

**INTRODUCTION TO THE GEOLOGY OF TURKEY: GEODYNAMIC  
EVOLUTION OF THE PRE-ALPINE AND ALPINE TERRANES**

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**ABSTRACT:** The Turkish orogenic collage can be divided into a number of Alpine tectono-stratigraphic units or terranes, which were formed in a wide range of tectonic settings, including active and passive continental margins, rifts, arc and suture complexes, related to the opening and closure of various Neotethyan oceanic branches. On the other hand, vestiges of former orogenic events such as Pan-African/Cadomian, Variscan and Cimmerian are represented by disrupted/metamorphosed tectono-stratigraphic units within the Alpine terranes.

In this brief review, the lithologies and tectonic relations of the Alpine and pre-Alpine terranes will be summarized and their tectonic evolution discussed.

## INTRODUCTION

All along its geological past Turkey has been located between the two mega-continents: Gondwana to the south and Laurasia to the north. It is generally accepted that numerous continental fragments belonging to one of these mega-continents were rifted off from the main body and amalgamated to the next, so that the Anatolian realm is made of several oceanic and continental “terranes” with different geological features. The last main orogenic event, the Alpine orogeny, related to the closure of various Neotethyan branches directly controls the present distribution of these terranes (Fig. 1).

In this review, the Pan-African/Cadomian, Variscan and Palaeotethyan terranes that occur as tectonic inliers within the Alpine terranes will be described and their Alpine evolution will be discussed. The aim of this review is to summarize briefly the processes and the products of the very complex Alpine events, excluding the Neotectonic period. It includes many oversimplifications for the sake of better-understanding of the very complex geology of the Turkish area. This review is based on the published and unpublished data of the author as well as findings and interpretations of many Turkish earth-scientists working on this subject.

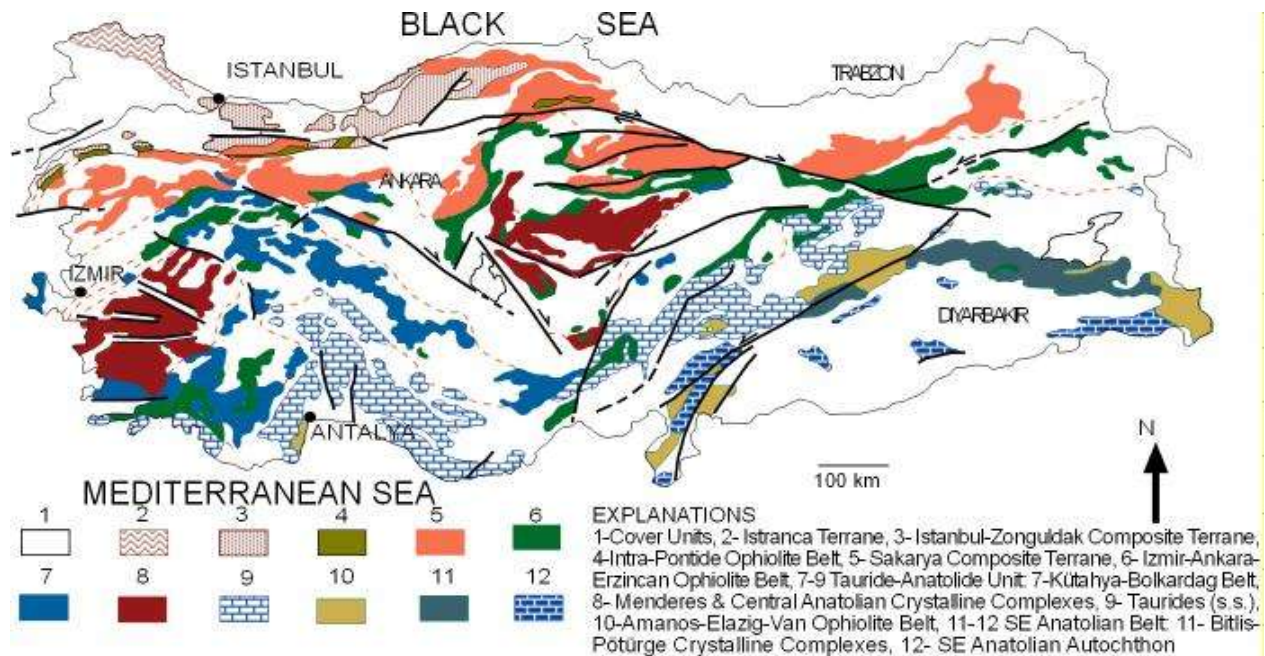


Figure 1- Distribution of the main Alpine terranes in Turkey (after Göncüoğlu et al, 1997)

## CLASSIFICATION OF THE TECTONIC UNITS

The following classification of the Turkish terranes will be mainly based on the Alpine period, the most prominent orogenic event. It finally controlled the paleo-geographical distribution of the pre-Alpine tectonic units and also changed their initial features. From S to N the Alpine terranes are: the Arabian Plate, the northern edge of the Gondwanan Arabian-Libyan Platform; the SE Anatolian Ophiolite Belt, remnants of the southern branch of Neotethys; the Tauride-Anatolide Composite Terrane, an Alpine microcontinent; North Anatolian Ophiolite Belt, representing the allochthonous oceanic assemblages and subduction-accretion complex of the Neotethyan Izmir-Ankara-Erzincan Ocean; Sakarya Composite Terrane, another Alpine microcontinent; Intra-Pontide Ophiolite Belt, remnants of a small branch of the Izmir-Ankara-Erzincan Ocean; Istanbul-Zonguldak Terrane another composite terrane of continental crust origin and Istranca Unit, a suspect terrane of Laurasian affinity (Fig. 2).

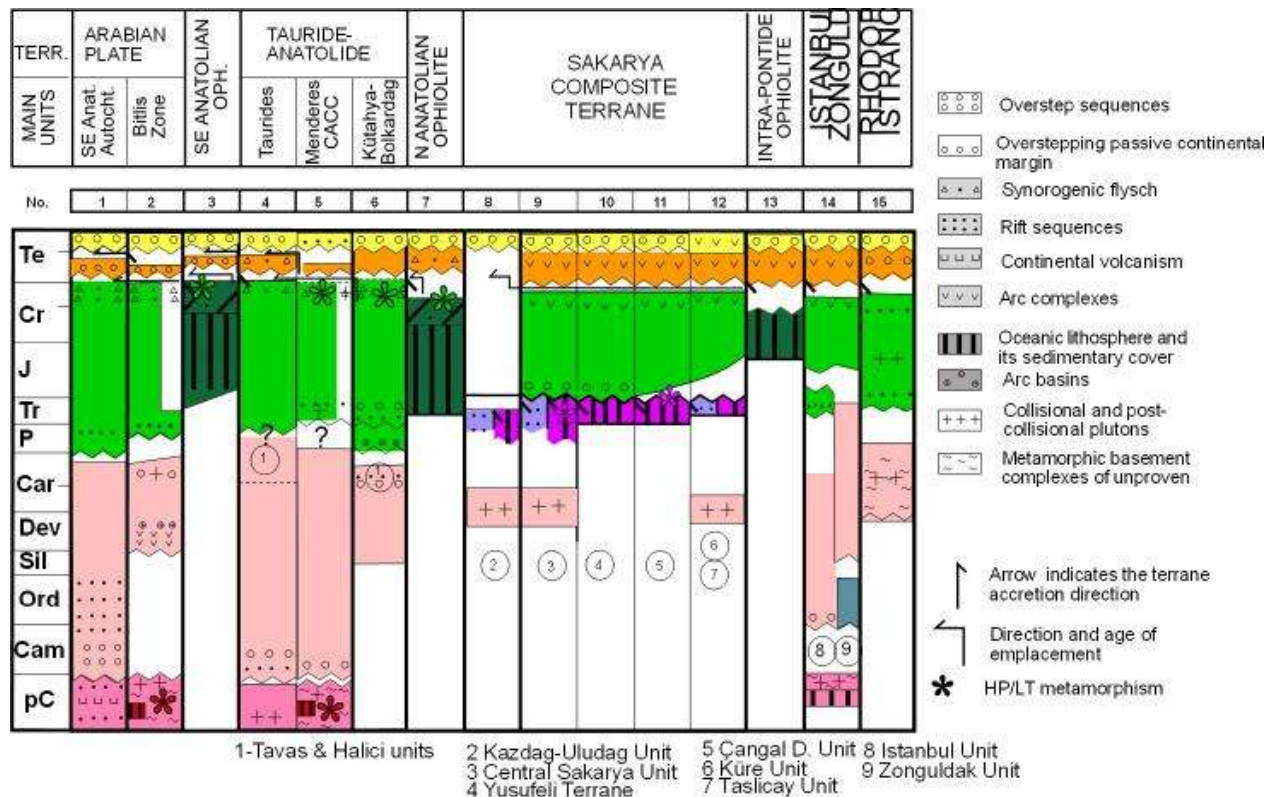


Figure 2- Generalized columnar sections of the Alpine terranes in Turkey (after Göncüoğlu et al, 1997)

## PRE-ALPINE AND ALPINE TECTONIC UNITS OF TURKEY

### 1- The Arabian Plate and the SE Anatolian Autochthon

The Arabian plate in southeast Anatolia comprises two main Alpine tectonic zones: Southeast Anatolian Autochthon and Bitlis Zone, representing the sliced and metamorphosed northern edge of the former.

#### A- Southeast Anatolian Zone (SAZ):

This unit is the northern promontory of the Arabian Platform, which mainly consists of a pan-African basement and its Paleozoic-Tertiary cover (Sungurlu, 1974).

SAZ is separated from the northerly located Bitlis Unit by an active thrust zone, known as “SE Anatolian Fold and Thrust Belt”, which can be traced south-eastward for hundreds of km’s (Zagros Fold and Thrust Belt).

The pre-Cambrian metamorphic basement of SAZ is locally observed in SE Anatolia (Ketin, 1964, 1966). It includes andesitic and rhyolitic lavas and pyroclastics with bimodal chemistry, alternating with fluvial-deltaic type red clastic rocks and mudstones (Fig. 3).

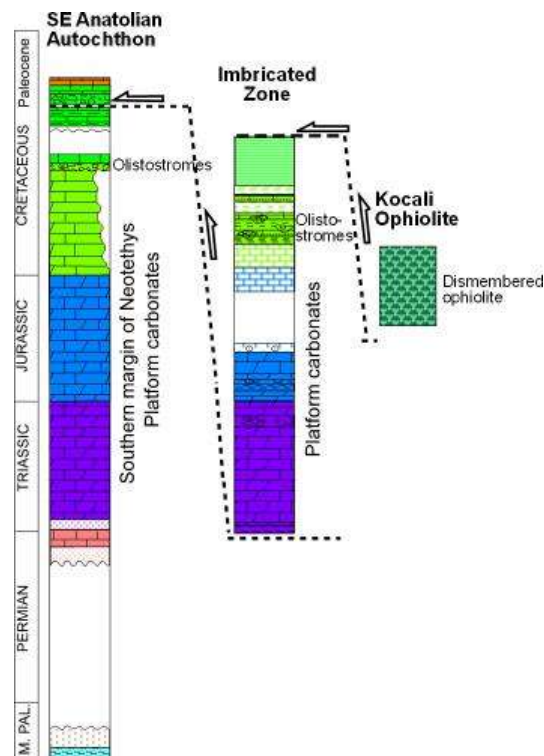


Figure 3- Composite stratigraphic section of the rock-units in the SE Anatolian Autochthon .

This rift-related basement complex is transgressively overlain by quartz-arenites that grade into shelf type carbonates and nodular limestones of Middle Cambrian age (Schmidt, 1966; Sungurlu, 1974; Dean, 1975, 2006; Demircan and Gürsu, 2009). They are followed by a thick package of Ordovician siliciclastic rocks. During Early Silurian a regional depositional break occurred in the region. The Late Silurian-Late Devonian deposition began unconformably with continental clastics and restricted marine sediments, followed by tidal-dominated clastics and terminated with regressive (fluvial) sediments in the central part of SE Anatolia. In the eastern areas, however, the Ordovician clastics are overlain by coastal to shallow marine sediments of Late Devonian-Early Carboniferous age (Perincek et al, 1991). A regional depositional break of Late Carboniferous-Early Permian age indicates to an important uplifting event, which is very probably related to the Variscan events in the northern terranes.

Late Permian shelf-type carbonate deposits are transitional to Triassic shallow marine sediments, indicating to the stabilization of the platform conditions in the northern margin of Gondwanaland during Late Paleozoic.

The Alpine cycle in SAZ has started with the Late Permian-Middle Triassic rifting (Altiner, 1989) and opening of the "Southern Branch of Neotethys (Sengör and Yilmaz, 1981)" between Arabian and the Tauride Platforms. The deposition up to the Early Cretaceous is characterized by platform carbonates on SAZ. During Late Cretaceous a change to foreland deposition and arrival of northerly derived ophiolitic nappes are recorded. Eocene bimodal volcanism (Erler, 1984), related to the opening and southward propagation of foreland basins and deformation of foreland sediments are following events.

Overstep sequences in SAZ are represented by upper Maastrichtian-lower Miocene shallow marine sediments. During late Early Miocene the second set of allochthons were emplaced onto the SAZ due to ongoing N-ward movement of the Arabian Plate. The boundary between the SAZ and the Tauride-Anatolide Platform in the N is an active thrust zone.

### **B- Bitlis Zone (BZ):**

BZ consists of a large number of S-verging slices of metamorphic and sedimentary rocks. It represents the northernmost edge of the Arabian Platform, which has been deformed and metamorphosed during the Alpine closure of the Southern Branch of Neotethys (Göncüoğlu and Turhan, 1984).

BZ is composed of post-Eocene imbricated tectonic slivers. The primary contact to the northern terrane, SE Anatolian Ophiolite Belt, is a thrust zone. Towards west BZ is bounded by the East Anatolian Fault, a major left-lateral strike-slip fault in SE Anatolia.

The basement rocks of the BZ comprise various para- and orthogneisses, migmatites, amphibolites and micaschists (Fig. 4). Bands and lenses of kyanite-eclogites are found as minor intercalations within the gneisses (Okay et al, 1985).

Petrographic data indicate to a plurifacial HT/HP event in the basement (Göncüoğlu and Turhan, 1984). The pre-Early Paleozoic age of the metamorphism in the basement is clearly documented by the presence of HT/HP metamorphic clasts in the basal micro-conglomerates of the Early Paleozoic cover. Rb/Sr isochrone ages about 450my from the basement (Helvacı and Griffin, 1984) confirm the geological data.

The basement is unconformably overlain by a low grade metamorphic sequence of Early–Middle Paleozoic age, where Givetian-Frasnian fauna could be documented in the recrystallized limestones (Göncüoğlu and Turhan, 1984). This lower part of the sequence is followed by olistostromal felsic metavolcanic/volcanoclastic rocks with the blocks of recrystallized limestones and intruded by granitoids of Carboniferous age (Göncüoğlu, 1984). Permian-Early Triassic platformal carbonates unconformably cover these rocks. The regional Permian unconformity and the presence of Carboniferous granitoids strongly suggest a Variscan event in BZ.

In BZ, the initiation of the Alpine cycle is characterized by the Middle Triassic metavolcanic and -volcanoclastics, which are related to the rifting and opening of the “Southern Branch of Neotethys”. These volcanic rocks are conformably overlain by a condensed series, mainly consisting of metapelites interlayered with basic metavolcanic, metachert and metatuffs of Late Triassic-Early Cretaceous age.

This sequence is interpreted as the northern slope deposits of the Arabian passive margin. Ophiolites and ophiolitic olistostromes of Late Cretaceous age are observed as thrust sheets on the metamorphics. The clastics of the Alpine cover sequence contain metamorphic mineral assemblages that indicate to an Alpine low-grade metamorphic event. This Alpine overprint is also documented by radiometric age data (Yazgan, 1984).

Overstep sequences in BZ are represented by Middle Eocene shallow marine sediments. During the Early Miocene the BZ is imbricated and emplaced on the foreland deposits of the SAZ.

Equivalents of Bitlis Terrane occur as metamorphic inliers within the Sanandaj-Sirjan Zone of the Zagros Belt.

## **2- Southeast Anatolian Suture Belt (SASB)**

The Southeast Anatolian Suture Belt is composed of different imbricated structural units representing oceanic and island-arc assemblages of the Southern Branch of Neotethys.



Southeast Anatolian Suture Belt is separated from the northern Tauride-Anatolide Terrane by pre-Maastrichtian S-verging thrusts, which were reactivated during Late Tertiary. I-type calcalkaline plutonic bodies (Baskil Magmatic Arc, Yazgan and Chessex, 1991) of Late Cretaceous age, created by the northward subduction of the Southern Branch of Neotethys at the southern active margin of the Tauride-Anatolide Platform (Malatya-Keban Metamorphics) represent the lowermost tectonic sliver of this terrane.

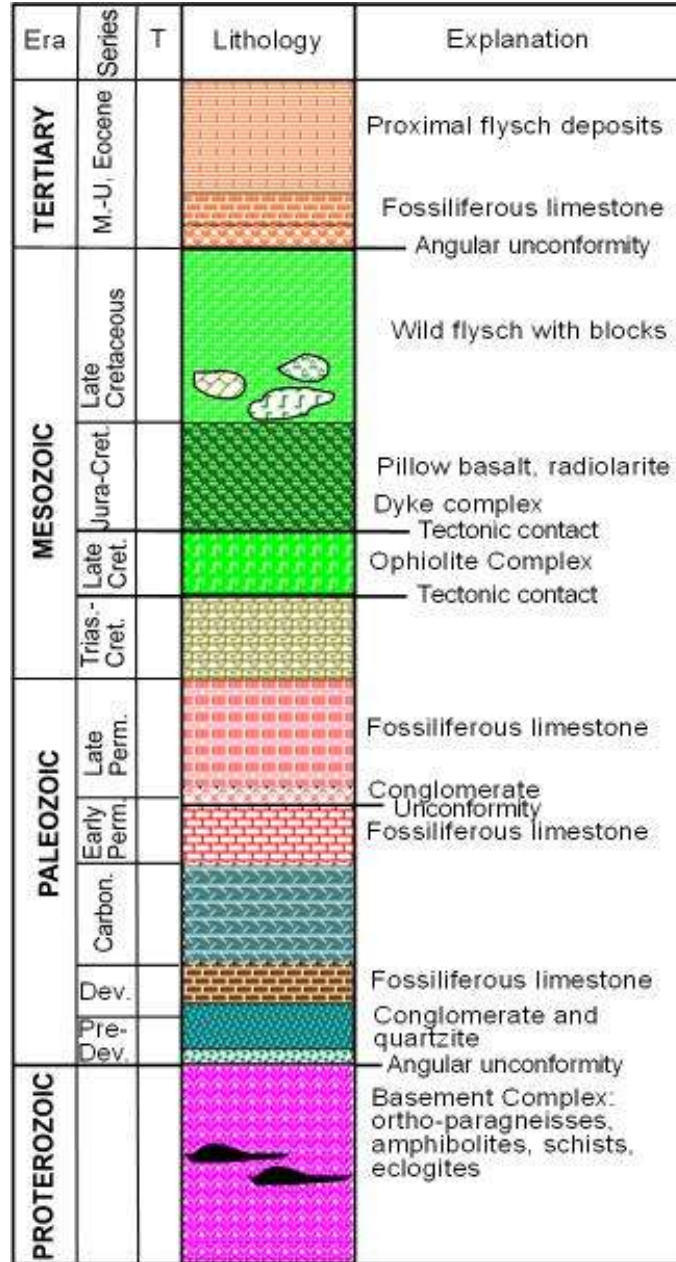


Figure 4- Generalized columnar section of the Bitlis Massif (Göncüoğlu and Turhan, 1984).

In the tectonic slivers with almost complete ophiolitic sequences (e.g. Guleman Ophiolites, Fig. 5), the relative abundance of peridotites versus lherzolites, abundance of podiform chromites and plagiogranites and a depleted mantle composition are the striking features indicating to a supra-subduction setting (Beyarslan and Bingöl, 2000; Robertson, 2002; Parlak et al, 2002, 2004; Bağcı et al, 2005).

Further ophiolites/meta-ophiolitic slivers intruded by dioritic-granodioritic bodies of Late Cretaceous age (Kömürhan Metaophiolites; Yazgan and Chessex, 1991) and its volcanic cover (Yüksekova Complex; Perincek and Kozlu, 1984) are interpreted as ensimatic arc complexes (Yılmaz, 1993). Slices of HP/LT metamorphosed basalts are reported from the eastern part of the belt (Göncüoğlu and Turhan, 1984). The paleontological data from the pelagic sediments of the epi-ophiolitic rocks suggest that the age of the ophiolitic unit is Jurassic-Late Cretaceous.

The Kızıldağ Ophiolite in Hatay and Guleman Ophiolite in Diyarbakir are the best examples of the allochthonous ophiolitic bodies in this belt. The former forms a more or less complete ophiolite succession (Tekeli and Erendil, 1986; Dilek and Thy, 2006) and displays, together with several other ophiolitic complexes of the Southeast Anatolian Ophiolite Belt supra-subduction zone type tectonic setting and can be correlated with the Zagros and Oman Ophiolites in the east and the Troodos Massif in Cyprus.

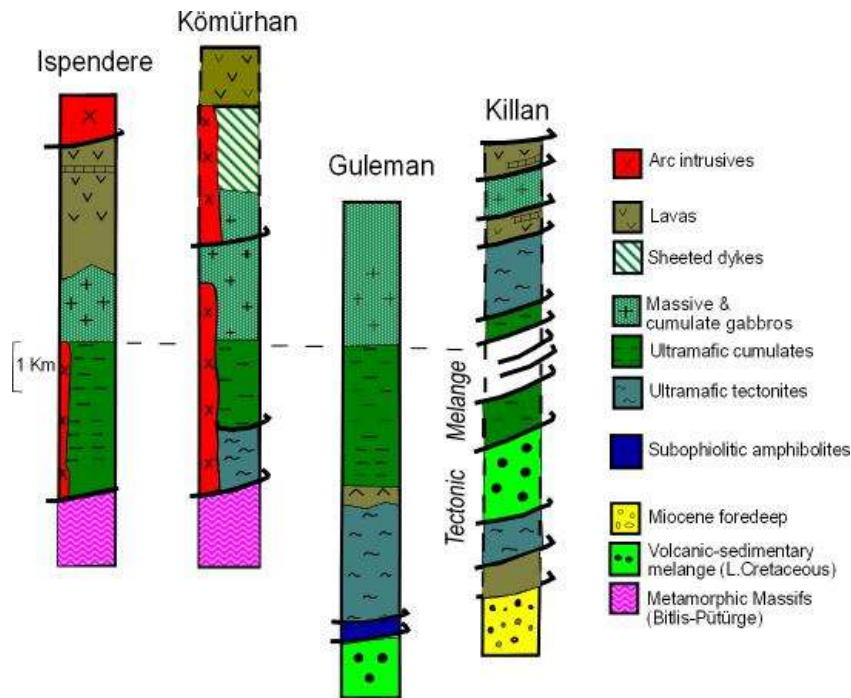


Figure 5- Generalized columnar sections of the ophiolitic members of the SE Anatolian Suture Belt (Özkan and Öztunalı, 1984; Robertson, 2002)

### 3- Tauride-Anatolide Unit (TAU)

The Tauride-Anatolide Unit represents the continental platform between the Neotethyan Izmir-Ankara-Erzincan Ocean to the north and the Southern Branch of Neotethys to the south. It comprises three groups of structural units. From south to north these are the Taurides (*sensu strictu*) a package of mainly non-metamorphic nappes, Anatolides representing the metamorphic central part and the Kütahya-Bolkardağ Belt, representing the northern margin of the platform.

#### A- Taurides

Taurides (*sensu strictu*) or the Tauride Belt is represented by a Neoproterozoic basement (e.g. Gürsu et al, 2004) and its non-metamorphic Paleozoic-Mesozoic cover made of platformal sediments. The Late Cretaceous closure of the northern and southern branches of Neotethys gave way to a double-verging napped structure, which consists of a number of tectono-stratigraphic units with distinctive stratigraphic and structural features characterizing different depositional environments of the platform. Based on the palinspastic reconstruction and interpretation of Özgül (1976, 1984) these units are arranged from north to south as: Bozkır Unit, Bolkar Dağı Unit, Aladag Unit, Geyik Dağı Unit, Antalya Unit and Alanya Unit (Fig. 6).

The initial thrusting of ophiolitic nappes and marginal sequences onto the Tauride platform has started during the Early Eocene. In Mid-Miocene the entire nappe-pile has been re-thrust on the Late Tertiary cover (Fig. 6).

The stratigraphy of the single tectonostratigraphic units of the Tauride unit is given in Figure 7 a and b.

In brief; outcrops of slightly metamorphosed Precambrian rocks are reported from different parts of the Taurides (Gürsu and Göncüoğlu, 2006). The relatively well-studied areas are located in Sandıklı Area, Anamur-Silifke region in Central Taurides and Feke Area in Eastern Taurides (Kozlu and Göncüoğlu, 1997; Özgül and Kozlu, 2002; Göncüoğlu et al, 2007). The basement in these localities comprises metaclastic rocks (slates, conglomerates and greywackes), stromatolitic limestones and lydites together with meta-rhyolites and quartz-porphyrines. Early Cambrian red clastics with trace fossils (Erdogan et al, 2004) overlie the basement with a gentle unconformity. On the basis of clay mineral studies Bozkaya et al (2006) suggest that the metamorphism was realized at very low grade conditions. In Sandikli area highly sheared and mylonitized porphyroids yielded xenocryst single zircon ages about 550 my (Kröner and Sengör,

1990, Gürsu et al, 2006) which suggests that the age of the metamorphic/deformational event is pan-African/Cadomian.

The platform-type deposition in Paleozoic sequences of the Taurides varies in different tectonostratigraphic units, especially in those in the north (Göncüoğlu et al, 2004 a). However, in general terms it can be correlated with the Southeast Anatolian Paleozoic sequences, thus

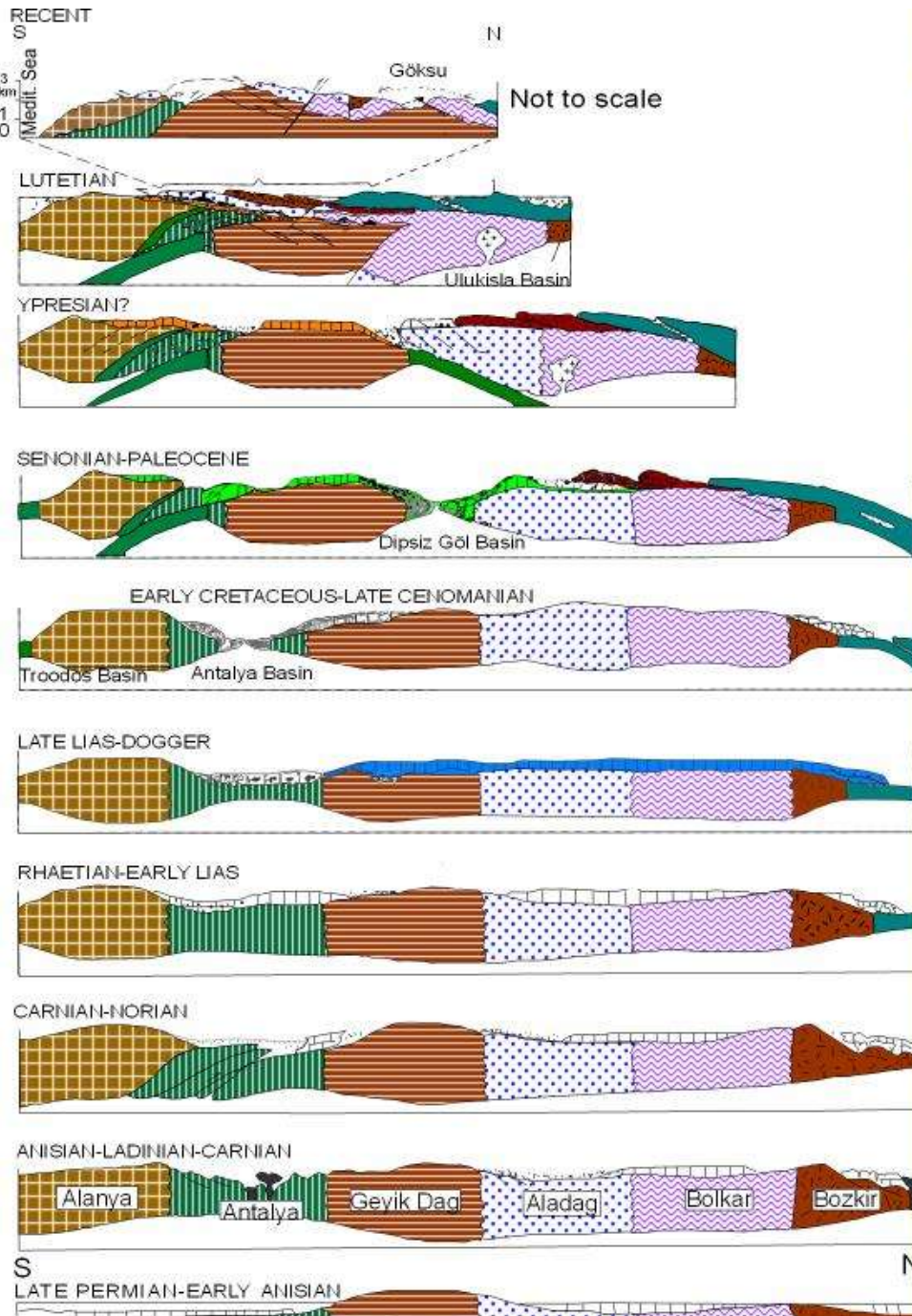


Figure 6- Original position and geodynamic evolution of the main tectonostratigraphic units of the Taurides within the Tauride-Anatolide Platform in Central Taurides (Özgül, 1984).

