Geoarchaeology of the ancient and medieval Danube Delta: Modeling environmental and historical changes. A review

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A B S T R A C T

The study presents a brief review of the main evolutionary stages of the Danube deltaic area, according to the most recent discoveries in the field, as well as an emphasis on the new delimiting criteria for the hinterland in the ancient (7th century B.C.–5th century A.D.) and medieval times (14th–18th centuries A.D.). A cartographic delimitation model for the studied settlements’ hinterlands was created. The Danube Delta is a dynamic interface between the geological history, the deltaic morphogenesis and the human occupation. The Danube Delta complex is one of the most important geo-political and cultural entities which can be described as a compound geographical unit that provides an exceptional biodiversity. Although this area has been intensely inhabited during the previous historical periods, underlined in the case of several ancient and medieval sources, only limited archaeological sites have been identified up to the present, and they are affected by the permanent extension and mobility of the Danube Delta. The Greek cities of Istrus/Histria and Orgame/Argamum, colonies established by Miletus, which later continued their development as Roman cities, were located in the lagoon region on the coast. The Roman fortification of Halybris was situated on the Danube Delta’s southern branch and the small bastion was located on the island called “Biserica”. Two other medieval fortresses were identified; Heraclea, probably a Genovese fortress (present-day Enisala), and the Ottoman fortification of Vadu, situated respectively at the western and southern limits of the Razim–Sinoie lagoon. There are still numerous scientific debates on the origin and evolution of the Danube Delta and the Black Sea. The specific studies on the recent evolution of the Danube’s mouths (Antiquity and the Middle Ages) can provide essential and significant contributions to the habitat’s dynamics in relation to the deltaic geomorphology. The rapid changes in the shoreline caused a massive exodus of the populations from the areas covered by water. The Milesian colonies of Histria and Argamum disappeared because of the rising sea level and because a barrier spit was built in front of the Halyhris Gulf, which caused the formation of the Razim–Sinoie lagoon.

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1. Introduction

Because of its geographic position and its geo-strategic significance, the Danube Delta has been the topic of numerous studies from various scientific domains. The multitude of geological, geomorphological, hydrological, climatic, and archaeological studies makes for valuable, yet slow and time consuming, genetic profiling and habitat reconstruction. Most of the data is conflicting, and extracting the truth is quite laborious.

The contention revolves around the multiple theories regarding the delta’s age and its spatial and chronological evolution. The temporal localization of the Ancient Greek, Roman, Byzantine and medieval settlements is a difficult endeavour, as the evolutionary history of the deltaic system has yet to be clearly and convincingly ascertained (Stefanescu, 1981; Romanescu, 1996a,b; Panin, 1997; Giosan et al., 2006). This state of affairs prompted an attempt to review the most important hypotheses on the genesis and evolution of the Danube Delta, chronologically and spatially, taking a critical and constructive view of the older (Antipa, 1910; Murgoci, 1912; Bratescu, 1922; Nastase, 1935, 1936; Valsan, 1936; Zenkovici, 1957; Cotet, 1960) and newer ideas (Panin, 1972, 1989, 1997; Stefanescu, 1981; Popescu, 2002; Romanescu, 2005; Giosan et al., 2006).

The genesis of the Danube Delta is strongly linked to that of the Black Sea. The location of the mouth of Danube shifted throughout time, as a function of the oscillating sea bed (Bleahu, 1962; Gavestecu, 1971; Panin, 1983; Ryan and Pitman, 1999; Carazza et al., 2003; Ryan et al., 2003; Romanescu, 2009; Carazza et al., 2010, 2012).
A comparative analysis of the studies on the Danube Delta has not been performed, despite the fact that it is stringently needed. The modern practice of interdisciplinary modelling of scientific knowledge allows for an easy amassing of the material required for such an analysis. Access to databases and the advent of the Internet has made the widespread dissemination of ideas possible. From this point of view, the Danube Delta and the Black Sea have a privileged position.

The importance of the Danube Delta, from Antiquity up to the present day, is reflected in the numerous mentions by the ancient Greek scholars and the medieval travellers. The mentioning of the Danube’s mouths in the oldest portolan charts that have survived and, last but not least, the vision of Noah’s flood as occurring in the Mediterranean basin, with repercussions on the Black Sea’s shoreline, constitute other topics of scientific investigation from related domains of study. As the two morphological units (the Danube Delta and the Black Sea) are inseparably linked, the use of the data available for the wider Mediterranean system is mandatory.

Studies on the Danube Delta were resuscitated in 1997 with the advent of the Black Sea deluge theory, which posits that the former freshwater lake became a saltwater sea (Ryan et al., 1997a, 1997b; Ryan and Pitman, 1999). The phenomenon occurred because of the melting of the Northern European ice sheets (ca. 8000 BP) and the rise of the level of the Mediterranean Sea (ca. 7150 BP) which overfl owed, via the Bosphorus, discharging a quantity of water 200 times larger than that of the Niagara Falls.

During the last 20 years, a series of specific or more general studies of the Black Sea and the Danube Delta have been published, particularly after the establishment of the GEOCOMAR Institute for Marine Research. Most of the studies were performed in cooperation, either with IFREMER from France, with Woods Hole from the US (Ryan et al., 1997a,b; Ryan and Pitman, 1999; Ballard et al., 2000; Popescu, 2002; Giosan et al., 2006; Yanko-Hombach, 2007; Yanko-Hombach et al., 2007; Lericolais et al., 2009), or with the Institute of Oceanography from Varna (Dimitrov, 2003; Dimitrov and Dimitrov, 2004).

