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Fresh and Brackish Water Ostracods of Upper Miocene Deposits, Arguvan/Malatya (Eastern Anatolia)

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Abstract: The Neogene Alibonca, Küseyin, Parçikan, Boyaca formations and the Mamaar volcanic unit occur at Arguvan (Malatya, Eastern Anatolia). Nine species of ostracods were identified and assigned to four genera in samples collected from the Küseyin and Parçikan formations. The faunal content in these units was characterized by few ostracod species and abundant individuals. Most samples contained fewer than nine species. *Ilyocypris bradyi*, *Ilyocypris gibba, Candona parallela pannonica* and *Heterocypris salina* are described in the Küseyin Formation. *Cyprideis pannonica, Cyprideis anatolica, Cyprideis torosa*, *Ilyocypris gibba, Candona angulata, Candona neglecta, Candona parallela pannonica* and *Heterocypris salina* are described in Parçikan Formation. *Cyprideis,* which has ecophenotypic ornamentations (smooth, punctuated, reticulated or nodes), is the dominant genus in the Parçikan Formation.

Lithological features and fossil contents of the Upper Miocene units suggest that the Küseyin Formation was deposited by a meandering river and the Parçikan Formation was formed in a shallow lacustrine environment associated with swamps.

The ostracod assemblages have been correlated with ostracod species of the Tethys and Paratethys regions. *Cyprideis pannonica* is observed in the Paratethys and Tethys bioprovinces. *Cyprideis torosa*, *Ilyocypris gibba, Ilyocypris bradyi*, *Heterocypris salina*, *Candona angulata, Candona neglecta* Sars are known in Europe and the Tethys bioprovince.

Key Words: Neogene, Eastern Anatolia, Ostracoda, freshwater, brackish water

Üst Miyosen Çökellerinin Tatlı ve Acısu Ostrakodları, Arguvan/Malatya (Doğu Anadolu)

Özet: Arguvan (Malatya, Doğu Anadolu) yöresinde Neojen birimleri Alibonca, Küseyin, Parçikan, Boyaca formasyonları ve Mamaar volkanik birimi ile temsil edilmektedir. Küseyin ve Parçikan formasyonlarından derlenen örneklerde ostrakodlardan dört cinse ait dokuz tür saptanmıştır. Bu birimlerin fauna içeriğini fert sayısı bol, tür sayısı az ostrakodlar oluşturmaktadır. Örneklerin çoğunda dokuz ostrakod türü daha az sayıda temsil edilmektedir. *Ilyocypris bradyi*, *Ilyocypris gibba, Candona parallela pannonica* and *Heterocypris salina* Küseyin Formasyonu'nda, *Cyprideis pannonica, Cyprideis anatolica, Cyprideis torosa*, *Ilyocypris gibba, Candona angulata, Candona neglecta, Candona parallela pannonica* and *Heterocypris salina* ise Parçikan Formasyonu'nda tanımlanmıştır. Ekofenotipik süslere (düz, noktalı, retiküllü ve nodlu) sahip *Cyprideis*'ler, Parçikan Formasyonu'nda baskın cins olarak gözlenmiştir.

Üst Miyosen birimlerinin litolojik özellikleri ve fosil içeriklerine göre, Küseyin Formasyonu menderesli akarsu ortamında, Parçikan Formasyonu ise bataklıkla ilişkili sığ göl ortamında depolanmıştır.

Ostrakod topluluğu, Tetis ve Paratetis ostrakodları ile karşılaştırılmıştır. İnceleme alanında, Paratetis ve Tetis bioprovenslerinde bilinen *Cyprideis pannonica*, Avrupa'da ve Tetis bioprovensinde bilinen ostrakodlardan *Cyprideis torosa*, *Ilyocypris gibba, Ilyocypris bradyi*, *Heterocypris salina*, *Candona angulata, Candona neglecta*'ın varlığı belirlenmiştir.

Introduction

Large Neogene basins formed in continental areas in the Eastern Mediterranean region (Figure 1). In Eastern Anatolia Neogene rocks are mainly characterized by fluvial and fluvio-lacustrine sediments alternating with several coal layers and associated with volcanic-volcaniclastic rocks. In addition, fresh to brackish water systems are widely distributed in Anatolia including the

