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MOLLUSCAN ASSEMBLAGE AND PALEOECOLOGY OF LOWER MIOCENE SEQUENCES OF MUNZUR MOUNTAINS (EASTERN ANATOLIA, TURKEY)

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Research Article

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ABSTRACT

The research subject is the Miocene aged units that located in the Munzur Mountains at the Ovacık district of the Tunceli province. There is a continuous sediment deposits from Paleozoic to Cenozoic at the Munzur Mountains. The neritic limestones of the Miocene Başpınar formation outcropping in the Ovacık district are rich in fossil groups of gastropods and bivalves. In this study, 336 samples from the Başpınar formation have been evaluated. Seven species of Gastropoda (Globularia carlei, Granulolabium plicatum, Granulolabium (Tiaracerithium) thiarella, Tympanotonus margaritaceus, Terebralia subcorrugata, Nassarius erunalae, Cerithium vulgatum,) and four species of Bivalvia (Cardita rusticana, Anadara aquitanica, Cubitostrea digitalina, Ostrea lamellosa) were identified. One more species of Bivalvia was identified by using open nomenclature (*Chlamys* sp.). The studied fossil assemblage of the Başpınar formation indicates a lower Miocene age. Furthermore, for the first time in this study, paleoecological species diversity is calculated by using the Simpson, Shannon-Weaver, Epilou and Margalef indices for the locations where the fossils were collected. Numerical results are obtained by comparing bivalves and gastropods. According to these results, the Gastropoda specimens shows higher dominance (Simpson index D = 0,82), higher species diversity (Shannon-Weaver index H = 2,53) and higher species richness (Margalef index M = 1,23) when correlated with Bivalvia specimens. The Epilou index value (Ep = 0,9) gives the result that the species numbers in the gastropods are approximately equal to each other.

1. Introduction

The study area is located 20 km northeast of Ovacık district of Tunceli province (Figure 1). Munzur Mountains which are located at the northeastern end of the Taurus belt, are associated with both the Pontids and the Taurids (Özer, 1994). The oldest units in the study area are Permian and the youngest units are Miocene aged. The gastropod and bivalve fossils found in Miocene sediments in the region, provide important insights for the Miocene paleogeography, biostratigraphy and paleoecology.

Since 1940's Munzur Mountains have been the subject of many studies about the determination of its geological features, geological mapping (Ketin, 1945; Baykal, 1953; Nebert, 1955 and 1959); petroleum exploration (Kurtman, 1961); the determination of coal potentials (Ağralı, 1967; Kurdoğlu, 1976); geological, tectonical and stratigraphical researchs (Özgül et al., 1981; Tüysüz, 1993; Özer, 1994). Nevertheless, no detailed studies were conducted about the bivalves and gastropods. With this study, detailed systematic studies and paleoecologic diversity applications have been made. The aim of this compilation and application study, is to put forward the systematics of the mollusk fossils and to make paleoecological species diversity (Simpson, Shannon-Wiener, Epilou and Margalef Indeces).

2. Material and Method

The materials examined in this study are the samples from the archives of the Directorate of MTA Natural History Museum (MTA project number: 8034 and inventory numbers: 80/175, 80/176, 80/177,

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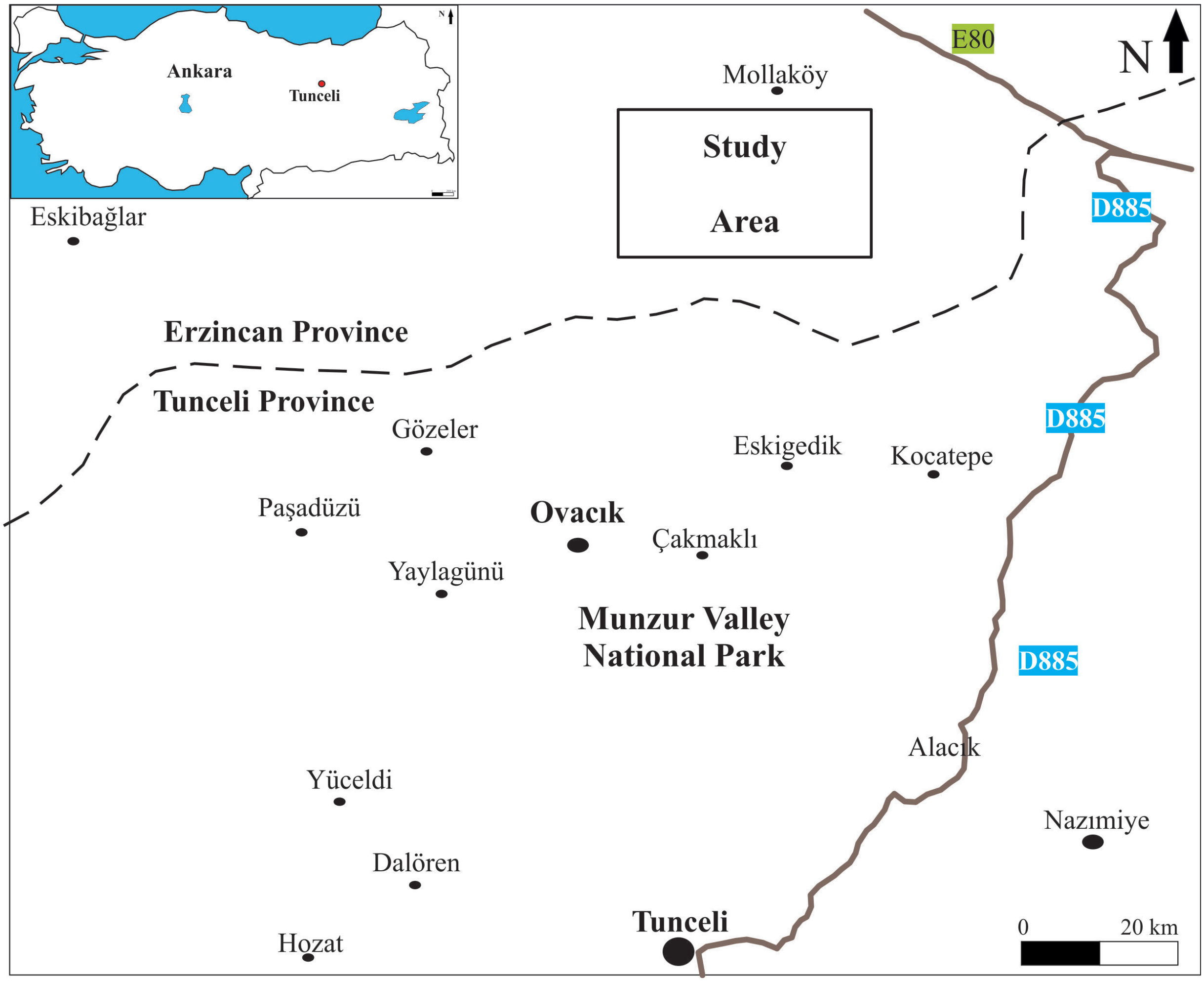


Figure 1- Location map of the study area.

80/178, 80/179, 80/180, 80/181, 80/182, 80/183, 80/184) which were collected for the project titled "Sedimentology and Biostratigraphy of the Lignite Bearing Lower Miocene Sediments from Munzur Mountains" carried out by Karabıyıkoğlu and Örçen (1986). A total of 336 samples are redescribed. Systematic determinations are made according to Moore (1964-1969) and Wenz (1938-1943).

For the characterization of these archive samples, Alpha (α) Species Diversity Quantitative Indixes (Simpson-D, Shannon-Wiener-H, Margalef-M ve Pielou-Ep) have been used. From these indices, Alpha (α) Diversity is used to calculate the quantitative variability of the environment (Whittaker, 1972). The total number of individuals for the identified species are counted, the required calculations were made with the formulas and a table of species diversity was created for the restricted location.

3. Regional Geology and Stratigraphy

Samples that constitute the subject of this work were taken from the area located 20 km to the northeast of Ovacık district of Tunceli province which is located at the 1: 25.000 scaled geological map Erzincan I42c3 (Figure 2).

According to the stratigraphical and the structural relationships, the rock units of the region can be seperated into three different groups; these are "Munzur Limestone Units", "Ovacık Units" and Tertiary "Post-Tectonic Units" (Figure 3) (Özgül et al., 1981).

Munzur Mountains are characterized by a sequence of Mesozoic limestones, late Cretaceous ophiolitic melange and early Miocene conglomerate, mudstone, marl, limestone and lignite interbeds. Locally, Quaternary sediments cover these units (Karabıyıkoğlu and Örçen, 1986).

