Ostracoda Assemblages and Palaeoenvironmental Characteristics of the Soma Formation (Late Miocene-Pliocene), İvrindi - NW Balıkesir, Turkey

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Abstract. In the present study, a non-marine ostracods assemblage was defined from the Upper Miocene-Pliocene Soma Formation cropping out İvrindi (NW Balıkesir). The Soma Formation composed mainly of clayey limestone, marl, tuffite, sandstone and conglomerate in the study area. Fourteen of 22 samples collected from the measured section have ostracod fossils and six species belonging to five genera have been identified in the area. These ostracod species are Cyprideis torosa, Cyprideis pannonica, Heterocypris salina, Heterocypris sp, Ilyocypris sp and Limnocythere sp. In general, species richness, diversity and preservation of the ostracod assemblages were poor throughout the section. The brackish water species Cyprideis were dominantly found at the lower level of the section, while Ilyocypris species, which generally survive in river mouths and can also live in oligohaline environments as well as slightly brackish water, was detected at the middle and upper levels of the section. These fossil assemblages suggest that in the study area, the bottom sequences of the Soma Formation were deposited under brackish water environment and changed to limnic condition at the upper levels during late Miocene-Pliocene.

1. Introduction

The study area is located in the İvrindi district of Balıkesir Province in the north-western Turkey (figure 1A). In the Northwest Anatolia, at the end of Cretaceous, the northern part of the Neo Tethys subducted beneath the Sakarya continent due to the collision of the African continent with the European continent. Because of this subduction, the Taurid-Anatolid platform collided with the Sakarya continent, and İzmir-Ankara-Erzincan suture zone was formed. The study area was exposed to intense tectonic events until the end of Tertiary and corresponds to the destruction zone of the Manisa-Balıkesir-Eskişehir line in the Late Cretaceous.

The study area and close region has become the subject of many researchers, due to the reasons mentioned above. For this reason, the study area is an important key to understand the geotectonic evolution of the region. Some of these studies: [1-9].
The purpose of the present study is to determine the age, ostracod content and palaeoecological characteristics of the Soma Formation, which is formed by the Neogene lacustrine sediments.

2. Stratigraphic Framework

The study area located between the Biga Peninsula and the Menderes massif in the south of the Marmara Sea, and consists of many rock units ranging from Paleozoic to Quaternary (Figure 1B). The stratigraphic division made by [8] was constructed based mainly on the stratigraphy of the geological units of the study area (Figure 2).

The study area is bounded by metamorphic rocks to the north and south [1]. Tertiary units are unconformably overlying the basement rocks (Figure 2). According to [8], the Middle Eocene aged Edincik Formation and Beyçayıri volcanites composed of andesitic lava and pyroclastic rocks are found in the bottom of the Tertiary sequence. These units are unconformably overlain by the conglomerate, sandstone and mudstone units of the Middle Eocene Fiçtepe formation. The Middle Eocene units are unconformably overlain by basaltic lava, pyroclastic, volcanoclastic and basaltic dykes of the Şahinli Formation. The Şahinli Formation was unconformably overlain by the reefal Soğucak Formation which was covered by the late Eocene- Ceylan Dededağ Volkanites. This sequence consists of marine ignimbrite, andesite and dacite. The Beybaşlı formation is represented by marl-mudstone-limestone alternation and unconformably overlain by Erdağ Volkanites. In the study area, the Oligocene sediments begin unconformably over the Eocene. The Oligocene unit was represented by granitoids of Biga peninsula. Miocene aged sediments, which commonly occur in the study area, begin with the early Miocene Küçükkuşuyu Formation consisting of conglomerate, sandstone, limestone, bituminous shale and tuff. These sediments are unconformably on the Oligocene units. The Early-Middle Miocene Çan Formation and the Middle Miocene Soma Formation were transitionally deposited with each other in the study area. These units appear to be transitional with middle Miocene volcanics. The İlyasbaşı Formation was deposited in the early periods of the late Miocene and unconformably overlain by the middle Miocene sediments. The İlyasbaşı Formation is covered unconformably by the Gazhandere formation. The Kirazlı-Çamrakdere-Alçitepe formations were deposited transitional with each other in the middle-late Miocene time and these formations are composed of sandstone-siltstone; marl, mudstone-siltstone-sandstone; limestone-marl units. [8] suggested that Taştepe basalts formed in the late Miocene and the Gülpinar formation consisting of fossil-bearing clayey limestone was unconformably overlain by the Taştepe basalts. At the top of the
study area are Plio-Quaternary Bayramiç Formation (conglomerate-sandstone, mudstone) and Quaternary alluvial units.

![Stratigraphic section of the study area](image)

**Figure 2. Generalized stratigraphic section of the study area (from [8])**

### 3. Soma Formation and İvrindi Section

The Soma Formation was first identified by [1]. The Soma Formation is represented by clayey limestone, claystone, marl, tuffite, sandstone and conglomerate in the study area. The sequence was white, yellow and grey coloured and the layers vary in thickness. The units are generally horizontally stratified, but they also show somewhat inclined or an overturned fold structure. Some levels of clay and carbonates exhibit a laminated structure. The tuffites are partly kaolinized. Although the Soma Formation is characterized by coaly bituminous shale in various places (i.e. Soma Basin), there are no signs of coal and charring in the study area. The thickness of the Soma Formation varies between 50-400 m in the Balıkesir [2].

