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OSTRACOD FAUNA AND ENVIRONMENTAL CHARACTERISTICS OF KÖPRÜKÖY / ERZURUM (EAST ANATOLIA) REGION

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Research Article

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ABSTRACT

The study was carried out within the Horasan Formation around Köprüköy located east of Erzurum. This formation outcrops in the region of Erzurum-Pasinler-Horasan forming the northernmost outcrop of neo-tectonic sediments in Eastern Anatolia. The unit is composed of pebble stones, clays and marl iterations. Ostracod, gastropod and pelecypod species are observed in the levels of clay stone with soft clasts and marl in the area. Generally, ostracod species which are unique to the Ponto-Caspian basin were described in these units within the scope of the study. These are ostracod species such as *Amnicythere idonea* Mandelstam, Markova, Rozyeva and Stepanajtys, *Candona (Caspiocypris) erzurumensis* Freels, *Candona* (*Caspiocypris*) *araxica* Freels, *Candona* (*Caspiocypris)* aff. *alta* (Zalanyi), *Candona (Lineocypris)* aff. *granulosa* Zalanyi, *Bakunella* cf. *dorsoarcuata* (Zalanyi), *Bakunella* cf. *subtriangularis* (Sveyer), *Candona* (*Candona*) *lycica* Freels, *Candona* (*Candona*) *armenia* Freels, *Candona* (*Candona*) aff. *elongata* (Svejer), and *Fossilyocypris sarızensis* (Şafak, Nazik and Şenol). There are also micro mollusk species such as *Gyraulus inornatus* and *Dreissena polymorpha* present in the sequence. Among these genera; *Candona* (*Candona*) is found in fresh water; *Candona (Caspiocypris), Candona (Lineocypris),* and *Fossilyocypris* indicate fresh - brackish water (oligohaline), *Bakunella* rarely characterizes fresh water but mostly brackish water, *Amnicythere* characterizes brackish water, and *Gyraulus, Dreissena* characterizes fresh water conditions. The ostracod fauna determined in this study indicates an age interval of Late Miocene-Pliocene for the formation and clearly supports previous studies in terms of age and environmental correlations.

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1. Introduction

The study area is located east of Erzurum in the area surrounding Köprüköy (Figure 1).

The study area and close surroundings have been studied by many researchers. Arni (1939), Pamir and Baykal (1943), Erinç (1953), Erentöz (1954), Rathur (1965), Akkuş (1965), Acar (1975), Atalay (1978), Tokel (1979), Soytürk (1973), Gedik (1985), Yılmaz et al. (1988), Bozkuş (1990,1993,1998,1999), Arbaş et al. (1991), Şengüler and Toprak (1991), Tarhan (1989,1991), Gevrek and Şengüler (1992), Keskin (1994, 1998), Yılmaz (1997), Bozkuş (1990, 1993, 1998), Dağıstan (2001), Öner et al. (2006), Konak and Hakyemez (2008), Kibaroğlu et al. (2011) and Kalkan et al. (2012) investigated the general geology and volcanism. Stratigraphy-sedimentology studies were completed by Demirtaşlı et al. (1965), and Gürbüz and Gülbaş (1999). Tokel (1984), Erdoğan (1967), Özcan (1967), Şengör and Kidd (1979), Şengör (1980), Yılmaz and Şener (1984), Şaroğlu (1986), Şaroğlu and Yılmaz (1984), Koçyiğit (1985), Barka et al. (1987), Bayraktutan et al. (1996), Bayraktutan (1999), Bozkuş (1999), Beer et al. (2003), Keskin (2005), and Gelişli and Maden (2006) studied tectonics and magmatism. Paleontology was studied by Şafak (2013) and Vasilyan et al. (2014). This study determines the genus and species of ostracods and micro mollusks taken from measured sections in the Erzurum–Köprüköy region and provides new assessment of paleoenvironmental conditions.

2. Material and Method

The study material was retrieved from 25 washed samples taken from measured sections in the Erzurum-Köprüköy area. The samples obtained from two measured sections by Kaya in 2013-2014 underwent a washing procedure, were dated based on ostracod

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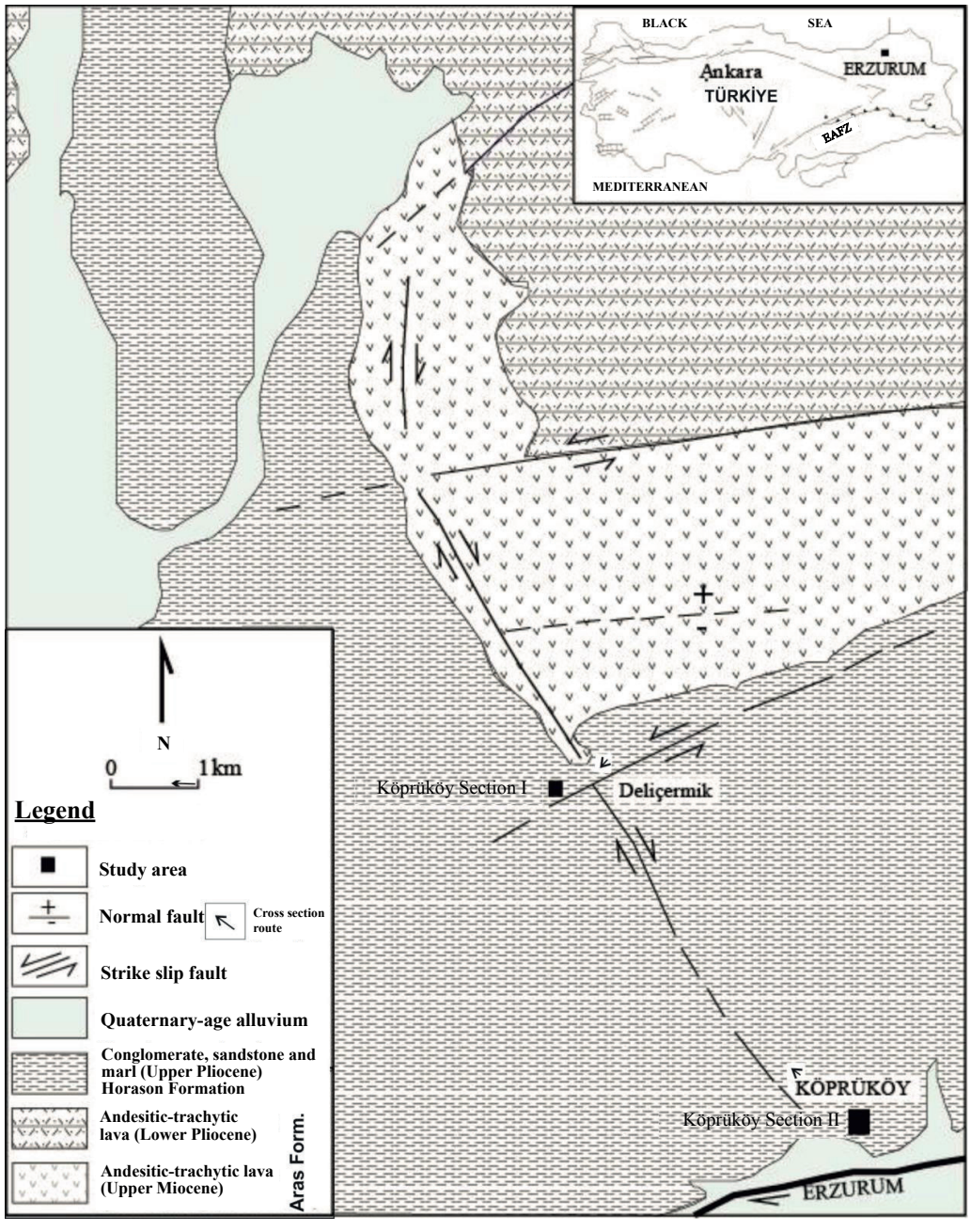

Figure 1- Geological map and section locations in the study area (adapted from Kalkan et al., 2012).

fauna and an attempt was made to infer environmental characteristics. The research identified 4 ostracod genera, 3 ostracod sub-genera and 11 ostracod species using the Hartmann and Puri (1974) classification for systematic identification. During the identification stage for mollusks, the studies by Sayar, 1991; Wenz, 1922; and Taner, 1980, 1997 were used. The SEM images of ostracod species and pelecypod species were taken at Meitam in Mersin University and are given in plates I-IV.

