UNDER THE MEDITERRANEAN I

Studies in Maritime Archaeology

edited by

STELLA DEMESTICHA & LUCY BLUE

WITH KALLIOPI BAIKA, CARLO BELTRAME,
DAVID BLACKMAN, DEBORAH CVIKEL, HELEN FARR
& DORIT SIVAN

HONOR FROST FOUNDATION

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Istros, Black Sea Coast, Romania

A geoarchaeological perspective on the location of the harbour(s)

Alexandra Bivolaru, Valentin Bottez**, Andrei Asăndulesei***, AESJBO Vladu**, Tiberiu Sava****, Matthieu Giaime*****, and Cristophe Morhange*******

Istros, founded during the 7th century BCE, is one of the oldest Greek colonies on the shores of the Black Sea. On the southern margin of the Danube delta, what was an ancient maritime city is now a landlocked archaeological site. Even though archaeological investigations have continued since 1914, the location of the harbour(s) remains unknown. Efforts to find a harbour are hindered by the complex geomorphological evolution of the Danube delta and by the long human occupation history of the site. However, a new perspective is offered by a geoarchaeological approach, combining coring with geophysical and archaeological investigations.

Keywords: Istros, ancient harbour, Black Sea, geoarchaeology, paleo-environment, coastal geomorphology.

Inhabited since the Neolithic, with traces of occupation since the Upper Palaeolithic, the Black Sea (Fig. 1) is a peculiar geographical unit, in which a variety of cultural environments developed, so it is almost impossible to speak about a 'collective culture of the Black Sea', in the way we speak of 'Mediterranean culture'. Nonetheless, both the Black Sea and the Mediterranean together represent the cradle of European culture, as their shores have provided favourable environments for human settlements since prehistory. Called Pontos Euxeinos by the Greeks, its shores were highly attractive and thus occupied early in the period of Greek colonization (8th century-5th century BCE), with Miletus the most active metropolis. On the western Black Sea coast, the present-day territory of Romania, numerous *poleis* and *emporia* were founded, among which the best known are Istros (Histria, Istria) – the topic of this paper – Tomis (present-day Constanța), and Callatis (present-day Mangalia). From the 1st century CE, the western Black Sea shore came under Roman and later Byzantine domination (Suceveanu and Barnea, 1991; Avram, 1998), and then passed, during the Middle Ages, under Genoese (Ciobanu, 1969; Balard, 1983) and later Ottoman (Brătianu, 1999) control. Remains of the succession of these various cultures are still visible and well preserved in many cases, including at Istros, as the area has been practically unoccupied during modern and contemporary periods, and so the taphonomic conditions are favourable.

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Figure 1. Satellite view of the Black Sea (Source: NASA).

Main aims

Our research aims to characterize the evolution of the landscape of Istros and to investigate the anchorage locations from the Archaic to the Late Roman Period. The area around Istros had a complex geomorphological evolution, at site level as well as at a regional scale. Additionally, the site's long occupational history creates a complex situation that makes it difficult to clearly identify structures and the position or positions of any harbours. This complicated setting requires a multidisciplinary approach, involving archaeology, history, geography, geophysics, and bio-sedimentology to: better contextualize the archaeological records; identify harbour structures; and characterize the environmental constraints and potential in the development of Istros.

Geoarchaeological research on the western Black Sea coast: state of the art

During the past three decades, geoarchaeological research on the Black Sea coast has been poorly implemented in comparison with the Mediterranean for various reasons including an overly conservative archaeological approach and a weak collaborative network between geosciences and archeo-sciences (Baralis *et al*., 2016: 4-5). However, in the past few years, a new research agenda has emerged. We are witnessing not only increasing collaboration between the various disciplines, but also international participation, which offers a solid framework for multidisciplinary research. In this respect, we can mention the Archéologie du Delta du Danube geoarchaeological research project, started 10 years ago, which studies the paleoenvironmental changes at the Neolithic site of Taraschina, located in the middle of the Danube delta (Carozza *et al*., 2010). There was also the Pont Euxin project (ANR 2009-2013), headed by Alexandre Baralis, which analysed the spatial organization of Greek colonies on the western Black Sea coast with special regard to Argamum (Orgamé, Romania) and Apollonia Pontica (Bulgaria) (Baralis *et al*., 2010; Bony *et al*., 2013; Baralis and Lungu, 2015). In 2015-2016, another multidisciplinary research programme, headed by Christophe Morhange, titled Geoarchaeology of Mediterranean deltaic environments. A comparative approach, was funded by A*MIDEX-GEOMED. It saw multidisciplinary research in four archaeological sites on the Romanian coast: Halmyris, Babadag, Enisala, and Istros (Fig. 2) (Giaime, 2016; Bivolaru *et al*., 2018; Giaime *et al*., 2018). The latest multidisciplinary project, initiated in 2016, is Environmental Change and Geoarchaeology in the Danube Delta since 6000 years, which focuses on the development of several archaeological sites in direct connection with the evolution of the Danube delta (Fig. 2).

At a national level, a series of interesting geomorphological investigations with a special focus on Istros has been undertaken in the Danube delta by a team of geomorphologists from the University of Bucharest (Preoteasa *et al.,* 2012; Vespremeanu-Stroe *et al.,* 2013).

Despite all these projects, no ancient harbour on the Romanian Black Sea coast has been identified with certainty. Still, we have some indications for: possible harbour structures at Orgamé (Bony *et al*., 2013; 2015); a

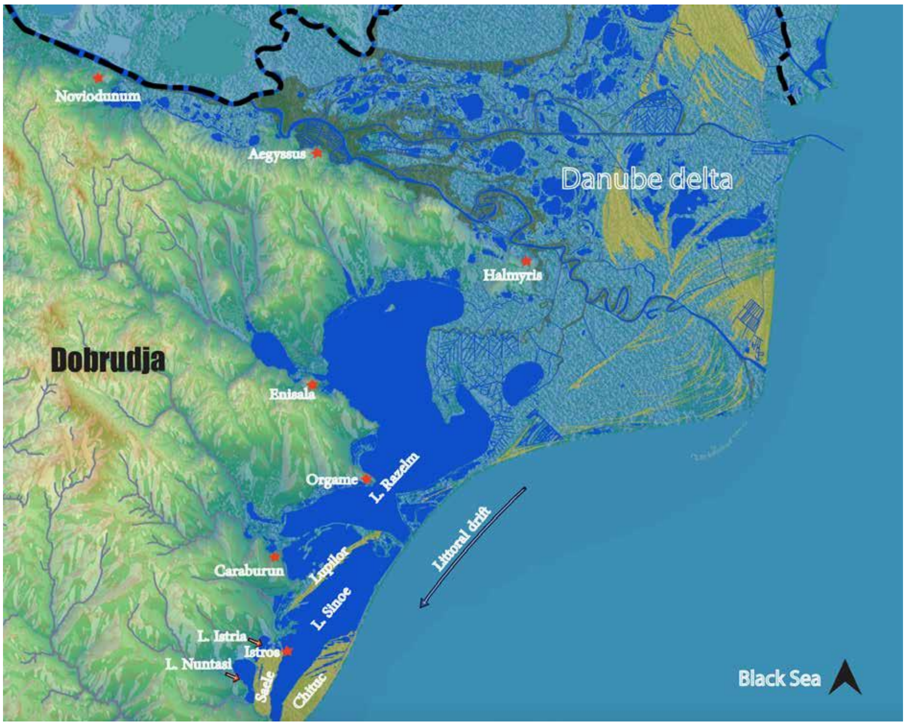


Figure 2. Istros and Danube delta localization within Dobrudja region. Present-day Dobrudja was part of the historical region of Scythia until the 1st century CE when it became Moesia Inferior under Roman rule (Credit: with permission after Stănică and Honcu, 2017. A. Bivolaru).

fluvial harbour at Halmyris (Giaime, 2016; Giaime *et al*., 2018); and a harbour basin at Istros (Höckmann *et al*., 1998; Bivolaru *et al*., 2018). Only further geoarchaeological investigations can shed light on these preliminary discoveries.

Methodology

Our research is the first holistic approach undertaken at Istros, bringing together archaeology, coastal geomorphology, and geophysics. Our paper describes the results from two drilling campaigns, followed by vertical gradient magnetometry and ground penetrating radar (GPR) investigations, and archaeological excavation. The present scientific approach is based on field and laboratory work and applies procedures and techniques relevant to a high-resolution paleo-environmental reconstruction and ancient harbour-basin identification. Details of the use of each method are presented in the following paragraphs.

Geographical setting

The Black Sea is the biggest anoxic basin in the world with a surface area of 423,000 km^2 of which 90% is the deeper basin, with oxygen completely absent starting at 190-200 m depth. After the reconnection with Mediterranean Sea *c.*9000 BP (Soulet *et al.,* 2011), the Black Sea and Mediterranean responded synchronously to glacio-eustatic changes (Brückner *et al.,* 2010). The Black Sea coastline is sinuous, with few promontories running offshore and numerous gulfs. The western coast is largely lowland with few cliffs, and beach-ridge plains separate the lagoons (*limanuri*) from the sea. The western Black Sea has a wave-dominated coast, a condition enhanced by the very low tidal range of 0.18 m (Medvedev *et al.,* 2016). The most important geomorphological feature of the western Black Sea coast is the Danube delta, the second largest delta in Europe, which is an active factor in shaping the shoreline. The Danube delta defines the mosaic-like morphology of the northwestern Romanian shore. The western part of the delta is characterized by a flat area of fluvial and lagoonal origin with a series of levees, while its southeastern part is constituted of marine sand bars, coastal dunes, and shallow lagoons.

