SAPIENZA UNIVERSITY OF ROME

ARCHMAT
(ERASMUS MUNDUS MASTER IN ARCHaeological MATerials Science)

Paleo-environmental reconstruction of Karaburun coast: A geoarchaeological approach

Awet Teklehimanot, 1825350

Donatella Magri, Sapienza University of Rome
(Supervisor)

Christophe Morhange, Aix-Marseille University, CEREGE Lab
(Co-Supervisor)

Rome, September 2018

Acknowledgements

This research, as a part of my Erasmus Mundus Master in ARCHMAT, is fully funded by the E. A. C. E. A. scholarships.

I would first like to express my very great appreciation to Professor Christophe Morhange (Aix-Marseille Université) and Professor Donatella Magri (La Sapienza Universita di Roma), my thesis advisors. Their considerate guidance, passionate motivations and incredible academic potential consistently allowed this paper to be my work and steered me in the right direction whenever I needed it.

I would also like to extend my gratitude to Alexandra Bivolaru (Aix-Marseille Université, CEREGE) and Matthieu Giaime (Aix-Marseille Université, CEREGE) for their support in my experimental work and I am gratefully indebted to their valuable assistance on this thesis.

Furthermore, I would like to send my heartfelt thanks to all the participants in the research for their genuine, polite and honest information. At last but not least, I would like to thank my beloved family for their moral support and motivations.

Abstract

Located between Istros and Orgamè, Karaburun is one of the archaic Greek colonies in the southern Danube delta with an occupation period beginning in the mid-6th c. BC. Nowadays, the remains of the ancient settlement are located close to the shores of lagoon Goloviţa within the Razelm-Sinoe lagoon system which forms the southern part of the Danube Delta. The archaeological and geomorphological data from the site indicates its co-existence with the neighboring ancient cities of Istros and Orgamè on the western Black Sea littoral. However, while research have been carried out in these two major cities, the case of Karaburun has been overlooked. Nothing has been done regarding questions of environmental evolution of the coast to explain the anthropogenic and natural processes that had impact on the settlement. The present study deals with the late Holocene coastal landscape transformation from a paleo-lake stage to the present-day lagoon system. It follows a geoarchaeological approach based on the multi-proxy analysis of 4 cores collected from the area surrounding the site. Sedimentology and fossil micro-fauna (mainly ostracods) methods coupled with ^{14}C (AMS) dates were applied with the aim to resolve the following questions: coastal dynamism and its connection with Istros and Orgamè. Moreover, various other factors that led to geomorphological reform in the southern Danube deltas are incorporated to answer the hypothesis raised here.

Keywords: Paleo-environment, Karaburun, bio-sedimentology, Black Sea, Southern Danube Delta

List of Figures

Table of Contents

Chapter One: Introduction

This thesis presents the paleoenvironmental aspect of Karaburun coasts, i.e. Acic-Suat area, an archaic Greek settlement in Southern Danube delta, western Black Sea (Fig. 1). "Karaburun/Caraburun" appears several times in the studies devoted to the territory of Istros, marking the most northerly of the Greek city before it continues, further north, Vişina and Orgamè settlements (Baralis et al., 2017). Although it was noticed as early as the end of the 19th century by K. F. Peters (Peters, 1867), who thought he would recognize the remains of Istros, its location is nowadays still subject to some approximations despite the discovery of archaeological materials, as well as surveys conducted in 1982-1983 by A. Avram, O. Bounegru and C. Chiriac (Avram et al., 1985). A geoarchaeological approach through the application of geoscience techniques developed and refined during the past two decades seems inevitable to comprehend the dynamism of the environmental as well as cultural territories of the settlement. Arising from two geoarchaeological projects (GEOMED, 2015 and COFUND, 2016), this work uses multi-proxy analytical methods such as sedimentology and microfossil analysis supported by relative and ^{14}C(AMS) chronologies.

The concept of coastal geoarchaeology and its methodologies have been applied in other sites of the Mediterranean (Morhange, 1994; Marriner & Morhange, 2007; Brückner et al., 2010; Goiran et al., 2010; Salomon et al., 2018), however, very little is said on the subject in Southeastern Europe, Western Black Sea littoral. This paper aims to give an insight on how the subject has developed over the last 20 years in this area and to present the pioneer projects related to coastal paleoenvironment. Ancient coastal (natural anchorages, artificial harbours, etc.) archives have been demonstrated to be appropriate to address many environmental and cultural questions, at multiple historical and geographical scales (Morhange et al., 2001). It is within this context that the hypotheses, research methodologies and scope of this paper have been formulated. A review of the theoretical and methodological literature on the the geomorphological and archaeological context of the Black Sea, the Danube delta and archaic Greek settlements in the Black Sea are given in chapter two. In the methodological literature review, only the general procedures are given since the specifics are referred to in chapter three.

The experimental part was carried out at the CEREGE laboratory, Aix-en-Provence, France. A suite of methodologies including sedimentology and fossil micro-fauna (ostracods) have been applied following Marriner & Morhange (2007). This was done on four cores extracted from the surrounding the site of Karaburun. Due to some limitations, however, only three of the cores are discussed in detail. The sedimentological analysis gave positive results, which helped to realise the evolution of the coastal environment. But regarding the ostracods, all the cores are devoid or with very low content (not more than 15 valves). Chronostratigraphic models were developed using the Tilia software and then the graphics were arranged with Adobe illustrator for better data representation.

Furthermore, a detailed interpretation of the results is given in chapter three. Despite the limitations, the results obtained gave an interesting evolutionary view of the Karaburun coasts. A synthesis of these data, complemented by archaeological and environmental studies of the Razelm-Sinoe lagoon complex, is given in chapter four to reach conclusions and hypothesise further investigation.

1.1. Context and Motivation of the study

The study of the relationships between ancient societies and their coastal environment has not been studied in detail until the 1990's (Marriner, Morhange, & Goiran, 2010). In southeast Europe, Romanian coasts of western Black Sea, there is much to be done concerning how ancient societies and their coastal environment responded to climatic disturbances during the last 6000 yrs. Nevertheless, this region shows a remarkable diversity of such phenomenon over space and time. Two geoarchaeological research projects (GEOMED &COFUND) are the pioneering works on this subject, hence are the basis for this work.

In 2015-2017, the GEOMED project-a collaborative network of international research between France, Spain, Italy, Romania, Israel and Russia- aimed at quantitatively characterising the connections that existed between the ancient societies and their environments at various temporal and spatial scales along the deltaic banks of the Mediterranean and the Black Sea. It followed a multidisciplinary approach including archaeological, historical, geographical, geomorphological and bio-sedimentological data as well as modelling and 3D reconstruction of archaeological sites. Using integrated methodologies that have been used and developed for over a decade, the project presented a synthesis of sedimentary archives from coastal areas in-line with archaeological context. The comparative analysis of data from Turia (Spain), Birgi/Mozia (Italy), Danube (Romania), Akko (Israel) and Kuban (Russia) allowed to cross-examine the economic, social and food supply strategies of these societies in relation to their degree of technical development and hence bring to the fore their adaptability in particularly mobile and changing environments.

A PhD project (COFUND, 2016-2019) launched new research focusing on the relationships that existed between ancient societies and climate changes, at different temporal and spatial scales along the coast of the Danube Delta (Romania and western Ukraine). This high-resolution research work based on a multidisciplinary and multi-sectoral approach includes biological (pollen, ostracods, arthropods), geological (sedimentology, isotopic geochemistry) and civilizational markers (archaeological reconstruction) under environmental stress. It uses sedimentary archives from coastal areas to reconstruct paleoenvironmental dynamics and climate to better contextualise the archaeological record. Looking at the late Holocene development of deltaic settlements and the geomorphology of their environments, it intends to describe the climatic forcing agents of such dynamism.

Along with the above mentioned projects, the following factors motivate this research: (i) the dearth of research on the utilisation of geomorphological and archaeological data to demonstrate the past human-environment-climate interaction in coastal landscapes; (ii) the difficulty to identify where the territories of archaic Greek colonies (i.e. Istros and Orgamè) laid in the southern Danube delta; (iii) to resolve problem ii, there is a need to contextualise the coastal environment of Karaburun with respect to lagoon Goloviţa and Orgamè, and the beach-ridge barriers. Although Caraburun seems to experience a less favourable nautical quality, its mere position in between the two-major archaic coastal cities with its well-protected maritime environment makes it a potential site for research.

1.2. Research hypotheses

Karaburun, a settlement with uncertain social/political status, shares the most northerly territory of Istros before it reaches further North to Orgamè (Baralis et al., 2017). This was a hypothesis given by K. F. Peters (Peters, 1867). Others, such as A. Avram, O Bounegru and C. Chiriac (Avram et al., 1985) suggested a similar location. Moreover, recent palynological and ichthyological studies (Baralis et al., 2017) along with ^{14}C chronology brought a new insight to the evolution of the settlement. Despite these premises on the existence, locality, and chronology of the site based on archaeological and historical sources, recent geomorphological studies related to the Danube delta and the western Black Sea coast argue a significant territorial dynamism in the southern Danube Delta due to fluvial deposition, sea level change and tectonic activities. Hence, by synchronising the archaeological context and environmental momentum mentioned above, the paleoenvironmental reconstruction of Karaburun theorises as follows:

1) Its socio-political proximity and maritime accessibility to Istros, Orgamè, the Black Sea and the Danube must necessarily be linked to the evolution of the beach-ridge barriers, i.e. Lupilor and Zmeica.

2) The lagoons - Sinoe, Zmeica, Goloviţa and Razelm - constitute the southernmost areas of the vast deltaic complex built by the Danube. This relatively shallow area has been constantly redesigned since the opening of the Black Sea by the powerful alluvial deposits carried by the river, which the sea long-shore currents redirect from its mouth towards the South, along the coast. The formation of Dunavăţ, which flows directly into the Razelm, has since accentuated this phenomenon. This high mobility of landscapes should have affected the southern banks of lagoon Goloviţa, a water column shared by both Orgamè and Karaburun.

1.3. Research Methodology

A suite of research methods was applied to investigate the hypotheses raised in this thesis. A phase of literary survey to understand the archaeological and historical background preceded the technical part. A high-resolution multi-proxy research approach of sedimentology to analyse four cores collected from an area surrounding the site was chosen to carry out the experimental part. These are granulometry and fossil micro-fauna (mainly ostracods).

The late Holocene paleoenvironments of Karaburun have been realised using geomorphological, sedimentological and geochronological methods on four stratigraphic cores. The coring strategy aimed to obtain basic lithostratigraphic information from all relevant sedimentary units with a focus on the ancient settlement's surroundings, along the southern shores of Goloviţa lagoon (Fig 2). The coring campaign was undertaken in May 2017 using a Cobra TT percussion corer (corer heads of 8 and 5 cm diameter) with a 6 cm diameter hand auger. The core database consists of 4 cores 1 to 5 m deep. Core descriptions (texture, micro-fauna, organic remains) and sampling were undertaken in the field. The sampling interval depends on the nature of the sediment but varied between 5 and 10 cm. In the laboratory, the textural parameters have been determined by sieving (Marriner & Morhange, 2007). Concerning paleo-biological analyses, attention was given to microfauna: ostracods (present in dry sand fraction >150 mm). Unfortunately, the ostracod content of the sediments was not only poor to nil (for some sediments), but almost all those counted were juvenile. The chronological framework is provided by radiocarbon dates performed at Poznan (Poland). All the radiocarbon dates have been corrected for atmospheric ^{14}C variations using the calibration curve, IntCal13 atmospheric curve (Reimer et al., 2013).

1.4. Scope and Limitations of the study

This study focuses on the reconstruction of coastal environment in the southern banks of lagoon Goloviţa from a geoarchaeological point of view. The experimental analysis was limited only to the paleoenvironment based on granulometric data. It focused on two of the four cores in which conclusions were drawn by comparison of our results with an existing database of the area. In addition to these, a preliminary observation of the ostracod analysis is provided.

Despite the limitations of site accessibility and delay of the complete radiocarbon dates, the study has put forward optimistic results.

Chapter Two: Theoretical and methodological literature review

2.1. Theoretical literature review

2.1.1. The western Black Sea coast: Geomorphology and geoarchaeology

The Black Sea is located between Europe, the Caucasus and Anatolia; stretching at a length of around 1,150 km from west to east and a width of 600 km from north to south, and yielding a total area of about 410,000 km² (Morhange et al., 2016). It constituted an interface open toward the north and the Azov Sea through the Strait of Kertch (Cimmerian Bosphorus), and toward the south-west and the Mediterranean via the Bosphorus of Thrace and the Marmara Sea. It is by this southern course that Neolithic technology reached the Balkans before penetrating westwards into Europe (Morhange et al., 2016). The Black Sea is a relatively new element in a geomorphological sense, in that its formation took place at the end of the Würmian glaciation when rising sea levels connected the basin to the world ocean. There is an intense debate on the chronology of this event (Soulet et al., 2011; Morhange et al., 2016). Its rich geoarchaeological record, however, provided an adequate understanding (Morhange et al., 2016) of the trending concepts of geo-catastrophism, relative sea-level changes and environmental dynamism since the last transgression. Albeit the recent studies from Romania (Baralis et al., 2012; Vespremeanu et al., 2013; Bony et al., 2015; Bivolaru et al., 2017), most of such evidences come from the Bulgarian shores (Slavova et al., 2012; Hristova & Peev, 2014; Baralis et al., 2016; Peev, 2016).

Evidence of many submerged archaeological sites (walls, quarters, harbour structures) along the Bulgarian coast (Peev, 2016) prompted to the interpretation that they were built during a regressive period. The eustatic theory of the evolution of the western Black Sea was related to the idea of the phanagroian regression first proposed by Fedorove (1977) (Peev, 2016). Since then, a large part of the investigations looking at late Holocene RSL (Relative Sea Level) evolution of the Black Sea presumed a high stand at the beginning of the 2nd millennium BC, followed by a significant decrease during the first half of the 1st millennium between 5 m to 10 m below present (Fedorov, 1977; Chepalyga, 1984; Shilik, 1997; Balabanov, 2009; Peev, 2016). This concept was mainly advocated by Russian investigators but was also accepted by Bulgarian scientists (Filipova-Marinova & Christova, 2001). These studies on the Bulgarian coast, as well as those around the Black Sea, have sought to explain the late Holocene coastal changes, including ancient settlements, as a result of important shifts in relative sea level (Fedorov, 1977; Chepalyga, 1984; Shilik, 1997; Balabanov, 2009; Peev, 2016). Although a number of Greek *poleis* around the Black Sea coasts are partially submerged, recent geoarchaeological studies (Brückner et al., 2010; Fouache et al., 2012; Vespremeanu et al., 2013) do not support eustatic oscillations, but rather widespread hydro-isostatic and neotectonic effects (Peev, 2016).

The Black Sea level was affected by a rapid increase of 50-90 m during its reconnection to the Mediterranean (Ryan et al., 1997; Major et al., 2002; Giosan et al., 2006). During the Late Bronze Age, it was about 1.6 to 5 m below present. This is confirmed by data from the Bay of Yarulgach where pottery from the middle of the 2nd millennium BC was found at a depth of 1 m b.m.s.l. (Shteglov et al., 1976), from Olbia (3420±50 BP at a depth of 1.6 b.m.s.l.; Shilik, 1972), and from Bug firth (3210±50 BP at a depth of 3 m b.m.s.l.; Kryzhitskyi and Shilik, 1974; Shilik, 1997-1999). In mid 2nd millennium BC, the so-called "Phanagorian regression" began and lasted until Late Antiquity. This hypothetical fall in the relative sea-level of the West Black Sea has been assigned to the 5th to 3rd c. BC. According to different authors and interpretations, the maximum ranges were between 2/3 m to 11 m below modern mean sea level (Fedorov, 1977; Chepalyga, 1984; Shilik, 1997; Balabanov, 2009). From the Bulgarian Black Sea coast, a series of sunken ancient harbour facilities (Karantinata, at Cape Galata, Apollonia Pontica-Sozopol) and parts of residential quarters of Hellenic *poleis* are known (Bizone, Mesambria, Apollonia Pontica)(Peev, 2016).

In general, the Black Sea level at the beginning of this period (6th c. BC) was around -4 m and reached the present level during the 6th century AD (Peev, 2016). The archaeological data are supported by geophysical observations, such as those from Franhti cave (Van Andel & Lianos, 1983). After the 6th century AD, apparently, there was a relatively rapid rise in relative sea level. The foundations of the tower in Chersonesos (6th-beginning of 7th c. AD) were at a depth of -1m b.m.s.l. (Antonova, 1971).

2.1.2. The Danube delta: Geomorphology, evolution and coastal progradation

During the period of glacial maximum, sea level was 120 m lower than today. The world's rivers at that time flowed across continental shelves either in depositional or entrenching modes and with a wide variety of channel types to form deltas and coastal plains on the outer edges of the continental shelf (Walker & Grabau, 1999). A recent research (Vespremeanu et al., 2017) defines deltas as large-scale coastal accumulation features continuously evolving to acclimatise to environmental changes induced from natural and anthropogenic factors, usually exhibiting a large diversity of landscapes. Thus, deltas have been attractions of various investigations that have created delta categories (Wright & Coleman, 1973; Galloway, 1975; Wright, 1977; Boyd et al., 1992), put forward worldwide conditions of delta development (Stanley & Warne, 1994), proposed common evolutionary controlling factors (McManus, 2002; Ericson et al., 2006; Syvitski & Saito, 2007; Anthony, 2015) and global responses (Syvitski et al., 2009), and established models of general deltaic morpho-dynamic processes (Syvitski et al., 2005; Jerolmack et al., 2007; Ashton & Giosan, 2011).

