Geophysical surveys around the mouth of the Ropotamo river

Yanko Ivanov[1], Spas Nikolov[1], Bozhurka Georgieva [1], Daniel Ishlyamski 1

[1]University of Mining and Geology "St. Ivan Rilski", Sofia, Bulgaria, e-mail: ianko@mail.bg, spas0423@gmail.com, bojurkageorgieva97@abv.bg, kirilishlyamski@abv.bg

Key words: geophysics, archaeology, Ropotamo river

Abstract
The report presents the preliminary results of the geophysical investigations carried out in the archaeological sites around the mouth of the Ropotamo River during the Geophysics Field Camp "Sozopol 2018" aiming to locate possible ancient river inflows and beds and find evidence for a hypothetical ancient settlement. Despite the early stage of investigation, the obtained results are promising enough to demonstrate the potential of the applied integrated approach and plan further investigations.

Геофизични проучвания около устието на река Ропотамо

Янко Иванов[1], Спас Николов[1], Божурка Георгиева[1] , Даниел Ишлямски[1]

[1] Минно геоложки университет „Св. Иван Рилски", София, България, ianko@mail.bg , spas0423@gmail.com , bojurkageorgieva97@abv.bg , kirilishlyamski@abv.bg

Абстракт
Докладът представя предварителните резултати от геофизичните проучвания проведени в археологическите терени около устието на река Ропотамо по време на Полевата практика по геофизика "Созопол 2018", целящи да локализират възможни древни речни притоци и корита и намерят доказателства за хипотетично древно селище. Въпреки ранната фаза на проучване, получените резултати са достатъчни, за да се демонстрира потенциала на приложения комплексен подход и планират бъдещи проучвания.

Ключови думи: геофизика, археология, р. Ропотамо

Introduction

The study of civilizations buried in the geological record represents the object of archaeology. The classical approach of doing archaeological study requires tremendous amount of work and involves trenching with trowels and brushes. Nowadays the geophysical methods have grown into standard archaeological field practice as a rapid, non-destructive way to understand the processes in the geological record, locate artifacts from ancient times and also help to widen the scope, see connections and reveal the bigger picture.

The presented surveys were conducted during the fourth consecutive Geophysics Field Camp "Sozopol 2018" held in July near the town of Sozopol, South-East Bulgaria. The field camp, sponsored by SEG Foundation and TGS, organizes the education and training of the students of Applied Geophysics at University of Mining and Geology "St. Ivan Rilski". Part of the student education is usually focused on investigation of archeological sites (Leshtakov et al., 2015), in this case the area around the mouth of Ropotamo River in the Ropotamo Nature Reserve (Fig. 1).

Ropotamo Nature Reserve is located about 50 km south of Bourgas, on the border between the towns of Sozopol and Primorsko. The small territory of just over 1000 ha, declared as protected site back in 1940 and Ramsar wetland in 1975, is a rare combination of the sea, a river, a marsh, dense forest vegetation, interesting rock formations ("Lion head", "Joyful rock" and "Snake Island"), beaches stripes and sand dunes. The fauna in the reserve is presented by large variety of mammal, bats, bird, amphibian, reptile species, turtle and fish species. The locality is also a shelter for many animal and plant species of national and international significance, including globally endangered species and endemites. This unique blend of

natural resources, flora and fauna is additionally enhanced by the many historical and archaeological findings in the reserve.

The conducted geophysical investigations relied on some of the most commonly used techniques: ground penetrating radar (GPR) (Tzankov & Yankova, 2013), ground magnetic field, electrical resistivity tomography measurements and also orthophotography. Depending on the goals of the particular survey and the specifics of the investigated sites either a single method or integrated approach was employed. The successful application of every method depends on the existence of certain physical contrast between the buried archaeological artifacts and the geological properties of the subsurface. Understanding the archaeological origin of the observed resistivity, magnetic or dielectric contrasts is fundamental for the proper interpretation of the obtained data and was one of the main aspects of the education during the field camp. The high resolution imaging and the significance of the corresponding physical parameters turn the ground magnetic and ground-penetrating radar methods into perfect tools for caring out high-speed surveys for evidence of ancient settlements and paleo-relief reconstruction. Certain conditions, however, such as extensive investigations and highly conductive environments, alternatively require the application of the electrical resistivity tomography (Dimovski et al., 2007).