Geomorphology of Istros' area

Istros is located in the Dobrudja region, in the Razelm-Sinoe lagoon system on the southernmost beach-ridge unit of the Danube delta (Fig. 2). The Vadu-Istros area is at the end of a littoral cell, and so is strongly affected by sedimentary deposition, as it acts as a trap for the sediments. In the context of general sea-level stabilization since 6000 BP and deltaic progradation (Anthony *et al*., 2014), the area has seen extremely important geomorphological changes and is defined by beach-ridge plains such as Chituc and Saele (on which Istros is located), coastal barriers (Lupilor), and shallow lakes (Sinoe to the east, Istria and Nuntași to the west) (Fig. 2).

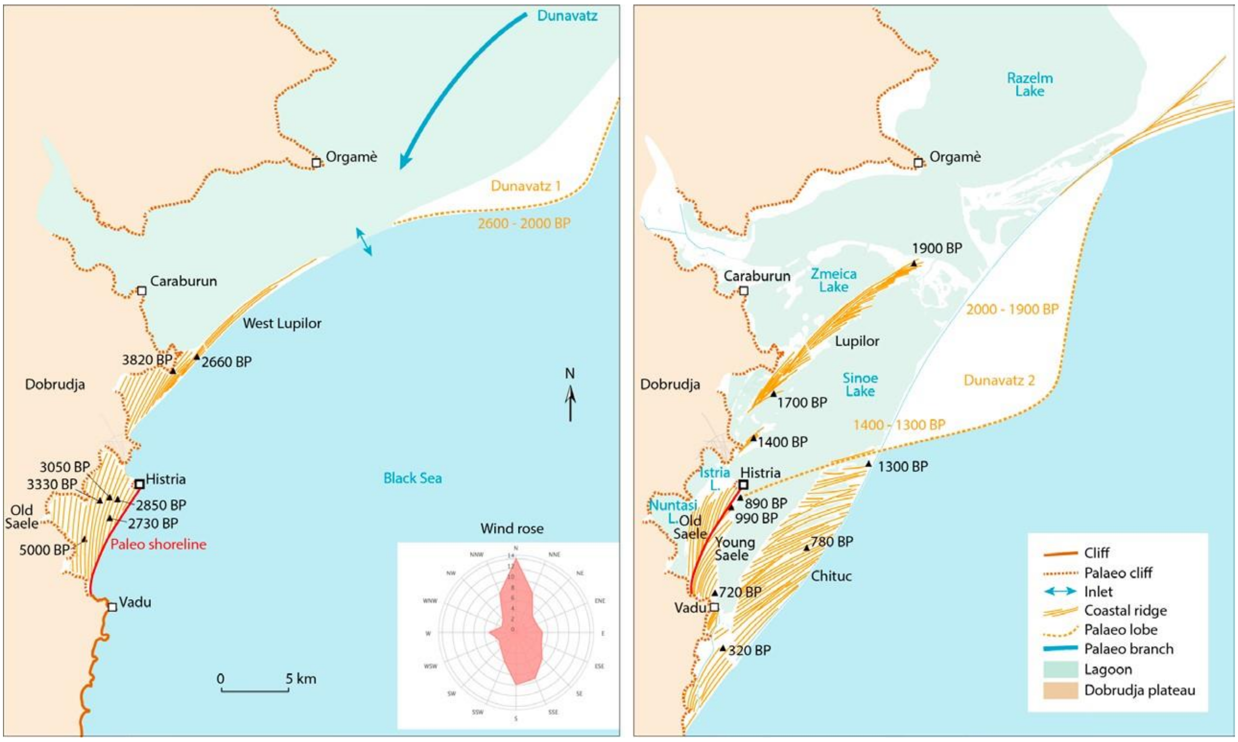


Figure 3. Geomorphological evolution of the area surrounding Istros since 5000 BP. The evolution of the Lupilor, Saele, and Chituc beach-ridge plains is directly related to the change in Dunavatz lobes (Modified after Vespremeanu-Stroe et al., 2017 by P. Pentsch).

The region around Istros has seen a lot of subsidence, notably on the Romanian shoreline where it stands at 4 mm per year (Polonic *et al*., 1999; Vespremeanu-Stroe *et al*., 2013). As such, under the influence of neo-tectonism and eustasy, archaeological layers dating to the period of Greek colonization can be found at a depth of 4-5 m (Dimitriu, 2010).

The Danube delta sedimentary input and the strong northern longshore current both play a role in the 'deadend' of the littoral cell, typified by coastal progradation – the advance of the land into the sea.

The deltaic input and the littoral drift created the Saele beach-ridge plain, which is 9.5 km long, and 3 km wide (Fig. 3). Saele is made up of two distinct geomorphological units: Old (West) Saele and Young (East) Saele (Hanganu, 2012: 58-60; Preoteasa *et al*., 2013: 566; Vespremeanu-Stroe *et al*., 2017: 545-546). The beachridge plain of Old Saele is Optically Stimulated Luminescence (OSL)-dated to *c.* 1350-850 BCE and is almost 2 km wide (Hanganu, 2012: 58-60; Preoteasa *et al*., 2013: 566). It connects the continent to the greenschist island where Istros' Acropolis is located. It has continuously and mistakenly been labelled a tombolo since so-termed by Vasile Pârvan in 1915, but none of the geomorphological processes involved in the formation of a tombolo is present here.

The Old (West) Saele ridge existed when Istros was founded – as attested by radiocarbon and OSL ages (Hanganu, 2012; Preoteasa *et al*., 2013; Bivolaru *et al*., 2018; Vespremeanu-Stroe *et al*., 2017), as well as by the archaeological indicators, such as archaic structures built directly on the sand. Istros lost its access to the sea when the Young Saele and Chituc beach-ridge plains formed as a strandplain. Although their development is a long-term process, these coastal ridges are younger than previously thought, as the OSL dates show (Vespremeanu-Stroe *et al*., 2016). The dating indicates that the evolution of the Young Saele-Chituc strandplain took place 1300-720 BP (Vespremeanu-Stroe *et al*., 2013, Vespremeanu-Stroe *et al*., 2016).

The beginning of the Young Saele-Chituc formation corresponds to the second half of the 7th century CE, when Istros was abandoned. However, the city's decline cannot be related only to a single long-term geomorphological process. Numerous cities and fortresses in the Dobrudja region were abandoned in the 6th-7th century CE amid a generally unstable geopolitical situation; at Halmyris, for example, the same association of environmental and geopolitical factors led to its abandonment in the 7th century (Giaime *et al*., 2018).

In modern times, the dams built on the Danube (especially the Iron Gates I and II dams), have caused the river's sedimentary load to fall from a multi-annual average value of 50 million tonnes per year to less than 25-35 million tonnes per year (Panin and Jipa, 2002). Therefore, the sandy barrier separating the Razelm-Sinoe area (Istros included) from the Black Sea has begun to erode (Dimitriu, 2010).

Istros: historical and archaeological context

Istros was a Milesian colony, founded during the second half of the 7th century BCE in the context of the Great Greek colonization. The city is one of the oldest Greek foundations on the Black Sea coast and was inhabited without interruption for 1300 years until the 7th century CE when it was abandoned as a result of general socio-political instability in the area. From its foundation, the city comprised two nuclei, the Acropolis and the Western Plateau (Fig. 4). Istros's long history can be divided into five main periods:

1. The Archaic period (7th century-6th century BCE): layers from this period have been identified on the Acropolis, where the Sacred Area is located (Alexandrescu, 2005; Avram and Bîrzescu, 2012; Avram *et al.,* 2013), as well as on the Western Plateau, where habitations (Dimitriu, 1966) and pottery kilns (Coja and Dupont, 1979: 18-33) were discovered. Along with these, a segment of the archaic defensive wall was discovered on the western part of the plateau (Coja, 1986: 98; Angelescu, 2005: 57-64; Suceveanu, 2005) (Fig. 4). Structures dating from this epoch were also identified in the centre and the southern part of the Acropolis (Bottez, 2015). Interestingly, there are no archaeological features from the Archaic period between the Classical defensive wall and the Western Plateau, a distance of 450 m.

2. The Classical period (5th-4th century BCE) was characterized by a flourishing economy. Around 450 BCE, Istros started to mint its own coins (Talmațchi, 2011). In addition to the previous occupation areas, new ones were built on the Western Plateau, as well as a new defensive wall for the Acropolis that encompasses a smaller area than the archaic wall (Fig. 4) (Angelescu, 2005: 65-71).

3. The Hellenistic period (4th century-1st century BCE), although initially prosperous, was later marked by geopolitical instability. The city was engaged in local conflicts (the war between Scythians north of the Black Sea and the northern Thracians), as well as regional (the wars between the Hellenistic kingdoms) (Pippidi, 1967). From the early 4th century BCE, a double defensive wall was built in Istros; one wall protected the Acropolis and enclosed a surface of about 10 hectares (Preda and Doicescu, 1966), and the other followed almost the same trajectory as the archaic wall (Fig. 4) (Angelescu, 2005: 70).

