Holocene ostracod and foraminiferal assemblages of the Romanian Black Sea shelf

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ABSTRACT

Qualitative and quantitative study of the ostracod and foraminiferal assemblages were performed on two cores, around 0.30 m depth bsf in thickness, collected from the Romanian Black Sea shelf. The lithology of the studied cores is characterised by grey and black muds, topped by a centimetre thick fluffy mud layer. One of the cores, MN 103_09, is placed on the Romanian inner shelf, at water depth of 17.80 m. The sediments of this core contain very few and small bivalve fragments and no gastropods. In this core, the ostracod and foraminiferal assemblages are influenced by a quite high-energy environment, due to the Sulina arm of the Danube Delta. This feature is mirrored in the poor preservation and low abundance of the species, as well as the mixed Caspian and Mediterranean character of the ostracod assemblages. The other studied core, MN 103_04, is situated on the Romanian outer shelf, at a water depth of 78 m. Its deposits commonly contain gastropods and bivalves, as well as microfauna displaying a low diversity and a very high abundance; the character of the ostracod assemblages is a Mediterranean one. Overall, the identified microfaunas of the two investigated cores reflect the environmental conditions of modern and/or latest Holocene sea-floor assemblages and their relationships to salinity, sediment input and water depth. Even the depositional time of the 30 cm cored interval in the two studied cores is quite different, i.e., possibly several hundreds of years, up to 1000 years, on the inner shelf and several thousands (from 3000 BP to the Present), in the outer shelf, the results are indicative for modern Black Sea conditions. A stable marine environment with a salinity around 17–18‰, comparable with the present one, could be assumed for the whole cored interval of the Romanian shelf. Besides, the age structure, i.e., the ratio between adults and juvenile taxa of ostracod population in the outer shelf indicates a moderate to high energy autochthonous thanatocoenosis, with some post-mortem disturbance by currents. By contrast, the ratio between adults and juvenile ostracod taxa in the inner shelf mirrored a taphocoenosis with post-mortem disturbance, sorting and transport. This assemblage, dominated mainly by disarticulated valves of juveniles, does not represent the environment in which the ostracods lived.

1. Introduction

The ostracod taxa are in general benthic organisms, their abundance and diversity being controlled by environmental factors such as the type of substrate, hydrodynamic conditions, salinity and temperature (Aiello et al., 2006). This group of organisms is very useful in deciphering environmental and climatic changes in the Earth history, and especially in the Quaternary (Horne et al., 2012), their fluctuation pattern being a good proxy of the water and surface sediments chemistry, as well as nutrients and sea-level fluctuation. This feature is very useful in interpreting environmental changes in various settings, such as fresh-water, brackish and marine ones.

Many ostracod species inhabiting the NW part of the Black Sea shelf are well adapted to fluctuating environmental conditions caused by the freshwater influx from the Danube, Dniester and Dnieper Rivers (Aksu et al., 2002; Opreanu, 2008). Nowadays, the diversity of typical marine ostracods is very poor in the Black Sea in contrast with the Mediterranean.

The present-day Black Sea ostracod community contains a mixture of brackish Caspian taxa, such as Candona sp., Candona fabaformis, Cyprideis sp., Amniclythera spp., Euxinocythere spp., Tyrrenocythere donetzienzis and Loxocaspia (= Loxoconcha) lepida, Black Sea endemic marine species, such as Pontocythere bacescoi, as well as Mediterranean immigrants, i.e., Leptocythere multipunctata.

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Since the Late Holocene, the foraminifers from the NW part of the Black Sea basin show a low diversity and a very high abundance. The foraminifer assemblages of the NW Black Sea region (i.e., Ukrainian and Romanian shelf) are exclusively benthonic (Yanko, 1990; Yanko-Hombach, 2007), being largely dominated by the representatives of the Ammonia genus (Yanko, 1990; Briceag et al., 2012).

Due to high salinity fluctuation of the NW part of the Black Sea, linked to the significant fluvial water input of the Danube, Dniester and Dnieper rivers (synthesis of data in Yanko-Hombach et al., 2007), a high morphological variability of Ammonia taxa was recorded in the Black Sea. Hence, at least 10 species of Ammonia could be found in Upper Holocene sediments of the Black Sea (Yanko, 1990), and each displays a specific ecological preference that varies from an oligohaline environment (1−5%) to a polyhaline one (18−25%).

