Journal of Micropalaeontology, **29:** 119–133. 0262-821X/10 $15.00 © 2010 The Micropalaeontological Society

Late Pleistocene to Recent ostracod assemblages from the western Black Sea

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ABSTRACT – During the last glacial phase the Black Sea basin was isolated from the world's oceans due to the lowering of global sea-levels. As sea-levels rose during the latest glacial and early Holocene period, the Black Sea was once again connected to the eastern Mediterranean via the Dardanelles–Marmara–Bosporus seaway. In recent years, trace element and stable isotope analyses of ostracod assemblages have yielded important details regarding the hydrological evolution of the Black Sea during these events. Despite this focus on the geochemical signatures of the ostracods, little if any attention has been paid to the taxonomic composition of the ostracod assemblages themselves and there are notably few publications on the sub-littoral fauna of this important water body. We present a summary of the most abundant ostracod taxa of the Black Sea during the late glacial to early Holocene phase (dominated by the Candonidae, Leptocytheridae and Loxoconchidae) and chart their response to the subsequent environmental changes in the early Holocene with the pre-connection, low salinity 'lacustrine' fauna being replaced by one with a more Mediterranean aspect. Many of these taxa are illustrated using SEM for the first time, providing an important initial step in establishing taxonomic stability within Black Sea ostracod studies and noting faunal similarities with neighbouring areas, such as the Caspian Sea. *J. Micropalaeontol.* **29**(2): 119–133, December 2010.

KEYWORDS: *Ponto-Caspian, Black Sea, Ostracoda, Pleistocene, Holocene*

BACKGROUND

The Black Sea is a large, deep-water epicontinental sea connected to the eastern Mediterranean Basin, and thereby the world's oceans, through a narrow and shallow series of corridors, the Dardanelles–Marmara–Bosporus seaway (Fig. 1). Today, there is an exchange between a lower and in-flowing warm, saline Mediterranean water and an upper out-flowing, cooler, fresher Black Sea water, the sea is now heavily stratified and is permanently dysaerobic at depth (Neretin *et al*., 2001). The mean salinity of the modern Black Sea is about 17‰ in most of the surface waters and as much as 23‰ in deep water. This situation was established during the early Holocene. During the last major glacial phase the Black Sea basin became isolated as the level of the eastern Mediterranean fell below that of the connecting pathway due to glacio-eustatic sea-level fall. Subsequently, as the global ice-sheets returned much of their water to the oceans, there was a period of significant post-glacial sea-level rise, the Black Sea and Mediterranean once again became connected during the early Holocene and the exchange of waters established. It is probable that this has occurred on a number of previous occasions during the Quaternary (Schrader, 1979).

The pattern of isolation followed by initial connection, then sea-level rise and subsequent stratification are recorded in the Black Sea sedimentary record. Ross *et al*. (1970) described the occurrence of three distinct units observed in the uppermost few metres of sediment cores recovered across the Black Sea basin which were dated using ^{14}C analysis of molluscs. The youngest sedimentary unit (Unit I, mid-Holocene to Recent) constitutes only a few tens of centimetres and displays very fine microlaminations of alternating light and dark layers. The light-coloured layers are almost exclusively composed of monospecific assemblages of the coccolithophorid *Emiliania huxleyi* (see Giunta *et al*., 2007 and Oaie & Melinte-Dobrinescu, 2009, for recent discussion). Major *et al*. (2002) further subdivided Unit III based on sedimentological and geochemical characteristics. On the continental shelf, Shcherbakov & Babak (1979) subdivided the sedimentary sequence based upon the sedimentology and mollusc composition (i.e. *Modiolus*, *Mytilus* and *Dreissena*), which were subsequently correlated with deep-sea cores by Giunta *et al*. (2007).

The middle unit (Unit II, early to mid-Holocene), again only a few tens of centimetres thick, comprises dark, fine-grained sediments with high organic content, i.e. a sapropel, and represents the establishment of anoxic conditions, probably associated with enhanced surface productivity and stratification. The oldest unit (Unit III, late glacial) comprises fine-grained detrital sediments, generally light in colour but with occasional dark–light alternations; this unit extended for many metres and represents a pre-connection, possibly 'lacustrine' phase with apparently well-ventilated bottom waters.

The precise timing, rate and flow-direction of the connection has been the subject of much discussion (Ryan *et al*., 1997; 2003; Ballard *et al*., 2000; Uchupi & Ross, 2000; Aksu *et al*., 2002; Siddal *et al*., 2004; Yanko-Hombach *et al*., 2007; Giosan *et al*., 2009; Lericolais *et al*., 2009 and refs therein) and was popularized through the work of Ryan & Pitman (1999). One of the major obstacles in unravelling the story of events has been the establishment of a robust chronology (Siani *et al*., 2000).

Recent studies have highlighted problems in interpreting radiocarbon dates obtained from the Black Sea with inconsistencies between dates on organic fractions and those of carbonate shells. Kwiecien *et al*. (2008) identified changing reservoir corrections depending on water depth of the sample material and the stratification status of the Black Sea at that time. During the glacial, low-level phase (or Black 'Lake' as they referred to it) the water column was well mixed, with a radiocarbon reservoir

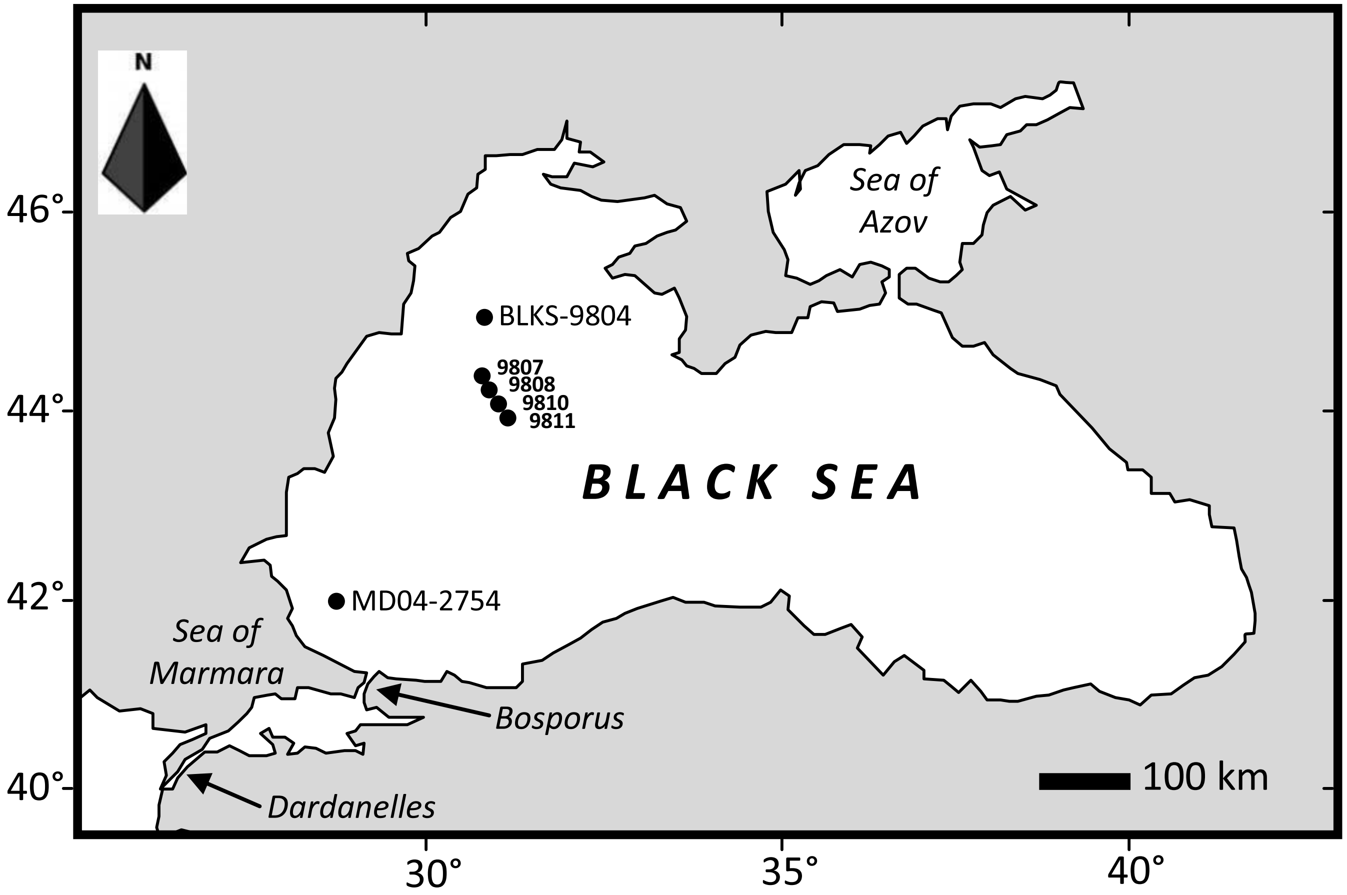


Fig. 1. Location map showing site of BLKS transect, NW Black Sea and Core MD04-2754 from the SW Black Sea.

age of about 1450 years throughout the Sea, which decreased to about 1000 years by the Bölling/Allerød interstadials, probably due to melt-water input, finally reducing to 400 years (almost normal marine values) in the post-connection period. Fontugne *et al.* (2009) showed that the ^{14}C activity of dissolved inorganic carbon (DIC) in the upper levels of the modern Black Sea are in equilibrium with the atmosphere and, therefore, no correction is necessary but that, at depth, the ^{14}C activity of DIC increases due to chemical and physical conditions in these stratified waters. They suggested that some of the large reservoir values observed previously may be associated with the action of chemautotrophic organisms in the deeper basins. Due to the problems associated with evaluating the reservoir age within the Black Sea (Fontugne *et al.*, 2009), all dates given in this paper are uncalibrated ^{14}C ages; ongoing ^{210}Pb studies will help to address such issues. The early Holocene flooding event (Unit III/Unit II transition) is now dated to around 8400 ^{14}C years BP and the Unit II/Unit I transition to about 3000 ^{14}C years BP.