The Soma Formation is rich in spores, pollen, ostracods, gastropods, fish, leaves and vertebrate bone fossils. Previous studies focusing on spores and pollen analyses suggested similar ages for the Soma Formation for instance [10] suggested the middle Miocene-Pliocene and [11] reported the Late Miocene on the other hand, based on plant and fish fossils [1] and [2] suggested the Late Miocene for the age of the Soma Formation.

The İvrindi section was measured at the 117 paces of 1:25,000 scale topographic maps with initial coordinates of 35 S 542108E and 43 82630N. The section was 23 metres in thickness (figure 3). The bottom level of the section starts with clayey limestone, and it continues with the alternation of siltstone and clayey marl units. The first six-meter part of the section composes of yellowish-white siltstone-clayey and clayey limestone layers alternations. These sequences include bivalve shells in some parts of the section. After these fossil-bearing levels, the fine-grained sandstone layers bearing claystone laminations were observed in the section and continued until the eight metres of the section. 22 micropaleontological samples were collected from these levels. The section continued with 4 metres-thick clay laminations bearing a cross-bedded sandstone level. The sandstone units have wave-ripple marks (figure 4A) and are overlain by clayey stromatolitic limestone (figure 4B-C). These stromatolitic levels include tuffite bands, as well as trace fossiliferous levels and silica ovules (figure 4D-E). The sandstone unit (after the 14 meters) continues with fine-bedded limestone and clayey limestone units. Also, siltstone and tuffite bands were observed at these levels, and after 23 meters of the section, it was overlain by the alluvium.
Figure 3. İvrindi stratigraphical measured section

Figure 4. Stratigraphic structures observed in Soma Formation: A. Planar parallel, wave-wise diagonal, eccentric cross-bedded sandstone. B. Lens-shaped Stromatolitic Limestone  C. Planar parallel-bedded fossiliferous limestone. D. Silica ovules seen in limestones. E. Fossiliferous limestone
4. The Ostracod Assemblages of the İvrindi Measurement Section

In order to determine the ostracod content of the section, 22 samples were collected from the area. Nine of them contained ostracod fossil. The studies such as [12], [13], [14], [15], [16], [17] and [18] were used for the fossil description and systematization of this work. The samples taken from the lower levels of the İvrindi section had abundant ostracod species. The valve/carapace ratio of these levels was rather low, and relatively abundant in number of individuals. In the upper levels of the section, the samples were either sterile or had low number of fossil.

The distributions and abundances of Ostracod species of the section are given in figure 5 and the SEM illustrations of the ostracods are given in figure 6. The stratigraphic and geographical spreads of the ostracod species are summarized below:

![Figure 5. Distribution and frequency of ostracods on the section](image-url)
Cyprideis pannonica (Mehes)
Figure 6a-b-c

Material: 34 valves, 1 carapace
Stratigraphical and Geographical Distribution: Kilitbahir (Çanakkale): Middle-Late Pannonian [19]; West Bakirkoy (Istanbul): Pliocene [20]; Malatya, Bala: Late Miocene [21]; Gelibolu Peninsula: Early-Late Pannonian-Ponsian [22]; Belgrade (Yugoslavia): Late Pannonian [23]; Lyon (France): Messinian [24]; Vienna Business (Australia): Early Pannonian [25]; Italy: Late Miocene [26]; Malatya: Late Miocene [16]

Stratigraphic level and age in this work: Sample number I-4, I-8, I-9, I-12, I-14, I-21, I-24. Late Miocene-Pliocene

Cyprideis torosa (Jones)
Figure 6d

Material: 13 valves, 9 carapaces
Stratigraphic and Geographical Distribution: Gelibolu Peninsula: Early-Late Pannonian (Ponsiyen) [22]; Eskisehir: Pliocene-Pleistocene [21]; Adana: Pliocene [28]; Italy: Messinian [26]; Guadalquivir Basili (Southern Spain): Messinian [29]; Yugoslavia: Pleistocene [23]; Africa: Miocene, Pliocene and Pleistocene-Recent [15]; Malatya: Late Miocene [16].

Stratigraphic Level and age in the Study: Sample number I-4; I-6, I-7, I-8, I-12, I-14; I-21. Late Miocene-Pliocene.

Ilyocypris sp (Ramdohr)

Material: 6 valves

Stratigraphic Level and age in the Study: Sample number I-14, I-21, I-24; Late Miocene-Pliocene

Heterocypris salina (Brady)
Figure 6g-h

Material: 16 valves
Stratigraphic and Geographical Distribution: Acıgöl-Hırkaköy: Late Miocene [14]; Ilgın (Konya): Early Pliocene [30]; Tufanbeyli (Adana): Pliocene [31]; Develiköy / Manisa: Early Pliocene [32]; Yalova: Neogene [33]; Spain, Azores, Canary Islands, Cape Verde Islands: Recent [34]; Magre River: Recent [35]; Malatya: Late Miocene [16].

