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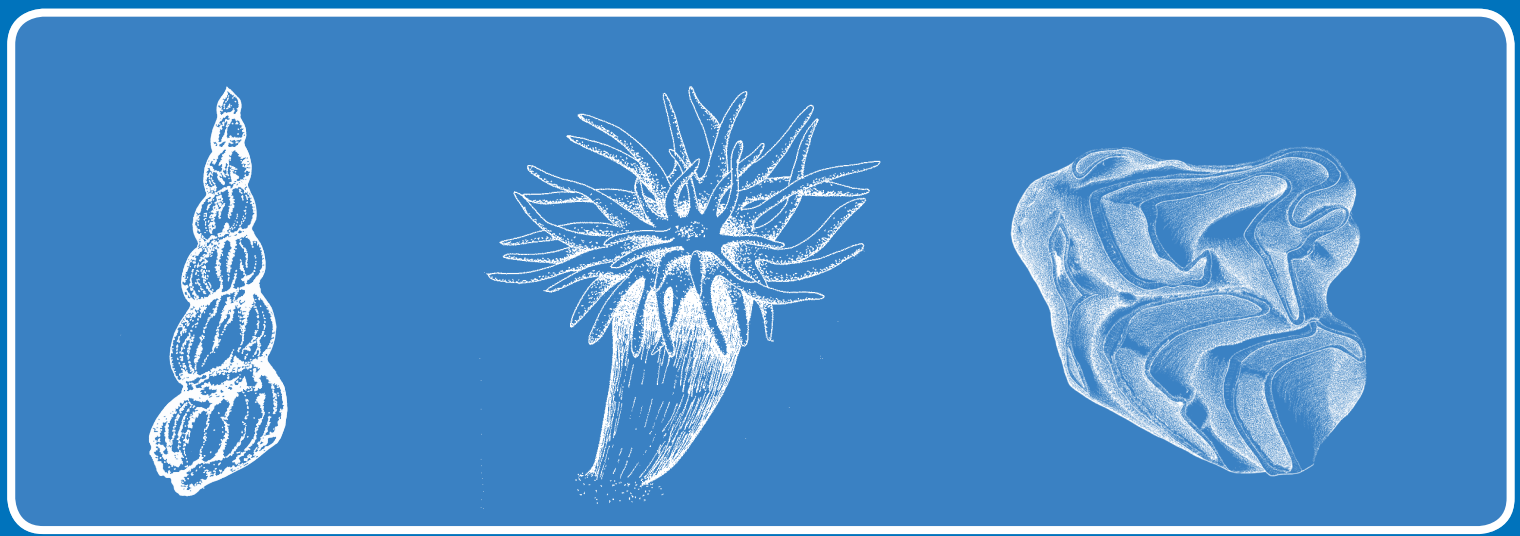

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Cover illustrations: (from left to right) Shell of the gastropod *Loxonema regium* De Koninck from the Carboniferous of Belgium (redrawn from De Koninck 1881); Solitary coral *Caninia* sp. from the Carboniferous of England (redrawn from Ramsbottom in McKerrow 1978); Tooth of the rare ruminant *Orygotherium escheri* von Meyer from the Miocene of Germany (after Rössner & Mörs 2001). **Back cover:** Atrium of the Munich Palaeontological Museum, view from the main entrance.

Umschlagbilder: (von links nach rechts) Gehäuse der Schnecke *Loxonema regium* De Koninck aus dem Karbon von Belgien (neu gezeichnet nach De Koninck 1881); Solitärkoralle *Caninia* sp. aus dem Karbon von England (neu gezeichnet nach Ramsbottom in McKerrow 1978); Zahn des seltenen Wiederkäuers *Orygotherium escheri* von Meyer aus dem Miozän von Deutschland (nach Rössner & Mörs 2001). **Rückseite:** Lichthof des Paläontologischen Museums München, Blick vom Haupteingang.

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Late Miocene non-marine ostracods from the Lake Küçükçekmece region, Thrace (Turkey)

By
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Abstract

Newly collected sediment samples from the Lake Küçükçekmece region, west of Istanbul, were analysed micropalaeontologically, and yielded non-marine, brackish water ostracod assemblages attributable to the Late Miocene (Khersonian to Maeotian). The faunas are dominated by *Cyprideis sublittoralis* Pokorný, 1952, accompanied by species of the genera *Euxinocythere, Loxoconcha* and *Xestoleberis*, and rare *Candona* and *Heterocypris*. This assemblage is suggestive of a mesohaline shallow water habitat. An identical fauna occurs in the immediate neighbourhood at Kalinoraburnu. Four additional, co-eval ostracode assemblages are reported in the literature from the area, and these faunas are here re-interpreted stratigraphically and palaeoecologically. Two of them contain mixed faunas, composed of marine ostracods from the Oligocene and non-marine (fresh- and brackish water) forms from the Late Miocene. The preferred interpretation of these mixed faunas is reworking of the Oligocene faunas during the Late Miocene.

Key words: Ostracoda, Late Miocene, brackish water, Ergene Basin, Thrace, Turkey.

Kurzfassung

Neue Proben aus der Gegend des Küçükçekmece Sees, westlich Istanbuls, wurden mikropaläontologisch untersucht und lieferten Ostracodenfaunen des Brackwassers, die dem Obermiozän (Kherson bis Maeot) zugeordnet werden. In diesen Faunen herrscht *Cyprideis sublittoralis* Pokorný, 1952 vor, begleitet von Arten der Gattungen *Euxinocythere, Loxoconcha* und *Xestoleberis* und seltenen *Candona* und *Heterocypris*. Diese Vergesellschaftung zeigt ein mesohalines Flachwasser-Habitat an. Eine identische Fauna wurde in der unmittelbaren Nachbarschaft bei Kalinoraburnu aufgefunden. Fossillisten von vier weiteren Faunen ähnlichen Alters aus diesem Gebiet finden sich in der Literatur und wurden stratigraphisch und paläoökologisch reinterpretiert. Zwei davon enthalten Mischfaunen, bestehend aus marinen Ostracoden des Oligozäns und nicht-marinen Ostracoden des Süß- und Brackwassers des Obermiozäns. Die Interpretation, dass diese Mischfaunen durch Umlagerung der oligozänen Faunen im Obermiozän enstanden sind, wird bevorzugt.

Schlüsselwörter: Ostracoda, Obermiozän, Brackwasser, Ergene Becken, Thrazien, Türkei.

Özet

Istanbulun batısı, Küçükçekmece Gölü semtinden, toplanan yeni numunelerin mikropaleontolojik incelemelerinden elde edilen veriler bu tabakaların acısu Ostracod'ları ihtiva ettiğini ve yaşca Üstmiyosen (Kherson–Maeot) yaşını kanıtlamaktadır. Bu Ostracod'lar içinde bulunan, *Cyprideis sublittoralis* Pokorný, 1952 başta gelir, bunu takip eden cinsler ve türleri ise *Euxinocythere*, *Loxoconcha* ve *Xestoleberis* ve nadir olarakta *Candona* ve *Heterocypris* bulunur. Bu toplum orta tuzlu (mesohalin) ortamı gösterir. Özdeş faunaya yakınında bulunan Kalinoraburnunda da raslanmıştır. Bu bölgede aynı yaşta bulunan daha dört fosil faunayı literatürde ki listede Stratigrafik ve Paleontolojik olarak verilmiştir. Bunun ikisi karışık fauna, Oligosenin denizel Ostracod'ları ve diyeri ise Miyosenin denizel olmayan tatlı- ve acısu Ostracod'larını içerir. Bu Oligosen faunasının allokton olarak Üst Mioyesen de bulunduğu kabul edilmiştir.

Anahtar sözlükleri: Ostracod, Üst Miyosen, Acısu, Ergene Havsası,Trakya,Türkiye.