BLACK SEA OSTRACODA

In a number of recent studies, ostracods have proven fundamental to achieving an understanding of the hydrological changes in the bottom waters of the Black Sea over the last 20 ka. They are the only benthic organisms with a significant fossil record, although they are generally absent from all environments within the current dysaerobic zone. Recent studies (Sergeeva, 2003) have shown that a significant soft-bodied meiobenthos still inhabits surficial sediments in deep-water parts of the basin, comprising taxa that have adapted from shallower depths and others that are endemic to the sulphidic zone. The environment should, therefore, be described as dysoxic rather than wholly anoxic. Trace-element chemistry and stable-isotope analyses of ostracod remains recorded in the sediments deposited during the last 15 000 years have been used to elucidate the hydrological history of the Black Sea basin (Major *et al.*, 2002; 2006; Bahr *et al.*, 2005; 2006). None of these studies, however, has considered the ostracod faunal record in any detail and none has published images or taxonomic details of the faunas encountered. It is the goal of this paper to record and illustrate many of the key taxa that constitute the distinct ‘Black Sea’ fauna (many using scanning electron microscopy (SEM) for the first time) that dominated the benthic environment before the establishment of deep-water anoxia and that probably still persist at intermediate depths today.

Kaminski *et al.* (2002) provided information on the late-Glacial to Holocene foraminiferal record of the Sea of Marmara; however, foraminifera are very rare in the deeper-water sediments of the Black Sea investigated in this study, and the few occurrences noted are considered to be allochthonous, reworked downslope. Again, within the Sea of Marmara there is a strong halocline due to the inflowing Mediterranean and outflowing

Black Sea waters and this has led to the establishment of low oxygen conditions in the deep-water parts of the Marmara (Kaminski *et al.*, 2002). Nazik (2001) recorded diverse ostracod assemblages in the surface sediments of the Sea of Marmara from depths of <72 m. The fauna comprised taxa that were also recorded from similar environments in the Mediterranean. In this paper we show that the pre-connection deep-water, ostracod fauna of the Black Sea basin has closer taxonomic links with the 'paratethyan' fauna found in the Caspian Sea today and suggest that the same taxa are probably present today at intermediate water depths of the Black Sea basin, above the modern dysaerobia.

Following the DSDP cruise investigations, Leg 42, in the Black Sea in 1972 (DSDP Volume XLII, Part 2), Olteanu (1978) and Benson (1978) briefly discussed the Pleistocene occurrence of ostracods in five of the recovered cores and provided line-drawing illustrations of some taxa. Many of the taxonomic determinations are tentative, based on very few specimens. Schornikov (1964, 1966a, b) has provided more detailed accounts of littoral ostracods from the northern Black Sea margins and Azov Sea (again with only line drawings), but there is little additional published data on Black Sea deep-water ostracods and still fewer SEM images.

BLACK SEA CORES

During the BlaSON (e.g. Popescu *et al.*, 2001; Major *et al.*, 2002) and ASSEMBLAGE (Lericolais *et al.*, 2009) geophysical and coring research cruises, a number of short (<2 m) and longer (<40 m) sediment cores were recovered from the western region of the Black Sea. These cores yielded *in situ* ostracods in more than 95% of the 'pre-flood' samples examined and are, therefore, known to have been deposited under oxygenated bottom-water conditions. The autochthoneity of ostracod assemblages within such samples is generally confirmed through examination of the adult to juvenile ratio following the procedures outlined by Whatley (1983), recently reviewed by Boomer *et al.* (2003).

Little detailed autecological information is available for many of the species, despite their regional importance, with some species also occurring in the Caspian Sea. It is not yet possible to draw detailed palaeoenvironmental interpretations, such as quantitative salinity reconstructions, from the occurrence/absence of indicator species or assemblage composition. In the following sections we report on the changing composition of ostracod assemblages from five short cores on the NW Black Sea shelf collected by the BlaSON Cruise in 1998 (cores BLKS-9804, 9807, 9808, 9810, 9811) and for a longer core (MD04-2754) collected from the French R/V *Marion Dufresne* during the ASSEMBLAGE cruise of 2004 (Table 1).

Core	Latitude (N)	Longitude (E)	Water depth (m)	Core length (cm)
BLKS-9804	44°12.02′	30°32.21′	101	81
BLKS-9807	44°5.76′	30°46.81′	163	325
BLKS-9808	44°5.47′	30°47.21′	186	370
BLKS-9810	44°4.04′	30°50.68′	378	770
BLKS-9811	44°3.02′	30°53.12′	500	757
MD04-2754	41°59.23′	28°40.99′	453	3217

Note that only the uppermost part of each core is discussed in the current paper.

Table 1. List of cores discussed in text with details of location, water depth and total core length.

BLKS cores

The BLKS cores are gravity cores, collected on a transect extending out across the Danube delta fan (Fig. 1)) during the BlaSON research cruise onboard the IFREMER R/V *Le Suroît*. The cores encompass depths that are still within the oxic zone through to those that are within the dysaerobic zone today. Although some of the cores penetrated to more than 5 m sediment depth (e.g. BLKS-9810), this paper will focus on the most recent sediments from each core. It is clear from the changing lithologies and from the radiocarbon dating evidence that not all three sedimentary units are recorded in all of the cores (see details on Fig. 2); this is largely due to their depositional depth within the basin, the shallowest three sites, BLKS-9804, 9807, 9808 never having experienced dysaerobia.

Equal volumes of sediment (approx 3–4 cm^3) were subsampled from the cores, dried and disaggregated in 2% hydrogen peroxide for up to 2 h before washing through a 63 μm sieve. The ostracods were totally picked and identified; the stratigraphical occurrence of the taxa is detailed on Figure 3. The range charts show that in the deeper parts of the basin, where the full sequence of units I, II and III are recorded (BLKS-9810, 9811), there is no post-sapropel 'recovery' as these sites are now within the dysaerobic zone. The few occasional occurrences are of juvenile valves, almost certainly transported from shallower depths.

Cores BLKS-9807 and 9808, recovered from the shelf edge, were the shallowest cores investigated in terms of their water depth. In these, only Unit III appears to be present (based on the lithology and ^{14}C dates in the former core), possibly a result of natural erosion, non-deposition due to changing water depth or problems during core recovery. These two shallow cores were never deep enough to develop the sapropel facies, while evidence from some of the pilot cores indicates that the very uppermost sediments (and sediment–water interface) have not necessarily been recovered from all cores. Discussion of the impact of changing sea-levels on the development and distribution of different sedimentary units during the late-glacial to early Holocene interval can be found in Lericolais *et al.* (2009).

Only four samples were available from the shallowest core (BLKS-9804), but they reveal in the upper few centimetres a switch from a pre-flood assemblage to one more typical of shallower depths, with elements, such as *Hiltermannicythere rubra*, that are more closely associated with the Mediterranean and Marmara (Nazik, 2001) seas today.

Core MD04-2754

This core was recovered during the ASSEMBLAGE research cruise onboard the French R/V *Marion Dufresne* during May 2004 as part of a sedimentary, geophysical and geochemical investigation of the western Black Sea. The core was recovered from a water depth of 453 m and was 32 m in total length. Only the uppermost 10 m were studied for ostracods (Fig. 4). Samples were prepared in a similar manner to those for the BLKS cores above.

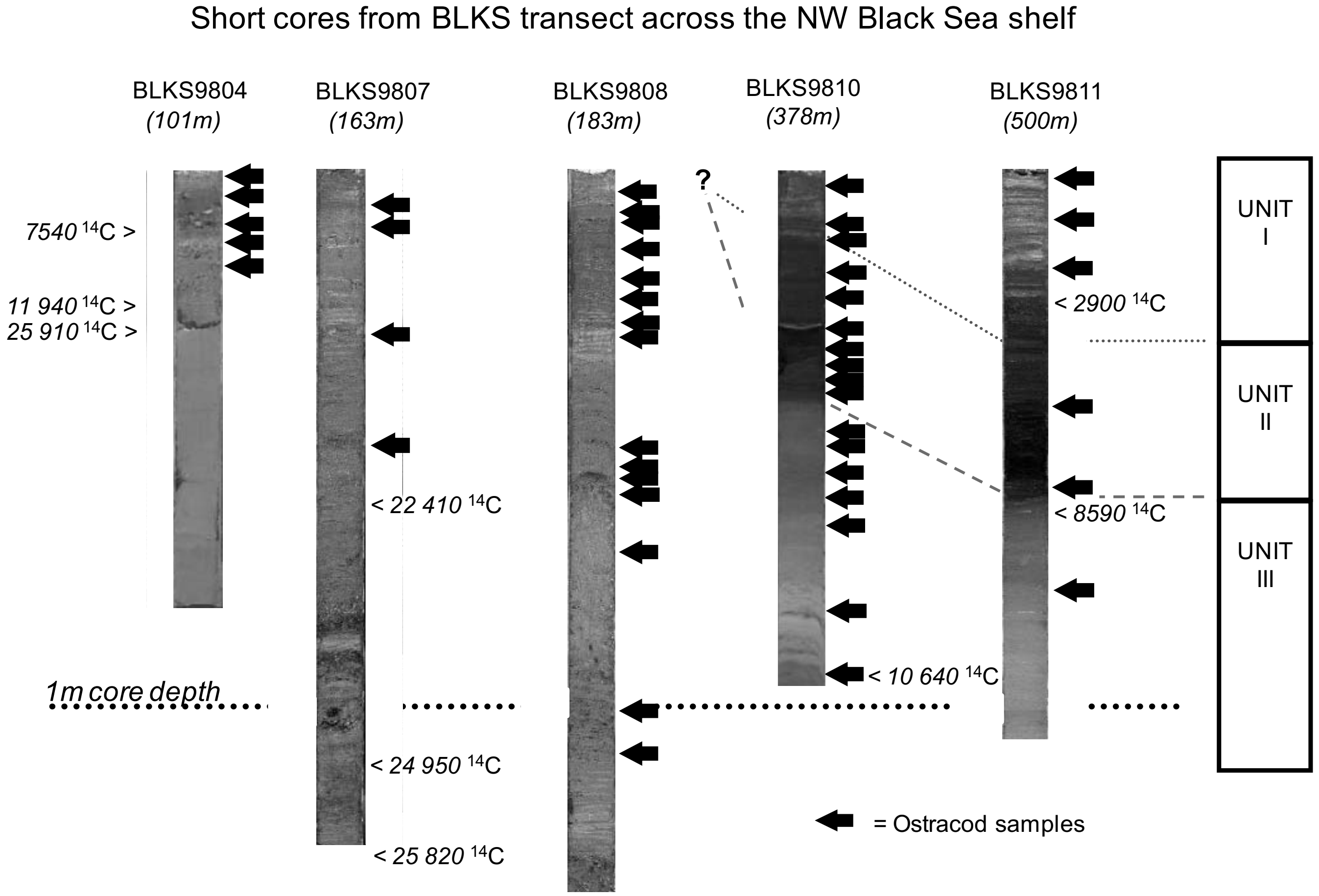


Fig. 2. Core photographs (approximately uppermost 1 m only), with indications of ostracod sampling levels and available uncalibrated radiocarbon dates. Sedimentary units discussed in text are noted on the right-hand side.