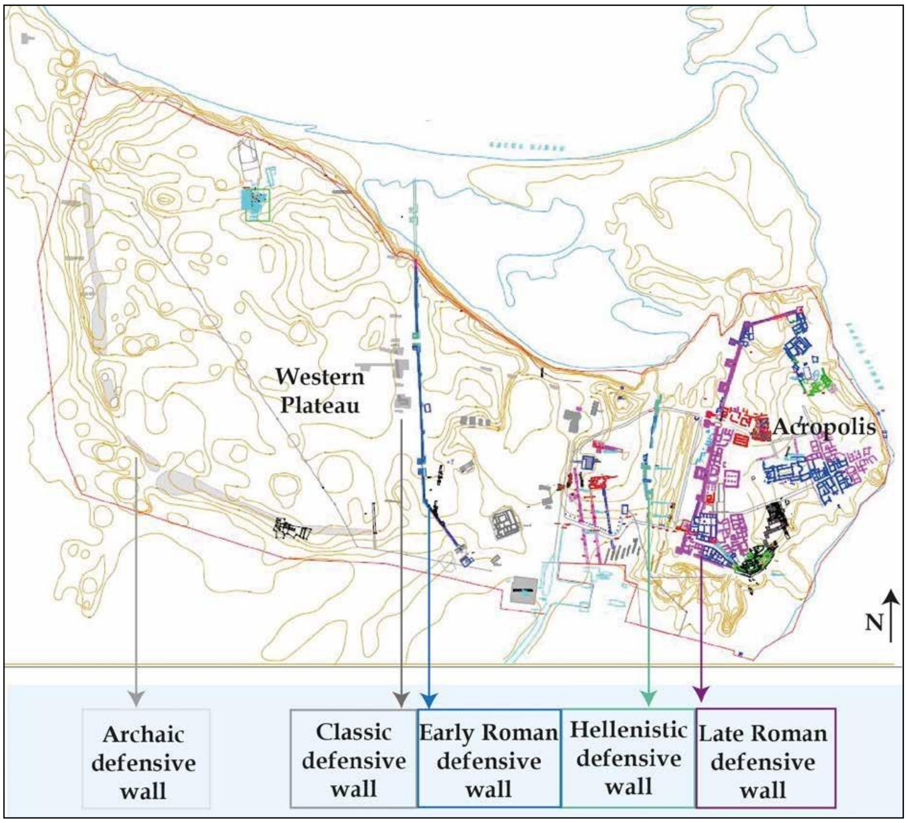


Figure 4. Main archaeological structures corresponding to the five occupational phases. Modified after Mehedințeanu 2003 (Credit: A. Bivolaru).

4. The Early Roman period (1st-3rd century CE) marks the end of Istros's autonomy. Despite this, the city became prosperous once again in the 2nd century CE, as demonstrated by its archaeological material. Another defensive wall was built (Fig. 4) (Florescu and Cantacuzino, 1954), west of the Hellenistic one, while the Sacred Area was abandoned and a residential district built over it (Avram *et al*., 2013). During this period, the city gained two bath complexes (Suceveanu, 1982), as well as the civil basilica in what is now called the Main Square. After a period of stability ensured by Emperor Trajan, Istros was confronted with increased barbarian pressure, starting with the Marcomanic Wars during the reign of Emperor Marc Aurelius. The peak of this conflict was during the second half of the 3rd century CE, when a Gothic invasion caused the city's most violent destruction (SHA, *Max. Balb.* 16.3 mentions the *excidium Histriae*) (Doruțiu-Boilă, 1985: 133-134).

5. The Late Roman Period (4th-7th century CE) represents the last phase of occupation at Istros. After the destruction in the 3rd century CE, a new, last defensive wall was built enclosing about 7 hectares (Fig. 4) (Domăneanțu, 1990). A final period of prosperity is attested archaeologically during the 6th century CE (Suceveanu, 2007). Then the city fell into decline, ending in its abandonment.

The problem of the ancient harbour(s):

archaeological indicators and contemporary research

Even though some secondary archaeological indicators attest the existence of a harbour, no archaeological structures yet discovered at Istros can be clearly related to a typical component of a harbour complex (breakwaters, moles, quays, etc.).

Epigraphic and numismatic sources

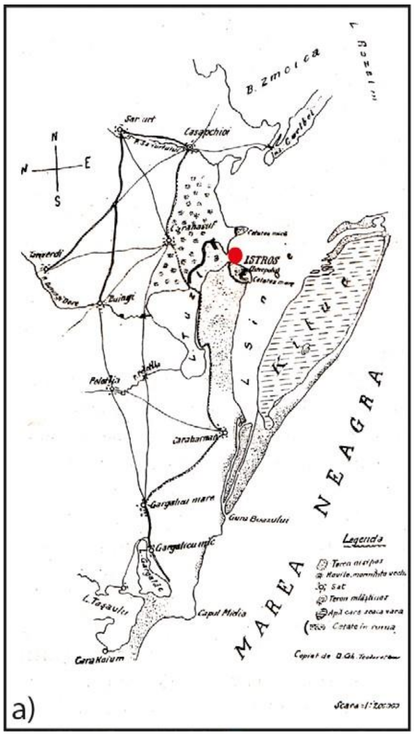
To date, we have 12 inscriptions mentioning the existence of the harbour (ISM I, nos. 10, 20, 25, 28, 32, 48, 64, 65, 112, 173, 178, and 179). The oldest is dated 300-200 BCE and the most recent in the 2nd century CE. Most of the inscriptions, including the one from the 3rd century BCE, are proxeny decrees (Cojocaru, 2016), which grant non-citizens unlimited access to the harbour. One inscription from the 2nd century BCE mentions the existence of an Istrian fleet that offered naval support to Apollonia Pontica (present-day Sozopol, Bulgaria) in its war with Messambria (present-day Nessebar, Bulgaria). A second brief mention of the Istrian fleet is made in another inscription from the 3rd century BCE. The existence of a fleet implies the existence of ship-maintenance structures adjacent to the harbour, such as shipsheds (Blackman *et al.*, 2013: 3). Accordingly, one can presume the existence of such structures at Istros (Höckmann, 2001).

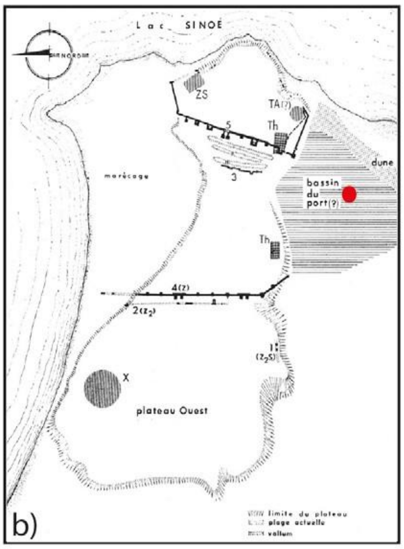
The inventory of inscriptions from the Hellenistic period ends with a secondary reference to the harbour. It is dated to the 2nd century BCE and mentions the cult of Aphrodite Pontia. Considering ancient sources (Demetriou, 2010: 70-81) and archaeological discoveries, the temples and sanctuaries of Aphrodite Pontia are located in the vicinity of harbours (Pippidi, 1983; Demetriou, 2010). Pausanias informs us of the existence of temples dedicated to Aphrodite Pontia on the shores of Epidauros, Limera, Tainaros, Aigion, and Patras (Demetriou, 2010: 70-81). The cult of Aphrodite with her marine epicleses (Pontia, Euploia, Pontica, Nauarchis, and Ourania) has also been attested at Olbia, Pantikapeion, Phanagoria, and Cyzicus (Pippidi, 1983) (Fig. 1).

The last two inscriptions, dated in the 2nd century CE, relate to the harbour and mention the 'remaking' of the harbour under the supervision of a Pontarch. We can interpret 'remaking' as a series of dredging and maintenance works to ensure access to a harbour (Pippidi, 1983: 314), or to relocate it, both due to siltation.

Another indirect proof of the harbour(s) existence is the discovery of two coins, dated to the reigns of Elagabalus (218-222 CE) (Pippidi, 1967: 229; Preda and Nubar, 1973: No. 719, 130; Varbanov, 2005: No. 658) and
Alexander Severus (222-235 CE) (Fig. 5), (Severeanu, 1931: 16-17; Varbanov, 2005: No. 668). On their reverse is a rectangular tower, which can be interpreted as a lighthouse, along with a river god (Danubius). Analogies for this representation are found in the Roman world

Figure 5. Roman coin depicting Alexander Severus on the obverse, the god Danubius and a possible lighthouse on the reverse (Severeanu, 1931: 16-17; Varbanov, 2005: no. 668). (Credit: I. Varbanov).





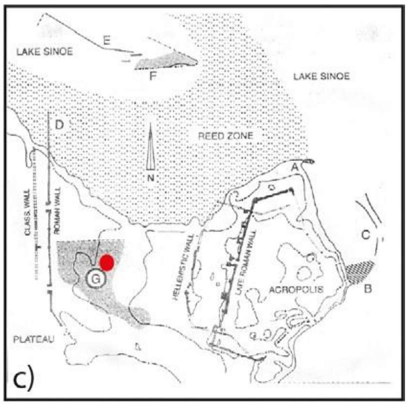


Figure 6. Previous theories about harbour location: a) to the north (Moisil, 1909); b) to the south (Theodorescu, 1970); c) in the central-northern area of the site (with permission, Höckman, 2001).

(Redde, 1979), and a similar parallelepiped tower with three levels and lateral openings is attested in Coruña, Spain (Dabîca, 2011: 217).