Only a few Holocene microfaunal works on the Romanian Black Sea shelf region have been published (Carailon, 1958, 1967; Olteanu, 1978). Most of the older works lack any illustrations of the taxa. Recent papers focused on Late Holocene ostracod assemblages of the NW Black Sea have been published by Olteanu (2003) and Opreanu (2006). Boomer et al. (2010) published data on the taxonomy of the ostracod taxa identified in the NW Black Sea, within a large interval, i.e., Pleistocene to Recent, including the latest Holocene. Qualitative and quantitative investigations of Late Holocene foraminiferal and ostracod assemblages from the Romanian Black Sea shelf (southern part) have been published by Briceag et al. (2012).

Since now, most of the investigations have been concentrated on biotic fluctuation identified in the Holocene deposits of the Black Sea from deeper parts of the basin. This study is focused on qualitative and quantitative analyses of microfaunas from Holocene deposits sedimented in shallow settings of the Black Sea (Romanian inner and outer shelf).

The main aim of this work is to investigate the latest Holocene sea-floor assemblages, including the recent microfaunas from water/sediment interface, along with their relationship to salinity and energy gradients related to the Danube mouth. Another aim is to reveal the character of the microfaunas, and to point out the Caspian and/or Mediterranean influences in the ostracod assemblages of the Romanian Black Sea shelf.

2. Regional setting

The Black Sea is a semi-enclosed marginal basin which connects with the Mediterranean Sea through the Bosphorus Strait, Marmara Sea and Dardanelles Strait. Beside the connection with the Mediterranean Sea, in the Late Pliocene–Pleistocene times the Black Sea experienced a period of connection with the Caspian Sea through the Manych Corridor due to the melt waters from the Scandinavian ice sheets (Fedorov, 1977; Badyukova, 2001; Chepalyga et al., 2004; Bahr et al., 2006; Kislov and Toropov, 2007).

The Black Sea is also the largest marine anoxic basin in the world. The anoxia is given by the vertical stratification of the Black Sea waters, the surface layer is well oxygenated and has a salinity of approximately 18⁰/oo, while the deep water layer, below 150−200 m, is anoxic and contains a high hydrogen sulfide concentration with a salinity of around 22.5⁰/oo (Ozsoy et al., 1995; Bahr et al., 2006; Murray et al., 2007). Through the Bosphorus Strait there are two strong directional currents that give this vertical stratification: one deep water current that brings high salinity Mediterranean waters into the Black Sea and another surface outflow current, which expels low salinity waters to Marmara Sea (Ozsoy et al., 1995).

The Black Sea continental shelf extends significantly in the northwestern part of the basin, covering almost 30% of the total Black Sea area and 90% of this geomorphologic province (Panin and Jipa, 2002). In this area, there is an important fluvial water and sediment discharge into the Black Sea from the Danube, Dniester, Dnieper and Southern Bug rivers (Tolmazin, 1985; Margvelashvily et al., 1999; Hiscott et al., 2007; among many others).

The Danube River is the main water and sediment supplier of the Romanian Black Sea region. The average Danube sediment discharge into the Black Sea basin is estimated by Panin and Jipa (2002) between 25 and 35 million t/y, of which 4−6 million t/y are sandy material. For the NW part of the Black Sea, the other three rivers Dniester, Dnieper and Southern Bug are low suppliers of sediment discharge, most of the sediments being deposited in isolated lagoons, separated by sand barriers from the open basin (Panin and Jipa, 2002).

The littoral area of the Romanian Black Sea is divided into two units: the Danube Delta coastal zone and the Southern Unit, which extends between Cape Măida and Romanian-Bulgarian border (Panin and Jipa, 2002). The Danube Delta coastal zone is characterised by a longshore sediment drift along the delta, with intense erosion of the delta littoral area located south of the Sulina mouth (Panin and Jipa, 2002). The Southern Unit is directly influenced by the Mâdia harbour jetties, which traps the sandy sediments of the longshore drift, causing sediment starvation of the entire southern coastal zone (Panin and Jipa, 2002).