Being one of the world's major deltas, and the second largest river delta in Europe, the Danube Delta was formed as a major coastal accumulation feature (with a total surface of 5480 km^2) under the combined deposition of sediment discharged by the Danube River and sediment brought by longshore currents, under the influence of sea level, tectonics and oceanographic conditions in the north-western Black Sea basin (Vespremeanu-Stroe et al., 2017). It has the widest (about 200 km) continental shelf in the entire basin resulted from the convergence of some of the biggest European rivers (Danube, Dnieper and Dniester) flowing into the northwest Black Sea. The Danube River is the most important water and sediment supplier of the Black Sea basin (and of the Mediterranean Sea), having a length of 2870 km, a drainage basin of about 817,000 km^2, an average water discharge of approximately 200 km^3/yr (6400 m^3/s) and a sediment discharge of 25 to 35 Mt/yr, of which 4–6 Mt/yr is sandy material (Panin & Jipa, 2002). The river presently flows into the sea through three main distributaries: the Chilia, which transports approximately 58% of the water and sediment discharge; the Sulina, the major economic waterway, 19%; and the Sf. Gheorghe, 23% (Vespremeanu-Stroe et al., 2017). According to Vespremeanu et al. (2017) first measurements on the Danube in mid-19th century (1857), before the regularisation works on Sulina, indicate a larger flow than nowadays on the Chilia (70%) to the detriment of Sulina (7%), whilst Sf. Gheorghe was nearly the same (Gâştescu, 2009; Vespremeanu et al., 2017).

Geologically, the Danube Delta overlaps the Pre-Dobrogean Depression (mainly overlying the Scythian Platform) and comprises a sequence of detrital deposits (tens to 220 m thick) formed largely during the Upper Pleistocene sea-level high-stands. Tectonically, the delta is situated in a mobile area affected by subsidence and weighty sediment accumulations (Zugrăvescu et al., 1998; Vespremeanu et al., 2017). By its position in SE Europe (45°N latitude crosses the central delta), the climate is temperate and continental. The Danube Delta is the driest region in Romania and one of the driest around the Black Sea, with mean annual rainfalls of 350–380 mm. The seasonal thermal amplitudes are of 22 °C with summer temperatures of 21.8 °C (the mean in July–August) and near 0 °C in wintertime(Vespremeanu et al., 2017).

The Danube Delta coast is characterised by tide less (maximum spring tide range of 0.12 m;) and medium-wave energy conditions. Prevailing short and steep wind waves have average offshore significant wave heights of 1–1.5 m with corresponding mean periods of 5–7 s.

Regular storm events generate waves 2 to 4 m high, especially during winter, with maximum offshore significant heights of up to 7–8 m during extreme storms (Vespremeanu et al., 2017). Northeasterly waves are dominant in terms of both magnitude and frequency approaching the shoreline at oblique angles and inducing strong southward oriented longshore drift which can reach 1 million m^3/yr (Vespremeanu et al., 2004; Dan et al., 2007). The mean relative sea-level rise registered during the last 150 yr. on the Danube Delta coast is 2.65 mm/yr at Sulina (Vespremeanu et al., 2004), resulting from a mix of eustatic sea-level rise and natural subsidence (Vespremeanu et al., 2017).

The delta plain delimited by a sand spit stretching in North-South direction is composed of two main units: i) the fluvial delta which occupies the western part (western delta), where prominent morphology is represented by fluvial levees, channels and lakes shaped by fluvial forces, and ii) the maritime delta in the east and south, composed by either large open-coast lobes (eastern delta) or abandoned lobes mostly affected by subsidence, where large lagoons subsequently developed (southern delta)(Vespremeanu et al., 2017).

Different morphogenetic theories assert that the early Danube Delta formation turned into a lagoon (semi-enclosed) by “an initial spit/barrier” (Vespremeanu et al., 2017). New ages derived for the modern delta front advancement into the Danube Bay, following the Black Sea reconnection to the World Ocean, indicate that early stage of delta development into the bay started 8–7.5 ka BP, which seems to precede (by >1000yr) the inception of the initial-spit. Samples from the sandy barrier (derived directly from the Initial Spit) at the present contact with the fluvial delta (western delta plain) show younger ages to the north, from older than 5.2 ka in the southwest of Caraorman beach ridge plain (or 4.5 ka in northern Caraorman) to 0.8 ka in the Jibrieni beach ridge plain (Fig 3b) (Vespremeanu et al., 2017). This chronology is indicative of a dynamic long-term behaviour of the barrier (Initial Spit), characterised by backward roll-over migration into the lagoon, broadly similar to the morpho-dynamic pattern of the present-day barrier spits (Sacalin, Musura, Oceakov) of the Danube Delta (Vespremeanu & Preoteasa, 2015). The long-term Initial Spit evolution makes impossible the dating of the former spit roots (its original position) as they no longer exist. Nevertheless, considering that the Black Sea experienced the same eustatic oscillations as the Mediterranean Sea and the Atlantic Ocean in the mid- and late Holocene (Brückner et al., 2010), it is reasonable to assume that the spit started to form at about the same time as many other old barrier spits (Curonian Spit, Cadiz Bay spit, Lisboa estuary) initiated, following the post-glacial sea-level rise deceleration, about 6500yr ago (Bitinas et al., 2001; Buynevich et al., 2015; Del Rio et al., 2015; Vespremeanu et al., 2017).

In attempting to reconstruct the spit formation using chronostratigraphic methods, Vespremmeanu et al. (2017) concluded that a time interval of 700–900 yr was necessary for the Initial Spit to connect with the updrift side of the SG1 (Sf. Gheorghe 1) lobe (from its inception ~6.7–6.5 ka until the attachment to the lobe around 5.8–5.7 ka), closing thus the Danube Bay. Normally, the distal part of a spit should be linear or, more often, convex seaward (Zenkovich, 1956; Deigaard & Fredsøe, 2005; Dan et al., 2011; Vespremeanu et al., 2017). On the contrary, the Initial Spit achieved an abnormal concave plan-shape in the southern part that suggests its connection with the deltaic coast which forced it to take the former contour of the updrift lobe side and to rework it.

Compared with the maritime delta, where the succession of the main open-coast lobes was established in the early-mid 20th century (de Martonne, 1931; Zenkovich, 1956) and the first absolute ages dated since the 1980s (Panin, 1983), the evolution of the fluvial delta remained almost unknown (Vespremeanu et al., 2017). In the absence of any chronological data or morphological analyses, the initial-spit was unanimously supposed to have closed the Danube Bay before the start of the delta plain formation. This interpretation was mostly inspired by the marked river-dominated morphology of the western delta plain (fluvial delta). As to the maritime delta, it began about 2000 yr after the bay head delta advancement into the Danube Bay (7.5-5.7 ka) - favoured by the limited fetch conditions specific to an open bay (before 6.5ka) or to a lagoon (semi-) closed by the initial-spit (6.5–5.7ka) where six large open-coast deltaic lobes were built (Vespremeanu et al., 2017). Four of them belong to Sf. Gheorghe, attesting its long history, whereas the other two have been created by the Sulina and Chilia distributaries. The spatial growth pattern of the maritime delta reflects successive advances of wave-and fluvial-influenced lobes triggered by avulsions of the Danube distributaries. The open-coast lobes are the fundamental structural units of the maritime delta created at a centennial to millennial-scale by the continuous encroachment of a branch into the sea, which gathers river-borne sediments and traps allochthonous sands supplied by longshore currents. The maritime delta occupies about half of the Danube delta, fronting the fluvial delta to the east, southeast and south. Its evolutionary model (i.e. the chronological order of the lobes) has been roughly established since the mid-20th century (de Martonne, 1931; Zenkovich, 1956; Panin, 1983) although, recently, new investigations have enabled more detailed and accurate reconstructions of the different deltaic units (Filip & Giosan, 2014; Preoteasa et al., 2016; Vespremeanu et al., 2013, 2016).

A model developed by by Vespremeanu et al. (2017) proposes the fluvial delta developed during two successive main phases: (i) an early bay-head delta advancement into an open Danube Bay, and (ii) a late stage of fluvial and peat aggradation (5.5ka - present) which configured the present expressive fluvial morphology. The first phase initiated ca. 8ka, with >1000yr before the relative stabilisation of sea level and of the Initial Spit formation, building the oldest deltaic lobe (Old Danube lobe: 8–5.5ka) which is now 4–6m below the delta plain due to sea level rise and subsidence.

For the southern (maritime) delta they argue that it was initially built by the deltaic lobes of Sf. Gheorghe arm (and its southern derivation Dunavăţ, called Peuce in the Antiquity) – down-drift unit of Old Sf. Gheorghe lobe in the north: 6–3.5ka; Old and New Dunavăţ lobes in the south: 2.6–2ka/2–1.3ka – whilst the current puzzle-like morphology was generated by the combined action of subsidence, neotectonics and wave reworking following lobe switching. For the eastern (maritime) delta, a detailed reconstruction of the open-coast lobes evolution highlighting the main characteristics of each evolutionary stage: rates of progradation, surface growth, resultant morphology. In reference to these, the main new findings are: 1) SG1 lobe created a much larger down-drift flank than was previously estimated (Panin, 1983; Giosan et al., 2006; Giosan et al., 2013), covering most of the Razelm and Goloviţa Lakes. It presents the characteristics of a subsided barrier-marsh plain currently lying at 3–5.5m under the topographic surface, due to active neotectonics southward of the Sf. Gheorghe fault; 2) Sulina (3.5–2/1.35ka) and modern Sf. Gheorghe (SG2: 2.1/1.35ka - present) lobes, which are the best preserved large open-coast lobes, developed barrier-marsh plains on the down drift flanks, with a multiple ridge set structure, following a cyclic pattern which seems to be specific for all asymmetrical wave-dominated lobes of the Danube, reflected by the cyclic succession of the following recurring stages: (a) subaqueous mouth-bar building, (b) barrier-island emergence, and (c) down-drift elongation and backward migration with frequent transformation into a barrier spit; 3) the Chilia branch reached the open sea around 0.9 ka, much earlier than the previous estimations (Giosan et al., 2006; Filip and Giosan, 2014). After a longer phase of wave-dominated river mouth (0.9–0.25ka) the increase in Chilia discharge imposed a fluvial dominated morphology of the lobe with mean progradation rates up to 100m/yr during the 19th and the beginning of the 20th centuries; 4) Abrupt changes occurred during the 20th century for the active open-coast lobes, as a consequence of human-induced depletion of sediment supplied by the Danube. These changes are indicative of the current transition from fluvial to wave-dominated morphology (Chilia lobe) or from an asymmetric to a deflected wave-influenced delta morphology (modern Sf. Gheorghe lobe) which marks a significant change in their long-term evolutionary pattern.

2.1.3. Geoarchaeology of Archaic Greek colonies in Southern Danube Delta

The period 7th-6th century BC marks the foundation of many archaic settlements along the Black Sea coast (Avram et al., 2004). They were established with the coming of the Milesian colonists, in the region between the Danube and the Black Sea (Dobruja), at locations where natural conditions were conducive for thriving socio-economic activities (Avram et al., 2004; Preoteasa et al., 2013). Before the coming of Milesians, these areas belonged to the diffusion area of the third phase of a middle Hallstatt culture, named after the eponymous site, the Babadag culture (Alexandru Avram, 2006). This is evident from the fortified sites (Babadag and Beidaud) and many unfortified settlements on both sides of the Danube belonging to the Babadag culture discovered by archeological investigations (Fig. 4). These pre-colonial settlements, however, were abandoned when the Greeks arrived. Avram (2006) presents remarkable maps of the territories before and after Milesian colonisation (Fig. 5); Istros and Orgamè engulfing Karaburun from south and north, respectively, are shown on the map. Istros, one of the oldest colonies founded on the Black Sea coast of southern Danube Delta during the Archaic period, in 657 BC, is the best preserved archeological site along the Romanian coast as no human development continued after its abandonment in the 7th century AD (Preoteasa et al., 2013). Orgamè, another major fortified coastal city, constitutes one of the four ancient Greek settlements in the Black Sea area. Established in the mid-7th c. BC, on the shores of Northern Dobrogea, the remains of the ancient city occupy the Cape of Dolojman, today overlooking a large lagoon complex located south of the mouths of the Danube(Bony et al., 2015).

Istros/Histria

Established by the Miletos in the mid-7th century BC, Istros was settled on the bay that later became the Razelm–Sinoe lagoon, after a geomorphologic evolution of the ancient landscape. It provides an excellent example concerning the problem of the territories of the Greek cities and geoarchaeology of the area (Avram et al., 2004; Preoteasa et al., 2013). Today, its acropolis lies far from the current shoreline (8 km), within what is today the Razelm-Sinoe lagoon system, which forms the southern compartment of the Danube Delta. The Histria region consists in an association of beach ridge plains (Saele and Chituc), sandy barriers and shallow lakes (Sinoe, Histria and Nuntasi) which together form the southernmost unit of the Danube Delta (Fig. 6). The Sinoe Lake, where the remains of Histria lie, is the southern compartment of the Razelm-Sinoe lagoon complex (Preoteasa et al., 2013).

A reliable data about the ancient city's evolution comes from the archaeological material. There are elements such as tumuli, defending walls, residential areas and aqueducts whose construction is precisely datable (Preoteasa et al., 2013). Their consideration within the original location and geological context is an important step in determining the temporal phases of this region evolution and the approximate position of the paleo-shorelines at Histria (Canarache, 1956; Bleahu, 1963; Coteţ, 1966; Alexandrescu, 1978; Pippidi et al., 1983; Ştefan, 1987). The common idea of the most theories is the formation of the Razelm-Sinoe lagoon system, and implicitly of the Histria region, as a result of the barrier systems construction which enclosed the ancient marine gulf. Most of the hypothesis indicate the eustatic sea level oscillations as the main controlling factor of the morphological changes (Bleahu,1963; Coteţ, 1966; Alexandrescu, 1978, Pippidi, 1983; Panin, 1983, 2003), while just a few suggest the correlated action of the neotectonics, erosion and coastal progradation as key-processes which contributed to the present day morphology (Canarache, 1956; Giosan et al., 2006; Vespremeanu et al., 2013b).

Orgamè

Known in ancient sources by its Latinized name of Argamum, this ancient coastal city originated at the proximal margin of the delta complex, in a lagoon naturally sheltered from the north-south longshore drift by the Cape Dolojman, with a favourable access to the black sea via an important natural outlet named Gura-portitei (Fig. 7) (Bony et al., 2015). Although human occupation of the Danube Delta began during the Neolithic period, the earliest attested traces of human occupation on Cape Dolojman date to the First Iron Age (~700 BC). Archaeological studies on this site began in 1926 with the work of P. Nicorescu, long before consistent excavations were launched in 1965 and had continued up to present day (Bony et al., 2015).

Ailincăi et al. (2006) argue that the 11th-9th c. BC settlements were the earliest phases of the Babadag culture in this area while M. Coja (1972) gives a later age of 8th-7th c. BC. The assessment of a new chronology supports these ages affirming to the existence of a Getic settlement (Thracian tribes inhabiting the regions on either side of the Lower Danube and who could be in communication with the ancient Greeks) on this site before the arrival of the Greek settlers. Orgamè' s history is characterised by two main periods of occupation. The first is related to the Greek colony. The exact date of its foundation is unclear, but the ceramic material found in the urban areas and at the necropolis' oldest burial mound, suggests installation of the Greek settlers in the mid-7th c. BC (Bony et al., 2015). Because of its considerable size (42 m in diameter), this mound is an exceptional monument in the burial area. It held ritual offerings across a long period from the mid-7th c. BC to the 3rd c. BC and has been defined as a heroon: the tomb of the colony's founder. This official burial clearly shows an autonomous political consciousness of the civic community during the Archaic period (7th-6th BC), underlining the high probability that Orgamè was an independent city during this early period. Since 1988, extensive excavations carried out by

V. Lungu (Lungu, 1997, 2001 & 2010; Bony et al., 2015) on several areas of the necropolis have uncovered around 80 burial mounds covering a total area of more than 100 ha. The predominant ritual practice from the 7th to the mid-3rd c. BC, remained the cremation of the dead followed by the deposition of their ashes in urns, an institution that naturally consumed considerable amounts of wood, accentuating the human impacts related to the Greek city (Bony et al., 2015).