The core displays an uppermost unit of finely laminated sediments (0–230 cm, equivalent to Units I and II), below which is a relatively sharp transition into quite homogeneous grey clays. Thus, no distinct anoxic sediments are developed at this site prior to the deposition of the coccolith-rich laminae of Unit I. A number of ^{14}C dates are available from the core (Table 2) and indicate relatively continuous sedimentation from at least 20.5 ka ^{14}C BP (*c.* 970 cm) to 5 ka ^{14}C BP (*c.* 154 cm).

FAUNAL RESPONSE

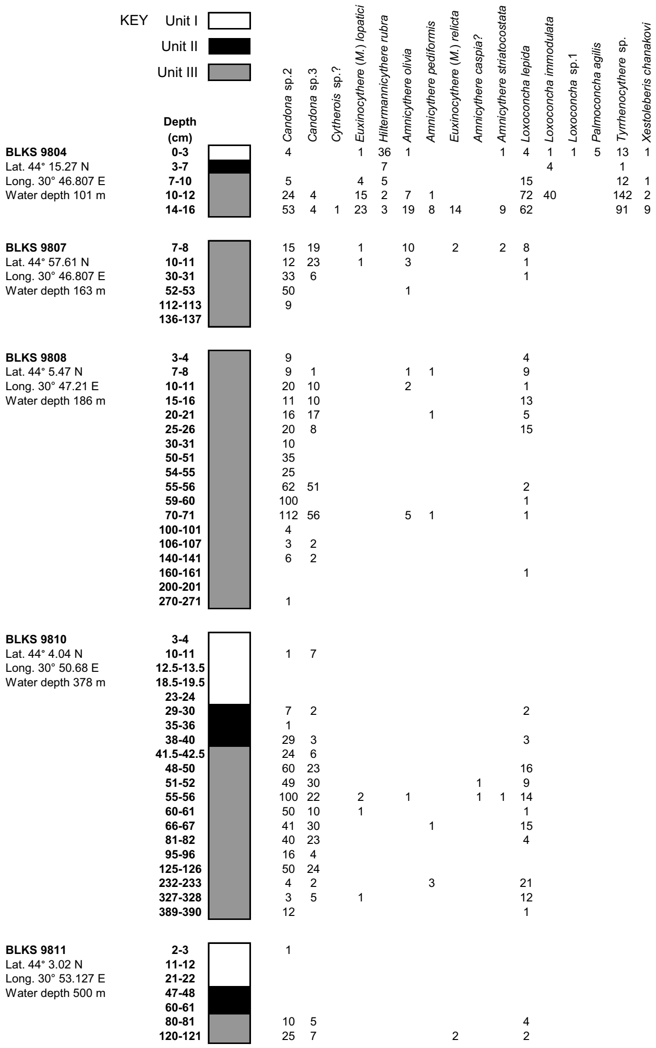
The faunal records from the most of the BLKS cores are too short to make meaningful comments regarding their detailed response to changing environmental conditions within the Black Sea basin. The more extensive faunal record from MD04-2754 (Figs 4, 5) suggests that the fauna can be subdivided into three distinct stratigraphical zones. The lowest zone (from the base of the sampled core up to about 430 cm) comprises relatively diverse assemblages with equal proportions of Candonidae, Leptocytheridae and Loxoconchidae. At about 420 cm core depth there is a marked decrease in species diversity, with a change to assemblages dominated by the Candonidae (Fig. 5). This is associated with changes in the geochemical profile and a sharp rise in the carbonate content of the sediments. Comparison with the dated records of Kwiecien *et al.* (2008) suggests that this event at about 15 ka BP is associated with the first of a number of distinct melt-water pulses that discharged into the Black Sea basin from the Eurasian region.

The next major faunal event, at a core depth of about 230–240 cm coincides with a decrease in carbonate content and an increase in organic carbon content, both clearly associated with the development of the sapropel following early Holocene flooding. From this point onwards to the top of the core, ostracods are all but absent with only a few, probably allochthonous, records.

Notwithstanding the relatively short and incomplete records from the BLKS cores, the pattern of faunal change in the NW Black Sea basin is in broad agreement with the record from MD04-2754 in the SW Black Sea.

TAXONOMY (BY IAN BOOMER)

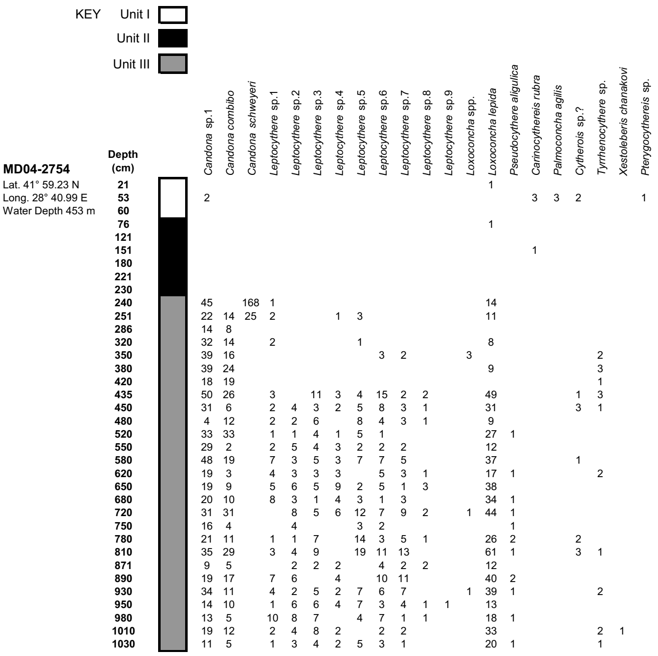
There are numerous taxonomic problems associated with Neogene to Recent ostracods from the Ponto-Caspian region. Many of the original publications referred to in the following pages, from the early to mid-twentieth century, were originally illustrated using only line drawings (or sketches); some key illustrations are often very small and of insufficient quality to assess the importance of particular features of outline or ornamentation.



KEY Unit I ☐
Unit II ■
Unit III ▨

	Depth (cm)		*Candona* sp.2	*Candona* sp.3	*Cytherois* sp.?	*Euxinocythere (M.) lopatici*	*Hiltermannicythere rubra*	*Amnicythere olivia*	*Amnicythere pediformis*	*Euxinocythere (M.) relicta*	*Amnicythere caspia?*	*Amnicythere striatocostata*	*Loxoconcha lepida*	*Loxoconcha immodulata*	*Loxoconcha* sp.1	*Palmoconcha agilis*	*Tyrrhenocythere* sp.	*Xestoleberis chanakovi*
BLKS 9804	**0-3**	☐	4			1	36	1				1	4	1	1	5	13	1
Lat. 44° 15.27 N	**3-7**	■					7							4			1	
Long. 30° 46.807 E	**7-10**	▨	5			4	5						15				12	1
Water depth 101 m	**10-12**	▨	24	4		15	2	7	1				72	40			142	2
	14-16	▨	53	4	1	23	3	19	8	14		9	62				91	9
BLKS 9807	**7-8**	▨	15	19		1		10		2		2	8					
Lat. 44° 57.61 N	**10-11**	▨	12	23		1		3					1					
Long. 30° 46.807 E	**30-31**	▨	33	6									1					
Water depth 163 m	**52-53**	▨	50					1										
	112-113	▨	9															
	136-137	▨																
BLKS 9808	**3-4**	▨	9										4					
Lat. 44° 5.47 N	**7-8**	▨	9	1				1	1				9					
Long. 30° 47.21 E	**10-11**	▨	20	10				2					1					
Water depth 186 m	**15-16**	▨	11	10									13					
	20-21	▨	16	17					1				5					
	25-26	▨	20	8									15					
	30-31	▨	10															
	50-51	▨	35															
	54-55	▨	25															
	55-56	▨	62	51									2					
	59-60	▨	100										1					
	70-71	▨	112	56				5	1				1					
	100-101	▨	4															
	106-107	▨	3	2														
	140-141	▨	6	2														
	160-161	▨											1					
	200-201	▨																
	270-271	▨	1															
BLKS 9810	**3-4**	☐																
Lat. 44° 4.04 N	**10-11**	☐	1	7														
Long. 30° 50.68 E	**12.5-13.5**	☐																
Water depth 378 m	**18.5-19.5**	☐																
	23-24	☐																
	29-30	■	7	2									2					
	35-36	■	1															
	38-40	■	29	3									3					
	41.5-42.5	▨	24	6														
	48-50	▨	60	23									16					
	51-52	▨	49	30							1		9					
	55-56	▨	100	22		2		1			1	1	14					
	60-61	▨	50	10		1							1					
	66-67	▨	41	30					1				15					
	81-82	▨	40	23									4					
	95-96	▨	16	4														
	125-126	▨	50	24														
	232-233	▨	4	2					3				21					
	327-328	▨	3	5		1							12					
	389-390	▨	12										1					
BLKS 9811	**2-3**	☐	1															
Lat. 44° 3.02 N	**11-12**	☐																
Long. 30° 53.127 E	**21-22**	☐																
Water depth 500 m	**47-48**	■																
	60-61	■																
	80-81	▨	10	5									4					
	120-121	▨	25	7						2			2					

Fig. 3. Stratigraphical distribution of ostracod species in BLKS cores from the NW shelf of the Black Sea. Samples given as depths within core, too few ^{14}C dates are available to be certain of age determinations.



