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# Revised Stratigraphy and Facies Analysis of Palaeocene-Eocene Supra-allochthonous Sediments (Denizli, SW Turkey) and Their Tectonic Significance

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**Abstract:** A non-metamorphosed sedimentary sequence of Late Palaeocene-Eocene age exposed to the south of Dereköy Village (east of Denizli) was formerly interpreted as the uppermost part of the Menderes Massif. However, detailed field data indicates that the Dereköy succession rests unconformably on the Lycian ophiolitic mélange and thus cannot be accepted as a part of the Menderes sequence.

The Dereköy succession consists of shelf to sub-marine sedimentary deposits that begin with a transgressive basal conglomerate, followed by limestone and then grading upward into clastic turbidites. The clastic beds have intra-basinal and extra-basinal fragments derived from carbonate lenses and the Lycian thrust sheets, respectively.

The basal conglomerate rests unconformably on Upper Cretaceous cherty limestone which has a block contact with the underlying Lycian mélange. Several carbonate blocks of both intra-basinal and extra-basinal origin are embedded in the clastic part of the sequence.

Detailed analysis of the sedimentary facies reveals that the sequence is represented by eight sedimentary facies. These facies can be organized into four facies associations: shelf, slope, inner fan and outer fan.

The sequence was thrust over by the Lycian ophiolite during Late Eocene time and is unconformably overlain by Upper Oligocene-Lower Miocene piggy-back basin sediments.

Key Words: stratigraphy, facies analysis, Palaeocene-Eocene, supra-allochthonous basin

## Paleosen-Eosen Yaşlı Nap-üstü Tortullarının Stratigrafisi, Fasiyes Analizi ve Tektonik Önemi

**Özet:** Denizli doğusundaki Dereköy güneyinde Geç Paleosen-Eosen yaşlı metamorfik olmayan bir tortul istif yüzlek verir. Bu istif, eski çalışmalarda, Menderes Masifi'nin en üst bölümü olarak yorumlanmıştır. Fakat, son arazi verileri, Dereköy istifinin Likya melanjı üzerinde uyumsuzlukla oturduğunu ve dolayısıyla, bu birimlerin Menderes istifinin bir parçası olarak kabul edilemeyeceğini gösterir.

Dereköy istifi transgressif taban konglomerası ve kireçtaşı ile başlayan ve üste doğru kırıntılı türbiditik malzemeyle devam eden şelf-derin deniz tortul çökellerinden yapılıdır. Taban konglomerası altlayan Likya ofiyolitleriyle blok dokanağı sunan Geç Kretase yaşlı çörtlü kireçtaşları üzerinde uyumsuzlukla oturur. İstifin kırıntılı bölümü içinde havza içinden ve havza dışından türeme karbonat blokları yer alır.

Sedimanter fasiyeslerin ayrıntılı analizi sonucunda, istifte sekiz sedimanter fasiyes ayırtlanmıştır. Bu fasiyesler dört fasiyes birliği adı altında toplanmıştır: şelf, yokuş, iç yelpaze, ve dış yelpaze fasiyes birliği.

İstif Geç Eosende Likya napları tarafından tektonik olarak üzerlenmiştir ve Geç Oligosen-Erken Miyosen yaşlı "piggy-back" havza tortulları tarafından uyumsuzlukla örtülmüştür.

Anahtar Sözcükler: stratigrafi, fasiyes analizi, Paleosen-Eosen, nap-üstü havza

## Introduction

Several stratigraphic sections from allochthonous thrust slices of southwestern Turkey reveal a sedimentary succession of Middle Palaeocene to Late Eocene age. This time interval is also known as the main deformation and metamorphism of the Menderes Massif as a result of burial beneath the Lycian nappes (e.g., Şengör & Yılmaz 1981; Satır & Friedrichsen 1986; Bozkurt & Satır 2000; Bozkurt & Oberhänsli 2001). The succession rests unconformably on the different tectonostratigraphic suites, such as the Lycian nappes (Poisson 1976; 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). This succession, as a whole, shows trangressive character at the base and a regressive tendency toward the top.

A sequence of Palaeocene-Eocene deposits stratigraphically above the Lycian nappes is exposed 25 km east of Denizli (Figure 1). The sequence (namely the Dereköy succession) was interpreted as the uppermost section of the Menderes Massif in previous studies (Poisson 1976, 1977). However, detailed geological mapping and several measured sections reveal that the sequence is not a part of the Menderes sequence, but, rather, represents the highest levels of the Lycian nappe complex in the study area.

This paper focuses on the stratigraphy, primary sedimentary structures, textures, facies and facies associations preserved in the sequence in order to elucidate the means of deposition and to infer the environment(s) of deposition. For this purpose, equivalent units – especially those overlying the Lycian nappes – are also considered.

The facies analysis offered here is based upon field observations. A facies was defined by a particular set of sediment attributes: a characteristic lithology, texture, suite of sedimentary structures, fossil content, geometry, and boundary relations. Facies were referred to objectively in purely descriptive terms, using a few pertinent adjectives as suggested by Tucker (1982). In the studied sedimentary sequences, it is often found that groups of facies occur together to form facies associations. These facies associations were also defined and interpreted with respect to other well-described facies associations. The simplified terminology of Walker (1984) for describing turbidite facies distinguishing classical turbidites from other coarser-grained members of the family has been adopted. In the sections showing internal organization of different lithofacies, the more detailed Mutti & Ricci-Lucchi (1975) turbidite-facies classification is also used in order to allow easier comparison with other well-described turbidite sequences. The description of facies by using the combination of the mentioned studies with the classical Bouma sequences (Bouma 1962; Table 1) led to the following six submarine-fan facies (Table 2).

## Stratigraphy

### *The Pre-Tertiary Basement*

The basement of the present area is made up of Menderes Massif metamorphic rocks and some thrust sheets of the Lycian nappes. These rocks occur in only small exposures in the region insofar as they are covered mostly by younger sediments. The metamorphic rocks of the Menderes Massif crop out north of Pamukkale (Figure 2) and consist of alternations of metaquartzite and various schists (mica schists and kyanite-chloritoid schists). The contact between the Menderes Massif and the Lycian nappes is not observed in the study area. The Lycian nappes forming the basement for the Palaeocene-Eocene sediments can be divided into two sub-units: the Lycian mélange and the Lycian metaclastic and metacarbonate rocks (Figure 2).

*The Lycian Mélange* – The name Lycian mélange is applied to a heterogeneous sequence characterized by blocks of all sizes embedded in a fragmented and sheared matrix of turbiditic and serpentinized materials. The unit can be correlated with the ophiolitic mélange described by Graciansky (1972) and Poisson (1977), the Dirmil olistostromal mélange described by Ersoy (1990), the upper part of the Tefenni nappe described by Özkaya (1990) and the Lycian mélange described by Collins & Robertson (1997, 1998). The formation includes blocks of recrystallized limestones, cherty limestones, bauxite-bearing limestones, dolomitic limestones, gabbros, submarine volcanics and radiolarites mixed in a matrix of turbiditic sandstone-shale alternations and sheared serpentinites. The lower contact of the ophiolitic mélange is not observed in the study area.

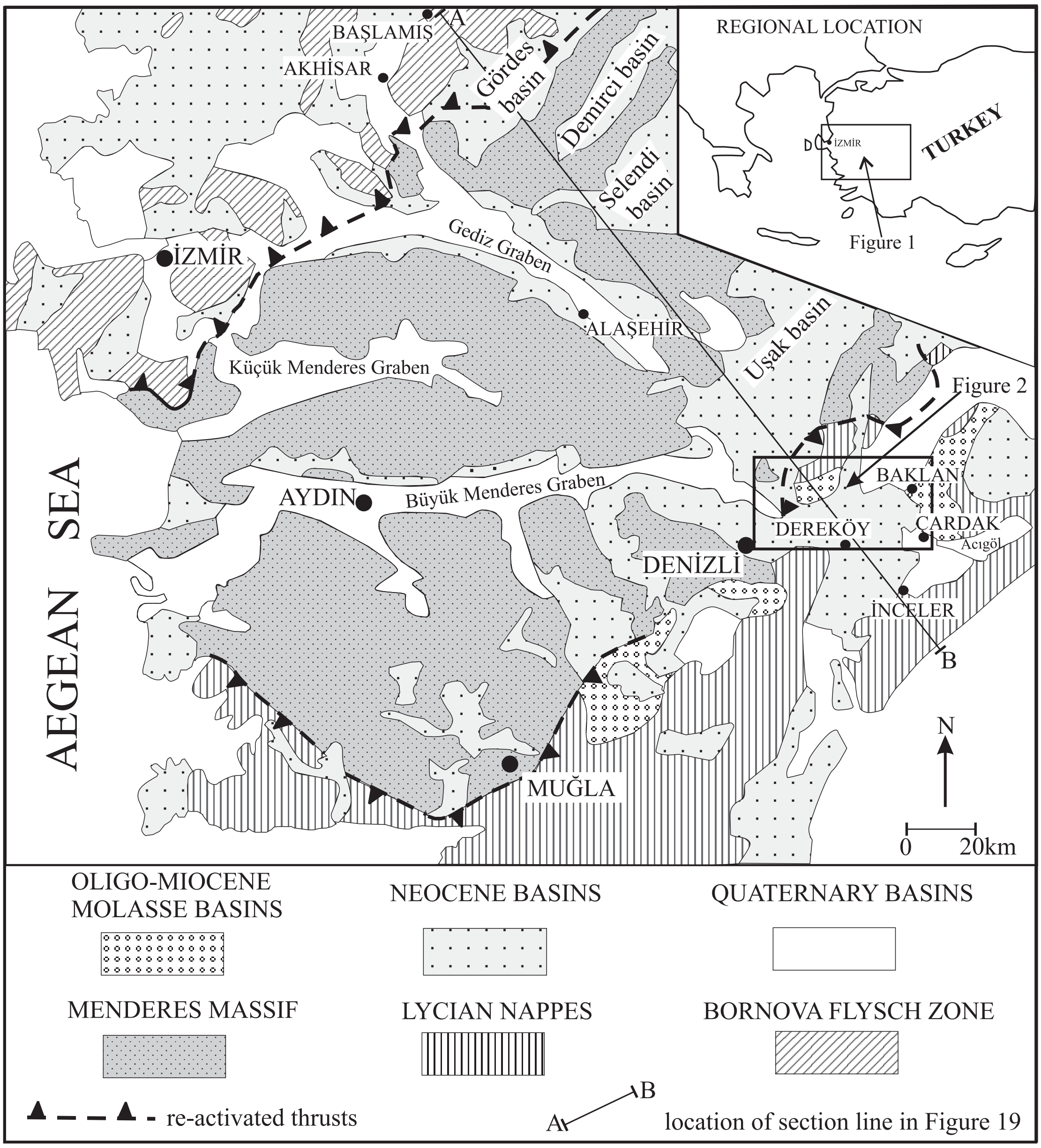


**Figure 1.** Regional map showing the main basement structures in SW Anatolia (Simplified from Şengör & Yılmaz 1981; Şengör *et al.* 1985; Konak *et al.* 1987; Bingöl 1989; Okay & Siyako 1991; Seyitoğlu & Scott 1996). Note location of the exposed supra-allochthon sedimentary rocks are indicated (e.g., Başlamış, Dereköy, Baklan, İnceler). A-B refers to the syntethic cross-section given in Figure 19.

At Kara Hill (Figure 2), the formation consists of mixture of greenish-grey sandstone-shale alternations, folded red cherts, sheared seprentinites, purple-green submarine volcanics, and dark-green ultrabasic rocks. In this complex lithology, the recrystallized limestones and dolomitic limestones are found as blocks of various sizes.

