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Sedimentary Properties of the Middle–Upper Eocene Formations in Çardak, Burdur and İncesu, SW Turkey

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Abstract: The integration of sedimentological, palynological and palaeontological data in three different outcrops in SW Turkey provides a clearer understanding of the palaeoenvironments in an area between the Çardak-Dazkırı Basin and the Isparta region during the Middle–Late Eocene. In this study, the Çardak-Dazkırı (Başçeşme Formation), Burdur (Varsakyayla Formation) and Isparta (Kayıköy Formation) areas have been studied for facies and facies associations. These formations contain alluvial fan, fan delta, shelf and related marine deposits. Detailed field observations allowed 34 lithofacies and 10 facies associations to be identified. The palynomorph assemblages in the Başçeşme and Varsakyayla formations contain biostratigraphically important taxa such as *Aglaoreidia cyclops*, *Triatriopollenites excelsus*, *Plicatopollis lunatus*, *Subtriporopollenites constans* and *Subtriporopollenites anulatus* ssp. n*anus*. The mangrove and back mangrove elements such as *Psilatricolporites crassus* and *Spinizoncolpites* sp. also occur in these palynomorph assemblages. The upper parts of the Başçeşme and Varsakyayla formations, which often exhibit reef developments, contain an assemblage of orthophragmines (*Discocyclina* sp.), nummulitids (*Nummulites* sp., *Assilina* sp., *Heterostegina* sp., *Operculina* sp.) and other benthic taxa (*Halkyardia* sp., *Fabiania* sp., *Asterigerina* sp., and *Sphaerogypsina* sp.). These assemblages indicate shallow benthic zones 18-20 (SBZ 18-20). The absence of foraminifera in the Kayıköy Formation does not allow a precise age of the unit to be determined. However, the occurrence of some planktonic foraminifera (Globigerinidae) and the presence of clastic sediments suggest a marine environment with turbidity currents. The lateral and vertical relations of the Başçeşme, Varsakyayla and Kayıköy formations suggest a marine transgression from west to east in SW Anatolia during the late Middle Eocene–Late Eocene.

Key Words: facies analysis, palynology, benthic foraminifera, Eocene deposits, western Taurides

Çardak, Burdur ve İncesu Havzalarında Orta–Üst Eosen Birimlerinin Sedimanter Özellikleri, GB Türkiye

Özet: GB Anadolu'da, Orta–Geç Eosen boyunca Çardak-Dazkırı ve Isparta arasında yüzlek veren üç farklı istifin paleoortamları, sedimantolojik, palinolojik ve paleontolojik verilerinin bütünlüğü ile daha iyi anlaşılabilmektedir. Bu çalışmada, Çardak-Dazkırı (Başçeşme Formasyonu), Burdur (Varsakyayla Formasyonu) ve Isparta (Kayıköy Fomasyonu) alanlarına ait birimlerin fasiyes ve fasiyes ilişkileri çalışılmıştır. Çalışma alanına ait tüm istifler, alüvyal yelpaze, yelpaze deltası, şelf ve denizel ortamı yansıtmaktadır. Ayrıntılı yapılan arazi gözlemlerine göre, 34 litofasiyes ve 10 fasiyes birliği tanımlanmıştır. Başçeşme ve Varsakyayla formasyonlarında bulunan palinomorf birliği, biyostatigrafik önemi olan *Aglaoreidia cyclops*, *Triatriopollenites excelsus*, *Plicatopollis lunatus*, *Subtriporopollenites constans* and *Subtriporopollenites anulatus* ssp. *nanus*, ve mangrov ve mangrove-gerisi ortamı karakterize eden *Psilatricolporites crassus* ve *Spinizoncolpites* sp. ile temsil edilir. Genellikle resif gelişiminin yaygın olarak görüldüğü Başçeşme ve Varsakyayla formasyonlarının üst kesimleri, zengin ve çeşitli orthophragmines (*Discocyclina* sp.), nummulitids (*Nummulites* sp., *Assilina* sp., *Heterostegina* sp., *Operculina* sp.) and diğer bentik foraminifer grupları (*Halkyardia* sp., *Fabiania* sp., *Asterigerina* sp., and *Sphaerogypsina* sp.) içermektedir. SBZ 18-20 (SBZ 18-20) sığ bentik zonlarını temsil eden bu topluluklar, denizel ortam değişikliklerini anlamada önemli bir araçtır. Kayıköy Formasyonu foraminifer açısından çok fakir olduğundan dolayı ayrıntılı olarak yaşlandırılamamıştır. Ancak, planktik foraminiferlerden Globigerinidae içermesi, birimin

açık şelf ortamında çökeldiğini göstermektedir. Diğer taraftan Kayıköy Formasyonuna ait istifin başlıca kumtaşı-şeyl ardalanmasından oluşan kırıntılı tortul bileşimi ve içerdiği tortul yapılar, türbidit akıntıların geliştiği denizel ortamı yansıtması bakımından önemlidir. Bartonian–Priabonian yaşlı bu üç formasyona ait tortul istiflerin yanal ve düşey yönde gösterdikleri litofasiyes değişimleri, GB-Anadolu'da Geç Eosen dönemi boyunca batıdan doğuya doğru bir transgresyonun geliştiğini yansıtmaktadır.

Anahtar Sözcükler: fasiyes analizi, palinoloji, bentik foraminifer, Eosen çökelleri, Batı Toroslar

Introduction

The Palaeocene–Eocene outcrops mark an important event in the history of basins developed before the neotectonic period, which is a known extensional tectonic regime in west Anatolia. During this time interval also occurred the main deformation and HP/LT metamorphism of the Menderes Massif as a result of burial beneath the Lycian Nappes (Şengör & Yılmaz 1981; Satır & Friedrichsen 1986; Bozkurt & Satır 2000; Bozkurt & Oberhänslı 2001; Sözbilir 2002). This Palaeocene–Eocene sedimentary succession rests unconformably on different tectonostratigraphic suites, such as the Lycian Nappes (Özkaya 1991; Şenel 1991; Collins & Robertson 1997, 1998, 1999), the Menderes Massif (Poisson 1976; Özkaya 1990, 1991; Özer *et al.* 2001) and the Beydağları carbonate platform (Özkaya 1991; Collins & Robertson 1998). The initial phase of nappe emplacement occurred during the latest Cretaceous (Collins & Robertson 1998), after which sedimentary basins developed on top of the imbricated Lycian basement during the Late Palaeocene–Early Eocene (Şenel 1991). The basin fill comprises basal conglomerates with clasts derived from the Lycian Nappes, bioclastic platform limestones and clastic turbidites and is interpreted as a supra-allochthonous unit (Sözbilir *et al.* 2001; Sözbilir 2002), thought to represent a temporal restoration of a passive margin during relative tectonic quiescence (Collins & Robertson 1998).

In this study the Middle–Upper Eocene sequences stratigraphically overlying the Lycian Nappes are represented by the Başçeşme and Varsakayayla formations, and the Kayıköy Formation on the Beydağları carbonate platform (Figures 1 & 2).

The purpose of this paper is to provide a facies description and interpretation of the Middle–Upper Eocene Başçeşme, Varsakyayla and Kayıköy formations, to identify the factors that controlled their deposition and to describe the palynological and foraminifera assemblages of these units that have been widely used in palaeoenvironmental interpretations.

Geological Setting

The Middle–Upper Eocene outcrops are distributed in the Çardak-Dazkırı (north of Acıgöl), Burdur (north of Lake Burdur) and Isparta (İncesu and Gönen towns) areas (Figures 1, 3, 4 & 6). These basins are located in the Western Anatolia extensional province characterized by numerous NW–SE-, NE–SW-, E–W-trending basins (Koçyiğit 1984, 2005) and rest on the Mesozoic Lycian Nappes and ophiolites (Sözbilir 2005).

The Palaeocene–Eocene sedimentary assemblages of southwestern Anatolia are made up mainly of conglomerate, sandstone, turbiditic sandstone-mudstone alternations, carbonaceous mudstone, bioclastic limestone interbeds and, locally, limestone blocks. The sedimentary features of these sedimentary constituents mainly indicate a supra-allochthonous basin type, which developed above the Lycian Nappe package (Sözbilir 2002). The supra-allochthonous sediments are separated from the basement rocks by a regional unconformity (Sözbilir 2002).

Following Poisson *et al.* (2003) the tectonic evolution of the study area and its surroundings can be divided into four main stages. These are in ascending order; (1) closure of the Pamphylian basin and emplacement of Antalya Nappes (Late Cretaceous–Early Palaeocene); (2) emplacement of Lycian Nappes (end of Eocene–Early Oligocene); (3) formation of the Oligocene molasse basins and (4) opening of the Baklan and Acıgöl grabens under NW–SE and N–S extensional regimes.

Deposition in the supra-allochthonous Eocene–Oligocene marine basins in SW Anatolia, was controlled mainly by the emplacement of the Lycian

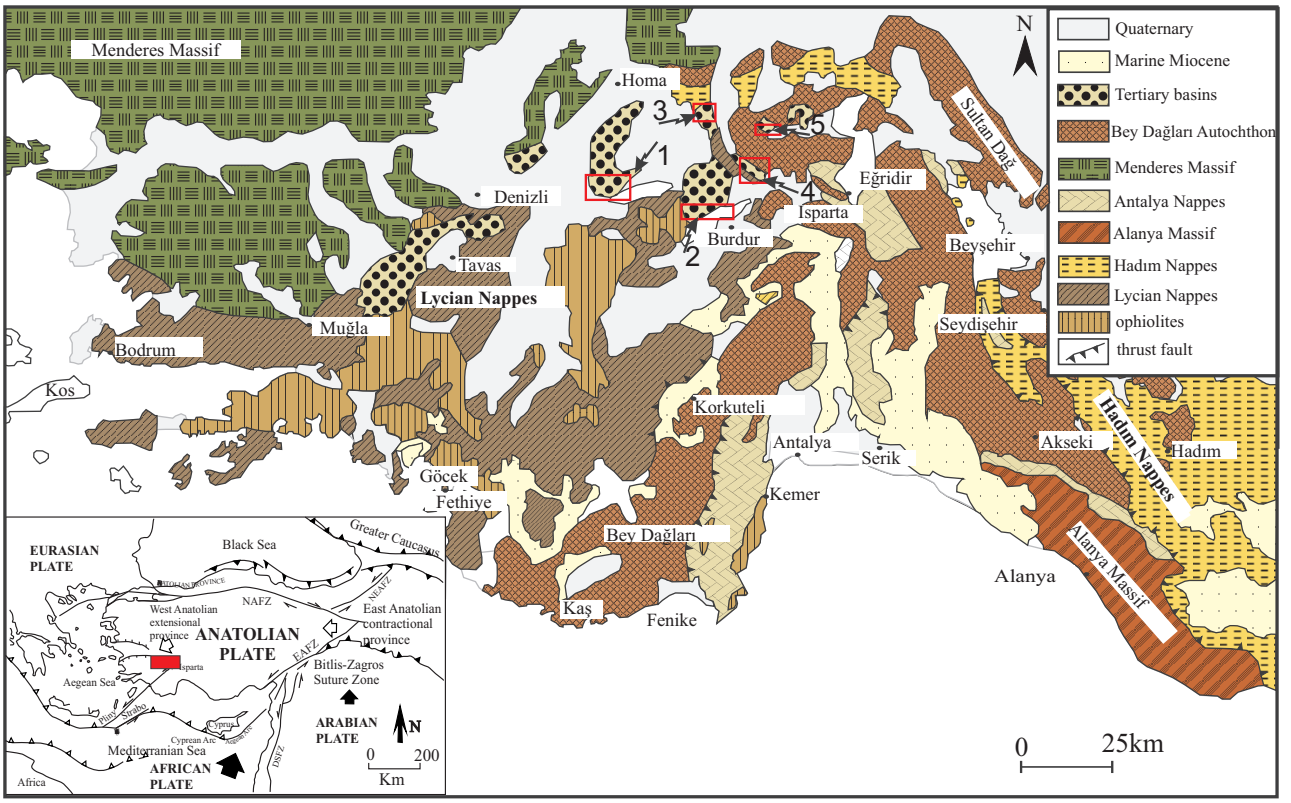


Figure 1. Simplified geological map of SW Turkey showing the study areas: (1) Çardak-Dazkırı, (2) Burdur, (3) İncesu, (4) İğdecik and (5) Gönen basins (modified from Gutnic 1977; Akgün & Sözbilir 2001).

Nappes in the region at the time. However, the mainly ophiolitic detrital constituents of the Başçeşme, Varsakyayla and Kayıköy formations indicate a Late Eocene synsedimentary emplacement of the ophiolite assemblages of the Lycian Nappes. The emplacement of the Lycian Nappes in SW Anatolia continued until the end of the Late Miocene. Field observations in the Burdur and Isparta regions show that ophiolitic allochthonous units of the Lycian Nappes are overthrust on to Early Miocene (Aquitanian–Burdigalian) marine sedimentary units. Multiple overthrust systems of the Lycian Nappes on to the Beydagları autochthonous carbonate and detrital units (Late Palaeocene to Early Miocene) suggest an anticlockwise rotation of the western side of the Isparta Angle. Palaeomagnetic studies (Kissel *et al.* 1993; van Hinsbergen *et al.* 2010) indicated that the Lycian block on the western limb of the Isparta Angle rotated anticlockwise by about 40° since the Eocene. Furthermore, the palaeomagnetic data suggest that the dominant tensional forces in the study area mainly trend NW–SE.

Stratigraphy

In this study, our field observations were focused on three different locations, namely the Middle–Upper Eocene deposits cropping out in the Çardak-Dazkırı (Başçeşme Formation), Burdur (Varsakyayla Formation) and İncesu (Kayıköy Formation) basins. The major geological characteristics of these Eocene basins are briefly described below.

Çardak-Dazkırı Basin

The Çardak-Dazkırı basin is located north of the Acıgöl Graben, mainly filled by Tertiary sedimentary sequences and characterized by molasse type clastic deposits (Figure 1) (Koçyiğit 1984; Göktaş *et al.* 1989; Yağmurlu 1994; Akgün & Sözbilir 2001; Sözbilir 2005). The Upper Eocene Başçeşme Formation, exposed near Başçeşme village and first named by Göktaş *et al.* (1989), unconformably rests on the Lycian Nappes (Figure 2) (Göktaş *et al.* 1989). The formation is composed mainly of a fining-upward

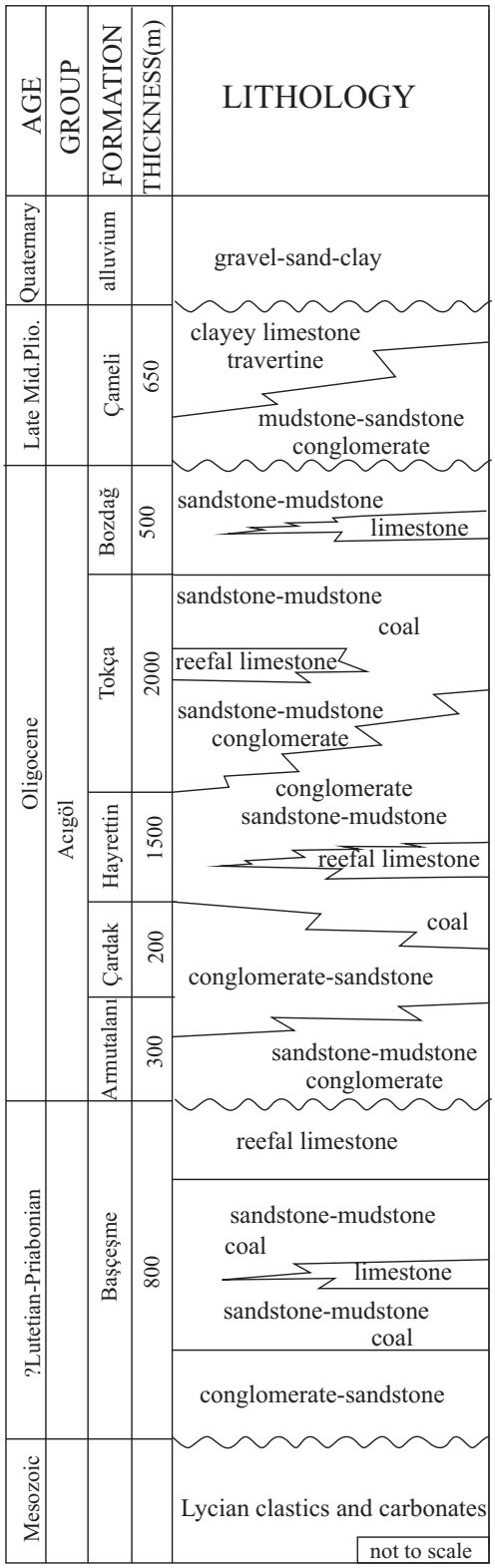


Figure 2. Generalized lithostratigraphic columnar section of the Çardak-Dazkırı basin (modified from Şenel 1997; Sözbilir 2005).

clastic sedimentary succession, which starts with pebble to cobble conglomerates at the base (Göktaş *et al.* 1989; Akkiraz 2008; Toker 2009; Toker *et al.* 2009). Vertically and laterally, these coarse conglomerates display gradual transition to a monotonous alternation of sandstone, mudstone with coal and reef carbonates (Göktaş *et al.* 1989; Akkiraz *et al.* 2006; Akkiraz 2008; Toker 2009). This internal lithological variation is divided into the following members: the reddish-claret Dazlak conglomerate; the Maden sandstone and coaly mudstone and the Asar limestone with corals, algae and benthic fragments (Figure 3b).