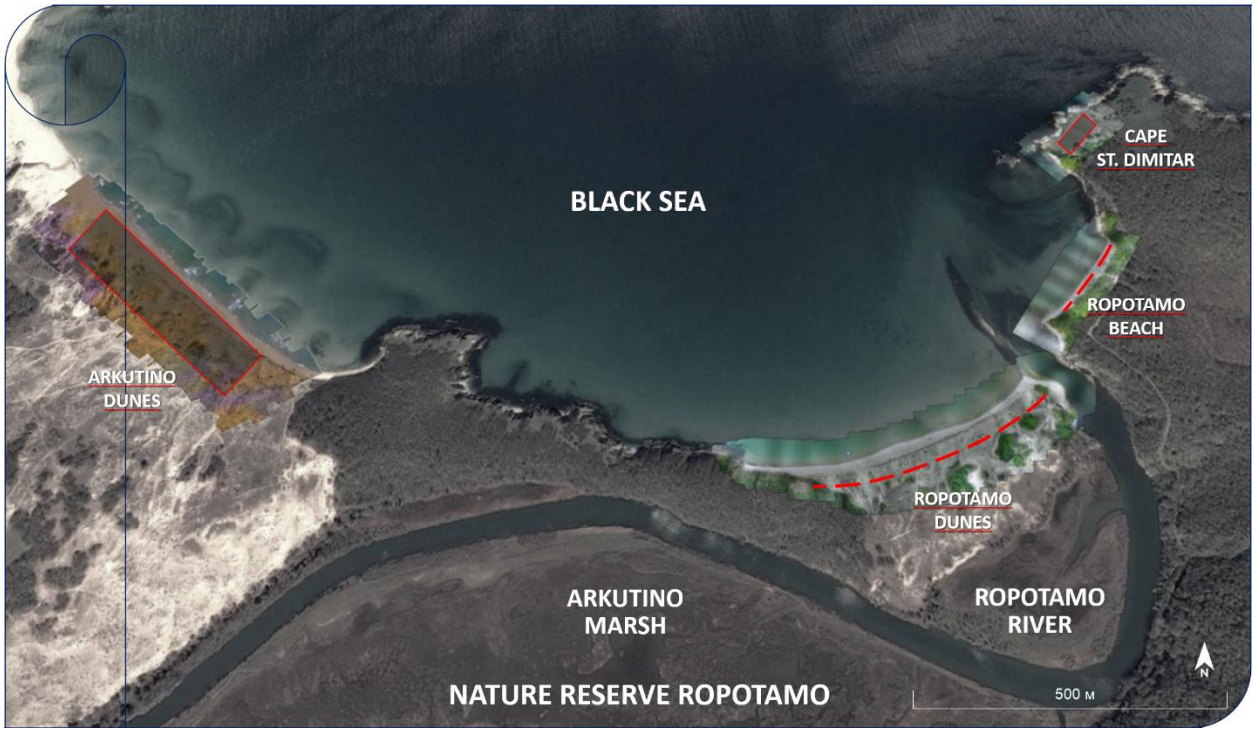


Figure 1. Map of the investigated archaeological sites around the mouth of the Ropotamo river

Arkutino beach and dunes

Aerial archaeology has a hundred-year history, not long after the camera was invented people first started capturing birds-eye views allowing identification of previously not recognized archaeological features. The use of remotely piloted aircraft systems (RPAS) for solving different practical problems is a new approach which is actively developed and should be enhanced and affirmed in solving number of problems related to monitoring and studying Earth's surface, as well as currently ongoing processes or phenomena (Tzankov & Kisyov, 2016; Tzankov & Parushev, 2016). A typical application is the ability to generate detailed digital terrain models, which is critical in planning, design and monitoring of engineering and others activities.