To the south of Belevi Village (Figure 2), blocks of recrystallized limestones, thick-bedded grey limestones and bauxite-bearing limestones are embedded in a mixture of fragmented and sheared serpentinites, green shales, gabbros, red cherts, submarine volcanics and red laminated limestones. The laminated limestones contain the following foraminifers of Late Cretaceous age:

**Table 1.** Bouma sequences used in the present facies study of the Dereköy succession. $T_a$– graded or massive sandstone, $T_b$– parallel-laminated sandstone, $T_c$– cross-laminated fine sandstone, $T_d$– faint parallel laminated siltstone (or mudstone), $T_e$– pelitic hemipelagic mudstone (after Bouma 1962).

| | |
|---|---|
| Complete Bouma sequence | $T_{a-e}$ =$T_{abcde}$ – whole divisions of Bouma are present |
| base-missing Bouma sequence | $T_{b-e}$ =$T_{bcde}$ – $T_a$ division of Bouma is missing<br>$T_{c-e}$ = $T_{cde}$ – $T_a$ and $T_b$ divisions of bouma are missing<br>$T_{d-e}$ = $T_{de}$ – $T_a$, $T_b$ and $T_c$ divisions of bouma are missing |
| top-missing Bouma sequence | $T_{a/e}$= $T_b$, $T_c$ and $T_d$ divisions of Bouma are missing<br>$T_{a-b/e}$=$T_{ab/e}$– $T_c$ and $T_d$ divisions of Bouma are missing<br>$T_{a-c/e}$=$T_{abc/e}$– $T_d$ division of Bouma is missing |
| base- and top-missing Bouma sequence | $T_{b/e}$ – Lower $T_a$ and upper $T_c$ and $T_d$ divisions of Bouma are missing<br>$T_{c/e}$ – Lower $T_a$ and $T_b$ and upper $T_d$ divisions of Bouma are missing |

**Table 2.** Simplified submarine fan-facies used in the present study (After Bouma 1962; Mutti & Ricci-Lucchi 1975; Walker 1979).

| | |
|---|---|
| Facies A | disorganized conglomerate facies |
| Facies C | alternations of complete and top-missing Bouma sequences with sole structures |
| Facies D | base-missing Bouma sequences interbedded with mudstones |
| Facies E | base- and top-missing Bouma sequences interbedded with mudstones, rare complete Bouma sequences |
| Facies F | olistostromes, rare top-missing Bouma sequences |
| Facies G | hemipelagic mudstone interbedded with thin sandstones |

*Globotruncana arca, Globotruncana stuarti, Globotruncana elevate,* and *Plaeoglobotruncana* sp.

To the east of Malı Mountain (Figure 2), at coordinates 12300N/94100E, the matrix include nannofossils, such as *Watznaueria barnesae* indicating the Campanian-Maastrichtian age. The ophiolitic rocks observed around the study area have also been accepted as Late Cretaceous in age (Ersoy 1990; Konak 1993). Around this locality, the matrix is made up of dark grey-green sandstone-shale alternations containing recrystallized limestone lenses and basic rock intercalations. The sandstones have sedimentary structures such as Bouma sequences of $T_{ab/e}$ and $T_{a-c/e}$ and sole structures which are the evidence of turbiditic facies.

In the mapped area (Figure 3), south of Dereköy village, the brecciated and sheared mudstones and weathered ultrabasic rocks are injected into a block of carbonate (Figure 4) suggesting that it was deformed with the mélange matrix. The carbonate block consists of grey-beige, thin- to medium-bedded recrystallized micritic limestones and grades upwards into thick-bedded to massive brecciated limestones. The clasts of brecciated limestone are the same composition as the surrounding limestone and, thus, they are intraformational in origin. Toward the top of the block, cherty limestones become dominant. The cherty limestones are grey, thin- to medium-bedded and contain chert bands reaching to 8-10 cm in thickness. The micritic limestone beds contain pelagic foraminifers indicating a Late Cretaceous age as follows: *Globotruncana stuarti, Globotruncana linneiana, Plaeoglobotruncana* sp., and Radiolaria. The unit is unconformably overlain by Palaeocene-Eocene sediments.

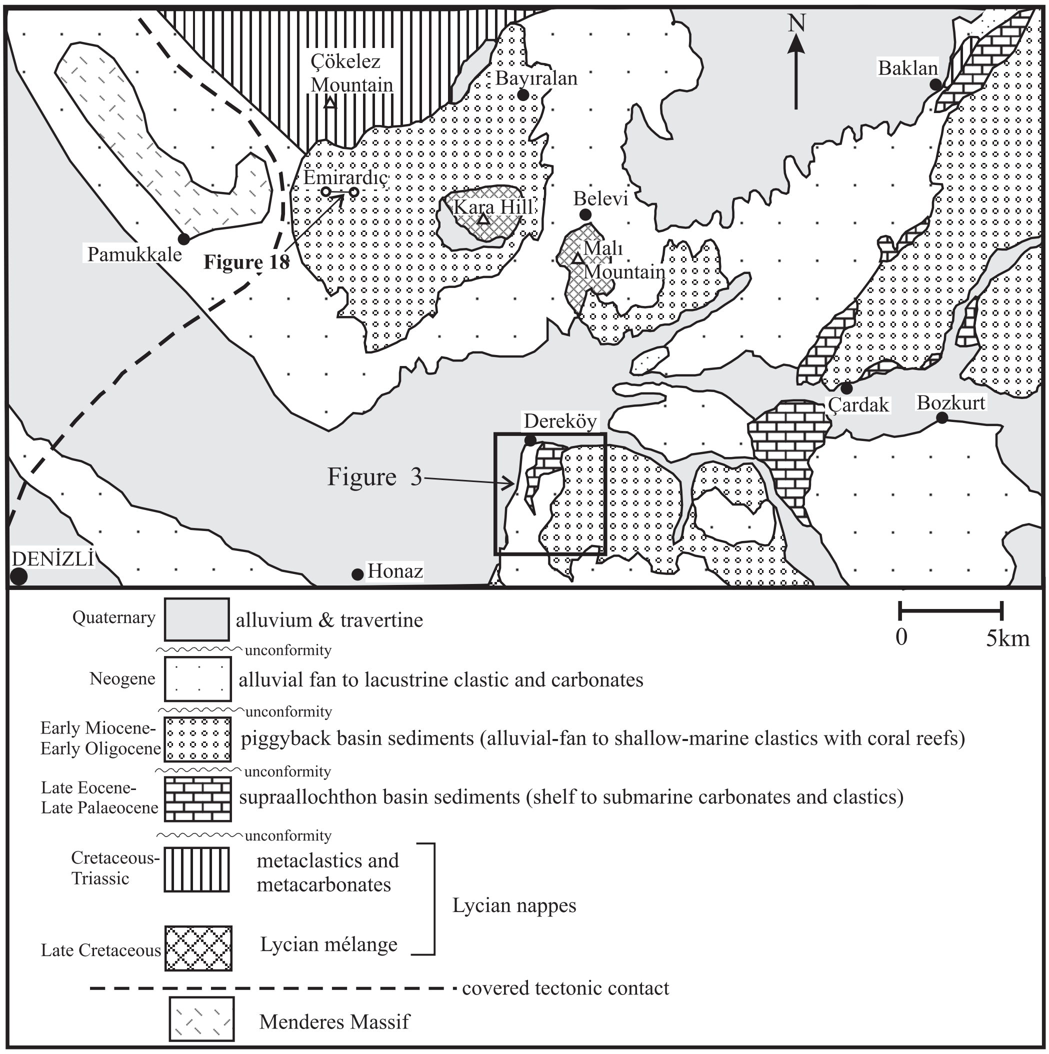


**Figure 2.** Simplified geological map showing the distribution of Palaeocene-Eocene sediments (compiled from Sözbilir 1997; Şenel 1997; Akgün & Sözbilir 2001) (see Figure 1 for location of the map).

*The Lycian Metaclastics and Metacarbonates* – Metasedimentary rocks forming Çökelez Mountain (Figure 2) has been applied to a sequence of Lycian nappes thrust above the Menderes metamorphics in the Çal-Çivril region outside the study area (Konak 1993; Sözbilir 1997; Özer *et al.* 2001). The unit, as a whole, may be correlated with the Lower Triassic-Cretaceous Ören Group described by Konak *et al.* (1987) and the Triassic-Cretaceous Sandak unit of Okay (1989). The lower metaclastic sequence is well exposed to the west of Çökelez Mountain (Figure 2), where the sequence starts with massive to thick-bedded, reddish-purple metaconglomerates that include sub-rounded to rounded clasts of quartz, quartzites and carbonates. The metaconglomerates are sorted, clast-supported, and mainly have a sandy matrix, but siliceous cement has also been observed. Toward the top, the metaconglomerates become thinner, and alternate with metasandstones. The metasandstones are reddish-brown and medium- to well-sorted, with crudely defined cross-bedding. They consist of quartz, feldspar, and rock fragments which are bounded by chloritoid matrix and siliceous cement. The conformably overlying metamudstones are brown-yellowish grey and alternate with thin-bedded claystones and thin lenses of recrystallized limestones. The metaclastic sequence is barren of fossils. The equivalent

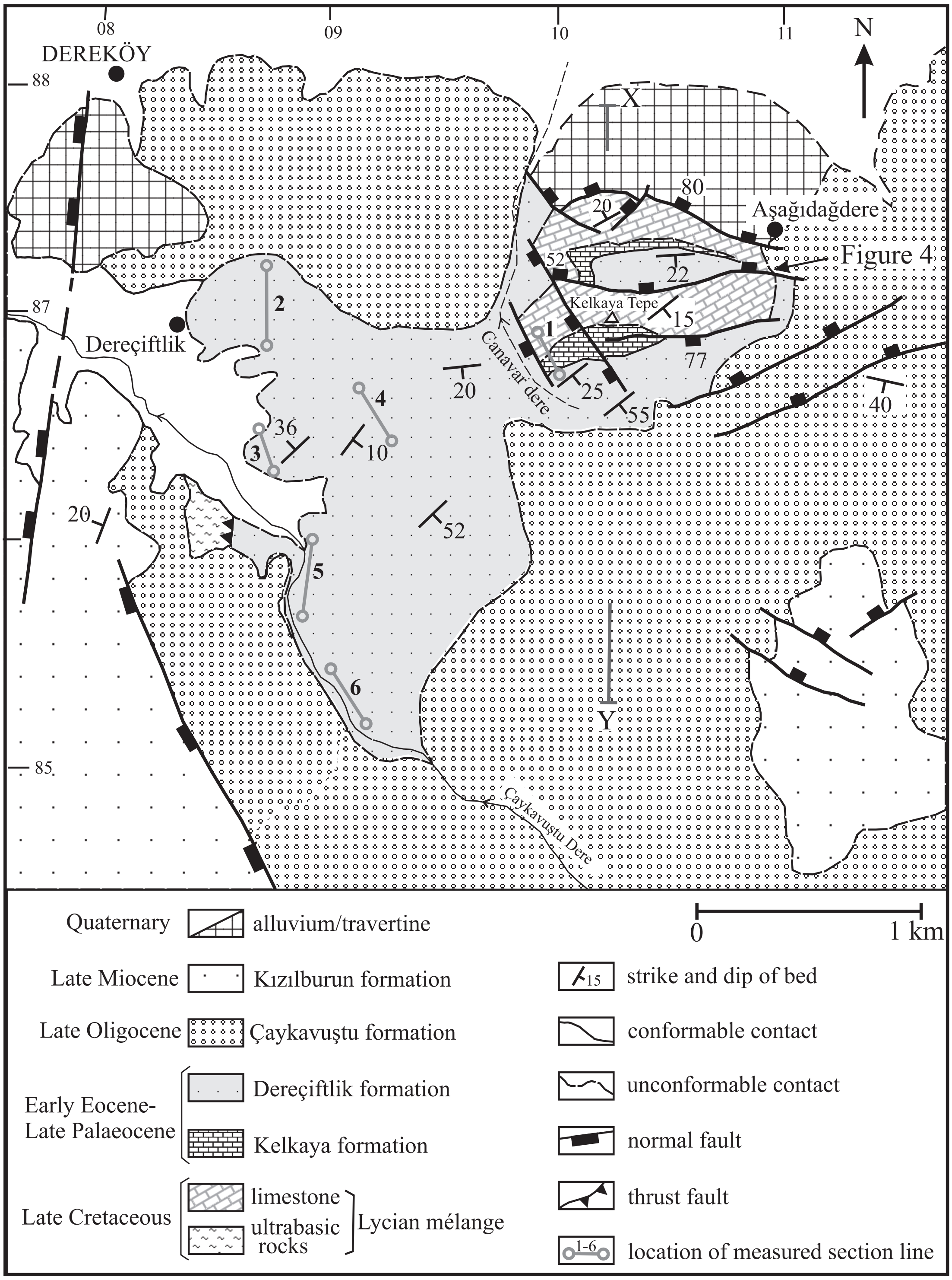


Figure 3. Geological map of the study area. Location of the measured sections are indicated. X-Y refers to the cross-section given in Figure 7. (see Figure 2 for location of the map).

