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Geology of Turkey: A Synopsis

Abstract

Turkey consists of several continental fragments which were joined together into a single landmass in the late Tertiary. During most of the Phanerozoic these continental fragments, called terranes, were separated by oceans, whose relicts - ophiolites and accretionary prisms - are widely distributed throughout the Anatolia. The three terranes in the northern Turkey, the Strandja, İstanbul and Sakarya, are collectively called as the Pontides. These Pontic terranes show Laurasian affinities, and were only slightly affected by the Alpide orogeny; they preserve evidence for Variscan and Cimmeride orogenies. The Pontic terranes were amalgamated into a single terrane by the mid Cretaceous times. The Anatolide-Tauride terrane south of the Pontides shows Gondwana affinities but was separated from Gondwana in the Triassic and formed an extensive carbonate platform during the Mesozoic. The Anatolide-Tauride terrane was intensely deformed and partly metamorphosed during the Alpide orogeny; this leads to the subdivision of the Anatolides-Taurides into several zones on the basis of the type and age of metamorphism. The Central Anatolian Crystalline Complex, or the Kırşehir Massif, is a large area of Upper Cretaceous metamorphic and plutonic rocks. Its affinity, whether part of the Anatolide-Tauride terrane or a terrane on its own, is still debated. The southeast Anatolia forms the northernmost extension of the Arabian platform. It shows a stratigraphy similar to the Anatolides-Taurides with a clastic-carbonate dominated Palaeozoic and a carbonate dominated Mesozoic succession. A new tectonic era started in Anatolia in the Oligo-Miocene after the final amalgamation of the various terranes. This neotectonic phase, which is continuing today, is characterized by continental sedimentation, widespread calcalkaline magmatism, extension and strike-slip faulting.

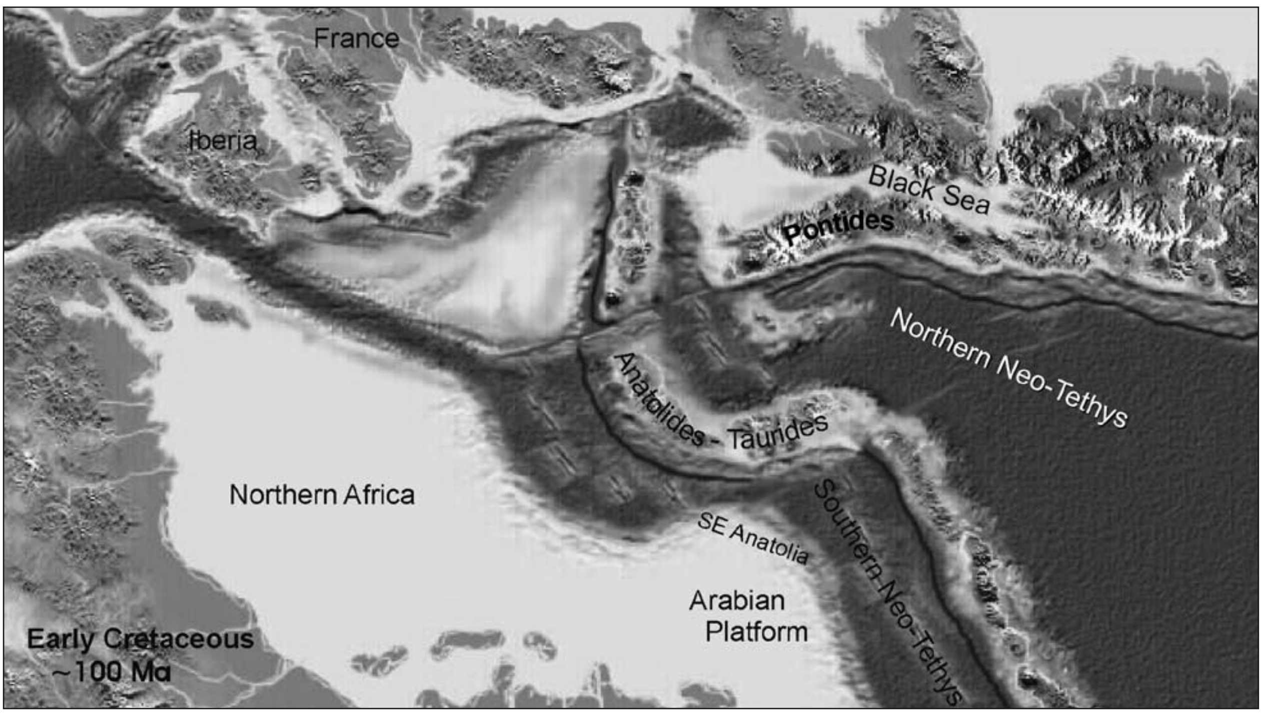

Fig. 1: A view of the Mediterranean palaeogeography during the Early Cretaceous (110 Ma). Modified after http://jan.ucc.nau.edu/~rcb7/globaltext.html. Note the absence of Anatolia as a single landmass.

Introduction

If we went back in time to 100 million years ago and looked at the Mediterranean from the space, we would have not recognised Anatolia. In the place of the Anatolia there was a large ocean, and the various continental fragments, which make up Anatolia, were distributed on either side of this ocean or formed islands within this ocean (Fig. 1). This ocean, called Tethys, existed at least since 350 Ma between the two large continents of Gondwana in the south and Laurussia in the north. A further complexity was that the Tethys was not a single wide ocean as the present-day Atlantic, but consisted of several relatively narrow oceanic seaways separated by island arcs or continental slivers, called terranes, much as the present-day southwest Pacific (Fig. 1). The final closure of the Tethyan oceans and the collision between the different terranes resulted in the Alpide orogeny and the creation of Anatolia as a single landmass in the Oligocene.

Turkey is characterized by a very complex geology, whose main features are still poorly understood despite an increasing amount of geological data that have become available in the last 25 years. The complex geology has resulted in widely different views on the geological evolution of Turkey. Every geological picture of Turkey will therefore be a personal one and subject to future modifications and corrections. The geology of Turkey as outlined here is based on over 30 years of fieldwork and extensive knowledge of the international and national geological literature on Turkey. The aim is to give a brief but comprehensive introduction to the geology of Anatolia. To keep the article to a manageable size, I have avoided discussion on the contentious issues, such as the location and nature of the Palaeo-Tethyan sutures, or the structure of the Menderes Massif and tried to restrict the cited literature to widely available sources.

Turkey is geologically divided into three main tectonic units: the Pontides, the Anatolides-Taurides and the Arabian Platform (Fig. 2, Ketin 1966). These tectonic units, which were once surrounded by oceans, are now separated by sutures, which mark the tectonic lines or zones along which these oceans have disappeared. The Pontides exhibit Laurussian affinities and are comparable to the tectonic units in the Balkans and the Caucasus, as well as those in the central Europe (Fig. 2). They all were located north of the northern branch of the Neo-Tethys. The complete closure of this ocean resulted in the İzmir-Ankara-Erzincan suture, which marks the boundary between the Pontides and the Anatolides-Taurides (Fig. 3). The Anatolides-Taurides show Gondwana affinities but were separated from the main mass of Gondwana by the southern branch of Neo-Tethys. They are in contact with the Arabian Platform along the Assyrian suture (Fig. 3). The northern margin of the Arabian Platform is represented by southeast Anatolia south of the Assyrian suture.

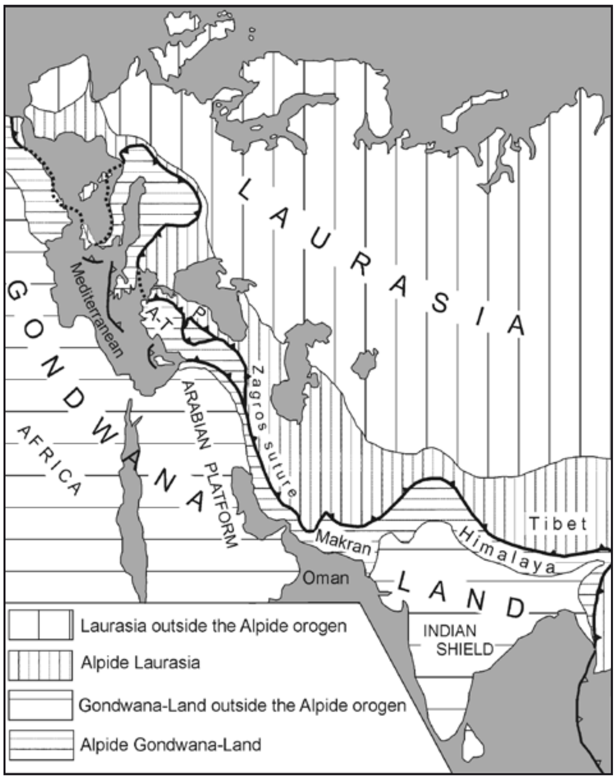

Fig. 2: Tectonic setting of Turkey within the Alpide-Himalayan chain (modified after Şengör 1987). A-T: Anatolides-Taurides; P: Pontides.

The Anatolian peninsula is surrounded on three sides by seas, which exhibit widely differing geological features. The Black Sea in the north is an oceanic back-arc basin. It formed during the Cretaceous behind and north of the Pontide magmatic arc as a result of the subduction of the northern Neo-Tethys ocean (e.g. Görür 1988). In the pre-Cretaceous times, the Pontides were adjacent to Dobrugea and Crimea. The Aegean is a geologically young sea, which started to develop during the Oligo-Miocene as a result of north-south extension above the retreating Hellenic subduction zone (e.g. Jolivet 2001). The Eastern Mediterranean represents a relic of the southern branch of the Neo-Tethys (Fig. 1), and is much older than the other seas (e.g. Garfunkel 2004).

The Palaeo- and the Neo-Tethys – Why the Two Oceans?

The geology of Turkey is closely linked up with the evolution of the Tethys ocean. Palaeogeographic reconstructions show that the Tethys ocean existed as a large embayment between Gondwana and Laurussian at least since the Carboniferous (e.g. Stampfli & Borel 2002). The Tethys ocean is commonly subdivided into Neo-