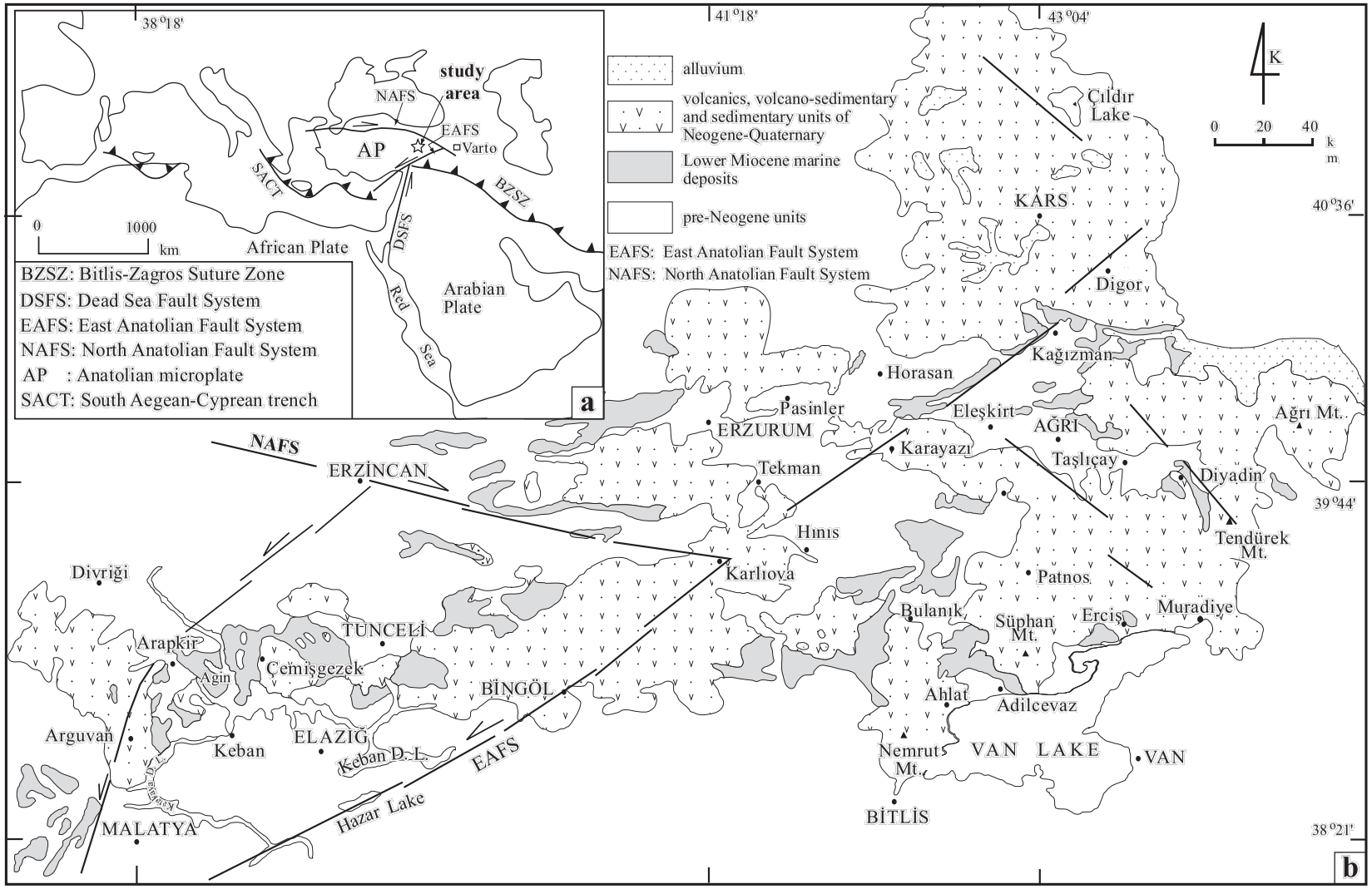

Figure 1. Simplified map showing major plates in the Eastern Mediterranean region and study area (a), and distribution of the Neogene-Quaternary units in eastern Turkey (b) (after Bilgiç 2002; Türkmen *et al.* 2007).

study area, located in the southern part of Arguvan (Malatya) in Eastern Anatolia (Figure 2). Several papers describe studies of fresh and brackish water ostracods from the Neogene of Turkey (Bassiouni 1979; Gökçen 1979a, b; Freels 1980; Şafak *et al*. 1992; Nazik *et al*. 1992, 2005; Tunoğlu 1984; Tunoğlu & Çelik 1995; Tunoğlu *et al*. 1995; Tunoğlu & Gökçen 1985, 1997; Ünal & Tunoğlu 1996; Tunoğlu & Ünal 2001a, b; Atay & Tunoğlu 2002; Witt 2003; Matzke-Karasz & Witt 2005). Detailed geological, petrographical, sedimentological research in this region has also been conducted (Şaroğlu & Güner 1981; Şaroğlu & Yılmaz 1984, 1986; Türkmen & Aksoy 1998; Ercan & Asutay 1993; Kürüm 1994; Alparslan & Terzioğlu 1996; Kürüm & Bingöl 1996; Sönmez 2004; Türkmen *et al*. 1998, 2004).

This paper aims to define fresh and brackish water ostracods from the Neogene in the Arguvan (Malatya) area in Eastern Anatolia and to correlate them with those in other Neogene basins in Turkey and Europe.

Material and Methods

In this investigation, 150 clastic samples were collected from three measured stratigraphic section. 100 grams of dry sediment was immersed in a 20% H_2O_2 (Hydrogen Peroxide) water solution, washed and passed through a 125 µm sieve and fossils were picked from the residue. Gastropods, gyrogonites and plant debris were found together with a well preserved ostracod fauna, found in the Küseyin and Parçikan formations.

Photographs were taken with a SEM (Jeol JSM-6400). The fossil material is housed in the Department of Geology, Faculty of Engineering & Architecture, Çukurova University in Adana, Turkey.

Geological Setting

The Neogene units in eastern Anatolia are represented by shallow marine, fluvial, and lacustrine sediments, coal seams and volcanic rocks, belonging to the Alibonca, Malatya volcanics, and the Küseyin, Parçikan and Boyaca formations (Figure 3). This sequence overlies the Permo–Triassic Keban metamorphic units.

The Alibonca Formation

This formation is characterized by reef core, reef front and lagoonal deposits including abundant Late Oligocene–Early Miocene benthic foraminifera around the Malatya area (Türkmen *et al*. 2004). The Küseyin Formation lies unconformably on the upper part of this unit outside the study area.

The Malatya Volcanics

This unit, named by Ercan & Asutay (1993), is composed of basalt and andesite in northern Arguvan and Arapgir. Its Early to Middle Miocene age has been established by radiometric data and its stratigraphic position (Türkmen *et al*. 2004).

The Küseyin Formation

This formation was defined by Önal (1995a, b). Its type-location is in Küseyin Village. Its sedimentolical features were studied by Türkmen *et al.* (2004, 2007). It is composed of red mudstone, overlain in turn by conglomerate and sandstone, and ís probably Late Miocene in age, according to stratigraphical relationship and ostracods (Türkmen *et al*. 2004). It is overlain by the Parçikan Formation in the study area.

The Parçikan Formation

It was named by Önal (1995a, b) and its sedimentological features were studied by Türkmen *et al*. (2004, 2007). The type-locality or location is close to Parçikan Village. This formation consists of fine, medium-grained sandstone, siltstone, organic-rich, grey-green claystone, marl, coal and clayey limestone levels (Figure 3). Ostracods, gastropods, gyrogonits and plant debris are abundant. Lignite deposits occur in both the lower and upper levels of the Parçikan Formation, which is Late Miocene in age, based on spore and pollen data (Türkmen *et al*. 2004) and ostracod assemblages. The Parçikan Formation is overlain by the Boyaca Formation.

