USE OF GEOELECTRICAL METHODS IN ARCHEOLOGICAL STUDIES. CASE STUDY: THE SAINT NICHOLAS CHURCH OF DENSUȘ

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Abstract. Geophysical electrical methods are used in identifying underground structures as well as in other domains (geology, geo-engineering, speleology, archeology, etc.). The paper presents the principle of geophysical electrical methods, along with the way they are applied in identifying archeological sites located at various depths. The selected case study is the Saint Nicholas Church from the Densuș locality, one of the oldest and the most important religious cult places in Romania, a symbol of our people's spirituality. The age of this church is contradictory and generated long debates within the Romanian scientific community. The Saint Nicholas Church from Densuș (Hunedoara County) is among the few remaining autochthonous pre-Christian temples. The core of the building is dated from 2nd Century AD. Some historians believe that, in the 4th Century, the temple was transformed into a church. Other historians claimed that the building of the Church took place in the 13th Century, as registered in historical manuscripts. However, a series of significant changes took place at the end of the 13th Century, and in the 14th and the 15th Centuries. Recent archeological studies revealed a nobility court dated from the second half of the 15th Century and the first half of the 16th Century. The court is located immediately next to the church at about 40 m distance from the church altar. It is also possible that these could be old fences buried into the ground, which could bring new information on the age of the church itself.

Key words. geoelectrical methods, resistivity, VES, archeology, Church in Densuș

INTRODUCTION

The geophysical electrical measurements (geoelectrical) are largely applied in the study of diverse underground irregularities. The rocks and geological formations may be distinguished by the way they conduct electricity, specifically by their physical property called electrical resistivity. The electrical current consists of the movement of electrical charge, which is represented by electrons or ions. Ions move within the fluids in the rock pores. The experimental results show that the largest contribution to the movement of electrical current through rocks and geological formations comes from their water content.

Considering the last decade scientific performance on the ability to process, display and interpret data, the geoelectrical measurements have started to be applied in numerous domains, such as the geo-science, but also in domains such as hydro-geology, speleology and archeology, as well as in environmental protection studies (soil and water pollution assessment, Rădulescu *et al*., 2006).

The geoelectrical investigations presented herein, which were performed in the area surrounding the Saint Nicholas Church (Hunedoara County), aimed at the identification of possible areas of interest from an archeological point of view. These are buried in the subsurface soil of the area described above. For this purpose, we performed geoelectrical measurements in three areas behind the church, on a total surface of 300 m^2, and at a distance of 40 m around the church. The results of the field study are presented in maps on: (1) apparent resistivity distribution at a depth of approximately 2 m, (2) detail geoelectrical pseudo-section, and (3) maps of the location of areas of interest from an archeological point of view obtained from geophysical data.

The resistivity values are from August 2006, which is the period of time when we performed the fieldwork. This is mentioned here because the precipitation regime may significantly modify (due to the water input) the resistivity values in general, and especially the surface horizon (which is the area of interest here).

The field measurements were performed using the INT91V3 resistivity meter. The processing and interpretation of data was performed with specialized software ("Comunicare", GeoBaza, SevSim, GTmap).

PRINCIPLE OF THE GEOELECTRICAL METHOD

By geoelectrical methods that use DC, the resistivity of underground materials can be measured by injecting DC of known intensity through two electrodes (current electrodes) placed on the surface of the land. The electric potential difference (voltage) subsequently resulted from another two electrodes, also placed on the land surface (Fig. 1). There are various options for the relative placement of the four electrodes, and each one particular grouping is called a measurement device. The best known and the most used devices are: Schlumberger, Wenner and axial dipole-dipole (Fig. 2).

The electrical resistivity of underground rocks is calculated based on the distance between the electrodes of the device used, the electrical current injected into the ground, and the electric potential difference (voltage) measured between the two measurement electrodes M and N. Numerical modelling of the physical processes (occurring when electricity crosses the non-homogenous resistivity media) is used. The real resistivity distribution may be obtained by field measurements, such as profiling or sounding. In profiling, the measurements are taken along a profile, which is equidistant and does not modify the geometry of the device and the distances between the electrodes. Resistivity profiling is useful in the identification of the lateral variations of resistivity values. The sounding measurements are performed by sequentially removing the current electrodes while keeping the measurement electrodes, and while maintaining the central position of the device. This technique is known as Vertical Electrical Sounding (VES) (Mundry, 1980). Through this last technique, by performing measurements exclusively on the soil surface, an image of the electrical properties' underground variations with depth may be obtained (Ştefănescu and Ştefănescu, 1974).