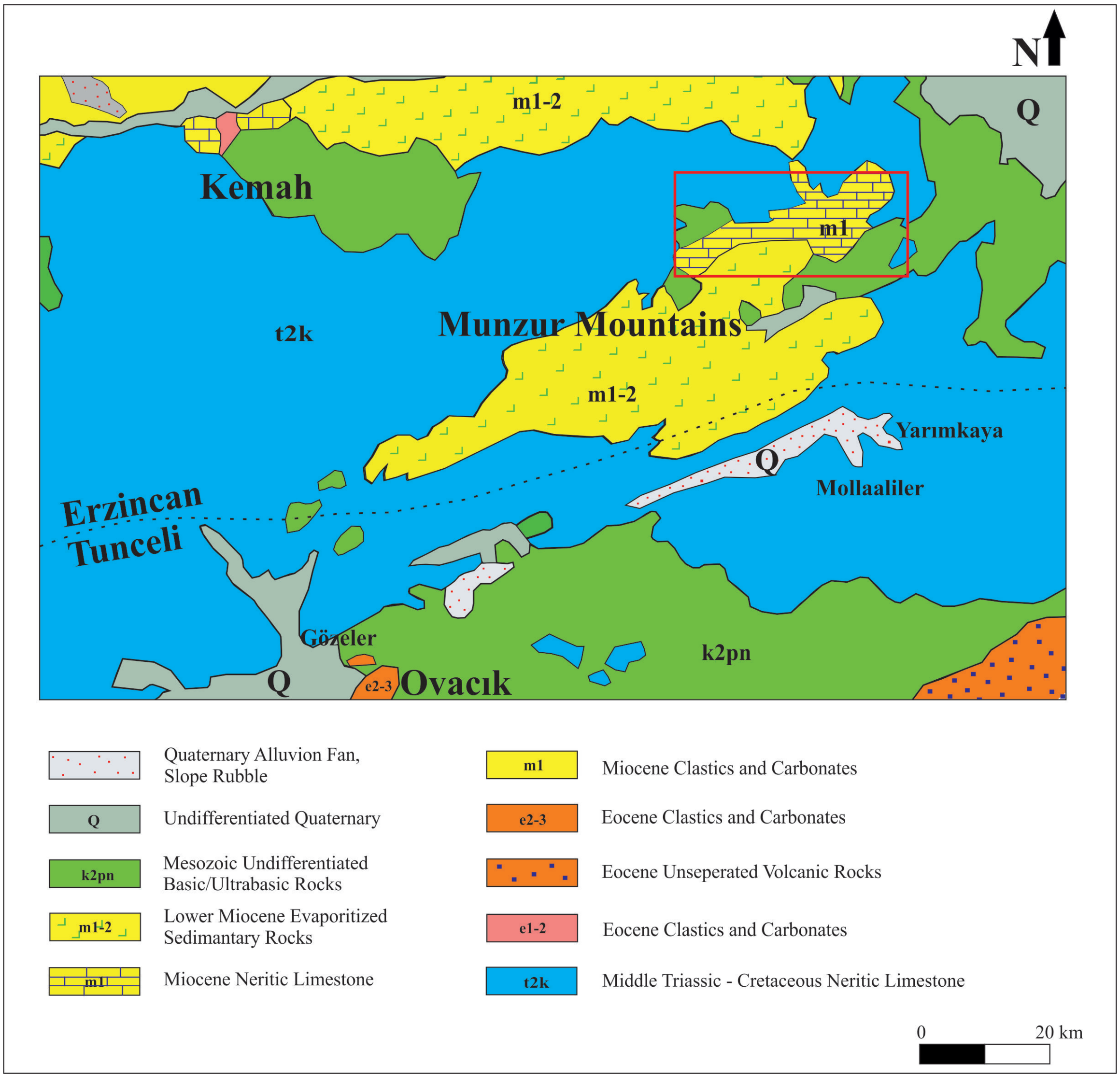


Figure 2- Geological map of the Munzur mountains (adapted from the Tarhan, 2008)

Mesozoic limestones are the most common units seen in the region. These units, defined as the “Munzur Limestone Units”, represent a large part of the Mesozoic (Upper Triassic - Upper Cretaceous) (Özgül, 1981). The unit with algal and reefal limestone facies is generally deposited on a shallow carbonate platform. At the last stages of sedimentation, the carbonate platform was replaced by deep sea sedimentation (Karabıyıkoğlu and Örçen, 1986).

The Upper Cretaceous Ophiolitic Melange overlies the Munzur limestones resting over a tectonic contact. This unit defined within the scope of the “Ovacık Group”, is called the Eriç Ophiolitic Complex and consists of various sizes of neritic and pelagic limestone blocks and ophiolites. (Özgül, 1981).

The Early Miocene “Başpınar formation” includes clastics, fossiliferous limestones and volcanic rocks. This unit begins with a conglomerate that contains pebbles and blocks of the basement rocks and overlies the Eocene rock units with an angular unconformity. On the other hand, it is locally overlain by Quaternary sediments. The limestone layers of the formation are quite rich in fossils. The beds contain micro and macro fossils of benthic organisms such as bivalves, gastropods, echinids and corals. The determination of the age of the formation was based on the Burdigalian fossil assemblages (Özgül et al., 1981).

Karabıyıkoğlu and Örçen (1986) stated that the sediments defined within the scope of the “Başpınar formation” are characterized by conglomerates,

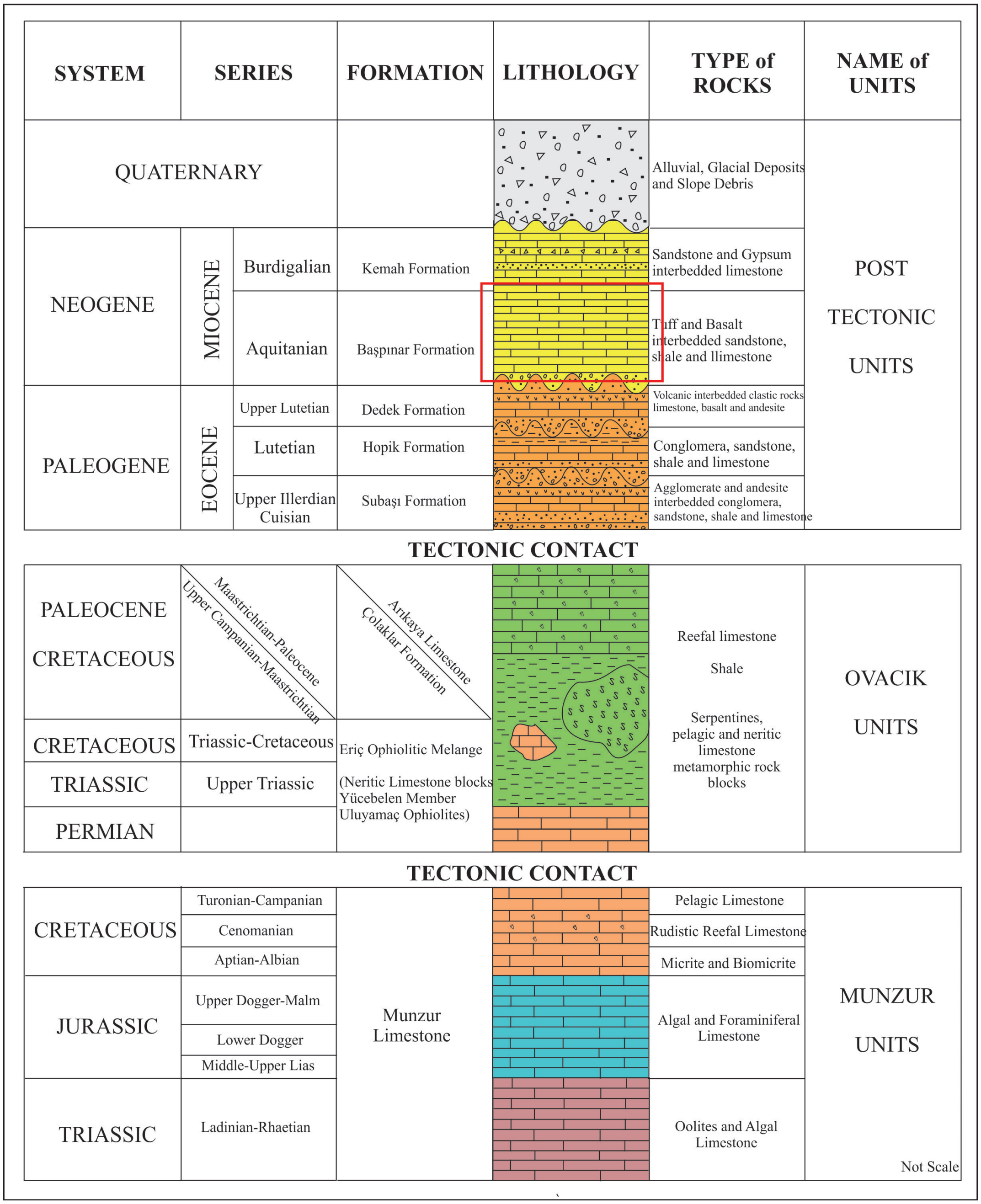


Figure 3- Litostratigraphy units of the Munzur mountains (modified from Özgül et al., 1981)

limestones, mudstones and marls, and a limited amount of marl layers interbeded with lignite. Based on the described micro and macro fossil samples, the authers suggested an early Early Miocene (Aquitanian) age for the formation.