The Boyaca Formation

This formation was described by Önal (1995a, b) and examined by (Türkmen *et al*. 2004, 2007). The type-locality is in Boyaca Village, within the study area. The Boyaca Formation is composed of reddish mudstone, silty mudstone, conglomerate and sandstone, deposited in a low-sinuosity river environment. Its Late Miocene age is based on its relationship with the underlying Parçikan Formation (Türkmen *et al*. 2004).

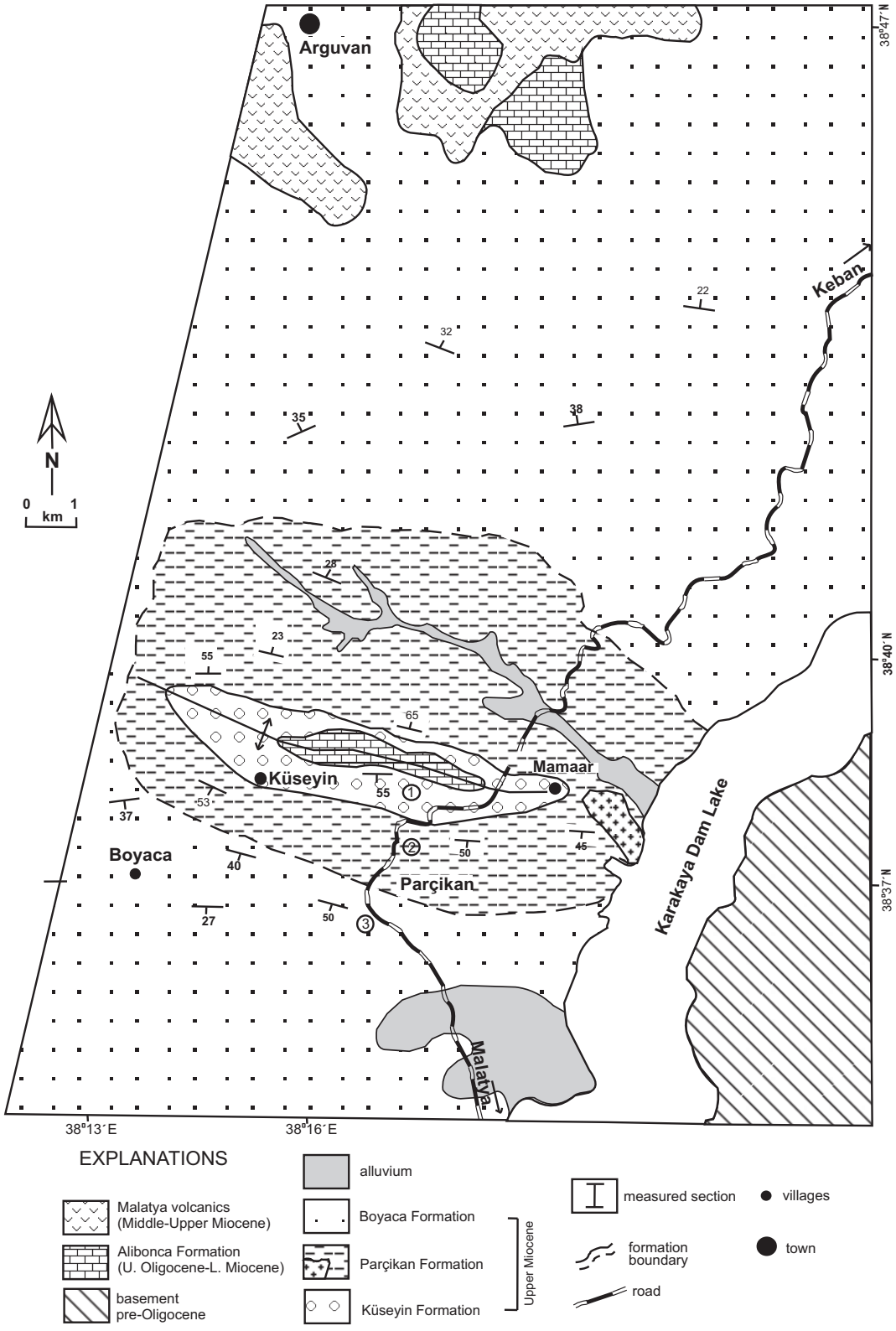

Figure 2. Simplified geological map of the study area (Türkmen *et al*. 2004), showing the locations of the sections in this study.

