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MOLLUSCAN BIOSTRATIGRAPHY OF EARLY MIOCENE DEPOSITS OF THE KALE-TAVAS AND ACIPAYAM BASINS (DENİZLİ, SW TURKEY)

Yeşim BÜYÜKMERİÇ[a]*

[aa]*Bülent Ecevit Universitesi, Mühendislik Fakültesi, Jeoloji Mühendisliği Bölümü, 67100 İncivez-Zonguldak/Türkiye, orcid.org/0000-0003-2678-3907*

Research Article

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ABSTRACT

In the present work, a stratigraphic framework of the early Miocene units of the Kale-Tavas and Acıpayam deposits is proposed. Two stratigraphic sections from the brackish-marine deposits of Aquitanian (Yenidere formation) and three sections from the shallow marine units of late Burdigalian (Kale formation) age have been logged. In total 23 mollusc species are identified similar to those of the areas in the Mediterranean province. The fauna indicates that the Mediterranean Tethys occupied the southwestern part of the Denizli region only during the early Miocene. A tectonic pulse in the basin during the early Miocene may have been very important to understand the limits of marine Tethyan influence in the area.

1. Introduction

The continuous northward drift of the African Plate has been driving regional differentiations in basin developments in the convergent boundary zone during the Cenozoic period (Meulenkamp et al., 2000; Meulenkamp and Sissingh, 2003). In Oligo-Miocene time, development of the basins in SW Anatolia was mainly influenced by these complex and successive regional geotectonic events as for example the emplacement of the ophiolithic Lycian nappes and later N-S extensional regimes (Şengör and Yılmaz, 1981; Koçyiğit, 1984; Şenel, 1997; Seyitoğlu and Scott, 1991; Collins and Robertson, 1998, 2003; Bozkurt, 2003; Sözbilir, 2005, Westaway , 2006; Westaway et al., 2005). Also global sea level fluctuations caused alternating marine-nonmarine phases in the region. These phases are represented by detritic and carbonated sediments, known as intramontane "Oligo-Miocene Lycian molasse" which are found in NE-SW directed intramontane Denizli, Kale-Tavas and Çardak-Dazkırı subbasins (Sözbilir, 2005) and Acıpayam piggy-back basin (Alçiçek and ten Veen, 2008).

Oligocene units are found in the middle and northeastern part of the Lycian molasse (Çardak-Dazkırı, Denizli and northeastern part of Kale-Tavas subbasins). Their invertebrate fossils represent late Rupelian – early Chattian (SBZ22 and P19) assemblages (İslamoğlu, 2008; İslamoğlu and Gedik, 2005; İslamoğlu et al., 2006; 2007; Özcan et al., 2008; İslamoğlu and Hakyemez, 2010).

Marine early Miocene units are only found in the south- southwestern part of the Kale-Tavas and Acıpayam basins (Figure 1). Although a few paleontological studies for early Miocene deposits are available in the region, the stratigraphical framework of the marine units is still controversial. In earlier works, two different early Miocene sedimentary cycles have been distinguished: the Aquitanian flysch and the Burdigalian-Helvetian marine-lagoonal unit (Altınlı, 1955 and Nebert, 1956; 1961). An early Aquitanian age was proposed based on the ostracod and foraminifer fauna for the base of early Miocene sections in the Yenişehir - Kale region (Gökçen, 1982). In subsequent work, however, these deposits were considered to belong to the middle part of the Oligocene Mortuma Formation (Akgün and Sözbilir, 2001). Some authors considered these deposits to be of late Oligocene age (Benda and Meulenkamp, 1990;

* *Corresponding author: Yeşim BÜYÜKMERİÇ yesim.buyukmeric@yahoo.com*
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Seyitoğlu and Scott, 1996). The Yenidere formation rests unconformably on the Mortuma formation, and was considered to be of Aquitanian age based on both its stratigraphical position (Hakyemez,1989) and palynomorph associations (Becker-Platen, 1970; Akgün and Sözbilir, 2001). The upper units consist of carbonates (Kale formation) that have been dated as Burdigalian (Hakyemez, 1989; Gökçen, 1982; Özcan et al., 2008).

Some levels of the Yenidere and Kale formations are rich in molluscs, but these were not previously studied. Detailed information on the mollusc content of the stratigraphical units will be helpful to understand the regional stratigraphy. This study aims to document the mollusc species in the Miocene Kale-Tavas and Acıpayam basins in order to assess palaeoenvironmental evolution as well as paleobiogeographic signature.

2. Material and Methods

This study is based on the MTA (General Directorate of Mineral Research and Exploration) project (16 B45). Initial paleontological results of Miocene faunas are reported in İslamoğlu et al. (2006, 2007). Here the mollusc faunas are studied within a stratigraphical context. They were collected as handpicking samples from outcropping surfaces and cleaned from sediment remains in the paleontology-sedimentology laboratory of MTA. Photographs were taken in the Natural History Museum, Vienna, Austria. Molluscs are in repositories of Bülent Ecevit University, Geological Engineering Department.

3. Geological Setting

Oligo-Miocene deposits in the Denizli region developed on an imbricated basement, comprising Mesozoic- Paleozoic rocks of the Menderese massive, the allochthonous Mesozoic rocks of Lycian nappes and Paleocene - Eocene supra-allochthonous sediments (Konak et al.,1986; Sözbilir, 2005). The Kale-Tavas subbasin is located in the southwestern part of the Denizli region (Figure 1). Its Oligo-Miocene sediments are described as Akçay group (Hakyemez, 1989). Oligocene marine-brackish deposits bearing

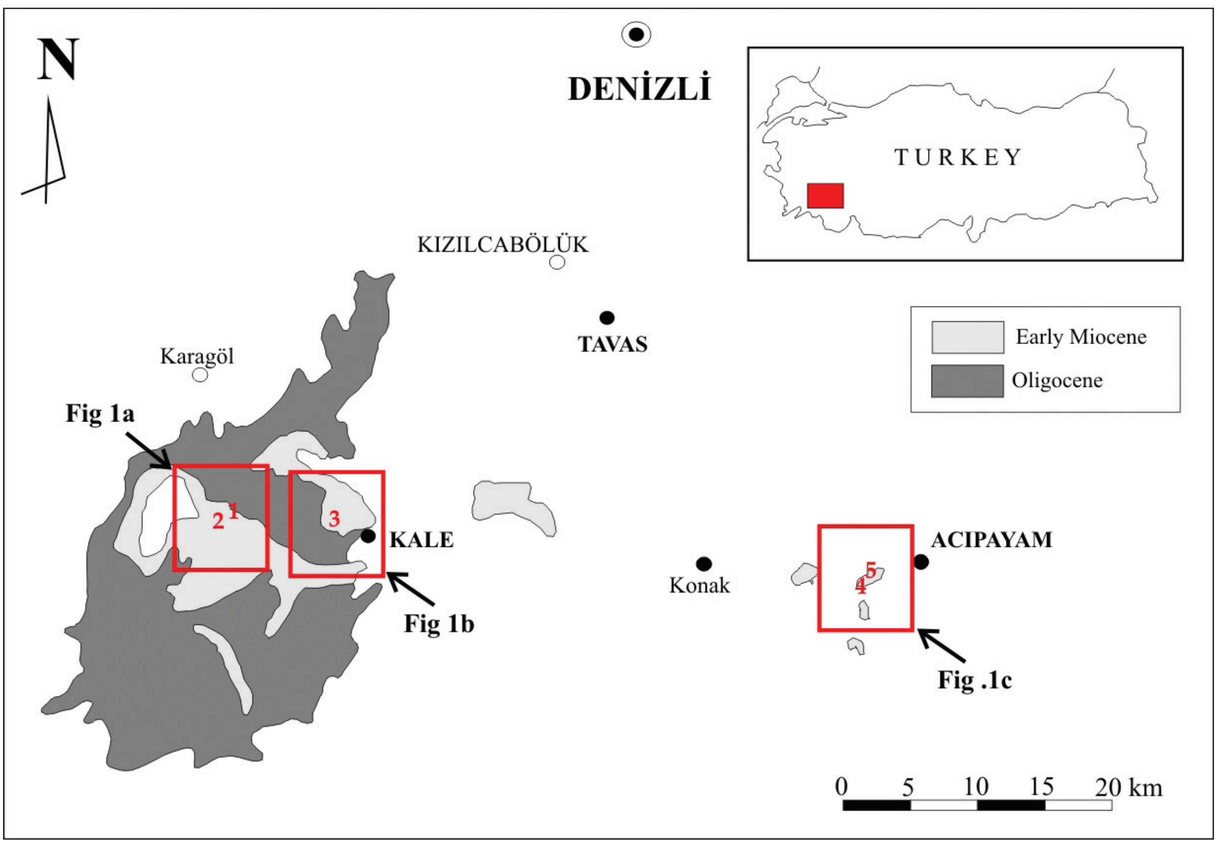

Figure 1- Oligo-Miocene units and measured stratigraphical sections in the studied region. Yenidere formation (Aquitanian): 1) Kurbağalık, 2) Sulugüme, Kale formation (Burdigalian): 3) Kale-Delibağ, 4) Kuleburnu, 5) Alacain (modified from the 1:500.000 geological map of the archive of MTA Geological Research Department).

molluscs are widely distributed in the middle, north and northeastern part of the Lycian molasse region (Çardak-Dazkırı/Acıgöl, Denizli and Kale-Tavas sub-molasse basins) (İslamoğlu, 2008; İslamoğlu and Hakyemez, 2010; İslamoğlu et al., 2005, 2006, 2007).