Burdur Basin

The Burdur basin is located on the northwestern side of Lake Burdur and filled with Tertiary deposits which are divided into supra-allochthonous sediments, the Acıgöl group and neo-autochthonous cover units (Yalçınkaya *et al.* 1986; Şenel 1997) (Figure 4). The pre-Eocene basement comprises ophiolitic melange and olisthostrome of the Lycian Nappes (Poisson 1977). The Varsakyayla Formation from around Varsakyayla village, named by Poisson (1977), is well exposed in this area and is mainly made up of locally channellized conglomerates, planar cross-bedded sandstones, massive and locally coaly mudstones and bivalve and gastropod-bearing limestone (Akkiraz 2008). The Varsakyayla Formation is linked with the Başçeşme Formation due to the similarities of their sedimentary constituents.

İncesu Basin

The İncesu Basin is located in the apex of the Isparta Angle and its deposits crop out around Gönen town to the north of Isparta (Figure 7). The Kayıköy Formation, named after Kayıköy village, where it is well exposed (Karaman *et al.* 1989), is generally greyish and includes very poorly sorted conglomerates, amalgamated sandstones with mudstone interbeds (Figures 13 & 14). The Kayıköy Formation is turbiditic and is composed mainly of sandstone and shale alternations and also contains clayey and cherty interbeds and conglomerate intercalations dominantly of turbiditic origin. The Middle–Late Eocene age of the formation is deduced from its stratigraphic position (Figure 6).

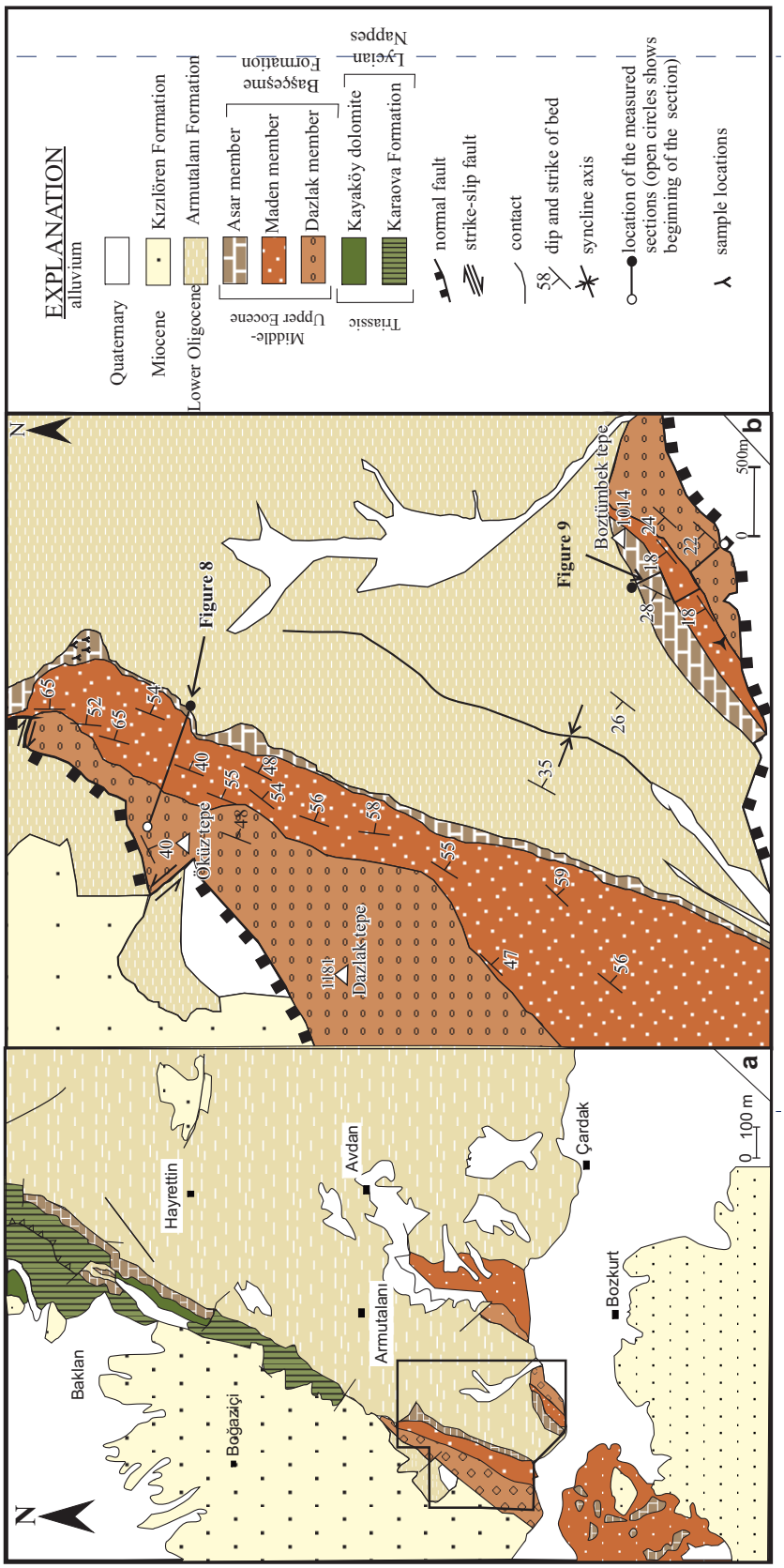


Figure 3. (**a**) Geological map of the Çardak-Dazkırı area. (**b**) Detailed geological map of the studied area, north of Başçeşme village. Locations of measured sections are indicated.

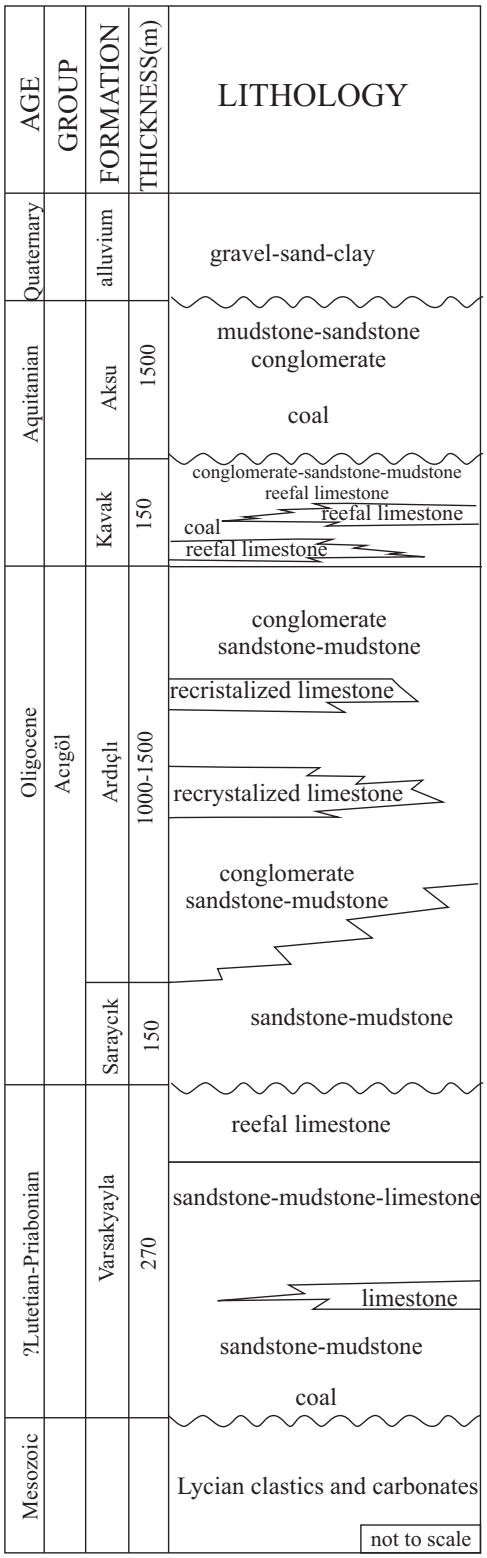


Figure 4. Generalized lithostratigraphic columnar section of the Burdur basin (modified from Yalçınkaya *et al.* 1986; Şenel 1997).

Facies and Facies Associations

In this section, three Eocene formations have been analyzed in terms of their facies associations. These associations are based on the facies defined on logged stratigraphic sections and used palynological data (Figures 8, 9, 11–14). Detailed descriptions of the sedimentary features and palaeoenvironmental interpretations of the facies and facies assemblages are given in Tables 1–4, 7 & 8. Facies classification of alluvial and fluvial environments is after Miall (1978), who assigned gravel-bearing successions to G facies, while sandy and clay facies were assigned to S and F facies, respectively. Small letters following the capital letter indicate the textural and structural characteristic of each facies.

Başçeşme Formation

The Başçeşme Formation is well-exposed on the north western margin of the Acıgöl Graben (Figure 3a). Two outcrop sections have been logged (Figure 3b), one of which is located northeast of Öküz Tepe, while the other is southwest of Boztümbek Tepe (Figure 3b). The Öküztepe section is up to approximately 240 metres thick and extends laterally over a few kilometres (Figure 8), while the Boztümbek section is approximately 360 metres thick (Figure 9). In sedimentary logs, fifteen lithofacies have been defined based on type of individual beds, grain size, primary sedimentary structures and fossil contents (Table 1). Field photos also illustrate some of the lithofacies features of the Başçeşme Formation (Figure 10). This lithofacies diversity was grouped into three main facies associations: FA1 to FA3 (Table 2). FA1 correlates with the coarse-grained Dazlak Member, FA2 correlates with the finer-grained Maden Member and FA3 correlates with the carbonate Asar Member (Figures 8 & 9).

Alluvial Fan Deposits (FA1): Description – The alluvial fan facies association is characterized by the relative abundance of facies Gmm, Gp, Sg, Sp, St, Shs (Table 1; Figures 8 & 9). The FA1 is generally made up of conglomerates intercalated with pebbly sandstones. This polygenetic conglomeratic facies association is commonly reddish and brownish, pebble to cobble grain size, thick bedded to massive, poorly-sorted, matrix-supported, with erosive

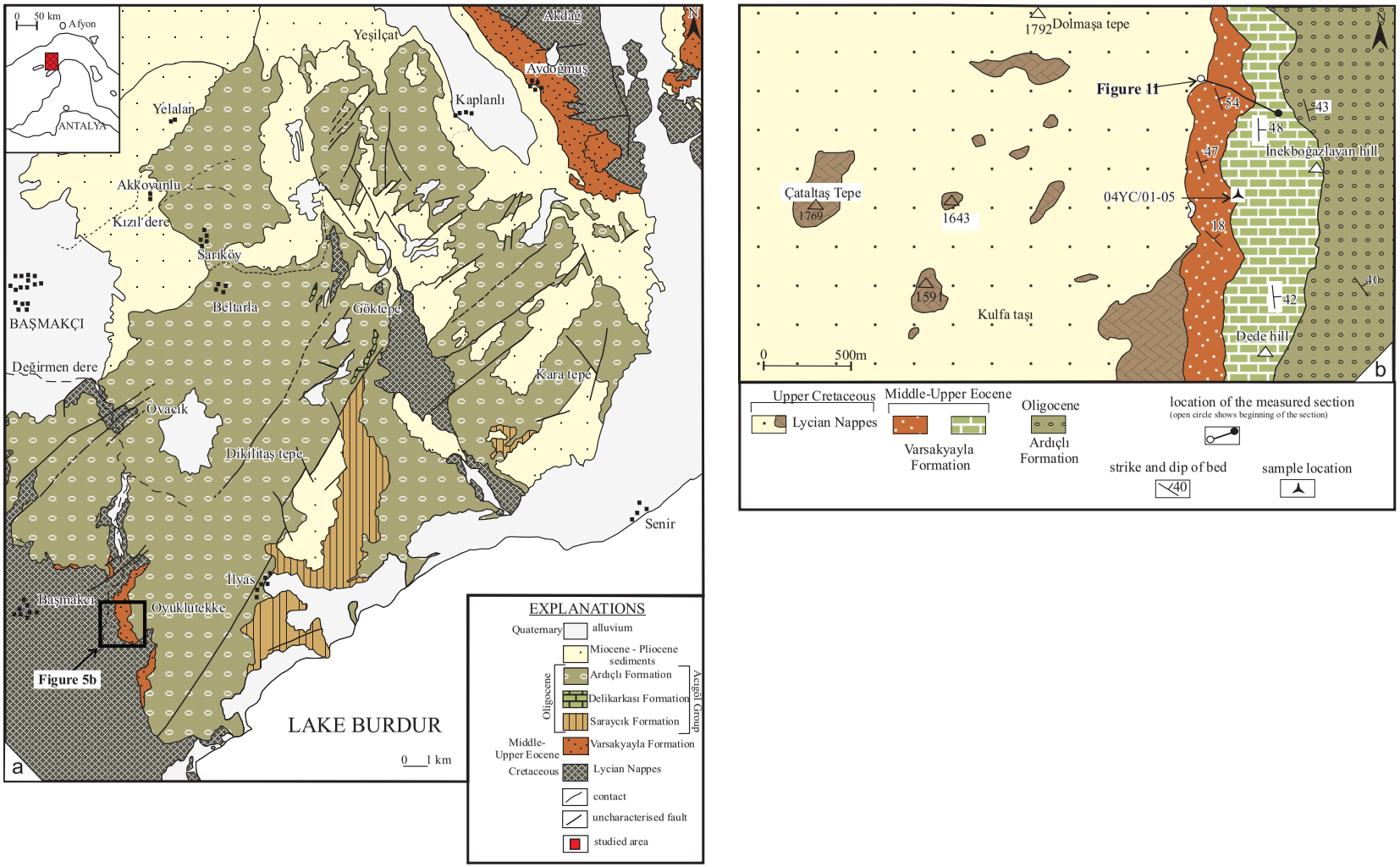


Figure 5. **(a)** Geological map of the northern part of Lake Burdur (modified from Şenel 1997b). See Figure 1 for location. **(b)** Detailed geological map of the northern side of Yukarıcimbili village (north of Lake Burdur). Location of measured sections, geological sections and sample locations are indicated.

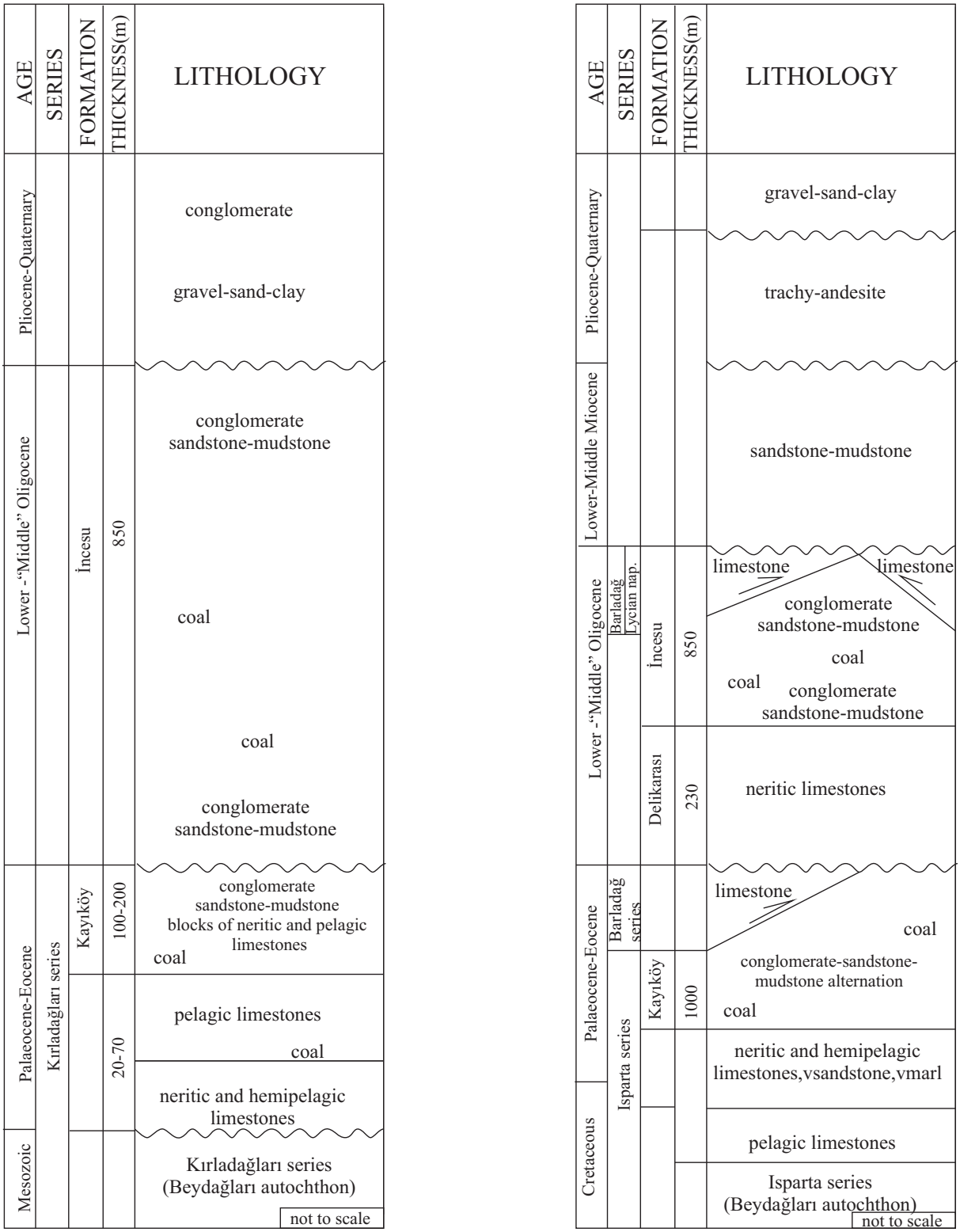


Figure 6. Generalized lithostratigraphic columnar sections of the İncesu Area, **(a)** Around İncesu Village. **(b)** Around İğdecik, Gümüşgün villages, and Gönen and Atabey towns. See Figure 7 for location (modified from Gutnic 1977; Görmüş & Özkul 1995;Yağmurlu 1994).

