MAGNETIC EXPLORATION APPROACH TO RESEARCH AND RECONSTRUCT THE ARCHAEOLOGICAL SETTLEMENT OF URLAȚI, PRAHOVA COUNTY

C.S. I. dr. Alin Frînculeasa[1]

Senior Geophysicist Cornel David[2]

C.S. I dr. habilitat Alexandru Popa[3]

Lect. dr. Mădălina Frînculeasa[4]

[1]Prahova District Museum of History and Archaeology, Archaeology Department, Toma Caragiu Street, no. 10, Ploieşti, **România**

[2]Geomathics One, 61 Buzestist., bl. A6, ap.29, Bucuresti 011013**, România**

[3] National Museum of Eastern Carpathians, Áron Gabór Street, no. 16, Sf. Gheorghe, **România**

[4]University Valahia of Târgoviște, Faculty of Humanities, Department of Geography, 35 Lt. Stancu Ion Street, Târgoviște, **România**

ABSTRACT

The settlement at Urlați (Prahova county), "*La Islaz"*, is a complex site from the archaeological point of view. The study presents the results of geophysical investigations (magnetometry) carried out before the starting of archaeological excavation (2013), as well as those carried out during the research campaign in 2018, which aimed at the possibility of extending the excavation to adjacent perimeters. The geophysical investigation demonstrates that magnetometry is capable of providing a rapid overview of the distribution of archaeological artefacts, of the spatial demarcation and extension of archaeological layers without alteration or destruction of any features of the site(s). Applying the geomagnetic method and techniques for prehistoric sites is very useful and efficient to determine the archaeological structures, avoiding large excavations, which consume too much time and money.

Keywords: Urlați archeological site, Archeogeophysics, Prehistoric site investigation, Magnetometry for archeology

INTRODUCTION

Geophysical methods have often been applied successfully for archaeological purposes, the initiation of an archaeological excavation being preceded, in many cases, by non-invasive methods survey in order to maximize efficiency and minimize the physical destruction of archaeological heritage (Ioane and Chitea 2013; Fassbinder, 2017; Chitea et al., 2019, Apostolopoulos et al. 2020). Of these, magnetometry is considered one of the most important non-invasive methods, with obvious results in the field of archaeology (Kvamme, 2006;). However, one drawback is its inability to discriminate accurately between layers at different depths; it tends to average readings over an approximate resolution depth (Aspinall et al., 2008).

Archaeological research in Romania benefited, in the last decades, from the information provided by geophysical investigations. These can be applied singularly (one method) or combined, depending on the relief or anthropogenic features of the site, land use, and geological particularities of the soil. The methods can be used in archaeological sites of all periods and in all forms of development and dimensions. Thus, their results are more and more frequently presented in the archaeological literature. For example, for the area in which the Urlați site pertain we can mention the works of David (2015), Țentea et al. (2018), Garvăn et al. (2020) and the publications of the authors of this paper Frînculeasa et al. (2013; 2014; 2015).

MATERIALS AND METHODS

a. The archaeological site from Urlați-location and archeological landmarks

The research presented here focuses on the study of the magnetic response of artifacts from the archaeological site "*La Islaz*" from Urlați, Prahova County. This site is located at the contact area between Romanian Plain and the Subcarpathian hills, at the foot of the Dealul Mare-Istrița massif. The archaeological research started in 2004, being suspended in 2006 and then reopened in 2013. The archaeological layers include settlements of the Neolithic (Starčevo-Criș culture), Eneolithic (Gumelnița culture), the Bronze Age (Tei Culture), the 2nd-3rd century AD (Chilia-Militari culture), the 5th-7th Centuries AD (Ipotești-Cândești culture), and the Middle Ages (17th-18th centuries AD) (Frînculeasa et al. 2017; 2018).

