Türkiye Jeoloji Bülteni **Cilt 56, Sayı 2, Nisan 2013**
Geological Bulletin of Turkey *Volume 56, Number 2, April 2013*

Ophiolites and Ophiolitic Mélanges of Turkey: A Review

Türkiye Ofiyolitleri ve Ofiyolitli Karışıkları: Genel Bakış

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ABSTRACT

The aim of the presented study is to review the ophiolites and ophiolitic mélanges of Turkey and their importance for constraints on the evolution of the region. On the basis of the existing data, the ophiolitic associations of Turkey are classified into three main groups.

1. Group comprises pre-Alpine ophiolites and mélanges located on the southern edge of the Istanbul zone. These associations are in Pre-Jurassic age, and represent ophiolitic sequences of the Pontide Suture zone. The Karakaya complex represents pre-Alpine ophiolitic mélange and developed during the emplacement of the pre-Alpine ophiolites. The opening and closing ages and polarity of the Paleotethys is still a question.

2. Group can be divided into two sub-belts and they are the Northern-Northeastern and the Southern sub belt. They are allied to the North Anatolian Ophiolitic Belt (NAOB). The northern-northeastern sub-belt extends from Izmir to eastward, continuing as the Ankara-Erzincan zone and as the Sevan-Akera sub-belt of the Lesser Caucasus Ophiolitic Belt (LCOB). This sub-belt directly represents the northern branch of Neotethys. The ophiolites of this sub-belt represent dismembered ophiolitic sequences and take place within the Late Cretaceous melanges. The southern sub-belt begins in the Marmaris area and continues eastward to the Hadim, Aladağlar, Tecer-Divriği, Erzurum, Kağızman areas, and then on to the Vedi sub-belt of the LCOB. The ophiolitic outcrops of the Hınıs area and northeast of Lake Van, may be the southernmost products of the southern sub-belt of the NAOB associations. In the framework of age, composition, and tectonic setting ophiolites and mélanges of the southern sub-belt and northern sub belt show similar characteristic features. Therefore the southern subbelt units may be tectonically transported products of the northern sub-belt. The opening of the northern branch of Neotethys began in Triassic time in the west, in the Jurassic in the east. The closing of the northern branch of Neotethys was initiated in the Late Cretaceous and ended in pre-Middle Eocene time.

3. Group is represented by the Southern and Southeastern Anatolian Ophiolitic Belt (SAOB) comprising Jurassic-Lower Cretaceous ordered ophiolitic sequences and Late Cretaceous mélanges. Opening of the southern Neotethys began in Triassic and closure began in the Late Cretaceous and ended in pre-Late Miocene.

2. and 3 groups of ophiolites with mélanges are separated from one another by the Taurus Unmetamorphic Axis of the Anatolide-Tauride block These ophiolites together include Mid Ocean Ridge Basalt (MORB) and Supra-subduction zone (SSZ) type ophiolites, emplaced along double northward subduction zones in Late Cretaceous. The emplacement style for the ophiolitic units along NAOB and SAOB show a flower structure, on the basis of the presence of north- and south-facing overthrusts.

Keywords:, Alpine ophiolites, mélanges, pre- Alpine ophiolites, sutures, Turkey.

ÖZET

Sunulan çalışmanın amacı Türkiye'nin ofiyolitleri ve ofiyolitik karışıkları ile bu birimlerin bölgenin evrimine yönelik sınırlamalarına ilişkin önemini gözden geçirmektir. Var olan verilere göre Türkiyedeki ofiyolitik topluluklar üç ana grup halinde sınıflandırılabilir.

***1. Grup,** İstanbul zonunun güney kenarında yer alan pre-Alpin ofiyolitleri ve ofiyolitik karışıkları kapsar. Bu topluluklar Jura öncesi yaşta olup Pontit Kenet zonunun ofiyolitik dizilerini temsil ederler. Karakaya kompleksi pre-Alpin ofiyolitik karışıkları temsil eder ve bu birimler pre-Alpin ofiyolitlerin yerleşimi sırasında oluşmuştur. Paleotetis'in açılma ve kapanma yaşı ile polaritesi esas olarak hala tartışma konusudur.*

***2. Grup,** iki alt kuşağa ayrılabilir ve bunlar Kuzey Anadolu Ofiyolit Kuşağı (KAOK) ile temsil edilir. Kuzey-Kuzeydoğu alt kuşağı, İzmirden doğuya doğru sıra ile Ankara-Erzincan zonu ve Küçük Kafkas Ofiyolit Kuşağının Sevan-Akera alt kuşağı olarak devam etmekte olup, Neotetisin kuzey kolunu doğrudan temsil eder. Bu alt kuşağın ofiyolitleri parçalanmış ofiyolitik dizileri temsil eder ve Üst Kretase yaşta ofiyolitik karışıklarla birlikte yer alır. Güney alt kuşağı ise Marmaris yöresinde başlar ve doğuya doğru sıra ile Hadim, Aladağlar, Tecer-Divriği, Erzurum, Kağızman yörelerinde devam ederek Küçük Kafkas Ofiyolit Kuşağının Vedi alt kuşağına bağlanır. Hınıs yöresi ve Van Gölünün kuzeydoğusundaki yüzeylemeler, KAOK topluluğunun güney alt kuşağının en güneyindeki parçaları olabilirler. Güney alt kuşağının ofiyolit ve karışıkları yaş, bileşim ve tektonik konum açısından kuzey alt kuşağının ofiyolitik birimlerine benzer özellikler sunarlar. Bu nedenle güneydeki birimler, kuzeydekilerin tektonik olarak taşınmış ürünleri olabilir. Neotetis'in kuzey kolunun açılması batıda Triyas'ta, doğuda Jurasik'te başladı. Neotetis'in kuzey kolunun kapanması ise Geç Kretase'de başladı ve Orta Eosen öncesinde sona erdi.*

***3. Grup,** düzenli Jura-Alt Kretase ve Geç Kretase yaşta ofiyolitik dizileri ve Geç Kretase yaşta ofiyolitli karışıkları kapsayan Güney ve Güneydoğu Anadolu Ofiyolit Kuşağı (GAOK) ile temsil edilir. Güneydoğu Anadolu'da Neotetis'in güney kolunun açılması Permiyen-Triyas döneminde, kapanma ise Geç Kretasede başladı ve Geç Miyosen öncesi dönemde sona erdi.*

2. ve 3. grup ofiyolitler ve karışıklar birbirlerinden Anadolu-Toros blokunun metamorfik olmayan ekseni ile ayrılırlar. Bunlar birlikte Okyanus Ortası Sırtı Bazaltları (OOSB) ve Yitim Zonu Üstü (YZÜ) türde ofiyolitler içermekte olup kuzeye dalımlı çift yitim zonu boyunca Üst Kretase'de yerleşmişlerdir. Ofiyolitik birimlerin yerleşme biçimi, KAOK ve GAOK boyunca kuzeye ve güneye bakan bindirmelerin varlığı gözetildiğinde bir çiçek yapısını gösterir.

***Anahtar kelimeler:** Alpin ofiyolitleri, karışıklar, kenedler, pre-Alpin ofiyolitler, Türkiye.*

INTRODUCTION

Ophiolites and ophiolitic mélanges are important rock associations for understanding the evolution of orogenic belts. In the light of modern global tectonic theories, ophiolitic rocks within mountain chains have been interpreted as oceanic lithospheric fragments obducted onto continental margins during orogenic processes (Gass, 1967; Coleman, 1971; Dewey and Bird, 1971; Dewey, 1975; Hall, 1976). In addition, the association which is characterized by blocks of relatively different components of rocks, up to a few kilometers in size and embedded in a matrix, is referred to as a mélange (Greenly, 1919; Bailey and McCallien, 1950; Hsü, 1968) or ophiolitic mélange (Gansser, 1974; Delaloye and Desmons, 1980; Desmons, 1981). The mélange is commonly considered to be a product of the intense tectonic deformation and mixing of rock material in trenches (Hamilton, 1969; Dewey and Bird, 1971; Hall, 1976). Thus, there should be relationships between suture zones and the sites of former oceans (Burke et al, 1977).

On the other hand, while some researchers emphasized the role of tectonic crushing (Hsü, 1968; Hamilton, 1969), others postulated gravity sliding (Dimitrijevic and Dimitrijevic, 1973; Norman, 1975) as a mechanism of emplacement for ophiolitic rock associations. Therefore, it is imperative that the development of ophiolites/ophiolitic rocks and mélanges be evaluated and interpreted holistically.

Turkey is a key domain for ophiolitic rock units in the eastern Mediterranean region. The ophiolitic units of Turkey and surrounding regions occupy an important part of the eastern Mediterranean region. In this study, the ophiolitic rock associations of Turkey have been investigated in detail and the ophiolites and ophiolitic mélanges have been differentiated (Figure 1).

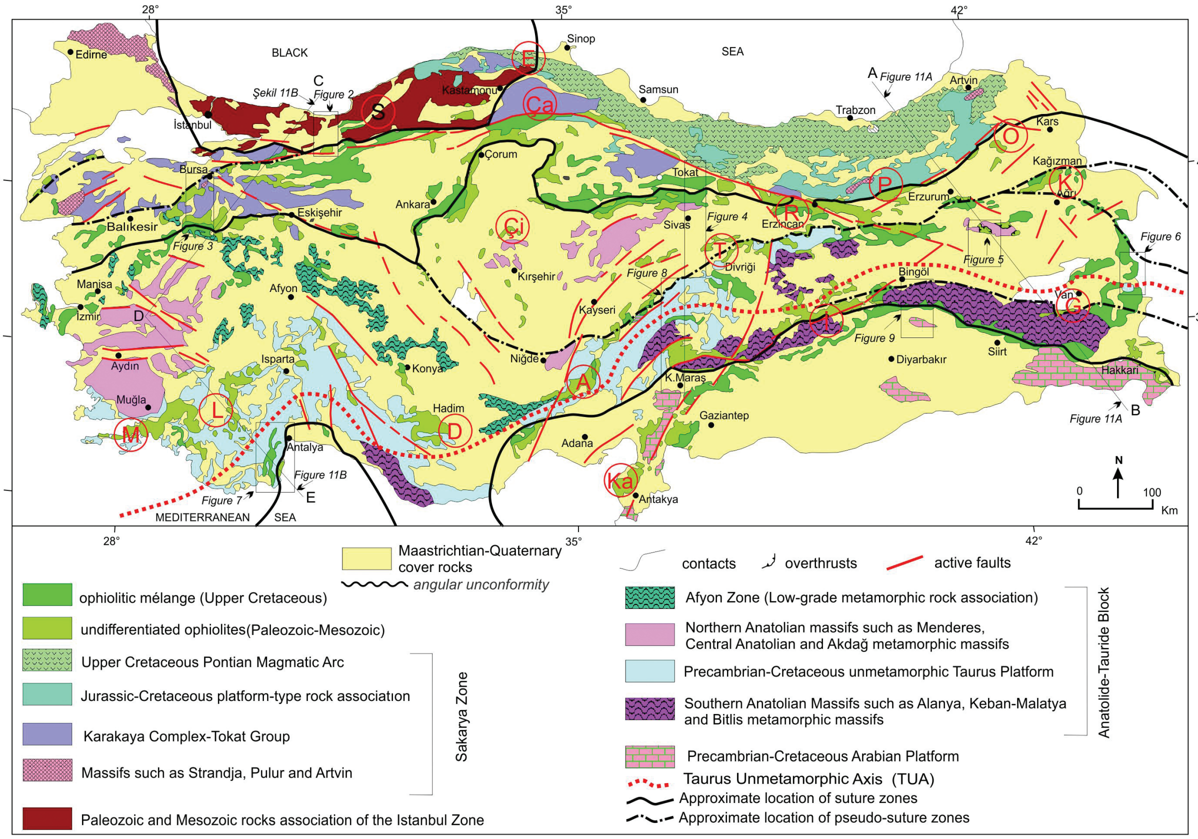

Figure 1. Ophiolites, ophiolitic mélanges and metamorphic massifs of Turkey (MTA, 2002 and our various observations). Important regions of the ophiolitic units have been indicated in circles with capital letters in red. A- Aladağ (Eastern Taurus), Ça- Çangaldağ and Kargı (Central Pontides), Çi- Çiçekdağ (Central Anatolia), D- Dipsizgöl (Hadim- Central Taurus), E- Elekdağ and Küre (Western Pontides), G- Gevaş (Van, Eastern Anatolia), İ- İspendere-Kömürhan, Guleman (Eastern Taurus), K- Kağızman (Ağrı, NE Anatolia), Ka- Kızıldağ (Antakya, Eastern Mediterranean), M- Marmaris (SW Taurus), O- Oltu (NE Anatolia), P- Pulur and Kopdağı (Eastern Pontides), T- Tecer and Divriği (East of the Central Anatolia), R- Refahiye (Erzincan), S- Sunnice- Çele (Western Pontides).