On the N Romanian Black Sea shelf several major depositional areas, such as the Delta Front and the Danube Prodelta, as well as the continental shelf and the shelf break, located between 100 and 200 m water depths, were delimited (Panin et al., 1983; Panin and Strecchie, 2006). The Delta Front extends to water depths between 15 and 45 m, while the Danube Prodelta could be found to depths of 50−60 m (Panin, 2003). Within the Danube littoral zones, superficial sediments are mainly fine to very fine well-sorted sands, sourced from the Danube and redistributed onshore by waves and currents (Stânciu et al., 2007).

Concerning the Holocene sedimentation of the Black Sea, Ross and Degens (1974) identified in the deep parts of the basin three lithological units: the oldest unit, Unit 3, the lacustrine lutite, deposited during the freshwater or oligohaline stage; Unit 2, the sapropel mud, corresponding to a brackish, anoxic phase, and the youngest unit, Unit 1, the microlaminated coccolith ooze, a pelagic sediment deposited under recent marine conditions, associated with the full invasion of the coccolithophorid species Emiliania huxleyi. These units can be found only in the deeper parts of the Black Sea, at water depths below 200 m (Giunta et al., 2007; Melinte-Dobrinescu and Briceag, 2011; Oaie and Melinte-Dobrinescu, 2012).

In the shallow setting of the NW Black Sea the lithological units of deeper parts of the basin could not be recognised. In this shallower setting (i.e., the Romanian Black Sea shelf), Giunta et al. (2007) and Oaie and Melinte-Dobrinescu (2012) identified the Shallow Unit, which corresponds to Unit 1 and Unit 2 deposited in the basinal setting.

3. Material and methods

For this study, two undisturbed cores collected by using a multicorer were analysed: (1) MN 103.04 at 78 m water depth, S of the Şfântu Gheorghe (Saint George) branch of the Danube Delta, at 44° 33′.00.378″ N; 30° 27′.01.04″ E; and (2) MN 103.09 at 17.80 m water depth, located in front of the Sulina branch of the Danube Delta, at 45° 07′.22.446″ N; 29° 47′.33.792″ E (Fig. 1). The two cores...
were acquired in May 2012 on a scientific cruise with the Geo-
EcoMar R/V Mare Nigrum, in the framework of the Black Sea Era Net
Project WapCoast.

Both MN 103_04 and MN 103_09 cores were investigated in
detail for micropaleontological purposes, primarily focusing on
ostracods and foraminifers. For this purpose the two cores were
continuously sampled, each sample covering 3 cm of the core.

A total of 19 micropaleontological samples were processed,
boiled with Na2CO3, washed through a 63
\( \mu \)m sieve, air-dried and
hand-picked under a binocular microscope. The photographs of the
microfaunal taxa have been taken using an Olympus SZ51 micro-
scope with an adapted Moticam 1000 digital camera.

Quantitative studies were achieved for ostracods and foramin-
ifers by counting the total number of specimens. For the ostracods,
the adult and juvenile specimens were counted, taking into
consideration the carapaces. This count was performed to distin-
guish between in situ and transported fossil taphocoenoses. Ac-

By Brouwers (1988), finer grained particles such as juvenile
valves are more readily transported over greater distances: hence,
transported assemblages have a clearly skewed adult to juvenile
ratio.

4. Results

4.1. Lithology and macrofaunal assemblages

The MN 103_09 lithology consists of fine-grained sediment, an
alternation of black muds and dark grey muds with a 3 cm light
brown fluffy mud layer in the uppermost part (Fig. 2). In this core,
there are very few and small bivalve fragments and no gastropods.
The bivalve fragments mainly belong to Mytilus galloprovincialis,
Dreissena polymorpha and Cardium spp. Another feature of this core
is the presence of many black fragments of organic matter (vegetal
remains) and limonitic oxidised crust fragments that contains
rounded quartz clasts.