Figure 2. Aerial photo of the area of Arkutino beach with the Ropotamo river on the left and the Arkutino marsh in the back.

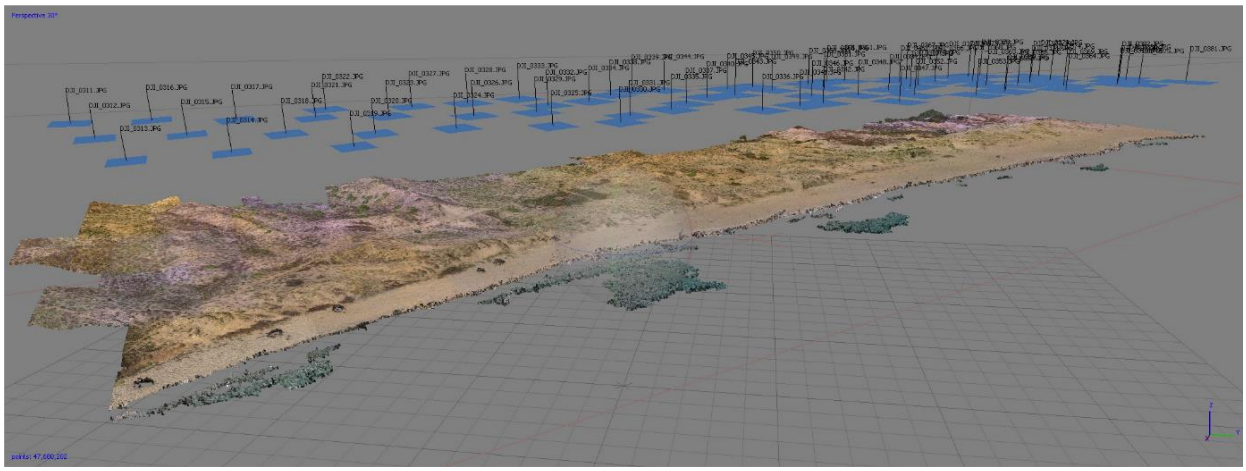


Figure 3. Working DEM of Arkutio beach and the dunes made with RPAS with scene positions on the top.

All of the investigated sites were observed with drone by orthophoto imaging (fig. 3). The shooting scenes were combined in digital models and different types of products were produced (orthomosaic maps, DEMs, pointclouds, etc.).

The area of the dunes behind the Arkutino beach was investigated with GPR. Four long semi parallel profile lines, 30 m appart, were recorded in the mainland along the line of the coast (Fig. 4). The radargrams in the figure are presented from south to north and the top one is in the most eastern (near the sea) as the last one is the most western (far from the sea). Except the first radargram, a complicated underground relief is registered by the georadar. Probably, this uneven surface is connected with the relief of the underlying clays and channels where freshwater infiltrates from the near located marsh. On the radargram on the top, which is about 30 m from the seaboard and just in front of the dunes, a possible saline water intrusion causes intensive absorption of the electromagnetic signal leading to lack of information in the cross-section. Three active freshwater infiltration channels (one on the left and two on the right) are easy to be seen on the radargram.