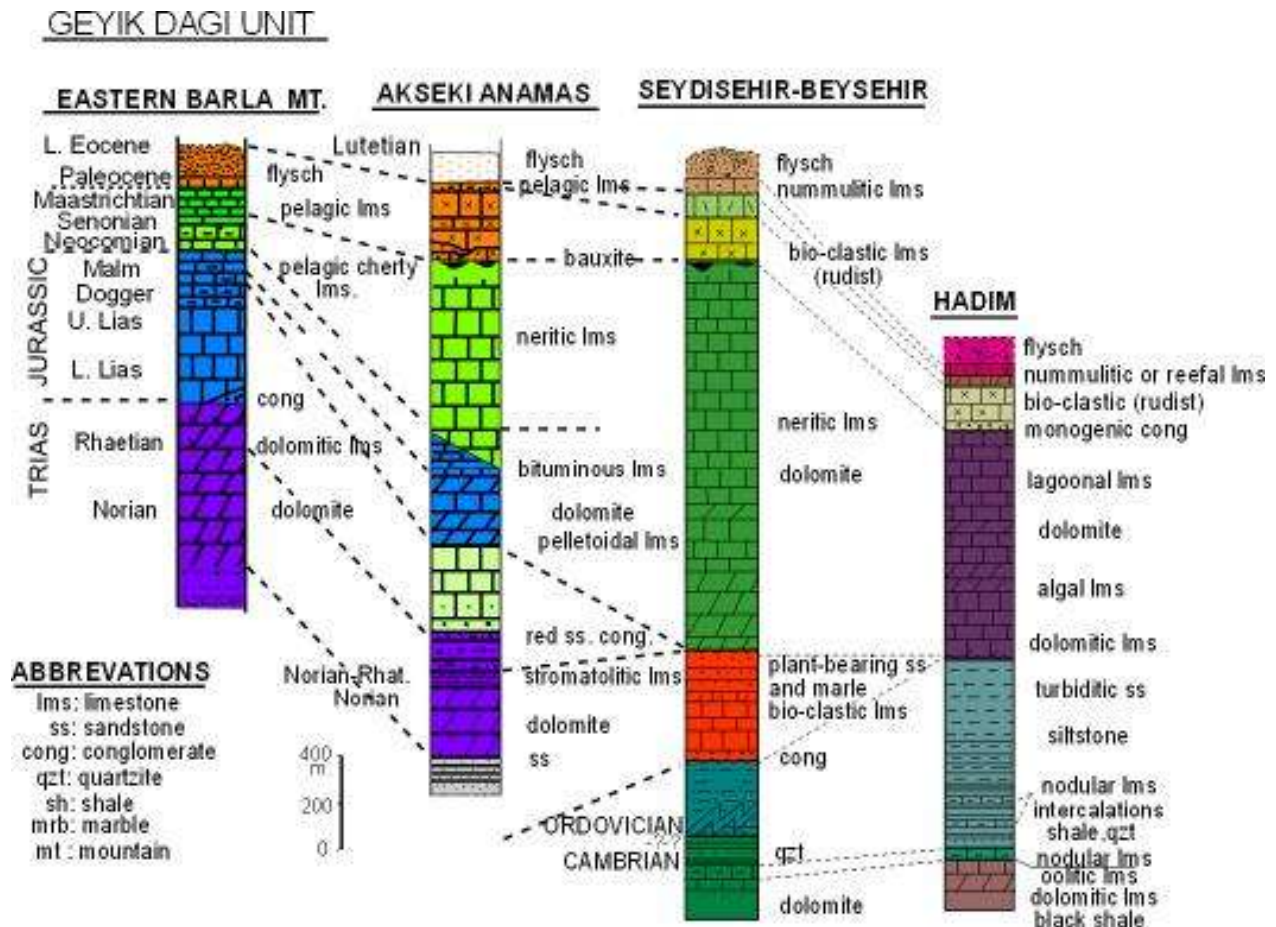


Figure 7a- Generalized stratigraphy of the Geyik Dağı tectono-stratigraphic unit in the Taurides (after Özgül, 1984).

indicating that Taurides and the Southeast Anatolian Zone formed together the northern part of a huge platform contiguous to the Gondwanaland, supported by the presence of Hirnantian glacial deposits (Monod et al, 2003). In Figure 8 the generalized columnar sections of the Paleozoic rock-units in the Taurides are presented for correlation. The main differences in this correlation chart are between the Paleozoic units in the northern part (Bolkardağ Unit and/or Kütahya Bolkardağ Belt) and the Geyikdağı Unit. In the former, the Silurian rocks reflect a basin-type deposition with oceanic basalts, whereas the Early Carboniferous is characterized by the development of flysch-type sediments. The absence of Late Paleozoic sediments, an important regional unconformity during Early Late Permian and the presence of Carboniferous pyroclastics in the northern tectonostratigraphic units in the Aladağ Unit, on the other hand suggests a Late Paleozoic event to the north of the Tauride Platform (Göncüoğlu et al, 2007).

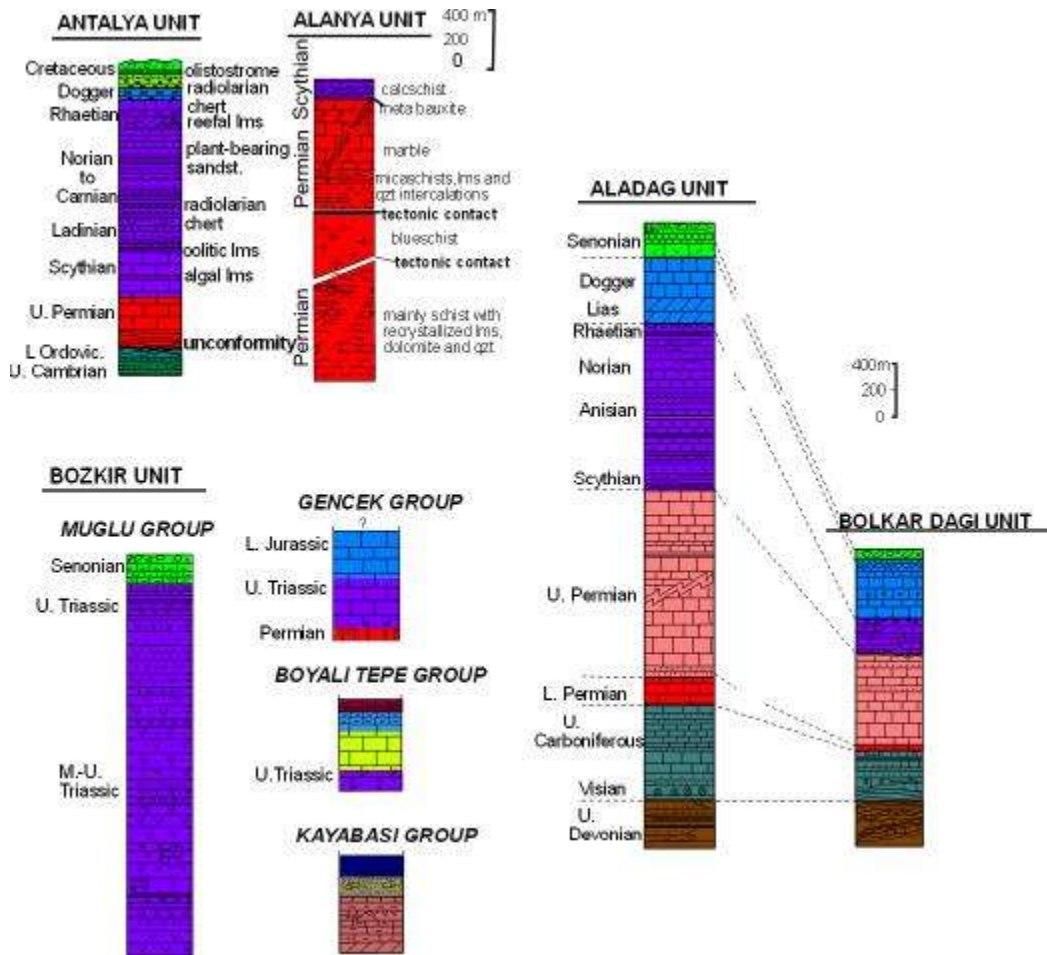


Figure 7b- Generalized stratigraphy of the Bozkır, Bolkar, Aladağ, Antalya and Alanya tectonostratigraphic units in the Taurides (after Özgül, 1984).

The Permian sequence represented by epicontinental carbonates is followed in the south and north of the platform by rift related Early-Middle Triassic sediments and volcanics which indicate to the opening of Neotethyan basins and thus the beginning of the Alpine cycle. The Bozkır unit, consisting of Triassic-Cretaceous pelagic sediments interlayered with basic volcanics and slices of ophiolites, which are interpreted as oceanic crust-starved slope-margin sequences. This unit is observed as a nappe-pile on the platformal carbonates of the Taurides. Bozkır Unit, however, is interpreted as allochthonous assemblages of the Izmir-Ankara Ocean, which have been tectonically transported ca 300km toward south, passing on the internal platform units such as Kütahya-Bolkardağ and Menderes.

Middle Triassic-Early Cretaceous time interval in the central part of the platform was dominated by neritic carbonates, while in the northernmost margin, facing the Izmir-Ankara-Erzincan Ocean

pelagic conditions continued. During the Senonian the oceanic basins to the south and north of the platform started to close. Ophiolitic as well as marginal sequences were thrust from north onto the more external parts of the platform, the resulting crustal thickening generated a metamorphic zone (Menderes and Kütahya-Bolkardağ units) to the north of it. The arrival of these external nappes onto the Taurides is Early Eocene.

The oldest lithologies of the overstep sequences in the Central Taurides is Lutetian in age (Özgül, 1976). The final re-thrusting of basement nappes in Western Taurides, however, is Middle Miocene.

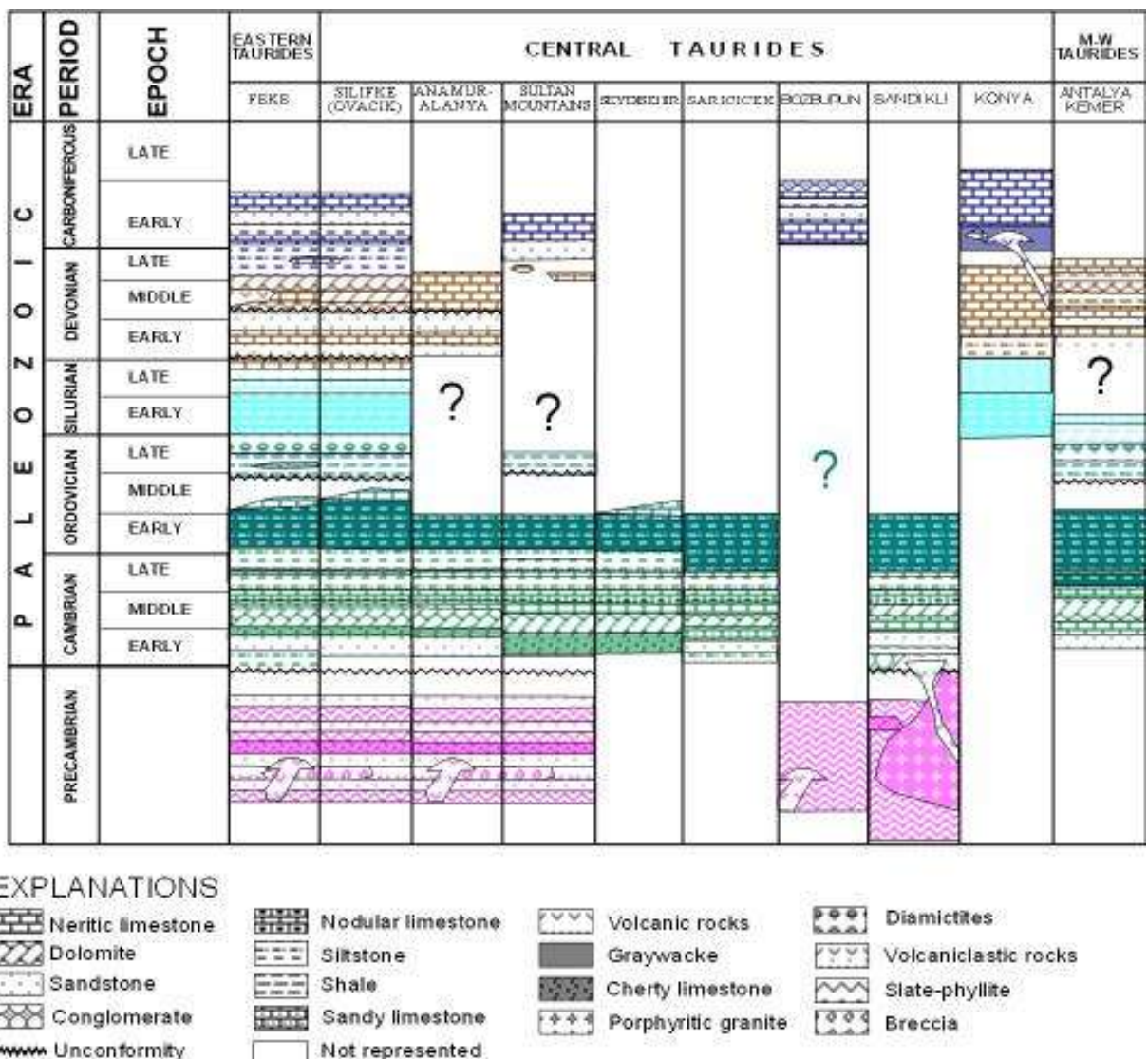


Figure 8- Generalized stratigraphic columnar sections of the Paleozoic rocks in the Tauride units (Göncüoğlu and Kozlu, 2000 and Göncüoğlu et al, 2004a).

## B- Anatolides:

Anatolides represent the metamorphic northern margin of the Tauride-Anatolide Platform, separated from the Sakarya Composite Terrane by the Neotethyan Izmir-Ankara Suture. Anatolides consist of two huge crystalline complexes: the Menderes Massif to the west and the Central Anatolian Crystalline Complex to the east (Fig. 9). Kütahya-Bolkardağ Belt (KBB) represents the northern and HP/LT metamorphic peripheral belt of the Menderes Massif and also corresponds to the allochthonous units such as Bozkır and Bolkar Dag Unit of Özgül (1976) which are observed as nappes on the northern flank of the Taurides.

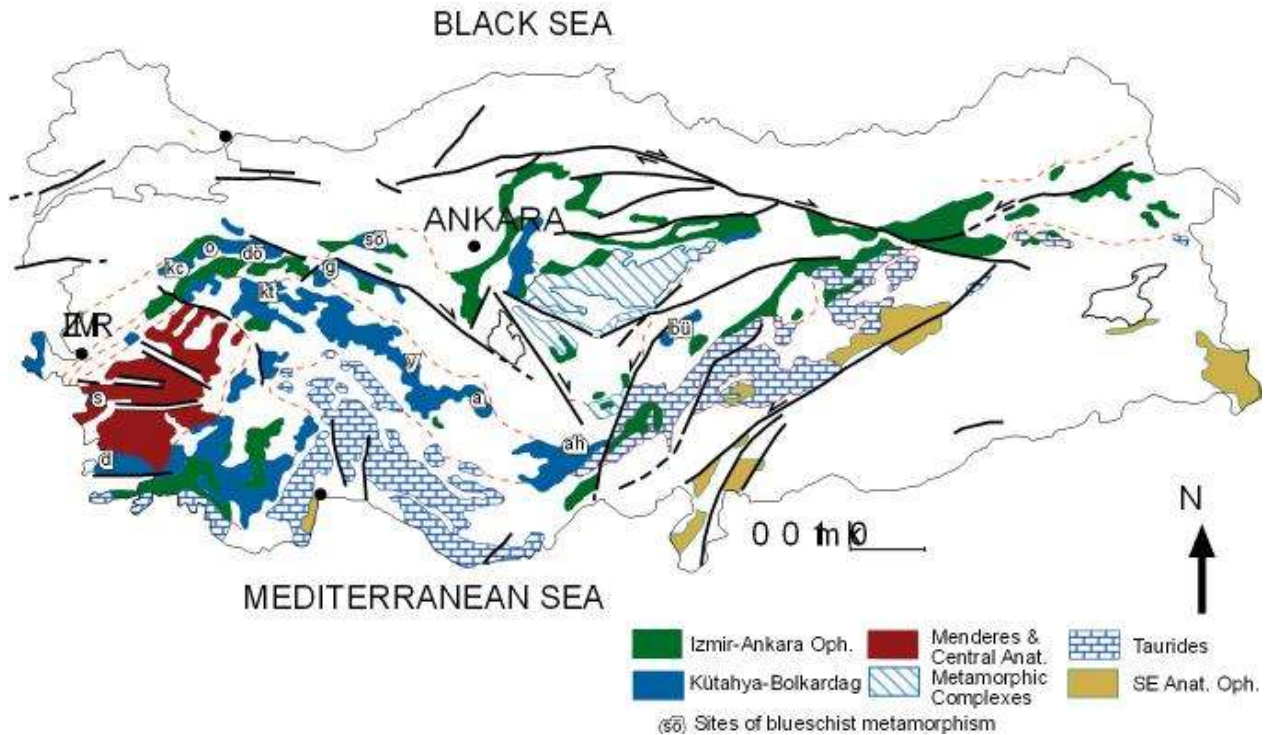


Figure 9- Distribution of the Tauride-Anatolide Unit in Turkey (after Göncüoğlu et al, 1997)

**a- Menderes Massif (MM):** This metamorphic core-complex forms the western nuclei of the Anatolides. Its petrographic features have been relatively well studied (for a brief review see Dora et al, 1991). The Menderes Massif comprises of a pre-Alpine "gneissic core" and an Alpine "schist and marble envelope" (Fig. 10).

The northern boundary of MM is rather a tectonic zone, where less metamorphosed slices of Kütahya-Bolkardağ unit are thrust onto the former.

The core of the MM consists, in ascending order of migmatites, para- and orthogneisses (leptites), amphibolites, granulites and eclogites (Oberhansli et al, 1997; Candan et al, 2001). It is generally accepted that the "core" of the MM was affected at least by two progressive metamorphic events. Sengör et al (1984b) suggests a depositional age of 680my for the



protoliths of the "core"-gneisses. The first metamorphic event in the partially melted gneisses, evidenced by an Rb/Sr whole rock isochrone age of 500my is regarded by the same authors as the age of the pan-African high-grade metamorphism. Dora et al (1991) confirm this data by additional Rb/Sr data. This event has probably led to the formation of the anatectic granitoids, which yield an Rb/Sr whole rock isochron age of 470my (Sengör et al, 1984b).

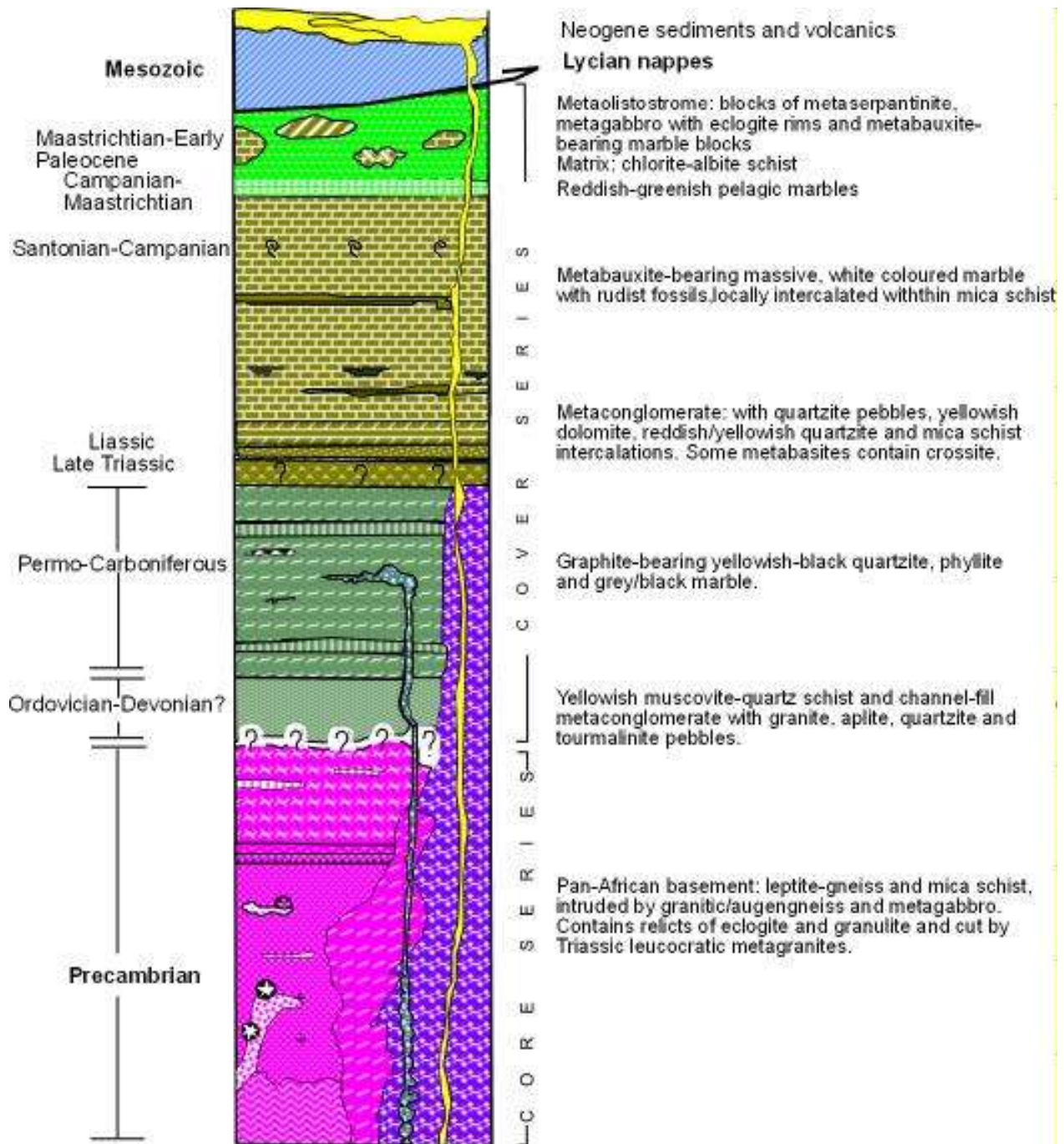


Figure 10. Generalized columnar section of the Menders Massif (Dora et al, 1991).

Recent work (Candan, 1994) suggests the presence of relict granulitic and eclogitic metamorphisms of pan-African age in the core series, thus suggesting a complex pan-African history.

The core is unconformably covered by the schist unit, which starts with metaconglomerates and consists mainly of kyanite+staurolite+garnet schists and garnet+mica schists with minor intercalations of metaquartzites and garnet amphibolites. Calc-schist and phyllite interlayers increase towards the top of the unit. Based on sparse paleontological data Konak et al (1987) suggest a Paleozoic age for this sequence. A post-pan-African/pre-Alpine metamorphic event accompanied by granite intrusions during Late Paleozoic in northern Menderes is suggested by Sengör et al (1984b).

The schist unit is conformably overlain by platform type marbles, calc-schists and dolomitic marbles of Mesozoic age. A conformable sequence represented by thin-bedded red marbles of Paleogene age forms the uppermost part of the Unit (Dora et al, 1991). The age of the Alpine main metamorphic event (Paleocene-Late Eocene) is documented by paleontological and geochronological data (Sengör et al, 1984a).

Recent work suggests that Menderes Unit has been effected by extensional tectonic and represents a Miocene “core-complex” (Bozkurt et al, 1993; Bozkurt and Oberhansli, 2001; Ring and Collins, 2005, Çemen et al, 2005). The E-W trending graben-structures in the massif indicate an ongoing extension in the eastern Aegean.

**b- Central Anatolian Crystalline Complex (CACC):** This unit forms the eastern continuation of the Anatolides. It has been separated from the main trunk of the Anatolides by the Tertiary Tuz Gölü Basin. CACC is bounded to the north by ophiolitic slivers of the Izmir-Ankara Suture Belt. Its southern boundary is covered by Tertiary sediments of Tuz Gölü, Ulukışla and Sivas Basins.

The lowermost unit of CACC is composed of sillimanite- cordierite bearing gneisses, pyroxene gneisses, micaschists, amphibolites, bands and lenses of marbles/calc-silicate marbles and migmatites (Fig.11). The zircon and sphene ages (Göncüoğlu, 1982; Köksal et al, 2004, 2007, 2008) from S-type granitoids suggests a Precambrian basement of Gondwanan origin.

A thick quartzitic band, probably representing a post- Pan-African transgression, is followed by an alternation of marbles, sillimanite gneisses, amphibolites, calc-silicate amphibolites and quartzites (Göncüoğlu, 1986). The amphibolites are originated from alkaline basalts, ascribed to the Triassic rifting event (Floyd et al, 2000).

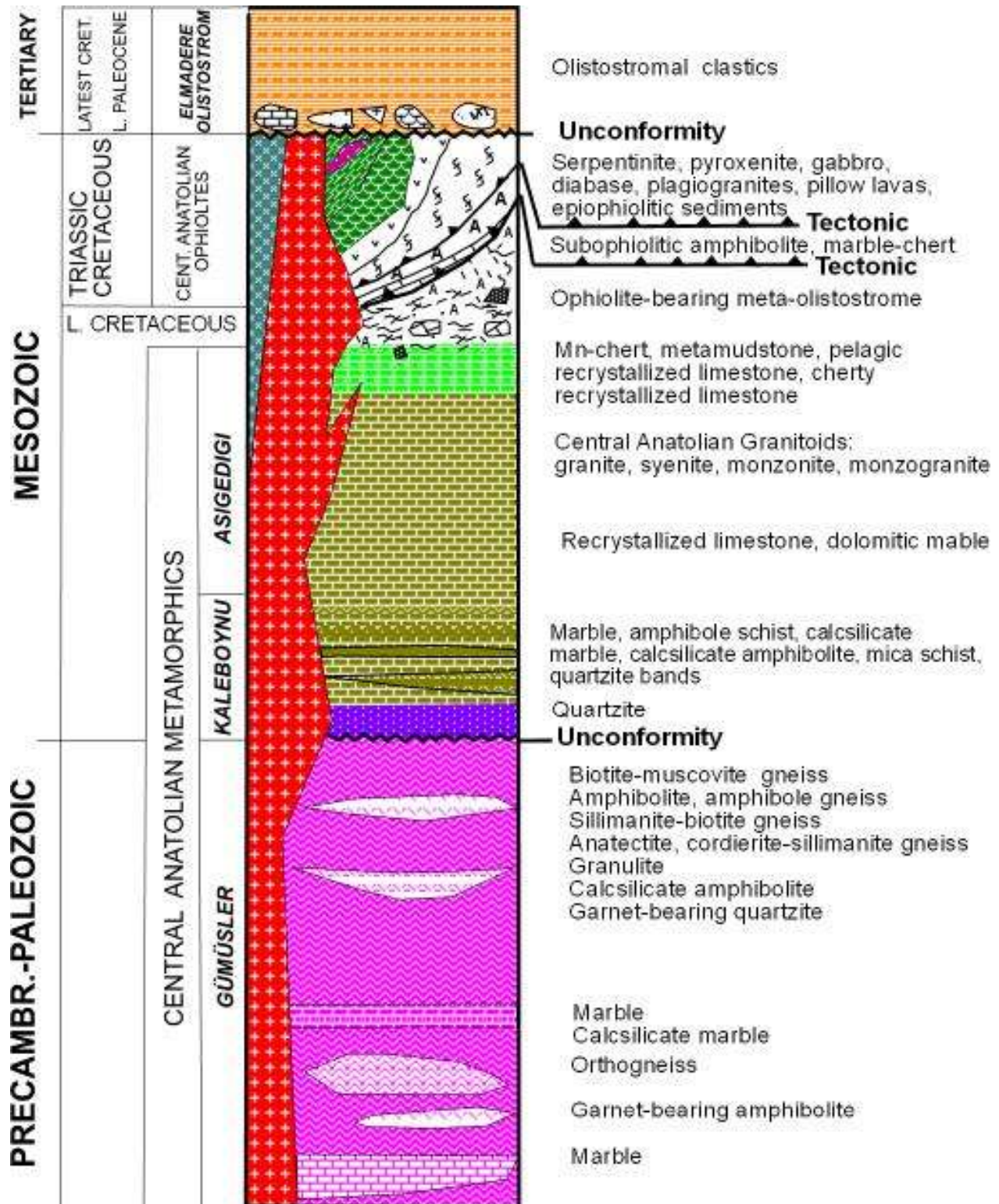


Figure 11- Generalized columnar section of the metamorphic rocks of CACC (Göncüoğlu et al, 1992b).

The upper unit of CACC consists of a thick sequence of marbles passing upwards into cherty marbles and finally into cherts and amphibole schists. Correlating these carbonates with those in Kütahya-Bolkardağ Belt, Göncüoğlu et al (1992b) suggests a Triassic-Early Cretaceous age for this very thick carbonate unit in the upper part of the metamorphic sequence. As it is the case in most Tauride-Anatolide units the upper part of the carbonate succession is characterized by slope- to basin-type sediments and followed by an ophiolite bearing meta-olistostrome and finally by disrupted supra-subduction zone-type ophiolites of Late Cretaceous age (Yaliniz et al, 1996; 2000; Yaliniz and Göncüoğlu, 1998). The metamorphics as well as the ophiolites are intruded by post metamorphic collision-type granitoides (Göncüoğlu and Türeli, 1994; Akıman et al, 1993; Boztug, 1998, 2000).

The Alpine metamorphism is supported by zircon, Rb/Sr and K/Ar mineral ages, which range between 74 and 78my (Göncüoğlu, 1982, 1986; Whitney et al, 2003). Non-metamorphic Upper Maastrichtian-Paleocene clastics unconformably overlie the CACC. Eocene marine deposits are formed along E-W trending transtensional basins, whereas Late Tertiary is characterized by fluvial and lagoonal sediments, which were affected by Neogene tectonics (Dirik and Göncüoğlu, 1996; Dirik et al, 1999; Ocakoğlu, 2004).

It is suggested that the pre-metamorphic stratigraphy of CACC correlate well with the Anatolide units and that CACC had been part of the Tauride-Anatolide Platform during the Alpine period. The southward emplacement of the ophiolitic nappes and related crustal thickening during the closure of the Izmir-Ankara-Erzincan branch of Neotethys has been the cause of the high-grade metamorphism in CACC units. The main difference from the MT is that the ophiolite emplacement, crustal thickening and thus the metamorphism were earlier than the former but coeval with the KBB.