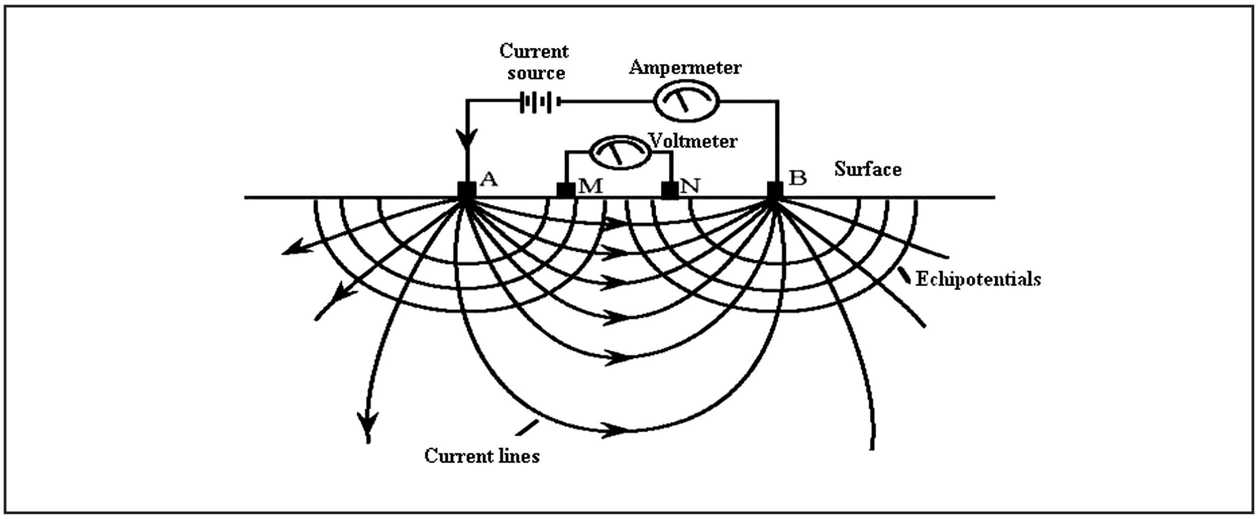

Fig. 1 The principle of geoelectrical DC measurements

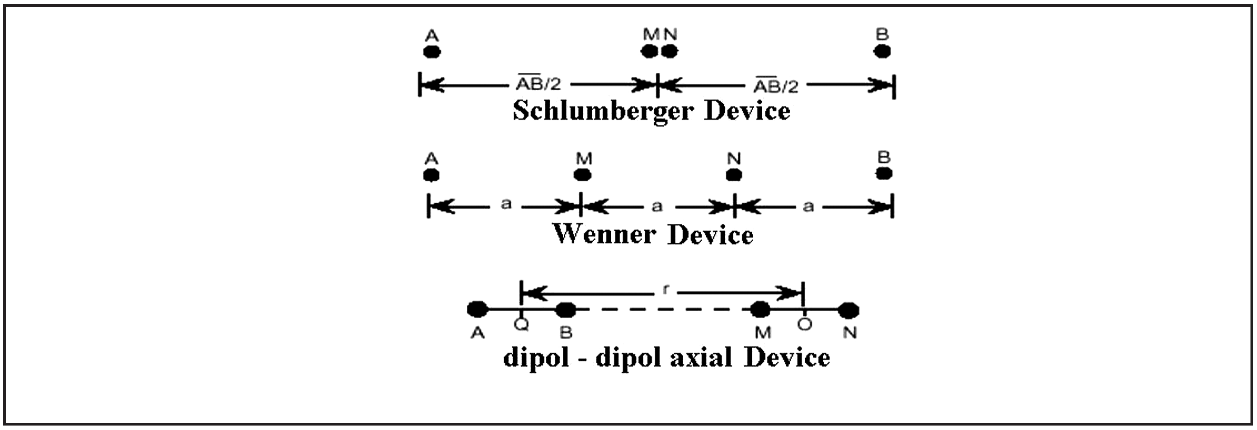

Fig. 2 Frequently used devices for geoelectrical measurements

Geoelectrical measurements cannot replace the direct investigations by drilling boreholes or ditches. However, these borehole investigations are a lot more expensive and take a long time.

The advantages of geoelectrical investigations come from the rapidity and the reduced costs of the method, as well as from the fact that they have a rigorous physical and mathematical base. Therefore, the measurements may have a qualitative interpretation, the equipment is relatively low cost and user friendly and can cover large areas of study in a short time.