The economic importance of Orgamè declined, like most Greek settlements in the region, during the first half of the 3rd c. BC. This chronology seems similar to that found along the Western Black Sea. In the 3rd c. BC, the agricultural practice of the ancient city of Apollonia Pontica (Bulgaria) also collapsed, as proven by the desertion of the agricultural buildings located around the city (Baralis et al., 2012). Orgamè regained importance in the 2nd c. AD. The military standing of the Northern borders of the Roman Empire explained the increasing attention of the authorities for the major settlements of Northern Dobrogea, leading to a new period of prosperity in the region. A new fortification wall was built to shield the city of Orgamè/Argamum while the regional agricultural system implemented a new model distinguished by the spread of individual farms along the main roads linking the two gates of the city (Baralis & Lungu, 2015). Nevertheless, the invasions of the early 7th c. AD affected the Roman administration of Dobrogea and also engulfed Orgamè/ Argamum. The harbor remained active until the 7th c. AD. Today, the harbor of ancient Orgamè/Argamum lies in Razelm-Sinoe lagoon. The city of Orgamè is located 60 km southwest of St. George's arm, 20 km from the Dunavăţ arm, 14 km from Gura-portitei and 2.5 km from the island of Bisericuta with archaeological remains, vintage Late Roman and Proto-Byzantine (Manucu-Adamesteanu, 2003). This location makes it a strategic site of human occupation (Bony et al., 2015).

2.1.4. Archaeological and Historical Context of Karaburun

Located directly opposite of Orgamè (Argamum), in a protected area that only imperfectly communicates by the sea with the city of Istros, the site is one of the constituent elements of a long chain of settlements scattered along the shores of the Goloviţa lagoon. Despite studies related to the region of Istros, this site is never mentioned elsewhere. A. Avram (2006) refers to some concentrations of ancient material situated north of the city, on the shore of Lake Sinoe: Karaburun, Sinoe–"Zmeica", where explorations have revealed 6th century BC pottery, and Sinoe-"insula Lupilor", a settlement placed on a peninsula, protected to the west by a vallum of earth or stone, c. 2 km long and oriented approximately N–S. Indeed, there is no doubt on its membership of the Istrian territory; however, its history appears hardly linear, as reflected by the chronological hiatuses (BARALIS et al., 2017). The archaeological documentation available to us constitutes items made of perishable materials (wood, textile), resulting in an overrepresentation of certain categories such as ceramics, which now occupies a prominent place in the material harvested. Among the various elements gleaned, it should be noted that Acic-Suat, at least at the beginning of the Hellenistic period, did not have a dense and continuous urban fabric. On the contrary, its internal organisation incorporated many vacant spaces. Similarly, the establishment dominated a narrow territory devoted to a subsistence on cereal and domestication. It is found to be incompletely integrated into regional trading networks, even though this community of Greek settlers had some non-Greek elements among them. Within it, the fishing activities occupied an interesting place, which was observed both on the archaic contexts and in the late-classical period and the beginning of the Hellenistic period, that is to say at a time when Istros had specific fishing rights on this area (Baralis et al., 2017). However, the species concerned did not come so much from the high seas as from fresh water, which illuminates in a rather unexpected light the economic and food strategy of the Greeks settled in contact with the Danube. In Roman times, however, the site changed its face and hosted a very different community whose installation is the subject of a methodical and regular development of space. This presence, which is perhaps not unrelated to the proximity of the limes, maintained a strong consistency with the data we have on the colonial settlements mentioned by several inscriptions discovered near the site. The information we have so far does not confirm the abandonment of the site.

2.2. Methodological literature review

2.2.1. Sediment sampling

Sediment samples for paleoenvironmental studies are generally extracted using a manual or a motorized corer (depending on the substratum). After an initial description of the main facies units and sedimentary structures, the core sections are divided into a series of sub-samples. The sampling interval varies depending on the nature of the sediments and the coring equipment employed. High-resolution (centimetric) sampling facilitates very precise reconstruction of environmental history and chronology. In reality, very few geoarchaeological teams engage in high-resolution laboratory studies due to their time-consuming nature (Marriner & Morhange, 2007).

Once the sediment samples are dried, they can be described using the Munsell colour scheme. Developed jointly by Munsell and the USDA Soil Conservation Service, these charts were initially used to classify soil colours but are now commonly used in all areas of the earth sciences and archaeology. The Munsell colour system specifies colours based on three dimensions, hue, lightness (called Value by Munsell), and chroma (difference from grey at a given hue and lightness). Although subjective, the charts provide a practical international standard for the communication and specification of sediment colour (Marriner & Morhange, 2007).

2.2.2. Sediment texture and granulometry

Particles or ‘clasts’ are the basic elements of any sediment. Therefore, separating these clasts into discrete fractions is a key inceptum for geoarchaeologists. In order to extract the maximum amount of paleoenvironmental information held within the coastal sediments, the sediment aggregates are wet sieved through two separate meshes (usually 2 mm and 50 μm) to separate out the gravels, sands and silts and clays fractions. The resulting dry portions are subsequently weighed, and data plotted against stratigraphic logs in percentages. The gravels fraction in ancient harbour sediments may comprise a suite of interesting material, from marine molluscs, seeds, and grains to ceramic shards. These all attest to the harbour basin being used as a base-level waste dump by human societies.

The sand fraction can be subjected to mechanical sieving to establish various grain size parameters including histograms, fractiles and graphical indices (Folk & Ward, 1957; Folk, 1966). A column of sieves descending in size from 1.6 mm to 0.063 mm is employed, and the separated sand fractions accordingly weighed. Results are subsequently statistically analysed, in concordance with various grain size parameters. The silts and clays fraction can also be investigated using laser particle sizing.

The formula to calculate the percentage of the fraction is:

$$\%\ of\ sed.\ Frac\text{-}i = \frac{weight\ of\ sed.fraction-i}{total\ weight\ of\ sed.fraction} \times 100\%$$

where the weight of sediment fraction-i is equal to the weight of each sediment fraction (g) (Folk, 1980).

2.2.3. Fossil micro-fauna (Ostracods)

Ostracods are microcrustaceans comprising soft body parts enclosed in a low-Mg calcite bivalve (Fig. 8) (Athersuch et al., 1989). They are typically around 1 mm in size but can vary between 0.2 and 30 mm. As with all crustaceans, ostracods grow by moulting. The carapace has numerous morphological characters which allow taxonomic and phylogenetic studies to be made on living and fossil specimens (J. Holmes & Chivas, 2002). They have a long and well-documented fossil record from the Cambrian to the present day and have been principally useful for the biozonation of marine strata on a local or regional scale.

Ostracods are excellent indicators of paleoenvironments because of (1) their ubiquity in both fresh and marine water; (2) their small size; and (3) their easily preservable carapaces. Their faunal composition, population density and diversity vary in time and space as a function of numerous environmental factors including water temperature, salinity, water depth, grain size, and anthropogenic impacts (Boomer & Eisenhauer, 2002). In many coastal and nearshore marine areas, human activities can significantly modify the natural coastal system (construction works, pollutants) leading to severe alterations in the different trophic levels of the ecosystems (Ruiz et al., 2005). Ancient anthropogenic activities can affect ostracods in three ways, as they may: (1) impact on the densities and diversities of the assemblages; (2) strongly influence the abundance and distribution of selected species; (3) affect the chemistry of their carapaces.

Although slightly different preparation techniques exist, ostracods are generally extracted from the dry sand fraction (>150 μm). A minimum of 100 valves is preferred to ensure statistical robustness. Identified taxa are most commonly assigned to five assemblages on the basis of their ecological preferences: freshwater, brackish lagoonal, marine lagoonal, coastal and marine (Müller, 1894; Bonaduce, 1975; Breman, 1975; Carbonel, 1980, 1982; Morhange et al., 2000). These discrete ecological groups render ostracods one of the best biostratigraphical markers in ancient harbour sequences. Potential research avenues include the application of ostracod test geochemistry to reconstruct ancient harbour salinity patterns and pollution levels (Ruiz et al., 2005; Marriner & Morhange, 2007).

Chapter Three: Materials, methods and results

3.1. Core description, sample preparation and preliminary analysis

This research presents four cores (Fig. 9) extracted in May 2017 from the southern shores of lagoon Goloviţa, around the Karaburun/Acic-Suat area. The coring campaign was undertaken in May 2017 using a Cobra TT percussion corer (corer heads of 8 and 5 cm diameter) boreholes used a 6 cm diameter hand auger. The maximum depth reached was 5 m in KA IV with the lowest in KA II reaching the bedrock at 1m depth. The coordinates and altitude reported at the current sea level were recorded for all the cores using a GPS. The description and sampling of the collected sediments was done first. The sampling interval was based on the nature of the deposit, ranging from 5-10 cm. The bio-sedimentological analysis was carried out at CEREGE (European Center of Research and Teaching in Environmental Geosciences), Aix-en-Provence, France.

In the laboratory, texture and ostracod analyses were performed according to the methodology developed by Marriner & Morhange (2007) and Marriner (2009). In a first stage, the sediments were dried in a special oven at 40°C, after which they were weighed and washed through two distinct sieves of mesh size 2 mm and 50 μm, to separate the granulometric fractions: ballast (> 2 mm), sands (between 2 mm and 50 μm) and silt and clays (< 50 μm). The sand fraction was also separated: coarse, medium and fine. Ostracods were selected, sorted and identified. They were extracted from the medium sand fraction (> 150 μm); their selection was performed using a Leica microscope, and identification of the species was done using a Leica MZ125 stereo-microscope based on the bibliography.

In addition to bio-sedimentological analyses, ^{14}C datings were carried out in Poznan, Poland, in order to achieve the chronology. However, only datings for KA IV are obtained so far. All calibrated dates are given in table 1. Samples submitted for analysis consisted in plant remains.

Marine Reservoir Effect for the Black Sea (498 ± 41 BP) (Stuiver & Reimer, 1993) was subtracted from radiocarbon data before calibration.

Sample name	***Lab. no.***	***Age 14C***	Materials dated	remark
KA_IV_1_80-90	Poz-100732	**185 ± 30 BP**	Plant material	contamination
KA_IV_2_120-130	Poz-100733	**205 ± 30 BP**	Plant material	contamination
KA_IV_2_180-190	Poz-100734	**620 ± 30 BP**	Plant material	
KA_IV_2_270-280	Poz-100735	**2135 ± 30 BP**	Plant material	
KA_IV_3_310-320	Poz-100736	**116.04 ± 0.33 pMC**	Plant material	modern

Table 1 Radiocarbon dates of KA IV

3.1.1. Bio-sedimentological and chronostratigraphic results

KA I

KA I (Fig. 9) was cored at an altitude of 0 m to a depth of 2.5 m. It is characterised by two bio-facies units (1 and 2) overlying a 1.5 m of altered bedrock. No ^{14}C datings are available for this core.

Unit 1 is present between 95 cm and 55 cm deep and is sedimentologically characterised by a relatively equal proportion of sand (dominated by the fine fraction), silts and clays (fig 10). Granulometric distribution indicates a relatively calm sedimentation environment, characterised by moderate energy, allowing the deposition of fine sand, silts and clays. The bottom 25 cm is composed almost entirely of peat. The ostracod content is negligible, with a juvenile form of *Cyprideis torosa* and *Candona neglecta*.

Unit 1 features a landlocked lagoon that is disconnected from the sea. In this case, we can consider that these facies correspond to the transition from a semi-open to a completely protected environment.

Unit 2 is located between 55 cm and 35 cm. It is characterised by the dominant presence of silts and clays with *Typha* roots. The sand continues to be present, but to a lesser extent than in Unit 1. There is an increase in fine sedimentation, typical to a protected environment. The bio-sedimentological indicators of this facies show a return of freshwater intake due to a (natural or artificial) increase in the sedimentary budget.

Between 35 cm and 0 cm, there is the filler part, consisting of a soil fraction and *Typha* roots.

KA II

Core KA II was taken out on the Northeastern part of the site at an altitude of 0 m. It goes 1m deep from the ground level, reaching the bedrock at only 40cm depth, which made it difficult to use it. The sedimentology is characterised by clays and silt mixed with *Typha* roots. It is devoid of fossils. For this core, there is no ^{14}C dating.

KA III

This core was carried out at a similar spot with KA II, at an altitude of 0 m above sea level. KA III goes 4.10 m deep reaching the bedrock at 3.93 m (Fig 11). It presents four stratigraphic units. It is characterised by a relatively similar proportion of sand, silt and clays, and ballast (being completely absent in Unit 2). The sand, mostly medium sand, is present all over the units while the coarse sand appears in the same stratigraphic sequence where the ballast is observed. The texture of this core is peculiar to the previous two, presenting a rich data on the environment.

Unit 1, 3.93 m to 3.2 m, features an open lagoon or a bay, given the bio-sedimentological information (mixed particle fractions, i.e. silts and clays, coarse sand and ballast, the presence of many molluscs and peat). In this case, it could be considered that these facies correspond to the transition from an open sea environment to a semi-open one.

Unit 2 is between 3.2 m and 1.90 m. Generally, it is characterised by the disappearance of the ballast, but also a substantial decrease of the sandy fraction, being replaced by silts and clays. Regarding sand texture, medium sand appears at a higher percentage than coarse sand. The fine fractions, consisting of the mixture of silt and clay and fine sand, which dominate this unit, are specific to a semi-enclosed lagoon, in contact with the sea, being a medium characterised by the same low energy that allows the storage of these sediments.

Unit 3 overlies Unit 2 from 1.9 m to 1.4 m. There is an abrupt decrease in the fine fraction (less than 10%). It is characterised by sands and gravel, and a small proportion of the fine fraction. This sudden change in granulometry corresponds to a very high energy event, most probably a freshwater effect from the Danube.

In Unit 4, 1.4 m to 0.7 m, the texture changes from sand and ballast to an increased proportion of silts and clays showing a relatively calm environment, hence protected. This uppermost unit is interpreted as a landlocked lagoon, which fits the results from KA I.

According to bio-sedimentological indicators, KA III switches from an open, low-energy marine environment (Unit 1) to a semi-open, sheltered lagoon environment in connection with the sea (Unit 2), to semi-closed lagoon with a very high energy event (Unit 3), to a landlocked lagoon (Unit 4). Fine sediments might suggest a possible anthropogenic intervention that has led to the creation of this depositional environment. The rapid increase in the amount of coarse fraction in Unit 3 corresponds to a high-energy event, although a detailed investigation is required to supplement this hypothesis.

For this core, no dating is obtained yet, and in the absence of sufficient micro-faunal content, the interpretations are merely based on the granulometric data.

KA IV

Coring KA IV (Fig. 12) was taken on the western area of the site at an altitude of 0 m. It reached a depth of 5 m from the ground level. This is the only core that never touched the bedrock and dating has been obtained. Based on the texture it is divided into four units. It is characterised by a relatively similar proportion of sand, silt and clays, and ballast. The sand, mostly medium sand, is present all over the units along with silts and clays, while the coarse sand and ballast are observed in a limited layer. This core is unique in that a pottery fragment is also present in unit 3, although it is not dated.

Unit 1 is present between 5 m and 3.85 m deep. Sedimentologically, it is almost entirely characterised by clays with less than 10% of the other sediment particles. Granulometric distribution indicates a very stable environment, allowing the deposition of clays. This could be related to a static water volume, perhaps a paleo-lake. This homogenous texture in KA IV is quite puzzling as it matches none of the previous cores, nonetheless, the lack of archaeological material and micro-fauna should agree with the early stage of the environments evolution.

Unit 2, 3.95 m to 3.4 m, shows two different phases. The bottom layer is dominated by a sand fraction. Compared to Unit 1 there is a sudden change in the amount of the fine sediments. The top part of unit two presents an increased proportion in the fine sediment, although the coarse sediments occupy a significant fraction. Such a distribution implies a quasi-calm environment with influence from a moving water body, hence a semi-protected lagoon.

Unit 3 exhibits a similar trend of Unit 3 of KA III, despite the difference in elevation. It occupies the section between 3.4 m to 2.6 m. As the graph shows, it is mostly composed of coarse sediments of sand and gravel. This is typical of a very high energy event (e.g. a storm).

Unit 4, 2.6 m to 0.8 m, seems to have an equal proportion of the sediments dominated by a fluctuating percentage of the fine fraction. The topmost layer, however, seems puzzling as it shows a sudden increase of gravels. The rippling nature of the percentages at this unit makes it very difficult to give conclusions on this unit but also of KA IV as a whole; thus, these results will be complemented by other sources in the next chapter.

3.2. Interpretation of results

The bio-sedimentological results of core KA IV, which is dated and has given good results is synchronised with KA I and KA III for interpretation of the results.

Unit 1: a paleo-lake with a possible marine influx existed in the southwestern margin of the lagoon- Goloviţa. The basal unit (Unit 1) is located between 5 and 3.95 m depth. It consists of an accumulation of clay and silt deposits (in KA IV) and a mass of shelly sandy-silt sediments and peat (in KA III), reflecting a less-active depositional environment and a dynamic depositional environment, respectively. This succession seems plausible since the depths do not overlap. However, in the absence of absolute dating, it stays merely speculation. The gravel fraction is almost absent in KA IV, but in KA III it increases dramatically mixed with shell fragments. It is precisely at the same depth, i.e. 3.95 m, that the fine fraction drops abruptly at the transition with the overlying unit. The sedimentation rate at the base of the unit is relatively calm, with a significant dynamism at the top. Concerning the microfauna, we observed a mixture of oligo- to mesohaline lagoon taxa, including coastal and Pontic species. The Pontic ostracods are characteristic of oligo- to mesohaline environments and marginal environments such as lagoons. They have good affinity with Mediterranean coastal mesohaline species and oligo- to mesohaline Mediterranean species (*Candona* spp., *Cypridopsis* spp., *Darwinula* spp. and the species *Cyprideis torosa*). The ecological assemblages that we observed in the sediments of Unit 1, although composed of few and juvenile specimens, are consistent with the ostracodological data of the Black Sea coast. The salinity of the Black Sea is not very high (18‰) and is lower at the coast (Schokalsky & Nikitine, 1927; Bony et al., 2015). This is consistent with the ostracod assemblages that we observed. Unit 1 corresponds to an open coastal environment of low salinity (oligo-mesohaline) typical of Black Sea coastal environments and the Danubian area. The transition in the top of this basal unit is the beginning of a naturally protected environment. Deltaic progradation of the Danube Delta (started around 5200 yr BP; Giosan et al., 2006) has led to a natural protection of the environment by building coastal barriers opposite the Cape Dolojman (Fig. 7) (Bony et al., 2015).