3. Stratigraphy

3.1. Horasan Formation

Definition: This formation was first described by Akkuş (1965) and Rathur (1965) and takes its name from Horasan county were it is best observed. It was studied in detail by Bozkuş (1993).

Distribution: Horasan formation outcrops around the Aras River near the Pasinler region.

Type location: 85 km from Erzurum province in Horasan county and surroundings.

Type section: Previous studies have emphasized the link with strike-slip faulting (Figure 2).

Reference sections: The measured sections in this study are reference sections controlled by strike-slip faulting.

Lithology: In the Middle Miocene ocean had retreated from the Erzurum-Pasinler-Horasan region, with terrestrial sediments specific to the neotectonic period deposited in the Late Miocene. In the Pliocene, basin specific formations were deposited, with increased uplift around the basin edges and resulting discontinuation of communication with other basins (Şaroğlu and Yılmaz, 1984).

The unit was described by Keskin (1994) as the Aras Formation, with the formation comprising terrestrial sediments including loosely consolidated pebble stone, sandstone, and claystone and marls with pyroclastic intercalations.

Yılmaz (1997) stated the Aras and Horasan formations comprised fluvial-lacustrine sediments of Pliocene age deposited in the Pasinler-Horasan basin developing above Late Miocene and older rocks controlled by strike-slip faults. Yellow-beige and grey color pebblestones, sandstone, siltstone and marl sequences from the Horasan formation westwards from Aliçeyrek village form a broad outcrop in the Pasinler-Horasan basin. The Horasan Fault zone, which controls the Aras River, comprises right and left strike-slip faults roughly parallel to the valley with mean strike N60-70E and 0.5-32 km length. The faults are dominated by left lateral strike-slip faults and they have affected the geomorphologic appearance of the basin.

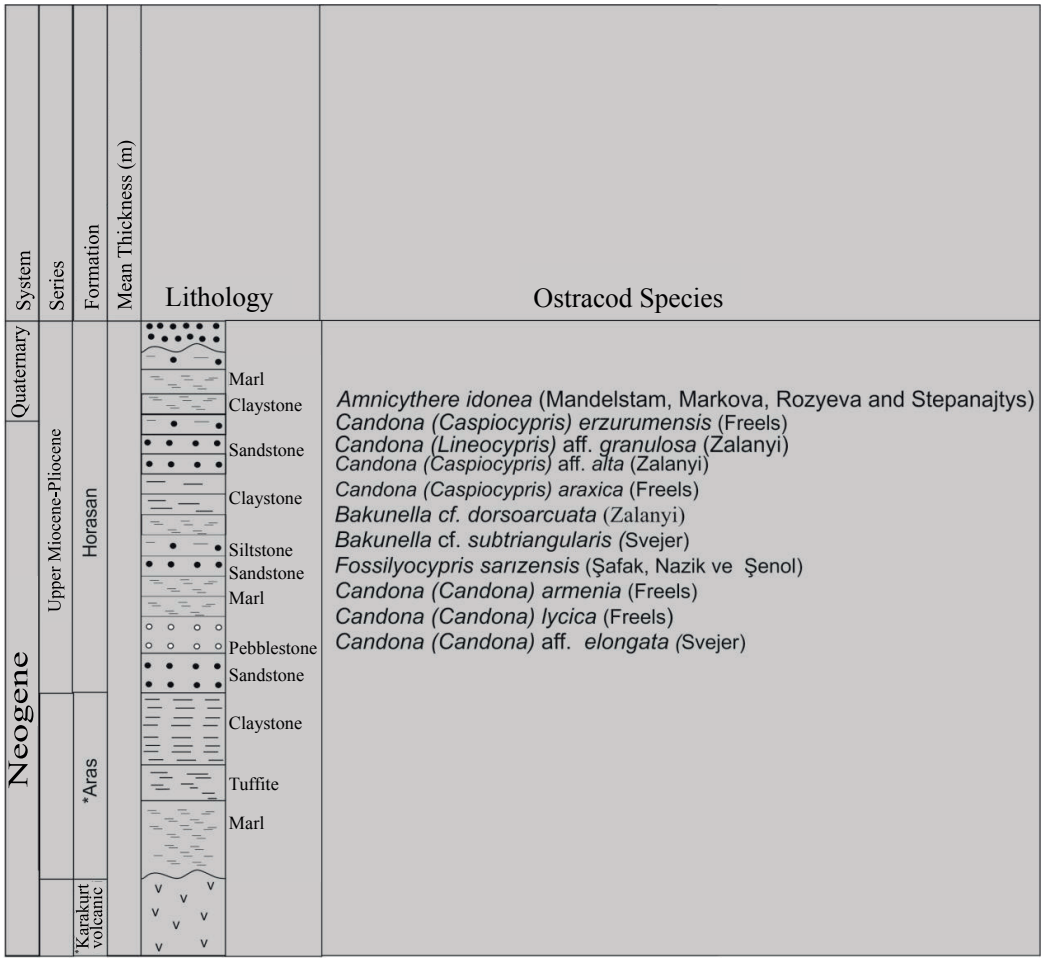

Figure 2- Generalized vertical section and ostracod findings in the study area (adapted from Bozkuş, 1993).

Konak and Hakyemez (2008) described the lower layers of the unit as brownish-greyish color loosely consoliated pebble stone and sandstones, grading up to yellow, grey, grayish, greenish pebble sandstone, sandstone with occasional pyroclastic lenses, siltstone, and marl intercalations. Especially at these levels siltstone and clayey marls with *Congeria* are common with intercalated thin lignite formations encountered.

As observed in photographs 1, 2 and 3, the lithology of the unit in the study comprises reddish, grading up to yellow, gray, grayish, greenish loosely consolidated sandstone, siltstone and marl intercalations.

Contact relations: According to Bozkuş (1993, 1999) within the left lateral strike slip basin, varying sizes of terrestrial sediments were deposited. The Aras Formation formed in a deep lake environment, while the conformably overlying large-fine clastic unit is the Horasan formation. These two units are emphasized as being Pliocene age. The Horasan formation has a conformable and transitional contact with the underlying Aras formation.

In the study by Konak and Hakyemez (2008), the lower limit of the Horasan Formation unconformably overlies Late Miocene volcanic rocks. In the southest of the mapped area, they stated small outcrops of underlying ophiolitic rocks were observed. The upper limit is overlain by Quaternary sediments above an unconformity. This formation comprised meandering river and delta deposits.

The base of the study unit conformably overlies Aras formation sediments, with the upper unit overlain by Quaternary sediments above an unconformity.

Thickness and Distribution: The thickness was 325 m (Bozkuş, 1993), while it was 50-60 m in this study.

Fossil Scope and Age: Previous studies (Erentöz, 1954*a,b*; Rathur, 1965; Arbas et al., 1991) have dated the unit as Late Pliocene-Early Pleistocene based on pelecypod, gastropod, ostracod and small mammalian fossils. Yılmaz and Şener (1984) stated the age of the formation was Late Pliocene.