**c- Kütahya-Bolkadağ Belt (KBB):** This unit represents the northernmost edge of the north-facing passive margin of the Tauride-Anatolide Platform. KBB constitutes a number of tectonic slices that belong to a- subducted and accreted rocks of the Izmir-Ankara oceanic lithosphere and the subduction-accretion prism, b- subducted and variably metamorphosed slope sediments of the Tauride-Anatolide platform, c- flysch-type deposits formed in fore-land basins on the platform, in front of nappes. The relatively northern units with distinct HP/LT metamorphism were ascribed by Okay (1985) to a separate belt (Tavşanlı Zone), whereas the southern ones lacking HP/LT metamorphism were named as the Afyon Zone.

The reconstructed stratigraphy of the KBB in its lower part comprises metasediments (mainly sandstones) alternating with felsic-intermediate meta-volcanics and volcanoclastics, black slates

and lydites intruded by granites. Radiometric age data suggests a Late Neoproterozoic age for this part of the sequence (Gürsu and Göncüoğlu, 2008). This Precambrian basement is unconformably overlain by quartzites, sandstones and slates with a few recrystallized limestone sequences. In the Konya region, a thick carbonate succession with Devonian fossils is overlain by a sedimentary mélangé with various blocks of Silurian, Devonian and Early Carboniferous limestones associated with bimodal volcanic rocks that were attributed to the Early Carboniferous back-arc deposition on the northern margin of the Tauride-Anatolide platform. (Özcan et al, 1989; Göncüoğlu et al, 2003a, 2007).

The Paleozoic rocks of the KBB are transgressively overlain by micro-conglomerates, quartzites and recrystallized limestones of Late Permian (Figures 12, 14). Rift related continental red clastics of Early Triassic age representing the opening of the Alpine Izmir-Ankara-Erzincan Ocean and thus, the separation of the Tauride-Anatolide Platform from the Sakarya Terrane, unconformably cover the Paleozoic basement (Göncüoğlu et al, 2003a).

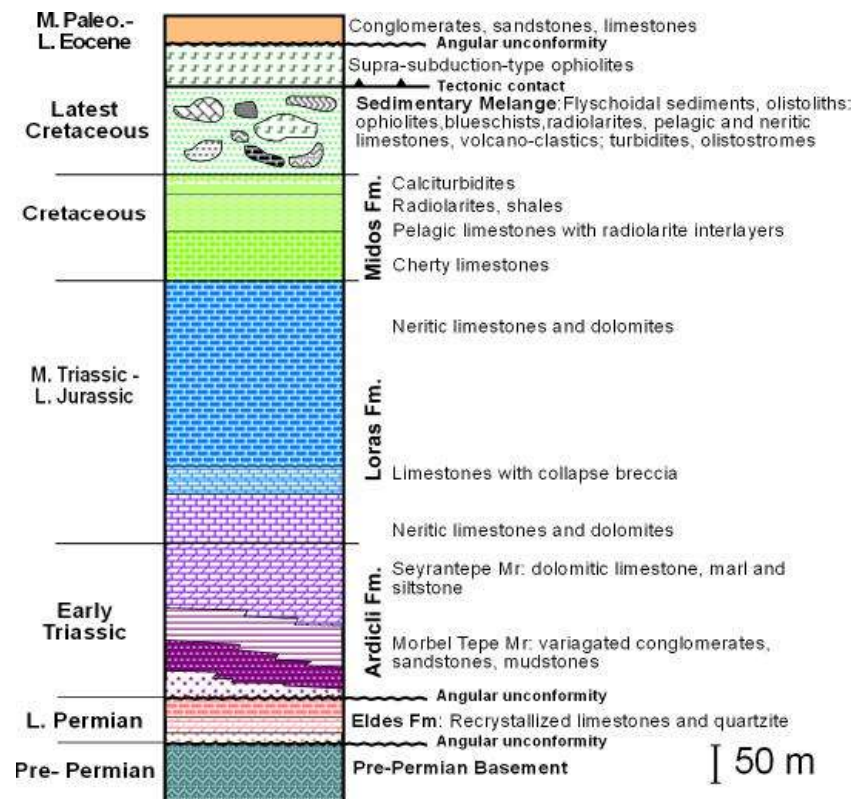


Figure 12- Generalized columnar section of the Paleozoic and Early Mesozoic rocks of the KBB (Göncüoğlu et al, 2003a)

The Middle Triassic-Early Cretaceous deposition is characterized by continuous platform-type carbonates, which is followed by pelagic micrites and radiolarian cherts indicating a deepening and transition to slope and basin conditions. This transition commences in some tectonic slivers already in Late Jurassic or Early Cretaceous. Late Maastrichtian fossils were found in the lower part of flyschoidal foreland deposits, represented by sedimentary mélanges and olistostromes with huge ophiolite, blueschist and neritic limestone blocks. Oceanic lithosphere of the Izmir-Ankara Ocean is observed as pieces of a discontinuous nappe on this mélange (Göncüoğlu et al, 2006 b). Upper Paleocene sediments in KBB represent the post-tectonic cover (Göncüoğlu et al, 1992a). We suggest that KBB was imbricated during Late Cretaceous and the oceanic, and subducted margin successions were emplaced first onto Menderes and subsequently as huge nappes onto the Taurides in further S during Middle Eocene.

Detailed work in the KBB (for a brief review see Göncüoğlu, 2007) has shown that the stratigraphy of the northern “Tavşanlı Zone” and the southern “Afyon Zone” is very similar (Figure 13). Moreover, HP/LT metamorphism, although variable, can be observed in both units. Hence a subdivision into two units is not justified.

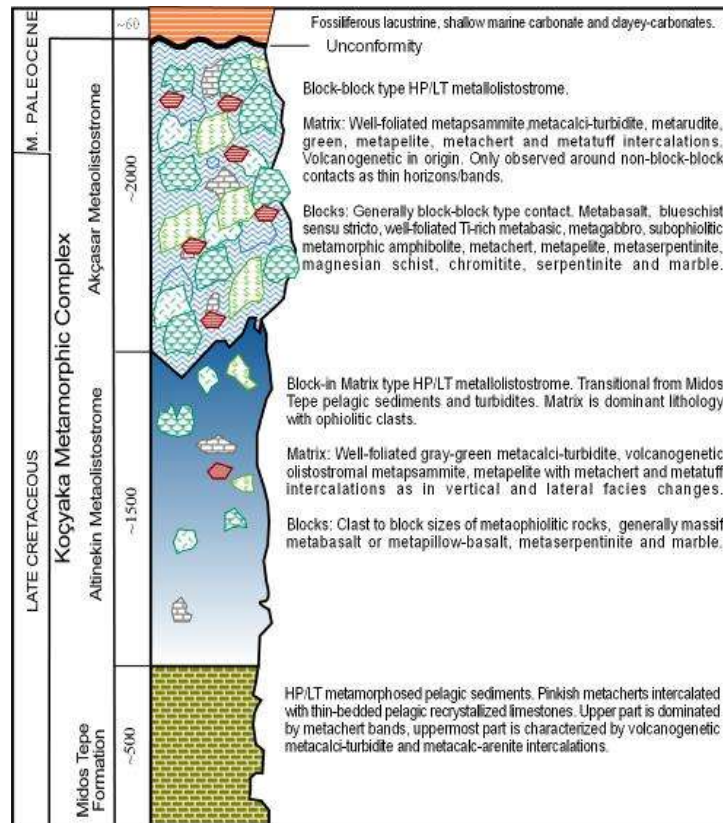


Figure 13- Stratigraphy of the Tavşanlı-type HP/LT platform and melange-complexes in Konya area (Floyd et al, 2003)

The well-developed HP/LT metamorphism of Alpine age (Okay, 1980; Kulaksız and Phillips, 1985; Okay and Kelley, 1994a) in this zone is attributed to the subduction of the passive margin sediments prior to the collision of the Tauride-Anatolide platform with the Sakarya Terrane (Okay, 1985, Floyd et al, 2003).

#### 4- North Anatolian Ophiolite Belt (NAOB)

The North Anatolian Ophiolite Belt represents allochthonous assemblages of the Neotethyan Izmir-Ankara-Erzincan Ocean, which were emplaced southward onto the Tauride-Anatolide Platform during Late Cretaceous. The units of Sakarya Composite Terrane tectonically overlie the ophiolites in NW Anatolia. In Central and East Anatolia, the ophiolites are thrust along steep basement-thrusts onto Tertiary basins (e.g. Çemen et al, 1999).

NAOB consists of huge bodies of almost complete ophiolitic sequences (Fig. 14) and tectonic mélanges of the Izmir-Ankara accretionary complex (Göncüoğlu et al, 1997; Okay and Tüysüz, 1999; Robertson, 2002)

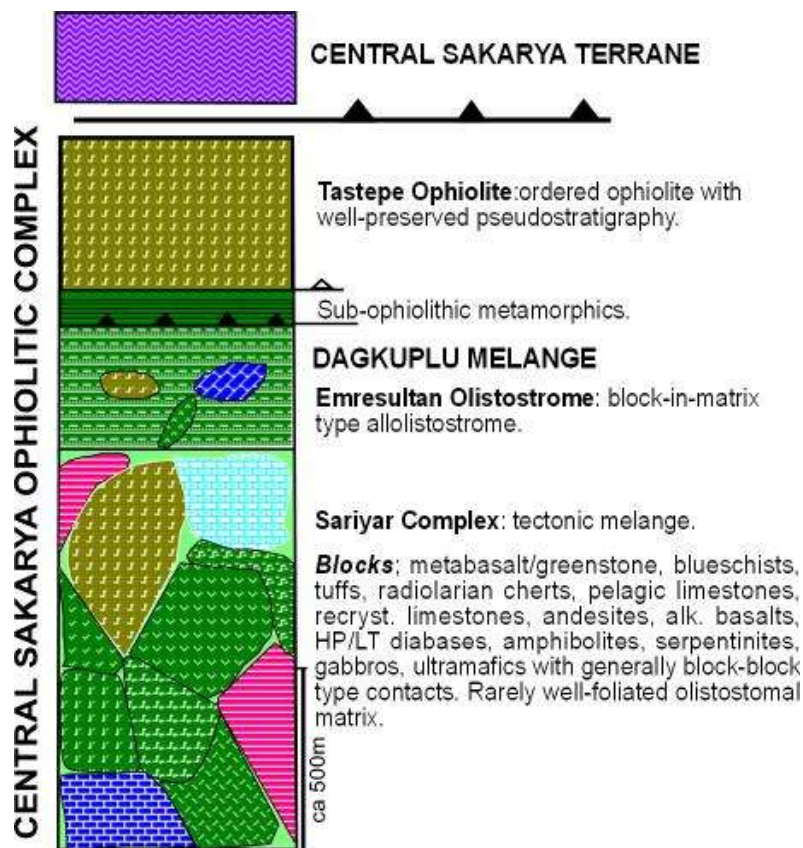


Figure 14- Rock units and structural relationships of the NA Ophiolitic units in the Central Sakarya area (Göncüoğlu et al, 2000a).

The ophiolites display characteristic geochemical features of MORB, OIB and supra-subduction zone-type ophiolites including island arc basalts, fore-arc and back-arc basalts (Göncüoğlu and Türel, 1993; Yalınz et al, 2000; Göncüoğlu et al, 2006a, b). These ophiolitic units and the mélanges are transported for more than a hundred meters towards south onto the Tauride-Anatolide Platform and are observed as allochthonous units.

The suture zone in situ is only observed in a Central Sakarya area, where Göncüoğlu et al (2000a) studied the structural relations and the internal stratigraphy of the allochthonous units in detail (Fig. 14 and 15). However, the allochthonous bodies of the mélangé complexes were studied in detail in Bornova (Aldanmaz et al, 2008 and the references therein), Ankara (Ankara mélangé, the classical work of Bailey and McCallien, (1954 in Sengör, 2003), and Sivas areas (Yılmaz, 1980).

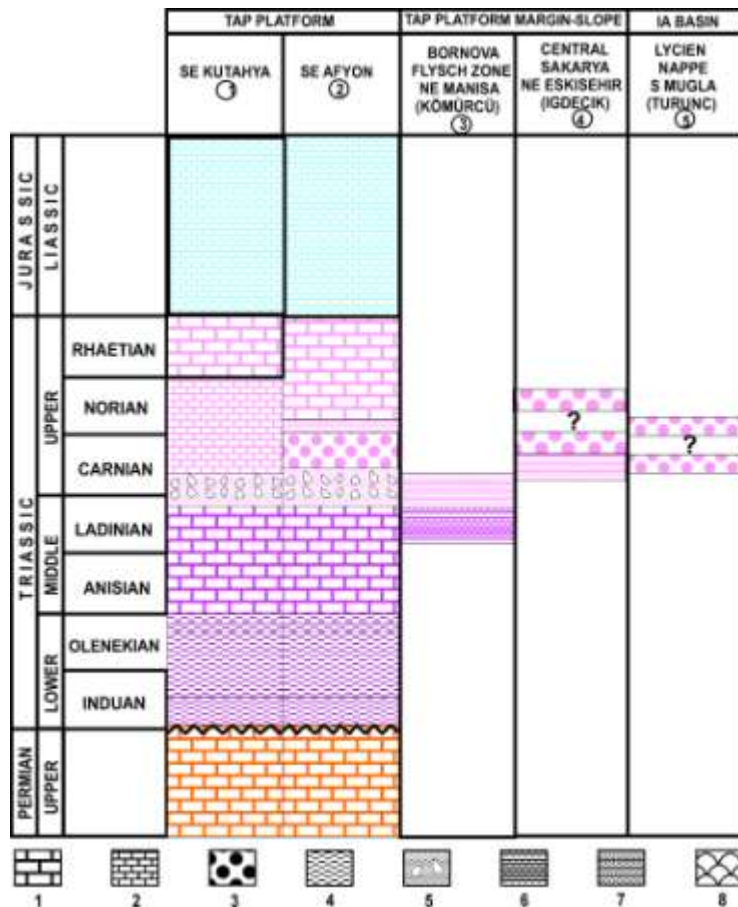


Figure 15- Correlation of the generalized columnar sections of the Izmir-Ankara Suture Belt with the Anatolides (Tekin and Göncüoğlu, 2007). Explanations: 1-platform carbonates, 2- slope-basin deposits, 3- continental clastics, 4- mudstone, 5- olistostromal deposits, 6-chert-mudstone alternations, 7- sandstone-mudstone-chert, 8- pillow-lava.



A well-documented blueschist metamorphism is recorded from the mafic volcanic blocks and slivers within the mélangé (Okay et al, 1998). The peak metamorphic conditions (20 Kb/430° C; 70 km subduction) are recorded in continental margin slivers of the Tauride-Anatolide platform, whereas melange blocks were subducted not deeper than 30 km (Okay and Kelley, 2007) Pelagic limestones and radiolarites associated with pillow-lavas in the mélangé yielded (Göncüoğlu et al, 2006a) formation ages that range from mid Triassic to Late Early Cretaceous (Fig. 16).

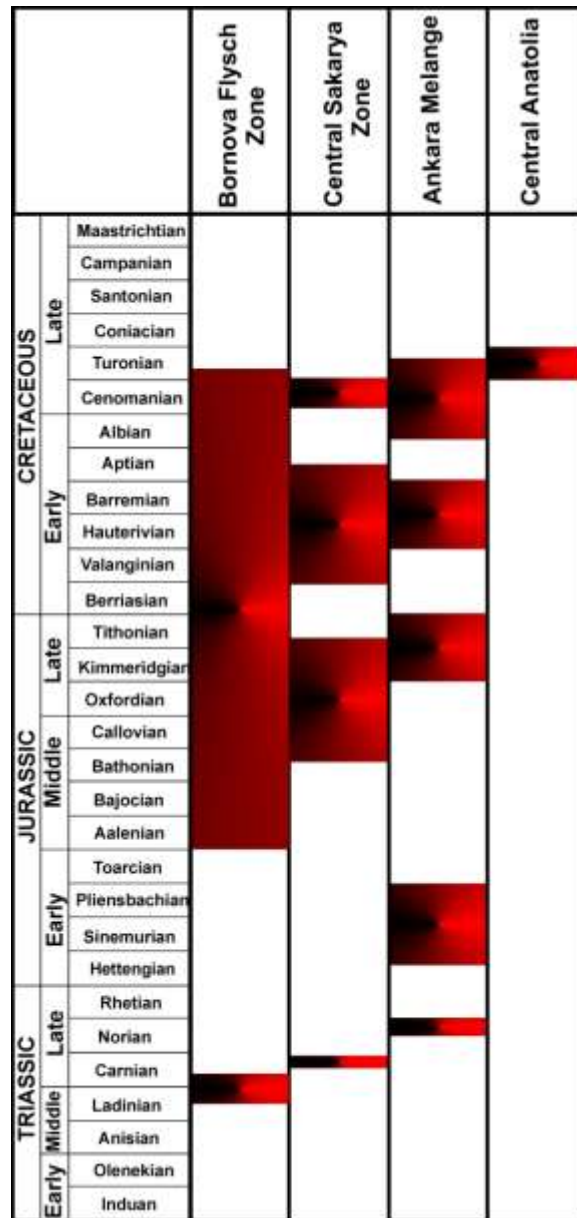


Figure16- Age of the radiolarian cherts within the mélangé complexes of the Izmir-Ankara Suture Belt (after Göncüoğlu et al, 2006b)

The geochemistry of the pillow-basalts within the melange shows the presence of MORB, OIB, and supra-subduction-type (island arc, fore-and back-arc type volcanics, e.g. Gökten and Floyd, 2007; Aldanmaz et al, 2008) volcanic rocks indicating a complex oceanic lithosphere-formation (Fig.17). The earliest ages of MORB are Carnian and the youngest ones are Cenomanian suggesting that the formation of Izmir-Ankara oceanic crust started as early as Middle Triassic (Fig. 16) and lasted until Late Cretaceous (Göncüoğlu et al, 2000a; Tekin et al, 2002). The presence of middle Cretaceous SSZ type ophiolites (Yaliniz et al, 2000, Göncüoğlu et al, 2006 a, b) together with radiometric ages around Albian-Campanian (Önen, 2003; Önen and Hall, 1993) indicate that its closure started along an N-directed intra-oceanic subduction (Fig. 18). The final closure, however, must have realized by formation of another subduction (e.g. Bektaş, 1983) beneath the northerly Sakarya continent during the end of Cretaceous, generating a marginal arc (Late Mesozoic-Tertiary Pontide Magmatic Arc). By this, the subduction/accretion complexes together with the pieces of the Izmir-Ankara oceanic lithosphere thrust towards S, onto of the Tauride-Anatolide Platform.

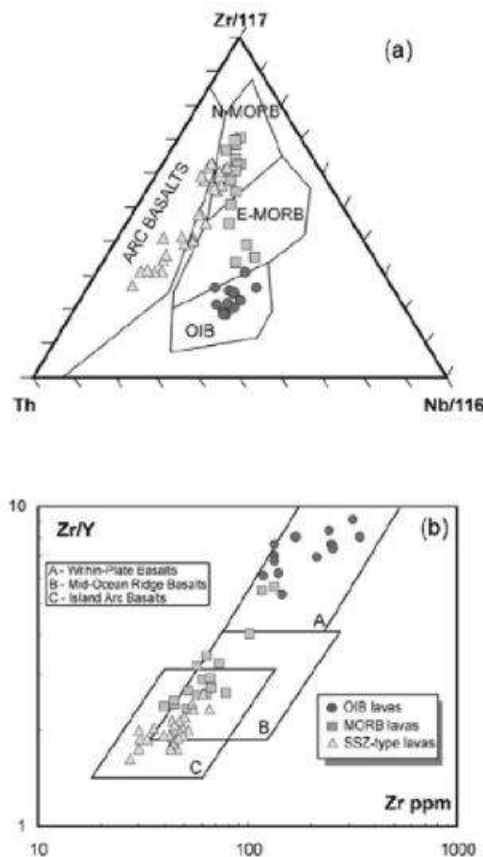


Figure 17- Geochemical features of the pillow-basalts in Bornova Melange of the Izmir-Ankara Suture (Aldanmaz et al, 2008)

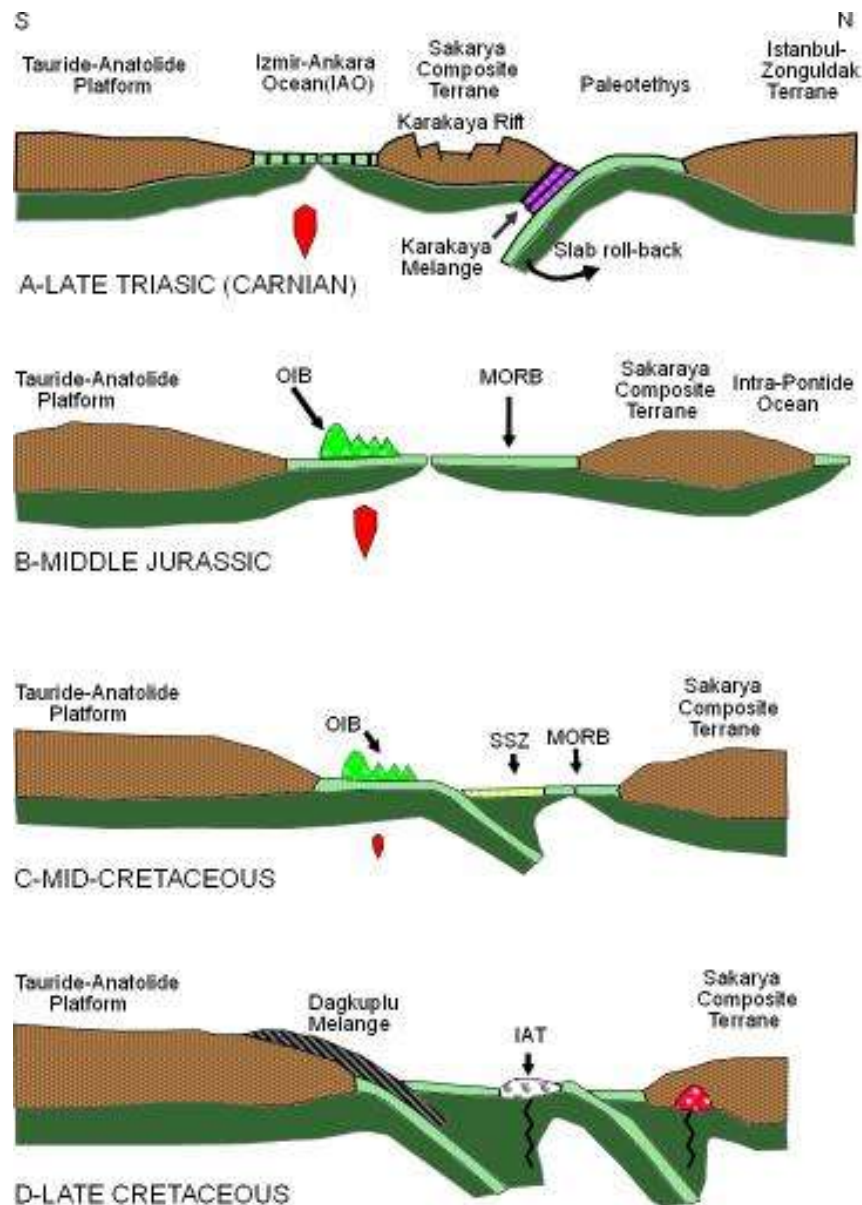


Figure 18- Geodynamic scenario for the closure of the Izmir-Ankara branch of Neotethys (after Yalınız et al, 2000)

## 5- Sakarya Composite Terrane

Sakarya Composite Terrane is an Alpine unit, which is bounded by the Izmir-Ankara Suture to the south and the Intra-Pontide Suture to the north. It is a 100-200km wide east-west trending belt covering almost the entire northern Anatolia (Fig. 19). It is considered as a composite terrane (Göncüoğlu et al, 1997) as it comprises several pre- Alpine terranes in its basement as tectonic assemblages presenting completely different geological histories. These

tectonostratigraphic units represent pieces of Variscan and Cimmerian continental as well as oceanic assemblages. The lower part of the overstep sequence is Early Jurassic in age, followed by a more or less continuous succession of Jurassic-Cretaceous platform sediments. From Late Cretaceous onward, slope-type sediments dominate, which in turn were covered by flysch-type deposits with ophiolitic blocks, derived from the northerly Intra-Pontide Ocean.

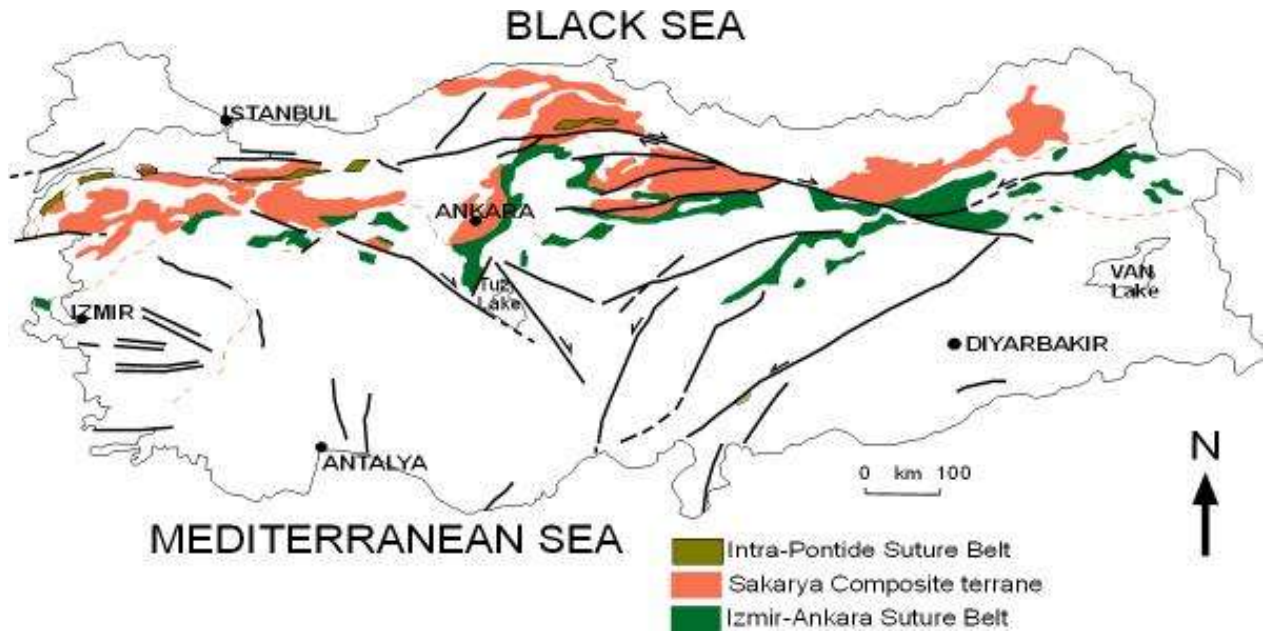


Figure 19- Distribution of the rock-units of the Sakarya Composite terrane and the Intra-Pontide and Izmir-Ankara Erzincan suture belts.

### A- Pre-Jurassic assemblages

The pre-Jurassic basement of the Sakarya Composite Terrane comprises Variscan massifs and the Cimmerian Karakaya Complex with Küre-Yusufeli ophiolites.

#### a- Variscan Terranes

They are represented by metamorphic massifs such as Kazdağ, Uludağ, Sögüt, Devrekani, Pulur and Harsdere massifs that occur as tectonic inlayers within the Sakarya Composite Terrane in N Anatolia. They comprise ortho- and paragneisses, amphibolites and marbles (Okay et al, 2006a). They are associated with metamorphic mafic and ultramafic rocks resembling ophiolites (e.g. Kazdağ: Bingöl et al, 1975; Duru et al, 2004; Pulur: Topuz et al, 2004). The age of the sedimentary protoliths are unknown, however the high-grade metamorphism in amphibolite to granulite facies is Late Carboniferous in age. The Variscan terranes are characterized by Late Carboniferous to Early Permian calc-alkaline magmatism, ascribed to the

arc-magmatism during the closure of the Variscan Ocean (Göncüoğlu, 1989). The oldest post orogenic –in regard to Variscan - cover rocks are latest Carboniferous in the NE Anatolia and Early Permian in the West. The Permian platform carbonates are covered by rift-related sediments of Triassic age (Turhan et al, 2004). They are also frequently observed as olistoliths in the Triassic Karakaya Complex (e.g. Bingöl et al, 1975).

#### **b- Cimmerian Terranes**

Karakaya Complex, and several volcanic-volcanosedimentary units in it were collectively identified as a subduction/ accretion complex (Tekeli, 1981; Sengör et al, 1984a; Tüysüz and Yigitbas, 1994). It is still the most debated geological unit in N Anatolia. Recently, Okay and Göncüoğlu (2004a) reviewed the available data and proposed the following subunits: i- HP/LT metamorphic assemblages including metabasic rocks and sediments of oceanic origin, ii- Hawaii-type oceanic islands and their platform and slope sediments, iii- flysch-type sediments with Paleozoic neritic limestone blocks, iv- dismembered ophiolites.

The HP/LT metabasic rocks include the “Nilüfer Volcanics” (Okay, 1986; Okay et al, 1991) shown on Figure 20. Their formation age is not known. The unit is metamorphosed in high-pressure greenschist-facies conditions, however, in several localities in the Sakarya Composite Terrane tectonic slices of metabasic rocks in blueschist and eclogite facies conditions were reported (Okay and Monie´, 1997). Their metamorphism is dated as latest Triassic (205–203 Ma, Okay et al, 2002). The Nilüfer-type volcanic rocks are dominantly ocean island assemblages including E-MORB and OIB-type pillow-lavas (Fig. 21). They alternate with early Middle Triassic neritic limestones, red mudstones and radiolarian cherts, black shales and volcanogenic sandstones (Sayit et al, 2008, Sayit and Göncüoğlu, 2009). Locally, the basic rocks include sodic amphiboles, indicating to an initial metamorphism developed in higher pressure conditions and hence to subduction. The flysch-type deposits are characterized by olistostromes. These clastic rocks act as the matrix for all other types of Karakaya lithologies. They also include neritic limestone blocks of dominantly Carboniferous and Permian age that belong to the Variscan basement. While the metamorphism occurs generally in lower greenschist facies conditions, the deformation is semi-brittle, giving a broken formation character to the unit.

Most typical representatives of the Cimmerian ophiolites in the Sakarya Composite Terrane are the Küre and Yusufeli Ophiolites.

