

Stratigraphy and tectono-sedimentary evolution of the Upper Cretaceous–Tertiary sequence in the southern part of the Malatya Basin, East Anatolia, Turkey

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Received 29 June 2005; accepted 27 June 2006

Abstract

The Malatya Basin is situated on the southern Taurus-Anatolian Platform. The southern part of the basin contains a sedimentary sequence which can be divided into four main units, each separated by an unconformity. From base to top, these are: (1) Permo-Carboniferous; (2) Upper Cretaceous–Lower Paleocene, (3) Middle-Upper Eocene and (4) Upper Miocene. The Upper Cretaceous–Tertiary sedimentary sequence resting on basement rocks is up to 700 m thick.

The Permo-Carboniferous basement consist of dolomites and recrystallized limestones. The Upper Cretaceous–Lower Paleocene transgressive–regressive sequence shows a transition from terrestrial environments, via lagoonal to shallow-marine limestones to deep marine turbiditic sediments, followed upwards by shallow marine cherty limestones. The marine sediments contain planktic and benthic foraminifers indicating an upper Campanian, Maastrichtian and Danian age. The Middle-Upper Eocene is a transgressive–regressive sequence represented by terrestrial and lagoonal clastics, shallow-marine limestones and deep marine turbidites. The planktic and benthic foraminifers in the marine sediments indicate a Middle-Upper Eocene age. The upper Miocene sequence consists of a reddish-brown conglomerate–sandstone–mudstone alternation of alluvial and fluvial facies.

During Late Cretaceous–Early Paleocene times, the Gündüzbey Group was deposited in the southern part of a fore-arc basin, simultaneously with volcanics belonging to the Yüksekova Group. During Middle-Late Eocene times, the Yeşilyurt Group was deposited in the northern part of the Maden Basin and the Helete volcanic arc. The Middle-Upper Eocene Malatya Basin was formed due to block faulting at the beginning of the Middle Eocene time. During the Late Paleocene–Early Eocene, and at the end of the Eocene, the study areas became continental due to the southward advance of nappe structures.

The rock sequences in the southern part of the Malatya Basin may be divided into four tectonic units, from base to top: the lower allochthon, the upper allochthon, the parautochthon and autochthonous rock units.

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Keywords: Stratigraphy; Tectono-sedimentary evolution; Upper Cretaceous–Tertiary sequence; Malatya Basin; East Anatolia

1. Introduction

The aim of this paper is to describe the stratigraphy and tectono-sedimentary evolution of rock units of Upper Cre-

taceous–Tertiary age in the southern part of the Malatya Basin, East Anatolia, Turkey (Fig. 1a and b).

The study area is located in the southern part of the Malatya Basin and covers approximately 40 km² (Fig. 2). The Malatya Basin as a whole is a major interior basin in East Anatolia, approximately 1000 km² in size, exposing Upper Cretaceous–Tertiary volcano-sedimentary rocks up to 4500 m thick. The stratigraphic, sedimentary and tectonic evolution of this basin is different from that of the rest of East

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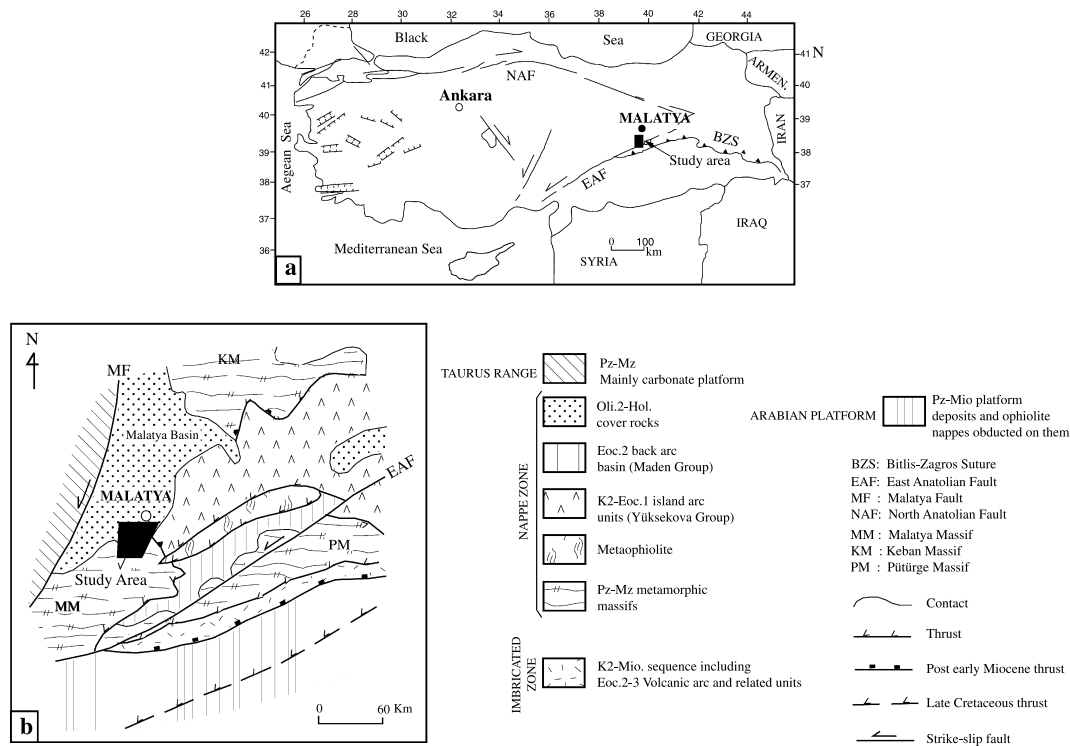


Fig. 1. (a) Location map (b) Simplified geologic–tectonic map of the Southeast Anatolian orogenic belt (modified after Perinçek, 1978; Yigitbas and Yilmaz, 1996).

Anatolia, and the basin contains economic resources such as lignite, clay minerals and gypsum. In addition the presence of mature source-rocks provides oil potential, making the Malatya Basin one of the most important basins in Turkey.

Pre-Upper Cretaceous basement rocks in this part of the Taurus consist of marble and recrystallized limestone, of Permo-Carboniferous age. The stratigraphy and tectono-sedimentary evolution of the basement rocks have been discussed by various workers (Perinçek, 1978; Gözübol and Önal, 1986; Yazgan and Chessex, 1991; Yoldas, 1992; Yılmaz, 1993; Yılmaz et al., 1993; Yılmaz and Yıldırım, 1996; Yigitbas and Yılmaz, 1996; Elmas and Yılmaz, 2003).

Upper Cretaceous–Paleocene rock units rest unconformably on the basement rocks, but on the southern side of the Malatya Basin they are faulted locally against the basement (Gözübol and Önal, 1986). Previous studies by Ayan and Bulut (1964), Akkus (1971), Ilker and Özyegin (1971), Orçen (1986), Bozkaya and Yalçın (1992), Önal and Gözübol (1992), Görmüş (1992), Sirel and Acar (1993), Gürer (1996), Alkan (1997), Demir (1997) and Sirel (1998) established the overall geology of the Malatya Basin and the neighboring areas. The basin is filled mainly by fluvial, alluvial, shelf and open marine sediments.

The present study was focused on the tectono-sedimentary evolution of the area. Geological maps were prepared at a scale of 1:25,000, and sections were measured at different locations to establish the stratigraphic framework, the characteristics and distribution of the sedimentary facies, the tectonic features of the basin, and to determine the geological setting of the deposits. In addition, samples were

collected to establish the age of the rock units. As the result of this study the Upper Cretaceous–Tertiary sequence has been divided into two groups and eight formations.