The early Miocene succession in the Kale-Tavas subbasin includes the Yenidere, Künar and Kale formations (Hakyemez, 1989). Early Miocene deposits are only exposed in the southwestern part of the region (Kale-Tavas sub-molasse basin) overlying clastic Oligocene units. The Yenidere formation consists of brackish – lagoonal sediments and includes shallow marine intervals, the latter are mostly restricted to the lower part of the formation. In overlying intervals terrestrial facies, including coal-bearing fine detritics representing swamp depositional environments are found. A number of the coal layers are exploited. The Yenidere formation represents a very short transgressive basal interval overlain by regressive deposits. It is rich in brackish molluscs and ostracods but lacks benthic and planktic foraminifers. The formation is overlain by the terrestrial Künar formation that consists of cross-bedded conglomerates (fluvial sediments: Hakyemez, 1989). This unit lacks any fossils. The Kale formation consists of shallow marine reefal carbonates and detritics representing a transgressive succession. Shallow marine molluscs, benthic foraminifers, corals and ostracods are common. The Yenidere and Kale formations overlay the Oligocene Mortuma formation with an angular unconformity. A conformable contact between Aquitanian and Burdigalian rocks was proposed based on observations of Akgün and Sözbilir (2001). However, in our work, the contact between the Yenidere and Kale formations could not be observed.

4. Results

4.1. Facies, Fossil Contents and Paleoecology

Five stratigraphic sections have been logged in the early Miocene Yenidere and Kale formations and five facies types are distinguished.

The localities, detailed lithological explanations and fossil contents of the sections are shown in the maps and tables (Figures 1a, 1b, 1c, 2-7). Correlation of the sections and facies are shown in the correlation table (Figure 8).

Coordinates and thickness of the sections are listed below:

Kurbağalık section: (9,5 m) (Yenidere formation), measured in an open coal pit, 12 km E of Kurbağalık, south of Gediktepe, geological map sheet (1:25.000) Denizli M21-d3, X: 52612, Y: 52000, Z: 800

Sulugüme section (98.6 m) (Yenidere formation), measured in the Sulugüme river valley, south of Arıkayası tepe, geological map sheet (1:25.000) Denizli M21-d3, X: 51800, Y: 50600; Z: 740.

Kale-Delibağ section (27.8 m) (Kale formation): meausured from the outcrop W of Kale town, N of Delibağ, near Kavakpınarı, geological map sheet (1:25.000) Denizli N21-b1, X: 62000, Y: 44800, Z: 1060.

Kuleburnu section (275 m): measured from the outcropsouth of Acıpayam - Mevlütler, geological map sheet (1:25.000) Denizli N22-b1, X: 02774, Y: 37448, Z: 1504.

Alacain section (173.8 m): measured from the outcrop, W of Acıpayam, geological map sheet (1:25.000) Denizli N22-b1, X: 02750, Y: 43050, Z: 1370

Unit 1: Brackish sediments with shallow marine intercalations

This facies is identified in the lower and middle part of the Yenidere formation (Figure 8). Shallow marine molluscs are found together with brackish molluscs indicating short-term proximal marine ingressions from the shore towards the near shore or estuarine environments. Shallow marine species such as *Turritella turris* de Basterot, 1825, *Mytilus (Crenomytilus) aquitanicus* (Mayer, 1858), *Anadara cardiiformis* (de Basterot, 1825), *Euspira helicina helicina* (Brocchi, 1814) and *Melongena lainei* (de Basterot, 1825) representing shallow marine environment (Lozouet et al., 2001, Landau et al., 2013). *Melanopsis hantkeni* Hofmann,1870 is confined to the estuarine –fluvial and river mouth nearshore paleoenvironments.

Unit 2: Brackish - Lagoonal sediments:

This facies is observed in the lower and middle levels of the Yenidere formation. Brackish – lagoonal facies include coal-bearing detritics (Kurbağalık and Sulugüme sections, Figure 8). *Mesohalina margaritacea* (Brocchi, 1814), *Granulolabium plicatum* (Bruguiére, 1792), *Terebralia lignitarum*

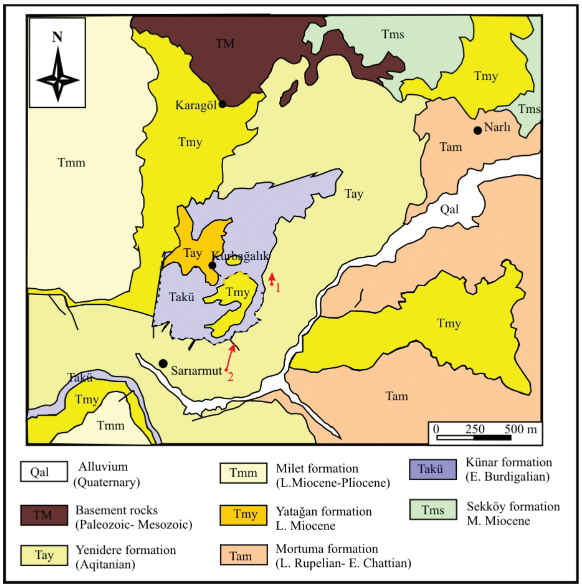

Figure 1a- Kurbağalık (1) and Sulugüme (2) sections and geological map of the surrounding area (Denizli N21, Hakyemez, 1982; Archive of MTA Geological Research Department).

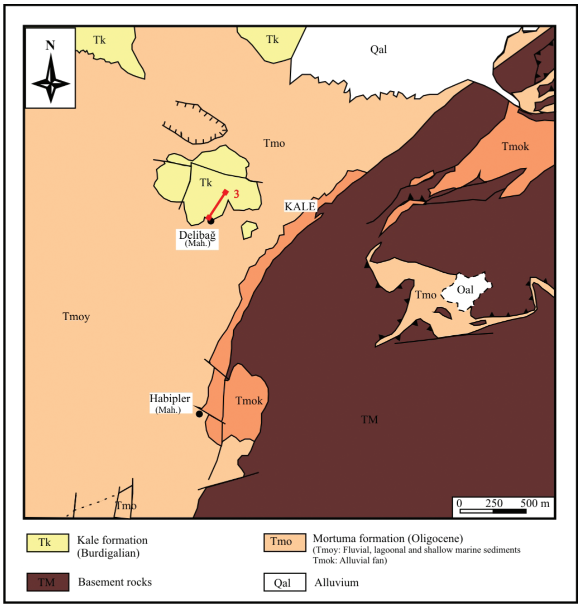

Figure 1b- Kale-Delibağ section (3) and geological map of the surrounding area (Denizli N21, archive of MTA Geological Research Department).

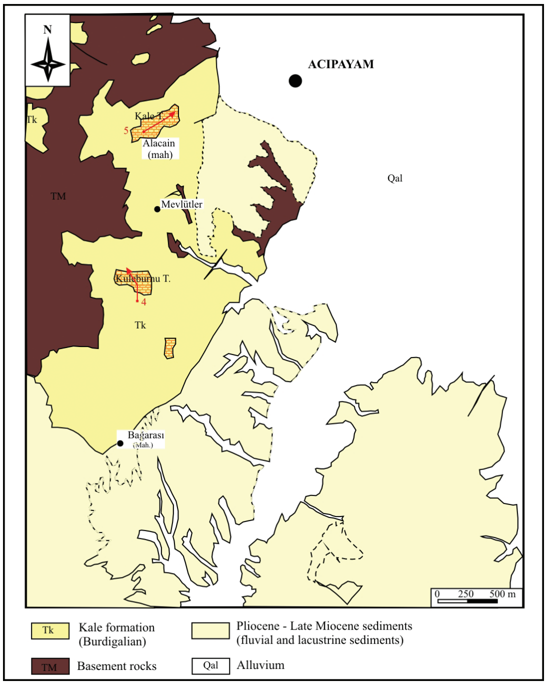

Figure 1c- Kuleburnu (4) and Alacain (5) sections and geological map of the surrounding area (Denizli N22; archive of MTA Geological Research Department).

