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# AFTERMATH OF THE FLOODING: GEOMORPHOLOGICAL EVOLUTION OF THE DANUBE DELTA AFTER THE BLACK SEA- MEDITERRANEAN RECONNECTION AND ITS IMPLICATIONS ON ENEOLITHIC SETTLEMENTS

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## Abstract

In this article we document the evolution of the internal area of the Danube Delta (i.e. the blocked delta) starting from the geo-archaeological and geomorphological investigations performed at Mila 23 district, following the discovery of the oldest human settlement in the Delta. The in-site and out-site field work and coring allowed us to specify the delta's early stages of evolution from 5600 to 4000 CAL BC. During this period, the site evolves as a freshwater bay-head delta flowing into a huge lagoon isolated from the open sea by Letea-Caraorman spits. The rapid sedimentation rate in the lagoon is interpreted as a response to base-level rise and overflowing as a result of humid conditions during 6-5 ky RCC, leading to the partial submersion of the site and probably to its abandonment around 4450 CAL BC.

**Keywords:** Danube, Romania, Eneolithic, Chalcolithic, bay-head delta, lagoon, submerged archaeological site, flooded landscape.

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## INTRODUCTION

The great Mediterranean deltas and the marginal seas (Marmara Sea, Black Sea, Azov Sea) are at the heart of the construction of numerous civilizations around the Mediterranean and it's not surprising they motivated the foundation of geoarchaeology as a discipline at the end of the '60s. Amongst the great deltas, the Danube Delta is perhaps the one least researched, despite its exceptional character due to both its size and position in a key area for the comprehension of the diffusion process of the Neolithic in Central Europe, between the steppes and the Balkans. The geopolitical situation, but mainly the difficulties faced in conducting investigations and coring on the site are the main reasons explaining this lag.

Most of the knowledge on the evolution of the Danube Delta comes from marine data, and it is sometimes difficult to reconcile the *off shore* and the on shore data, mainly obtained from the external part of the delta (Antipa, 1915 and 1941; Panin, 1972; ...). Moreover, information regarding human settlements in the Danube Delta remains very fragmentary. The available data (Micu, 2004; Dimitriu, 2012) have privileged the theory of reluctance to the center, given the low number of known sites. It is also true that up to this day this remains the area with the lowest population density in the European Union. However, from the end of the '70s, Bolomey (1978) suggested that the absence of Neolithic settlements was actually related to a taphonomic bias. The paleogeographic changes together with the changes of water level and sedimentation should be the main reasons.

Since the mid '90s, discussions concerning the evolution of the Danube Delta, its human settlements and the low western plains of the Black Sea (Romania and Bulgaria) focused on the question of the Mediterranean-Black Sea flooding and the rapid rise of sea level. This hypothesis, formulated for the first time by Ryan et al. (1997), is since then known as *Noah's Flooding*. The main idea is that, at the end of the postglacial sea level rise, the global ocean flooded the Black Sea via the Mediterranean Sea, at different rates in time compared to the rest of the Mediterranean, due to the thresholds of Bosphorus and Dardanelles, with unusual rapidity and impact mainly due to the morphology of the passive margin west of the Black Sea.

Since it was first formulated, this hypothesis, founded mainly on the *off shore* data, has been subject

to *ad hoc* adaptations that led to an older dating (7300-8900 BP) and to limiting the amplitude of the flooding (from 130m to less than 100m), hence the consequences on the continental domain and on the settlements (Soulet et al. 2011). However, there is no consensus regarding this model (see Yanko-Homback, 2007) that has been subject to ample debates (Giosan et al. 2009). Though this model assumes numerous archaeological implications, archaeological data were seldom used in the argumentation starting from exact facts. Geomorphological data regarding the evolution of the areas of the delta were also only marginally integrated in the general overview.

In this study, we propose an approach of the evolution of the Danube Delta based on our archaeological, geomorphological and paleoecological investigations. More precisely, we show, starting from investigations around the site from Taraschina, the evolution of the upper part of the Danube Delta, *i.e.* Panin's (1972) bay-head delta, in terms of paleogeography, of processes and of control factors.