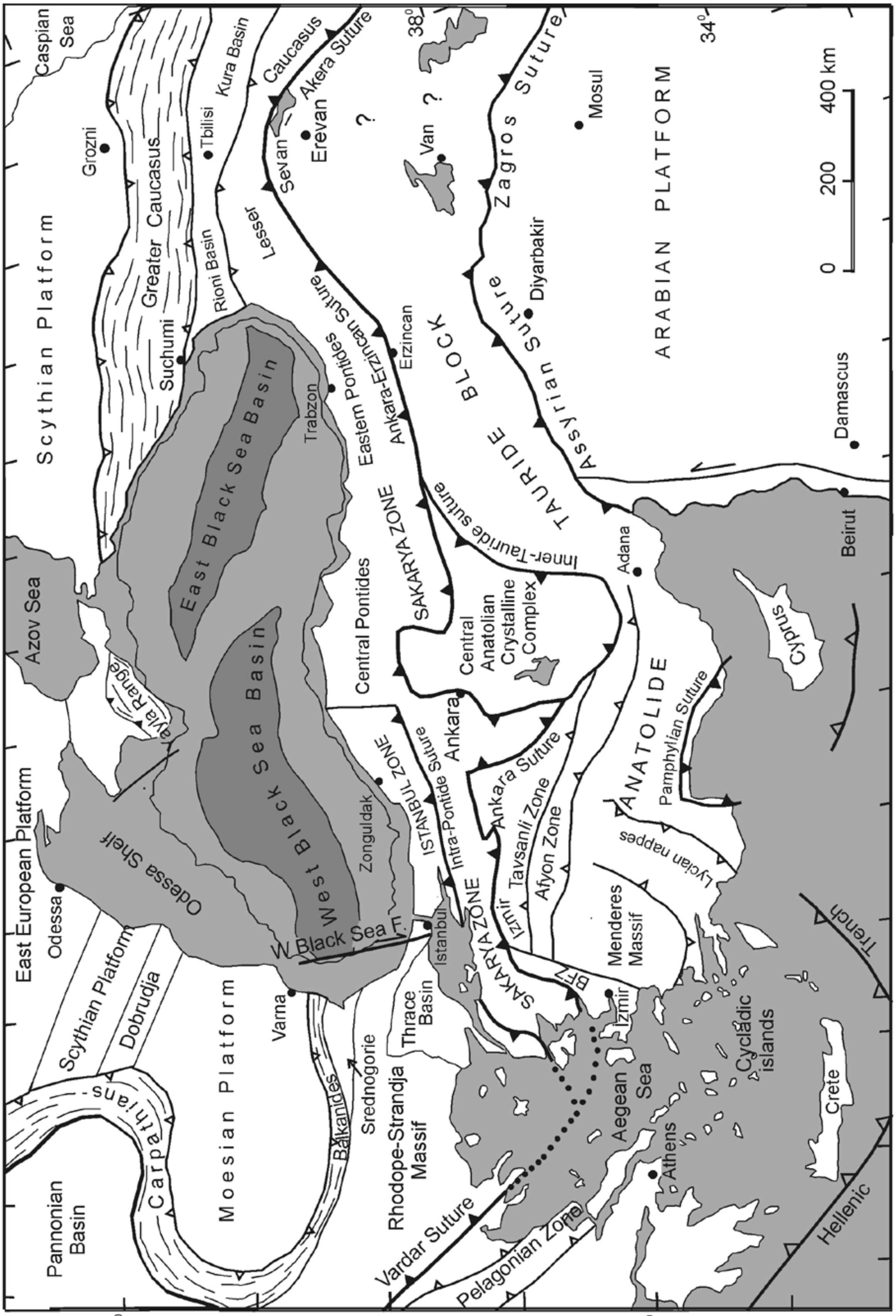

Fig. 3: Tectonic map of north-eastern Mediterranean region showing the major sutures and continental blocks. Sutures are shown by heavy lines with the polarity of former subduction zones indicated by filled triangles. Heavy lines with open triangles represent active subduction zones. The Late Cretaceous oceanic crust in the Black Sea is shown by grey tones. Small open triangles indicate the vergence of the major fold and thrust belts. BFZ denotes the Bornova Flysch Zone (modified after Okay & Tüysüz 1999).

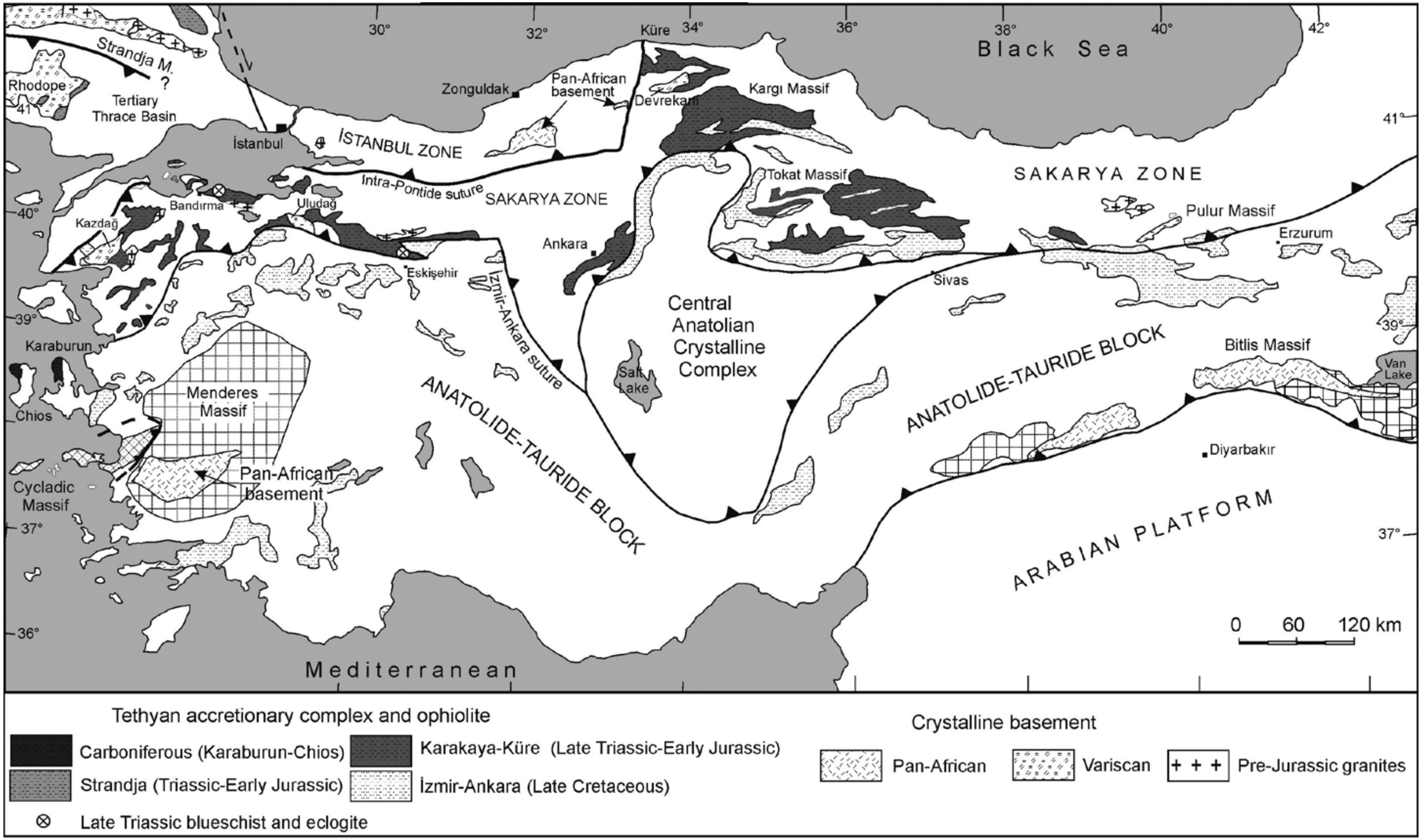

Fig. 4: Distribution of different basement types and accretionary complexes in Turkey (modified from Okay *et al.* 2006).

Tethys and Palaeo-Tethys, although there is little agreement on the definition of these terms and the location of these oceans (e.g. Şengör 1984; 1987; Stampfli 2000; Robertson *et al*. 2004). Nevertheless, there is a good reason for the existence of two distinct oceans rather than a single continuous Tethyan ocean, at least from the perspective of the Anatolian geology. The existence and age span of former oceans can be inferred from their preserved relics - ophiolites and accretionary complexes. All ophiolites in Turkey, which are directly or indirectly dated, are of Cretaceous age (Parlak & Delaloye 1999; Robertson 2002). The ophiolitic melanges, which generally represent former oceanic accretionary complexes, comprise radiolarian cherts of Triassic, Jurassic and Cretaceous ages (Bragin & Tekin 1996; Tekin *et al.* 2002), as well as fragments of Jurassic ophiolite (Dilek & Thy 2006). Therefore, the ophiolites and ophiolitic melanges in Anatolia represent fragments of Triassic and younger oceans. What is the evidence than for a Palaeozoic Tethys ocean? Although this question was discussed extensively in the 1980's (cf. Şengör *et al*. 1980; Şengör 1984), concrete evidence for a Palaeozoic Tethyan ocean came more recently from the Karakaya Complex, a highly deformed and partly metamorphosed tectono-stratigraphic unit in the Pontides, now widely interpreted as the accretionary complex of a Palaeozoic to Triassic Tethyan ocean (Tekeli 1981; Pickett & Robertson 1996; Okay 2000). The Karakaya Complex comprises Carboniferous and Permian radiolarian cherts, small undated ophiolite fragments and Triassic eclogites and blueschists (Okay & Göncüoğlu 2004). It represents the subduction-accretion units of a Permo-Triassic and possibly older Palaeo-Tethyan ocean.

The Permo-Triassic Karakaya Complex and the Cretaceous ophiolitic melange are intimately imbricated along the İzmir-Ankara-Erzincan suture (Fig. 4, e.g. Bozkurt *et al*. 1997; Okay *et al*. 2002). The well known Ankara melange of Bailey and McCallien (1953) comprises both the Palaeo- and Neo-Tethyan melanges. This indicates that there was no continental sliver between the Palaeo- and Neo-Tethyan oceans in the Anatolian transect with the implication that the İzmir-Ankara-Erzincan suture between the Pontides and the Anatolides-Taurides represents the trace of both the Palaeo-Tethyan and the main Neo-Tethyan sutures. The Palaeo- and Neo-Tethyan oceans must have co-existed during the Triassic but little is known about their spatial relations.

Conjugate or Exotic Margins

Opening of an ocean includes a rifting stage, where the continental crust is broken apart, such as that occurred during the opening of the Atlantic ocean. During the closure of the intervening ocean these conjugate margins could be brought back together. Alternatively the closure of an oceanic lithosphere can juxtapose continental pieces, which were never contiguous. A good example of this process is the case of the Indian subcontinent, which was rifted off from Gondwana and collided with Asia in the Eocene.

In Anatolia there are examples of both conjugate and exotic margins. The Anatolide-Taurides and the Arabian Platform represent approximate conjugate margins. They share a common Palaeozoic stratigraphy, including evidence for a common latest Ordovician glaciation (Monod *et al*. 2003). They were rifted off during the Triassic and were reassembled in the Miocene. In contrast, the Pontides and the Anatolide-Taurides were never contiguous. Although both are Gondwana terranes and have a similar latest Preacambrian Pan-African/Cadomian crystalline basement, they were located at widely separated margins of Gondwana. The Pontide terranes were rifted off from Gondwana during the Ordovician (Okay *et al*. 2008a), whereas the Anatolide-Taurides in the Triassic. Therefore, the common pictures of a northern Neo-Tetyhan ocean opening between the Pontides and the Anatolide-Taurides have no place in reality.

The Pontides

The Pontides comprise the region north of the İzmir-Ankara-Erzincan suture. They are folded and thrusts faulted during the Alpide orogeny but were not metamorphosed. In contrast to the Anatolides-Taurides, they bear evidence for Variscan (Carboniferous) and Cimmeride (Triassic) orogenies. The Pontides consists of three terranes, which show markedly different geological evolutions. These are the Strandja, İstanbul and Sakarya terranes.

The Strandja Massif

The Strandja Massif forms part of the large crystalline terrane in the southern Balkans, which also includes the Rhodope and Serbo-Macedonian massifs (Fig. 3). It consists of a Variscan crystalline basement overlain by a Triassic-Jurassic continental to shallow marine sedimentary sequence (Fig. 5). The basement is made up of predominantly quartzo-feldispathic gneisses intruded by Late Carboniferous and Early Permian (257 ± 6 Ma) granitoids (Okay *et al.* 2001; Sunal *et al.* 2006). The basement lithologies form a belt about 20 km wide extending from Bulgaria to Çatalca near İstanbul (Fig. 6).