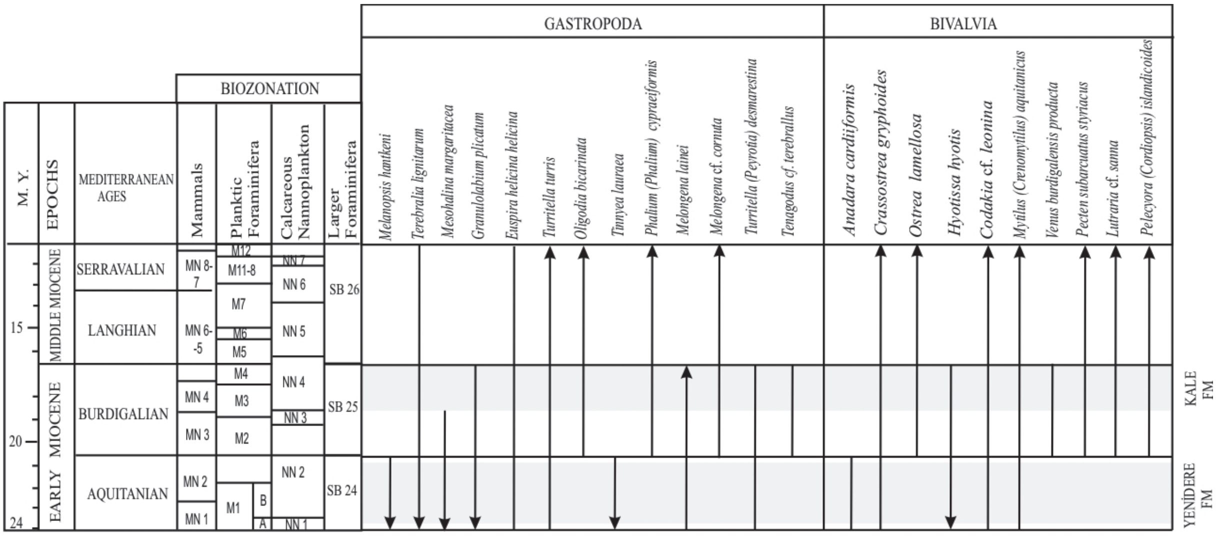

Figure 2- Stratigraphical ranges of the mollusc species in the Kale-Tavas subbasin.

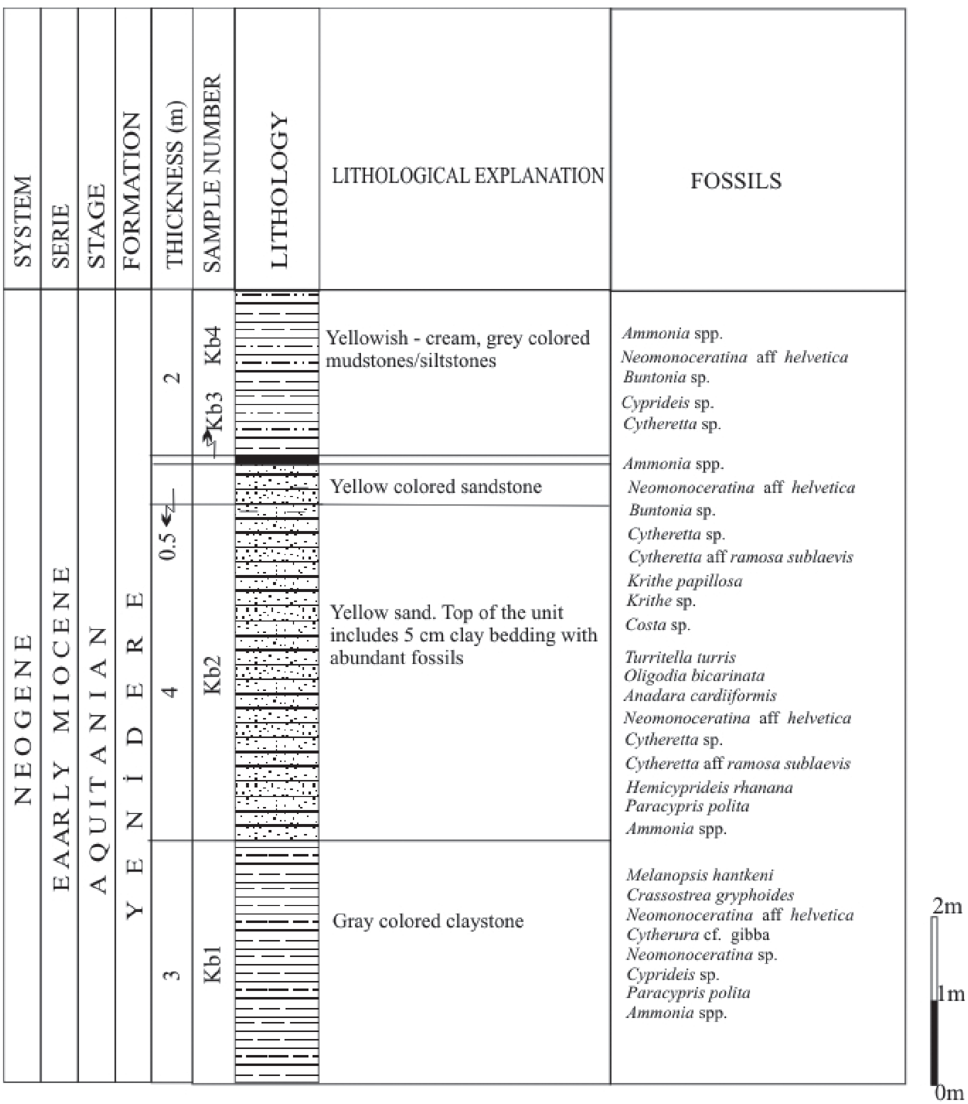

Figure 3- Kurbağalık measured stratigraphical section.

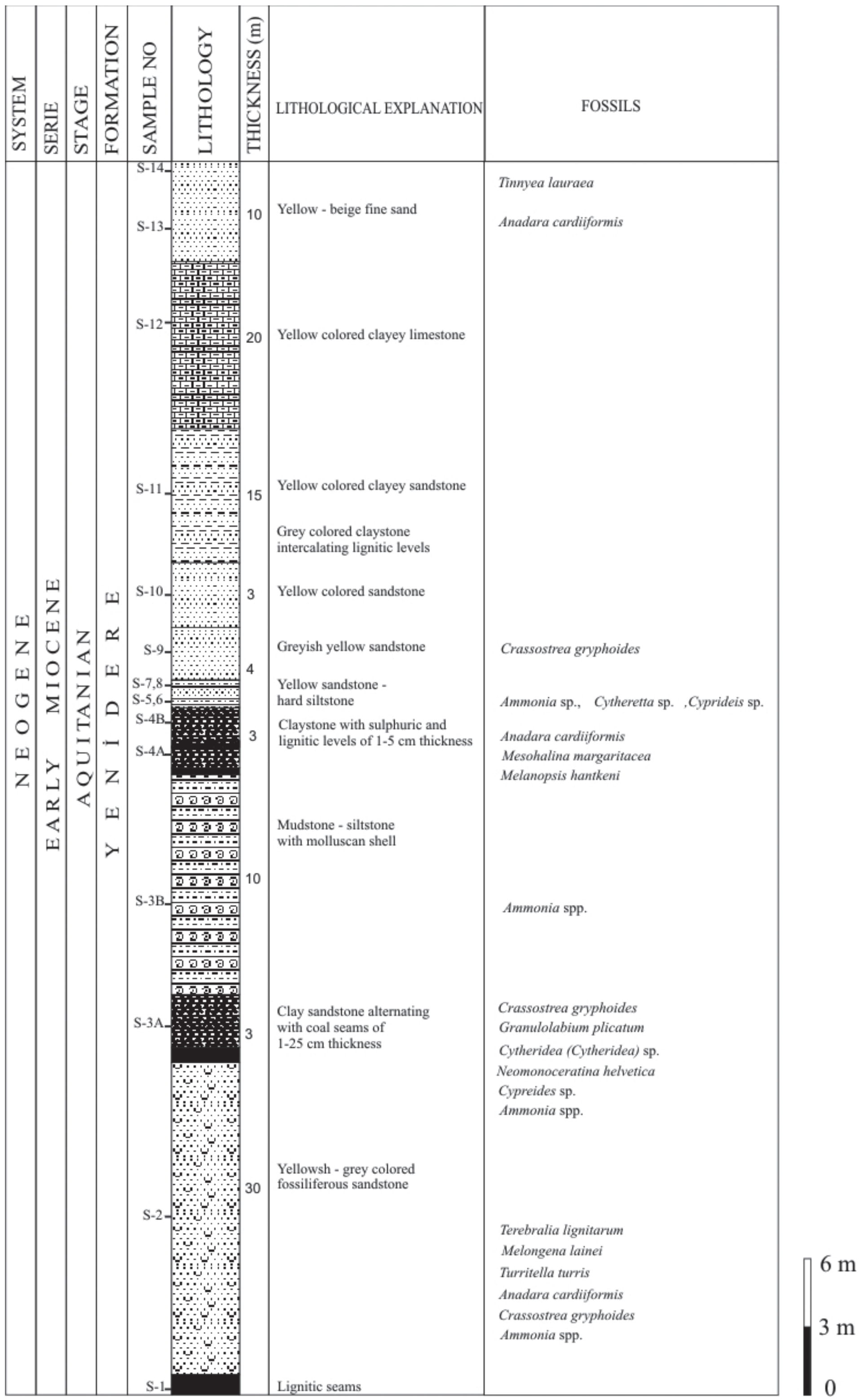

Figure 4- Sulugüme measured stratigraphical section.