The general disadvantages of the method are related to the necessity to achieve contact between the electrodes and the environment to be investigated. This leads to the impossibility to perform continuous measurements, even though some have been attempted (Georgescu and Gavrilă, 1989). However, if the surface soil is very resistant, then the data acquisition process is slowed down significantly, if not impossible. If the soil surface is very conductive, then another limitation of this method comes up. None of these limitations mentioned above is essential for most of the sedimentary environments in our country (or for the case study presented here), because these are not very resistive or very conductive on the surface.

Form the field measurements, a series of voltage values are obtained (ΔV) in μV units. For the interpretation, the apparent resistivity measure (in Ω.m) is used and obtained from field measurements, by using the following formula:

$$\rho_a = K \times \Delta V / I \qquad (1),$$

where I is the intensity of the current injected into the ground, and the factor K (geometrical factor) is determined based on the distance between the electrodes of the device:

$$K=2\pi/(1/AM-1/AN-1/BM+1/BN) \qquad 2)$$

The data acquisition in the field and the data processing is performed using specific software, as underlined above.

THE METHODOLOGY USED

In the case of geoelectrical measurements performed around the church in Densuș, we adopted a field methodology that is specific for archeological research. The method used was dictated by the specific field conditions, the bodies to be identified and the surface and depth distribution of these bodies. From the field observations and from the discussions with specialists, we concluded that the level of interest from an archeological point of view was between 0-2 m; the dimension of the bodies of interest was in the order of meters, and the majority of the interest zones are the remains of old construction bodies.

In the first phase, to obtain the resistivity distribution with depth and to have a picture of the depth of the possible zones of archeological interest, we decided to perform the research by geoelectrical profiling, using an AMNB device.

CASE STUDY – SFANTU NICOLAE CHURCH IN DENSUS

Located at about 10 km north of Ulpia Traiana Augusta Sarmizegetusa – the former capital of Roman Dacia – and about 10 km west of the Hațeg Town, the Saint Nicholas Church in Densuş, symbolic monument of the Hațeg Land (Rusu, 1991), has been the object of many controversies regarding its origin and age (Luca, 2005a). Some historians think that this construction was initially designed as a mausoleum for the Roman General Longinus Maximus (a close friend of Emperor Trajan, the conqueror of Dacia), or that it was originally a Roman temple of God March. Nicolae Iorga considered that the monument was built in the 16th century, and the art historian Vătăşeanu, in the last quarter of the 13th century.

The church in Densuş (Fig. 3) is probably one of the few pre-Christian autochthonous temples remaining. The core of the building was dated in the 2nd century AD (Luca, 2005b). Some historians assume that it was transformed into a church in the 4th century by the Goths. Constantin C. Giurescu dated this church from 1280. The memorial home of the Densuşianu brothers, Aron and Nicolae, Romanian scholars, is also present in the courtyard of the church.

The church in Densuş has a strange look due to the fact that it was built with river stones, bricks with Roman inscriptions, Roman column parts, funeral stones and sewage tubes, all of the materials probably taken from Ulpia Traiana Sarmizegetusa. Observing the particular aspect of the church, George Calinescu wrote that in Densuş there is a church that is "bizarre, made of marble and columns from Sarmizegetusa. A small pole of the four supporting the tower, there is a Roman stela engraved with the name of Longinus. It is a piece of marble with an elegant inscription, luminous and beautiful as a statue. Hidden in the shadow, barely lightened by a few sun rays passing through tiny windows… it gives the impression of a divine piece stolen by the genius of the night".

Father Alexandru Gherghel, the church priest, said that, even if it looks heavy and built from a mixture of Dacian and Roman blocks, the church is light as a bird ready to take off into the sky. It was designed that way, with the famous "sparrow tail" to the southeast, stone tiles arranged as a screen (an architectural element that is specific to the Dacian buildings), which come down from the roof to the altar. From the existing data, it seems that this church has never been abandoned. It has remained a cult temple for all the people in Țara Hațegului (= the Hațeg Land).

In the last years, inside the perimeter of Saint Nicholas Church in Densuş, several archeological investigations revealed the presence of some sites in the immediate neighbourhood of the church (Rusu *et al.,* 2000; 2001). Significant studies for the church took place inside and outside the church. These studies identified a new archeological site 40 m east of the church altar. There, a nobility court from the

Fig. 3 The Saint Nicholas Church in Densuș (photo by S.A. Szobotka)

second half of the 15th century and the first half of the 16th century was discovered. The archeological inventory stored at the Archeology and Art History Institute in Cluj-Napoca is to become the property of the Deva County Museum and consists of funeral pieces, tools and construction accessories.