The Küre Terrane is an imbricated unit, comprising slices of Early Mesozoic clastics (Fig.22) within a dismembered ophiolitic assemblage (Küre Ophiolite, Aydın et al, 1987; Ustaömer and Robertson, 1999). It contains disrupted ophiolites, basic volcanics with Cyprus-type massive

sulfide deposits, deep-sea radiolarites, turbidite sequences and flyschoidal sequences including olistostromes. Immobile major- and trace element data on volcanic rocks indicate MORB and

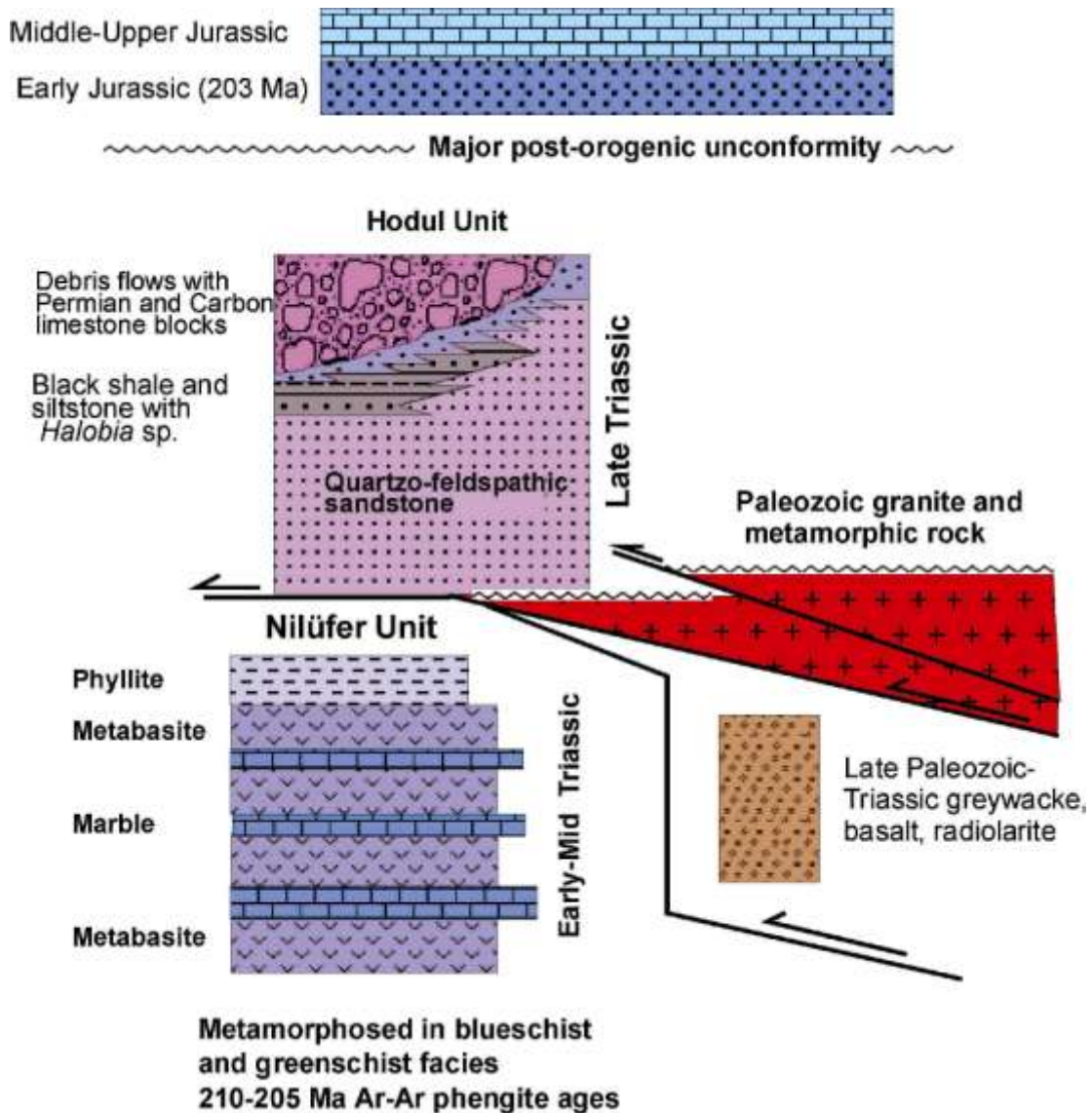


Figure 20- Sub-units of the Karakaya Complex (from Okay et al, 1991)

VAB-type characteristics and strongly suggest that the Küre Terrane was generated in a supra-subduction-type tectonic setting (Ustaömer and Robertson, 1999). Kozur et al (2000) suggests a Mid Triassic-Early Jurassic depositional age for the flyschoidal sequences and correlates this unit with the Karakaya Complex.

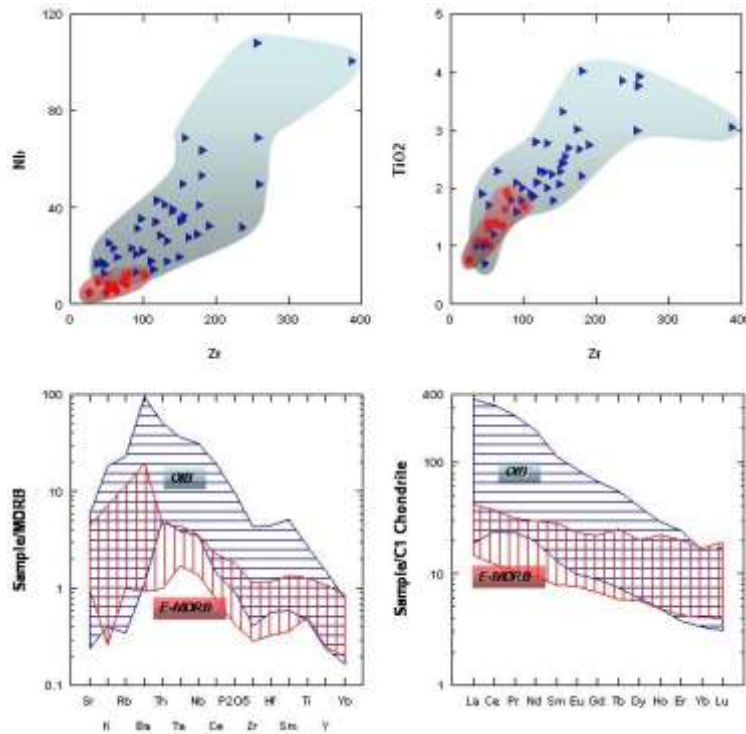


Figure 21- The OIB-type samples are highly enriched in HFSE (Nb and  $\text{TiO}_2$ ) relative to the E-MORB group (A and B). These samples have distinctive trace element patterns, including REE. variable enrichment of incompatible elements relative to N-MORB, D) fractionation of HREE relative to LREE indicating that residual garnet may have been involved in the source (Sayit et al, 2008).

In N central Anatolia several metamorphic ophiolite-bearing units such as Çangal Dağ, Elekdağ Domuzdağ and Kargı were ascribed to the Paleotethyan oceanic lithosphere and accretionary complexes (Okay and Tüysüz, 1999). The Çangal Dağ mainly consists of basic lavas, sheeted dykes, mafic- and ultramafic cumulates and serpentinized peridotites (e.g. Eren, 1979). The immobile trace element geochemistry of the basic volcanics within this terrane indicates a volcanic -arc type tectonic setting and thus the unit is interpreted as remnants of an ensimatic arc that had developed on a supra-subduction type oceanic crust (Ustaömer and Robertson, 1999). Elekdağ Unit includes bands and lenses of eclogites and overlies a glaucophane-bearing ophiolitic mélangé along tectonic contact. The  $\text{Cr}/\text{Cr}+\text{Al}$  ratio of the Cr-spinels of the ultramafics is  $>0.8$  and hence suggests a supra-subduction setting (Ustaömer and Robertson, 1999). The basal mélangé complex was metamorphosed to greenschist facies. Figure 23, based on recent studies, however, shows that these metaophiolitic assemblages are younger (alpine, Okay et al., 2006b; Tüysüz and Tekin, 2007) and of Neotethyan (Intra-Pontide Ocean) origin.

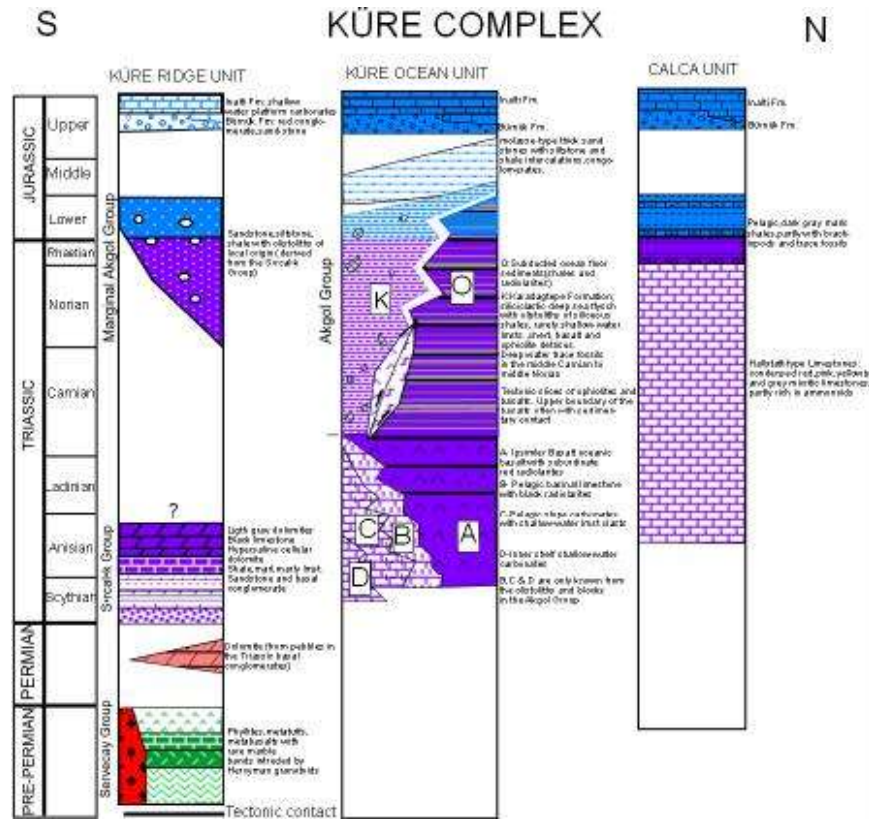


Figure 22- Tectonic units of the Küre Complex and their stratigraphy (Kozur et al 2000).

Tectonic Unit	Lithology-Ages-Origin	Metamorphism-Ages
Küre Complex	Mélange with ophiolite blocks (SSZ-type) - TRIASSIC	Sub-sea floor metamorphism- PRE- LATE JURASSIC
Çangaldag Unit	Metabasalts-metagabbros ?	HP/LT metamorphism LATE CRETACEOUS
Elekdag Unit	Ophiolitic mélange –MID JURASSIC	HP/LT metamorphism- LATE CRETACEOUS
Domuzdag Metamorphics	Ophiolitic mélange –MID JURASSIC	Polimetamorphic, ALBIAN
Kargı Metamorphics	Tectonic slices of platformal successions and oceanic assemblages- of Paleo- and Neotethys	Amphibolite Facies LATE CRETACEOUS

Figure 23- Rock units, metamorphism and suggested ages of the tectonic assemblages in central N Anatolia.



The Yusufeli tectonostratigraphic unit in NE Anatolia consists of ultramafic-mafic assemblages, associated sediments and an epi-ophiolitic cover (Yilmaz and Sengör, 1985). Together with the Demirkent Unit, consisting essentially of serpentinized ultramafics, meta-gabbros, meta-diabases, amphibolites and amphibole gneisses (Konak et al, 1991) it is the easternmost representative of the Paleotethyan ophiolites in Turkey.

The formation age of the Karakaya Complex is Late Permian to Late Triassic so far documented by paleontological data (Göncüoğlu et al, 2004 c). The deformation and accompanying HP/LT metamorphism of the Karakaya Unit is latest Triassic (Okay et al, 2002). Views on the structural setting, age of deposition and metamorphism of this complex are still controversial (see Okay and Göncüoğlu, 2004a, Robertson et al, 2004).

Karakaya Complex as a whole is interpreted by Okay et al (1991) as the representative of Permo-Triassic intra-oceanic fore-arc complex, sliced with Late Paleozoic-Triassic accretionary complexes of the Paleotethyan active margin, which was located to the south of Central Sakarya Terrane (Fig.24).

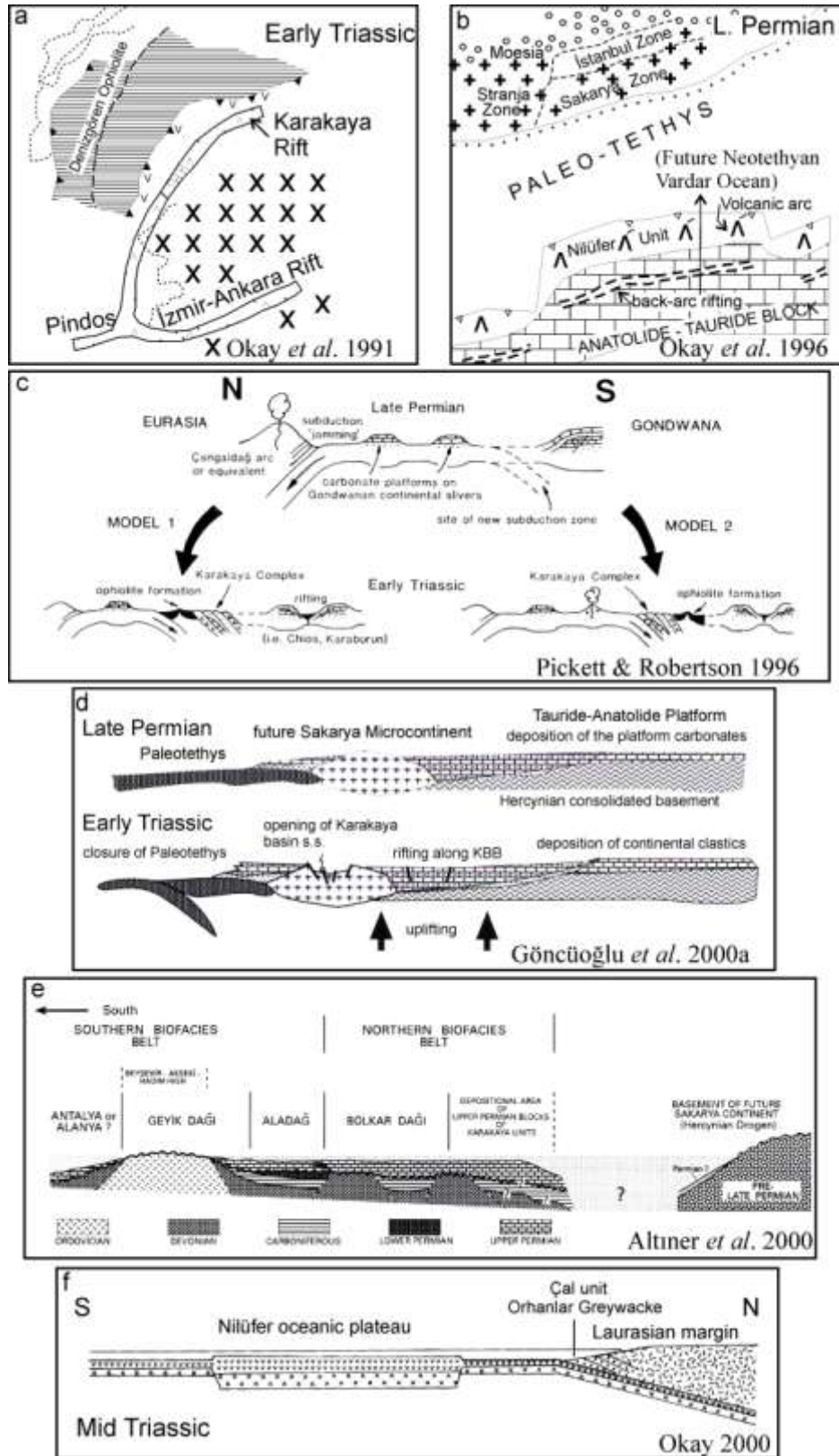


Figure 24- Geodynamic models for the tectonic evolution of the Karakaya Complex (Okay and Göncüoğlu, 2004a).

Sengör and Yilmaz (1981), however, suggest that Karakaya Complex has formed as a marginal basin within the Variscan Sakarya Microplate which was located to the south of the southward subducting Paleotethys (Fig. 24). Göncüoğlu et al (2004c) interpreted the complex as remnants of a subduction-accretion prism, formed by southward subducting Paleotethyan oceanic lithosphere and emplaced on the Triassic autochthonous rift-related deposits of the Variscan Sakarya units. Sayit and Göncüoğlu (2009) suggest that the OIB and E-MORB-type oceanic assemblages of Middle Triassic are indicative for a pre-Middle Triassic opening (Fig. 25) of Paleotethys.

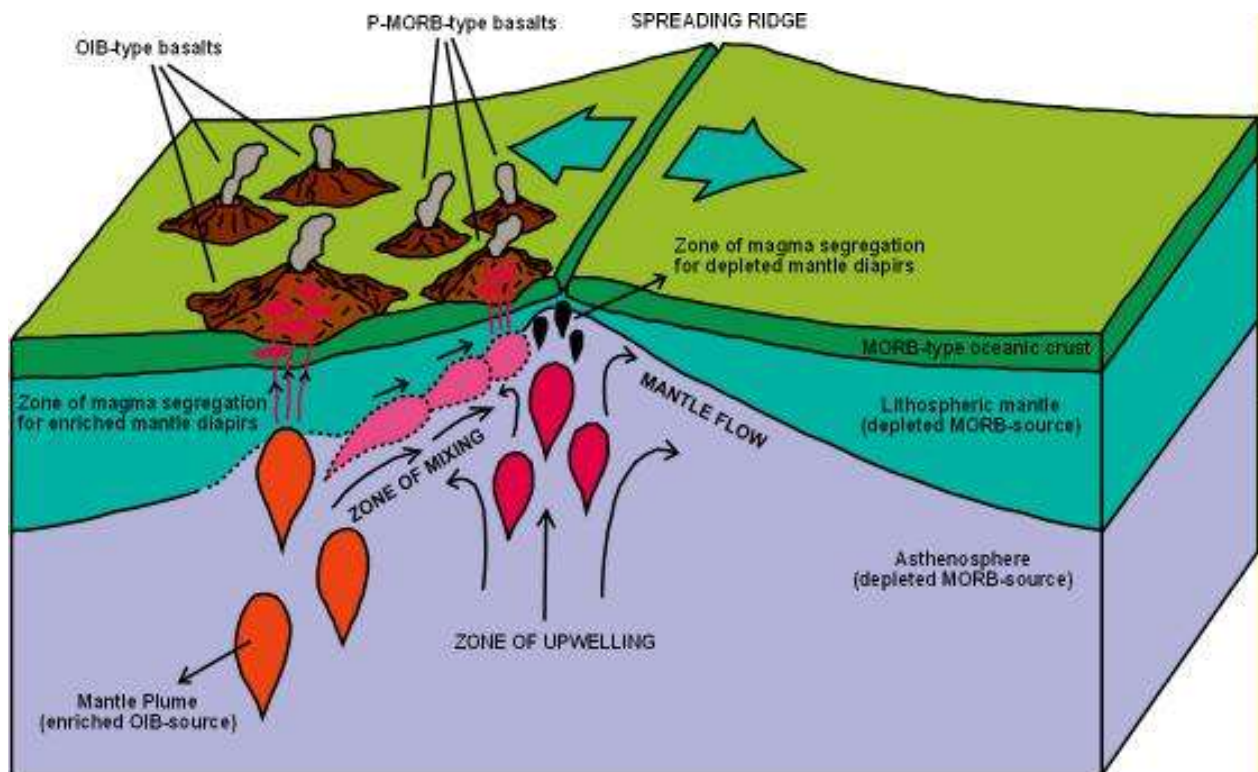


Figure 25- Model for the formation of OIB and E-MORB-type volcanic assemblages in the Karakaya Complex (Sayit and Göncüoğlu, 2009).

### **B- Mesozoic Cover of the Sakarya Composite Terrane**

The stratigraphy of the Mesozoic cover units of the Sakarya Composite Terrane differs very much in the eastern and the western parts.

In the eastern areas, known as the “Pontide Magmatic Arc”, there is a distinct zonation in the Eastern Pontides: a Northern Zone where magmatic arc-type rocks dominate, and a Southern Zone mainly with sedimentary rock-assemblages (Okay and Sahintürk, 1998). The boundary between these two zones is more or less the Niksar-Ispir-Ardanuç line (Fig. 19).

In the Southern Zone, the Mesozoic cover starts unconformably with Liassic conglomerates and volcanoclastic rocks, followed by Mid Jurassic clastics and coal seams. The conformably overlying Late Jurassic-Early Cretaceous (Abtian) succession is represented by limestones and dolomites. The Turonian- Senonian series mainly comprise turbidites, unconformably overlain by Tertiary basic volcanic rocks (Fig.26).

The Northern Zone includes two distinct volcanic cycles:

- |   |   |
|---|---|
|   | f- dacite-rhyodacite lavas (mineralized)              |
| Upper Volcanic Cycle (Turonian- Paleogene): | e- upper basic series (basalt lava and dolerite)      |
|   | d- volcanosedimentary rocks                           |
| Lower Volcanic Cycle (Malm-Turonian):       | c- dacite-rhyodacite lavas-pyroclastics (mineralized) |
|   | b- dacite lavas-pyroclastics                          |
|   | a- lower basic series (basalts, andesites, diabases)  |

The igneous rocks are interpreted as representatives of a magmatic arc (Tokel, 1977; Karlı et al, 2004; Boztuğ et al, 2007) formed by the subduction of the Izmir-Ankara-Erzincan oceanic lithosphere beneath the Sakarya Composite Terrane during the Late Mesozoic. The igneous rocks of the Lower Volcanic Cycle are mainly tholeiitic, formed by the subduction induced melting, whereas the Upper Volcanic Cycle mainly includes calcalkaline rocks, followed by shoshonitic assemblages.

In the western part of the Sakarya Composite Terrane, to the west of Sinop, the Alpine deposition starts on the Cimmerian basement (formed by the amalgamation of the Paleotethyan elements) either with Liassic (in the west) or with Malm (in the central part). In both areas the deposition is characterized by platform to slope type carbonates during the Late Jurassic to Early Cretaceous interval (Fig.27). The Late Cretaceous sediments are mainly of flysch-type. They were formed by the closure of the Intra-Pontide oceanic basin to the north of the Sakarya Composite Terrane and deposited on the passive margin of the Sakarya microplate. The following emplacement of ophiolite-bearing oceanic assemblages onto these flysch-basins from north to south realized during latest Cretaceous time, prior to the oblique collision of the Sakarya and Istanbul-Zonguldak plates.

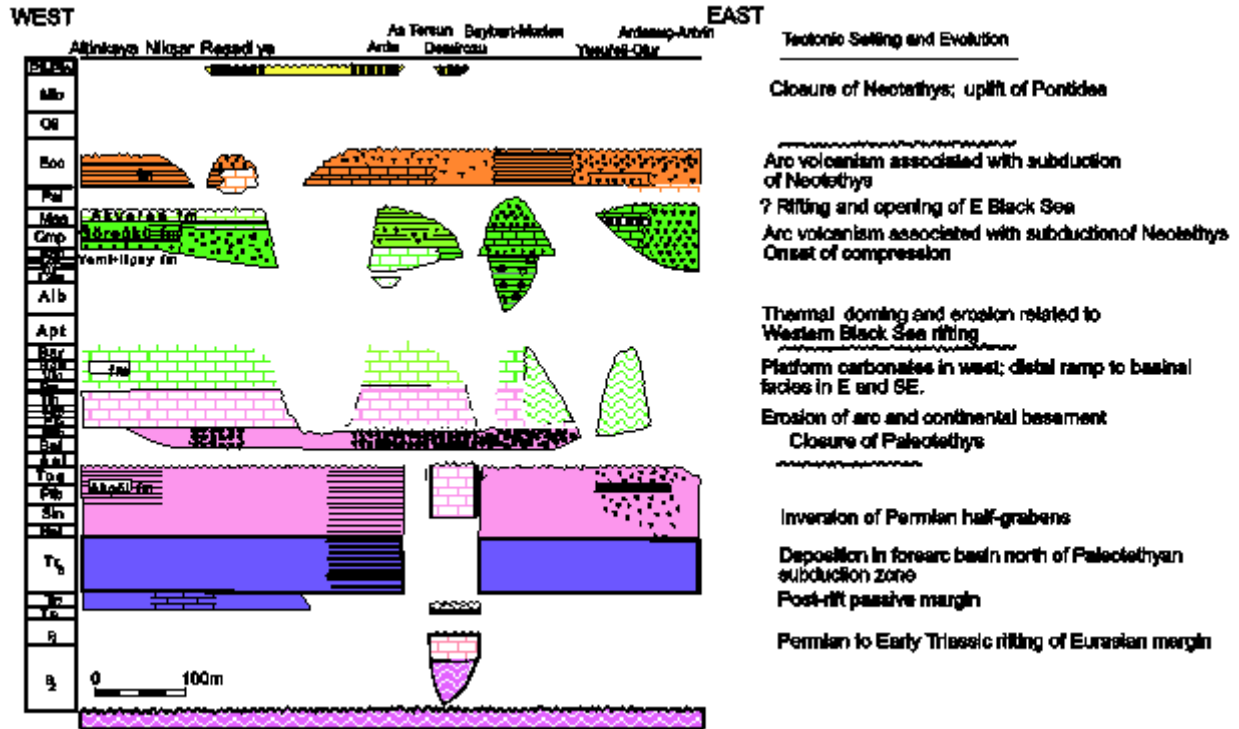


Figure 26- Alpine overstep sequences of the Sakarya Composite Terrane in N central and NE Anatolia (Robinson et al, 1995)

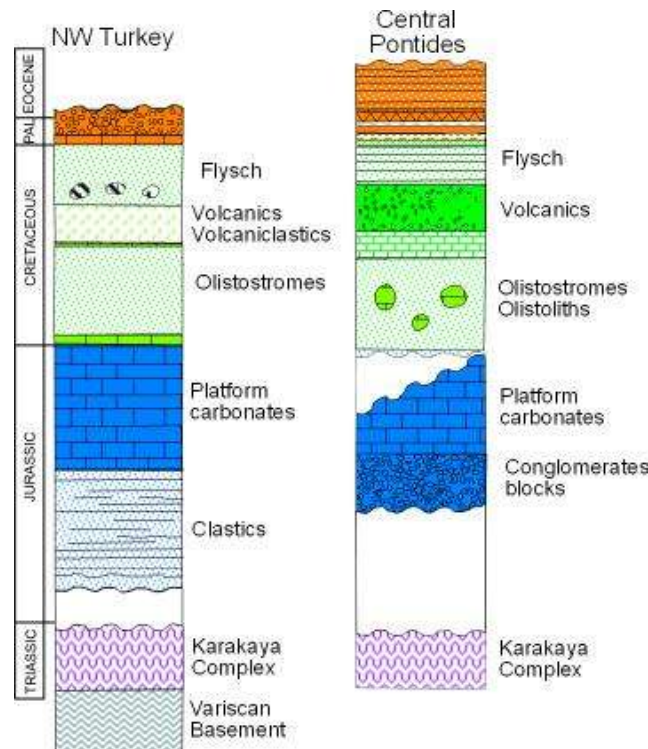


Figure 27- Generalized columnar section of the Sakarya Composite Terrane's cover in NW Anatolia (Saner, 1980; Altınır et al, 1991)

## 6- Intra-Pontide Ophiolite Belt

The Intra-Pontide Ophiolite Belt is composed of imbricated structural units representing oceanic assemblages and mélangé complexes generated in a northern branch of Neotethys, which was located between the Sakarya Composite Terrane in the South and Rhodope-Istranca and Istanbul-Zonguldak (Yılmaz, 1990; Göncüoğlu et al, 1997; Elmas and Yigitbas, 2001; Yigitbas et al, 1999; Göncüoğlu et al, 2008) terranes in the North (Fig. 28).

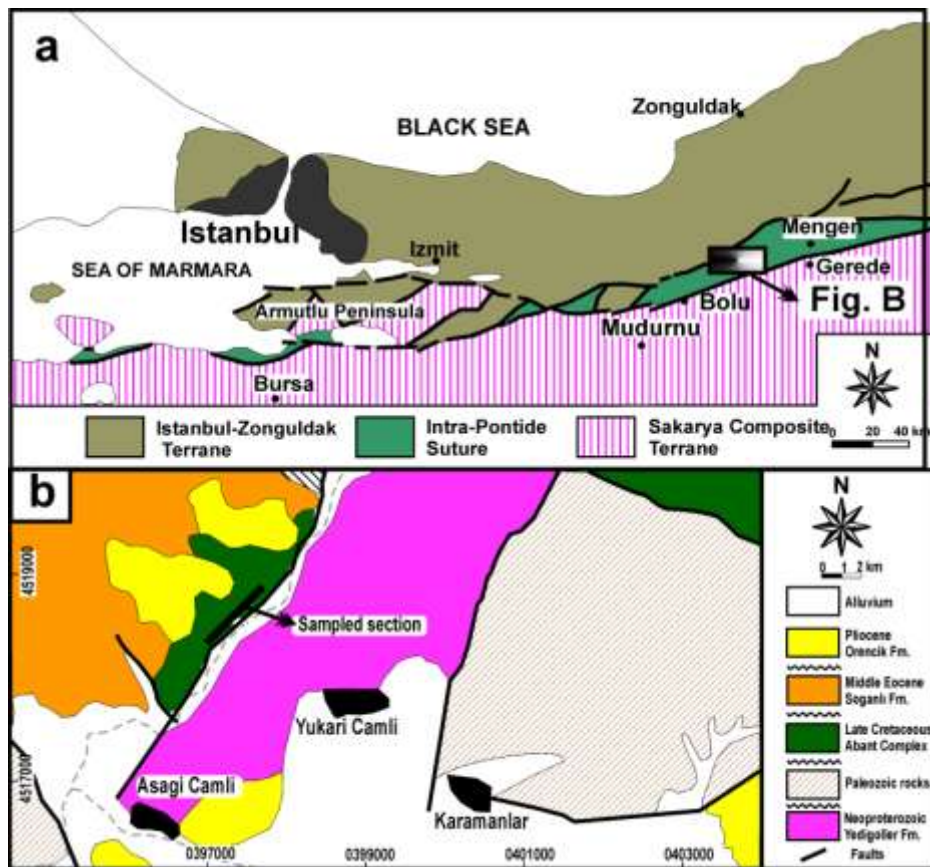


Figure 28- a: Location and tectonic setting of the Intra-Pontide Suture Belt in NW Anatolia and b: the distribution of melange complexes (after Göncüoğlu et al, 2008).