Unit 2: semi-enclosed lagoon, located between 3.95 m and 3.4 m depth, is distinguished by sand accumulation, which contrasts with the silty clay texture of the underlying unit (10% of the sands fraction versus 80% for Unit 1). The sediment is well sorted and enriched in medium sand and gravel particles, confirming a fair energy context. The shift between Unit 1 and Unit 2 is relatively abrupt, indicating a rapid transformation of the dynamic marine environment into a protected and calm environment (equivalent to the case in KA III). This stratigraphic unit archives a changing environment marked by the transition from a marine-protected bay to a semi-closed pond.

Unit 3: a lagoon with high energy event, 3.4 m and 2.6 m depth. A plant remain at 2.7 to 2.8 m depth has been dated to 2135 ± 30 BP (211-55 cal. yr BC). This event appears in alignment with the chronology of lupilor beach ridge plain, i.e. west lupilor (2.6-2 ka) and east lupilor (2-1.7 ka), formed in association with the two deltaic-lobes of the Dunavăţ (Vespremeanu et al., 2016 & 2017). The grain-size analyses indicate a sedimentary texture different from Unit 1, being composed of 80% sands and gravel. Hence, it confirms a storm event. Marine microfauna is absent from this unit. Bony et al. (2015) argue that on the Chituc barrier at the ancient pass of Gura Portitei, present Black Sea storm deposits constitute accumulations of *Buccinum undatum*. Therefore, the presence of this species suggests a sedimentary record of a storm. The decrease in organic matter can be explained by the sedimentation of lagoonal and fluvial shells on the shore due to the reopening of the environment to fluvial inputs in the lagoon.

Unit 4: Non-coastal wetland, corresponds to the uppermost unit. The sediment is an organic black mud (with significant gravels content only in KA IV) rich in *Typha* roots. This plant thrives in fresh water to lightly brackish environments (salinity of around 5‰) and on sandy loam soils. This unit corresponds to the onset of the present-day wetland, observed on the current boundaries of the Razelm-Sinoe lagoon complex. It corresponds to the final stage in the infilling of the lagoon margins.

Chapter Four: Synthesis of Results

4.1. Results from previous environmental and archaeological studies around Karaburun

Amongst the previous studies around Karaburun, a research campaign in Orgamè (Cape Dolojman area) is the best reference. This is a paleoenvironmental analysis on two cores (O1: 4.5 m to the substrate, O2: 8.5 m) taken from the area of the ancient port of Orgamè, 100 m and 300 m from the promontory, respectively. Out of all the cores realized, 4 main units were identified, corresponding to the main stages followed in the evolution of the environment around the Razelm and Golovița lagoons (Fig. 13).

Unit A, the oldest, is present in core O2 between 9.00 and 4.1 m depth. It has a sandy-clay texture and is dated at 8.55 m and 6.15 m depth, respectively, at 4044-3790 cal. BC and 3631-3350 cal. BC. The sedimentation rate then seems high (5 mm/year) before decreasing thereafter abruptly (2 mm/year). This layer corresponds to infralittoral sand deposits related to the relative rise of the sea level. It illuminates the existence of a marine bay located in the distal margin of the Danube. This is the famous marine gulf described by P. Alexandrescu (1978).

Unit B, which overlaps Unit A, is placed in core O2 between 4.1 m and 2.4 m depth. Composed of very black organic loams, it is dated at its base at 1211-1001 cal. BC and at its top of 409-234 cal. BC. The macrofauna characterizes a lagoon environment in connection with the sea. This environment reflects, like the other two units, the development of clogging dynamics by the sedimentation of the Danube and the concomitant formation of arrows. It is characteristic of coastal environments located in the distal margin of a delta. This process leads to a progradation of the coast and the transformation of the environment into an oligohaline wet zone whose opening towards the high sea is reduced with time.

Unit C was observed in core O2 between 2.4 m and 0.5 m depth. It is characterized by a coarse sediment that evokes the establishment of a more competent environment due to the proximity of the upper infralittoral floor and the impact of the waves on the lagoon bottoms. The macrofauna is very similar to that found today on the coast of Orgamè (Argamum). Its deposit is contemporary to 345 cal. BC-69 cal. AD. It corresponds to the proximity of the shore of an oligohaline fluvial lagoon.

Unit D develops from 0.5 m depth. It occupies the top part of the core and gathers a black loam, rich in organic matter, with many leaves and stems of *Phragmites australis*. It corresponds to the current *Phragmites* wetland bordering the lagoon complex of Razelm-Sinoe.

Chronologically, from 4300 cal. yrs. BP the environment is enriched in fine particles, while the competence of the marine environment gradually decreases. The Danubian contributions are then more consistent and the macrofauna adopts a lagoon profile. Off Orgamè (Argamum), the situation also appears more and more protected, the gradual erection of the Zmeica barrier resulting in relative protection of this area. Its stabilization, around 3000 years cal. BP, seems to be at the origin of a decrease of the Danubian contribution, which intervenes at a moment when the connection of the lagoon with the sea becomes more restricted. However, the transformation of shorelines to wetland *Phragmites australis* occurs in Orgamè (Argamum) only around 1000 years cal. BP.

These results therefore allow the foundation of Orgamè (Argamum) and Acic-Suat to be placed in their geomorphological context. The latter does not intervene on the banks of a vast marine gulf, as supposed until now, but takes place on the contrary within a lagoon which does not communicate with the open sea by some barriers and whose connection with Istros is to be subjected to further research. These observations shed somewhat different light on the historical and economic issues surrounding the establishment.

Beside geomorphological studies, these cores were also used for palynological analyses. The paleoenvironmental signal observed around the Razelm and Goloviţa lagoons is organized around three major phases that accompany the evolution of vegetation in this region since the Neolithic period. In the first phase (A), between 6540 BP (528 cm) and ca. 3570 years BP (335 cm), the region of Orgamè (Argamum) shelters a vital forest cover. During the second phase (B), between ca. 2735 BP (335 cm) and ca. 400 years BP (90 cm), the landscape records an alternation between forest dynamics and steppe cover before the environment, during the third phase (C), ca. 400 years BP to the sub-current time, becomes drier with a remarkably reduced forest cover and steppe dominant (Baralis et al., 2017).

Thus, from ca. 6540 years BP to ca. 3570 years BP (A), the landscapes around Orgamè (Argamum) were generally inhabited by a dense forest cover (fig 17) dominated by different species characteristic of temperate forests (*Quercus deciduous*, *Carpinus betulus*, *Corylus*, *Alnus*, *Betula*, *Fagus* and *Tilia*) as well as by some Gymnosperms (*Pinus* and *Abies*). The presence of hygrophilous / hydrophilic taxa in the area of the ancient port of Orgamè (Argamum) similarly suggests the existence on these coastal areas of riparian forest vegetation similar to that currently found in marsh/swamp areas along the banks of the Razelm. However, during this extended period, the paleoenvironmental signal records an alternation between drier conditions (ca 5955 BP-ca. 4750 BP and ca 4280 BP-ca. 3570 BP) and wetter (ca. 4750 yrs. BP and ca 4280 BP yrs.) that affect the forest cover, while between ca. 5955 BP and ca. 4750 BP primary anthropogenic indicators tend to increase at a time when some taxa, such as *Quercus* deciduous, *Corylus* and *Alnus*, decrease sharply around 5055 years BP, while the presence of *Pinus* and *Abies* increases. This phenomenon is reversed however after ca. 4750 years BP, since the potential increase in rainfall and the reduction of anthropic pressures seem to have favored the progressive replacement of pioneer species such as *Pinus* by forest species such as *Quercus* deciduous, *Corylus*, *Alnus* and *Fagus*. Within Unit B (Early Iron Age-Late Middle Ages), the environmental signal is more marked, mainly as a result of reduced availability of freshwater. These oscillations reflect a less flexible environment, with a reduced forest cover whose dominant component is now *Pinus*. This forest cover, however, disappears gradually, replaced by an open area, favorable to the development of a steppe. Unit C, however, between 1450 and 950 BP, shows the development of a global cooling phase (Dark Medieval Age) accompanied by a concomitant increase in humidity. This supply of fresh water promotes around the Razelm the development of riverine vegetation at a time when the Dunavăţ already found in the Razelm its outlet. At the end of this period, the forest cover is very small, whereas the Chenopodiaceae are on the contrary abundant. A peak of fires is recorded towards ca. 400 years BP.

These results show that the expansion of the settlement during the First Iron Age, laterally with the establishment of Greek settlements along the coastline, led to a metamorphosis of landscapes marked by a decline in forest cover, whose composition evolves in favor of pioneer species such as pine. The latter betrays by its development because of the many cuts practiced, while alongside the coast is set up the coastal steppe which still characterizes the region of Orgamè (Argamum). The different stages of forest cover recovery do not structurally change the landscape pattern, especially during the Hellenistic period, which is accompanied by a disruption of the regional occupation networks in Northern Dobruja, resulting in the abandonment of many Greek settlements.

A research by Baralis et al. (2017) used satellite and aerial photos, combined with surface surveys coupled with a high-precision recording of archaeological sites by the use of a GPS in real time to investigate ancient occupation of the area around Karaburun and Acic-Suat. The objective was to restore the old network of roads, while identifying the possible traces of agricultural parcels, and to locate new establishments. At the regional level, this work resulted in the reconstruction of several routes linking Orgamè (Argamum) to its immediate hinterland or structuring the area north of Istros. Although no major signal of Karaburun was traced, two roads converge towards the peninsula located north-east of the Acic-Suat hill. A first road runs along the coastline in a north-south direction and runs from the cape towards the city of Istros, while a second axis follows the southern shores of the Goloviţa lagoon to the west towards Baia (Figs 13 and 14).

Macrobiological and archaeozoological studies were conducted to understand the development of the Karaburun territory and how it relates to neighboring communities in the hinterland, especially the neighboring cities of Orgamè (Argamum) and Istros. The macrobiological data provided a particularly fascinating light on the life of this establishment. In addition to the use of the reed for roofing, they reveal the use by the inhabitants, whether for the construction of buildings, cooking fuel and heating, as well as for the manufacture of everyday objects, of a range of woody species in which the oak predominates. In this sense, the latest analyses conducted by T. Popova (2017) (in Baralis et al., 2017) have enriched the knowledge of the territory. They revealed the presence of alder, maple, hornbeam, willow and poplar for the archaic and classical periods, as well as for the beginning of the Hellenistic period. This set is completed later by beech and pine during Roman times, illuminating a landscape that pollen diagrams tell us open on the coast, but that we now know punctuated along rivers and wetlands of specific woody vegetation. At the same time, vine seems present at the beginning of the 3rd century BC, as in the 2nd century BC., but in proportions much more modest than those granted to the cereals which predominate by far the assemblages (Baralis et al., 2017). The wheat-millet-barley trilogy here structures the agricultural areas around Acic-Suat, but its inhabitants do not seem to neglect either the engrain or the rye, while these species are accompanied by many wild herbs some of which can be put in relation to possible fallows. Finally, by chance of conservation or difference in dietary practices, legumes are represented here only by lentils and peas, while elderberry, consumed in the non-Greek habitat of Zimbru, is here in the end of its appearance. These various elements thus reveal landscapes dominated by cereals, forcing the inhabitants of Acic-Suat to import the wine and oil necessary for their consumption.

The Archeozoological results from Acic-Suat show that beef dominates the flocks, followed by pork and goats during the archaic period (Baralis et al., 2017). This is not the case here where goats occupy a prominent place followed by beef and pork. The inhabitants of Acic-Suat, by their eating habits, affirm here certain peculiarities. Goats make up 45.2% of the packs, followed by beef (33.6%) and pork (9.6%). Horses and dogs reach 8.4% and 3.2% respectively. Among the peculiarities, it should be noted that the cattle in Acic-Suat seem to have a smaller size than in the hinterland and they are slaughtered relatively late, certainly after being grown. They therefore serve as essential animals and their value remain important. The percentage value of bones with traces of weatherization appear to be particularly high compared to what has been observed on the Zimbru and Călugăra sites. More surprisingly, dogs and horses are subject to one-off consumption, which is not a Greek practice. However, this use has already been recognized in settlements such as Călugăra. This unexpected element informs in an interesting way the identity of the inhabitants of Acic-Suat that the absence of burials in the excavated areas did not allow to approach so far. The establishment presents a Greek profile, in particular by its ceramic technology or by the quantity of the vases, which one does not find the equivalent on other sites, or in the late-classical and Hellenistic period by the construction techniques that are used. Nevertheless, this prevalence of Greek identity does not prohibit the presence within it of non-Greek elements carrying their own modes of consumption, without the status of these people - dependents, slaves, wives ... -being known. These practices, attested during the archaic period, continue until the beginning of the Hellenistic period.

Archeological and ichthyological analyses attest to the consumption of fish at Acic-Suat, both during the archaic period and during late-classical and Hellenistic times. Many weights for nets have been discovered during excavations. They are most often made in a variety of materials, such as ceramic fragments or amphora belly. Their abundance allows to link this food practice to an investment of the inhabitants in the fishing activities. However, only the completion of fish-habitat analyses will make it possible to specify to what extent fishing played a role, fundamental or complementary, in the economic strategies of the settlers. From now on, the preliminary results help to disprove some myths that Greeks are only oriented towards the high seas species, either because of their food habits or even to feed a trade based on salting. However, it is here in contrast to freshwater species that predominate. Cyprinids, pike, perch, but also sturgeon, which will be important to measure, represent what the Greek settlers seem to have picked or selected by settling on the banks of the lagoons of Razelm and Goloviţa.

4.2. Comparison with Orgamè' s paleoenvironment

Orgamè and Karaburun share the same lagoon environment. The sheer fact that Orgamè was a well-established harbor with a favourable access to the Black sea from a natural inlet, still, makes it difficult to assume a similar situation in Karaburun. Surprisingly, even with the least data obtained from the cores in Karaburun, interesting relations (also variations) were found with those from Orgamè.

The three cores from Orgamè show a classic environmental transformation (Bony et al., 2015). The reduction in accommodation space gradually led to the transition from a marine environment to a quasi-closed lagoon (3660 cal. yr BP) to an oligohaline lagoon (2300 cal. yr BP) whose margins were progressively transformed into a coastal wetland dominated by *Phragmites australis* (1000 cal. BP) (Bony et al., 2015). This transformation agrees with the case of Karaburun, especially around 2135 cal. BP (see Fig 12), where the environment switches from a semi-enclosed lagoon to a landlocked wetland. In KA III and KA IV there is an event of high energy which probably could correspond to a local storm as we do not see it in the case of Orgamè, although it should be noted that a complete dating is required to confirm this hypothesis. In Orgamè' s shoreline (core O1), we observe the transition from a marine bay to a lagoon environment occurred at 4300 cal. yr. BP due to the progradation of the coastline (Fig. 16). In this case it is logical to assume the same situation in Karaburun since they share the same shoreline at a larger scale. The high sedimentation rates recorded at the bottom of the Unit A core O2 (in Orgamè) and KA IV(Karaburun) could be explained by an increase in the discharge of the Danube river around 5000 cal. BP, when sea level stabilized (Giosan et al., 2006; Bony et al., 2015). These being the main explicable contrast, Orgamè' s well-defined evolutionary facies should by default be able to show a perfect sequence of the environmental dynamics that took place in the Razelm-Sinoe lagoon complex.

Conclusion

In a general sense, the results exhibit a characteristic model of coastal evolution in a deltaic context. From ca. 5000 years onwards, massive sediment supply from the Danube, on the southern coast of St. George's arm, engendered a two-phase model of paleoenvironmental change: (1) the closure of the bay at ca. 1500 cal. BC (3600 cal. BP) due to the formation of the Lupilor barrier; and (2) the evolution of a freshwater lagoon environment around ca. 300 cal. BC (ca. 2250 cal. BP) due to the formation of the Dunavăţ arm inside the lagoon (Bony et al., 2015). As shown in the graphs, Karaburun context fits indisputably in this model realized in Orgamè by Bony et al. (2015). An interesting conclusion of this study is that the formation of Dunavăţ lobe and the transformation in lagoon of Goloviţa takes credit, as hypothesized before, between Orgamè/Argamum and Karaburun.

Limitations and Future Research

In the absence of a complete radiocarbon dates of the cores and sufficient macro/micro-fossil data, attention was given to sedimentological results. Conclusions on the geomorphological evolution of the coastal area and its impact on the occupation history of the site are made with a limited scope. Nevertheless, these paleogeographic premises are expected to add a lot to the archeological interpretation. Thus, the below mentioned are proposed for future research:

- Carrying out cores on the eastern as well as Northern areas, as close as the present-day shoreline.