Modern studies

The problem of the ancient harbour(s) at Istros has attracted the attention of researchers for more than a century. Constantin Moisil (1909) remarked on a possible submerged harbour in the northern side of the site (Fig. 6a). In a report of 1915, Vasile Pârvan, the archaeologist who started excavations at Istros, mentioned the existence of a possible harbour basin in the small natural depression located in the middle of the site. In the rainy season, this became a shallow, marshy area with access from the north; when it dried, it left a layer of salt – hence the name Sărătură (trans. salted area) (Pârvan, 1915). In an article in 1916, Pârvan presented a series of structures located north of the site, which he interpreted as harbour structures (Pârvan, 1916: 198). No precise geographical indications, drawings, or maps were offered by the author, so it is hard to pinpoint these structures. In the 1950s, Vasile Canarache suggested the harbour could be in the northern part of the site (Canarache, 1956), founding his theory on the discovery of a 200 m-long structure, oriented SW-NE, in Lake Sinoe. In the 1970s, a new theory was elaborated by Dinu Theodorescu who, based on indirect archaeological evidence, placed the harbour on the southern side (Fig. 6b) (Theodorescu, 1970). Considering the information provided by aerial photos, Alexandru Ştefan supported Theodorescu's theory about the harbour's position to the south, but he did not exclude the possibility of a NE location (Ştefan, 1987), a theory also advocated by Octavian Bounegru (1988). Bounegru (2003) postulated the possibility of two harbour basins, located south and north. In the light of geophysical investigations, Olaf Höckmann (Höckmann *et al*., 1998; Höckmann, 2001) postulated that the harbour was in the central-northern side of the site (Fig. 6c), without denying the probability of a southern location as well. Marcu Botzan (1989) suggested a 'race to the sea' – that the harbour was relocated in response to the coast's progradation – basing his theory on a series of ample fluctuations of the Black Sea's mean level between the 9th century BCE and the 7th century CE. Although a possible relocation of the harbour basin should not be rejected, strong regressions and transgressions affecting the Black Sea mean level have been ruled out by recent studies (Porotov, 2007; Brückner *et al*., 2010; Fouache *et al*., 2012).

In search of the harbour(s): the current multidisciplinary approach

The geomorphological situation and the harbour(s) issue

The dramatic metamorphosis of the landscape around Istros during the past two millennia hinders the discovery of any harbour, harbours, or harbour basins. Therefore, we must understand the geomorphological evolution of the landscape – the aforementioned beachridge plains (Saele and Chituc) – and of the Danube delta, the dominant factor in this transformation. In recent years, a team led by Alfred Vespremeanu-Stroe (University of Bucharest) has conducted a series of geomorphological research missions in and around Istros, providing new insights. The researchers have identified a former deltaic lobe in front of the current Periteaşca beach-ridge plain (Fig. 2). The lobe was created by a palaeo-branch of the Danube, the Dunavatz, from around 2600 BP (Fig. 4), (Vespremeanu-Stroe *et al*., 2013; Vespremeanu-Stroe *et al*., 2017). Around 2000-1900 BP, the Dunavatz changed direction, moving southwards and creating another deltaic lobe, 16-20 km south of the first, abandoning the first lobe (Fig. 3) (Vespremeanu-Stroe *et al*., 2013; Vespremeanu-Stroe *et al*., 2017). The new deltaic lobe grew fastest around 1400-1300 BP, extending downdrift close to Istros's northern coast (Fig. 3) (Hanganu, 2012: 65-67; Preoteasa *et al*., 2013: 566-569; Vespremeanu-Stroe *et al*., 2017: 545). A high sedimentary input has been observed after 1400-1300 BP, related to the erosion of the second deltaic lobe. The increase in the supply of sediment led to the formation of the Young (West) Saele and the Chituc strandplain (Fig. 3).

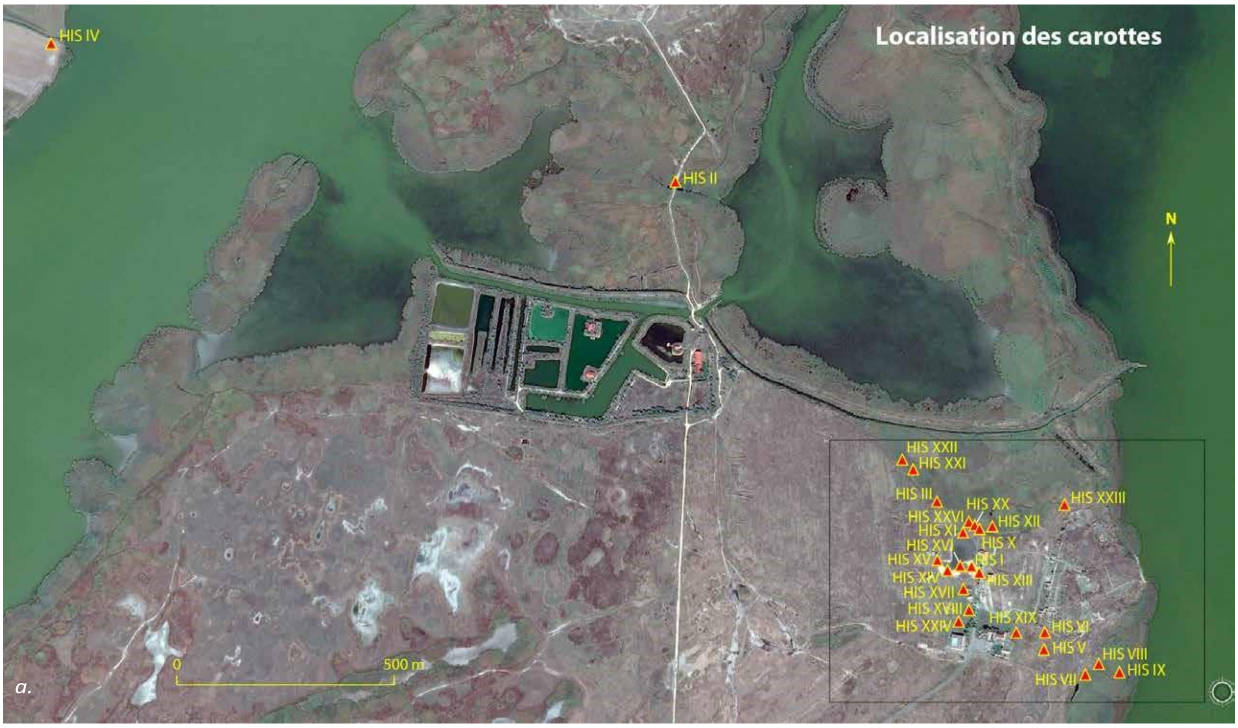
The different alignments of Young Saele (east-west) and Old Saele (northwest-southeast) can be explained by the rapid silting-up of the littoral cell, caused by the erosion of the lobe and by local neotectonism (Hanganu, 2012: 65-67; Preoteasa *et al*., 2013: 566-569; Vespremeanu-Stroe *et al*., 2017: 545). The neotectonism caused the emergence of a contact ridge between Old Saele and Young Saele, which explains the age hiatus between the two geomorphological units (Fig. 3) (Hanganu, 2012: 103-104; Preoteasa *et al*., 2013: 567-568). This ridge maintained Istros' access to the sea until the 6th century CE. Furthermore, neotectonism is at the origin of the Sinoe, Istria, and Nuntași lakes. Lake Sinoe was formed after the subsidence of the Young SaeleChituc strandplain, which evolved as a geomorphological feature at least 950-660 BP (Hanganu, 2012: 70; Preoteasa *et al.*, 2013: 567). The new data, especially the OSL ages, which show the same chronology (1300-700 BP) for Young Saele and Chituc (Hanganu, 2012: 69-70; Preoteasa *et al*., 2013: 569; Vespremeanu-Stroe *et al*., 2017: 545), oppose previous theories that suggest the formation of the Chituc beach-ridge plain caused the transformation of the former Sinoe gulf into a lake (Bleahu, 1963; Coteț, 1966; Panin *et al*., 1983; Panin, 2003).

Coring campaigns and bio-sedimentological indicators

Drilling campaigns and bio-sedimentological analyses were undertaken to define the paleoenvironmental evolution of the site and to reconstruct the location of the harbour or harbours in relation to the past natural conditions. The coring campaign used a percussion corer (Cobra TT). The first coring campaign took place at Istros in 2015, when four long, continuous cores were extracted (Fig. 7). In 2017, using the same technique, an intensive drilling campaign yielding 23 long continuous cores was undertaken. Extraction tubes 40-70 mm in diameter were used. The cores were 2-7 m long. Bedrock was reached at 2-2.5 m below the surface on the southern side of the greenschist island, and up to 5 m below the surface on the northern side. The cores were altitudinally benchmarked relative to the present local Black Sea standard sea-level using a GPS. Core description (texture, macrofauna, organic remains) and sampling were undertaken during fieldwork. The sedimentological description (composition, texture, and colour) and the sampling of cores were carried out directly in the field. Depending on the sediment, the sampling was performed at intervals of 50-100 mm. Bio-sedimentological analyses were undertaken in the sedimentology laboratory of the CEREGE, based on the methodology detailed in Marriner and Morhange (2007). The general sediment texture, including gravel (>2 mm), sand (50 µm-2 mm), and silty clay (smaller than 50 µm) fractions, was determined by wet sieving. Ostracoda were picked from the >160 *µ*m fraction and identified to species level, when possible, using reference manuals (Athersuch *et al*., 1989; Meisch, 2000) and scientific papers (such as Frenzel and Boomer, 2005; Opreanu, 2005; Briceag and Ion, 2013; Williams, 2012; Salel *et al*., 2016). Macro-fossils larger than 1 mm were also identified and assigned to assemblages according to the Mediterranean classification system (Doneddu and Trainito, 2005; Poppe and Goto, 1991; 1993).