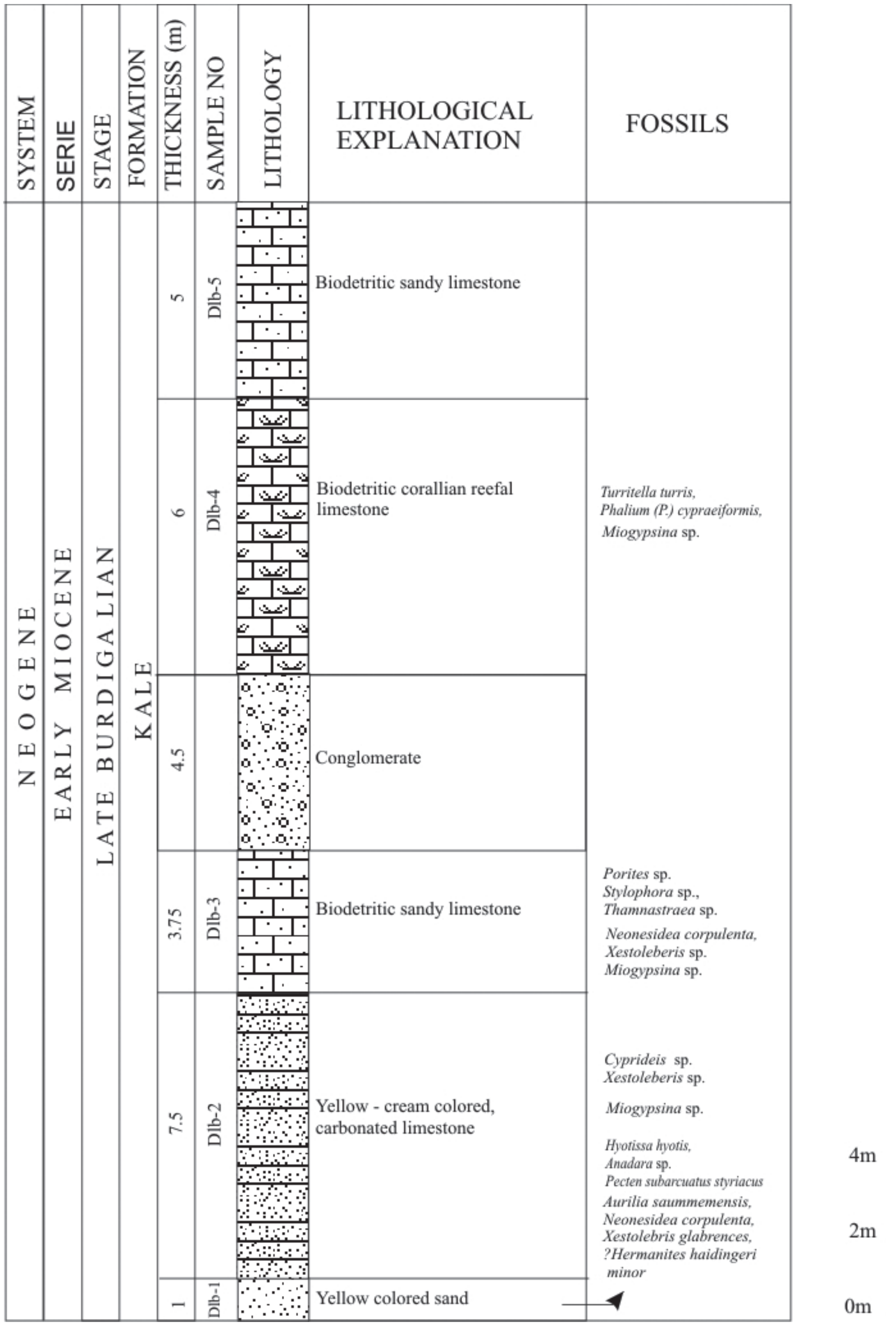

Figure 5- Kale-Delibağ measured stratigraphical section.

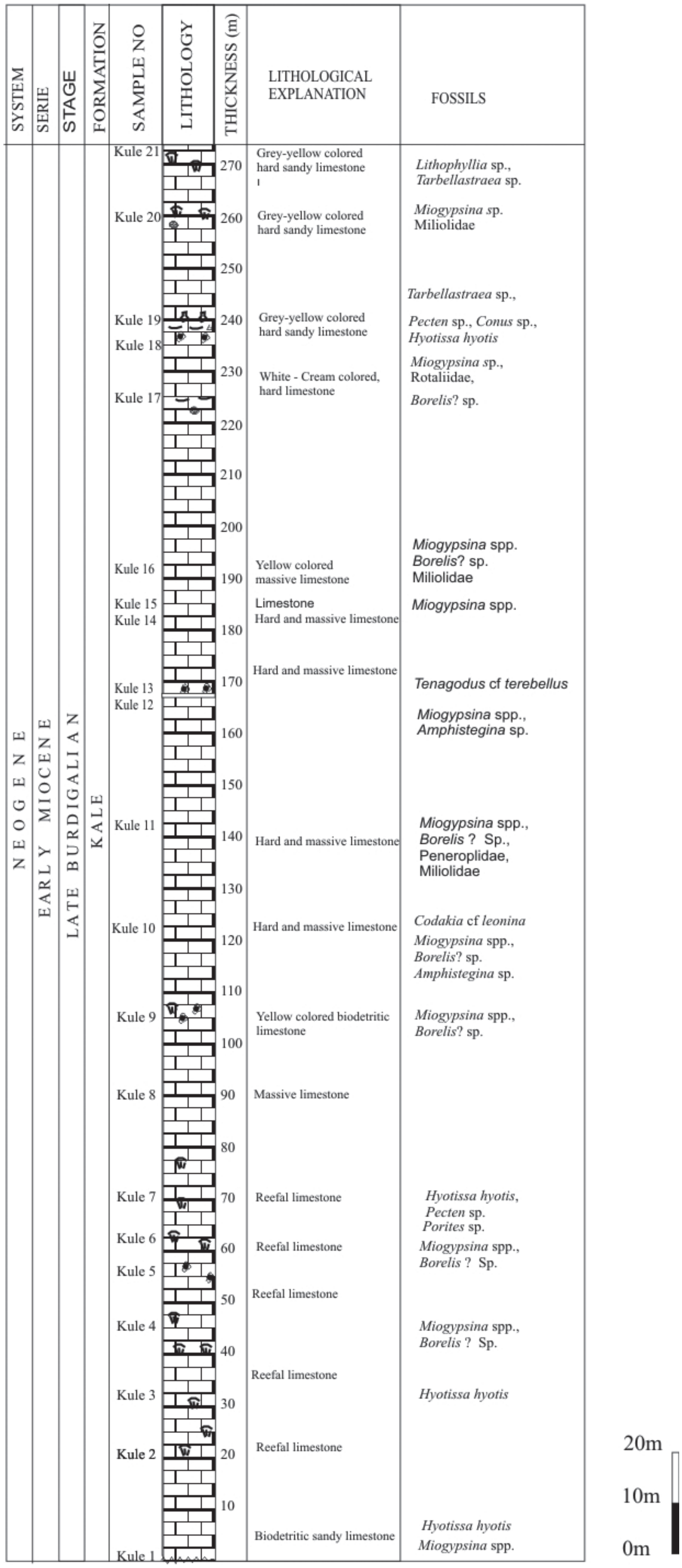

Figure 6- Kuleburnu measured stratigraphical section.