According to the ostracod fauna described in this study, the age of the unit is Late Miocene-Pliocene.

Environment: According to the fauna in this study the unit developed in fresh water and brackish water (oligohaline) environmental conditions.

Correlation: The Horasan Formation (Bozkuş, 1993) is conformable and transitional with the underlying Aras formation and was described as the Aras Formation by Keskin (1994).

3.2. Measured Sections and Fossil Assemblages

In the study area within the Horasan formation, measured sections were examined with frequent sampling from lithologies related to the fault with high possibility of fossil levels. Two sections were studied.

3.2.1. Köprüköy Measured Section 1

On I47b1 sheet 1/25000 scale map beginning at coordinates X_1: 39°58'22. 74'', Y_1: 41°52'22.75'' and ending at X_2: 39°58'31.04'', Y_2: 41°52'0.17'', a total of 24 wash samples were obtained from this 60 m thick measured section.

In terms of ostracod species, samples numbered 4, 6, 15, 19 and 24 from 4.6 m, 10.2 m, 30 m, 44 m and 55.7 m contained *Candona* (*Caspiocypris*) *erzurumensis* Freels; samples numbered 3, 10 and 19 from 4.6 m, 18.8 m and 44 m contained *Candona* (*Caspiocypris)* aff. *alta* (Zalanyi); samples 10 and 24 from 18.8 m and 55.7 m contained *Candona (Caspiocypris) araxica* Freels, samples 6, 18, 21 and 24 from 10.2 m, 39.9 m, 47.8 m and 55.7 m contained *Bakunella* cf. *dorsoarcuata* (Zalanyi), samples 6, 13 and 20 from 10.2 m, 27.4 m and 45.5 m contained *Candona* (*Candona*) *lycica* Freels; samples 4 and 22 from 4.6 m and 51.2 m contained *Candona* (*Candona*) *armenia* Freels, and samples 21, 22 and 23 from 47.8 m, 51.5 m and 55 m contained *Fossilyocypris sarızensis* (Şafak, Nazik and Şenol) (Figure 3).

The ostracods such as *Candona* (*Caspiocypris*) *erzurumensis, Candona* (*Caspiocypris)* aff. *alta,* and *Candona (Caspiocypris) araxica* in this section are freshwater-brackish water (oligohaline), while ostracods like *Candona* (*Candona*) *lycica,* and *Candona* (*Candona*) *armenia* are freshwater, *Fossilyocypris sarızensis* is freshwater-brackish water (oligohaline) and *Bakunella* cf. *dorsoarcuata*

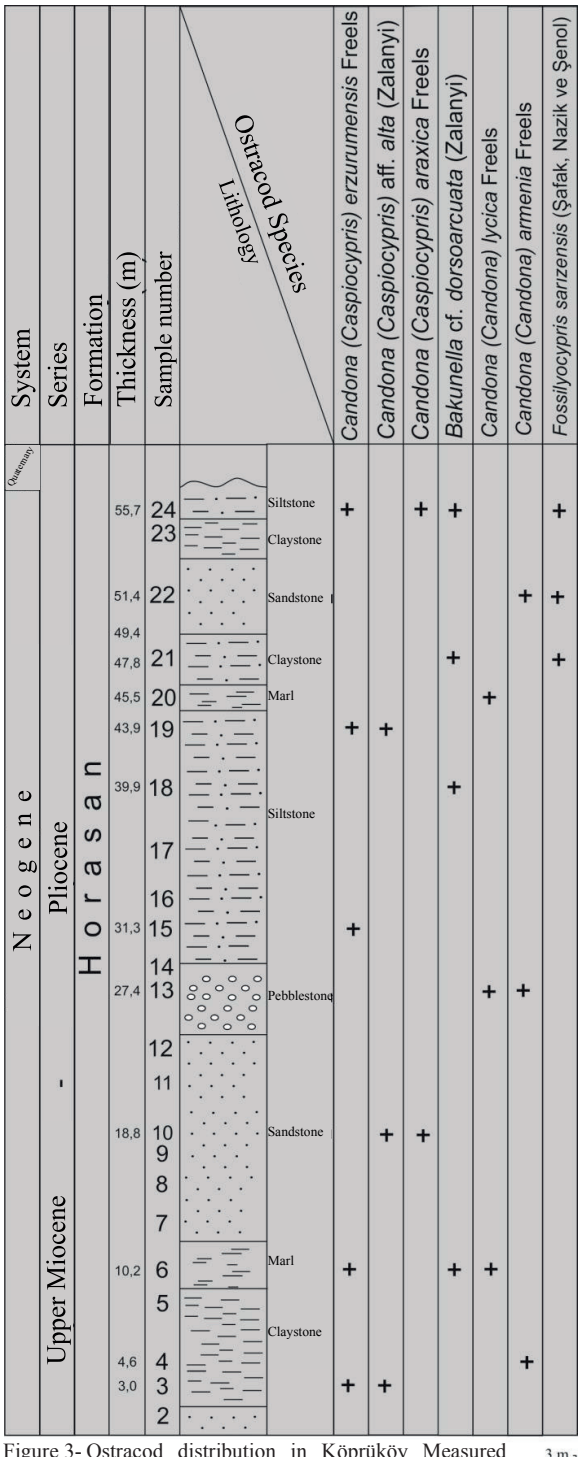

Figure 3- Ostracod distribution in Köprüköy Measured Section 1.

is generally found in brackish water and rarely in freshwater conditions (Remane, 1958) (Morkhoven, 1963).

These species indicate transition from fresh water to oligohaline conditions.

3.2.2. Köprüköy Measured Section 2

On 1/25000 scale I47b1 sheet map, a 10 m thick measured section beginning at X_1: 39°58'53.10", Y_1: 41°51'38.27" and ending at X_2: 39°58'50.87", Y_2: 41°51'36.34" was taken and a total of 9 wash samples were obtained.

In the sequence, samples number 6 and 8 from 5.6 m and 8.2 m contained *Amnicythere idonea* Mandelstam, Markova, Rozyeva and Stepanajtys; samples 1, 4 and 8 from 0.7 m, 3.8 m and 8.4 m contained *Candona (Caspiocypris)* aff. *alta* (Zalanyi); samples 4, 6 and 8 from 3.8 m, 5.6 m and 8.4 m contained *Candona (Caspiocypris) erzurumensis* Freels; samples 5 and 8 from 3.8 m and 8,4 m contained *Candona (Lineocypris)* aff. *granulosa* Zalanyi; samples 4 and 7 from 3.8 m and 7.2 m contained *Bakunella* cf. *subtriangularis* (Sveyer); and samples 6 and 8 from 5.6 m and 8.4 m contained *Candona (Candona) armenia* Freels; and sample number 6 from 5.6 m contained *Candona* (*Candona*) aff. *elongata* (Svejer) ostracod species. Also samples 1, 3, 5, 7 and 9 contained micropelecypods like *Dreissena polymorpha* (Pallas) and micro gastropod species like *Gyraulus inornatus* (Brusina) (Figure 4*a, b*).

In terms of environment, ostracods like *Candona (Caspiocypris)* aff. *alta*, *Candona (Caspiocypris) erzurumensis* and *Candona (Lineocypris)* aff. *Granulose* are freshwater-brackish water (oligohaline), while ostracods like *Candona (Candona) armenia* and *Candona* (*Candona*) aff. *Elongate* are freshwater species. Ostracods like *Amnicythere idonea* occur in brackish water, while *Bakunella* cf. *subtriangularis* generally occurs in brackish water and rarely in freshwater (Remane, 1958) (Morkhoven, 1963).

These species reflect the transition from freshwater to oligohaline conditions.

