows drawing conclusion that the intensive local anomalies on the first profile are probably caused by archaeological objects.

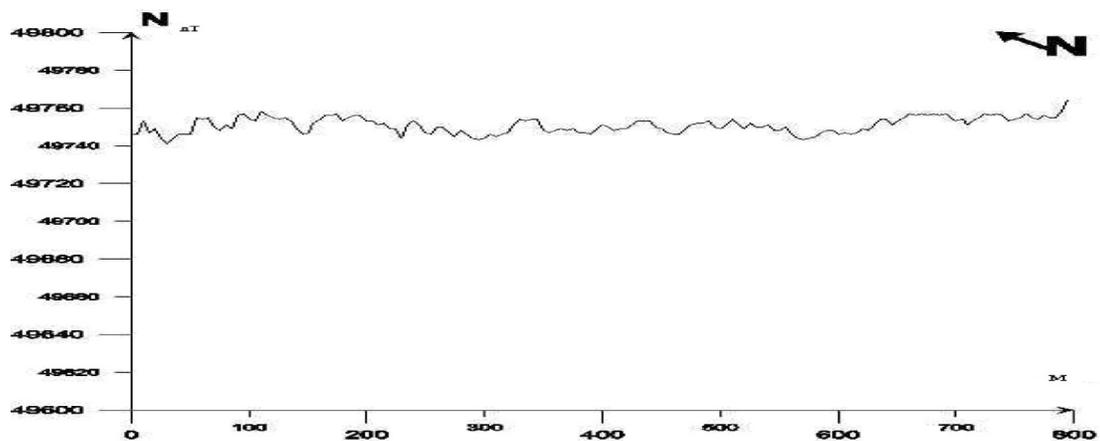


Fig. 11. Magnetic field profile 2 (test area Shiraki1)

Another example is a magnetic survey on the barrow (also in Shiraki plain). The magnetic field on the profile crossing the barrow is shown in Fig. 12. It is evident that absolute values of magnetic field above barrow is significantly less than in surrounding area and the field minimum coincides with the top of the barrow, which confirms results obtained by GEORADAR ( compare Figs. 1-4 and 12).

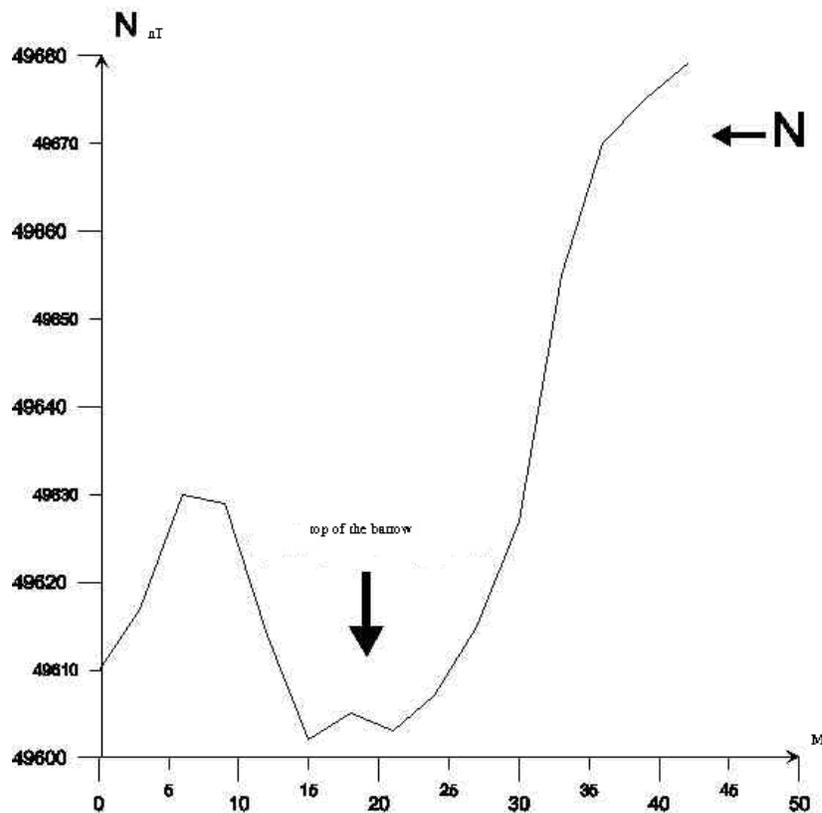


Fig. 12. Magnetic field profile across barrow (test area Shiraki2).