The Başpınar formation contains limestones and clastic rocks that reflect the litoral and sublitoral environmental conditions. To the north, in the high regions of the Munzur Mountains, clay-silt grade rocks and limestone layers are the dominant lithologies. The gypsum and coal beds found in the northeast of Ovacık district reflect a deltaic environment. The Başpınar Formation is interbedded with tuff, agglomerate and basalt in the South of the Ovacık. Volcanics are not present in the region of Munzur Mountains (Özgül et al., 1981).

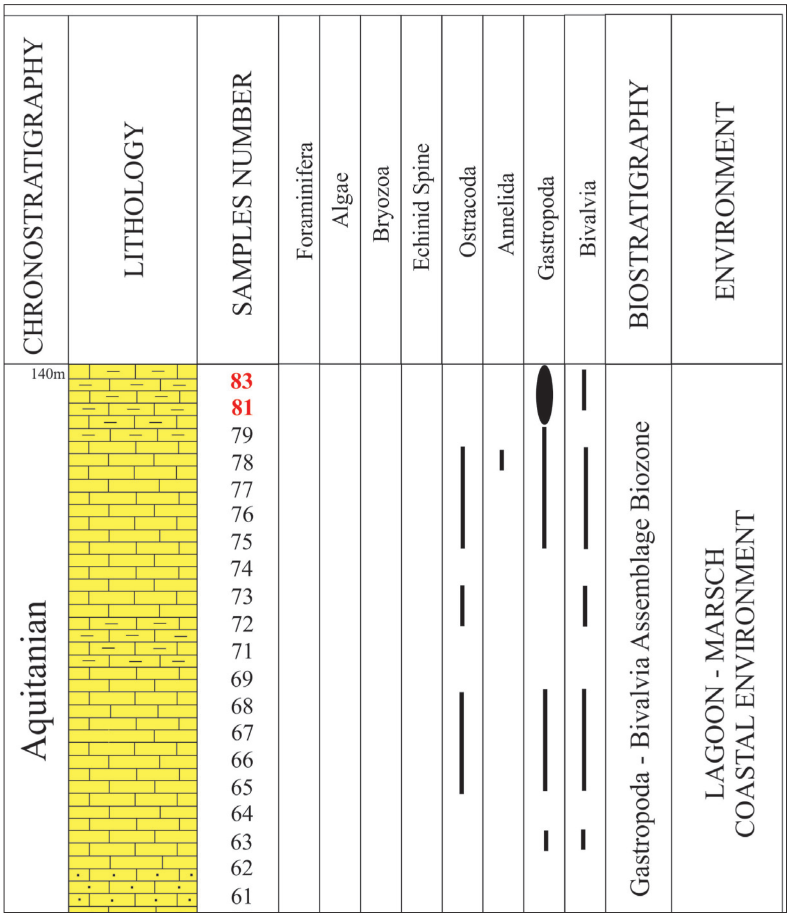


Figure 4- Distribution of described fossils of Tırbi Musa yaylası section (modified from Karabıyıkoğlu and Örçen, 1986)

4. Tırbi Musa Yaylası Section

The specimens (81-83) of Tırbi Musa Yaylası Section measured for the project were titled "Sedimentology and Biostratigraphy of the Lignite Bearing Lower Miocene Sediments from Munzur Mountains" by Karabıyıkoğlu and Örçen (1986) (Figure 4).

The section has total thickness of 140 m and alternated marl and limestone. The ecological characteristics of the described fossils are taken into consideration and tried to explain environmental interpretation.

5. Systematic Paleontology

Genus: *Globularia* Swainson, 1840

Globularia carlei (Finlay, 1927)

Plate I, Figures 1a, b, c

1927 *Natica carlei* Finlay, page 498, plate 57.

1961 *Globularia (Cernina) carlei* (Finlay), Dey, page 54, plate 5, figures 3-6.

2009 *Globularia carlei* (Finlay), Harzhauser et al., page 338, figures 2c, d.

2010 *Globularia (Globularia) carlei* (Finlay), Kulkarni et al., page 327, figures 3b1, 3b2

2011 *Globularia carlei* (Finlay), Hasani and Vaziri, page 127, figures 7C_1-C_2

Description: The shells are trochiform, 5-6 whorls, the last whorl encloses all the previous whorls and constitute 5/6 of the total height. There is a small nucleus in the centre and this embryonic shell is followed by teleoconch. The sutures are slightly inclined and deep; thin oblique eadial ridges can be observed on the shell surface. The aperture is wide and elongated downward.

Dimensions: Ten partly damaged shells

Height: 30 mm, Width: 25 mm, The last whorl height: 25 mm.

Similarities and Differences: The mouth structure, the stepwise transition of the whorls and the pointed protoconch are the similar features with the specimens of Dey (1961), Harzhauser et al., (2009), Kulkarni et al., (2010) and Hasani and Vaziri (2011).

Paleogeographical Distribution and Paleoecological Features: *Globularia carlei* is widespread in Burdigalian of Kutch basin and Kerala in India (Harzhauser et al., 2009), Miocene epoch in Kachchh, Gujarat in southwest India and Kenya (Dey, 1961; Kulkarni, 2010), in Early Miocene of Sirjan-Kerman in Iran (Hasani and Vaziri, 2011). The genus Globularia is living epifaunally and it is a sediment grazer in the lagoon or shallow subtidal environments.

Stratigraphical Distribution: Lower Miocene

Genus: *Granulolabium* Cossmann, 1889

Granulolabium plicatum (Bruguiére, 1789)

Plate I, Figures 2a, b

1789 *Cerithium plicatum* Bruguiére, page 488, plate 11.

1906 *Potamides (Pirenella) plicata* (Bruguiére), Cossmann, Serie 78, page 116, plate 11, figures 17,18.

1924 *Pirenella plicata* (Bruguiére), Cossmann and Peyrot, serie 73, page 267-269, plate 5, figures 99-101; plate6, figures 42, 44.

1939 *Pirenella plicata* (Bruguiére), Stchépinsky, page 35, plate 10, figures 25-27.

1946 *Pirenella plicata* (Bruguiére), Stchépinsky, page 138, plate 30, figures 13-14.

1958 *Pirenella plicata* (Bruguiére), Hölzl, page 191.

1973 *Pirenella plicata* (Bruguiére), Baldi, page 259, plate 29, figure 3.

1986 *Granulolabium plicatum* (Bruguiére), Lozouet, page 27, figures 1-5.

2001 *Granulolabium plicatum* (Bruguiére), Lozouet et al., page 27, plate 8, figures 1a-1b, 2a-2c, 3a-3c.

2002 *Granulolabium plicatum* (Bruguiére), Harzhauser, page 73, plate 1, figures 17-20.

2004 *Pirenella plicata* (Bruguiére), Özoğul, page 18, plate 1, figures 1-3,

2004 *Granulolabium plicatum* (Bruguiére), harzhauser, page 120, plate 4, figures 13-14, plate 5, figures 1-4.

2007 *Granulolabium plicatum* (Bruguiére), harzhauser, page 95, plate 2, figure 10.

Description: The shell is medium-sized conical, the number of whorls are 8-9, the suture is not deep; there are spiral bands on the whorls and there is four quadrangular granules side by side and from top to bottom. The aperture is narrow, the siphon is short, the columella edge is flat.

Dimensions: Seventy-eight partly damaged shells

Height: 30 mm, Width: 25 mm, The last whorl height: 25 mm.

Similarities and Differences: It shows similar characteristics with the samples of Cossmann (1906), Cossmann and Peyrot (1924), Özoğul (2004) and Harzhauser (2002, 2004, 2007) in terms of the numbers of the whorls, granules on the whorls and aperture morphology.

Paleogeographical Distribution and Paleoecological Features: It is characteristic in Aqutaine Basin in France and in Aquitanian of Italy (Cossmann and Peyrot, 1924). It is widespread in Eggenburgian of the Vienna Basin (Hölzl, 1958), in Hungary (Egerian), in Germany (Burdigalian) (Baldi, 1973). It is one of the widespread form in the Late Oligocene and Miocene seas in Europe. It is found in a large part of the Western Tethys, and then slowly disappears after Early Miocene. Lastly iti is observed at Carpathians, Korneuburg, Vienna Basin of Paratethys (Harzhauser, 2007). It is observed at Lower Miocene in Sivas, Turkey. (Stchépinsky, 1939) and Lower Miocene in Erzincan-Turkey (Özoğul, 2004). Lozouet (1986) has performed a study for the *Granulolabium* genus by using Nannoplankton biozone. According to this study, samples taken from 5 different regions of Oligocene-Early Miocene age, *Granulolabium* genus was determined as typical lagoonal and very shallow coastline form and inhabit the oligohaline salinity. The living representatives of this genus have an epifaunal lifestyle in muddy areas and lagoons in the mediolitoral zone (10- 150 cm) and are sediment grazers (Lozouet vd., 2001; Harzhauser and Mandic, 2001).