- A detailed analysis of the relationship between Lupilor barrier and the river that overlooks it.

- Areal survey in search of more archaeological indicators of environmental transformation.

It is hopeful that the thesis has been as clear and objective as possible and that it demonstrated the usefulness of this type of research to decipher landscape transformation. However, the subject is still not exhausted, and is left open for a more detailed analysis of the objectives studied in the present thesis.

Annex

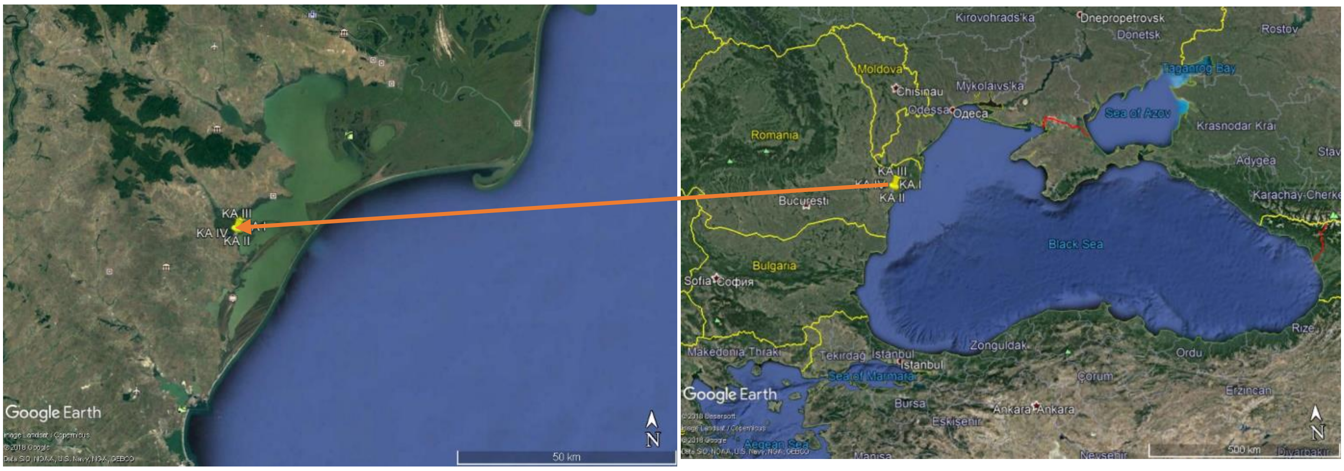

Figure 1 Location of Karaburun

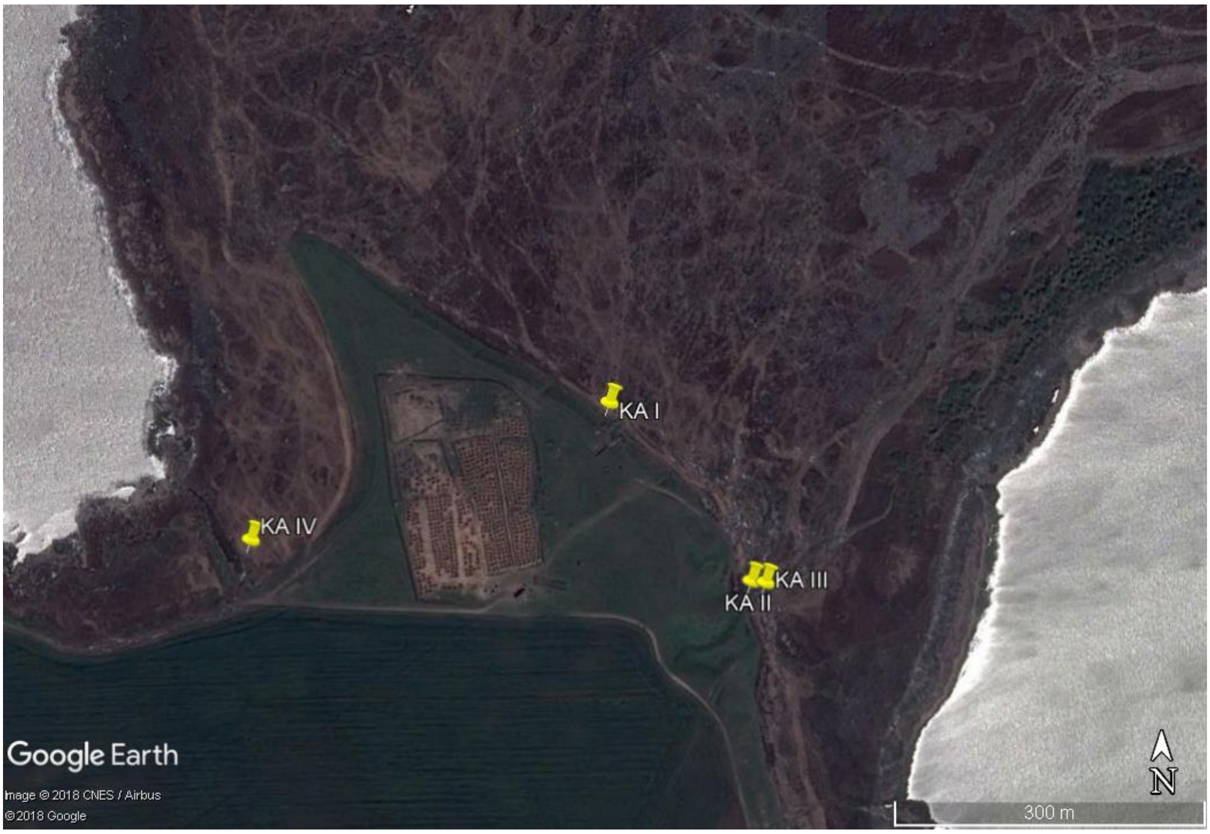

Figure 2 Location of cores (KA I, KA II, KA III, KA IV)

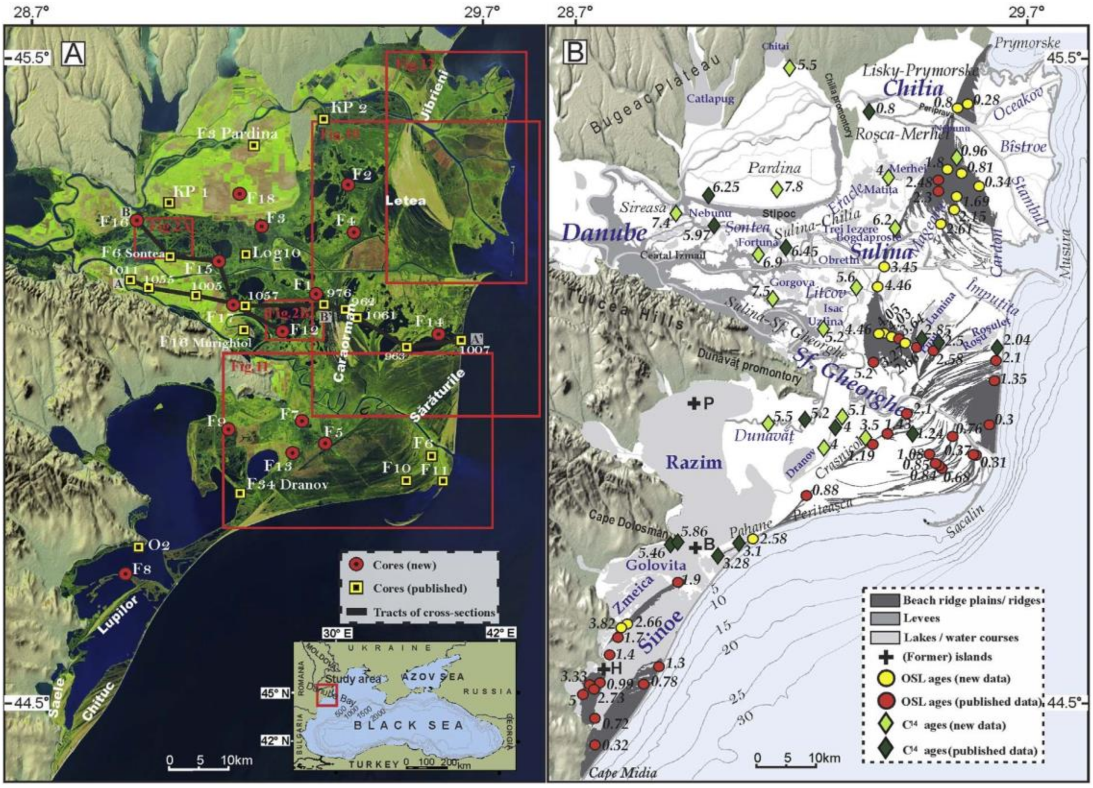

Figure 3 . The map of Danube Delta with the main geomorphological features of the delta plain (after Vespremeanu et al., 2017)

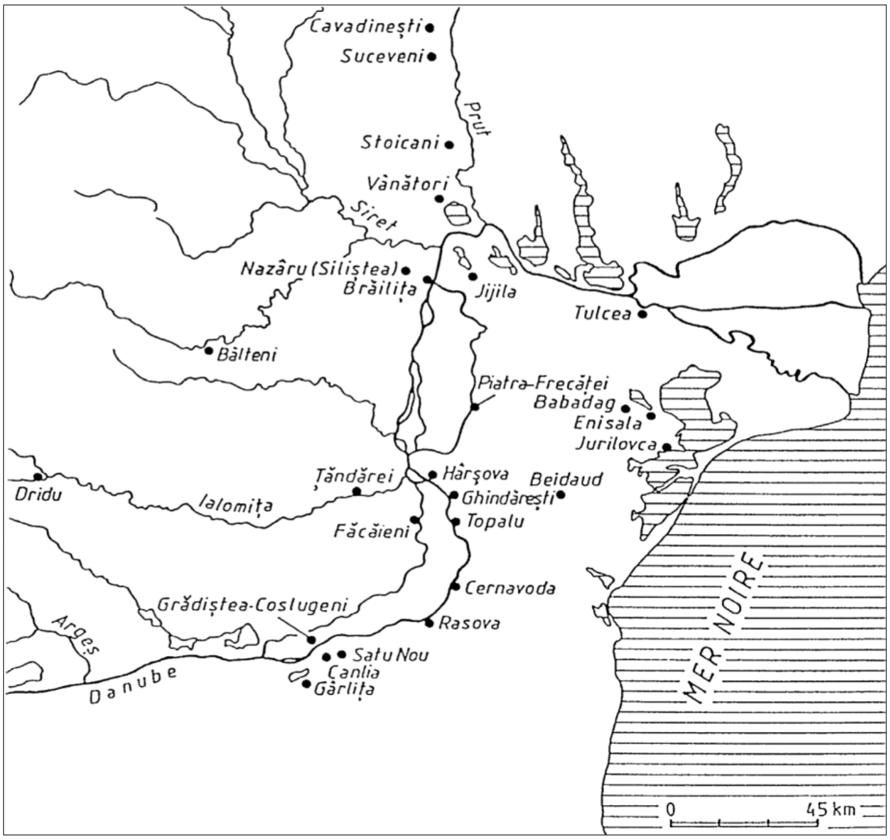

Figure 4 Site map of the Babadag culture (after Avram, 2006)

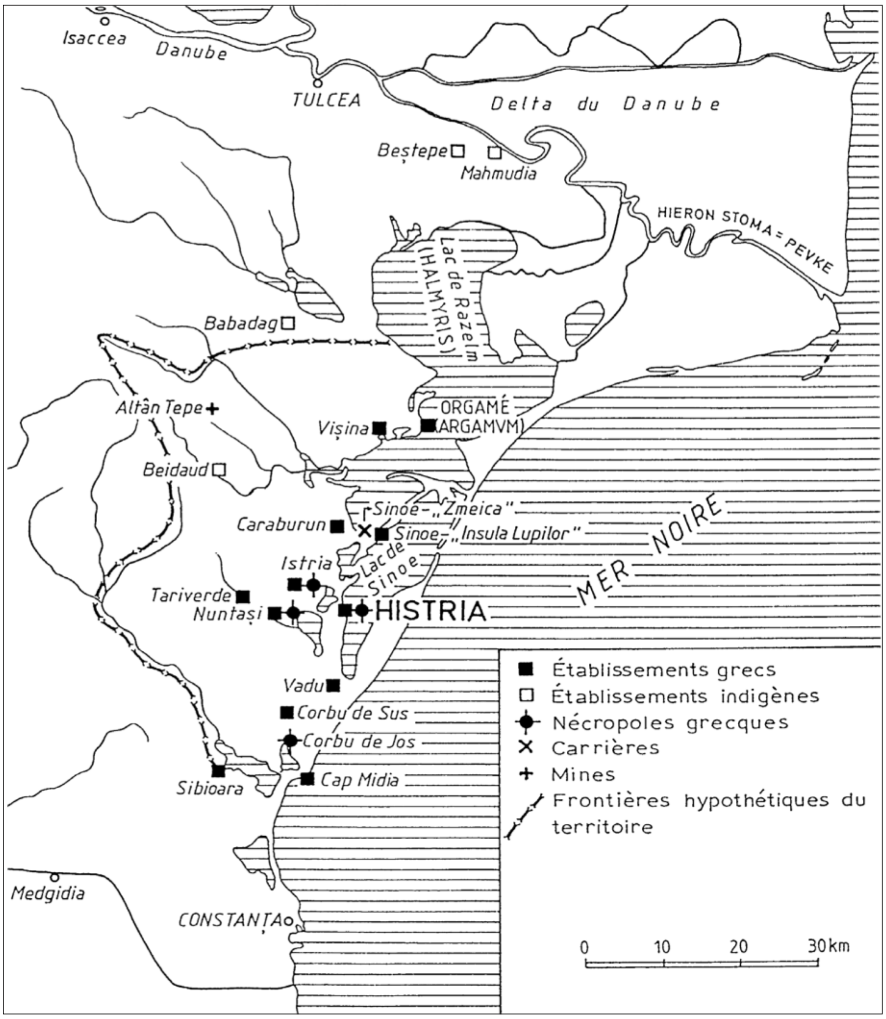

Figure 5 Territory of Istros: Archaic period (after Avram, 2006)

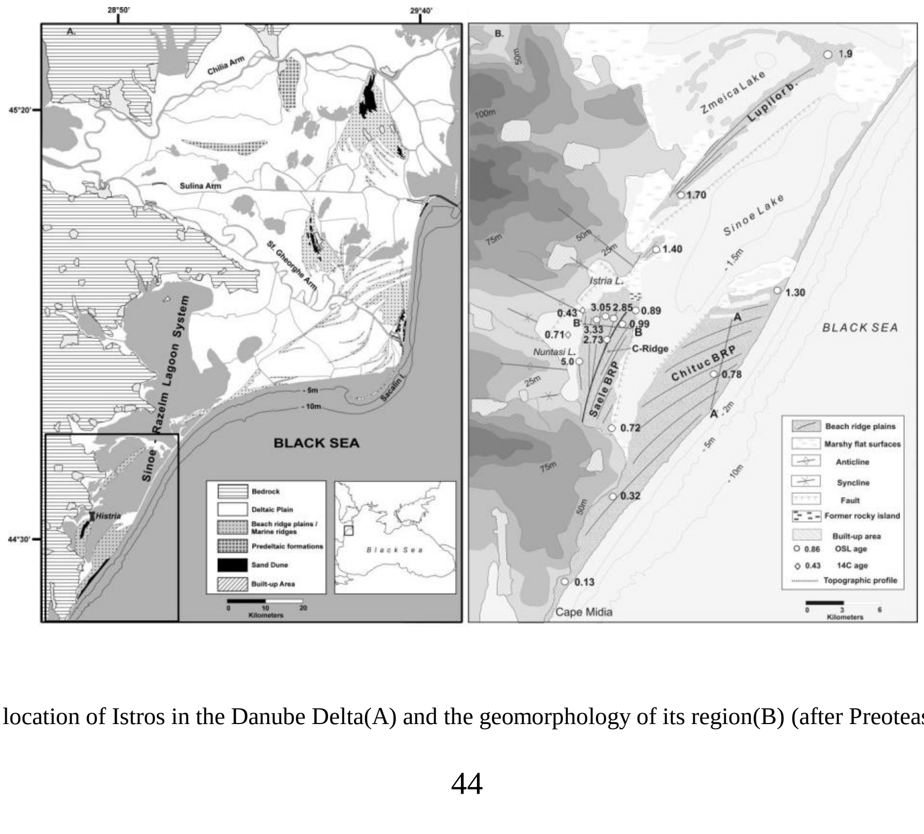

Figure 6 The location of Istros in the Danube Delta(A) and the geomorphology of its region(B) (after Preoteasa et al., 2013)