A sedimentary sequence of Triassic and Jurassic age lies unconformable on the Variscan basement (Chatalov 1988). The Triassic series resemble the Germanic Triassic facies with a thick sequence of Lower Triassic continental clastic rocks overlain my middle Triassic shallow marine carbonates (Fig. 5, Hagdorn & Göncüoğlu 2007). At around the Jurassic-Cretaceous boundary (150-155 Ma) the Strandja Massif underwent a second

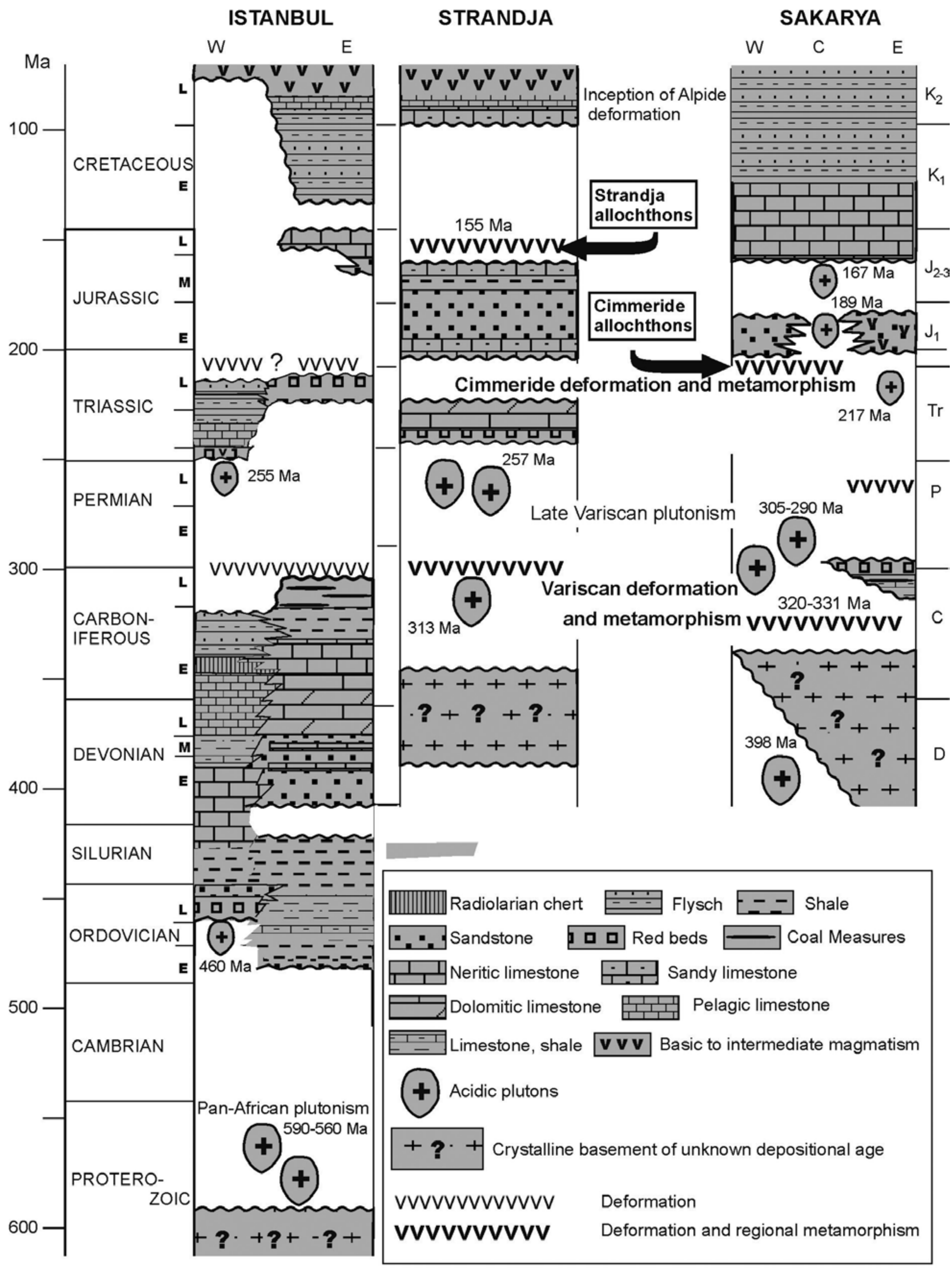

Fig. 5: Synthetic stratigraphic sections of the Istanbul, Strandja and Sakarya Zone terranes (Okay *et al.* 2008).

phase of deformation and metamorphism involving north to northeast vergent thrusting (Okay *et al*. 2001).

Following this mid-Mesozoic orogeny, the metamorphic rocks were exhumed and then were unconformably overlain by mid Cretaceous (Cenomanian) shallow marine sandstones. These sandstones pass up into a thick sequence of volcanic and volcanogenic rocks of Late Cretaceous age, which extend into the Sredna-Gora zone in Bulgaria (Fig. 3 and 6). This Upper Cretaceous magmatic belt can be followed all along the Pontides along the Black Sea coast and represents a magmatic arc developed above the northward subducting Neo-Tethyan ocean. In the Strandja Massif the Late Cretaceous magmatism also produced large number of andesitic dykes, sills, small intrusions and the Demirciköy pluton with an age of ca. 78 Ma (Moore *et al*. 1980).

The Istanbul Terrane

The İstanbul terrane is a continental fragment, 400 km long and 55 km wide on the south-western margin of the Black Sea (Fig. 3). It has a late Precambrian crystalline basement characterized by gneiss, amphibolite, metavolcanic rocks, metaophiolite and voluminous Late Precambrian granitoids (Chen *et al*. 2002; Yiğitbaş *et al*. 2004; Ustaömer *et al*. 2005). The basement is mainly exposed in the Bolu Massif north of Bolu (Fig. 7) and is unconformably overlain by a continuous and well-developed sedimentary succession of Ordovician to Carboniferous in age (e.g., Görür *et al.* 1997; Dean *et al.* 2000). There are marked stratigraphic differences between the western and eastern parts of the Istanbul terrane (Fig. 5 and 7). In the west the early Carboniferous is represented by deep sea turbidites forming a sandstone-shale sequence, over 2000-m-thick. Most of the European part of Istanbul north of the Golden Horn is built on this Carboniferous sandstone-shale sequence. In the east around Zonguldak the Early Carboniferous consists of shallow marine carbonates, which pass up into coal measures. These stratigraphic differences indicate a Carboniferous palaeogeography, which was characterized by deep siliciclastic sea in the west and by a shallow marine to continental area in the east. A similar facies changes during the Carboniferous is observed in northwest Europe (cf. Okay *et al.* 2006).

The Palaeozoic rocks were deformed by folding and thrusting during the Carboniferous and are overlain unconformable by a Triassic sedimentary sequence. The Triassic series is well developed east of Istanbul and shows a typical transgressive development starting with red sandstones with basaltic lava flows, passing up into shallow marine and then into deep marine limestones and ending with Upper Triassic deep sea sandstones and shales (Fig. 5). In the western part of the Istanbul Zone, the Jurassic and Lower Cretaceous sequence is absent, and the Palaeozoic and Triassic rocks are unconformable overlain by Upper Cretaceous-Palaeocene clastic, carbonate and andesitic volcanic rocks. In contrast, in the eastern part of the Istanbul Zone there is a thick Middle Jurassic to Eocene succession marked by small unconformities.

The Istanbul Zone shows a similar Palaeozoic-Mesozoic stratigraphy to that of Moesian Platform, and prior to the late Cretaceous opening of the West Black Sea Basin it was situated south of the Odessa shelf (Okay *et al* 1994). Together with similar Palaeozoic sequences farther west, including the Carnic Alps in Austria and Krajstides in Bulgaria, the Istanbul Zone and its continuation in the Scythian platform formed part of the passive continental margin of Laurasia. With the inception of back-arc spreading in the Late Cretaceous, the Istanbul Zone was rifted off from the Odessa shelf and was translated southward opening the West Black Sea basin in its wake (Okay *et al*. 1994).

The Istanbul terrane is separated from the Sakarya terrane by the Intra-Pontide suture marking the trace of the Intra-Pontide ocean (Şengör & Yılmaz 1981). During the Carboniferous the Intra-Pontide ocean probably formed the eastern extension of the Rheic ocean (Okay *et al*. 2006; 2008); it closed following the collision of the Istanbul and Sakarya terranes in the mid Carboniferous. The different Mesozoic stratigraphies of the Istanbul and Sakarya terranes suggest that the Intra-Pontide ocean reopened during the Triassic only to close again in the mid-Cretaceous.

The Sakarya Terrane

Basement and the Jurassic-Cretaceous Sedimentary Cover

The Sakarya terrane forms an elongate crustal ribbon extending from the Aegean in the west to the Eastern Pontides in the east (Fig. 3). In contrast to the Istanbul terrane, the sedimentary sequence starts with Lower Jurassic sandstones, which rest on a complex basement. The crystalline basement of the Sakarya terrane can be broadly divided into three types:

(1) A high-grade Variscan metamorphic sequence of gneiss, amphibolite, marble and scarce metaperidotite; the high-grade metamorphism is dated to the Carboniferous (330-310 Ma) by zircon and monazite ages from the Pulur, Kazdağ and Gümüşhane massifs (Fig. 4, Topuz *et al*. 2004; 2007; Okay *et al*. 2006). This Variscan basement was probably overlain by Upper Carboniferous molasse, which is only preserved in the Pulur region in the easternmost part of the Sakarya Zone (Okay 6 Leven 1996).

(2) Palaeozoic granitoids with Devonian, Carboniferous or Permian crystallization ages (Delaloye & Bingöl 2000;

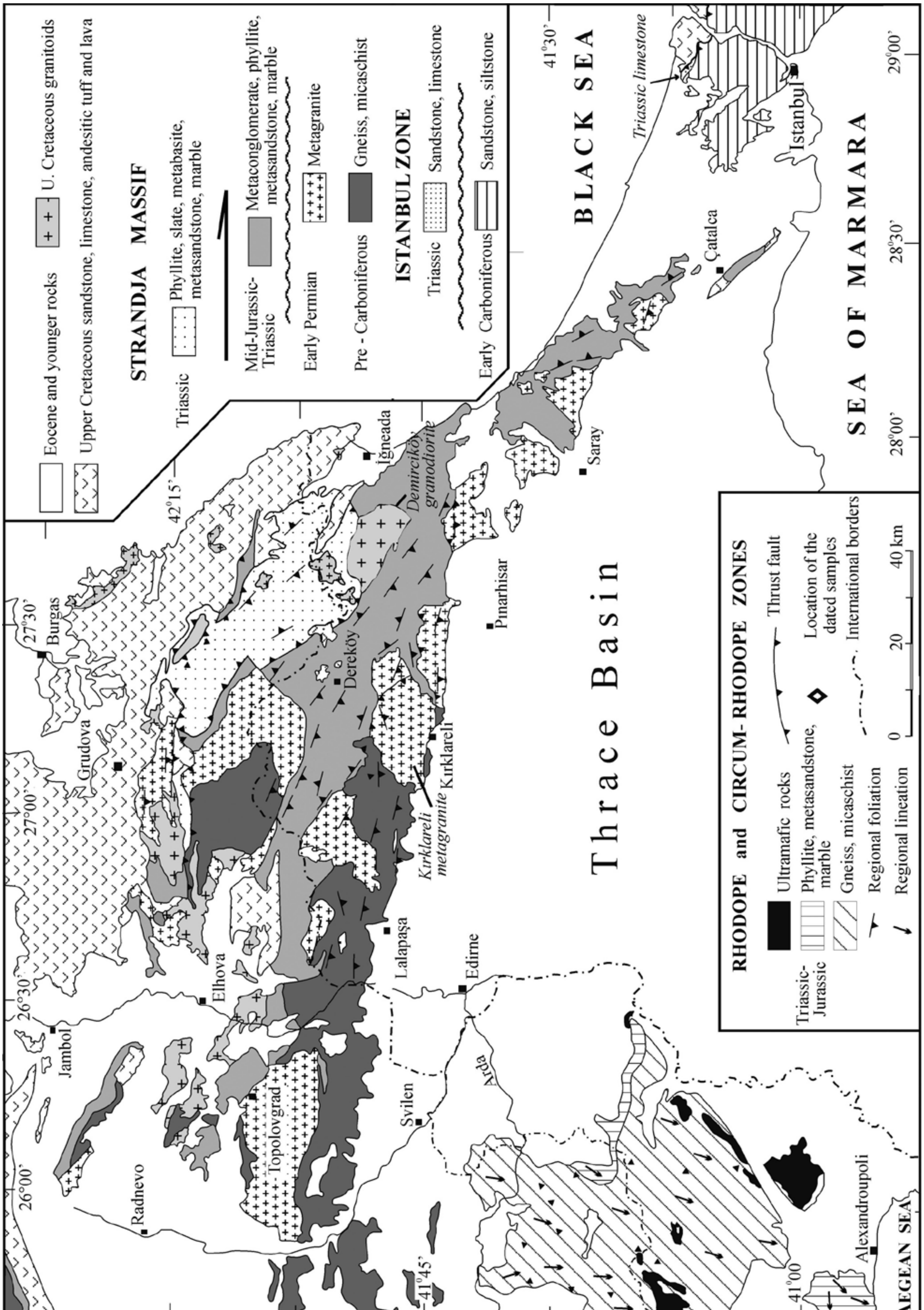

Fig. 6: Geological map of the Strandja Massif (modified from Okay *et al*. 2001).