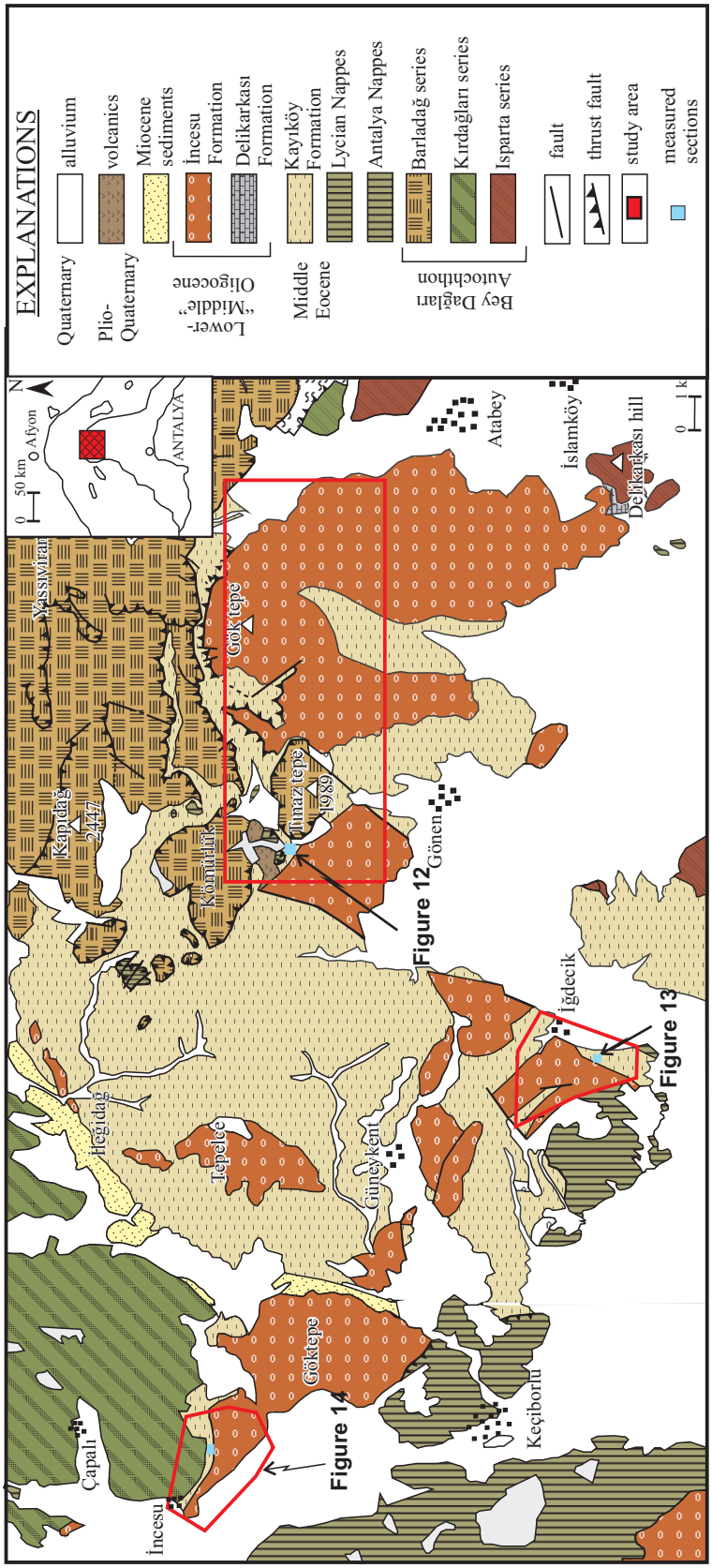


Figure 7. Simplified geological map of north Gönen Town (modified from Gutnic 1977; Yağmurlu 1994).

Table 1. Description and environmental interpretation for the lithofacies in the Başçeşme Formation.

Facies	Description	Interpretation
Gmm; massive conglomerates	granule to cobble size, massive, matrix-supported, chaotic, pebbles are rounded to sub-rounded, poorly sorted to unsorted, generally erosive basement, irregular top, reddish-claret coloured, locally contains sandstones; dimensions: bed thickness up to 10 m, lateral extent: tens to hundred metres, commonly intercalated with facies Sb,Sr	debris-flow deposits
Gp; panar cross-bedded conglomerates	granule to pebble size clast supported by coarse sandy matrix, subangular and poorly sorted clasts, sand lenses, generally fining upward with erosive base, planar cross bedded, channel fill occurs, reddish-brown coloured; dimensions: bed thickness up to 4 m, lateral extent: few ten metres; intercalated with facies Sr	channel fill
Gms, matrix-supported gravelstone	granule to pebble size clasts supported by sandy matrix, poorly sorted, poorly bedded, few crudely developed normal to inverse grading,yellowish red coloured,angular to subangular clasts; dimensions: bed thickness up to 6 m, lateral extent: few tens metres, intercalated with facies Sb, Sl,Fl and C	debris flow to hyper-concentrated flow deposits
Sg, gravelly sandstones	granule to coarse-grained sandstones, poorly sorted and rounded, cross-laminated, channel-fills, reddish coloured, dimensions; bed thickness up to 20 cm, laterally extent: few metres, intercalated with facies Gmm, Gp	deposits from sand-dominated chanellized flows
Shs, horizontally stratified sandstones	medium- to fine-grained sandstone, moderately sorted, horizontally stratified bioturbated, locally ripple laminations on top, locally hematite concretions bearing, reddish-yellowish red coloured; dimensions: bed thickness up to 30 cm, laterally extent: few tens of metres, intercalated with facies Gms,Sg	planar bed flow, upper flow regime
Sr, rippled sandstones	medium- to fine-grained sandstone, generally parallel laminated at the bottom and ripples at the top of bed, lenses with mud, greyish red coloured; dimensions: bed thickness up to 20 cm, lateral extent: few metres, intercalated with facies Sp, Gmm	subaqeous deposits at lower flow regime
Sp, planar cross-stratified sandstones	medium- to fine-grained sandstone, moderately sorted, massive bedding, planar cross-stratified, yellowish red coloured, dimensions: bed thickness up to 25cm, laterally extent few of metres, intercalated with facies Gmm, Gh	lower flow regime, sand waves
Sm, massive sandstones	medium- to fine-grained sandstone, moderately sorted, normal graded, greyish red coloured; dimensions: bed thickness up to 35 cm; lateral extent: a few metres; intercalated with facies Gh, Fm	rapid sedimentation, sediment gravity flow
Sf, fosilliferous sandstones	medium- to coarse-grained sandstone, moderately sorted, planar cross-stratified, corals, gastropods and bivalves-bearing, greyish red coloured; dimensions: bed thickness up to 60 cm; lateral extent: a few tens of metres; intercalated with facies Fm	decreasing current velocity
Sc, calcareous sandstones	medium- to coarse-grained sandstone, massive bedding, calcareous sandstone, yellow coloured; dimensions: bed thickness up to 5 m; lateral extent: a few metres; intercalated with facies Sf, Lr	edge of bank platform and shelf
Ls, sandy limestone	Sandy limestone with bioclast, grainstone, flat bedded, coarse grain size, fossil fragments such as bivalves, benthic foraminifers, yellowish grey coloured; dimensions: bed thickness up to 5 m; lateral extent: a few metres; intercalated with facies Lr	sporadic storms and currents across reef, relatively low wave and current energy
Fm, massive mudstone	mudstone, laminated, medium- to coarse-grained sandstone, massive bedding, greyish yellow coloured; dimensions: bed thickness up to 50 cm; lateral extent: a few metres; intercalated with facies Sg, Sf	suspension sediments, overbank deposits, waning currents
Lr, reefal limestones	reefal limestone, flat bedding, mixing of coarse skeletal fragments such as corals, bivalves, benthic foraminifers and algal mounds, abundant milliolid association, greyish yellow coloured; dimensions: bed thickness up to 10 m; lateral extent: a few tens of metres; intercalated with facies Sc	low energy, sporadic currents and quiescent shallow water
C, coal-coally mudstone	coal, horizontally laminated, dark brown-black coloured, abundant plant fragments; dimensions: bed thickness up to 40 cm; lateral extent: a few tens of metres; intercalated with facies Sm, Fm	subaerial low energy, channel overbanks, vegetated swamps deposits and marsh, coastal plain

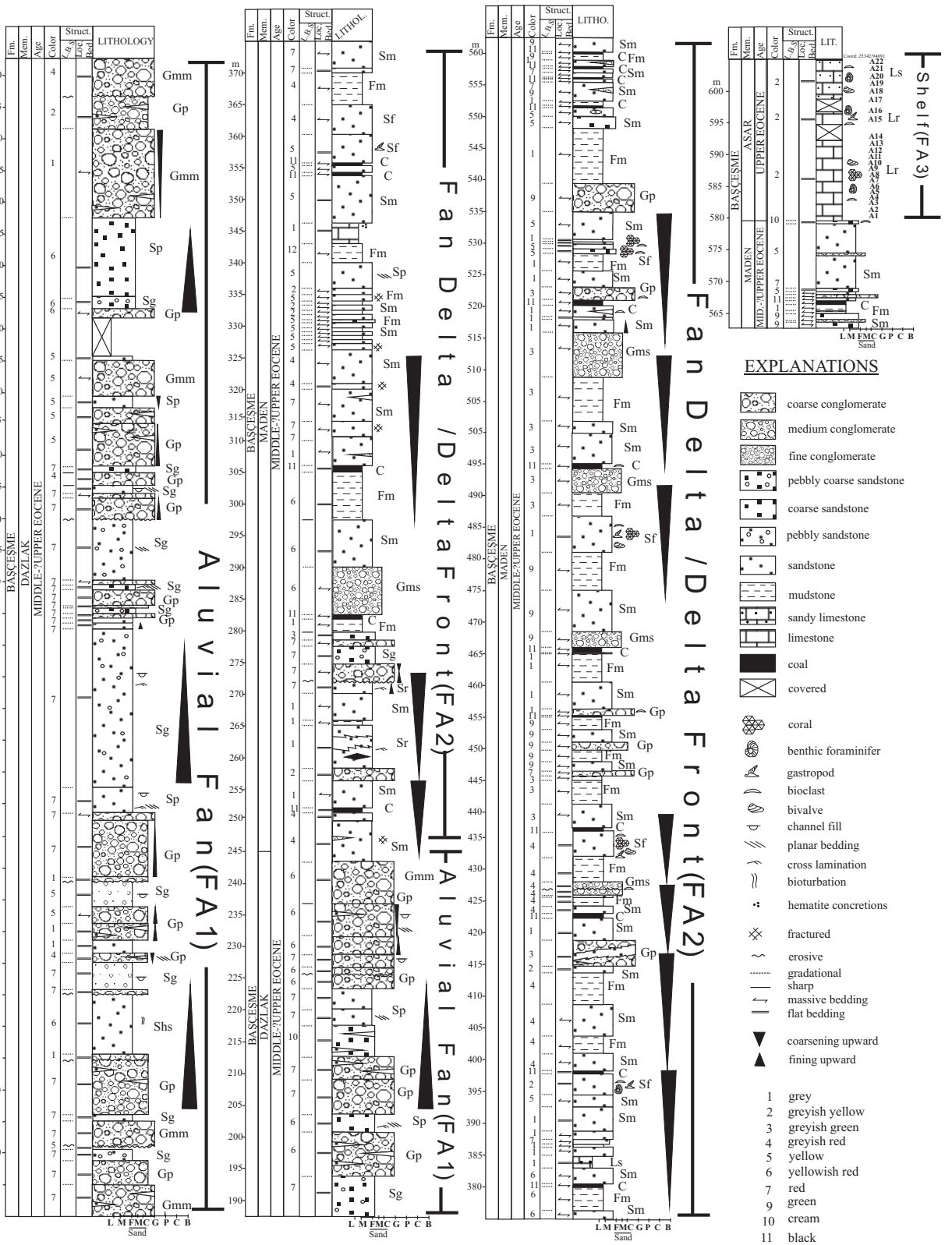


Figure 8. Measured section of the Başçeşme Formation northeast of Öküztepe. See Figure 3b for location.

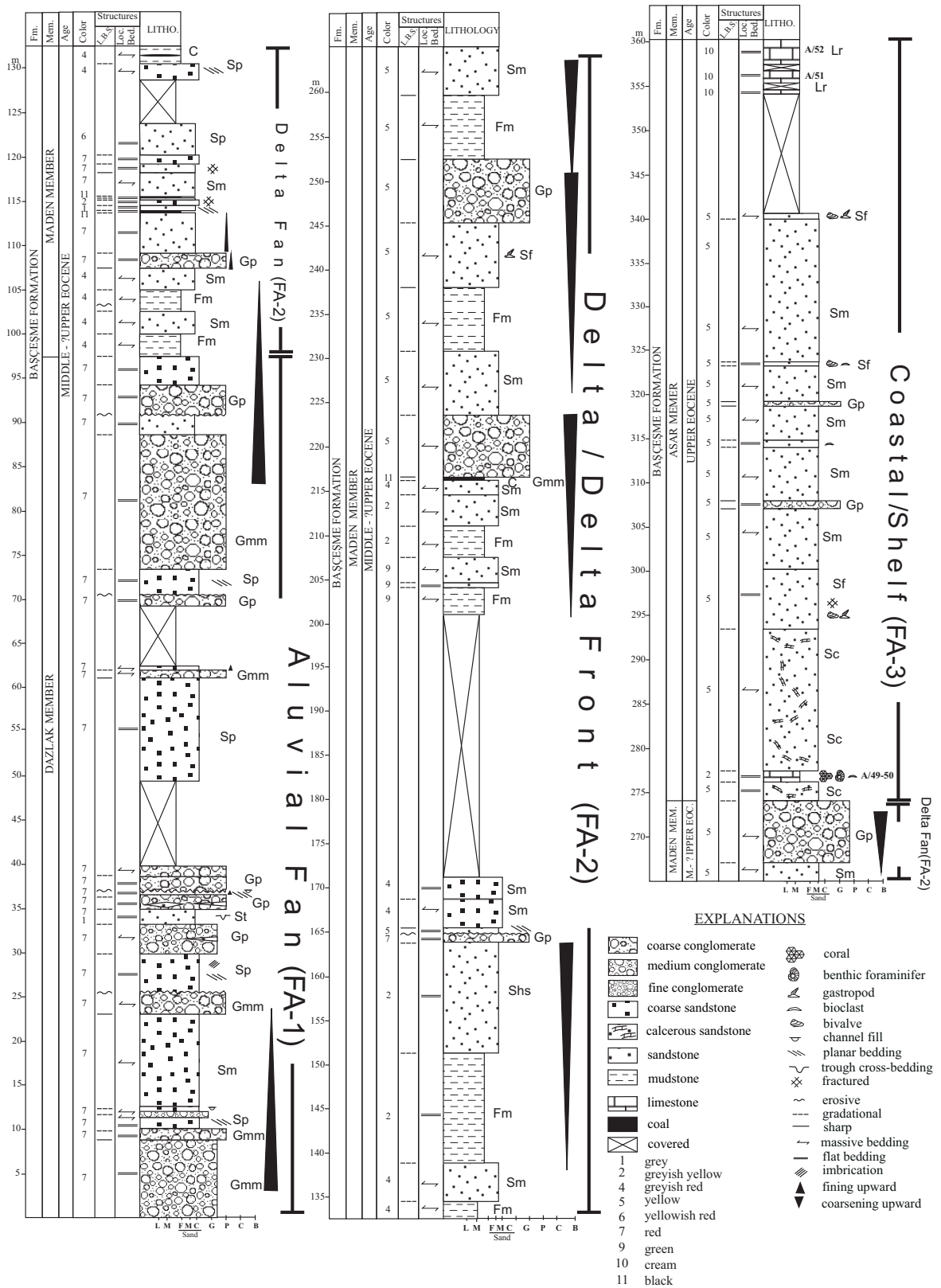


Figure 9. Measured section of the Başçeşme Formation south of Boztümbek Tepe. See Figure 3b for location.

Table 2. Facies associations of the Başçeşme Formation.