The oceanic assemblages of the Intra-Pontide Ophiolite Belt are thrust southward onto Upper Cretaceous flyschoidal sequences of the Sakarya Composite Terrane. To the north the ophiolites are overthrust by the Istanbul Terrane (Göncüoğlu and Erendil, 1990, Robertson and Ustaömer, 2005).

Large bodies of ultramafic and volcano-sedimentary rocks, basic lavas, radiolarian cherts and allochthonous blocks of Jurassic-Early Cretaceous neritic-pelagic limestones are the main constituents of the unit (Okay et al 1991). The original contacts of the rock-units are affected by oblique and strike-slip movements within the still active North Anatolian Transform Fault. In NW Anatolia the Upper Cretaceous *mélange* is known as Arkotdağ *Mélange* to the east and Abant Complex (e.g. Göncüoğlu et al, 2008) to the west of Bolu.

The Arkotdağ *Mélange* is composed of a sedimentary *mélange* with blocks of serpentinites, gabbros, and pillow basalts, pelagic limestones and radiolarian cherts. Locally, the unit is several kilometers thick and associated with intensively deformed and slightly metamorphosed debris flows. A tectonic sliver of this *mélange* to the east of Bolu comprises massive and pillow lavas that includes radiolarian chert interlayers and intra-pillow mudstones. The silicified mudstones from the upper part of an intact section yielded moderately preserved but diverse radiolarians of late Kimmeridgian to early Tithonian age. Geochemically, the associated tholeiitic basalts suggest generation in a mid-ocean ridge setting. Combined with data from a number of similar occurrences (Robertson and Ustaömer, 2005) along the inferred suture belt in NW Anatolia, it is concluded that the ridge-spreading in the Intra-Pontide Ocean continued at least from middle Middle Jurassic to middle Late Cretaceous.

The overstep sequence starts with Lutetian shallow-marine sediments. The opening age of the Intra-Pontide oceanic branch has not yet been clearly documented. The interpretations include a wide range of suggestions, including a Jurassic opening age (e.g. Robertson, 2004), which seems to be most appropriate. It is commonly accepted that its oceanic lithosphere had been consumed by northward subduction, giving way to the Eocene calcalkaline arc-granites in the Armutlu Peninsula in NW Turkey.

## **7- Istanbul-Zonguldak Composite Terrane**

The Istanbul-Zonguldak Composite Terrane consists of two Paleozoic terranes and their Mesozoic overstep sequences. Okay et al (1994) suggest that Istanbul Terrane was attached up to the Early Eocene to the Moesian Platform and has gained its present structural position by southward migration along two main strike-slip faults by the opening of a westerly Black Sea basin (Fig.29).

### A- Istanbul Terrane:

This terrane includes a Cadomian-consolidated basement, unconformably covered by a well-developed sequence, extending without any major break from Early Ordovician to the Late Carboniferous. The basement is made up of ortho- and paragneisses, meta-gabbros, ortho-amphibolites and amphibole-gneisses and oceanic basic igneous rocks intruded by arc-type granitoids (ca 500ma, Ustaömer and Rogers, 1999).

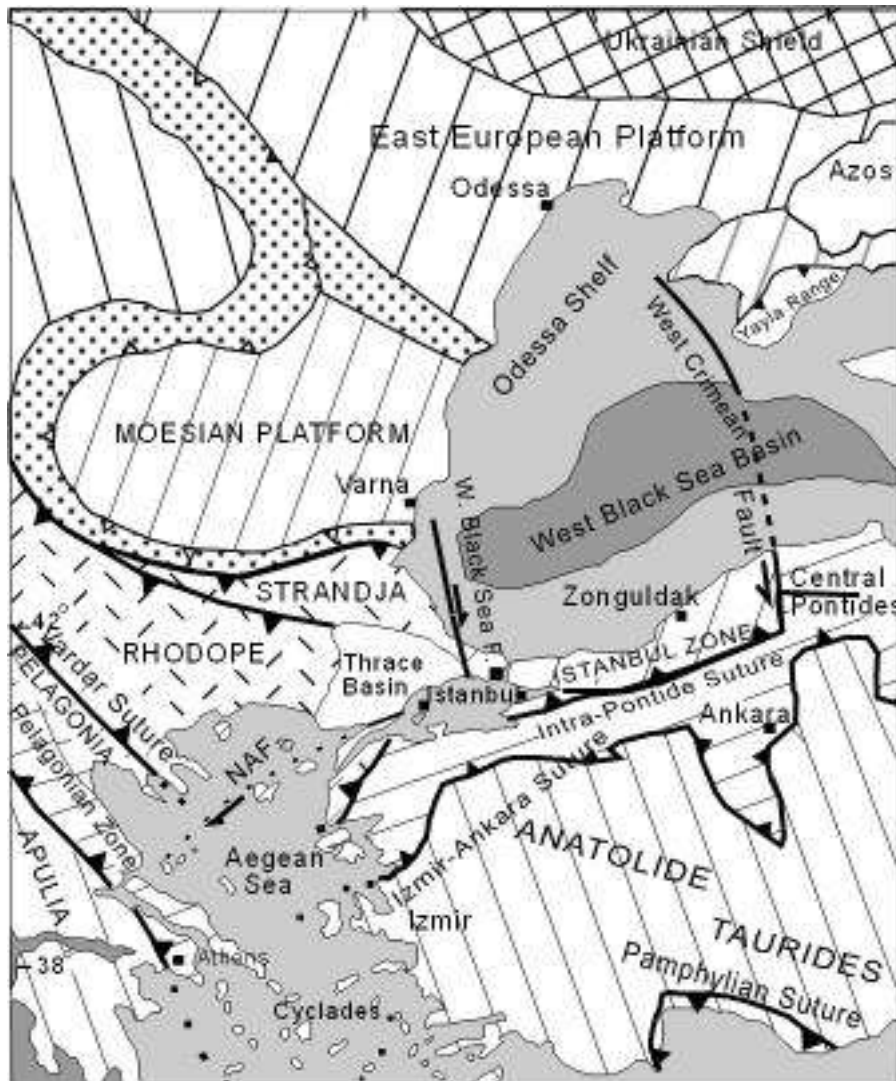


Figure 29- Tectonic setting and structural relations of the Istanbul-Zonguldak Terrane (map after Okay et al, 1994).

The unit as a whole is interpreted to include slivers of an intra-oceanic island-arc, oceanic and continental crust that were accreted during the Late Neoproterozoic (Göncüoğlu et al, 1997;



Yigitbas et al, 2004). This accretion is ascribed to the Cadomian event rather than the Pan-African event in N Africa. The overlying Paleozoic succession, represents a passive continental margin deposition from Early Ordovician to Early Devonian (Yanev et al, 2004), and is conformably overlain by Middle Devonian to lowermost Carboniferous (Kaya 1973) slope-type sediments (for a detailed review see (Gedik et al, 2005) and flysch-type sediments of Visean age (Fig. 30). This Paleozoic succession is affected by Variscan deformation and unconformably overlain with Early Triassic continental clastics, which pass upwards to an Alpine-type Triassic sequence.

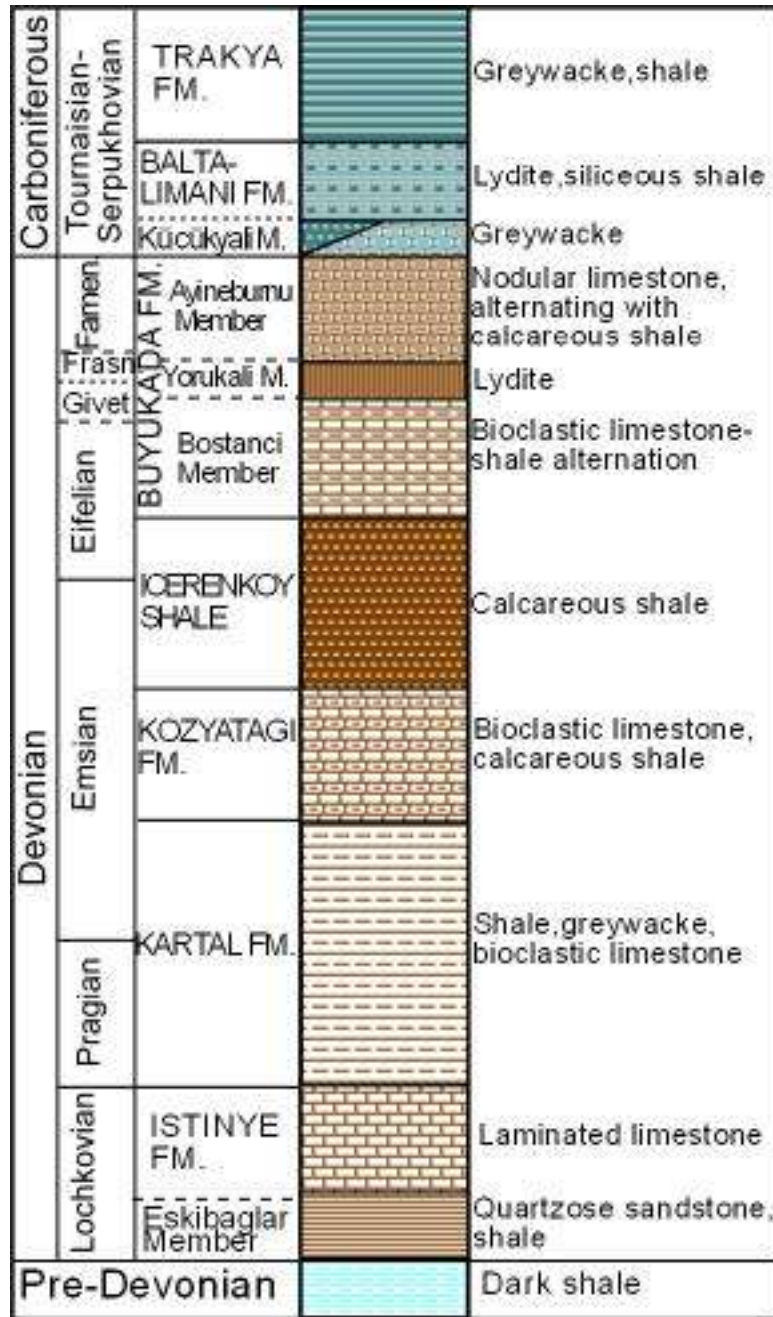


Figure 30- Generalized columnar sections of the Upper Paleozoic rocks of the Istanbul Terrane in Istanbul area (Göncüoğlu et al, 2004b).

### B- Zonguldak Terrane

To the E of Çamdağ, this unit has a common basement with the Istanbul Terrane with Cambrian granitoids (Chen et al, 2002). In the Zonguldak area, a distinct unconformity separates the early Late Silurian and the Early Devonian successions (Dean et al, 2000), indicating to a Caledonian-time event (Göncüoğlu and Kozur, 1998). The Middle Devonian and Early Carboniferous

succession is in contrast to the Istanbul Terrane mainly made up of shelf-type carbonates, followed by the well-known non-marine, coal bearing units of Carboniferous (Fig 31). Continental clastics of middle Permian to Scythian age lie unconformably over the deformed Paleozoic Sequence in western and central parts. This succession is interpreted as a Permo-Triassic molasse-type deposition. Middle Jurassic granitoids intrude the unit in the southeastern part (Yilmaz and Boztug, 1986).

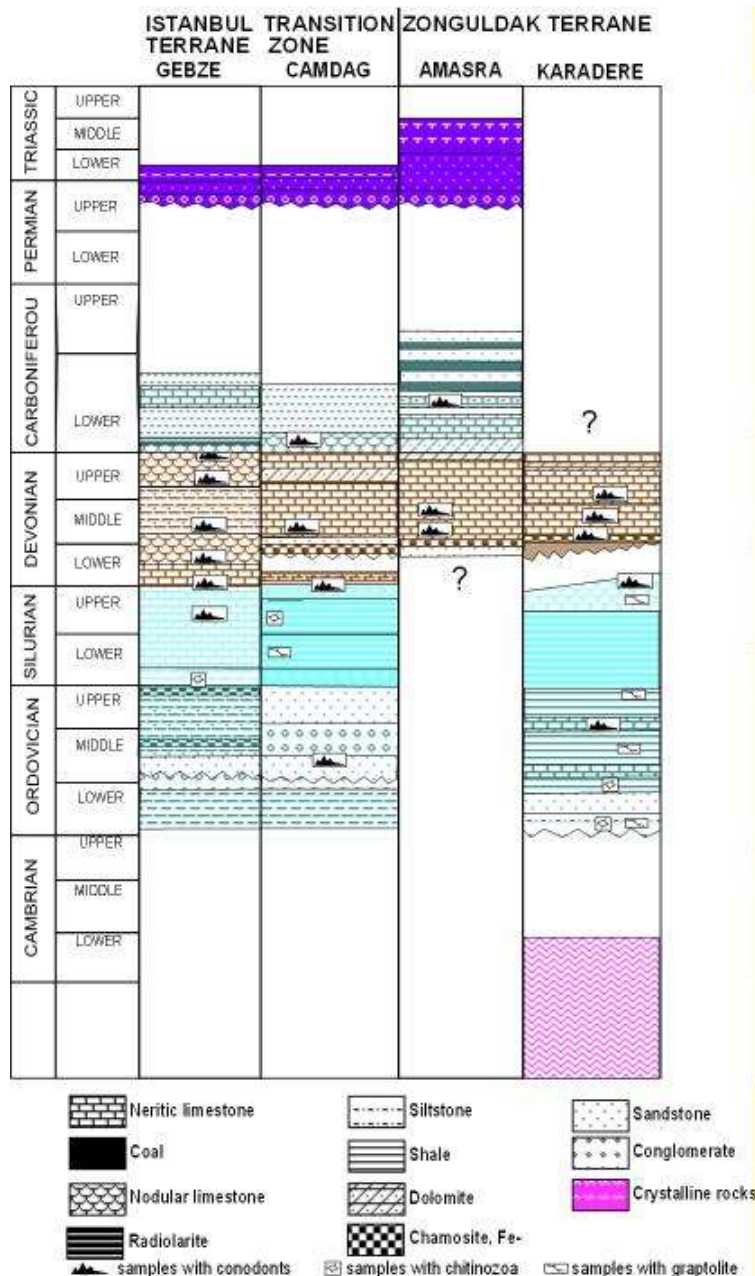


Figure 31- Stratigraphy of the Zonguldak terrane (Göncüoğlu et al, 2003b)

### C- Alpine cover of the Istanbul-Zonguldak Terrane

The post-Triassic cover of the Istanbul Terrane is made up of Cretaceous flysch-type sediments that unconformably cover earlier successions. In the Zonguldak Terrane, on the other hand the Alpine cover sequences rest on an irregular (fault-controlled) basement, where Mid Jurassic to Early Cretaceous basins (Fig. 32) was formed (Tüysüz, 1999). The Berriasian-Campanian volcano-sedimentary deposits here are interpreted as rift-sediments, related to the opening of Black Sea Basin to the north (e.g. Görür, 1988; Derman, 1990).

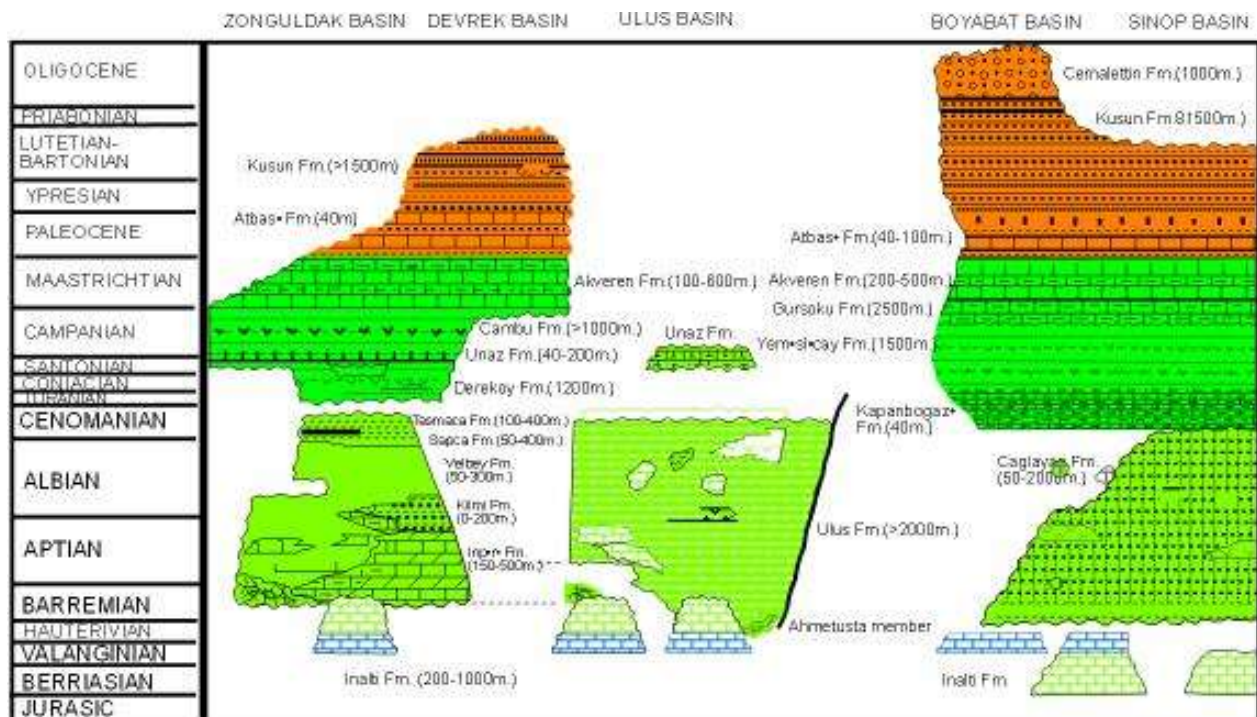


Figure 32- Mesozoic-Tertiary cover of the Istanbul-Zonguldak terranes (Tüysüz, 1999).

The Early Tertiary deposits in the Istanbul-Zonguldak terrane are represented by carbonates and clastics with volcanic intercalations and were deposited in E-W trending narrow basins.

## 8- Rhodope - Istranca Composite Terrane

The Rhodope-Istranca Terrane includes a complex tectonic unit located to the N of the Intra-Pontide Ophiolite Belt and to the W of the Istanbul-Zonguldak Terrane (Fig. 33). It includes the

metamorphic complexes such as the Serbo-Macedonian Massif, Rhodope Massif and Istranca (Strandja) Massifs of the E Balkan Peninsula (Papanikolaou and Demirtaşlı, 1987). In NW Anatolia, it is represented by two distinct units.

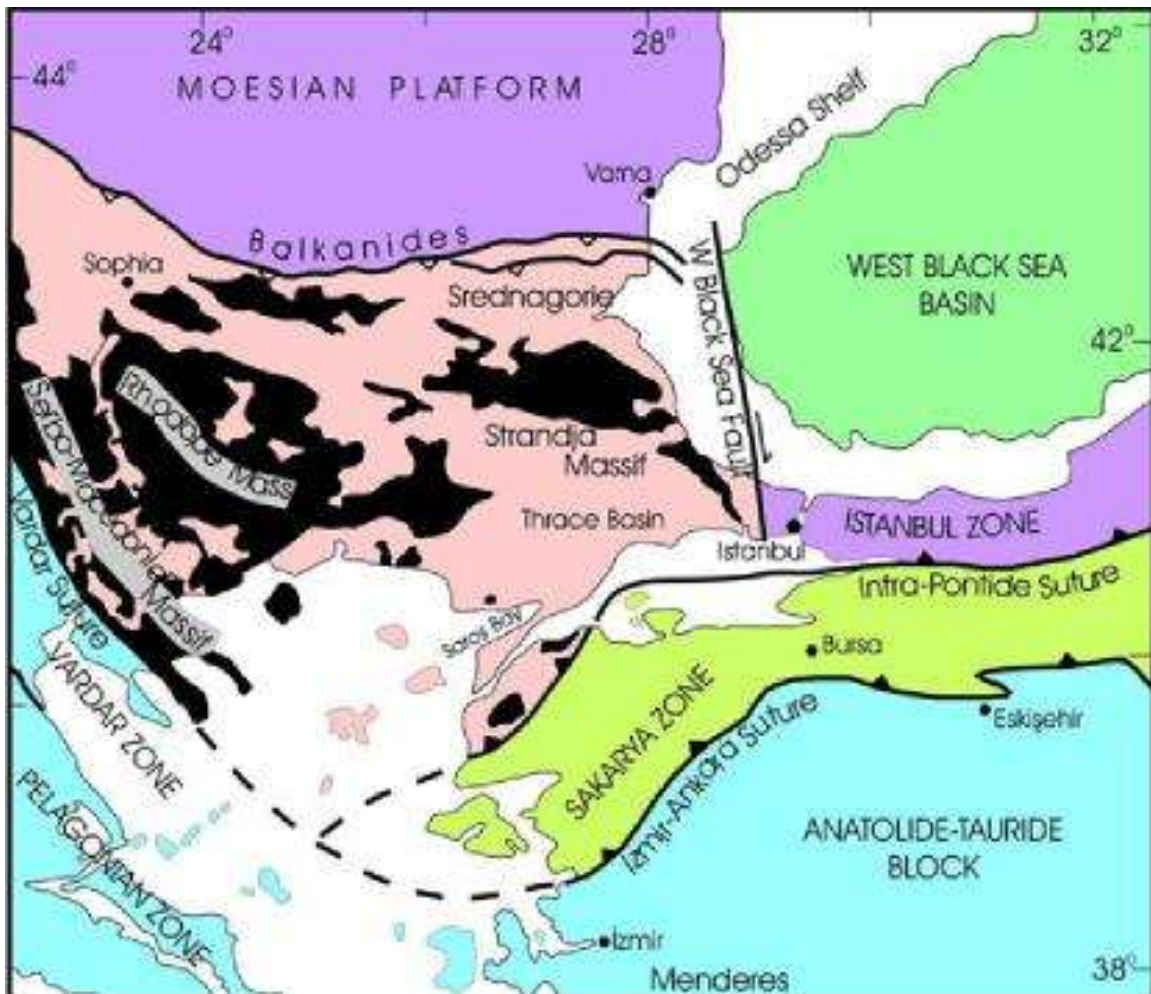


Figure 33- Distribution of the Rhodope-Istranca Terrane in NW Anatolia (Okay et al, 2001)

#### A- Istranca Terrane

The Istranca Terrane is characterized by a complex nappe-pile that includes metamorphic assemblages (Fig. 34) unconformably overlain by Tertiary sediments of the Thracian basin. Its western continuation is found in the Balkans.

The gross-structure of metamorphic rock units in this area is characterized by distinct nappes.

The stratigraphically lowermost units of the terrane include gneisses, amphibolites and amphibole-schists with minor intercalations of meta-pelites. This lower sequence (*Lower Nappe* of Okay et al., 1991) is intruded by 244my old (Variscan) granitoides with blastomylonitic textures Aydin (1974). The recent study by Okay et al (2001) with new single zircon data yielded ages that range between 221-309 Ma. This crystalline basement is unconformably overlain by continental metaclastics and shallow-marine metacarbonates assigned (Çağlayan et al, 1992) to Triassic-Mid Jurassic. These carbonates include in Bulgarian Istranca Devonian conodonts and corals (Yanev et al, 2004).

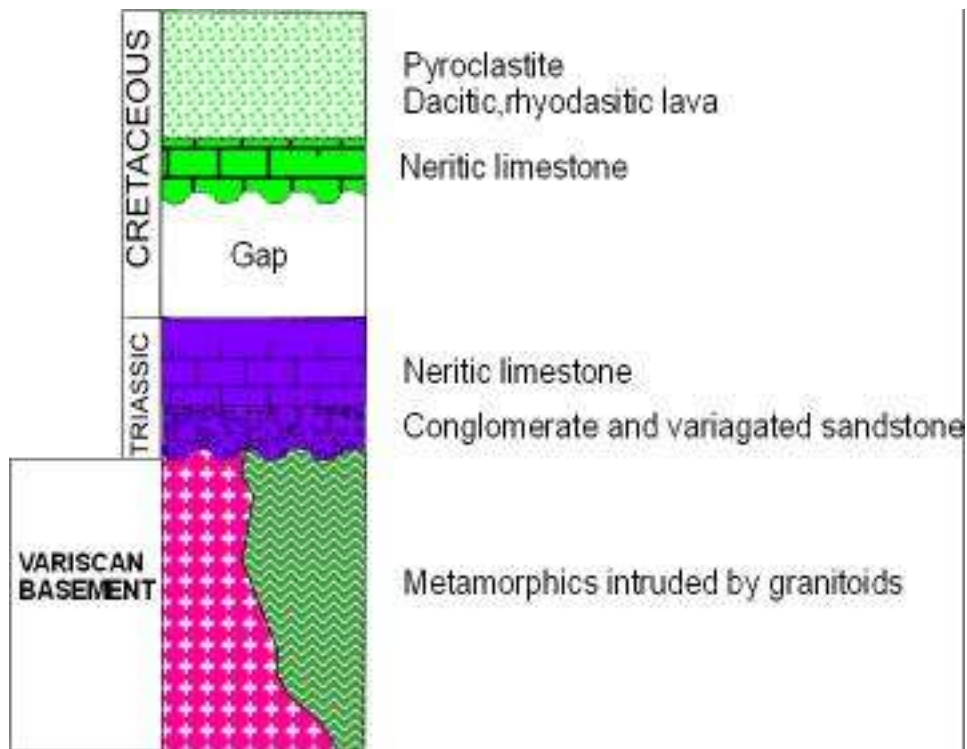


Figure 34- Generalized columnar section of the Istranca Massif (after Aydin, 1974)

The overlying units, also known as the *Upper Nappe* (Okay et al, 2001) with turbiditic metaclastic rocks and metabasics is of Triassic age (Fig. 35), based on fossil findings from the Bulgarian (Chatalov et al, 1988) and Turkish (Hagdorn and Göncüoğlu, 2007) parts. The Istranca Terrane is interpreted as the southern part of the Moesian and the juxtaposition of the nappes is assigned to the closure of a Paleotethyan ocean to the south of this platform (Fig. 36, Okay et al, 2001). Both nappes and their tectonic boundaries are covered by Upper Cretaceous

sedimentary and volcanic rocks intruded by calcalkaline granodiorites-diorites, interpreted to be arc-plutons formed during the northward subduction of the Neotethyan Vardar oceanic plate.

AGE	LITHOLOGY	EXPLANATIONS	
Early-Middle Triassic		Sandy recrystallized limestone with bivalvia, calcschist	
		Medium to thick-bedded marble	
		Micaceous meta-siltstone	
		Thick-bedded marble with crinoids	
		Calcschist and phyllite	
		Metapelite and meta-siltstone	
		Recrystallized sandy limestone and calcschist with crinoids, calcschist	
		Chlorite-bearing metapelite, laminated metapelite	
		Recrystallized sandy limestone with bivalve calcschist	
		Meta-sandstone with burrows	
		Phyllite and red meta-sandstone with burrows	
		Meta-conglomerate	
	— Unconformity —		
			Meta-sandstone, meta-greywacke and garnet-bearing greenschist

Not to scale

Figure 35- Triassic succession of Istranca Terrane in Turkey (Hagdorn and Göncüoğlu, 2007)

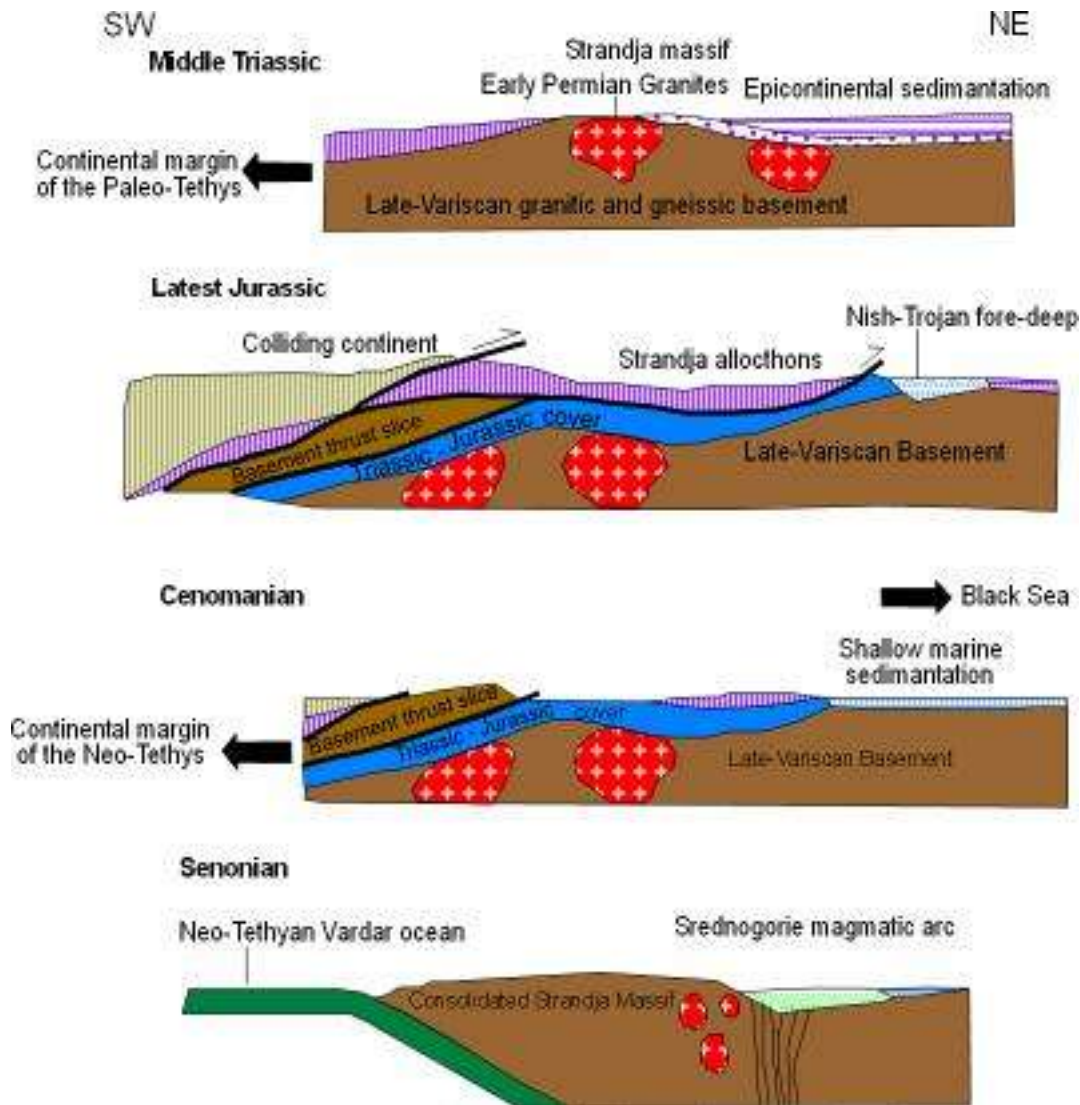


Figure 36- Geological evolution of the Istranca Terrane (after Okay et al, 2001).