## 1. STUDY AREA

### 1.1 The Lower Danube System

The Lower Danube corresponds to the end of the Danube River system after it exits the Dacian basin and the Wallachian plains. This part of the linear river divides into 4 main morphological units (figure 1A):

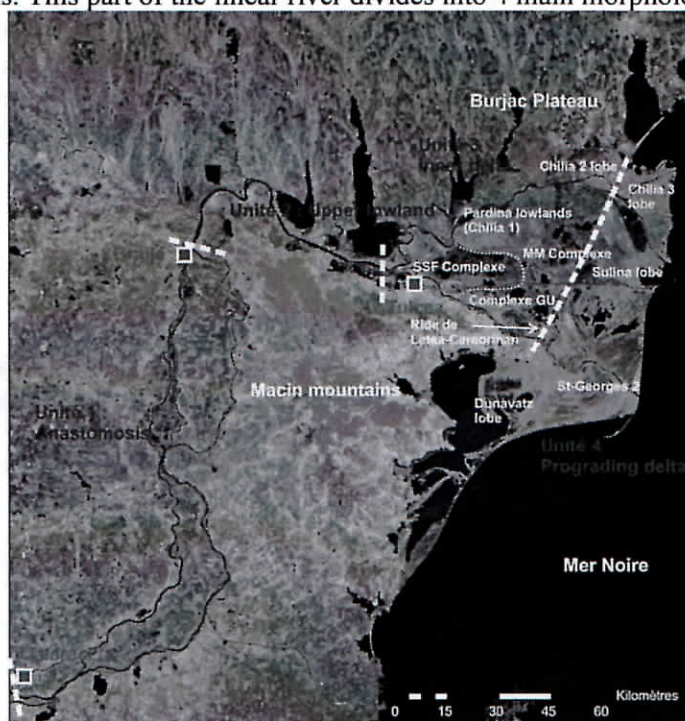


Figure 1. Main geomorphological units of the lower Danube  
SSF complex: sireasa-sontea-fortuna; GU complex: gorgova-uzina; MM complex: matita-merhei

1 – North of Calarasi, taking the direction South-North and drawing up the shape of Dobrudja region, the Danube considerably extends its plains that reach 20 km wide. It then develops a series of great anastomoses that are now polderized.

2 – Between Braila and Tulcea, the Danube retakes a general W to E direction associated with a pronounced narrowing of its alluvial plain. Then the valley is marked by a strong dissymmetry between the south – the relapsed shale plateau of Macin Mountains – and the north, the Moldavian loess plateau, occupied by systems of partially drained lakes.

3 – Between Tulcea and Crisan, an internal delta is developing, characterized by a first separation of the Danube between the northern branch of Chilia and the southern branch of Sulina-St. George. This area divides into three units. At north, Pardina lowland is separated from the deltaic system by the lacustrine ridge of Chilia and forms Chilia lobe (Carozza et al., 2012). Its evolution is still little known, but it could correspond to an evolution phase of the lacustrine delta (Philip et al., 2011). It extends to the East by a second lobe, Chilia 2, formed under lagoonal conditions (bay-head delta, Nichols, 1997). To the SW, between Tulcea and Mila 23, a very fragmented fluvial-lacustrine unit developed (Sireasa-Sontea-Fortuna and Gorgova-Uzina areas, Panin, 2004). At SE, the river and sea dynamics behind Letea-Caraorman spit

gave birth to a landscape dominated by large lacustrine systems (Matita-Merhei area).

4 – Downstream of the same spit, a prograding external delta is taking shape, representing part of the best known deltaic system. South, St. George branch constructed two distinct lobes. The first lobe – probably the oldest one of the prograding deltaic system – corresponds to St. George lobe (Panin, 1972). At south it comprises the secondary lobe of Dunavat, formed by a diffluence in Razim-Sione lagoon (Panin, 2003 and Giosan et al., 2006). In the central part, Sulina branch is associated with the most important lobe of the Danube Delta system. North of Chilia branch, a new lobe has been developing (Chilia 3) along three recent periods that are morphologically characterized by deltas dominated by fluvial processes (Giosan et al., 2005). Given its territorial importance, the Danube Delta has long time been the object of geographic, geomorphological and geological research (Antipa 1915 and 1941; Bratescu, 1942; Valsan, 1934; Cote, 1960; Liteanu et al., 1961, as main old references). These investigations have led to the definition of the delta's great prograding entities: the lobes of Saint George, Sulina and Chilia.