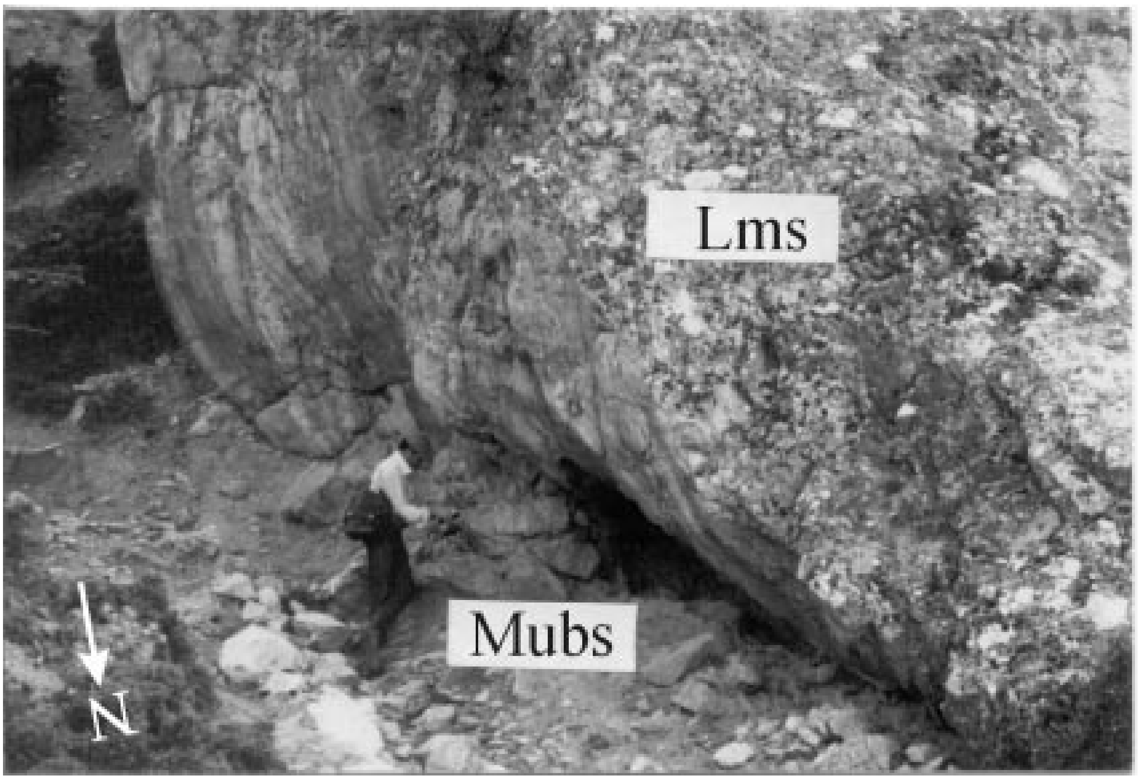


**Figure 4.** Field view of the contact relationships between the limestone block (Lms) and the underlying sheared mudstones and ultrabasic rocks (Mubs). View to SW (see Figure 3 for location). Grid reference: 10950N/87100E.

unit in SW Turkey is the well-known Karaova Formation which has been accepted as Triassic in age (Phillipson 1915; Konak *et al.* 1987; Okay 1989).

The upper metacarbonate sequence conformably overlies the metaclastics and consists of, from bottom to top, yellowish-grey, thin- to medium-bedded and laminated limestones, thick-bedded beige-grey-yellowish-pink and brecciated limestones, thin- to medium-bedded blackish-grey dolomitic limestones and thick-bedded white-grey limestones. No identifiable fossils occur in the sequence except for shell fragments of rudists and gastropods, observed only in the upper part of the sequence. These observations indicate a Cretaceous age; however, Konak *et al.* (1987) and Okay (1989) suggest a Jurassic-Cretaceous age for the equivalent units. The metacarbonate sequence can also be correlated with the Gereme Formation described by Phillipson (1915), Graciansky (1972) and Bernoulli *et al.* (1974).

### *The Supra-allochthonous Basin Sediments*

A Palaeocene-Eocene stratigraphic sequence, consisting primarily of basal conglomerates, bioclastic limestones, mudstones, and sandstone-shale alternations, overlies allochthonous rocks of the Lycian nappes (Figure 5). The supra-allochthonous basin sediments are here divided into two distinct units: Kelkaya Formation and Dereçiftlik Formation.

*Kelkaya Formation* – The basal section of the Dereköy succession is here named the Kelkaya Formation. The type section is observed on Kelkaya Tepe, along Canavar Dere (Figure 6).

The Kelkaya Formation consists of basal conglomerates, pebble sandstones and reefal-bioclastic limestones. Carbonate-cemented, poorly sorted, and clast-supported basal conglomerates include fragments of limestone, dolomite, laminated clayey limestone, recrystallized limestone, chert, metaquartzite, and ultrabasic rocks. Clasts of the limestones and ultrabasic rocks are subrounded to rounded, whereas cherts and metaquartzites are sub-angular to sub-rounded.

The conglomerates are poorly sorted and the maximum clast size of the conglomerates reaches 20 cm in diameter. The conglomerates grade upward into

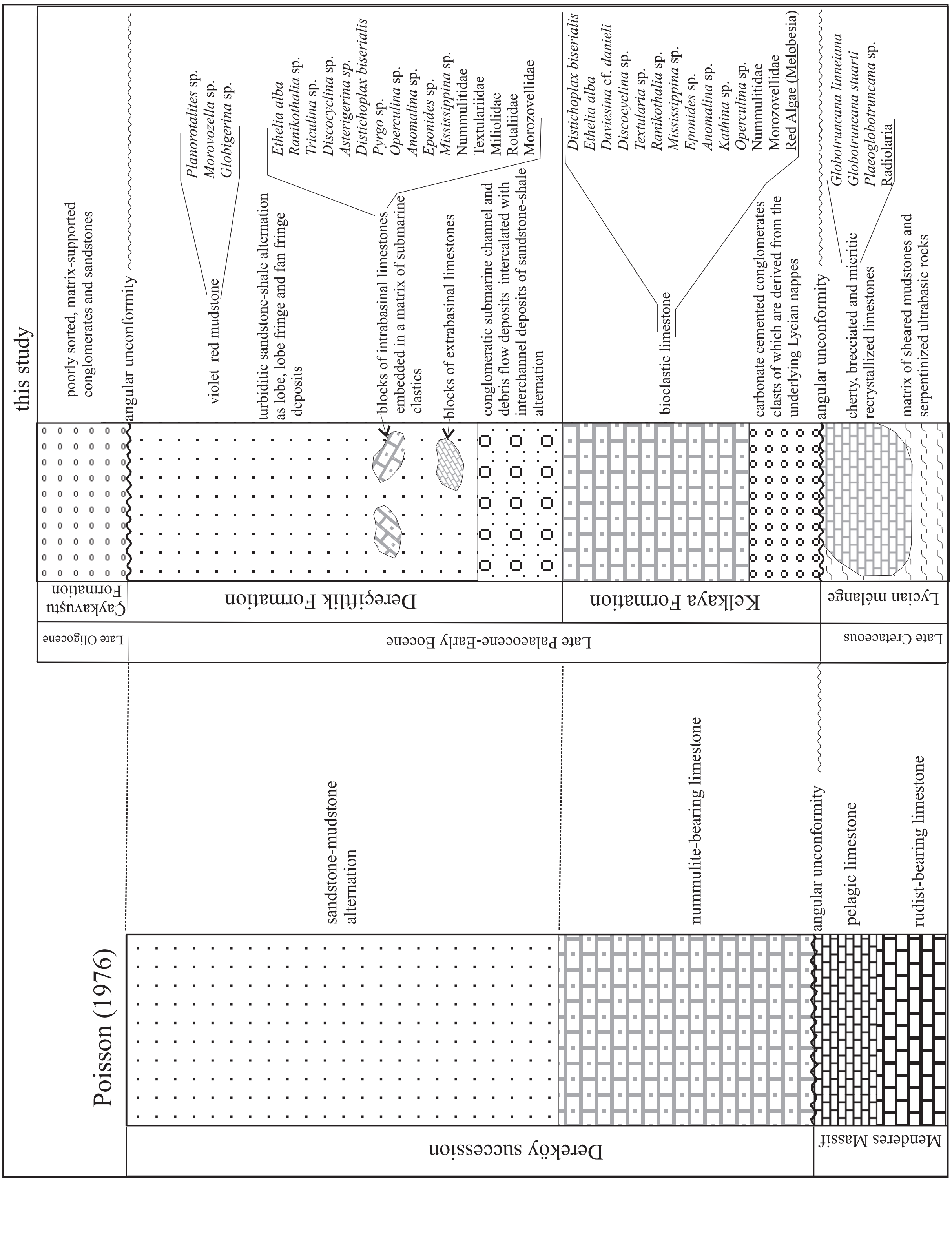


**Figure 5.** Generalized lithostratigraphic section of the study area and its correlation with that of Poisson (1976).

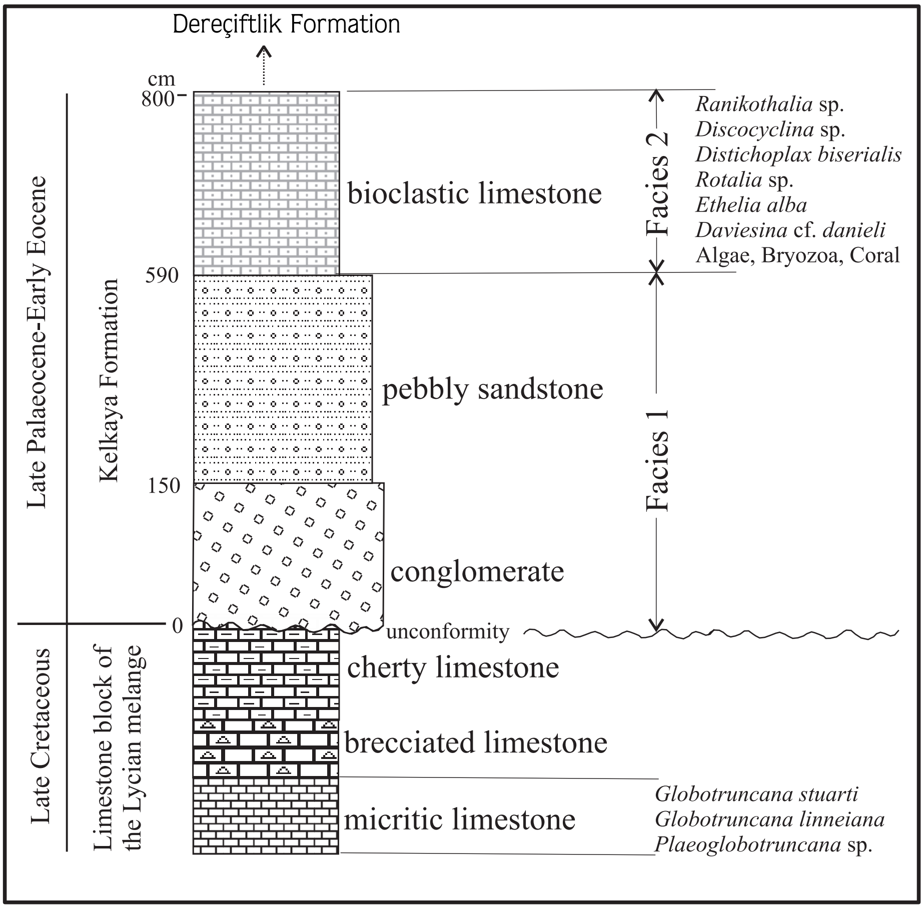


**Figure 6.** Measured section-1 showing the basal section of the Kelkaya Formation. Note the transgressive nature of the sequence (see Figure 3 for location).

reefal-bioclastic limestones containing some extraclasts with a compositions similar to the conglomerates. The grain size of clasts observed in the bioclastic-limestones range from sand to blocks (up to 3 m in diameter), although sands predominate. The bioclasts are of corals, gastropods, bivalves, echinoids, and benthic foraminifera. The Kelkaya Formation is, based on the following fossil contents, of Late Palaeocene-Early Eocene age: *Distichoplax biserialis, Ethelia alba, Daviesina* cf. *danieli, Ranikothalia* sp., *Discocyclina* sp., *Rotalia* sp., *Anomalina* sp., *Textularia* sp., *Eponides* sp., *Operculina* sp., *Kathina* sp., *Mississippina* sp., Nummulitidae, Morozovellidae, and red algae (Melobesia).