Our investigations focused on the exterior area of the church. The purpose was to identify some possible underground structures, which may indicate the presence of archeological sites. The discovery of some new sites could bring clarifications on the age of the church controversy.

RESULTS

In the study area, we performed a geoelectrical cross section on the SE-NW direction. The results are displayed in Fig. 4. The distribution of resistivity is relatively uniform, and the resistivity values range between 10-120 ohmm. The area of large resistivities is located in the AB/2 interval, between 0 and 5 m. From an archeological point of view, this is the depth of interest. From a geological point of view, the base rock in this region is placed below the depth of 5 m.

Based on the measured VES, we performed an inversion process in order to find the real resistivity and the real distribution of the archeological areas of interest. The inversion results are presented in Fig. 5.

Based on the inversion data we performed the geoelectrical cross section, which is presented in Fig. 6

In this section we identified a zone of resistivity between 0 and 3 m. This zone tends to extend downwards on the NW direction. The base rock is made of clays and is at a depth between 3 and 7 m. Based on these observations, we employed the geoelectrical profiling method using an AMNB device with AB_{max} = 18m and MN = 1m. The results are presented in a graph in Fig. 7.

The resistivity distribution on the surface soil reveals the presence of a new area of high resistivity (coloured in red and yellow) located in the center of the studied perimeter. This area is located between two other areas of minimum resistivity (coloured in blue) (Figs 7 and 8). Moreover, we observed a preferred area of maximum resistivity values (coloured in red), extended on the WE and NS directions (Figs 7 and 8). Based on the geophysical observations and the field investigations, we considered that the maximum resistivity areas (in red) are the zones of archeological interest.

CONCLUSIONS

The studies based on geophysical electrical methods (geoelectrical) performed in the Saint Nicholas Church in Densuş (Hunedoara County) provide an image of the apparent resistivity distribution for depths between 0 and 2 m. These investigations ended with the identification of a possible high resistivity zone, which may indicated the presence of archeological sites.