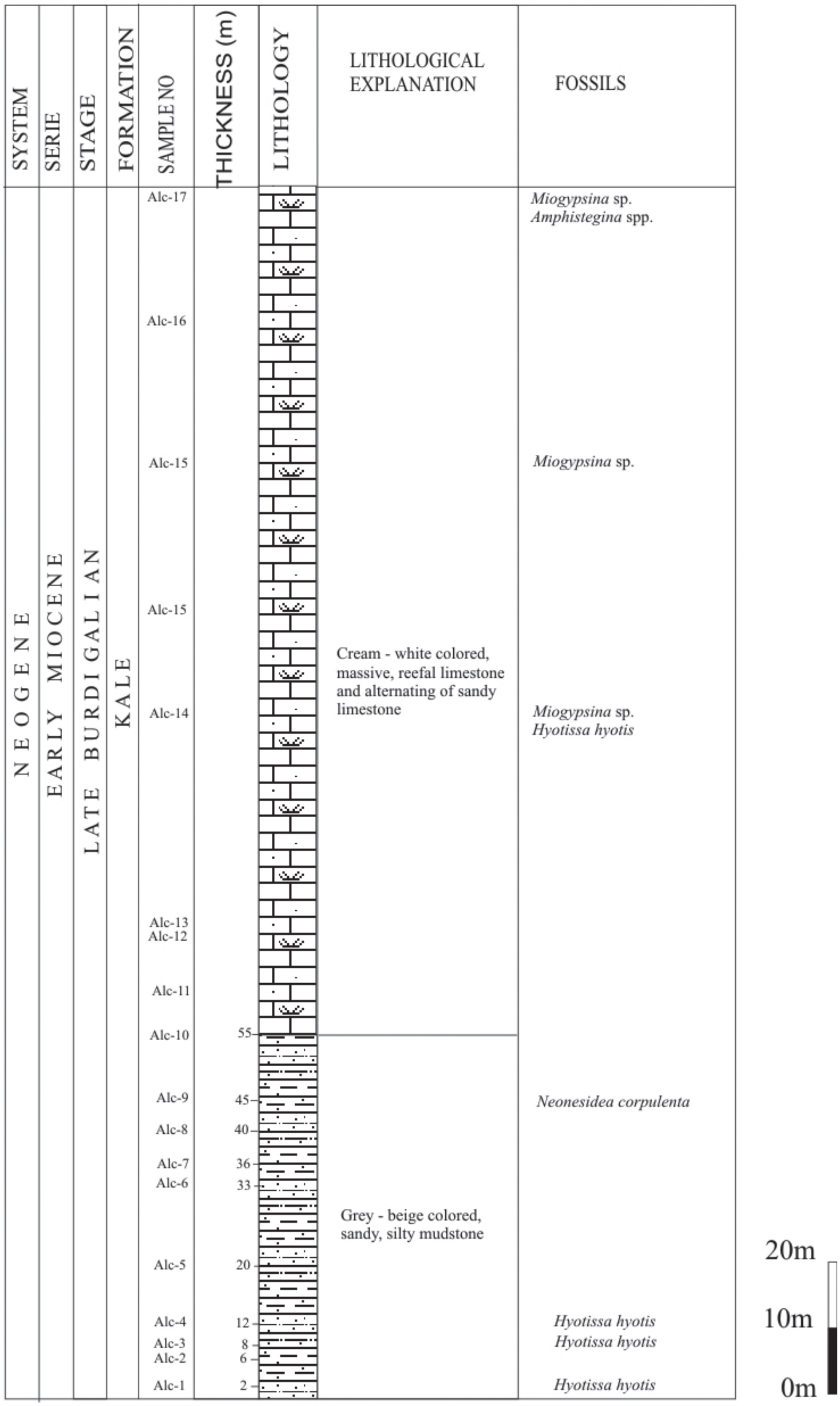

Figure 7- Alacain measured stratigraphical section.

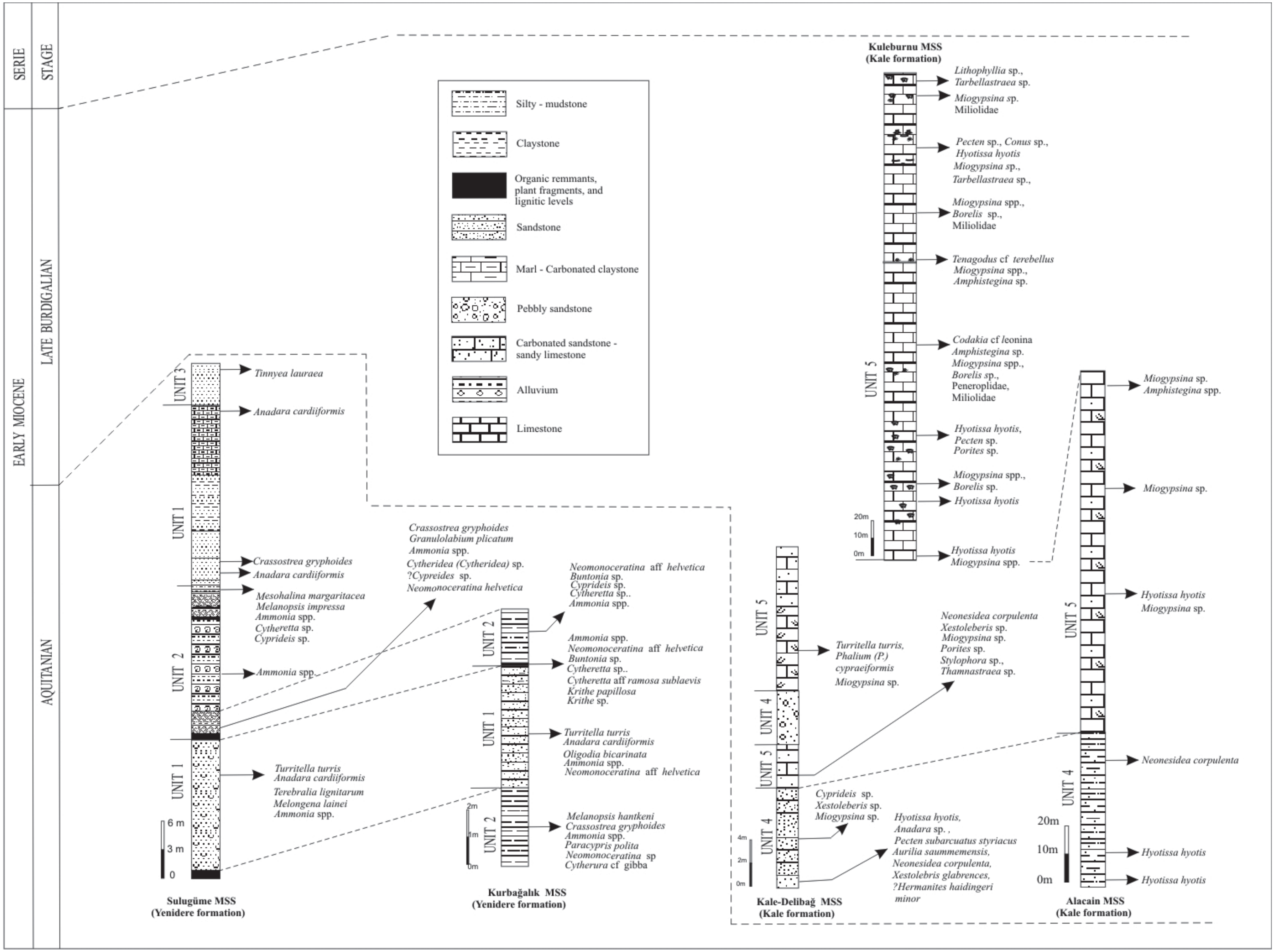

Figure 8- Litho-biostratigraphical correlation table of the measured sections.

(Eichwald, 1830), *Granulolabium plicatum* (Bruguiére, 1792), and *Crassostrea gryphoides* (Schlotheim, 1813) are common species. *Mesohalina margaritacea* and *Granulolabium plicatum* are reported from lagoonal to littoral environments indicating oligo/mesohaline salinities (Báldi, 1973; Barthelt, 1989; Harzhauser and Mandic, 2001). *Terebralia lignitarum* (Eichwald, 1830) is common in the brackish units of the Oligocene in the Denizli (İslamoğlu, 2008) and Serravalian Karaman basins (Landau et al., 2013). The low diversity bivalve assemblage is predominated by the brackish ostreid *Crassostrea gryphoides* (Schlotheim, 1813).

Unit 3: Swamp - marsh sediments:

This facies forms the uppermost fine detritics of the Yenidere formation (Sulugüme section, Figure 8) and is dominated by *Tinnyea lauraea* (Mathéron, 1842) and *Melanopsis hantkeni* Hofmann, 1870, representing a swamp environment (İslamoğlu et al. 2008; Neubauer et al. 2013; Harzhauser et al. 2016). *Melanopsis* - *Mesohalina (*synonym of *Tympanotonos*: Harzhauser et al., 2016) communities are also considered to represent, low salinity assemblages with freshwater influences from the mainland, brackish water lagoons or mangrove swamps possibly under influence of rivers (Báldi, 1973). *Melanopsis hantkeni* Hofmann, 1870 is confined to oligohaline estuarine–fluvial and river mouth nearshore paleoenvironments (Barthelt, 1989; Harzhauser and Mandic, 2001; Neubauer et al. 2013, 2016; Harzhauser et al., 2016). This unit includes also a few thick coal seams exploited economically.

Unit 4: Shallow marine detritics:

The facies is observed in the Kale formation (Delibağ section, Figure 8). Grey - beige colored, sandy-silty mudstones, sandy limestones. Mollusc contents and coral fauna are poor. Only ostreid bivalves [*Ostrea lamellosa* Brocchi, 1814*, Hyotissa hyotis* (Linnaeus, 1758)] and *Porites* colonies were observed. *Hyotissa hyotis* is a stenohaline ostreid living in the sublittoral environments under fully marine conditions (Harzhauser and Mandic 2001). A single balanid species, *Creussia miocaenica* Prochazka, 1893 is also found (plate 2, Figure 6).

Unit 5: Carbonates - Reefal carbonates:

This facies is defined in the Kale formation (Figure 8). Light grey - yellow - beige coloured hard limestone - reefal limestone - detritic limestones. The ostreid bivalve *Hyotissa hyotis* is a commonly occurring species. Benthic foraminifers (*Miogypsina, Amphistegina, Borelis*), red algae and corals (*Porites, Tarbellastraea*) are also abundant.

4.2. Biostratigraphy

Molluscan findings from the Yenidere and Kale formations are recorded herein for the first time. Two stratigraphical sections from the Yenidere formation (Kurbağalık, Sulugüme; Figure 1a) and three sections from Kale formation (Delibağ, Kuleburnu, Alacain) have been logged and sampled for molluscs. The distribution of benthic foraminifers, ostracods and corals collected from the same sections supports Aquitanian and late Burdigalian ages of the formations (İslamoğlu et al. (2006, 2007).

In total, 23 molluscan taxa are identified and all biostratigraphical data are interpreted together. Figure 2 gives the stratigraphic ranges of molluscs, correlated with geochronologic and biostratigraphic data modified from previous works (Rögl 1996, 1998; Rögl et al. 1993; Cahuzac and Poignant 1997; Steininger 1999; Harzhauser et al. 2002, Gradstein et al. 2004). Occurrence of each mollusc species in the sections is given (Table 1). Characteristic mollusc species are illustrated in Plates 1-3.

