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SHALLOW SUBSURFACE GEOPHYSICAL INVESTIGATION OF A CHALCOLITHIC SITE WITHIN THE DANUBE DELTA

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Introduction

Coastal environments of Mediterranean and Black Seas, especially those associated with large deltaic-estuarine systems, have represented, due to their rich natural resources, favourable areas for the development of prehistoric societies since the Late Glacial and Early Holocene time. Particularly on the western Black Sea coast, the embayment of the Danube Estuary, around 5.4 ky. BC, at a past sea level close to the present one (Lericolais et al., 2009), triggered the formation of the delta, whose entire evolution (delta lobes and coastline) was heavily influenced by the combined effects of the regional subsidence (-2 to -4 mm/y today), eustasy (+0.5-1.0 mm/y rise today) and the huge Danube's sedimentary discharge (over 50 mil. t/y in past). Thus, any prospective archaeo-cultural layer corresponding to Late Prehistory, located in past not too high above the sea level, could now be placed at a burial depth that exceed 4-5 m (Dimitriu, 2010) in this subsiding region, abundantly alluvia fed.

Neolithic - Eneolithic (end of 6th ÷ start of 4th Mil. BC) settlements belonging to Hamangia, Boian and Gumelnița cultures, all revealing at least one habitation level, have been discovered in many Northern Dobrogea sites located on terraces, cliffs and promontories of the paleo-seashore, today the western border of the delta plain (Istria, Baia, Ceamurlia, Lunca, Enisala, Sarichioi, Nufăru, Mahmudia, etc.) and, within the plain, on higher ground (Popina Is., Taraschina Mound).

Regional setting

The Taraschina site, located in the central delta plain, near Mila 23 village (Fig.1), has a surface that exceeds 15,000 m² and is located on a mound around 2 m above the mean Danube waters level. It was discovered in the 1990s, but its systematic archaeological investigation only started in 2008. Mainly based on ceramic data, the site was attributed to Gumelnița A1, its age being of 4.5 ÷ 4.3 ky. BC (Chalcolithic) according to regional radiocarbon chronology (Carozza et al., 2010). The micro topographic analysis and coring established that the site of Taraschina is a tell built up from a succession of paleosoils, domestic structures and sterile levels corresponding to the degradation of architecture. The site was also occupied in the Antiquity and Medieval times.

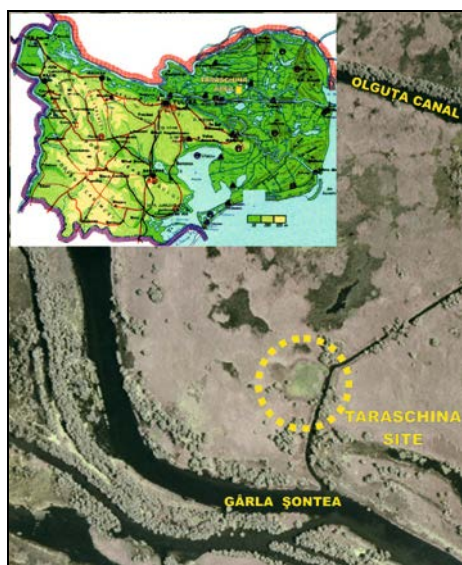


Fig.1 Map of Tulcea County and the location of Taraschina site within the Danube Delta

From the geological point of view, Taraschina site is regionally located in the Pre-Dobrogea Depression, part of the Scythian Platform. On a less regional scale, the most prominent deep tectonic structure is the Sulina Graben, due to whom the platform basement, which among other petrographic terms, also includes igneous intrusions able to generate intense regional magnetic anomalies (e.g. Chilia magnetic anomaly), are placed at a depth of around 5000 m (Dimitriu, 2001). The sedimentary cover of the platform may also comprise thin effusive volcanics of Permian age, but still located at greater depth and

therefore unable to generate local magnetic anomalies. The sedimentary deposits of the delta, mainly consisting of sequences of sand, gravel, silt and clay, achieve a thickness of 200-220 m (Spânoche & Panin, 1997) and do not comprise rocks able to generate intense magnetic anomalies. Thus, the only anomalous sources able to generate the local magnetic anomalies mapped at Taraschina are most probably very shallow and of anthropogenic origin.

Methods and results

The site is already subject of many interdisciplinary investigations: archaeological disclosures and coring, palaeobiology, palinology, microbiology, sedimentology, micromorphology, geophysics, petrophysics, geochronology, etc.

This paper is only presenting the first results of the magnetic mapping carried out in 2010 and of the 2³/4D modelling of the shallow subsurface that followed. Two Geometrics G-856 proton procession magnetometers were used for the field works, one in a gradient array (the two sensors were placed at 0.75 m and 2.75 m above the ground), the second as a field base station, set up to measure total geomagnetic field every 15 seconds. The global accuracy of the meters is 0.1 nT. The geophysical measurements were carried out in 20x20 m panels, the density of the network being of 1x1 m. Finally, an area of around 4125 m² was covered.