KEY Unit I ☐
Unit II ■
Unit III ▨

	Depth (cm)		*Candona* sp.1	*Candona combibo*	*Candona schweyeri*	*Leptocythere* sp.1	*Leptocythere* sp.2	*Leptocythere* sp.3	*Leptocythere* sp.4	*Leptocythere* sp.5	*Leptocythere* sp.6	*Leptocythere* sp.7	*Leptocythere* sp.8	*Leptocythere* sp.9	*Loxoconcha* spp.	*Loxoconcha lepida*	*Pseudocythere aligulica*	*Carinocythereis rubra*	*Palmoconcha agilis*	*Cytherois* sp.?	*Tyrrhenocythere* sp.	*Xestoleberis chanakovi*	*Pterygocythereis* sp.
MD04-2754																							
Lat. 41° 59.23 N	**21**	☐														1							
Long. 28° 40.99 E	**53**	☐	2															3	3	2			1
Water Depth 453 m	**60**	☐																					
	76	■														1							
	121	■																					
	151	■																1					
	180	■																					
	221	■																					
	230	■																					
	240	▨	45		168	1										14							
	251	▨	22	14	25	2			1	3						11							
	286	▨	14	8																			
	320	▨	32	14		2				1						8							
	350	▨	39	16							3	2			3						2		
	380	▨	39	24												9					3		
	420	▨	18	19																	1		
	435	▨	50	26		3		11	3	4	15	2	2			49				1	3		
	450	▨	31	6		2	4	3	2	5	8	3	1			31				3	1		
	480	▨	4	12		2	2	6		8	4	3	1			9							
	520	▨	33	33		1	1	4	1	5	1					27	1						
	550	▨	29	2		2	5	4	3	2	2	2				12							
	580	▨	48	19		7	3	5	3	7	7	5				37				1			
	620	▨	19	3		4	3	3	3		5	3	1			17	1				2		
	650	▨	19	9		5	6	5	9	2	5	1	3			38							
	680	▨	20	10		8	3	1	4	3	1	3				34	1						
	720	▨	31	31			8	5	6	12	7	9	2		1	44	1						
	750	▨	16	4			4			3	2						1						
	780	▨	21	11		1	1	7		14	3	5	1			26	2			2			
	810	▨	35	29		3	4	9		19	11	13				61	1			3	1		
	871	▨	9	5			2	2	2		4	2	2			12							
	890	▨	19	17		7	6		4		10	11				40	2						
	930	▨	34	11		4	2	5	2	7	6	7			1	39	1				2		
	950	▨	14	10		1	6	6	4	7	3	4	1	1		13							
	980	▨	13	5		10	8	7		4	7	1	1			18	1						
	1010	▨	19	12		2	4	8	2		2	2				33					2	1	
	1030	▨	11	5		1	3	4	2	5	3	1				20	1				1		

Fig. 4. Stratigraphical distribution of ostracod species in core MD04-2754. Samples given as depths within core; for discussion of chronology see text.

Sample depth (cm)	Code	^{14}C age (ka BP)
153–155	FG-70	4750 ± 30
201–202	FG-69	5840 ± 30
234–235	FG-54	7420 ± 40
240–242	FG-55	9390 ± 80
378–380	FG-56	13 020 ± 120
426–428	FG-57	16 660 ± 210
970–971	FG-51	20 450 ± 60

Table 2. List of radiocarbon dates (uncalibrated) from core MD04-2754.

Researchers have often been led to rely on secondary illustrations by workers subsequent to the type designation (e.g. the plates of Agalarova *et al.* (1961) and Mandelstam *et al.* (1962) provide much more detailed illustrations for many of the taxa first described by Livental (1929; 1938)). There is a particular problem with so many closely related and morphologically similar taxa, further complicated by the evidence for polymorphism within some species (see Schornikov (1966b) for examples). Many new taxa described in those papers have been illustrated using only single specimens, while the location or status of some collections remains uncertain. Enquiries by the senior author and others (e.g. Gliozzi, Rome) with Russian colleagues have now ascertained that the collections of Livental (1929; 1938), formerly housed in Baku, are now lost (Malakhat Efendiyeva, Geological Institute, Baku, pers. comm.); the same is almost certainly true for the collections of Agalarova *et al.* (1961). Material figured by Suzin (1956) from the Miocene of the North Caucasus, formerly deposited in Grozny, must also be considered to be lost (Stepanova, Tesakova, pers. comms). The collections of Mandelstam *et al.* (1962) and Schweyer (1949) are all currently housed in the VNIGRI collections, St Petersburg.

Although Schornikov (1964; 1966a) has described soft-parts for some of the species mentioned herein, there are many that are known only from hard parts, yet may still be extant in the region; further collections are required to fill this knowledge gap.

The taxonomy section below considers some of the most abundant and some relatively minor but distinct elements of the assemblages encountered in the latest Pleistocene to Holocene sediments of the Black Sea. A more detailed and complete revision of the Ponto-Caspian fauna is undoubtedly required, together with full SEM and soft-part illustration where possible.

Class **Ostracoda** Latreille, 1806
Order **Podocopida** Sars, 1866
Suborder **Cypridocopina** Jones, 1901
Superfamily **Cypridoidea** Baird, 1845
Family **Candonidae** Kaufmann, 1900
Genus *Candona* Baird, 1845

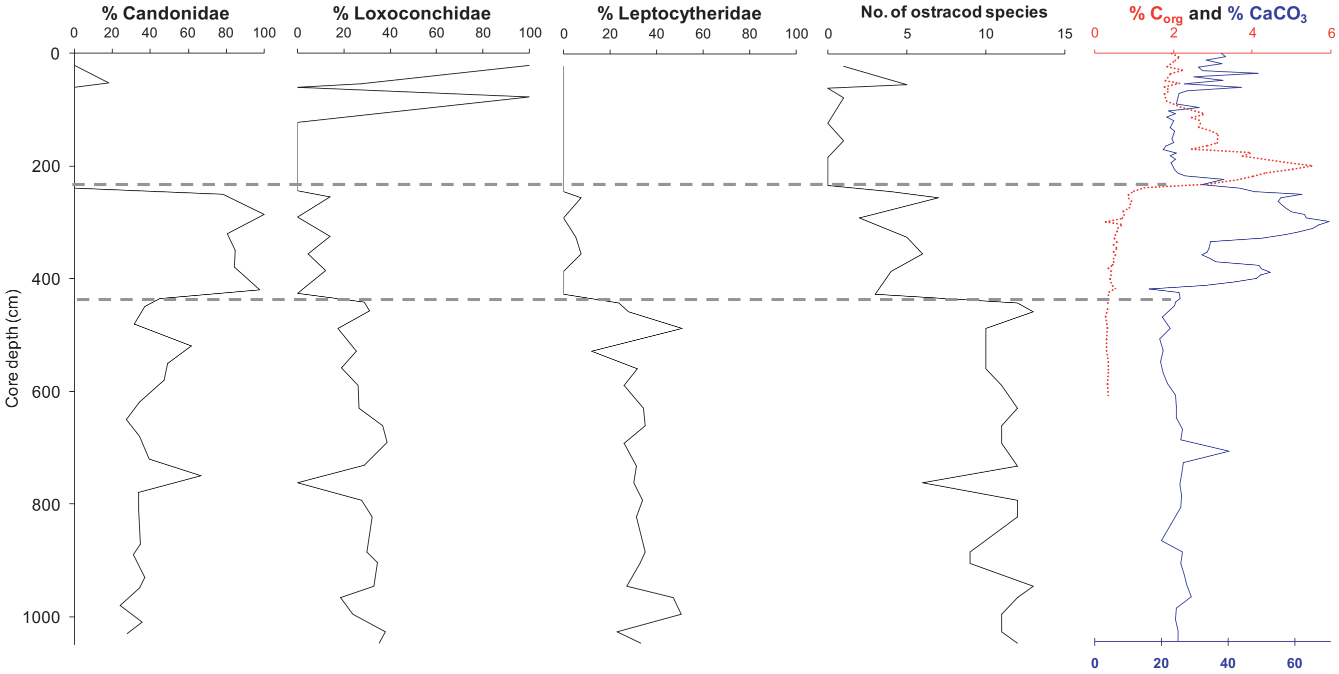


Fig. 5. Changing faunal composition, diversity and %$CaCO_3$/% organic carbon composition from core MD04-2754. Dashed lines indicate major faunal changes discussed in text.

Remarks. Many large, smooth-shelled species have been reported from Pleistocene to Recent sediments in the Ponto-Caspian region. For example, Agalarova *et al*. (1961) described almost 100 species that could tentatively be assigned to the Candonidae. A great number of these were referred to *Candona* but many other new genera were also established, e.g. *Caspiella*, Mandelstam, 1956 (often mis-spelt as *Caspiolla*) and *Caspiocypris*, Mandelstam, 1956. It is likely that many previously described species are true candonids/*Candona* but, in the absence of detailed soft-part information for the majority of taxa, this cannot be confirmed. The genus *Candona* is retained here until a more detailed review is undertaken.

Candona schweyeri Schornikov, 1964
(Pl. 1, fig. 7)