4.2.1. Aquitanian (Yenidere Formation)

The stratigraphical range of molluscan species in the Kurbağalık and Sulugüme sections from the Yenidere formation indicates an Aquitanian age (Figures 2-4). *Mesohalina margaritacea* (Brocchi. 1814) became extinct during the mid-Burdigalian (Harzhauser et al., 2016). *Tinnyea lauraea* (Mathéron, 1842) originated in the Oligocene and was common during the early Miocene (Harzhauser et al. 2016). *Granulolabium plicatum* (Bruguière, 1792) is specific for Oligocene, but also abundant in the Aquitanian stratotype deposits (Lozouet et al. 2001) and Eggenburgian - Karpatian settings in Austria, Central Paratethys (Harzhauser et al. 2003). *Turritella (Peyrotia) desmarestina* de Basterot, 1825 is known from early Miocene deposits (Lozouet et al. 2001). The taxonomic position of *Melanopsis hantkeni* Hofmann, 1870 is discussed by Harzhauser et al. (2016). It is a geographically wide-spread species known from the Oligocene deposists of the Central Paratethys, also extending to Greece and Iran (Harzhauser, 2004), Turkey (Thrace and Denizli basins: Islamoğlu, 2008; İslamoğlu and Hakyemez,

Table 1- Occurrence of the mollusc species in the sections

	Yenidere formation (Aquitanian)										Kale formation (Late Burdigalian)													
	Kurbağalık		Sulugüme								Delibağ		Kuleburnu								Alacain			
	Kb1	Kb2	S2	S3	S4b	S3a	S6	S9	S13	S14	Dlb1	Dlb4	Kule1	Kule3	Kule7	Kule10	Kule13	Kule17	Kule18	Kule19	Alc1	Alc3	Alc4	Alc14
Melanopsis hantkeni Hofmann, 1870	X				X		X																	
Terebralia lignitarum			X																					
Mesohalina margaritacea					X		X																	
Granulolabium plicatum				X		X																		
Euspira helicina helicina			X																					
Turritella turris		X	X									X												
Oligodia bicarinata		X																						
Tinnyea lauraea										X														
Phalium (Phalium) cypraeiformis												X												
Melongena lainei			X																					
Melongena cf. *cornuta*			X																					
Turritella (Peyrotia) desmarestina			X																					
Tenagodus cf. *terebellus*																	X							
Modulus sp.												X												
Conus sp.																				X				
Crommium sp.												X												
Anadara cardiiformis		X	X		X		X		X															
Anadara sp.											X													
Crassostrea gryphoides	X		X	X		X		X																
Ostrea lamellosa																		X	X					
Hyotissa hyotis											X		X	X				X	X	X	X	X	X	X
Codakia cf. *leonina*																X								
Mytilus (Crenomytilus) aquitanicus			X																					
Venus (Antigona) burdigalensis producta														X										
Pecten subarcuatus styriacus											X					X								
Pecten sp.														X						X				
Lutraria cf. *sanna*																X								
Pelecyora (Cordiopsis) islandicoides																X								

2010; İslamoğlu et al. 2008), misidentified as *M. impressa* Krauss, 1852 (Harzhauser et al. 2016). The present study shows that the stratigraphical range of *M.hantkeni* extends to Aquitanian. *Terebralia lignitarum* (Eichwald, 1830) is known from late Oligocene - middle Miocene deposits (Landau et al. 2013).

This Aquitanian mollusc assemblage is associated with early Miocene ostracods, *Neomonoceratina helvetica* Oertli, 1958, *Paracypris polita* Sars, 1866, *Cytheretta* aff. *ramosa sublaevis* Triebel, 1952, *Cytherura* cf. *gibba* (Mueller, 1785) and *Krithe papillosa* (Bosquet, 1852). The age of the formation is also supported by palynomorph assemblages (Akgün and Sözbilir, 2001).

4.2.2. Late Burdigalian (Kale Formation)

The molluscan assemblage of the Kale formation represents a late Burdigalian age (Figure 2). The mollusc-bearing levels of three sections (Kale-Delibağ, Kuleburnu and Alacain) contains the gastropods *Turritella turris* de Basterot, 1825, *Tenagodus* cf. *terebellus* Lamarck, 1818, *Conus* sp. and bivalves *Hyotissa hyotis* (Linnaeus, 1758), *Codakia* cf. *leonina* (de Basterot, 1825), *Ostrea lamellosa* Brocchi, 1814, *Venus (Antigona) burdigalensis producta* Schaffer, 1910 and *Pecten subarcuatus styriacus* Hilber, 1879 (Figure 2). The first occurrences of *Oligodia bicarinata* (Eichwald, 1830), *Phalium (Phalium) cypraeiformis* (Borson, 1820), *Melongena* cf. *cornuta* (Agassız, 1843), *Pecten subarcuatus styriacus* Hilber, 1879, *Lutraria* cf. *sanna* de Basterot, 1825, *Pelecyora (Cordiopsis) islandicoides* (Lamarck, 1818) and *Ostrea lamellosa* Brocchi, 1814 have been reported from Burdigalian deposits (Figures 4-6). *Venus (Antigona) burdigalensis producta* Schaffer, 1910 *and Tenagodus* cf. *terebellus* Lamarck, 1818 are characteristic species for Burdigalian (Schultz and Piller, 2005). The stratigraphical range of *Hyotissa hyotis* is between Oligocene - Burdigalian. The absence of *Mesohalina margaritacea* (Brocchi, 1814), that became extinct during the mid-Burdigalian (Harzhauser et al., 2016) restricts the age of the association to late Burdigalian.

The ostracod species *Aurila soummamensis* Coutelle and Yassini, 1974, *Neonesidea corpulenta* (Mueller, 1894), *Xestoleberis glabrences* (Reuss, 1850), *Hermanites* aff. *haidingeri minor* Ruggieri, 1962 support a Burdigalian age. The Kale-Delibağ section was dated as Burdigalian by previous workers, based mainly on the occurrence of the larger benthic foraminifer species *Miogypsina intermedia* Drooger (SBZ25 biozone) (Özcan et al. 2008).

5. Discussion

5.1. Correlation and Paleoenvironmental History of the Basin

Aquitanian and Late Burdigalian deposits of the Kale-Tavas molasse subbasin are extremely poor in molluscs, benthic foraminifers and coral fossils. Although it is not possible to observe the contact between Aquitanian and late Burdigalian, their fossil content show important faunal differences and facies changes. The correlation of the units is based on the analyses of lithology, paleoecology and biostratigraphy of measured stratigraphical sections, as presented above. Lateral facies relationships can only be observed in the sections within the same formation. The lowermost coarse detritic interval (grey colored, thick bedding, poorly sorted conglomerates) of the Aquitanian Yenidere formation overlies the terrestrial part of the late Rupelian - early Chattian Mortuma formation discordantly (Figures 9, 10). Shallow marine intervals are intercalated in the lower and middle parts of the Yenidere formation. However, the formation shows an overall regressive tendency, with increasing swamp deposits and thicker lignitic coal seams in the upper parts. The Yenidere formation is overlain by the terrestrial Künar formation that consists of cross-bedding conglomerates (fluvial sediments: Hakyemez, 1989). In previous works, an early Aquitanian age was proposed based on the ostracod and and foraminifer fauna for the base of the early Miocene deposits in the Kale region (Gökçen, 1982). Considering the stratigraphical relationship between Yenidere and Kale formations, the age of the Künar formation should be considered as early Burdigalian.

The shallow marine - reefal facies of the Kale formation rests on the terrestrial units of the Mortuma formation (late Rupelian - early Chattian) with an angular discordancy. The mollusc assemblage of the Kale formation documents a late Burdigalian age and fully marine species representing tropic-subtropic conditions.

5.2. Early Miocene Paleobiogeography of the Region

The molluscan assemblages described here are quite similar to the early Miocene faunas of the area of the Bay of Biscay through the Mediterranean basins to as far to the east as Central Iran (Harzhauser et al. 2002). During the early Miocene the closure time of the Tethian corridor took place, preventing further faunal exchanges between the western Indian - eastern African provinces and the eastern Mediterranean seaway between the Anatolian and Arabian/African plates (Rögl, 1998, 1999; Harzhauser et al., 2002).