4. Systematics

The study identified a total of 11 ostracod species with 1 *Amnicythere*, 3 *Candona* (*Caspiocypris*), 1 *Candona* (*Lineocypris*), 2 *Bakunella*, 3 *Candona* (*Candona*), 1 *Fossilyocypris*, 1 *Dreissena*, and 1 *Gyraulus* species identified. Additionally 1 pelecypod and 1 gastropod species were identified. Ostracods are given in terms of their place in systematic classification.

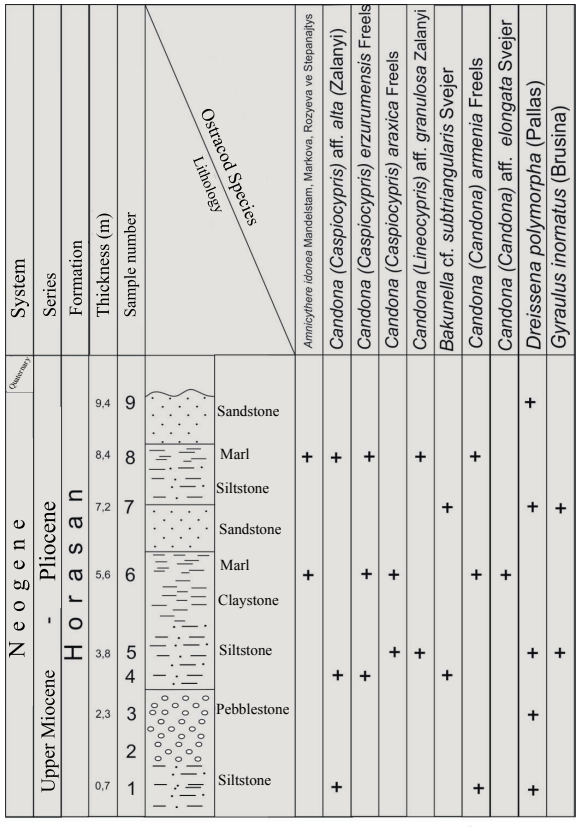

Figure 4- Ostracod distribution from Köprüköy Measured Section 2.

Photograph 1- General appearance of Horasan formation and measured section 1.

Photograph 2- General appearance of Horasan formation.

Photograph 3- General appearance of Horasan formation.

Systematic classification was made according to the classification of Hartmann and Puri (1974). Additionally, the classifications by Moore (1961), Morkhoven (1963) and Freels (1980) were used. Salinity of ostracod environments was determined according to Remane's (1958) criteria.

Subclass: Ostracoda Latreille, 1806

Order: Podocopida Sars, 1866

Superfamily: Cytheracea Baird, 1850

Family: Leptocytheridae Hanai, 1957

Genus: *Leptocythere* Sars, 1922-1928

Subgenus: *Leptocythere* Sars, 1922-1928 and *Amnicythere* Devoto, 1965

Species-type: *Cythere pellucida* Baird, 1850

Stratigraphic Distribution: Oligocene-Present

Environment: Some species typically occur in brackish water, others in shallow marine (littoral) environments (Morkhoven, 1963).

***Amnicythere idonea* Mandelstam, Markova, Rozyeva ve Stepanajtys, 1962**
(Plate 1, Figure 1)

1962 *Leptocythere idonea* Mandelstam, Markova, Rozyeva and Stepanajtys

1978 *Amnicythere idonea* (Mandelstam, Markova, Rozyeva and Stepanajtys), Carbonnel, page 112, plate 1, figure 18; plate 2, figures 4-5.

1999 *Leptocythere idonea* Mandelstam, Markova, Rozyeva and Stepanajtys, Gliozzi, plate 1, Figure a.

2016 *Amnicythere idonea* Mandelstam, Markova, Rozyeva and Stepanajtys, page 859, plate 5, figures 1-6.

Geographic and chronostratigraphic distribution: *A. idonea* in Turkmenistan (Caspian Basin) in the Pliocene (Mandelstam et al, 1962); west of Tethys by Carbonnel (1978) in Corsica (Aleria Basin), found in Spain (Vera Basin), in France (Ron Basin) in the Late Messinian, in Italy (Le Vicenne) in Late Messinian (Gliozzi, 1999). Stoica et al. (2016) studied Paratethys ostracods in the Lago-Mare region of Spain, with new evidence of variation in internal basins during high sea level in the Late Miocene-Pliocene and identified *Amnicythere idonea*.

Locations in this study: samples numbered 6 and 8 from Köprüköy Measured Section 2, Pliocene.

Superfamily: Cypridacea Baird, 1845

Family: Candonidae Kaufmann, 1900

Subfamily: Candoninae Kaufmann, 1900

Genus: *Candona* Baird, 1854

Subgenus: *Candona (Caspiocypris)* Mandelstam, 1956

Species-type: *Bairdia candida* Livental, 1929

Stratigraphic distribution: Oligocene (Eocene?) - Present

Environment: Freshwater, rarely brackish water (Morkhoven, 1963)

***Candona (Caspiocypris) erzurumensis* Freels, 1980**
(Plate I, Figures 2-3)

1980 *Candona (Caspiocypris) erzurumensis* Freels

2013 *Candona (Caspiocypris) erzurumensis* Freels, Şafak, page 78, plate II, figure 3.

Stratigraphic and Geographic distribution: Erzurum-Pasinler, Turkey - Late Miocene (Freels, 1980), Erzurum/Hınıs - Pliocene (Şafak, 2013).

Locations in this study: Samples 3, 6, 15, 19 and 24 in Köprüköy Measured section 1 and samples 4, 6 and 8 in Köprüköy Measured section 2, Late Miocene-Pliocene

***Candona (Caspiocypris) araxica* Freels, 1980**
(Plate I, Figure 4-8)

1980 *Candona (Caspiocypris) araxica* Freels

2001 *Candona (Caspiocypris) araxica* Freels, Tunoğlu, page 134, Figure 4; page 138, figure 5.

2013 *Candona (Caspiocypris) araxica* Freels, Şafak, page 79, plate II, figure 1-2.

Stratigraphic and Geographic Distribution: Erzurum-Pasinler, Turkey - Upper Miocene-Pliocene (Freels, 1980), Black Sea Region, Turkey - Middle-Late Miocene-?Pliocene (Tunoğlu, 2001), Erzurum/Hınıs - Pliocene (Şafak, 2013).

Locations in this study: samples 10 and 24 in Köprüköy Measured Section 1, samples 5 and 6 in Köprüköy Measured section 2, Late Miocene-Pliocene.

***Candona (Caspiocypris)* aff. *alta* (Zalanyi, 1929)**
(Plate II, Figures 1-7)

Aff. 1929 *Paracypris alta* n.sp., Zalanyi, Morpho-System, Studien, page 44, figure 14.

Aff. 1971 *Candona (Thaminocypris) alta* (Zalanyi), Krstic, Table II, 3-5.

1974 *Candona (Caspiocypris) alta* (Zalanyi, 1929), Hanganu, Table III, 10-12.

1980 *Candona (Caspiocypris)* aff. *alta* (Zalanyi, 1929), Freels, plate 4, figure 1-8.

1992 *Candona (Caspiocypris) alta* (Zalanyi), Şafak, Nazik and Şenol, pl. 4, Fig. 1.

1992 *Candona (Caspiocypris) alta* (Zalanyi), Nazik, Şafak and Şenol, plate II, figure 8.

2005 *Candona (Caspiocypris) alta* (Zalanyi), Vasiliev, Krijgsman, Stoica and Langereis, page 242, plate 1, figure 7.

2013 *Candona (Caspiocypris) alta* (Zalanyi), Şafak, page 78, plate II, figure 4-5.