The synthesis proposed by GeoEcoMar researchers, and by Panin in particular (1972), based on geomorphological investigations and coring, distinguishes a two-phase evolution of the delta. First, an early phase associated with the internal delta, called “bay-head delta” (unit 3) and dominated by the fluvial processes upstream of Letea-Caraorman spit, followed by a prograding phase (the delta *sensu stricto*, unit 4), when the external lobes formed; the number of the lobes varies depending on the author. The first chronological data (Panin, 1983) establish the evolution of the delta from 12500 BP until now. Giosan et al. (2006) suggested a shorter evolution, i.e. after 6000 BP. However, the latest investigations rely exclusively on prograding delta data that is not integrated with the information from the internal delta. This internal area upstream of Letea-Caraorman spit has actually drawn little of the researchers' attention and remains very little known. The discovery of the oldest human settlement in the Danube Delta (Carozza, Bem and Micu, 2011 and Carozza et al., 2012) in these sectors is of major importance for the comprehension of the paleogeographic evolution, processes and factors that control the dynamics of this unit.

## 1.2 Taraschina Site

The site from Taraschina was discovered in the '90s (Micu et al., 2009). It's located at the heart of the northern unit of the internal delta (Sireasa-Sontea-Fortuna area, figure 2), situated 2.3 km east of Fortuna Lake, between Sontea channel – that borders the site at the east and south – and Olguta channel at north. Sontea channel could represent an ancient anastomosis of Chilia branch before flowing into Pardina lowland, as the map of the Danube Delta from 1887 seems to indicate (the European Commission of the Danube, 1887), but the chronology of its functioning and its relation with the site remain uncertain.

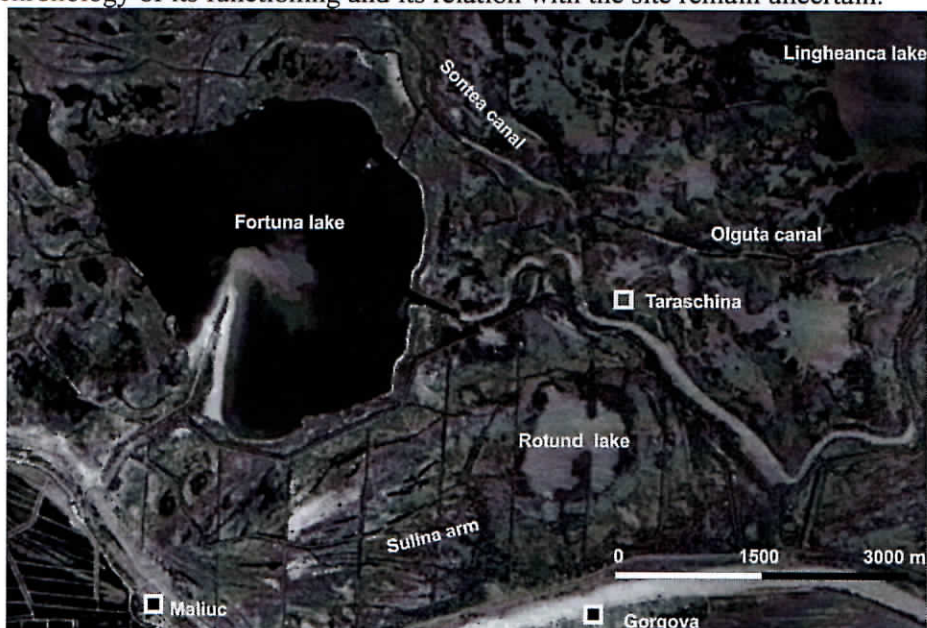


Figure 2. Map of Taraschina site and its surrounding environment

Topographically speaking, the site is a loose quadrangular flat-top promontory that dominates from around 1,25 m a wet alluvial plain of reed (figure 3). Morphologically, it appears that the eastern part of the site was partially destroyed by the construction of a small navigational channel in the second half of the 20<sup>th</sup>

century and digging dents its western flank. Today, the site spreads over a surface of at least 10,000 sqm. The surface prospection allowed at first to establish the dating to the Eneolithic, more precisely to Gumelnita A1 culture (~6500 BP or 4600/4350 cal BC), thus making it the most ancient human settlement in the Danube Delta. There is also evidences of protohistorical and roman habitation of the site.