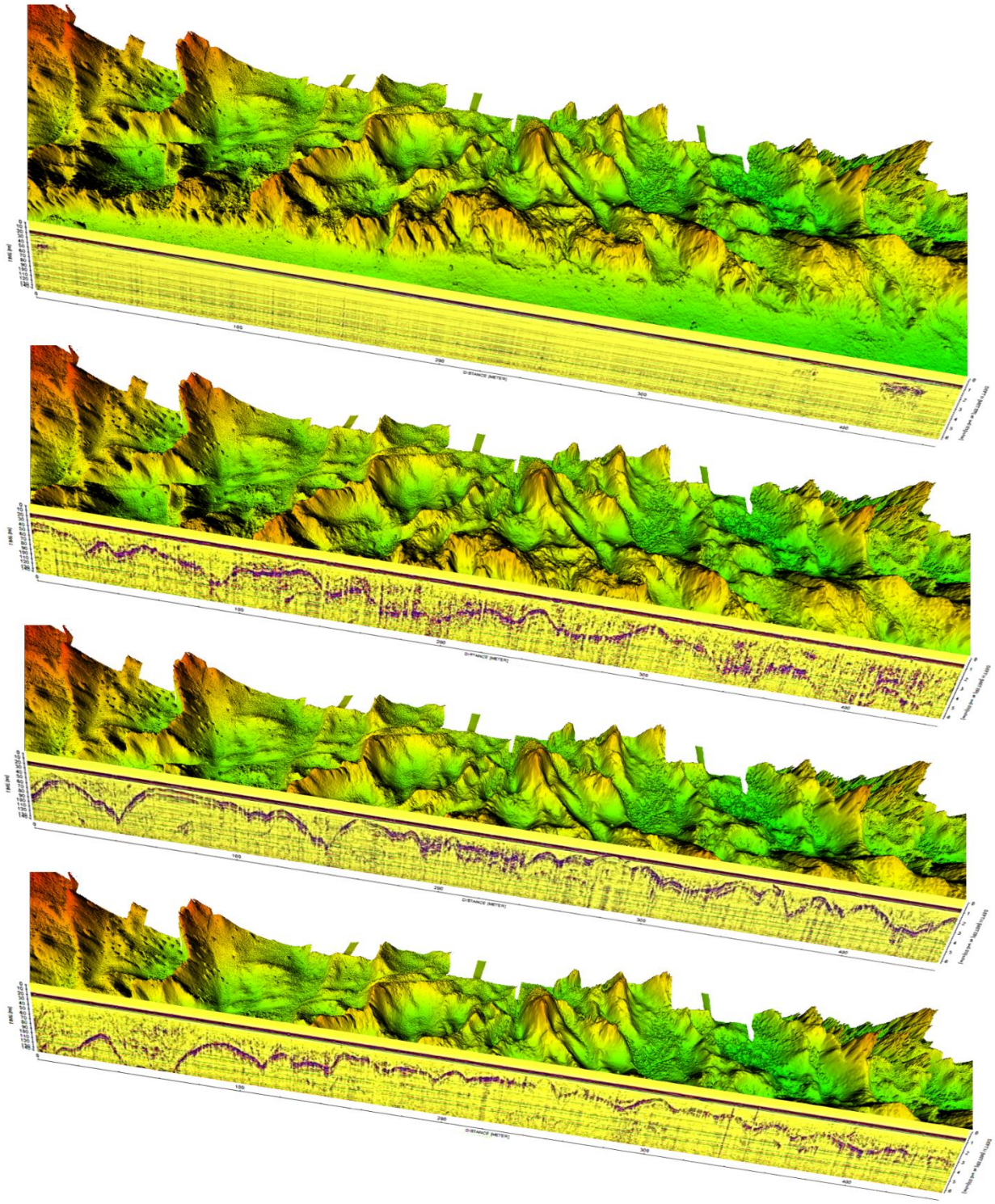


Figure 4. Artistic preview of the DEM of the relief and the four semi-parallel GPR lines along the covered by dunes inner land of the Arkutino beach

Ropotamo Beach and Dunes

Previous geophysical surveys (Vagalinski et al., 2017) followed by underwater archaeological excavation in the sea bay around the mouth of the Ropotamo river revealed well preserved stratigraphy and reached a settlement from the Early Bronze Age at a depth of 2.5 m under sea bottom. The purpose of the current geophysical surveys was to find evidence supporting the hypothesis that the Bronze Age agglomeration was located at the shore of a small stream, a right inflow of the Ropotamo River and locate its possible ancient beds.