In the Kale-Tavas molassic subbasin, *Melanopsis hantkeni Granulolabium plicatum*, *Terebralia lignitarum*, *Mesohalina margaritacea* and *Mytilus (Crenomytilus) aquitanicus* are common species in the Aquitanian deposits, also abundantly occurring in the early Miocene sublittoral coastal mudflats and swamps in Greece, Iran and Turkey (Thrace, Denizli, Mut, Sivas basins). *Terebralia lignitarum*, *Pelecyora (Cordiopsis) islandicoides, Turritella turris, Oligodia bicarinata, Ostrea lamellosa, Crassostrea gryphoides, Codakia leonina* and *Pecten subarcuatus styriacus* are found in the upper Burdigalian deposits, but also reported from the western Taurids (*Antalya basin:* İslamoğlu, 2002; İslamoğlu and Taner, 2003*a, b*). *Turritella desmarestina, Venus (A.) burdigalensis producta*, *M. cornuta* are known from the upper Burdigalian settings (*Kasaba basin, W. Taurids*: İslamoğlu, 2004*a,b*; İslamoğlu and Taner, 2002; 2003*a*). *Crassostrea gryphoides* (Schlotheim, 1813) is a common species in the upper Burdigalian deposits of Kahramanmaraş (Hoşgör, 2008) and Antalya basins (İslamoğlu and Taner, 2003*a*). *V. burdigalensis producta,* found in the Kale formation, is characteristic species for Eggenburgian of the Central Paratethys (Hoernes, 1870; Schaffer, 1912; Papp,1952; Schultz and Piller, 2001, 2003 and 2005). It was also reported from the upper Burdigalian units of the Kasaba basin (İslamoğlu and Taner, 2003*a*). *Terebralia bidentata, Mytilus* (*Crenomytilus*) *aquitanicus* and *Hyotissa hyotis* are reported from the late Burdigalian (Mut Basin: M.Taurids, S Turkey) (Atabey et al., 2000; Mandic et al., 2004).

5.3. Timing of Late Oligocene - Early Miocene Tectonics

The molasse sediments of SW Anatolia have been intensively studied, because of their importance for regional tectonics. It is suggested that these deposits developed during post-orogenic tectonic activities such as compression, extension and uplifting (Koçyiğit, 1984). The late Oligocene to early Miocene age is accepted either for a southeastward emplacement of the Lycian nappes (Collins and Robertson, 1998, 2003; Akgün and Sözbilir, 2001) or for a NW-SE trending extensional collapse of the Lycian orogene (Seyitoğlu and Scott, 1996; Bozkurt, 2003), resulting in depositional sequences in the emerged areas and surrounding interconnected depressons of the Lycian orogene (Sözbilir, 2005). It was also suggested that the Acıpayam area is the youngest and non-folded piggy-back succession of the Lycian Nappes (Alçiçek and ten Veen, 2008).

Some previous works refer to a regional Aquitanian transgression in the foreland that left a marine sedimentary unit before the final emplacement of the Lycian Allochthon (Poisson, 1977; Şenel, 1997). However, we here demonstrate that the Aquitanian period is represented by rhytmic deposits with a regressive tendency, whereas the early Burdigalian is represented by thick coarse fluvial sedimentation and the late Burdigalian by transgressive sedimentation comprising mainly thick carbonates. Two stratigraphical gaps are demonstrated by the presence of unconformities between the Chattian - Aquitanian and Oligocene - late Burdigalian deposits. Thus, our findings support the idea that uplifting of the source area and subsidence of the basin affected the stratigraphical framework of the Kale-Tavas and Acıpayam subbasins (Sözbilir, 2005; Alçiçek and ten Veen, 2008).

6. Conclusions

Molluscan biostratigraphical data indicates that the Yenidere formation developed during the Aquitanian whereas the Kale formation is of late Burdigalian age. The Yenidere formation consists of brackish – lagoonal, and sometimes terrestrial facies such as swamps, coal-bearing detritics as well as very shallow marine ingressions. The represented mollusc faunas can be correlated with coeval Aquitanian and late Burdigalian assemblages in the Mediterranean- Iranian province. The presence of angular disconformities could be determined between the Oligocene (late Rupelian - early Chattian) units (Mortuma formation), the Aquitanian (Yenidere formation) and between Oligocene - late Burdigalian (Kale formation) units. The stratigraphical relationship between Aquitanian and late Burdigalian units were not observed. These findings help the understanding of timing of Oligo-Miocene tectonic pulses in the basin, which probably occurred at the end of the Oligocene and in the latest Aquitanian – earliest Burdigalian. Mollusc faunas lack Indo-Pacific species. Therefore during early Miocene times, the region was part of the Eastern Mediterranean-Iranian province.

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PLATES

Plate 1

Figure 1a-b. *Granulolabium plicatum* (Bruguière, 1792), BEUN-2016-DM001

Figure 2a-b. *Terebralia lignitarum* (Eichwald, 1830), BEUN-2016-DM002

Figure 3. *Melanopsis hantkeni* Hofmann, 1870, BEUN-2016-DM003

Figure 4. *Oligodia bicarinata* (Eichwald, 1830), BEUN-2016-DM004

Figure 5a-b. *Turritella turris* de Basterot, 1825, BEUN-2016-DM005

Figure 6. *Turritella turris* de Basterot , 1825, BEUN-2016-DM006

Figure 7a-b. *Tinnyea lauraea* (Mathéron, 1842), BEUN-2016-DM007

Figure . 8a-b. *Melongena lainei* (de Basterot, 1825), BEUN-2016-DM008

Figure 9. *Crommium* sp. BEUN-2016-DM027

Figure 10. *Mesohalina margaritacea* (Brocchi, 1814), BEUN-2016-DM009

Figure 11a-b. *Euspira helicina helicina* (Brocchi, 1814), BEUN-2016-DM010

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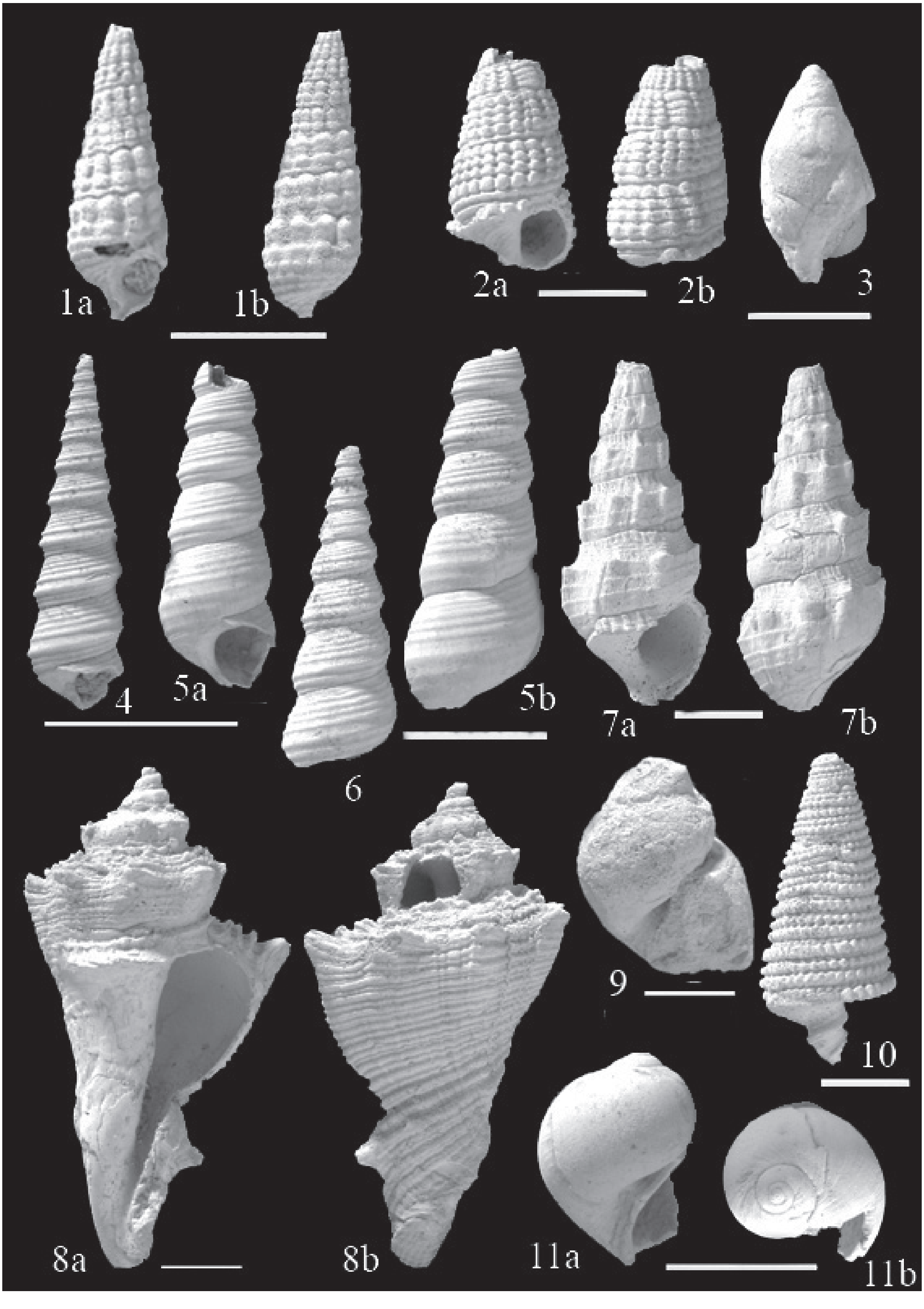
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Plate 2

Figure 1a-b. *Melongena lainei* (de de Basterot, 1825), BEUN-2016-DM011

Figure 2. *Melongena* cf. *cornuta* (Agassız, 1843), BEUN-2016-DM012

Figure 3. *Modulus* sp., BEUN-2016-DM013,

Figure 4a-b. *Phalium (Phalium) cypraeiformis* (Borson, 1820), BEUN-2016-DM014

Figure 5. *Turritella (Peyrotia) desmarestina* de Basterot, 1825, BEUN-2016-DM015