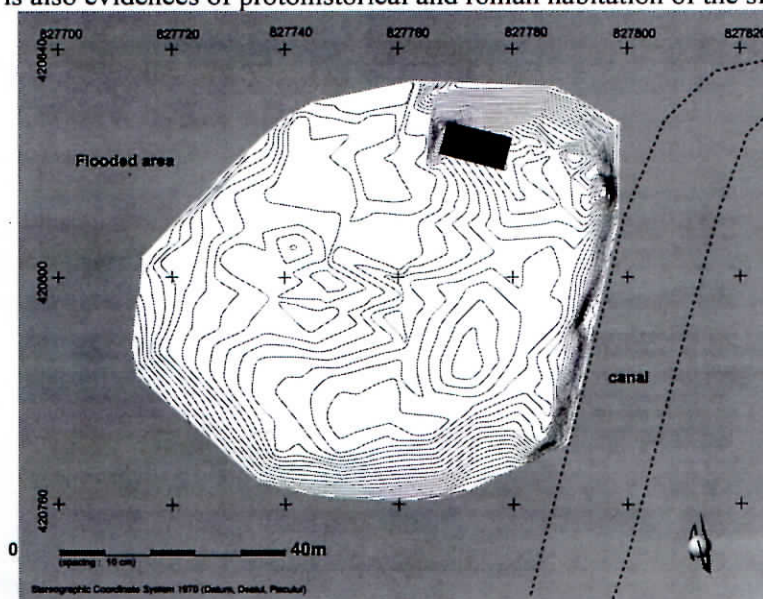


Figure 3. Microtopography of Taraschina site

## 2. METHODS

In order to evaluate the duration of site habitation period and to reconstruct its environment, the coring technique was used by means of a Cobra mechanic corer (figure 4). The coring on the site aims to establish the long chronology of the habitation period, otherwise inaccessible by classic excavations due to the thickness of the sequence and to the presence of ground water. It also aims to determine the nature of the substratum of the site. The gathered data intends to establish the paleotopography prior or contemporary with the settlement, as well as the nature, the processes and chronology of the sedimentation around the site. For this purpose, we used a reference core (core 10) to perform at GeoEcoMar a complete sedimentary facies analysis, including a granulometric analysis with a Malvern Mastersize 2000 granulometer, in order to identify the sedimentation processes. We also performed an analysis for magnetic susceptibility. To this, we added the data from the XRF analysis – core scanner in Epc laboratories, in Bordeaux, at 10 and 40 KV. The average sampling resolution is 2 mm. Palynological tests made on the samples distributed within the core have proved negative, while the study of the rich ichthyofauna and molluscs provides paleoecological information on the deposit environment. The chronology of core 10 relies on six <sup>14</sup>C dating on charcoal that allows us to put in sequence the data gathered on the site.

Table 1. <sup>14</sup>C Radiocarbon Dating in Core 10

Sample number	Lab code	Material	Age 14c	Cal BC (2σ)
Tar 158	Poz-42867	Charcoal	5390 ± 80 BP	4366-3996 BC
Tar 190	Poz-42868	Wood	5600 ± 40 BP	4503-4351 BC
Tar 223	Poz-40109	Charcoal	5470 ± 40 BP	4443-4239 BC
Tar 244-246	Poz-42870	Charcoal	5610 ± 40 BP	4521-4356 BC