Stratigraphic and Geographic Distribution: Caspian Basin (Zalanyi, 1929); Romania - Sarmatian (Hanganu, 1974); Sivas and Şebinkarahisar, Turkey - Late Miocene (Freels, 1980), Sarız and Tufanbeyli, Turkey - Pliocene (Şafak et al., 1992; Nazik et al., 1992); South Carpathians - Mio-Pliocene (Vasiliev et al., 2005); Hınıs/Erzurum - Early Pleistocene (Şafak, 2013).

Locations in this study: samples 10 and 19 in Köprüköy Measured Section 1, samples 1, 4 and 8 in Köprüköy Measured Section 2, Late Miocene-Pliocene

Subgenus: *Candona (Lineocypris)* Zalanyi, 1929

Species-type: *Lineocypris trapezoidea* Zalanyi, 1929

Stratigraphic distribution: (?Early Cretaceous) Pliocene-Present

Environment: Fresh water, generally deep lakes (Morkhoven, 1963)

***Candona (Lineocypris)* aff. *granulosa* Zalanyi, 1959**

(Plate II, Figure 8)

1959 *Candona granulosa* n. sp. Zalanyi, page 223, figure 5

1967 *Candona (Caspiocypris)* sp., Sokac, T. I: 4.

1972 *Candona (Lineocypris) granulosa* Zalanyi, Sokac, T. XXVI:7-13.

1980 *Candona (Lineocypris)* aff. *granulosa* Zalanyi, Freels, page 144, plate 6, figure 17-20.

Stratigraphic and Geographic Distribution: In the Pannonian Basin in the former Yugoslavia (Montenegro) – Pontian (Sokac, 1967, 1972); Turkey (Samsun, Erzurum) – Late Miocene (Freels, 1980).

Locations in this study: samples 5 and 8 in Köprüköy Measured section 2, Late Miocene-Pliocene.

Genus: *Bakunella* Schneider, 1958

Species-type: *Pontocypris dorsoarcuata* Zalanyi, 1929

Stratigraphic distribution: Pliocene-Present

Environment: brackish water, rarely freshwater (from Tunoğlu, 2003)

***Bakunella* cf. *dorsoarcuata* (Zalanyi, 1929)**

(Plate III, Figure 1-4)

1929 *Pontocypris dorsoarcuata n. sp.* Zalanyi, page 37, figure 11, 12.

1949 *Bythocypris guriana* (Lıvental) Svejer, t. III: 2.

1965 *Bakunella dorsoarcuata* (Zalanyi), Stancheva, page 15-16, plate 4, figure 8.

1967 *Bakunella dorsoarcuata* (Zalanyi), Agalarova, plate 3, figure 3-5.

1969 *Candona* (*Bakunella) dorsoarcuata* (Zalanyi) Gramann, page 495, plate 32, figure 5a,b.

1972 *Bakunella dorsoarcuata* (Zalanyi), Krstic, T. XXIII: 2-4.

1978 *Bakunella dorsoarcuata* (Zalanyi), Olteanu, page 1019, plate 6, figure 3-4.

1980 *Bakunella dorsoarcuata* (Zalanyi), Freels, page 32, plate 3, figure 10-15.

1991 *Candona* (*Bakunella) dorsoarcuata* (Zalanyi), Jiricek & Riha, pl. 6, fig. 4.

1998 *Candona* (*Bakunella) dorsoarcuata* (Zalanyi),Tunoğlu, Ünal and Bilen, page 96-97, plate 9, figure 1-3, 9, 10, plate 16, figure 1-4.

2001 *Candona* (*Bakunella*) *dorsoarcuata* (Zalanyi), Tunoğlu, page 131-133.

2003 *Candona* (*Bakunella*) *dorsoarcuata* (Zalanyi), Tunoğlu, page 31, plate 6, 1-3, 9, 10; plate 9, 1-4.

2011 *Bakunella dorsoarcuata* (Zalanyi), Olteanu, page 127, plate X, fig.

2011 *Bakunella dorsoarcuata* (Zalanyi), Floroiu, page 36.

2013 *Bakunella dorsoarcuata* (Zalanyi), Stoica, Floroiu, Krijgsman and Vasiliev**,** page 139, plate 1, figure 27.

2013 *Bacunella* cf. *dorsoarcuata* (Zalanyi), Vesel-Lukic, Tadesse and Poljak**,** page 413-414.

2013 *Bakunella dorsoarcuata* (Zalanyi), Pipik, Starek, Seko and Sykorova, page 291-294.

2013 *Bakunella dorsoarcuata* (Zalanyi), Floroiu, Stoica, Vasiliev and Krijgsman, page 131-132.

Stratigraphic and Geographic Distribution: Russia-Volga shore – Pliocene (Svejer, 1949); Kabistan, Azerbaijan, Ukraine, Bulgarian coast – Pontian (Stancheva, 1965); Black Sea coast – Pontian-Pliocene (Agalarova, 1967); Strimon Basin, Greece – Pontian (Gramann, 1969); Pannonian Basin, former Yugoslavia – Neogene (Krstic, 1972); Romania – Late Pontian (Hanganu, 1966); Pannon Lake – Late Miocene (Pipik et al., 2013); Dasic Basin, Eastern Carpathians, Romania – Late Miocene-Early Pliocene (Stoica et al., 2013); Eastern Slovenia – Late Miocene (Vesel-Lukic et al, 2013); Eastern Carpathians – Pontian (Floroiu et al., 2013); Black Sea coast, Turkey – Late Miocene (Freels, 1980); Araklı, Trabzon – Pontian (Tunoğlu et al.,1998); Eastern Black Sea region – Pontian (Tunoğlu, 2003); Bucharest, Romania (Dasic Basin) – Pontian-Maeotian (Floroiu, 2011).

Locations in this study: samples 6, 18, 21 and 24 in Köprüköy Measured Section 1, Late Miocene-Pliocene.

***Bakunella* cf. *subtriangularis* (Svejer, 1949)**

(Plate III, Figure 5-8)

1949 *Bythocypris subtriangularis* Svejer, Pliyosen, page 63, T. III: 6.,

1980 *Bakunella* cf. *subtriangularis* (Svejer), page 33, plate 3, figure 16-17.

Stratigraphic and Geographic Distribution: Lower Volga region, Russia – Pliocene (Svejer, 1949); Erzurum, Pasinler Basin, Turkey – Late Miocene; Konya-Beyşehir Basin – Pliocene-Early Pleistocene (Freels, 1980).

Locations in this study: samples 4 and 7 in Köprüköy Measured Section 2, Late Miocene-Pliocene.

Subgenus: *Candona (Candona)* Baird, 1845

Species-type: *Cypris candida* O.F.Müller, 1776

Stratigraphic distribution: (?Eocene) Oligocene-Present

Environment: Generally freshwater (Morkhoven, 1963)

***Candona (Candona) lycica* Freels, 1980**

(Plate IV, Figure 1-3)

1981 *Candona (Candona) lycica* n.sp. Freels, page 73 , plate 11, figure 12-13, plate 12, figure 1-6

Stratigraphic and Geographic Distribution: Suşehri, Sivas, Şebinkarahisar, Turkey – Late Miocene (Freels, 1980).

Locations in this study: samples 6, 13 and 20 in Köprüköy Measured Section 1, Late Miocene-Pliocene

***Candona (Candona) armenia* Freels, 1980**

(Plate IV, Figure 4-5)

1980 *Candona (Candona) armenia* n.sp. Freels, page 71 , plate 11, figure 9-11

Stratigraphic and Geographic Distribution: Erzurum-Pasinler-Horasan, Turkey – Late Miocene (Freels, 1980).

Locations in this study: samples 4, 13 and 22 in Köprüköy Measured Section 1, samples 6 and 8 in Köprüköy Measured Section 2, Late Miocene-Pliocene.