Şekil 1. *Türkiye'nin ofiyolitleri, ofiyolitli karışıkları ve metamorfik masifleri (MTA, 2002 ve çeşitli gözlemlerimiz). Ofiyolitik birimlerin bulunduğu önemli bölgeler daireler içinde kırmızı büyük harflerle gösterilmiştir. A- Aladağ (Doğu Toroslar), Ça- Çangaldağ ve Kargı (Orta Pontitler), Çi- Çiçekdağı (Orta Anadolu), D- Dipsizgöl (Hadim- Orta Toros), E- Elekdağ ve Küre (Batı Pontitler), G- Gevaş (Van, Doğu Anadolu), İ- İspendere-Kömürhan, Guleman (Doğu Toroslar), K- Kağızman (Ağrı, KD Anadolu), Ka- Kızıldağ (Antakya, Doğu Akdeniz), M- Marmaris (GB Toroslar), O- Oltu (KD Anadolu), P- Pulur ve Kopdağı (Doğu Pontidler), T- Tecer and Divriği (Orta Anadolu'nun doğusu), R- Refahiye (Erzincan), S- Sunnice-Çele (Batı Pontitler).*

Indeed, in previous studies, the ophiolitic rock assemblages in Turkey have been divided into three groups by Juteau (1980). These are, namely, the Northern Ophiolitic Belt, the Peri-Arabic Belt, and the Tauride Ophiolitic Belt. Attempts to place Tauric subduction in the geodynamic history of Turkey have led to two conflicting alternative models (Michard et al., 1984). **The first model** involves a single Tethyan ocean between the Pontides and the Tauric-Arabian platform, subducting northward beneath the Pontides and southward beneath the Taurides. The latter led to the Late Cretaceous opening of back-arc basins, such as the Elazığ back-arc basin, which effectively split the formerly continuous Tauric-Arabian platform. On the other hand, Ricou et al. (1984) and Whitechurch et al. (1984) supported the idea that the eastern Mediterranean ophiolites originated from a single ocean basin in central Turkey to the north of the Tauride belt. This model also implies a single ocean basin and suggests that ophiolites have been thrust over the Tauride belt and transported for a long distance over the platform carbonates. **The second model** involves a northern Tethyan ocean and a southern Mesogean ocean, both were subducting northward (Biju-Duval et al., 1977) and/or subduction of Paleotethys and the northern and southern branches of Neotethys (Şengör and Yılmaz, 1981; Robertson and Dixon, 1984). This last model implies that the Pontides evolved as the active margin of southern Eurasia.

The ophiolitic rock assemblages along the Tauride Belt crop out either to the north or the south of the Taurus Calcareous Axis (TCA), and the TCA represents a carbonate platform of Mesozoic age that contains generally dismembered relicts of oceanic lithosphere derived from the northern branch of the Neotethyan Ocean during Late Cretaceous time (Juteau, 1980; Şengör and Yılmaz, 1981). It is suggested that the ophiolitic wildflysch of the Taurus suture in SE Turkey represents trench mélanges that were not subducted but were thrust out of the trench zone due to uplifting associated with the final phase of subduction (in Late Cretaceous time) between the Arabian Foreland to the south and the Bitlis Massif to the north (Hall, 1976). In addition, the Mediterranean ophiolites are thought to have formed in a divergent (spreading) tectonic setting during the early stages of oceanic subduction (suprasubduction zone) (Pearce et al. 1984; Robertson, 1994).

In conclusion, there are many disagreements on definition, distribution, characteristic features, tectonic setting, geological age and correlations of the ophiolites and mélanges of Turkey, the main reason for which is the lack of sufficient data. The aim of the present paper is to review the main characteristics of these ophiolitic rock associations and to evaluate them based upon current studies. First, pre-Alpine ophiolites with mélanges have been defined, and then Alpine ophiolitic associations have been classified into two groups, the main features of which have been presented in detail; these are separated from one another by the TUA. In this context, it may be possible to better grasp the discussions and constraints on the evolution of the region, and to elucidate the relationship between the ophiolitic rock associations and suture zones in such a way as to secure a fresh understanding.

PRE-ALPINE OPHIOLITES AND MÉLANGES

The oldest, metamorphosed ophiolites, located to and in the south and southeast of the İstanbul zone (Okay et. al., 1994), have been interpreted as ophiolites derived from the Paleo-Tethyan Ocean

(Şengör et al., 1980). The Karakaya Complex developed during the emplacement of the ophiolites. Therefore, these meta-ophiolites with the complexes likely originated from the same oceanic realm. In the presented study, pre-Liassic ophiolites and melanges have been defined as the products of the pre-Alpine ophiolitic complexes.

Pre-Alpine Ophiolites

These ophiolites form a discontinuous linear belt of oceanic fragments immediately, locating to and in the south and southeast of the İstanbul zone, constitute the peri-İstanbul zone ophiolites. The characteristics of pre-Alpine ophiolites have been presented in terms of definition and distribution, characteristic features, tectonic setting, geological age, correlation and conclusions.

Definition and distribution

Outcrops of the pre-Alpine and/or Paleotethyan ophiolites are not widespread. Some of the ophiolites belong to the pre-Alpine ophiolites, such as those known as the Almacık meta-ophiolite (Figure 2), Çele meta-ophiolite (Figure 1, S). However, the Elekdağ, Çangal and Küre units (Figure 1, E) had been interpreted as ophiolitic remnants of the Paleo-Tethys, as well (Yılmaz and Şengör, 1985). Then, the Çangal unit has been defined as the Çangal complex and as a product of oceanic arc (Ustaömer and Robertson, 1997). In addition, Permo-Triassic and Cretaceous complexes of the Central Pontides had been differentiated from each other by Okay et al. (2006). In this area (Figure 1, Ça), Çangaldağ and Kargı complexes represent Permo-Triassic units. Similarly, Permo-Triassic and Upper Cretaceous complexes differentiated from each other in the Tokat area (Yılmaz and Yılmaz, 2004a).

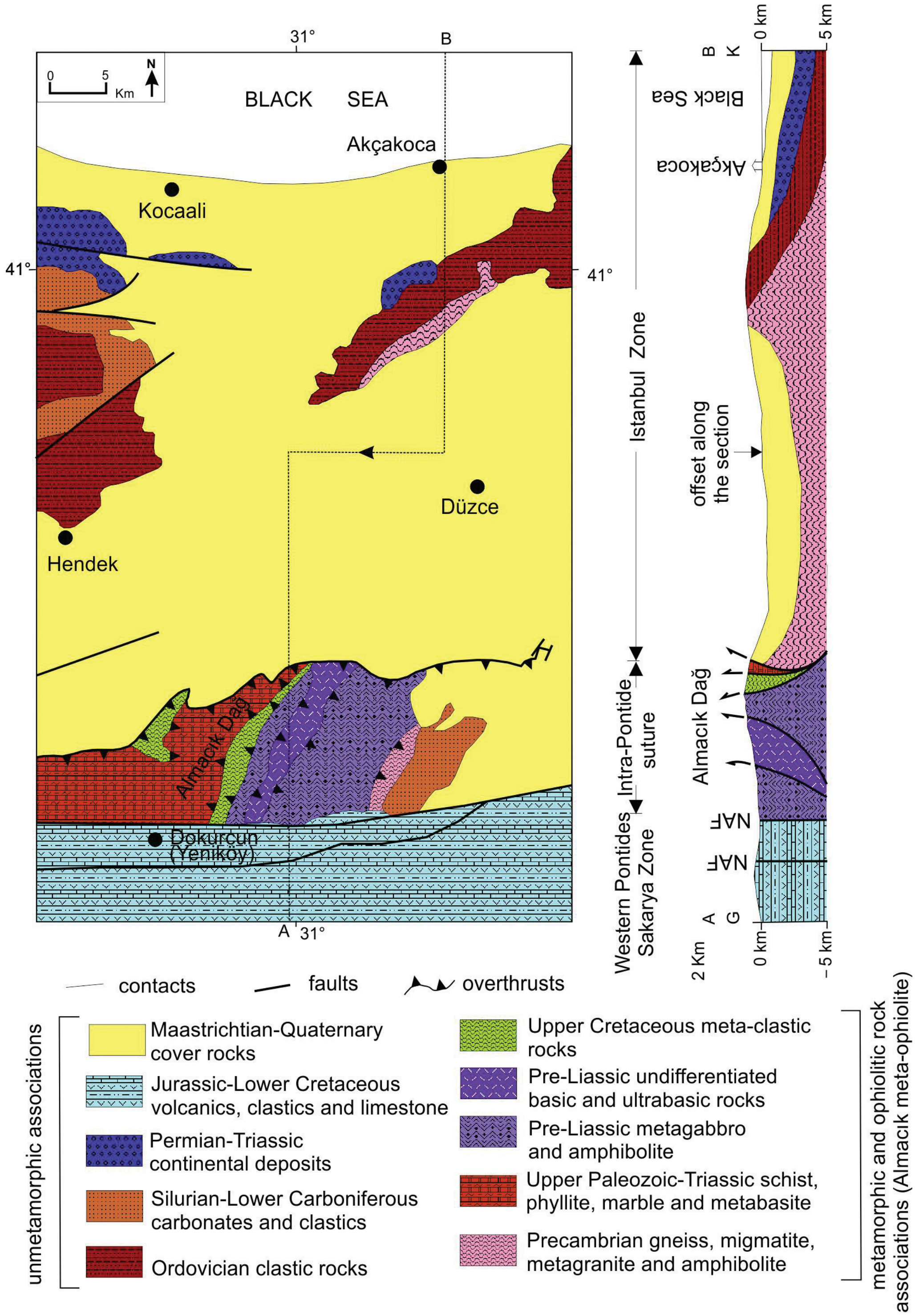

Figure 2. Simplified geological map and cross-section of the area among Akçakoca, Hendek, Düzce and Dokurcun (Gedik and Aksay, 2002; Pehlivan et al., 2002).

Şekil 2. *Akçakoca, Hendek, Düzce ve Dokurcun arasında yer alan bölgenin yalınlaştırılmış jeoloji haritası ve enine kesiti (Gedik ve Aksay, 2002; Pehlivan vd., 2002). Yer için Şekil 1'e bakınız.*

Isolated outcrops of the Paleotethyan ophiolites are scarce and their main outcrops occur between the İstanbul zone and the Pontides (and/or Sakarya Continent). The Almacık Dağ area (Figure 2) is a typical place, where the metamorphic and unmetamorphic units of ophiolites have been separated from one another. Figure 2 shows the setting of the Paleotethyan suture zone, which is situated between the unmetamorphic İstanbul zone and the western Pontides. The eastern part of this complex contains island-arc meta-tholeiites and transitional to calc-alkaline metabasites that chemically are quite similar to those of the Çele meta-ophiolite (Bozkurt et al., 2008).