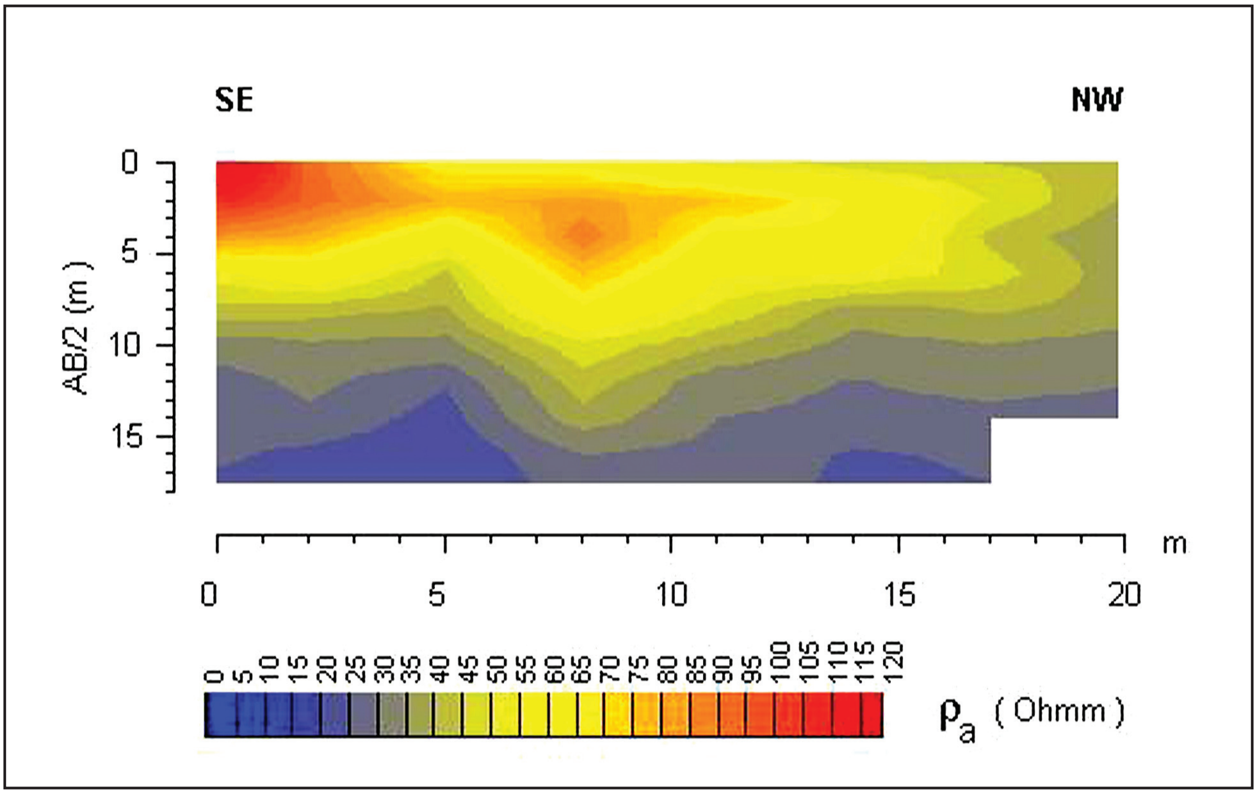

Fig. 4 Geoelectrical pseudo-section at the Densuș Church

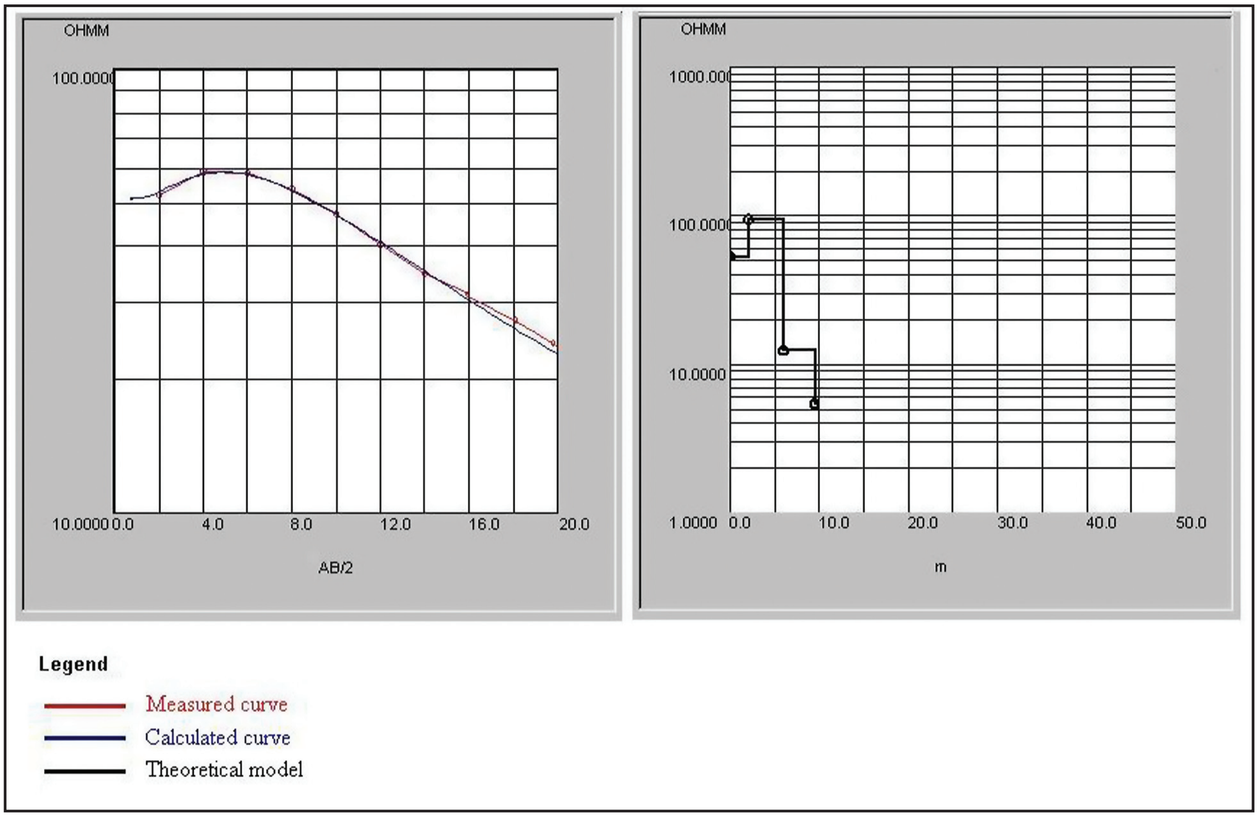