Facies Associations	**Constituent Lithofacies**
FA1, alluvial fan facies associations	Gmm, Gp, Sg, Sp, Sm, Shs
FA2, fan-delta/delta front facies associations	Gms, Shs, Sr, Sm, Sf, Ls, Fm, C
FA3, shelf facies associations	Gp, Sm, Sf, Sc, Ls, Lr

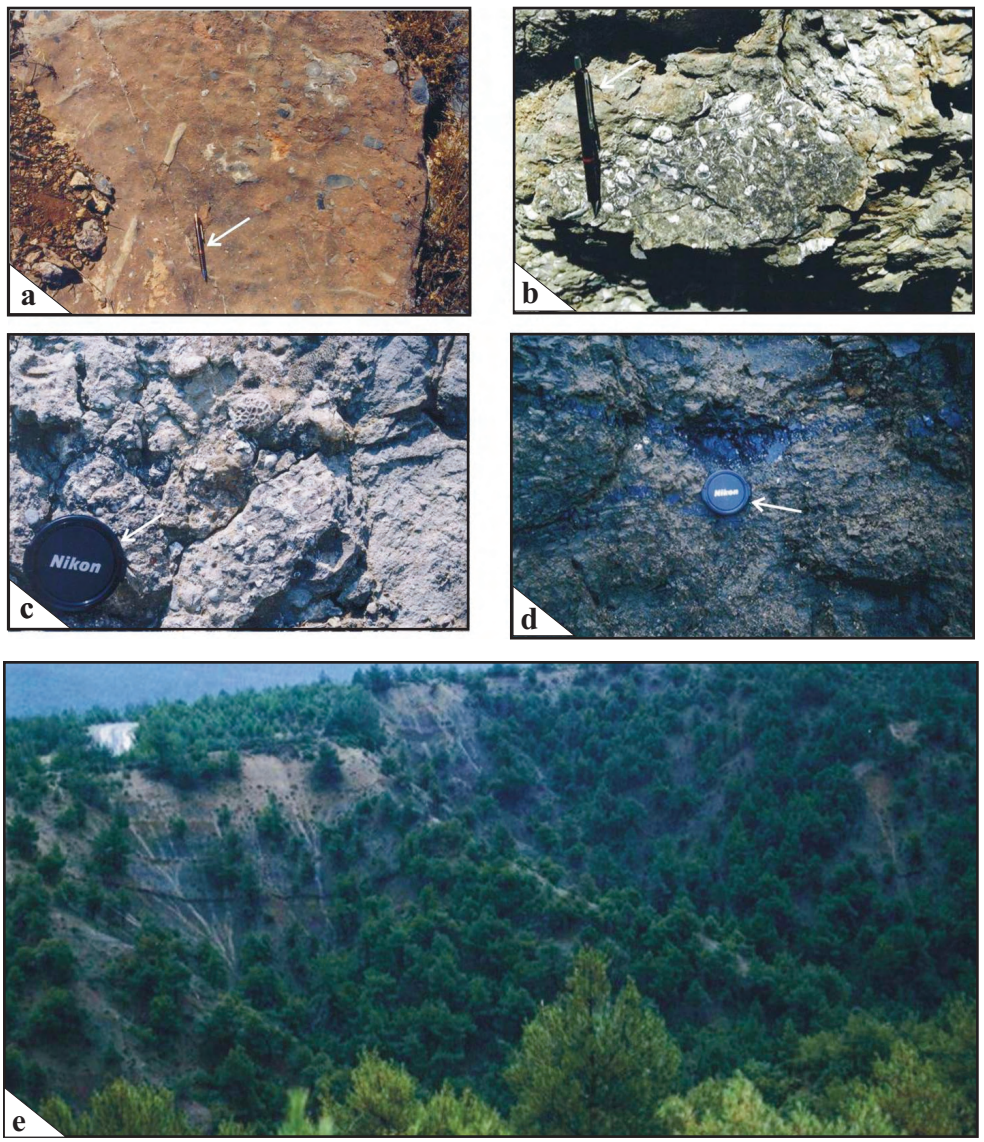


Figure 10. Field photographs of **(a)** bioturbation traces in the Dazlak member **(b)** bivalves, gastropods and bioclasts in the Maden member, **(c)** coral colony and gastropods in the Maden member, **(d)** coal lens in the Maden member, **(e)** coal seams in the Maden member. White arrows indicate the scale of the photos. Pencil is ~15cm long; Lens cap is ~50mm in diameter.

bases and irregular tops, generally structureless and chaotically organized, with sub-rounded to rounded clasts (Facies Gmm) (Figures 8 & 9). They can be traced laterally for up to a hundred metres. The most common clast components are black dolomites, serpentinites, and ophiolitic fragments that are most probably derived from the Lycian Nappes. The cross-bedded conglomerates are compositionally the same as the massive conglomerates (Gmm), but differ in exhibiting planar cross-bedding (facies Gp) (Figure 9). Clasts within the conglomerate are poorly-sorted, within a coarse-grained matrix. The coarse-grained gravelly sandstones (facies Sg) are commonly observed as interbeds in conglomerates and are poorly sorted and cross-laminated (Figures 8 & 9). Planar cross-stratified sandstones and trough cross-bedded sandstones (facies Sp, St) were also observed in massive conglomerates. Horizontally stratified bioturbated sandstones (facies Shs) consist of medium–fine-grained sandstones with hematite concretions and locally ripple laminations on top (Figure 9).

Interpretation – The abundance of matrix-supported, massive to thick bedded, and scarcity of internal structures in reddish conglomerates and sandstone beds of the FA1 indicate mainly debris flow processes of alluvial fan deposition (Reineck & Singh 1975; Miall 1996). The clasts are polygenetic and derived from basement metamorphic rocks by dominantly cohesive and stream debris flow (Nemec & Steel 1984; Göktaş *et al.* 1989; Nemec & Postma 1993; Blair 1999; Sözbilir 2002). All these facies of FA1 suggest deposition in an alluvial fan setting in front of high ground fed from a Lycian Nappes source area. In the upper parts of the fan (facies Gmm, Gp, Sg, Sp), with a steeper gradient, high energy flow dominated and thus, overbank deposits are rarely preserved. Generally, the FA1 facies association demonstrates a fining upward sequence and laterally passes into fan deltaic conditions.

Fan-delta/Delta Front Deposits (FA2): Description – The Fan delta/delta front facies association is composed of Gms, Shs, Sp, Sr, Sf, Sm, Ls, Fm, C facies (Table 1; Figures 8 & 9). The grain size is highly variable, ranging from fine grained to gravel size. Horizontal lamination, ripples, planar cross-bedding, normal graded bedding, and bioturbations are characteristic syn-sedimentary structures and occur at various stratigraphic levels (facies Shs, Sr and Sm) and fragments of fossils such as corals, gastropods and bivalves were also observed in FA2 (facies Sf) (Figure 9). Coarsening-upwards sequences were commonly observed in this facies association. The mudstone and coal are intercalated with massive sandstones (facies Sm) (Figure 8). Intercalation of debris flow facies such as Gmm and Sp indicates an interfingering relationship with FA1.

Interpretation – The sand-dominated FA2 facies association was probably deposited in a delta setting at the toe of FA1 where the alluvial fan system is continuous through to a fan delta system. This facies association concordantly overlies the alluvial fan sediments (FA1). Coal layers represent quiescent subaerial conditions and the massive, laminated mudstone with shell fragments indicates an alluvial swamp environment.

Shelf Deposits (FA3): Description – The shelf facies association is composed of Sf, Sc, Ls, Lr facies varieties (Tables 1 & 2; Figures 8 & 9). The sandstones mostly consist of gastropod, bivalve- and bioclast-bearing fossiliferous sandstones and calcareous sandstones (facies Sc and Sf). Sandy limestones with benthic foraminifera and bivalves and reef limestones were observed at the top of FA3. The lateral extent of these facies usually exceeds tens of metres.

Interpretation – The FA3 facies was probably deposited in a lagoon and shelf environment and is characterized dominantly by sandy limestone and reef limestone. This facies association overlies fan delta sediments (FA2). The calcareous sandstone (facies Sc) commonly occurs near the seaward edge of the bank platform and shelf. The development of this deposit requires sand-size sediments and a means of removing sediment smaller or larger than sand-size material. These requirements coincide with wave action or strong tidal currents in an area of high carbonate production (Tucker & Wright 1990). The sandy limestone represents open shelf environments (facies Ls). The limestone contains corals, benthic foraminifera and bivalves typical of a shelf environment. However, the presence of abundant milliolid association in packstones indicates back-reef or lagoonal environmental conditions (Toker 2009).

Fossil Contents – Benthic foraminifera have been identified, particularly in the FA3 facies association of the Asar Member (Başçeşme Formation) (Figures 8 & 9). The *Nummulites* assemblage, including *Nummulites fabianii* and *Nummulites striatus*, was identified and in addition, *Fabiania cassis*, *Eorupertia magna*, *Halkyardia minima*, *Spahaerogypsina globulus Asterigerina rotula*, *Quinqueloculina* sp., *Asterigerina* sp., *Discocyclina* sp., *Cibicides* sp., *Heterostegina* sp., *Eponides* sp., *Amphistegina* sp., *Alveolina* sp., *Assilina* sp., *Halkardia* sp., *Nummulites* sp., *Operculina* sp., *Praebulalveolina* sp., *Eorupertia* sp., *Fabiania* sp., *Neoalveolina* sp., *Halkyardia* sp., *Anomalina* sp., *Mississippina* sp., *Pararotalia* sp., *Pyrgo* sp., *Rotalia* sp., *Sakesaria* sp. and *Orbitolites* sp., were recorded from reef limestones (Akkiraz *et al.* 2006; Akkiraz 2008). The nummulitids (*Nummulites fabianii*) indicate Shallow Benthic Zonation (SBZ) 19 or 20 (Less *et al.* 2008). *Heterostegina* sp., which is found in the Başçeşme Formation, occurs in SBZ 18-19 and indicates an upper Bartonian–Priabonian age (Özcan *et al.* 2007). Furthermore, *Fabiania cassis*, *Halkardia* sp., *Rotalia* sp., Miliolids, coralline red algae, corals, gastropods and bivalves in these sections of the Başçeşme Formation indicate a Bartonian–Priabonian age. In this part of the section, a shallow shelf is indicated by the presence of *Nummulites* and towards deeper water, a distal-middle ramp is indicated by orthophragminid assemblages (Bassi 2005).

Varsakyayla Formation

The Varsakyayla Formation is well exposed southwest of the Burdur Basin (Figure 5). One outcrop section has been logged through this formation (Figure 11). The section is north of Yukarıcimbilli village and up to approximately 270 m thick (Figure 5a). Sedimentary logs defined ten lithofacies based on types of individual beds, grain size, primary sedimentary structures and fossil contents (Table 3). The observed lithofacies diversity was classified into three main facies associations: FA4, FA5 and FA6 (Table 4). A further fifteen samples were analysed palynologically (Table 7).

Fluvial Deposits (FA4): Description – The fluvial facies association (FA4) includes Gh, Sm, Sp, Sr, Fm facies varieties (Table 4; Figure 11). The facies association is predominantly sandy facies comprising medium- to fine-grained, moderately sorted sandstones, interbedded with conglomerates and thick-bedded mudstones. Planar cross bedding, ripple lamination, channel-fills, hematite concretions, plant debris and bioclasts are common sedimentary structures in the sandstones, together with sharp, sometimes erosive bases (facies Sp and Sr). The conglomerates have interbeds of sandstones which are horizontally bedded, poorly sorted and are supported by a sandy, silty matrix. Clasts are rounded to well-rounded in the pebble to gravel range (facies Gh). The clasts in the conglomerates are polygenetic and mainly derived from ophiolites of the Lycian Nappes. Mudstones in the fluvial facies are massive to thick bedded, have sharp contacts at base and top and contain plant debris (facies Fm). The gravel and medium-sand-dominated units in this facies are mostly grey.

Interpretation – The sandy-muddy dominant facies association (FA4) contains trough cross-bedding and fining-upward cycles indicating the dominance of fluvial distributary system during deposition. The sand and mud dominated facies assemblage is characterized by a very high proportion of floodplain facies, with fewer channel-fill deposits (Nichols & Fisher 2007). Planar-cross bedding is produced by the downstream migration of two dimensional bedforms (Harms *et al.* 1982). Overbank deposits are represented by thick-bedded, greyish mudstone.

Fan Delta Deposits (FA5): Description – The fan delta facies association (FA5) is composed of Gmm, Gh, Sm, Sp, Sf, Sc, Fm lithofacies (Table 3; Figure 11). The coarse-grained gravels in the FA5 facies association consist of matrix-supported, weakly stratified, massive, poorly sorted, rounded to subrounded pebble to cobble gravels, (facies Gmm) with horizontally bedded sandy, silty matrix-support, erosive bases and locally irregular tops (facies Gh). The FA5 facies association is characterized by mostly sandy facies (facies Sm, Sp, Sf, Sc) which are medium to coarse grained, and moderately sorted. Planar cross-bedding and locally channels are common sedimentary structures in the sandstones (facies Sp, Sm). Benthic shell fragments such as shallow water gastropods and bivalves are abundant in this facies association, and individual beds are bioturbated and

Table 3. Description and environmental interpretation for the lithofacies in the Varsakyayla Formation.

Facies	Description	Interpretation
Gmm, massive conglomerates	ganule to cobble size clast, silty, sandy and gravelly matrix-supported, massive and unstratified, poorly sorted rounded to subrounded, generally erosive basement, locally sand lenses, average clasts size is up to 23 cm, grey-greyish yellow coloured; dimensions: bed thickness up to 4 m; lateral extent: few tens of metres; commonly intercalated with facies Sp, Sc, Lr	debris dlow deposits
Gh, horizontally bedded conglomerates	ganule to pebble size clasts, supported by sandy, silty matrix, horizontally bedded, rounded to well rounded, erosive basement and some part irregular top, sand lenses are common, grey-greyish yellow coloured; dimensions: bed thickness up to 2 m; lateral extent: less than 10 metres; commonly intercalated with facies Sp, Lr	debris flow to hyper-concentrated flow regime
Sm, massive sandstones	medium- to coarse-grained sandstone, moderately sorted, massive bedded, locally sand lenses, fractured, bioclasts, bioturbated, greyish coloured; dimensions: bed thickness up to 1–2 m; lateral extent: few tens of metres intercalated with facies Sp, Sf	deposits from lower-concentrated flow regime
Sp, planar cross-stratified sandstones	medium- to coarse-grained sandstone, pebbly, poorly sorted, sharp base, planar cross-bedded, hematite concretions, some part channelized, greyish yellow coloured; dimensions: bed thickness up to 50 cm; lateral extent: few tens metres; commonly intercalated with facies Gmm, Sm	mid-channel sand bars
Sf, fosilliferous sandstones	medium- to coarse-grained sandstone, moderately sorted, sharp base, cross-stratifed, gastropods, bivalves bearing, flat bedded, greyish cream coloured; dimensions: bed thickness up to1 m; lateral extent: tens of metres; intercalated with Fm	decreasing velociy of water close to shelf
Sc, calcareous sandstones	medium- to coarse-grained sandstone, moderately sorted, calcareously, fining upward, contains shell fragments (benthic foraminifera, gastropods, bivalves etc.), sharp base and top, cream coloured; dimensions: bed thickness up to 1 m; lateral extent: few tens of metres; intercalated with Lr	sporadic storms, back-reef zone of land
Sr, ripple-laminated sandstones	medium- to fine-grained sandstone, moderately to well-sorted, sharp base, fining upward, flat bedded, parallel laminated at base and rippled laminated on top, grey coloured; dimensions: bed thickness up to 60 cm; lateral extent: tens of metres; intercalated with Sm, Sp, Fm	subaqeous deposits at lower flow regime
Fm, massive mudstone	mudstone, massive, sharp at base and top, plant debris, greyish yellow coloured; dimensions: bed thickness up to 40 cm; lateral extent: tens of metres; intercalated with facies Sp, Sm	lower flow regime, channel overbank deposits
C, coal-coally mudstone	coal, carbonaceous mud, dark brown-black coloured, plant remains; dimensions: bed thickness up to 20 cm; lateral extent: less than 10 metres; intercalated with facies Fm	vegetated swamp deposits, low energy flow
Lr, reefal limestone	limestone, included gastropods, bivalves, corals and algal mounds, cream coloured; dimensions: bed thickness up to 3 m; laterally extent: less than 10 meters; intercalated with Sc, Sh	reef framework, shelf

Table 4. Facies associations of the Varsakyayla Formation.