The ophiolites along the Sünnice Dağ (Fig.1, S) are named as the Çele meta-ophiolite and, with their cover - the Yellice Formation (Yiğitbaş and Elmas, 1997; Tüysüz et. al., 2004) - represent other outcrops of the Paleotethyan ophiolites. The Küre Nappe (Yılmaz and Şengör, 1985), and/or the Küre meta-ophiolites (Şengör et. al., 1984; Ustaömer and Robertson, 1999) are outcrops of Paleotethyan ophiolites. However, some units, representing the basement of the İstanbul zone along the Sünnice Dağ, had been interpreted as relicts of the Pan-African basement (Okay et al., 2008).

Pre-Alpine ophiolites are also interpreted as products of the Intra-Pontian Ocean (Şengör et. al., 1980). However, the existence of this ocean is speculative and controversial. There are no precise data about the age of opening and closure of this ocean. The passive continental- margin sequences along both sides of the ocean are no longer discernible. Because of these discrepancies, it is difficult to establish the setting of the Intra-Pontide Ocean in paleogeographic reconstructions for the Paleotethyan ocean.

Stratigraphical features

The Almacık meta-ophiolite and Çele meta-ophiolite at least represent ophiolitic slices, although the rocks have been deformed via metamorphism and tectonism. From bottom to top, in general, this sequence includes serpentinized peridodite, amphibole gneiss, metagabbro-amphibolite, metadiabase and metalava (Yiğitbaş and Elmas, 1997).

The Çangal complex represents an oceanic arc (Ustaömer and Roberson, 1997), comprising serpentinite, metagabbro, metadiabase, metaspilite and metaporphyrite which took on their present disposition through conditions of ~ 3.5/ 5 Kb P and T of ~ 350ºC and higher (Yılmaz, 1983).

The Küre meta-ophiolite has also been studied in detail. For instance, Şengör et al. (1984) interpreted the Küre Nappe as a subduction-accretion complex which accumulated along the northern margin of the Cimmerian Continent (later the Sakarya Continent). This unit includes SSZ zone and oceanic-ridge basalts (Ustaömer and Roberson, 1997). In addition, intrusive lherzolites cut the lower part of the basalts, which form the volcanic upper unit of the Küre ophiolite. The lherzolites are massive in character, occurring in tabular forms with hectometric dimensions. High T-low P conditions are indicated by mineral compositions (Çakır et. al., 2006). In short, it can be said that the pre-Alpine ophiolites represent an ordered ophiolitic sequence, and that the various levels of the sequence have been defined in detail.

Ophiolite geochemical signature and tectonic setting

Despite hydrothermally induced element migration, a tholeiitic affinity is recognizable in the distribution of the less mobile elements of the pillow lavas in the Paleotethyan ophiolites of northern Turkey (Yılmaz and Şengör, 1985).

On the other hand, trace-element geochemical data suggest that the Küre Ophiolite represents a fragment of a marginal basin generated above a subduction zone (Ustaömer and Robertson, 1999; Kozur et. al., 2000) and/or a Tethyan suprasubduction marginal basin (Çakır et. al., 2006). The Küre Ophiolite is interpreted as a product of the Paleotethyan ocean, as evidenced by the presence of IAT- to MORB-type extrusive rocks and a depleted mantle sequence (Ustaömer and Robertson, 1999).

On the basis of geochemical data presented by Okay and Tüysüz (1999) and Moix et al. (2008), the subduction of the Intra-Pontian Ocean should be northward. The tectonic units and ophiolites of the region were assembled following a continental collision between Gondwanaland and Laurasia during the Late Cretaceous (Yılmaz et al., 1995). During this collision, Pre-Alpine ophiolites may have been also added to the Intra-Pontide Suture Zone.

In addition, south-facing overthrusts are dominant along Paleotethyan ophiolites in the area between Küre and Kargı (Yılmaz and Şengör, 1985). However, Ustaömer and Robertson (1997) suggest a model showing at first northward, and then southward. In the framework of this model, both south-facing and north-facing overthrusts have been defined.

On the other hand, ophiolitic rock associations of the Intra-Pontide Ophiolitic Belt have been thrust southward onto the western Pontides and, in turn, have been overthrusted by the İstanbul zone to the north. However, northwest-facing and southeast-facing overthrusts are widespread (Gedik and Aksay, 2002; Pehlivan et al., 2002) along the suture in the Almacıkdağ area as well (Figure 2).

In fact, pre-Middle Jurassic and younger structures have not been separated from each other among the pre-Alpine ophiolites. Therefore, it is difficult to reach a conclusion concerning the polarity of the subduction responsible for the emplacement of the ophiolites and mélanges.

Geological age

The geological age of the pre-Alpine ophiolites may have been reset from Precambrian to Triassic. For instance, the Lower Ordovician Kurtköy Formation unconformably overlies the Çele meta-ophiolite. The nappe package and ophiolites were metamorphosed together during the Coniacian-Santonian interval (Yılmaz et al., 1995).

On the basis of a radiometric age from metagranite (Okay et al., 2008) that intruded the meta-ophiolitic rocks, the age of the Çele meta-ophiolite may be Cambrian and/or Precambrian (Chen et. al., 2002). However, on the basis of paleontological and other geochronological data, the age of the Küre meta-ophiolite is at least pre-late Middle Jurassic, and probably between Late Triassic and Middle Jurassic (Aydın et. al., 1995; Kozur et. al., 2000; Terzioğlu et. al., 2000; Çakır et. al., 2006).

Although the age of these ophiolites may be pre-late Middle Jurassic, it is thought to be in the time interval between Precambrian and Triassic, in general.

Pre-Alpine Ophiolitic Mélanges

Although there are many local names such as Almacık ophiolitic mélange (Pehlivan et al., 2002) and Arkotdağ mélange (Tokay, 1973) for the Late Cretaceous products of the Intra-Pontide Ocean in the same region, the term Karakaya Complex generally represents pre-Alpine ophiolitic mélanges, which tectonically overlie Hercynian basement, including a thick graywacke section with Devonian, Carboniferous and Permian limestone olistoliths, which are intercalated with abundant basic lavas and volcaniclastic and pelagic rocks of Triassic age.

Definition and distribution

The Karakaya Complex is a metavolcano-sedimentary unit, a strongly deformed and locally metamorphosed Permo-Triassic orogenic series in the Pontides. The name Karakaya Formation was introduced by Bingöl et al (1975). This unit was renamed the Karakaya Complex by Şengör et al (1984). The complex comprises several mappable rock units (Okay et. al., 1991).

Although there is general agreement that the Karakaya Complex is restricted to the Sakarya Zone (Okay, 1989) and/or Sakarya Composite Terrane (Göncüoğlu et. al., 1997) of the western and central Pontides, it also exists along the southern edge of the eastern Pontides as far east as the Erzincan area and the Lesser Caucasus as accreted tectonic slices along the North Anatolian-Lesser Caucasus Ophiolitic Belt.

Stratigraphical features

The Karakaya Complex is divided into two subtectonic units: the Lower Karakaya Complex and the Upper Karakaya Complex (Okay and Göncüoğlu, 2004).

The Lower Karakaya Complex has been mapped under various names, and comprises a highly deformed sequence of metabasites intercalated with phyllite and marble, representing a typical metavolcano-sedimentary unit in the Tokat area (Yılmaz and Yılmaz, 2004a). The rocks of the unit are generally foliated, isoclinally folded and are cut by copious shear zones.

he Upper Karakaya Complex is made up of several tectono-stratigraphic units. However, there is general agreement that this complex includes a thick series of arkosic sandstones, graywacke, basalt, limestone, grain flows, debris flows, and olistostromes, and also the Akgöl Formation. In most studies, the Akgöl Formation is considered separately from the Karakaya complex (Okay and Göncüoğlu, 2004); this formation comprises dark gray to black shales and siltstones intercalated with scarce turbiditic sandstones and includes blocks of spilite, diabase, gabbro and serpentinite within the clastic rocks of the formation.

Ophiolite geochemical signature and tectonic setting

Two models have been proposed to explain the tectonic setting of the Karakaya Complex: (1) a rift model and (2) a subduction-accretion model.

The mafic volcanic rocks in the Lower Karakaya Complex generally display a within-plate geochemical signature, and have been interpreted as an oceanic island (Çapan and Floyd, 1985). In addition, the first model assumes that the Karakaya Complex was deposited in a Late Permian rift, which developed into a small, oceanic marginal basin that subsequently closed in the Late Triassic via southward subduction (Koçyiğit, 1987; Genç and Yılmaz, 1995; Göncüoğlu et al., 2000).

The subduction-accretion model was first proposed by Tekeli (1981a), and was later modified by Pickett and Robertson (1996) and Okay (2000). In fact, southward-dipping subduction (eg Şengör and Yılmaz, 1981) and northward- dipping subduction (Okay, 2000; Stampfli et al., 2001) have been suggested for the emplacement of the Karakaya complex.

In addition, on the basis of Robertson and Ustaömer (2012), the accretionary prism of the Karakaya complex was emplaced northward over deltaic to deep marine cover sediments of the Sakarya Continenet during Norian time. These models assume that the Karakaya Complex developed via subduction-accretion processes acting on the oceanic crust during the Late Paleozoic-Triassic time interval. Despite these explanations, the original place of subduction and emplacement mechanism of the Karakaya complex remains controversial.

Geological age

Paleontological data from the Karakaya Complex are limited. Scarce chert and pelagic limestone blocks of Carboniferous age have been recognized in arkosic sandstones northeast of Balya (Okay and Mostler, 1994), and north of Bursa these clastic rocks contain a large number of olistoliths of Permian and Triassic age (Kaya et al., 1986).

Early Triassic conodonts are reported from marbles intercalated with metabasites that crop out south of Bursa; that is, from the type locality of the Nilüfer Unit (Kozur et al., 2000). Similarly, Middle Triassic conodonts are described from Kozak Dağ in northwestern Anatolia (Kaya and Mostler, 1992). Lower Triassic foraminifera have been determined from a low-grade-metamorphic clastic series (Akyürek et al., 1979).

Middle Triassic (Anisian) limestone blocks are also reported from the Akgöl Formation (Önder, 1988; Kozur et. al., 2000). Based on trace-fossil content, Kozur et al. (2000) suggested a Late Triassic age for the clastic rocks. The Upper Triassic-Liassic, foraminifera-bearing Akgöl Formation is cut by Middle-Jurassic granitoids (Boztuğ et al., 1984).

Radiometric age data from the Karakaya Complex that crops out north of Eskişehir (Okay et. al., 2002) yield latest Triassic ages (205-203 Ma). In the Pulur Massif of the eastern Pontides, a metabasite-phyllite-marble series, the Hossa Group of Okay (1996), has yielded Early Permian (263-260 Ma) Ar-Ar and Rb-Sr phengite and amphibole ages (Topuz et al., 2004). The age range of this complex is from Permian to Triassic in the Tokat area (Yılmaz, 1982; Yılmaz and Yılmaz, 2004a).

In spite of differences mentioned above, it can be concluded that the Karakaya Complex represents an orogeny caused by Latest Triassic northward obduction of subducted-accreted products of Paleotethys (Tekeli, 1981a; Koçyiğit et al., 1991; Okay et al., 1996).

ALPINE OPHIOLITES AND MÉLANGES

The Alpine ophiolites and mélanges of Turkey can be divided into two main belts. As indicated in Figure 1, the red dotted line represents the Taurus Unmetamorphic Axis (TUA), which separates these ophiolitic belts from one another. The Northern and Northeastern Anatolian Alpine Ophiolitic Belt (NAOB) represents the northern branch of Neotethys, whereas the Southern and Southeastern Anatolian Alpine Ophiolitic Belt (SAOB) represents the southern branch of Neotethys.

The Northern-Northeastern Anatolian Alpine Ophiolitic Belt

The North Anatolian Ophiolitic Belt (Yılmaz, 1989; Yılmaz and Yazgan, 1990) and/or the Northern-Northeastern Anatolian Alpine Ophiolitic Belt (NAOB) include two sub-ophiolitic belts as well: the northern and the southern sub-belts.