The current study aims to review and analyse the most pertinent literature on the genesis of the Danube Delta and, implicitly, of the Black Sea. The previous theories are subjected to scrutiny, and the information concerning the genesis of the Black Sea, the recent development of the Romanian littoral, and the historical location of the human settlements, is filtered, structured and presented in a coherent manner.

2. Regional setting

The Danube Delta is situated in the north-western sector of the Black Sea basin, in a mobile region of the terrestrial crust (the Predobrudjan Depression). Its limits are: 44°46’00”N (Periteasca), 45°30’00”N (South of Sasik Lake), 28°40’24”E (ceatalul Chilia), 29°40’50”E (east of the Chilia secondary delta). With its surface of 5600 km², the Danube Delta, together with the flood-plain sector between Ceatalul Ismail and the city of Galati, represents the most important terminal plain of any European river (except the Volga and Kuban deltas (Fig. 1)). The Ukrainian part, about one-fifth of the total delta area, covers 125,000 ha, of which 75,000 ha are land (Fig. 2). The Danube Delta Biosphere Reserve is comprised of the deltaiac surface between the three arms, the Danube’s floodplain stretching from Ceatalul Ismail to the city of Galati, and the Razim–Sinoie lagoon complex.

The Razim–Sinoie lagoon complex is situated in the south-eastern sector of Romania, in the north-eastern part of Dobrudja. Its western and northern limits are represented by the mainland of Northern Dobrudja, the north eastern limit is represented by the Danube Delta, and the eastern limit by the Black Sea. Its limits are: 44°21’30”N (Midia Cape), 45°02’30”N (Agighiol), 28°32’40”E (Tasaul), 29°08’30”E (Gura Dranov).

Razim Lake used to communicate with the Black Sea through the sector called Gura Portitei (“the mouth of the small gate”). In 1960 this opening was artificially closed so that the lake should evolve in forced conditions (Romanescu, 2009; Romanescu and Bounegru, 2009). The area of the Razim–Sinoie lagoon complex (waters, swamps, levees) has increased progressively, from 76,949 ha in 1835 to 93,156 ha in 1883, and to 96,950 ha in 2005 (including the abutting swampy areas) (Romanescu, 1996a, 2005, 2006).

The Razim–Sinoie lagoon complex is the largest lake complex in Romania, and it represents an association of three genetic types.
(Gastescu, 1971; Breier, 1976); marine lagoons with one shore representing the previous maritime cliff, currently fossilised (the four large lagoons: Razim, Golovita, Zmeica and Sinoie); marine liman coasts that occupy the river mouths in the former gulf (Calica, Agighiol, Babadag, etc); and lakes between levees, belonging to the group of marine coastal barriers situated between the Razim–Sinoie complex and the Black Sea (Cosna, Periterasca, Pahane Ranec, Leahova Mare, Leahova Mica, Edighiolurile, etc).

The invariably murky deltaic area was inhospitable for sustained human settlement. Conversely, the adjacent continental shelf favoured the establishment of human settlements during ancient and medieval times: Noviodunum (Roman, Byzantine and medieval city), Aegyssus (ancient Roman city), Preslav (Byzantine city), Salsovia (ancient Roman city), Halmiris (ancient Roman city), Dunavat (ancient Roman fortress), Agighiol (Thracian necropolis), Toprachioi (Roman fortress and supply point), Babadag (Thracian and Roman fortress), Ibida (ancient Roman city), Enisala/Heraclea (Genovese mediaeval city), Beidaud (Thracian fortress), Bisericuta (Roman fortress), Orgame/Argamum (ancient Greek and Roman city), Histria (ancient Greek city), and Vadu (Ottoman fortress; Fig. 3). The denizens selected the firm lands with fertile soils which were safe from flooding, particularly the fluvial and marine terraces (Howard and Macklin, 1999; Romanescu, 2005; Howard et al., 2008), instead of the more easily available deltaic lands which were murky and floodable as a result of the permanent subsidence processes (Bratescu, 1922; Cotet, 1960; Bleahu, 1962; Romanescu, 1996a,b; Bridgland and Westaway, 2008; Westaway et al., 2009; Carozza et al., 2010, 2012).

3. Materials and methods

As a consequence of the polemics surrounding the genesis and evolution of the Danube Delta, a synthesis is required which can present as accurately as possible the natural environment in

Fig. 2. Map of surface geologic deposits (2000 BP—Present).
existence during the historical eras of the Holocene. The crux of the issue is the age of the Danube Delta; ages going to as much as 12,000 BP and as young as 5000–6000 BP have been advanced. To this purpose, over 1500 reference works have been consulted, out of which only those containing the most germane material for understanding the region’s past have been selected.

For an accurate understanding of the phenomena in question, a detailed incursion into the highly troubled past of the Black Sea has been made. The sources consulted refer to various domains of study: geology, geophysics, geomorphology, climatology, hydrology, bio-pedology, archaeology, limnology, oceanography, cartography, and literature (ancient and medieval writings). The cartographic material was processed using the CorelDRAW Graphics Suite 12 software program. The topographic underlay was rebuilt from 1:25,000 scaled topographical maps edited by DTM, the 1982 edition. Alongside historical information, use was made of novel and private information acquired from the Institute of Ecomuseal Research from Tulcea.

In as much as the chronology used in this article is concerned, the Western Pontic area has a specific periodization. Thus, for the historical eras, the following schema was used: the Greco-Roman Antiquity (7th century B.C.–5th century A.D.), the Byzantine era (6th–13th centuries A.D.), the Middle Ages (14th–18th centuries) (Suciuveanu et al., 2003; Angelescu and Bottez, 2009; Bounegru, 2009; Micu et al., 2009; Carozza et al., 2010, 2012).