***Candona (Candona)* aff. *elongata* (Svejer, 1949)**

(Plate IV, Figure 6)

Aff. 1949 *Bythocypris elongata* Svejer, page 62, plate IV, figure 9-12.

1963 *Bythocypris elongata* Svejer, Mandelstam ve Schneider, page 138, plate 17, figure 2.

1980 *Candona (Candona)* aff. *elongata* (Svejer), Freels, page 82, plate 13, figure 9-12

2010 *Candona (Candona) elongata* (Svejer), Şafak, page 57, plate III, Figure 3.

Stratigraphic and Geographic Distribution: Lower Volga and Caspian Basin – Pliocene-Early Pleistocene (Mandelstam and Schneider, 1963); Denizli-Sarayköy-Güney-Babadağ, Turkey – Late Miocene (Freels, 1980; Şafak, 2010).

Locations in this study: sample 6 in Köprüköy Measured Section 2, Late Miocene-Pliocene.

Family: Ilyocyprididae Kauffmann, 1900

Genus: *Ilyocypris* Brady ve Norman, 1889

Species-type: *Cypris gibba* Ramdohr, 1808

Stratigraphic distribution: Triassic-Present

Environment: Freshwater – oligohaline salt falts and mainly muddy bottoms (Morkhoven, 1963)

***Fossilyocypris sarızensis* (Şafak, Nazik ve Şenol, 1992)**

(Plate IV, Figure 7)

1975 *Ilyocypris caspiensis* (Negadev) Kazmina, page 45-46, plate I, figure 16-17, plate XVIII, figure 5-6.

1988 *Ilyocypris caspiensis*? Krstic, Figure I.

1992 *Ilyocypris sarızensis* Şafak, Nazik and Şenol, page 177, plate II, figure 1-7.

2004 *Fossilyocypris sarızensis* (Şafak, Nazik and Şenol) Krstic, Markovic and Keyser, page 313, plate 2, figure 7-8.

Stratigraphic and Geographic Distribution: species originally described in southeast Turkey – Pliocene (Şafak et al., 1992). Global distribution west Siberia (Novosibirsk, Tomsk, Omsk) and different sections of the Altay mountains – generally lower-middle, rarely Upper Quaternary sequences (Kazmina, 1975); Vojvodina, north Serbia – Pliocene (Krstic, 1988); Central and eastern Europe – Late Pliocene and Middle Pleistocene (Krstic et al., 2004).

Locations in this study: samples 21, 22 and 24 in Köprüköy Measured Section 1, Pliocene.

5. Discussion and Conclusion

This study was conducted on units within the Horasan Formation near Köprüköy east of Erzurum. This formation is found in the Erzurum-Pasinler-Horasan region forming the northernmost section of deposits from the neotectonic period in Eastern Anatolia. Previous studis have determined that the sea retreated from the Erzurum-Pasinler-Horasan region in the Middle Miocene, with terrestrial sediments unique to the neotectonic period deposited in the Upper Miocene with basin formations deposited in the Pliocene as the basin edges were uplifted and connections with other basins were cut (Şaroğlu and Yılmaz, 1984). This study observed well-preserved ostracod, gastropod and pelecypod genera and species in soft clastic claystone, siltstone and marl levels of the Horasan Formation.

Amnicythere idonea is found in Turkmenistan (Caspian Basin), west of Tethys (Aleria and Vera Basins) and in Italy in the Pliocene and Late Messinian (Mandelstam et al., 1962, Carbonnel, 1978, Gliozzi, 1999); and in Spain in the Late Miocene-Pliocene (Stoica et al., 2016).

Candona (Caspiocypris) erzurumensis is found in Turkey in Erzurum Pasinler and Hınıs in the Late Miocene and Pliocene (Freels, 1980, Şafak, 2013).

Candona (Caspiocypris) araxica is found in Turkey in Erzurum-Pasinler and the Black Sea region in the Late Miocene-Pliocene, Middle-Late Miocene-?Pliocene and in the Pliocene (Freels, 1980; Tunoğlu, 2001, Şafak, 2013).

Candona (Caspiocypris) aff. *alta* is found in the Caspian Basin, Romania and Southern Carpathians in the Sarmatian and Mio-Pliocene (Zalanyi, 1929; Hanganu, 1974, Vasiliev et al., 2005). In Turkey it is

found in Sivas, Şebinkarahisar and Sarız, Tufanbeyli and Erzurum-Hınıs in the Late Miocene and Pliocene, and Pliocene-Early Pleistocene (Freels, 1980; Şafak et al.,1992; Nazik et al., 1992; Şafak, 2013).

Candona (Lineocypris) aff. *granulosa* is found in the Pannonian Basin in the former Yugoslavia in the Pontian (Sokac, 1967, 1972) and in Turkey in Samsun and Erzurum in the Late Miocene (Freels, 1980).

Bakunella cf. *dorsoarcuata* is found in Russia and on the Black Sea coast in the Pliocene (Svejer, 1949, Agalarova, 1967); in Azerbaijan, Ukraine, northern Bulgaria, on the Black Sea coast, in the Strimon Basin in Greece, Pannonian Basin in Romania, Eastern Carpathians, in the Black Sea region of Turkey near Trabzon, Araklı in the Pontian (Stancheva, 1965; Agalarova, 1967; Gramann, 1969; Hanganu, 1966; Pipik et al., 2013; Floroiu et al., 2013; Tunoğlu, 2003; Floroiu, 2011). It is also found in the eastern Carpathinas in the Late Miocene-Early Pliocene (Stoica et al., 2013), on the Black Sea coast in Turkey and in eastern Slovenia in the Late Miocene (Freels, 1980, Vesel-Lukic et al., 2013).

Bakunella cf. *subtriangularis* is found in Turkey in the Konya-Beyşehir Basin in the Pliocene-Lower Pleistocene and in the Erzurum-Pasinler Basin in the Late Miocene (Freels, 1980) and in the Lower Volga region of Russia in the Pliocene (Svejer, 1949).

Candona (Candona) lycica is found in Sivas-Suşehri and Şebinkarahisar in Turkey in the Late Miocene (Freels, 1980).

Candona (Candona) armenia is found in the Erzurum-Pasinler-Horasan region in Turkey in the Late Miocene (Freels, 1980).

Candona (Candona) aff. *elongata* is found in the Lower Volga and Caspian Basin in the Pliocene-Early Pleistocene (Mandelstam and Schneider, 1963) and in Denizli-Sarayköy-Güney-Babadağ in Turkey in the Late Miocene (Freels, 1980, Şafak, 2010).

Fossilyocypris sarızensis is found in Turkey and Serbia in the Pliocene (Şafak et al., 1992; Krstic, 1988), in the Mediterranean and Central and Eastern Europe in the Late Plicoene (Krstic et al., 2004) and in Siberia in the Quaternary (Kazmina, 1975).

Of these genera *Candona (Caspiocypris)* and *Candona (Lineocypris)* characterize freshwater-brackish water (oligohaline) conditions, while *Candona (Candona)* represents freshwater, *Bakunella* characterizes rarely freshwater and mainly brackish water, *Amnicythere* is found in brackish water and *Gyraulus* and *Dreissena* characterize freshwater conditions.

The ostracod fauna identified in this study, along with the micromollusk fauna clearly indicate an assemblage supporting these interpretations in terms of age and environmental correlations. According to the fauna, the age of the formation is determined as Late Miocene-Pliocene.

The ostracod and micromollusk species defined in the study and the environmental conditions represented by these species taken together and reviewed in light of previous studies indicate the Horasan Formation was deposited in the interval from the Late Miocene to Pliocene when generally freshwater and brackish water (oligohaline) conditions dominated.