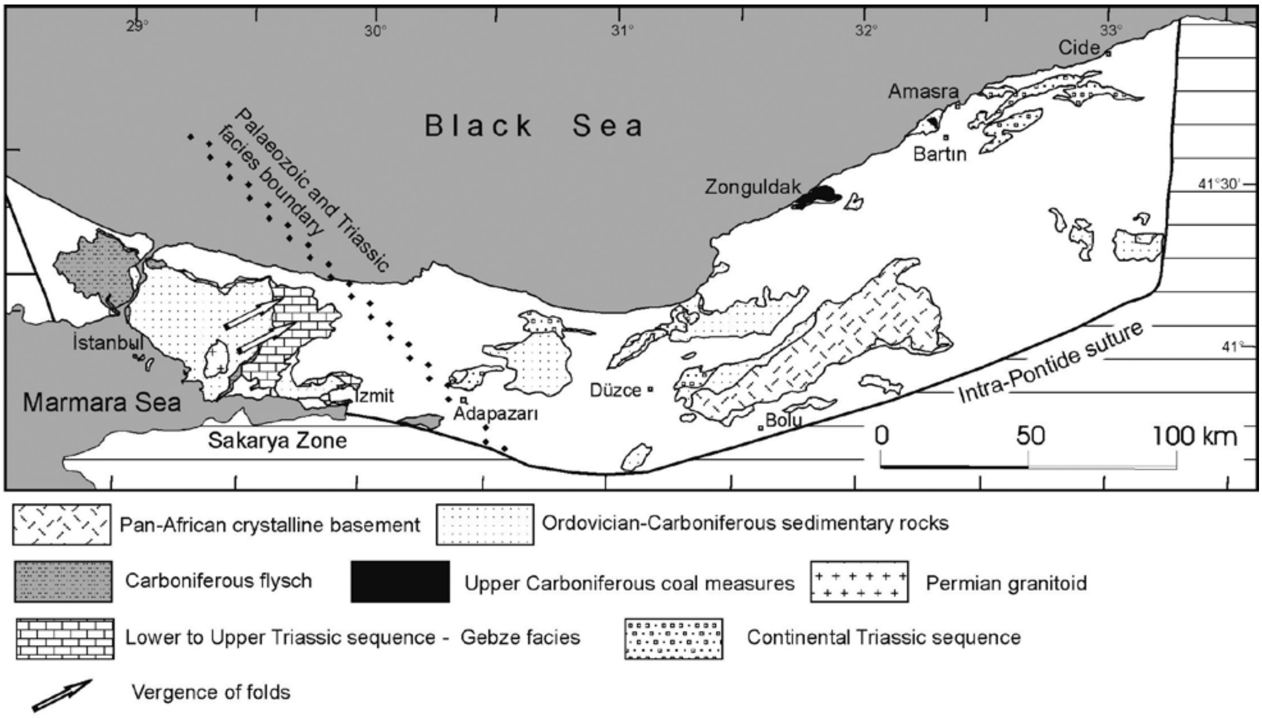

Fig. 7: The distribution of the pre-Jurassic rocks in the Istanbul terrane (Okay *et al*. 2006). Note the different Carboniferous and Triassic facies in the west and east, and the facies boundary that is highly oblique to the Intra-Pontide suture.

Okay *et al*. 2002; 2006; Topuz *et al*. 2007). Small outcrops of these Palaeozoic granitoids are scattered throughout the Sakarya terrane (Fig. 4), and are unconformable overlain by Jurassic and younger sediments.

(3) A low-grade metamorphic complex (the lower Karakaya Complex) dominated by Permo-Triassic metabasite with lesser amounts of marble and phyllite. The Lower Karakaya Complex represents the Permo-Triassic subduction-accretion complex of the Palaeo-Tethys with Late Triassic blueschists and eclogites (Okay & Monié 1997; Okay *et al*. 2002), accreted to the margin of Laurussia during the Late Permian to Triassic.

The Lower Karakaya Complex is overlain by a thick series of strongly deformed clastic and volcanic rocks with exotic blocks of Carboniferous and Permian limestone and radiolarian chert. Several subunits are differentiated within this Upper Karakaya Complex, which are interpreted as trench turbidites or accreted oceanic islands (Okay & Göncüoğlu 2004). The age of these units ranges from Permian to the Late Triassic.

This complex basement was overlain unconformably in the Early Jurassic by a sedimentary and volcanic succession. The Early Jurassic is represented by fluvial to shallow marine sandstone, shale and conglomerate in the western part of the Sakarya Zone; in the eastern part volcanoclastic rocks are typically intercalated with the sandstones (Fig. 5). In the central Pontides granitic rocks were intruded into the basement during the Early to Mid Jurassic (Yılmaz & Boztuğ 1986). The Lower Jurassic clastic and volcanoclastic series are overlain by an Upper Jurassic-Lower Cretaceous limestone sequence, which can be followed throughout the Sakarya Zone (Altıner *et al*. 1991). In the Eastern Pontides the Upper Jurassic – Lower Cretaceous limestones show an increasingly deeper marine character as they are traced south indicating the presence of a passive margin overlooking an ocean in the south.

The limestones are overlain in the mid-Cretaceous by deep sea sandstones and shales marking the onset of the Alpide orogeny. In the Eastern Pontides an ophiolitic melange was emplaced northward during this period leading to a local phase of contractional deformation (Okay & Şahintürk 1997).

Cimmeride Orogeny in the Sakarya Terrane – Accretion Rather than Collision

Orogens that arise from collision of continental fragments, such as the Himalaya, have long lifespans and effect large areas, in contrast, accretion of oceanic fragments to an active continental margin result in brief periods of localised deformation. The Late Triassic – Early Jurassic deformation and metamorphism in the Sakarya terrane, referred to as the Cimmeride orogeny, fall into this second category. In the latest Triassic and earliest Jurassic a large oceanic plateau or large number of oceanic islands were accreted to the southern margin of the Laurussia (Pickett & Robertson 1996; Okay 2000).

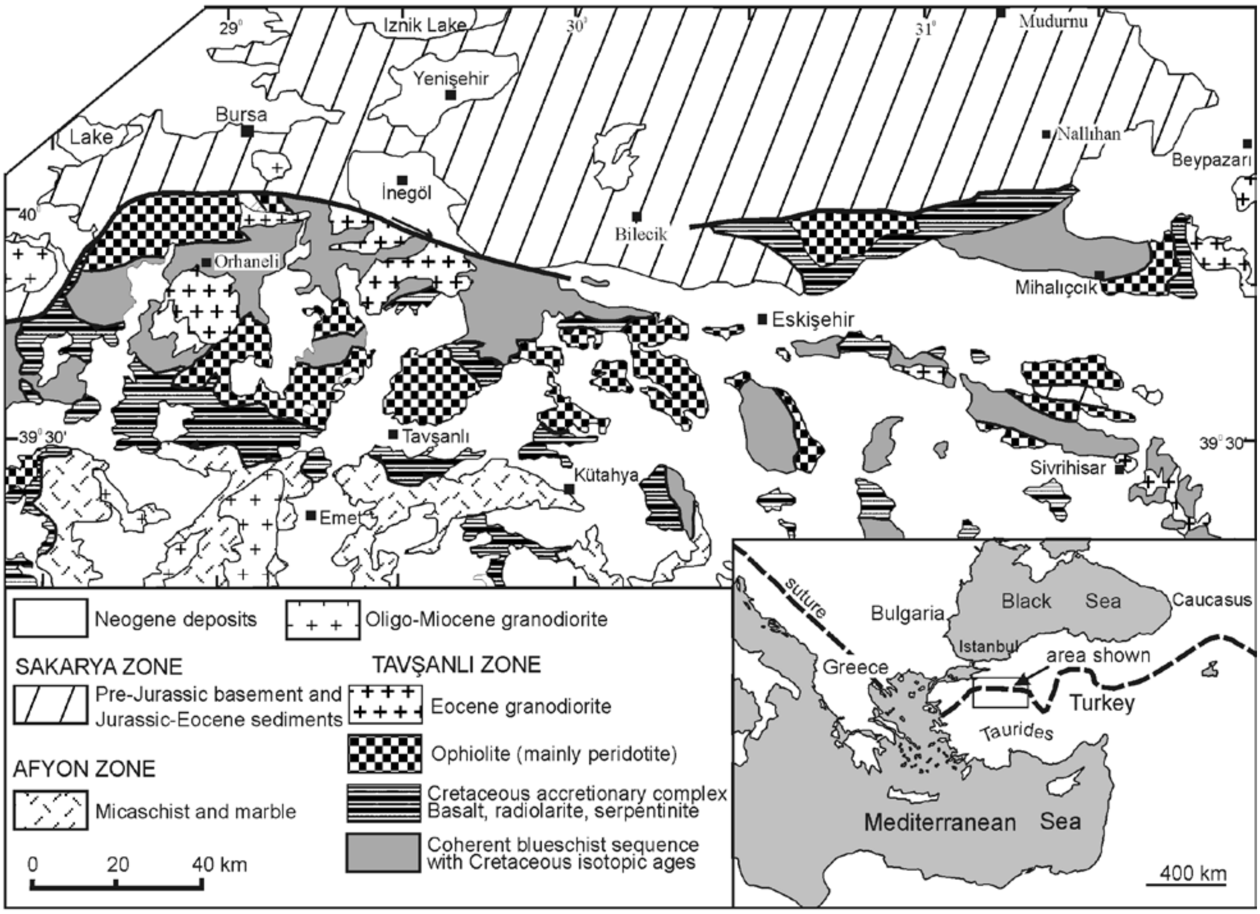

Fig. 8: Geological map of the Tavşanlı Zone (Okay 2002).

This accreted mafic crust, which comprises late Triassic eclogites and blueschist, along with earlier accreted trench sediments constitute the Karakaya Complex of the Sakarya terrane (Fig. 4). A still unanswered question is the source of the large number of exotic Permian and Carboniferous limestone olistoliths within the Upper Karakaya Complex (Leven & Okay 1996). New palaeomagnetic data suggest a Gondwana origin for at least the Permian limestones from the Karakaya Complex (Meijer *et al*. 2007). However, the continental basement, on which these limestones were deposited, is missing.

Recent isotopic dating has shown that accretion of mafic crust to the southern margin of Laurussia also occurred during the Early Permian in the eastern part of the Sakarya terrane (ca. 260 Ma, Topuz *et al.* 2004b). The Sakarya terrane appears to have been an active margin during the Permian and Triassic with episodic accretion of oceanic edifices to the Eurasia.

Early Jurassic (Sinemurian) marks the end of Palaeo-Tethyan subduction-accretion in the Pontides. Continental to shallow marine sediments of this age lie with a pronounced angular unconformity over the Karakaya Complex as well as on the Variscan metamorphic and plutonic rocks.