2. Geologic, stratigraphic and structural setting

The rock units in the study area are divided into: Malatya Metamorphics (Permo-Carboniferous); the Gündüzbey Group (Upper Cretaceous–Lower Paleocene), the Yesilyurt Group (Middle-Upper Eocene) and the Beylerderesi Formation (Upper Miocene) (Figs. 2 and 3).

This region is situated in the Malatya Nappe Zone of Yılmaz (1993). The nappe zone consists of metamorphic and ophiolitic rock units (Elmas and Yılmaz, 2003) forming a stack of thrust sheets, with the Malatya Metamorphics at the top and serpentinite of the Maden Complex underlying the metamorphic rocks (Figs. 4 and 5). From north to south the basement to the Malatya Basin is formed of serpentinite (meta-ophiolite) of the Yüksekova Group, the product of Late Cretaceous to Early Eocene island-arc volcanism on an ophiolitic basement (Yılmaz et al., 1993) and the Malatya Metamorphics (the Malatya Massif and the Keban Massif) (Fig. 1b). Within the basin, the Late Cretaceous–Early Paleocene Gündüzbey Group was deposited in a fore-arc environment contemporaneously with the formation of the Yüksekova Group.

The basement of the Eastern Taurus was formed tectonically during the late Campanian–early Maastrichtian (Yazgan and Chessex, 1991) by an arc-continent collision between the Keban and Arabian microplates.

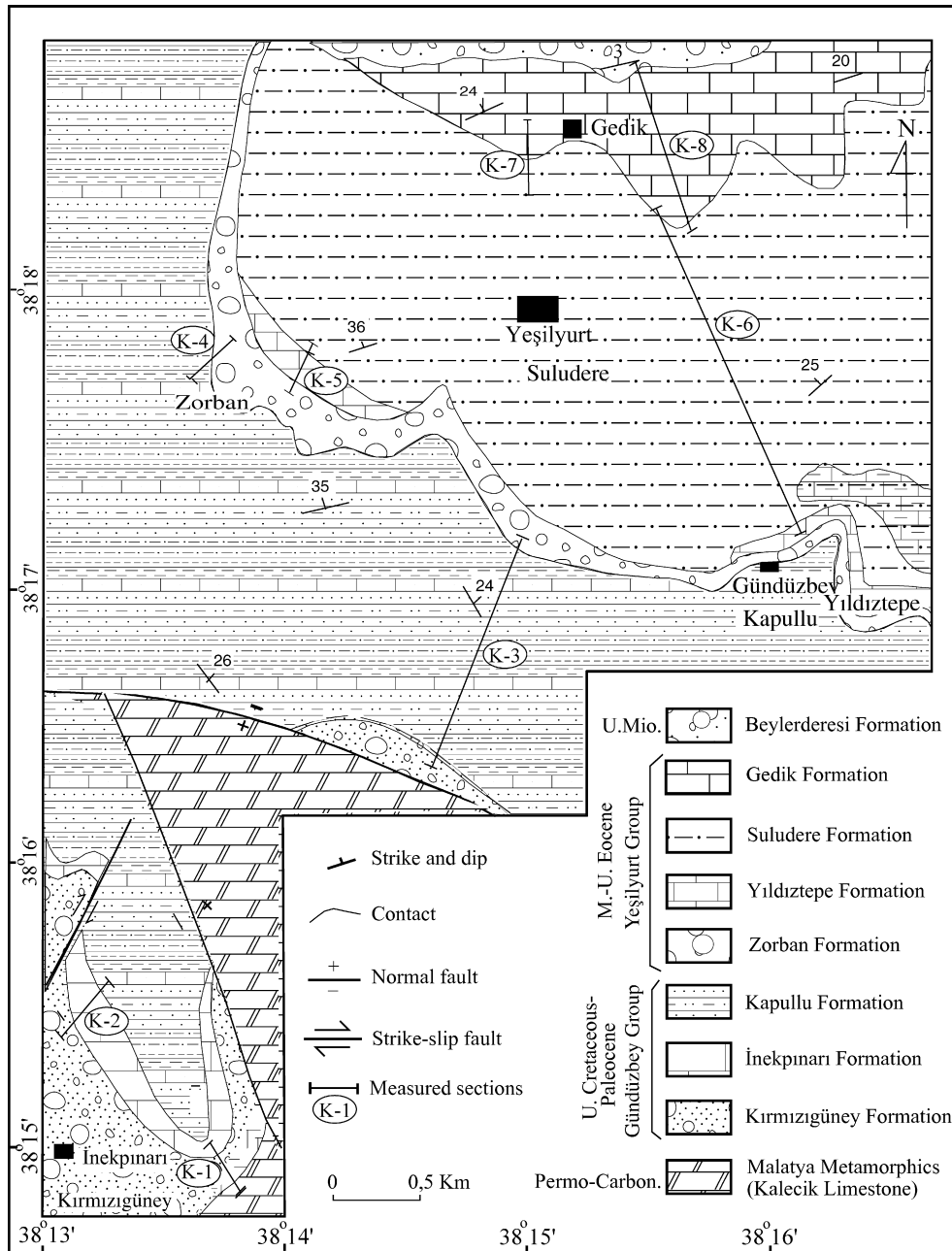


Fig. 2. Geological map of the study area.

2.1. Permo-Carboniferous basement rock units

The basement rocks are included in the ‘Suture Mountains Rock Unit’ (Fig. 4) and consist of marble, recrystallized dolomitic limestone, phyllite and schist, which were named the ‘Malatya Metamorphics’ by Sungurlu (1972). Their Permo-Carboniferous age is shown by the occurrence of foraminifers *Neoschwagerina* sp., *Schwagerina* sp., *Fusulina* sp., *Millerella* sp. and other Fusulinidae. The Malatya Metamorphics are divided into four formations: Pınarbaşı Formation; Koltik Limestone; Düzagaç Formation; and Kalecik Limestone (Gözübol and Önal, 1986). The Kalecik Limestone covers the southern part of the study area and

consists of dolomite and recrystallized limestone and has been thrust over the Eocene rocks of the Maden Complex as part of the Malatya Nappe (Fig. 4).

2.2. Upper Cretaceous–Paleocene

2.2.1. Gündüzbey Group

The Gündüzbey Group (Gözübol and Önal, 1986) consists of sandstone and mudstone with interbedded conglomerate, shelf carbonates and flysch-like deposits with a total thickness exceeding 310 m. The group is divided into three formations: the Kırmızıgüney, İnekpınarı and Kapullu Formations (Figs. 2 and 3). Generally, the unit

Age	Group	Formation	Thickness (m)	LITHOLOGY	DESCRIPTION	FOSSILS	Evolution		
								Group	Formation
Tertiary	U. Miocene	Beylerderesi	?	Conglomerate-sandstone-mudstone alternation	Unconformity Nummulite-bearing limestone	<i>Globigerina</i> sp., <i>Globigerinatheka</i> sp., <i>Eorupertia</i> sp., <i>Fabiania cassis</i> , <i>Asterigerina</i> sp., <i>Nummulites</i> sp., <i>Alveolina</i> sp., Rotalidae, Miliolidae	Terrestrial Deposition		
								Middle-Upper Eocene	Yesilyurt
	Yıldıztepe	12	Nummulite-bearing reefal limestone	<i>Nummulites bayhariensis</i> , <i>Alveolina</i> sp., <i>Asterigerina</i> sp., <i>Europertia</i> sp., <i>Fabiania cassis</i> , <i>Linderina</i> sp., <i>Textularidae</i>	Terrestrial Deposition				
						Zorban	44		Sandstone and mudstone interbedded conglomerate
	Cretaceous-Paleogene	Gündüzbey	Kapullu	112	Conglomerate interbedded limestone-sandstone-mudstone alternation				
						Kırmızıgüney	156		Sandstone and mudstone interbedded conglomerate
		Upper Cretaceous-Paleocene	İnekinari	42	Rudist-bearing reefal limestone				
						Permo-Carboniferous	Kalecik		

Fig. 3. Generalized stratigraphic section of the study area.

rests unconformably on the basement rocks (Malatya Metamorphics), but locally on the southern side of the Malatya Basin it is faulted against the basement rocks. From planktic (*Globotruncana aegyptiaca* Nakkady, *Globotruncanella havanensis* (Voorwijk) and *Gansserina gansseri* (Bolli)), benthic foraminifera (*Orbitoides medius* (d'Archiac), *Omphalocyclus macroporus* (Lamarck) and *Haymanella paleocenica* Sirel) and Pelecypoda (*Vaccinites loftusi*) the age of the Gündüzbey Group is Upper Cretaceous–Early Paleocene (Gözübol and Önal, 1986; Sirel, 1998).