### B- Ezine Terrane

To the NW of Kazdağ in NW Anatolia (Fig.33) a completely different tectonic unit (Karadağ Unit) had been described by Okay et al (1991). From the bottom to the top (Fig. 37) the unit includes, a slightly metamorphic unit with clastics (conglomerates and sandstones) and recrystallized limestones (Geyikli Formation), Middle-Upper Permian platform-type carbonates (Karadağ Formation), and a Triassic turbiditic unit with limestone blocks (Çamköy Formation).



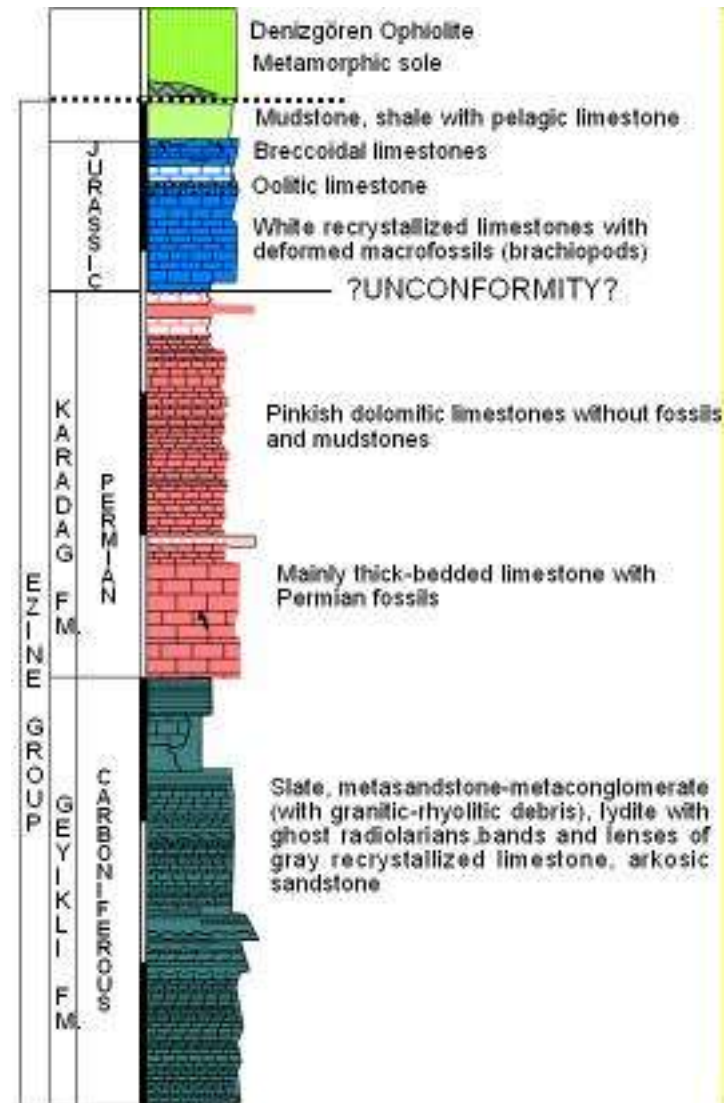


Figure 37- Generalized columnar section of the Ezine Terrane ( modified from Boccaletti, 2003).

This platform-type succession is tectonically overlain by the Denizgören ophiolite (Okay et al, 1991). It is almost totally made of serpentized harzburgite and underlain by sub-ophiolitic amphibolites. Geochemical analyses from the peridotite suggest supra-subduction zone (SSZ) tectonic setting.. The age of the sub-ophiolitic amphibolite facies metamorphism is  $125 \text{ Ma} \pm 2$ , interpreted as the age of the inception of the obduction process at or near the ridge (Boccaletti, 2003). This age is slightly older than the  $^{40}\text{Ar}/^{39}\text{Ar}$  ages ( $117 \pm 1.5$  and  $118.3 \pm 3.1 \text{ Ma}$ ) found by Okay et al (2006a).

The Ezine Terrane resembles the Pelagonian Zone of Greece, by considering the Permian successions. It is arbitrarily considered as a part of the Rhodope, but should be actually evaluated as a suspect terrane.

## LATE AND POST ALPINE FORMATIONS: THE TERTIARY BASINS OF TURKEY

The closure of the Neotethyan oceanic basins in the Turkish area; namely the Intra-Pontide, Izmir-Ankara and Amanos-Elazığ-Van-Zagros oceanic basins, has resulted in the emplacement of the oceanic-accretionary prism complexes towards south onto the passive margins of the Sakarya, Tauride-Anatolide and SE Anatolian micro-plates respectively. This event is associated with the formation of fore-land fore-deep-type flysch basins, where tectonic slices of allochthonous oceanic material (ophiolite complexes, blueschist facies metamorphic rocks) together with slices of former continent margin assemblages (mainly former slope deposits) were emplaced for tens of kilometers onto the passive margins during the latest Cretaceous-Early Tertiary period.

This is followed by the formation of numerous molasses-type basins in Anatolia, which were formed all along the Paleogene time (Görür and Tüysüz, 2001). By this, Early Tertiary is the time of Alpine collisional period, accompanied by the generation of huge post-transensional and transpressional basins.

Some of these basins (e.g. Sivas, Çankırı, Şarkışla, Ulukışla, Tuz Gölü basins in central Anatolia) are related to post-collisional extension, whereas others (e.g. the Thrace Basin in NW Anatolia, Adana, W Taurus and SE Anatolian basins) were formed in front of advancing nappes. In the former ones including Tuz Gölü Basin, together with Sivas and Şarkışla basins in central Anatolia the basin development started above the ophiolitic rocks with olistostromal clastics (e.g. Şarkışla Basin, Gökten, 1986) associated with within-plate-type alkaline volcanism (e.g. Ulukışla Basin, Kurt et al, 2008). Paleocene and Eocene are characterized by continental red clastics, evaporites and lagoon and reef-type carbonates at the basin-margins (Fig. 38). In the depocenters, turbiditic sandstones with olistoliths are common. Marine deposition has ended at the end of Eocene or probably Early Oligocene. A regional transpressional event resulted in thrusting of basin-margin successions and basement rocks onto the basin sediments (Dirik et al, 1999). This period lasted until middle Miocene in the Sivas basin. Thereafter, Miocene-Pliocene continental (fluvial to lake sediments associated with lavas and volcanoclastic rocks) deposition dominated in almost all of these basins (e.g. Temel, 2001, Helvacı et al, 2009).

In the Thrace Basin in NW Anatolia (Fig. 39) the basin-margins are dominated by carbonates during the Eocene, whereas turbidites were deposited in the basin-centers until Early Miocene. After a gap in Early-Middle Miocene the basin-fill is dominated by continental clastics and carbonates.

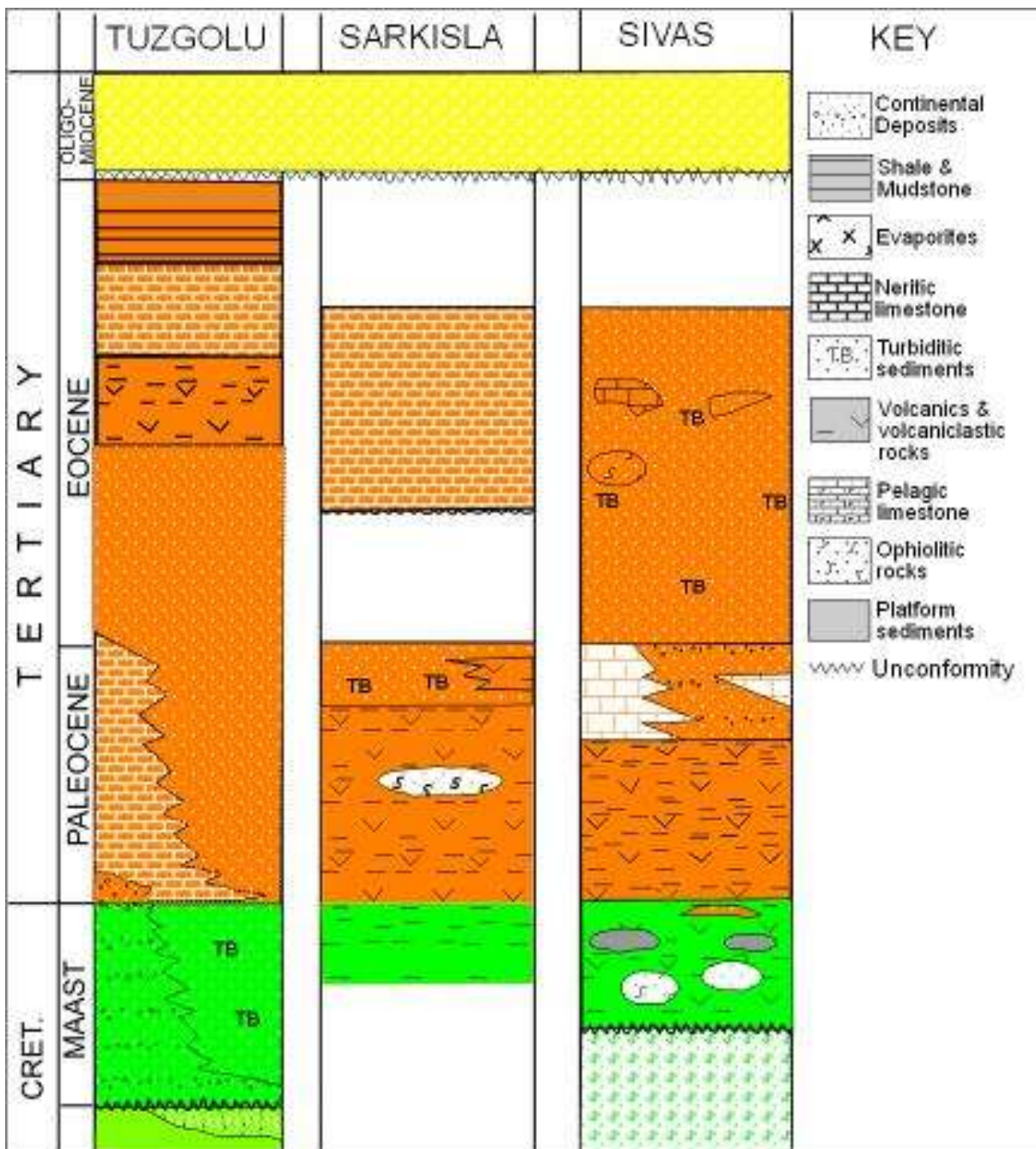


Figure 38- Stratigraphy of the Tuz Gölü, Şarkışla and Sivas basins in central Anatolia (after Gökten, 1983; Görür et al, 1984; Clark and Robertson, 2002)

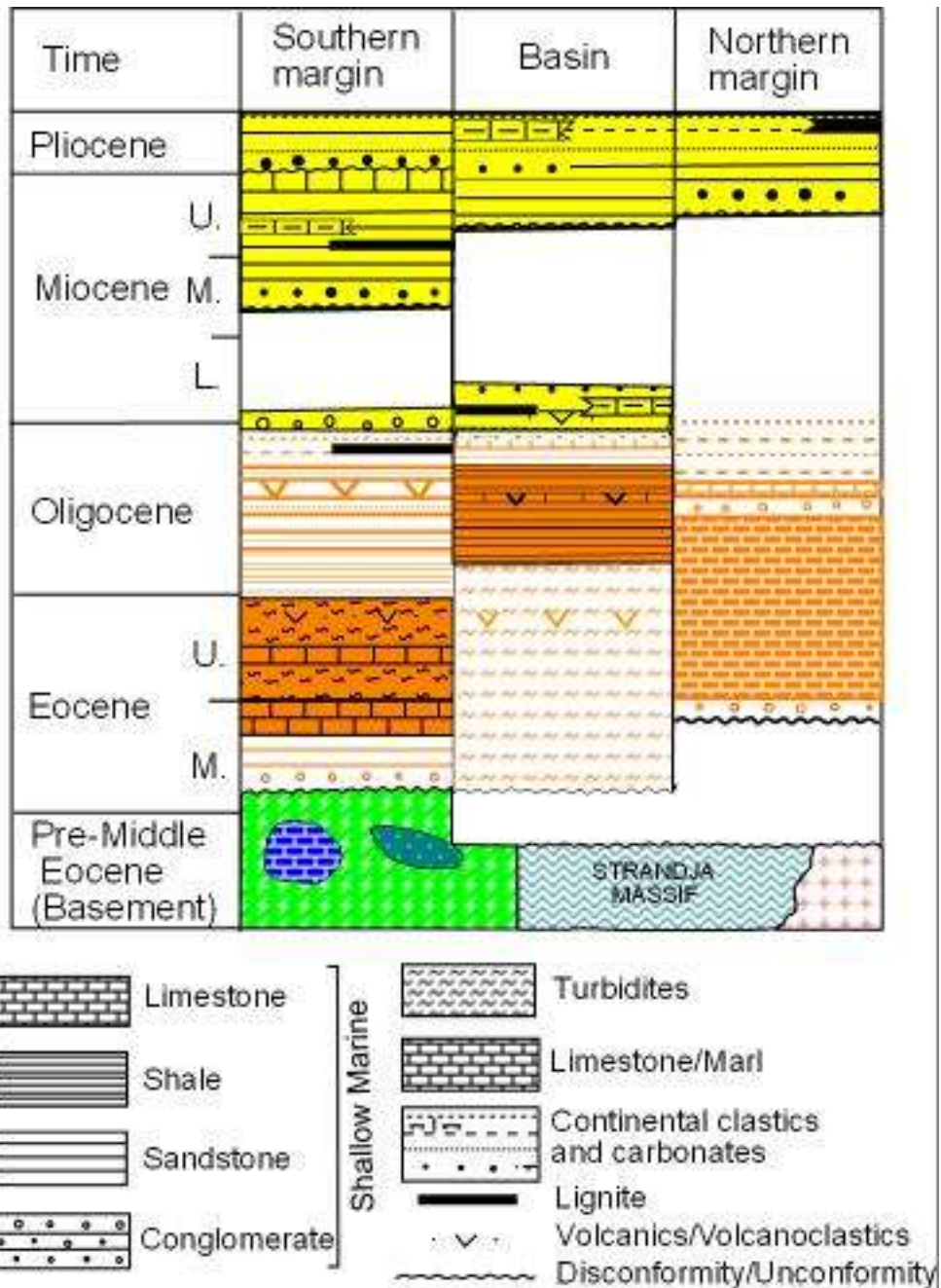


Figure 39- Stratigraphy of the Thrace Basin (after Çağlayan et al, 1992)

### THE NEOTECTONIC PERIOD

The Neotectonic Period covering the Late Miocene-Quaternary time-span in Turkey is out of the scope of this review. However, very briefly, this period is mainly characterized by a reorganization of the plate-boundaries after the closure of the Neotethyan oceans in the Anatolian peninsula. The only active subduction zone during this period is the Hellenic Subduction Zone in southern Aegean, along which the remnant Eastern Mediterranean plate

was subducting towards north beneath the Aegean-Anatolian plates. This new reorganization of the plate movements was triggered by the collision of the Anatolian plates and the Arabian promontory. By this, first the East Anatolian continental crust shortened and thickened, resulting in the formation of the waste collision-type East Anatolian Volcanic Province (Sengör, 1991, Koçyiğit et al, 2001; Keskin, 2003). Ongoing compression resulted in the rupture of the Anatolian continental crust along two main transform faults: the right-lateral North Anatolian Transform Fault dissecting north Anatolia in E-W direction from the N Aegean to East Anatolia and the left-lateral East Anatolian Transform Fault as the northern continuation of the Dead Sea Transform (Rojay et al, 2001) trending in NE-SW direction (Fig. 40).

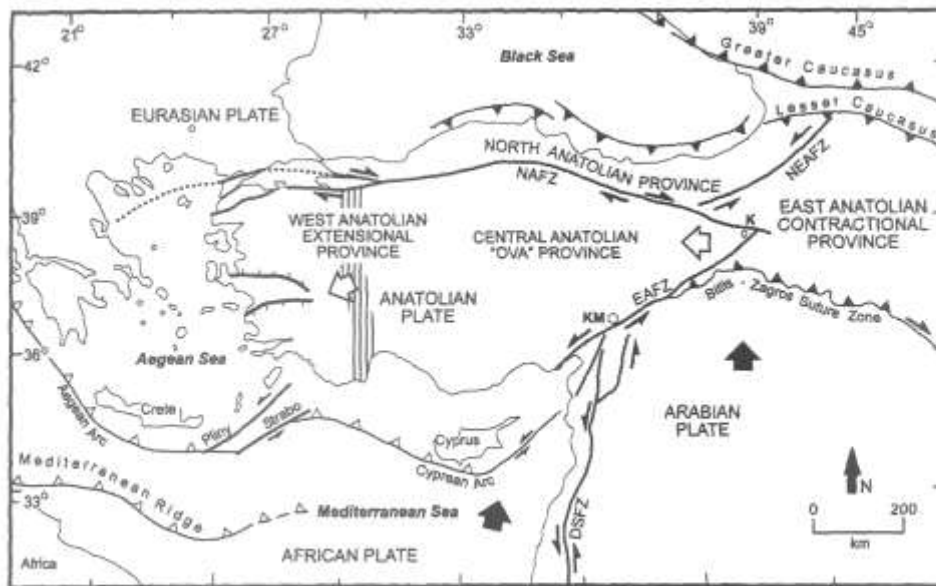


Figure 40- Simplified tectonic map of Turkey showing the major Neotectonic elements and the direction of tectonic transportation (NAFZ: North Anatolian Transform Fault; EAFZ: East Anatolian Transform Fault; EFZ: Ecemiş Fault Zone; SLF: Tuz Gölü Fault Zone). Arrows indicate the sense of tectonic transportation (Bozkurt, 2001).

The main bulk of Anatolia (Anatolian Block as a distinct plate) escaped –and still escaping– during this period towards west and southwest. The westward escape of Anatolia along the main transform faults is accompanied by the formation of second-grade strike-slip faults and fault-zones (e.g. Ecemiş and Tuz Gölü faults, e.g. Dirik, 2001) along which Late Neogene–

Quaternary pull-apart basins were formed. Another implication of this event is the formation of the main volcanic provinces and volcanoes (e.g. Erciyes and Hasandağ volcanoes).

The West Anatolian continental crust, on the other hand, was the side of extension during the Neotectonic period where core-complexes (e.g. the Menderes Core Complex) and numerous intra-cratonic fault-controlled basins (grabens; e.g. Aegean Graben System) were generated during the Neogene. This extension was also accompanied by alkaline to tholeiitic volcanism (Yılmaz, 1989; Savaşçın and Oyman, 1998). Both the transform and the normal faults (Fig.41) in Turkey are the foci of the recent earthquakes.

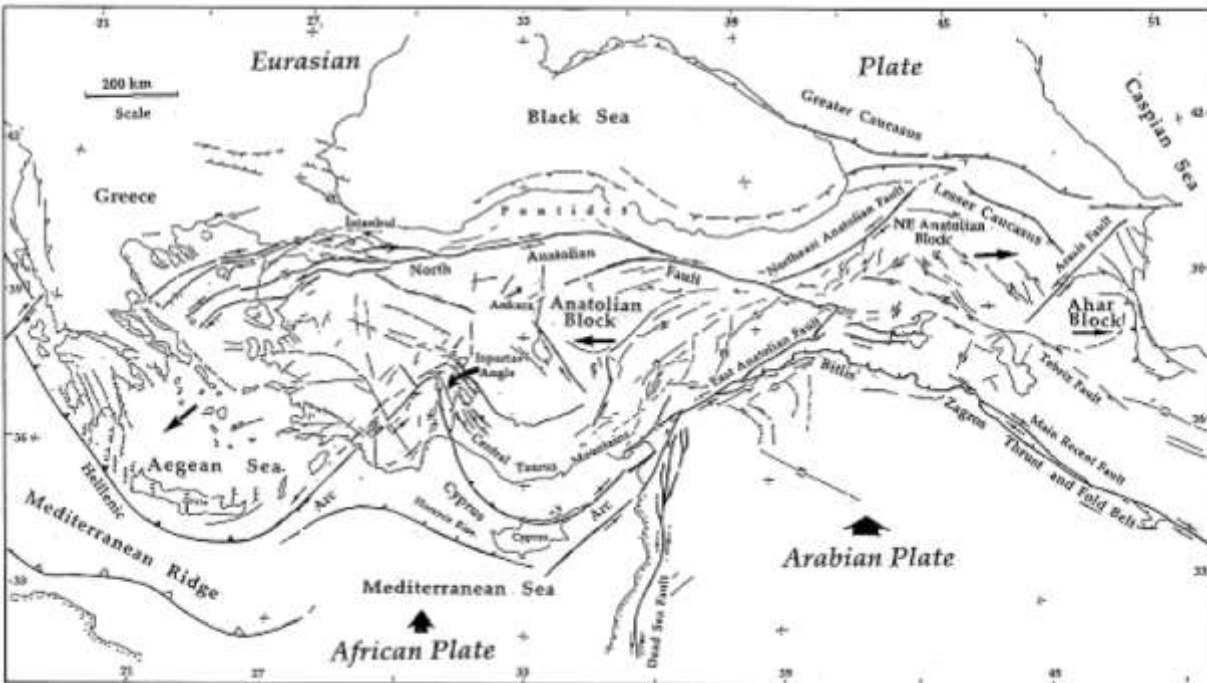


Figure 41- Distribution of the active faults in Turkey (Şaroğlu et al, 1992; Barka and Reilinger, 1997).

### OUTSTANDING PROBLEMS AND CONCLUDING REMARKS

Rifting of a number of continental microplates from the main continental blocks, their drift through time across the oceans, their subduction/collision with other plates during the Cadomian, Variscan, Cimmerian and Alpine orogens has created a very complex geological puzzle in the Turkish area. Hence, there are quite a lot of outstanding problems due to limited data, as well as a number of disagreements in proposed geodynamic scenarios.

An attempt to review the geodynamic evolution of this very complex area necessitates an objective evaluation of these disagreements and problems not yet solved.

To start with the earliest events; these are alternatively called as Pan-African (e.g. Şengör et al, 1984) or more recently as Cadomian (e.g. Ustaömer et al, 2005), as proposed by Murphy ve Nance (1991) for peripheral orogens at the extremity of Gondwana during Late Neoproterozoic). In this sense, no pre-Cadomian rocks or events has been proven yet in Anatolia, even if there are some > 600 Ma zircon ages, mainly obtained from cores of alpine ones. However, Neoproterozoic granitoids in Menderes (Candan and Dora, 1998), Central Anatolian (Göncüoğlu, 1982) and Bitlis (Okay et al, 1985) massifs intrude a polymetamorphic basement with granulitic ortho- and para-gneisses and eclogites. Hence, the presence of a pan-African metamorphosed/consolidated basement can not be excluded. Cadomian units were described from several localities in the basements of almost all alpine terranes with the exception of the Sakarya Composite Terrane (Fig 2). As originally suggested by Göncüoğlu (1996, Göncüoğlu et al, 1997, Gürsu and Göncüoğlu, 2006), the N Gondwanan origin of the Cadomian units in Turkey is confirmed by recent zircon data (e.g. Ustaömer et al, 2005, 2007; Okay et al, 2008). An outstanding problem (e.g. Bozkurt et al, 2008) relates to the presence of Cadomian ophiolites (Göncüoğlu et al, 1997; Yiğitbaş et al, 2004) in the Istanbul-Zonguldak Terrane, indicative for the involvement of an oceanic lithosphere and hence the location, subduction direction and exact life-span of the corresponding ocean.

In the southern terranes, Cambrian is marked by a marine transgression above post-Cadomian continental clastics, probably indicating an extensional event on the Cadomian basement (e.g. Gürsu et al, 2005; Bozkaya et al, 2006). In the northern terranes, however, the marine transgression onto the Cadomian arc-rocks is earliest Ordovician in age (Lakova et al, 2006). The Ordovician is characterized in all terranes by siliciclastic rocks indicating that they were located on N Gondwana margin in similar paleogeographic settings. The Mid Ordovician (Darrivilian) limestone lithofacies in the Taurides (Kozlu et al, 2002), is recently recognized also in Zonguldak Terrane (Göncüoğlu, 2008) that is also indicative for similar paleo-latitudes. Towards the end of Ordovician the northern terranes must have been in lower latitudes, as they do not include the Hirnantian glacio-marine deposits reported (Monod et al, 2003) in the Taurides. With the exception of the Istanbul Terrane, where carbonate deposition dominated, Silurian deposits are very similar in all terranes. These similarities may suggest that the Rheic Ocean must have been located to the north of the Anatolide terranes, which is in contrast with Stampfli and Kozur (2006) reconstructions. The late Early Devonian is characterized by local unconformities that may mark the early Variscan events. Well-documented Variscan events were mainly described in the northern terranes (e.g. Görür et al, 1997) and along a narrow zone in the northern margin of the Anatolides (Özcan et al, 1989). Obviously, the northern terranes

migrated across the closing Rheic Ocean towards Laurussia (e.g. Yanev et al, 2006). Yet there is no consensus on the paleogeographic configuration of the Turkish terranes and on the subduction polarity of the Rheic oceanic lithosphere. Recent discovery of Carboniferous metamorphic rocks (Topuz et al, 2004) and arc-type granitic intrusions in İstanbul-Zonguldak basement (e.g. Nzegge et al, 2006); and Sakarya basement (Yılmaz, 1981; Okay et al, 2006a); back-arc type volcanics in N Anatolides (Göncüoğlu et al, 2007); post-collisional granites in Bitlis Massif (Göncüoğlu and Turhan, 1997) and remnants of Carboniferous ocean-islands in the Taurides (Göncüoğlu et al, 2000b) clearly shows that the Variscan events are not restricted to the İstanbul Terrane as previously believed (e.g. Sengör et al, 1984). In brief, the Variscan history is scarcely understood and some models proposed (e.g. Stampfli, 2000; Moix et al, 2007a) are not based on solid evidence. Hence, detailed work is required for the paleogeographic settings of the continental microplates and oceanic basins.

The Late Paleozoic- Early Mesozoic Cimmerian events related to the closure of the enigmatic Paleotethyan oceanic branch was mainly observed in the Sakarya Composite Terrane (Okay and Göncüoğlu, 2004), with several less-known outcrops in the eastern Pontides. Recently, new models (e.g. Moix et al, 2007b) were proposed, involving a multi-armed (Paleotethys, Küre, Meliata, Maliac, Pindos, etc) Late-Paleozoic-Triassic Tethys with an additional oceanic branch between the Taurides (s.s.) and the Anatolides. Once more there is no consensus at all on the number, locations, life-spans and subduction polarities of these oceanic branches/marginal basins (for a brief review see Robertson et al, 2004) and the Karakaya Complex as a product of its closure. Moreover, these new suggestions are not in accordance with field data (for a brief discussion see e.g. Göncüoğlu et al, 2003a)

The distribution of the alpine terranes is relatively better-known, as they are marked by ophiolitic suture zones (Fig 1 and 2). However, there are still a number of unknowns in several aspects. To start with the southern Neotethyan branch; there are disagreements on the location of the suture and its western continuation (e.g. Parlak and Robertson, 2004). The former problem is mainly based on presence of ophiolitic nappes above and beneath the Bitlis/Pütürge metamorphic complexes. One model (e.g. Yazgan, 1984; Göncüoğlu and Turhan, 1984) suggests that these metamorphic complexes represent the subducted and partly metamorphosed passive margin of the Arabian Platform and the southern Neotethyan branch was to the N of them. By this the oceanic lithosphere subducted to the N, generating the island arcs (e.g. Yüksekova arc, Yılmaz 1993) and the continental arc (Elazığ arc, e.g. Parlak, 2006). The other model (e.g. Robertson, 2002, 2004) advocates that the oceanic basin was located between the Bitlis/Pütürge metamorphic complexes and the SE Anatolian Autochthon



representing the N promontory of the Arabian Platform. The opening age of this oceanic branch is also yet not well-documented in the Turkish area. In contrast to the Permian opening ages reported from Zagros (e.g. Stampfli et al, 2002) the paleontological ages obtained from W (e.g. Tekin, 2002) and E Turkey (e.g. Tekin and Bedii, 2007) are Late Triassic.

Izmir-Ankara-Erzincan Ocean is considered as the main northern Neotethyan sea-way. The initial models (Şengör and Yılmaz, 1981; Yılmaz et al, 1995) assume that it was opened between the Sakarya Composite Terrane in the N and the Anatolides in the S during the Jurassic. Subsequent work on the suture complexes has shown that it actually opened already during the Triassic (Tekin et al, 2002) and closed by two northward directed subduction zones; one beneath the Sakarya Composite Terrane generating the Pontide arc (e.g. Tokel, 1977) and another intraoceanic one creating the supra-subduction-type oceanic crust (Yalınız et al, 1996; Toksoy-Köksal, 2001). Recently, new models were proposed (e.g. Stampfli and Kozur, 2006), where the Izmir-Ankara Ocean has opened at the end of Triassic as a marginal basin above the northward subducting S Neotethyan oceanic lithosphere. These highly speculative and complex multi-armed Northern Neotethys (Vardar, Lycian, Izmir-Ankara oceans) models are not supported by reliable field-data and are matters of debate (e.g. Robertson et al, 2004; Göncüoğlu et al, 2006 b, 2008).