Mid-Cretaceous Amalgamation and the Late Cretaceous Pontide Magmatic Arc

The three Pontic terranes were amalgamated into a single plate in the mid Cretaceous following the closure of the Intra-Pontide ocean and opening of the Black Sea. Recent isotopic data from the eclogites and blueschists in the Central Pontides indicate that the Neo-Tethys was already subducting under the Pontides in the Early Cretaceous (ca. 105 Ma, Okay *et al.* 2006). However, the magmatic arc started to develop only in the Late Cretaceous (Turonian, ca. 90 Ma, Robinson *et al*. 1995; Okay & Şahintürk 1997). The Upper Cretaceous magmatic arc can be traced along the Black Sea coast from Georgia to the Sredna Gora in Bulgaria. However, it is best developed in the Eastern Pontides, where a sequence of submarine lavas, pyroclastic rocks and intercalated sediments form a volcanic pile more than 2000 metres thick. The volcanic rocks were accompanied by large calc-alkaline plutons, which form the back bone of the Eastern Pontide mountains. Large number of Kuruko type Pb-Zn-Cu deposits are associated with the volcanic and subvolcanic rocks in the Eastern Pontides (e.g. Akıncı 1984). The arc magmatism switched off in the Maastrichtian, although the collision between the Pontides and the Anatolides-Taurides

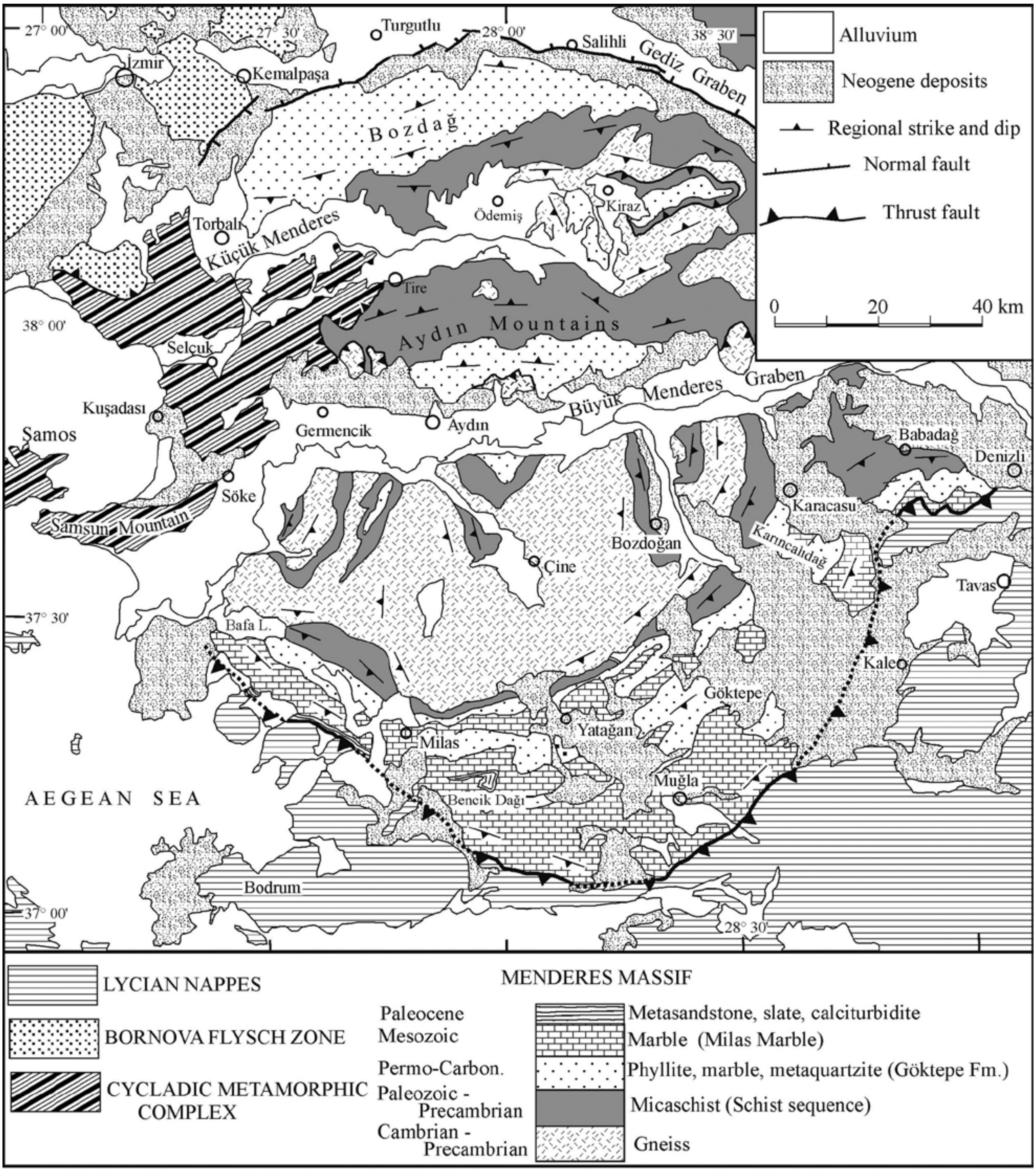

Fig. 9: Geological map of the Menderes Massif (modified after Okay 2000).

were delayed until the Late Palaeocene-Early Eocene. The collision was followed by uplift and extensive erosion. A new cycle of deposition and volcanism started in the Middle Eocene, which was probably related to extension associated with the opening of the Eastern Black Sea basin. The sea finally left the Pontides by the end of the Eocene and the region has been a land area since the Oligocene.

The Anatolide-Taurides

The Anatolide-Tauride terrane forms the bulk of the southern Turkey and in contrast to the Pontic continental fragments shows a Palaeozoic stratigraphy similar to the Arabian Platform, including common glacial deposits of Late Ordovician age (Monod *et al*. 2003). During the obduction, subduction and continental collision episodes in the Late Cretaceous and Palaeocene, the Anatolide-Tauride terrane was in the footwall position and therefore underwent much stronger Alpide deformation and regional metamorphism than that observed in the Pontic zones. During the mid Cretaceous a very large body of ophiolite and underlying tectonic slices of ophiolitic melange were emplaced over the Anatolide-Tauride terrane. The northern margin of the Anatolide-Tauride terrane underwent HP/LT (high pressure/low temperature) metamorphism at depths of over 70 km under this oceanic thrust sheet. Erosional remnants of this thrust sheet of ophiolite and ophiolitic melange occur throughout the Anatolide-Taurides. Although widely called a melange, it generally lacks all encompassing matrix, and represents rather a highly sheared Cretaceous accretionary complex. With the inception of continental collision in the Palaeocene, the Anatolide-Tauride terrane was internally sliced and formed a south to southeast vergent thrust pile. The contraction continued until the Early to Mid-Miocene in the western Turkey and is still continuing in the eastern Anatolia. The lower parts of the thrust pile in the north were regionally metamorphosed, while the upper parts in the south form large cover nappes. The different types and ages of Alpide metamorphism leads to subdivision of the Anatolide-Taurides into zones with different metamorphic features, in a similar manner to the subdivision of the Western Alps into Helvetics and Penninic zones, albeit with a different polarity. There are three main regional metamorphic zones in the Anatolide-Taurides in the western Anatolia: A Cretaceous blueschist belt, namely the Tavşanlı Zone in the north, a lower grade high-pressure metamorphic belt, the Afyon Zone in the centre and the Barrovian-type Eocene metamorphic belt, the Menderes Massif in the south (Fig. 3). To the northwest of Menderes Massif there is a belt of chaotically deformed uppermost Cretaceous-Palaeocene flysch with Triassic to Cretaceous limestone blocks. This Bornova Flysch Zone has an anomalous position between the Izmir-Ankara suture and the Menderes Massif. Taurides, which lie south of the metamorphic regions, consist of a stack of thrust sheets of Palaeozoic and Mesozoic sedimentary rocks (e.g. Gutnic *et al*. 1979; Özgül 1984). The Central Anatolian Crystalline Complex north of the Taurides is a region of metamorphic and plutonic rocks with Cretaceous isotopic ages. The question of the affinity of the Central Anatolian Crystalline Complex, whether part of the Anatolide-Tauride terrane, or a single terrane on its own, is not yet solved.

Although the Anatolide-Tauride terrane shows a variety of metamorphic, structural and stratigraphic features, there are some stratigraphic elements common to all of these zones, which distinguish the Anatolide-Tauride terrane as a single palaeogeographic entity. These elements are: a late Precambrian crystalline basement, a mixed clastic-carbonate Palaeozoic succession and a thick Upper Triassic to Upper Cretaceous carbonate sequence. On the other hand, Variscan deformation or metamorphism, and Triassic subduction-accretion units, characteristic features of the Pontides, are not observed in the Anatolide-Tauride terrane. During the Mesozoic the Anatolide-Taurides were the site of an extensive carbonate platform, where deposition of several thousand meters thick shallow marine carbonates took place. Hence, the name Anatolide-Tauride platform is also applied to this unit.

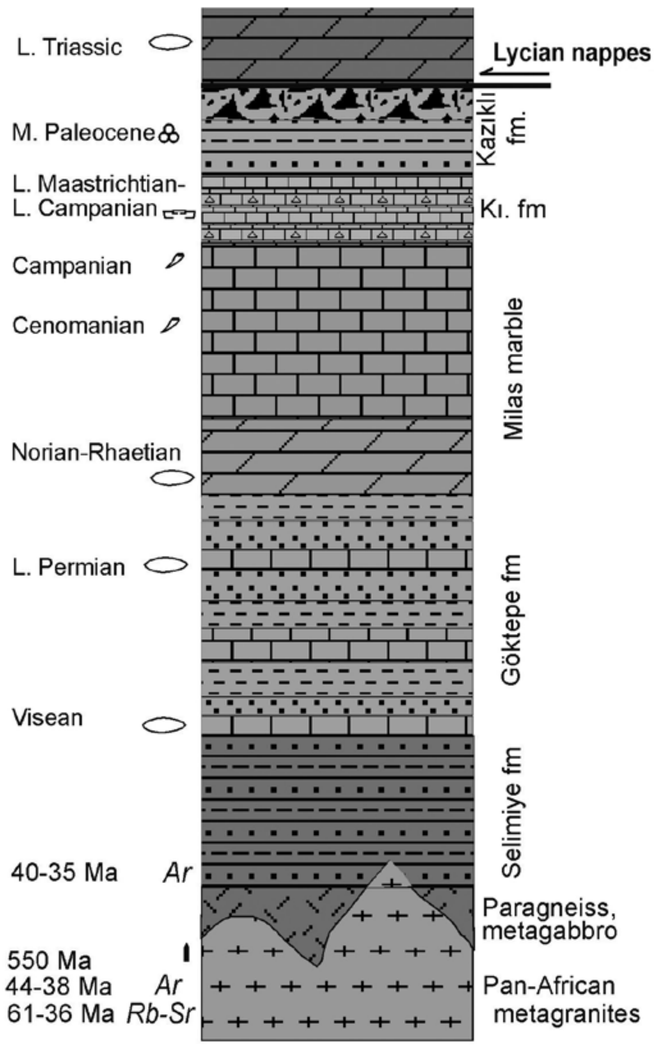

Fig. 10: Synthetic stratigraphic section of the Menderes Massif (modified after Okay 2002).

Bornova Flysch Zone

The Bornova Flysch Zone is a 50 to 90 km wide and ~230 km long, tectonic zone between the Menderes Massif and the İzmir-Ankara suture (Figure 3). It consists of chaotically deformed upper Maastrichtian-Lower Palaeocene greywacke and shale with blocks of Mesozoic limestone, mafic volcanic rock, radiolarian chert and serpentinite (Erdoğan 1990; Okay *et al.* 1996). Many of the blocks must have been initially olistoliths but were subsequently tectonized. The size of the Mesozoic limestone blocks can be as large as 10 km or more, although some of the large "blocks" may consist of tectonically juxtaposed smaller blocks. The proportion of the ophiolitic clasts in the sheared clastic matrix increases eastward and the Bornova flysch passes laterally to an ophiolitic melange. In the east the Bornova Flysch Zone is in contact with the Menderes Massif along post-Eocene normal faults.