2.2.2. Kırmızıgüney Formation

The Kırmızıgüney Formation is characterized by reddish-brown, sandstone–mudstone with interbedded conglomerates (Fig. 3). The thickness in the type section is 156 m (Fig. 6K-1), reaching up to 330 m in the southwest-

ern part of the basin. The conglomerates are thick bedded (3 m), poorly to moderately sorted, well consolidated and generally matrix-supported. Clasts, in the range of pebbles to boulders, measuring up to 3 m in diameter, are generally subrounded to rounded. The conglomerates show overall fining upward. Clasts of marble, dolomite and schist were derived from the underlying basement rocks. The conglomerates interfinger with the other rock types of the Kırmızıgüney Formation. The beds show trough cross-stratification. Paleocurrent measurements on the conglomerates in the southern part of the basin indicate transport from south to north. The interbedded, well-consolidated, poorly sorted sandstones are generally reddish and thin to thick bedded (5–100 cm). Tabular cross bedding is not common. The beds are laterally discontinuous, showing a passage from conglomerate to sandstone by a reduction

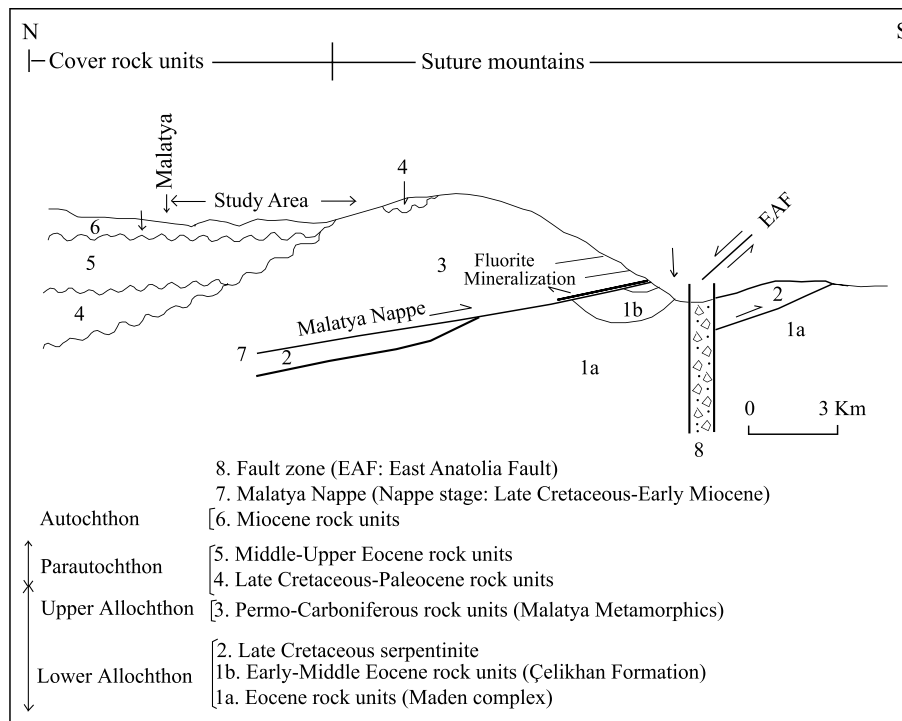


Fig. 4. Schematic cross-section showing stratigraphic and tectonic relations between Suture Mountain rock units and cover rock units in the southern parts of the Malatya Basin (EAF: East Anatolia Fault) (simplified from Önal and Gözübol, 1992).

in grain size. Mudstones are generally reddish-brown, thin to thick bedded (5 cm–3 m), tabular laminated and well consolidated and show an overall upwards fining.

The Kırmızıgüney Formation was deposited directly on basement rocks (Fig. 11B and C). The sedimentary and stratigraphic features indicate deposition in alluvial and fluvial environments. The unit grades laterally and vertically into the overlying İnekpınarı Formation (Fig. 3). No fossils were found in the Kırmızıgüney Formation in the study area, but from its vertical and lateral association with İnekpınarı Formation, where the age is well-controlled by fossils (see below), the unit is of upper Campanian–Maas-trichtian age.

2.2.3. İnekpınarı Formation

The İnekpınarı Formation at the type locality in the southwestern part of the Malatya Basin consists of a sandy limestone at the base, followed by rudist, algae, coral and foraminifera-bearing reefal limestone, calcirudites, calcarenites and sandstones with mudstone interbeds. The limestones are gray-white, thin to thick-bedded (10–400 cm). In the type section a rudist reef 0–3 m thick occurs in the lower part of the unit (Fig. 6K-2). Sandy limestone, sandstone and mudstone are common within the lower and middle parts of the unit.

The unit forms a transgressive sequence, gradational vertical and laterally with the underlying and overlying units (Fig. 3). At the type section, the İnekpınarı Formation is 42 m thick (Fig. 6K-2). Rudist (*Balabania cf. acuticostata* and *Vaccinites loftusi*) fossils (Önal and Gözübol,

1992) and benthic foraminifera (*Orbitoides medius* (d'Arch-iac) and *Omphalocyclus macroporus* (Lamarck)) indicate that the age of the unit is upper Campanian–Maas-trichtian. Its composition, lithologic features and the included fossils indicate that it was deposited in shelf lagoon, winnowed platform and reefal environments (Figs. 3, 6K-2 and 8).

2.2.4. Kapullu Formation

The Kapullu Formation is made up of interbedded pelagic limestone, mudstone and sandstone, locally including olistostromes, calcirudites, calcarenites and cherty limestones. The thickness in the type section is 112 m (Fig. 6K-3), but in the eastern part of the basin increases to 340 m. The Kapullu Formation grades laterally and vertically into underlying the Kırmızıgüney and İnekpınarı formations. In the southwestern part of the basin the contact between the Malatya Metamorphics of the basement and the Kapullu Formation is a normal fault.