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PLATE

PLATE I

Figure 1. *Amnicythere idonea* Mandelstam, Markova, Rozyeva and Stepanajtys, 1962

Shell, right outer appearance, Köprüköy Measured Section 2, sample no. 6

Figures 2-3. *Candona (Caspiocypris) erzurumensis* Freels, 1980

Shell, left outer appearance, Köprüköy Measured Section 1, sample no. 19

Right shell, outer appearance, Köprüköy Measured Section 2, sample no. 6

Figures 4-8. *Candona (Caspiocypris) araxica* Freels, 1980

Left shell, outer appearance, Köprüköy Measured Section 2, sample no. 6

Shell, left outer appearance, Köprüköy Measured Section 2, sample no.5

Left shell, outer appearance, Köprüköy Measured Section 2, sample no. 6

Shell, left outer appearance, Köprüköy Measured Section 1, sample no. 24

Shell, left outer appearance, Köprüköy Measured Section 1, sample no. 10

PLATE I

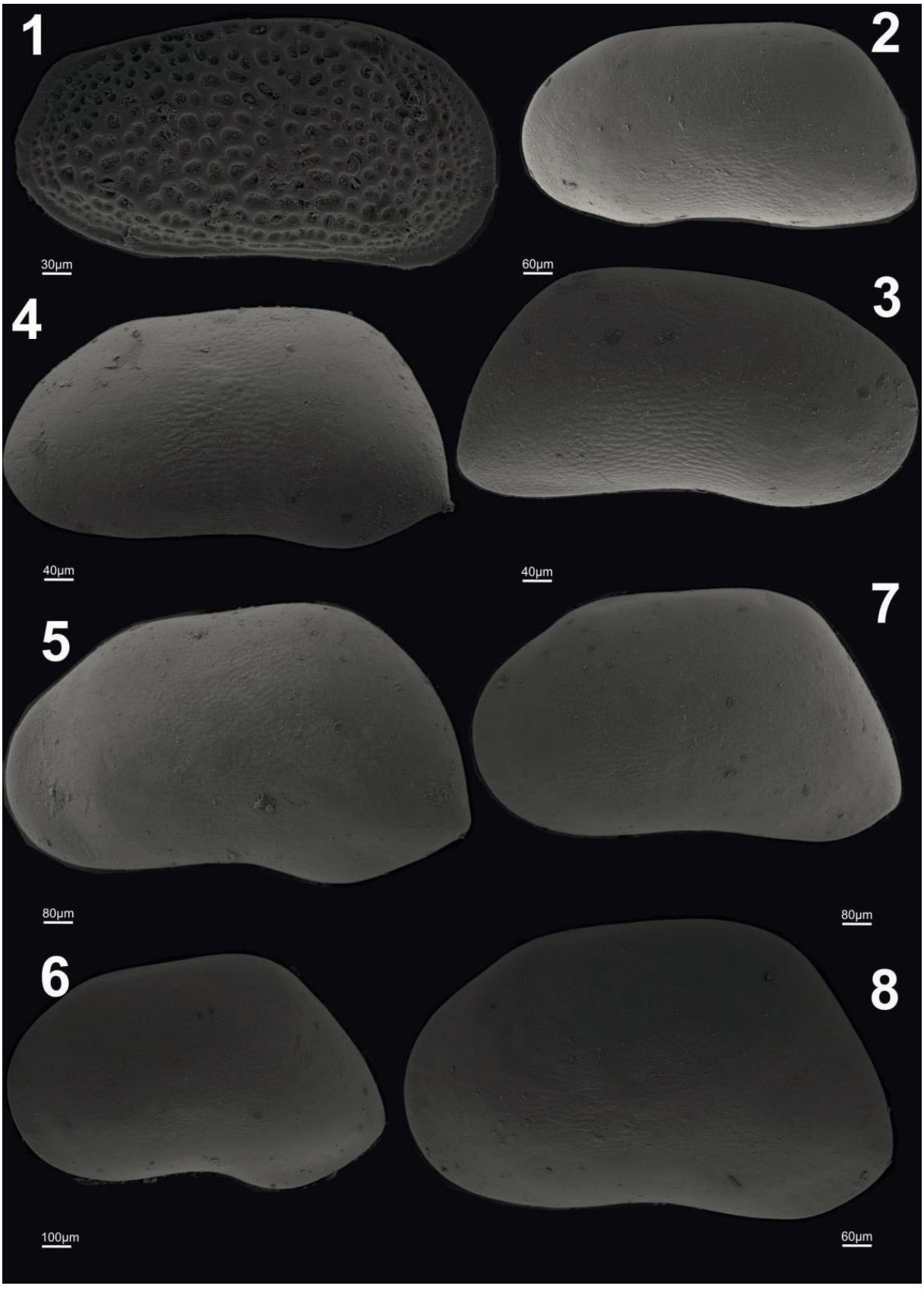

PLATE II

Figures 1-7. *Candona (Caspiocypris)* aff. *alta* (Zalanyi, 1929)