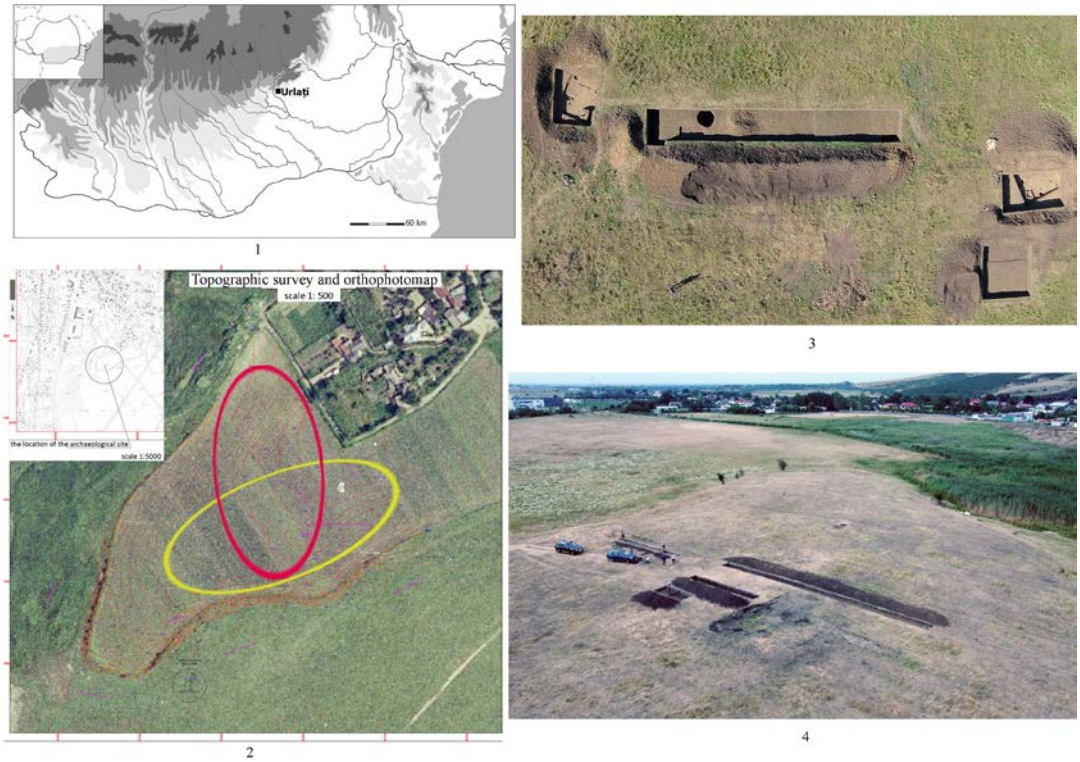

Figure 1 - Location of Urlați în southern Romania (1); Topographic survey and orthophotomap and the site within the locality with the areas investgated în 2012 (yellow limit) and 2018 (red limit) (2); Aerial images of the archaeological research (3-4)

The site is situated in the southeastern part of Urlati, about 400 m north of the P&G industrial park. The site's ending is in the form of a crane, a foot that descends smoothly from the northeast to the southwest. The level difference from the field that is located to the southeast is of a maximum 3 m. The site is bordered, to the north and west, by a wet area, covered with specific vegetation. To the south and southeast there are uncultivated agricultural lands, and to the northeast, courtyards of the locals.

The level of habitation does not exceed 0.70 m in thickness, being a relatively modest one in terms of the material and the number of archeological complexes discovered. Both surface dwellings and pit houses were investigated. Archaeological materials such as pottery, mammalian bones, flint, stone and bone tools, anthropomorphic and zoomorphic plastic, were found, all in fragmentary condition. The surface dwellings had a wooden structure, with twig walls, clay mixed with dry straw and clay floor. They were destroyed by fires. The pit houses were partially dug into the ground, had a wooden and clay superstructure, and the roof was made of twigs, earth, and straw.