The planimetry and altimetry topographic works carried out on the central area of the site with both a Trimble R3 differential GPS system and a total station were able to materialize on the ground the geophysical measurements network and also to issue the first micro-elevation model of the site (Fig. 2). The relative accuracy of these measurements, relative to a local reference system, is within a few centimetres for X and Y coordinates and better than 1 cm for the elevations.

Quick, in situ magnetic susceptibility measurements have been made on samples of surface soil, soil contemporaneous with the archaeologically investigated cultural layer and several artefacts: adobe, baked (fired) adobe and ceramic fragments.

The domain of variation and average value of the magnetic susceptibility in situ measured are as follows: soil – 0.10÷0.14 (0.12) muSI, adobe – 0.22÷0.44 (0.32) muSI, fired adobe – 3.93÷4.05 (3.99) muSI and Gumelnița ceramics – 4.15÷4.20 (4.17) muSI (for the conversion of these data to CGS units consider the formula: 1uCGS = 4π uSI). A more refined petrophysical analysis, carried out on up to 8 m long cores extracted from the site is on the run.

The maps of the local geomagnetic total field anomaly, obtained at the levels of 0.75 m and 2.75 m above the ground are presented in Fig. 3. The maps of the local total geomagnetic field vertical gradient was also created, presenting numerous resemblances with the magnetic anomaly map obtained at the level of 0.75 m above the ground.

Discussion

The mound shape of the site has been confirmed by the topographic mapping, the total variation of the ground level being of around only 55 cm. The gentle relief of the surface (Fig. 2), which nowadays is almost flat, is due to alluvial burial of the mound, which in Prehistory time was



Fig. 2 Elevation model of central part of Taraschina site (altitudes are relative to a local altimetry system)

probably many meters above the sea and river waters level, thus being suitable for a safe centennial habitation.

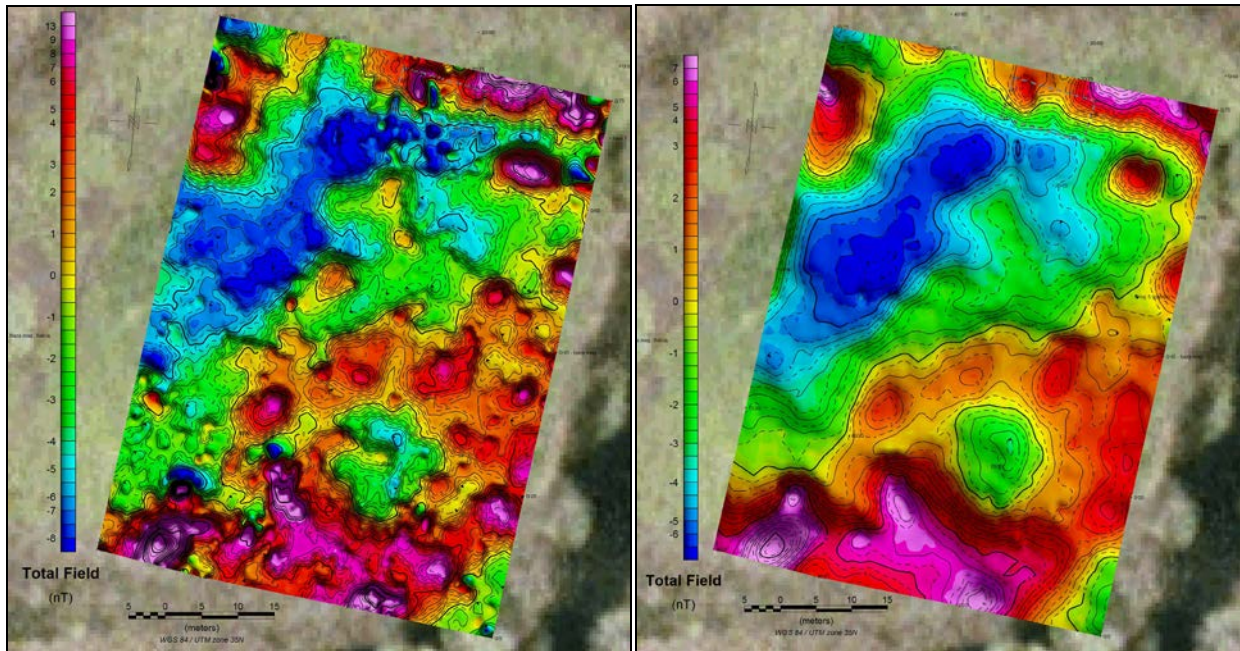


Fig. 3 Maps of the geomagnetic total field at height of 0.75 m (left) and 2.75 m (right) above the ground

The amplitude of the magnetic anomalies measured at 2.75 m height above the ground (Fig. 2, right) ranges within 15-20 nT. No remote influence, i.e. a regional gradient, due to a long wavelength magnetic anomaly located outside the mapped area is noticed, sustaining the hypothesis according to which all mapped anomalies are generated by sources exclusively located at shallow depth below the surface, probably belonging to one or more cultural layer(s). By far, the most prominent anomalous feature of the map is the ring shape anomaly, or chain of individual anomalies mapped in the southern half of the investigated area.