Stratigraphic Distribution: Lower Miocene

Genus: *Granulolabium* Cossmann, 1889

Subgenus: *Tiaracerithium* Sacco, 1895

Granulolabium (Tiaracerithium) thiarella (Grateloup, 1832)

Plate I, Figures 3a, b

1895 *Tiaracerithium pseudotiarella* var. *pseudopicta* Sacco, serie 17, page 35, plate 2, figure 92.

1922 *Pirenella pseudotiarella* d'Orbigny, Cossmann and Peyrot, serie 73, page 278, plate VI, figures 40-41.

1922 *Pirenella pseudotiarella* d'Orbigny var. *pictoides* Cossmann ve Peyrot, serie 73, pages 53-57, plate 6, figure 41.

1986 *Granulolabium (Tiaracerithium) pseudotiarella* (d'Orbigny), Lozouet, page 185, plate 2, figure 5.

2001 *Granulolabium (Tiaracerithium) thiarella* (Grateloup, 1832), Lozouet et al., page 28, plate 8, figure 4.

Description: The shell is quite small conic and the number of whorls are 9-10, begining from protoconch the first eight whorls are striae and the last two whorls are with tubercules.

Dimensions: Fifty-five well preserved shells

Height: 9 mm, Width: 5 mm, The last whorl height: 2,5 mm.

Similarities and Differences: The samples are similar with the figures 40-41 of Cossmann and Peyrot (1922) and plate 8, figure 4 of Lozouet et al. (2001) in terms of whorl morphology, the first eight whorls are striae and tubercules on the last two whorls.

Paleogeographical Distribution and Paleoecological Features: It is characteristic in Aquitaine basin in France (Cossmann and Peyrot, 1922; Lozouet et al., 2001). This genus is living epifaunally in the lagoon or shallow subtidal environments and it is a grazer (Lozouet 1986-2001).

Stratigraphic Distribution: Lower Miocene

Genus: *Tympanotonus* Schumacher, 1817

Tympanotonus margaritaceus Brocchi, 1814

Plate I, Figures 4a, b, c

1814 *Murex margaritaceus* Brocchi, page 447, plate 9, figure 24.

1921 Tympanotomus margaritaceus (Brocchi); Wenz, p. 131, pl. 15, fig. 1.

1921 *Tympanotomus margaritaceus* (Brocchi), Wenz, page 131, plate 15, figure 1.

1922 *Tympanotonus margaritaceus* (Brocchi), Cossmann and Peyrot, serie 73, page 248-253, plate 5, figures 60, 64, 67; plate 7, figures 1, 2, 6.

1938 *Tympanotonus (T.) margaritaceus* (Brocchi), Wenz, page 739-740, figure 2142.

1946 *Tympanotonus margaritaceus* (Brocchi), Stchépinsky, page 61, plate 30, figures 3-6.

1996 *Tympanotonus (T.) margaritaceus* Brocchi, Taner, plate 2, figures 3, 3a.

2001 *Tympanotonus margaritaceus* (Brocchi), Harzhauser and Mandic, page 696, plate 1, figures 4-6.

2001 *Tympanotonus margaritaceus* (Brocchi), Harzhauser and Kowalke, page 364, figures 5.7-5.9.

2004 *Tympanotonus margaritaceus* (Brocchi), Harzhauser, page 98, plate 5, figure 11.

2005 *Tympanotonus margaritaceus* (Brocchi), Esu et al., page 78.

2008 *Tympanotonus margaritaceus* (Brocchi), İslamoğlu, page 266.

2010 *Potamides (Mesohalina) margaritaceus* (Brocchi), Esu and Girotti, plate 6, figures 1-3.

Description: The shell is medium-sized, straight conical; number of whorls is 6-7 in the broken sample; suture is not deep; the whorls are decorated with two rows of thick and a thinner middle row of tight nodular granules; the mouth is narrow and siphon is short.

Dimensions: Fourty-five partly damaged shells

Height: 15 mm, Width: 5 mm, The last whorl height: 5 mm

Similarities and Differences: Although most of the samples have been broken, the tight nodular granules, the short siphon and the mouth structure constitute the similarities with the *Tympanotonus margaritaceus* specimens of Cossmann (1922), Stchépinsky (1946) and Harzhauser (2004). Even if the fossils described by Esu and Girotti (2010) as *Potamides (Mesohalina) margaritaceus* (plate 6, figure 1-3) are similiar to our specimens, they have more whorls.

Paleogeographical Distribution and Paleoecological Features: *Tympanotonus margaritaceus* specimens is characteristic in Aquitaine basin in France. They are wide spreading from Hungary to the Pyrenees in Middle Miocene (Taner, 1996). Most *Potamides* live in shallow lagoons, low or variable salinity and salty inland lakes and muddy coastal plains (Esu and Girotti, 2010; Harzhauser, 2004). The genus *Tympanotonus* lives epifunally in coastal, lagoonal or subtidal environments and herbivorous. (Lozouet et al., 2001, Esu et al., 2005; Esu and Girotti, 2010).

Stratigraphic Distribution: Lower-Middle Miocene

Genus: *Terebralia* Swainson, 1840

Terebralia subcorrugata (d'Orbigny, 1852)

Plate I, Figures 5a, b

1852 *Cerithium subcorrugatum* d'Orbigny, 3, page 80.

1906 *Terebralia subcorrugata* (d'Orbigny), Cossmann, serie 7, page 125, plate 10, figures 21-22.

1922 *Terebralia subcorrugata* (d'Orbigny), Cossmann and Peyrot, page 260, plate 6, figures 61-62.

1986 *Terebralia subcorrugata* (d'Orbigny), Lozuet, page 169, figure 1d.

2001 *Terebralia subcorrugata* (d'Orbigny), Lozouet et al., page 26, plate 8, figures 6a-6b, 7a-7b, plate 9, figure 10.

2003 *Terebralia subcorrugata* (d'Orbigny), İslamoğlu and Taner, serie 127, page 29-65, plate 2, figures 4a, 4b, 5, 6.

2005 *Terebralia subcorrugata* (d'Orbigny), Esu et al., page 78.

2010 *Terebralia subcorrugata* (d'Orbigny), Esu and Girotti, seri 53 (1), page 137-174.

Description: The shell is medium conical, number of whorls is 8-9, suture line is not deep, there are four rows spiral strips on each whorl, side by side granulated; the last is whorl is wide, mouth is nearly rounded.

Dimensions: Twenty-eight partly damaged shells

Height: 30 mm, Width: 25 mm, The last whorl height: 25 mm.

Similarities and Differences: Number of whorls, granules and mouth structure is similiar to the specimens of Cossmann (1906), Cossmann and Peyrot (1922), İslamoğlu and Taner (2003) and Esu and Girotti (2010).

Paleogeographical Distribution and Paleoecological Features: It is typical in Aquitaine basin in France (Cossmann and Peyrot, 1922). It is widespread in Aquitanian in Italy; Sarmatian in Austria, Hungary and Poland; Oligo-Miocene (Aquitanian) Mainz, Bavaria, Northern Alps, Vienna, Greece and Turkey (Lozuet, 1986; Esu and Girotti 2010); Early Miocene in Antalya, Turkey (İslamoğlu and Taner, 2003). The genus *Terebralia* lives epifaunally in lagoon or limited subtidal zone and it is a sediment grazer (Esu and Girotti, 2010).

Stratigraphic Distribution: Lower Miocene

Genus: *Cerithium* Bruguière, 1789

Cerithium vulgatum Bruguière, 1792

Plate I, Figures 6a, b, c

1757 *Cerithium goumier* Adanson, page 156, plate 10, figure 3.

1792 *Cerithium vulgatum* Bruguiére, page 481.

1883 *Cerithium vulgatum* var. *mutica* Bruguiére, Bucquoy, Doutzenberg and Dollfuss, page 5, plate 22, figures 1-15.

1895 *Cerithium vulgatum* var. *spinosa* Bucquoy, Sacco, serie 17, page 6, plate 1, figures 15-31.

1922 *Cerithium (Vulgocerithium) vulgatum* Bruguiére, Cossmann and Peyrot, serie 73, page 188, plate 5, figures 33-34.

1997 *Cerithium (Thericium) vulgatum* Bruguiére, Anistratenko, page 69, figure 1a.

2004 *Cerithium (Thericium) vulgatum* Bruguiére, Landau et al., page 8, plate 1, figures 10-11.

2006 *Cerithium (Thericium) vulgatum* Bruguiére, Chirli, page 87, plate 35, figures 7-15.

2013 *Thericium vulgatum* (Bruguiére), Harzhauser et al., page 359, plate 1, figure 7.

Description: The shell is medium sized conical, the number of whorls is 8-9, the suture is not deep and it is like a chain. There are beaked granules on the whorls and the number of granules are 10-12 at the last whorl. And also there are four chain-like lines on the last whorl similar to the suture line.

Dimensions: Sixty-five partly damaged shells

Height: 40 mm, Width: 15 mm, The last whorl height: 15 mm.