*Dereçiftlik Formation* – The Dereçiftlik Formation comprises the turbiditic part of the supra-allochthonous sequence. The formation consists of, from bottom to top, coarse-grained sandstone, conglomerate, pelagic mudstone, and sandstone-shale alternations. The interfingering coarse-grained sandstones and micro-conglomerates are greyish-green. The pelagic mudstones are pinkish-purple and intercalated with thin lenses of sandstone. The sandstone-shale alternations constitute partial and complete Bouma sequences and contain limestone blocks of intrabasinal and extrabasinal origin. The extrabasinal blocks are derived from cherty limestones of the Lycian mélange and their average size is 5.5x3.5 m. The intrabasinal blocks were derived from the bioclastic limestones of the Kelkaya Formation and their average size is 5.0x2.0 m. The sandstone-shale alternations are injected into the cracks of these blocks.

The intrabasinal blocks observed in the formation include some fossils that are dated as Late Palaeocene-Early Eocene. The fossil contents are as follows: *Distichoplax biserialis, Ethelia alba, Ranikothalia* sp., *Triculina* sp., *Discocyclina* sp., *Asterigerina* sp., *Pyrgo* sp., *Rotalia* sp., *Anomalina* sp., *Eponides* sp., *Operculina* sp., *Kathina* sp., *Mississippina* sp., Textulariaidae, Miliolidae, Rotaliidae, Nummulitidae, Morozovellidae. As is seen, the fossil contents of the intrabasinal blocks and the reefal limestones of the Kelkaya Formation are almost the same.

The Dereköy succession is unconformably overlain by Upper Oligocene conglomerates and sandstones of the Çaykavuştu Formation (Figure 7).

## Description and Interpretation of Facies

During the field study, eigth individual facies were established. These facies are described and interpreted below.

### *Facies 1: Carbonate-cemented Conglomerate*

*Description* – This facies is exposed around Kelkaya Hill (Figure 3), at the localities of 09950N/86750E and 10040N/87260E, and forms the lowest part of the Kelkaya Formation. The main lithologies are carbonate-cemented conglomerate and pebbly sandstone (Figure 6). The conglomerate is clast-supported, poorly sorted, carbonate-cemented and well-consolidated. The clasts of the conglomerate are, in decreasing order of abundance, micritic limestone, dolomite, laminated clayey limestone, recrystallized limestone, chert, metaquartzite and ultrabasic rocks. The maximum size of the clasts reaches up 20 cm in diameter. The clasts of limestones and ultrabasic rocks are subrounded, whereas chert and metaquartzite grains are angular to sub-angular. A thick, massive bed of pebbly sandstone forms the upper part of this facies.

*Interpretation* – The carbonate-cemented conglomerate facies marks the basal section of the sequence. It can, on the basis of clast composition and internal textures, be interpreted as a transgressive channel-lag conglomerate. Clasts of micritic and recrystallized limestone may have been derived from the underlying block within the Lycian mélange. The composition of the other clasts is consistent with a source from elsewhere in the Lycian mélange. These data suggests that the Lycian nappes not only form the basement for the depositional basin, but also acted as a source region for the various fragments of the channel-lag conglomerate.

### *Facies 2: Bioclastic Limestone*

*Description* – This facies crops out at two localities: (1) approximately 300 m north of the peak of Kelkaya Hill and (2) 100-250 m south-southeast of Kelkaya Hill. The bioclastic limestones form the upper part of the Kelkaya Formation (Figure 6) and have a gradational contact with the overlying turbiditic part of the Dereçiftlik Formation. The bioclasts are made up of foraminifers, algae, bryozoa, and corals. Some sand-sized extrabasinal grains (e.g., cherts and ultrabasic rocks are present toward the top of the facies).

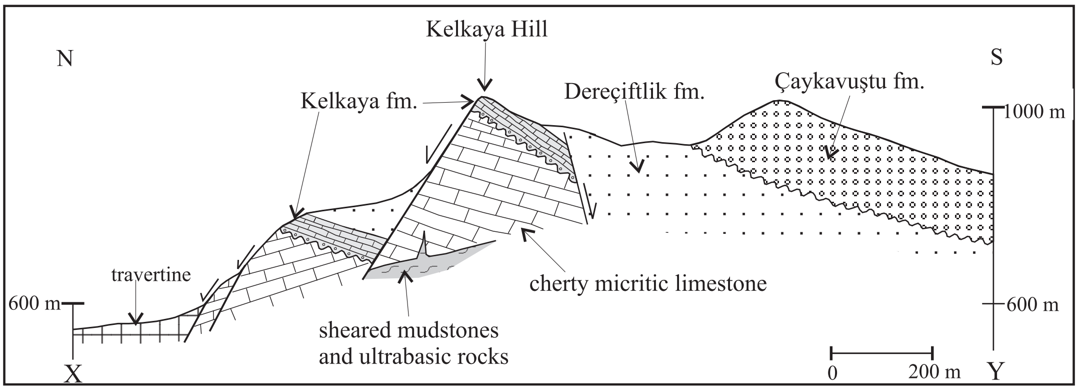


Figure 7. Cross-section showing contact relationships of the supra-allochthonous sediments with the underlying Lycian mélange and the overlying Upper Oligocene sediments. Note the presence of sheared mudstones and ultrabasic rocks injected into the cherty micritic limestone (see Figure 3 for location).

*Interpretation* – The faunal content of the bioclastic limestone facies suggests a reefal-shallow shelf environment of approximately 20-30 m deep. Presence of some extrabasinal clasts suggests that the Lycian nappes have continued their advance above the carbonate platform.

### *Facies 3: Disorganized Conglomerate with Olistoliths*

*Description* – This facies is exposed in the Dereçiftlik Formation, to the south of Dereçiftlik village (Figure 3). The conglomerate is made up of poorly sorted, angular to sub-angular clasts and has a chaotic appearance. The clasts do not show any preferred orientation, and lack any normal or inverse grading. One of the most significant features is the absence of mud matrix; instead, sand occurs as matrix material between the clasts.

The olistoliths are made up of both extrabasinal and intrabasinal lithologies. Intrabasinal olistoliths were derived from the bioclastic limestone of the Kelkaya Formation, whereas extrabasinal olistoliths are cherty and recrystallized limestones from the underlying limestone block within the Lycian mélange (Figure 8). The average size of the olistoliths is 3.0x5.5 m. There are some normally graded coarse sandstone to mudstone beds between the olistoliths. In places, graded units appear as matrix between the olistoliths. These normally graded beds also occur between the conglomerate beds, such as $T_{ab/e}$ and $T_{ac}$ Bouma divisions (Figure 9).

*Interpretation* – The graded beds are interpreted as the deposits of turbidity currents which flowed downslope under the influence of gravity. The coarser chaotic units may have been transported by other mechanisms, such as debris flows. Many exotic blocks or olistoliths (described in the literature) occur as outsized clasts within laterally extensive mass-flow deposits, and were probably rafted passively within or upon submarine slides or mass flows (Abbate *et al.* 1970; John 1978). This facies can also be compared with facies F of Ricci-Lucchi (1975). It is commonly accepted that facies F forms by gravity slumping and sliding which may have taken the form of debris flows in channelized situations, or as semi-coherent slump accumulations in or near lower-slope environments (Ingersoll 1978).

### *Facies 4: Clast- to Matrix-supported Conglomerate*

*Description* – This facies is present in the Dereçiftlik Formation and forms the lower parts of Figures 10 & 11.

Figure 8. Field view of an extrabasinal limestone block embedded in the matrix of disorganized conglomerate and turbiditic sandstone. Note the injection of matrix (arrowed) into the block. Hammer is 33 cm. View to SE. Grid reference: 08900N/87000E.

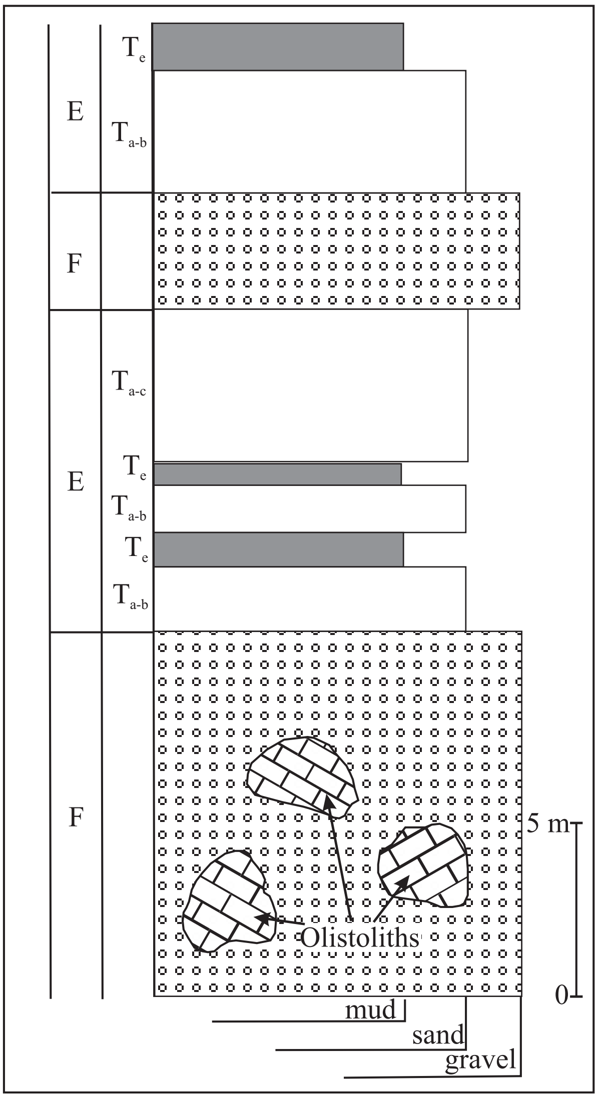


**Figure 9.** Measured section-2 showing olistolith-bearing disorganized conglomerate facies 3 of the Dereçiftlik Formation. Capital letters indicate correlation with facies classification of Mutti & Ricci-Lucchi (1975) (see Figure 3 for location).

In Figure 10, it consists of coarse-grained conglomerates that form lenticular bodies. The clasts are limestones, cherts, quartzites and ultrabasic rocks. The disorganized conglomerate facies is matrix-supported and poorly sorted. The basal contact of this facies has not been observed. This facies is overlain by $T_{a-b}$ Bouma sequences, and rarely by $T_a$, $T_b$, $T_{b-c}$, and $T_{a-c}$ beds and alternating thin shales. The sandstone/shale ratio in this facies is very high. Most of the sandstone beds have scoured surfaces, and bed amalgamation is common.