The Bornova Flysch zone has formed by the rapid foundering and destruction of the Anatolide-Tauride carbonate platform during the Maastrichtian - early Palaeocene. Large sections of relatively intact carbonate platform are exposed on the island of Chios and on the adjacent Karaburun Peninsula, where the stratigraphy is also most complete (Erdoğan *et al.* 1990). The blocks in the Bornova Flysch Zone generally consist of Triassic, Jurassic and Cretaceous marine limestones. Late Cretaceous is represented by deep marine red limestones, which lie unconformably over the older carbonates. The stratigraphy of some of the blocks in the Bornova Flysch Zone is similar to those described from the Lycian nappes, 300 km to the southeast (Okay & Altıner 2007). This biostratigraphic similarity lends strong support for a northerly origin of the Lycian nappes. The flysch and the blocks are unconformably overlain by undeformed late Early Eocene (late Cuisian) neritic limestones. This constrains the age of the deformation in the Bornova Flysch Zone to late Palaeocene.

Recent detailed biostratigraphic studies on the carbonate and radiolarian chert blocks in the Bornova Flysch Zone have provided two important clues regarding the geological evolution of Anatolia. Radiolaria in various chert blocks have shown to have mid- to late-Triassic (Ladinian to Carnian) ages indicating that the northern Neo-Tethys was already open by the mid-Triassic (Tekin & Göncüoğlu 2007). Detailed biostratigraphy in the carbonate blocks showed that the subsidence and fragmentation of the Anatolide-Tauride carbonate platform started in the mid-Cretaceous (late Cenomanian, ca. 95 Ma, Okay & Altıner 2007). This subsidence must have been related to the early stages of the ophiolite obduction

The Tavşanlı Zone

The Tavşanlı Zone is a regional blueschist belt in northwest Turkey, ~250 km long and ~50 km wide, immediately south of the main Neo-Tethyan suture (Fig. 1 and 8). The blueschist sequence in the Tavşanlı Zone consists of Permo-Triassic metapelitic schists at the base, Mesozoic marbles in the middle and a series of metabasite, metachert and phyllite at the top (Okay 1984). The blueschists represent the subducted and subsequently exhumed passive continental margin of the Anatolide-Tauride terrane. Phengite Rb-Sr and Ar-Ar data from the blueschists indicate a Late Cretaceous (80 ± 5 Ma) age for the HP/LT metamorphism (Sherlock *et al.* 1999). The coherent blueschist sequence is tectonically overlain by a Cretaceous accretionary complex of basalt, radiolarian chert and pelagic shale. The accretionary complex exhibits generally a low-grade incipient blueschist metamorphism. Large tectonic slabs of ophiolite, predominantly peridotite, lie over the coherent blueschists or over the accretionary complex. The whole tectonostratigraphic pile is intruded by calc-alkaline Eocene plutons, which form an elongate belt, 400 km long and 60 km wide, extending from the Sivrihisar region in the central Anatolia to the Marmara Sea (e.g. Harris *et al*. 1994; Okay & Satır; 2006; Altunkaynak 2007). This Eocene magmatic belt constitutes either a magmatic arc or has formed as a result of slab break-off. Locally a low pressure - high temperature metamorphism has accompanied the intrusion of granodiorites.

The Menderes Massif and the Afyon Zone

The Menderes Massif is a major metamorphic complex in western Turkey; it bears imprints of Precambrian and Eocene metamorphic and deformational events (e.g. Şengör *et al.* 1984; Bozkurt & Oberhansli 2001). The Menderes Massif is tectonically overlain in the south by the Lycian nappes, and in the northwest is by the Bornova Flysch Zone (Fig. 3). The region of the Samsun peninsula and Ephesus, long considered as part of the Menderes Massif, is now regarded as part of the Cycladic metamorphic complex (Fig. 9, Okay 2001). The Cycladic metamorphic complex, which includes much of the Cycladic islands in the Aegean, shows Eocene high pressure metamorphism (e.g. Dürr 1986; Okrusch & Bröcker 1990). South of Tire it lies tectonically over the micaschists of the Menderes Massif.

East-west trending Neogene grabens subdivide the Menderes Massif into southern, central and northern submassifs (Fig. 9). The Menderes Massif sequence is simplest and best known in the southern submassif (Çine submassif). The structure in the central and northern submassifs is more complicated and involves large scale overturning and thrusting.

The Menderes consists of a Precambrian core of micaschists, gneiss and minor granulite and eclogite intruded by voluminous metagranites with latest Precambrian (~550 Ma) intrusion ages (Fig. 10, Candan *et al*. 2001). This Precambrian crystalline basement is overlain by Palaeozoic to Lower Tertiary metasedimentary rocks constituting the cover series. The oldest fossiliferous series in the cover sequence are the Permo-Carboniferous marble, quartzite and phyllite of the so-called Göktepe Formation. Through a clastic interval the Göktepe Formation is overlain by a thick sequence of Mesozoic marbles with emery horizons. The top part of the marble sequence contains shallow marine fossils of Upper Cretaceous age. This platform limestone sequence

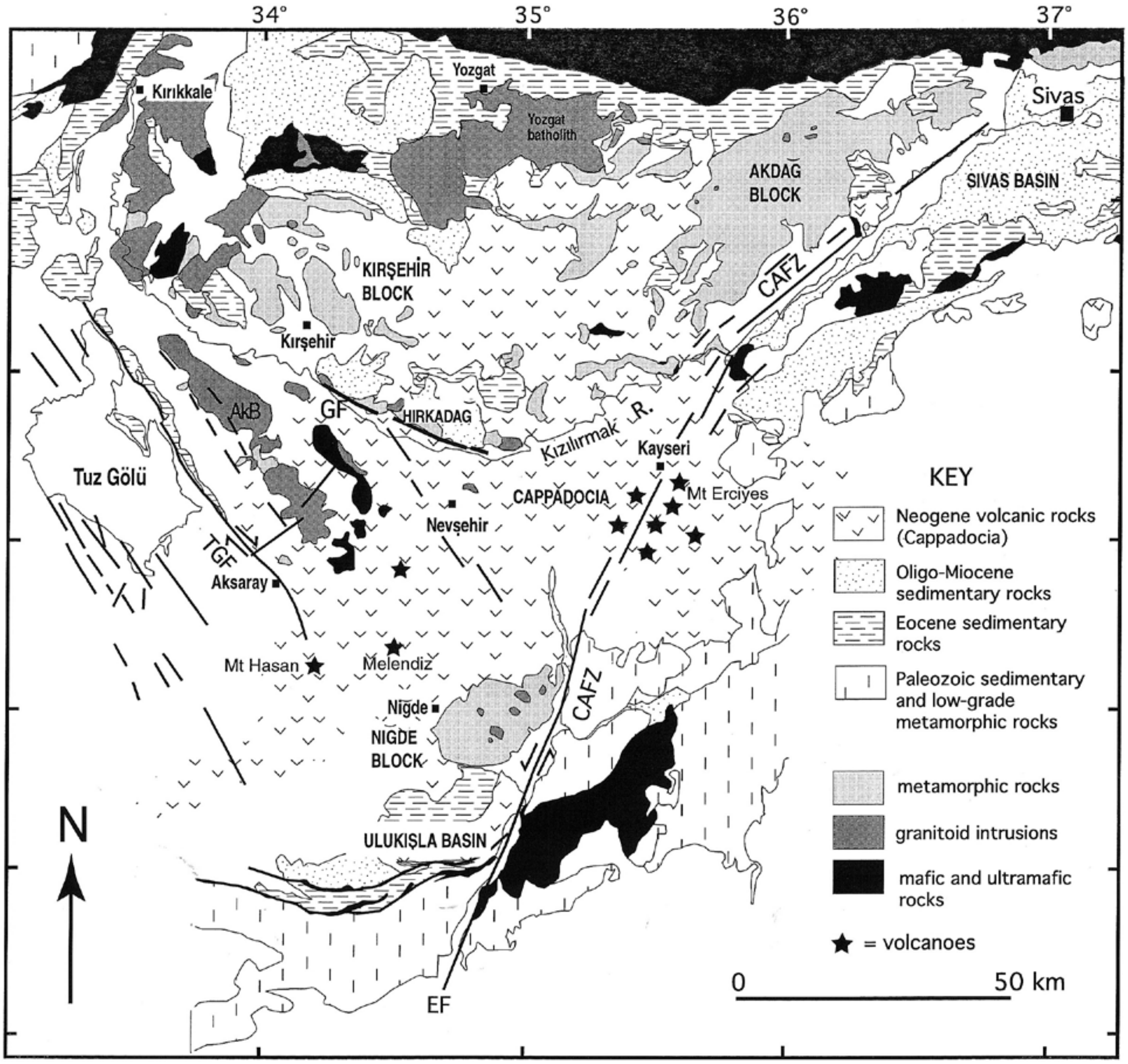

Fig. 11: Geological map of the Central Anatolian Crystalline complex (modified after Whitney & Dilek 2001).

is overlain by red pelagic recrystallized limestones and then by a slightly metamorphosed flysch sequence with serpentinite blocks. The Lycian nappes lie tectonically on the flysch sequence (Fig. 11).

The Palaeocene foraminifera from the top of the Menderes metamorphic sequence, and Ar-Ar muscovite cooling ages of 43-37 Ma from the metagranites and the overlying schists (Hetzel & Reischmann 1996) constrain the age of the main Alpine metamorphism in the Menderes Massif as latest Palaeocene-Early Eocene. The regional metamorphism in the Menderes Massif is of Barrovian type and has developed in greenschist and amphibolite facies with peak metamorphic pressures of ca. 9 kbars (Okay 2001; Whitney & Bozkurt 2002). The recent discoveries of carpholite in the cover sequence of the Menderes Massif (Rimmele *et al.* 2003) indicate medium pressure - low temperature conditions and is compatible within the overall Barrovian metamorphism of the Menderes Massif. The Eocene regional metamorphism and deformation of the Menderes Massif is a direct consequence of the southward propagation of the Palaeocene collisional front between the Sakarya Zone in the north and the Anatolide-Tauride terrane in the south (Şengör *et al.* 1984).

The Afyon Zone occupies the region between the Menderes Massif and the TavşanlıZone (Fig. 3). It exhibits the typical Tauride stratigraphy with a mixed carbonate-clastic Palaeozoic series overlain by Mesozoic marbles but shows a low-grade medium to high pressure metamorphism characterized by extensive occurrences carpholite and local sodic amphibole (Candan *et al*. 2005). The metamorphic rocks are tectonically overlain by an ophiolitic melange and by ophiolites. The age of regional metamorphism is not analytically determined but is stratigraphically constrained as latest Cretaceous to Palaeocene.