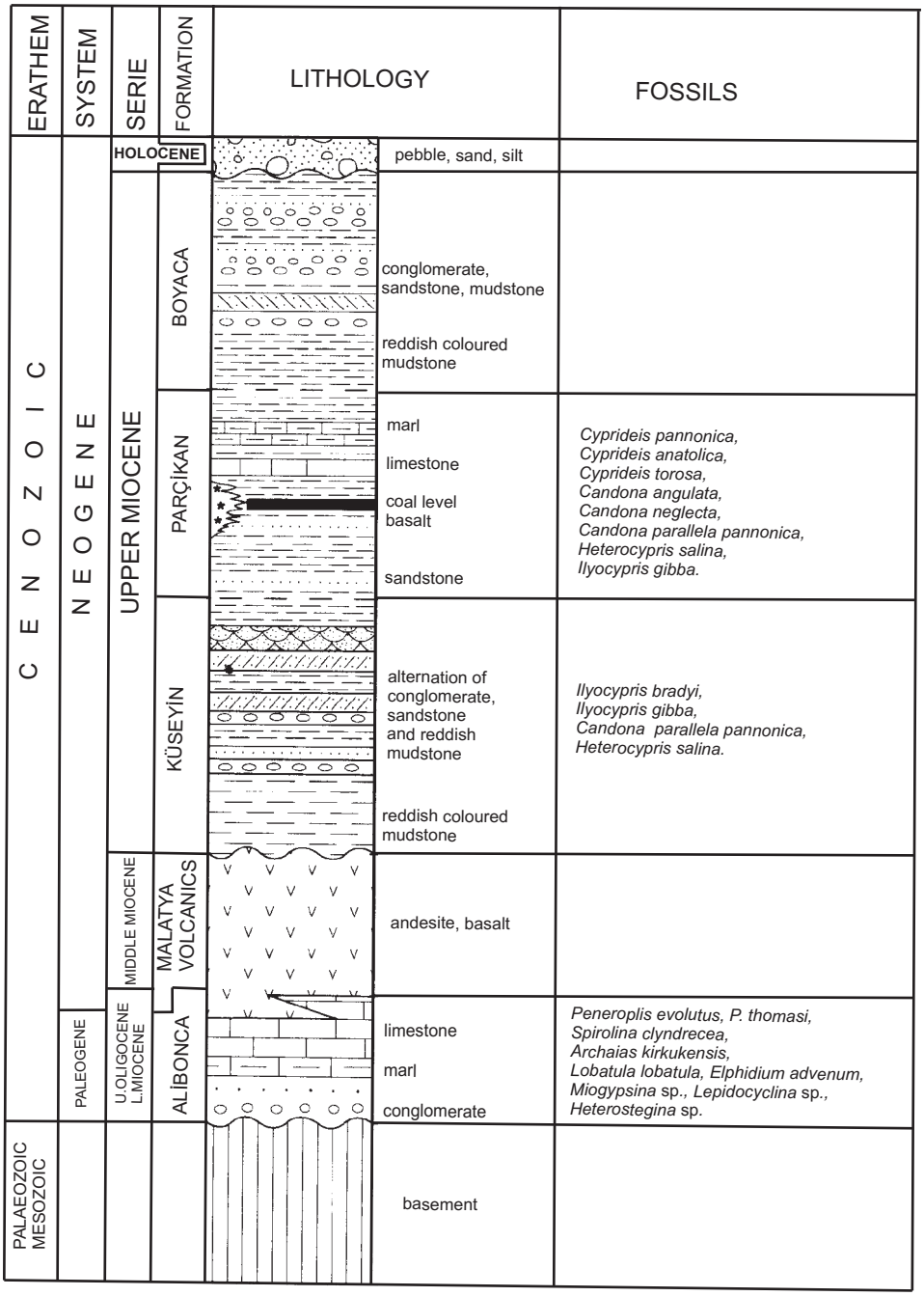

Figure 3. Generalized stratigraphic section of the Arguvan-Parçikan (Malatya) area (Türkmen *et al*. 2004).

Climatic and Tectonic Evolution in the Miocene of Eastern Anatolia

Miocene floral data indicate that climate in Turkey was warm subtropical in the Early Miocene, subtropical in the Middle Miocene and temperate in the Late Miocene (Akgün & Akyol 1992; Kayseri & Akgün 2006). The warm climatic conditions determined with the quantitative climatic values during the Late Miocene in Anatolia are defined by the widespread presence of *Ilex*, Fagacea and *Corylus* in Central Anatolia (Kayseri & Akgün 2006). In the Malatya Basin, the dominance of pollen from *Pinus*, *Quercus*, *Castanea*, *Cyrillaceae* and *Ulmus*, as