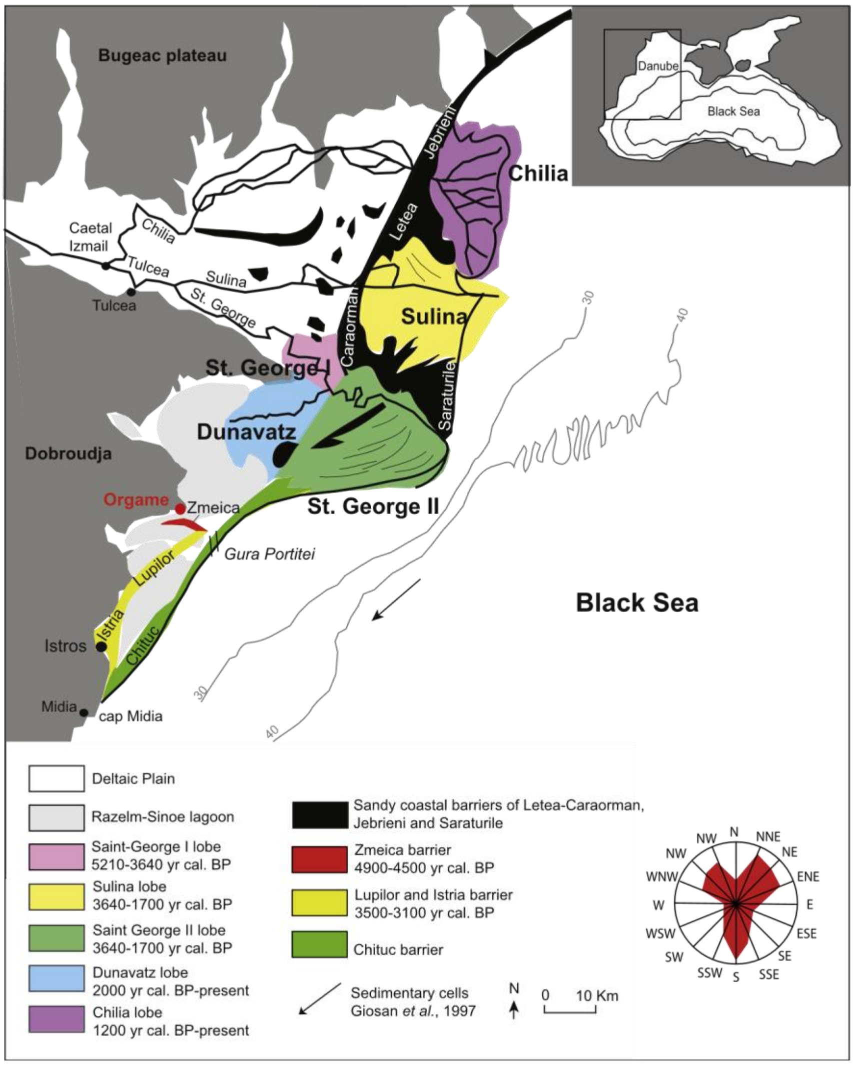

Figure 7 Location of Orgamè' s ancient harbor in the present Razelm-Sinoe Lagoon, Danube Delta (after Bony et al., 2015)

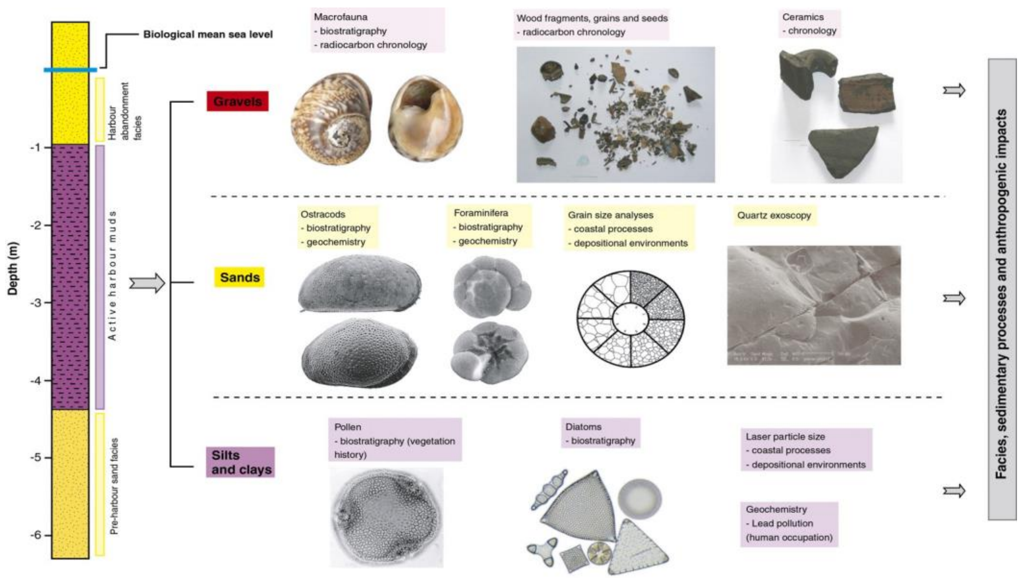

Figure 8 Facies, sedimentary processes and anthropogenic impacts: research tools used in the study of ancient harbor sequences (after Marriner and Morhange, 2007).

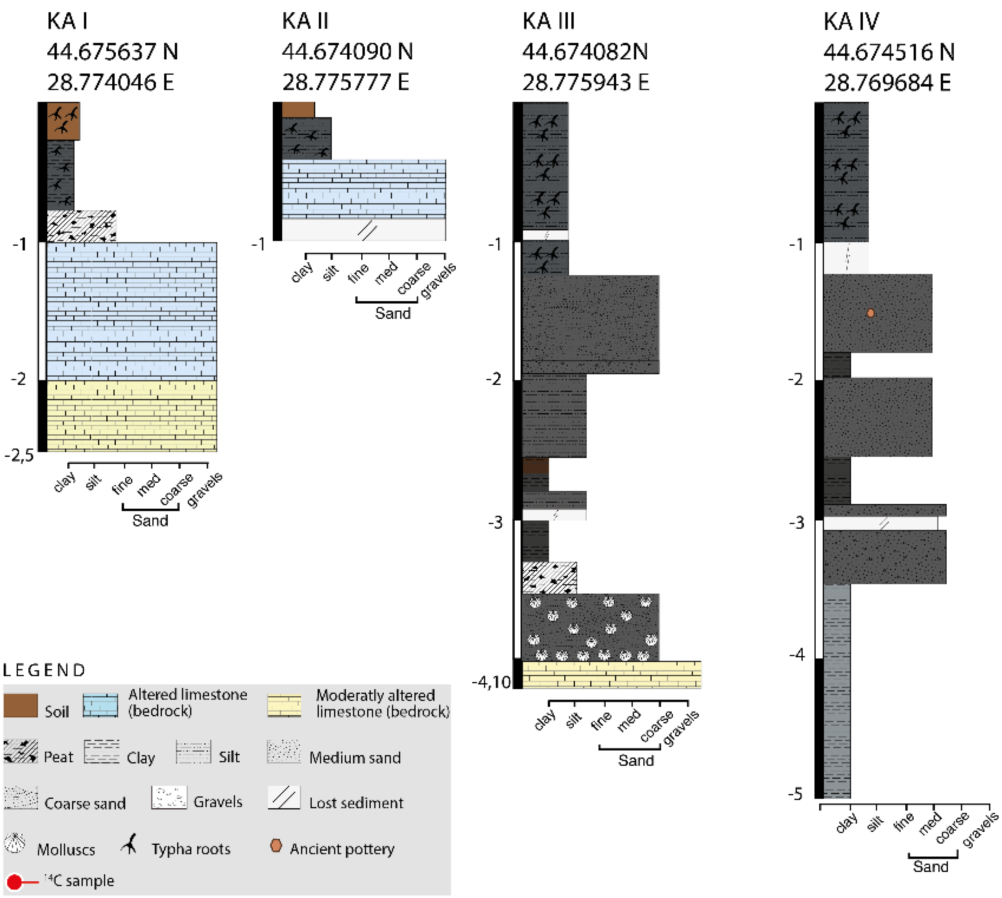

Figure 9 Stratigraphy of the four cores from Karaburun

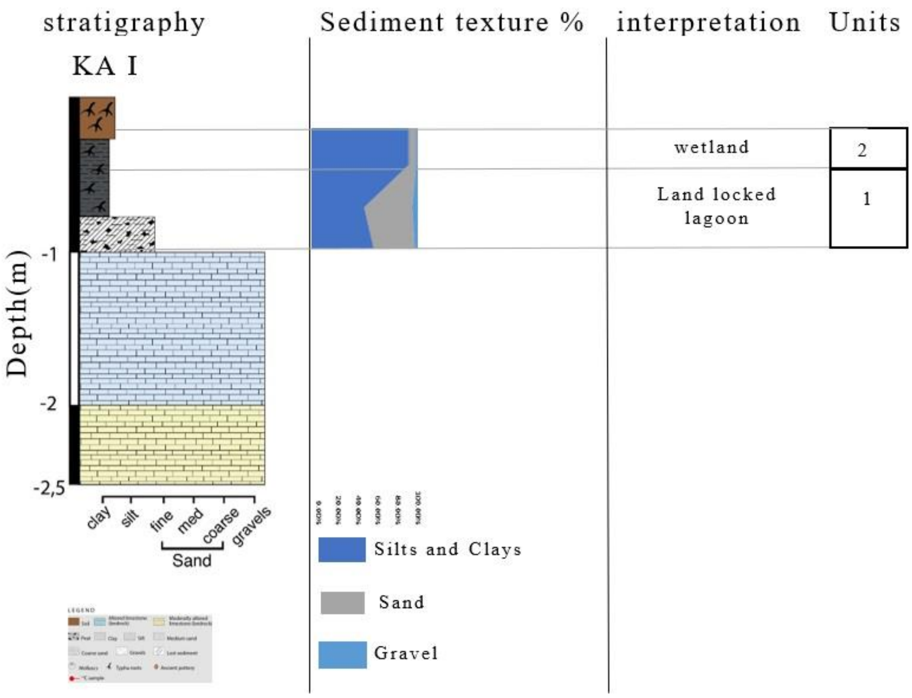

Figure 10 KA IV stratigraphy and texture

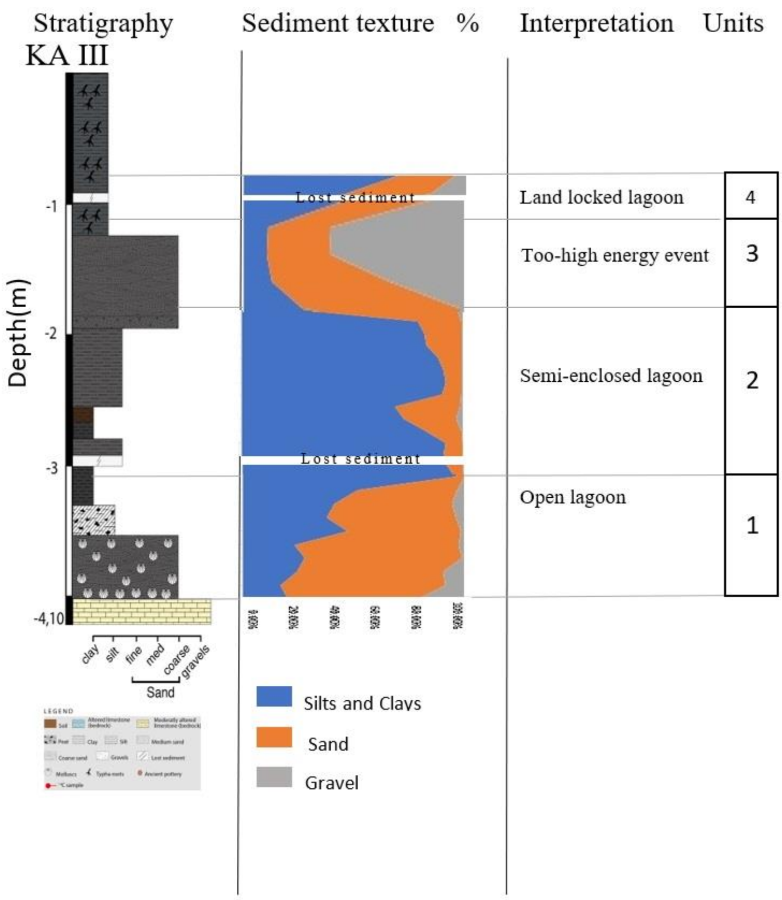

Figure 11 KA III stratigraphy and texture

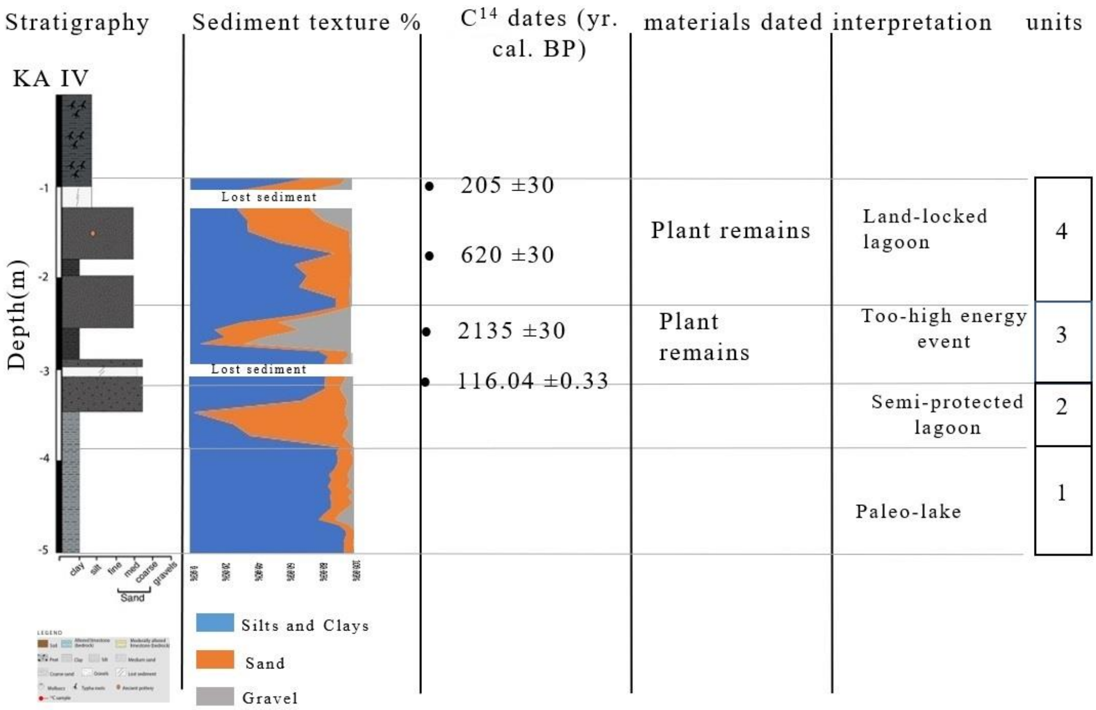

Figure 12 KA IV stratigraphy and texture

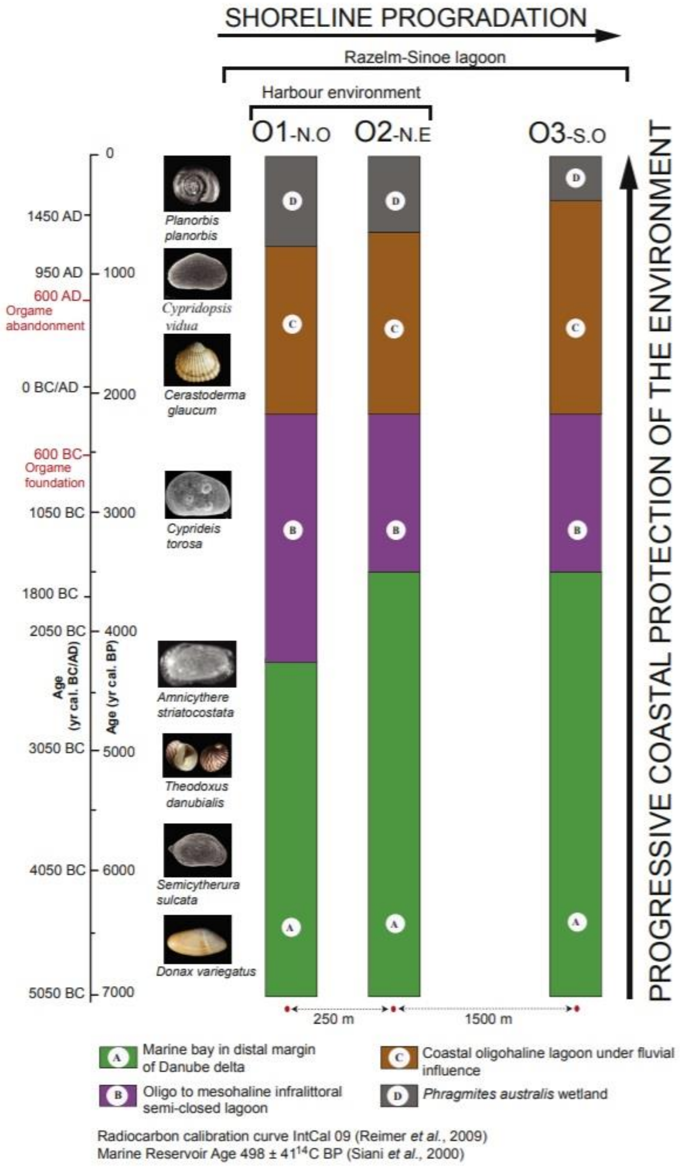

Figure 13 Stratigraphy of the cores from Orgamè (after Bony et al., 2015)