1. Introduction

New sediment samples from the Lake Küçükçekmece area have yielded a rich ostracod fauna that includes several age-

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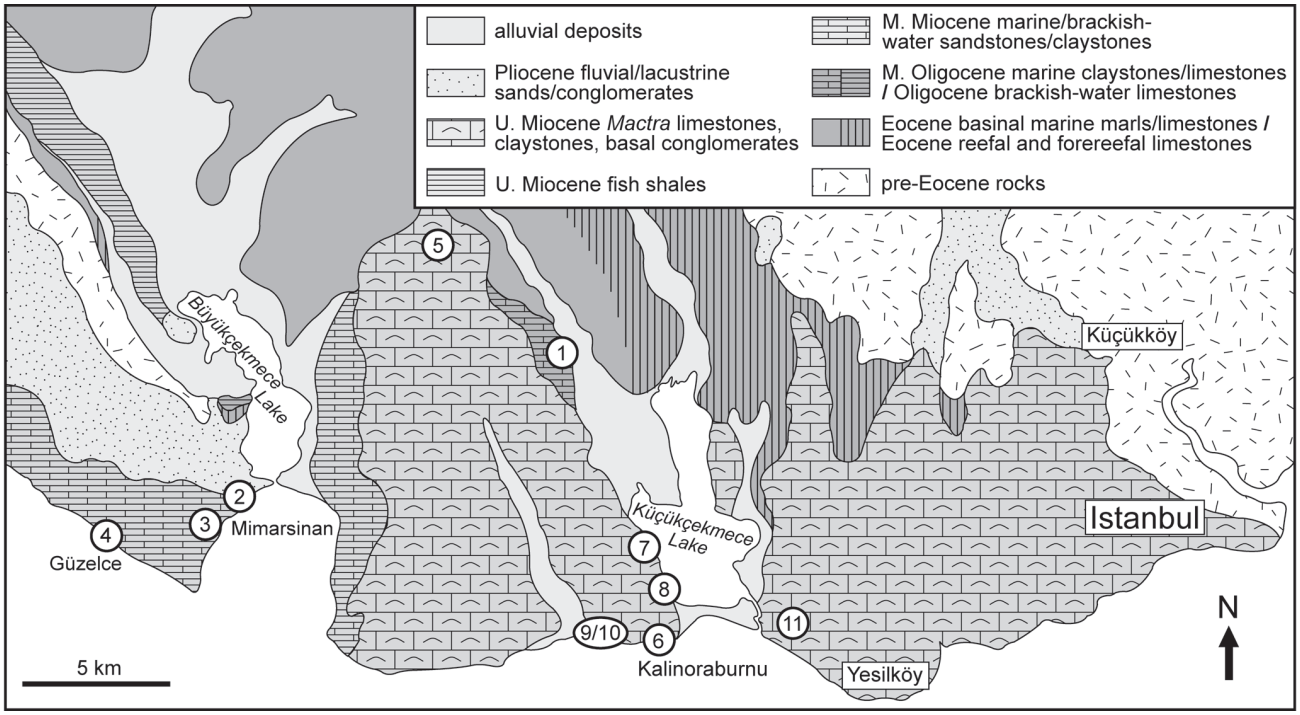
diagnostic Late Miocene taxa. These taxa are documented in this paper. The area between Lake Büyükçekmece and Istanbul is covered by sediments of almost horizontal or hardly dipping attitude that are Late Sarmatian to Early Maeotian in age (Kopp et al. 1969: 71) and may reach ca. 100 m in thickness. The Geological Map of Turkey 1:500.000, sheet Istanbul, 2002 edition (Şenel 2002) shows basically the same situation, i.e. Miocene sediments cropping out over a large area, but on some sample locations, the map indicates Oligocene.

Middle to Late Miocene (Sarmatian to Pannonian) flora and fauna, otoliths but also fish remains and molluscs, have been reported from the locality Avcılar, W of Lake Küçükçekmece and ca. 20 km SW of Istanbul (Rückert-Ülkümen 1996: 117).

The geographical position of the Ergene Basin between the central and the eastern Paratethys results in ostracod faunas containing elements from both realms. Synopses used of the chronostratigraphical subdivision and terminology of both regions are those of Vrsaljko (1999) and Popov et al. (2004). The former also includes earlier versions of subdivisions and their letter codes.

Stratigraphical terminology is ambiguous since the Sarmatian sensu central Paratethys only corresponds with the lower part of the Sarmatian sensu eastern Paratethys. The latter is subdivided into an early (sub)stage Volhynian, a middle Bessarabian and a late Khersonian stage, the latter corresponding to the late Early Pannonian. The Middle to Late Pannonian corresponds to the Maeotian (Vrsaljko 1999: tab. 1; Popov et al. 2004). This correspondence has already been demonstrated in Jiricek & Riha's (1991) ostracod zonations.

The Küçükçekmece faunas are compared with other ostracod assemblages from the area, i.e. the triangle between Lake Büyükçekmece in the W, Lake Küçükçekmece in the E and the Sea of Marmara in the S. These assemblages include two samples with „mixed faunas" (Malz 1992: 87), i.e. containing marine Oligocene and non-marine (fresh- and brackish water) Miocene taxa.



Textfigure 1: Geological sketch-map of the surroundings of the Büyükçekmece and Küçükçekmece lakes: Distribution of the major stratigraphical units of the Tertiary west of Istanbul and sample localities 1 to 6 in Rückert-Ülkümen & Kaya (1993) and 7 to 11 in this paper. Modified from fig. 1 in Rückert-Ülkümen & Kaya (1993).

Localities:

No.	Name	Age	Taxonomic groups studied
1	Kartal Tepe	Middle Oligocene	calc. nannoplankton, foraminifers
2	Mimarsinan Köyü	Late Miocene	molluscs
3	S of Mimarsinan Köyü	Middle Miocene	sporomorphs, foraminifers, molluscs
4	Güzelce Köy	M.-L. Miocene	sporomorphs, molluscs, otoliths
5	Hoşdere	Late Miocene	ostracods, fish remains, mammalia
6	Kalinoraburnu	Late Miocene	ostracods, otoliths, fish remains
7	Küçükcekmece 1	Late Miocene	ostracods
8	Küçükcekmece 2	Late Miocene	ostracods
9	Ambarlıköy	Late Miocene	ostracods, molluscs
10	Ambarlıköy	Late Miocene	ostracods, molluscs
11	Küçükcekmece area	(M.-) L. Miocene	ostracods

In northeastern Thrace, near the basin margin S of the Istranca Massif, „mixed faunas" have been documented by Sönmez-Gökçen (1973) and Gökçen (1975), including Akviran-Inceğiz and Çatalca (Sönmez-Gökçen 1973: fig. 1, tabs 5 and 6), and Pınarhisar and Poyralı (Sönmez 1963: tab. 1; Gökçen 1975: figs 1, 3 and 4). In these publications, the ostracod assemblages are assigned to the Oligocene, but without giving credit to taxa of differing ecological requirements and stratigraphical distribution.

The recognition of Oligocene species that have been reworked into Neogene sediments relies on the dating of the marine and non-marine taxa. However, in the two samples discussed in this paper, i.e. Küçükçekmece 1 and 2, reworked ostracods have not been recognized.

2. Material

The Küçükçekmece samples 1 and 2, both composed of white to grey sandy limestones and marls, have been collected from near the western shore of Lake Küçükçekmece, have been washed, and the microfossils have been picked by Dr. N. Rückert-Ülkümen, Bayerische Staatssammlung für Paläontologie und Geologie, Munich.

A schematized columnar section of the Neogene of the Küçükçekmece region is provided in Rückert-Ülkümen & Kaya (1993: fig. 5). The provenance of the material for this study is indicated in Textfigure 1. Both sites are loacted SSE of sample locality 5, from which the ostracod fauna studied by Malz (1992) was collected (Rückert-Ülkümen & Kaya 1993: 60). Sample 1 (locality 7 in Textfig. 1) comes from ca. 12.5 km SSE of locality 5, and sample 2 (locality 8 in Textfig. 1) from about 1.6 km further south.