From the lithological point of view, the MN 103_04 core consists
of grey muds, with 2 cm of black fluffy mud at the top (Fig. 3). In this
core, except its top, i.e., the black fluffy mud, a very rich gastropod
and bivalve assemblage is present. The gastropods are mainly
represented by Cerithidium pusillum and Rissoa spp. The bivalve
assemblage commonly contains Modiolus phaseolinus, M. gallopri-
vincialis, Abra alba and Cardium spp.

4.2. Ostracod assemblages

The MN 103_09 core contains 12 ostracod species, belonging to
11 genera (Fig. 3). The ostracod fauna from this core is represented
by Pseudocandona sp., Candona schweyeri Schornikov, C. fabaerum
(Fischer), L. multipunctata (Sequenza), Semicytherura sp., Cyprideis
torosa (Jones), P. granulata (Sars), C. variabilis Müller, X. corneli
Caraion, T. donetziensis (Dubowsky), Amnicythere quinquetuberculat-
ata (Schweyer) and Cytherois sp (Fig. 5).

In the MN 103_04 core, the ostracod fauna consists of 7 species
belonging to 7 genera (Fig. 2). Most of the encountered specimens
are well preserved, and both adult and juvenile (carapaces and
valves) are present. The ostracod assemblage is represented by the

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Fig. 2. Lithology and microfaunal (ostracods and foraminifers) distribution and abundance in the MN 103_04 core. Ostracod abundance is given for adult, juvenile and carapaces specimens/sample.

Fig. 3. Lithology and microfaunal (ostracods and foraminifers) distribution and abundance in the MN 103_09 core. Ostracod abundance is given for adult, juvenile and carapaces specimens/sample.

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species *L. multipunctata* (Sequenza), *P. granulata* (Sars), *C. variabilis* Müller, *C. diffusa* (Müller), *X. corneli* Caraiion, *Cythereis rubra pontica* Dubovski and *Paradoxostoma simile* Müller (Fig. 5).

The ostracod diversity is relatively low (7 species), while the abundance (= number of the recorded specimens) is very high (Figs. 2 and 4). In particular, a very high abundance was recorded in the intervals 15–18 cm and 24–29 cm. In general, the abundance decreases from the base toward the top of the investigated core. The oldest sediments contain ostracod assemblages clearly dominated by *P. granulata* and *X. corneli*, which are making together over 90% of the total assemblages. Both these taxa show a decrease in abundance in younger sediments. In the middle part of the studied core (i.e., the interval 15–18 cm), the highest abundance, 4305 specimens, is shown by *C. diffusa*, representing almost 90% of the assemblages. *L. multipunctata* and *P. simile* are present sporadically in the encountered assemblages, while *C. variabilis* and *C. rubra pontica* are almost continuously present, but with a low abundance, decreasing from the base towards the top of the core.

4.3. Foraminiferal assemblages

The foraminiferal assemblages of both cores contain well-preserved benthic foraminifers. The planktonic foraminiferal taxa present in the encountered assemblages are entirely reworked from pre-Holocene deposits, and they represent less than 1% of the total assemblages.

In the inner shelf core MN 103_09, the assemblages are represented by the benthic foraminiferal taxa *Ammonia* spp., *Cribroelphidium poeyanum* and *Nonion matagordanus* (Fig. 2). A few reworked planktonic taxa belonging to the *Globigerina* genus were observed towards the base of this core. As in the deeper core MN 103_04, the *Ammonia* taxa are dominating the foraminiferal assemblages, representing 75 up to 90% of the total assemblages (Fig. 6), but the number of recorded specimens is much lower than in the outer shelf core. The next abundant species found in the core MN 103_09 is *C. poeyanum*, which represents 15–35% of the identified foraminiferal assemblages.