The northern sub-belt begins in İzmir (Figure 1) and continues eastward to Ankara, then Erzincan and, finally, to the Sevan-Akera sub-belt of the Lesser Caucasus Ophiolitic Belt. The southern sub-belt begins in the Marmaris area in SW Turkey and continues eastward to the Hadim, Aladağlar, Tecer-Divriği, Erzurum and Kağızman areas (Figure 1), and onward to the Vedi sub-belt of the Lesser Caucasus Ophiolitic Belt. The scattered ophiolitic outcrops of eastern Anatolia, such as the ophiolites of the Hınıs area and to the northeast of Lake Van, may be the southernmost products of the southern sub-belt. Both sub-belts include allochthonous outcrops of ophiolites and Upper Cretaceous mélanges which together record, at very least, the destruction of the northern branch of Neotethys.

However, there are some ophiolitic units, representing Alpine ophiolites along the Intra-Pontide suture as well. For instance, Domuzdağ complex is one of them and includes ophiolitic fragments, which representing Cretaceous HP/LT metamorphic rocks. The Intra-Pontide oceanic basin has also been interpreted as a branch of Neotethys (Göncüoğlu et. al., 2008). On the basis of data from the Arkotdağ mélange (Tokay, 1973), it is suggested that ridge-spreading in the Intra-Pontian Ocean continued at least from Middle Jurassic to middle Late Cretaceous time (Göncüoğlu et, al., 2008). This area may be a critical as a place where ophiolites and mélanges of Paleotethys and Neotethys are intermixed. However, there has not been yet enough data to support this interpretation.

The characteristics of the ophiolites and ophiolitic mélanges of the NAOB have also been presented in order of definition and distribution, characteristic features, tectonic setting, geological age, correlation and conclusions, respectively, within the framework of certain particular locations.

Definition and distribution

The northern sub-belt of the NAOB is directly located along both sides of the North Anatolian-Lesser Caucasus suture, whereas the southern sub-belt of the NAOB represents typical ophiolitic outcrops and an accretionary complex; these were emplaced southward onto the Tauride-Anatolide Platform during Late Cretaceous time. However, there are many scattered outcrops of the northern branch of Neotethys along the north side of the TUA (Fig.1). The ophiolites and mélanges of the NAOB can be grouped regionally as NW/SW Anatolian, Central Anatolian and NE-E Anatolian ophiolites and mélanges. Some of the ophiolites and mélanges of each region have been studied in detail.

For instance, in NW Anatolia, the Orhaneli (Bursa) ophiolite (Sarıfakıoğlu et al., 2008) is a typical ophiolitic outcrop situated 20 km south of Bursa (Figure 3), and is associated with an Upper Cretaceous mélange (Özkoçak, 1969), which is located along the tectonic boundary between the western Pontides to the north and the Anatolide-Tauride block to the south (Figure 3). This ophiolite with mélange is a product/marker of the İzmir-Eskişehir-Ankara Suture (e.g., Okay and Tüysüz, 1999). However, the Marmaris ophiolites (Çapan, 1981), including the Lycian ophiolitic nappes, make up the southern sub-belt of the NAOB and the SW Anatolian region (Figure 1, M and L). These nappes represent the allochthonous parts of the Anatolian Terrane and overly the Beydağları/Menderes autochthonous rocks in the west (Brunn et al., 1971; Ricou et. al., 1979; Moix et. al., 2008). There is a consensus that the Menderes Massif represents a tectonic window beneath the ophiolitic nappes (eg. Okay, 2008).

In the central Anatolian region to the north, the Ankara Mélange (Bailey and McCallien, 1950; Özkaya, 1982; Çapan et. al., 1983) and the Kalecik Unit (Tüysüz et al., 1995) in the Ankara-Çankırı region, the Çiçekdağ ophiolite (Figure 1, Çi) in the Central Anatolia (Yalınız et al., 2000), Yeşilırmak Group (Yılmaz et al., 1997a, b) with the Tekelidağ Mélange (Yılmaz, 1981a, 1982; Yılmaz and Yılmaz, 2004a) between Tokat and Sivas (Figure 4), and the Refahiye Complex with the Karayaprak Mélange (Figure 1, R) in the Erzincan area (Yılmaz, 1985a) make up the northern sub-belt of the NAOB.

However, the Bozkır Unit of the Hadim area and Dipsizgöl (Fig.1 D) Ophiolitic Mélange (Özgül, 1976), the Aladağ Ophiolite (Tekeli, 1981b), and the Tecer and Divriği (Figure 1, T) (Güneş) ophiolites (Çapan, 1981; Yılmaz and Yılmaz, 2004b; Parlak et. al., 2006) represent the southern sub-belt of the NAOB. The Central Anatolian Massif may represent a tectonic window beneath the ophiolitic nappes as suggested by Yılmaz and Yılmaz (2004a; 2006).

In the NE-E Anatolian region to the north, the pre-Liassic Karayaşmak ultramafic-mafic association (Eyuboğlu et al., 2010) along the Pulur Massif (Okay et al., 1991), the Kopdağı ophiolites (Akdeniz, 1994) to the northeast (Fig.1, P) of Aşkale (Erzurum), and the Demirkent Magmatic Complex to the east of Yusufeli with Güvendik dyke complex (Konak et. al., 2009) in the Oltu region (Figure 1, O) are parts of the northern sub-belt of the NAOB, whereas the Şahvelet ophiolites and Bozyukuştepe Mélange (Figure 5) in the Erzurum area (Yılmaz et. al., 1988, 1990, 2010), and the Kağızman Ophiolites with mélanges in the northern part of the Ağrı Province (Figure 1, K) are part of the southern sub-belt of the NAOB. The Mehmetalan Unit (Şenel, 1987) of the Van area and ophiolites to the north of Hınıs (Figure 5) including ophiolites with ophiolitic mélange, may be the southernmost outcrops of the southern sub-belt. For instance, the Akdağ Metamorphics of the Hınıs area crop out beneath ophiolites as a tectonic window (Yılmaz et al., 1988). In this framework, it is clear that NAOB includes pre-Alpine and Alpine ophiolites together.

As a result, the Menderes Massif, the Central Anatolian Crystalline Complex and the Akdağ metamorphics of the East Anatolia collectively represent the metamorphic northern margin of the Tauride-Anatolide block (Figure 1).

Stratigraphical features

The ophiolites of the northern and southern sub-belt of the NAOB comprise dismembered ophiolitic sequences. The ophiolitic series mainly include mantle peridotites, mafic-ultramafic cumulates and plagiogranites notwithstanding some local differences. For instance, the Orhaneli ophiolite and the Dağküplü ophiolite consist mainly of ultramafic cumulates and subordinate mafic cumulates in the NW Anatolian region (Sarıfakıoğlu, 2006; Sarıfakıoğlu et al., 2008). In addition, magmatic mineral assemblages of plagioclase and pyroxene are still preserved in gabbros of the Anatolian ophiolites (Önen, 2003). The secondary mineral assemblages in the diabase dykes show that the Anatolian ophiolites have not been affected by the HP/LT metamorphism recorded in the Orhaneli Group (Okay and Whitney, 2010).

The Lycian Nappes represent the uppermost tectonic units in the region and consist of ultramafic tectonites (e.g., the Marmaris ophiolites) which are cut by isolated diabase dykes (Juteau, 1980). The tectonites are underlain by a metamorphic sole composed of amphibolite and quartzite resting on a tectonic mélange.

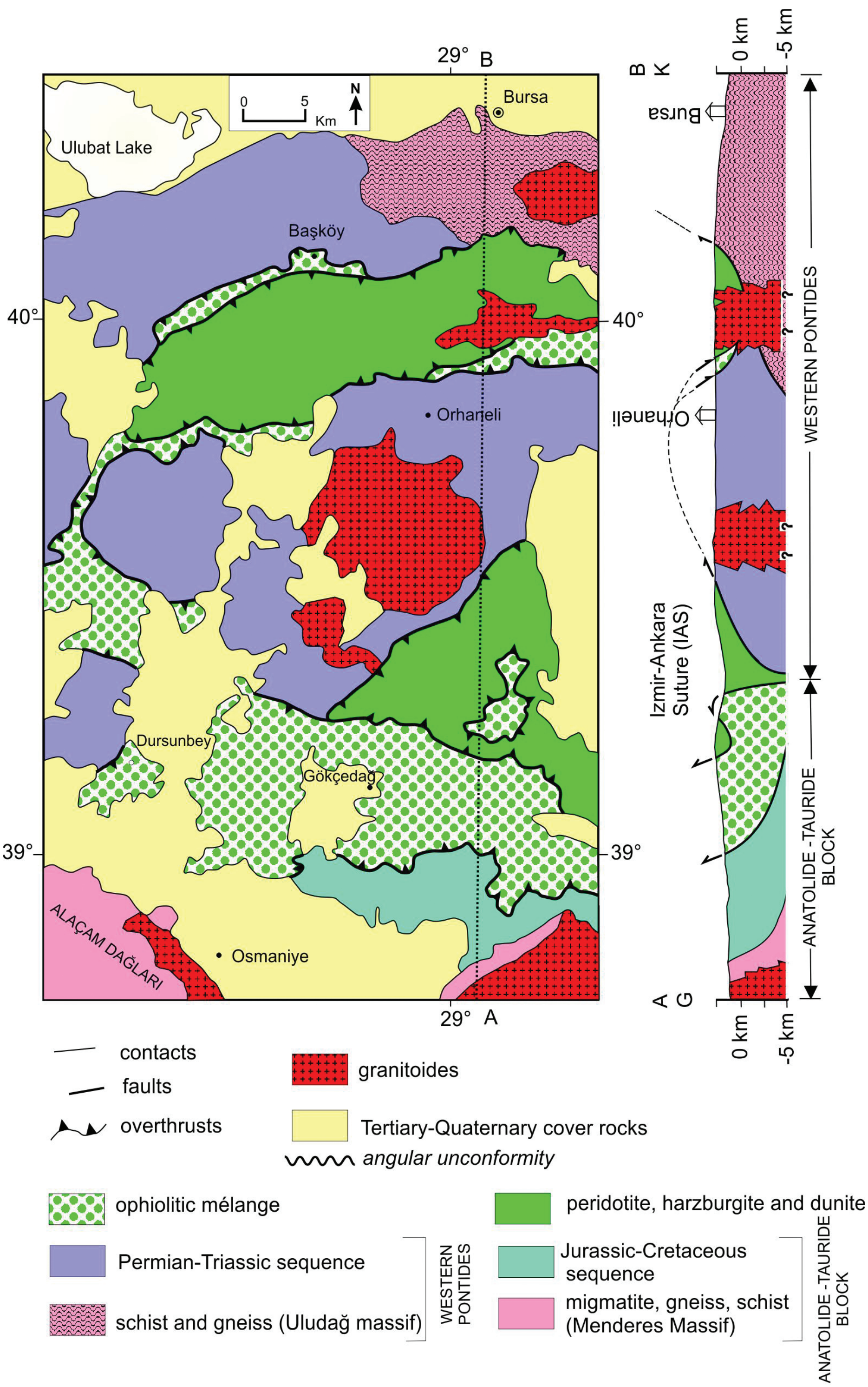

Figure 3. Geological map and cross-section of the southern part of the Bursa Province (after Okay, 1996 and MTA, 2002). See Figure 1 for location

Şekil 3. *Bursa'nın güney kesiminin jeoloji haritası ve enine kesiti (Okay, 1996 ve MTA, 2002'den yararlanılarak hazırlanmıştır). Yer için Şekil 1'e bakınız.*