Central Anatolian Crystalline Complex

The Central Anatolian Crystalline Complex is a large region of metamorphic and granitic rocks with Cretaceous isotopic ages. An extensive Neogene sedimentary and volcanic cover leads to the subdivision of the Central Anatolian Crystalline complex into several submassifs; the important ones include Kırşehir, Akdağ and Niğde massifs (Fig. 11). The Central Anatolian Crystalline complex is regarded either as the metamorphosed northern margin of the Anatolide-Tauride terrane (e.g. Poisson *et al*. 1996; Yalınız *et al*. 2000) or a distinct terrane separated from the Anatolide-Taurides by the Inner Tauride Suture (Fig. 1, Şengör *et al*. 1982; Görür & Tüysüz 2001; Whitney & Hamilton 2004). The metamorphic rocks of the Central Anatolian Crystalline Complex constitute a coherent metasedimentary sequence of gneiss, micaschist, metaquarzite, marble and calc-silicate rock, which are isoclinally folded and multiply deformed (Seymen 1983). The regional metamorphism varies from greenschist to granulite facies and is of high temperature - medium/low pressure type. The maximum pressure attained during the metamorphism is ~6 kbar corresponding to depths of ~20 km (Whitney *et al*. 2003). This low to medium pressure metamorphism was overprinted in several submassifs by a lower pressure metamorphism associated with the emplacement of granitic intrusions. The age of regional metamorphism is Late Cretaceous (91-85 Ma) based on monazite and zircon U-Pb dating (Whitney *et al.* 2003; Whitney & Hamilton 2004). The metamorphic rocks are tectonically overlain by an unmetamorphosed Late Cretaceous accretionary complex of basalt, radiolarian chert, pelagic limestone, sandstone and serpentinite. The accretionary complex as well as the metamorphic rocks is intruded by granitic rocks, which cover large areas in the Central Anatolian Crystalline Complex. The plutonic rocks are mainly quartz-monzonites, quartz-monzodiorites, monzonites and monzodiorites with a calc-alkaline character, and their trace element geochemistry is compatible with a syn- to post-collisional tectonic setting (Akıman *et al*. 1993; Erler & Göncüoğlu 1996; İlbeyli *et al*. 2004). There are also minor crustally derived peraluminous plutons. The K/Ar biotite and hornblende, titanite and zircon ages from the granitic rocks generally range from 95 to 70 Ma (Whitney *et al*. 2003; Köksal *et al*. 2004; Boztuğ *et al*. 2007). An upper age limit on the granitic magmatism as well as on regional metamorphism is provided by the Upper Maastrichtian terrigeneous to shallow marine clastic and carbonate rocks, which lie unconformably on the metamorphic as well as on the granitic rocks (Seymen 1983).

The Taurides

The Taurides consist of a stack of thrust sheets; each thrust sheet generally consists of Palaeozoic to Early Tertiary sedimentary rocks. The topmost thrust sheet, on the other hand, is generally made up of ophiolite and/ or ophiolitic melange, which form large isolated bodies through the Taurides (e.g. Gutnic *et al*. 1979; Özgül 1984). The thrusting occurred in the Late Cretaceous, in the Eocene and in the Early Miocene, and shows southward younging. The earliest contractional event was the obduction of the ophiolite over the Anatolide-Tauride terrane during the mid Cretaceous. As outlined above the obduction event was associated with the deep subduction and high pressure metamorphism of the northern margin of the Anatolide-Taurides and the generation of the Tavşanlı Zone. The more distal portions of the obducted ophiolite were emplaced over the Cretaceous sedimentary rocks of the Taurides.

The continental collision during the late Palaeocene-Early Eocene between the Anatolide-Taurides and the Pontides led to a second phase of contraction by folding and thrusting in the Taurides. Major events during this Eocene phase include the thrusting of the Lycian nappes over the Menderes Massif and the consequent regional metamorphism of the Menderes Massif. Most of the present nappe structure in the Central and Eastern Taurides has formed during the Eocene. In the Early Miocene the Lycian nappes were thrust south-eastward over the Beydağları authochthon.

The thrust sheets are generally thought to have been emplaced from north to south with the possible exception of the Antalya Nappes around the bay of Antalya, which are widely regarded to have been thrust northward. The Antalya nappes are generally regarded as representing the southern passive continental margin of the Anatolide-Taurides. West of the Antalya Bay they are tectonically overlain by the Tekirova ophiolite, regarded as a fragment of the southern branch of the Neo-Tethys. East of the Antalya Bay, the metamorphic Alanya nappes with blueschists and eclogites lie tectonically over the Antalya nappes. The other important metamorphic massif in the Taurides is the Bitlis Massif in southeast Anatolia.

The Bitlis Massif

The Bitlis Massif in the eastern Taurides forms an arcuate metamorphic belt, about 30 km wide and 500 km long, rimming the Arabian Platform in southeast Anatolia. It is separated from the Arabian Platform by a narrow belt of Upper Cretaceous to Eocene flysch and ophiolitic melange. The Bitlis Massif is generally considered as part of the Anatolide-Taurides, and was thus separated during the Mesozoic and Tertiary from the Arabian Platform by the southern branch of the Neo-Tethys.

Stratigraphically the Bitlis Massif is divided into two units, a Lower Unit representing the Precambrian basement and an Upper Unit representing the overlying Phanerozoic sequence (Göncüoğlu & Turhan 1984; Çağlayan *et al.* 1984). The Lower Unit consists of gneiss, amphibo-

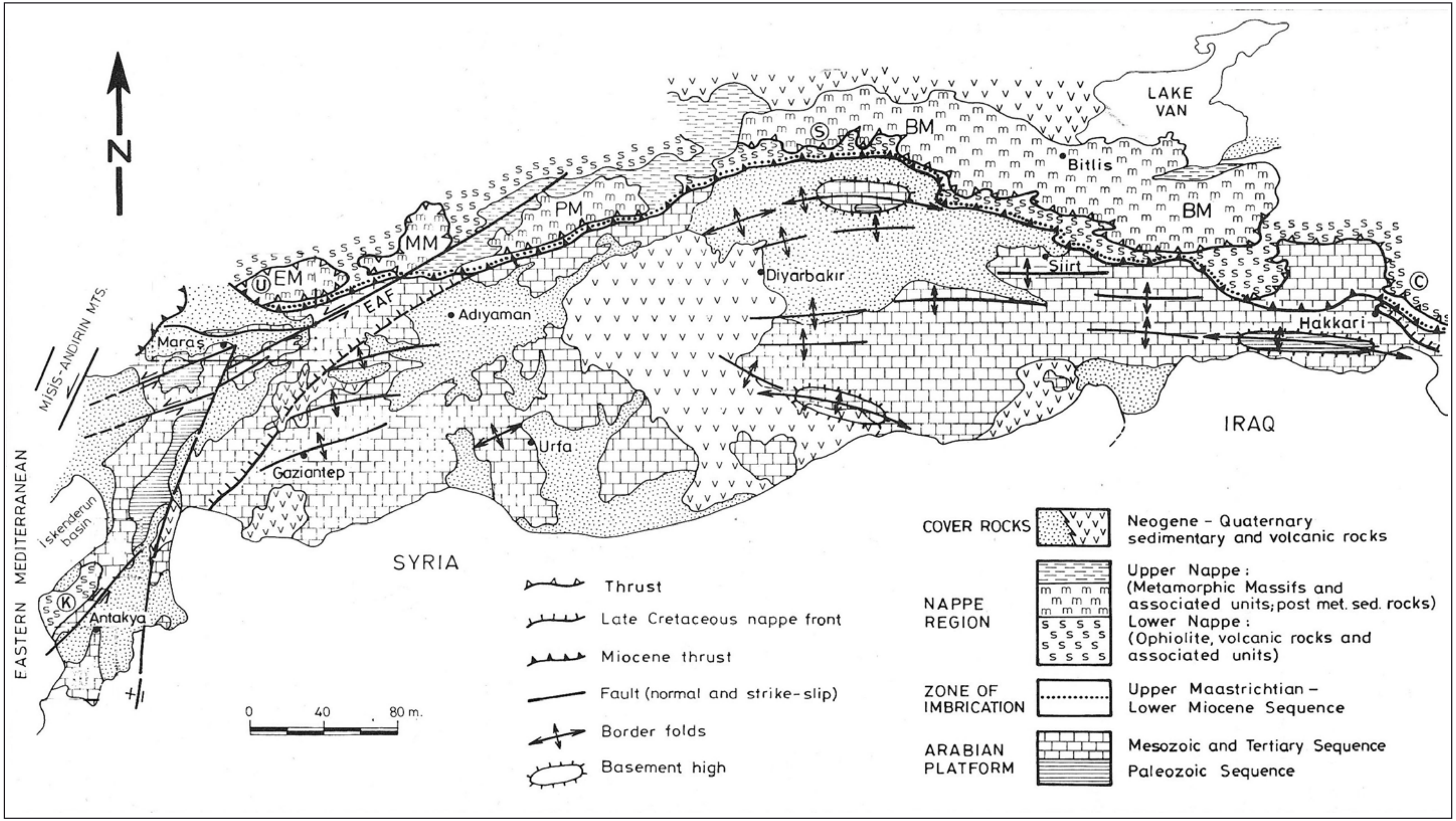

Fig. 12: Geological map of the southeast Anatolia (Yılmaz 1993).

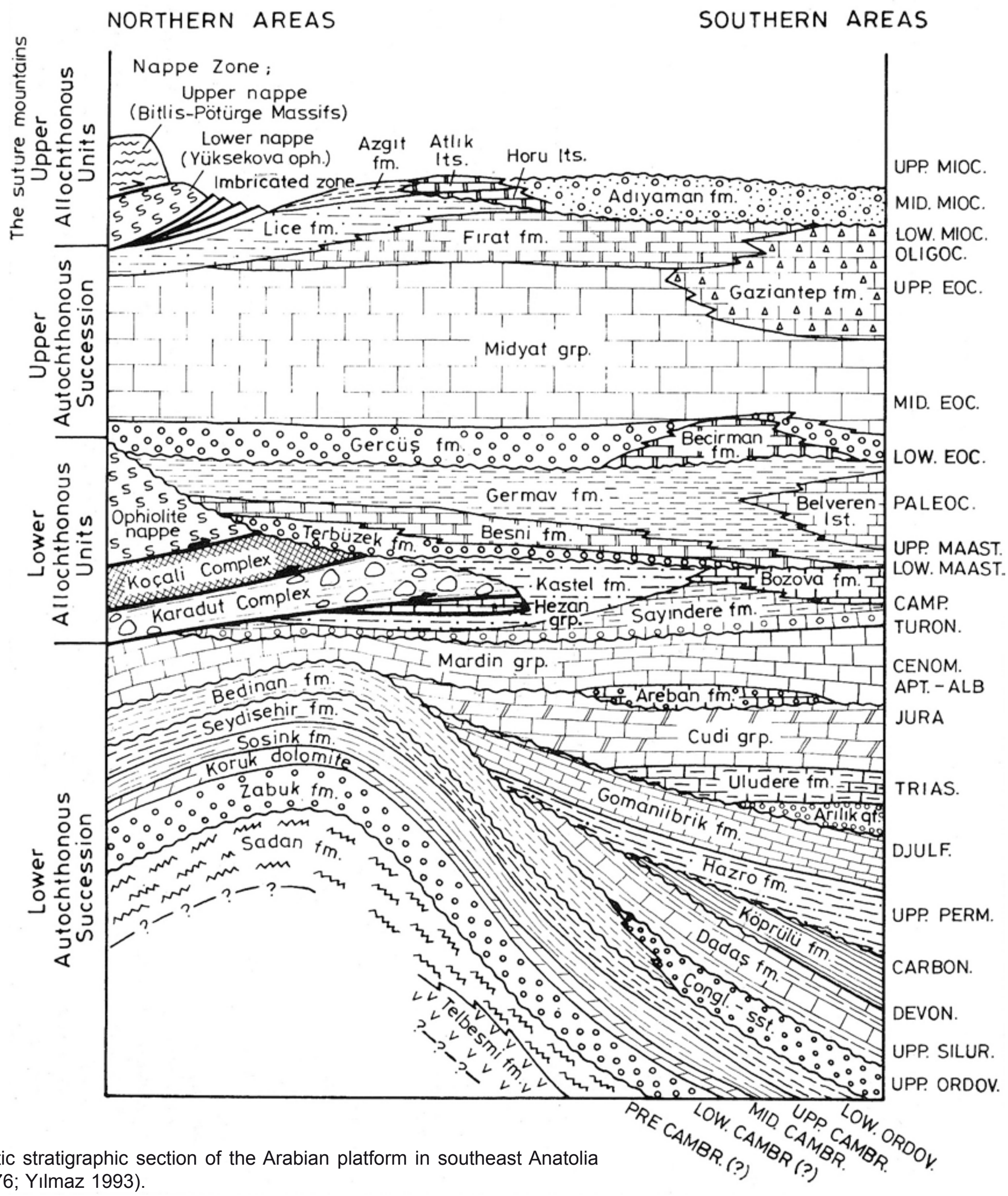

Fig. 13: Synthetic stratigraphic section of the Arabian platform in southeast Anatolia (after Yalçın 1976; Yılmaz 1993).

lite, micaschist and eclogite. It shows two stages of metamorphism - a high-grade metamorphism of Precambrian age and a lower grade Late Cretaceous Alpide metamorphism. Like in the Menderes Massif, leucocratic granitoids have intruded the Lower Unit after the late Precambrian metamorphism. The Upper Unit is made up of schist, phyllite, marble and metavolcanic rocks. It represents the metamorphosed Palaeozoic-Mesozoic sequence of the Anatolide-Tauride terrane. The Bitlis Massif has undergone a low to medium grade Alpide metamorphism. A single K/Ar age from the western part of the Bitlis Massif near Pütürge is 71.2 ± 3.6 Ma (Maastrichtian) (Hempton 1985).