b. *Working method*

The magnetic method is a geophysical method that measures the natural magnetic field or its gradients, with the help of specific instruments named magnetometers/gradiometers. It calculates the characteristics of the subsoil in terms of the magnetic properties, by studying the local variation of the magnetic field (Telford et al. 1990; Oswin 2009). The strength or relative change of a magnetic field at a particular location is used in archaeology for locating artifacts and other traces of civilization. The results are highly influenced by the contrast between the magnetic properties of the archaeological features and the surrounding soil. This difference allows the highlighting of magnetic anomalies, which may indicate the presence of buried structures of anthropogenic origin. The results are interpreted according to the amplitude of the magnetic anomalies, to their shapes or spatial extensions. Thus, intense anomalies, which sometimes exceed 50 nT, are usually recorded in the case of sources containing ferromagnetic materials or in the case of objects with thermo-remanent magnetism, such as furnaces and other artifacts made of burnt clay. Massive bodies of iron or ferromagnetic alloys produce anomalies of the order of hundreds or thousands of nT, depending on the mass of the object and the depth of burial. Refined magnetic anomalies, having order of a few nT, are registered in the case of a contact between a clay/marly deposit and a coarse material (gravels, sands, boulders). Also, some anomalies indicate the presence of old ditches, clogged with another type of material than the substrate. It is important to know the general context in which the target bodies of the magnetic research are performed. Measurements performed on the total magnetic field can be submitted to advanced data processing in order to extract information on the physical characteristics and the burial depth of the sources that produce the detected anomalies. The gradient is defined as the change in the field divided by distance. Gradient measure derived by making the difference between the magnetic field measured (most of the time for high precision) simultaneously in 2 positions, (the sensors being laterally distanced or vertical separated)

The geophysical investigations at the Urlați site, *La Islaz*, were carried out in two stages (Figure 1.2). The first one, before the excavations began (2012), was made by Geomathics One (Cornel David) (Figure 2). In this stage, were performed total magnetic field measurements using GSM19W type Overhauser magnetometers, with the base station located near by the investigated perimeter. The primary data were obtained by

continuous recordings on parallel profiles, with a sampling rate of 0.2s. The height of the magnetic sensor from the ground was 0.7 m. The average cover of the area was about 7-8 samples/sqm and the accuracy of measurements was about 0.1 nT. The magnetometers have built-in GPS, which allows their synchronization and, at the same time, serves to perform DGPS correction, to improve the accuracy of positioning measurements.

In the perimeter delimited by the metallic fence (Figure 2), the measuring points were positioned at a 0.5-0.6 m. Otherwise, the surface of the land was delimited by squares with a side of 30 m, inside which the movement was made on profiles spacing 0.6 m. The primary data were corrected by the diurnal variation of the Earth's magnetic field and were interpolated in the network 0.5×0.5 m within the SURFER16 program, Also several analytic processing were performed (‘high pass', 'low pass ' and ‘band pass' filters, vertical and horizontal derivatives of the total magnetic field). The subsequent data processing was performed in three variants of combining the surfaces, taking into account the particularities of the effects due to the surrounding disturbing sources:

a. the entire surface, from which the neighboring surfaces with very strongly disturbing sources, such as the power line, the wire fence, and the concrete pillars on the south-eastern limit were physically removed;

b. the median surface of the perimeter; the south-western extremity was abandoned since few and debatable anomalies were registered in it because there is various garbage (household waste/debris) deposited on the surface of the land;

c. only the surface inside the metal enclosure.