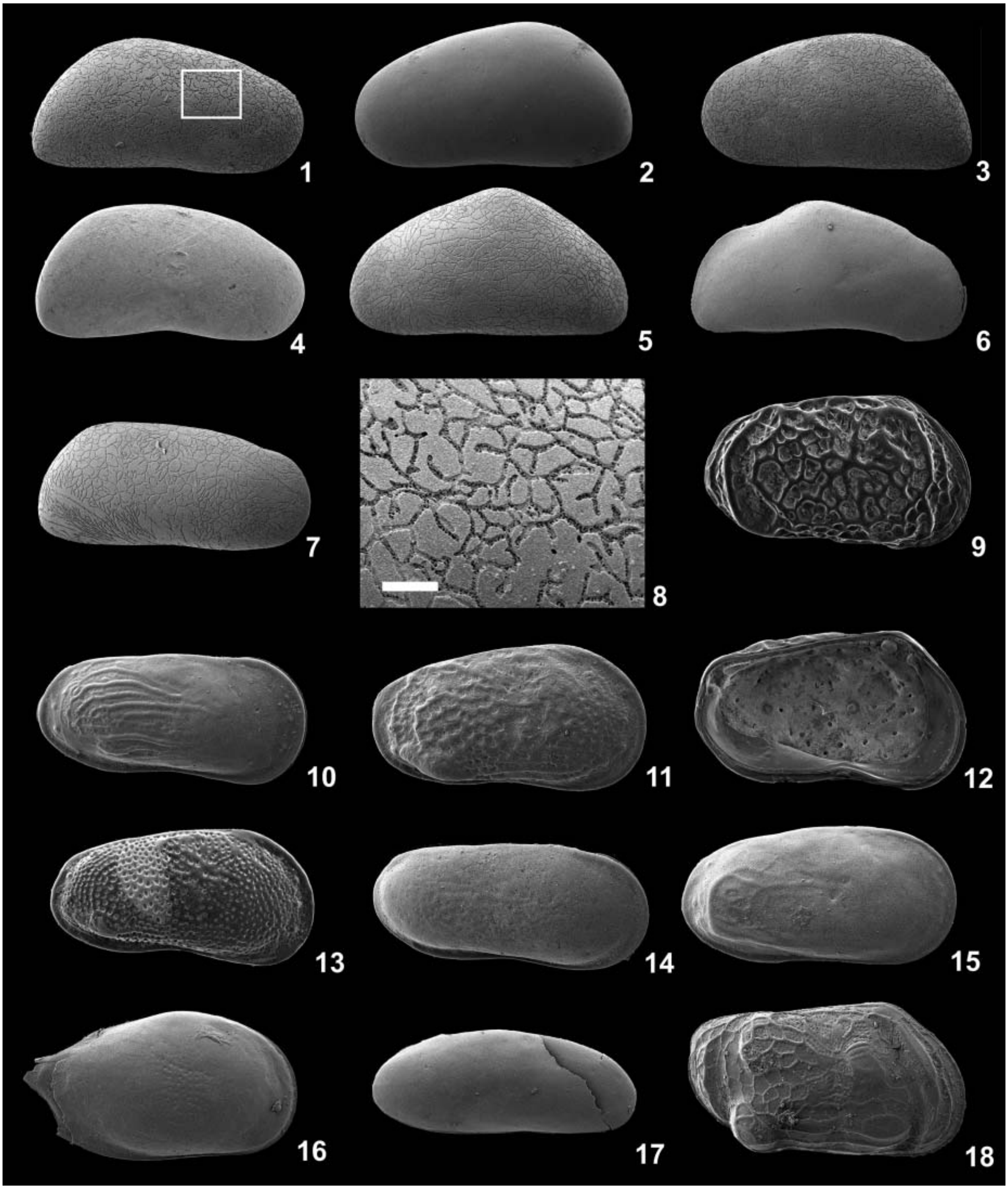
1949 *Bythocypris elongata* Schweyer: 62, pl. 4, figs 7–8.
1961 *Candona elongata* (Schweyer); Agalarova *et al*.: 60.
1962 *Bythocypris elongata* Schweyer; Mandelstam *et al*.: 138, pl. 17, fig. 2.
1964 *Candona schweyeri* Schornikov: Pl. 1, figs 1–13.

Remarks. *Candona schweyeri* was established by Schornikov (1964) as a *nom. nov*. for *Bythocypris elongata* Schweyer (1949), which he re-assigned to *Candona*. The bi-nomen *C. elongata* already being occupied, Schornikov (1964) stated that it was a younger homonym of *C. elongata* Herrick, 1879 and *C. elongata* Vávra, 1891, although that record should be recorded as *Candona elongata* Brady & Norman, 1889 in Vávra, 1891 and is also a homonym of at least four further species (Kempf, pers. comm.). The species differs from the other large, smooth-shelled candonids encountered in the present study by the rather straight dorsal margin with a maximum height close to the posterior. Schornikov (1964) recorded this species from deltas of the Black and Azov Sea basins. He described this and the other taxa he discussed as having 'Caspian origins', having been recorded in the late Neogene deposits of the southern parts of what was then the USSR.

Candona sp. 1
(Pl. 1, figs 1–3, 8)

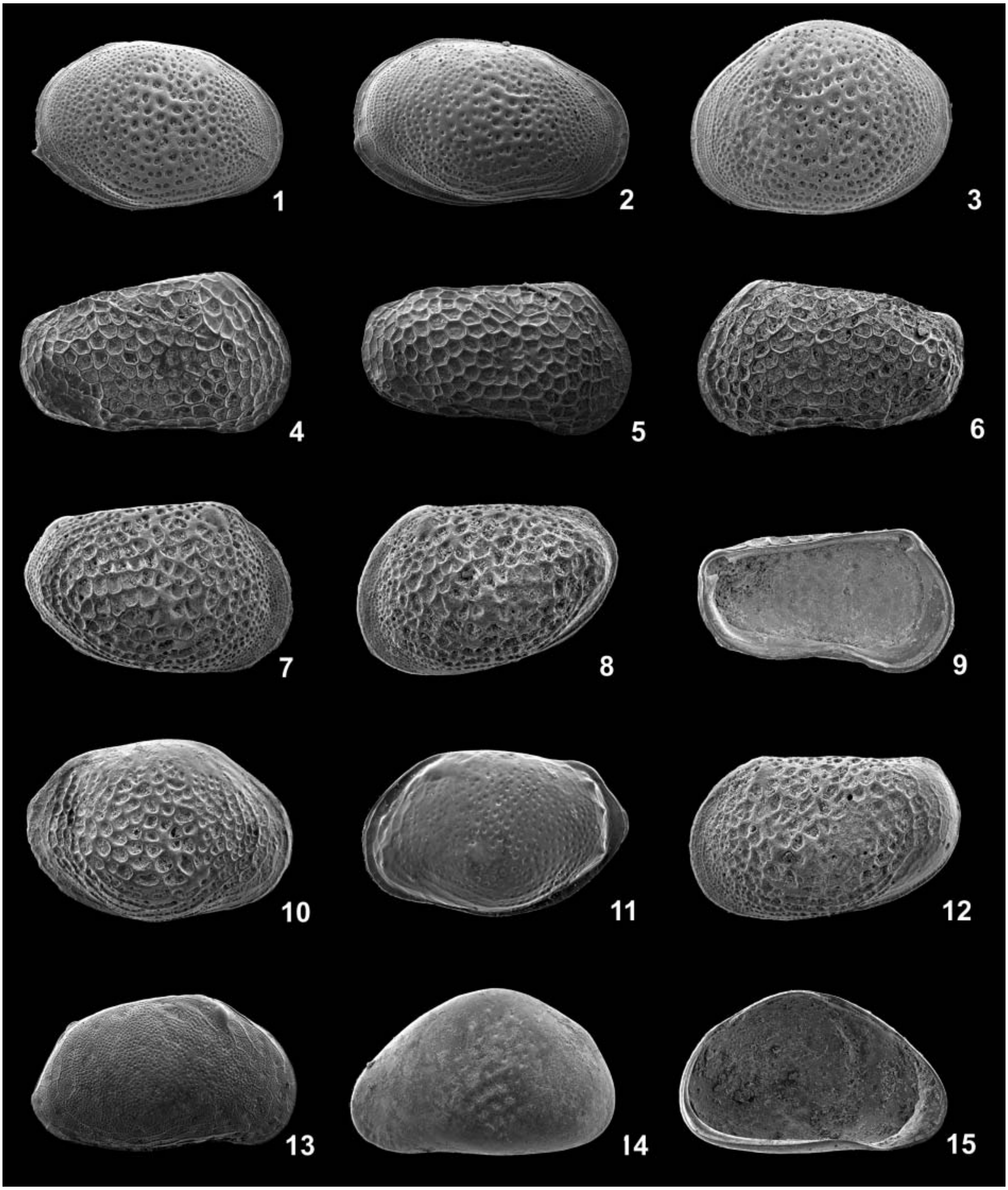
?1929 *Candona Abichi* Livental: 51, pl. 2, figs 34–37. (Note that Livental (1929) capitalized the species names of some of the newly described taxa in this 1929 publication.)
?1961 *Candona abichi* Livental; Agalarova *et al*.: 59, pl. 35, fig. 1a–b.
?1961 *Candona combibo* Livental; Agalarova *et al*.: 58, pl. 31, fig. 1a–b, pl. 32, fig. 1a–b, pl. 33, fig. 4a–b.
?1962 *Candona abichi* Livental; Mandelstam *et al*.: 28, pl. 13, figs 7–9.

Remarks. This species is difficult to assign to an established taxon due to the hand-drawn nature of many type figures and the lack of soft-parts. The species outwardly resembles the *C. candida* group of Eurasian species but has a distinctly rounded postero-dorsal margin in lateral view. This is the most abundant species encountered in this work and almost certainly has been recorded in other studies, although probably under a range of different names. It perhaps most closely resembles the illustrations of *C. abichi* Livental, as figured by Mandelstam *et al.* (1962, pl. 13, figs 7–9). However, the type figures are somewhat less convincing, given the suggestion of a more distinct postero-ventral angularity. The specimen figured by Agalarova *et al.* (1961) as *C. abichi* is unlikely to be conspecific. *Caspiocypris lyrata* (Livental) in Agalarova *et al*., pl. 4, figs 1–3 is a similar



Explanation of Plate 1.

All specimens adult, external lateral views unless otherwise stated. **figs 1–3, 8**. *Candona* sp. 1: **1,** RV (OS 16854) × 39, specimen shows bacterial or algal 'micro-crazing', MD04-2754, 350 cm; **2,** LV (OS 16855) × 36, MD04-2754, 350 cm; **3,** LV (OS 16856) × 38, specimen shows bacterial or algal 'micro-crazing', MD04-2754, 550 cm; **8,** detail of micro-crazing on (1) approx ×500, scale bar 5 µm. **fig. 4**. *Candona* sp. 2, RV (OS 16857) × 39, BLKS-9804 10–12 cm. **figs 5–6**. *Candona* sp. 3: **5,** LV (OS 16858) × 38, specimen shows bacterial or algal 'micro-crazing', MD04-2754, 890 cm; **6,** RV (OS 16859) × 34, MD04-2754, 650 cm. **fig. 7**. *Candona schweyeri* Schornikov, 1964, RV (OS 16860) × 42, MD04-2754, 240 cm. **figs 9, 12**. *Euxinocythere* (*Maeotocythere*) *lopatici* (Schornikov, 1964) n. comb., BLKS-9804, 0–3 cm: **9,** RV (OS 16861) × 80; **12,** LV internal lateral (OS 16862) × 80. **fig. 10**. *Amnicythere striatocostata* (Schweyer, 1949) Stancheva, 1990, RV (OS 16863) × 78, MD04-2754, 650 cm. **fig. 11**. *Euxinocythere* (*Maeotocythere*) *relicta* (Schornikov, 1964) n. comb., RV (OS 16864) × 90, MD04-2754, 650 cm. **fig. 13**. *Amnicythere pediformis* (Schornikov, 1966) Tarasov, 1996, RV (OS 16865) × 77, BLKS-9804, 14–16 cm. **fig. 14**. *Amnicythere propinqua* (Livental, 1929) Stancheva, 1968, RV (OS 16866) × 100, MD04-2754, 950 cm. **fig. 15**. *Amnicythere caspia*? (Livental, 1930 *nomen nudum*), RV (OS 16867) × 90, MD04-2754, 650 cm. **fig. 16**. *Pseudocythere aligulica*? (Stepanaitys, 1962) n. comb., RV (OS 16868) × 96, MD04-2754, 1030 cm. **fig. 17**. *Cytherois* sp.? RV (OS 16869, specimen now broken anteriorly) × 97, MD04-2754, 450 cm. **fig. 18**. *Amnicythere bendovanica* (Livental, 1935) n. comb., RV, probably A-1 (OS 16870) × 80, MD04-2754, 950 cm.