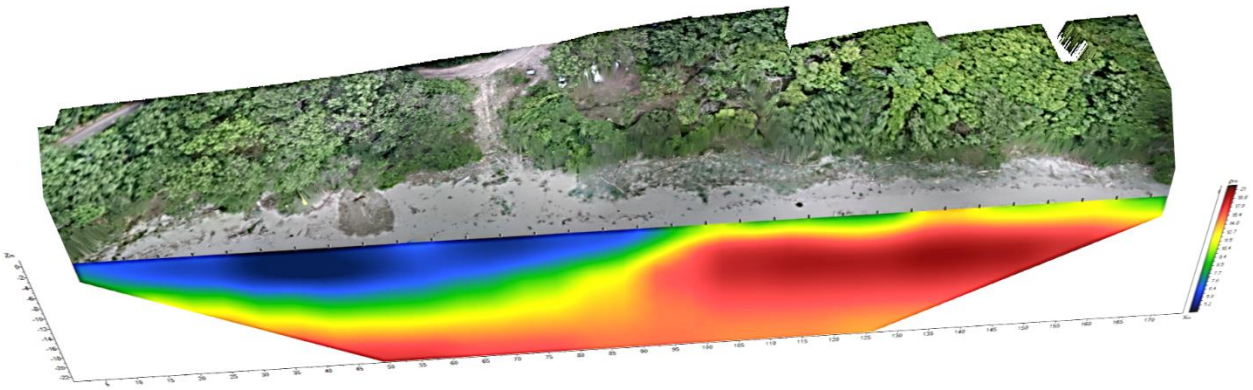


Figure 5. Ortophoto image with a resistivity tomography on the beach east of the Ropotamo river's mouth.

The investigation of the hydrogeological conditions was carried out using two electrical resistivity tomographic profiles (ERT) with lengths of 167,5 and 467,5 m and a maximum reached depth of 20 m. The first profile was located on the beach along the coastline on the east site of the Ropotamo River's mouth and revealed that the first 10 m underlying the beach close to Cape St. Dimitar are characterized by low resistivity values supporting the hypothesis of a possible streamlet there (Fig. 5). The second profile followed the dunes along beach on the west side but the obtained results cannot provide clear evidence of the changes of the river's bed in the ancient times due to the complex relief. (Fig. 6).

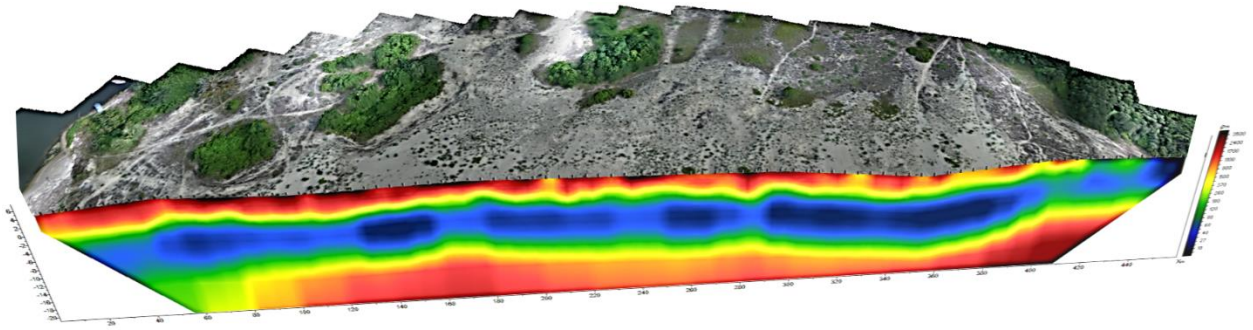


Figure 6. Ortophoto image with a resistivity tomography over the dunes west of Ropotamo river's mouth.

Cape St. Dimitar

Cape St. Dimitar area was investigated with geomagnetic gradientometry and GPR. Both methods cover the same area with size 42 x 90 m. The aim of the survey was to discover traces of settlement connected with the remains found underwater during the archaeological excavations in 2017 (Vagalinski et al., 2017).

The data from the geomagnetic surveys was used to produce various maps of the field distribution (fig. 7). Two anomalous areas (outlined in red on fig. 7) appear in the maps of the investigated area. It is possible to interpret them as appearance of anthropogenic structures connected with the ancient settlement, but for clearer suggestions, further processing of the data and investigations should be done. It is obvious, that geological bodies as dykes or veins evoke the larger and intensive geomagnetic anomalies crossing the investigated area.