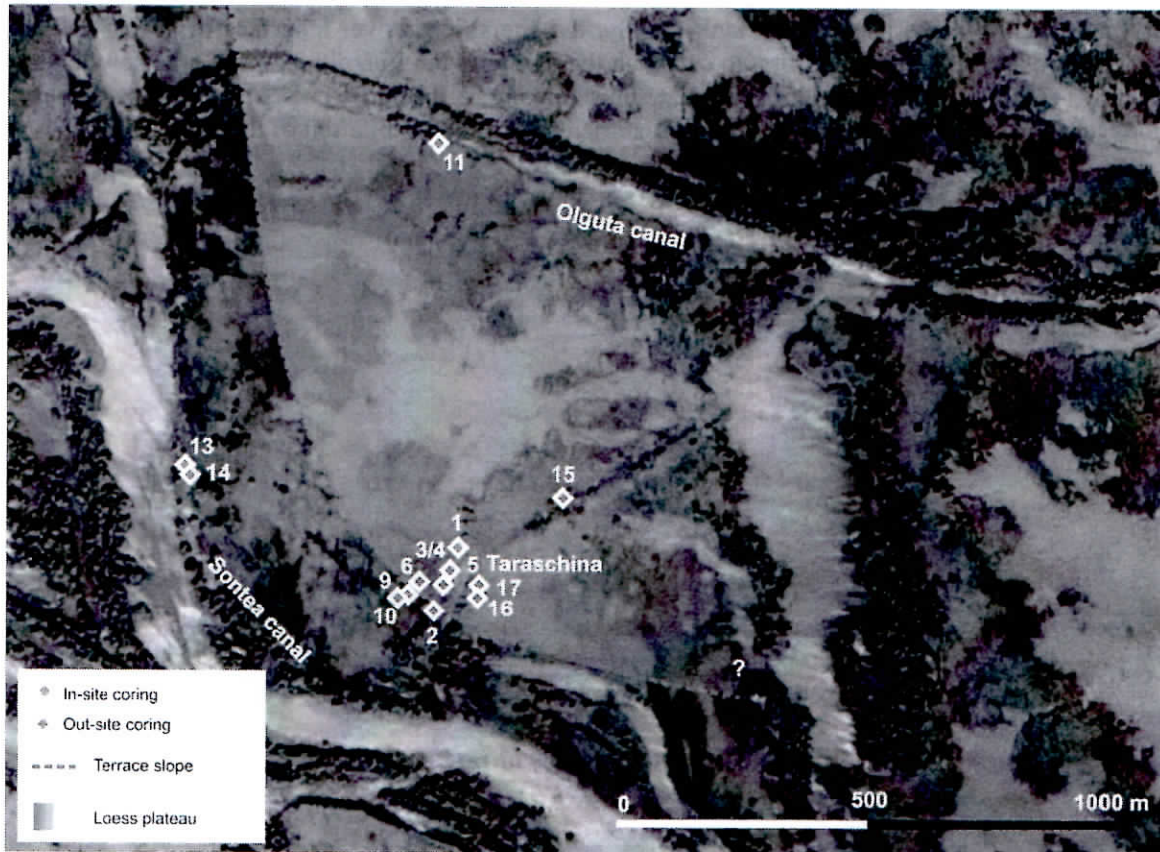


Figure 4. Map of Taraschina in-site and out-site coring

### 3. RESULTS

The results presented here concern mainly core 10, which will be placed in context. Core 10 was taken from west of the actual site. It is 3 m long and cuts through a “recent” sedimentary sequence, touching the substratum, which is of lemon-yellow colour corresponding to a partially remaniated loess formation (figure 5). This level was found in the cores at variable altitudes. It clearly stands out by its strong signal of magnetic susceptibility decreasing to the top, indicating the existence of paleosoil.