Facies Associations	Constituent Lithofacies
FA4, fluvial facies associations	Gh, Sm, Sp, Sr, Fm
FA5, fan delta facies associations	Gmm, Gh, Sm, Sp, Sf, Sc, Fm,
FA6, shallow shelf facies associations	Gmm, Sp, Sc, Lr

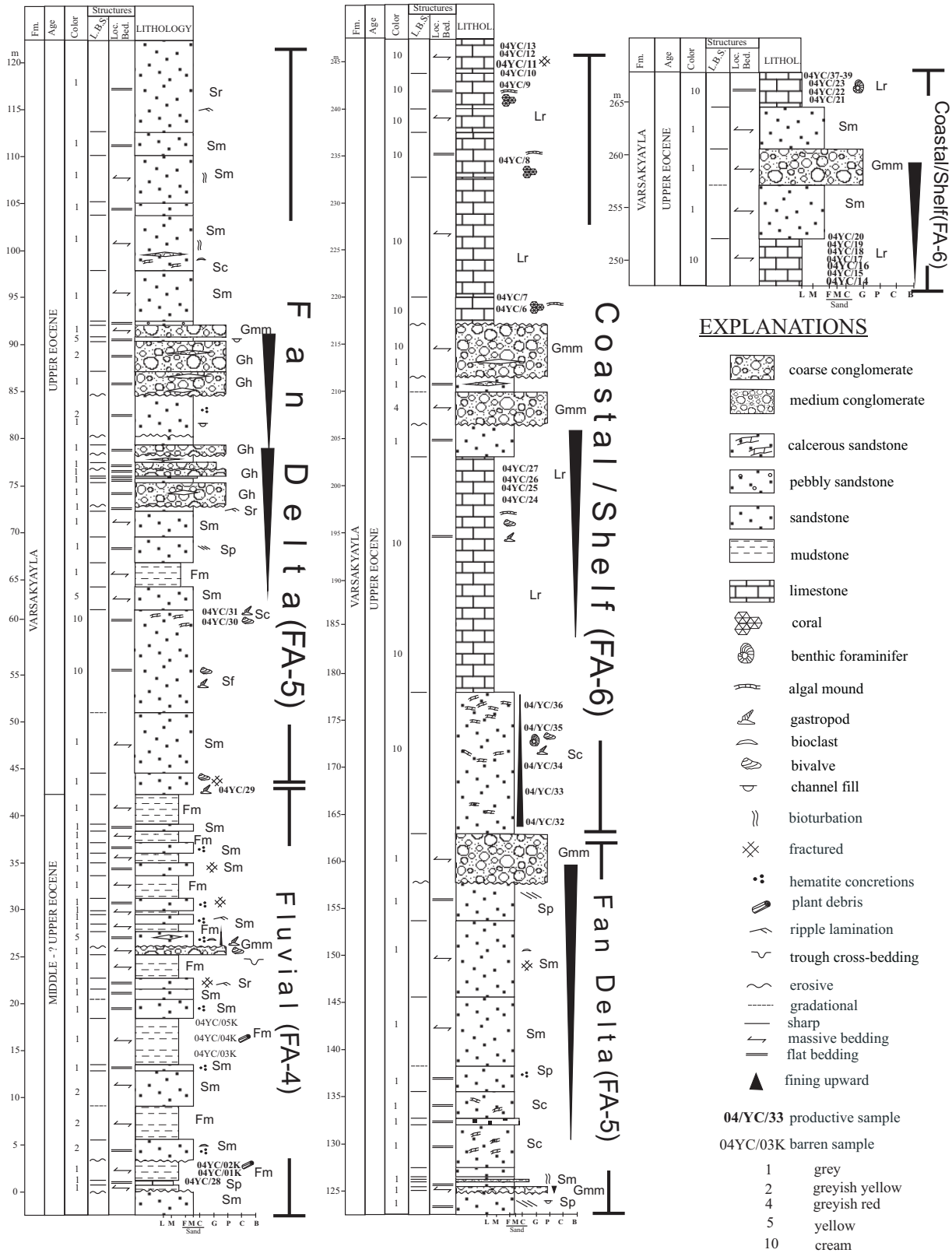


Figure 11. Measured section of the Varsakyayla Formation north of Yukarıcimbili village. See Figure 3 for location.

have sharp bases. The finer unit (facies Fm) present in FA5 consists of massive to thick bedded mudstone, with grey plant fragments and bioturbation.

Interpretation – The FA5 facies association represents deposition in a deepening-upward fan-delta system in the Varsakyayla Formation. FA5 is probably deposited on a fan-delta front and fan-delta slope. The fan-delta front facies is characterized by pebble to cobble conglomerates, sandstones in both channelized and nonchannelized horizontally bedded units. Fan-delta slope strata are dominated by extensively bioturbated, locally cross-bedded, coarse sandstones, overlain by sandstone/fossil conglomerate couplets (Figure 11). Thus, the fan-delta slope sandstones record deposition in shoreface to inner-shelf environments (Rigsby 1994).

Shelf Deposits (FA6): Description – The shelf facies association (FA6) is composed of Gmm, Sp, Sc, Lr facies (Table 3, Figure 11). Coarser-grained conglomerates are rarely preserved and their lateral extent is very limited in FA6 (facies Gmm). Conglomerates with erosive bases are intercalated with sandstones. This facies association dominantly consists of creamy bioclastic limestone (facies Lr). The bioclasts include foraminifera, algae, corals and bivalves and consist of beds of dense skeletal limestone rich in miliolid foraminifera and coralline algae alternating with calcareous sandstones (facies Lr, Sc).

Interpretation – The FA6 facies association was presumably deposited in a shelf environment. The calcareous sandstone with shell fragments was probably deposited in a back-reef sand facies (Figure 11) (Toomey 1981). All the features of the back-reef zone of land fringing platforms are strongly influenced by the both water exchange between the open sea and influx of river water (Einsele 2000). Limestone composed of corals and algal mounds is called bind stone or frame stone. The ratio of organisms comprising the skeleton components of these limestones (facies Lr) exceeds 50%. The shelf facies association is characterized by the presence of abundant shallow-marine fauna, as observed in the bioclastic limestone facies of the upper part of the Varsakyayla Formation. The marine transgression is also well documented by presence of reef limestones containing rich marine fossils, such as coral reefs, benthic foraminifera and echinoderms.

Palynological Contents – Five palynological samples were collected from the clastic part of the Varsakyayla Formation (Figure 5a). However, only two samples were suitable for palynological counting. Due to the low diversity and relative percentages of the species, 175 pollen grains in one sample and 164 pollen grains in the other one could be counted (Table 5). In total, 37 spore pollen species were determined. Only two spore species, *Leiotriletes triangulus* and *Baculatisporites primarius* ssp. *Oligocaenicus*, were counted. The angiosperm pollen average is always higher than that of spores and gymnosperm. The pollen species *Plicatopollis plicatus* (~13%), *Momipites punctatus* (~10%) *Momipites quietus* (8%), *Tricolpopollenites retiformis* (15%) and *Tricolpopollenites liblarensis* (8%) had high percentages. The other angiosperms had comparatively lower percentages (1–3%). Marine *Cleistosphaeridium* sp. and *Cordosphaeridium* sp., and undifferentiated dinoflagellate cysts were also described from the samples (Table 5).

The characteristic Early Eocene taxa Normapolles, such as *Basopollis*, *Interpollis* and *Urkutipollenites*, do not occur in the Varsakyayla Formation. According to Riegel *et al.* (1999), the variety of Normapolles is higher in the Early Eocene than in the Middle Eocene. Normapolles were not recorded from the Middle–?Late Eocene coal occurrences of central Anatolia by Akyol (1980), Akgün (2002) and Akgün *et al.* (2002). However, the species *Plicatopollis lunatus*, *Triatriopollenites excelsus*, *Subtriporopollenites anulatus* ssp. *nanus* and *Compositoipollenites rhizophorus* ssp. *Burghasungensis*, generally observed in Eocene sediments, were also identified from the Varsakyayla Formation.

Furthermore, the palynomorph content of the two samples is similar to the palynomorph content of the Maden member (Başçeşme Formation) previously made by Akkiraz *et al.* (2006). In particular, the mangrove species *Psilatricolporites crassus* (*Pelliciera*) is present in high percentages in the Maden member (upper part of the Başçeşme Formation) and also occurs in the Varsakyayla Formation, as a few grains. The clastic parts of the Varsakyayla Formation are well correlated with the Maden member (Başçeşme Formation). However, the diversity of species obtained from the Varsakyayla Formation is less than

Table 5. Quantitative counting results of palynomorphs in the Varsakyayla Formation of the Burdur Area.

TAXA		Palaeovegetation Types	Sample numbers	
SPORE			04/YC01	04/YC02
Leiotriletes triangulus		Swamp - Freshwater		1
Baculatisporites primarius ssp. *oligocaeinus*	(Osmundaceae: *Osmunda*)		2	
GYMNOSPERMOUS				
Pityosporites microalatus	(Pinaceae: *Pinus* haploxylon type)	Montane	11	4
ANGIOSPERMOUS				
MONOCOTYLEDONEAE				
Arecipites brandenburgensis	(?Arecoideae, ?Palmae)	Back - Mangrove	1	
DICOTYLEDONEAE				
Triatriopollenites rurensis	(Myricaceae: *Myrica*)	Lowland - Riparian		3
Triatriopollenites bituitus	(Myricaceae: *Myrica*)		1	
Triatriopollenites excelsus ssp.*typicus*	(Myricaceae)			1
Plicatopollis lunatus	(Juglandaceae)			2
Plicatopollis plicatus	(Juglandaceae)		18	25
Momipites punctatus	(Juglandaceae: *Engelhardia*)	Lowland - Riparian	14	18
Momipites quietus	(Juglandaceae: *Engelhardia*)		12	15
Subtriporopollenites anulatus ssp. *nanus*	(Juglandaceae: ?*Carya*)		2	
Intratriporopollenites indubitalibis	(Tiliaceae)		1	
Compositoipollenites rhizophorus ssp. *burghasungensis*	(Icacinaceae)		1	1
Polyporopollenites undulosus	(Ulmaceae: *Ulmus*)			1
Tricolpopollenites retiformis	(Saliaceae: *Salix/Platanus*)		29	24
Tricolpopollenites microhenrici	(Fagaceae: *Quercus*)		4	3
Tricolpopollenites parmularius	(?Fagaceae, ?Eucommiaceae: ?*Eucomminia*)		1	
Tricolpopollenites henrici	(Fagaceae: *Quercus*)	Montane	1	
Tricolpopollenites liblarensis ssp. *liblarensis*	(?Fagaceae)		9	21
Tricolpopollenites liblarensis ssp. *fallax*	(?Fagaceae)		17	7
Tricolporopollenites asper	(Fagaceae: *Quercus*)		2	
Tricolporopollenites pseudocingulum	(Anacardiaceae: *Rhus*)			1
Tricolporopollenites cingulum ssp. *oviformis*	(Fagaceae: *Castanea,Castanopsis,Lithocarpus,Pasania*)		11	5
Tricolporopollenites cingulum ssp. *fusus*	(*Trigonabalanus*)	Lowland - Riparian	7	2
Tricolporopollenites cingulum ssp. *pusillus*	(Fagaceae: *Castanea,Castanopsis,Lithocarpus,Pasania*)		3	2
Tricolporopollenites marcodurensis	(Vitaceae: *Cissus*)	Unknown		1
Tricolporopollenites megaexactus ssp. *exactus*	(Cyrillaceae)		2	3
Tricolporopollenites megaexactus ssp. *brühlensis*	(Cyrillaceae)		10	7
Tricolporopollenites edmundi	(Mastixiaceae)	Lowland - Riparian		1
Tricolporopollenites microreticulatus	(Oleaceae: *Olea, Fraxinus, Ligustrum*)		6	5
Tricolporopollenites oleoides	(Oleaceae)		1	
Tricolporopollenites villensis	(Cupuliferae)			2
Tricolporopollenites solé de portai	(?Fabaceae, ?Rosaceae, ?Anacardiaceae)	Unknown		1
Tricolporopollenites kruschi ssp. *pseudolaesus*	(Nyssaceae)			1
Psilatricolporites crassus	(*Pelliciera*)	Mangrove	2	2
Tetracolporopollenites obscurus	(Sapotaceae)	Lowland - Riparian	1	
INCERTAE CEDIS				
Cleistosphaeridium sp.		Shallow - marine	1	
Cordosphaeridium sp.			2	
Undifferentiated dinoflagellate cysts			3	4
Total			175	163

in the Maden member (see Akkiraz *et al.* 2006 for the whole assemblage).

Foraminifera Contents – In this study, thirty-seven samples suitable for analysis of benthic foraminifera in the Varsakyayla Formation contained: *Nummulites fabianii* Prever, *Peneroplis* sp., Peneropliidae, *Halkyardia minima, Mississippina* sp., *Textularia* sp., *Planorbulina* sp., *Linderina*? sp., Discorbiidae, *Ditrupa* sp., *Halkyardia minima* Liebus, *Eorupertia magna* Le Calvez, and *Sphaerogypsina globolus* (Table 6; Figure 11). Haurinidae and Rotaliidae occur rarely in samples. Also, *Nummulites fabianii* (nummulitids) primarily occur in samples 04YC/32–04YC/36, 04YC/24–04YC/25, 04YC/13–04YC/22 and 04YC/37–04YC/39 (Figure 11). In this study no orthophraminids have been identified in any of the sections. Small benthic foraminifera (miliolids), fragments of bivalves and corals were also observed. The abundance of nummulitids suggests an inner and middle shelf environment, deposited during late Middle Bartonian–Priabonian (SBZ 18-20).

Samples between 04YC/06 and 04YC/12 have a reef character, and do not include *Nummulites* and *Discocyclina*, because these kinds of shallow marine environments are not their optimal living conditions. Samples between 04YC/29 and 04YC/31 indicate a shelf lacustrine environment. Samples 04YC/32–04YC/36 and 04YC/25–04YC/27 indicate a deeper marine carbonate shelf environment. Sample 04YC/24 indicates a reef environment. Samples between 04YC/06 and 04YC/11 indicate a shelf environment, while samples between 04YC/12 and 04YC/23 suggest a deeper shelf environment. Sample 04YC/21 indicates a shallow marine environment. Samples between 04YC/37 and 04YC/39 suggest a carbonate shelf environment (Figure 11). Anomaliniidae, Discorbiidae, Peneropliidae, Textulariidae and Valvuliniidae were also described from the samples (Table 6).

Kayıköy Formation

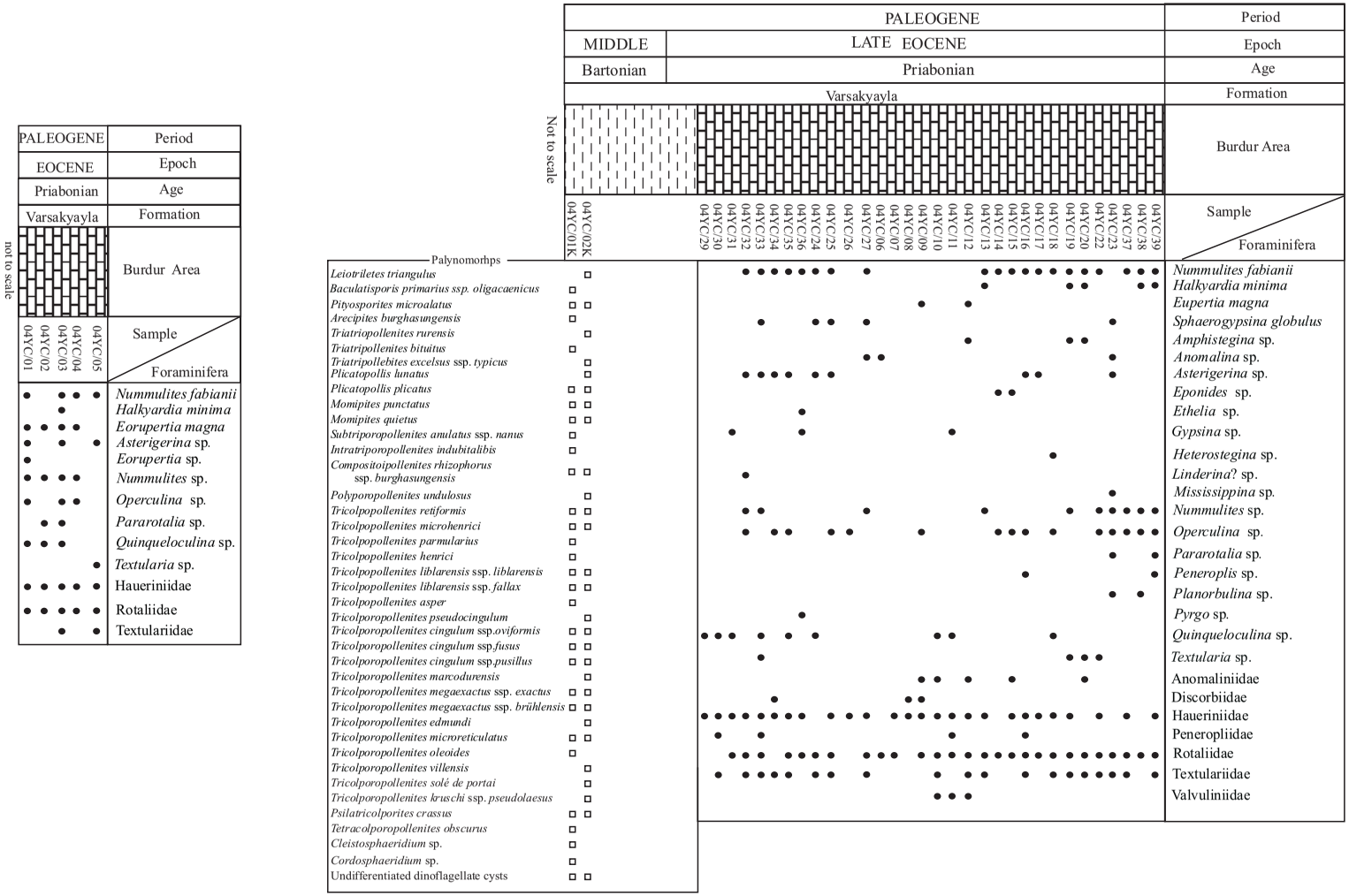
The Kayıköy Formation is well-exposed around Gönen and Atabey towns and İncesu village (Figure 7). Four outcrop sections were logged through the Kayıköy Formation to document its lithological characteristics (Figures 12, 13 & 14a, b). Nine lithofacies were defined, based on type of individual beds, grain size, and sedimentary structures (Table 7). Measured sections were logged in three different places: two from southeast of İncesu, while a third was logged east of Karakaya Tepe and the last section was logged from the northeastern part of Kızıldere north of Gönen (Figures 12–14). The lithofacies diversity was grouped into main four main facies associations, FA7 to FA10 (Table 7).