The chronology is based on 30 Accelerator Mass Spectrometry (AMS) radiocarbon determinations performed at the Poznan Radiocarbon Dating Centre and at Ro-AMS (IFIN-HH, Bucharest), on charcoal and marine shells (Table 1). We calibrated the ages using Calib 7.1 (Stuiver and Reimer, 1993) and IntCal13 and Marine13 curves (Reimer *et al.,* 2013). For dated shell samples we used a local marine reservoir age of 498 ± 41 14C years BP years (Siani *et al.,* 2000). The discovery of numerous fragments of ceramics allowed us to obtain a high-precision relative chronology for the stratigraphic units through the study of the ceramics typologies. These results confirmed the robustness of the radiocarbon chronology.

Based on the bio-sedimentological analysis of 13 cores (Fig. 8), on chronostratigraphy and in-field observations, we propose a preliminary model for the location of the harbour basin. An initial anchorage, corresponding to the Archaic period, might have been possible on the southern part of the island, on a protected beach, taking into account the NE direction of the storm winds



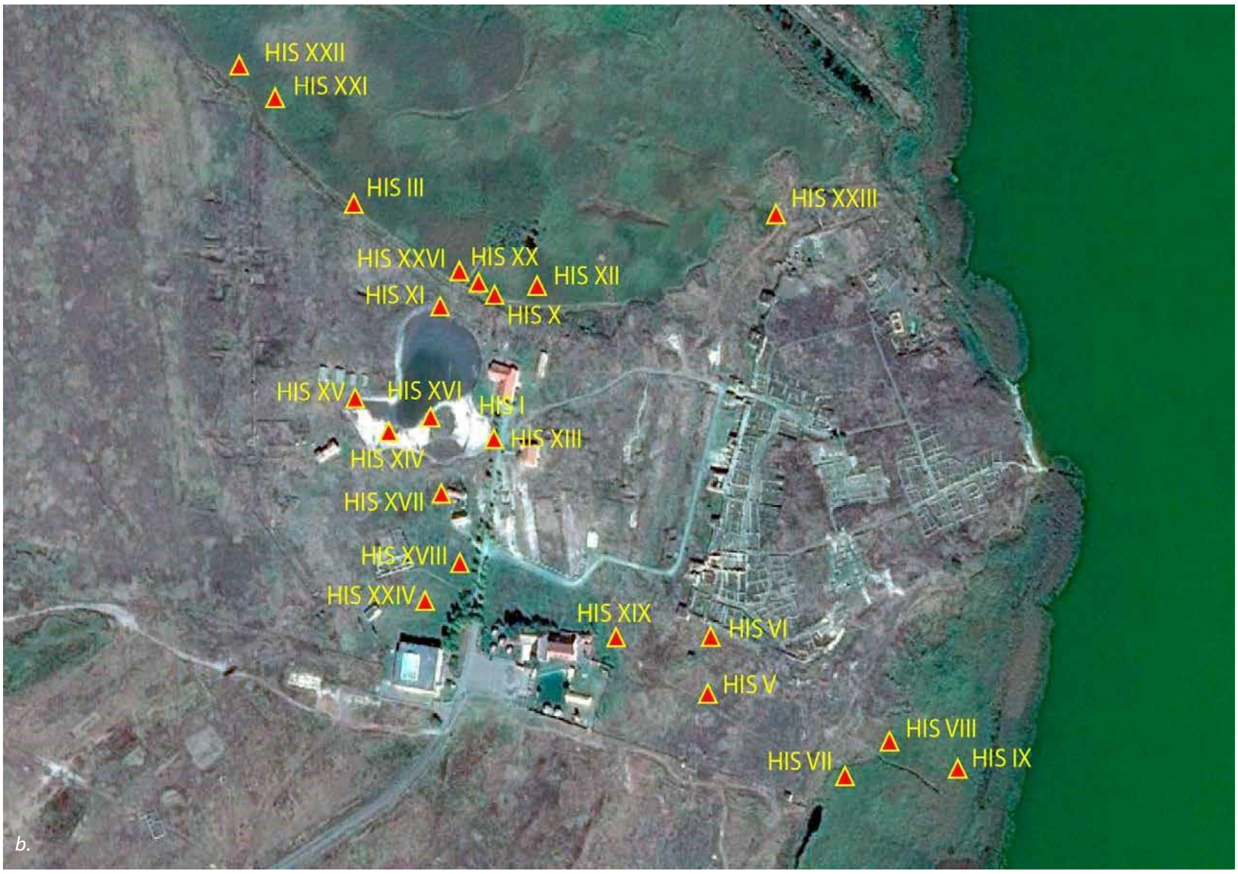


Figure 7. a) Location of coring; b) core locations on the archaeological site (Credit: P. Pentsch).

(Zăinescu *et al.*, 2017), as well as the prevalence of northern wind. The possibility of a second anchorage beach on the northern side of the island is not excluded, as the bio-sedimentological composition of cores HIS XXIII and of the upper unit of HIS XXVII, located in its northwestern corner, is similar to that of cores taken in its southern part (HIS V and HIS IX) (Fig. 8). This sedimentological fraction is defined by coarse yellow bioclastic sand, that together with the low abundance of biological indicators, translates to an energetic environment, such as an exposed beach. A finer sedimentary sequence, characterized by fine micaceous grey sands and silts, was identified in the central-northern part of the site (cores HIS I, HIS XIII and HIS XV). This calm and protected depositional environment, facilitating the accumulation of fine sediments, could also correspond to a harbour basin. Access to the open sea could have been realized via a southern channel, as indicated by the bio-stratigraphy of cores HIS XVIII and HIS XIX. Istros might have had one protected occidental harbour basin – a cothon-type harbour (Carayon, 2005) – and two anchorage areas: southern and northern (Fig. 9). This urban configuration was possible until the beginning of the Late Roman Period (4th century CE), when the city's surface shrank, occupying only the Acropolis (7 hectares) with the abandonment of the investigated area.

From a paleoenvironmental point of view, at site scale, our data suggest the presence of a water body between the Acropolis (palaeo-island) and the Western Plateau. Hence, a question arises: how was communication between the two habitation nuclei possible? We observed in the field the presence of a ridge of uncertain origin (natural or anthropic), which forms the northern limit of the *Sărătură* depression (Fig. 10). Since it appeared a promising area for our research, two cores were drilled on the ridge (HIS X and HIS XX) and a completely different sedimentological composition from the other cores was found. The upper sequence of these cores is defined by silts and clays, overlying a fine grey sand unit, which led us to the supposition that the ridge was built as a dam or as a causeway, allowing communication between the two nuclei. In order to understand the function of the ridge, the information offered by cores was further investigated via geophysical survey and archaeological excavation.