4. Results

The first ideas on the formation of the basin of the Mediterranean Sea, and implicitly of the Black Sea, were advanced by the Ancient Greeks. Among the most audacious and at the same time true, was the scenario advanced by Strabo which constituted the embryonic form of the future Deluge theory: "But what I wish to learn is this: supposing the bed of the Euxine Sea was lower than that of the Propontis and of the sea next after the Propontis before the opening of the outlet at Byzantium, what was there to prevent the Euxine from being filled up by the rivers, whether it was previously a sea or merely a lake greater than Lake Maeotis? If this point be conceded, then I shall go on to ask this question too: Is it not true that the water-levels of the Euxine and the Propontis were such that, so long as they remained the same, there could be no straining for an outflow, for the reason that resistance and pressure were equal, but that, as soon as the inner sea reached a higher level, it set up a strain and discharged its excess water? And is not this the reason why the outer sea became confluent with the inner sea and why it assumed the same level as the inner sea—regardless of whether the latter was originally a sea or once a lake and later a sea—simply because of its mingling with the inner sea and prevailing over it? For if this point be granted as well as the first, the outflow that now takes place would go on just the same, but it would not be away from a higher sea-bed, or from a sloping one, as Strato contended."

(Strabo, Book I, 6.) (Strabon, 1974).

The writings of the Ancient Greek scholars and medieval European travellers have captured numerous remarks concerning the morphology and morphometry of the deltaic area. Most of these
primary sources are in the form of cartographic documents and literary works. Among these are the writings of Herodotus, Eratosthenes, Apollonius Rhodius, Polybius, Akvymnos of Chios, Strabo, Seneca, Pomponius Mela, Pliny the Eder, Ptolemy, Marinus, Arrian, Castorius, Isidore of Seville, Giovanni di Carignano, Pietro Vesconti, Marino Sanudo, Angelino Dulcerto, Enea Silvio Piccolomini, and Georg Reichersdorfer (Romanescu, 1995). For reconstructing the antique deltaic landscape, the works of Herodotus, Strabo and Ptolemy are particularly noteworthy.

Herodotus, the parent of history and geography, asserts that the “Ister empties into the sea through five mouths, having previously been split in two arms, two flow days before”. “In that part of Thrace which stretches to the sea, has Scythia immediately contiguous to it; where Thrace ends, Scythia begins, where the coast forms a gulf through which the Ister passes, commencing at the south-east, and emptying itself into the Euxine.” These remarks lead some to conclude that the Danube emptied into the sea through five mouths, but inside a large gulf.

Strabo states that the Danube emptied into the sea through seven mouths. Close to the river’s mouths there was Peuce Island (“island of pines”). Strabo delivers precise lengths, asserting that between the city of Histria and Hierostoma (“the holy mouth”, the largest and southernmost one) the distance is of 500 stadia.

Ptolemy presents the most accurate mathematical data concerning the positions of the seven mouths of the Danube and of the Peuce Island. His mathematical coordinates helped elaborate a morphological model of the deltaic area during his time (Fig. 4).

The data and the cartographic representations cannot be considered exact, since the necessary knowledge and equipment for accurate measurements were not available at that time. Furthermore, much of the information provided by the Ancient Greek scholars can be erroneous because it represents second or third-hand knowledge collected from sailors, merchants or other scholars who were more-or-less knowledgeable on the topic. Not always does it come from personal experience. Even Herodotus (Book IV) mentions that “I will pass what I could learn from hearsay” and that “nobody can positively inform me”, and that “we know of this thing from the Scythians”, etc.

On the map of D. Cantemir from 1737 there are five mouths depicted, while on that from 1835, edited by the General Staff of the Russian Empire in 1835, only three main river mouths are present (Romanescu, 1995).

Portolan charts and maps present a general view of the deltaic space. Accurate depictions began with the Russian Map from 1835 which was rendered using topographical measurements.

The first scientific texts on the genesis and the evolution of the Danube Delta were produced by Antipa (1910), Murgoci (1912), Bratescu (1922), Valsan (1936) and Nastase (1935, 1936). Antipa gives credit to the idea of an initial bay that eventually silted up with alluvial deposits from the Danube. Murgoci continues the idea of a gulf that formed following a marine transgression associated to a lowering of the foundation. He first identifies the Peuce Island, with the Chilia pre-deltaic landmass, but he subsequently re-addresses the issue and asserts that the island actually constituted the current extremity of the Dunavat Peninsula, separated many years before by an arm that once washed the course of the current Beilbugac corridor. As did the previous two scholars, Bratescu also suggest that the delta was formed on an initial bay that gradually silted up, but in which the main role was played by the Sulina branch. He was the first researcher to contend that the Danube Delta could not have been just 1500 years old, but that it was much older. Valsan describes the formation of the Sulina secondary delta (triangular in shape) and the role played by the branch of the same name. The spur of the current Sulina mouth and the funnel of the St. Gheorghe mouth are the remains of a major complex of double tombolo barrier spits and shallow lagoons. Nastase describes the ancient water-courses from the continental platform, and locates the legendary Peuce Island on the Chilia pre-deltaic landmass.