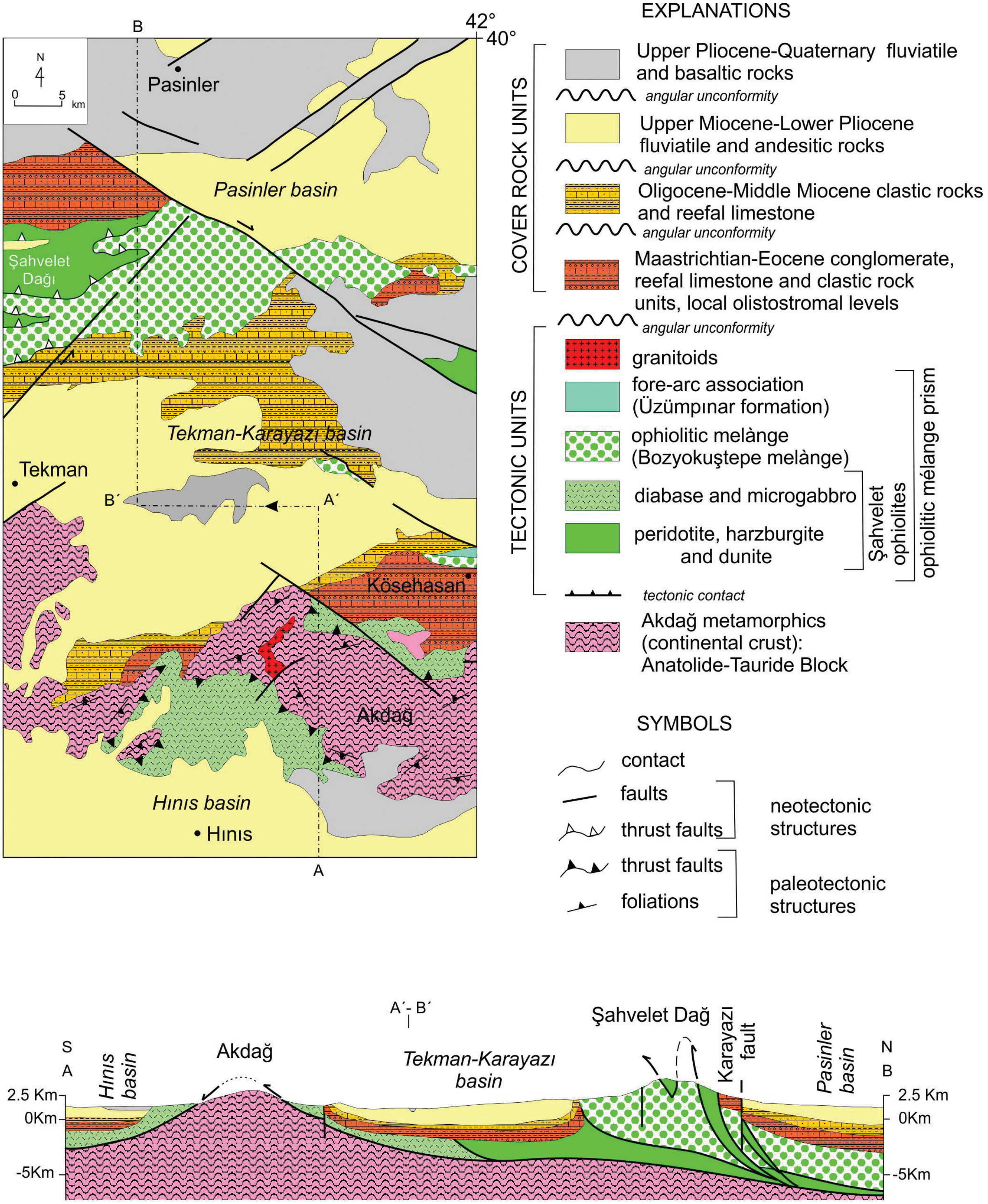

Figure 5. Geological map and cross-section of the area between Pasinler and Hınıs (Erzurum) (Yılmaz et al., 1990, 2010). See Figure 1 for location.

Şekil 5. *Pasinler ile Hınıs (Erzurum) arasındaki bölgenin yalınlaştırılmış jeoloji haritası ve enine kesiti (Yılmaz vd., 1990, 2010). Yer için Şekil 1'e bakınız.*

In the Central Anatolia, ophiolites of the Kalecik Unit in the Ankara-Çorum area constitute an ordered ophiolitic slice within ophiolitic mélange (Tüysüz et. al., 1995). The following units (from bottom to top) of the Çiçekdağ ophiolite are recognized: layered and isotropic gabbro, plagiogranite, a dyke complex, a basaltic volcanic sequence and a Turonian-Santonian epi-ophiolitic cover (Yalınız et al., 2000). In the area between Tokat and Sivas, there are dismembered ophiolitic outcrops within the Tekelidağ mélange (Yılmaz, 1981a, 1982). The Erzincan Nappe includes ophiolites and mélange with reworked materials. The dyke complexes of the Yusufeli and Oltu areas (Konak et. al., 2009) may be a horizon within the ophiolitic sequence.

On the other hand, the ophiolites of the southern sub-belt of the NAOB represent obducted slices of the oceanic crust with ophiolitic mélanges on the Taurus Platform. On the basis of data presented by Çapan (1981), the ophiolites of Marmaris, Mersin, Pozantı, Pınarbaşı and Divriği were obducted ophiolites on the Taurus Platform and should belong to the same oceanic crust and, thus, be cogenetic throughout the Taurus Belt. Among these, the Divriği ophiolite comprises an ordered ophiolitic sequence which from bottom to top includes mantle tectonites, ultramafic to mafic cumulates, isotropic gabbros and a sheeted dyke complex (Yılmaz and Yılmaz, 2004b).

The Şahvelet ophiolites of the East Anatolia region represent dismembered ophiolitic slices in mélange and comprise serpentinite, peridotite, gabbro and diabase (Yılmaz et al. 1990). The Kağızman ophiolites and Mehmetalan unit of the Van area (Şenel, 1987) have characteristics those are similar to the ophiolites (including mélanges) exposed in the Erzurum area.

Ophiolite geochemical signature and tectonic setting

Although the NAOB can be divided into two sub-belts, there are also many scattered outcrops of ophiolites along the belt. Therefore, the ophiolite geochemical signature and tectonic setting of the units should be discussed in detail.

The field and petrochemical studies suggested that the Orhaneli ophiolite and the Dağküplü ophiolite developed as products of island-arc tholeitic (IAT) and/or boninite-like magmatism in an intraoceanic suprasubduction zone system (Sarıfakıoğlu, 2006; Sarıfakıoğlu et. al., 2008). On the basis of data presented by Tüysüz et al. (1995), as a result of collision between the Sakarya and Kırşehir microcontinents, ophiolites, mélange units and ensimatic- arc volcanic rocks were emplaced along the suture. In addition, it has been suggested by Gökten and Floyd (2007) that the tholeiitic compositions of pillow basalts within the ophiolitic mélange around Ankara have affinities with both N- and E- type MORB, although most of them are probably representative of tholeiitic ocean islands.

In the Muğla area to the north of TUA, the models suggested for the origin of ophiolites indicate that the cpx-harzburgites are products of first- stage melting and low-degrees of melt rock interaction that occurred in a mid-ocean ridge (MOR) environment (Uysal et al., 2012).

The geochemical characteristics of volcanic rocks of the Çiçekdağ ophiolite in the Central Anatolia are similar to supra-subduction zone type ophiolites, which were emplaced by movement of the south-facing arc and/or north-dipping subduction.

In the area of the Tokat and Sivas provinces, the petrochemical features of volcanic rocks in ophiolitic mélange resemble those of tholeiitic rocks that form at mid-ocean ridges, whereas the Upper Cretaceous (possibly Turonian) volcanic rocks seem to be identical to those of island arcs (Yılmaz, 1981b). In addition, the abyssal-tholeiitic level of the Erzincan-Refahiye ophiolite is thought to represent fragments of upper mantle and oceanic crust (Buket, 1982; Yılmaz, 1985a) that were generated from the ridge of the Tethyan ocean. On the other hand, chemical analyses of basic volcanic rocks in the mélange of the Erzincan Tanyeri area indicate compositions consistent with low-K tholeiites and calc-alkaline basalts of an island-arc setting (Bektaş, 1981). Consequently, it has been suggested that the ultramafic and leucocratic rocks of the Refahiye ophiolite developed in the earliest stages of island-arc development in a suprasubduction setting (Rice et al., 2009) and a fore-arc tectonic setting in the northern branch of the Neotethyan ocean, with characteristics similar to most of the eastern Mediterranean Cretaceous ophiolites (Sarıfakıoğlu et. al., 2009). In addition, the Karayaşmak ultramafic-mafic association was derived from high-Al hydrous basaltic magmas which developed via partial melting of previously subducted and metasomatized subcontinental lithospheric mantle (pre-Liassic, Alaskan-type ultramafic-mafic complex) in the Eastern Pontides (Eyüboğlu et al., 2010).

The geochemical evidence suggests that the Divriği ophiolite formed in a suprasubduction-zone tectonic setting with the metamorphic sole rocks to the north of the Tauride platform (Parlak et al., 2006).

For instance, Okay and Siyako (1993) indicated the position of the İzmir-Ankara Neotethyan suture between İzmir and Balıkesir. In this framework, the Orhaneli ophiolite with mélange reflects a flower structure between the Anatolide-Tauride block and the western Pontides (Figure 3). In this area, both north-facing and south-facing overthrusts are common along the ophiolitic units (Okay, 1996; MTA, 2002).

In the area between the Ilgaz-Kargı Massif and Çankırı Basin, south-facing overthrusts are dominant along ophiolitic tectonic units and indicate evolution of a south-facing arc system with intra-oceanic subduction (Tüysüz et. al., 1995).

However, the area between Reşadiye (Tokat) and Uzunyayla (Sivas) is characterized by complex structure (Figure 4). In this area, there are both paleotectonic and neotectonic structures due to a process of new basin formation. Insofar as it is necessary to distinguish these structures from each other, Yılmaz and Yılmaz (2004a) first divided the paleotectonic and neotectonic structures and then interpreted the emplacement of ophiolites and mélanges in the Tokat area. In this area, the İzmir-Ankara-Erzincan suture separates the central Pontides from the Anatolide-Tauride block (Figure 4). On the basis of their interpretation, the ophiolites with mélanges were obducted onto the northern and southern platforms thus configuring a flower structure, and subsequently this structure was deformed via collisional and post-collisional tectonic processes.

In the East Anatolia between Erzurum and Hınıs, south-facing overthrusts predominate (Figure 5) and the Akdağ Metamorphics of eastern Anatolia are exposed as a tectonic window beneath the ophiolites and may represent the metamorphic equivalents of the Central Anatolian Crystalline Complex (Yılmaz et al., 1988, 1990, 2010). Similarly, in the Saray (Van) area (Figure 6), south-facing paleotectonic overthrusts predominate along the southern boundary of the ophiolites and ophiolitic mélanges (Yılmaz et. al., 2010). Therefore, these ophiolites may be the southernmost products of the northern branch of Neotethys.

In conclusion, it may be said that the ophiolites of the NAOB are products of MORB-, OIB- and SSZ-type tectonic settings, including fore-arc, island-arc and back-arc basalts. To explain such a system, double subduction with northward polarities is suggested for the northern branch of Neotethys.

Geological age

Many geochronological and paleontological studies have been done in NW Anatolia. For example, Harris et al. (1994) obtained an age of 101±4 Ma by means of Ar-Ar dating of the garnet-amphibolite metamorphic sole beneath an ophiolitic slab. Ar-Ar dating has also been done on metamorphic sole rocks – that is, basement to the Tavşanlı (Kütahya) ophiolites; an age of 93±2 Ma was obtained from these rocks (Önen and Hall, 2000). Radiolarian ages obtained from the Bornova Flysch Zone indicate an Upper Ladinian to Upper Carnian deepening of the Tauride-Anatolide Platform and also opening of the Neotethyan İzmir-Ankara seaway (Tekin and Göncüoğlu, 2007); moreover, formation of OIB-type intra-plate seamounts within the İzmir-Ankara Ocean began in the late Bathonian and persisted until early Aptian (Göncüoğlu et al., 2006). The age of the mélange in NW Anatolia is Late Cretaceous (Özkoçak, 1969).