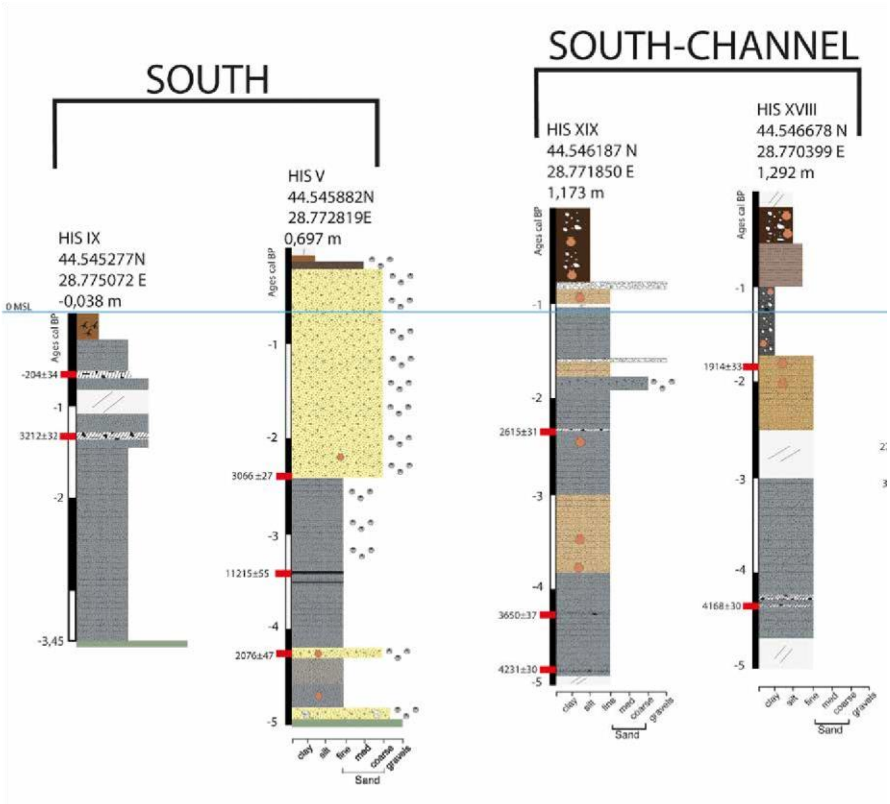
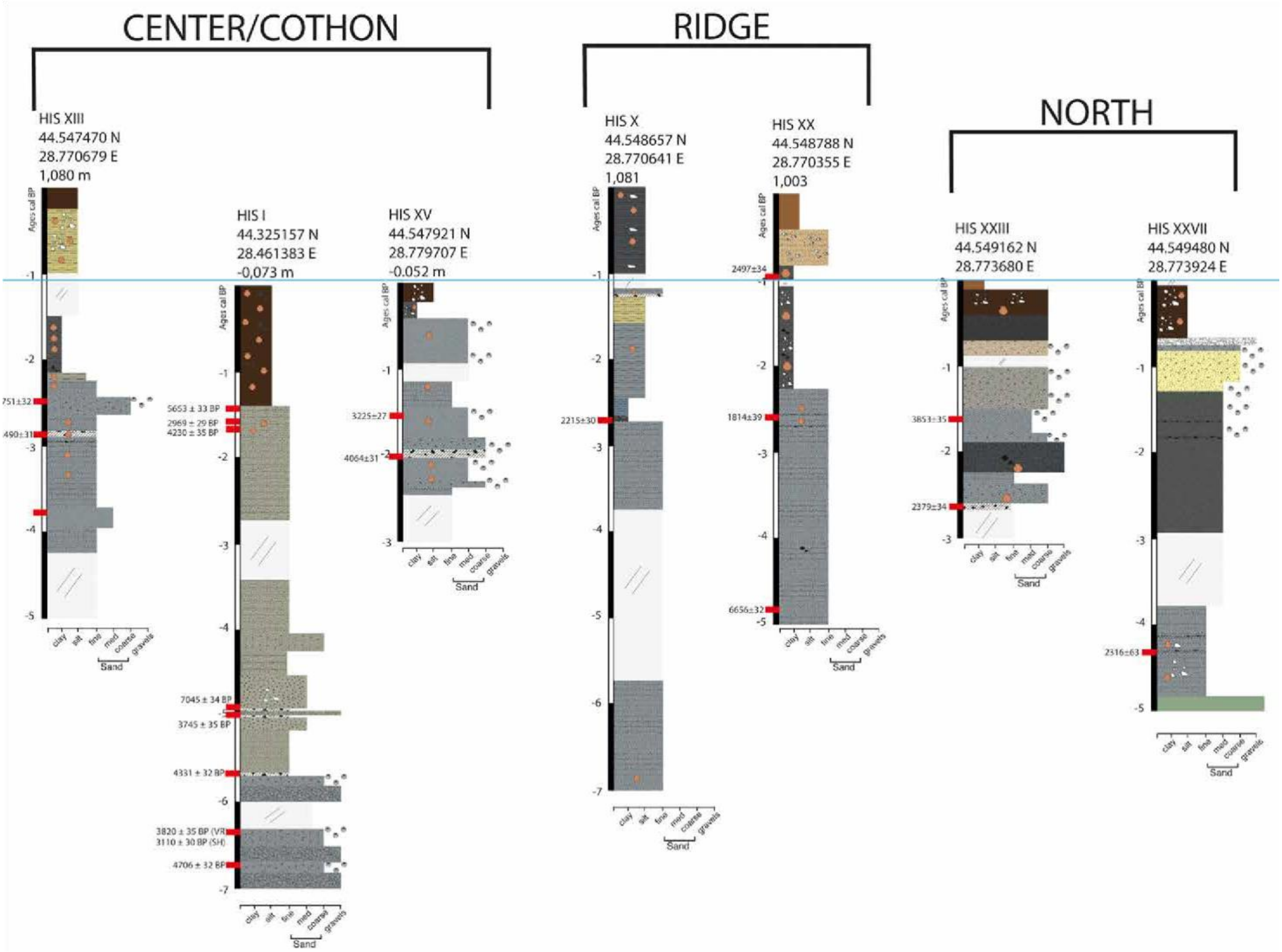


Figure 8 (above and opposite page). The cores used in this study, grouped by research area at site level. The cores are positioned with respect to mean sea-level (Credit: A. Bivolaru).

Geophysical investigations

The non-invasive investigation started in the summer of 2017, and therefore the results presented here are preliminary. Even though there were prior attempts to carry out a geophysical survey of the archaeological site, we do not yet have a complete plan of the city. This should be obtainable at least for the parts of the site that have not been affected by the hydro-geomorphological processes that are active in the area, and for the areas where systematic archaeological research has been undertaken for more than a century. A detailed city plan, together with the identification of archaeological structures that could provide clues to the possible location of the harbour(s), constitute the main objectives of our project.

The campaign that was undertaken in the summer of 2017 was based, on magnetometry: vertical gradient magnetometric survey regularly combined with GPR measurements (Fig. 9). For the magnetometry, we used Sensys equipment with five sensors installed at intervals of 0.5 m and 0.25 m above ground level; we covered a surface of approximately 4 hectares. The GPR profiles were measured with equipment produced by Malå Geoscience, with a 500 MHz antenna. The magnetometric measurements covered a large part of the area around the Early Roman defensive



wall, a surface between the latter and the classical defensive wall, and an area delimited by the northern half of the archaic defensive wall. We sounded the southeastern part of the area between the Early and the Late Roman defensive walls by creating several GPR profiles where, based on sedimentological data, we supposed there is a channel.

Even though modern interventions on the site have generated many perturbations that have sometimes obstructed the archaeological layers, we managed to identify several structures that have a high degree of magnetic susceptibility that could be attributed to cultural layers. Among these are the linear features in the area delimited by the archaic defensive wall: some are also identifiable on the ortho-rectified aerial photographs. These, together with other positive structures in the area, are probably part of a city grid that reminds us of a Milesian or Hippodamian plan (Fig. 9). In the northwestern sector of the Early Roman defensive wall there are also several positive characteristics of a circular or rectangular shape, some aligned or disposed in clusters (Fig. 9). Several of these present strong signs of burning, which are reflected in a powerful thermoremanent magnetism. The southern sector of the same Early Roman defensive wall is highly disturbed, especially by modern interventions, which makes it difficult to identify archaeological structures. There is, though, the possibility that the large anomaly in the southern extremity, which presents strong signs of burning, is also archaeological (Fig. 9). In the southeastern part of the area, between the two Roman defensive walls, there are no structures that manifest a contrast of magnetic susceptibility. In this area, the GPR profiles show continuous sloping structures, oriented southwards. These cannot be interpreted with certainty for the moment, but they can be related to manmade, sloping cobble-stone structures discovered in the proximity of our GPR-investigated area in 2006-2008

Core	Alt (STEREO 70)	Depth below MSL (cm)	Material	Lab code	Age BP & error	Age reservoir	cal 2σ	Remark
HIS_I	-0.073	148-149	wood	RoAMS 526.67	5653(33)	-	4549-4442 BCE	Rejected
HIS_I	-	151-161	charcoal	RoAMS 525.67	2969(29)	-	1278-1107 BCE	Accepted
HIS_I	-	161-162	organic matter	Poz-78016	4230(35)	-	2911-2851 BCE	Rejected
HIS_I	-	483-485	wood	RoAMS524.67	7045(34)	-	6003-5873 BCE	Rejected
HIS_I	-	489-493	organic matter	Poz-78019	3745(35)	-	2213-2035 BCE	Accepted
HIS_I	-	560-570	vegetal remains	RoAMS 523.67	4331(32)	-	3021-2892 BCE	Accepted
HIS_I	-	633-643	organic matter	Poz-78021	3820(35)	-	2351-2192 BCE	Rejected
HIS_I	-	633-643	marine shells	Poz-78333	3110(30)	498(41)	479-190 BCE	Rejected
HIS_I	-	643-653	wood	RoAMS 522.67	4706(32)	-	3470-3373 BCE	Accepted
HIS_V	0.697	171-181	Abra alba shells	RoAMS 834.90	3066(27)	498(41)	1411-1260 BCE	Accepted
HIS_V	-	276	wood	Roams 835.90	11215(55)	-	11258-11030 BCE	Rejected
HIS_V	-	350-360	Abra alba shells	RoAMS 836.90	2076(47)	498(41)	204 BCE-25 CE	Rejected
HIS_IX	-0.038	54-57	charcoal	RoAMS 838.90	-202(34)	-	1955-1957 CE	Accepted
HIS_IX		116-126	vegetal remains	RoAMS 837.90	3213(32)	-	1543-1417 BCE	Rejected
HIS_X	1,081	156-161	charcoal + VR	RoAMS 840.90	2215(30)	-	370-201 BCE	Accepted
HIS_XIII	1,080	142-157	Cerastoderma sp.	RoAMS 842.90	2751(32)	498(41)	976-882 BCE	Accepted
HIS_XIII	-	172-182	vegetal remains	RoAMS 843.90	3490(31)	-	1894-1740 BCE	Accepted
HIS_XV	-0.52	98-108	vegetal remians	RoAMS 845.90	3225(27)	-	1544-1430 BCE	Accepted
HIS_XV	-	148-151	vegetal remains	RoAMS 846.90	4064(31)	-	2680-2487 BCE	Accepted
HIS_XVIII	1,292	101-111	vegetal remains	RoAMS 848.90	1914(33)	-	9-172 CE	Accepted
HIS_XVIII	-	276-284	peat	RoAMS 849.90	4168(30)	-	2820-2660 BCE	Accepted
HIS_XIX	1,173	122-132	vegetal remains	RoAMS 850.90	2615(31)	-	860-791 BCE	Accepted
HIS_XIX	-	311	peat	RoAMS 851.90	3650(37)	-	2137-1927 BCE	Accepted
HIS_XIX	-	363-364	peat	RoAMS 852.90	4231(30)	-	2909-2858 BCE	Accepted
HIS_XX	1,003	12-0	charcoal	RoAMS 853.90	2497(34)	-	790-510 BCE	Rejected
HIS_XX	-	152	charcoal + VR	RoAMS 855.90	1814(39)	-	119-263 CE	Accepted
HIS_XX	-	380-390	peat	RoAMS 856.90	6656(32)	-	5636-5526 BCE	Accepted
HIS_XXIII	0	0	vegetal remains	RoAMS 860.90	3853(35)	-	2461-2267 BCE	Rejected
HIS_XXIII	-	0	peat	RoAMS 861.90	2379(34)	-	543-391 BCE	Accepted
HIS_XXVII	0	0	peat	RoAMS 863.90	2316(63)	-	545-201 BCE	Accepted

Table 1. Radiocarbon ages of cores used in this study.