Major Channel Deposits (FA7): Description – The major channel facies association (FA7) is characterized by the relative abundance of facies F1, F2, F3, F4, F5 and F6 (Table 8; Figure 12). It is dominated by pebble to cobble grain size conglomerates intercalated with pebbly sandstones. Conglomerates are generally thick-bedded to massive, very poorly sorted, sandy silt matrix-supported, well-rounded, erosively based and amalgamated (Figure 12). Pebbly sandstones are poorly sorted and pebbles and granules are dispersed in a matrix of sand (facies F4). Scours and load casts at the bottom of the bed are common sedimentary structures (Table 7). However, disorganized and stratified sandstones were also observed in the FA7 facies associations (Figure 12).

Interpretation – The FA7 facies assemblages, composed of conglomerate and sandstone, represent long distance transport by high concentration turbidity currents or debris flows and final rapid sedimentation of all grains (Stanley & Kelling 1978; Nemec *et al.* 1980). Gravels may slide into place on liquefied mud. Some muddy gravel occurrences could have formed from thorough mixing of gravel and mud after sliding down a steep slope (Crowell 1957). Stratified sandstones are represented by deposits from traction bed loads or traction carpets at the base of a high-concentration turbidity current (Hendry 1973, 1978; Mutti & Ricci-Lucci 1975; Hein 1982; Hein & Walker 1982; Lowe 1982; Surlyk 1984). Disorganized sandstones were deposited by rapid sedimentation from a high-concentration turbidity current by consolidating a dense cohesionless suspension and/or post-depositional liquefaction to destroy any previously formed sedimentary structures. Grain flow processes on steep slopes could form disorganized sands (Piper 1978; Lowe 1982).

Proximal (Upper) Fan Deposits (FA8): Description – The proximal (upper) fan facies association (FA8)

Table 6. Occurrence of palynomorphs and benthic foraminifera in the Varsakyayla Formation. See figure 5 for sample location.



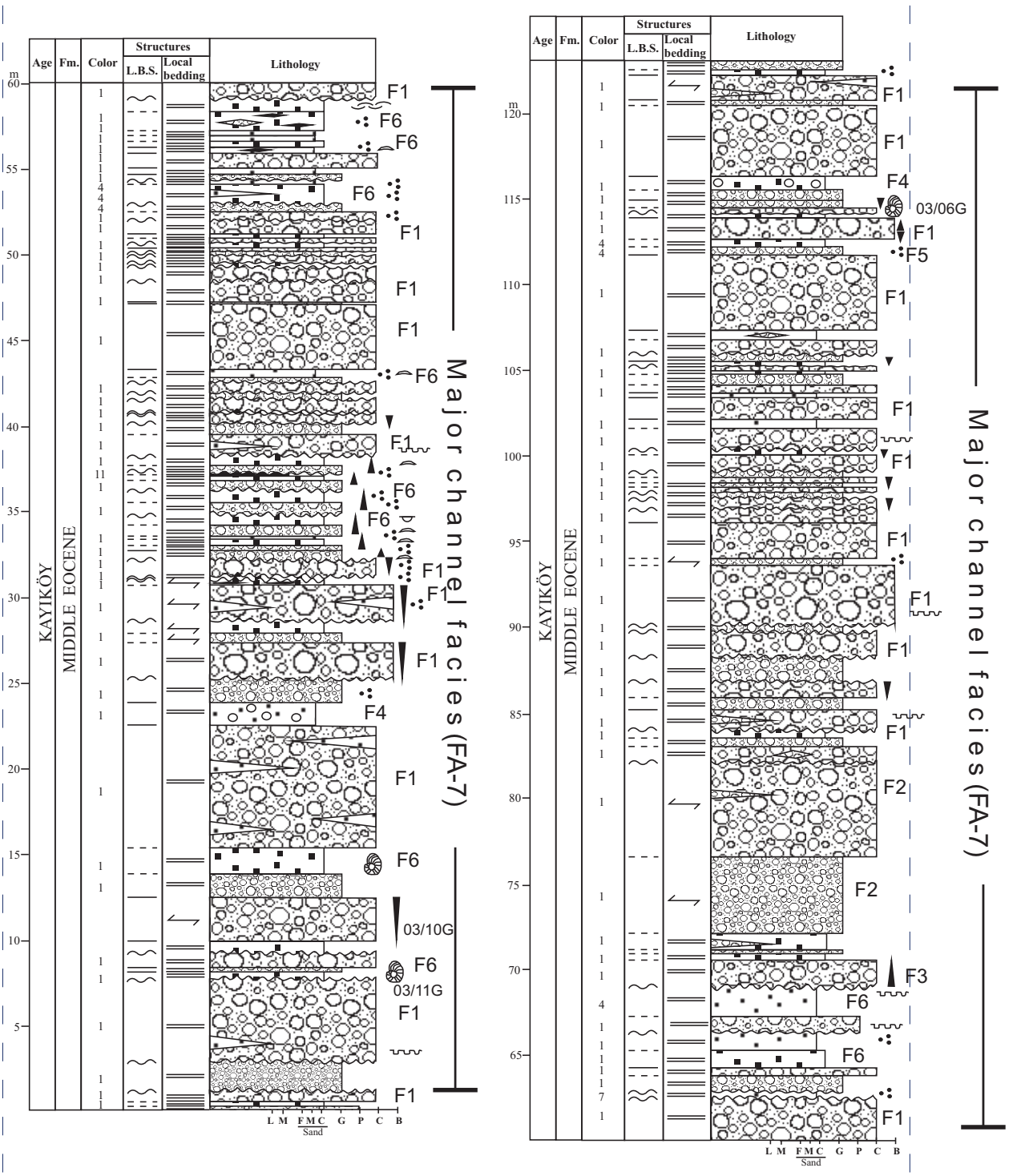


Figure 12. Measured section of the Kayıköy Formation in the northeastern part of Kızıl Dere, north of Gönen Town.

is characterized by lithofacies F1, F2, F3, F5, F6 and F9 (Table 8 and Figure 13). It consists of massive, pebble to cobble grain size conglomerates, bedded, disorganized conglomerates and medium- to coarse-grained sandstones. Conglomerates are badly sorted but fine upwards, with well-rounded clasts, sharp

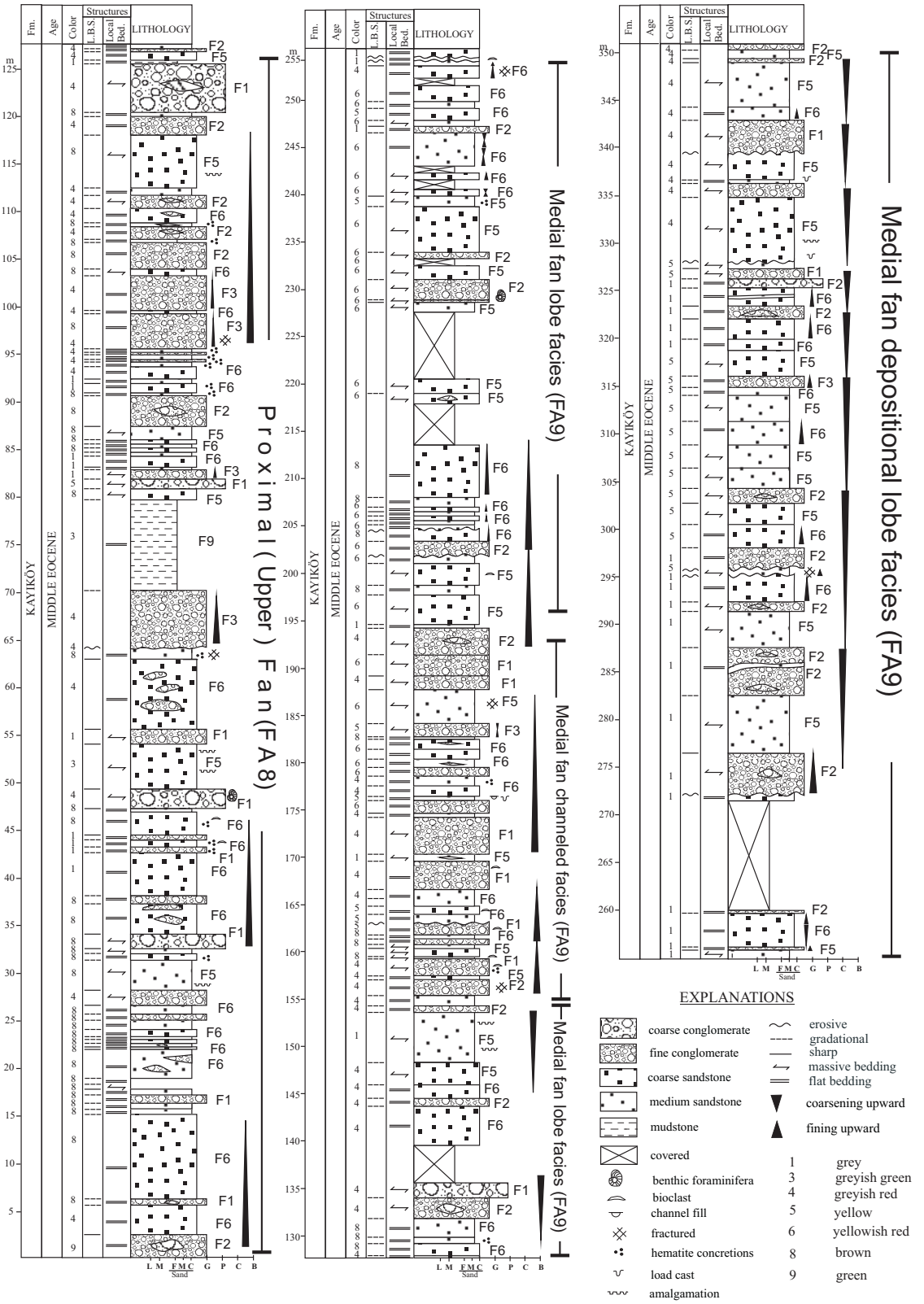


Figure 13. Measured section of the Kayıköy Formation east of Karakaya Tepe.

Table 7. Description and environmental interpretation for the lithofacies in the Kayıköy Formation.

Facies	Description	Interpretation
F1, disorganized conglomerates	granule to cobble size clasts, very poorly-sorted, well-rounded clasts, sandy, silty matrix-supported, locally sandstone lenses, non-stratified bedded, flat basement and irregular top surface, hematite concretions, grey coloured; dimensions: bed thickness up to 6 m; lateral extent: less than five metres; intercalated with Sm	subaqueous debris flow, long distance transport by high concentration
F2, poorly sorted gravel with gravel clusters	granule to cobble size clasts, very poorly-sorted, well-rounded clasts, clast- to matrix-supported with a coarse-grained sandy matrix, locally iregular clusters of cobble to boulder size clasts, erosive base, locally normal graded, green-brown coloured; dimensions: bed thickness up to 4 m; laterally extent: few tens of metres; intercalated with facies F5	rapid deposition from turbulent hyperconcentrated flows and coarser gravel clusters; reflect hydraulic lateral grain size segregation
F3, normal graded gravels	granule to pebble size clasts, normally graded clast-supported by medium- to coarse-grained sand, sandy matrix, moderately to poorly sorted, well-rounded clasts, locally erosive basement, commonly fining upward, greyish coloured; dimensions: bed thickness up to 1 m; lateral extent: few tens of metres; intercalated with facies	deposition by waning high-density turbidity flows
F4, disorganized pebbly sandstones	medium- to coarse-grained sandstone, pebbly, massive bedded, poorly sorted, flat based and irregular upper surface common structures are scours and load casts at the bottom of bed, greyish coloured; dimensions: bed thickness up to 2 m; lateral extent: less than ten metres	long-distance transport by high concentration turbidity current; rapid collective grain deposition of a pebble-sand
F5, disorganized sandstones	medium- to coarse-grained sandstone with sharp flat undulose or loaded base, gravel lenses in some part bioclasts, bioturbated, amalgamated, greyish, yellowish red coloured; dimensions: bed thickness up to 70 cm; lateral extent: few metres; intercalated with facies F2, F6	rapid deposition from high concentration turbidity current
F6, stratified sandstones	medium- to coarse-grained sandstone, moderately cemented, matrix-supported, parallel stratified, locally normal to inverse graded, locally gravel lenses, benthic foraminifera fragments, greyish coloured, dimensions; bed thickness up to 2 m, laterally extent few metres, intercalated with facies F5	traction bed load of high concentration turbidity current
F7, thick bedded sandstone-mudstone couplets	medium-grained sandstone-mudstone couplets, medium-thick- bedded, well-developed normal graded, sand/mud ratio is high, generally sharp base, contact, locally erosive base, partly sandstone lenses visible in mudstone, pervasive Tabc Bouma divisions are present, load structures in sandstones and parallel laminations, amalgamations, yellowish coloured, sand; lateral extent: few metres	deposition by high-concentration turbidity current
F8, thin bedded sandstone-mudstone couplets	medium-grained sandstone-mudstone couplets, medium-thick-bedded, well-sorted, well-developed normal graded, sand/mud ratio is low, generally sharp base, contact, locally erosive base, partly sandstone lenses visible in mudstone, pervasive Tabc Bouma divisions are present, load structures in sandstones and parallel laminations, amalgamations, yellowish coloured; lateral extent: few metres	deposition by low-density turbidity currents
F9, mudstone/shale	mudstone, flat bedded partly massive, sharp base and upper surface, parallel lamination on top, fractured, burrows, grey coloured; dimensions: bed thickness up to 2 m; lateral extent: tens of metres; intercalated with facies	deposited suspension of low-density turbidity currents

bases, contain benthic shell fragments and are intercalated with sandstones (facies F1) (Figure 13). The sandstones are poorly-sorted, flat based and bioturbated. Most of them have scoured surfaces, and bed amalgamation is present (Figure 13).

Interpretation – The massive, disorganized conglomerates of the Kayıköy Formation are considered to be debris flow deposits in the proximal (upper) fan (FA8), associated thin alternating sand and mud deposits that can be interpreted as overbank

deposits. Similar disorganized conglomerates can be interpreted as relating to deposition within either the proximal (upper) fan or proximal parts of the medial fan distributary channels (Table 7; Figure 13). All these coarse clastics represent high-concentration, turbidity currents (Mutti & Ricci-Lucci 1975).

Medial Fan Deposits (FA9): Description – The medial fan facies association (FA9) includes the F1, F2, F3, F5 and F6 facies varieties (Table 7, Figure 13). Medial fan deposits were observed as two different facies, namely the medial fan channel facies and medial fan depositional lobe facies. The medial fan channel facies is characterized by massive poorly-sorted conglomerates, with well-rounded clasts, sharp bases and locally irregular tops, hematite concretions and bioclasts (Figure 13). The depositional lobe facies is composed of medium- to coarse-grained, thick-bedded, parallel stratified, non-channelized, thickening-upward sandstones with load casts, (facies F5 and F6; Figure 13). These thick-bedded sandstones are characterized by classical Bouma sequences but complete Bouma sequences are absent. Most of the beds consists of T_{a-c} Bouma sequences, whereas the T_b, T_{ab}, $T_{bc/e}$ divisions are less commonly observed. The sand/mud ratio of these deposits is very high and bed amalgamation is typical.

Interpretation – The middle fan association (FA9) is also a combination of channel-fill deposits (facies F1), interchannel deposits (facies F2, F3, F4) and overbank deposits (facies F6 and F9). The sandstones, with sharp, scoured to flat bases, normal grading and parallel laminated tops, suggest deposition from traction bed loads or traction carpets at the base of a high- concentration turbidity current (Hendry 1973, 1978; Hein 1982; Hein & Walker 1982; Lowe 1982; Surlyk 1984). The base-missing sandstone beds (T_b, T_{bc}) are interpreted as the deposits of low-concentration turbidity currents (Lowe 1982). The medial fan depositional lobes occur as thickening-upward and thinning-upward sequences which correspond to lobe progradation and lobe abandonment, respectively.

Distal Fan Deposits (FA10): Description – The distal fan association (FA10) includes facies F1, F6, F7, F8 and F9 (Table 8; Figure 14a, b) and is dominated by moderately thick, massive mudstone with thin (0.5–5 cm), fine-grained sandstones which are massive, or exhibit Bouma $T_{d/e}$ sequences characteristic of this facies. The sandstone beds show typical base-missing Bouma sequences, such as $T_{d/e}$, T_{b-e}, $T_{b/e}$. The sandstone/mud ratio is less than 1. The lower contacts of sandstone beds are sharp, whereas the upper contact of the same beds is gradational with overlying mud beds (Figure 14b).

Interpretation – The distal fan facies association (FA10) comprises thin and fine turbidites (facies F8 and facies F9) and mud interbedded with base-missing sandstone beds. They were probably deposited by low-concentration turbulent flows far from channel sources (Bouma 1962, 1964; Stow *et al.* 1996; Einsele 2000).

Formanifera Contents – The Kayıköy Formation is characterized by a lack of fossil content and only yielded a few fossil samples, such as *Nummulites* sp., *Assilina* sp., *Discocyclina* sp., Rotaliidae and Nodosariidae (Plate 3). Some samples also contain planktonic foraminifera, such as *Globigerina* sp., and Globigerinidae. This formation is repesented by flysch deposits containing planktonic foraminifera and thin-bedded mudstone-sandstone alternations.