Explanation of Plate 2.

All specimens adult, external lateral views unless otherwise stated. **figs 1–3**. *Loxoconcha lepida* Stepanaitys, 1962: **1,** RV female (OS 16871) × 60, BLKS-9804, 10–12 cm; **2,** RV male (OS 16872) × 60, MD04-2754, 350 cm; **3,** LV female (OS 16873) × 65, BLKS-9804, 10–12 cm. **figs 4–6, 9**. *Amnicythere olivia* (Livental, 1938) Stancheva, 1968, all BLKS-9804, 10–12 cm except (5): **4,** RV female (OS 16874) × 68; **5,** RV male (OS 16875) × 68, MD04-2754, 350 cm; **6,** LV female (OS 16876) × 66; **9,** LV male internal (OS 16877) × 69. **figs 7–8, 12**. *Loxoconcha immodulata* Stepanaitys, 1958, BLKS-9804, 0–3 cm: **7,** RV female (OS 16878) × 82; **8,** LV female (OS 16879) × 75; **12,** LV male (OS 16880) × 72. **fig. 10**. *Loxoconcha* sp. 1, RV (OS 16881) × 69, BLKS-9804, 0–3 cm. **fig. 11**. *Palmoconcha agilis* (Ruggieri, 1967) Ruggieri, 1992, LV (OS 16882) × 68, BLKS-9804, 0–3 cm. **fig. 13**. *Tyrrhenocythere* sp., RV (OS 16883) × 39, BLKS-9804, 10–12 cm. **figs 14–15**. *Xestoleberis chanakovi* Livental, in Agalarova *et al*., 1961, BLKS-9804, 10–12 cm: **14,** LV (OS 16884) × 57; **15,** LV internal (OS 16885) × 61 showing *Xestoleberis* ‘spot’.

species for which, although designated as a Livental species, no record can be found of its original description and the Agalarova *et al.* publication appears to be the only such description and designation of the species. This appears to be a not uncommon situation.

Some of the candonid valves recovered in this work have clear evidence of 'microbial' borings (*c.* 5 μm scale) on the external surfaces of the valves (Pl. 1, fig. 8). These have not yet been encountered on the internal surfaces, leading to the conclusion that they represent *ante mortem* damage.

Candona sp. 2
(Pl. 1, fig. 4)

2008 *Candona schweyeri* Schornikov; Opreanu: 61, fig. 10.

Remarks. Similar to *Candona* sp. 1 but with a more broadly-rounded posterior margin, flatter dorsal and more incurved ventral margin in the right valve. This species dominates candonid assemblages from the NW Black Sea, being commonly recorded in the BLKS cores but apparently absent from the SW Black Sea (MD04-2754). For now, the two appear to be geographically mutually exclusive but, given the similarity of the two taxa, further discrimination may later prove their co-occurrence in some samples. The more northern distribution for *Candona* sp. 2 is further supported by the only other published record, that of a right valve figured by Opreanu (2008) from the Romanian sector of the Black Sea.

Candona sp. 3
(Pl. 1, figs 5–6)

?1949 *Bythocypris* sp. n. Schweyer: 64, pl. 3, fig. 8.

Remarks. A distinct, large and fragile species with a triangular dorsal margin in lateral outline and an 'over-hanging' antero-ventral margin. Many authors have figured candonid species with a high dorsal arch, giving a strongly 'triangular' aspect in lateral view. The illustrated right valve (Pl. 1, fig. 6) is an adult, but the left valve is an A-1 instar. No intact adult left valves of this species have been recovered so far. Its closest affinities would appear to be with the left valve of *Bythocypris* sp. n. figured by Schweyer (1949). Agalarova *et al.* (1961) illustrate species, such as *C. cavis* 'Mandelstam in litt.' (p. 59, pl. 35, fig. 4), which appear morphologically similar to the illustrated left valve of the current species. So far only recorded from the NW Black Sea.

Suborder **Cytherocopina** Gründel, 1967
Superfamily **Cytheroidea** Baird, 1850
Family **Leptocytheridae** Hanai, 1957

Remarks. The majority of small cytheroidean taxa encountered in Pleistocene–Recent sediments from the Ponto-Caspian region can be assigned to the Leptocytheridae. Gliozzi *et al.* (2005) reviewed the Neogene brackish-water leptocytherids from southern Europe, summarizing the major morphological traits and generic assignments. They discussed a number of leptocytherid genera and subgenera; of these, *Amnicythere*, *Euxinocythere* (*Euxinocythere*) and *E.* (*Maeotocythere*) are represented in the present material. The genus *Leptocythere sensu stricto* is probably not present within these assemblages.

Amnicythere was originally erected as a subgenus of *Leptocythere* (Devoto, 1965) to distinguish leptocytherid species from the Pleistocene of Italy which had both branching and simple anterior marginal pore canals (AMPCs), the presence of a snap pit/knob (a simple closed-carapace 'locking' system along the inner ventral margin) and secondary ornamentation (the latter being clearly more of a specific difference and one that is not uncommon within *Leptocythere*). Stancheva (1968) later emended the diagnosis, noting also the different structure of the hinge and raised it to generic rank. As Gliozzi *et al.* (2005) note, the genus appears to have radiated within the Neogene of eastern Paratethys and constitutes a major component of Ponto-Caspian assemblages.

Stancheva (1968) also erected a new genus *Euxinocythere* and two subgenera *E.* (*Euxinocythere*) and *E.* (*Maeotocythere*) within the Leptocytheridae, both of which have recent representatives in the Ponto-Caspian region. The three genera are most easily distinguished on their lateral outline and hingement. *Amnicythere* species are typically elongate (similar externally to *Leptocythere sensu stricto*) but possess rather simple and slender hinges with smooth median elements (in left valve), with perhaps only a weak anterior thickening. In contrast, species assigned to both subgenera of *Euxinocythere* are often more quadrate in lateral outline, *E.* (*Euxinocythere*) particularly so. The median and terminal hinge elements are much more robust than is the case for *Amnicythere*. In *E.* (*Euxinocythere*), the median element becomes expanded anteriorly into a series of toothlets that increase in size terminally. In *E.* (*Maeotocythere*) this pattern is repeated at both the anterior and posterior extremities of the median element, in this genus the posterior tooth and socket are often found immediately at the rather sharp postero-cardinal angle and the elements may be curved across this apex. Both subgenera of *Euxinocythere* are often more heavily calcified than species of *Amnicythere* examined to date.

Genus *Amnicythere* Devoto, 1965 (emend. Stancheva, 1968)

Amnicythere bendovanica (Livental, 1935) n. comb.
(Pl. 1, fig. 18)

?1935 *Cythere bendovanica* Livental: details unknown
1940 *Cythere bendovanica* Livental; Agalarova *et al.*: 46, pl. 2, fig. 3.
1961 *Leptocythere bendovanica* (Livental); Agalarova *et al.*: 125, pl. 72, figs 5–6.
1962 *Leptocythere bendovanica* (Livental); Mandelstam *et al.*: 235, pl. 38, fig. 5.

Remarks. A distinctive, small to medium-sized, rather quadrate, species, with two weak swellings or tubercles postero-ventrally and postero-dorsally. Strong lateral ribs parallel both the anterior and posterior margins. Both Agalarova *et al.* (1961) and Mandelstam *et al.* (1962) figure a species which they refer to this species, putting it into synonymy with *Cythere bendovanica* Livental of Agalarova *et al.* (1940). Both ascribe original species authorship to Livental but neither give a publication year nor full authorship citation. Agalarova *et al.* (1940), however, synonymizes it with *Cythere bendovanica* 'Livental, 1935' (without further detail); the current author has not been able to obtain that source and it is not referenced by any other subsequent publications. It is possible that this was an unpublished report and the name may therefore be a *nomen nudum*. The figured specimen in this work (Pl. 1, fig. 18) is an A-1 instar. Adults appear rare, none has been recovered intact, but seem broadly similar to the late instars. Based on the observed internal features the species is probably best accommodated within *Amnicythere*.

Amnicythere caspia? (Livental, 1930 *nomen nudum*)
(Pl. 1, fig. 15)

?1930 *Cythere caspia* Livental: details unknown.
?1938 *Cythere caspia* Livental: 62, Pl. 1, figs 20–22.
1961 *Leptocythere caspia* Livental; Agalarova *et al.*: 108, pl. 63, figs 4–6.
1962 *Leptocythere hilda* Stepanaitys; in Mandelstam *et al.*: 252, pl. 40, fig. 15.

Remarks. A species with a recurved or C-shaped rib on the postero-lateral surface, broadly paralleling the posterior margin, although more angular than that margin. The rib, which is particularly strongest/inflated at its postero-ventral extent, marks the posterior termination of the lateral surface; there may be weak secondary ribbing/reticulation within the posterior third of the valve.

No 1930 publications by this author can be traced and, although it is mentioned in the synonymy list for this species by Agalarova *et al.* (1961), it does not appear in their references. The same publication date is given in the synonymy of *Cythere caspia* by Livental (1938), together with an abbreviated reference which is noted as being 'рукопись', i.e. 'a manuscript'. Again the full title does not appear in the reference list and it must be assumed, therefore, that the species is currently a *nomen nudum*.