In the Systematics section (Section 3.1), only the factual and potential Miocene age-diagnostic taxa are considered. The material is housed in the Bayerische Staatssammlung für Paläontologie und Geologie, Munich (accession numbers of illustrated specimens: BSPG 1980 X 1364–1379).

3. Ostracoda

Abbrevations: vr = very rare, 1 specimen; r = rare, 2–5 specimens; c = common, 6–20 specimens; a = abundant, 21–100 specimens; va = very abundant, >100 specimens.

C = carapace, R = right valve, L = left valve, V = valve. l = length, h = height, w = width.

The following taxa have been identified in the two Küçükçekmece samples:

No. 1
Candona (Candona) compressaeformis Mandelstam, 1963; vr
Euxinocythere (Euxinocythere) immutata Stancheva, 1972; c
Cyprideis sublittoralis Pokorný, 1952 + juv.; va
Urocythereis crenulosa (Terquem, 1878); r
Loxoconcha sp. A; c
Loxoconcha sp., aff. *ovulata* (Costa, 1863); vr

No. 2
Candona (Candona) mutans Pokorný, 1952; r
Heterocypris salina (Brady, 1868); r
Euxinocythere (Euxinocythere) immutata Stancheva, 1972; a
Euxinocythere (Euxinocythere) topolensis Stancheva, 1972; r
Cyprideis sublittoralis Pokorný, 1952 + juv.; va
Loxoconcha sp. A; c
Loxoconcha sp.; r
Xestoleberis spp.; a

3.1 Systematics

Superfamily Cypridoidea Baird, 1845
Family Candonidae Kaufmann, 1900
Subfamily Candoninae Kaufmann, 1900

Genus *Candona* Baird, 1845
Subgenus *Candona* Baird, 1845

Candona (Candona) compressaeformis Mandelstam, 1963

Pl. 1, Fig. 2

1998 *Candona (Candona)* sp. 1 – Pipík: pl. 1, fig. 2.
v 2005 *Candona (Candona) compressaeformis* Mandelstam, 1963 – Matzke-Karasz & Witt: 120, pl. 1, fig. 3. (Further synonyms).

Material: Sample Küçükçekmece 1: 1 R.

Measurements (mm): R: l = 1.160, h = 0.564, l/h = 2.057.

Other regional occurrences: The species is known from the Pannonian of the central Paratethys, the Upper Pliocene of the eastern Paratethys and the Pliocene to Pleistocene of Anatolia (references surveyed in Matzke-Karasz & Witt 2005: 120).

Palaeoecology: Freshwater (Pipík 1998: 168 for *Candona (Candona)* sp. 1).

Candona (Candona) mutans Pokorný, 1952
Pl. 1, Fig. 1

* 1952 *Candona mutans* n. sp. – Pokorný: 376, pl. 1, fig. 9.
1952 *Candona* cf. *mutans* n. sp. – Pokorný: 377, pl. 1, fig. 8.
1985 *Candona mutans* Pokorný 1952 – Jiřiček: 386, pl. 49, figs 7, 8.

Material: Sample Küçükçekmece 2: 2 R.

Measurements (mm): R: l = 0.727–0.731, h = 0.382–0.398, l/h = 1.837–1.903.

Remarks: Pokorný (1952: 376) described this species from the *Congeria subglobosa* Zone of Hodonín (southern Moravia), which corresponds with the Pannonian E of the central Paratethys (Čtyroký 1994: tab. 4) and Lower Maeotian of the eastern Paratethys (Vrsaljko 1999: tab. 1).

Jiřiček (1985) regards *C. mutans* as conspecific with *C.* cf. *mutans*, an interpretation that is followed here. However,

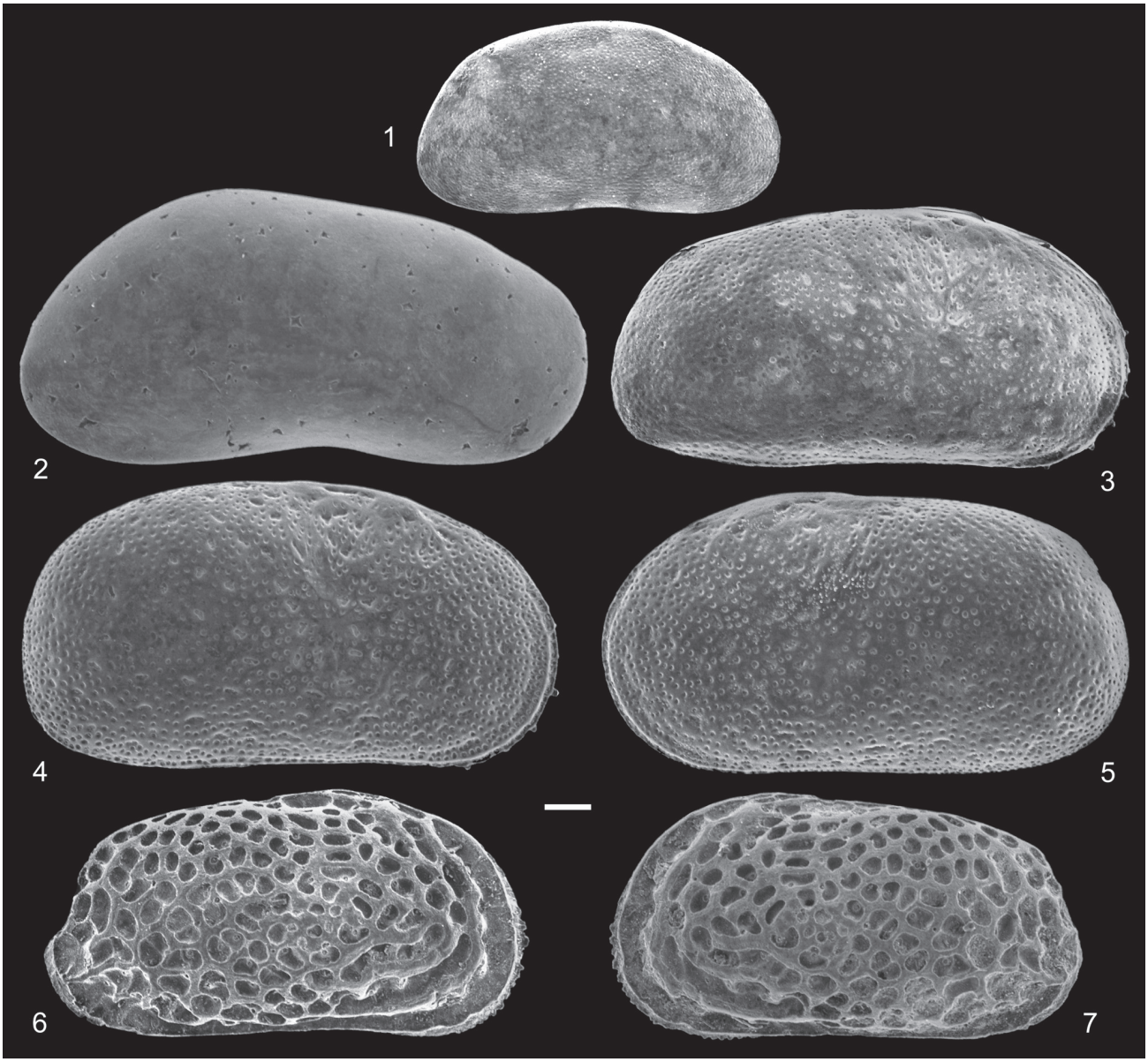


Plate 1:

Küçükçekmece 1: Figs 2, 6, 7; Küçükçekmece 2: Fig. 1, 3–5. Scale bar: 0.1 mm.

Fig. 1: *Candona* (*C.*) *mutans* Pokorný, 1952
R (l = 0.727, h = 0.382 mm), external view, ca. x 75; BSPG 1980 X 1364.

Fig. 2: *Candona* (*C.*) *compressaeformis* Mandelstam, 1963
R (l = 1.160, h = 0.564 mm), external view, ca. x 75; BSPG 1980 X 1365.