In the MN 103_04 core, the benthic foraminiferal assemblages consist of taxa belonging to the *Ammonia* and *Lagena* genera, and include also *C. poeyanum*, *N. matagordanus*, *Eggerella scabra* and *Laryngosigma williamsoni* (Figs. 3 and 5). The reworked planktonic foraminiferal assemblages are composed of *Globigerina* taxa. In situ foraminiferal assemblages are largely dominated by the *Ammonia* taxa, which represent over 95% of total recorded foraminifera (Fig. 6). The abundance of *Ammonia* spp. shows high fluctuation, from over 2500 specimens in the interval 15–18 cm to 185 specimens in the interval 0–3 cm. The next common taxon is *C. poeyanum*, but its abundance is much lower than *Ammonia* spp., representing up to 2% of the total assemblages. Moreover, towards the upper part of the deeper core MN 103_04, *C. poeyanum* was not observed. The other encountered foraminiferal taxa have a sporadic occurrence in the outer shelf, appearing consistently in the interval 9–18 cm (Fig. 6).

5. Discussion

5.1. Age model

5.1.1. Inner shelf core MN 103_09

The core MN 103_09 is located on a very shallow setting, at around 18 m water depth, in front of the Sulina branch, on an area that belongs to the Danube Delta Front (Panin and Jipa, 2002). In the absence of numerical dating it is very hard to compute the age of the 30 cm-thick sedimentary sequence. The calcareous nanoplankton could not give any information for this site, as *E. huxleyi* does not occur in any sample of the core MN 103_09, probably due to low salinity values (below 11‰) of the surface-water during the whole depositional interval.

In the area where the core MN 103_09 is located, the Sulina Palaeo-delta has spread, between 7000 and 2000 BP (Panin, 1996, 2003). Taking into account this palaeogeographical setting and also the fact that the ostracod assemblages are brackish of Caspian type, but also marine, i.e., Mediterranean in character, the 30 cm core sediments are younger than 2000 BP, when the shoreline retreated and the sea covered the Sulina Palaeo-delta.

On the other hand, a huge quantity of sediments is brought by the Danube in this area, between 51 and 70 M t/y (Panin, 1996). From the three Danube Delta branches, the middle one, Sulina, in front of which the studied core is located, presently discharges around 20% of total Danube waters, but the percentage was less during the last centuries, increasing from 7–9% to 16–17% in 1921 (Almazov et al., 1963). Hence, it is to suppose this important sediment input is spread offshore, partly in front of the Sulina mouth, even if the dominant long-shore direction in front of the Danube Delta littoral zone is southwards, a pattern that is partly mirrored by the development of Sakhalin Island south of the Sfântu Gheorghe branch (Panin, 1989, 1996; Stanică et al., 2007).

Numerical ages of very young deposits, i.e., the last thousand years, are not available for the Romanian Black Sea shelf. Aycük et al. (2004) found, in a core on the Romanian coast, located near the Danube Delta, a sedimentation rate of 0.20 ± 0.01 cm/y by using 210Pb method and 0.15 ± 0.03 cm/y by using 137Cs. Based on these data, the 30 cm thick sedimentary sequence was deposited within an interval no older than the last 1000 years.

5.1.2. Outer shelf core MN 103_04

The core MN 103_04, which is 29 cm in length, is characterised by the presence of marine microfaunas, from base to top. Moreover,
Fig. 5. Ostracods and foraminifers from the MN 103_04 core, except Plate Figure 31 from MN 103_09 core, all valves and carapaces of ostracods belong to adult individuals: LV – left valve, RV – right valve; E – external lateral view; I – internal lateral view; C – carapace. 1 – 4 Palmoconcha granulata (Sars): 1 – LV, E, 24–29 cm; 2 – RV, E, 9–12 cm; 3 – LV, E, 9–12 cm; 4 – LV, I, 9–12 cm; 5 – 8 Cytheromorpha variabilis Müller, 24–29 cm: 5 – LV, E, 6 – RV, E, 7 – LV, E, 8 – RV, E; 9 – 12 Callistocythere diffusa (Müller): 9 – LV, E, 9–12 cm; 10 – RV, E, 15–18 cm; 11 – LV, E, 9–12 cm; 12 – RV, E, 24–29 cm; 13 – 20 Xestoleberis cornelia Cariou, 24–29 cm: 13 – LV, E; 14 – RV, E; 15 – LV, E; 16 – RV, E; 17 – LV, I; 18 – RV, I; 19 – C, dorsal view; 20 – C, ventral view; 21 - 24 Cythereis rubra pontica Dubovski: 21 – LV, E, 24–29 cm; 22 – RV, E, 9–12 cm; 23 – LV, E, 9–12 cm; 24 – RV, E, 9–12 cm; 25 – 27 Paradoxostoma similis Müller, 24–29 cm: 25 – LV, E; 26 – RV, E; 27 – LV, E; 28 – 31 Ammonia tepida (Cushman), 28, 29–24–29 cm, spiral view; 30, 31 – 9–12 cm, umbilical view; 32 Nonion matagordanus Koedeld, 15–18 cm, spiral view; 33 Cribroelphidium poeyanum (d’Orbigny), 24–27 cm, spiral view; 34 Laryngosigma williamsoni (Terquem), 9–12 cm, side view; 35 Eggerella scabra (Williamson), 21–24 cm, side view.
in the whole cored interval, blooms of the coccolithophorid *E. huxleyi* are present (Melinte-Dobrinescu and Ion, 2013). *E. huxleyi* is a calcareous nannoplankton species that is believed to have invaded the Black Sea at ~3400 BP (Hay et al., 1991; Arthur and Dean, 1998). Therefore, the studied sediments are at least younger than 3400 BP, representing an interval of modern conditions on the Black Sea floor, well above the youngest reconnection with the Mediterranean Sea.