Zenkovich (1957) was the first to propose the idea of an initial spit and secondary deltas (Fig. 5). The ideas were based on Polybius’ statements according to which “the Ister, which flows from Europe, and discharges itself into the Pontus by many mouths, has already, with the sand and other matter which it brings, formed a bank which is called by the seamen Stethe, of almost a thousand stadia in length, and at the distance of one day’s course from land; against which the vessels that pass through the Pontus, as they are sailing in mid-sea, often strike unwarily in the night.”

Cotet (1960), in a more elaborated manner, confirmed the hypotheses and lines sketched by Zenkovich, supplemented by considerations on the mechanism behind the formation of all of the barrier spits. His work is one of the most comprehensive descriptions of this type, and was later the basis for many of the interpretations advanced by contemporary specialists. He stresses the formation of the first main spit and of the central branch (Sulina). Unfortunately, these last considerations lack referencing. The two authors failed to chronologically confine the unwinding phenomena.

An outline of the deltaic space and of the corresponding ages are to be found in the works of Panin (1972, 1974, 1983, 1989, 1996), etc. The main stages of the Danube Delta evolution during the Holocene were identified and dated through corroboration of geomorphologic, structural, textural, geochemical, mineralogical and faunal analyses, and 14C dating (Table 1).

For the year 1996, two errors appear to be present, as the data from the text does not correspond to the attached graph (the correct dataset is the one in parentheses) (Table 1).

In almost all of the author’s papers on this topic, the ages do not correspond in their entirety. The ages appear to have been changed depending on the trend of the period in which the articles were published or were based on dates other than the initial ones, without due mention. Regardless of the precise reasons, the most trustworthy are the latest dates, from 1997.

In 1996, Romanescu recreated the natural environment of the Danube Delta as it was during the Villafrianchian, when the level of the Black Sea was at least 100 m lower than the current one. The study relied on the analysis performed on 110 geological core samples, some of which were 500 m in length. The deltaic paleo-territory acted as a submerging area, with an extension towards the central part of the Pontic Basin. The eastern part of the delta was overlooked by two hilly outcrops—Letea and Caraorman—with relative altitudes of +65 m and +45 m, respectively. They are

![Fig. 4. The Danube Delta area during the time of Ptolemy (reconstruction using the mathematical coordinates).](image-url)
Fig. 5. The evolutionary stages of the Danube Delta according to Zenkovici V. P. (1957).

Currently covered by deltaic sediments and are found at respective depths of ~35 and ~55 m. The pre-deltaic outcrops constituted the nucleus of the initial spit, onto which the material carried by the Danube and its tributaries was deposited (Romanescu, 1996a, 1996b) (Fig. 6).

The first to describe the formation and evolution of the barrier spits facing the Razim–Sinoie lagoon complex was Stefanescu (1981). The study was based on the geomorphological interpretation of the toponyms found in the southern part of the Danube Delta. By addressing the etymology of the available toponyms, their origins and chronology, he successfully explained and pinpointed the barrier spits. The order in which they formed and their relative age coincide, for the most part, with those advanced by Giosan et al. (2006). For the deltaic area, a maximum age of 5000 years is given.

The most recent studies on the age and evolution of the Danube Delta and of the Razim–Sinoie lagoon complex contradict, in certain aspects, the image presented by some authors (Giosan et al., 2006). For the delta’s southern part, the ages obtained by Stefanescu (1981). In this case, the Sf. Gheorghe I secondary delta has an age of ca. 5000 years (5.5–4.9 BP). For the Razim–Sinoie lagoon complex, the following levees can be distinguished: Lupilor 4.9–4.6–3.5–3.2, Saele 3.7–3.4–1.6–1.2, Chituc sud 1.0–0.7, Tigianus-Periteasca 0.8–0.5. It would appear that these ages are fully in accordance with reality, as they can be correlated with many other pieces of data available from dedicated literature.

The data on the genesis and evolution of the Danube Delta and of the Razim–Sinoie lagoon complex must be corroborated by that concerning the basin of the Black Sea and of the historical evolution of the main archaeological sites of the area.

5. Discussion

Given that the studies on the genesis and evolution of the Danube Delta are extremely numerous and inconsistent, it is particularly hard to trace a correct physiognomy, by historical eras, of a highly dynamic, continuously evolving space.

The hydrogeomorphological data must be correlated with the archaeological. Up until 1997, when the Noah’s Flood hypothesis was advanced, the attempts to reconstruct the environment around the Black Sea seemed like an easy undertaking. The new theory, which excited the minds of most of the researchers and spawned fierce debate, complicated the issue to a considerable degree. Opinions were expressed for (Ryan et al., 1997a,b, 2003; Ryan and Pitman, 1999; Ballard et al., 2000; Dimitrov, 2003; Dimitrov and Dimitrov, 2004; Giosan et al., 2006) and against the “Deluge” (Dolukhanov and Shilik, 2007; Hiscott et al., 2007; Kuprin and Sorokin, 2007; Panin and Popescu, 2007; Shmuratko, 2007; Shushi, 2007; Yanko-Hombach, 2007; Yanko-Hombach et al., 2007).

Level oscillations in the Black Sea lead to transformations in the shoreline and the occupation or freeing of land surfaces. In such a scenario, the population, first attracted by the marine environment, is afterwards forced to change its habitat. Whereas in the case of changes occurring gradually the movement is slow and without catastrophic consequences, in the case of sudden events, such as floods, tsunami waves, and rapid rises in the sea level (30–60 cm per day in the case of Noah’s Flood), the movement must be done quickly, with catastrophic consequences.

Between approximately 12,000 and 15,000 years ago, the last transgression occurred in the Black Sea (Würm) and the level rose from ~130 m to the current one. Accumulative and erosive structures were formed during the level’s stable periods, which currently repose on the continental shelf.