Figs 3-5: *Cyprideis sublittoralis* Pokorný, 1952
Fig. 3: R♂ (l = 1.109, h = 0.545 mm), external view, ca. x 75; BSPG 1980 X 1366.
Fig. 4: R♀ (l = 1.091, h = 0.589 mm), external view, ca. x 75; BSPG 1980 X 1367.
Fig. 5: L♀ (l = 1.093, h = 0.587 mm), external view, ca. x 75; BSPG 1980 X 1368.

Figs 6-7: *Urocythereis crenulosa* (Terquem, 1878)
Fig. 6: R (l = 0.978, h = 0.491 mm), external view, ca. x 75; BSPG 1980 X 1369.
Fig. 7: L (l = 0.960, h = 0.493 mm), external view, ca. x 75; BSPG 1980 X 1370.

differences with regard to the measurements (mm) are problematic: Pokorný (1952: 377) gives the following values for his specimens from Hodonín: l = 0.48–0.59, h = 0.29–0.35. These values agree with his figures. However, Jiřiček (1985) indicates other measurements for his specimens from Hodonín: l = 0.70–0.75, h = 0.30–0.35. These values appear slightly too low, relating the length of the right valve from Hodonín, pl. 49, fig. 8, with its height. In this way, values of h are calculated at 0.36–0.37. The present specimens are finely punctated, already observed by Pokorný (1952).

Other regional occurrences: In the Pannonian D-E of the central Paratethys (Jiřiček 1985: tab. 11).

Palaeoecology: Still brackish water (3–8‰), water depth few cm to several m (Pokorný 1952: 364–366).

Superfamily Cytheroidea Baird, 1850
Family Limnocytheridae Klie, 1938
Subfamily Leptocytherinae Hanai, 1957

Genus *Euxinocythere* Stancheva, 1968
Subgenus *Euxinocythere* Stancheva, 1968

Euxinocythere (Euxinocythere) immutata Stancheva, 1972
Pl. 2, Figs 1–4

* 1972 *Euxinocythere (E.) immutata* sp. n. – Stancheva: 123, pl. 1, fig. 10.
1984a *Euxinocythere (E.) immutata bononiensis* sp. n. – Stancheva: 40, pl. 1, fig. 6.
1990 *Euxinocythere (E.) immutata immutata* Stancheva, 1972 – Stancheva: 66, pl. 23, fig. 5.
1990 *Euxinocythere (E.) immutata bononiensis* Stancheva, 1984 – Stancheva: 67, pl. 23, figs 7, 8.

Material: Sample Küçükçekmece 1: ♀: 1 C, 1 R, 3 L ; ♂: 1 R, 1 L ; Sample Küçükçekmece 2: ♀: 11 C, 14 R, 7 L; ♂: 2 C, 2 R, 1 L; juv.: 2.

Measurements (mm): L♀: l = 0.618–0.638, h = 0.311–0.327, l/h = 1.951–1.987; R♀ l = 0.604, h = 0.313, l/h = 1.930; R♂: l = 0.690, h = 0.349, l/h = 1.977; C♂: l = 0.655, h = 0.340, w = 0.276, l/h = 1.926.

Remarks: Measurements (mm) taken from Stancheva (1972, 1984a, 1990) are combined for l = 0.550–625, h = 0.275–0.350, and it appears that these are rather the dimensions of ♀♀ specimens.

The differences between the *E. (E.) immutata* subspecies represent variations in ornamentation, where *E. (E.) immutata bononiensis* exhibits the complete ornamentation composed of small pits, a ridge composed of three parts running from the eye spot in direction of the onset of the ventral margin, two ridges framing the anterolateral sulcus like a "v", and a ridge parallel to the posterior margin ending posteroventrally in a box-like extension, usually a feature of males only (Stancheva 1990: 67). Variations exist that display weaker ribs and a reduced number of small pits, finally resulting in the smooth *E. (E.) immutata immutata*, which possesses only the basic pattern of weak ridges. Since both forms occur at the same stratigraphical level and represent zonal markers for the Early Khersonian (Stancheva 1984b: 69), distinguishing between both subspecies is not recommended.

Other regional occurrences: In the *Euxinocythere (E.) immutata* Zone of the Early Khersonian of northern Bulgaria (Stancheva 1990).

Palaeoecology (genus): Euryhaline, prefering oligo- to mesohaline, shallow water environments, but also in freshwater (Gross 2004: 79).

Euxinocythere (Euxinocythere) topolensis Stancheva, 1972,
Pl. 2, Fig. 5

* 1972 *Euxinocythere (E.) topolensis* sp. n. – Stancheva: 121, pl. 1, fig. 6.
1990 *Euxinocythere (E.) topolensis* Stancheva, 1972 – Stancheva: 76, pl. 25, figs 7, 8.

Material: Sample Küçükçekmece 2: ♀: 1 L; ♂: 1 R.

Measurements (mm): L♀: l = 0.620, h = 0.313, l/h = 1.981; R♂: l = 0.751, h = 0.381, l/h = 1.971.

Other regional occurrences: In the Late Khersonian *Euxinocythere dilecta* Zone of Northeastern Bulgaria (Stancheva 1972: 121; 1984b: fig. 2).

Palaeoecology: See *E. (E.) immutata*.

Family Cytherideidae Sars, 1925
Subfamily Cytherideinae Sars, 1925

Genus *Cyprideis* Jones, 1857

Cyprideis sublittoralis Pokorný, 1952
Pl. 1, Figs 3–5

* 1952 *Cyprideis heterostigma* (Reuss 1850) *sublittoralis* n. ssp. – Pokorný: 380, pl. 3, figs 1–5; pl. 5, figs 5, 8; textfigs 17, 18.
1960 *Cyprideis heterostigma sublittoralis* Pokorny – Kollmann: 167, pl. 15, figs 10,11; Beilage 3, figs 8a, b.
1979 *Cyprideis sublittoralis sublittoralis* Pokorny 1952 – Bassiouni: 79, pl. 9, figs 1–4.
1983 *Cyprideis sublittoralis* Pokorný – Jiřiček: pl. 7, fig. 39.
1985 *Cyprideis sublittoralis* Pokorný, 1952 – Jiřiček: 399, pl. 54, figs 1–3.
1991 *Cyprideis sublittoralis* Pokorny – Jiricek & Riha: pl. 5, fig. 5.
2001a *Cyprideis sublittoralis* Pokorny, 1952 – Tunoğlu & Ünal: 172, pl. 1, fig. 9.

Material: Sample Küçükçekmece 1: total >200 (est.) ♀: very few C, mainly R and L; ♂: R and L; juv.; Sample Küçükçekmece 2: total >300 (est.) ♀: very few C, mainly R and L; ♂: R and L; juv. This species is dominating the ostracod fauna.

Measurements (mm): R♀: l = 1.089–1.091, h = 0.591–0.589, l/h = 1.843–1.852; L♀: l = 1.093–1.109, h = 0.587–0.605, l/h = 1.833–1.862; C♀: l = 1.091, h = 0.600, b = 0.496, l/h = 1.818; R♂: l = 1.002–1.109, h = 0.509–0.545, l/h = 1.969–2.035; L♂: l = 1.009–1.118, h = 0.511–0.564, l/h = 1.975–1.982.

Remarks and relations: The ornamentation of the valves is similar to that seen in *C. macrostigma* Kollmann, 1960, while the ornamentation of *C. sublittoralis* is somewhat coarser; moreover the latter species is slightly larger (Gross 2004: 82).

The dimensions given by Tunoğlu & Ünal correspond well with those of the specimens of Thrace; they result in l/h-ratios of 1.91–2.0; however, the l/h-ratio of the figured specimen is calculated at 1.65, which is due probably because

the image is distorted by scanning electron microscopy. Noded specimens are extremely rare.