Similarities and Differences: Number of whorls, chain-like suture line, and granules are the similiar features to *C. vulgatum* var. *spinosa* and *C. vulgatum* var. *mutica* specimens of Sacco (1895) and Bucquoy et al. (1883). The species *Thericium vulgatum* described by Harzhauser et al. (2013) on a single eroded specimen is considered synonymous with *Cerithium vulgatum* Bruguière, 1792.

Paleogeographical Distribution and Paleoecological Features: It was described in Aqutine Basin in France (Cossmann and Peyrot, 1922); widespread from Miocene to Pliocene in Italy, in Tortonian at northern Italy (Sacco, 1895); Lower Miocene in Mediterranean and Atlantic region (Harzhauser et al., 2013). The genus *Cerithium* lives muddy and sandy grounds epifaunally in shallow subtidal environments that is the irregular sea water changes and rich in organic matters and it is a sediment grazer (Satyanarayana and Sundaram, 1972).

Stratigraphic Distribution: Miocene - Pliocene

Genus: *Nassarius* Duméril, 1805

Nassarius erunalae Landau et al. 2013

Plate I, Figures 7a, b, c

2013 *Nassarius erunalae* Landau et al., 11-13, page 175, plate 26, figures 7a-7b; 8a-8b.

Description: The specimens are very small and conical, 4-5 whorls, the final whorl height is approximately two times higher than the spir height; protoconch is rounded. The whorls are decorated with thick vertical lines, these lines constitute small granules towards the suture line. The mouth is extended downward, anterior is open; there are 2-3 lateral lines on the columella edge.

Dimensions: Twelve well preserved shells

Width: 5 mm, Height: 10 mm, The last whorl height: 5 mm.

Similarities and Differences: In terms of the number of whorls, granules and aperture structure of have similar features with the specimens of Nassarius *erunalae* Landau et al. (2013).

Paleogeographical Distribution and Paleoecological Features: Proto-Mediterranean Sea (Serravalian) in Karaman Basin, Turkey. The family of Nassaridae lives epifaunally in lagoons or limited shallow subtidal zones and it is carnivorous. (Carpentier et al., 1998).

Stratigraphic Distribution: Middle Miocene

Genus: C*ardita* Bruguière, 1792

Cardita rusticana Mayer, 1861

Plate II, Figures 1a, 1b

1861 *Cardita rusticana* Mayer, Mayer, serie 9, page 361.

1899 *Cardita rusticana* Mayer, Sacco, serie 27, page 11, plate 4, figure 1.

1914 *Cardita rusticana* Mayer, Cossmann and Peyrot, serie 2, page 40, plate 2, figures 15-20.

2012 *Cardita rusticana* Mayer, Cahuzac et al., page 388, plate 1.3.

Description: The shell is oval, the anterior side is short and rounded, the posterior side is straight from the umbo to the paleal edge, the paleal side has a long arc shape. The teeth are heterodontic; the hook is inflated and curved towards the front edge. The shell is decorated with radial lines and there are sequent granules along the lines.

Dimensions: Two well preserved valves

Height: 15 mm, Length: 25 mm.

Similarities and Differences: In terms of the anterior and the posterior sides features, teeth and sockets of the clamping system, swelling of the hook and sharp radial lines, *Cardita rusticana* Mayer is similiar to the specimens Sacco (1899) and Cossman and Peyrot (1914).

Paleogeographical Distribution and Paleoecological Features: It is characteristic in Aquitaine basin in France. The specimens are widespread in Tertiary (Tongriano) of Italy (Sacco, 1899); Miocene of Austria, Poland and Russia (Cossmann and Peyrot, 1914). The genus *Cardita* lives infaunally and facultatively mobile in lagoons or limited subtidal environments and it is a suspension feeder (Carpentier et al., 1998).

Stratigraphic Distribution: Miocene

Genus: *Anadara* Gray, 1847

Anadara aqutanica (Mayer, 1861)

Plate II, Figures 2a, 2b

1831 *Arca diluvii* Lamarck, du Bois de Montpéreux, page 63, plate 7, figures 10, 11, 12.

1861 *Arca aquitanica* Mayer, seri 9, page 362.

1882 *Arca diluvii* (Lamarck), Bucquoy, Dautzenberg and Dollfus, 2, plate 31, figures 13-17.

1898 *Anadara diluvii* (Lamarck), Sacco, seri 26, page 20, plate 4, figures 7-12.

1914 *Arca (Anadara) diluvii* (Lamarck), Cossmann and Peyrot, seri 2, page 149, plate 8, figures 3-6; plate 10, figure 53.

2005 *Anadara* cf. *A.diluvii* (Lamarck), Esu et al., page 78.

2010 *Anadara* cf. *A. aquitanica* (Mayer), Esu and Girotti, 53 (1), page 137-174.

Description: The shell is oval, the anterior side is short and round, the posterior side is straight from the hook and joins with the palial edge, approximately forming a right angle. The palial edge is long arc shaped. The umbo is inflated and curved towards the anterior side. The shell is decorated with radial lines and 2-3 growth lines which are parallel to the palial side.

Dimensions: Twenty-four well preserved valves

Height: 15 mm, Length: 25 mm.

Similarities and Differences: The shapes of the anterior and posterior sides and the radial growth lines on the shell are similar to *Arca (Anadara) diluvii* in Cossmann and Peyrot (1914), *Anadara* cf. *A.diluvii* in Esu et al. (2005) and *Anadara* cf. *A. aquitanica* in Esu and Girotti (2010).

Paleogeographical Distribution and Paleoecological Features: The specimens are widespread in Tertiary (Tongriano) of Italy (Sacco, 1898); Aquitanian-Burdigalian of Aquitaine basin in France (Cossmann and Peyrot, 1914); Oligo-Miocene (Aquitanian) of Mainz, Bavaria, Northern Alps, Vienna, Greece and Turkey (Esu and Girotti, 2010). The genus *Anadara* lives semi-infaunally and facultively mobile in sandy and pebbly substrates in litoral zone (infra-circalittoral zone) and it is a suspension feeder (Esu and Girotti, 2010).

Stratigraphic Distribution: Lower-Middle Miocene

Genus: *Ostrea* Linnaeus, 1815

Ostrea lamellosa Brocchi, 1814

Plate II, Figures 3a, 3b

1814 *Ostrea lamellosa* Brocchi, Brocchi, tome 2, page 564.

1831 *Ostrea lamellosa* Brocchi, du Bois de Montpéreux, page 74, plate 8, figures 13-14.

1870 *Ostrea lamellosa* Brocchi, Hörnes, seri 2, page 444, plate 71, figures 1-4.

1882 *Ostrea edulis* var. *lamellosa* Brocchi, Bucquoy, Dautzenberg and Dollfuss, seri 2 (14), plate 5, figures 1, 2, 3, 4.

1914 *Ostrea lamellosa* Brocchi, Cossmann and Peyrot, page 378, plate 22, figures 7-9.

1999 *Ostrea lamellosa* Brocchi, Munteanu and Munteanu, seri 2, plate 3, figures 3a, b.

2001 *Ostrea lamellosa* Brocchi, Schultz, page 358, plate 55, figures 1a-1b.

2003 *Ostrea lamellosa* Brocchi, İslamoğlu and Taner, page 8, plate 2, figures 1a, 1b, 2.

2003 *Ostrea lamellosa* Brocchi, Videt, page 36, plate 8, figures 1-4.

2004 *Ostrea lamellosa* Brocchi, Özoğul, page 32, plate 7, figures 1a-b, 2a-b; plate 8, figures 1a-b, 2a-b.

2014 *Ostrea lamellosa* Brocchi, Mikuž and Gašparič, page 159, plate 3, figures 1a-1b.

Description: The shell is very close to oval and small. The right valve is slightly convex and ornamented with regular and marked lamellae. The ligament is preserved and the umbo is not too swollen; the muscle scar is close to the posterior side; thin concentric growth lines are present over the shell surface.

Dimensions: Eight damaged valves

Height: 25 mm, Length: 20 mm, Thickness: 3 mm.

Similarities and Differences: In terms of the ligament, the umbo, the muscle scar pattern and the morphology of lamellae are similar to the specimens of *Ostrea lamellosa* Brocchi, 1814 from Munteanu and Munteanu, 1999; İslamoğlu and Taner, 2003; Videt, 2003; Özoğlu, 2004; Mikuž and Gašparič, 2014.

Paleogeographical Distribution and Paleoecological Features: The specimens are widespread in Lower to Middle Miocene of Austria, France, Germany and Italy; in Lower Miocene of Aquitaine Basin in France (Cossmann and Peyrot, 1914); Middle Miocene of Loire Basin; Eggenburgian-Badenian of Vienna basin (Schultz, 2001). It appears in the Lower Miocene in Mediterranean Basin and spreads rapidly during the Middle and Upper Miocene (Videt, 2003), in the Lower Miocene at Erzincan province of Turkey (Özoğlu, 2004) and Miocene in Slovenia (Mikuž and Gašparič, 2014). The species *Ostrea lamellosa* lives stationary epifaunal in coastal shallow tidal zone and it is a suspension feeder (Dewiyanti and Sofyatuddin, 2012).