The pelagic limestones are greyish, thin to medium-bedded (10–50 cm), consisting of biomicrite (rarely micrite) and reddish, medium-bedded silicified micrite, partially clayey. Limestones generally occur in the eastern part of the basin. The mudstones are greenish, moderately consolidated thin to thick-bedded (5–110 cm), generally tabular cross-laminated and locally calcareous mudstone. The turbiditic sandstones are brownish, thin to medium-bedded (5–50 cm), well-consolidated and with a moderate lateral extent. Internally, they may appear crudely normally graded and parallel laminated, developing an incomplete turbidite sequence (Td-e). The bases of the beds are sharp

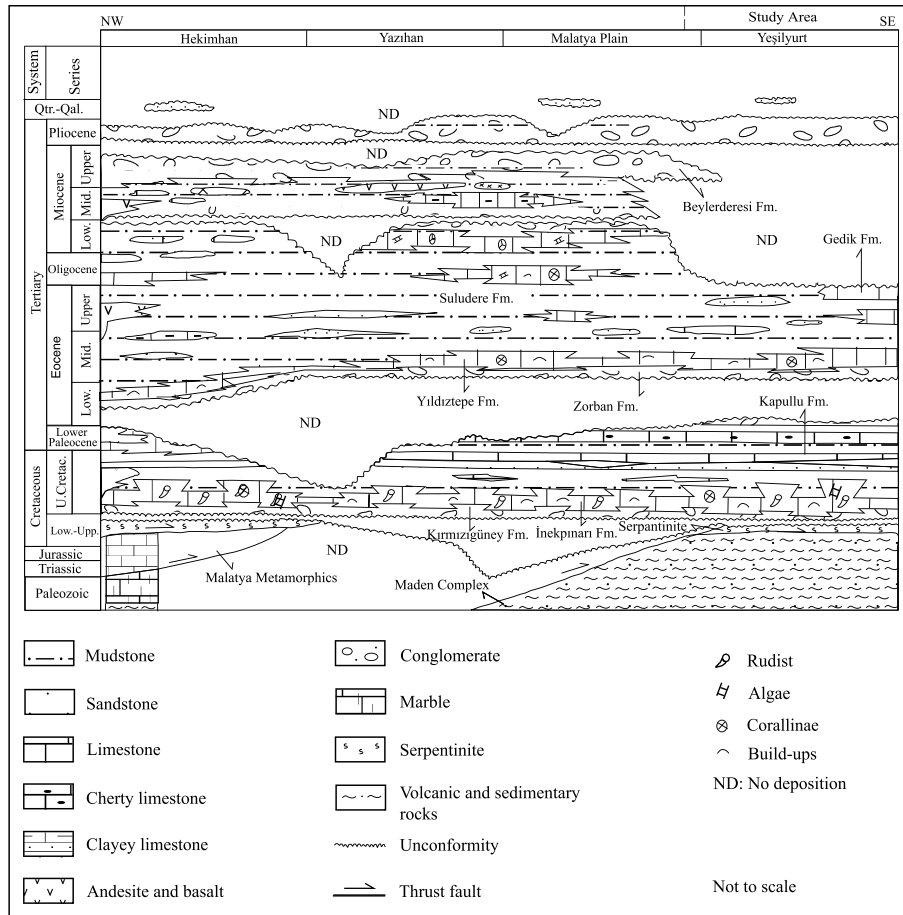


Fig. 5. Schematic cross-section showing stratigraphic and tectonic relations of the basement rock units and cover rock units in the Malatya Basin (Qtr: Quaternary, Qal: Alluvium).

with flute and groove marks. Reddish cherty limestones occur in the upper part of the unit, and are medium-bedded (40–100 cm). Olistostromes occur in the middle part of the unit. They were derived from the Malatya Metamorphics and the underlying older beds. Clasts are marble, dolomite, assorted schists, metasandstones and pelagic limestones. They were transported by gravity flow down a continental slope to the deep sea.

The foraminifera found within the Kapullu Formation indicate a Maastrichtian–Lower Paleocene age (Önal and Gözübol, 1992; Demir, 1997; Sirel, 1998): *Omphalocyclus macroporus* (Lamarck) *Haymanella paleocenica* Sirel and *Planorbulina create* (Marsson). Composition, lithologic features and fossils indicate that the formation was deposited in foreslope and deep shelf margin environments (Figs. 3, 6K-3, and 8).

2.3. Middle-upper Eocene

2.3.1. Yesilyurt Group (Gözübol and Önal, 1986)

The Yesilyurt Group consists of sandstone and mudstone with interbedded conglomerate, shelf carbonate and flysch-like successions; its total thickness exceeds 345 m. The Yesilyurt Group was deposited in a variety of environ-

ments, ranging from alluvial and fluvial, via shelf lagoon, carbonate buildups, to foreslope and deep shelf margin environments. The Yesilyurt Group has been divided into four formations (Figs. 2 and 3). These are, in ascending stratigraphic order, are the Zorban, Yıldıztepe, Suludere and Gedik formations. The unit rests with angular unconformity on the Gündüzbey Group (Upper Cretaceous–Paleocene). According to the fossils found (Planktic foraminifera: *Acarinina bullbrookii* (Bolli), *Globigerina eocena* Gümbel, *Turborotalia cerroazulensis pessagnoensis* (Toumarkine and Bolli) and *Turborotalia cerroazulensis cerroazulensis* (Cole) and benthic foraminifera: *Eorupertia* sp. and *Linderina* sp.) the age of the Yesilyurt Group is Middle-Upper Eocene.

2.3.2. Zorban Formation

The Zorban Formation begins with basal conglomerates resting on an erosional surface cut into the underlying Kapullu Formation. It consists of reddish-brown sandstone–mudstone with interbedded conglomerates. The conglomerates are medium to thick-bedded (60–800 cm), poorly to moderately sorted, well consolidated and generally matrix-supported. The clasts vary from pebbles to boulders up to 1 m diameter. Clasts are generally sub-

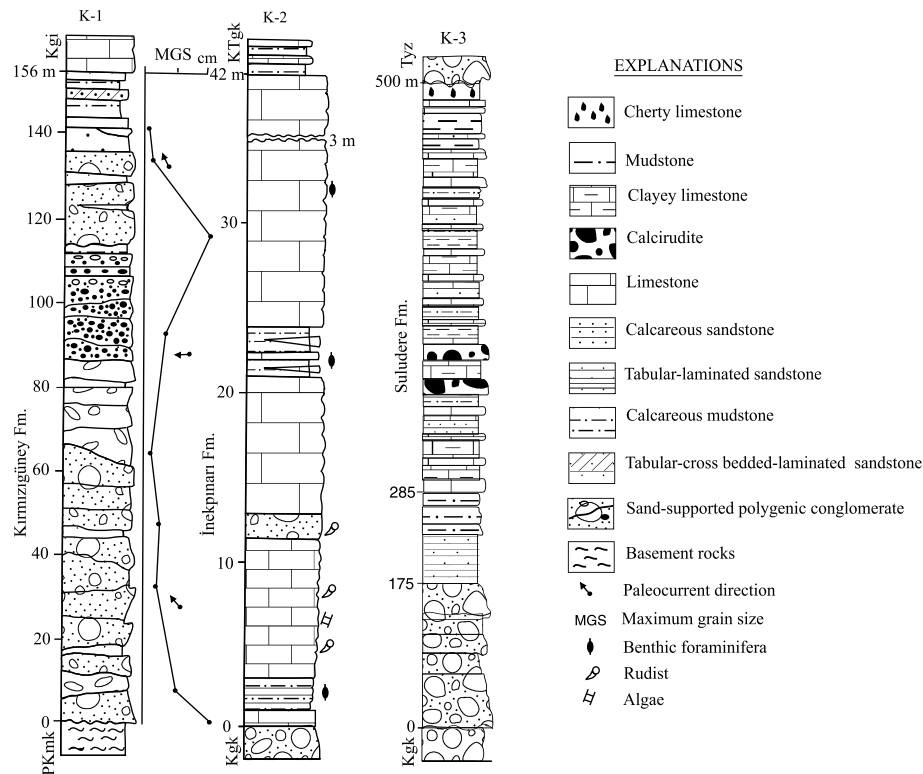


Fig. 6. Type sections of the Kırmızıgüney, İnekkınarı and Kapullu formations (PKmk: Malatya Metamorphics, Kgk: Kırmızıgüney Formation, Kgi: İnekkınarı Formation, KTgk: Kapullu Formation, Tyz: Zorban Formation).

rounded to rounded and show an overall fining upward. The clasts were derived from the underlying rock units and consist of marble, schist, limestone, sandstone and conglomerate. These coarse clastics interfinger and alternate with the other rocks types of the Zorban Formations. The beds of the conglomerate contain trough and tabular cross-stratification. Sedimentary structures indicate that the transport direction was from south to north.