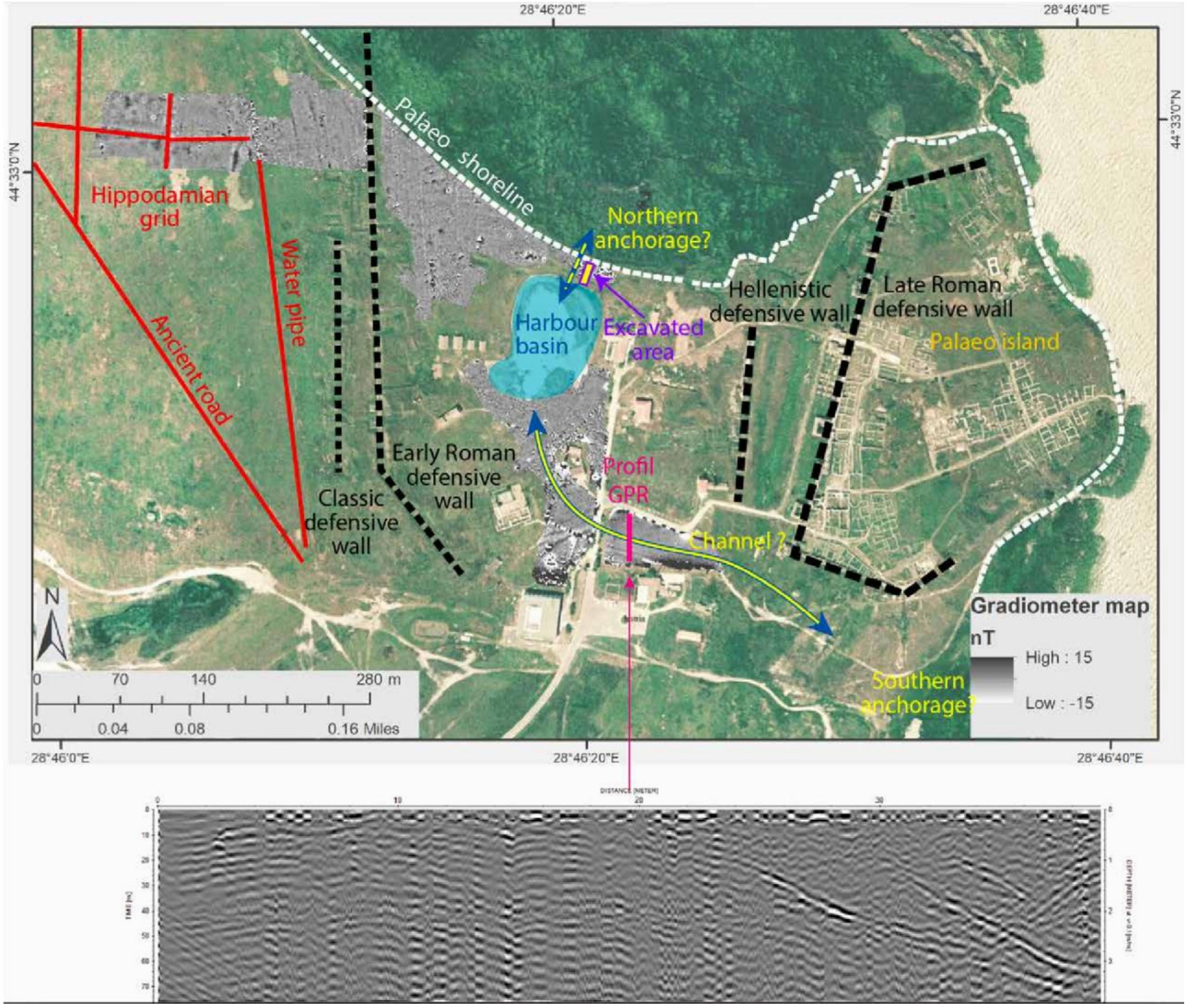


Figure 9. Possible harbour and anchorage locations based on the present geoarchaeological investigation (sedimentary cores, vertical gradient magnetometry, GPR and archaeological excavation). A protected harbour could have been located in the central-western part of the site, connecting a southern and/or northern anchorage via a channel (Credit: A. Asăndulesei, P. Pentsch).

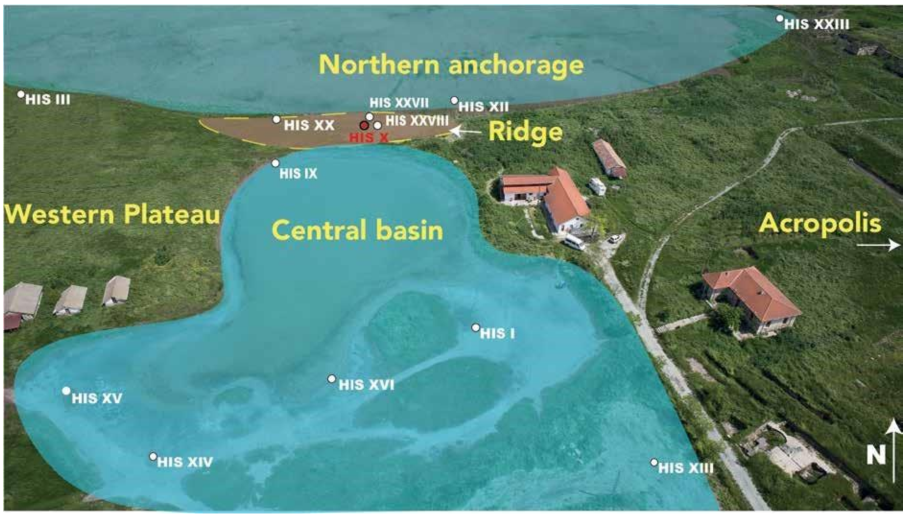


Figure 10. Position of the ridge and the two bodies of water. Core HIS X (in red) indicates a possible causeway/dam in this area (Credit: A. Bivolaru, A. Asăndulesei).

(Dabîca, 2011), interpreted as ramps related to harbour activity. Until further investigations, the observed features could also correspond to successive phases of accumulation of a beach-ridge.

Archaeological excavation

In 2017 and 2018, we conducted two archaeological surveys, S001 (with an additional trench named S002) and S003. The surveyed sector was named Sărătură because of its vicinity to the natural depression. The two trenches are located on the ridge between the northern margin of the Sărătură depression and the northwestern marshy shore of Sinoe lake (Fig. 11).

The 2017 trench is oriented N-S (perpendicular on the ridge) and measured 17 m long, 2 m wide, and 1.8 m deep (Figs 12-13). The excavation was stopped at this depth because of the groundwater table, which prevented us from going deeper in the absence of professional equipment.

Stratigraphically, we identified 22 units registering successive phases of occupation-abandonment-levelling. We discovered three archaeological structures at different depths, oriented NW-SE, and a semi-circular structure (Fig. 14). Also, we brought to light a rectangular structure, oriented N-NW-S-SE, that we preliminarily interpreted as a pilaster base, associated with the second Late Hellenistic structure (Fig. 14). All three superposed structures are rectangular and are built from local greenschist and limestone. They are made of medium stones (approx. 400 × 400 mm), faced only on the western side. The semi-circular structure is built of small stones – greenschist and limestone – and bricks. The so-called pilaster base is built of greenschist and limestone bonded with earth. During the excavation, no debris that could have been associated with a superstructure was discovered. For each structure an occupation layer has been identified, followed by an abandonment and afterwards by levelling with sand. An important remark relates to the spatial distribution of the structures: they are all located in the centre of the 17 m-long trench. No other structures have been identified south or north of them, and the artefacts recovered from these areas are very few in comparison to the quantity discovered in the area where the structures are concentrated.

The pottery from the excavation is in a relatively advanced stage of fragmentation, which makes its study difficult, but it can be mentioned that there are at least two, and possibly three phases. The material from the highest levels is dated from the middle of the 1st to the beginning of the 2nd centuries CE. There were fragments with a wider dating range within these contexts, up to the end of the 2nd-beginning of the 3rd centuries CE, but their association with a large number of sherds generally dated from the second half of the 1st century CE (50/75-100/125 CE) shows that some of these forms have an early dating in this case.

A second group corresponding to a second phase consists of material associated with the end of the 1st century BCE-beginning and the first half of the 1st century CE. The material is very heterogeneous and is defined by pottery, bones, worked antler (Beldiman *et al.*, 2019), metallic fragments, several coins, a large number of terracotta statuette fragments, and a Hellenistic stamped tile. 'Transitional' pottery types appear in these contexts marking the shift from the Late Hellenistic period to the Early Roman. From these contexts, we recovered Early Roman ceramics together with Late Hellenistic fragments and even forms and products that present the characteristics of both.