According to experience in the interpretation of many other magnetic mappings of archaeological sites of Neolithic-Eneolithic age, gained for instance in north-eastern Moldavia at Scânteia-Cucuteni culture (Ghiță & Manea, 1995) or in southern Wallachia at Vitănești-Gumelnița Culture (Dimitriu et al., 2002), all these interpretations being confirmed by latter archaeological disclosures, such annular shape anomalies, less extended (3x4 m up to 10x12 m), are generated by fired dwellings whose adobe walls are collapsed generally toward the interior. Due to the high temperature attained, ferrous hydroxides contained by clays turn to ferrous oxides, the process being accompanied by an important increase of magnetic susceptibility and also of the remnant magnetization of the clays, which in many situations exceeds the amplitude of the induced magnetization. Thus, a notable consequence of the firing is the substantially increase of magnetic detection capability.

As the diameter of the annular shape feature, incompletely mapped (!), is around 40 m, a similar interpretation is unlikely if we consider the anomaly as being exclusively generated by a single anthropogenic source of Chalcolithic age buried at 1÷2 m depth. Alternatively, the ring shape feature could be due either to several Chalcolithic dwellings disposed in a circular manner on the top of the mound or to a circular light fortification (possibly a soil and wood made wall), probably of roman age.

The several 2D and 2½D simulation models of the subsurface, built up for the interpretation of the ring shape magnetic anomaly (Fig. 4), sustain these both interpretations, by revealing the presence of at least two shallow (depth of 1 to 2 m), tabular anomalous sources, thick around 1m,

which probably belong to one or more cultural layers, possibly composed of anthropogenic materials: baked and not adobe, fragments of ceramics, other artefacts.

Other positive magnetic anomalies have been mapped entirely or only partial in the northern half of the investigated area. The sources of these anomalies are even shallower (less than 1m) according to the geophysical modelling and some of them are, at least partly, due to modern ferrous objects, such as the geodetic benchmarks placed by archaeologists prior to the geophysical mapping.

The map of the local magnetic anomalies measured at 0.75 m

height above the ground displays a more mosaicked view (Fig. 3, left). The amplitude of magnetic anomalies is now ranging in a wider domain, up to 150 nT. The main magnetic anomalies, already highlighted by the previously described map, are of course present but overlapped by numerous positive, negative, sometimes bipolar, relatively intense but short wavelength anomalies generated by sources placed very shallow or laying on the ground surface, covered by the very dense vegetation. Many of these superficial anomalous sources are probably contemporaneous and due to the agricultural and pastoral use of the land, but some of them still could belong to the archaeo-cultural heritage, thus being of interest for further investigation.

The map of the vertical gradient reveals the disappearance of the annular anomalous feature but the enhanced visibility of the very local anomalies. As in theory the depth of investigation of the magnetometric vertical gradient arrays is equal to the distance separating the two sensors, it results that the burial depths of the sources is less than 1.25 m for the very local anomalies and greater for those generating the ring shape feature. This map also clearly highlights the perturbations of the magnetic field (i.e. small orthogonal anomalous features) introduced by the archaeological field works (the disclosed panel and the soil dumped around) carried out in the northern part of the investigated area prior to the geophysical mapping.

Conclusions

The first results of the study stress the good applicability of magnetometry in this environment, based on the clear contrasts of petrophysical properties existing below the surface. The importance of planning future, non-destructive geophysical mappings, also including other geophysical methods, i.e. GPR, electrometrics, etc., prior to any further archaeological work is also obvious.

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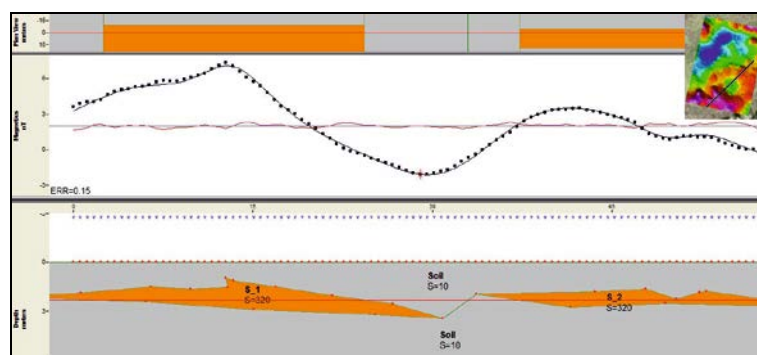


Fig. 4 2.5D simulation model of the shallow subsurface based on the modelling of the 2.75 m height magnetic data (magnetic susceptibility values considered by the model are in $\mu\text{u CGS}$)