Other regional occurrences: Pokorný (1952: 380) described this species from the *Congeria subglobosa* Zone of Hodonín (southern Moravia), which corresponds to the Pannonian E of the central Paratethys (Čtyroký 1994: tab. 4). Bassiouni (1979) elevated the form to the rank of species, and uses specimens from Hodonín to illustrate the differences to *Cyprideis sublittoralis adentata* Bassiouni, 1979 from the Upper Miocene of SW-Anatolia. Jiricek & Riha (1991: pl. 5, fig. 5) also illustrate a specimen from Hodonín and indicate Upper Pannonian as the stratigraphical horizon. Theses authors regard the form as an index species for Ostracod Zone 18 (Jiříček 1983: 204, 206), Late Pannonian of the central Paratethys (Jiříček & Riha 1991: 440), corresponding to the Late Maeotian of the eastern Paratethys (Jiricek & Riha 1991: 438).

Following Kollmann (1960: Beilage 2), the species occurs in the Middle Pannonian D and less frequently in E of the Inner Alpine Tertiary Basin of eastern Austria. According to Jiříček (1985: tab. 11) the stratigraphical range extends from the Pannonian D to E, which correlates with the Late Khersonian to Early Maeotian (Vrsaljko 1999: tab. 1). The species has also been reported from the Gelibolu Neogene Basin, NW-Turkey, where it occurs in the Upper Pannonian to Pontian (Tunoğlu & Ünal 2001a: tab. 1).

Summarizing, the species occurs in the early Middle to Late Pannonian in central Paratethys terminology or in the Late Khersonian to Early Maeotian in eastern Paratethys terminology.

Palaeoecology: Pokorný (1952: 136) discusses in detail the depositional environment of the stratum typicum of this species, i.e. the grey marly clay of the „basal horizon" of the *subglobosa*-beds: Brackish (3–8‰), shallow water, a few cm to several m deep, low energy conditions and some oxygen deficiency, eurythermal. Large populations points to abundant food (including plant detritus and animal remains) on the bottom. The majority of species of this genus inhabit brackish (meso-polyhaline) waters (van Morkhoven 1963: 290).

Family Hemicytheridae Puri, 1953
Subfamily Urocythereidinae Hartmann & Puri, 1974

Genus *Urocythereis* Ruggieri, 1950

Urocythereis crenulosa (Terquem, 1878)
Pl. 1, Figs 6–7

1969 *Urocythereis margaritifera alba* n. ssp. – Uliczny: 65, pl. 15, fig. 9.
2006 *Urocythereis crenulosa* (Terquem, 1878) – Mostafawi & Matzke-Karasz: 39, pl. 6, fig. 9; pl. 8, fig. 1. (Additional synonyms).

Material: Sample Küçükçekmece 2: 1 R, 1 L.

Measurements (mm): R: l = 0.978, h = 0.491, l/h = 1.992; L: l = 0.960, h = 0.493, l/h = 1.947.

Remarks and Relations: Dimensions (mm) of the specimens from the Pliocene of Cephalonia, Greece, in Uliczny (1969: 66) are for R♀: l = 0.95, h = 0.49 and for L♂: l = 0.97, h = 0.49, which correspopnds very well with the dimensions of the specimens from Thrace. According to Jiříček (1985: 379), *Leptocythere maeotica, Xestoleberis maeotica* and *Urocythereis* div. sp. are charateristic taxa of the Maeotian, which, according to this author, corresponds with the Pannonian E of the central Paratethys.

Other regional occurrences: *U. crenulosa* is known from the Pliocene to Recent of the Mediterranean (Mostafawi & Matzke-Karasz 2006). The genus is known to have existed since the Miocene (Benson et al. 1961: Q306).

Palaeoecology (genus): Marine, epi-neritic, down to 40 m (van Morkhoven 1963: 153). Marine ostracod taxa as other marine organisms occur already in brachyhaline waters (±18–±30‰) and are missing from proper brackish waters (Hiltermann 1966: 490).

Family Loxoconchidae Sars, 1925
Subfamily Loxoconchinae Sars, 1925

Genus *Loxoconcha* Sars, 1866

Loxoconcha sp. A
Pl. 2, Figs 6–8

Material: Sample Küçükçekmece 1: ♀: 1 C, 3 R, 4 L; ♂: 1 R; Sample Küçükçekmece 2: ♀: 1 C, 2 R, 4 L; ♂:1 R.

Measurements (mm): R♀: l = 0.616–0.618, h = 0.398–0.404, l/h = 1.525–1.553; L♀: l = 0.582–0.615, h = 0.380–0.404, l/h = 1.448–1.539; R♂: l = 0.658, h = 0.409, l/h = 1.609.

Remarks: This species is characterized by a straight dorsal margin parallel to the ventral margin and conspicuous sieve-type lateral pore canals.

Relations: Compared to *Loxoconcha granifera* (Reuss, 1850) sensu Gramann (1969: 509, pl. 35, figs 8, 9; l = 0.53–0.62; h = 0.35 mm), *Loxoconcha* sp. A is larger. Moreover, the dorsal margin is sloping towards the posterior end. *L. granifera* in Gramann (1969) is not identical with *L. granifera* sensu Reuss (1850). The latter taxon is characterized by a pitted outer surface of the valves, presence of spines along the anterior and posterior margins, and is more elongated as shown by Gross (2004: 89, pl. 15, figs 1–13).

Palaeoecology (genus): *Loxoconcha* occurs in mesohaline brackish and in mainly littoral marine environments (Gross 2002: 112).

Loxoconcha sp., aff. *ovulata* (Costa, 1863)
Pl. 2, Fig. 9

aff. 1979 *Loxoconcha ovulata* (Costa) – Athersuch: 141, pl. 6, 142, 144, 148, 150.
aff. 2008 *Loxoconcha ovulata* (Costa, 1863) – Faranda & Gliozzi: 222, pl. 9, figs 1, 2.

Material: Sample Küçükçekmece 1: ♀: 1 C.

Measurements (mm): C♀: l = 0.800, h = 0.535, w = 0.435, l/h = 1.495.

Relations: On cursory examination, this species may be mistaken for the Late Miocene *Loxoconcha rhombovalis* Pokorný, 1952. The fundamental difference is a punctate ornamentation with pits diminishing in size towards the margins, whereas *L. ovulata* displays pits increasing in size towards the margins, pits becoming oval and rectangular. The specimen is very close to Late Miocene to Quaternary specimens from the Mediterranean region. The posterior part of the dorsal margin of L of the Thracian female carapace shows a slight upswing to the posterior end, whereas the Holocene forms exhibit a straight posterodorsal outline towards the posterior cardinal angle.

Other regional occurrences: Faranda & Gliozzi (2008) give Late Miocene to Recent (Late Tortonian and Messinian to Recent) as the stratigraphical range for *C. ovulata*.

Palaeoecology: See *Loxoconcha* sp. A.

3.2 Palaeoecological and stratigraphical evaluation

3.2.1 Palaeoecology

The palaeoecological information deductable from the various taxa recorded for Küçükçekmece 1 and 2 can be summarized as follows: Very abundant *Cyprideis*, common to abundant *Euxinocythere* and *Xestoleberis*, common *Loxoconcha*, and rare *Heterocypris salina* indicate mesohaline (±5–±18‰) brackish waters. The remaining genera, i.e. very rare to rare *Candona*, freshwater to oligohaline, and rare marine *Urocythereis*, may suggest the occasional reaching of the end values of above salinities, meaning the faunal content over the sample is not uniform.

Within the Late Miocene of the central Paratethys, Rundić (2006: 97) distinguishes several ostracod assemblages based on salinity. The one assemblage composed of *Cyprideis*, *Amplocypris, Leptocythere*, *Hemicytheria, Loxoconcha* and *Xestoleberis* represents meso- to polyhaline habitats. Replacing *Leptocythere* by Leptocytherinae, the Küçükçekmece assemblages appear to fit into this segment, although *Amplocypris and Hemicytheria* are not present. In contrast, the *Candona*-dominated assemblage described by Malz (1992) indicates a freshwater to oligohaline environment (see Section 4.4 of this paper).