Stratigraphic Distribution: Miocene

Genus: *Cubitostrea* Sacco, 1897

Cubitostrea digitalina (Eichwald, 1830)

Plate II, Figures 4a, 4b

1830 *Ostrea digitalina* Eichwald, page 213.

1831 *Ostrea digitalina* Eichwald, du Bois de Montpéreux, page 74, plate 8, figures 13-14.

1999 *Cubitostrea digitalina* (Eichwald), Munteanu and Munteanu, seri 2, plate 4, figures 8a, b.

2005 *Cubitostrea digitalina* (Eichwald), El-Hedeny, 24 (2), page 719-733, plate II, figures A-B.

2013 *Cubitostrea digitalina* (Eichwald), Hosseinipour and Dastanpour, page 1984, plate 1, figures f-h.

Description: The shell is small and triangular shaped. The valve is quite flat and ornamented with concentric lamellae. The ligament is not good preserved.

Dimensions: Six damaged valves

Width: 20 mm, Height: 25 mm, Thick:4 mm.

Similarities and Differences: In terms of the shape and the radial growth lines of the shell our samples are similiar to the specimens of du Bois de Montpéreux (1831) and El-Hedeny (2005).

Paleogeographic Distribution and Paleoecologic Features: It is widespread in France, Germany, Austria and Bulgaria in Miocene (Munteanu and Munteanu, 1999) and in Egypt in Middle Miocene (El-Hedeny, 2005). The genus *Cubitostrea* lives stationary epifaunal in shallow subtidal zone and it is a suspension feeder (Dewiyanti and Sofyatuddin, 2012).

Stratigraphic Distribution: Miocene

Genus: *Chlamys* Röding, 1798

Chlamys sp.

Plate II, Figures 5

Description: The shell is small-sized and triangular with thick radial lines over the shell surface.

Dimensions: Three damaged valves

Height: 35 mm, Width: 40 mm.

Similarities and Differences: Our specimen shows similiar characteristic features to *Chlamys (Aequipecten) liberata* (Cossmann and Peyrot, 1914; page 126, plate 17, figures 14-17) which is widespread in Lower Miocene (Aquitanian) but it is left open to nomenclature as there is only one broken shell. The genus *Chlamys* lives stationary epifaunal and it is a suspension feeder.

6. Paleoecological Species Diversity

In this study, a total of 336 fossils specimens are identified and the paleoecological species diversity is calculated for the interpretation of the paleoenvironment of the study area.

The determination of diversity for specific geographical areas is important for paleoecological interpretations. In this regard, a new science branch “Ecometry Studies” has been developed (Simpson, 1949; Shannon-Weaver, 1948). Ecometry is based on numerical expression of ecological concepts. It was developed to estimate the diversity of ecosystems in a specific area for different branches of science (biology, zoology, botany) quantatively. Biological richness or diversity refer to the differences and variability of the organisms, the environment they live in and their interactions with this environment (Gaston and Spicer, 2004).

Various indices are being used to determine the ecological species diversity and distribution of a region. Alfa (α) diversity which is determined locally gives the number of species in a single habitat. Beta (β) diversity is the ratio of species among local habitats. The gamma (γ) diversity also shows the diversity but in a greater extent where the research area is formed by numerous smaller sampling areas. Gamma diversity is expressed by the formula "$\gamma = \alpha \times \beta \times$ total habitat area" (Gülsoy and Özkan, 2008).

Diversity studies on fossil molluscs have started in the 1990s (CoBabe et al., 1994; Strong et al., 2008; Dinapoli et al., 2010; Petrova et al., 2012; Sharma et al., 2013). This study is unique as it is conducted on archived fossil samples. Only the alfa (α) diversity index values are calculated because the fossil samples were gathered from a restricted area. Four different index values are used for calculations and according to these formulas an attempt is made to interpret the paleoecological diversity numerically.

6.1. Simpson (D) Index: This index, which is used to introduce the environmental diversity, shows the predominance of species. Dominancy is limited between 0 and 1; the greater the D values, the greater the diversity of the environment (Simpson, 1949).

$$D = 1 - C \qquad C = \Sigma \, [\, Ni\,(Ni-1) \,/\, N\,(N-1) \,]$$

Ni: total number of individiuals of a species

N: total number of individiuals

6.2. Shannon – Weaver (H) Index: It indicates species diversity. Its value is limited between 0 and 5; H > 2,5 indicates that species diversity is increased. (Shannon and Wiener, 1949).

$$H = - \Sigma \, [\, pi \log_2 (pi)] \qquad pi = Ni / N$$

Ni: total number of individiuals of a species

N: total number of individiuals

6.3. Margalef (M) Index: It indicates species richness. It is not limited to any value. The highest M value indicates the highest species richness. (Margalef, 1958).

$$M = (S - 1) / \ln N$$

S: number of species

N: total number of individiuals

6.4. Pielou (Ep) Index: Its value is limited between 0 and 1 and indicates the distribution of dominance according to species. If there are equal numbers of individuals in each species, Ep value is 1 (Pielou, 1960).

$$Ep = H / \log_2 S$$

H: Shannon-Weaver Index

S: number of species

7. Discussions and Conclusions

As a result of individual counts, the numbers and percentages of the species are determined (Table 1) and percentage (%) distribution graphics were prepared (Figure 5).

Table 1- Number of species and percentages of Gastropoda and Bivalvia

Species	Number	%
Globularia carlei	10	3
Granulolabium plicatum	78	27
Granulolabium (Tiaracerithium) thiarella	55	19
Terebralia subcorrugata	28	10
Nassarius erunalae	12	4
Tympanotonus margaritaceus	45	15
Cerithium vulgatum	65	22
Total Gastropoda	293	87
Cardita rusticana	2	5
Anadara aquitanica	24	56
Ostrea lamellosa	8	18
Cubitostrea digitalina	6	14
Chlamys sp.	3	7
Total Bivalvia	43	13

Accordingly, the fossils belongs to Gastropoda class (87%) is more dominant than bivalves. This dominancy is due to the gastropods are more mobile and are more adaptable to sea level changes and salinity.

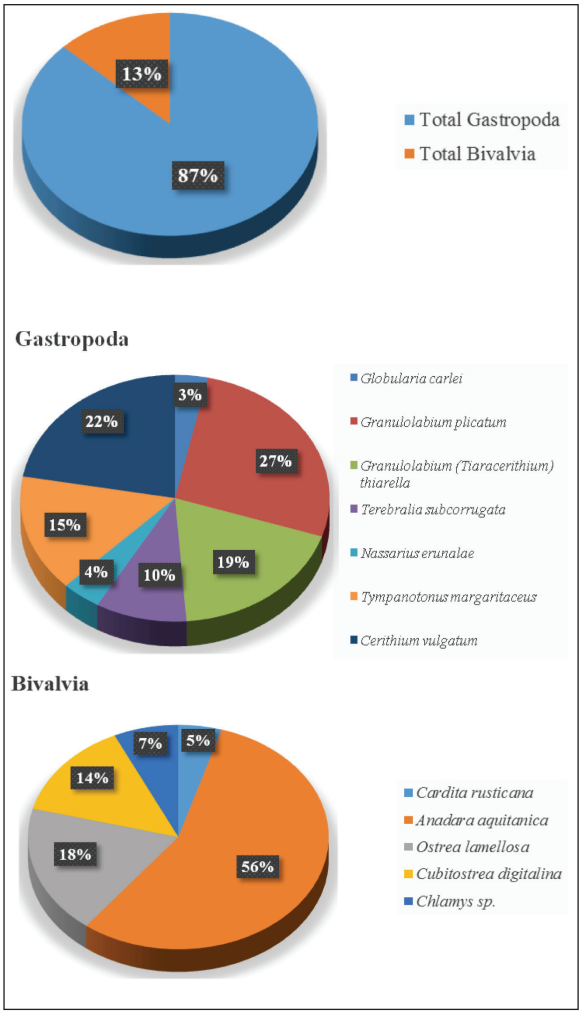


Figure 5- Graphics of Species Percentage Distribution (Gürsoy, 2016).

Result of the diversity index (Simpson, Shannon – Wiener, Margalef, Pielou) values of the specimens which were gathered from the Başpınar Formation of Tunceli-Ovacık district that are calculated by the appropriate formulas;

- The index values of the Gastropoda species are higher than the Bivalvia, this indicates the dominance of gastropods in the habitat (Table 2);

- Simpson Index value for gastropods is close to 1 (D = 0,82) and this indicates a more or less equality in diversity among the species;

- The Shannon-Wiener Index value is greater than 2,5 for gastropods, and this shows a greater variety for this class (Table 2);

- The Epilou Index value, which indicates the distribution of dominance by species, is (Ep = 0,9) for gastropods indicating that the defined gastropod species are approximately equal in number (Table 2).