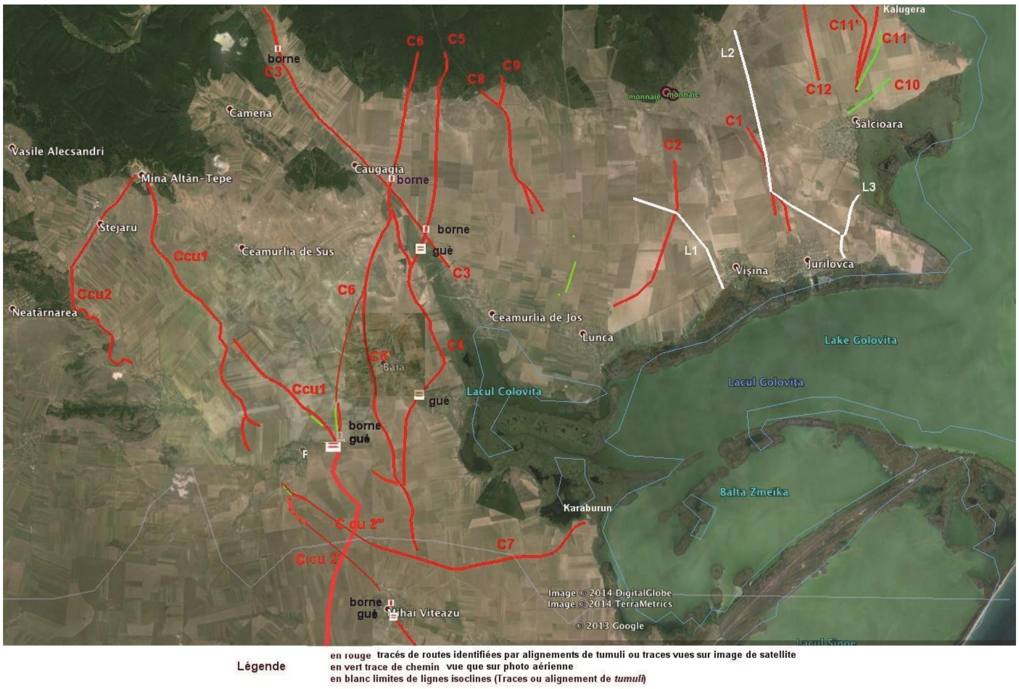

Figure 14 Satellite image analysis of Karaburun/Acic-Suat

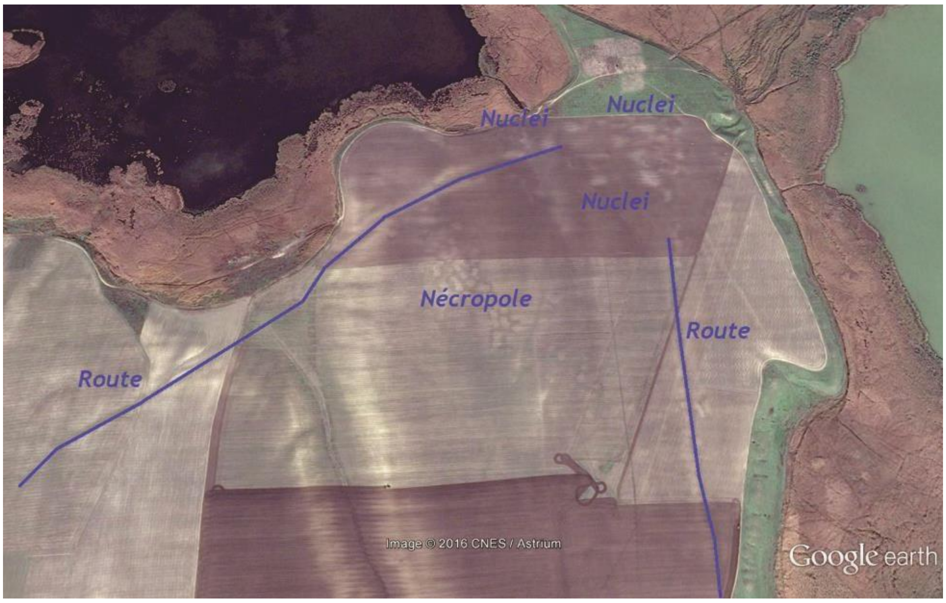

Figure 15 The two ancient routes diverging to/from Karaburun

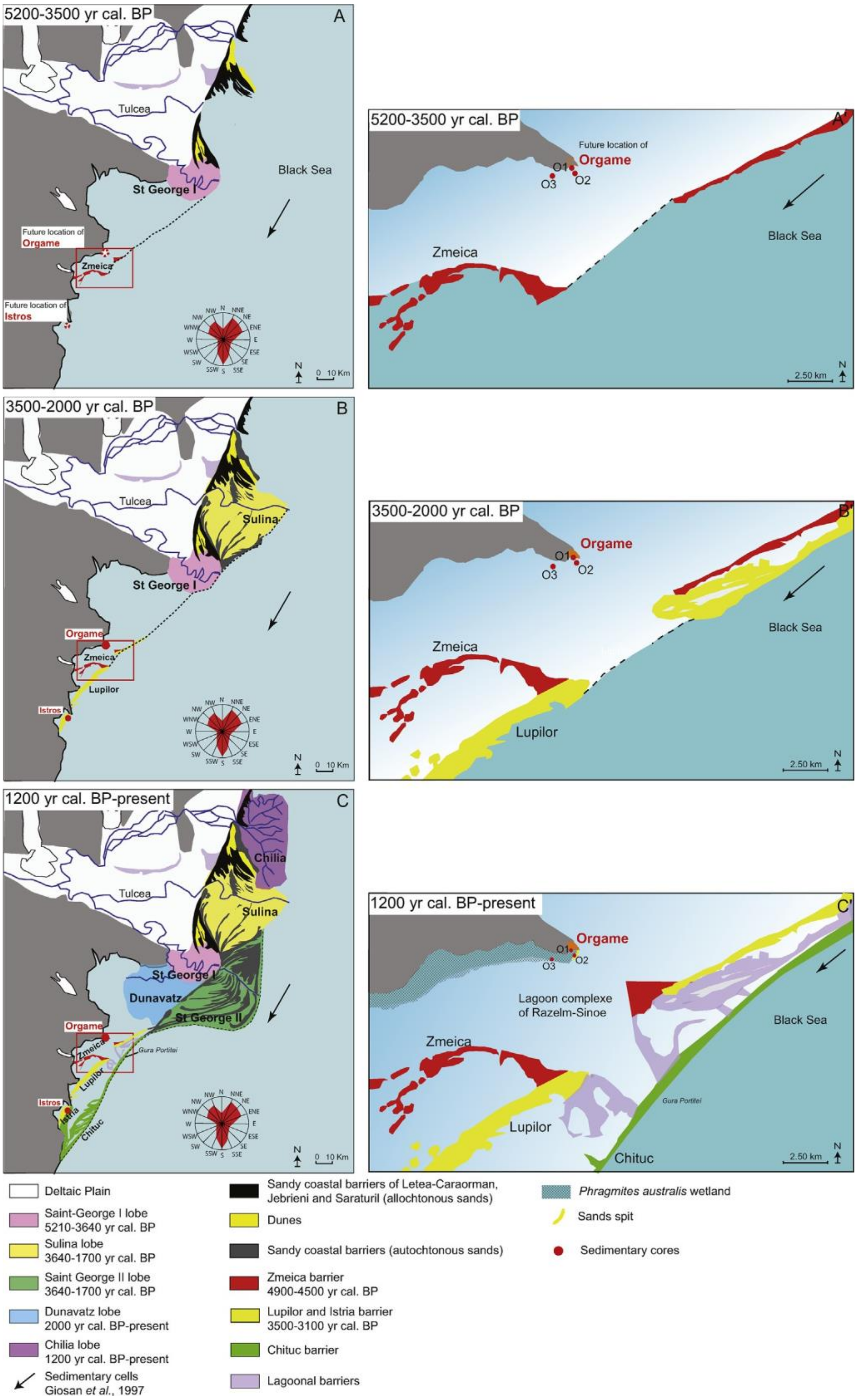

Figure 16. Paleo-geographical reconstruction of Orgamè' s coastal landscapes (after Bony et al., 2015)

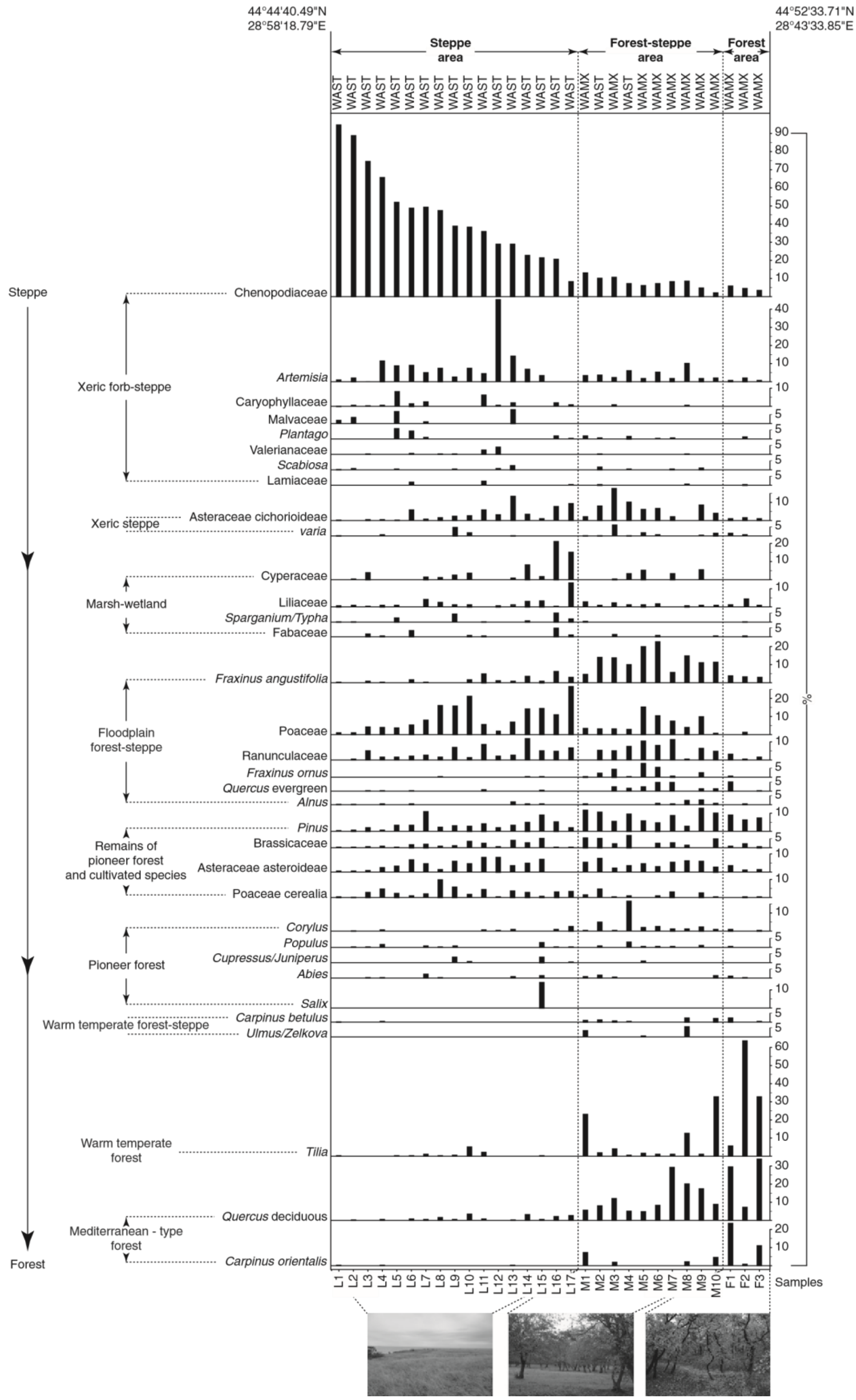

Figure 17 Pollen diagram and vegetation zones from the northern Dobrogea transect. Taxa are arranged from the steppe zone to the forest area. In each vegetation cluster, taxa are ordered according to their frequencies, from the most represented to the low (after Rossignol et al. 2012)

Bibliography

Ailincăi, S., Mirițoiu, N., & Soficaru, A. (2006). A pit with human remains attributed to the Babadag culture discovered in pre-colonial level at Orgamè, în Mănucu-Adameşteanu. In *A la recherche d'une colonie. Actes du Colloque International* (Vol. 40, pp. 81–107).

Alexandrescu, P. (1978). Notes de topographie histrienne. *Dacia NS, 22,* 331–342.

Anthony, E. J. (2015). Wave influence in the construction, shaping and destruction of river deltas: A review. *Marine Geology, 361*, 53–78.

Antonova I. (1971). Fortifications of Chersonesos harbour in the Medieval Ages. *Antiquity and the Middle Ages*, *7*, 102–118(in Russian).

Ashton, A. D., & Giosan, L. (2011). Wave-angle control of delta evolution. *Geophysical Research Letters, 38*(13).

Athersuch, J., Horne, D. J., & Whittaker, J. E. (1989). Marine and brackish water ostracods (superfamilies Cypridacea and Cytheracea). Keys and notes for the identification of species. In *Synopses of the British Fauna New Series* (Vol. 43, pp. 1–343). Brill Archive.

Avram, A., Hind, J., Tsetskhladze, G. (2004). The Black Sea Area. In T. H. Hansen, M. H., Nielsen (Ed.), *An Inventory of Archaic and Classical Poleis* (pp. 924–973). Oxford.

Avram, A. (2006). The Territories of Istros and Kallatis . *Surveying the Greek Chora, Black Sea Region in a Comparative Perspective, 4,* 59–80.

Avram, A., Bounegru, O., & Chiriac, C. (1985). Cercetari perieghetice in teritoriul Histriei (I). *Pontica*, *18*, 113–124.

Balabanov, I. P. (2009). Paleogeographic background to modern natural condition of the Caucasus littoral Holocene terraces and their long-term development forecast. In *Dalnauka, Moscow*.

Baralis A., Lungu V., Panayotova K., Blanco T., B. G. et al. (2012). Le programme ANR Pont-Euxin: bilan des campagnes 2012 à Apollonia du Pont (Sozopol, dpt. de Bourgas, Bulgarie) et Orgamè/Argamum (Jurilovca, dpt. de Tulcea, Roumanie). *Dialogues d'histoire Ancienne*, *38*(2), 165–187.

Baralis, A., & Lungu, V. (2015). Stratégies coloniales et réseaux d'occupation spatiale getes sur le littoral de la Dobroudja du Nord: les acquis du Programme ANR Pont-Euxin. *The Danubian Lands between the Black, Aegean and Adriatic Seas (7th Century BCe10th Century AD) BAR International Series, Oxford*, 1–19.

Baralis, A., Lungu, V., & Dupont, P. et al. (2017). L'établissement d'acic-Suat (commune de Baia, département de Tulcea). Méthodologie d'une enquête pluridisciplinaire. *Pontica, 50,* 455–488.

Baralis, A., Panayotova, K., Bogdanova, T., Gyuzelev, M., Nedev, D., & Gospodinov, K. (2016). Apollonia Pontica (Sozopol, Bulgaria): The results of the Franco-Bulgarian archaeological mission. *The Black Sea in the Light of New Archaeological Data and Theoretical Approaches: Proceedings of the 2nd International Workshop on the Black*

Sea in Antiquity Held in Thessaloniki, 18-20 September 2015, (September), 153–179.

Bitinas, A., Damušyte, A., Hütt, G., Jaek, I., & Kabailiene, M. (2001). Application of the OSL dating for stratigraphic correlation of Late Weichselian and Holocene sediments in the Lithuanian Maritime Region. *Quaternary Science Reviews, 20*(5–9), 767–772.

Bivolaru A., Giaime M., Morhange C., Rossi V., Andrieu-Ponel V., Marriner N., et al. (2017). Coastal geoarchaeology of the Danube delta. Results from Halmyris, Enisala and Istros.(unpublished paper).

Bleahu, M. (1963). Observatii asupra evolutiei zonei Histria ın ultimele trei milenii. *Probleme de Geografie*, *9*, 45–56.

Bonaduce, G. (1975). Distribution of ostracoda in the Adriatic Sea. *Pubblicazioni Della Stazione Zoologica Di Napoli*, *40*, 154.

Bony, G., Morhange, C., Marriner, N., Baralis, A., Kaniewski, D., Rossignol, I., & Lungu, V. (2015). History and influence of the Danube Delta lobes on the evolution of the ancient harbour of Orgame (Dobrogea, Romania). *Journal of Archaeological Science*, *61*, 186–203.

Boomer, I., & Eisenhauer, G. (2002). Ostracod faunas as palaeoenvironmental indicators in marginal marine environments,. In J. A. Holmes & A. R. Chivas (Eds.), *The Ostracoda: Applications in Quaternary Research, Geophysical Monograph, vol. 131. American Geophysical Union, Washington DC* (pp. 135–149).