Sandstones are generally thin to thick bedded (20–900 cm), well consolidated, poorly sorted, fine to coarse-grained and interbedded with conglomerates. Several types of the cross-strata within the sandstone are present, including trough and tabular in the lower part of the unit (Fig. 7K-4). The mudstones are thin to thick-bedded (30–640 cm), tabular laminated and moderately consolidated.

The thickness of the formation is 44 m in the type section (Fig. 7K-4). Foraminiferal assemblages found in the upper part of the Zorban Formation, indicate a Middle Eocene age. Fossil content, sedimentary and stratigraphic features of the formation indicate that it was deposited in alluvial fan, braided river and shallow marine environments. From these features, it is clear that it had an overall transgressive development.

2.3.3. Yıldıztepe Formation

The Yıldıztepe Formation is characterized by foraminifera, algae, coralline-bearing reef-like limestones with mudstone, calcareous sandstone, claystone and sandy limestone interbeds. The limestones are composed generally of bio-

lithic, biostromitic, biomicritic and sandy micritic limestones. As shown in the type section (Fig. 7K-5), calcareous sandstone and mudstone alternations occur in the lower part of the unit; in the upper part of the formation calcareous sandstones pass into limestone. Limestones are white-gray, medium to thick-bedded (25–300 cm), and include coral build-ups up to 30 m thick. In the type locality the Yıldıztepe Formation commences with a calcareous sandstone and mudstone alternation resting on the underlying Zorban Formation. The thickness of the unit in the type section is up to 12 m (Fig. 7K-5).

Benthic foraminifera (*Nummulites bayhariansis* Checchia-Rispoli and *Fabiania cassis* (Oppenheim)) indicate a Lutetian age, Önal and Gözübol (1992), Sirel and Acar (1993), Demir (1997) and Sirel (1998). Its composition, lithologic features and fossils indicate that the formation was deposited in a shelf lagoon and associated reefal environments (Fig. 9). The lagoonal environments are characterized by abundant Miliolids.

2.3.4. Suludere Formation

The Yıldıztepe Formation grades vertically and laterally into Suludere Formation. The Suludere Formation is a flysch-like succession made up of interbedded conglomerates, sandstones and mudstones, arranged in a series of generally thickening upward sequences, with lenticular limestone and marl. The thickness in its type section is 243 m (Fig. 7K-6), increasing to 350 m in the western part of the basin.

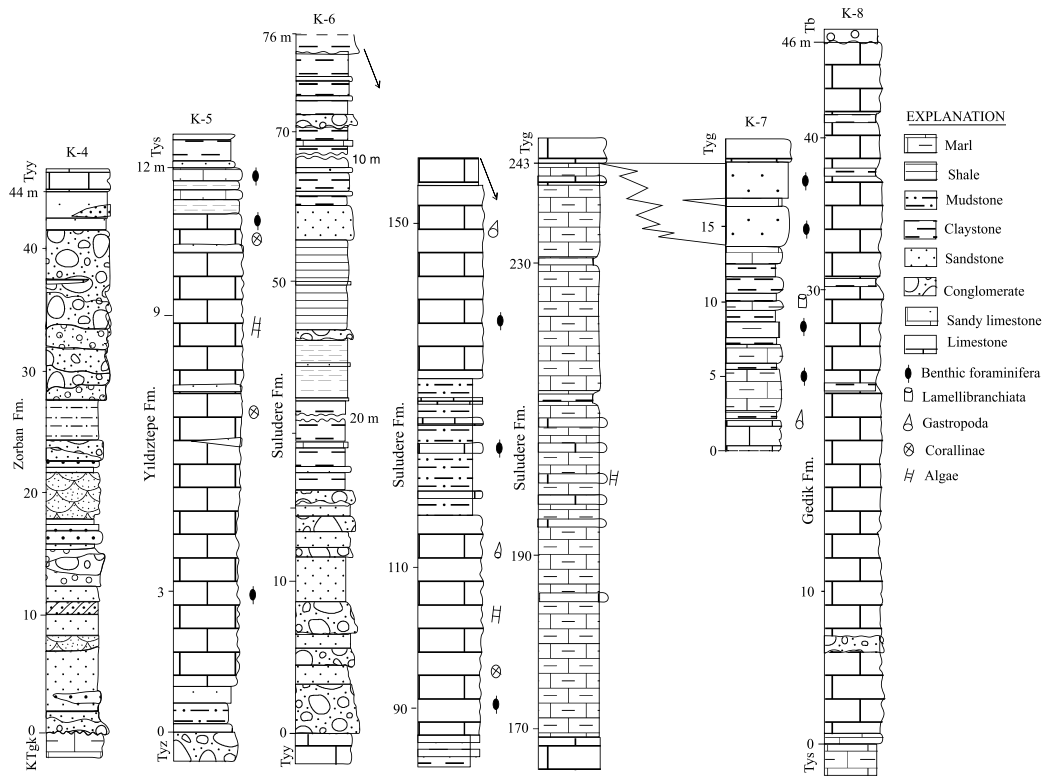


Fig. 7. Type and reference sections of the Zorban, Yildiztepe, Suludere and Gedik formations (KTgk: Kapullu Formation, Tyz: Zorban Formation, Tyy: Yildiztepe Formation, Tys: Suludere Formation, Tyg: Gedik Formation).

The conglomerates are greyish, medium to thick-bedded (65–320 cm). The beds are medium grained and well consolidated, persisting laterally to several hundreds of meters. They may be graded crudely and frequently show fining upwards and parallel lamination. The bases of the beds are sharp, with abundant flute and groove marks, while the tops grade into sandstone. A sandy matrix supports most of the conglomerates. The sandstones are brownish, thin to thick-bedded (5–320 cm), well consolidated and of moderate lateral extent. The beds show internal structures including a crude normal grading, with parallel laminated upper parts. The mudstones are greyish medium to thick-bedded (50–300 cm) and parallel laminated. Local gray-white limestone beds are calcarenites and calcirudites, lenticular, thin to thick-bedded (20–400 cm), with a bed thickness of up to 29 m. Lenticular marls in the upper part of the unit are yellowish-whitish, medium to thick-bedded (50–180 cm), with a thickness of up to 74 m.

The lower part of the unit consists of proximal turbidites, but the middle part is comparable to classical distal turbidites. Sandstones in the upper part of the unit contain plentiful benthic foraminifera (Fig. 7K-7). Planktic (*Acarinina bullbrookii* (Bolli), *Globigerina eoacaena* Gümbel, *Turborotalia cerroazulensis pessagnoensis* (Toumarkine and Bolli) and *Turborotalia cerroazulensis cerroazulensis* (Cole)) and benthic foraminifera (*Eorupertia* sp. and *Linderina* sp.) fossils indicate that the Suludere Formation is of Middle to Upper Eocene age (Gözübol and Önal, 1986; Sirel and

Acar, 1993; Demir, 1997). The sedimentary features and fossils indicate that the formation was deposited as neritic shelf (carbonates) in foreslope and deep shelf-margin environments (Fig. 9).

2.3.5. Gedik Formation

The Gedik Formation consists of limestone with sandy limestone, calcirudite and calcareous mudstone interbeds. The limestones are gray-white and thin to thick-bedded (20–150 cm). A lenticular coral build-up is present in the lower part of the unit. In the type section, the Gedik Formation is 46 m thick (Fig. 7K-8). The calcareous mudstones are green-colored, thin to medium-bedded (10–40 cm) and rarely (tabular) laminated. The calcirudites are greyish, medium to thick-bedded (30–50 cm), poorly sorted, micrite supported, ungraded, badly organized, but well consolidated with poorly rounded clasts.