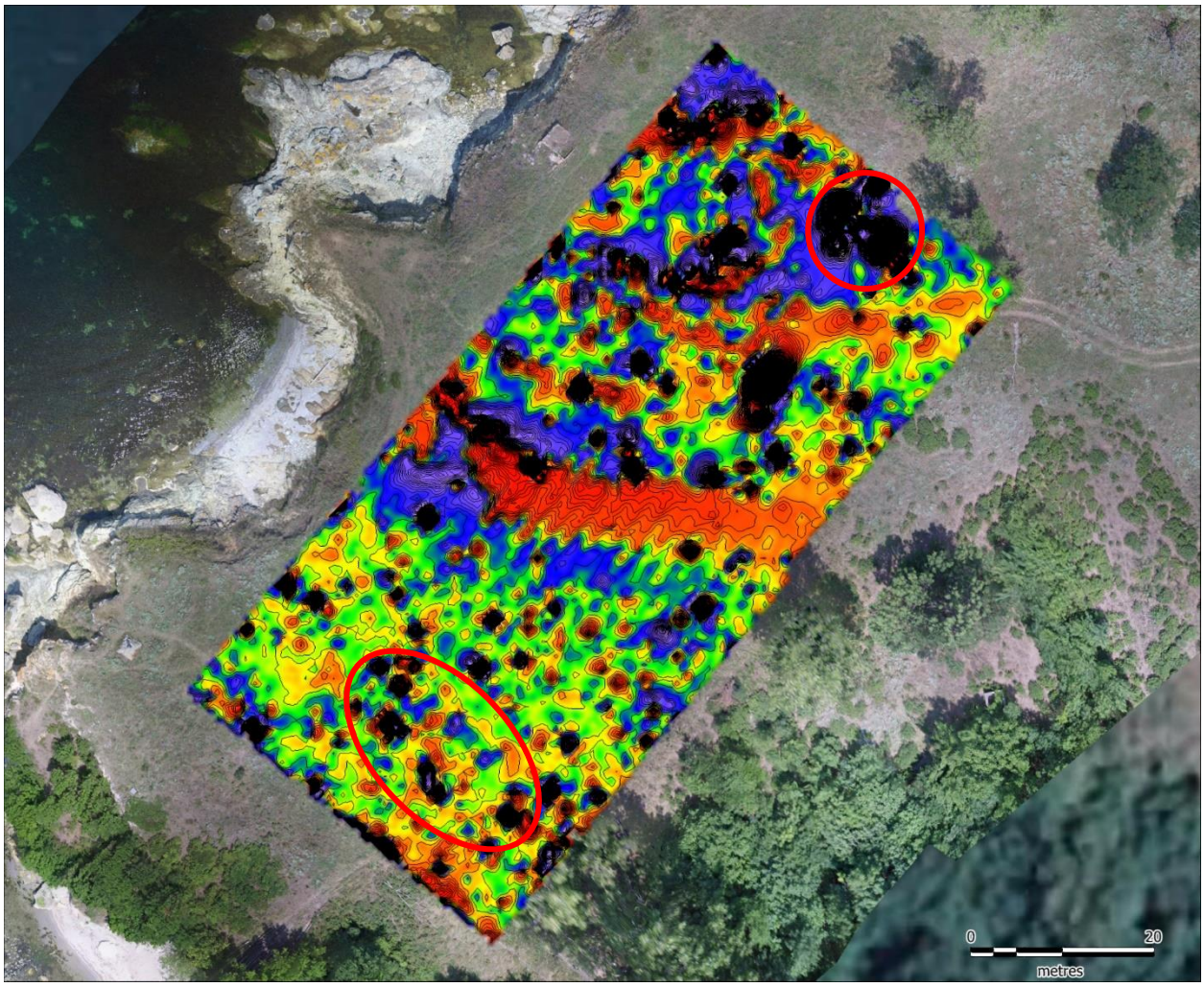


Figure 7. Vertical Magnetic Gradient map of the investigated archaeological site on Cape St. Dimitar