Stratigraphic level and age in this study: Sample number I-6, I-7, I-8, I-11, I-12. Late Miocene-Pliocene

Heterocypris sp
Figure 6f

Material: 6 valves l carapace

Stratigraphic level and age in this work: Sample number I-4, I-6, I-8, I-11, I-12, I-14. Late Miocene-Pliocene.

Limnocythere sp.
Şekil6e

Material: 5 valves

Stratigraphic Level and age of the Work: Sample number I-14, I-21. Late Miocene-Pliocene.
Figure 6. Scanning Electron Microscope (SEM) images of the Ostracods

a. *Cyprideis pannonica* (Mehes) (sample no I-6 right valve, external view), b. *Cyprideis pannonica* (Mehes) (sample no I-6, left valve, external view), c. *Cyprideis pannonica* (Mehes) (sample no I-24; left valve, external view), d. *Cyprideis torosa* (Jones) (sample no I-4; left valve, external view), e. *Limnocythere* sp (sample no I-63; right valve, external view), f. *Heterocypris* sp (sample no I-4; right valve, external view), g. *Heterocypris salina* (Brady) (sample no I-11; right valve, external view), h. *Heterocypris salina* (Brady) (sample no I-11; right valve, external view).

5. Paleoenvironmental interpretation and age

Micropaleontological studies showed that the species belonging to genus *Cyprideis* dominated within the ostracod fauna compared to other species. *Cyprideis* species are generally euryhaline species that live in shallow waters [13].

*Cyprideis torosa* is one of the most common ostracod species known in Europe, Asia, Mediterranean, North America and Africa. They live in the paralic realm (e.g. delta, lagoon) and brackish-coastal facies (Figure 7A). [34] reported that *C. torosa* is at the top of the food chain and is tolerant to water temperature changes (eurythermics). They can also live in shallow, brackish water environments where organic particles are abundant. Nodes and tubercles on *C. torosa* are frequently used in paleoenvironmental reconstruction studies. It was determined that *Cyprideis torosa* had nodes in the study area. [16] emphasized that these nodes may be related to the water salinity was less than 5 ‰.

*Cyprideis torosa* and *C. pannonica* were dominant species in the throughout the section. *C. pannonica* represents the late Sarmatian-early Pannonian Zones of the Central Paratethys [25]. *Cyprideis torosa* is a cosmopolitan species that reflects both the Tethys and Paratethys Provence, although *C. pannonica* represented only Paratethys Provence.

*Heterocypris salina* can live in almost all fresh water environments (Figure 7A). [15] reported that this species is present in small and slightly saline water with other halophilic ostracods, however it...
was also suggested that *H. salina* cannot be proposed as a characteristic fossil for a saline environment unless it is present with other forms representing this environment.

*Ilyocypris* species prefers generally low salinity permanent shallow water environments (Figure 7A). They are good swimmers and found in clay, fine muddy or sandy bases [12]; [15].

The genus *Limnocythere* represents mostly freshwater environments, but according to [15], some species of this genus can also live in slightly saline continental waters (Figure 7A).

As a result, considering the habitat represented by *Cyprideis* species, it can be said that the environment was brackish in the basal part of the section where the *Cyprideis* species were abundantly found. On the other hand, the ostracod species such as *Ilyocypris, Limnocythere* which represent freshwater environments were found at the middle and upper levels of the section. This indicates that the environment changed from euryhalin to oligohaline.

Considering the stratigraphic distribution (Figure 7B) of ostracods in the study area, species such as *Cyprideis torosa* and *Heterocypris salina* are known from early Miocene. However, the first appearance of *Cyprideis pannonica* is the Late Miocene, the last appearance of this species is early Pleistocene. Therefore, it can be suggested that the age of Soma Formation is Late Miocene-Pliocene.

6. Conclusions
The Soma Formation composed of clay limestone, claystone, marl, siltstone, tuffite, sandstone and conglomerate in a large part of the study area. The Soma Formation also includes coal and bituminous shale levels in various places (within the Soma Basin), however, there are no coal bands in the study area.

In previous studies, Soma Formation was aged as Late Miocene-Pliocene [1], Middle Miocene [10] Vindobonian [37] and Mid-Late Miocene [11]. Both the stratigraphic position of the Soma Formation and the ostracods defined in this study indicate that the formation deposited in the Late Miocene-Pliocene.
The predominant group of defined ostracods (*Cyprideis* species) was found in the lower levels in large numbers and they generally represent the brackish environment. The species such as *Ilyocypris* and *Limnocytere*, which live in the fresh water environment, show that the environment has changed from euryhaline to oligohaline condition at the middle- and upper levels of the İvrindi section.

Considering the stratigraphic distribution of the ostracods identified in the study area, it can be said that the species reflect both the Tethys and Paratethys provinces, which are observed on the Mediterranean coasts of Europe, West and Central Asia and North Africa.

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