The Inner-Tauride Ocean, another point of disagreement was initially proposed (Şengör and Yılmaz, 1981) as a branch of Izmir-Ankara Ocean that opened during the Jurassic (Görür et al, 1984) between the Central Anatolian Crystalline Complex and the Taurides. Seemingly, it was subducted north-northeastward and created the arc granites (Görür et al, 1984, 1989) in the Central Anatolian Crystalline Complex. Recently, several detailed work has shown that these Central Anatolian granites are not arc-related (e.g. Göncüoğlu and Türeli, 1994; Otlu and Boztuğ, 1998; Boztuğ, 1989; Aydın et al, 1998), the metabasic rocks in the “suture” are Late Cretaceous – Eocene in age and not oceanic (e.g. Kurt et al, 2008). Moreover, it has been shown that the Tuz Gölü-Ulukışla Basin complex, juxtaposing the “suture” is a latest Cretaceous extensional system (Çemen et al, 1999) and the gross stratigraphy of the Crystalline Complex is very similar to the Anatolides (Göncüoğlu, 1981). By this, Goncuoglu et al (1992) suggest that this “suture” is representing a post-collisional basin. However, some other studies (e.g. Dilek et al, 1999; Kadioğlu et al, 2006) still claim for a subduction-related event. The most critical evidence of this suggestion is the high pressure metamorphic rocks at the Bolkardağ (e.g. Demirtaşlı et al, 1984), which is ascribed to the partial subduction (Dilek et al, 1999) of the Tauride-Anatolide’s N margin beneath the Central Anatolian Crystalline Complex. In brief, the properties of the Inner Tauride Ocean are not known and there are a number of questions to be

answered. The problem with the Intra-Tauride Suture directly relates to the geological evolution of the Central Anatolian Crystalline Complex. Since the initial suggestion of Özgül (1976), this unit was considered as the northern promontory of the Tauride-Anatolide microcontinent. This suggestion was supported by the detailed mapping in the Crystalline Complex (e.g. Özer ve Göncüoğlu, 1983; Seymen, 1984; Göncüoğlu et al, 1991, 1992 etc). Recently, this unit is considered as a Eurasian terrane and juxtaposed during the Carnian with the Gondwanan Tauride-Anatolide platform (e.g. Stampfli and Kozur, 2006; Moix et al, 2008). It rifts off Gondwana by the opening of the Pindos Ocean at the end of Triassic and amalgamates again with the main Tauride-Anatolide body during Santonian. No solid data is presented for these models in the corresponding papers.

The Intra-Pontide Suture is mainly accentuated by the presence of two completely different continental microplates; the Istanbul-Zonguldak Terrane to the N and the Sakarya Composite Terrane to the S (Şengör and Yılmaz, 1981). In NW Anatolia, the suture juxtaposes the North Anatolian Transform Fault and can be traced only by discontinuous outcrops of ophiolites, and ophiolitic mélanges. By this feature, Elmas and Yigitbaş (2001) argued that the no Intra-Pontide Ocean existed in this area. This suggestion is also supported in the evolutionary cartoons of Stampfli and Kozur (2006). However, oceanic basalts of middle Middle Jurassic to middle Late Cretaceous are recently proven from NW Anatolia (Becaletto et al, 2005; Göncüoğlu et al, 2008). Nevertheless, the data on its original location and opening age are still scarce and there are disagreements on its subduction polarity as well as eastern continuation to the E of Kastamonu. Moreover, in the N Central Pontides there are several ophiolitic units, which were attributed (e.g. Yılmaz et al, 1997) to Paleotethys without reliable age data. More recently, some of them are proven to be alpine (e.g. Okay et al, 2006b; Tüysüz and Tekin, 2007). A detailed study of these mainly metamorphic units may contribute to fix the location of the Intra-Pontide suture towards E of Kastamonu.

Regarding the alpine history of the Istanbul-Zonguldak and Istranca terranes, the main problem remains their paleogeographic setting during the very complex alpine events. It is commonly accepted that the Istanbul-Zonguldak Terrane was on the northern margin of the Intra-Pontide oceanic branch until the opening of the Black Sea basin during the Late Cretaceous (e.g. Okay and Tüysüz, 1999). However, geophysical data from Black Sea offshore (Banks and Robinson, 1997) do not confirm the presence of the bounding strike-slip faults, along which it is assumed to be translated to the S. Towards E, some tectonic inlayers in the Central and Eastern Pontides displaying similarities to the Istanbul-Zonguldak terrane in their stratigraphy and magmatic evolution (e.g. Devrekani Metamorphics, Boztuğ and Yılmaz, 1995) were previously considered

as klippen on the Karakaya-type Cimmerian mélanges (Akgöl Flysch of Şengör et al, 1984). This is not confirmed by field-data (e.g. Kozur et al, 2000) and a systematic reevaluation of the tectonic units in the Central Pontides is needed.

Recent work on the Istranca Terrane (Okay et al, 2001; Göncüoğlu et al, 2006c) suggests that it probably includes nappes of different Balkan terranes and is actually also a composite terrane in the sense of Howell (1989).

To conclude, the last fifty years of geological mapping in Turkey, associated with some limited biostratigraphic and petrological work has only helped to recognize the main geological problems. To solve them, additional studies using conventional methods accompanied by geochronological, geophysical (paleomagnetic and seismic) and microtectonic work is inevitable.

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### **REFERENCES**

- Akıman, O., Erler, A., Göncüoğlu, M.C., Güleç, N., Geven, A., Türeli, K. and Kadioğlu, Y. 1993. Geochemical characteristics of granitoids along the western margin of the Central Anatolian Crystalline Complex and their tectonic implications. *Geol. Journ.*, 28, 371-382.
- Aldanmaz, E., Yalınız, M.K., Güçtekin, A. and Göncüoğlu, M.C. 2008. Geochemical characteristics of mafic lavas from the Tethyan ophiolites in western Turkey: implications for heterogeneous source contribution during variable stages of ocean crust generation. *Geol. Mag.*, 145, 37-54.
- Altınır, D. 1989. An example for the tectonic evolution of the Arabian Platform margin (SE Anatolia) during Mesozoic and some criticism of the previously suggested models. In: Sengör, A.M.C.(Ed.), *Tectonic Evolution of Tethyan Regions*, Kluwer Acad. Pub., 117-129.
- Altınır, D., Koçyiğit, A., Farinacci, A., Nicosia, U. and Conti, M.A. 1991. Jurassic-Early Cretaceous stratigraphy and paleogeographic evolution of the southern part of North-Western Anatolia (Turkey). *Geologica Romana*, 27, 68p.
- Aydın, Y. 1974. *Etude petrographique et geochemique de la partie centrale du Massif d'Istranca*: Univ. Nancy, PhD Thesis, 131p.
- Aydın, M., Sahintürk, O., Serdar, H.S., Özçelik, Y. Akarsu, I., Ungör, A., Çokuğraş, R. and Kasar, S. 1987. Çamdağ (Sakarya)-Sünnücedağ (Bolu) yöresinin jeolojisi. *Geol. Soc. Turkey Bull.*, 30, 1-14.
- Bağcı, U., Parlak, O. Höck, V. 2005. Whole-rock and mineral chemistry of cumulates from the Kızıldağ (Hatay) ophiolite (Turkey): clues for multiple magma generation during crustal accretion in the southern Neotethyan ocean. *Mineral. Mag.*, 69, 53-76.

Banks, C.J. and Robinson, A. 1997. Mesozoic strike-slip back-arc basins of the Western Black Sea region. In: A.G. Robinson (Ed.), Regional and petroleum geology of the Black Sea and surrounding region. Am. Ass. Petrol. Geol., Memoir, 68, 53-62.

Barka, A. and Reilinger, R. 1997. Active tectonics of the Eastern Mediterranean region: deduced from GPS, neotectonic and seismicity data. *Annals of Geophysics*, 40, 587-610.

Beccaletto, L., Bartolini, A.C., Martini, R., Hochuli, P.A. and Kozur, H. 2005. Biostratigraphic data from the Cetmi Mélange, northwest Turkey: Palaeogeographic and tectonic implications. *Palaeo. Palaeo. Palaeo.*, 221, 215-244.

Bektaş. O. 1983. Kuzeydoğu Pontid magmatik yayındaki (I) tipi granitik kayalar ve jeotektonik konumları. 37. Türkiye Jeoloji Kurultayı, Bildiri Özleri, 49-50.

Bektaş, O., Şen, C., Atıcı, Y. Ve Köprübaşı, N. 2000. Migration of the Upper Cretaceous subduction-related volcanism towards the back-arc basin of the eastern Pontide magmatic arc (NE Turkey). *Geol. Journal*, 34, 95-106.

Beyarslan, M. and Bingöl, A.F. 2000. Petrology of a supra-subduction zone ophiolite (Elazığ, Turkey). *Canad. Journ. Earth Sci.* 37, 1411-1424

Bingöl, E., Akyürek, B. and Korkmazer, B. 1975. Biga yarımadasının jeolojisi ve Karakaya Formasyonunun bazı özellikleri. *Proceedings of 50th Anniv. of Turkish Republic, MTA Publ.*, 70-77.

Boccaletti, L. 2003. Geology, correlations and the geodynamic evolution of the Biga Peninsula (NW Turkey). Ph. D Theses, Lausanne Univ., 187p.

Bozkaya, H., Gürsu, S. and Göncüoğlu, M.C. 2006. Mineralogical evidence for the Cadomian tectonothermal event in the western Central Taurides (Sandıklı-Afyon area), Turkey. *Gondwana Research*, 10, 301-315.

Bozkurt, E. 2001. Neotectonics of Turkey-a synthesis. *Geodynamica Acta*, 14, 3-30.

Bozkurt, E. and Oberhänsli, R. 2001. Menderes Massif (Western Turkey): structural, metamorphic and magmatic evolution - a synthesis. *Int. Journ. Earth Sci.*, 89, 679-708.

Bozkurt, E., Park, R.G. and Winchester, J.A. 1993. Evidence against the core/cover interpretation of the southern sector of the Menderes Massif. *Terra Nova*, 5, 445-451.

Bozkurt, E., Winchester, J.A., Yiğitbaş, E. and Ottley, C.J. 2008. Proterozoic ophiolites and mafic-ultramafic complexes marginal to the İstanbul Block: An exotic terrane of Avalonian affinity in NW Turkey. *Tectonophysics*, 461, 240-251.

Boztuğ, D. 1998. Post-Collisional Central Anatolian Alkaline Plutonism, Turkey. *Turkish Journ. Earth Sci.*, 7, 145-165.

Boztuğ, D. 2000. S and A-type intrusive associations: geodynamic significance of synchronism between metamorphism and magmatism. In: Bozkurt, E., Winchester, J. and Piper, J.A., (eds.) *Tectonics and magmatism in Turkey and the Surrounding Area. Geol. Soc. London Special Publ.*, 173, 441- 458.

Boztuğ, D., Jonckheere, R., Wagner, G. A., Ercin, A. I., Yegingil, Z. 2007. Titanite and zircon fission-track dating resolves successive igneous episodes in the formation of the composite Kackar batholith in the Turkish eastern Pontides. *Int. Journ. Earth. Sci.*, 96, 875-886.

Boztuğ, D. and Yılmaz, O. 1995. Metamorphism and geological evolution of the Daday-Devrekani massif, Kastamonu region, Western Pontides, Northern Turkey. *Geol. Bull. Turkey*, 38, 33-58.

Candan, O. 1994. Relict granulite-facies metamorphism in the Menderes Massif. *Turkish Journ. Earth Sci.*, 4, 35-55.

Candan, O. and Dora, O. 1998. Granulite, eclogite and blueschist relics in the Menderes massif: An approach to Pan-African and Tertiary metamorphic evolution *Geol. Soc. Turkey Bull.*, 41, 1-35.

Candan, O., Dora, O. Ö., Oberhänsli, R., Çetinkaplan, M., Partzsch, J.H., Warkus, F. C. and Dürr, S. 2001. Pan-African high-pressure metamorphism in the Precambrian basement of the Menderes Massif, western Anatolia, Turkey. *Int. Journ. Earth Sci*, 89, 793-811.

Chatalov, G.A. 1988. Recent developments in the geology of the Strandzha Zone in Bulgaria. *Bull. Tech. Univ. Istanbul*, 41,433-465.

Chen, F., Siebel, w., Satır, M., Terzioğlu, N. and Saka, K. 2002. Geochronology of the Karadere basement (NW Turkey) and implications for the geological evolution of the İstanbul zone. *Int. Journ. Earth Sci.*, 91, 469-481.

Clark, M. and A. Robertson, A.H.F. 2002. The role of the Early Tertiary Ulukisla Basin, Southern Turkey in suturing of the Mesozoic Tethys Ocean. *Journ. Geol. Soc. London*, 159, 673-690.

- Çemen, I., Göncüoğlu, M.C. and Dirik, K. 1999. Structural evolution of the Tuz Gölü (Salt Lake) basin: evidence for late Cretaceous extension and Cenozoic inversion in central Anatolia, Turkey. *Journ. Geol.*, 107, 693-706.
- Çağlayan, A., Şengün, M. and Yurtsever, A. 1992. Structural evolution of the Strandjha Massif, Thrace, Turkey. *ISGB Abstracts*, 7.
- Çemen, I., Tekeli, O., Seyitoglu, G., Isik, V. 2005. Are turtleback fault surfaces common structural elements of highly extended terrains? *Earth-Science Reviews* 73, 139– 148.
- Dean, W.T. 2006. Cambrian Stratigraphy and Trilobites of the Samur Dag Area, South of Hakkari, Southeastern Turkey. *Turkish Journ. Earth. Sci.*, 15, 225-257.
- Dean, W.T. 2006. Cambrian stratigraphy and trilobites of the Samur Dag Area, South of Hakkari, southeastern Turkey. *Turkish Journ. Earth. Sci.*, 15, 225-257.
- Dean, W.T., Monod, O., Rickards, R.B., Demir, O., Bultynick, P. 2000. Lower Paleozoic stratigraphy and paleontology, Karadere Zirze area, Pontus Mountains, northern Turkey. *Geol. Mag*, 137, 555-582.
- Demircan, H. & Gürsu, S. 2009. New trace fossils finding in Telbesmi Formation in Southeast Anatolian Autochthon Belt (Turkey). *IPETGAS 2009 Proceedings*, Ankara.
- Demirtaşlı, E., Turhan, N., Bilgin, A.Z. and Selim, M. 1984. Geology of the Bolcardağ Mountains. In: Tekeli, O. ve Göncüoğlu, M.C. (Eds) *Int. Symposium on the Geology of the Taurus Belt*, 125-142, MTA Publ.
- Derman, S. 1990. Batı Karadeniz Bölgesinin Geç Jura-Erken Kretase evrimi. 8. Petrol Kongresi Proceedings, 328-339.
- Dilek, Y. and Thy, P. 2006. Age and petrogenesis of plagiogranite intrusions in the Ankara mélange, central Turkey. *Island Arc*, 15, 44 – 57.
- Dilek, Y., Whitney, D.L., and Tekeli, O. 1999. Links between tectonic processes and landscape morphology in an Alpine Collision Zone, South-Central Turkey. *Annals of Geomorphology*, 118, p. 147–164
- Dirik, K. 2001. Neotectonic evolution of the northeastward arched segment of the Central Anatolian fault zone, Central Anatolia, Turkey. *Geodynamica Acta*, 14, 147-158.
- Dirik, K. and Göncüoğlu, M.C. 1996. Neotectonic characteristics of the Central Anatolia: *Int. Geol. Rev.*, 38/9, 807-817.
- Dirik, K., Göncüoğlu, M.C. and Kozlu, H. 1999. Stratigraphy and pre-Miocene tectonic evolution of the southwestern part of the Sivas Basin, Central Anatolia, *Geol. Journ.*, 34, 303-319.
- Duru, M., Pehlivan, S., Şentürk, Y., Yavaş, F. and Kar, H. 2004. New results on the lithostratigraphy of the Kazdağ Massif in northwest Turkey. *Turkish Journ. Earth Sci.*, 13, 177–186.
- Dora, O.O., Kun, N. and Candan, O. 1991. Metamorphic history and geotectonic evolution of the Mendere Massif. *IESCA Proceedings*, 102-115.
- Elmas, A. and Yiğitbaş, E. 2001. Ophiolite emplacement by strike-slip tectonics between the Pontide Zone and the Sakarya Zone in northwestern Anatolia, Turkey. *Int. Journ. Earth Sci*, 90, 257-269.
- Erdoğan, B., Uchman, A., Güngör, T. and Özgül, N. 2004. Lithostratigraphy of the Lower Cambrian metaclastics and their age based on trace fossils in the Sandıklı region, southwestern Turkey. *Geobios*, 37, 346-360.
- Eren, H. 1979. Kastamonu-Taşköprü bölgesi metamorfiteilerinin jeolojik ve petrografik etüdü. *Istanbul Tech. Univ, PhD Thesis*, 155p.
- Erler, A. 1984. Tectonic setting of the massive sulfide deposits of the Southeast Anatolian Thrust Belt. In: Tekeli, O. and Göncüoğlu, M.C. (eds) *Int. Symposium on the Geology of the Taurus Belt*, 237-244, MTA Publ.
- Floyd, P.A., Göncüoğlu, M.C., Winchester, J.A., and Yalınız, M.K. 2000. Geochemical character and tectonic environment of Neotethyan ophiolitic fragments and metabasites in the Central Anatolian Crystalline Complex, Turkey. In: Bozkurt, E., Winchester, J. and Piper, J.A. (eds.) *Tectonics and magmatism in Turkey and the Surrounding Area*. *Geol. Soc. London Spec. Publ.*, 173, 183-202.
- Floyd, PA, Özgül, L., Göncüoğlu, M.C. 2003. Metabasite blocks from the Koçyaka HP-LT metamorphic rocks, Konya, central Anatolia: geochemical evidence for an arc—back-arc pair? *Turkish Journ. Earth. Sci.*, 12, 157-174.
- Gedik, I., Pehlivan, S., Duru, M. and Timur, E. 2005. 1/50.000 scaled geological map and explanations: Sheet Bursa G23b. *MTA 1/50.000 scaled geological maps series*, 17, 1-49.

Gökten, E. 1983. Şarkışla (Sivas) güney-güneydoğusunun stratigrafisi ve evrimi. Geol. Soc. Turkey Bull., 26, 167-176.

Gökten, E. 1986. Paleocene carbonate turbidites of the Şarkışla region, Turkey-their significance in an orogenic basin. Sedimentary Geology, 49, 143-165.

Gökten, E. and Floyd, P.A. 2007. Stratigraphy and geochemistry of pillow basalts within the ophiolitic mélangé of the Izmir–Ankara–Erzincan suture zone: implications for the geotectonic character of the northern branch of Neotethys. Int. Journ. Earth Sci., 96, 725-741.

Göncüoğlu, M.C. 1977. Geologie des westlichen Niğde Masifs. Bonn Univ. Ph.D. Theses, 176 s (unpublished).

Göncüoğlu, M.C. 1982. Zircon U/Pb ages from paragneisses of the Nigde Massif (Central Anatolia). Geol. Soc. Turkey Bull., 25, 61-66.

Göncüoğlu, M.C. 1984. The metamorphism and age of the Muş- Kızılağaç Metagranite. MTA Bull, 99/100, 37-48.

Göncüoğlu, M.C. 1986. Geochronological data from the southern part (Niğde Area) of Central Anatolian Massif. MTA Bull., 105/106, 111-124.

Göncüoğlu, M.C. 1989. Structural framework of the Anatolian Hercynites. 28th Int. Geol. Cong. Abstracts, 563-564.

Göncüoğlu, M.C. 1996. Terranes with contrasting pre-lower Paleozoic basement rocks in NW Gondwana; geodynamic implications. Revista Yacimiento Petroliferos Fiscales Bolivianos, 17, 475-476.

Göncüoğlu, M.C. 2007. Geology of the Kütahya-Bolkardağ Belt. Menderes Massif Colloquium Proceedings, 39-43.

Göncüoğlu, M.C. 2008. Correlation of Darriwilian successions in Gondwanan (SE Anatolian Autochthon and Taurides) and Peri-Gondwanan (Istanbul and Zonguldak) terranes in Turkey. Int. Cong. Paleozoic Climates, August 22-31 Lille, France, Abstracts, 41.

Göncüoğlu, M.C. and Erendil, M. 1990. Armutlu Yarımadasının Geç Kretase öncesi birimleri Turkish Assoc. Petrol. Geol., 8.Congress, Proceedings, 161-168.

Göncüoğlu, M.C. and Kozlu, H. 2000. Early Paleozoic evolution of the NW Gondwanaland: data from southern Turkey and surrounding areas. Gondwana Research. 3, 315-324.

Göncüoğlu, M.C. and Kozur, H. 1998. Remarks on the pre-Variscan development in Turkey. In: Linnemann, U., Heuse, T., Fatka, O., Kraft, P. Brocke, R. and Erdtmann, B.T. (eds), Pre-variscan Terrane Analyses of "Gondwanean Europa", Proceedings, Schriften des Staatl. Mus. Min. Geol. Dresden, 9, 137-138.

Göncüoğlu, M.C. and Türel, T.K. 1993. Petrology and geodynamic interpretation of plagiogranites from Central Anatolian ophiolites (Aksaray-Turkey). Ofioliti, 18, 187.

Göncüoğlu, M.C. and Türel, T.K. 1994. Alpine collisional-type granitoids from the Central Anatolian Crystalline Complex. Journ. Kocaeli Univ., 1, 39-46.

Göncüoğlu M.C. and Turhan, N. 1984. Geology of the Bitlis Metamorphic Belt. In: Tekeli, O. and Göncüoğlu, M.C.(Eds) Int. Symposium on the Geology of the Taurus Belt, 237-244, MTA Publ.

Göncüoğlu, M.C., and Turhan, N. 1997. Rock units and metamorphism of the basement and Lower Paleozoic cover of the Bitlis Metamorphic Complex, SE Turkey: In: Göncüoğlu, M.C. and Derman, A.S.(eds), Lower Paleozoic Evolution in northwest Gondwana, Turkish Assoc. Petrol. Geol., Spec. Publ., 3, 75-81.

Göncüoğlu M.C., Özcan, A., Turhan, N. and Işık, A. 1992a. Stratigraphy of the Kütahya region. Field Guide Book, ISGB, 3-11, MTA Publ., Ankara.

Göncüoğlu, M.C., Erler, A., Toprak, V., Yalınz, K., Olgun, E. and Rojay, B. 1992b. Orta Anadolu Masifinin Batı Kesiminin Jeolojisi, Bölüm II. Orta Kesim: TPAO Rap.No:3155, 76 p.

Göncüoğlu, M.C., Kozlu, H. and Dirik, K. 1997. Pre-Alpine and Alpine terranes in Turkey: explanatory notes to the terrane map of Turkey. Ann. Geol. Pays Helleniques, 37, 515-536.

Göncüoğlu, M.C., Turhan, N., Şentürk, K., Özcan, A., Uysal, Ş. and Yalınz, K. 2000a. A geotraverse across NW Turkey: tectonic units of the Central Sakarya region and their tectonic evolution. In: Bozkurt, E., Winchester, J. and Piper, J.A. (eds.) Tectonics and magmatism in Turkey and the Surrounding Area. Geol. Soc. London Spec. Publ., 173, 139-161.

Göncüoğlu, M.C., Yalınz, M.K., Floyd, P.A. 2000b. Petrology of the Carboniferous volcanic rocks in the Lycian Nappes, SW Turkey: implications for the Late Paleozoic evolution of the Tauride-Anatolide Platform. IESCA 2000, Izmir, Sept.25-29, 2000, Abstracts, 213.

Göncüoğlu, M.C, Turhan, N. and Tekin, K. 2003a. Evidence for the Triassic rifting and opening of the Neotethyan Izmir-Ankara Ocean, northern edge of the Tauride-Anatolide Platform, Turkey. *Bull. Geol. Soc. Italy, Special Volume 2*, 203-212.

Göncüoğlu, M.C., Lakova, I, Kozlu, H. and Sachanski, V. 2003b. The Silurian of the Istanbul Unit in the Çamdağ area, NW Turkey. In: Ortega, G and Acenolaza, G.F. (eds), *Proceedings of the 7.Int Graptolite Conference, Serie Correlacion Geologica*, 18, 129-131.

Göncüoğlu, M.C. Göncüoğlu, Y., Kozlu, H. and Kozur, H. 2004a. Geological evolution of the Taurides during the Infra-Cambrian to Carboniferous period: a Gondwanan perspective based on new biostratigraphic findings. *Geol. Carpat.*, 55/6, 433-447.

Göncüoğlu, MC, Boncheva, I. and Göncüoğlu, Y. 2004b. First finding of Middle Tournasian conodonts in the Griotte-type limestones of the "Palaeozoic of Istanbul": Implications for the Variscan evolution. *Revista Italiana Paleont. Strat.*, 110, 431-439.

Göncüoğlu, M.C., Kuwahara K., Tekin, U.K., Turhan, N. 2004c. Upper Permian (Changxingian) Radiolarian Cherts within the Clastic Successions of the "Karakaya Complex" in NW Anatolia. *Turkish Journ. Earth. Sci.*, 13, 201-213.

Göncüoğlu, M.C., Yalınız, K. and Tekin, U.K. 2006a. Geochemical features and radiolarian ages of volcanic rocks from the Izmir-Ankara Suture Belt, Western Turkey. *Proceed. Int Symp. Mesozoic Ophiolite Belts of the N Balkan Peninsula (Belgrade-BanjaLuka, 11 May-6 June, 2006)* 41-44.

Göncüoğlu, M.C., Yalınız, K. and Tekin, U.K. 2006b. Geochemistry, tectono-magmatic discrimination and radiolarian ages of basic extrusives within the Izmir-Ankara Suture Belt (NW Turkey): Time Constraints for the Neotethyan Evolution. *Ofioliti* 31, 25-38.

Göncüoğlu, M.C., Özgül, N., Gedik, I., Okuyucu, C., Saydam, GD. and Timur, E. 2006c. Paleozoic units and their correlation in Bulgarian and Turkish terranes. *TUBITAK-BAS Final Report*. 174s.

Göncüoğlu, MC, Çapkinoğlu, S., Gürsu, S, Noble, P, Turhan, N, Tekin, UK, Okuyucu, C. and Göncüoğlu, Y. 2007. The Mississippian in the Central and Eastern Taurides (Turkey): constraints on the tectonic setting of the Tauride-Anatolide Platform. *Geol. Carpat*, 58, 427-442.

Göncüoğlu, M.C., Gürsu, S., Tekin, U.K. and Köksal, S. 2008. New data on the evolution of the Neotethyan oceanic branches in Turkey: Late Jurassic ridge spreading in the Intra-Pontide branch. *Ofioliti*, 33, 153-164.

Görür, N. 1988. Timing of opening of the Black Sea basin. *Tectonophysics*, 47, 247-262.

Görür, N. and Tüysüz, O. 2001. Cretaceous to Miocene palaeogeographic evolution of Turkey: Implications for hydrocarbon potential. *Journ. Petrol. Geol.* 24, 119-146.

Görür, N., Oktay, F.Y., Seymen, I., and Şengör, A.M.C. 1984. Paleotectonic evolution of Tuz Gölü basin complex, Central Turkey. In: Dixon, J. E., and Robertson, A. H. F. (eds). *The geological , evolution of the Eastern Mediterranean*. *Geol. Soc. London, Spec. Publ.*, 17, 81–96.

Görür, N., Monod, O. and Okay, A. I. 1997. Palaeogeographic and tectonic position of the Carboniferous rocks of the western Pontides (Turkey) in the frame of the Variscan belt. *Bull.Soc. Geol. France*, 168, 197-205.

Görür, N., Tüysüz, O. and Şengör, A.M.C. 1998. Tectonic evolution of the Central Anatolian Basins. *Int. Geol. Rev.*, 40, 831-850.

Gürsu, S. and Göncüoğlu, M.C. 2006. Petrogenesis and tectonic setting of Cadomian felsic igneous rocks, Sandıklı area of the western Taurides, Turkey. *Int. Journ. Earth Sci*, 95, 741-757.

Gürsu, S. and Göncüoğlu, M. C. 2008. Petrogenesis and geodynamic evolution of the Late Neoproterozoic post-collisional felsic magmatism in NE Afyon area, Western Central Turkey. In: *The boundaries of the West African craton (Ennih, N. and Liégeois, J.-P. (eds). The boundaries of the West African Craton*. *Geol. Soc. London, Spec. Publ.*, 297, 409–431.

Gürsu, S., Göncüoğlu, M.C., Bayhan, H. 2004. Geology and petrology of the pre-Middle Cambrian rocks in Sandikli area: Implications for the Pan-African evolution in NW Gondwanaland. *Gondwana Research*, 7/4, 923-935.

Gürsu, S., Göncüoğlu, M.C., Kozlu, H., Barç, D. ve Gürler, H. 2005. The characteristic features of the Early Paleozoic succession in Mardin-Derik Area (Eastern Turkey) and its correlation with different tectono-stratigraphic units in Central and Western Taurides. *IESCA 2005 Abstracts*, 46

Hagdorn, H. and Göncüoğlu, M. C. 2007. Early-Middle Triassic echinoderm remains from the Istanca Massif, Turkey. *N. Jb. Geol-Paleont. Abh.*, 246, 235-245.

Helvacı, C. and Griffin, W. L. 1984. Rb/Sr geochronology of the Bitlis Massif, Avnik Area. *Geol Soc. London Spec. Publ.*, 17, 403-413.

Helvacı, C., Ersoy, E.Y., Sözbilir, H., Erkul, F., Sümer, O. and Uzel, B. 2009. Geochronology and  $Ar^{40}/Ar^{39}$  geochronology of Miocene volcanic rocks from the Karaburun Peninsula: Implications for amphibole-bearing lithospheric mantle source, Western Anatolia. *Journ. Volcan. Geotherm., Res.*, 185, 181-202.