Boyd, R., Dalrymple, R., & Zaitlin, B. A. (1992). Classification of clastic coastal depositional environments. *Sedimentary Geology*, *80*(3–4), 139–150.

Breman, E. (1975). *The distribution of ostracodes in the bottom sediments of the Adriatic Sea*. Vrije Universiteit.

Brückner, H., Kelterbaum, D., Marunchak, O., Porotov, A., & Vött, A. (2010). The Holocene sea level story since 7500 BP - Lessons from the Eastern Mediterranean, the Black and the Azov Seas. *Quaternary International*, *225*(2), 160–177.

Buynevich, I. V, Bitinas, A., & Pupienis, D. (2015). Aeolian sand invasion: georadar signatures from the Curonian Spit dunes, Lithuania. In *Sand and Gravel Spits* (pp. 67–78). Springer.

Canarache, V. (1956). Observaţii noi cu privire la topografia Histriei. *Studii Si Cercetari de Istorie Veche*, *7*(2–3), 289–315.

Carbonel, P. (1980). Les ostracodes et leur interêt dans la définition des écosystèmes estuariens et de plateforme continentale. In *Essais d'application à des domaines anciens. Mém. Inst. Géol. Bassin d'Aquitaine* (Vol. 11, pp. 1–378). Université de Bordeaux I.

Carbonel, P. (1982). Les ostracodes, traceurs des variations hydrologiques dans les systèmes de transition eaux douces-eaux salées. *Mémoires de La Société Géologique de France*, *144*(11), 117–128.

Chepalyga, A. L. (1984). Inland sea basins. In B. C. W. VELICHKO A. A, WRIGHT H. E. (Ed.), *Late Quaternary Environments of the Soviet Union* (p. 237-240). Minneapolis:

University of Minnesota Press.

Coja, M. (1972). Cercetări noi în aşezarea greco-romană de la Capul Dolojman–Argamum (?). *BMI*, *41*(3), 33–42.

Coteţ, P. V. (1966). Ţărmul Mării Negre şi evoluţia lui în timpuri istorice (cu privire specială asupra regiunii Histria). *Histria*, *2*, 337–352.

Dan, S., Stive, M., Walstra, D. J., & Sabatier, F. (2007). Sediment budget of the Danube Delta coastal zone. In *Coastal Sediments' 07* (pp. 207–220).

Dan, S., Walstra, D.-J. R., Stive, M. J. F., & Panin, N. (2011). Processes controlling the development of a river mouth spit. *Marine Geology*, *280*(1–4), 116–129.

De Martonne, E. (1931). Europe Centrale, volume II. Paris.

Deigaard, R., & Fredsøe, J. (2005). The shape of equilibrium coastlines. In *Proceedings of International Coastal Symposium. Innovation Center of East-Iceland, Höfn, Iceland* (pp. 134–149).

Del Rio, L., Benavente, J., Gracia, F. J., Alonso, C., & Rodríguez-Polo, S. (2015). Anthropogenic influence on spit dynamics at various timescales: case study in the Bay of Cadiz (Spain). In *Sand and Gravel Spits* (pp. 123–138). Springer.

Ericson, J. P., Vörösmarty, C. J., Dingman, S. L., Ward, L. G., & Meybeck, M. (2006). Effective sea-level rise and deltas: causes of change and human dimension implications. *Global and Planetary Change*, *50*(1–2), 63–82.

Fedorov, P. V. (1977). Late Quaternary history of the Back Sea and evolution of the southern seas of Europe. *Pleistocene Paleogeography and Sediments of the Southern Seas of the USSR. Nauka, Moscow*, 25–32(in Russian).

Filip, F., & Giosan, L. (2014). Evolution of Chilia lobes of the Danube delta: Reorganization of deltaic processes under cultural pressures. *Anthropocene*, *5*, 65–70.

Filipova-Marinova, M., & Christova, R. (2001). Sea level fluctuations in the Western part of the Black Sea during the Holocene. *Comptes Rendus de l'Académie Bulgare Des Sciences*, *54*(5), 59–64.

Folk, R. L. (1966). A Review of Grain-Size Parameters. *Sedimentology*, *6*(2), 73–93.

Folk, R. L. (1980). *Petrology of sedimentary rocks*. Hemphill Publishing Company.

Folk, R. L., & Ward, W. C. (1957). Brazos River bar [Texas]; a study in the significance of grain size parameters. *Journal of Sedimentary Research*, *27*, 3–26.

Fouache, E., Kelterbaum, D., Brückner, H., Lericolais, G., Porotov, A., & Dikarev, V. (2012). The Late Holocene evolution of the Black Sea - a critical view on the so-called Phanagorian regression. *Quaternary International*, *266*, 162–174.

Galloway, W. E. (1975). Process framework for describing the morphologic and stratigraphic evolution of deltaic depositional systems. In M. L. Broussard (Ed.), *Deltas, Models for*

Exploration (pp. 86–98). Houston Geological Society.

Gâştescu, P. (2009). The Danube Delta biosphere reserve. Geography, biodiversity, protection, management. *Rev Roum Géogr*, *53*, 139–152.

Giosan, L., Constantinescu, S., Filip, F., & Deng, B. (2013). Maintenance of large deltas through channelization: nature vs. humans in the Danube delta. *Anthropocene*, *1*, 35–45.

Giosan, L., Donnelly, J. P., Constantinescu, S., Filip, F., Ovejanu, I., Vespremeanu-Stroe, A., … Duller, G. A. T. (2006). Young Danube delta documents stable Black Sea level since the middle Holocene: Morphodynamic, paleogeographic, and archaeological implications. *Geology*, *34*(9), 757–760.

Goiran, J.-P., Tronchère, H., Salomon, F., Carbonel, P., Djerbi, H., & Ognard, C. (2010). Palaeoenvironmental reconstruction of the ancient harbors of Rome: Claudius and Trajan's marine harbors on the Tiber delta. *Quaternary International*, *216*(1–2), 3–13.

Holmes, J., & Chivas, A. R. (2002). *The Ostracoda: Applications in Quaternary Research*. *Geophysical Monograph* (Vol. 131). Washington DC: American Geophysical Union.

Hristova, R., & Peev, P. (2014). Sea level rise and human adaptation to environmental changes during the late prehistory along the western Black Sea coast. *Comptes Rendus De L Academie Bulgare Des Sciences*, *67*(5), 693–698.

Jerolmack, D. J., & Mohrig, D. (2007). Conditions for branching in depositional rivers. *Geology*, *35*(5), 463–466.

Kryzhitskyi S. and Shilik K. K. (1974). Underwater works in Olbia. *Arkheologicheskie Otkrytija 1973*, 304-305, (in Russian).

Lungu, V. (1997). La tombe du héros et l'organisation de la nécropole d'Orgame, în Lungu, V. In *Pratiques funeraires dans l'Europe des XIIIe-IVe s. av. J.-C. Actes du IIIe Colloque International d'Archéologie Funéraire, Tulcea* (pp. 67–87).

Lungu, V. (2001). 'La tombe d'un héros et l'organisation de la nécropole d'une cité milésienne du Pont-Euxin: le tumulus T-A95 d'Orgame'. *Talanta*, 32–33.

Lungu, V. (2010). Greek-Ionian Necropoleis in the Black Sea Area: Cremation and Colonisation. *Archaic Greek Culture: History, Archaeology, Art and Museology*, 51–58.

Major, C., Ryan, W., Lericolais, G., & Hajdas, I. (2002). Constraints on Black Sea outflow to the Sea of Marmara during the last glacial/interglacial transition (Vol. 190, pp. 19–34).

Manucu-Adamesteanu, M. (2003). Orgame. *Ancient Greek Colonies in the Black Sea*, *1*, 341–388.

Marriner, N. (2009). *Geoarchaeology of Lebanon's ancient harbours*. Archaeopress.

Marriner, N., & Morhange, C. (2007). Geoscience of ancient Mediterranean harbours. *Earth-Science Reviews*, *80*(3–4), 137–194.

Marriner, N., Morhange, C., & Goiran, J.-P. (2010). Coastal and ancient harbour geoarchaeology. *Geology Today*, *26*(1), 21–27.

McManus, J. (2002). Deltaic responses to changes in river regimes. *Marine Chemistry*, *79*(3–4), 155–170.

Morhange, C. (1994). La mobilité récente des littoraux provençaux: éléments d'analyse géomorphologique. Université de Provence-Aix-Marseille I.

Morhange, C. et al. (2016). Geomorphology and geoarchaeology of Black Sea coasts. *Journal of Mediterranean Geography*, *126*(December), 11–14.

Morhange, C., Goiran, J.-P., Bourcier, M., Carbonel, P., Le Campion, J., Rouchy, J.-M., & Yon, M. (2000). Recent Holocene paleo-environmental evolution and coastline changes of Kition, Larnaca, Cyprus, Mediterranean Sea. *Marine Geology*, *170*(1–2), 205–230.

Morhange, C., Laborel, J., & Hesnard, A. (2001). Changes of relative sea level during the past 5000 years in the ancient harbor of Marseilles, Southern France. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *166*(3–4), 319–329.

Müller, G. W. (1894). *Ostracoden des Golfes von Neapel un der angrenzenden Meerabschnitte*. *Fauna and Flora des Golfes von Neapel* (Vol. 21).

Panin, N. (1983). Black Sea coast line changes in the last 10.000 years. A new attempt at identifying the Danube mouths as described by the ancients. *Dacia. Revue d'Archéologie et d'Histoire Ancienne Bucuresti*, *27*(1–2), 175–184.

Panin, N. (2003). The Danube Delta. Geomorphology and Holocene Evolution: a synthesis/Le delta du Danube. Géomorphologie et évolution holocène: une synthèse. *Géomorphologie: Relief, Processus, Environnement*, *9*(4), 247–262.

Panin, N., & Jipa, D. (2002). Danube River sediment input and its interaction with the north-western Black Sea. *Estuarine, Coastal and Shelf Science*, *54*(3), 551–562.

Peev, P. (2016). Using archaeological data to infer past relative sea-level positions along the Bulgarian coast of the. *Journal of Mediterranean Geography*, *126*, 17–24.

Peters, K. F. (1867). Grundlinien zur Geographie und Geologie der Dobrudscha. In *Denkschriften der kaiserlichen Akademie der Wissenschaft in Wien, MathematischNaturwissenschaftliche Klasse 27 (1867)* (Zweite Abt, pp. 83–144).

Pippidi, D. M., & Romania, A. R. S. (1983). Inscripţiile din Scythia Minor greceşti şi latine. Histria Şi Împrejurimile. Editura Academiei Republicii Socialiste Romania, Bucureşti. 14-37.

Preoteasa, L., Vespremeanu-Stroe, A., Hanganu, D., Katona, O., & Timar-Gabor, A. (2013). Coastal changes from open coast to present lagoon system in Histria region (Danube delta). *Journal of Coastal Research*, *65*, 564–569.

Preoteasa, L., Vespremeanu-Stroe, A., Tătui, F., Zăinescu, F., Timar-Gabor, A., & Cîrdan, I. (2016). The evolution of an asymmetric deltaic lobe (Sf. Gheorghe, Danube) in association with cyclic development of the river-mouth bar: Long-term pattern and present adaptations to human-induced sediment depletion. *Geomorphology*, *253*, 59–73.

Reimer, P. J., Bard, E., Bayliss, A., Beck, J. W., Blackwell, P. G., Ramsey, et al. (2013). IntCal13 and Marine13 radiocarbon age calibration curves 0–50,000 years cal BP. *Radiocarbon*, *55*(4), 1869–1887.

Ruiz, F., Abad, M., Bodergat, A. M., Carbonel, P., Rodríguez-Lázaro, J., & Yasuhara, M. (2005). Marine and brackish-water ostracods as sentinels of anthropogenic impacts. *Earth-Science Reviews, 72*, 89–111.

Ryan, William B F, Pitman III, Walter C, Major, Candace O, Shimkus, K. et al. (1997). An abrupt drowning of the Black Sea shelf. *Marine Geology*, *138*(1–2), 119–126.

Salomon, F., Goiran, J. P., Noirot, B., Pleuger, E., Bukowiecki, E., Mazzini, I., … Germoni, P. (2018). Geoarchaeology of the Roman port-city of Ostia: Fluvio-coastal mobility, urban development and resilience. *Earth-Science Reviews*, *177*(October 2017), 265–283.

Schokalsky, J., & Nikitine, B. (1927). L'océanographie de la Mer Noire d'après les explorations hydrographiques Russes. In *Annales de Géographie* (Vol. 36, pp. 385–400). JSTOR.

Shilik K. K. (1972). Determination of the height and absolute age of new Black Sea terraces in Olbia. *Reports of USSR Academy of Sciences*, *203*(5), In Russian.

Shilik, K. K. (1997). Oscillations of the Black Sea and ancient landscapes. *Colloquia Pontica*, *3*, 115-130.

Shilik K. K. (1999). Fluctuations of the Black Sea level according to geological, archaeological and historical data. *Dobrudzha*, *14–16*, 10–36(in Russian).

Shteglov A., Balt T., B. M. et al. (1976). Works on the Tarkhankut Peninsula. In *Arkheologicheskie otkrytija 1975* (p. 409-411 (in Russian)).

Slavova, K., Chterev, K., Dimitrov, D., Peychev, V., & Dimitrov, P. (2012). Ancient coastlines of the Black Sea and conditions for human presence - Black Sea expedition 2011. *Геология И Полезные Ископаемые Мирового Океана*, *3*(June 2018), 91–97.

Soulet, G., Ménot, G., Lericolais, G., & Bard, E. (2011). A revised calendar age for the last reconnection of the Black Sea to the global ocean. *Quaternary Science Reviews*, *30*, 1019–1026.

Stanley, D. J., & Warne, A. G. (1994). Worldwide initiation of Holocene marine deltas by deceleration of sea-level rise. *Science*, *265*(5169), 228–231.

Ştefan, A. S. (1987). Évolution de la côte dans la zone des bouches du danube durant l'antiquite in Déplacements des Lignes de Rivage en Méditerranée d'aprés les Données de l'Archéologie. *Editions Du CNRS, Colloques Internationaux, Paris*.

Stuiver, M., & Reimer, P. J. (1993). Extended 14 C data base and revised CALIB 3.0 14 C age calibration program. *Radiocarbon*, *35*(1), 215–230.

Syvitski, J. P. M., Kettner, A. J., Correggiari, A., & Nelson, B. W. (2005). Distributary channels and their impact on sediment dispersal. *Marine Geology*, *222*, 75–94.

Syvitski, J. P. M., Kettner, A. J., Overeem, I., Hutton, E. W. H., Hannon, M. T., Brakenridge, G. R., … Giosan, L. (2009). Sinking deltas due to human activities. *Nature Geoscience, 2*(10), 681.

Syvitski, J. P. M., & Saito, Y. (2007). Morphodynamics of deltas under the influence of humans. *Global and Planetary Change, 57*(3–4), 261–282.

Van Andel, T. H., & Lianos, N. (1983). Prehistoric and historic shorelines of the Southern Argolid Peninsula: A subbottom profiler study. *International Journal of Nautical Archaeology, 12*(4), 303–324.

Vespremeanu-Stroe, A., & Preoteasa, L. (2015). Morphology and the cyclic evolution of Danube delta spits. In *Sand and Gravel spits* (pp. 327–339). Springer.

Vespremeanu-Stroe, A., Preoteasa, L., Hanganu, D., Brown, A. G., Bîrzescu, I., Toms, P., & Timar-Gabor, A. (2013). The impact of the Late Holocene coastal changes on the rise and decay of the ancient city of Histria (southern Danube delta). *Quaternary International, 293*, 245–256.

Vespremeanu-Stroe, A., Preoteasa, L., Zăinescu, F., Rotaru, S., Croitoru, L., & Timar-Gabor, A. (2016). Formation of Danube Delta beach ridge plains and signatures in morphology. *Quaternary International, 415*, 268–285.

Vespremeanu-Stroe, A., Zăinescu, F., Preoteasa, L., Tătui, F., Rotaru, S., Morhange, C., et al. (2017). Holocene evolution of the Danube delta: An integral reconstruction and a revised chronology. *Marine Geology, 388,* 38–61.

Vespremeanu, E., Vespremeanu-Stroe, A., & Constantinescu, Ş. (2004). The Black Sea level oscillations in the last 150 years. *Analele Universităţii Bucureşti–seria Geografie*, *53,* 69–76.

Walker, H. J., & Grabau, W. E. (1999). World deltas and their evolution. *Acta Geographica Sinica*, *66*(1), 30–41.

Wright, L. D. (1977). Sediment transport and deposition at river mouths: a synthesis. *Geological Society of America Bulletin*, *88*(6), 857–868.

Wright, L. D., & Coleman, J. M. (1973). Variations in morphology of major river deltas as functions of ocean wave and river discharge regimes. *AAPG Bulletin*, *57*(2), 370–398.

Zenkovich, V. P. (1956). Zagadka dunaiskoi delty. *Priroda*, *45*(3), 86–90.

Zugrăvescu, D., Polonic, G., Horomnea, M., & Dragomir, V. (1998). Recent vertical crustal movements on the Romanian territory, major tectonic compartments and their relative dynamics. *Revue Roumaine Géol Géophys Géogr, Série Géographie*, *42,* 3–14.