Table 8. Facies associations of the Kayıköy Formation.

Facies Associations	**Constituent Lithofacies**
FA7, major channel facies associations	F1, F2, F3, F4, F5, F6
FA8, proximal (upper) fan facies association	F1, F2, F3, F5, F6, F9
FA9, medial (middle) fan facies association (channeled and depositional lobes)	F1, F2, F3, F5, F6
FA10, distal fan/basin plain facies association	F1, F6, F7, F8, F9

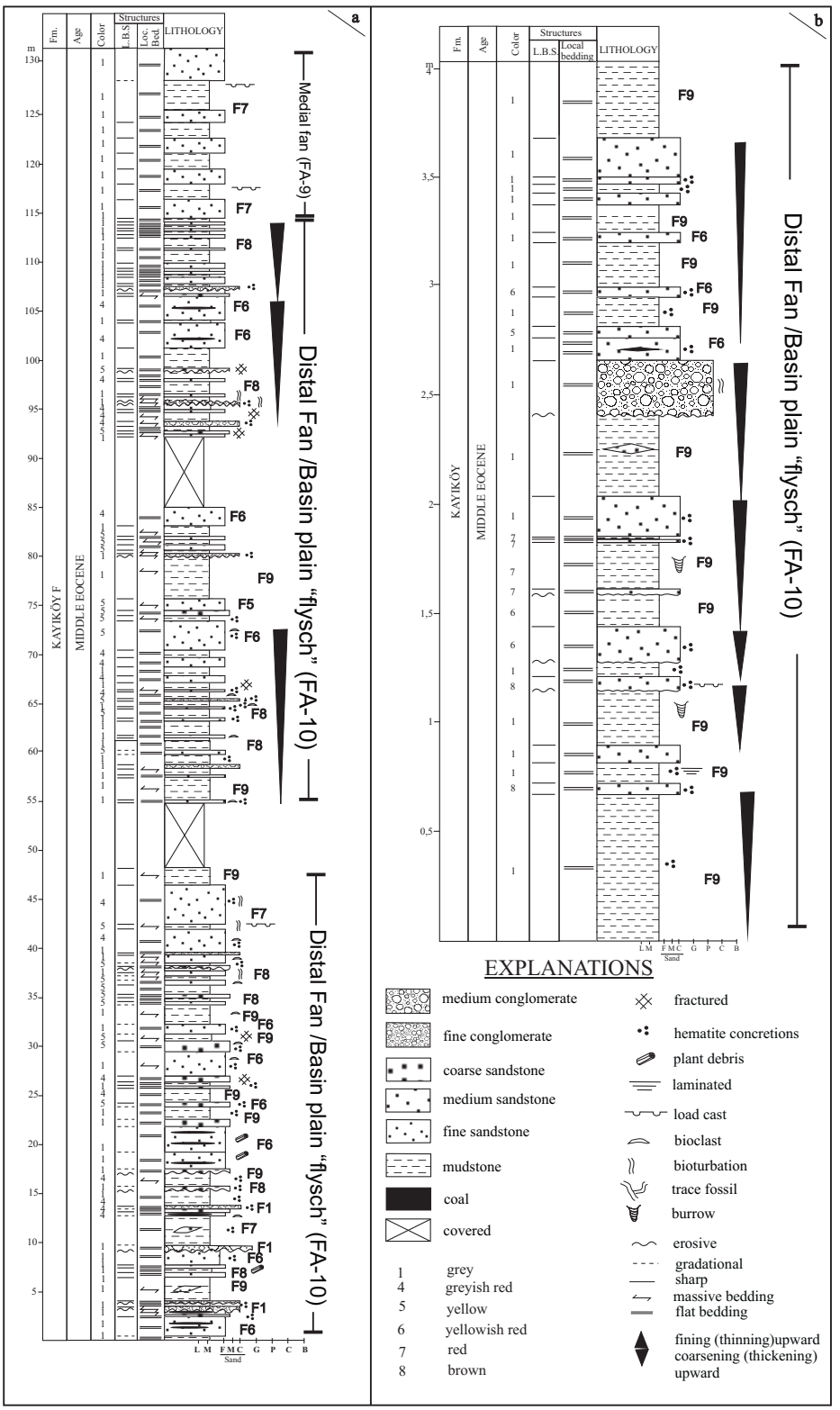


Figure 14. **(a)** Measured section of the İncesu Formation near the Oluk Çeşme southeast of İncesu village, **(b)** Measured section of the Kayıköy Formation northeast of İncesu. See Figure 7 for location.

Depositional Systems

The collected data, comprising a preliminary facies analysis of the Middle–Late Eocene terrigenous sequences of the Başçeşme, Varsakyayla and Kayıköy formations, and tectonic structures which have progressively affected these transgressive deposits, let us establish a palaeoenvironmental model. Figures 15–17 schematically illustrate the depositional system in the Başçeşme, Varsakyayla and Kayıköy formations, based on the data presented so far. The deepening trends of these units and correlation of the sections, based on facies relations and fossil contents, can be shown in block diagrams.

The Çardak-Dazkırı area was affected by post-orogenic tectonic processes (Koçyiğit 1984; Göktaş *et al.* 1989; Sözbilir 2005). Therefore, providing detailed facies analysis and palaeontological data is very useful in order to understand the palaeoenvironmental history of this basin. The basal part of the Eocene deposits in this basin is composed of transgressive units. This transgressive sedimentation started with the Dazlak member (FA1) (Başçeşme Formation) while the prograding fan delta and shelf deposits are represented by the Maden (FA2) and Asar members (FA3) (Başçeşme Formation). The Dazlak member, deposited mostly by debris flow processes of alluvial fan deposits, consists of a thick unfossiliferous polygenetic conglomeratic succession. Fan deltaic sandstone-mudstones intercalated with coal seams (Maden member) grade up into shallower marine sandstones and reef limestones (Asar member) in the Bartonian–Priabonian. In the upper part of the Asar Member the foraminifera *Fabiania cassis*, *Eorupertia*

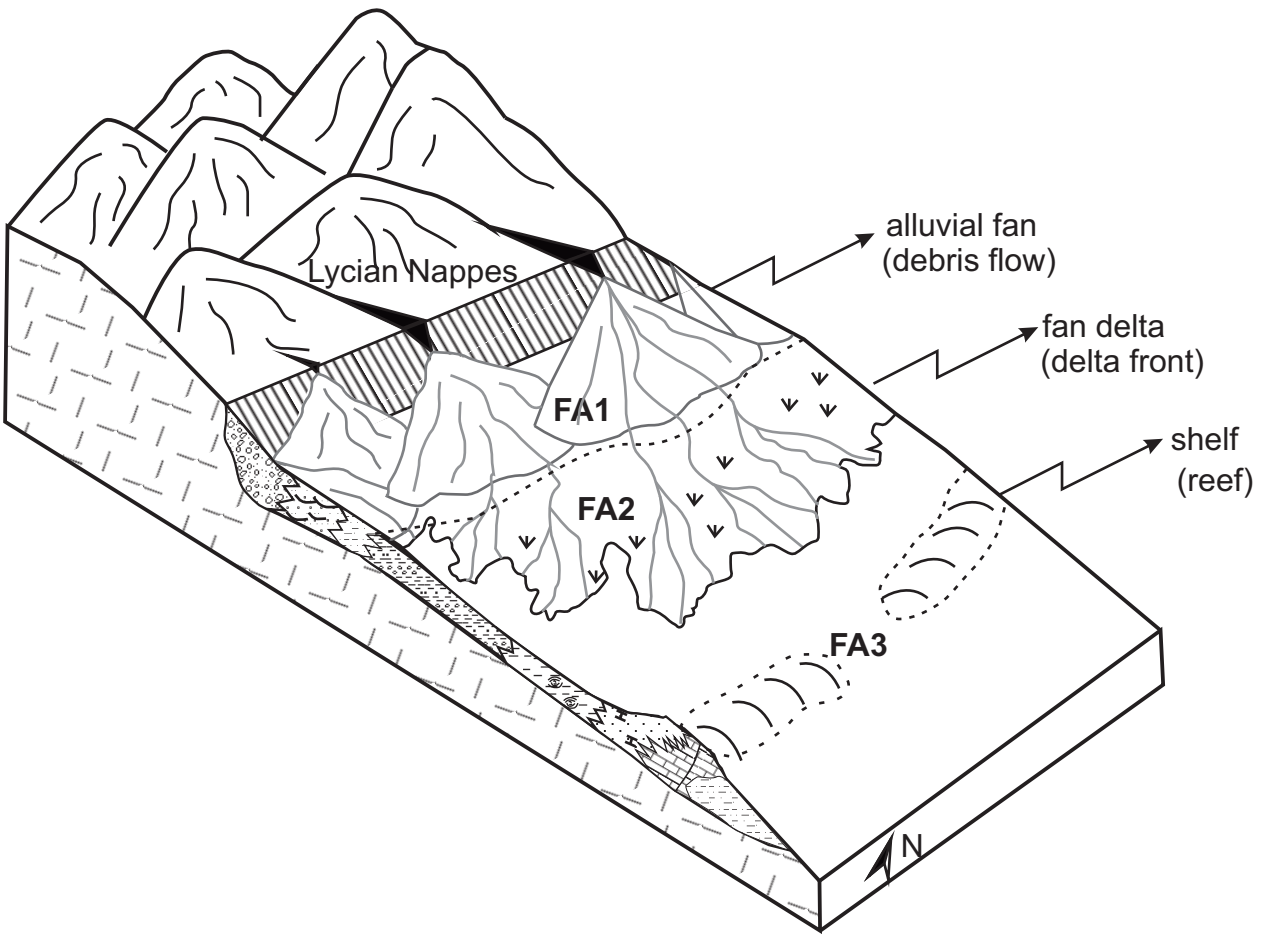


Figure 15. Schematic block diagram of the alluvial fan to shelf setting, showing generalized subenvironments and their respective lithofacies in the Başçeşme Formation during the Eocene.

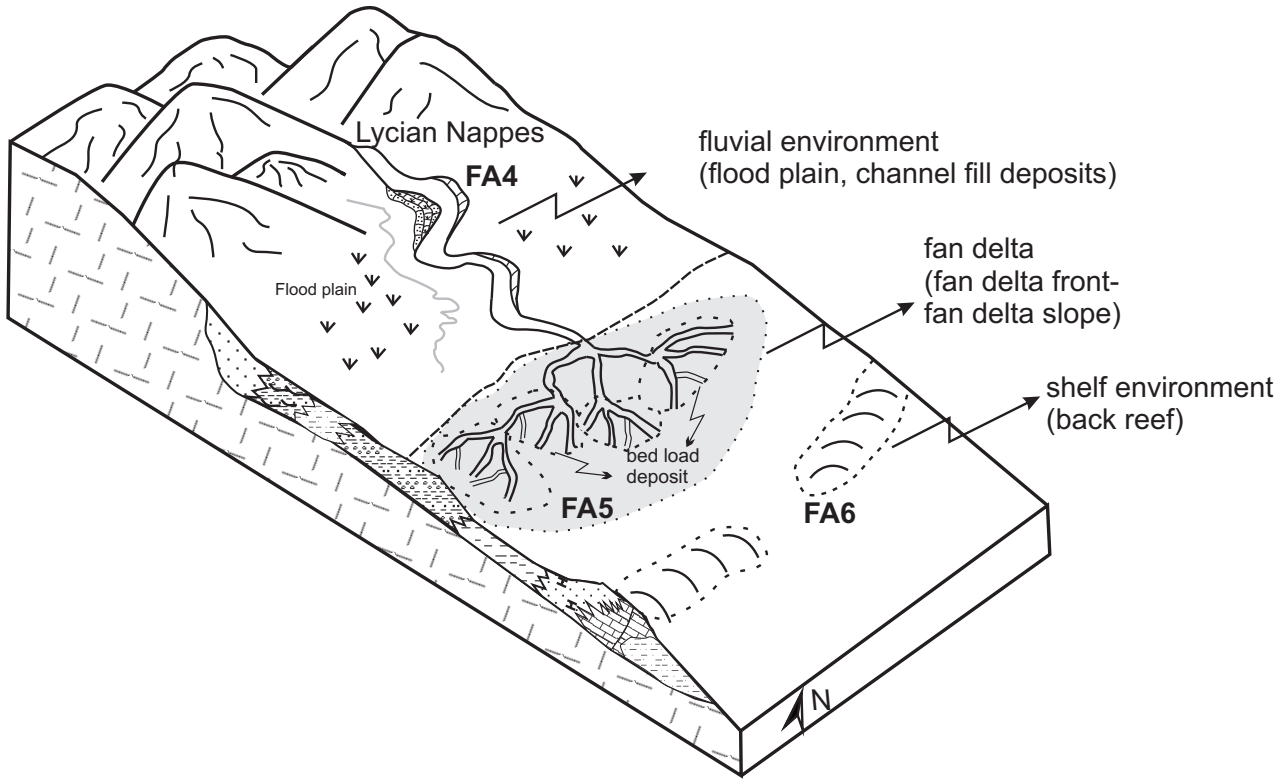


Figure 16. Schematic block diagram of the fluvial to shelf setting, showing generalized subenvironments and their respective lithofacies in the Varsakyayla Formation during the Eocene.

magna, *Halkyardia minima*, *Sphaerogypsina globulus* *Asterigerina rotula*, *Quinqueloculina* sp., *Asterigerina* sp., *Discocyclina* sp., *Cibicides* sp., *Heterostegina* sp., *Eponides* sp., *Amphistegina* sp., *Alveolina* sp., *Assilina* sp., *Halkardia* sp., *Nummulites* sp., *Operculina* sp., *Praebulalveolina* sp., *Eorupertia* sp., *Fabiania* sp., *Neoalveolina* sp., *Halkyardia* sp., *Anomalina* sp., *Mississippina* sp., *Pararotalia* sp., *Pyrgo* sp., *Rotalia* sp., *Sakesaria* sp. and *Orbitolites* sp., indicate an inner to middle shelf environment.

The other Eocene outcrop located in the Burdur area is a transgressive deposit starting with the Varsakyayla Formation. The basal part of the Varsakyayla Formation is composed mainly of sandstones with trough and planar cross-bedding and ripple lamination and mudstones with plant debris. These unfossiliferous clastic deposits represent a fluvial environment (FA4) and change up-section to fine-grained fan-deltaic (FA5) and shallow marine (FA6) sediments containing small benthic foraminifera, coral reefs and echinoderms in the late Bartonian–Early Priabonian. A benthic foraminifer assemblage, *Nummulites fabianii* Prever, *Peneroplis* sp., Peneropliidae, *Halkyardia minima, Mississippina* sp., *Textularia* sp., *Planorbulina* sp., *Linderina*? sp., Discorbiidae, *Ditrupa* sp., *Halkyardia minima* Liebus, *Eorupertia magna* Le Calvez, and *Sphaerogypsina globolus* from the uppermost part of the sequence records an inner and middle shelf environment.

In the eastern part of the study area in the Isparta region, marine conglomerate, sandstone and mudstone (Kayıköy Formation) was deposited in a flysch-like unstable basin. Major channel facies (FA7) changes to the lateral and medial fan association (channel and depositonal lobe facies) (FA9) and distal fan (thin-bedded sandstone-mudstone alternations) association (FA10). Fossils from the Kayıköy Formation indicate a depositional environment in which the benthic foraminifera, *Nummulites* sp., *Assilina* sp., *Discocyclina* sp., Rotaliidae and Nodosariidae are rarely found, although planktons

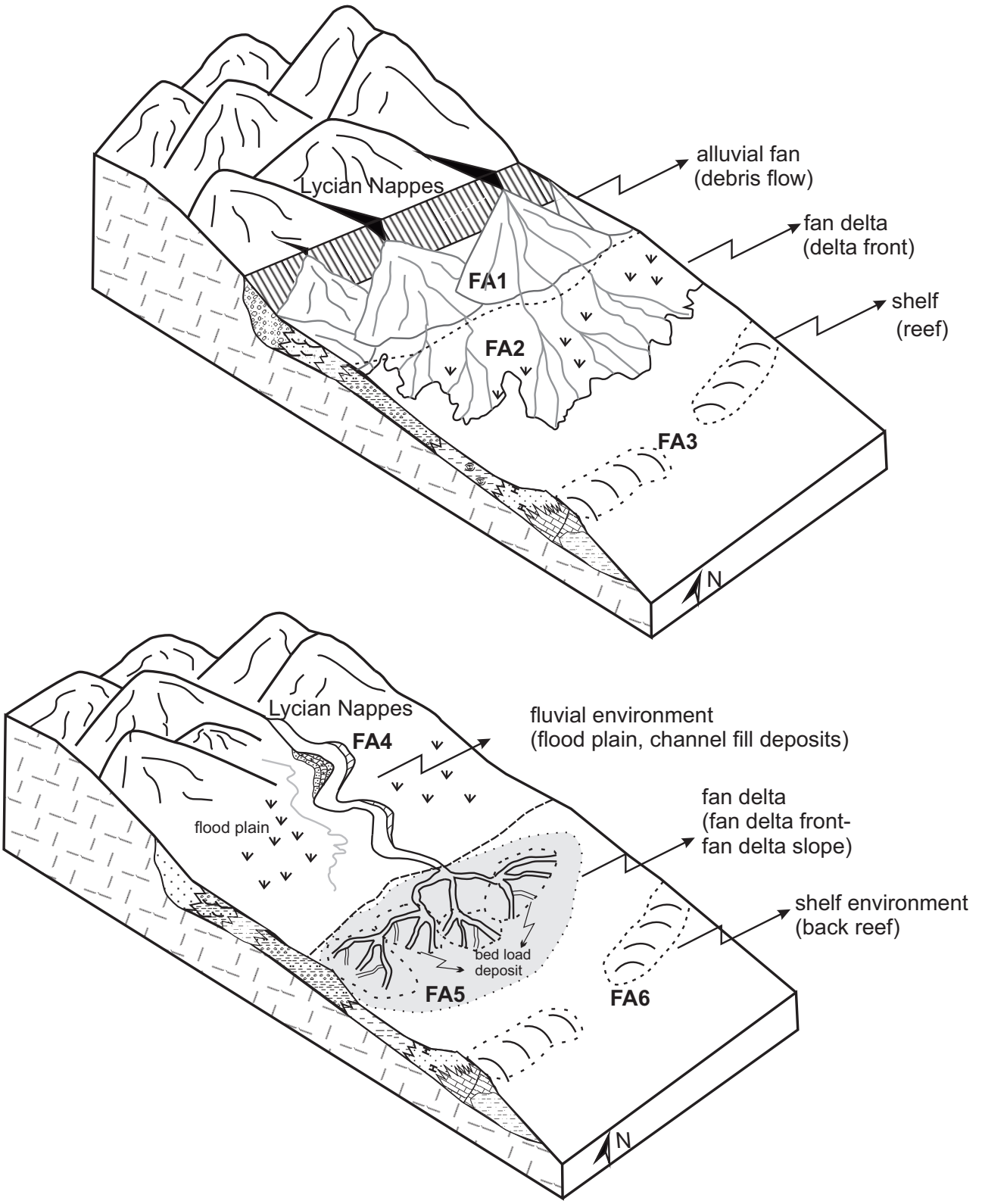


Figure 17. Schematic block diagram of the marine setting, showing generalized subenvironments and their respective lithofacies in the Kayıköy Formation during the Eocene.

like *Globigerina* sp., and Globigerinidae are frequently present in these transgressive deposits.