In the lower part of Figure 11, clast- and matrix-supported pebble conglomerates form a 65-cm-thick bed that overlies an erosional surface. Here, this facies is made up of three beds fining and thinning upward with thicknesses of 25, 15 and 5 cm.

*Interpretation* – The disorganized conglomerate subfacies can be interpreted as analogous to “facies A” of Mutti & Ricci-Lucchi (1975), which they interpreted it as a debris-flow deposit (Middleton & Hampton 1973). Similar disorganized conglomerates have been interpreted by Walker (1975) as relating to deposition within either the inner-fan or proximal parts of the mid-fan distributary channels.

Presence of scoured surfaces, high sandstone/shale ratios and amalgamated beds suggest superposition of minor channelling for the graded-laminated sandstone interbedded with the shale subfacies. These minor channels are typically located in the upper part of the main channel.

These conglomerate beds are closely comparable to the graded-stratified model of Walker (1975, 1977), the re-sedimented marine conglomerates of Surlyk (1978), and to Lowe’s (1982) R3S1 divisions, representing deposits of high-density, turbidity currents.

### *Facies 5: Cross-laminated Sandstone Interbedded with Mudstone*

*Description* – The facies is present in the Dereçiftlik Formation and logged in Figures 10 & 11. In Figure 10, this facies consists mainly of the thin- to medium-bedded cross-laminated Bouma division ($T_c$), whereas some individual $T_b$ beds are also present.

In the upper part of the section shown in Figure 11, this facies consists of greenish-grey, thin-laminated shale packets, the thickness of which vary between 175 cm and 350 cm. In this facies, five sandstone beds are present. All of these sandstone beds have sole marks and complete Bouma sequences ($T_{a-e}$), except for the lowest one which has only the graded division ($T_a$) of the Bouma sequence. The sandstone beds are medium-bedded and do not show any bed amalgamation. Plant remains/carbonized matter is found on bedding planes in the lower intervals of parallel lamination ($T_b$). The dimensions of carbonized fragments vary between 1 mm and 1 cm.

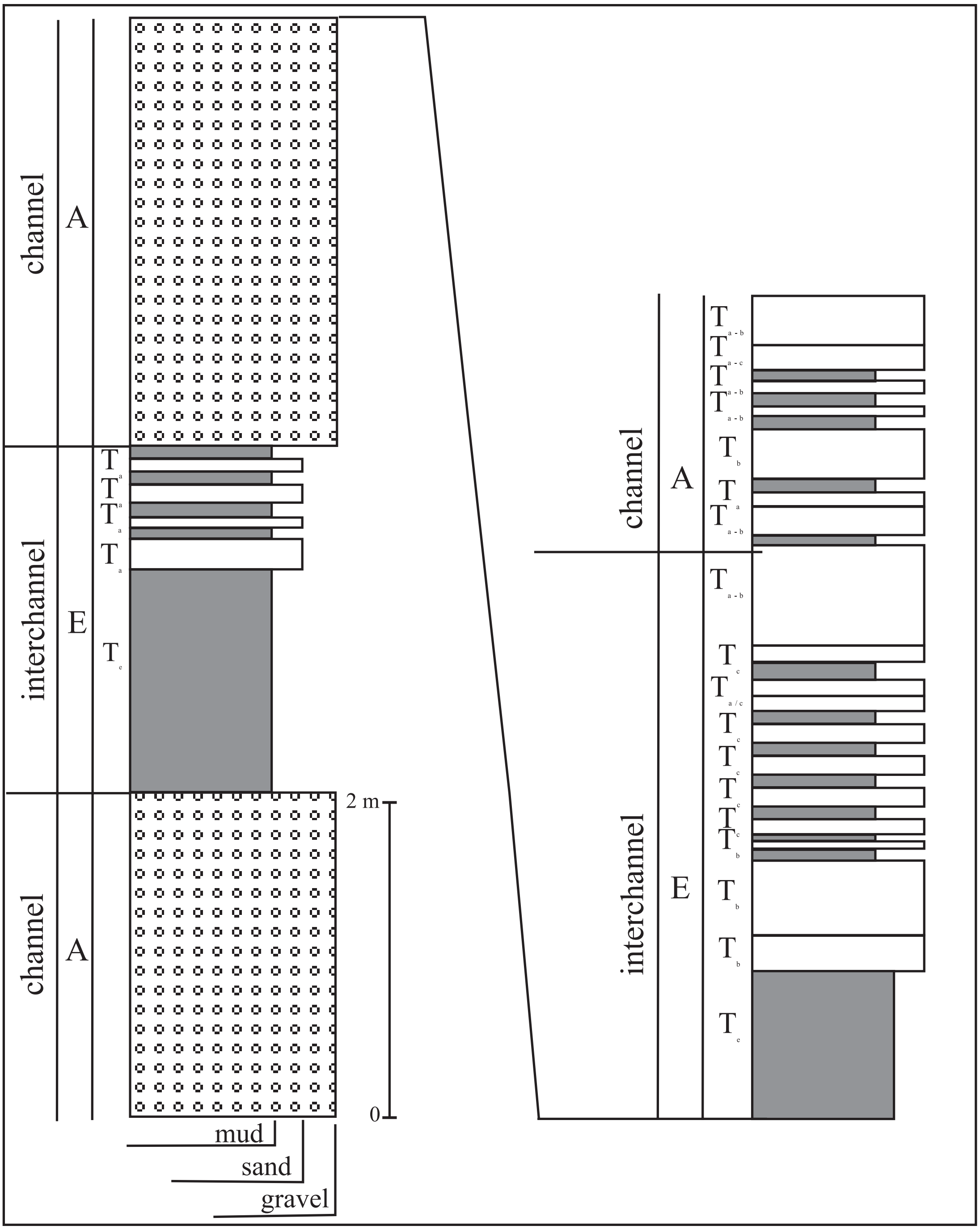


Figure 10. Measured section-3 showing the channel (facies 4) and interchannel facies (facies 5). Capital letters indicate correlation with facies classification of Mutti & Ricci-Lucchi (1975) (see Figure 3 for location).

*Interpretation* – This facies resembles facies E of Ricci-Lucchi (1975), which has been interpreted to be especially frequent in channelized cycles as interchannel deposits. This facies is considered by Mutti & Ricci-Lucchi (1972) to be a typical product of deposition in local, minor depressions.

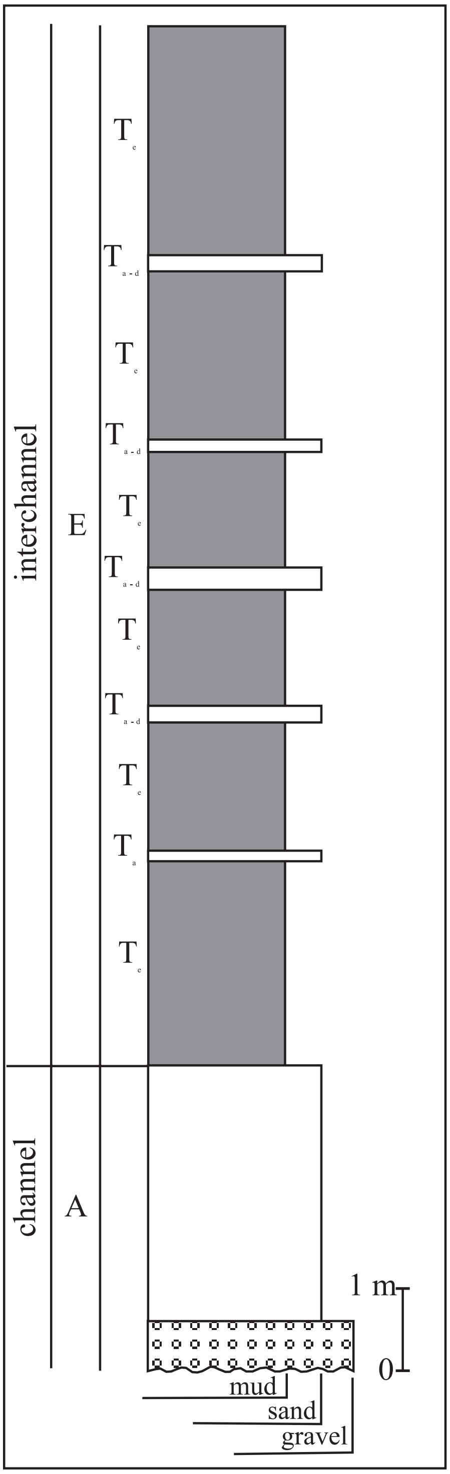


**Figure 11.** Measured section-4 showing the channel (facies 4) and interchannel facies (facies 5). Capital letters indicate correlation with facies classification of Mutti & Ricci-Lucchi (1975) (see Figure 3 for location).

The very thick shale-rich facies is interpreted as an interchannel deposit that accumulated over the channel-fill after the channel was abandoned (Lash 1986). The individual sandstone beds are interpreted as the deposits of crevasse splays.

### *Facies 6: Amalgamated Sandstone Interbedded with Mudstone*

*Description* – This facies is exposed in the Dereçiftlik Formation, at the locality 08900N/85350E along Çaykavuştu Dere (Figure 12). The lobe facies consists of medium- to thick-bedded sandstone. The thick-bedded turbidites are characterized by classical Bouma sequences. Complete Bouma sequences are scarce, and most of the beds consist of $T_{a-c/e}$ Bouma sequences, whereas the $T_b$, $T_{ab}$, $T_{bc/e}$ divisions are less commonly observed. The sandstone/shale ratio of these deposits is very high and bed amalgamation is typical (Figure 13).

Similar facies were logged at different levels in Figure 14. The facies consists mainly of complete Bouma sequences ($T_{a-e}$); however, some truncated sequences ($T_{a-b}$, $T_{a-d}$) are observed. The sandstone/shale ratio of this facies is >1. The thickness of each individual sandstone lobes are, in ascending order, 25, 40, 50, 195, 65 and 30 cm. Some of the thick sandstone beds have sole structures.

*Interpretation* – The sharp, scoured to flat bases, normal grading and parallel- to cross-laminated tops suggest deposition from waning, sand-rich turbulent flows (Lowe 1982). The base-missing sandstone beds ($T_b$, $T_{bc}$) are interpreted as the deposits of low-density turbidity currents (Lowe 1982).

The complete and truncated Bouma sequences of this facies are interpreted as the C facies of Mutti & Ricci-Lucchi (1975). The sandstone lobes occur as thickening-upward and thinning-upward sequences which correspond to lobe progradation and lobe abandonment, respectively.