- According to the Margalef index value, the class with the highest M value has the highest species richness; Gastropods have a higher species diversity than bivalves with a value of 1,23 (Table 2).

Table 2- Diversity index values of Gastropoda and Bivalvia.

Diversity Indexes	Gastropoda	Bivalvia
Simpson (D) (0-1)	0,82	0,64
Shannon-Weaver (H) (0-5)	2,53	1,8
Margalef (M) (limitsiz)	1,23	1,06
Epilou (Ep) (0-1)	0,9	0,33

The Başpınar Formation was characterized by a sequence of conglomerate, mudstone, limestone and marls. The age of the formation was assigned to Burdigalian (Özgül et al. 1981) and to Aquitanian (Karabıyıkoğlu and Örçen, 1986) by previous workers. As described fossils of this study, table 3 and table 4 are made.

These tables show the distribution of species identified from various locations in Europe, Balkans and Asia until today. Among the collected samples, the most commonly found species (*Cerithium vulgatum, Tympanotonus margaritaceus, Terebralia subcorrugata, Granulolabium plicatum*, *Granulolabium (Tiaracerithium) thiarella* and *Anadara aquitanica*) are the ones that have a distribution in the Aquitanian basin in France (Eames and Clarke, 1967). Besides these species *Ostrea lamellosa, Cubitostrea digitalina* and *Cardita rusticana* (Table 4) can be found up to Middle Miocene.

The Başpınar formation is characterized by a sequence of conglomerates, mudstones, limestones and marls and assigned to Burdigalian (Özgül et al., 1981) and to Aqutanian (Karabıyıkoğlu and Örçen, 1986) by the previous workers. In this study, the age of the formation is assigned as Aquitanian-Burdigalian (Table 5) and according to the environmental features of the fauna we can conclude that the paleoenvironmental conditions were that of a brackish water lagoon.

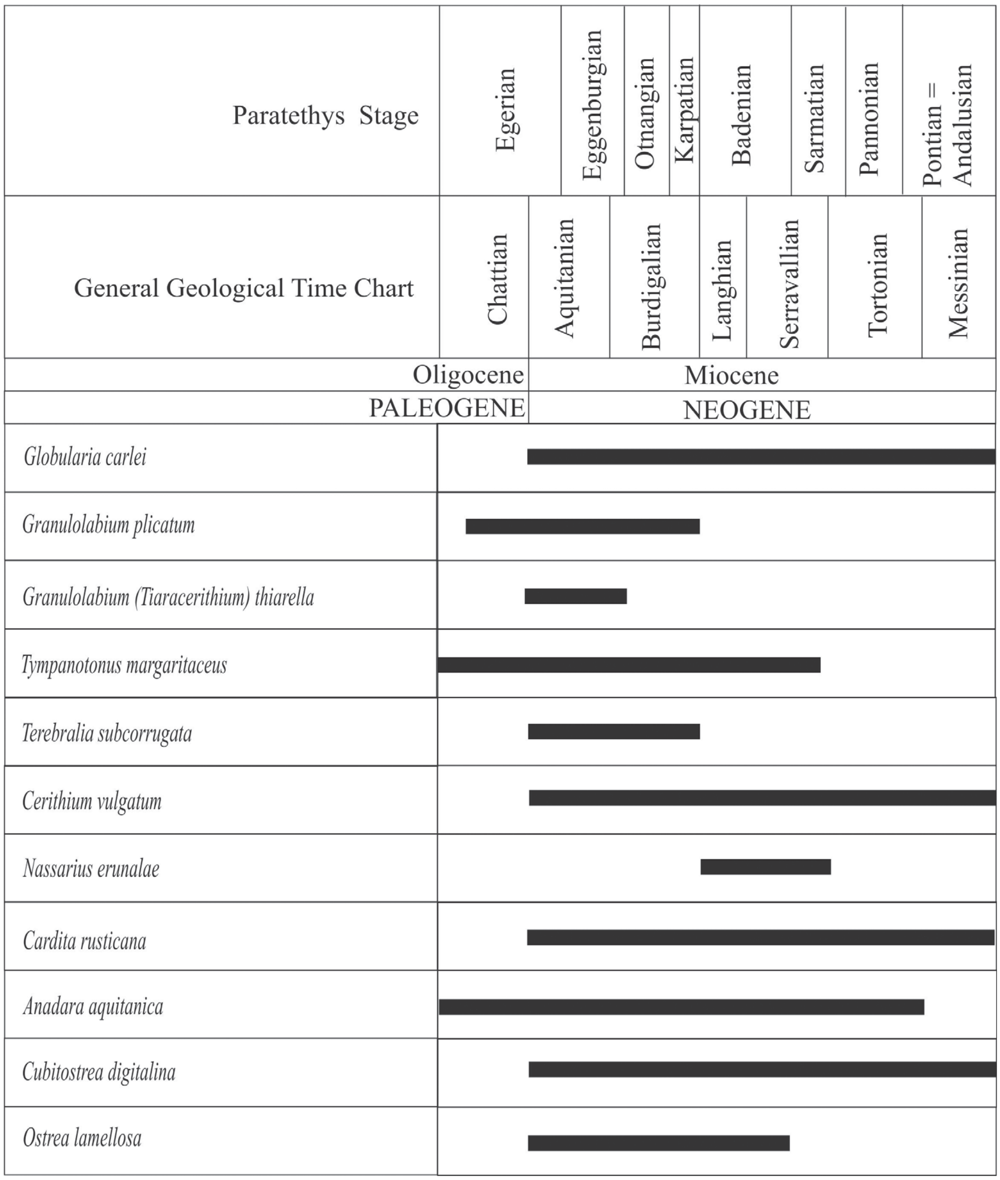
Table 3- Paleogeographic distribution of described species belongs to Gastropoda class.

Gastropoda	*Globularia carlei*	*Granulolabium plicatum*	*Granulolabium (Tiaracerithium) thiarella*	*Tymponatonus margaritaceus*	*Terebralia subcorrugata*	*Cerithium vulgatum*	*Nassarius erunalae*
France	Aquitanian (Cossmann and Peyrot, 1917)	Aquitanian (Cossmann and Peyrot, 1917)	Aquitanian (Cossmann and Peyrot, 1922; Lozouet, 2001)	Aquitanian (Cossmann and Peyrot, 1922; Lozouet, 2001)	Aquitanian (Cossmann and Peyrot, 1922; Lozouet, 2001)	Aquitanian (Cossmann and Peyrot, 1922)	
Italy		Aquitanian (Cossmann, 1906)	Aquitanian (Sacco, 1895)	Late Oligocene (Esu and Girotti, 2010)		Tortonian (Sacco, 1895) Middle Miocene (Harzhauser, 2013)	
Austria		Eggenburgian (Hölzl, 1958)		Early Miocene (Harzhauser and Kowalke, 2001)			
Germany		Burdigalian (Baldi, 1973)					
Hungary		Egerian (Hölzl, 1958)					
Poland							
Russia							
India	Burdigalian (Dey, 1961; Kulkarni, 2010)						
Kenya	Miocene (Dey, 1961; Kulkarni, 2010)						
Iran	Early Miocene (Hasani and Vaziri, 2011)						
Turkey		Early Miocene (Özoğul, 2004)		Egerian-Eggenburgian [illegible]	Early Miocene (İslamoğlu and Taner, 2003)		Middle Miocene (Landau et al., 2013)

Table 4- Paleogeographic distribution of described species belongs to Bivalvia class.

Bivalvia	*Anadara aquitanica*	*Cardita rusticana*	*Cubitostrea digitalina*	*Ostrea lamellosa*
France	Aquitanian-Burdigalian (Cossmann and Peyrot, 1914)	Aquitanian (Cossmann and Peyrot, 1914)	Aquitanian (Montpéreux, 1831) Miocene (Munt. and Munt., 1999)	E.-M.Miocene (Munt. and Munt., 1999)
Italy	Tongriano (Sacco, 1898)	Tongriano (Sacco, 1899)		E.-M.Miocene (Munt. and Munt., 1999)
Austria		Miocene (Cossmann and Peyrot, 1914)	Miocene (Munt.and Munt., 1999)	Eggenburgian-Badenian (Munt. and Munt., 1999)
Germany	Oligo-Miocene (Esu and Girotti, 2010)	Miocene (Cossmann and Peyrot, 1914)	Miocene (Munt.and Munt., 1999)	E.-M.Miocene (Munt. and Munt., 1999)
Poland		Miocene (Cossmann and Peyrot, 1914)		
Hungary				Eggenburgian-Badenian (Munteanu and Munteanu, 1999)
Bulgaria			Miocene (Munteanu and Munteanu, 1999)	Miocene (Munteanu and Munteanu, 1999)
Russia		Miocene (Cossmann and Peyrot, 1914)		
Greece	Oligo-Miocene (Esu and Girotti, 2010)			
Egypt			Middle Miocene (El-Hedeny, 2005)	
Turkey	Oligo-Miocene (Esu and Girotti, 2010)			E.-M.Miocene (Özoğul, 2004)

Table 5- Stratigraphic distribution of described species (Correlation chart between Global and Paratethys time scales were adapted from Leever et al., 2010).