The Arabian Plattform

The southeast Anatolia forms the northernmost extension of the Arabian Platform. During the Mesozoic and Tertiary the Arabian Platform was separated from the Anatolide-Taurides by the southern branch of the Neo-Tethys, which today is represented by the Assyrian suture (Şengör & Yılmaz, 1981). The Arabian Platform has a Pan-African crystalline basement overlain by a Palaeozoic to Tertiary sedimentary sequence. In most areas of the southeast Anatolia only the Cretaceous and younger deposits crop out on the surface. The lower parts of the sequence are exposed in number anticlines (Rigo de Righi & Cortesini 1964). These include the Amanos mountains west of Gaziantep, the Derik and Hazro anticlines south and north of Diyarbakır respectively, and the Zap anticlines south of Hakkari (Fig. 12). In the Zap anticline between Hakkari and Çukurca the Cambrian to Carboniferous sequence is dominated by clastic rocks, whereas the Permian to Eocene sequence is largely shallow marine carbonates (Fig. 13, Perinçek 1990).

During the Late Cretaceous and Tertiary ophiolites, ophiolitic melanges and thrust sheets were emplaced over the Arabian Platform, which are denoted as the "Lower Nappe" in Fig. 12. This was part of an extensive emplacement of the oceanic lithosphere over the continent extending from Antakya on the Mediterranean coast to Oman in Arabia. The continental collision with the Anatolides-Taurides occurred later during the Miocene, when a second set of allochthonous units including the Bitlis Massif and the underlying mélange units were emplaced over the Arabian Platform (Fig. 12).

Three important allochthonous units mapped over large areas south of the Bitlis Massif are briefly described below

The Hakkari and Maden Complexes

The Hakkari Complex covers large areas southeast of the Bitlis Massif, where it tectonically overlies the Eocene and Miocene formations of the autochthon. The lower part of the Hakkari Complex consists of slightly metamorphosed Eocene siltstone, shale and fine-grained sandstone with limestone intercalations. Near Hakkari the slates are overlain by medium bedded dark Eocene carbonates (Perinçek, 1990). The aggregate thickness is more than 2000 metres. This sedimentary sequence is tectonically overlain by a mélange of Lower to Middle Eocene pelagic and neritic limestone, serpentinite, gabbro, basalt and amphibolite in a strongly deformed shale matrix (Perinçek 1990).

The Maden Complex is the age equivalent of the Hakkari Complex in regions west of Hakkari. It differs from the Hakkari Complex by the presence of abundant volcanic rocks. It crops out widely along the southern margin of the Bitlis Massif, as tectonic slivers, either directly under the Bitlis metamorphic rocks or through an intervening thrust sheet of the ophiolitic melange. The Maden Complex consists of Eocene sandstone, conglomerate, red pelagic limestone, basaltic lava, and tuff. In a few localities the Maden Complex is reported as lying unconformably over the Bitlis metamorphic rocks, however, in most places it is positioned between the Tertiary formations of the Arabian Platform and the Bitlis Massif. Yiğitbaş and Yılmaz (1996) regard the Maden Complex as products of a short-lived Mid-Eocene back arc basin, above the northward dipping subduction zone between the Arabian Platform and the Anatolide-Taurides.

The Yüksekova Complex

The Yüksekova Complex is the typical Upper Cretaceous ophiolitic melange with very wide outcrops in southeast Anatolia. It consists of a chaotic jumble of basalt, gabbro, serpentinite, pelagic limestone, radiolarian chert, neritic limestone, granodiorite, sandstone, siltstone, shale with an estimated vertical thickness of about 2000 metres. The youngest limestone blocks in the Yüksekova Complex give Coniacian-Campanian ages (Perinçek 1990). North of Hakkari it forms large flat lying klippen over the Eocene aged Hakkari Complex, and is tectonically overlain by the Bitlis metamorphic rocks. In the Bitlis-Baykan region the Yüksekova Complex forms tectonic slivers between the Bitlis metamorphic rocks and the underlying Maden Complex (Göncüoğlu & Turhan 1992).

Cretaceous-Tertiary Basin – Fore-Arc to Fore-Deep

Starting with the Late Cretaceous several possibly interconnected clastic basins started to form around the Central Anatolian Crystalline Complex. The best exposed and most studied among these is the Haymana basin, which is filled by predominantly clastic sediments, 5 km thick, of Late Cretaceous (Late Campanian) to Eocene age. The Haymana basin rests partly on ophiolitic melange and partly on the Central Anatolian Crystalline Complex (Görür *et al.* 1984; Koçyiğit 1991). It is regarded as a fore-arc to fore-deep basin. The Haymana basin is probably connected under the Neogene cover to the Tuzgölü and to the Ulukışla basins, which lie farther southeast. The Tuzgölü basin is largely covered by the Neogene sediments and our knowledge of the basin stratigraphy comes from the subsurface data. The Tuzgölü basin extends south-eastward towards the Ulukışla basin, which is situated between the Taurides and the Niğde Massif of the Central Anatolian Crystalline Complex. Both the Tuzgölü and Ulukışla basins comprise a Maastrichtian to Eocene sequence. The lithostratigraphy in the Tuzgölü basin is similar to the Haymana basin (Çemen *et al*. 1999), in contrast, the Ulukışla basin comprises a thick sequence of Early Tertiary basalts and andesites (Clark & Robertson 2002), absent in the other basins.

The Sivas basin shares common features with the Ulukışla basin including a tectonic position between the Taurides and the Central Anatolian Crystalline Complex, a substratum of ophiolitic melange and a Maastrichtian to Eocene sedimentary sequence (e.g. Poisson *et al*. 1996; Dirik *et al*. 1999). However, the Sivas basin has also a thick, evaporite-rich Oligo-Miocene series not observed in the other internal basins. Although all the internal basins have a basement of ophiolitic melange, none were formed on the oceanic crust; rather the basins have developed after the tectonic emplacement of ophiolite and ophiolitic melange over the Anatolide-Tauride carbonate platform.

Unlike the internal basins, the Thrace basin in northwest Turkey is only of Eocene-Oligocene age. It is a triangular-shaped, clastic basin, which has formed on the complex junction between the Strandja, Rhodope, Sakarya and Istanbul terranes. In the centre of the basin the thickness of the sedimentary rocks exceeds 8 km (Fig. 3, Turgut *et al*. 1991; Görür & Okay 1996). The sedimentary rocks are predominantly composed of an upward shallowing sequence of sandstone and shale. The sequence starts with deep marine turbidites of Eocene age and ends with continental Oligocene sandstone, shale and lignite. The deltaic Oligocene sandstones form reservoirs for natural gas. The Thrace basin rests on the metamorphic rocks of the Strandja and Rhodope massifs in the north and on an ophiolitic melange in the south. It is probably a fore-arc basin formed above the northward subducting Intra-Pontide ocean.

The Neotectonic Phase

By the end of the Oligocene most of the Anatolian terranes were amalgamated into a single landmass. The only exception was a narrow sea way between the Arabian Platform and the Anatolides-Taurides in southeast Anatolia. The Miocene collision between Arabian and the Anatolian plates (e.g. Şengör *et al*. 1985; Yılmaz 1993; Robertson & Grasso 1995) eliminated this last vestige of the intact oceanic crust in Anatolia. This ushered a new tectonic era in Turkey characterized by continental sedimentation and widespread calc-alkaline magmatism. The tectonic regime in this new phase was dominated by extension and strike-faulting.

During the Miocene most of the western and central Anatolia was the site of large lakes surrounded by swamps. Sediments to the lakes were supplied by nearby volcanoes and by uplifted ranges of older sedimentary and metamorphic rocks. The subsiding lakes were filled by a sequence of sandstone, shale, limestone, tuff, basalt and andesite. The magmatism was initially calc-alkaline with a composition ranging from basaltic andesite to rhyolite (e.g. Aldanmaz *et al.* 2000; Yılmaz *et al*. 2001). In the Late Miocene it switched to alkaline with the generation of minor amounts of alkali basalts. The Neogene continental deposits of western Turkey comprise the world’s largest borate reserves (e.g. Helvacı 1995), as well as rich deposits of sodium sulphate, lignite and clay. The tectonic regime during the Neogene was characterized by extension and strike-slip faulting. Large low-angle extensional faulting was creating space for the Miocene basins as well as exhuming deeply buried crystalline rocks. Recent studies have shown that some of the crystalline complexes of western Anatolia, such as the Kazdağ or Simav massifs, were exhumed at the footwalls of large low-angle normal faults (e.g. Okay & Satır 2000; Işık *et al*. 2004). The underlying cause of the regional extension was the southward migration of the Hellenic trench, which also led to the opening of the Aegean Sea as a back-arc basin.

The grand structure of the neotectonic phase is without doubt the North Anatolian Fault, a right-lateral strike-slip fault which extends for 1200 km from the eastern Anatolia into the Aegean Sea (e.g. Barka 1992; Şengör *et al*. 2005). The classical view is that the North Anatolian Fault was initiated as an escape structure following the Miocene collision between the Arabian and Anatolian plates. However, recent studies have shown that right-lateral strike-slip faults with cumulative offsets of 100 km or more, existed during the Oligocene in the western Anatolia (Zattin *et al*. 2005; Uysal *et al*. 2006; Okay *et al.* 2008). These structures were transporting continental crustal fragments into the north-south extending Aegean region suggesting that the underlying cause of the westward translation of Anatolia was, and is still is the pull of the Hellenic subduction zone rather than the push of the Arabian Plate.

Conclusions

Geologically Turkey consists of a mosaic of several terranes, which were amalgamated during the Alpide orogeny. The relics of the oceans, which once separated these terranes, are widespread through the Anatolia; they are represented by ophiolite and accretionary complexes.

The three terranes, which make up the Pontides, namely the Strandja, Istanbul and Sakarya terranes, have Laurasian affinities. These Pontic terranes bear evidence for Variscan and Cimmeride orogenies. Their Palaeozoic and Mesozoic evolutions are quite different from the Anatolide-Taurides. The Pontides and the Anatolide-Taurides evolved independently during the Phanerozoic and they were first brought together in the Tertiary.

In contrast to the Pontic terranes, the Anatolide-Tauride terrane has not been affected by the Variscan and Cimmeride deformation and metamorphism but was strongly shaped by the Alpide orogeny. It was part of the Arabian Platform and hence Gondwana until the Triassic and was reassembled with the Arabian Platform in the Miocene. The Anatolide-Tauride terrane is subdivided into several zones mainly on the basis of type and age of Alpide metamorphism. The southeast Anatolia forms the northernmost extension of the Arabian Platform and shares many common stratigraphic features with the Anatolide-Tauride terrane.

The final amalgamation of the terranes in the Oligo-Miocene ushered a new tectonic era characterized by continental sedimentation, calc-alkaline magmatism, extension and strike-slip faulting. Most of the present active structures, such as the North Anatolian Fault, and most of the present landscape are a result of this neotectonic phase.

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