3.2.2 Biostratigraphy

The common to abundant non-marine (fresh- to brackish water) species *Euxinocythere (E.) immutata* Stancheva, 1972 is the zonal marker for the *Euxinocythere (E.) immutata* Zone of the Early Khersonian of the Euxinian Basin of northeastern Bulgaria (Stancheva 1984b: 73). This zone corresponds to the level of *Mactra tumida* (Stancheva 1976: 58) recognized by Popov et al. (2004: fig.) as being characteristic of the Khersonian. In Serbia, in the western part of the Dacian Basin, *E. (E.) immutata* ranges from the Late Bessarabian to Early Khersonian (Rundić 2006: tab. 2).

Euxinocythere (E.) topolensis Stancheva, 1972, which is rarely found, represents one of the index-fossils of the *Euxinocythere (E.) dilecta* Zone of the Late Khersonian of northeastern Bulgaria (Stancheva 1976: 58).

Cyprideis sublittoralis Pokorný, 1952 and *Candona (C.) mutans* Pokorný, 1952 characterize the Pannonian D and E of the central Paratethys, which corresponds to the Middle Pannonian (Kollmann 1960: Beilage 3). In eastern Paratethys chronostratigraphy, this corresponds with the Late Khersonian to Early Maeotian (Vrsaljko 1999: tab. 1). The presence of the genus *Urocythereis* points to the Maeotian (Jiříček 1985: 379).

Summarizing, the autochthonous non-marine ostracod assemblage from Küçükçekmece samples 1 and 2 indicates a Khersonian to Maeotian (Late Miocene) age of the deposits. This concurs with data derived based on mammal fossils. For example, De Bruijn et al. (1992: 98) attribute Küçükçekmece to the European mammal zone MN11, which correlates with the Late Khersonian to Early Maeotian (Popov et al. 2004: tab.), Early Maeotian (Harzhauser & Piller 2007: fig. 1), or basically the entire Maeotian (Vrsaljko 1999: tab.1). Molluscs, i.e. the *Mactra* faunas from beds with *Hipparion gracile*, also are indicative of a Khersonian age (Chaput & Gillet 1938: 363).

There appear to exist certain relations with the Upper Miocene of the Gelibolu Peninsula (West of the Dardanelles). The best correlation is with the A IV Zone defined by Tunoğlu & Ünal (2001b: 19) based on the co-occurrence of *Cyprideis sublittoralis*, *Heterocypris salina*, *Loxoconcha* sp. and *Xestoleberis* sp. This assemblage zone is regarded as Late Pannonian in age; the gastropods from this unit indicate a Maeotian age. The ostracod assemblage points to a brackish water depositional environment (Tunoğlu & Ünal 2001b: 20).

4. Additional Miocene assemblages from the Küçükçekmece area

Not considered here are other faunas from localities in the Ergene Basin, the region between Akviran and İnceğiz, as well as from Çatalca (Sönmez-Gökçen 1973: tabs 2, 5, 6) and Pınarhisar (Gökçen 1975; Malz in Rückert-Ülkümen 1990: 30). A study of Pınarhisar material by the author is in progress. The following list presents other Küçükçekmece assemblages, arranged according to their level of similarity (from the highest to the lowest) to the faunas from Küçükçekmece 1 and 2.

4.1 Samples Kalinoraburnu (Rückert-Ülkümen & Kaya 1993: 62, fig. 1) [Locality 6 in Textfigure 1]

Non-marine (fresh- to brackish water) taxa:
Candonid ostracods; r
Heterocypris cf. *salina* (Brady, 1868); c

Euxinocythere (Euxinocythere) immutata Stancheva, 1972; c
Euxinocythere (Euxinocythere) topolensis Stancheva, 1972; a
Cyprideis sublittoralis Pokorný, 1952 + juv.; va
Loxoconcha sp. A; c
Loxoconcha sp.; r
Xestoleberis spp.; c

The Kalinoraburnu site is located ca. 2 km to the south of Küçükçekmece 2. The faunal composition is very similar to Küçükçekmece 1 and 2, and Ambarlıköy (see section 4.2 of this paper); Oligocene taxa are also missing. The preservation, however, is different; carapaces are generally filled with clear calcite and often at least parts of the original shell are missing. Another difference concerns the abundance of *E. (E.) topolensis*, which is absent from the Küçükçekmece 1 sample and rare in sample 2. This indicates that the Kalinoraburnu samples are younger, probably Late Khersonian to Maeotian (Late Miocene) in age. The assemblages represent a mesohaline (±5–±18‰) shallow water habitat like that at the Küçükçekmece 1 and 2 localities.

The otolith fauna also suggests a Late Miocene (Rückert-Ülkümen & Kaya 1993: 61), respectively Sarmatian to Pannonian age (Rückert-Ülkümen 1996: tab. 1), translating after Popov et al. (2004: tab.) into Volhynian to Early Maeotian of the eastern Paratethys chronostratigraphy.

4.2. Samples Ambarlıköy (profiles 7 and 8), coast of the Sea of Marmara (Gillet et al. 1978: 57–58, fig. 1) [Localities 9 and 10 in Textfigure 1]

4.2.1 Profile 7

Non-marine (fresh- to brackish water) taxa:
Candona (C.) sp., ex gr. *neglecta* Sars, 1887
Euxinocythere (E.) cf. *acsaica* (Suzin, 1956)
Cyprideis sp., ex gr. *torosa* (Jones, 1850)
Loxoconcha sp.
Xestoleberis sp.

4.2.2 Profile 8

Non-marine (fresh- to brackish water) taxa:
Candona (C.) sp., ex gr. *neglecta* Sars, 1887
Candona (Sinegubiella) sp.
Ilyocypris sp.
Euxinocythere (E.) cf. *acsaica* (Suzin, 1956)
Cyprideis sp., ex gr. *torosa* (Jones, 1850)
Xestoleberis labiata Brady & Robertson, 1894

In the western segment (7), the lower part of the section consists of conglomerates, sand/sandstones and silt/siltstones, while the upper part is composed of limestones. In the eastern section (8), limestones alternate with sandy limestones and silt/siltstones. A lignite bed at the change from clastics to carbonates shows the Kızılhisar sporomorph assemblage (Gillet et al. 1978: 58), which corresponds with the Khersonian to Maeotian (Freels 1980: tab. 1). These authors attribute the ostracod assemblage to the Sarmatian to Pontian. However, a Khersonian age is more likely based on subgenus *Candona (Sinegubiella)*, in the Pannonian Basin, *Congeria* Beds: Pannonian to Pontian (Kristić 1972: 96); *Euxinocythere (E.)* cf. *acsaica*, in Bulgaria: Khersonian (Stancheva 1972: 128); *Xestoleberis labiata*, in Greek Macedonia: Pontian, but also in the underlying Dafni Beds (Gramann 1969: 512). The latter beds have been attributed to the Upper Tortonian by Mostafawi (1996: 168, plate caption). This assignment agrees better with the Khersonian, as is also shown by the mainly brackish mollusc fauna with *Mactra bulgarica* Toula in these samples (Gillet et al. 1978: 58).

The generic composition of the ostracod assemblages compares well with the mesohaline assemblages from Küçükçekmece 1 and 2, and Kalinoraburnu, located adjacent to Ambarlıköy.