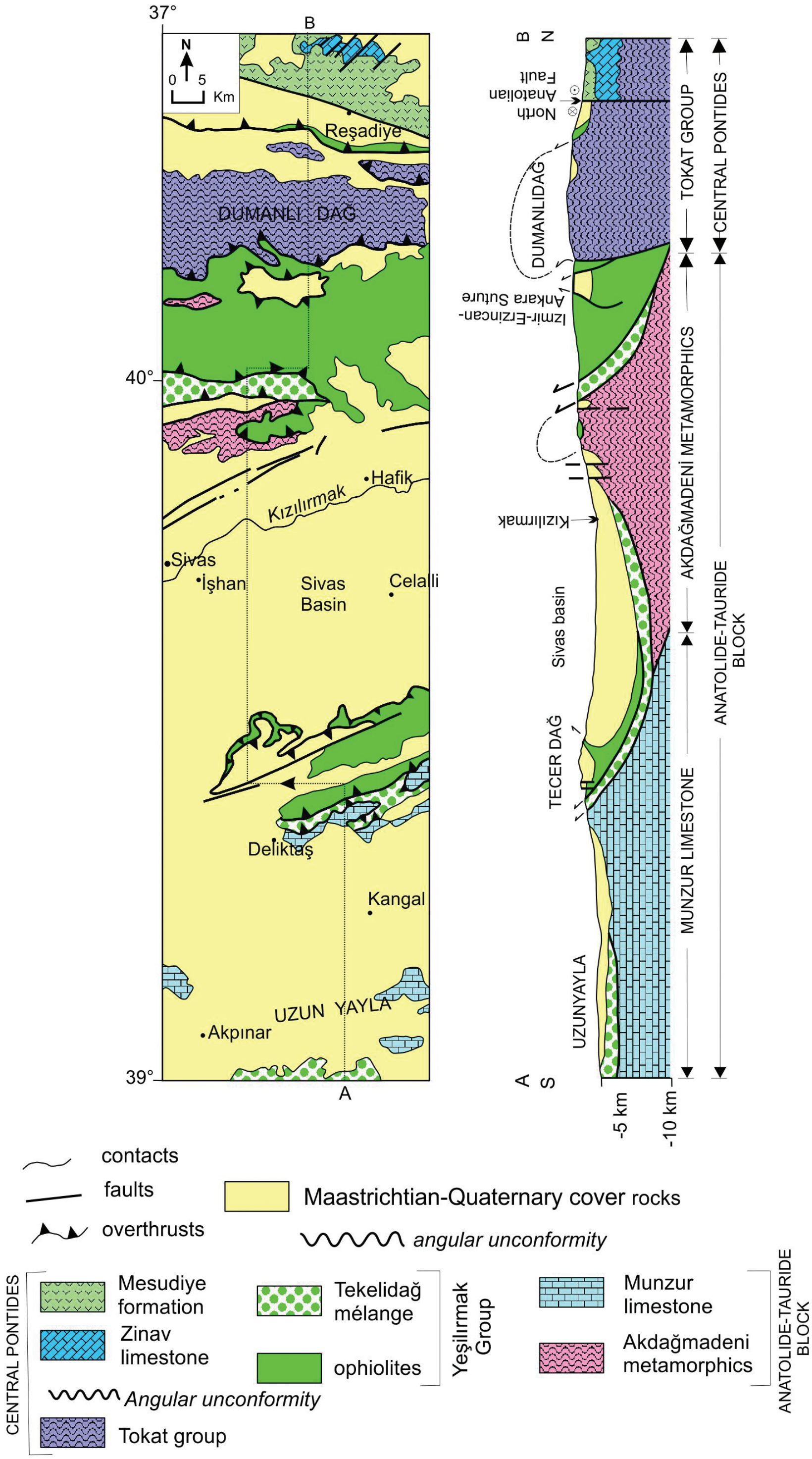

Figure 4. Geological map and cross-section of the area between Reşadiye (Tokat) and Uzunyayla (Sivas) area (Yılmaz, 1982; Yılmaz et al., 1993a). See Figure 1 for location.

Şekil 4. *Reşadiye(Tokat) ile Uzunyayla (Sivas) arasında yer alan bölgenin jeoloji haritası ve enine kesiti (Yılmaz, 1982; Yılmaz vd., 1993a). Yer için Şekil 1'e bakınız.*

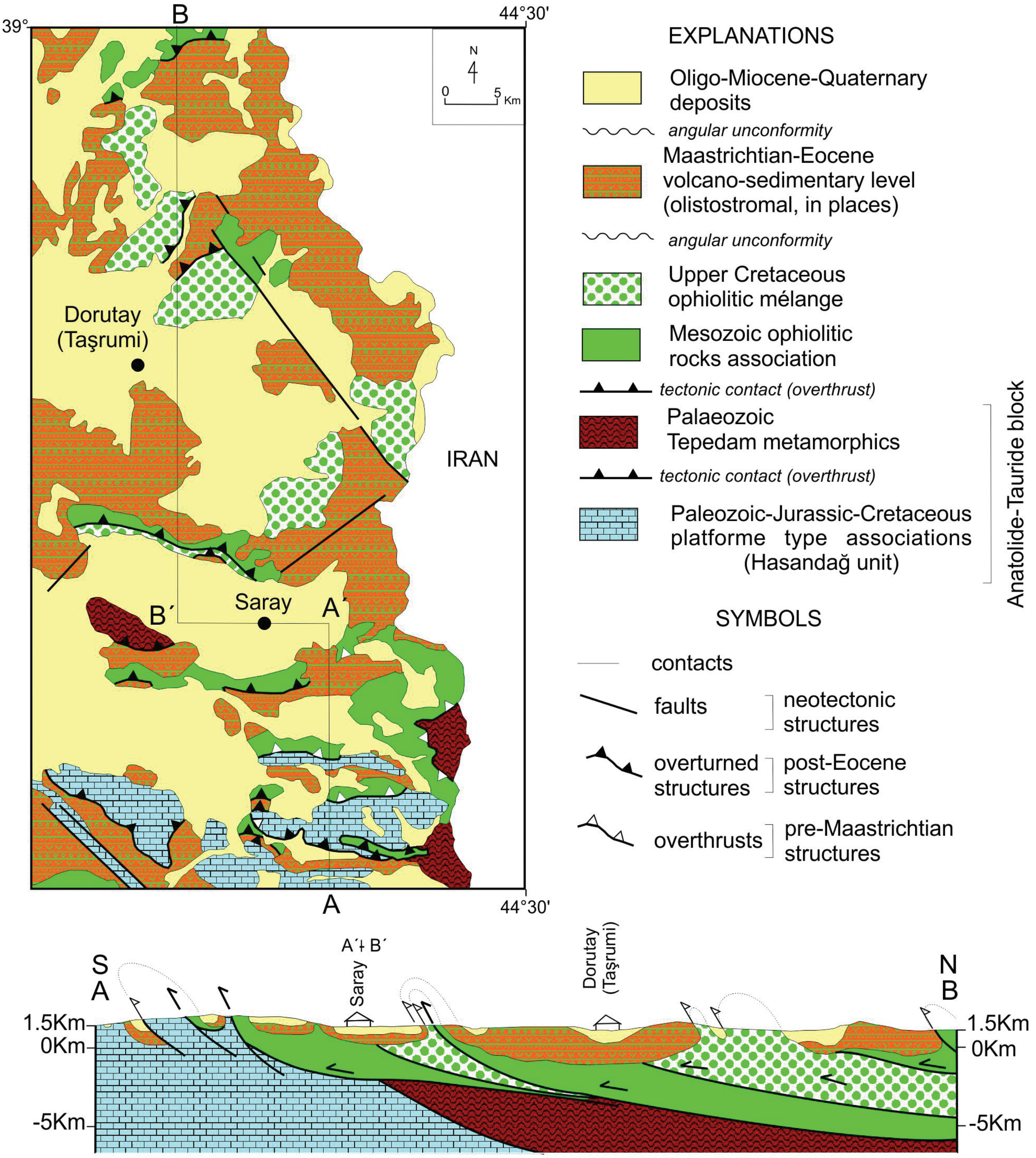

Figure 6. Simplified geological map and cross-section of the area east of Lake Van; AIP: Anatolian-Iranian Platform (Şenel, 1987; Yılmaz et al., 2010). See Figure 1 for location.

Şekil 6. *Van'ın doğu kesiminin yalınlaştırılmış jeoloji haritası ve enine kesiti, AİP:Anadolu-İran Platformu (Şenel, 1987; Yılmaz vd., 2010). Yer için Şekil 1'e bakınız.*

In SW Anatolia, along the Lycian Nappes, the age of the Burdur mélange is Cenomanian-Santonian (Özkaya, 1982). K/Ar dates from metamorphic-sole rocks yield a date of 104±4 Ma for the Lycian Nappes, and these dates have been interpreted as the ages of the initial displacement of ophiolitic rocks under intraoceanic conditions (Thuziat et al. 1981; Dilek and Moores, 1990). The ophiolites and mélanges are unconformably overlain by limestones, mudstones, basalts and turbidites of Maastrichtian-Eocene age. The Irmak mélange in the Ankara region may be Senomanian-Senonian in age based upon the results of paleontological studies, and Maastrichtian clastic rocks unconformably overlie this mélange (Çapan et. al., 1983). The age of the mélanges and ensimatic arc is Cenomanian-Maastrichtian in the area between the Ilgaz-Kargı Massif and the Çankırı Basin, and Late Paleocene and younger sedimentary rocks overlie unconformably all tectonic units and the intervening contacts (Tüysüz et al., 1995). From a NW-SE section between Eldivan (Çankırı) and Çiçekdağı (Kırşehir), SSZ-type ophiolite and its plagiogranites yielded an age of 180.48±0.34 Ma (Dilek et. al., 2009).

However in the area between Tokat and Sivas, the age of ophiolites may be Jurassic-Lower Cretaceous, but the mélange is Late Cretaceous in age and overlain by a Santonian-Campanian fore-arc unit (Yılmaz, 1981a, 1982; Yılmaz and Yılmaz, 2004a). Maastrichtian clastic rocks overlie the ophiolitic units and continental fragments throughout the region, from Tokat to the Munzurdağ (Yılmaz and Yılmaz, 2006). However, in the Erzincan area, limestone blocks, Liassic lavas and different Jurassic-Cretaceous limestones are abundant in the Upper Cretaceous mélange. Reworked materials derived from the mélange occur within the Maastrichtian-Paleocene clastic rocks. The ophiolites of the Kop Dağı area (Akdeniz et al., 1994) and dyke complexes between Yusufeli and Oltu (Konak et. al., 2009) are tectonic slices within the Upper Cretaceous mélange (Yılmaz et al., 2000). The age of the ophiolites and ophiolitic mélange in the Divriği area is also Late Cretaceous (Yılmaz and Yılmaz, 2004b).

The pre-Liassic mélange of the Tokat area occurred in a trench and/or an arc-trench gap (Tekeli, 1981a). There is also pre-Liassic ophiolite in the Erzincan area (Tatar, 1978; Koçyiğit, 1990, 1991), Early Jurassic SSZ type ophiolites also (Altıntaş et al., 2012) along the NAOB. Different ophiolites from Precambrian to Late Cretaceous age occurred along the Lesser Caucasus Ophiolitic Belt (Belov et al., 1978; Zakariadze et al., 1983) which represents the easternmost extension of the NAOB. In addition, a pre-Liassic Alaskan-type ultramafic-mafic complex also occurs in the eastern Pontides (Eyüboğlu et al., 2010).

In the Erzurum-Hınıs area, the ophiolitic mélange is composed of volcano-sedimentary matrix that encloses a mixture of diverse blocks of Triassic to Cenomanian age and, upward, pelagic limestone of Campanian age. Maastrichtian-Eocene units with olistostromal levels -comprising materials reworked from the ophiolitic units - rest upon the ophiolitic nappes and continental metamorphic rocks along a regional uncorformity (Yılmaz et al., 1988, 1990).