Livental's drawings (1938; p. 62, Pl. 1, figs 20–22) depict a distinctly laterally-compressed carapace which may be a slight exaggeration. The specimens observed in the current study are certainly not as inflated as most of the other leptocytherid taxa encountered but are not as obviously compressed as those he figures. As with other species considered here, a number of other published illustrations may depict the same, or closely related species (e.g. *Leptocythere spectabilis* (Markova) in Mandelstam *et al.*, 1962, p. 108, pl. 34 fig. 5a–b). The material figured by Agalarova *et al.* (1961) and the fragment illustrated as *L. hilda* by Mandelstam *et al.* (1962) are almost certainly conspecific.

Amnicythere olivia (Livental, 1938) Stancheva, 1968
(pl. 2,figs 4–6, 9)

1938 *Cythere olivia* Livental: 62, Pl. 1, figs 27–29.
?1949 *Cythere ergeniensis* Schweyer: 34, pl. 8, figs 4, 6.
?1956 *Leptocythere olivina* Livental; Agalarova: 106, pl. 11, fig. 32.
1962 *Cythere olivina* Livental in Mandelstam *et al.*: 194, pl. 30, figs 9–10, pl. 35, fig. 12.
1978 *Leptocythere ergeniensis* (Schweyer); Olteanu: pl. 4, fig 1, pl. 5, fig 3.
2008 *Amnicythere olivina* (Livental); Opreanu: 59, fig. 5.

Remarks. In 1938 Livental described *Cythere olivia* from the Pleistocene of the Baku region. Agalarova *et al.* (1961) later referred to *Leptocythere olivina* (Livental), giving the correct page and figures numbers of the Livental (1938) species in synonymy, thereby introducing a spelling error that may have been perpetuated (see Mandelstam *et al.* (1962) and Agalarova (1956) for examples). It is possible, however, that the two are distinct species. Subsequently, in Mandelstam *et al.* (1962) a new species from the Pleistocene of Turkmenistan is designated as *Leptocythere olivina* Livental (designated as sole author); no other taxa are referred to in synonymy but the present author (IB) believes this also to be the same species. Although all the illustrated type specimens are line drawings, the present author believes them to be conspecific with *L. olivia*. In view of the arrangement of the hingement particularly, this species is best accommodated within the genus *Amnicythere*. Stancheva (1968), in her review of the family Leptocytheridae, placed both *L. olivina* (Livental) (*sic.*) and the similar *L. palimpsesta* (Livental, 1929) in the present genus.

The species belongs to a group of morphologically similar taxa that occur in the Pleistocene and Holocene deposits of both the Black and Caspian Sea (see *Leptocythere* sp. 9, Boomer *et al.* (2005, Pl. 1, fig. 11) for Caspian example). Many of these related species are commonly referred to either the present species or to *Leptocythere palimpsesta* (Livental, 1929).

The current species is probably related to a number of closely related taxa originally described by Livental in 1929 (see, particularly, *Limnicythere nitida*, p. 37, pl. 2, figs 3–4 and *Cythere fragilis*, Pl. 1, figs 1–2). In both Mandelstam *et al.* (1962) and Agalarova *et al.* (1961), the descriptions of *L. olivina* mention similarities to *Leptocythere andrussovi* (Livental) from which it differs 'by the absence of two protuberances in the posterior'. Note that this species was also mis-spelt, having originally been designated as *Cythere andrusovi* Livental. Again, without the original Livental material, the taxonomic status of many of these taxa remains uncertain.

The specimen figured by Opreanu (2008, p. 59, fig. 5), which she cites incorrectly as *Amnicythere olivina* (Livental, 1929), is almost certainly con-specific (a male left valve), coming from late Quaternary sediments in the Romanian coastal sector of the Black Sea. Olteanu (1978), in his reconnaissance of ostracods from the DSDP cruise, illustrated line drawings of a species, *Leptocythere ergeniensis* (Svejer) [=Schweyer], which also resembles the present material, although not the original illustration by Schweyer (1949).

Amnicythere pediformis (Schornikov, 1966) Tarasov, 1996
(Pl. 1, fig. 13)

1966a *Leptocythere pediformis* Schornikov: 33, pl. 2, figs 1–13.
1996 *Amnicythere pediformis* (Schornikov); Tarasov: 853.
2005 *Leptocythere* sp. 2 Boomer *et al.*: Pl. 1, fig. 13.

Remarks. An elongate species with moderately straight dorsal and slightly sinuous ventral margins converging slightly posteriorly. Key external ornament consists of fine, regular punctation, slightly coarser in the postero-lateral region and decreasing in size towards all margins. Although this species may well have been recorded by previous authors (e.g. *Leptocythere saluta* Livental, pl. 55, fig. 3 in Agalarova *et al*., 1961), only the figures by Schornikov can be included here with any confidence, given the lack of any other useful morphological characteristics. The species also occurs in contemporaneous deposits within the Caspian Sea (Boomer *et al*., 2005).

Amnicythere propinqua (Livental, 1929) Stancheva, 1968
(Pl. 1, fig. 14)

1929 *Cythere propinqua* Livental: 20, Pl. 1, figs 21–24.

Remarks. From the original illustrations this appears to be a relatively unornamented taxon, elongate with evenly rounded anterior and posterior margins. As such, there are few key characteristics on which to base specific identification with any certainty. Similar unornamented species are not uncommon in the literature and the species is also thought to occur in the Caspian Sea (author's unpublished information). Schornikov (1966b) suggested that *Leptocythere propinqua* (Livental) was a smooth variant of *Leptocythere cymbula* (Livental) but the current author believes the two are distinct species.

Amnicythere striatocostata (Schweyer, 1949) Stancheva, 1990
(Pl. 1, fig. 10)

1949 *Cythere striatocostata* Schweyer: 27–28, pl. 9, fig. 8.
1961 *Leptocythere striatocostata* (Schweyer); Agalarova *et al*.: 108, pl. 63, figs 1–3a, b.
1962 *Leptocythere striatocostata* Mandelstam *et al*.: 138, pl. 41, fig. 17.
1964 *Leptocythere striatocostata* (Schweyer); Schornikov: 1284, pl. 6, figs 1–15.
2008 *Amnicythere striatocostata* (Schweyer); Opreanu: 58, fig. 1.

Remarks. There are a number of related taxa in the literature which appear to share the features of the present material (e.g. *Leptocythere cornutocostata* Schweyer in Mandelstam *et al*., 1962, pl. 37, fig. 11, but not the type figure of that species). An elongate leptocytherid carapace with generally weak, longitudinal ribs along the postero-lateral flanks that may extend anteriorly. Schornikov (1964) illustrated some of the morphological variability observed within this species. Other related genera are known from the Caspian Sea (Boomer, unpublished data). It is possible that many of the figured specimens assigned to this taxon represent more than one species.

Genus *Euxinocythere* Stancheva, 1968
Subgenus *Euxinocythere* (*Maeotocythere*) Stancheva, 1968

Euxinocythere (*Maeotocythere*) *lopatici* (Schornikov, 1964) n. comb.
(Pl. 1, figs 9, 12)

?1929 *Cythere Bosqueti* Livental: 24, Pl. 1, fig. 27.
?1949 *Cythere bosqueti* Livental; Schweyer: 25, pl. 9, fig. 7.
?1961 *Leptocythere postrugosa* Agalarova in Agalarova *et al*.: 83, pl. 49, figs 5–6.
?1962 *Leptocythere bosqueti* (Livental); Mandelstam *et al*.: 225, pl. 36, figs 8–11.
1964 *Leptocythere lopatici* Schornikov: 1279, pl. 2, figs 1–7, pl. 3, figs 1–11.
2008 *Euxinocythere lopatici* (Schornikov); Opreanu: 60, fig. 7.

Remarks. A rather distinctive species, although some variation in the degree and position of ribbing and reticulation patterns can be observed within the present material and between Black Sea and Caspian assemblages (IB, unpublished data). The species is broadly similar to that described as *Cythere bosqueti* by Livental (1929); despite the simplistic illustration of a single valve, it is distinctive and must at least be closely related. Many authors have subsequently illustrated similar specimens, see synonymy list above. *L. bosqueti* (Livental), illustrated by Olteanu (1978, pl. 4, fig. 2), has much reduced central reticulation but must also be closely related.

Schornikov (1964) described *Leptocythere lopatici* from the Azov–Black Sea region, discriminating it from the similar *L. bosqueti* by the degree and positioning of the ornament. It is possible, however, that this is intra-specific variation and that *L. lopatici* Schornikov, and possibly *L. postrugosa* Agalarova, are junior synonyms of *L. bosqueti*. The present material is referred to *L. lopatici*, as the illustrations are so similar to the present material that no comparison can be made with the types of *L. bosqueti*. Some of the specimens recovered within the current project have yielded evidence of a thick exocuticle still in place, which has the apparent effect of reducing the degree of reticulation on the external surface of the carapace. A similar effect is seen on the specimen illustrated by Opreanu (2008).

Euxinocythere (*Maeotocythere*) *relicta* (Schornikov, 1964) n. comb.
(Pl. 1, fig. 11)

1964 *Leptocythere relicta* Schornikov: 1282. pl. 4, figs 1–9, pl. 5, figs 1–9.
2008 *Euxinocythere lopatici* Schornikov; Opreanu: 60, fig. 7.

Remarks. Schornikov (1964) described three new species of *Leptocythere* from the deltas flowing into the Azov–Black Sea basin; one of these (*L. relicta*) illustrates an elongate leptocytherid with rather regularly spaced, shallow reticulae which may vary in strength and distribution across the lateral faces. Similarly, there is variation in the morphology of the postero-lateral surface where the reticulation grades into short ribs/elongate nodes and the postero-ventral margin of the lateral surface may be variable in its form and position. The hingement observed on the current species is a little more robust than on the original drawings but, given the variability in the type description, these are not considered significant enough to warrant specific separation.

Family **Loxoconchidae** Sars, 1925
Genus *Loxoxoncha* Sars, 1866

Loxoconcha lepida Stepanaitys, 1962
(pl. 2, figs 1–3)

1962 *Loxoconcha lepida* Stepanaitys in Mandelstam *et al.*: 178, pl. 28, fig. 7.
1962 *Loxoconcha unodensa* Mandelstam in Mandelstam *et al.*: 178, pl. 28, fig. 9.
1964 *Loxoconcha lepida* Stepanaitys; Schornikov: 1290, pl. 11, figs 1–12.
2008 *Loxoconcha lepida* Stepanaitys; Opreanu: 61, fig. 9.