The unit forms a regressive sequence interfingering vertically and laterally with the underlying the Suludere Formation. It is overlain with angular unconformity by the Beylerderesi Formation (Fig. 2). Benthic foraminifers (*Eorupertia* sp. and *Fabiania cassis* (Oppenheim)) fossils found within the limestones indicate a Middle-Upper Eocene age (Fig. 9; Önal and Gözübol, 1992; Demir, 1997). The composition, lithologic features and fossils (Fig. 9) indicate that the Gedik Formation was deposited in shelf lagoon and reefal environments. The presence of Miliolids confirms a shelf lagoon environment.

2.4. Upper Miocene

2.4.1. Beylerderesi Formation

The Beylerderesi Formation (Gözübol and Önal, 1986) begins with basal conglomerates, unconformably overlying the older rock units in the northern part of the study area. The formation consists of reddish-brown conglomerate–sandstone–mudstone alternations. The thickness of the type section is 50–500 m (Önal and Gözübol, 1992). The conglomerates are thick bedded (20–500 cm), poorly to moderately sorted, well consolidated and generally sand-supported. The clasts are in the range of pebble to boulder size, up to 4.5 m diameter, generally subrounded to rounded, and show upward fining. The clasts consist of marble, dolomite, limestone and schist derived from the underlying rock units. The conglomerate beds often show trough cross-stratification. The sandstones are generally reddish, thin bedded (2–20 cm), cross-bedded, well consolidated and poorly sorted. The beds are laterally discontinuous, passing from conglomerate to sandstone by a reduction in grain size. The mudstones are reddish-brown, thin to

thick bedded (5–300 cm), tabular laminated and well consolidated. The unit rests with angular unconformity on the Yesilyurt Group (Middle-Upper Eocene).

No fossils have been found in the Beylerderesi Formation in the study area. The most likely age of the unit is Upper Miocene (Gözübol and Önal, 1986). Its sedimentary and stratigraphic features indicate deposition in alluvial and fluvial environments.

3. Paleoenvironmental interpretations

3.1. Upper Cretaceous–Lower Paleocene sequence

This sequence consists of the Kırmızıgüney, İnekpınarı and Kapullu formations (Fig. 3). Depositional environments of the İnekpınarı and Kapullu formations are defined according to Wilson (1975; as modified by Flügel, 2004), and the environmental distribution of selected index planktic and benthic foraminifer in the study area, are given in Fig. 8. Facies are defined from the bottom to the top of the sequence as follows: (1) Alluvial and fluvial

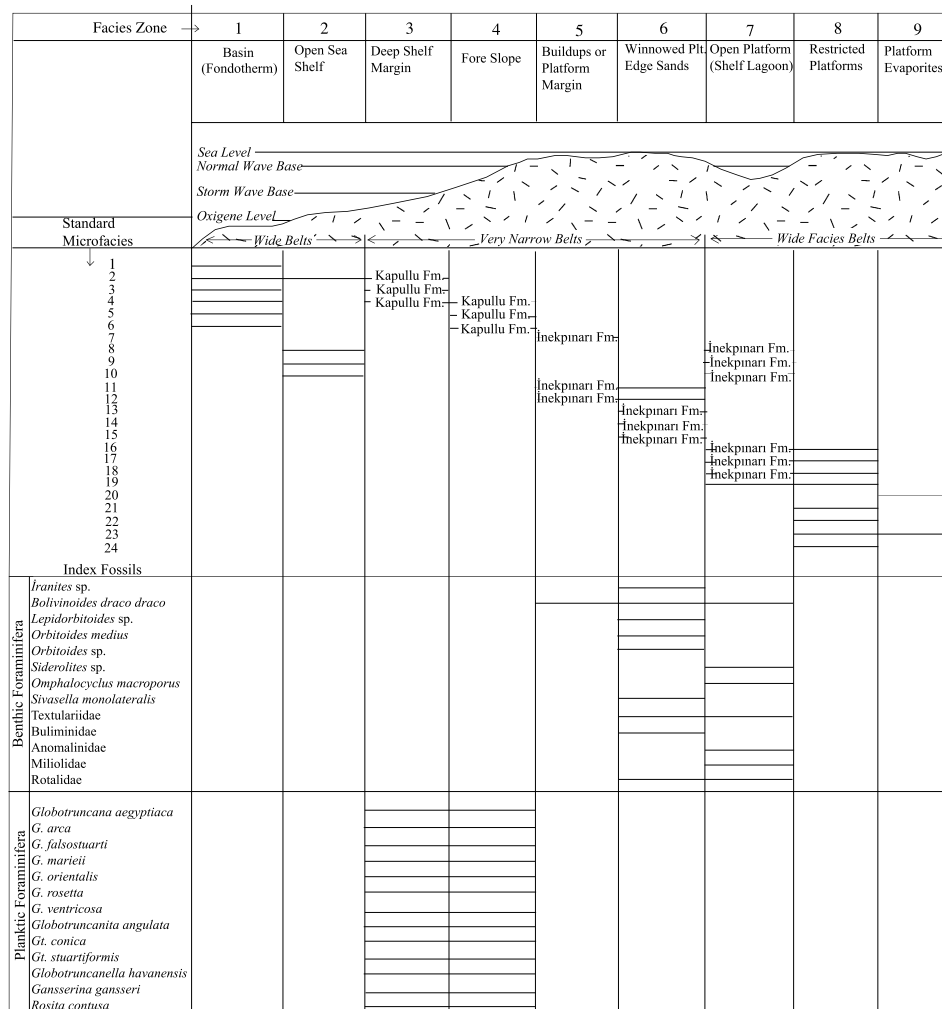


Fig. 8. Interpreted depositional environments of the İnekpınarı and Kapullu formations according to the facies model of Wilson (1975; modified by Flügel, 2004) and environmental distribution of selected index planktic and benthic foraminifer fossils in the study area.