The outer shelf MN 103_04 core is situated on the area where the mud is rich in the bivalve mollusc, *Modiolus*. On the Romanian shelf three principal genera of bivalve molluscs occur: *Modiolus*, *Mytilus* and *Dreissena* (Fig. 7). *Modiolus*-rich mud occurs at the top at the water/interface sediments, at water depths between 50 and 125 m, *Mytilus*-rich mud is generally found between shelf-break and 40–50 water depth, while *Dreissena*-rich mud is found in the area of sediment-starved slope, at water depth in general over 150 m (Radan, pers. comm.; Panin and Jipa, 2002; Lericolais et al., 2009, 2010; Nicholas et al., 2011). From a stratigraphical point of view, *Modiolus*-rich mud overlies *Mytilus*-rich mud, which overlies the *Dreissena*-rich mud.

There are only a few published numerical ages on the Holocene sediments of the NW Black Sea region, the Romanian shelf. In core B2KS24 (Figs. 1 and 7), the following numerical ages were recorded: in the *Modiolus*-rich mud, 2820 ± 30 BP; towards the top of the

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**Fig. 6.** Fluctuation in diversity (number of species/sample) and total abundance (number of specimens/sample) of foraminiferal taxa encountered in the studied cores (MN 103_04 and MN 103_09) and Ammonia spp. abundance (number of specimens/sample) and percentages.
Mytilus-rich mud 5530 ± 30 BP; at the base of this unit, 6520 ± 40 BP, and in the Dreissena-rich mud, at 80 cm depth bsf, 11,060 ± 40 BP (Giunta et al., 2007; Lericolais et al., 2009). Recently, Nicholas et al. (2011) studied the shallow marine deposits of the core 45B (Figs. 1 and 7), from young to old, consists of Modiolus-rich mud, Mytilus-rich mud and Dreissena-rich mud. They found in the middle part of the Mytilus-rich mud, at a depth of around 30 cm an age of 8530 ± 45 BP, while in the middle part of the Dreissena coquina they reported three numerical ages, the oldest one being 8820 ± 70 BP (Fig. 7). These authors have not reported any numerical ages for the youngest lithological unit, i.e., the Modiolus-rich mud.

To summarize, the single dating of the Modiolus-rich mud, the unit characterising the studied core from the Romanian outer shelf, is 2820 ± 30 BP. Taking into account these data, and also the fact that everywhere in the NW Black Sea shelf, the thickness of the Modiolus-rich mud is around 30–40 cm, the 29 cm cored interval of MN 103_04 approximately comprises an interval between 3 ka BP and the present.