### *Facies 7: Mudstone Interbedded with Thin Sandstone*

*Description* – This facies is observed in the eastern part of Çaykavuştu Dere, at 08840°N/85780°E (Figures 12 & 14). These deposits occur in packets between tens of centimeters and 9-m thick, the bulk of which comprise

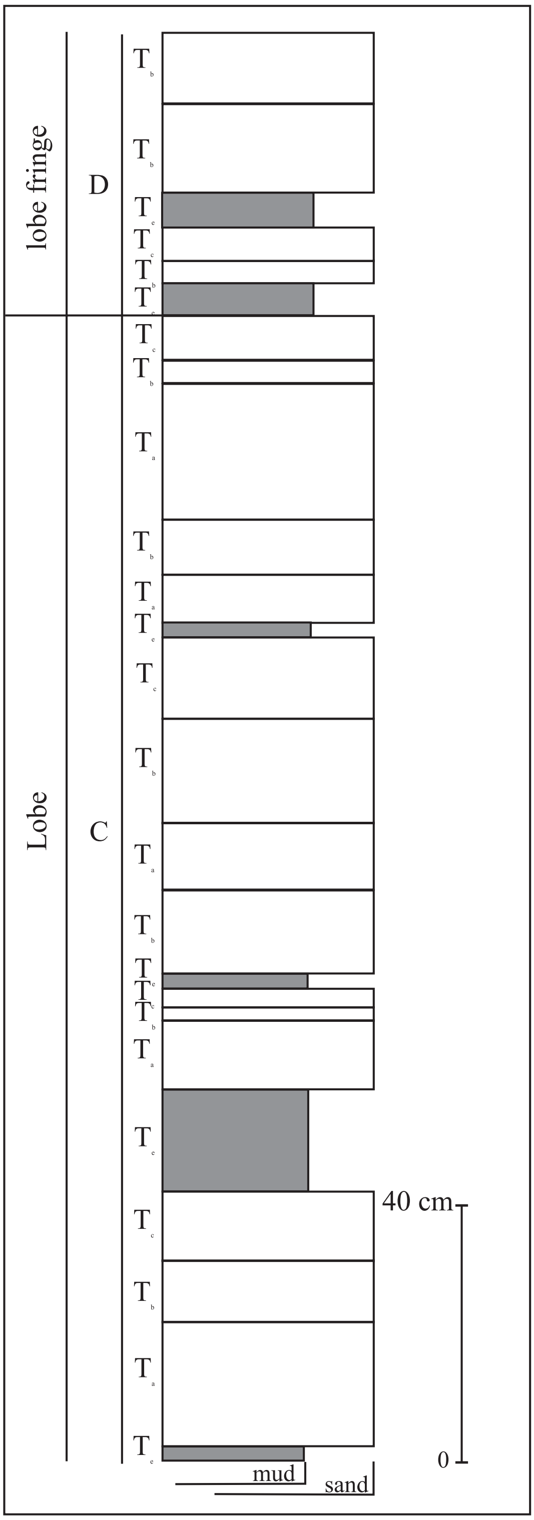


**Figure 12.** Measured section-5 showing the lobe (facies 6) and lobe fringe facies (facies 7). Note the amalgamated nature of the turbiditic sandstone beds. Capital letters indicate correlation with facies classification of Mutti & Ricci-Lucchi (1975) (see Figure 3 for location).

mainly thin (3-10 cm) and very thin sandstone beds (less than 3-cm thick). The sandstone beds show typical base-missing Bouma sequences, such as $T_{d/e}$, $T_{b-e}$, $T_{b/e}$, $T_e$, $T_{b-c/e}$. Sandstone/shale ratios are <1. The lower contact of sandstone beds is sharp, whereas the upper contact of the same beds is gradational with the overlying shale beds (Figure 15).

*Interpretation* – The shale interbedded with base-missing thin sandstone is similar to the facies D of Mutti & Ricci-Lucchi (1975). Facies D sandstone beds were probably deposited by low density turbulent flows far from channel sources (Ingersoll 1978). This facies can be interpreted as lobe-fringe and/or fan-fringe deposits.

### *Facies 8: Red Mudstone*

*Description* – This facies is seen in the upper part of the Dereçiftlik Formation and crops out in the western side of the Çaykavuştu Dere, at 08730N/85580E. The Violet red mudstone facies is concordantly underlain by a thin turbidite layer and disconcordantly overlain by conglomerate beds of the Çaykavuştu Formation. The facies contains planktonic foraminifera such as *Planorotalites* sp., *Globigerina* sp., and *Morozovella* sp.

*Interpretation* – This facies may be correlated with facies G of Mutti (1977). Facies G has been interpreted as deposited from dilute suspensions (fine-grained turbidity and nepheloid flows) and by continuous rain of hemipelagic sediment in basin-plain settings (Ingersoll 1978).

## Facies Associations

The eight individual facies described above have been grouped into four submarine facies associations, based on the following environmental categories: shelf, slope, inner fan, and outer fan facies associations (Figure 16).

### *Facies Association I: Shelf*

The shelf facies association is characterized by the presence of abundant shallow-marine fauna as observed in the bioclastic limestone facies of the Kelkaya Formation. This facies association is only observed around Kelkaya Hill. The carbonate-cemented conglomerate marks the lower part of this facies association.

**Figure 13.** Field photograph showing the amalgamated sandstone beds in facies 6. View to E. Grid reference: 08900N/85350E.

The faunal content of this facies association suggests a shallow shelf environment (20-30 m) for the deposition of the limestone beds. The transition from coarse-grained detrital sediments to carbonate sediments suggest a transgressive tendency in the shelf deposits.

### *Facies Association II: Slope*

Chaotic deposits exhibiting gravity slumping and re-sedimentation such as facies 3 (disorganized conglomerate with olistolith), are accepted to have formed in lower-slope environment. Olistoliths within this environment are variable in size and include both intra- and extra-basinal rocks.

### *Facies Association III: Inner Fan*

The inner fan association is characterized by channel-fill deposits enclosed in shale and medium to thinly interbedded sandstone. The general character and sedimentary features of these facies indicate the operation of a variety of re-sedimentation mechanisms, including turbidity and debris flows (Table 3).

Conglomerates are probably restricted to channels, mainly the inner-fan channel (Walker 1984). Channel-fill sequences consist of thinning- and fining-upward sequences. Thus a typical inner-fan channel has a conglomeratic basal fill, and passes upward into finer conglomerates, coarse-grained sandstones and medium- to fine-grained sandstones.

### *Facies Association IV: Outer Fan*

The outer-fan rocks comprise three main lithological associations, interpreted by analogy with those described by Mutti & Ricci-Lucchi (1975) and Mutti (1977), namely, lobe, lobe- fringe, and fan-fringe deposits (Figures 12 & 14).

Lobe deposits mainly occur as amalgamated, medium- to very thick-bedded, medium- to coarse-grained sandstone beds showing $T_{a-c/e}$, $T_{a-e}$, $T_{a-b/e}$ Bouma sequences. The sandstone/shale ratio within these packets is >1 (Table 4).

Lobe fringe deposits have sandstone/shale ratios <1 and are sandier than fan-fringe deposits. Bed thicknesses are up to 50 cm, although thin- to medium-bedded (10-30 cm) divisions are fairly abundant. Virtually all of the

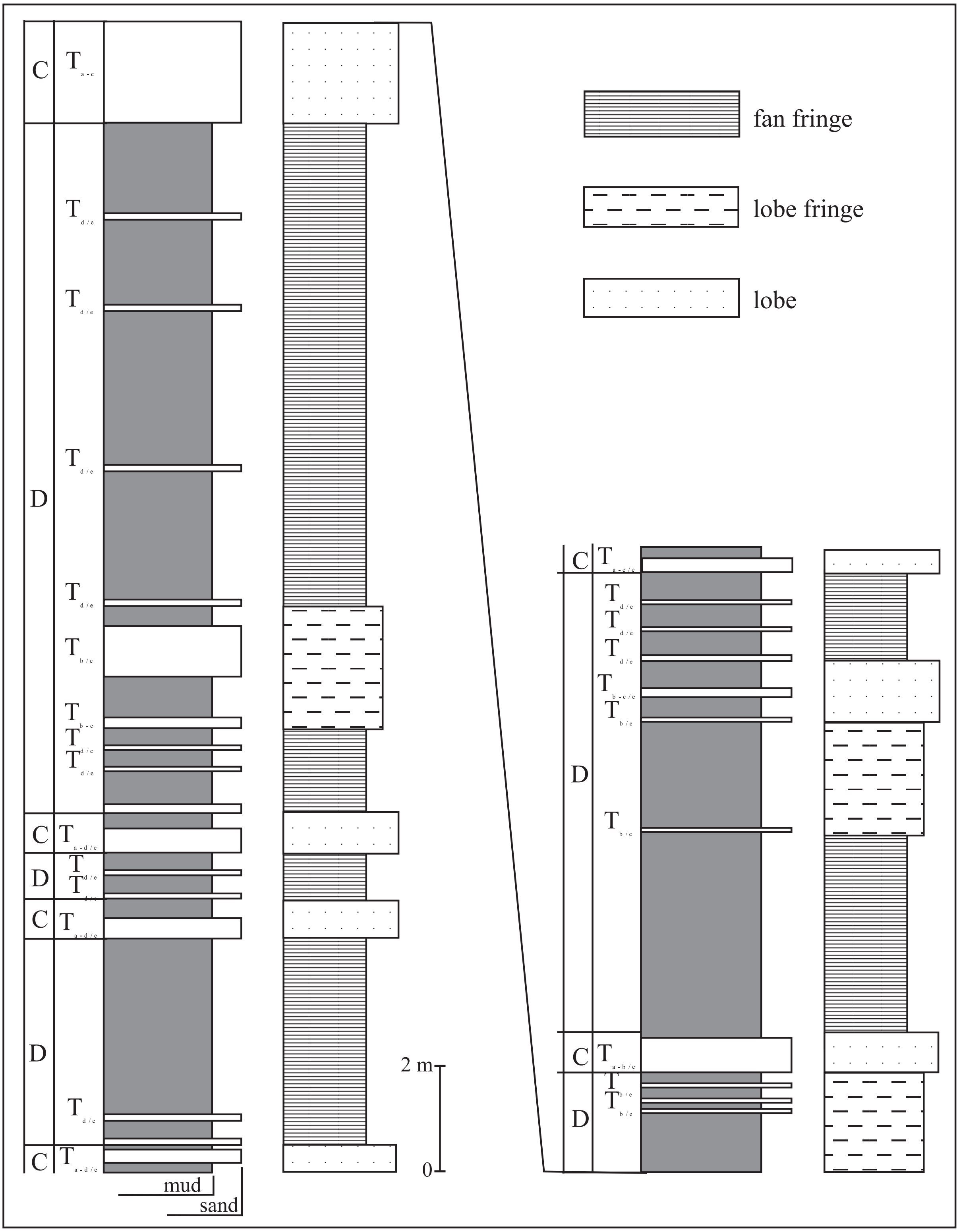


**Figure 14.** Measured section-6 showing the lobe (facies 6), lobe fringe and fan fringe facies (facies 7). Capital letters indicates correlation with facies classification of Mutti & Ricci-Lucchi (1975) (see Figure 3 for location).

**Table 3.** The main features of the inner fan deposits (facies association III).

| Interpretation | Channel | Inter-channel |
|---|---|---|
| Definition | very thick- to thin-bedded turbidite and other mass-flow deposits (debris-flow deposits common) | thin- to very thin-bedded bedded turbidites |
| Bedding pattern | irregular, wedging | sheet-like |
| Bouma sequences | $T_{a-b}$, $T_a$ | $T_{c/e}$, rare $T_{b/e}$ |
| Typical grain size | pebble to medium-grained sandstone | fine-grained sandstone to mudstone |
| Sand/shale ratio | more than one (>1) | close to one or less than one (≤1) |
| Other | disorganized and normal graded beds, amalgamation common | amalgamation absent |

**Table 4.** The main features of the outer fan deposits (facies association IV).

| Interpretation | Lobe | Lobe fringe | Fan fringe |
|---|---|---|---|
| Definition | very thick- to medium-bedded turbidites | thin- to very thin-bedded turbidites | very thin-bedded mudstones and fine sandstones |
| Bedding pattern | sheet-like | sheet-like | sheet-like |
| Bouma sequences | $T_{a-c/e}$, $T_{a-e}$, $T_{a-b/e}$ | $T_{b-e}$, $T_{d/e}$, $T_{b/e}$, $T_{b-c/e}$ | $T_{d/e}$, $T_e$ |
| Typical grain size | coarse- to medium- grained | fine- to very fine- grained | fine-grained sandstone to mudstone |
| Sand/shale ratio | more than one (>1) | less than one (<1) | less than one (<<1) |
| Other | amalgamation and sole marks common | sole marks rare or absent | sole marks absent |

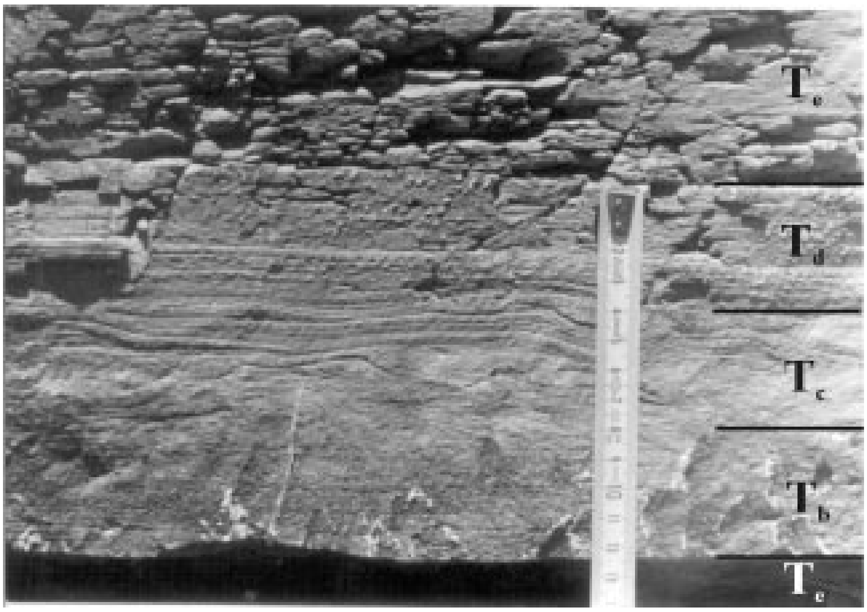


**Figure 15.** Field photograph showing a good example of base-missing bouma sequence observed in the Facies 7. Bouma divisions are indicated on the photo. Grid reference: 08840N/85780E.