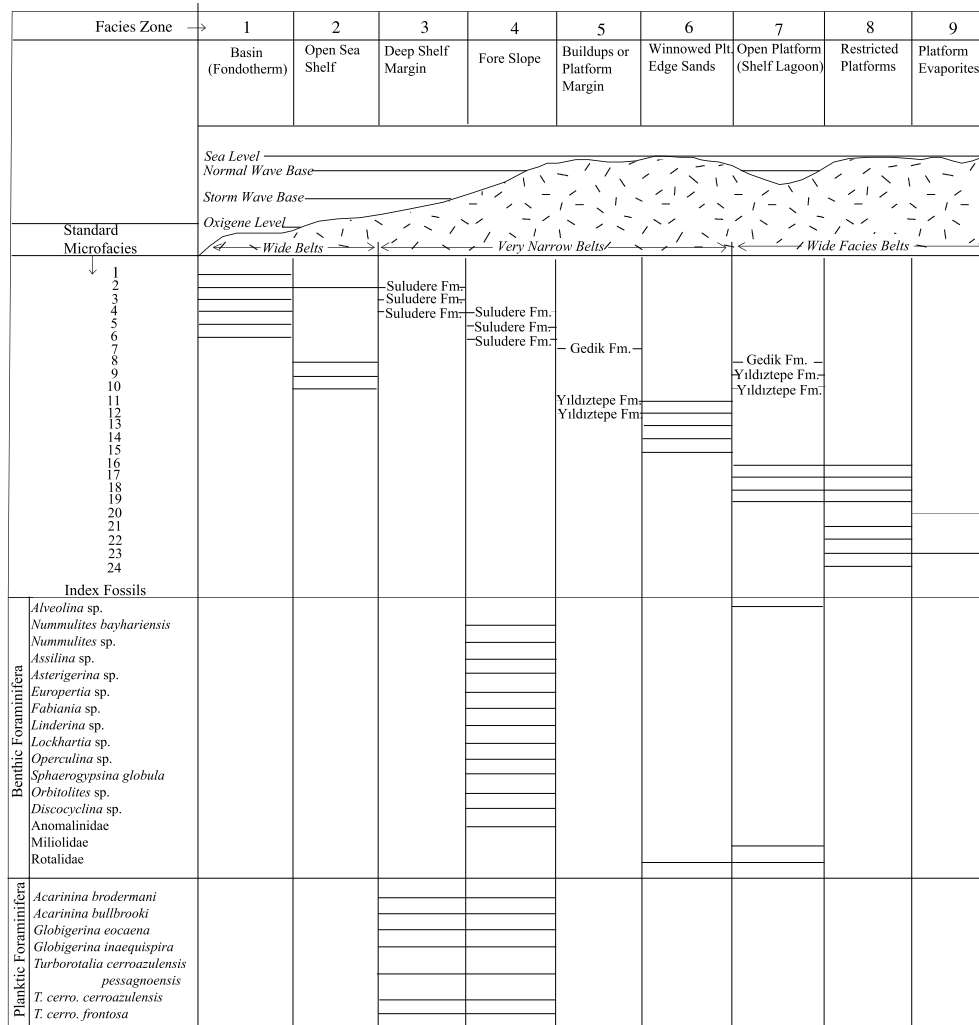


Fig. 9. Interpreted depositional environments of the Yıldıztepe, Suludere and Gedik Formations according to the facies model of Wilson (1975; modified by Flügel, 2004) and environmental distribution of selected index planktic and benthic foraminifer fossils in the study area.

facies; (2) Marine to lagoon facies; (3) Calcarenite and calcirudite facies; (4) Reefal facies; (5) Foreslope facies; (6) Open shelf and basin facies; (7) Cherty limestone facies.

3.2. Middle-Upper Eocene sequence

This sequence includes the Zorban, Yıldıztepe, Suludere and Gedik formations (Fig. 3). The depositional environments of these formations, defined according to Wilson (1975; re-arranged by Flügel, 2004), as indicated by selected index planktic and benthic foraminifer fossils are shown in Fig. 9. Facies are defined from bottom to top of the sequence as follows: (1) Alluvial and fluvial facies; (2) Marine to lagoon facies; (3) Reefal facies; (4) Foreslope facies; (5) Open shelf and basin facies.

3.3. Upper Miocene sequence

This is represented by the Beylerderesi Formation (Fig. 3) composed of reddish-brown sandstone–mudstone with interbedded conglomerate cycles. No fossils were

found in the alluvial and fluvial terrestrial deposits of this formation (Fig. 3).

4. Tectonic evolution of the Malatya Basin

The Southeast Anatolian Belt constitutes the western part of the Bitlis-Zagros orogen, and is a good example of a collision-related mountain range (Sengör and Kidd, 1979; Sengör and Yilmaz, 1981). In the Late Cretaceous, to the west, the southern branch of Neotethys formed between the Arabian Plate and the Taurus Belt (Fig. 10A). The arrangement of the Malatya metamorphic units belonging to the Taurus Belt indicate that ophiolite was obducted onto the Arabian Platform during late Campanian–early Maastrichtian time (Elmas and Yilmaz, 2003). In the Malatya Basin, the Campanian–early Paleocene interval, represented by the Gündüzbey Group, is composed of alluvial–fluvial–reefal and flysch-like sedimentary rock associations, deposited in a fore-arc environment at the same time as the formation of the Yüksekova Group (Fig. 10B and C). During late Cretaceous–early

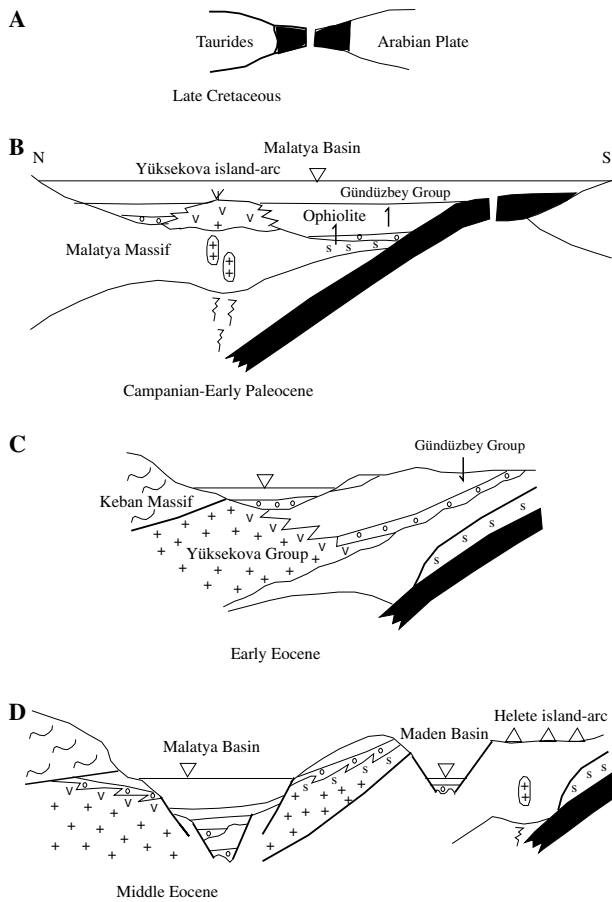


Fig. 10. Tectonic evolution of the Malatya Basin from Late Cretaceous to Middle Eocene.

Paleocene time, the study area was located in the southern part of the fore-arc. In the Malatya Basin, volcanic activity in the Yüksekova island-arc ended in late-early Paleocene time and basal sedimentation (the Gündüzbey Group) occurred in the late Campanian and continued into the early Paleocene, and ended in late-early Paleocene time. Both of these events were due possibly to the southward advance of the ophiolitic nappe (Fig. 4).

During Middle Eocene time, the Yüksekova island-arc volcanism was replaced to the south by the Helete volcanic island-arc (Yılmaz, 1993). The Maden Group was formed in a short-lived back-arc basin behind the Helete volcanic chain (Elmas and Yılmaz, 2003). The Maden Basin closed at the end of the Middle Eocene, due to the southward advance of the nappes that were emplaced onto Maden Group (Yılmaz, 1993; Yığıtbas and Yılmaz, 1996) (Fig. 4). The Middle-Upper Eocene Malatya Basin was formed due to block faulting in a back-arc setting at the beginning of the Middle Eocene (Fig. 10D). The basin closed at the end of the Lower Miocene (Alkan, 1997; Demir, 1997; Önal, 1998), but in the study area, it had closed already by the end of the Upper Eocene. Closure was related to the southward emplacement of the nappes (Fig. 4). The Middle-Upper Eocene interval is represented by continental-shallow marine and deep-sea deposits (the Yesilyurt Group).