Figure 6. *Creussia miocaenica* Prochazka, 1893 (balanid species), dorsal view, BEUN-2016-DM016

Figure 7-8-9. *Crassostrea gryphoides* (Schlotheim, 1813), BEUN-2016-DM017

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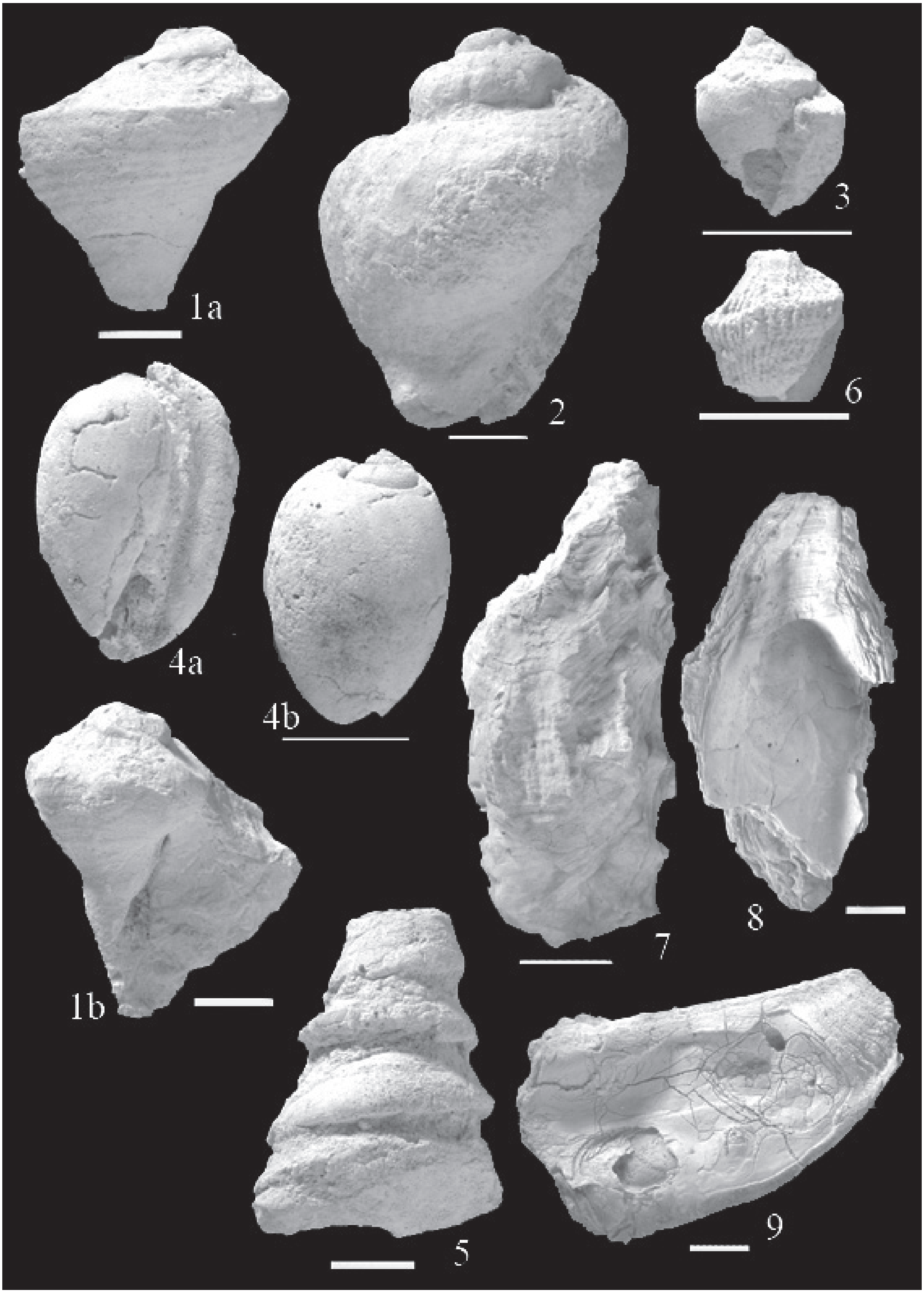
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Plate 3.

Figure 1a-b. *Ostrea lamellosa* Brocchi, 1814, BEUN-2016-DM018

Figure 2a-b. *Hyotissa hyotis* (Linnaeus, 1758), BEUN-2016-DM019

Figure 3a-b. *Codakia* cf. *leonina* (de Basterot, 1825), BEUN-2016-DM020

Figure 4. *Lutraria* cf. *sanna* de Bastetot, 1825, BEUN-2016-DM021

Figure 5. *Pelecyora (Cordiopsis) islandicoides* (Lamarck, 1818), BEUN-2016-DM022

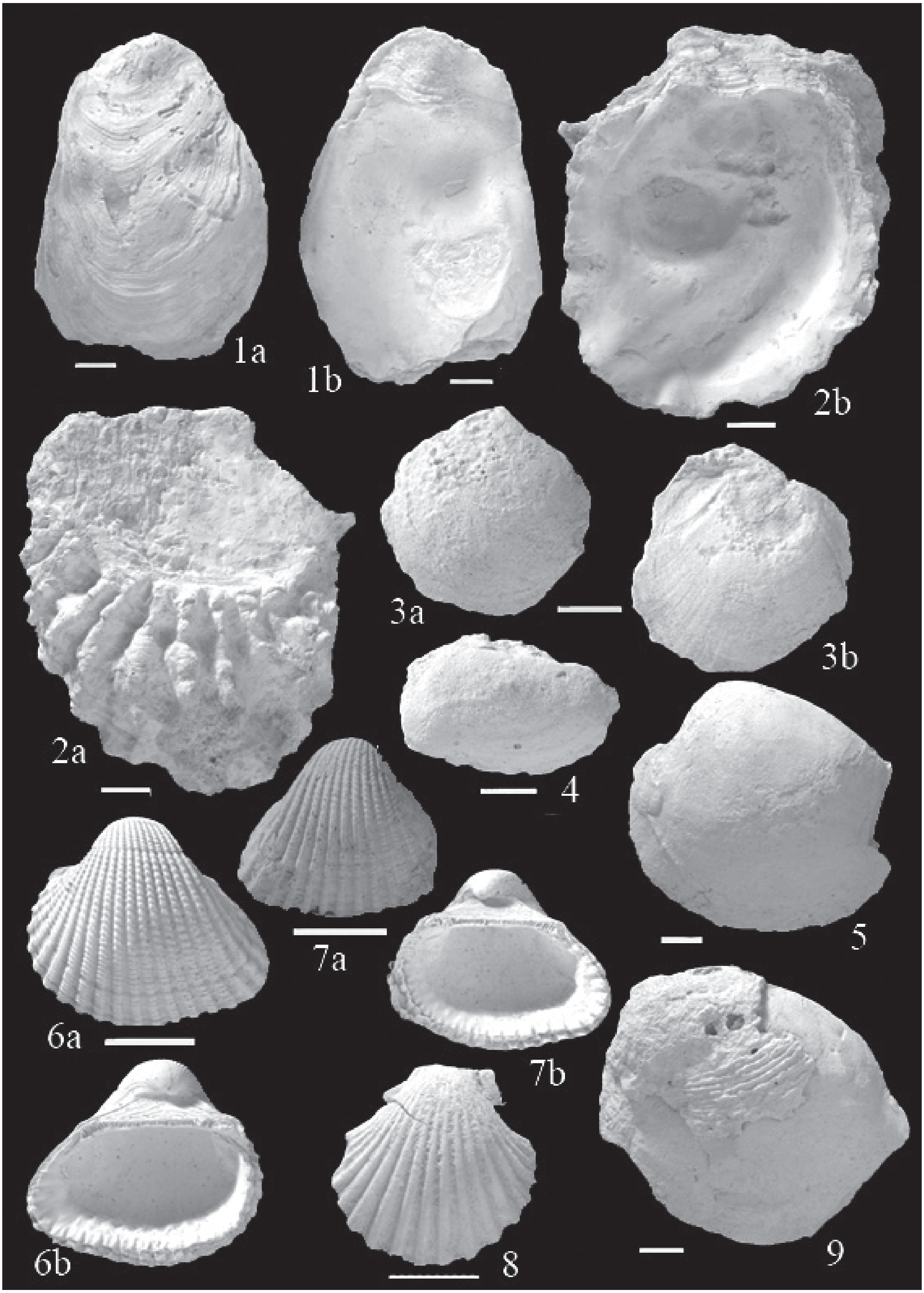
Figure 6a-b. *Anadara cardiiformis* (de Basterot, 1825), BEUN-2016-DM023

Figure 7a-b. *Anadara cardiiformis* (de Basterot, 1825), BEUN-2016-DM024

Figure 8. *Pecten subarcuatus styriacus* Hilber, 1879*,* BEUN-2016-DM025

Figure 9. *Venus (Antigona) burdigalensis producta* Schaffer, 1910, BEUN-2016-DM026

scale bar is 1cm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