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PLATES

PLATE I

1a, b, c *Globularia carlei* (Finlay, 1927)

2a, b *Granulolabium plicatum* (Bruguiére, 1789)

3a, b *Granulolabium (Tiaracerithium) thiarella* (Grateloup, 1832)

4a, b, c *Tympanotonus margaritaceus* (Brocchi, 1814)

5a, b *Terebralia subcorrugata* (d'Orbigny, 1852)

6a, b, c *Cerithium vulgatum* (Bruguiére, 1792)

7a, b, c *Nassarius erunalae* Landau et al., 2013

(The bars shows that 1 cm for each sample.)

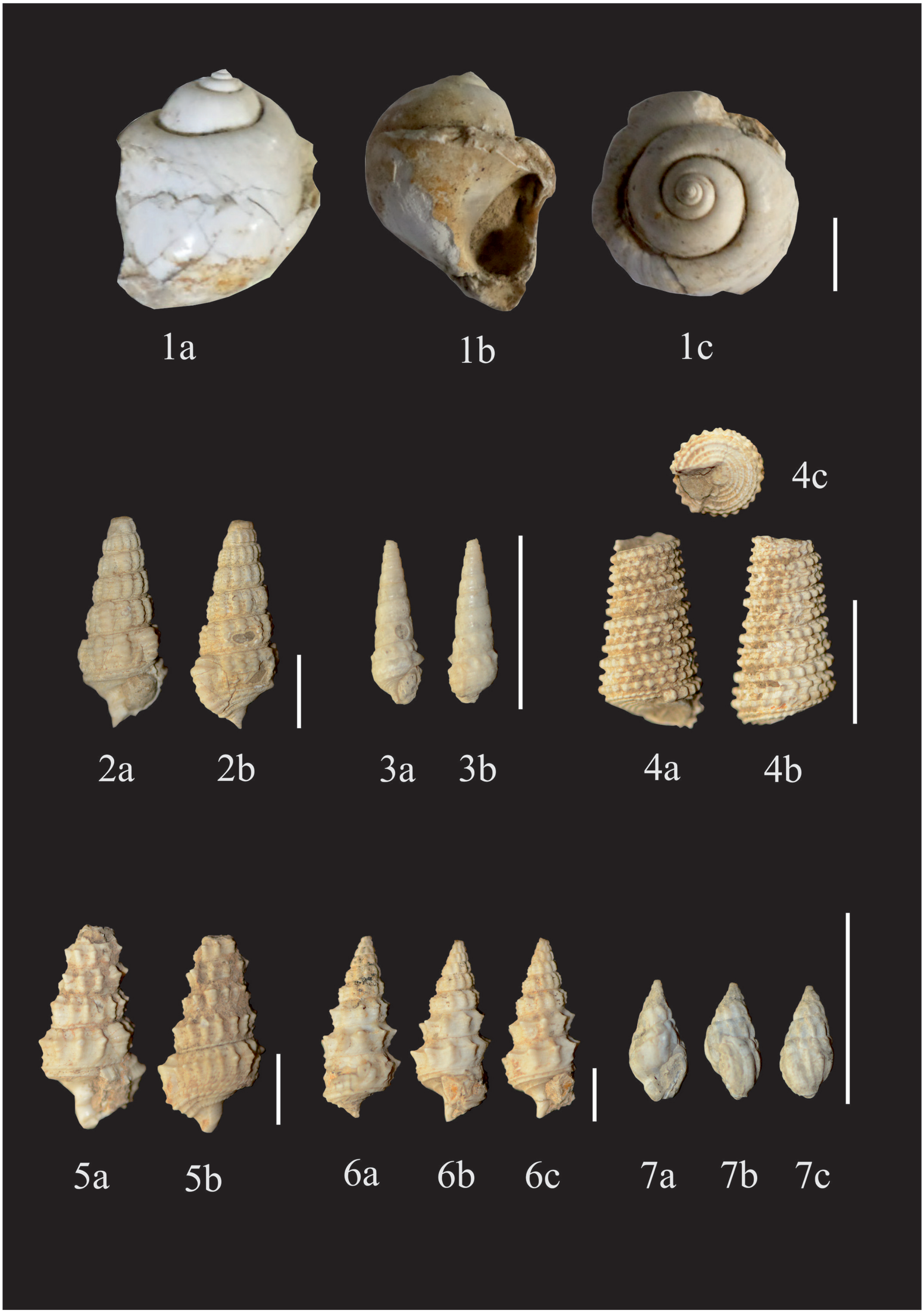

1a
1b
1c
4c
2a
2b
3a
3b
4a
4b
5a
5b
6a
6b
6c
7a
7b
7c

PLATE II

1a, b *Cardita rusticana* Mayer, 1899

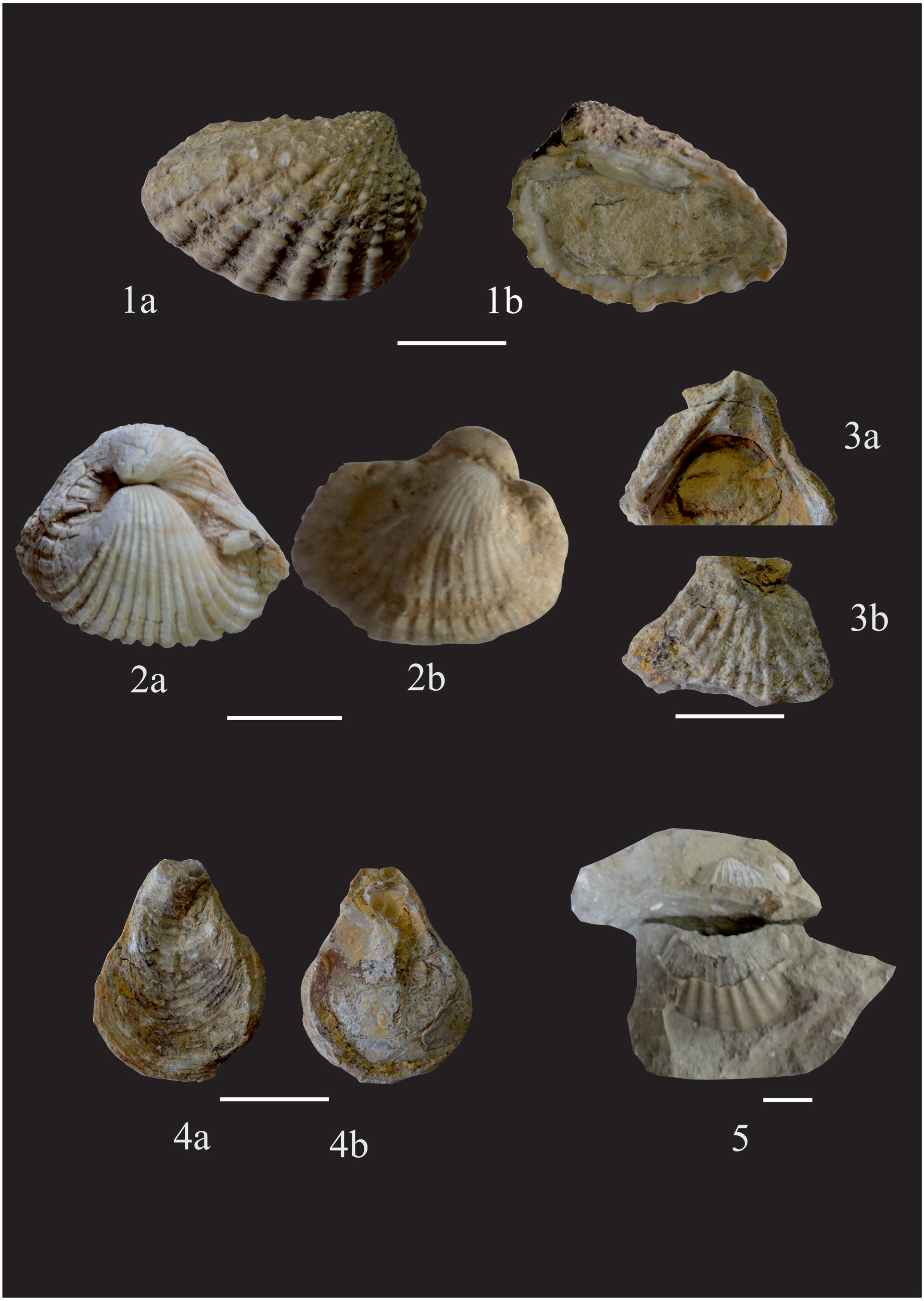
2a, b *Anadara aqutanica* Mayer, 1861

3a, b *Ostrea lamellosa* Brocchi, 1814

4a, b *Cubitostrea digitalina* Eichwald, 1830

5 *Chlamys* sp.

(The bars shows that 1 cm for each sample.)


1a
1b
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2b
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4b
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