The idea of a gradual rise of the sea level, endorsed by the vast majority of Russian scholars, was, for a long time, the accepted one (Ross et al., 1970; Deuser, 1974; Ross and Degens, 1974). According to this scenario, the levels of both the Mediterranean and the Black Sea rose simultaneously during the interglacial eras until the communication through the Bosphorus and the Dardanelles was

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<tr>
<th>Phases-deltas</th>
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<td>Letea-Caraorman spit</td>
<td>Age BP</td>
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<td>Chilia Delta</td>
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<td>Sinoie-Cosna Delta</td>
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restored ca. 9000 BP. The flow of the saltwater from the Mediterranean into the Black Sea, penetrating by means of the bottom current, had as a consequence the increase in salinity in the basin’s deep sector which lead to a water stratification and, implicitly, to the formation of an anoxic environment.

Despite this, the rise was gradual but not even. Thus, several stationary and regression stages occurred during this time span. The research conducted in the Caucasus area identified six major transgressive phases (Ostrovskiy et al., 1977):

- Transgression at ~60 m (12,000–11,500 BP), associated with the Younger Dryas. The fauna is specific to the Neoeeuxine. It was followed by a regression at ~80 or ~85 m;
- Transgression at ~45 m (10,700–9700 BP), with marine fauna. It was followed by a regression at ~60 or ~70 m, accompanied by the restoration of the lacustrine regime;
- Transgression at ~30 m (7900–6800 BP), interpreted as an equivalent of the Bugaz marine fauna in the Strait of Kerch. It was followed by a regression at ~55 or ~60 m;
- Transgression at ~10 m (7900–6800 BP), interpreted as the period during which the Vityaz marine fauna was established in the Strait of Kerch and the “Old Terrace of the Black Sea”. It marks the establishment of the current ecological conditions. It was succeeded by a regression at ~25 or ~27 m (6200–5800 BP);
- Transgression at +3 to +4 m (5700–4000 BP; Ostrovskiy et al., 1977—or 4000–3500 BP), interpreted as a period of Djemetinsk deposits with marine fauna (suggesting a salinity maximum) and of the “New terrace of the Black Sea”. It was followed by the Phanagorian regression at ~6 or ~8 m (3500–1500 BP) or ~10–15 m (3000–2200 BP) when the first Greek colonies were established on the “New Terrace”;
- The Nymphaean transgression at +2 m (2000–1000 BP), with the current fauna. It was followed by a slight decrease (~3 m) in the 14th–15th centuries, and a continuous rise up to today.

The numerical ages obtained by classic methods must be reconsidered, so as to correlate them with the more recent and more precise results produced by AMS spectrometry. The Bugaz marine period, which occurred between 9200 and 8400, is disproved by numerous AMS dates which indicate the presence of freshwater fauna up to ca. 7100. The eventual neo-tectonic rise of the terraces from the Caucasian coast is not addressed in correcting the above-mentioned depths.

A new scenario was proposed in 1997 (Ryan et al., 1997a, 1997b). It suggests that the rising of the sea level, after the glacial maximum, took place more rapidly in the Black Sea (14,000 BP) and lead to its spilling into the Marmara Sea and the Mediterranean, whose sea levels were at ~90 m. Subsequently, during the Younger Dryas, a new fall of the level of the Black Sea to ~150 m occurred. The Black Sea’s level seemed to have remained at this value (as a consequence of water evaporation and reduced fluvial inflow) until ca. 7150. The continuous rise of the level of the Mediterranean Sea depends on that of the ocean. When it reached over the Bosporus as a gigantic waterfall pouring into the northern basin, it caused the last quick rise of the level of the Black Sea. The swift water flow into the inferior lake caused an erosion of the current Bosporus Strait and the quasi-instantaneous (over a few months) fill of the Black Sea basin. The phenomena were accompanied by the introduction of marine fauna and of the anoxic environment in the deep basin.

This catastrophic event caused the migration of the Neolithic populations, eventually giving birth to the myth known as the “Deluge” (Ryan and Pitman, 1999). The authors construct their theory on the apparent discrepancy between the lacustrine and the marine deposits. The dating of the marine fauna suggested an age of 7150 years in all of the areas investigated. The simultaneous appearance of this fauna and the beginning of sapropel deposition in the deep basin suggest that these two events can be ascribed to a catastrophic event. Likewise, the recent fill of the Bosporus Strait can also be taken into consideration (Popescu, 2002).

A series of studies advanced a new opposing theory (Stanley and Blanpied, 1980; Aksu et al., 1999). According to these researchers, it was the melting of the ice sheets which followed the Younger Dryas that caused the rise of the Black Sea level. Towards 9500 BP the connection through the Bosporus was restored, but the flow of saltwater from the Mediterranean was hindered by the opposite freshwater currents running from the Black Sea into the Mediterranean Sea. Towards 7200–7000 BP, the Black Sea’s freshwater current became sufficiently weak as to allow the penetration of saltwater from the opposite direction and the establishment of a two-way circulation system via the Bosporus. This theory was based on the morphology of the sedimentary bodies from the Marmara Sea (Lane-Serff et al., 1997). The presence of the S1 sapropel layer (10,000–6300 BP) in the eastern Mediterranean can be explained by an input of freshwater from the Black Sea.