5.2. Palaeoenvironmental setting

5.2.1. Inner shelf core MN 103_09

In the inner shelf core MN 103_09, 17.80 m water depth, in front of the Sulina branch of the Danube Delta, the ostracod and
foraminiferal assemblages are influenced by the relatively high-energy environment linked to the Danube mouth. This feature is reflected in the preservation of the taxa, most of them being broken. Possibly, they were at least partially transported from the Danube Delta area. The significant fresh-water and sediment input of the Danube is also emphasized by the presence of centimetre to millimetre black organic matter and limonitic oxidised crust fragments that contain rounded quartz clasts.

Moreover, based on the taphonomy of the ostracods from this core, following the steps for the biostratigraphical assessment of ostracods described by Boomer et al. (2003), the ostracod assemblages represent a taphocoenosis with post-mortem disturbance, sorting and transport. This assemblage, dominated mainly by disarticulated valves of juveniles, does not represent the environment in which the ostracod taxa were lived.

In the identified assemblages there are Caspian in origin fresh to brackish water ostracod taxa, such as *Pseudocandona* sp., *C. schwertyi*, *C. fubaearmiformis*, *C. torosa* and *T. donetziensis*, as well as marine ones, i.e., *P. granulata*, *C. variabilis* and *P. simile* (Figs. 3 and 6). Additionally, *C. torosa*, an extremely euryhaline ostracod that could survive in a wide salinity range of 0–60‰ (De Deckker, 1981), sporadically occurs with a low abundance. Despite this significant salinity range, the maximum even 30‰ C. torosa abundance was recorded between 2 and 16 m (Opreanu, 2004). This species was encountered in the Caspian Sea, with the highest abundance in the US 09 core-top from the water depth of 13 m and a salinity of approximately 13‰ (Boomer et al., 2005). Nowadays, *C. torosa* is the only living ostracod species in the Aral Sea, after the local extinction of all the other taxa, as the salinity has risen above 24‰, due to the anthropogenically-induced salinity increase (Boomer et al., 1996). *C. torosa* was identified in the Danube Delta and in the low salinity Razelm-Sinoe lagoon of the N Romanian Black Sea coast (Opreanu, 2004).

Analysis of calcareous nannoplankton of this core, using the same samples as for microfaunas, indicates that no in situ Holocene species (i.e., *E. huxleyi*) is present (Melinte-Dobrinescu and Ion, 2013). The calcareous nannofloras inhabiting the Late Holocene up to the present Black Sea surface waters are found above 11‰ salinity, the minimum value required for the survival and growth of *E. huxleyi* (Bukry, 1974). Therefore, the surface-water salinity in the whole depositional interval cored was lower than 11‰.

5.2.2. Outer shelf core MN 103_04

Core MN 103_04 is located at 78 m water depth, S of the Sfântu Gheorge (Saint George) branch of the Danube Delta. The observed microfaunal assemblages are typical for a marginal marine setting where the species diversity is generally low, but specimen abundance is relatively high (Lord et al., 2012). All the identified ostracod taxa of MN 103_04 core have a Mediterranean origin and inhabit well oxygenated environments with fine-grained substratum, i.e., clayey silts according to the grain size analysis.

The ostracod cored minerology of the MN 103_04 core (Fig. 2) could be found also in the present day living ostracod communities of NW Black Sea (Opreanu, 2006). This author encountered the following living ostracod species, with very high abundances in specific bathymetric intervals, as follows: *L. multipunctata* and *C. variabilis* between 30 and 80 m, *C. diffusa* between 30 and 50 m, *X. cornelii* between 60 and 70 m, *P. granulata* between 70 and 80 m and *C. rubra pontica* between 50 and 60 m. Notably, the highest density of the present-day ostracod communities is recorded in the bathymetric interval comprised between 30 and 80 m (Opreanu, 2006), an interval characterised by stable marine conditions.