4.3. Samples "Istanbul-Çekmece" (Sönmez-Gökçen 1973: 16–18; no precise locality given)

Non-marine (fresh- to brackish water) taxa:
Candona cf. *praecox* Straub, 1952 = *Candona* sp. juv.
Pseudocandona compressa (Koch, 1838)
Heterocypris cf. *salina* (Brady, 1868)
Ilyocypris gibba (Ramdohr, 1808)
Cyprideis tuberculata (Méhes, 1908)
Paralimnocythere cf. *rostrata* Straub, 1952

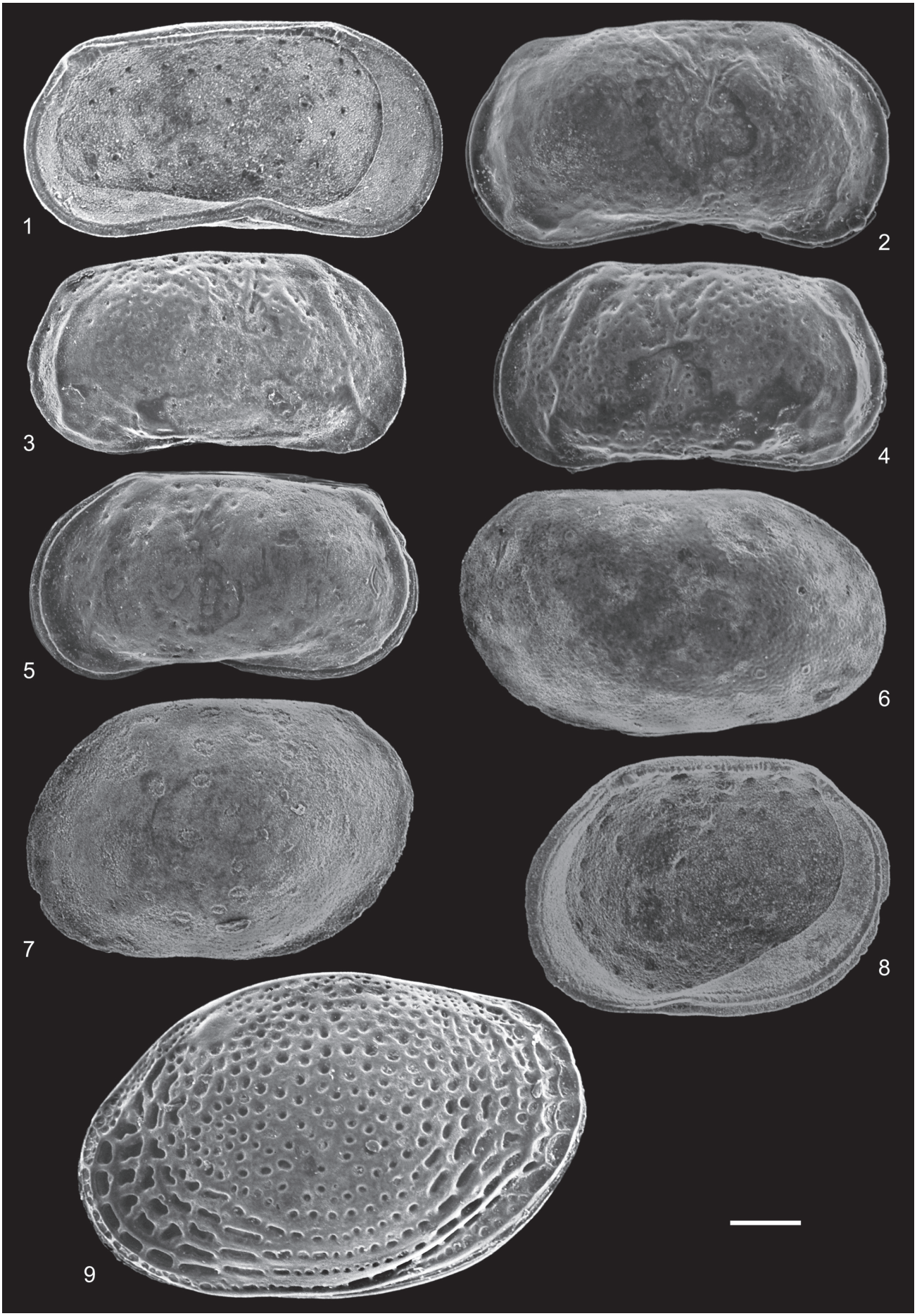
Plate 2:
Küçükçekmece 1: Figs 7, 9; Küçükçekmece 2: Figs 1–6, 8. Scale bar: 0.1 mm.

Figs 1-4: *Euxinocythere (E.) immutata* Stancheva, 1972
Fig. 1: L♂ (l = 0.656, h= 0.342 mm), internal view, note snap-knob, ca. x 120; BSPG 1980 X 1371.
Fig. 2: R♂ (l = 0.690, h= 0.349 mm), external view, ca. x 120; BSPG 1980 X 1372.
Fig. 3: R♀ (l = 0.604, h= 0.313 mm), external view, ca. x 120; BSPG 1980 X 1373.
Fig. 4: L♀ (l = 0.618, h= 0.311 mm), external view, ca. x 120; BSPG 1980 X 1374.

Fig. 5: *Euxinocythere (E.) topolensis* Stancheva, 1972
L♀ (l = 0.620, h= 0.313 mm), external view, ca. x 120; BSPG 1980 X 1375.

Figs 6-8: *Loxoconcha* sp. A
Fig. 6: R♂ (l = 0.658, h = 0.409 mm), external view, ca. x 120; BSPG 1980 X 1376.
Fig. 7: L♀ (l = 0.600, h = 0.409 mm), external view, ca. x 120; BSPG 1980 X 1377.
Fig. 8: R♀ (l = 0.616, h = 0.404 mm), internal view, ca. x 120; BSPG 1980 X 1378.

Fig. 9: *Loxoconcha* sp., aff. *ovulata* (Costa, 1863)
C (l = 0.800, h = 0.535 mm), from left, ca. x 120; BSPG 1980 X 1379.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This fauna has been attributed to the Sarmatian (sensu eastern Paratethys) by Sönmez-Gökçen (1973: 16). The result of the revision is Late Miocene (Late Bessarabian to Khersonian). Of biostratigraphical significance are *Cyprideis tuberculata*, in the Pannonian Basin: Pannonian α-β (Krstić 1968: 127) = Early Pannonian = Late Bessarabian to Khersonian (Vrsaljko 1999: tab. 1) and *Heterocypris salina*, in Anatolia: Late Miocene to Pleistocene (Freels 1980: tab.1). Problematic is *Paralimnocythere rostrata*, which occurs from the Early Miocene (Late Ottnangian) to Middle Miocene (Badenian) in southern Germany (Witt 2000: tab. 4). The genus is known from the Miocene to Recent (Meisch 2000: 437).

The palaeoecological interpretation is hampered by the absence of quantitative data. Based on Gross' (2004: tab. 3) compilation of salinity demands using the Venice System of 1958, the ecological requirements of the above taxa range from predominantly limnic (for *Pseudocandona compressa* and *Ilyocypris gibba*) to predominantly mesohaline (for *Cyprideis tuberculata* and *Heterocypris salina*).

4.4. Samples Küçükçekmece, locality 5: Hoşdere (Malz 1992: 87–92; Rückert-Ülkümen & Kaya 1993: 60–62) [Locality 5 in Textfigure 1]

Left: taxonomy used by Malz (1992); right: revisions by Witt, this paper

Freshwater taxa:
Candona sp., juv.; va
Heterocypris sp.; r
Herpetocypris sp. = cyprid ostracod; vr

Marine taxa:
Cytheridea sp., juv.; vr
Schuleridea (Amphischuleridea) sp. = *Aequacytheridea* sp.; c
Paracyprideis sp.; c
Buntonia sp. = *Cuneocythere (C.) marginata* (Bosquet, 1852); vr
Bosquetina sp.; va
Pterygocythereis sp., ex gr. *cornuta* (Roemer, 1838); va
Loxoconcha sp.; c

The sample is derived from moderately cemented pebbly sands. In Anatolia, *Heterocypris* occurs from the Late Miocene to Pleistocene (Freels 1980: tab. 1). Most species of this genus are freshwater forms, but some may also occur in oligo- to mesohaline waters (van Morkhoven 1963: 46). However, the occurrence of the *Herpetocypris* in the sample from Küçükçekmece, locality 5 is questionable because the stratigraphical range of that genus has been indicated as Pleistocene to Recent (van Morkhoven 1963: 51), whereas, based on regional geological considerations, a Late Miocene age for this assemblage is more likely. Pokorný (1952), Krstić (1960), Miletić-Spajić (1960), Sokač (1963), and Jiřiček (1974), amongst others, have formerly used the generic name *Herpetocypris* Brady & Norman, 1889 instead of *Amplocypris* Zalányi, 1944, a genus known from the Neogene.