In conclusion, pre-Alpine and Alpine ophiolites coexist along the northern sub-belt of the NAOB. However, the Alpine ophiolites include Jurassic-Cretaceous MORB-type and Upper Cretaceous SSZ-type ophiolites along the NAOB. The coexistence of pre-Alpine and Alpine ophiolites along the NAOB may be related to a congruent Paleotethys and Neotethys and/or a long-lived relict basin of Paleotethys. Otherwise, pre-Alpine ophiolites may be interpreted as reworked materials of Paleotethys.

The Southern and Southeastern Anatolian Alpine Ophiolitic Belt

The South and Southeast Anatolian Alpine Ophiolitic Belt (SAOB) includes ophiolites and mélanges of the southern branch of Neotethys. This belt begins SW of Antalya and continues toward Southeast Anatolia to Cilo Mountain around Hakkâri. The Taurus Unmetamorphic Axis (TUA) separates the SAOB associations from the NAOB associations (TUA, Figure 1). First, the characteristics of ophiolites and then the ophiolitic mélanges of each region will be presented under separate headings below.

Definition and distribution

Originally, the ophiolitic associations of the region were named complexes, such as the Antalya complex, Maden complex (Perinçek 1979a, Perinçek 1990), Hatay complex, and so on. Subsequently, the ophiolites and mélanges have been differentiated from one another. In this framework, the Tekirova ophiolite, Mersin ophiolite, Kızıldağ ophiolite, İspendere-Kömürhan meta-ophiolite and/or Guleman ophiolite, and the Cilo ophiolite are well known ophiolitic rock units of the SAOB. In addition, the Göksun ophiolite and Gevaş ophiolite may be other ophiolitic units of the SAOB, since they are located to the south of the TUA, as shown in Figure 1 (Yılmaz et al., 2010).

However, the ophiolitic mélanges of this belt have been defined under different names, such as the Kumluca mélange around Antalya (Figure 7), the mélanges of Antalya basin in the Western Taurides (Yılmaz et al, 1981a; Yılmaz, 1984), Dipsizgöl melange in the Central Taurides (Özgül, 1984), Dağlıca complex (Perinçek and Kozlu, 1984) and/or the Dağlıca mélange (Yılmaz et al., 1993a) to the north of the Binboğa Mountains in the Eastern Taurides and the Koçali complex (Perinçek, 1979a, 1979b, 1990; Perinçek and Özkaya 1981) or mélange in the Southeast Anatolia (Figs. 8 and 9).

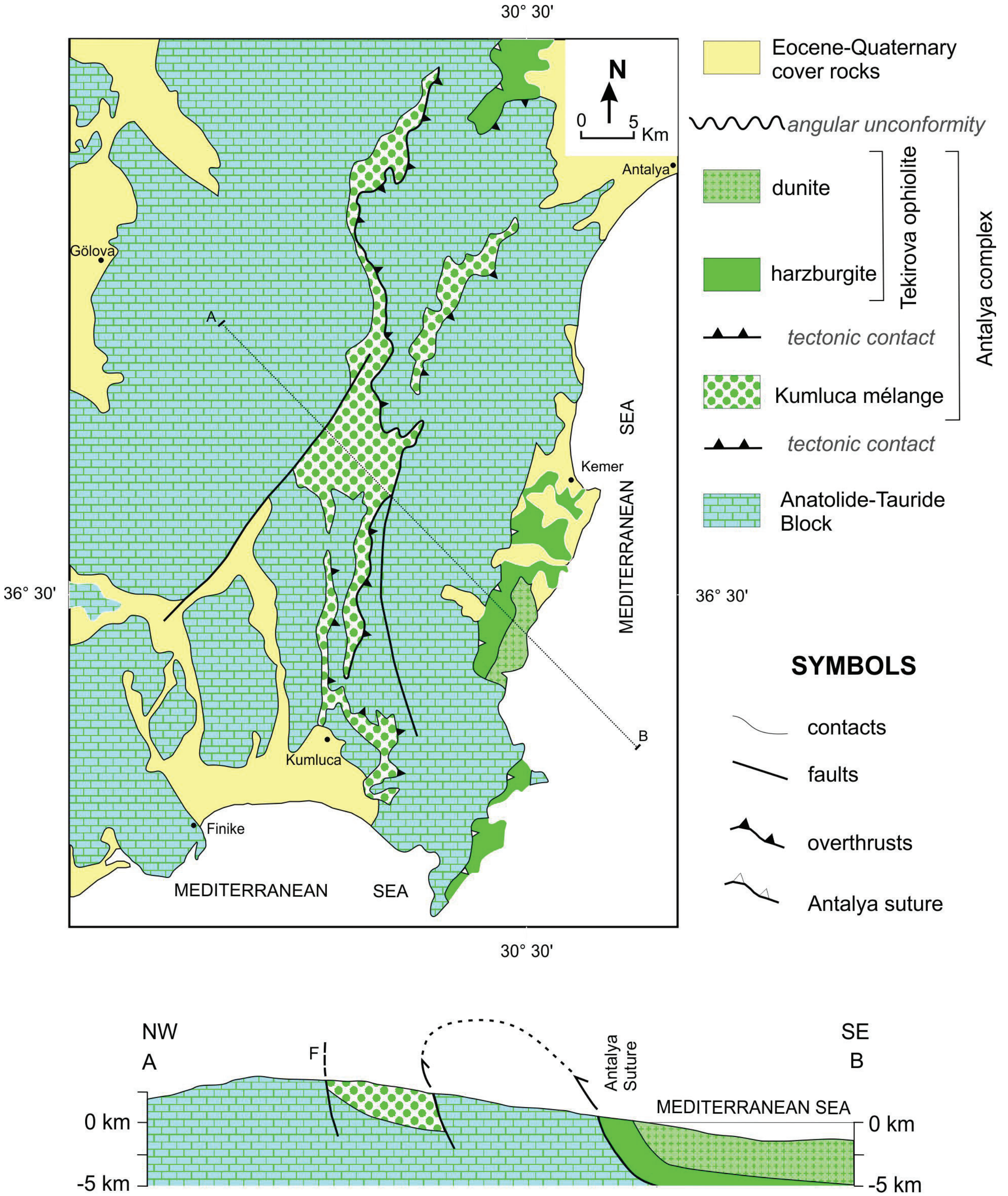

Figure 7. Tectonic units and their relationships in the Antalya area (Yılmaz et al., 1981a, Yılmaz, 1984; Şenel, 1997; MTA, 2002). See Figure 1 for location

Şekil 7. *Antalya yöresi tektonik birlikleri ve ilişkileri (Yılmaz vd., 1981a, 1984; Şenel, 1997; MTA, 2002). Yer için Şekil 1'e bakınız.*

From these units, the Antalya Complex lies in a critically important area near the junction between the Hellenides and Taurides, in an area with a few contrasting geological histories (Brunn, 1974; Monod, 1976; Robertson and Woodcock, 1982). The Antalya Complex includes a lava-sedimentary mélange and together with ophiolitic rocks (Robertson, 1993). Harzburgite and dunite are mappable units of this ophiolite (Figure 7). In this area, the Antalya suture is a tectonic contact between the ophiolites and the western Tauride unit. The Mersin and Pozantı-Karsantı ophiolites contain tectonites underlain by an amphibolite sole, cumulates, and pillow lavas with volcano-sedimentary intercalations (Parlak et al., 1995, 1997, 2002).

Other ophiolitic rock units, such as the Kızıldağ (Figure 1, Ka; Antakya), Göksun (Figure 8), İspendere-Kömürhan, Guleman (Figure 1, İ) and also Gevaş and Cilo ophiolites (Figure 1, G) form a discontinuous nonlinear belt and represent relicts of obducted ophiolites of the SAOB. These ophiolites, and also the Koçali mélange (Figure 9), are widespread throughout the region and are exposed to the north of the Arabian Platform in SE Turkey. The Koçali mélange is composed of blocks of ophiolites with epi-ophiolitic sedimentary rocks, and overlies a wildflysch of the Karadut complex tectonically (Perinçek, 1979a,b).

All of the ophiolitic massifs mentioned above are characterized by ophiolitic sequences and were emplaced with mélanges during closure of the southern branch of the Neotethyan Ocean in Late Cretaceous time along the southern side of the TUA. During the Late Cretaceous-Early Tertiary, there was a change from platform (that is, the Arabian Platform) to foreland basin. The emplacement of ophiolitic nappes coincided with this change.

In general, the volcano-sedimentary units of Late Cretaceous (Maastrichtian)-Tertiary age that crop out in the Southeastern Anatolian Orogenic Belt are commonly referred to as the Maden complex (Perinçek 1979a,b, Yazgan, 1983; Aktaş and Robertson, 1984). However, the Maden mélange (Hempton, 1985) is defined as back-arc basin sediments and volcanic rocks metamorphosed to the greenschist facies. Thus, the Maden unit is redefined as a volcano-sedimentary succession of Middle Eocene age (Perinçek, 1979a,b) representing a local short-lived back-arc basin which reached the stage of an embryonic ocean (Yiğitbaş and Yılmaz, 1996). In our opinion, the Eocene Maden complex and/or Maden mélange may be reworked materials of the Koçali mélange along the Southeast Anatolian Orogenic Belt.

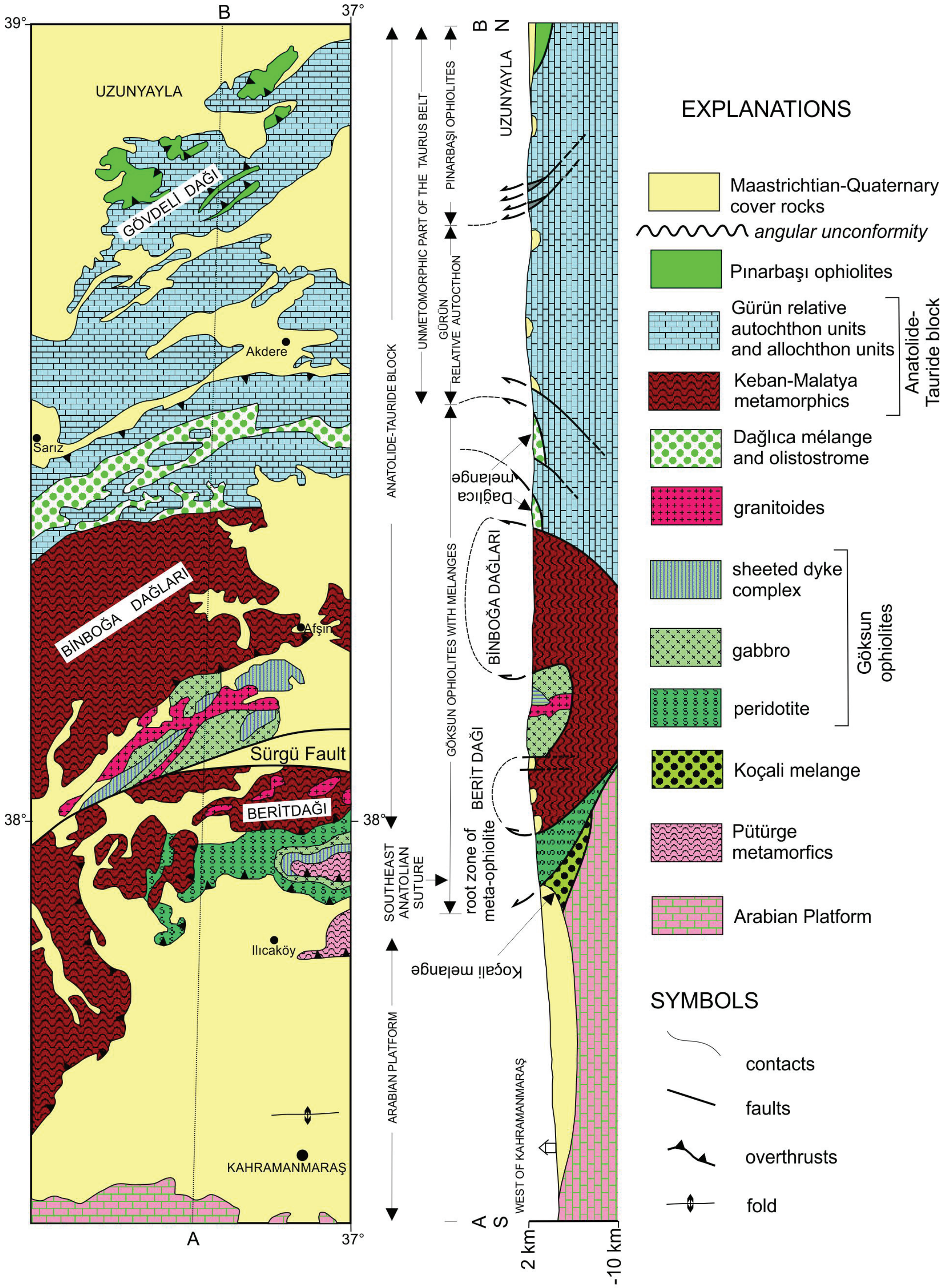

Figure 8. Geological map and cross-section of the area between Uzunyayla and Kahramanmaraş (Tarhan, 1985; Yılmaz et al., 1993a). See Figure 1 for location.