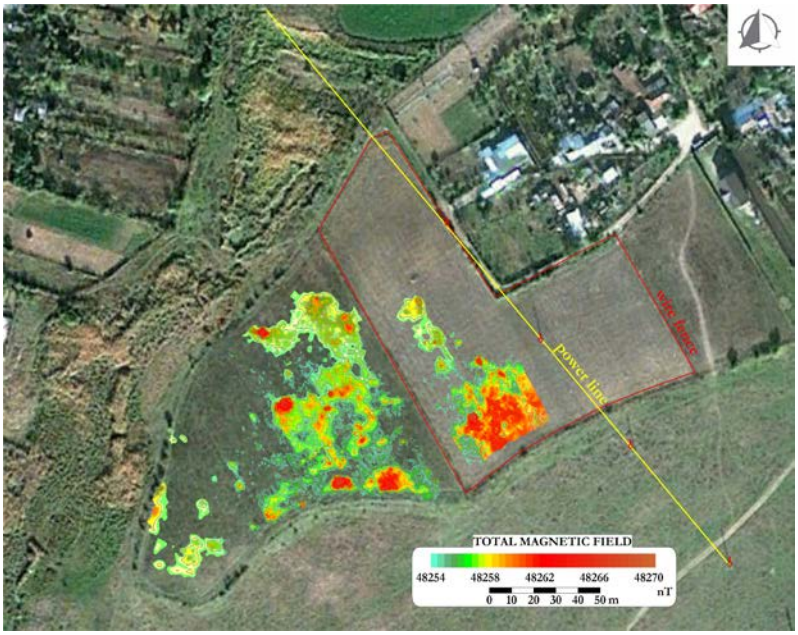

Figure 2 - Investigated perimeters (2012) and resulted total magnetic field map

In the second stage (Figure 3), the investigations consisted in measuring the vertical component of the earth's magnetic field. They were carried out by Alexandru Popa using an equipment based on 5 fluxgate (Dr. Förster) probes, with an accuracy of measurements of about 0.1-0.5nT. The two magnetic sensors of each probe are mounted on a non-metallic bar, positioned at 0.6 m vertical interval giving as the vertical gradient of the magnetic field. The flow probes were mounted in-line, on a non-metallic trolley, at a distance of 50 cm from each other, so that during the movement a strip of 2.5 m width

was measured. In the direction of movement, an impulse is recorded every 5 cm. The system was propelled by a single person, with a speed of about 0.6-1.2 m/s.

The geomagnetic values acquired using the mentioned equipment were compensated by the median filter algorithm and then plotted. For data interpretation purposes we used a grayscale, where the low values, which corresponds to a lower magnetization of the investigated surface, are represented in lighter color tones, and the while the higher values are coded using ones in darker tones. The resolution of raster images obtained by interpolation is about 20×20 cm. The images were georeferenced in a Q (quantum)-GIS data processing system but can be opened in any modern GIS system (ArcGIS, Global Mapper, MapInfo, gvSIG, etc).

Figure 3 - The vertical gradient of the magnetic field (2018)

In 2018, the magnetic measurements were carried out in four perimeters (Figure 3). They total an area of 5900 m^2. Their arrangement in the field was dictated by the

results of previous archaeological researches extended over a time span of 6 years, by the configuration of the relief, as well as by the local limitations due to private properties.

Perimeter A (a surface with dimensions of 55×19.5 m) was drawn in the southern part of the promontory on which the archaeological site is located (Figure 3A). Its western limit was determined by the position of the archaeological excavation section. Perimeter B was drawn on the side opposite to perimeter A, west of the area archaeologically researched in previous years (2013-2017). This perimeter covered an area of 60×34.5 m (Figure 3B). Perimeter C was located north of perimeters A and B. Emerging from the relief configuration, perimeter "C" could be drawn on a surface with the dimensions of 55×22 m (Figure 3C). Perimeter D was established northeast of perimeter C, without common points. Perimeter D has an area of 40×42 m (Figure 3D).