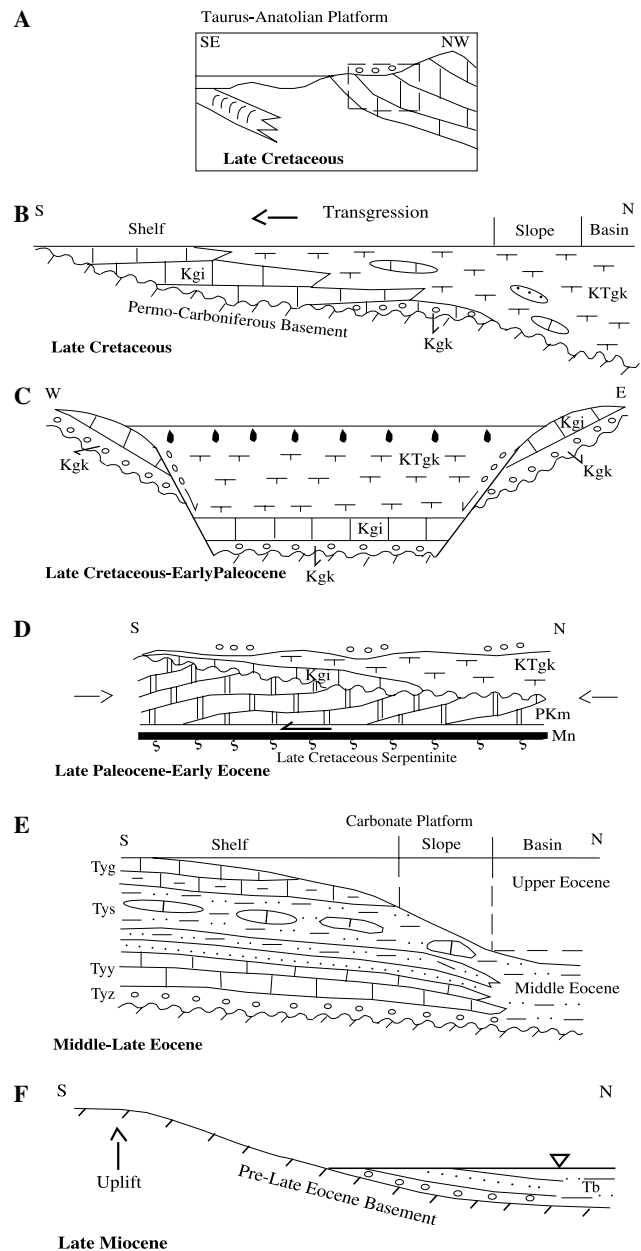


Fig. 11. Paleogeographic cross-section, depositional models and paleostructural cross-sections of the southern parts of the Malatya Basin for late Cretaceous–late Miocene (PKm: Malatya Metamorphics, Kgk: Kırmızıgüney Formation, Kgi: İnekpınarı Formation, KTgk: Kapullu Formation, Tyz: Zorban Formation, Tyy: Yıldıztepe Formation, Tys: Suludere Formation, Tyg: Gedik Formation, Tb: Beylerderesi Formation, Mn: Malatya Nappe).

5. Tectono-sedimentary evolution of the study area

The southern assemblage of the Malatya Basin is a transgressive sequence, which begins in the Late Cretaceous–Early Paleocene with continental deposits of the Kırmızıgüney Formation (Kgk) composed of sandstone and mudstone interbedded with conglomerate (Fig. 11A–C). This is followed by the İnekpınarı Formation (Kgi) of rudist-bearing reefal limestones (Fig. 11B and C), which passes into conglomerate interbedded with limestone, sand-

stone and mudstone alternations, and cherty limestones of the Kapullu Formation (KTgk) (Figs. 11B and C). Step-wise growth faults possibly of Upper Cretaceous age, which occur dominantly at the contact between the Upper Cretaceous and rocks and the basement of Permo-Carboniferous Malatya Metamorphics, in the southern part of the basin have a large displacement. Alluvial, fluvial, shelf, slope and basin sediments were deposited locally during Late Cretaceous–Early Paleocene time in a symmetric depression controlled by growth faults along the southern margin of the basin which operated throughout the Late Cretaceous (Alkan, 1997; Demir, 1997) (Fig. 11C). In addition, intraformational breccias, synsedimentary mesoscopic folds and olistoliths are observed, indicating the continuation of synsedimentary tectonism on the southern margin of the basin during the deposition of the Kapullu Formation. Sedimentation was terminated by a regression in the Early Paleocene. During the Late Paleocene–Early Eocene the Malatya area was uplifted, possibly due to the southward advance of the ophiolite nappe (Fig. 11D).

During the Early Eocene the extensional regime changed to a compressional regime. In this new tectonic regime, the Permo-Carboniferous Malatya Metamorphics and Upper Cretaceous–Lower Paleocene units in the basin were imbricated southward to form the Malatya Nappe. The area became continental as a result of this early Eocene compressive tectonism and uplift (Fig. 11D). This compressive phase was completed at the end of the Early Eocene.

At the beginning of the Middle Eocene the compressional regime changed to an extensional regime and the Malatya Basin was formed due to block faulting (Özkul and Kerey, 1996; Alkan, 1997; Demir, 1997; Önal, 1998). This region was affected by this extensional tectonic regime, with strong subsidence, throughout Middle-Late Eocene time (Fig. 11E). The southern assemblage of the Malatya Basin is a transgressive sequence, which begins with the Zorban Formation (Tyz) of sandstone, and mudstone with interbedded conglomerate (Fig. 11E), followed by the Yıldıztepe Formation (Tyy) of *Nummulites*-bearing reefal limestones, which pass upward into the flysch-like Suludere Formation (Tys), which again shoal upward into *Nummulites*-bearing limestones of the Gedik Formation (Tyg) (Fig. 11E). These regressive shallow marine sediments are interpreted as indicating a change in the tectonic regime towards the end of the Late Eocene, giving rise to uplift and erosion. In the Upper Miocene a new phase of subsidence resulted in the deposition of red clastic sediments of the Beylerderesi Formation (Tb) (Fig. 11F). In the northern parts of the basin, marine sedimentation developed during the Oligocene–Lower Miocene, while in the study area to the south sedimentation was continental (Fig. 5). The N–S compression which affected the region during the Late Paleocene, Early Eocene and at the end of the Eocene, was probably related to the movement of the Malatya Nappe (Fig. 4).

The Suture Mountains Rock Unit forms a nappe package consisting of the Permo-Carboniferous Malatya Meta-

morphics at the top, underlain by the Upper Cretaceous serpentinite and the Middle-Upper Eocene Maden Complex and Çelikhan Formation at the base (Fig. 4).

6. Conclusions

The southern part of the Malatya Basin contains a sedimentary succession up to 700 m thick resting on basement rocks and divided into three main sequences, each separated by an unconformity. From base to top, these are: (1) Upper Cretaceous–Lower Paleocene, (2) Middle-Upper Eocene and (3) Upper Miocene.

The Late Cretaceous–Early Paleocene interval is represented by continental, shallow and deep marine sedimentary rock associations of the Gündüzbey Group developed in the southern part of a fore-arc environment simultaneously with the Yüksekova Group.

The Middle-Late Eocene interval consists of continental, shallow and deep marine sedimentary rock associations of the Yesilyurt Group developed in a back-arc basin behind the Helete volcanic chain.

The Upper Miocene sedimentary sequence was deposited in alluvial and fluvial environments.

The rock succession which occurs in the southern part of the Malatya Basin may be classified, from base to top, into four tectonic units: the lower allochthon (Basement rocks) the upper allochthon (Basement rocks), the paraautochthon (Late Cretaceous–Early Paleocene and Middle-Late Eocene) and autochthonous rock unit (Late Miocene). During Late Paleocene, Early Eocene and at the end of the Eocene, a N–S compressional regime occurred in the region probably originating from movements of the Malatya Nappe.

Acknowledgments

The Turkish Council supported Fieldwork for Scientific and Technical Research (TUBITAK, Project No.: TBAG-647) in Ankara. The authors wish to thank the management and technical staff of Tübitak for their assistance we also thank Didem Eren and Çigdem Dagdeviren for drafting assistance.

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