According to the current stage of the analysis and the interpretation of the GPR data (fig. 8), the georadar registered several anomalies at different depths, which could be caused by remains from the ancient anthropogenic activities. One of the anomalies shown on fig. 8 concur with anomalie registered in the geomagnetic field. According to its shape, it is very likely to be connected with a building remnants. Interpretation of the other anomalies is still in discussion and is forthcoming that data should be compared with results from former investigations and aerial photography from the first half of the XX century.

Conclusion

Despite the early stage of investigation, the obtained results are promising enough to demonstrate the potential of the applied integrated approach to study the sedimentary layers and separate the geological features from preserved archaeological artifacts especially when archaeological surveys are constrained by a lack of excavations, exposures and stratigraphic data. During the field days in the Ropotamo Nature Reserve, the students participated in the filed camp had the chance to apply different geophysical methods, compare their effectiveness, produce various 2D and 3D models of the subsurface within depths that are usually of importance for archaeology and plan further investigations.

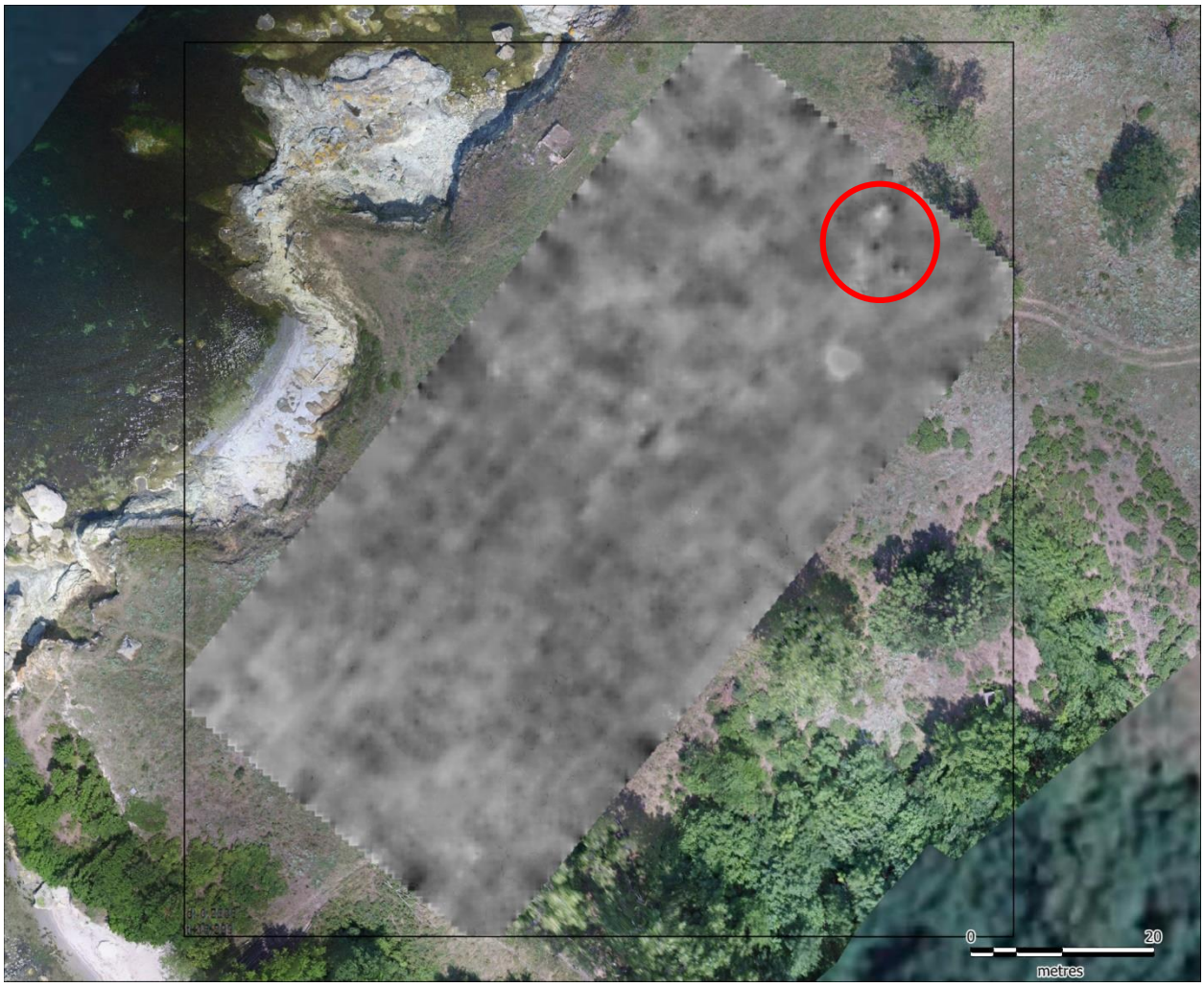


Figure 8. Ground-penetrating radar map of the investigated archaeological site on Cape St. Dimitar

Acknowledgments
All participants in Geophysics Field Camp "Sozopol 2018" are extremely grateful to SEG, SEG Foundation and TGS for the provided funding and the opportunity to fulfill our Geophysics Field Camp for a fourth successive year.

Rerefences

Lawrence B. C., L. K. Kenneth L. Kvamme. Ground-Penetrating Radar for Archaeology, Wiley-Blackwell, 2016.

