Magnetometric and electrometric investigations in the Beroe submerged archaeologic site

Anghel Sorin
National Institute for Research and Development on Marine Geology and Geoecology – GeoEcoMar 23-25 Dimitrie Onciul Street, RO-024053, Romania
soanghel@geecomar.ro

Abstract. In ancient times, Dobrogea was known as Schythia Minor or Mikra Skythia. In the 1st century BC, the respective territory was under the influence of the Pontic kingdom of Mithridate the VIth Eupator. From 28 BC it was integrated in the Roman province of Moesia Inferior by Emperor Augustus. Most Roman-Byzantine fortresses have been established by the Romans on the site of former Getic settlements: Tropaeum Traiani, Capidava, Carsium, Beroe, Troesmis, Arrubium, Dinogeia, Noviodunum, Ibida, Durostorum. The Roman-Byzantine fortress of Beroe-Ostrov grew around the Roman castrum of Beroe, where the Vth Legion was stationed in the Ist and IInd centuries. One can find here the partially unearthed ruins of a Roman and Byzantine fortress, dating back to the Ist-VIth and Xth-XIIth centuries, and nearby, those of a Paleo-Christian basilica, dating back to the Vth-VIth centuries. The latter is situated aside from the former cemetery, which has been used between the Ist-XIIth centuries. As a result of conflicts between the Dacians of Dobrogea (the Comati) and the Romans, the fortress was destroyed, and was re-inhabited once the Byzantines returned to the Lower Danube, under Emperor Ioan Tzimiskes. The Roman and Byzantine fortress from Beroe is located 3 km to the South of Ostrov village, in North Dobroudja, the north side of Moesia Inferior province. We carried out magnetometric and electrometric measurements in the Beroe archaeological site, located in the Dobrogea region of Romania. We analyzed the results to see if we could find the orientation of the walls or any other evidence of a former human presence within a limited area submerged beneath the Danube River. We showed the estimated depth of the site and the possible orientation of a wall. The geophysical data was acquired on the water (Danube River) within the submerged zone using marine equipment designed for that purpose (G822 device with cesium) with a gradient array and AGI minisiting electrometer with 100 m length. The area of investigation was 100 by 50 meters, and it was located in the NE part of the site, having a grid density of 10 by 10 meters. The data we obtained in this study indicates the possible presence of submerged artefacts. Magnetic susceptibility measurements indicate a possible magnetic contrast between the regional geological background (local limestone rocks used in the construction of the fortress walls, mortar, etc.), characterized by low, sometimes even diamagnetic magnetic properties and artifacts such as bricks, backed (fired) adobe, ceramic fragments, showing relatively high magnetic susceptibilities.
1. Introduction
The interest area is rich in historical monuments. In the following territorial administrative units there are monuments of national importance (category I and IV): Smîrdan (Obelisk of the soldiers in War of Independence), Jijila (romanbyzantine fortress and archaeological site), Măcin (Arrubium fortress, Muslim cemetery and Roman necropolis), Turcoaia (Troesmis fortress complex and medieval settlement), Ostrov (Beroe fortress and necropolis) and Luncăvița (fortified settlement).

There are also many monuments of local interest in the following territorial administrative units: Jijila (Getic settlement), Luncăvița (Getic settlement, archaeological site and Roman-byzantine settlement), Carcaliu (archaeological site and Eneolithic settlement), Hamcearca (fortified settlement), Cerna (Traian archaeological site and Roman and Neolithic settlement), Peceneaga (fortification, archaeological site, Roman and Neolithic settlement), Topolog (Roman and Neolithic settlement, archaeological site and Getic settlement) and Casimcea (archaeological site, Roman and Neolithic settlement).

During the Geophysical investigation carried out during 2016-2017, at Piatra Frecatei site (on the place of old Beroe fortress) was found materials dated in XI-XII centuries. Beroe fortress (Figure1) was on the Danube River bank, 3 km from the village of Ostrov (Tulcea County).

![Figure 1. Photograph of the Beroe area, Romania, showing the remains of the ancient city](image1)

2. Description of the analyzed magnetic field data
The magnetic data was acquired on the water (Danube River) within the submerged zone using marine equipment designed for that purpose (G822 device with cesium) with a gradient array (Figure 2). The area of investigation was 100 by 50 meters, and it was located in the NW part of the site, having a grid density of 10 by 10 meters (Figure3).

![Figure 2. Photograph showing the device used for data acquisition and also the submerged area that was investigated](image2)
Figure 3. Plan of investigation area

The grid values are in meters and the anomaly values are displayed in the color legend bar in nT (Figure 4). We observe the first positive anomaly near the negative anomaly that is located in the northern part of the area. This anomaly correlates well with the existing city remains because it is a continuation of Figure 3 and indicates a continuation of the wall. Modeling using PotentQ (Figure 5) has also shown a buried structure that can be approximated to the remains of a wall [1].

Figure 4. Magnetic field anomaly map
Figure 5. The model magnetic anomaly and the resultant buried wall

3. Analysis of the electrometric data

The use of resistivity methods in archaeological exploration precedes the use of other methods (Wynn, 1986). They were first used in the 1940’s in England (Atkinson, 1952; Aitken, 1974), and allow to distinguish stone foundations and remains, that are more resistive, buried ditches, more conductive, as well as cavities, whose behaviour depends on the material they host.

The resistivity measurements were done with an Intel91 resistivity meter. We planned to acquire profile, but due to bad weather conditions, only two were done [2]. The profiles had a length of 50 meters and a depth of 6 m, and they were obtained using the vertical electrical profiling (VSP) method with a Schlumberger array [3]. The streamer length was 100m. The distance between the electrodes was 5m (21 electrodes). The vsp points were located 10 m apart, the MN distance was 5 meters (Rădulescu, V) and the AB distance started at 10 meters up to 100m (Figure 6). For electrometric investigation on the Danube river, we was used a small boat (Figure 7).
The cable was positioned on the surface of the water with the help of floats (Figure 7). When conducting geophysical surveys in archaeological exploration it must be kept in mind that a uniform coverage of the survey area is needed. Thus, the first step in field operations is the gridding of the total area to investigate. With the red color, we can see the major resistivity anomaly which indicate the potential sanstone wall. After geophysical data acquisition stage, exist o very good correlation into the magnetometric and resistivity anomalies (Figure 4-6) and marks the existence of buried archeological structures.

Figure 6. Apparent resistivity section – profile1 (left) and profile2 (right)

Figure 7. Electrometric acquisition data on the Danube rive
4. Conclusions
Magnetic and electrometric measurements were carried out within a submerged area of the Beroe archaeological site. After the data analysis, we have established the most probable orientation (Georgescu, P., and Gavrilă, I., 1989) of a buried wall and created an hypothesis that requires more investigation to explore its validity. We also established the depth of the site and the fact that the VSP investigations need to be redone with a shallower depth as target (Project -FLUVIMAR).

References
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