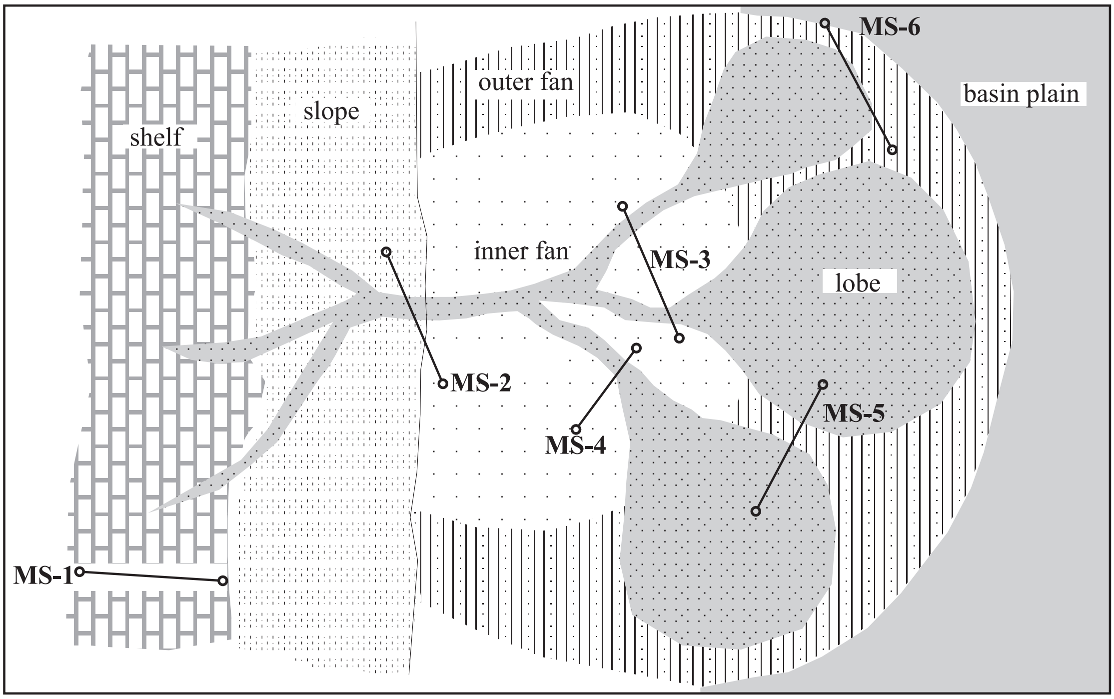


Figure 16. A synthetic submarine fan model used for the environment of deposition of the Dereköy succession. MS-1 to MS-6 refer to the location of the measured sections.

turbidite beds of the lobe-fringe deposits display base-missing Bouma sequences (i.e. $T_{b-e}$, $T_{d/e}$, $T_{b/e}$, $T_{b-c/e}$, and $T_e$ sequences). The distinction between lobe and lobe-fringe deposits is necessarily fixed arbitrarily such that packets of amalgamated sheet sandstones are interpreted as lobes, whereas the non-amalgamated sheet sandstones are interpreted as lobe fringe deposits.

Internal depositional structures and grain size indicates that thin-bedded lobe-fringe deposits of the Dereçiftlik Formation are products of waning and relatively dilute turbidity currents that carried fine-grained sand, silt, and mud as suspended loads. The thin-bedded, lobe-fringe deposits are interpreted as the distal equivalents of the coarse-grained, and thick-bedded sandstone bodies that comprise the depositional lobes of outer-fan environments. Thus, in this model, highly concentrated turbidity currents that reached the outer fan environment dropped their coarsest suspended load first. Through successive events, these sediments formed the coarse-grained, thick-bedded sandstone bodies of the depositional lobes. Farther downslope, the same current became dilute suspensions carrying and depositing progressively finer-grained material which accumulated as peripheral fringes around the lobes (Ingersoll 1978).

## Stratigraphic Correlation of the Supra-allochthonous Successions

The sedimentary facies and stratigraphic position of the Palaeocene-Eocene Dereköy succession suggest that the basin of deposition developed on the Lycian nappes. Similar successions are exposed in the northern and southern Menderes Massif as three separate outcrops at Akhisar-Başlamış, Baklan-Çardak, and İnceler (see Figure 1). These successions formed on the Bornova Flysch Zone and on the different structural units of the Lycian thrust sheets, and developed as supra-allochthon basins during the Late Palaeocene-Late Eocene. The supra allochthonous sediments are separated from the Lycian nappes by a regional unconformity and unconformably overlain by Lower Oligocene-Lower Miocene terrestrial to shallow marine sedimentary rocks (Figure 17).

To the north of the Menderes Massif, around the Başlamış Village (Akhisar), Başlamış Formation of Late Palaeocene-Middle Eocene age rests unconformably on the Bornova Flysch Zone (Akdeniz 1980; Okay & Siyako 1991). The formation is unmetamorphosed and consists, from bottom to top, of basal conglomerate, and sandstone and mudstone with lenses of reefal-bioclastic

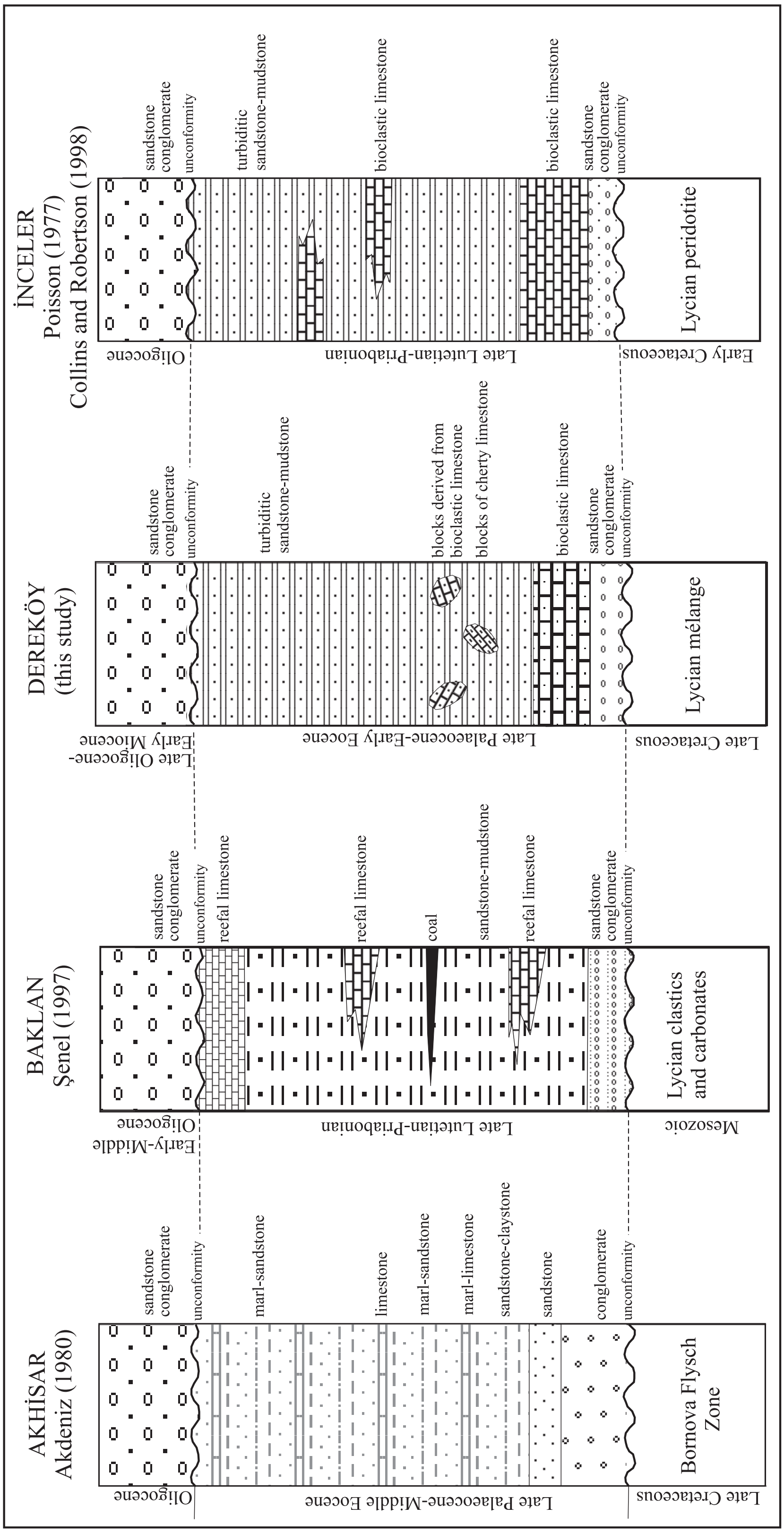


**Figure 17.** Stratigraphic correlations of the Late Palaeocene-Late Eocene supra-allochthon sedimentary successions that developed on the different tectonostratigraphic units.

limestone. It is unconformably overlain by terrestrial red clastic rocks of Oligocene age (Akdeniz 1980).

The İnceler succession forms the uppermost section of the Tefenni nappe (Özkaya 1990; Collins & Robertson 1997). Ultramafic rocks of the Tefenni nappe are mainly peridotite tectonites. They are unconformably overlain by shallow-marine limestones and clastics of Early-Middle Eocene age as documented earlier by Poisson (1977) and Collins and Roberson (1997). The İnceler succession consists of carbonate-cemented conglomerate, cream-coloured limestone with abundant benthic foraminifera and corals, and grey to cream-coloured fossiliferous sandstone and mudstone with limestone intercalations. In the area of Baklan-Çardak, 10 km north of İnceler, however, the unconformably underlying units are the Lycian metacarbonates and metaclastics (Figure 17). The Baklan succession is unconformably overlain by red molasse deposits of Early Oligocene age (Şenel 1997).

Correlative units of similar age are also reported from south of the study area, in the Korkuteli and Elmalı areas. Clastic rocks with pelagic limestones of Middle Eocene (Lutetian) age were reported by and named the Elmalı Formation by Önalan (1979). The formation forms the lowest unit of the Elmalı Group of Ersoy (1990) which is also known as the Elmalı thrust slice (Özkaya 1990, 1991). The Elmalı Formation can be correlated with the Lutetian-Priabonian Yavuz Formation of Poisson (1977) that lies between allochthons as a tectonic slice (Ersoy 1990). Upper Cretaceous-Lutetian sediments with basalt intercalations are found in the upper part of the Köyceğiz thrust slice which rests tectonically on the Elmalı thrust slice (Özkaya 1990). The Tavas thrust slices, which are accepted as slivers of the southern Menderes Massif (Okay 1989; Özer *et al.* 2001), also contain a sedimentary succession of Palaeocene-Eocene age. The succession rests unconformably on Maastrichtian Hippuritid-bearing limestones and consists of clastics with limestone and spilite interlayers (Özkaya 1990).