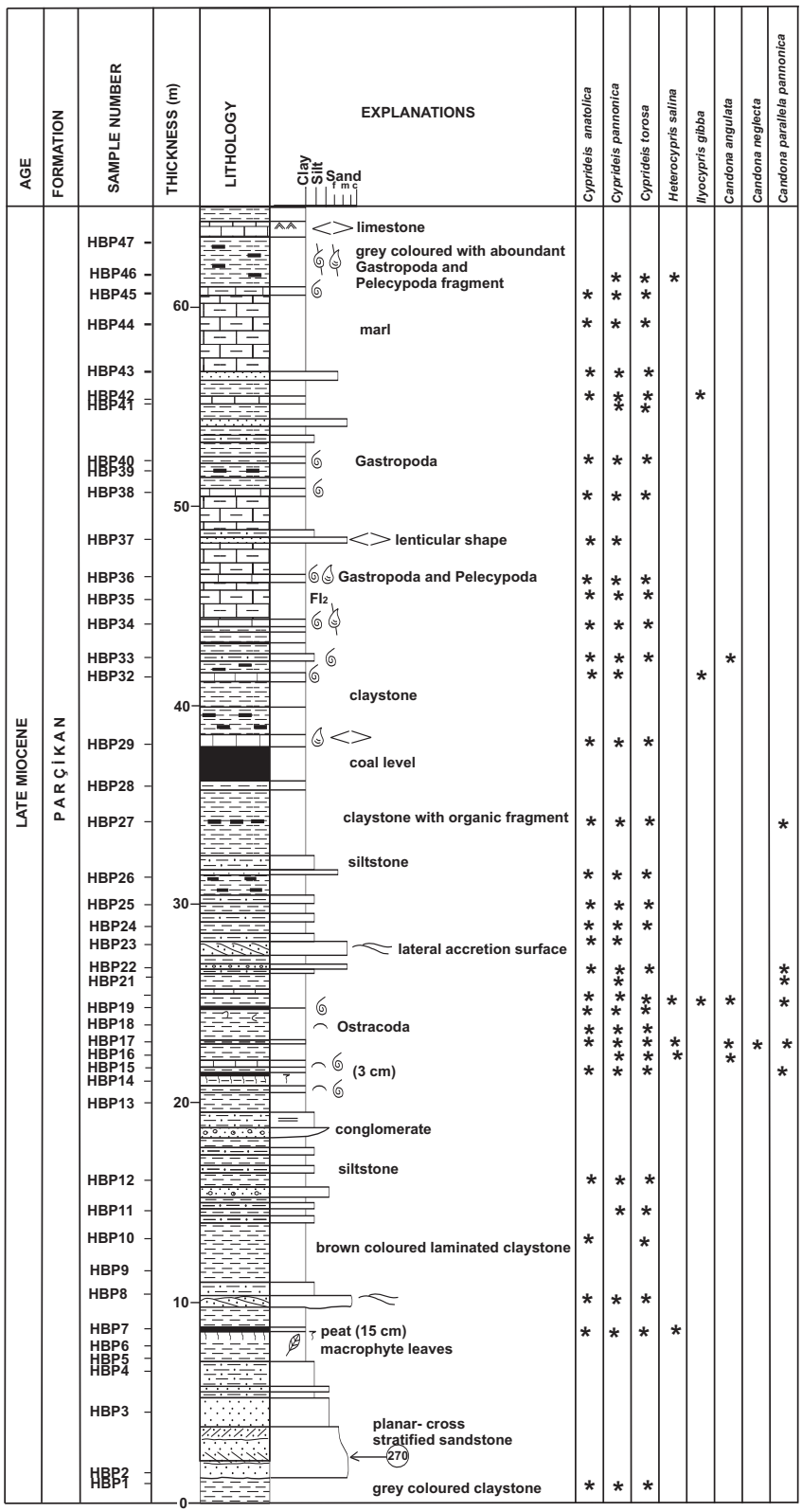

Figure 4. Measured stratigraphic section of the Parçikan Formation.

well as the presence of subtropical plant taxa, such as *Alnus*, *Carya*, and *Engelhardia*, suggest a subtropical (moist and hot) palaeoclimate in the Late Miocene (Türkmen *et al*. 2007).

The Tertiary marine regression was related to regional uplift following the closure of Neotethys and regional continent-continent collision in the Middle Miocene, marking the beginning of the Neotectonic period (Şengör 1980; Şengör & Yılmaz 1983; Jackson & McKenzie 1984; Dewey *et al*. 1986; Hempton 1987). Both strike-slip and extensional regimes alternated and coexisted in the Neogene period and, gave rise to a number of fault-controlled basins in Eastern Anatolia. Tectonic evolution during the Early Neogene in Eastern Turkey was largely controlled by the convergent and colliding Arabian and Anatolian plates. ENE–WSW-directed folds and thrust faults developed related to a NNW–SSE compressional regime. During the Oligocene–Early Miocene, shallow-marine carbonate and clastics were deposited in Eastern Turkey. Fluvial and lacustrine deposits accompanied by Middle Miocene volcanism filled E–W-trending intramontane basins, related to N–S extension (Aksoy *et al*. 1996, 2005). Alluvial and lacustrine facies associations mostly developed in the fault-bounded basin in Eastern Anatolia.

Thick alluvial and lacustrine facies were deposited during the Late Miocene in the Malatya Basin, in Eastern Turkey, which is an NE–SW-oriented graben, developed in an extensional setting in the Middle to Late Miocene. Facies distributions in such basins are mainly controlled by tectonics, climate, hinterland characteristics, base level-changes and sediment supply (Nichols & Watchorn 1998; Bohacs *et al*. 2000; Nichols & Uttamo 2005).

Similar architectural styles observed in the alluvial and lacustrine units were interpreted as a tectonic signature likely to characterize high-accommodation basins that subsided rapidly along the basin bounding faults (Davies & Gibling 2003). The Malatya basin-fill characteristics and the regional tectonics indicate that the alluvial and lacustrine facies associations were developed in response to regional extension related to strike-slip movement of the Malatya Fault Zone in a subtropical climate.

Non-marine Ostracod Faunas of the Arguvan/Malatya (Eastern Anatolia) and Their Correlations With Other Neogene Basins of Tethys and Paratethys

Published data by Van Morkhoven (1963), Krstic (1968), Kilenyi (1972), Hartmann & Puri (1974), Bassiouni (1979), Gökçen (1979a), Freels (1980), Nazik *et al*. (1992), Şafak *et al*. (1992), Tunoğlu & Çelik (1995), Şafak (1997a, b), van Harten (2000), Tunoğlu & Ünal (2001a), Witt (2003), Atay & Tunoğlu (2004), Keyser (2005) were used for identification of ostracod taxa. Nine species belonging to four genera were described from 150 rock samples. A low diversity fauna was recorded in the Parçikan and Küseyin sections in which *Cyprideis* is the dominant genus. The ostracod assemblage is supposed to be *in situ* due to the presence both of well preserved juvenile specimens and adult carapaces.

Ilyocypris bradyi (Sars), *Ilyocypris gibba* (Ramdohr), *Candona parallela pannonica* (Zalanyi) and *Heterocypris salina* (Brady) are found in the two of nine samples collected from the Küseyin Formation. *Cyprideis pannonica* (Mehes), *Cyprideis anatolica* Bassiouni, *Cyprideis torosa* (Jones), *Ilyocypris gibba* (Ramdohr), *Candona angulata* Mueller, *Candona neglecta* Sars, *Candona parallela pannonica* (Zalanyi) and *Heterocypris salina* (Brady), characean gyrogonites and gastropod shells were identified in the Parçikan Formation (Figures 4 & 5, Plate I).

C. pannonica, *C. anatolica* and *Cyprideis torosa* were consistently common throughout the Parçikan section. *H. salina* was present at 8 m, between 21 to 25 m and 64 m in the claystone level of the Parçikan section. *Candona* species were found between 21 to 34 m of the Parçikan section (Figure 4). *H. salina*, *I. bradyi*, *I. gibba* and *C. parallela pannonica* were determined in the marl and claystone levels of the Küseyin Section. The smooth and noded *C. torosa* specimens were found together with *Heterocypris*, *Ilyocypris* and *Candona* at different levels of Parçikan Section.