According to other researches, the sapropel deposits from the Sea of Marmara (10,000–6400 BP) could not have been formed in the presence of a high-intensity water current such as one caused by a catastrophic flood, but its presence is compatible with the idea of a steady inflow of freshwater from the Black Sea that caused a stratification of the water body (Çagatay et al., 2000).
Using data obtained from the Bosporus Strait, the researchers showed that the Sea of Marmara was filled 26,000 BP, while the marine fauna first appeared in the deposits 5300 BP. Several explanations are suggested for this incongruity: the previous marine deposits were eroded; the initial connection between the Black Sea and the Sea of Marmara followed a different path (the Sakarya Valley) (Algan et al., 2001).

Relying on data obtained on the Turkish coast of the accreting floodplain of the Sakarya River, they claim that the level of the lake rose up to \(-18 \text{ m} 7200 \text{ BP}\) (Görür et al., 2001) (when the freshwater fauna was replaced by the marine one), which contradicts the level of \(-150 \text{ m} 7150 \text{ BP}\) (Ryan et al., 1997a). The hypothesis is also backed by seismic or sedimentologic (particularly palynological) data obtained from the Marmara Sea (Hiscott and Aksu, 2002; Aksu et al., 2002a,b; Mudie et al., 2002a,b).

Nonetheless, these studies basically rely on data captured either in the Marmara Sea or the Mediterranean Sea, either on the Turkish coast of the Black Sea (particularly narrow and complicated from a tectonic point of view). The arguments supplied are more-or-less “indirect” and, as a consequence, the subject is prone to interpretation: the creation of the S1 sapropelic layer in the Mediterranean Sea cannot be attributed only to the influx of freshwater from the Black Sea; supplementary or alternative causes can be identified in the increase of the Nile’s inflow, regional climatic changes and the increase in precipitation quantities, or in an influx of water originating from the meltdown of the glaciers (Popescu, 2002).

The scenario suggested by Ryan et al. (1997a,b) was refurbished by integrating several elements of the classic theory (Ostrovskiy et al., 1977; Fedorov, 1978). Thus, the Black Sea was indeed filled with sediments as a consequence of a catastrophic event, but it had a more reduced amplitude (\(-80 \text{ to } -30 \text{ m}\)) and it occurred earlier (towards 8630 BP). These results were obtained from measurements on BlaSON cores, particularly on SR isotopes \(^{87}\text{Sr}/^{86}\text{Sr}\), on the Sr/Ca ratio and on \(^{18}\text{O}\), as markers of salinity (Major, 2002).

The proponents of the gradual rise of the level of the Black Sea bring forward arguments that are meant to discredit the existence of the “Deluge”: “On average, sea level rose gradually, but in an oscillating manner, to its present level, and perhaps slightly higher, averaging 3 cm per 100 years but certainly not 15 cm per day (almost 55 m per year) as postulated by the ‘Noah’s’ hypothesis. A rate of sea-level increase of 3 cm per 100 years would not be noticed by local inhabitants and would not have accelerated their dispersion into the interior of Europe. This brings us to conclusion that ‘Noah’s Flood’ in the Black Sea is a contemporary legend” (Yanko-Hombach, 2007). To others, the available data indicated even lower rates: “During periods of acceleration, the rate of sea-level rise could reach 50–65 mm/year” (Shuisky, 2007).

Therefore, approximately 9000 BP ago the area of the Danube Delta was a landmass with a hilly relief (i.e., Letea and Caraorman) (Romanescu, 1996a,b), separated by water streams that stretched towards the freshwater lake located in the central part of the basin of the Black Sea, with a level of \(-120 \text{ m}\) (Ryan et al., 1997a,b). Immediately after the flood (7150 BP), the level rose to \(-15 \text{ m}\) from the current one and the water became salty (Ryan et al., 1997a,b). As before, the Danube emptied itself at a considerable distance from its current mouths.

The rapid rise of the Black Sea level sparked radical changes in the environment and hence among the recent prehistorical populations living during the Neolithic and Chalcolithic (7500–4000 BP). If the rise was sudden, of 30–60 cm per day during “Noah’s Flood”, then it follows that the basin was filled in a matter of months. If the increase occurred gradually, the 80 m rise took place in ca. 2000 years (Lericolais et al., 2009). This phenomenon coincides with the emergence and development of the first agropastoral communities on the continental platform north-west of the Black Sea (Carozza et al., 2010, 2012).

The Early Neolithic is absent from Dobrudja, north-eastern Wallachia and north-eastern Bulgaria (Fig. 7). It is more than certain that the remains of this era have been covered by the advancing water (Dolukhanov and Arslanov, 2009; Dolukhanov et al., 2009). The rise of the level of the planetary ocean during the Neolithic led to drastic changes in the life of the coastal communities: “Understanding human responses to climatic and environmental variability during the early Holocene can provide

Fig. 7. Location of the earliest sites attesting the Neolithic across Europe, Anatolia and the Near East (Forenbaher and Miracle, 2005; Pinhasi et al., 2005; Turney and Brown, 2007) based on median probability calibrated radiocarbon ages.
important lessons for mitigating the effects of future change. Between 8740 and 8160 calendar years before present (relative to AD 1950; BP), the remnant Laurentide Ice Sheet collapsed, resulting in the largest single North Atlantic freshwater pulse of the past 100,000 years, raising global sea levels by up to 1.4 m and culminating in hemispheric cooling. At around the same time in Europe, the archaeological record indicates there was an abrupt expansion of Neolithic farming into areas previously inhabited by Mesolithic hunter-gatherers (Turney and Brown, 2007).