The function of these structures is unclear because the narrow width of the trench (2 m) prevents a definitive interpretation; still, we can draw some conclusions. First, the quasi-total absence of Late Roman material (only a few pottery sherds were discovered in the vegetal layer) indicates that the area was no longer in use during the Late Roman Period. The lack of structures and reduced number of artefacts in the northern and southern extremities of the trench and the thick layers of sand discovered in these areas might indicate works (that is the intentional deposition of sand), related to the micro-topography, such as stabilization or levelling of the land. The fact that the structures are faced on only one side suggests that only one side was visible. This indication, along with their orientation, which has remained the same for at least three centuries, led us to interpret them as possible terracing structures.

The 2018 excavation consists of a trench 15 m long and 2 m wide, with a depth of 0.50-0.70 m. The section (S003) is located east of the 2017 excavation, perpendicular to it and oriented E-W (Figs 12-13). On the northern side, the excavation possibly overlapped about 1 m of a test pit excavated in the 1980s and its resulting spoil. The substructure of a street was found over a length of 7 m, at a depth of -0.54 m in the eastern end of the section and -0.70 m in the western end (Fig. 15). It is built of stones, fragments of tiles and bricks, as well as ceramic and bone fragments, bound with yellow clay. In the rest of the trench, no other structure was clearly identified. In squares B_{3-4} at a depth of -0.64 m, a limestone slab was identified, oriented NW-SE and heavily weathered. Another possible slab was observed when clearing the ground, located at the SE corner of the identified one and with the same orientation, but it was impossible to conserve it as the limestone was highly degraded; however, it was recorded in position. The archaeological material discovered in 2018 is heterogeneous and with a high degree of fragmentation. The ceramic material constitutes most of the assemblage. From the chronological point of view, it corresponds mostly to the Late Hellenistic-Early Roman periods (1st century BCE-1st century CE).

Discussion and perspectives

As shown by previous studies (Preoteasa *et al.*, 2012; 2013; Vespremeanu-Stroe *et al.*, 2017), Istros had access to the sea throughout its existence. The transformation from a maritime city to a landlocked site happened after the abandonment of the city in the 6th century CE, as proven by the new OSL ages from Sinoe lake (Vespremeanu-Stroe *et al.*, 2017). Although the city had access to the open sea, it suffered because of the impact of high sedimentation related to deltaic progradation, as the area is the end of a littoral cell. Under the impact of the sediment supply, together with climate, movements of the Earth's crust (tectonics and isostasy), soil erosion, and land use, the identification of the harbour or harbours is challenging. Along with these factors, the

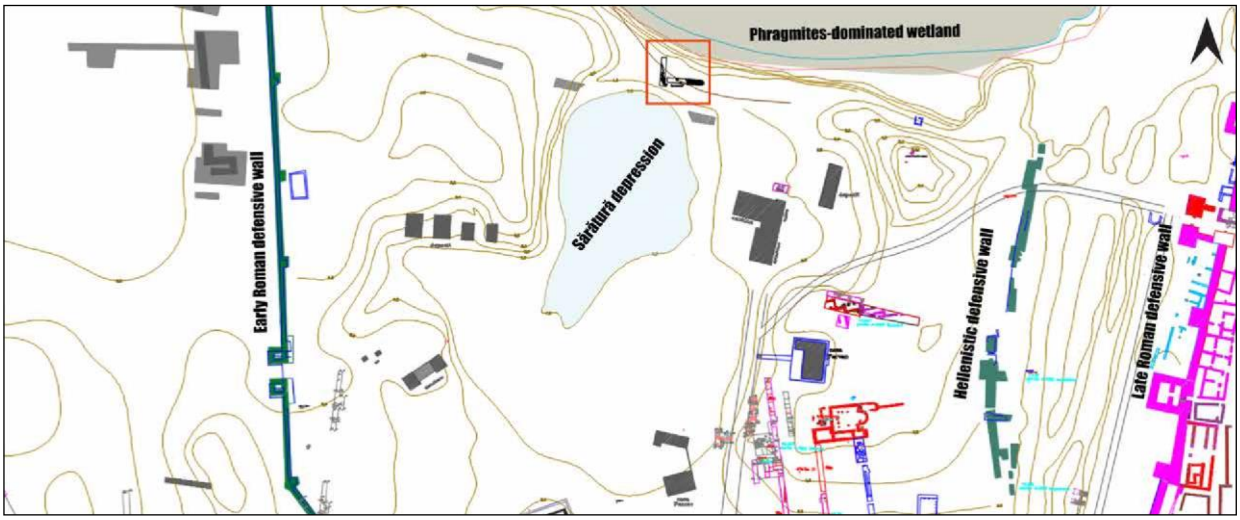


Figure 11. Localization of archaeological surveys. Above: the position of the excavation on the general topographical plan (Credits: V. Bottez after Mehedințeanu, 2003). Right: the investigated area, aerial view from a drone (Credit: A. Bivolaru, A. Asăndulesei).

intense occupation of the city for 1300 years complicates the problem, as Istros underwent numerous urban changes, for both natural and cultural reasons.

Our paleoenvironmental reconstruction indicates the presence of seawater in the central-northern part of the site (Sărătură depression), as well as south of it, in what we called the 'channel' area. The dominance and monospecificity of brackish-marine taxa both for ostracods (Pontocythere elongata) and molluscs (Abra alba) suggest a shallow-water, coastal habitat. The low species diversity, typical of lagoonal environments (Carbonel, 1980; Guelorget and Perthuisot, 1983; Akoumi-

Figure 12. General archaeological plan (Sărătură sector) (Credits: V. Bottez).

Figure 13. Aerial photo of the excavation (Sărătură sector) (Credits: L. Cliante).

Figure 14. The structures discovered in 2017 (Credit: A. Bivolaru).

nanki and Nicolaidou, 2007; Bony *et al*., 2015), suggest the existence of an open lagoon, with a strong seawater influence, in the aforementioned zone. However, the environment of this area is a low-energy setting, as shown by the presence of thick, fine-sand deposits, overlapped by fine-sediment layers (silts and clays) from which we recovered numerous artefacts, mostly ceramic sherds. The presence of the artefacts proves substantial anthropogenic activity in the area. In contrast, the cores from the northern and southern sides of the island, show a much coarser grain size distribution, fewer or no biological proxies, and fewer archaeological indicators. Even though suitable for landing boats or ships, none of these areas indicates a protected harbour-like environment.

The localization of a protected, most probably manmade harbour basin in the central-northern part of the site is revealed by bio-sedimentological signals. Two questions arise from its possible identification: firstly, when was the basin built and when did it of go out of use; and secondly, how was passage between the two nuclei achieved if the harbour basin separated them?

For the chronology, we know from epigraphic sources that a harbour installation existed at least since 300-200 BCE. Moreover, the existence of a fleet mentioned in the 3rd century BCE implies the existence of certain ship-maintenance structures. As such, from at least the end of the Classical period and beginning of the Hellenistic period, Istros had a manmade harbour structure. Based on our chronostratigraphic data, a radiocarbon age of 370-201 cal BCE was obtained from core HIS X, in a transitional phase from fine grey sand to fine grey silts, associated with a change in biological content. The shift between ostracod taxa from *Pontocythere elongata* to *Cyprideis torosa* and *Heterocypris salina* means a decrease in salinity, indicating a low input of seawater. A clear change is observed in the depositional mechanism, corresponding most probably with the harbour basin set-up. Moreover, in the cores from this zone, we noticed many chronological aberrations, corresponding perhaps to maintenance or dredging works, which we know were implemented sometime in the 2nd century CE from epigraphical sources (ISM I 178; ISM I 179). A more refined chronology would help our research, most probably obtained using other dating methods, such as OSL.

The construction of the harbour has very important implications in terms of topography and urban planning. The question of connecting the Acropolis and the Western Plateau led us to open an excavation in an area long-ignored by archaeologists. The discovery of the substructure of a street shows that at least during the beginning of the Late Hellenistic-Early Roman period, the ridge area was used as a passage. Also, the lack of Late Roman material originating from occupational or abandonment layers shows clearly that the area was no longer used by the end of the Early Roman period. The four structures discovered in 2017 could have been used as terracing constructions to facilitate the connection between the Acropolis and the Western Plateau. Their spatial distribution, located in a small part of the 17 × 2 m trench, and the thick layers of sand present north and south of them could indicate the presence of a natural border – a waterbody. The sand layers may correspond to stabilizing or levelling the land. The reduced amount of construction materials found may be an indicator of the low height of these structures or of the use of adobe which, for taphonomic reasons, has not been preserved. Their orientation NW-SE could also be related to communication between the central basin and the northern anchorage spot, marking a possible channel. The substructure of the street exhibits a slope westward, towards the terracing/bordering structures. The relationship between the structures and the street is still unclear, but the structures might represent a step or limit to the former.

At the same time, the heterogeneity of the material found in the abandonment levels may indicate the use of the space as a waste depot. A similar situation, with highly varied ceramic material broken *ab antiquo* was described as a harbour depot by Cibecchini and Bargagliotti (2011) at Portus Sabris. Rubbish often accumulates at the base of quays and in unloading areas (Morhange *et al.*, 2015). Thus, we can advance the hypothesis that the ridge was linking an unloading area related to the harbour basin located in the central part of the site with the two habitation nuclei, the Acropolis and the Western Plateau.

All these results provide new, valuable information concerning how the city functioned, the location of its main economic hotspots – the harbour(s) – and how the two main urban units, the Acropolis, and the Western Plateau, were connected.

Figure 15. The substructure of the street discovered in 2018 (Credit: A. Bivolaru).

Acknowledgements

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