Bassiouni (1979), Gökçen (1979a, b, 1982), Freels (1980), Tunoğlu (1984), Tunoğlu & Çelik (1995), Tunoğlu *et al*. (1995), Tunoğlu & Gökçen (1985, 1997), Şafak *et al*. (1992), Nazik *et al*. (1992), Tunoğlu & Ünal

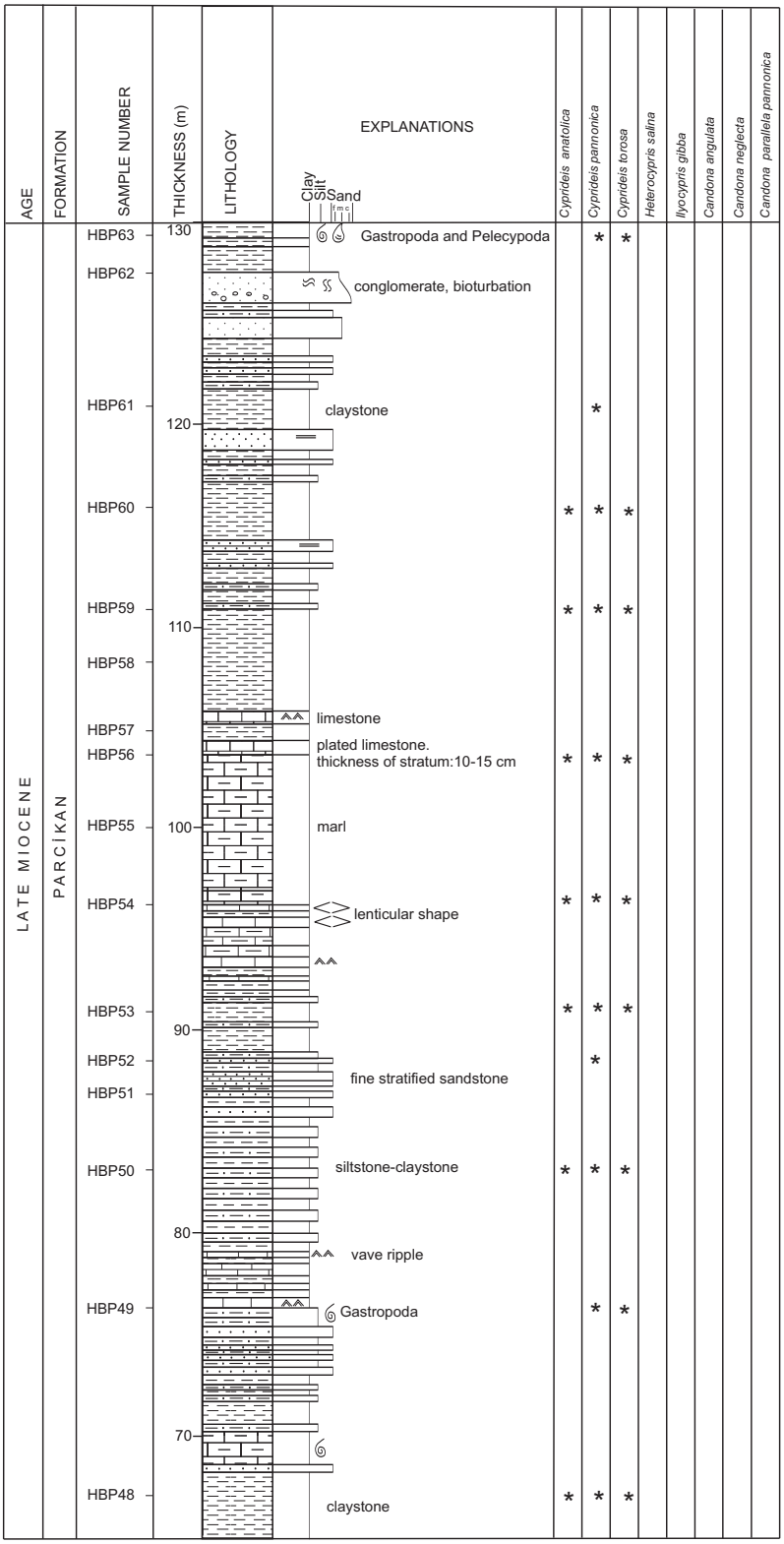

Figure 5. Continuation of the measured stratigraphic section of the Parçikan Formation.

(2001a, b), Atay & Tunoğlu (2002), Witt (2003), Matzke-Karasz & Witt (2005) studied fresh and brackish water ostracods from the Neogene of Turkey. Bassiouni (1979) investigated brackish and marine ostracods from the Neogene in different areas of Turkey, but, as he gave only general information about non-marine ostracods in the Malatya area, non-marine ostracods of the Arguvan district (Malatya) were studied in this project. Biostratigraphic subdivision of the Late Miocene has not been established in the study area, but the chronostratigraphic approach was carried out using ostracod studies of Tethys and Paratethys and palynological data. *C. neglecta, C. torosa*, *I. bradyi*, *I. gibba, H. salina* are recorded from the Miocene to the Recent.

The first appearance of *Cyprideis* was pointed out in the Upper Volhynian in Eastern Paratethys, and the Sarmatian in the Central Paratethys region (Carbonnel & Jiricek 1977; Jiricek 1983). The first *Cyprideis* level was recognized in Middle Tortonian brackish water deposits in Crete of the Eastern Mediterranean by Sissingh (1974). Also, *C. pannonica* was described in zone NO-15 and NO-16 (Lower Pannonian) of the Paratethys (Jiricek 1983; Jiricek & Riha 1991). In addition, this species was found in the Upper Miocene of the Lago Mare environment in the Eastern Mediterranean (Spezzaferri *et al.* 1998). Other occurences are recorded in the: (i) Lower Pannonian of the Vienna Basin (Kollmann 1960), (Jiricek & Riha 1990), (ii) Upper Miocene of Italy (Decima 1962), (iii) Upper Miocene (Messinian) of the Mediterranean (Carbonnel 1978), (iv) Upper Miocene of Marmara, Southwest and Middle Anatolia, Turkey (Bassiouni 1979), (v) Pannonian–Pontian of the Bakırköy, İstanbul, Turkey (Şafak 1997b), and (vi) Pannonian–Pontian of the Gelibolu Peninsula, Turkey (Ünal & Tunoğlu 1996; Tunoğlu & Ünal 2001a, b; Atay & Tunoğlu 2002).