Fig. 5 Inversion Results

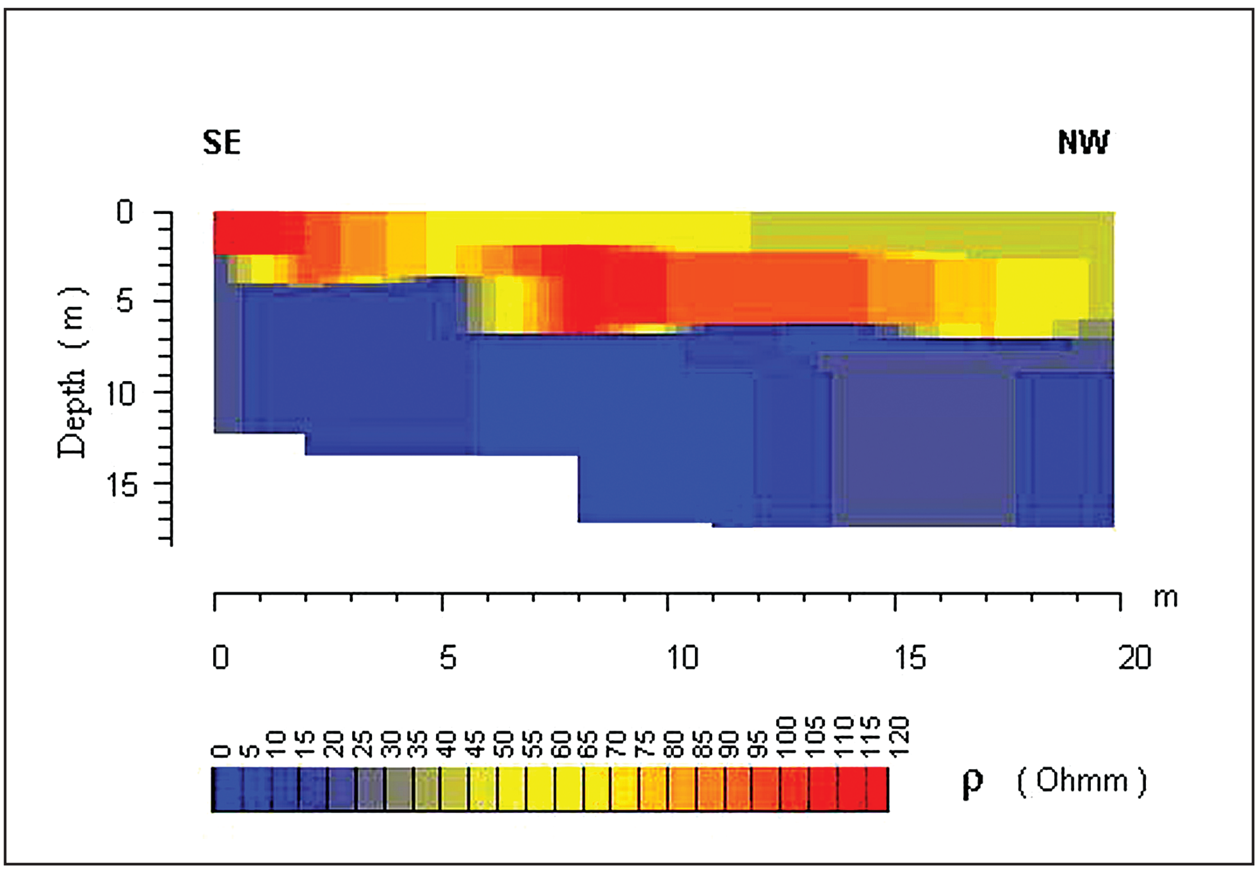

Fig. 6 Geoelectrical Section (The Church in Densuș)