Recently, Ivanova et al. (2012) found *C. rubra pontica* in a core from the NE part of the Black Sea, i.e., the Caucasian outer shelf, and categorised this taxon along with other species, such as *P. granulata*, *C. variabilis* and *P. simile*, according to the Vienna System (Perkins, 1974), as polyhaline species (18–30‰). On the other hand, the ostracod *X. cornelii*, present also in the core MN 103_04, is considered to be a mesohaline species (5–18‰) (Ivanova et al., 2012). In the 15–18 cm bsf of the outer shelf core, *X. cornelii* yielded an increase in abundance as well, but this is much lower than the one recorded by *C. diffusa*. At the core bottom (24–29 cm), *C. diffusa* abundance is decreasing, while the mesohaline ostracod *X. cornelii* abundance is increasing, along with other polyhaline ostracod species, i.e. *P. granulata*, *C. variabilis*, *P. simile* and *C. rubra pontica*. The presence of these taxa in the ostracod assemblages indicated a salinity value of around 18‰ (Ivanova et al., 2012), that is the lower limit to survive for the polyhaline ostracod *C. diffusa* and the upper limit of the mesohaline ostracod *X. cornelii*.

The two cored intervals, i.e., 15–18 cm and 24–29 cm, of the site MN 103_04, are also characterised by a very high abundance of foraminiferal species belonging to the *Ammonia* genus (Fig. 5). In the top of the core (0–3 cm), in the flufy mud layer, the ostracod and foraminiferal assemblages show a lowering in the abundance (Figs. 2 and 5).

The ostracod assemblage of MN 103_04 core consists of a mixture of adults and juveniles. The juvenile valves encountered in all the samples are dominated by larger, later instars, while the smaller instars are almost completely missing. This feature is possibly linked to the removal by the currents or dissolution of weakly calcified small instars (Boomer et al., 2003). Nevertheless, the adult valves are more numerous than the juvenile ones at almost all the encountered species. Taking into account this feature, and according to the findings of Boomer et al. (2003), on the relationship between ostracod population age structures and the degree of reworking and the environment where they live, we assume that the ostracod assemblages indicate, in the outer shelf core from the NW Black Sea, a moderate to high energy autochthonous thanatocoenosis, with some post-mortem disturbance by currents.

6. Conclusions

The abundance and distribution pattern of benthic ostracod and foraminiferal assemblages have been documented in two cores situated in the NW part of the Romanian Black Sea shelf. The ostracod and foraminifer response to the salinity and water depth variations is reflected by the different character of the identified microfaunas from the inner shelf (core MN 103_09) and the outer shelf, respectively (core MN 103_04).

Offshore of the Danube mouths, close to the Sulina branch, the benthic ostracod faunas contain a mixture of Caspian and Mediterranean in origin taxa. Additionally, both the ostracod and foraminifer taxa yielded a low abundance. The degree of preservation is poorer compared to assemblages observed in deeper parts of the Romanian shelf. A similarity in microfaunal assemblage could be observed between the inner shelf MN 103_09 core, situated at a water depth 17.80 m, in front of the Danube Delta, and the previously studied EF 08-01 core (Briceag et al., 2012), at water depth 28.15 m, in the southern part of the Romanian shelf (Fig. 1). In this very shallow setting, i.e., below 30 m water depth, the currents have a direct influence on the microfaunal associations by mixing fresh-water from the Danube with marine waters, and adjusting the degree of in situ assemblages.

In the outer shelf, i.e., core MN 103_04, at 78 m water depth, the ostracod assemblages contain exclusively Mediterranean taxa. This feature suggests stable marine conditions for the whole cored interval (3000 BP to the present), with water salinity values close to today’s, around 17–18‰. These results are consistent with the ones of Briceag et al. (2012) on the microfaunas identified in the 45 cm of sediments of the core BS 08–055 (S Romanian outer shelf,
43°54′35″N; 29°21′20″ E, water depth 66.80 m — (Fig. 1). In this core, a high abundance of the Mediterranean in origin ostracod taxa, such as *P. granulata*, *C. diffusa*, *X. cornelli* and *C. rubra pontica*, was observed. This ostracod assemblage is represented by a mixture of valves and carapaces belonging to adults and juveniles, with the smaller instars missing. This assemblage indicates also a moderate energy autochthonous thanatoconiosis, as that recorded by the ostracod assemblages of MN 103_04 core. The microfaunal character reflects stable marine conditions, at a water depth below 60–70 on the Romanian Black Sea outer shelf, from 3000 BP to the present. This environmental setting allows the Mediterranean taxa to thrive.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.quaint.2013.09.028.

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