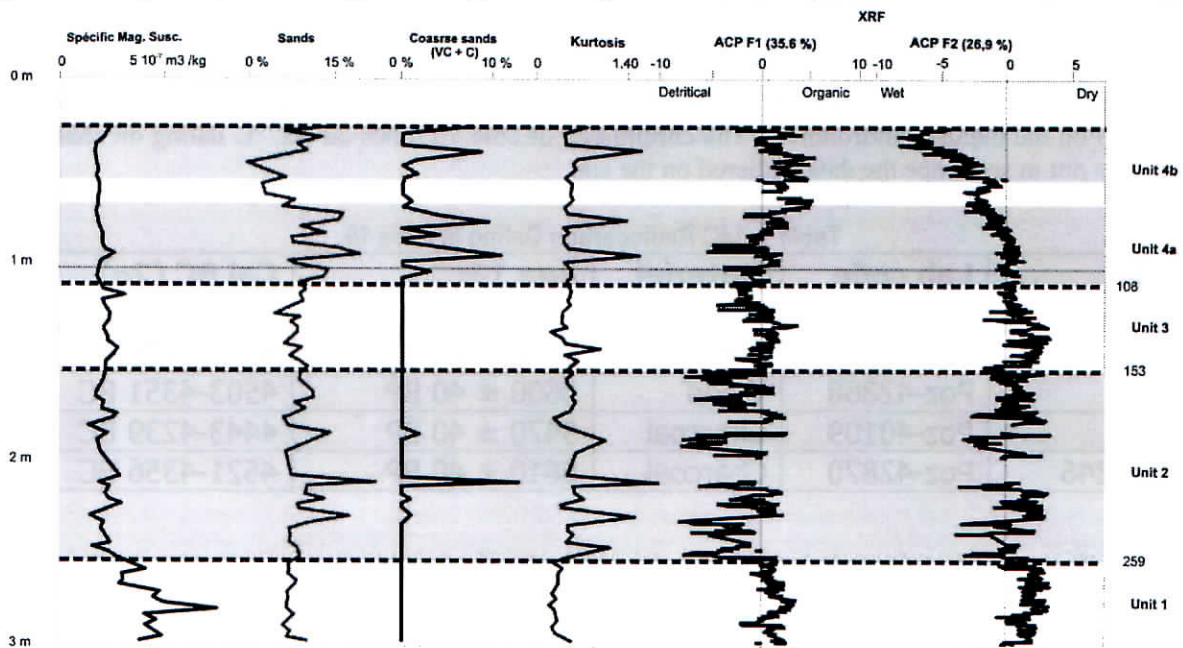


Figure 5. Multiproxy analysis of core 10

The sedimentary facies analysis and the granulometry allow us to divide a sedimentary sequence into three parts. From 259 cm to 179 cm, we noticed the alternation of grey laminated levels and more organic levels. The dark grey levels are associated with an augmentation of the sandy fraction and a good granulometric selection indicated by kurtosis. These levels are interpreted as detrital contributions of the flooding. They alternate with clay-organic levels in marsh context. This unit can be interpreted as a fluvial-lagoonal sequence. From 179 to 108 cm, the authigenic facies become dominant, indicating fluvial contributions. This is also accompanied by a lower sandy fraction, mainly coarse sand.

From 108 to 0 cm, the disappearance of the light grey authigenic levels and the appearance of the dark organic levels mark the immersion and the development of a histosol on fluvial formations. The lower part of this soil actually indicates a return of detrital contributions marked by an increase of the sandy fraction, mainly coarse sands. A PCA on the XRF data confirms the entire split and the score evolution on F1 and F2 axes (figure 6). Axes 1 and 2 explain 35.6% and 26.9%, respectively, of the total variance of 65.2%. Axis 1 is strongly linked to clastic input in the sequence. Axis 2 opposes the present soil (very negative values) and the lacustrine sediments.

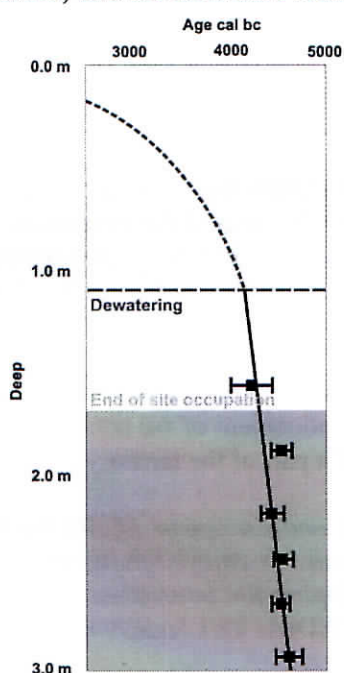


Figure 6. Deep radiocarbon age model of core 10

This information is related to the paleoecological data, mainly from the ichthyofauna and the malacofauna. 115 fish bone remains were sampled at 250 to 155 cm. Above 150 cm, no such remains were identified. The fish bones mainly belong to *Acipenser sturio* (sturgeon), *Esox lucius* (pike), *Cyprinus Carpio* (carp), *Silurus glanis* (catfish), *Perca fluviatilis* (perch) and *Sander lucioperca* (zander). While certain species are migratory and can live in very salty water, the entire specter is compatible with a freshwater fluvial-lagoonal environment. This is confirmed by the malacological remains that comprise bivalves (*Unio sp.* and *Anodonta*) and gastropods (*Borystenia-Valvata-naticina*), which are freshwater to slightly euryhaline animals. Thus, the overall data indicate a freshwater fluvial-lagoonal landscape with regular sediment contributions from flooding by one of the Danube's branches.