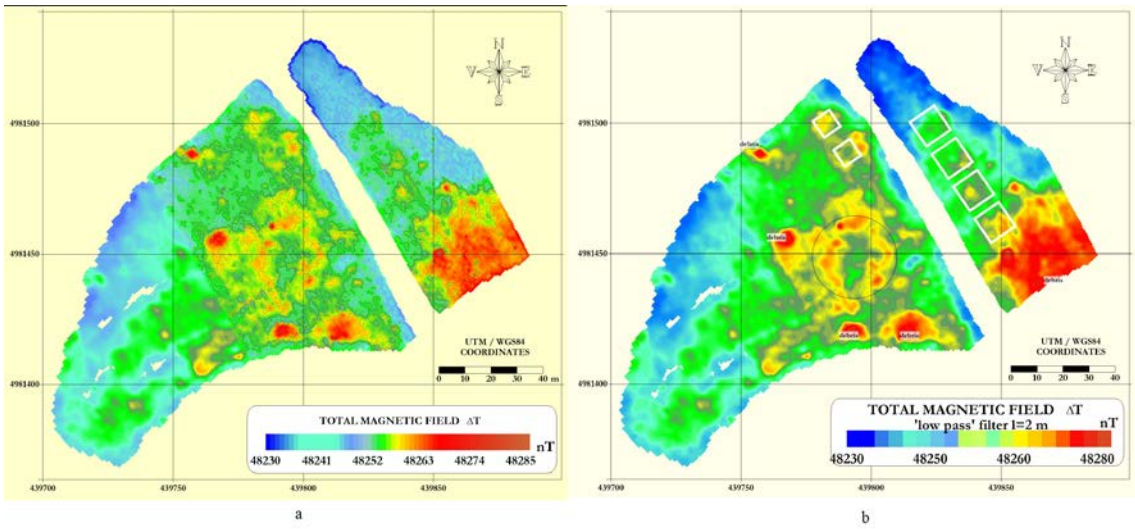

Figure 4 - Primary map of the total magnetic field (a) and total magnetic field map after applying ‘bandwidth’ filtering (b)

RESULTS AND DISCUSSIONS

The processing of data obtained from investigations in 2012 helped us generate interpolated maps of total magnetic field (Figure 4). Their analysis highlights the on-site presence of some magnetic bodies, with the intensity varying in a range of values between 6 and 15 nT, which can be associated with archaeological structures:

1. Structures that produce anomalies of the magnetic field within the range of 7-12 nT were divided in polygons and were interpreted as remains of the living quarters and a more intense bipolar anomaly that could represent fire hearths.

2. Structures with poorly defined shape, but characterized by the presence of magnetic anomalies with dimensions and amplitudes close to those mentioned before appears towards the northeastern limit of the investigated perimeter. It is possible they occupy the entire area included in the fence (Figure 5b).

3. An anomaly, or a group of anomalies that can be circumscribed by a circle with a diameter of 35-40 m or, possibly, by a square with this side. The structure occupies the central part of the area and is surrounded by a series of local, bipolar

anomalies, with amplitudes of 4-7 nT. It represents a construction or a group of constructions that, by form and position, could have been of higher rank. (Figure 5c)

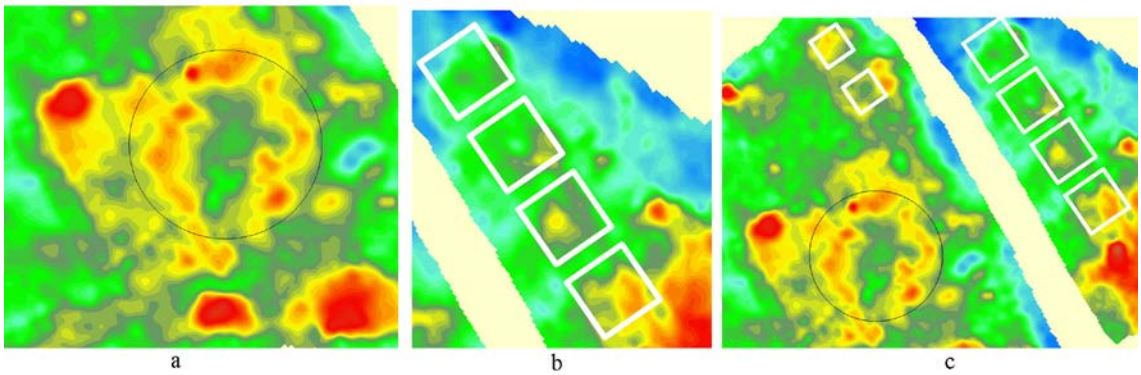

Figure 5 - Processed magnetic data. Magnetic anomalies associated with archaeological structures. Details.

The relatively low intensity of magnetic anomalies is due to the fact that the sources consist of materials with low magnetic properties, such as partially burned clays. A plausible way to interpret the nature of the magnetic anomalies would be that they represent construction elements (walls, foundations) made of clay reinforced with wickerwork, that were, at some point, set on fire. However, the firing temperature was not high enough for the entire material to acquire magnetic properties, as is the case with burnt bricks. Only locally and with different intensities, the primary material acquired magnetic properties, and therefore, the registered anomalies are not very eloquent regarding the shape of the foundations of the structures. We consider that the results in some sectors have been distorted by the geophysical noise given by the rubbish illegally deposited.