Traces of the Neolithic population (Hamangia culture) around the Danube Delta and the Razim–Sinoie lagoon complex are widespread: Mangalia, Tatlageac, Techirghiol-Zarguzan, Agighiol, Siutghiol, Tasaui, Cargalac, Sinoie, Istria (Voinea and Caraivan, 2010). The only significant discoveries for the Chalcolithic have been recorded on the right bank of the Sf. Gheorghe branch: ceramics at Mahmudia (Manucu-Adamesteanu and Oberländer-Tarnoveanu, 1984), shards from Nufaru (Gumelnita culture), shards on the Popina island (Hamangia culture) (Comsa, 1971), a Gumelnita A1 dwelling at Mila 23 (Taraschina) (Micu et al., 2009). The dwelling from Taraschina is a habitation implanted on a deltaic lobe and dates to ca. 4500–4300 BC. The archaeozoological analyses suggest an open environment, where domestic animals were present. The faunal ensemble is typical of an extremely rich and varied environment, with forests, open spaces and wet areas (lakes, river branches, swamps, etc.) (Carozza et al., 2010, 2012). If the findings are confirmed, it appears that the Danube Delta, west of the initial barrier spit, is much older than Giosan et al. (2006) suggested.

Between 6050 and 5600 BP the summers lasted longer and were hotter. The sea level rose up to 2 m above the modern one (Voinea and Caraivan, 2010). The Old Black Sea transgressive stage further raised the level up to 3–5 m above the current one (4000–3500 BP in the Sub-Boreal phase) (Giosan et al., 2006; Voinea and Caraivan, 2010). The Sf. Gheorghe I secondary delta dates from this period (Fig. 8). Some geo-archaeological studies indicate a somewhat regular repetitive pattern of rising and falling phases of the oceanic level during the Climatic Optimum: “The gradual transition to pottery-making and agriculture in the northern Pontic area

Fig. 8. The schematic representation of the natural environment during the formation of the Sf. Gheorghe I secondary delta.
occurred during the Holocene Climatic Optimum, 7000–5200 cal BC, and was not related to a catastrophic flooding. Transgression/regression cycles in the Black sea during the Holocene occurred with a periodicity of 1250 years” (Dolukhanov and Shilik, 2007).

The Phanagorian regression constituted the subsequent phase (Feodorov, 1971, 1978), during which the Greek colonies on the Romanian Black-Sea coast were founded (Panin, 1983; Romanescu, 2008; Caraivan, 2010). The Nymphean transgression (“Istria”— Bleahu, 1962; “Dzhemetianian”— Neveskaya, 1963) is characterised by a rise of the sea level of 1–3 m above the current one (Fedorov, 1978) that leads to the abandonment of the colonies around the Razim–Sinoie lagoon complex (Histria, Argamum, Bisericuta, Vadu, Halmyris). The Heraclea (Enisala) fortress ceased to be inhabited in the Middle Ages, when the level apparently rose no more than 1 m above the modern one but which was enough to flood the harbour at the base of the inselberg (600–700 BP). In the case of Argamum, the harbour extends to a distance of 10 m from the actual shoreline, to a depth of 2 m (Anghel, 2007). Approximately 2000 BP (i.e., during the Roman period) the sea level in the central basin of the Mediterranean was 1.35 ± 0.07 m (Lambeck et al., 2004) or 0.8 ± 0.4 m (Pirazzoli, 2005) lower.

Fig. 9. The schematic representation of the natural environment during the formation of the Sulina secondary delta and of the barrier spits from the Razim–Sinoie lagoon complex.

Approximately 2500 BP, during the Phanagorian regression, the sea level was 12 m (Giosan et al., 2006) or 2 m (Caraivan et al., 2003) lower than it is today. The wave-cut terraces that were created are not submerged. The Greek colonists made their appearance at this time, founding cities on the Romanian coast. The largest of them was Histria, which extended long into the sea, on the Surozhian terrace that today is submerged at a depth of 2–3 m (Popov and Zubakov, 1975).

If during the last 5000 years the sea level around the Danube Delta witnessed oscillations between –2 m and +1.5 m (Giosan et al., 2006), then the natural environment from the surrounding landmass suffered relatively few transformations (Fig. 9). It follows that the settlements already existing around the Razim–Sinoie lagoon complex survived only if they were also dependent on the hinterland. Those with full access towards the sea, towards Halmyris bay, had the unpleasant surprise of being cut off from the trade routes when their harbours were flooded by the rising water levels.

The Ancient Greeks travelled in the western part of the Black Sea during the Nymphean transgression, when the water level was 1–2 m higher. The Beibugeac corridor was thus covered by waters
and constituted a water-passage which separated the Dobrudjan mainland from the current tip of the Dunavat peninsula. The peninsula’s outmost sector, surrounded by waters, could very well have been the legendary Peuce Island. Location of this island in the eastern section of the Dunavat peninsula has been suggested since the early 20th century (Murgoci, 1912).

The current bottom of the Beibugeac corridor is at only 2–3 m above the Black Sea level. The slight increase was due to an active colmation process resulting from the accelerated erosion of a surface lacking a vegetation mantle, occurring in a relatively arid climate with sudden, heavy rains.