The chronology of the sequence relies on six  $^{14}\text{C}$  dating obtained mainly on the inferior part of the sequence. This dating doesn't indicate inversion and allows us to point to an average fast sedimentation speed of almost 2,5 cm. per year<sup>-1</sup>, for the two meters from the base of the core; whereas the evolutions at the top of the sequence is still poorly constraints.

The covering of the loess substratum by fluvial-lacustrine sedimentations occurred around 4450 cal BC. The rise of the local water level follows until around ~4200-4150 cal BC. The final flooding of the plain could have produced around 4100-4000 cal BC.

#### 4. DISCUSSION

The data gathered from cores 4, 5 and 6, together with the data from the diggings (Carozza, Bem and Micu, 2011 and Carozza et al., 2012) show that the site from Taraschina is a stratified habitat (figure 5). The habitation sequence is thick, of almost 3m, and lies on a characteristic loess terrace that constitutes the substratum of the site. Cores 5 and 6 trench this level on 4 m deep. The altitude of the substratum decreases at west, towards Sontea channel, thus confirming the hypothesis of a natural branch incised in the substratum and rearranged during recent periods. In this case, Sontea branch could have appeared at the same time with the human settlement on the site.

In any case, the habitat is implanted in the border of a plateau that dominates by a few meters the fluvial-lagoonal area in course of aggradation. In core 10, the fluvial-lagoonal formations covering the loess substratum were dated to 4450 cal BC. The site from Taraschina was then already implanted since 4800-4580 cal BC. The last Eneolithic habitation of the site is dated to 4490-4350 cal BC. It seems thus that the rise in water level and the abandonment of the site coincide. As the paleoecological data from core 10 indicates, the environment around the site from 4450 to 4000 cal BC is exclusively freshwater fauna. This information confirms that old data of Panin (1972), who pointed out that in the deep drilling in bay-head delta sector (drills 1001, 1055 and 1059) he didn't find any freshwater to slightly euryhaline fauna until a depth of about 20 meters. These data suggest the isolation of the fluvial-lagoonal area upstream of the delta

by a sandspit. The age of Letea-Caraorman spit could thus be prior to the beginning of the progradation of St-George lobe, dated to 3500-2900 cal BP (Giosan et al., 2006). Two radiocarbon dating analyses made by Giosan et al. (2006, additional material) on the most inner sandy bar of Caraorman spit, on one hand, and of Letea spit on the other, indicate a coherent age of 5600-5480 cal BC and 5600-5300 cal BC, respectively. It also shows that at that time, the sandspit already isolated the internal lagoon (Carozza et al., 2012). At that time, the all Black Sea evolution models add up to indicate a slightly negative level compared to the sea level between -7 and -4 m, increasing slowly at around 1 m ky<sup>-1</sup>. The data gathered on the site is compatible with this model, but suggest the creation of more important available space. It could be associated with a lagoonal overflow level, linked to a wetter episode identified by Rholing et al. (2002) in the Aegean Sea (RCC 6-5, Mayewski et al., 2004) and registered here by overrepresentation of the rise in water level in the basal unit. These episodes could favour the progradation of sedimentary systems in the internal delta. The significant diminution of sedimentation after 4000 cal BP occurs at the same time with the beginning of progradation of St. George lobe, indicating the start of dynamics dominated by by-passing in the internal delta. Since then, only the most important rises in the water level or flooding could provide the sedimentary contributions to this slow-evolving area.

## CONCLUSION

The investigations carried out in the area of internal delta around Taraschina site allow us to better understand the evolution of the internal Danube delta. They clearly indicate that this area of the internal delta evolves in the freshwater lagoonal area since less than 5600-5400 cal BC and corresponds to an embayment or a bay-head delta (Nichols, 1997). A sandspit used to isolate this lagoon from the sea. Between that date and 4450 cal BC, the rise of the sea level, perhaps accompanied by lagoonal overflowing due to significant freshwater contributions of the Danube along RCC 6-5, led to rapid trapping of the sediments around the site, drastically changing the paleogeography of this site. Therefore, the site was partially made of sediments. The synchronicity of the transgression of fluvial-lacustrine formations with the abandonment of the site suggests a direct (increased frequency of high water level) or indirect effect (flooding of a part of the territory).

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