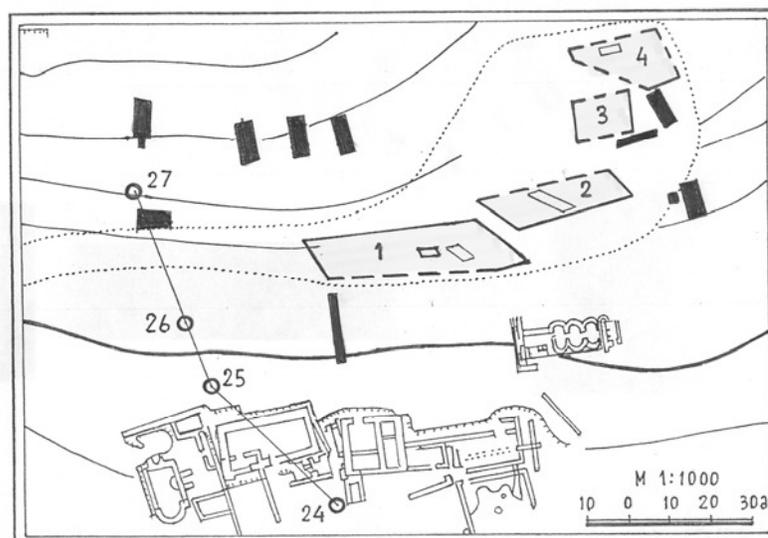
Above results show that precise magnetic survey (in the range of several nT) is very efficient method for revealing buried archaeological objects.

### 5. The electrical prospecting method

A method of electrical prospecting enables to distinguish objects with different conductivity in dozens of meters' depth (walls, foundations, graves, voids, etc). Institute of Geophysics own an up-to-date equipment SAR and many years' experience in using this method.

The fig.6 below shows the results of electrical prospecting fulfilled by institute of Geophysics on the Armaztsikhe-Bagineti complex (near Mtskheta) (Apakidze, Tabagua et al, 2001; Chanturishvili, Chelidze, Tabagua et al, 2001). The results obviously show that use of geophysical methods makes archaeological investigations easier.

In the figure the black rectangles indicate soil processing areas carried out earlier without using geophysical methods. The so called anomalous areas distinguished by geophysical electrical prospecting method are marked with figures 1, 2, 3, 4. The rectangles in these areas stand for the bore holes made on the basis of the geophysical results. It turned out that making bore holes without the use of geophysical methods ended with no results, i.e. they could not reveal the covered archaeological objects. Meanwhile, the efficiency of the bore holes made on the basis of geophysical methods is high: some certain cultural layers (a wall, a floor, etc) were discovered during all test excavations of the anomalous areas. Finally, as a result of two seasons' geophysical expeditions some unknown archaeological objects of 1700 m<sup>2</sup> area were discovered with minimal expenses (1400 GEL) on the territory of Armaztsikhe.



*Figure 9.* The results of the electrical prospecting carried out on Armaztsikhe-Bagineti complex. The black rectangles indicate excavation areas without the use of geophysical methods. In fact nearly all the works ended with no results. In the areas 1, 2, 3, 4 electrical prospecting by direct current method was conducted. The anomalies in these areas are marked with rectangles. Excavations made obvious that there were covered archaeological object such as walls, foundations and cultural layers in all the anomalous areas.

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## **Археогеофизика – новые перспективы**

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### **Резюме**

Основу археогеофизики составляет контраст физических свойств (электропроводности, диэлектрической или магнитной проницаемости) погребенного археологического объекта и вмещающей геологической среды, в результате чего физическое поле, измеренное на поверхности, проявляет аномалию. Современные точные приборы и специальные программы обработки позволяют быстро и достаточно точно установить местоположение, размеры и глубину залегания погребенного археологического объекта. Приводится краткий обзор современного состояния археогеофизики в мире и в Грузии. Изложены базовые положения основных археогеофизических методов: георадиолокационного (георадара), магнитного и электроразведочного. Проанализированы результаты археогеофизических исследований в районе Шираки (георадар) и Армазцихе-Багинети (электроразведка).

## **არქეოგეოფიზიკა – ახალი პერსპექტივები**

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### **რეზიუმე**

არქეოგეოფიზიკის ფუნდამენტურ საფუძველს წარმოადგენს ფიზიკური თვისებების კონტრასტი არქეოლოგიური ძეგლის შემადგენელი მასალისა და მის ირგვლივ არსებული გარემოს შორის. თუ რაღაც განსხვავებული ფიზიკური თვისებების (ელექტროწინალობის, დამაგნიტების) მქონე სტრუქტურა დაფარულია ნიადაგის ფენით, ის იწვევს დღის ზედაპირზე გაზომილი ველის შეცვლას, ე.წ. გეოფიზიკურ ანომალიას. თანამედროვე ზუსტი ხელსაწყოები და მონაცემთა დამუშავების სპეციალური პროგრამები შესაძლებლობას იძლევა საკმაოდ ზუსტად დადგინდეს დაფარული ძეგლის ადგილმდებარეობა, მისი ჩაწოლის სიღრმე, ზომები და სხვა დეტალები. მოყვანილია არქეოგეოფიზიკის თანამედროვე მდგომარეობის მიმ ოხილვა მსოფლიოსა და საქართველოში. მოყვანილია ძიების ძირითადი მეთოდების: გეორადარის, მაგნიტური და ელექტრული საბაზისო აღწერა. გაანალიზებულია არქეოგეოფიზიკური კვლევის შედეგები შირაქისა და არმაზციხე-ბაგინეთის რაიონებში.