Archaeological excavations have confirmed the existence of two surface dwellings dating from the Eneolithic era, the Gumelnița culture (4350-4250 BC) made of wood and clay, heavily burnt, but inconsistent as a construction structure. Being discovered on the surface (-030-0.50 m depth) they were exposed to external natural factors or ploughing, and "the bricks" of burnt clay, were degraded and decomposed in time, remaining only the massive pieces. Besides, subsequent dwellings have also contributed to the poor state of preservation of these constructions from the Eneolithic era (Frînculeasa et al. 2018). The geophysical investigations from 2018 were conducted in order to see if the area contains archaeological features not revealed during the previous six archaeological campaigns.

The results of the geomagnetic investigations carried out in 2018 consist in:

a) In perimeter A we found the presence of light-colored linear anomalies, arranged perpendicular to the length of the perimeter, which probably represents the traces of "control" sections/ditches, drawn by the team of archaeologists in previous years. Besides, there is also the presence of smaller bipolar anomalies. In the image (Figure 3A), they are observed by the contrast of black and white and are known as metallic "bi-poles". Most often, we deal with debris of modern origin, which are not conclusive for our research. In the south of perimeter “A” (Figure 3, Figure 6) there was observed an agglomeration of large anomalies that may represent traces of an intact archaeological complex with the dimensions of about 4.5×7 m. The approximately circular anomalies found in this perimeter seem to describe the contour of a construction with pillar pits.

This interpretation is sustained also by the presence of the oval shaped anomaly (1.4×2.5 m) (Figure 6.3.B) which indicates the presence of an oven or fireplace.