Remarks. A common, strongly dimorphic species with distinctive circular arrangement of reticulae that fine towards all margins. Schornikov (1964) recorded living specimens of *L. lepida* (Stepanaitys) from deltas in the Azov–Black Sea basin. He also synonymized the species with *L. unodensa* described in the same original publication (Mandelstam *et al.*, 1962), where a male and a female valve were described as separate species. This species also occurs in the Caspian Sea.

Loxoconcha immodulata Stepanaitys, 1958
(pl. 2, figs 7, 8, 12)

1958 *Loxoconcha immodulata* Stepanaitys: 19, Pl. 1, fig. 18.
1962 *Loxoconcha immodulata* Stepanaitys; Mandelstam *et al.*: 175, pl. 28, fig. 2.
1974 *Loxoconcha immodulata* Stepanaitys; Morduchai-Boltovsky: 199, fig. 172.
1996 *Loxoconcha immodulata* Stepanaitys; Boomer *et al.*: 81, Pl. 1, fig. 18.

Remarks. A reticulate species of *Loxoconcha* with marked sexual dimorphism, distinguished by having a marked eye-spot, triangular lateral outline in females and quadrate outline in males, which have much reduced ornament in the central to posterodorsal region of the lateral surfaces. The species described as *L. immodulata* Stepanaitys, 1958 from the Black Sea and figured by Morduchai-Boltovsky (1974) and Boomer *et al.* (1996) from the Aral Sea have much weaker development of the primary reticulation, but this is probably an environmental or eco-phenotypic effect. This species is also present in the Caspian Sea. The year of publication for this species was given erroneously as 1962 by Boomer *et al.* (1996) and Faranda *et al.* (2007). Faranda *et al.* (2007) place *L. immodulata* in *Loxoconchissa* (*Loxocaspia*). The current author does not consider the generic and subgeneric diagnoses to be distinct from *Loxoconcha* and has retained this generic assignment.

Loxoconcha sp. 1
(pl. 2, fig. 10)

Remarks. A species with ventro-lateral extension or overhang, reticulation is coarsest in the mid-valve area, fining towards the margins. Many similar taxa are illustrated within Agalarova *et al.* (1961) and Mandelstam *et al.* (1962) but at this stage it is not possible to be certain of their synonymy. The Black Sea samples include a number of rare loxoconchid species.

Genus *Palmoconcha* Swain & Gilby, 1974

Palmoconcha agilis (Ruggieri, 1967) Ruggieri, 1992
(pl. 2, fig. 11)

1967 *Loxoconcha agilis* Ruggieri; 377, pl. 37, fig. 6, text-figs 442-446.
1975 *Loxoconcha* aff. *L. agilis* Ruggieri; Bonaduce *et al.*: 102, pl. 65, figs 9–14.

Remarks. A loxoconchid whose general carapace features and presence of a smooth median hinge element places it within *Palmoconcha*. Originally described from the late Miocene of Italy, this apparently long-ranging species occurs in the Late Holocene sediments of the Black Sea, in relatively shallow waters. The species forms part of the 'Mediterranean' fauna (together with taxa such as *Hiltermannicythere rubra*), which has become established in the 'post-connection' period. The species bears a strong resemblance to the specimens figured by Bonaduce *et al.* (1975) as *Loxoconcha* aff. *L. agilis* from the Recent sediments of the Adriatic Sea. The species was also recorded by a number of authors from the Marmara and Black seas (e.g. Nazik, 2001; Ongan *et al.*, 2009).

Family **Trachyleberididae** Sylvester-Bradley, 1948
Genus *Tyrrhenocythere* Ruggieri, 1955

Tyrrhenocythere sp.
(pl. 2, fig. 13)

Remarks. There are a number of species of *Tyrrhenocythere* described from Pleistocene to Recent sediments in the eastern Mediterranean and Ponto-Caspian region. Specific differentiation is difficult due to the great similarity in lateral outline of different but closely related species (and/or the occurrence of polymorphy; Schornikov, 1981), strong sexual dimorphism in most species (the figured specimen is a male) and lack of significant distinguishing external characteristics. Although originally derived from marginal marine ancestors (Pipik, 2007), the genus is known to occur in continental water bodies throughout the Ponto-Caspian region, including the Aral Sea (Boomer *et al.*, 1996) and Caspian Sea (Athersuch, pers. comm.).

Family **Bythocytheridae** Sars, 1866
Genus *Pseudocythere* Sars, 1866

Pseudocythere aligulica? (Stepanaitys, 1962) n. comb.
(Pl. 1, fig.16)

?1962 *Cytherura aligulica* Stepanaitys in Mandelstam *et al.*: 182, pl. 28, fig. 15.

Remarks. Stepanaitys (in Mandelstam *et al.*, 1962) figured a single valve of this new species with a remarkably similar lateral outline to the present material, although it lacks the distinctive postero-ventral spine seen in most species of *Pseudocythere* and has some ornament in the central valve area. The present species has only weakly developed central reticulation but may well be conspecific.

Family **Paradoxostomatidae** Brady & Norman 1889
Genus *Cytherois* G.W. Müller, 1884

Cytherois sp.?
(Pl. 1, fig.17)

Remarks. A rather small, thinly calcified species which is only tentatively assigned to this genus based on its external lateral outline, lack of ornamentation and common occurrence in brackish-water habitats across much of NW Europe together with the Loxoconchidae and Leptocytheridae, as here. No internal features were observed due to the fragile nature of the specimens. Occurs in many samples but often no more than 1–2 specimens are found.

Family **Xestoleberididae** Sars, 1928

Xestoleberis chanakovi Liventál, in Agalarova *et al*., 1961
(pl. 2, figs 14–15)

?1949 *Xestoleberis* sp. Schweyer: 51, pl. 11, fig. 6.
1961 *Xestoleberis chanakovi* Liventál; Agalarova *et al*.: 156, pl. 93, figs 5, pl. 96, figs 1–4.
1962 *Xestoleberis chanackovi* (*sic*.) Liventál; Mandelstam *et al*.: 183, pl. 28, fig. 16.

Remarks. A relatively large, highly-arched species of *Xestoleberis* with distinct mid-lateral, shallow punctation present on all valves, best developed in late instars and adults. Recorded by both Agalarova *et al*. (1961) and Mandelstam *et al*. (1962) as a Liventál species, but neither give a date of publication. Mandelstam *et al*. (1962) apparently spelt the name *chanackovi* incorrectly, although the two may be distinct species. The original description for this species cannot be found amongst Liventál's publications. As the first published record, that of Agalarova *et al*. may have priority but, for now, it should be considered a *nomen nudum*. Of those specimens figured in Agalarova *et al*. (1961), perhaps those best fitting the present material are those on plate 96 (figs 3–4), where the lateral outline and shallow development of just a small, central area of ornamentation are similar. Schweyer (1949) figured a species from the Pliocene of the Caucasus–Volga region (incorrectly cited as 1948 by Mandelstam *et al*., 1962), which bears a strong similarity to the present species in lateral outline but no evidence of mid-valve pitting is seen in the illustration.

Atay & Tunoğlu (2002) refer to *Xestoleberis* (*Xestoleberis*) *chanakovi* Stancheva, probably in error, in their comments for two species (*Xestoleberis* sp. 2 and *X*. sp. 3) from middle–late Pannonian sediments around the Çanakkale Bridge. No further taxonomic or literature details are given and the illustrated specimens are too poorly preserved to be certain of their affinities. Olteanu (2006) refers to *Pontoleberis chanakovi* (Liventál) in a table of species occurrences from the Gurian (Early Pleistocene) of the Ponto-Caspian basin, but no specimens are illustrated.

DISCUSSION

Boomer *et al*. (2005) noted that the Ponto-Caspian fauna has its origins in the Paratethyan sea of the late Neogene and reflects the remnants of a low–brackish-water fauna, adapting to salinity changes and isolation. The assemblages described here have clear affinities with those described in numerous studies of late Neogene to Recent ostracods from the former Soviet Union, Eastern Europe and eastern Mediterranean regions. The late Quaternary and Holocene assemblages for the Black and Caspian seas share common taxa which can be traced back to late Pliocene–Pleistocene periods when the two were connected. Since separation, the two have also established additional, endemic components. The Aral Sea is much shallower and is geologically very young compared to the Black and Caspian seas. The low diversity Aral Sea ostracod fauna (Boomer *et al*., 1996) is, therefore, relatively recently established, derived largely from elements of the Black and Caspian Sea fauna and it lacks a distinctive endemic component.

From the faunal evidence presented, it is clear that the ostracod response to major hydrological events in the Black Sea is reflected in changing diversity, abundance and assemblage composition throughout the late glacial to Holocene interval.

In this paper we have highlighted some of the taxonomic problems of the Ponto-Caspian ostracod fauna. These problems concern both common and rare taxa and must be addressed if future palaeoenvironmental interpretations (both faunal and geochemical) based on ostracods from this region are to be compared meaningfully. A full taxonomic revision of the Ponto-Caspian ostracod fauna is required.

ACKNOWLEGEMENTS

The authors thank all participants of BlaSON (1998, IFREMER/GeoEcoMar bilateral project) and ASSEMBLAGE (2004, EU-funded project EVK3-CT-2002-00090) for their assistance during these cruises and the support of LSCE, CNRS, IFREMER and IPEV during this research. In particular, IB thanks Claudia Strechie (GeoEcoMar, Bucharest) for providing material and data from the BlaSON cruise. IB acknowledges the support of a Leverhulme Trust award during this research (F/00 125/G). John Athersuch (Stratadata, UK) and Elsa Gliozzi (Rome) are thanked for their many discussions on Ponto-Caspian ostracods and commenting on an earlier draft of this paper. Anna Stepanova and Ekaterina Tesakova (Moscow) are also thanked for assistance during writing.

Manuscript received 10 July 2010
Manuscript accepted 29 July 2010
Scientific editing by Alan Lord

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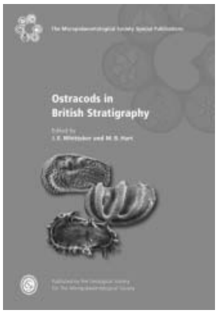

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Editors: J E Whittaker & M B Hart

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•May 2009
•496 pages
•Hardback
•Prices:
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