Prof. A. Lord, Senckenberg, at the author's request, was so kind to compare Malz' *Herpetocypris* specimen in the Senckenberg collection (Xe 15376) with *Amplocypris pamiri* (Sönmez, 1963) specimens from Pınarhisar, Thrace. The result of his effort is, in brief (written communication, 08.04.2009): It is different from the Pınarhisar *Amplocypris* and is even not an *Amplocypris* based on important details of the inner lamella, being very narrow, and the marginal pore canals. It is also not a *Herpetocypris* sensu van Morkhoven (1963: 51) and Meisch (2000: 323). The large specimen (1,62 mm in length) is for the time being best named a "cyprid ostracod".

A Late Miocene ("younger than Sarmatian, presumably Pannonian") age for the sample from locality 5 is indicated by mammal fossils (Heissig in Rückert-Ülkümen & Kaya 1993: 62).

Malz (1992: 90) suggests an Oligocene age for the marine taxa, which is supported by *Pterygocythereis* sp., ex gr. *cornuta* (Roemer, 1838), in Europe: Eocene to Early Miocene (Guernet 1990: 279); *Aequacytheridea* sp., in Europe: Palaeogene resp. Oligocene (van Morkhoven 1963: 308, 310; Sönmez-Gökçen 1973: tab. 3); *Bosquetina* sp., in Europe and Asia Minor: Eocene to Recent (van Morkhoven 1963: 168) and *Cuneocythere (C.) marginata* (Bosquet, 1852), in Europe: Oligocene (Keij 1957: 75; Sönmez-Gökçen 1973: 53; tab. 3), thus supporting the reworking model and refuting the tidal action model for the mixing of co-eval marine and non-marine taxa. Both models have been outlined by Malz (1992: 88–89).

There is further evidence for reworking: Malz observed only a few juveniles of the marine elements, in contrast to the freshwater genus *Candona* of which more than one larval stage was found. Marine thick-shelled forms very abundantly occurring like *Pterygocythereis* sp., ex gr. *cornuta* and *Bosquetina* sp., and the common *Aequacytheridea* sp. are all in the narrow range of 0,86–1,04 mm long. This indicates a sorting by water current.

Oligocene foraminifera are absent; it is possible that their different shapes separates them in currents from the ostracods. Rich Oligocene foraminiferal assemblages are documented in partly extensive fossil lists (Lindenberg in Rückert-Ülkümen 1965: 318; Sönmez-Gökçen 1973: 102; Hagn in Rückert-Ülkümen & Kaya 1993: 55). Slides of the latter contain a number of ostracods; however, *Aequacytheridea*, *Paracyprideis*, *Cuneocythere*, *Pterygocythereis* and *Bosquetina* have not been found.

The foraminifera signal a deep neritic depositional environment (Hagn in Rückert-Ülkümen & Kaya 1993: 55). The ostracods with very abundant *Pterygocythereis* and *Bosquetina* also indicate an infraneritic realm. *Pterygocythereis* has a depth distribution of 10–150 m, *Bosquetina* of 20/40–200m (van Morkhoven 1963: 215 and 169 resp.).

One fundamental difference exists between the Küçükçekmece 1 and 2 samples and the sample investigated by Malz. The latter sample contains a low diversity freshwater to oligohaline Late Miocene ostracode assemblage and a number of reworked marine Oligocene ostracods, the former representing a higher diversity mesohaline Khersonian to Maeotian assemblage, and no reworked marine Oligocene ostracods. The sample sites are located along the western shore of Lake Küçükçekmece, some 13 km apart.

4.5. Samples Küçükçekmece area (Gökçen 1975: fig. 8) [Locality 11 in Textfigure 1]

Left: taxonomy after Gökçen (1975); right: revisions by Witt, this paper.

Non-marine (fresh- to brackish water) taxa:
Cypridopsis modesta Sönmez-Gökçen, 1973
Moenocypris (Isomoenocypris) pamiri = *Amplocypris pamiri* (Sönmez, 1963)

Marine taxa:
Clithrocytheridea faboides (Bosquet, 1852) = *Aulocytheridea faboides* (Bosquet, 1852)
Pokornyella bituberculata Sönmez-Gökçen, 1973
Leguminocythereis cf. *sorneana* Oertli, 1956
Triginglymus sp.

Gökçen (1975: fig. 8) refers this assemblage, including the new taxa, to the (Early) Oligocene, but does not distinguish between the non-marine and marine taxa. The marine taxa are clearly Oligocene in age, which is documented by comparison with assemblages from European Oligocene basins (Sönmez-Gökçen 1973: tab. 8). Indicative of an Oligocene age are *Aulocytheridea faboides* (Bosquet, 1852), in France: Middle Eocene (Lutetian) to Oligocene (Ducasse et al. 1985: tab. 14) and *Leguminocythereis* cf. *sorneana* Oertli, 1956, in Switzerland: Oligocene (Oertli 1956: 91).

As a range for the new non-marine taxa introduced by Sönmez-Gökçen (1973), (Middle to) Late Miocene is the best option. *Cypridopsis* ranges from the Oligocene to Recent (van Morkhoven 1963: 47). *Isomoenocypris* Sönmez, 1963 is regarded here as a junior synonym of the non-marine (mesohaline) genus *Amplocypris* Zalányi, 1944. *Amplocypris* has been described from fresh/brackish water (Middle to) Late Miocene deposits from Hungary, and represents age-diagnostic species in the Pannonian and Pontian (Sokač 1972: encl. 2; Krstić 1973: 92). Pokorný (1952: 142) stated that this generic name is invalid because no type-species had been designated. This problem has been cleared up by Swain in Benson et al. (1961: Q213), who designated *A. sinuosa* Zalányi, 1944 as the type-species. The marine Oligocene taxa are therefore interpreted as reworked into (Middle to) Late Miocene brackish water deposits.

Table 1 summarizes the palaeoecological and stratigraphical interpretation of the Miocene samples.

5. Conclusions

Ostracod faunas with age-diagnostic taxa indicating a Late Miocene (Khersonian to Maeotian) age are present in the Neogene of the area between lakes Büyükçekmece and Küçükçekmece, west of Istanbul. Most ostracod assemblages are suggestive of a brackish (mesohaline) water habitat, one to a freshwater to oligohaline, and another one to a freshwater to mesohaline environment. Two assemblages are interpreted as „mixed faunas". Oligocene marine ostracods are found reworked into Late Miocene non-marine (fresh- to brackish water) sediments. In northeastern Thrace close to the basin margin S of the İstranca Massif, at Akviran-İnceğiz, Çatalca, Pınarhisar and Poyralı, additional „mixed faunas" have been described in Turkish publications, but have not been specified as such. In these publications the ostracod assemblages are regarded as Oligocene, but the co-occurrence of taxa of differing ecological and stratigraphical distribution has not been addessed.

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Table 1: Palaeoecological and stratigraphical interpretation of the Miocene samples.

Sample(s)	Section	Salinity	Chronostratigraphy
Küçükçekmece 1	3.2	mesohaline	Khersonian – Maeotian
Küçükçekmece 2	3.2	mesohaline	Khersonian – Maeotian
Kalinoraburun	4.1	mesohaline	Late Khersonian – Maeotian
Ambarlıköy	4.2	mesohaline	Khersonian
Istanbul-Çekmece	4.3	freshwater to mesohaline	Late Bessarabian - Khersonian
Küçükçekmece, Hoşdere	4.4	freshwater to oligohaline	Late Miocene *
Küçükçekmece area	4.5	mesohaline	(Middle to) Late Miocene *

* with reworked Oligocene ostracod taxa

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