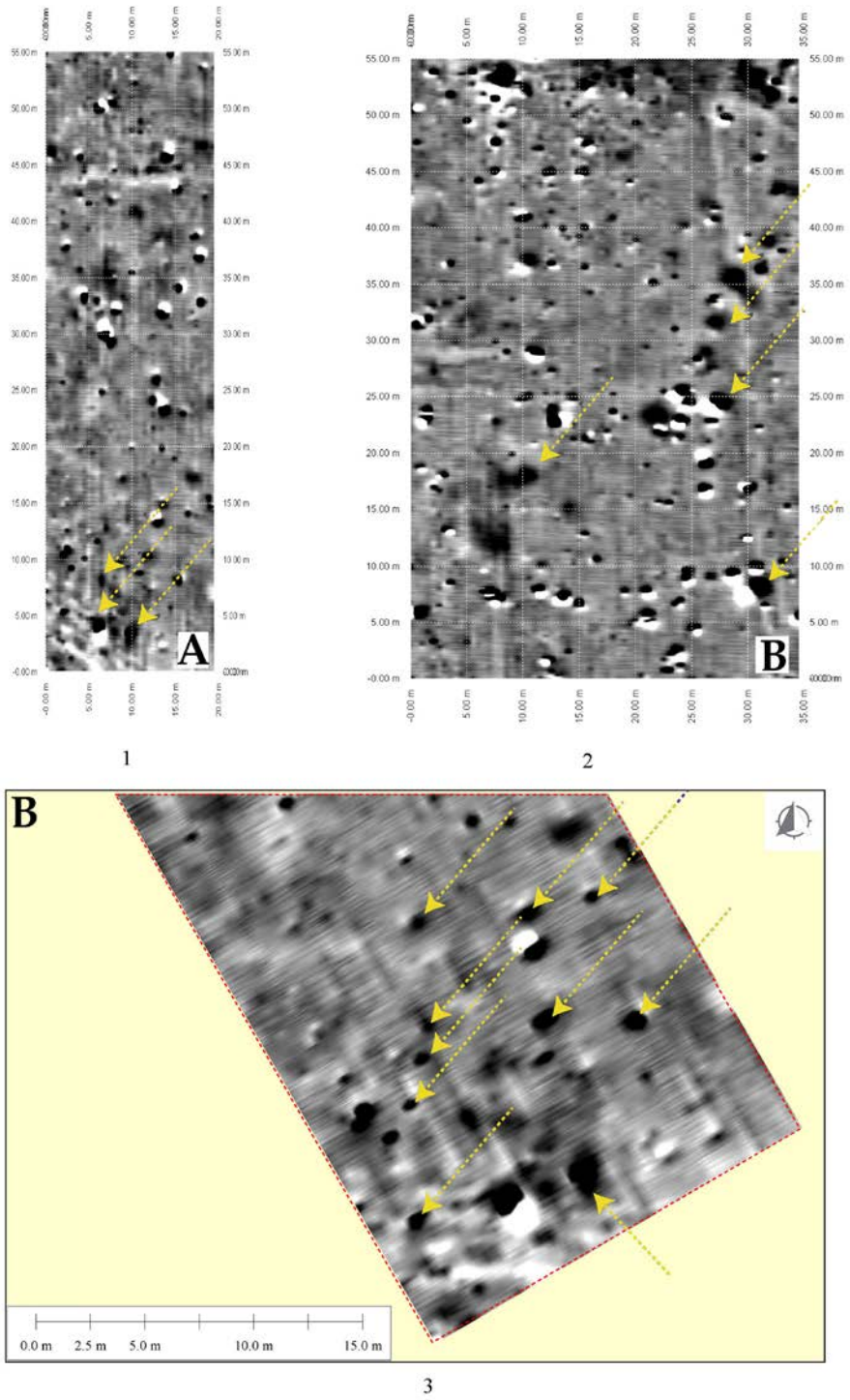

Figure 6 - Processed magnetic data form perimeters A and B
(yellow arrows = magnetic anomalies)

b) In perimeter B (Figure 3B) we observed an elongated anomaly of large size and light color (ie. with negative magnetic values!) representing the traces of a ditch (Figure 3). This anomaly intersects on its route a series of approximately aligned anomalies of about 21 m in length. In the northeastern part, two other large anomalies (about 3.5 m) were identified, which can be attributed to the same complex.

c) At the limit between the investigated surfaces named B and C, there is an anomaly of about 6×8 m (Figure 3C). In the eastern part of perimeter C, there are 2-3 anomalies with a pronounced "archaeological" character, anomalies that reach dimensions of about 3×1.5 m, 1.7×2 m, 1.7×1.2 m, or even 2.2×1.7 m (predominantly rectangular) (Figure 3C). Based only on the magnetic results, it is difficult to accurately postulate the origin or nature of the archaeological complexes that can be associated with them. We are fully aware of the fact that the dimensions of the anomalies do not reflect the real dimensions of the presumed archaeological structures.

d) Perimeter D (Figure 3D) is bounded on the south by a fence with reinforced concrete pillars that could not be removed during the research (one of them is represented in the image processed by the strong light-colored anomaly approximately in the middle of the perimeter). Apart from the anomalies caused by these disturbing elements, we noticed the presence of small anomalies that accumulate negative and positive values, which were associated with metal objects from recent periods, like those in the previous perimeters.

Overall, the magnetic probe managed to determine perimeters with archaeological potential, adjacent to previous excavations, that could be addressed in future campaigns.

CONCLUSIONS

Due to magnetic method's sensitivity to buried iron oxides, it has become one of the most important methods for detecting and mapping artifacts and structures within archaeological sites. Detailed modeling of the magnetic response, in addition to fast and efficient visualization, can provide important information for the reconstruction of an archaeological landscape only intuited by the archaeologist. It can change the vision of approach and interpretation of the cultural ensemble. Usually, the archaeological sites are very complex and due to the limitations of magnetometry, other complementary geophysical methods are required.

In the case of the archaeological site at Urlați, the magnetic investigations outline the theoretical framework of the strategy of future archaeological excavations and bring additional information necessary for the site's protection, management and promotion. In the future we intention to use of other geophysical methods to help to unveil the story of this location.

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