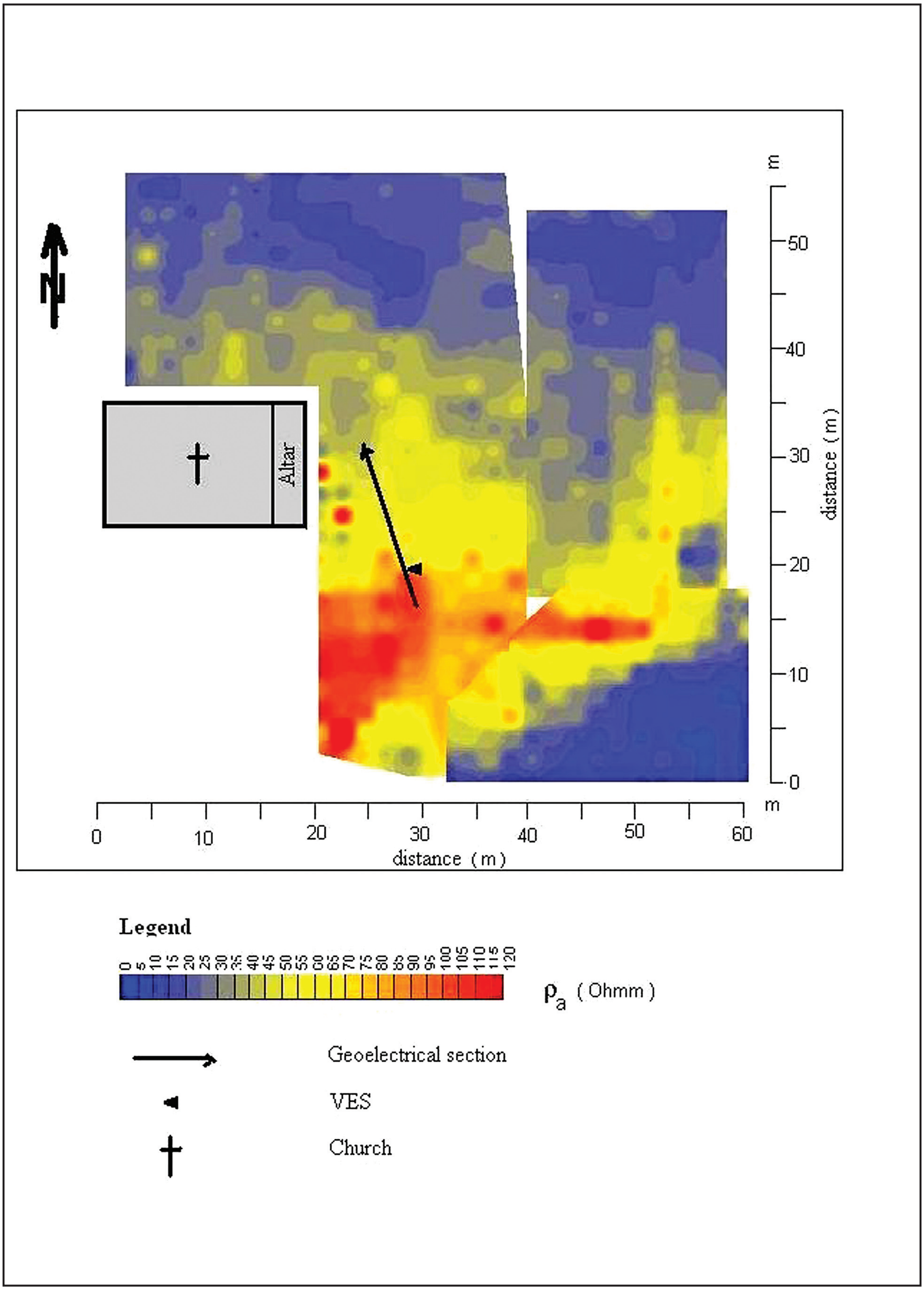

Fig. 7 Apparent resistivity distribution (ρ_a) at approx. 2 m depth (The Church in Densuș)