## Discussion on Tectonic Implications

The detrital framework of the Dereköy succession is composed of extra-basinal grains, both siliciclastic and carbonate, and intra-basinal grains, almost coeval with the deposits made up of shelf-carbonate allochems, argillicaeous rip-up clasts and glauconite (Sözbilir 1995). All of the extra-basinal grains are derived from the different tectonostratigraphic units of the Lycian nappes. According to ternary diagrams of Dickinson and Suczek (1979), which are used for determining the provenance of arenites, the data points of the arenites from the turbiditic part of the Dereköy succession plot in the domain of recycled orogen provenance (for detail see Sözbilir 1995). This means that the source area of the supra-allochthonous sediments had the characteristics of a recycled orogenic belt.

The first appearance of metamorphic-derived sedimentary rocks did not occur until Early Miocene time to the south of Çökelez Mountain, in Emirardıç (Sözbilir *et al.* 2000; Akgün & Sözbilir 2001). At that locality, a good section of the upper part of the Denizli molasse is observed (Figure 18). The section begins at its base with planar-bedded sandstone and grades into sandy limestone with coral and benthic foraminifera which indicate an Early Miocene age. These fossil-rich beds are conformably overlain by sandstone and conglomerate. The conglomerate consists of clasts of marble, schist, metaquartzite, gneiss and ophiolitic rocks. This data suggests that initial subaerial exposure of the Menderes Massif in the study area took place during Early Miocene time.

Important detrital episodes in the Dereköy succession provide evidence for discrete phases during the evolution of the basin in which the strata were deposited. The main episodes appear to be related to: (1) trangression over the Lycian nappes and the birth of a narrow carbonate shelf (Late Palaeocene-Early Eocene); (2) collapsing and drowning of the shelf causing turbiditic deposition in a submarine-fan environment; (3) a low-stand of sea level causing a deltaic-regressive sequence with coal formation (Middle-Late Eocene, Baklan succession); (4) NW-SE-trending orogenic compression, causing closure of the basin and incorporating its sediments into the Lycian nappes; (5) extensional collapse of the Lycian orogen and deposition of Oligocene-Lower Miocene piggy-back basin sediments (Figure 19).

## Conclusion

The unmetamorphic Palaeocene-Eocene sedimentary succession at Dereköy formed in a supra-allochthonous basin. The succession is characterized by eight sedimentary facies that are interpreted to represent shelf, slope, channel, interchannel, lobe, lobe fringe and fan-

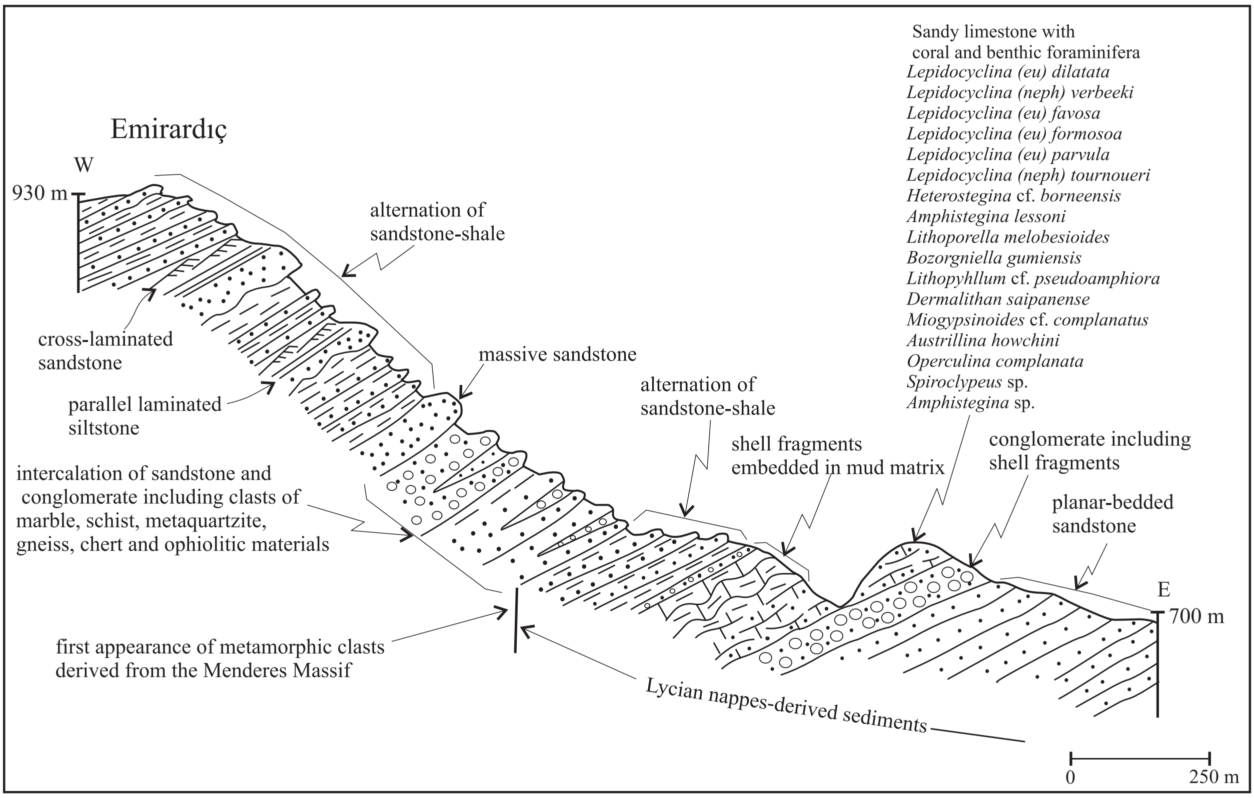


**Figure 18.** Cross-section showing first appearance of metamorphic clasts in the upper part of the molasse sediments. Fossil contents are from Akgün & Sözbilir (2001) (see figure 2 for location).

fringe environments. A basal conglomerate unconformably overlies the Lycian mélange. This is itself overlain by pebble sandstones which grade upward into bioclastic limestones that contain Late Palaeocene-Early Eocene fossils. Overlying these shelf deposits are disorganized conglomerates, with blocks of intrabasinal and extrabasinal origin, interpreted as slope deposits. These sediments pass upward into turbiditic clastic beds which are characterized by complete, base-missing and top-missing Bouma sequences, and interpreted as an extensive turbidite fan system.

The supra-allochthonous sediments are unconformably overlain by Lower Oligocene-Lower Miocene deposits which formed in a piggy-back basin during, late SE-directed thrust sheet translation.

The four successions, already described in the text, probably developed in connected depressions during the Palaeocene-Eocene (Figure 19). The presence of ophiolite-derived sediments through these successions is indicative of the subaerial exposure of the Lycian ophiolites by Palaeocene time. The Late Eocene phase of thrust-sheet translation (Collins & Robertson 1998, 1999) resulted in the closure of the supra-allochthonous basin and thrust the ophiolitic nappes onto the basin sediments. During the extensional collapse of the Lycian orogen (Collins & Robertson 1998; Lips *et al.* 2001), the Başlamış and the Dereköy, Baklan and İnceler successions may have been separated by gravitational spreading of the thrust piles (Figure 19).

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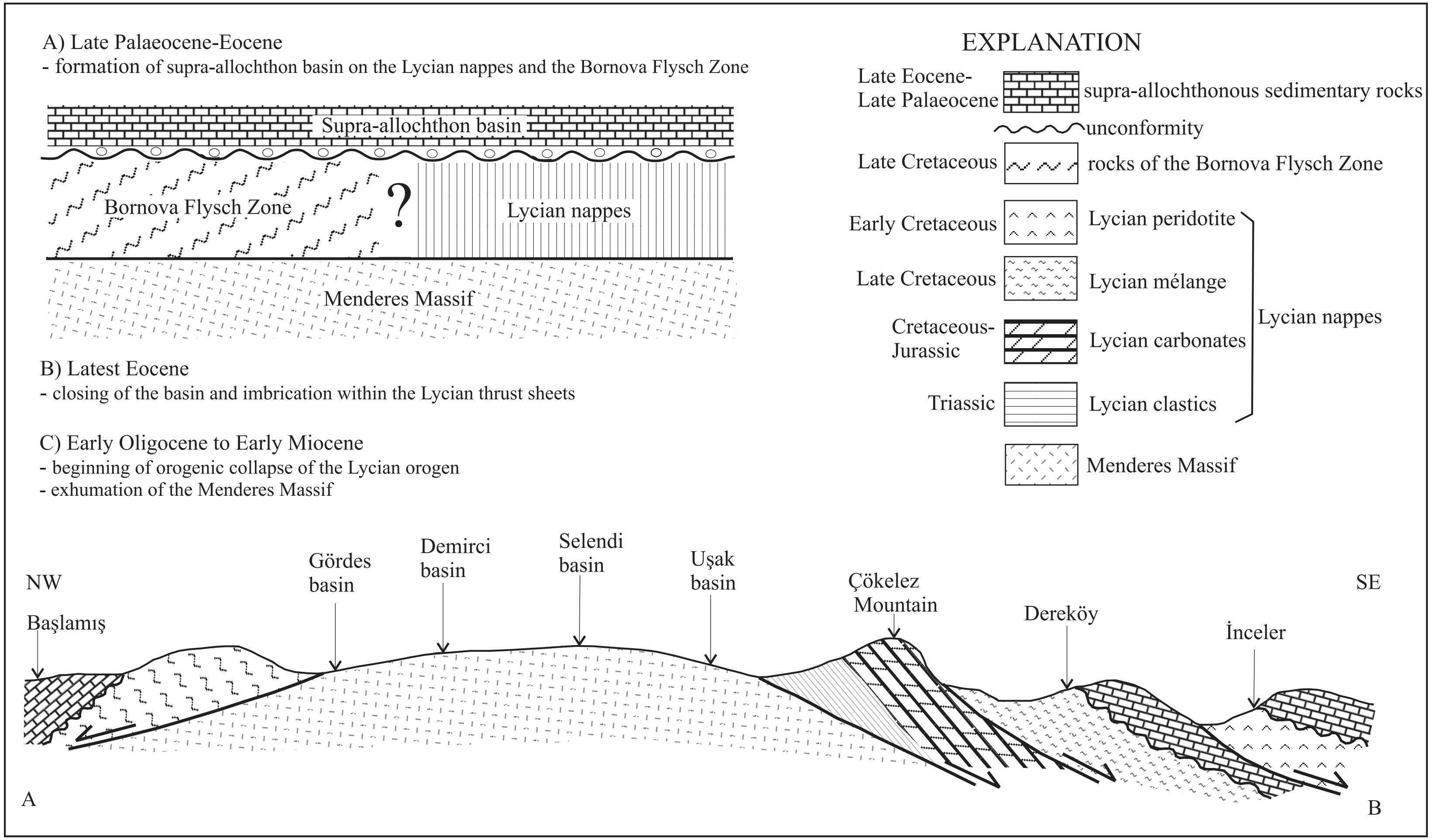


**Figure 19.** Geological history and a combined synthetic cross-section which summarizes existing works in the region (Poisson 1977; Okay & Siyako 1991; Seyitoğlu & Scott 1994; Bozkurt & Park 1997a, 1997b, 1999; Sözbilir 1997; Seyitoğlu 1997; Collins & Roberson 1998; Hetzel *et al.* 1998; Ring *et al.* 1999; Bozkurt & Satır 2000; Bozkurt 2001; Gessner *et al.* 2001; Lips *et al.* 2001; Özer *et al.* 2001; Rimmelé *et al.* 2001) in conjunction with the field observations of this study (see Figure 1 for location).

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