In the study areas, Bartonian–Priabonian deepening trends may result from global sea level changes, as well as post-orogenic tectonic movements. During the Middle–Late Eocene, the transgressive sedimentation in these basins caused by rising sea level can be linked to global warming effects. This climatic change is detected by palynofloral features. The mangrove species *Psilatricolporites crassus* (Pelliciera) occurs in the palynoflora of the Varsakyayla Formation and this indicates warm climatic conditions, as the mangroves need a tropical and humid climate to develop (Frederiksen 1985; Westgate & Gee 1990). In addition only planktonic foraminiferal fauna was found in the Kayıköy Formation.

Conclusions

This paper presents a new aspect of the interpretation of the Middle–Late Eocene sedimentary evolution of the Başçeşme, Varsakyayla and Kayıköy formations. Three Eocene formations in SW Turkey: the Başçeşme Formation (north of Acıgöl), the Varsakyayla Formation (north of Lake Burdur) and the Kayıköy Formation (north of Isparta) were all investigated sedimentologically, palynologically and palaeontologically.

- Detailed observations showed that within the Başçeşme, Varsakyayla and Kayıköy formations are thirty-three lithofacies, which can be grouped into ten facies associations. The first depositional setting is represented by the alluvial fan, fan-delta and shallow marine settings in the Başçeşme Formation, which can be well correlated with the middle and upper part of the Varsakyayla Formation. The Kayıköy Formation is dominantly characterized by flysch-type sandstone-mudstone alternations.
- Coaly seams of the Başçeşme and Varsakyayla formations were deposited during the Middle–?Late Eocene, as indicated by the presence of stratigraphically important species such as *Aglaoreidia cyclops*, *Triatriopollenites excelsus*, *Subtriporopollenites anulatus* ssp. *nanus*, *Subtriporopollenites constans*, *Plicatopollis lunatus, Compositoipollenites rhizophorus* ssp. *burghasungensis* and *Nowemprojectus tumanganicus*.
- Palaeoclimatically, the mixture of temperate and tropical taxa indicates that from the coastal to montane environments prevailed during the Middle–Late Eocene. The presence of warm Tethys waters permitted growth of mangroves in western Anatolia at this time.
- Benthic foraminiferal fauna such as *Nummulites fabianii* (nummulitids), deposited in an inner-middle shelf environment, indicates a Late Bartonian–Priabonian age in the Varsakyayla Formation. However, the orthophragmines (with genera *Discocyclina*) indicate a Priabonian age and deposition on a distal shelf. The Kayıköy Formation is characterized by Globigerina sp. and Globigerinidae planktic foraminifera, indicative of a marine environment. The variation of the depositional environment is interpreted as a result of the sea level changes in the western Taurides.

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PLATE 1

Figure 1. *Nummulites fabianii* Prever, sample A4 (Başçeşme Formation)
Figure 2. *Assilina* sp., sample A3 (Başçeşme Formation)
Figures 3, 4. *Discocyclina* sp., sample A14 (Başçeşme Formation)
Figures 5, 6. *Praebullalveolina* sp., **Figure 5.** Sample A6; **Figure 6.** Sample A15 (Başçeşme Formation)
Figures 7–9. *Cibicides* sp., **Figure 7.** Sample A1; **Figure 8.** Sample A18; **Figure 9.** Sample A15 (Başçeşme Formation)

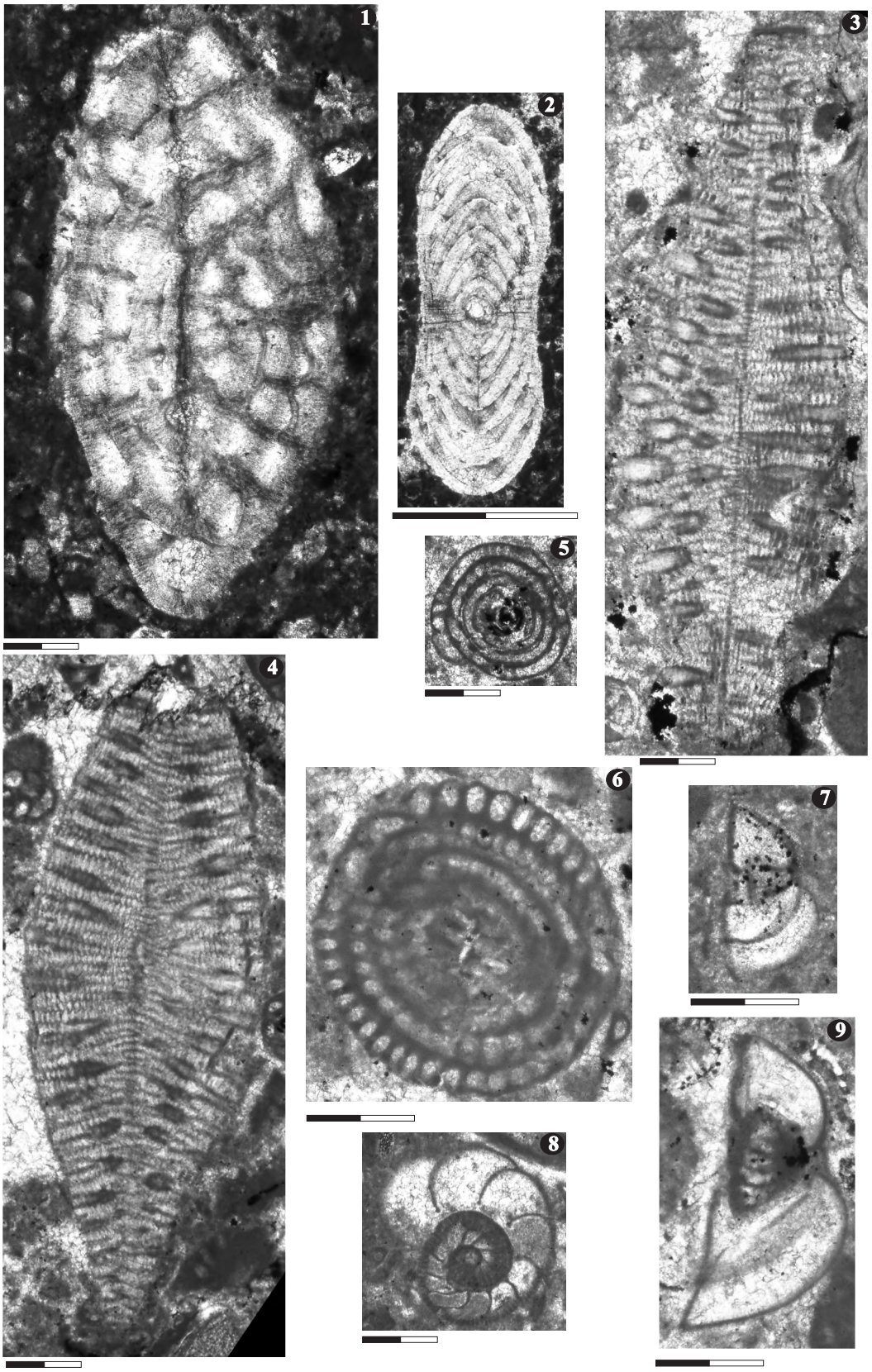
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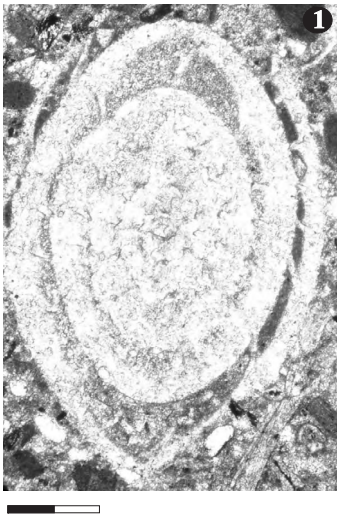
PLATE 2

Figures 1–3. *Nummulites fabianii* Prever, **Figure 1.** Sample 04YC/01; **Figures 2, 3.** Sample 04YC/14 (Varsakyayla Formation).
Figure 4. *Eorupertia magna* Le Calvez, sample 04YC/01 (Varsakyayla Formation).
Figures 5–7. *Peneroplis* sp., sample 04YC/16 (Varsakyayla Formation).
Figures 8, 9. Peneropliidae, sample 04YC/11 (Varsakyayla Formation).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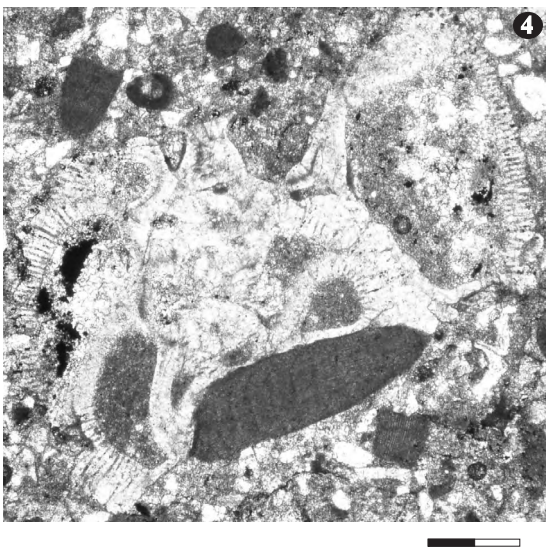
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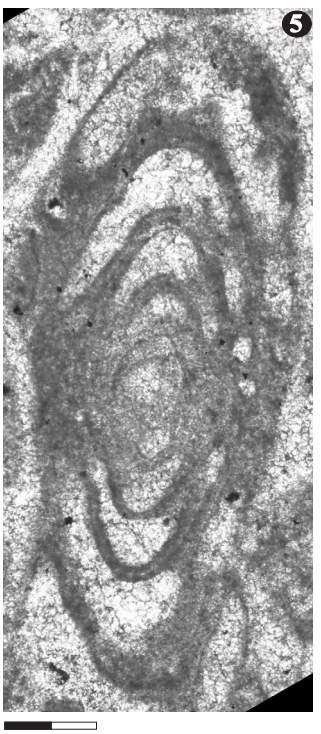
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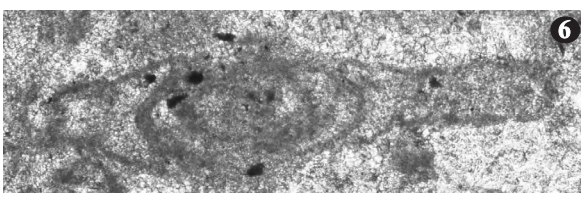
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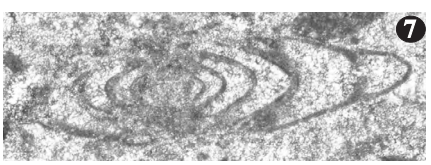
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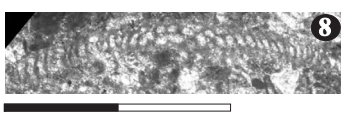
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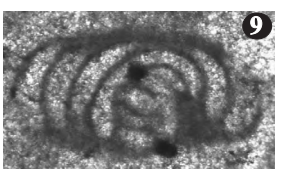
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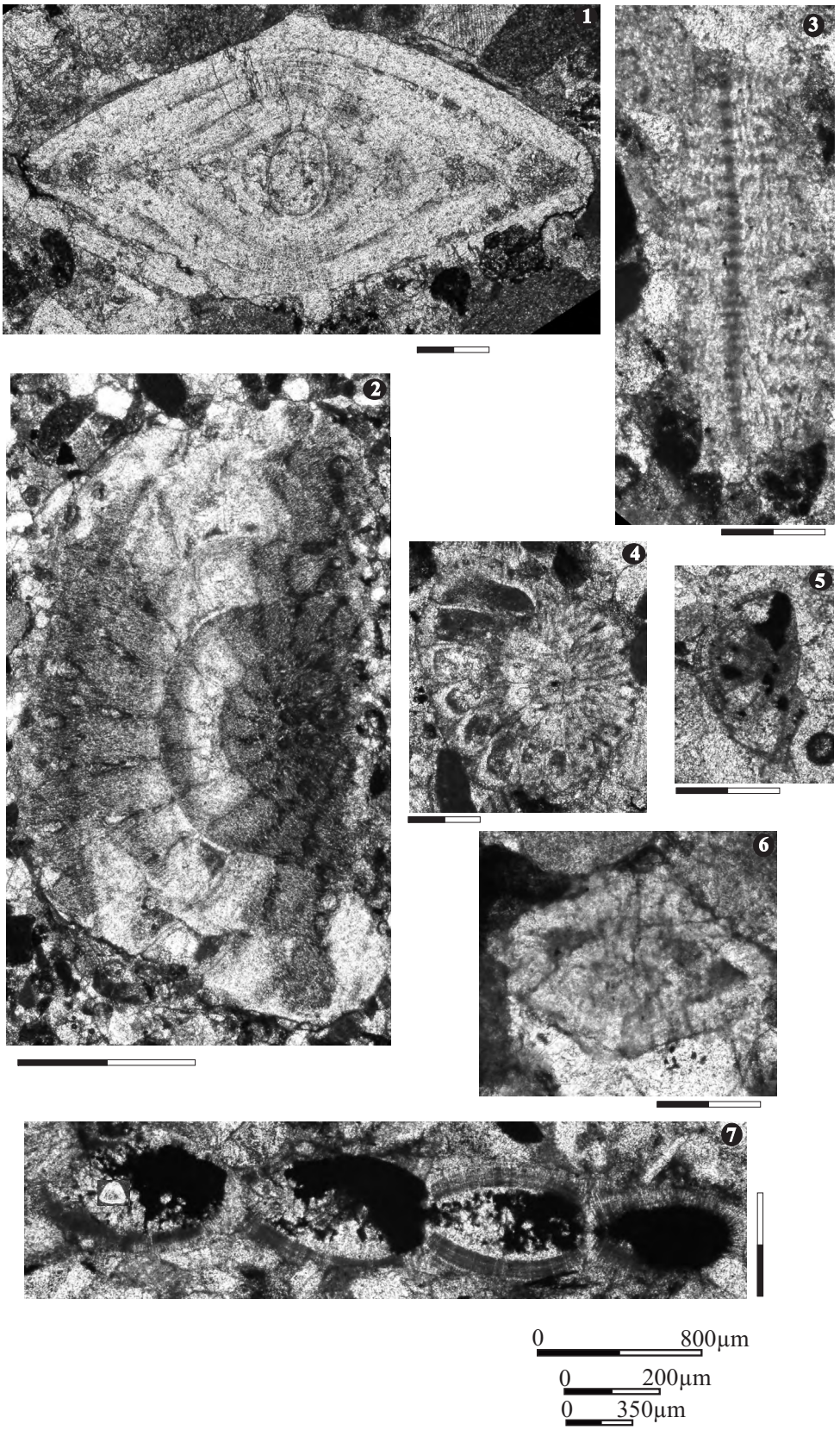
PLATE 3

Figure 1. *Nummulites* sp., sample 03/10G (Kayıköy Formation).
Figure 2. *Assilina* sp., sample 03/13G (Kayıköy Formation).
Figure 3. *Discocyclina* sp., sample 03/14G (Kayıköy Formation).
Figures 4–6. Rotaliidae, **Figure 4.** Sample 03/13G; **Figure 5.** Sample 03/11G; **Figure 6.** Sample 03/06G (Kayıköy Formation).
Figure 7. Nodosariidae, sample 03/11G (Kayıköy Formation).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