The most important proof for the existence of such a connection is the existence of a military harbour (castrum) at the corridor’s exit to the deltaic area, towards the Sf. Gheorghe branch. It is a defensive structure of the Halmyris fortress, mentioned in the Scutum Durae Europi document (Cumont, 1928). In this primary source the harbour is described as the main supply and storage base for the commodities and equipment transported by the marine vessels. Here, goods were unloaded and stored, to be later loaded onto river ships and barges for distribution upstream. The document belonged to a soldier or officer of the cohors XX Palmyrenorum, and was written between 238 and 240 AD. The author of the manuscript seems to have travelled on a ship, mentioning as he travelled the settlements and harbourages along the coastline (Suceveanu et al., 2003). The Danube is mentioned twice: ICTPOC POT and DANOY-BIC. These two instances refer to two branches: Peuce or Hieron Stoma (the current Sf. Gheorghe) and Sulina. On the course of the ICTPC IOT the settlement of OYDMYPIA is mentioned, identified with Halmyris on account of similar equivalencies present in late Roman texts (Suceveanu et al., 2003). The sources attest to the fact that the settlement had direct access to the sea, most probably at its southern edge, through the Beibugeac corridor. It appears that a fort also existed on the peninsula’s southern margin, toward the Halmyris bay, identified today with the ancient Gratiana (NDOr. XXXIX) erected during the reign of Valens (Suceveanu et al., 2003).

The Greek, Roman and Genovese colonies from the Razim–Sinoie lagoon complex disappeared between the 5th and 7th century AD (Histria, Argamum), the 3rd and 4th century AD (Halmyris), or the 8th and 14th century AD (Heraclea) (Bounegru, 2009). Even though the barrier spits started forming much earlier, some settlements continued to live on for several hundred

![Fig. 10. Tectonic pattern of the Eastern Mediterranean, Black and Azov seas. The map is focused on the tectonic structure of the western Aegean–Anatolian microplates and the Black Sea. Sources: Dinu et al. (2005), Aksu et al. (2002a,b), Spadini et al. (1996), Brückner et al. (2010). Abbreviations: NAFZ ¼ North Anatolian Fault Zone, EAFZ ¼ Eastern Anatolian Fault Zone, PST ¼ Pliny-Strabo Trenches, ATD ¼ Adjaro-Trialet Depression, TB ¼ Taupse Basin, KTD ¼ Kerch-Taman Depression, KaD ¼ Karkinot Depression, NKD ¼ North Kilia Depression, SSR ¼ Suvorov-Snake Island Ridge, HD ¼ Histria Depression.](image1)

![Fig. 11. The distribution of the natural resources available in the area of the Razim–Sinoie complex.](image2)
years. Proof for this comes from Histria, where the Christian basilica was still in use during the 5th century (Angelescu and Bottez, 2009). The gradual flooding of this city was facilitated by the perpetual subsidence of the deltaic area (Histria Depression) (Fig. 10). In the same vein, for some authors, the rise of the sea level during the last 10,000 years is a consequence of tectonic processes (Shmuratko, 2007).

The cities from the Razim–Sinoie lagoon complex seem to have ceased to exist because of the limited natural resources available on the mainland (Fig. 11). They owed their survival mainly to the marine resources and the practicing of trade. The diminished attention to the mainland was also a consequence of the hostility expressed by the natives against the colonists: “the shores of the Euxine are inhabited by the most ferocious people in the world. None of those who enter the land of the Scythians will make it alive.” (Herodotus, Book IV).

The topographical and geopolitical limits of the colonies’ catchment basins are negatively affected by the morphology of the Dobruja Plateau: the highest elevations are found in the eastern half, and this causes a strong reduction of the drainage area. Three such limits can be drawn for Histria, which take account of the topography (a method employed in geomorphological and hydrological studies) (Fig. 12). Despite all attempts to expand the limits, they remained nonetheless reduced and consequently the resources were limited. The positioning of the human settlements took advantage of certain features of the Danube Delta: the availability of some natural resources (land and aquatic), defence in case of invasion, adequate water depths for building harbours, international traffic routes, and good visibility (Fig. 12).

6. Conclusions

The “Noah’s Flood” theory triggered debates in scholarly circles as to the manner of interpreting the data concerning the natural environment of the Black Sea during the Holocene. Opinions for or against the “Deluge” lead to the apparition of interdisciplinary studies that sought to settle the controversies over the genesis and evolution of the deltaic areas from the mouths of the Danube. Most of the recent geo-archaeological data argue for the existence of the Deluge in the Mediterranean Basin: a part of the coastal settlements on the Black Sea were affected by the sudden rise of the sea level.

The review of the most important studies on the Danube Delta and the Razim–Sinoie lagoon complex was carried out with regard to the evolution of the inhabited areas. If the Neolithic is absent from the investigated area, the Chalcolithic is well attested on the landmass. The most important settlements appeared during the Greek, Roman and Genoese colonisation eras.

The disappearance of the colonies was due to the fact that the level of the Black Sea rose by 1–2 m during the last 2500 years, and the harbours serving the cities were covered by the rising waters. Their decline can also be attributed to their disproportionate reliance on marine resources, when compared to the continental ones. The latter were relatively scarce, and the colonies used only the clay for pottery manufacturing, the limestone for construction, and the freshwater which they transported via aqueducts.

By highlighting certain geomorphological, archaeological and geopolitical features, the position of the legendary Peuce Island is also inferred: in the western extremity of the Dunavat peninsula. The island was separated from the mainland along the path today followed by the Beibugeac corridor, at whose end the Halmyris military harbour used to exist.

The founding of the colonies around the Razim–Sinoie lagoon complex depended on the available natural resources and the defence strategy: promontories, mineral and freshwater resources, good visibility, the crossing of sea and river navigation routes, etc. The disappearance of the once flourishing settlements was due to the build-up of the barrier spits which blocked the access to the
lagoon, the colmation of the lagoonic curvette and the implicit reduction of the water depth, and the depletion of natural resources from around the shoreline.

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