The first appearance of *C. torosa* was in the Late Miocene and its stratigraphical range is Miocene to Recent. Its general distribution is widespread throughout the brackish coastal waters of Europe, Western and Central Asia, the Mediterranean region of North Africa, the Middle East and North America and lakes in the Central Africa (van Harten 2000; Meisch 2000). The *C. torosa* Zone has been correlated with NP-20 of Blow (1969) in the Piacenzian and NO-14 of Central Paratethys in the Romanian by Jiricek (1983). A I-*Cyprideis pannonica* and *Cyprideis torosa* assemblage Zone is described from the Early Pannonian in the Gelibolu Peninsula (NW Turkey) by Tunoğlu & Ünal (2001a). Other Neogene occurences are in the: (i) Messinian of Italy (Decima 1962); (ii) Neogene of the Rhone Basin (Carbonnel 1969), (iii) Pliocene of various areas of Turkey (Bassiouni 1979), (iv) Pliocene of southern Aegean Islands (Sissingh 1974), (v) Pannonian–Pontian of Bakırköy, İstanbul, Turkey (Şafak 1997b), (vi) Pannonian–Pontian of the Gelibolu Peninsula, Turkey (Tunoğlu & Ünal 2001a, b; Atay & Tunoğlu 2002), and (vis) Pannonian to Pleistocene of NW Anatolia (Matzke-Karasz &Witt 2005) .

The Late Miocene to Recent *H. salina* is common in the slightly brackish waters along the coasts of the North and Baltic Seas (Meisch 2000). This species is found in the Middle Miocene of Serbia (Krstic 1972), in the Upper Miocene of SW Anatolia (Freels 1980), in the Upper Miocene in Slovakia (Pipik 2001), in the Upper Miocene–Lower Pliocene of Western Anatolia (Witt 2003), and in the Pannonian–Pleistocene of NW Anatolia (Matzke-Karasz &Witt 2005).

A fossil record of *I. gibba* is found in the Upper Miocene of France (Carbonnel 1969), in the Lower Miocene and Pliocene of Central Anatolia (Tunoğlu & Çelik 1995; Tunoğlu *et al.* 1995) and in the Pannonian of Slovakia (Pipik 1998). Its general distribution is Europe, Africa, the Middle East, Central Asia, China, and both North and South America (Meisch 2000).

I. bradyi ranges from Miocene to Recent (Meisch 2000) and is distributed across Europe, North Africa, the Middle East, central Asia, China and North America.

C. neglecta ranges from Upper Miocene to Recent. It is found in the Upper Miocene of France (Carbonnel 1969), in the Pliocene of the Eastern Taurides (Şafak *et al.* 1992) and Central Anatolia (Tunoğlu *et al.* 1995). Its general distribution is across Europe, North Africa, Asia, and North America (Meisch 2000).

Meisch (2000) claimed that *C. angulata* ranges from the Lower Pleistocene to Recent, but it has also been found in the Upper Miocene in Bulgaria (Stancheva 1963, 1990) as well as the Pliocene to Lower Pleistocene (Gurnet *et al.* 1976).

C. parallela pannonica is known from the Upper Pannonian of Hungary (Zalanyi 1959), the Tortonian of Trebon Basin (Kheil 1964) and the Pontian to Holocene of Turkey (Gökçen 1979a, b; Nazik *et al.* 1992; Şafak *et*

al. 1992, 1999; Tunoğlu *et al*. 1997; Tunoğlu & Ünal 2001a, b).

C. anatolica was firstly described in the Pliocene of Turkey by Bassiouni (1979). It has since been found in the Upper Miocene–Pliocene sequence of the Antakya Basin (Şafak 1993), Pannonian–Pontian of Bakırköy, İstanbul (Şafak 1997b) and Upper Miocene of Hatay (Parlak *et al*. 1998) in Turkey, but remains only known in Turkey.

Results

Ostracod faunas of the 150 samples from the Küseyin and the Parçikan formations have been studied and nine species were found. Ostracod assemblages have been succesfully applied to the interpretation of different depositional sequences. Size, shape and ornament of individual ostracod shell are important indicators of palaeoenvironmental condition (Boomer *et al*. 2003). Nodose *Cyprideis* occur at different levels of the Parçikan Formation. Modern *Cyprideis torosa* develop phenotypic tubercles on one or both valves when moving to less saline environments (Van Morkhoven 1963; Keyser 2005). These nodes of *Cyprideis torosa* only occur at water salinities of about 2–5‰ (Boomer *et al*. 2003). Keyser (2005) stated that nodose ostracods can be used as an environmental marker for low salinity and/or low calcium content. Bassiouni (1979) stated that 'the rarity or the complete absence of the noded *Cyprideis* morphotype in the Upper Miocene may prove at least temporal dry climatic conditions which led to meso- to pliohaline-water salinity'. Nodose ostracods reflect that there was a decrease in salinity and an increase in organic matter in their environment (Rundic 2001). *Cyprideis torosa* tolerated a wide salinity range (1‰ to more than 40‰), although the presence of *Ilyocypris* at some levels of the studied formation suggests that salinities never exceeded about 5‰ (oligohaline). *I. gibba* is found in small and shallow permanent water bodies with clayey, fine-mudded or sandy substrate and *I. bradyi* lived in both muddy and sandy substrates (Meisch 2000). *C. neglecta* is reported from slightly salty inland and coastal waters within a salinity range of 0.5–16‰ (Meisch 2000) and generally with muddy substrates (Besonen 1997). *C. angulata* clearly prefers slightly salty waters (Meisch 2000).