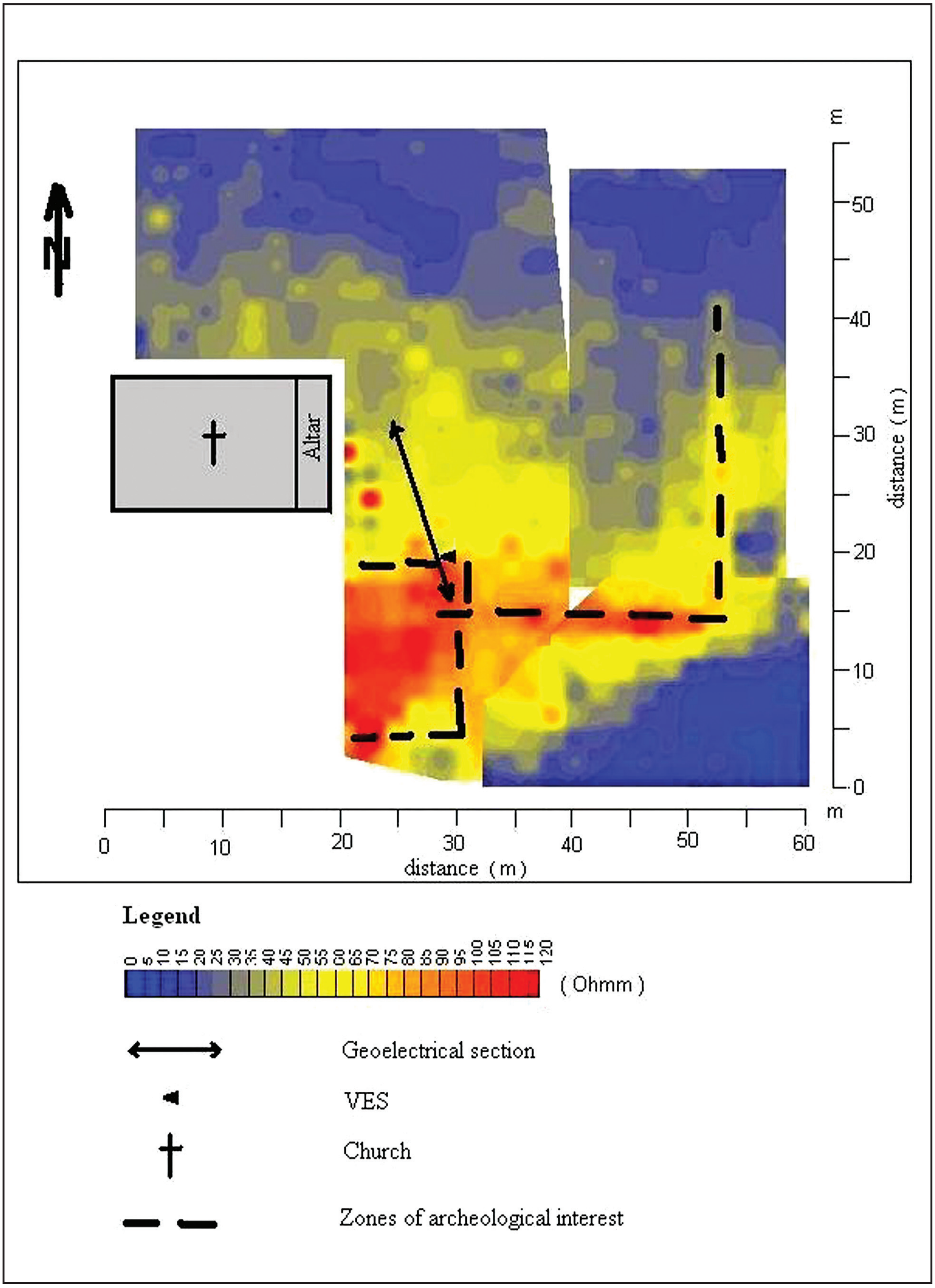

Fig. 8 Zones of archeological interest outside the perimeter of the Church in Densuș

In the herein presented case study, no previous geoelectrical measurements had been performed. Therefore, there had been no previous data on the physical property values and their surface or vertical distribution. This is why the establishment of the research methodology should be completed by additional studies using low depth borehole data, more VES measurements for verification and the comparison of data with observations from existing archeological profiles.

The data we obtained in this study indicates the possible presence of archeological sites behind the church altar, towards the SE and circa 30 m from the church wall. It is also possible that other archeological areas of interest are present in the immediate surroundings of the church as well as in its yard; they could be identified after further measurements are carried out to generate more geophysical data.

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REFERENCES

Luca S.A., 2005a. Repertoriul arheologic al județului Hunedoara. Editura Altip, Alba-Iulia, 237 pp.

Luca S.A, 2005b. Arheologie și istorie (III). Descoperiri din județul Hunedoara. Editura Economică, Sibiu – București, 376 pp.

Georgescu P., Gavrilă I., 1989. Influence of electrical prospecting arrangement on apparent resistivity anomalies, *Rev. Roum. Geol. Geophy. Geogr*., serie de Geophysique, 33,1.

Mundry E., 1980. The effect of a finite distance between potential electrodes on Schlumberger resistivity measurement – A simple correction graph. *Geophysics*, 45 (12), 1872-1875.

Rădulescu, V., Rădulescu F., Stan, I., 2006. Geoelectrical measurements applied to the assessment of groundwater quality. *Geo-Eco-Marina 12*, 107-110.

Rusu A.A., 1991. Bisericele românesti din districtul Hațeg pana la 1700. *Acta Terrae* 1, 129-142.

Rusu A.A., Măzgan V., Burnichioiu I., Crângaci M., Botez A., 2000. Densuș, com. Densuș, jud. Hunedoara. Punct: Biserica Sfântul Nicolae. *Cronica Cercetarilor Arheologice*, Campania 1999, p. 34.

Rusu A.A., Măzgan V., Burnichioiu I., 2001. Densuș, com. Densuș, jud. Hunedoara. Punct: Biserica Sfântul Nicolae. *Cronica Cercetarilor Arheologice*, Campania 2000, p. 78.

Ştefănescu S. S., Ştefănescu D., 1974. Mathematical models of conducting ore bodies for DC electrical prospecting. *Geophysical Prospecting*, 22.