Leshtakov, P., Ch. Tzankov, At. Kisyov, K. Dimitrov. Geophysical survey in a prehistoric site in the Alepu lagoon area, Sozopol municipality. Archaeological Discoveries & Excavations in 2015, NIAM-BAS, 944-948, 2016.

Loke, M. H., R. D. Barker. Rapid least-squares inversion of apparent resistivity pseudosections by a quasi-Newton method, Geophysical Prospecting, 1996.

Tzankov, Ch., At. Kisyov, P. Leshtakov. Geophysical studies of traces of ancient mining and metallurgy in the eastern part of the Srednogorian metallogenic zone. Proc. 9th Congress of Balkan Geophysical Society, 5-9 November 2017, Antalya, Turkey.

Tzankov, Ch., At. Kisyov. Application of the remotely piloted aircraft systems (RPAS) for remote sensing. XIV National science-practical session for young engineers, 19-20 April 2016 (on CD in Bulgarian).

Tzankov, Ch., Iv. Parushev. Application of non-professional remotely piloted aircraft systems (RPAS) for solving practical problems. Annual of UMG "St. Ivan Rilski", Vol. 59, 2016, pp 138-187 (in Bulgarian).

Tzankov, Ch., M. Yankova. The georadar enters extensively in field geophysics. Minno delo i Geologia journal, vol. 5/6, 2013, pp 31-35 (in Bulgarian).

Vagalinski L., K. Dimitrov, K. Velkovsky, D. Stoev, N. Prahov. Underwater geophysical survey in the area of submerged settlement in the sea bay at the mouth of Ropotamo river. Archaeological Discoveries & Excavations in 2017, NIAM-BAS, 717-718, 2018 (in Bulgarian).

Vagalinski L., J. Adamas, K. Dimitrov, K. Bachvarov, R. Pacheco-Ruiz, V. Draganov, D. Garbov, J. Roennby, F. Pedrotti, N. Prahov, Z. Georgieva, P. Georgiev. Underwater archaeological excavation in the sea bay at the mouth of Ropotamo river. Archaeological Discoveries & Excavations in 2017, NIAM-BAS, 720-723, 2018 (in Bulgarian).

Димовски, С., Н. Стоянов, Ч. Гюров. Ефективност на електротомографията за детайлно геоелектрично картиране на приповърхностния геоложки разрез. – БУЛАКВА, 4, 47-55, 2007.

Смекалова Т, О. Восс, А. Мельников, Магнитная разведка в археологии, Доля, 2007