The Parçikan Formation has mainly clays and muds with intercalations of silty and sandy material and lignite seams. Gastropods were often abundant enough to form shelly beds. In conclusion, ostracod faunas of the Parçikan Formation and its lithological properties indicate mainly brackish and occasionally fresh water conditions in the study area. *Cyprideis torosa*, *Ilyocypris gibba*, *Ilyocypris bradyi*, *Heterocypris salina*, *Candona angulata* and *Candona neglecta* are the cosmoplitan species in Europe and Tethys bioprovince. As *Cyprideis pannonica* and *C. parallela pannonica* Paratethyan ostracod are found in the Malatya-Arguvan region of eastern Anatolia. Tethyan and Paratethyan ostracods are found in the region.

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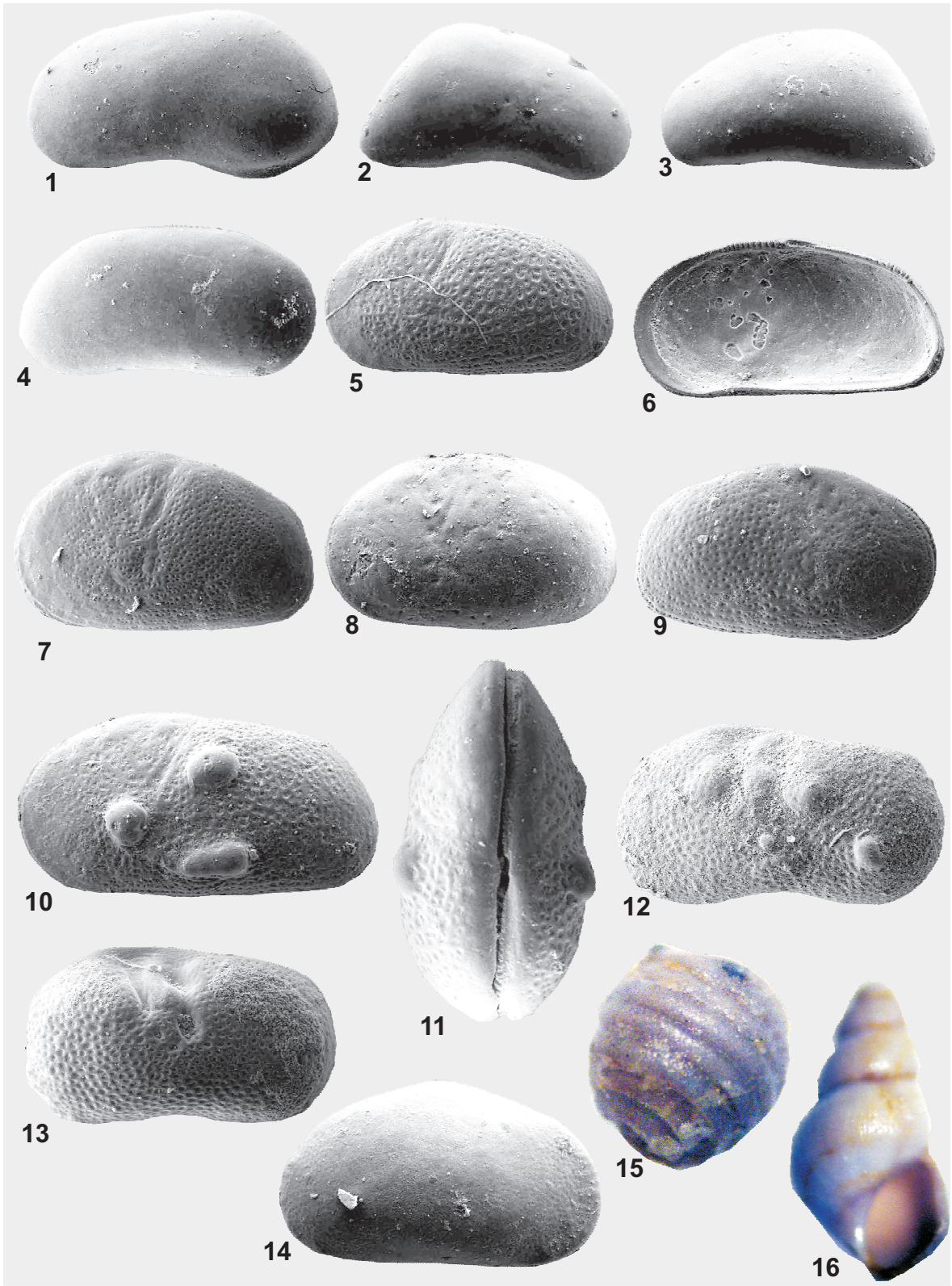
Plate I. Ostracods of the Neogene in the study area.

1. *Candona neglecta* Sars, outside view of left valve, X50. 2–3. *Candona angulata* Mueller.
2. Outside view of the right valve, X 45.
3. Outside view of left valve, X 45, HBP-17, Parçikan Formation.
4. *Candona parallela pannonica* (Zalanyi), outside view of right valve, X 80, HBP-17, Parçikan Formation.
5–6. *Cyprideis torosa* (Jones), 5. Outside view of left valve, X 56, 6. Inside view of the right valve, X63, HBP-25, Parçikan Formation.
7. *Cyprideis anatolica* Bassiouni, outside view of right valve, X85, HBP-25, Parçikan Formation.
8–9. *Cyprideis pannonica* (Mehes), 8. Outside view of left valve, X65, 9. Outside view of right valve, X68, HBP-17, Parçikan Formation.
10–11. *Cyprideis torosa* (Jones) with nodes, 10. Outside view of left valve, X85, 11. Dorsal view, X80, HBP-25, Parçikan Formation.
12. *Ilyocypris gibba* (Ramdohr), outside view of left valve, X83, HBP-32, Parçikan Formation.
13. *Ilyocypris bradyi* (Sars), outside view of left valve, X83, HK-7, Küseyin Formation.
14. *Heterocypris salina* (Brady), outside view of left valve, X80, HBP-17, Parçikan Formation.
15. Characean gyrogonites, X35, HBP-42, Parçikan Formation. 16. Gastropoda, X20, HBP-16, Parçikan Formation.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