Shell, right outer appearance, Köprüköy Measured Section 2, sample no. 8

Right shell, outer appearance, Köprüköy Measured Section 2, sample no. 8

Shell, right outer appearance, Köprüköy Measured Section 2, sample no. 4

Shell, right outer appearance, Köprüköy Measured Section 2, sample no. 8

Right shell, outer appearance, Köprüköy Measured Section 2, sample no. 4

Shell, right outer appearance, Köprüköy Measured Section 1, sample no. 19

Shell, left outer appearance, Köprüköy Measured Section 1, sample no. 10

Figure 8. *Candona (Lineocypris)* aff. *granulosa* Zalanyi, 1959

Shell, left outer appearance, Köprüköy Measured Section 2, sample no. 5

PLATE II

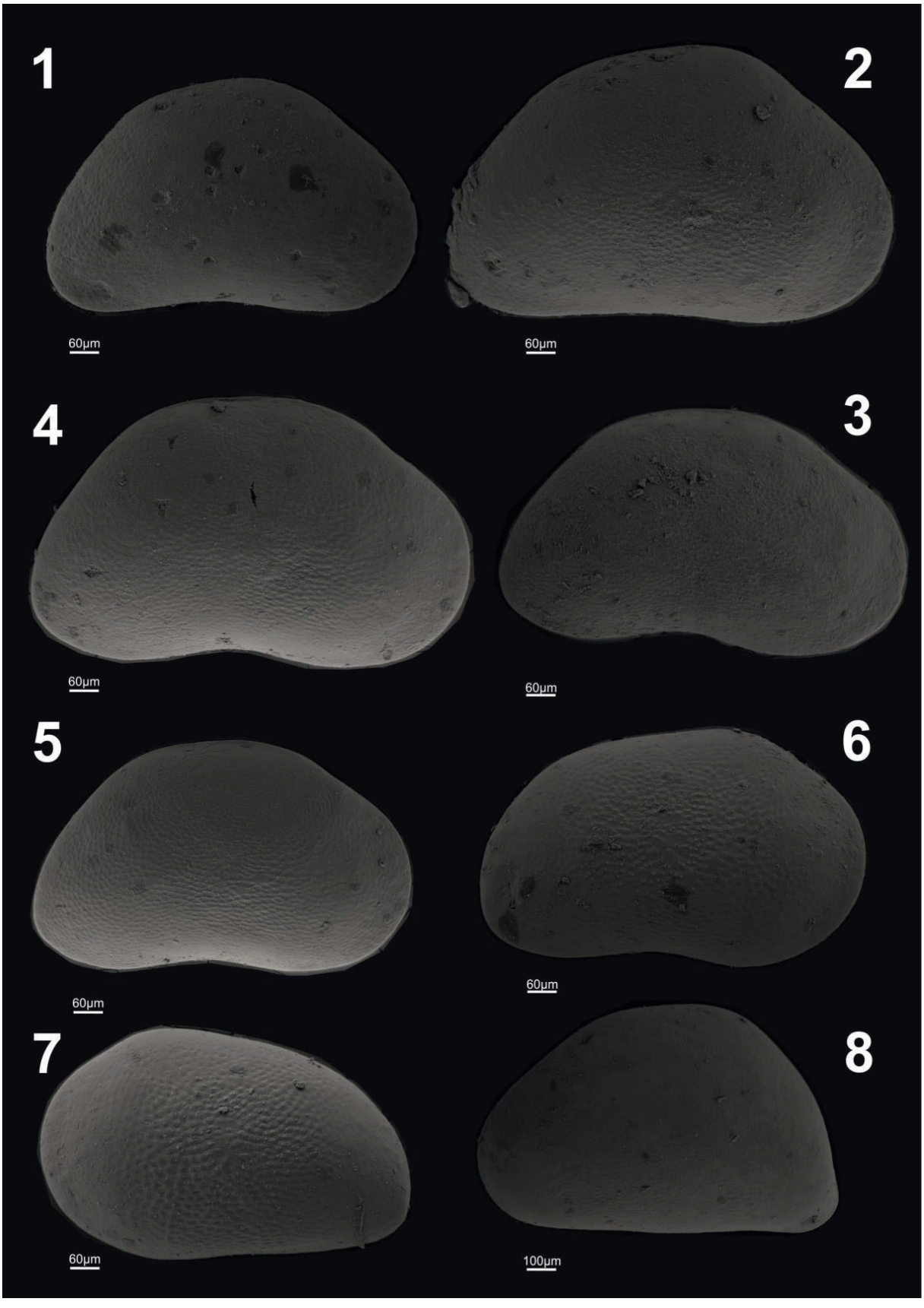

PLATE III

Figures 1-4. *Bakunella* cf. *dorsoarcuata* (Zalanyi, 1929)

Shell, left lateral appearance, Köprüköy Measured Section 1, sample no. 6

Shell, left outer appearance, Köprüköy Measured Section 1, sample no. 6

Left shell, outer appearance, Köprüköy Measured Section 1, sample no. 18

Shell, right outer appearance, Köprüköy Measured Section 2, sample no. 21

Figures 5-8. *Bakunella* cf. *subtriangularis* (Svejer, 1949)

Shell, left outer appearance, Köprüköy Measured Section 2, sample no. 4

Shell, right outer appearance, Köprüköy Measured Section 2, sample no. 4

Left shell, outer appearance, Köprüköy Measured Section 2, sample no. 4

Shell, left outer appearance, Köprüköy Measured Section 2, sample no. 7

PLATE III

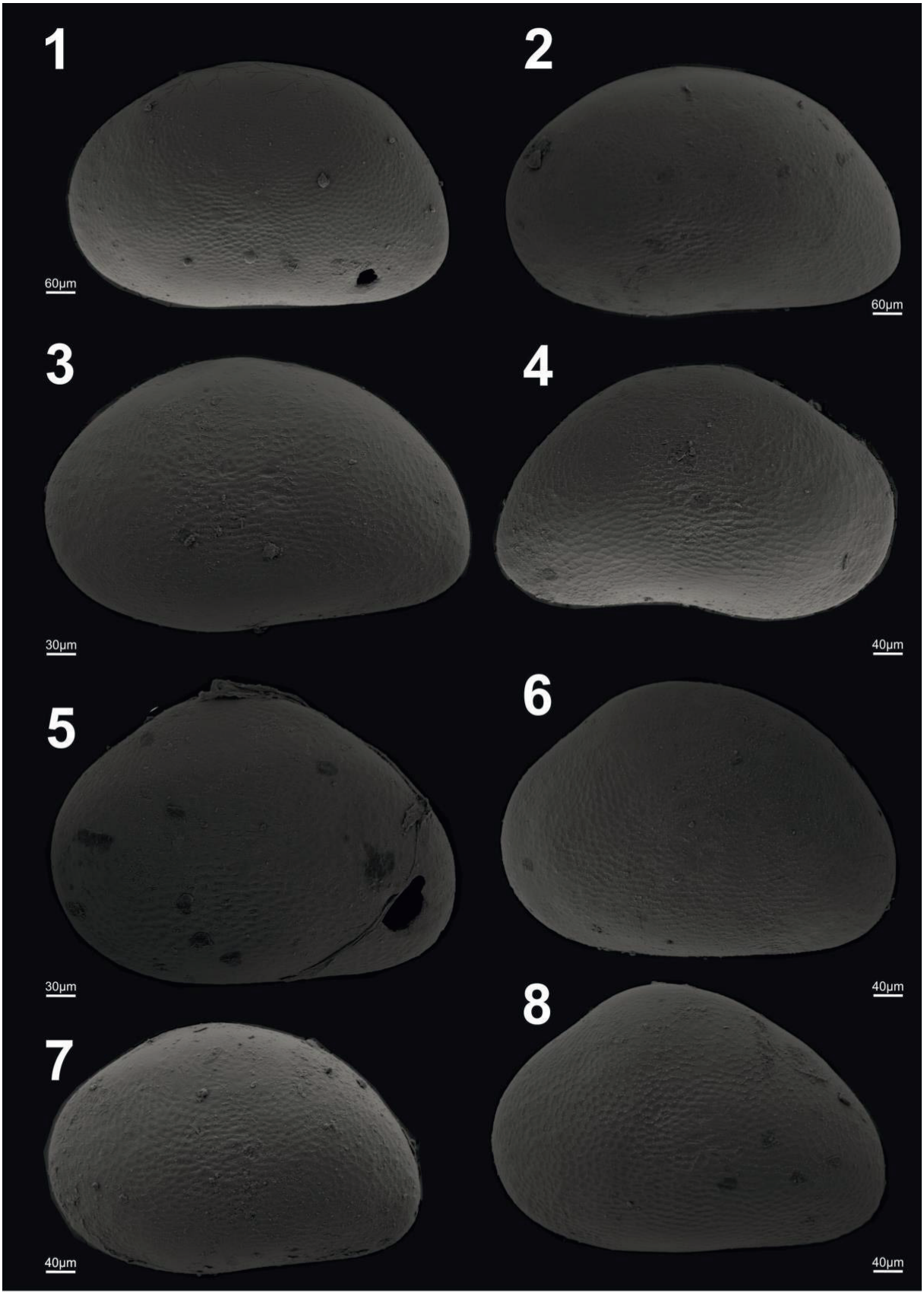

PLATE IV

Figures 1-3. *Candona (Candona) lycica* Freels, 1980

Right shell, outer appearance, Köprüköy Measured Section 1, sample no. 13

Shell, left lateral appearance, Köprüköy Measured Section 1, sample no. 13

Shell, left lateral appearance, Köprüköy Measured Section 1, sample no. 20

Figures 4-5. *Candona (Candona) armenia* Freels, 1980

Left shell, outer appearance, Köprüköy Measured Section 1, sample no. 13

Shell, left outer appearance, Köprüköy Measured Section 1, sample no. 4

Figure 6. *Candona (Candona)* aff. *elongata* (Svejer, 1949)

Right shell, outer appearance, Köprüköy Measured Section 2, sample no. 6

Figure 7. *Fossilyocypris sarızensis* (Şafak, Nazik and Şenol, 1992)

Right shell, outer appearance, Köprüköy Measured Section 1, sample no. 21

Figure 8. *Dreissena polymorpha* (Pallas,1771)

Right shell, outer appearance, Köprüköy Measured Section 2, sample no. 9

PLATE IV