Howell, D.G. 1989. Tectonics of suspect terranes, mountain building and continental growth. Chapman and Hall, 156p.

Karslı, O., Aydın, F., Sadıklar, M.B. 2004. The morphology and chemistry of K-feldspar megacrysts from İkizdere Pluton: evidence for acid and basic magma interactions in granitoid rocks, NE-Turkey. *Geochemistry*, 64, 155-170.

Kadioğlu, Y.K., Dilek, Y and Foland, K.A. 2006. Slab break-off and syncollisional origin of the Late Cretaceous magmatism in the Central Anatolian Crystalline Complex, Turkey. *Geol. Soc. America Spec. Papers*, 409, 381-415.

Kaya, O. 1973. Paleozoic of Istanbul. *Ege Univ. Fen. Fak. Publ.*, 40: 143pp, Izmir.

Keskin, M., 2003. Magma generation by slab steepening and breakoff beneath a subduction-accretion complex: An alternative model for collision-related volcanism in Eastern Anatolia, Turkey. *Geophys. Res. Letters*, 30, 1-4.

Ketin, İ. 1964. Güneydoğu Anadolu Paleozoik teşekküllerinin jeolojik etüdü hakkında rapor (1. kısım: Derik-Bedinan, Penbeği-Tut ve Hazro bölgesi). *TPAO Arama Grubu* 287, 1-36 (in Turkish).

Ketin, İ. 1966. Güneydoğu Anadolunun Kambriyen teşekkülleri ve bunların Doğu İran Kambrieni ile mukayesesi. *Maden Tetkik ve Arama Dergisi* 66, 75-87 (in Turkish with English abstract).

Koçyiğit, A., Yılmaz, A., Adamia, S. and Kuloshvili, S. 2001. Neotectonics of East Anatolian Plateau (Turkey) and Lesser Caucasus: implication for transition from thrusting to strike-slip faulting. *Geodinamica Acta*, 14, 177-195

Koralay, O.E., Dora, O.Ö., Chen, F., Satır, M. ve Candan, O. 2004. Geochemistry and geochronology of orthogneisses in the Derbent (Alaşehir) Area, E part of the Ödemiş-Kiraz Submassif, Menderes Massif: Pan-African magmatic activity. *Turkish Journ. Earth. Sci.*, 13, 37-61.

Köksal, S., Romer, R.L., Göncüoğlu, M.C. and Toksoy-Köksal, F. 2004. Timing of the transition from the post-collisional to A-type magmatism: titanite U/Pb ages from the alpine Central Anatolian Granitoids, Turkey. *Int. Journ. Earth Sci*, 93, 974-989.

Köksal, S., Möller, A., Frei, D., Göncüoğlu, M. C., Köksal-Toksoy, F. 2007. Petrological characteristics and LA-SF-ICP-MS U-Pb ages of S-type Granitoids from Central Turkey. *Geochim. Cosmochim. Acta*, 71 (15) Suppl. 1 Goldschmidt 2007, p 503.

Köksal, S., Göncüoğlu, M.C. Toksoy-Köksal F. 2008. Zircon typologies and internal structures as petrogenetic indicators in contrasting granitoid types from central Anatolia, Turkey. *Mineral Petrol.*, 93, 185-211.

Konak, N., Akdeniz, N. and Öztürk, E. 1987. Geology of the south of Menderes Massif. IGCP No: 276 Field-Guide Book, 42-53, MTA Publ.

Konak, N., Ercan, T. and Bilgin, Z.R. 1991. Structural features and definition of pre-Jurassic rocks between Oltu-Artvin. *Suat Erk Geology Symposium, Abstracts*, 11.

Kozlu, H. and Göncüoğlu, M. C. 1997. Stratigraphy of the Infracambrian rock-units in the Eastern Taurides and their correlation with similar units in Southern Turkey. In: Göncüoğlu, M.C., Derman, A. S.(eds). *Early Paleozoic Evolution in NW Gondwana*. *Turkish Assoc. Petrol. Geol. Spec. Publ.*, 3, 50-61.

Kozlu, H., Göncüoğlu, M.C., Sarmiento, G. and Gül, M.A., 2002. Mid-Ordovician (Late Darriwilian) conodonts from the southern Central Taurides, Turkey: geological implications. *T. Jr. Earth. Sci.*, 11, 113-126

Kozur, H., Aydın, M., Demir, O., Yakar, H., Göncüoğlu, M.C. and Kuru F. 2000. New stratigraphic results from the Paleozoic and Early Mesozoic of the Middle Pontides (Northern Turkey). *Geol. Croat.*, 53, 209-268.

Kröner, A. and Şengör, A.M.C. 1990. Archean and Proterozoic ancestry in late Precambrian to early Paleozoic crustal elements of southern Turkey revealed by single-zircon dating. *Geology*, 18, 1186-1190.

Kulaksız, S. and Phillips, W.R. 1985. Radiometric age of the southern metamorphic rocks of Kaymaz-Sivrihisar region, preliminary results. *Geol. Soc. Turkey, 32. Ann. Meeting, Abstracts*, 4.

Kurt, M.A., Alpaslan, M., Göncüoğlu, M.C. and Temel, A. 2008. Geochemistry of late stage medium to high-K calc-alkaline and shoshonitic dykes in the Ulukışla Basin (Central Anatolia, Turkey): Petrogenesis and tectonic setting. *Int. Geochemistry*, 46, 1143-1163.



Lakova, I., Sachanski, V. and Göncüoğlu, M.C. 2006. Earliest cryptospore record in NW Anatolia dated by graptolites and acritarchs, Lower Ordovician Bakacak Formation, Zonguldak Terrane, NW Anatolia. GCP 503 Ordovician Paleogeography Ann. Meeting, 30 Aug- 1Sept., Glasgow-UK, Abstracts and Field Excursion Guide, 30-31.

Matte, P. 2003. The Variscan collage and orogeny (480–290 Ma) and the tectonic definition of the Armorica microplate: a review. *Terra Nova*, 13/2, 122 – 128.

Moix, P., Vachard, D., Martini, R., Stampfli, G. M., Pille, L. and Wernli R. 2007a. New Carboniferous, Permian and Triassic results from the Lycian Nappes (south-western Turkey): paleogeographic implications. 5. Swiss Geoscience Meeting, Abstracts, 2p.

Moix, P., Kozur, H.W., Stampfli, G.M. and Mostler, H. 2007b. New paleontological, biostratigraphic and paleogeographic results from the Triassic of the Mersin mélange, SE Turkey. In: Lucas, S.G. and Spielmann, J.A. (eds). *The Global Triassic*. New Mexico Museum of Natural History and Science Bulletin 41, 282-311.

Moix, P., Beccaletto, L., Kozur, HW, Hochard, C., Rosselet, F. and Stampfli, GM. 2008. A new classification of the Turkish terranes and sutures and its implication for the paleotectonic history of the region. *Tectonophysics*, 451, 7-39.

Monod, O., Kozlu, H., Ghienne, J-F, Dean, W.T., Günay, Y., Le Hérisse, A., Paris, F. and Robardet, M. 2003. Late Ordovician glaciation in southern Turkey. *TerraNova*, 15, 249-257.

Murphy, J.B. ve Nance, R.D. 1991. Supercontinent model for the contrasting character of Late Proterozoic orogenic belts. *Geology*, 19/ 5, 469-472.

Nzegge, O.M., Satir, M., Siebel, W. and Taubold, H. 2006. Geochemical and isotopic constraints on the genesis of the Late Paleozoic Deliktaş and Sivrikaya Granites from the Kastamonu Granitoid Belt (Central Pontides, Turkey). *N. Jb. Mineralogie*, 183,: 27-40.

Oberhansli, R., Candan, O., Dora, O.O. and Dürr, S. 1997. Eclogites within the Menderes Massif, Western Turkey. *Lithos*, 41, 135-150.

Ocakoglu, F. 2004. Mio-Pliocene basin development in the eastern part of the Cappadocian Volcanic Province (Central Anatolia, Turkey) and its implications for regional tectonics. *Int. Journ. Earth. Sci*, 93, 314-328.

Okay, A.I. 1980. Mineralogy, petrology, and phase relations of glaucophane-lawsonite zone blueschists from the Tavşanlı Region, Northwest Turkey. *Contrib. Mineral. Petrol*, 72, 243-255.

Okay, A.I. 1985. Metamorphic belts in northwest Turkey. *Ketin Symposium Proceedings*, Geol. Soc. Turkey Publ., 83-92,

Okay, A.I. 1986. Tectonic units and sutures in the Pontides. *Tectonic evolution of the Tethyan region*, Kluwer Acad. Publ.109-116.

Okay, A.I. and Monie, P. 1997. Early Mesozoic subduction in the Eastern Mediterranean: Evidence from Triassic eclogite in northwest Turkey. *Geology*, 25, 595-598.

Okay, A.I. and Tüysüz, O. 1999. Tethyan sutures of northern Turkey. *Geol. Soc. London, Spec. Publ.*, 156, 475-515

Okay, A.I. and Göncüoğlu, M.C. 2004b. The Karakaya Complex: A review of data and concepts. *Turkish Journ. Earth. Sci.*, 13, 75-95.

Okay, A.I. and Kelley, S.P. 2007. Tectonic setting, petrology and geochronology of jadeite + glaucophane and chloritoid + glaucophane schists from north-west Turkey. *Journ. Met. Geol.*, 12, 455-466.

Okay, A.I. and Şahintürk, O. 1998. Geology of the Eastern Pontides. *Am. Assoc. Petrol. Geol.*, *Memoir*, 68, 291-313.

Okay, A.I., Arman, M.B. and Göncüoğlu, M.C. 1985. Petrology and phase relations of the kyanite-eclogites from eastern Turkey. *Contrib. Mineral. Petrol.*, 91, 196-204.

Okay, A.I., Siyako, M. and Burkan, K.A. 1991. Geology and tectonic evolution of the Biga Peninsula, northwestern Turkey. *Bull. Tech. Univ. Istanbul*, 44, 91-256.

Okay, A.I., Şengör, A. M. C. and Görür, N. 1994. Kinematic history of the opening of the Black Sea and its effects on the surrounding regions. *Geology*, 22, 267-270.

Okay, A.I., Harris, N.B. and Kelley, S.P. 1998. Exhumation of blueschists along a Tethyan suture in northwest Turkey. *Tectonophysics*, 285, 275-299

Okay, AI, Monod, O. and Monie E. 2002. Triassic blueschists and eclogites from NW Turkey: vestiges of the Palaeotethyan subduction. *Lithos*, 64, 155-178.

Okay, A.I., Satir, M. and Siebel, W. 2006a. Pre-Alpide Palaeozoic and Mesozoic orogenic events in the Eastern Mediterranean region In: Gee, D. G. and Stephenson, R. A. (eds). *European Lithosphere Dynamics*. Geol. Soc. London, Memoirs, 32, 389–405.

Okay, A.I., Satir, M., Tüysüz, O., Akyüz, S. and Chen, F. 2001. The tectonics of the Strandja Massif: late Variscan and mid Mesozoic deformation and metamorphism in the northern Aegean. *Int. J. Earth Sci.*, 90, 217-233.

Okay, A.I., Tüysüz, O., Satir, M., Özkan-Altiner, S., Altiner, D., Sherlock, S., and Eren, R.H. 2006b. Cretaceous and Triassic subduction accretion, HP/LT metamorphism and continental growth in the Central Pontides, Turkey. *Geol. Soc. Am. Bull.*, 118, 9/10, 1247-1269.

Önen, A. P. 2003. Neotethyan ophiolitic rocks of the Anatolides of NW Turkey and comparison with Tauride ophiolites. *Journ. Geol. Soc. London*, 160, 947-962.

Önen, A. P. and Hall, R. 1993. Ophiolites and related metamorphic rocks from the Kütahya region, north-west Turkey. *Geol. Journ.*, 28, 399-412.

Otlu, N. and Boztuğ, D. 1998. The coexistence of the silica oversaturated (ALKOS) and undersaturated alkaline (ALKUS) rocks in the Kortundag and Baranadag plutons from the central Anatolian alkaline plutonism, E Kaman/NW Kırşehir, Turkey. *Turkish Journ. Earth Sci.*, 7, 241-258

Özcan, A., Göncüoğlu M.C., Turhan, N., Uysal, Ş. and Şentürk, K. 1989. Late Paleozoic evolution of the Kütahya-Bolkardağ Belt. *METU Journ. of Pure and Appl. Sci.* 21, 211-220.

Özer, S. and Göncüoğlu, M.C., 1983. Orta Anadolu masifi doğusunda (Akdağmadeni-Yıldızeli) ilginç metamorfik parajenezler. *MTA Bull.*, 95/96, 173-176.

Özgül, N. 1976. Torosların bazı temel jeolojik özellikleri. *Geol. Soc. Turkey, Bull.*, 19, 75-87.

Özgül, N. 1984. Stratigraphy and tectonic evolution of the Central Taurides. In: Tekeli, O. and Göncüoğlu, M.C.(eds). *Int. Symposium on the Geology of the Taurus Belt*, 77-90.

Özgül, N. ve Kozlu, H. 2002. Kozan-Feke (Doğu Toroslar) yöresinin stratigrafisi ve yapısal konumu ile ilgili bulgular. *Turkish Assoc. Petrol Geol. Bull.*, 14, 1-36.

Özkan, Y.Z. and Öztunalı, Ö. 1984. Petrology of the magmatic rocks of Guleman Ophiolite. In: Tekeli, O. and Göncüoğlu, M.C.(eds) *Int. Symposium on the Geology of the Taurus Belt*, 285-294.

Parlak, O. 2006. Geodynamic significance of granitoid magmatism in the southeast Anatolian orogen: geochemical and geochronological evidence from Göksun–Afşin (Kahramanmaraş, Turkey) region. *Int. Journ. Earth Sci.*, 95, 605-627.

Parlak, O. ve Robertson, A.H.F. 2004. The ophiolite-related Mersin Melange, southern Turkey: its role in the tectonic–sedimentary setting of Tethys in the Eastern Mediterranean region. *Geol. Mag.*, 141, 257-286

Parlak, O., Höck, V., Kozlu, H., Delaloye, M. 2004. Oceanic crust generation in an island arc tectonic setting, SE Anatolian orogenic belt (Turkey). *Min. Mag.*, 141, 583-603.

Parlak, O., Önal, A., Höck, V., Kürüm, S., Delaloye, M., Bağcı, U. and Rızaoğlu, T. 2002. Inverted metamorphic zonation beneath the Yüksekova ophiolite in SE Anatolia. *1st International Symposium of the Faculty of Mines (ITU) on Earth Science and Engineering, 16–18 May 2002, Istanbul-Turkey*, 133.

Papanikolaou, D.J. and Demirtaşlı, E. 1987. Geological correlation between Alpide segments of the Hellenides-Balkanides and Taurides-Pontides. In: Flügel, H.W., Sassi, F.P. and Grecula, P. (eds). *Pre-Variscan and Variscan events in the Alpine-Mediterranean Mountain Belts*, Mineralia Slov. Monography, 387-396.

Perinçek, D., 1980. Bitlis metamorfiterinde volkanitli Triyas. *Bull. Geol. Soc. Turkey*, 23, 201-211.

Perinçek, D. and Kozlu, H. 1984. Stratigraphy and structural relations of the units in Afşin-Elbistan-Doğanşehir region (Eastern Taurus). In: Tekeli, O. and Göncüoğlu, M.C. (eds). *Int. Symposium on the Geology of the Taurus Belt*, 199-208, MTA Publ.

Perinçek, D., Duran, O., Bozdoğan, N. and Çoruh, T. 1991. Stratigraphy and paleogeographical evolution of the autochthonous sedimentary rocks in the SE Anatolia. In: Turgut, S. (ed). *Ozan Sungurlu Symposium Proceedings*, 274-305, O. Sungurlu Foundation, Ankara.

Ring, U. and Collins, A.S. 2005. U–Pb SIMS dating of synkinematic granites: timing of core-complex formation in the northern Anatolide belt of western Turkey. *Journ. Geol. Soc.*, 162, 289-298.

Rojay, B., Heimann, A., and Toprak, V. 2001. Neotectonic and volcanic characteristics of the Karasu fault zone (Anatolia, Turkey): The transition zone between the Dead Sea transform and the East Anatolian fault zone. *Geodinamica Acta*, 14, 197-212

Robertson, A.H.F. 2002. Overview of the genesis and emplacement of Mesozoic ophiolites in the Eastern Mediterranean Tethyan region. *Lithos*, 65, 1-67.

- Robertson, A.H.F. 2004. Development of concepts concerning the genesis and emplacement of Tethyan ophiolites in the Eastern Mediterranean and Oman regions. *Earth-Science Reviews*, 66, 331-387.
- Robertson A.H.F. and Ustaömer T. 2005. Tectonic evolution of the Intra-Pontide suture zone in the Armutlu Peninsula, NW Turkey. *Tectonophysics*, 381: 175-209.
- Robertson, A.H.F., Ustaömer, T., Pickett, E.A., Collins, A.S., Andrew, T. and Dixon, J.E. 2004. Testing models of Late Palaeozoic–Early Mesozoic orogeny in Western Turkey: support for an evolving open-Tethys model. *Journ. Geol. Soc London*, 161, 501–511.
- Robinson, A.G, Banks, C.J., Rutherford, M.M. and Hirst, J.P.P. 1995. Stratigraphic and structural development of the Eastern Pontides, Turkey. *Journ. Geol. Soc. London*, 152, 861-872.
- Saner, S. 1980. Palaeogeographic interpretation of the Jurassic and younger sediments of the Mudurnu-Göynük basin. *Bull. Geol. Soc. Turkey*, 86, 32-48.
- Savaşçın, M.Y. ve Oyman, T. 1998. Tectono–magmatic evolution of alkaline volcanics at the Kırka–Afyon–Isparta structural trend, SW Turkey. *Turkish Journ. Earth Sci.*, 7 , 201–214.
- Sayit, K. and Göncüoğlu, M.C. 2009. Geochemistry of mafic rocks of the Karakaya complex, Turkey: evidence for plume-involvement in the Palaeotethyan extensional regime during the Middle and Late Triassic. *Int. Journ. Earth. Sci.*, 98, 157-185.
- Sayit, K., Göncüoğlu, M.C. and Furman, T. 2008. E-MORB- and OIB-type metabasalts from the Karakaya Complex: Trace element evidence for melting across the spinel-garnet transition. *Eos Transactions AGU*, 89(53), Fall Meeting Supplement, Abstract V43B-2163.
- Schmidt, G. C., 1966. Stratigraphy of Lower Paleozoic rock units of petroleum distinct V-Turkey. *Bulletin of Petroleum Administration Publication* 11, 73-90.
- Seymen, I. 1984. Kırşehir metamorfitlelerinin jeolojik evrimi. In: *Ketin Symposium. Geol. Soc. Turkey Publ.*, 133–148
- Sungurlu, O. 1974. VI Bölge kuzeyinin jeolojisi ve petrol olanakları. 2. Petrol. Congress Proceedings, 85-107.
- Stampfli, G. M. 2000. Tethyan oceans. In: Bozkurt, E., Winchester, J. A. and Piper, J. D. (eds) *Tectonics and Magmatism in Turkey and the Surrounding Area*. In: Bozkurt, E., Winchester, J. and Piper, J.A. (eds). *Tectonics and magmatism in Turkey and the Surrounding Area. Geol. Soc. London Spec. Publ.*, 173, 1-23.
- Stampfli, G.M., Kozur, H.W. 2006. Europe from the Variscan to the Alpine cycles. In: Gee, D.G., Stephenson, R.A. (Eds.), *European lithosphere dynamics. Geol. Soc. London, Memoir*, 57–82.
- Stampfli, G.M., von Raumer, J.F., Borel, G.D. 2002. Paleozoic evolution of pre-Variscan terranes: from Gondwana to the Variscan collision. In: Martínez Catalán, J.R., Hatcher Jr., R.D., Arenas, R., Díaz García, F. (eds). *Variscan–Appalachian dynamics: The building of the late Paleozoic basement: Geol. Soc. America, Spec. Paper*, 364, 263–280.
- Şaroğlu, F., Emre, Ö. and Boray, A. 1992. *Türkiye Diri Fay Haritası. MTA Genel Müdürlüğü Yayını*, Ankara.
- Şengör, A.M.C. 1991. Late Paleozoic and Mesozoic tectonic evolution of the Middle Eastern Tethysides: implications for the Paleozoic geodynamics of the Tethyan realm. *Memoir de Geologié*, 10, 111-149.
- Şengör, A.M.C. 2003. The repeated discovery of mélanges and its implication for the possibility and the role of objective evidence in the scientific enterprise. *Geol. Soc. America, Spec. Paper* 373, 365-384.
- Şengör, A.M.C. and Yılmaz, Y. 1981. Tethyan evolution of Turkey: a plate tectonic approach, *Tectonophysics*, 75, 181-241.
- Şengör, A.M.C., Yılmaz, Y. and Sungurlu, O. 1984a. Tectonics of the Mediterranean Cimmerides: nature and evolution of the western termination of Paleo-Tethys. In: Dixon, J. E., and Robertson, A. H. F., (eds). *The geological evolution of the Eastern Mediterranean. Geol. Soc. London, Spec. Publ.* 17, 77-112.
- Şengör, A.M.C., Satır, M. and Akkök, R. 1984b. Timing of tectonic events Menderes Massif, western Turkey. Implications for tectonic evolution and evidence for Pan-African basement in Turkey. *Tectonics*, 3, 693-707.
- Tekeli, O. 1981. Subduction complex of pre-Jurassic age, northern Anatolia, Turkey. *Geology*, 9, 68-72.
- Tekeli, O. and Erendil, M. 1986. Geology and petrology of the Kızıldağ Ophiolite (Hatay). In: Tekeli, O. and Göncüoğlu, M. C. (eds). *Int. Symposium on the Geology of the Taurus Belt*, 127-147, MTA Publ.

Tekin, U.K. 2002. Lower Jurassic (Hettangian-Sinemurian) Radiolarians from the Antalya Nappes, Central Taurids, Southern Turkey. *Micropaleontology*, 48, 177-205.

Tekin, U.K. and Bedi, Y. 2007. Ruesticyrtiidae (Radiolaria) from the middle Carnian (Late Triassic) of Köseyahya Nappe (Elbistan, eastern Turkey). *Geol. Carpat.* 58, 153-167.

Tekin, U.K. and Göncüoğlu, M.C. 2007. Discovery of the oldest (upper Ladinian to middle Carnian) radiolarian assemblages from the Bornova Flysch Zone in western Turkey: Implications for the evolution of the Neotethyan Izmir-Ankara Ocean. *Ofioliti*, 32, 131-150.

Tekin, U.K., Göncüoğlu, M.C., and Turhan, N. 2002. First evidence of Late Carnian radiolarian fauna from the Izmir-Ankara Suture Complex, Central Sakarya, Turkey: Implications for the opening age of the Izmir-Ankara branch of Neotethys. *Geobios*, 35, 127-135.

Temel, A. 2001. Post-collisional Miocene alkaline volcanism in the Oglakci region, Turkey: Petrology and geochemistry. *Int. Geol. Rev.*, 43, 640-660.

Tokel, S. 1977. Eocene calc-alkaline andesites and geotectonism in Black Sea Region. *Geol. Soc. Turkey Bull.*, 20, 49-54.

Toksoy-Köksal, F., Göncüoğlu, M.C., and Yalınız, M.K. 2001. Petrology of the Kurancali Phlogopitic Metagabbro: An island arc-type ophiolitic sliver in the Central Anatolian Crystalline Complex. *Int. Geol. Rev.* 43/7, 624-639.

Topuz, G., Altherr, R., Kalt, A., Satır, M., Werner, O. and Schwartz, W.H. 2004. Aluminous granulites from the Pular Complex, NE Turkey: a case of partial melting, efficient melt extraction and crystallization. *Lithos*, 72, 183-207.

Turhan, N., Okuyucu, C. and Göncüoğlu, M.C. 2004. Autochthonous Upper Permian (Midian) Carbonates in the Western Sakarya Composite Terrane, Geyve Area, Turkey: Preliminary Data. *T. Jr. Earth. Sci.*, 13, 215-229.

Tüysüz, O. 1999. Geology of the Cretaceous sedimentary basins of the Western Pontides. *Geol. Journ.*, 34, 75-93.

Tüysüz, O. and Yiğitbaş, E. 1994. The Karakaya Basin: a Palaeo-Tethyan marginal basin and its age of opening. *Acta Geologica Hungarica*, 37/3-4, 327-350.

Tüysüz, O., Tekin, U. K. 2007. Timing of imbrication of an active continental margin facing the northern branch of Neotethys, Kargı Massif, northern Turkey. *Cretaceous Research*, 28, 754-764

Ustaömer, P. A. and Rogers, G. 1999. The Bolu Massif: remnant of a pre-Early Ordovician active margin in the west Pontides, northern Turkey. *Geol. Mag.*, 136, 579-592.

Ustaömer, T. and Robertson, A.H.F. 1999. Geochemical evidence used to test alternative plate tectonic models for pre-Upper Jurassic (Paleotethyan) units in the Central Pontides, Turkey. *Geol. Journ.*, 34, 25-53.

Ustaömer, P.A., Mundil, R. and Renne, P.R. 2005. U/Pb and Pb/Pb zircon ages for arc-related intrusions of the Bolu Massif (W Pontides, NW Turkey): evidence for Late Precambrian (Cadomian) age. *Terra Nova*, 17 215 – 223.

Ustaömer, P.A., Ustaömer, T., Collins, A.S. ve Robertson, A.H.F. 2007. Geochronology and tectonic setting of the granitoidic intrusions in the Bitlis Massif, SE Turkey. *Geophysical Research Abstracts*, A4717.

Whitney, D.L., Teyssier, C., Fayton, A.K., Hamilton, M.A. and Heizler, M. 2003. Tectonic controls on metamorphism, partial melting and intrusion: timing and duration of regional metamorphism and magmatism in the Niğde Massif. *Tectonophysics*, 376, 37-60.

Yalınız, K. and Göncüoğlu, M.C. 1998. General geological characteristics and distribution of Central Anatolian Ophiolites. *H.Ü. Yerbilimleri*, 20, 19-30.

Yalınız, M.K., Floyd, P.A. and Göncüoğlu, M.C. 1996. Supra-subduction zone ophiolites of Central Anatolia: geochemical evidence from the Sarıkaraman Ophiolite, Aksaray, Turkey: *Min. Mag.*, 60, 697-710.

Yalınız, M.K., Göncüoğlu, M.C., Özkan-Altınır, S. and Parlak, O. 2000. Formation and emplacement ages of the SSZ-type Neotethyan Ophiolites in Central Anatolia, Turkey: Paleotectonic implications. *Geol. Journ.*, 35, 53-68.

Yanev, S., Göncüoğlu, M.C., Boncheva, I., Gedik, I., Lakova, I., Maliakov, Y., Özgül, N., Sachanski, V., Sağlam, G. and Timur, E. 2004. Correlation of the Paleozoic terranes in Bulgaria and NW Turkey: preliminary results. In: Chatzipetros, A. A. and Pavlidis, S. B. (eds) *Proceed. 5. Int. Symp. Eastern Meditt. Geol.*, Thessaloniki, 14-20 April 2004, 215-218.

- Yazgan, E. 1984. Geodynamic evolution of the Eastern Taurus region. In: Tekeli, O. and Göncüoğlu, M. C. (eds). Int. Symposium on the Geology of the Taurus Belt, 199-208, MTA Publ.
- Yazgan, E. and Chessex, R. 1991. Geology and tectonic evolution of Southeastern Taurides in the region of Malatya. Turkish Assoc. Petrol. Geol. Bull., 3, 1-42.
- Yiğitbaş, E., Elmas, A. and Yılmaz, Y. 1999. Pre-Cenozoic tectonostratigraphic components of the western Pontides and their geological evolution. Geol. Journ., 34: 55-74.
- Yiğitbaş, E., Kerrich, R., Yılmaz, Y., Elmas, A. and Xie, Q. 2004. Characteristics and geochemistry of Precambrian ophiolites and related volcanics from the Istanbul–Zonguldak Unit, Northwestern Anatolia, Turkey: following the missing chain of the Precambrian South European suture zone to the east. Precamb. Res., 132, 179–206.
- Yılmaz, A. 1980. Tokat ile Sivas arasındaki bölgede ofiyolitlerin kökeni, iç yapısı ve diğer birimlerle ilişkisi. Ankara Univ. PhD Theses, 110p.
- Yılmaz, O. and Boztuğ, D. 1986. Kastamonu granitoid belt of northern Turkey: first arc volcanism product related to the subduction of the Paleotethys. Geology, 14, 179-183.
- Yılmaz, Y. 1981. Sakarya kıtası kenarının tektonik evrimi. İ. Ü. Yerbilimleri Dergisi, 1, 33-52.
- Yılmaz, Y. 1984. Amanos dağlarının jeolojisi. *TPAO Survey Group* 1920, 1-591 (in Turkish).
- Yılmaz, Y. 1989. An approach to the origin of young volcanic rocks of Western Turkey. In: Şengör, A.M.C. (ed), Tectonic Evolution of the Tethyan Region. Kluwer Academic Publishers, 159-189.
- Yılmaz, Y. 1990. Allochthonous terranes of Tethyan Middle East: Anatolia and the surrounding regions. Phil. Trans. R. Soc. London, A 331, 611-624.
- Yılmaz, Y. 1993. New evidence and model on the evolution of the Southeast Anatolian orogen. Geol. Soc. Am. Bull., 105, 251-271.
- Yılmaz, Y., Genç, S.C., Yiğitbaş, E., Bozcu, M. and Yılmaz, K. 1995. Geological evolution of the Late Mesozoic continental margin of northwestern Anatolia. Tectonophysics 243, 155–171.
- Yılmaz Y., Tüysüz O., Yigitbaş E., Genc S.C. and Şengör A.M.C. 1997. Geology and tectonic evolution of the Pontides. In: A.G. Robinson (ed). Regional and petroleum geology of the Black Sea and surrounding region. Am. Assoc. Petrol. Geol. Memoir, 68, 183-226.
- Yılmaz, Y. and Şengör, A. M. C. 1985. Palaeo-Tethyan ophiolites in northern Turkey: Petrology and tectonic setting. Ophioliti, 10, 485-504.