Şekil 8. *Uzunyayla ile Kahramanmaraş arasındaki bölgenin jeoloji haritası ve enine kesiti (Tarhan, 1985; Yılmaz vd., 1993a). Yer için Şekil 1'e bakınız.*

Stratigraphic features

The ophiolites of the SAOB, in general, occur as ordered ophiolitic sequences. The Antalya Complex includes ophiolite and mélanges. The ophiolite comprises harzburgitic tectonites, cumulates, isotropic gabbro, sheeted dykes, volcanics and associated sedimentary rocks (Juteau, 1975; Robertson and Woodcock, 1982; Bağcı et al., 2006). The mélanges of this region are represented by a volcano-sedimentary unit.

The Mersin ophiolite comprises ultramafic cumulates showing adcumulate-heteradcumulate texture, consisting mainly of dunite, wehrlite and pyroxenite. Igneous lamination, size grading and rhythmic layering are observed as accumulation features in the ultramafic cumulates. Mafic cumulates, mainly gabbro, leucogabbro, olivine gabbro and anorthosite, constitute almost two-thirds of the whole cumulate section (Parlak et al., 1996).

The Kızıldağ ophiolite includes a well-developed sheeted dyke complex and poorly preserved volcanic complex (Tekeli et al., 1983; Erendil, 1983). At the north of the Göksun area, the Dağlıca mélange is composed of a volcano-sedimentary unit in the north, whereas the Göksun meta-ophiolite (Tarhan, 1982,1984) and/or the Göksun ophiolite in the south (Yılmaz et al., 1993a) and İspendere-Kömürhan ophiolite (Yazgan, 1983) represent ordered ophiolitic sequences including, from bottom to top, serpentinite and peridotite, wehrlitic and gabbroic cumulates, isotropic gabbro and, locally, a diabasic sheeted dyke complex and pelagic volcaniclastic rocks. The ultramafic cumulates of the Guleman ophiolite begins with dunites that are followed upward by alternations of wehrlite and clinopyroxenite. The gabbroic section comprises represented by troctolite, gabbro and quartz diorite (Özkan and Öztunalı, 1984, Aktaş and Robertson, 1984).

The Gevaş ophiolite is exposed in an E-W-trending narrow belt immediately to the south of Lake Van, and comprises serpentinized ultramafic rocks, cumulate and isotropic gabbros, microgabbro and plagiogranite overlain by extrusive rocks and pelagic sediments (Yılmaz et al., 1981b). In addition, the Cilo ophiolite includes two tectonic slices, showing reversed stratigraphic order. Whereas the lower slice comprises pillow lavas with dykes and sill layers, the upper slice is made up of cumulate sequences; both slices are cut by some granitic injections (Yılmaz et al., 1979; Yılmaz, 1985b).

In southeastern Anatolia, the Koçali mélange represents an imbricated unit that is located between wildflysch of the Karadut complex and ophiolitic sequences. The matrix of the mélange is made up of sheared serpentinites or multicolored radiolarian mudstones, cherts, shales and interlayered basaltic lavas (Yılmaz et. al., 1993b).

As a result, it may be concluded that the ophiolites and ophiolitic mélanges of this belt are tectonic alternations, and were formed and emplaced synchronously.

Ophiolite geochemical signature and tectonic setting

The ophiolites of the Antalya Complex possibly formed in an oceanic ridge (Juteau et al., 1977) and/or a suprasubduction zone (Robertson, 1993; Bağcı et al., 2002, 2006). In terms of trace- and rare-earth-element chemistry, the Mersin ophiolite has the chemical signature of MORB and VAB, suggesting a suprasubduction zone. Structural evidence from the sub-ophiolitic metamorphic sole suggests that the Mersin ophiolite was obducted over the Bolkardağ Mesozoic carbonates, from SE to NW (Parlak et al., 1995). The MORB- and

VAB- type tectonic settings are valid for other ophiolitic massifs along the SAOB (Erendil, 1983; Aktaş and Robertson, 1984; Tarhan, 1986; Dilek, 1995; Parlak et al., 2009; Varol et al., 2011). Field, geochemical and petrographical evidence suggest that the Cilo ophiolite also represents an ensimatic island-arc association emplaced onto the Arabian Platform (Yılmaz, 1985b).

In southeastern Turkey, the Bitlis Massif as the main metamorphic unit of the eastern Taurus Belt is thrust southward over an ophiolitic-flysch complex, which is also thrust southward over sedimentary rocks of the Arabian foreland (Hall, 1976). This geodynamic setting is valid for a great number of the ophiolitic units of southeastern Turkey. Within this framework, the Koçali mélange developed in a subduction zone between the Bitlis Massif and the Arabian foreland (Hall, 1976). Detailed mapping of the Bitlis Suture, to the southwest of Lake Hazar also shows that thrust faults between units are north-dipping, listric and, collectively, make up a thin-skinned system (Sungurlu, 1974; Sungurlu et al., 1984; Hempton, 1985).

The ophiolites of SE Turkey were emplaced northward as large slices, possibly over the arc-trench gap, and also moved southward by gravity-sliding onto the formerly passive Arabian margin (Aktaş and Robertson, 1984).

However, there is a critical area between Uzunyayla and Kahramanmaraş where the setting of the ophiolites and mélanges has been approached and discussed from different points of view. For instance, Yılmaz et al. (1993a) suggested that the Göksun ophiolite originally may have been a klippe from the overturned ophiolitic sequence over the Keban-Malatya Metamorphic Unit; conversely, on the basis of evidence presented by Perinçek and Kozlu (1984), Yılmaz et al. (1993b) and Robertson et al. (2006), this ophiolite (and/or the Berit ophiolite) may crop out as a tectonic window beneath the Malatya Metamorphic Unit. If that is the case, the huge metamorphic nappe should have passed over the ophiolite; therefore, the ophiolite should have been highly metamorphosed. However, the Göksun ophiolite has not been metamorphosed to a high grade, although the root zone comprises high-grade meta-ophiolitic rocks within the Pütürge Metamorphics. Therefore, the Southeastern Anatolian Suture should be situated between the Pütürge Metamorphics and Keban-Malatya Metamorphics of the Anatolide-Tauride Platform (Figure 8).

Robertson et al. (2006) pointed out that the Binboğa mélange (Dağlıca mélange of Yılmaz et al., 1993a) was a product of a northerly Mesozoic oceanic basin, and the Berit (or Göksun) ophiolite formed as an incipient oceanic arc within the southern branch of Neotethys during the Late Cretaceous. In addition, on the basis of Parlak et al. (2012) tectonic restoration of the region suggests that an ocean basin existed between the Malatya- Keban platform to the north and Bitlis-Pütürge continental unit to the south and Upper Cretaceous ophiolites and incipient volcanic arc are interpreted to have formed above a north-dipping subduction zone within this ocean.

It is compulsory to consider the geology of the eastern Taurides as a whole. The Gürün relative autochthon (Yılmaz et al., 1993a) constitutes the main axis of the Taurus Carbonate Platform, which separates the northern ophiolitic associations (e.g., the Pınarbaşı ophiolite and Kireçliyayla mélange) from the southern ophiolitic associations (e.g., the Göksun ophiolite and Dağlıca mélange) as seen in Figure 8. However, the age of the ophiolitic associations on both sides is Late Cretaceous, while the age of the platform is Cambrian-Lower Eocene without a break between Uzunyayla and Beritdağ areas along the Gürün relative autochthon (Yılmaz et al., 1993a). In this framework, the northern ophiolitic association is part of the northern branch (and/or Inner Taurides) of Neotethys, whereas the southern ophiolitic association is part of the southern branch of Neotethys. In addition, the tectonic setting of the ophiolites is another important question. On the basis of our field study, the setting of ophiolites is different from that previously envisaged, vis-à-vis Yılmaz et al. (1993b) and Robertson et al. (2006).

Figure 8 shows the setting of the tectonic units between Uzunyayla and Kahramanmaraş. The root zone of the ophiolite can be seen to the north of Ilıcaköy. The Göksun ophiolite is situated between Binboğa Dağ and Berit Dağ, and the top of the ophiolite is not tectonically overlain by the Keban-Malatya Metamorphics. The northern contact represents a young, overturned structure. It is clear that the lower levels of this ophiolite are gabbro and the upper levels are a sheeted dyke complex preserved along this overturned structure. The southern contact is an active fault (the Sürgü fault). In addition, the ophiolite is located between the root zone and the Dağlıca mélange to the north (Yılmaz et al., 1993a), and the Dağlıca mélange is located to the south of the TUA. In this area, the ophiolite and mélange together are products of the southern branch of Neotethys. As a result it is not necessary to interpret the setting of the ophiolite as a tectonic window in the Göksun area. The original setting of the ophiolite may have been changed later during collisional processes.

Figure 9 shows the setting of the tectonic units in the area between Bingöl and Silvan (Diyarbakır). This section is a characteristic one; here, it is possible to exactly determine the present relationships between the Anatolide-Tauride block (that is the Bitlis Massif) and Arabian Platform with the Southeast Anatolian Suture. The Koçali mélange with associated ophiolite represents a suture-zone product.

In addition, it is possible to envisage a combined setting for the ophiolites and different ophiolitic mélanges in the Late Cretaceous. Figure 10 shows a simplified setting for the ophiolitic associations along a geotraverse between the İstanbul zone and the Arabian Platform during Late Cretaceous time. In the beginning of the Late Cretaceous, all data allow us that double arc systems were active both to the south of Pontides and also to the north of the Arabian Platform (Figure 10A). This perspective explains, better than previously proposed models, the setting of the ophiolitic associations and the reasons for the metamorphic complexes with their evolutionary history. In addition, it is clear that metamorphic complexes along both sides of the TUA are equivalents of the Anatolide-Tauride Platform, which cropped out beneath ophiolitic associations as tectonic windows and suggest intense deformation of platforms near suture zones (Figure 10B).

In fact, along the Southeast Anatolian Suture, south-facing overthrusts predominate (Figure 11A) and were reactivated during the late Tertiary. However, in the Gevaş (Yılmaz et al., 1981b) and Göksun areas (Yılmaz et al. 1993a), north-facing overthrusts are defined along northern contacts of the ophiolitic units. On the basis of these data, the structures delineating the ophiolitic units show both south- and north-facing overthrusts together in the same tectonic settings (Yılmaz et al., 2010).

In short, many of the ophiolites of southern Turkey formed during the progressive elimination of the southern branch of Neotethys above a north-dipping, intra-oceanic subduction zone.

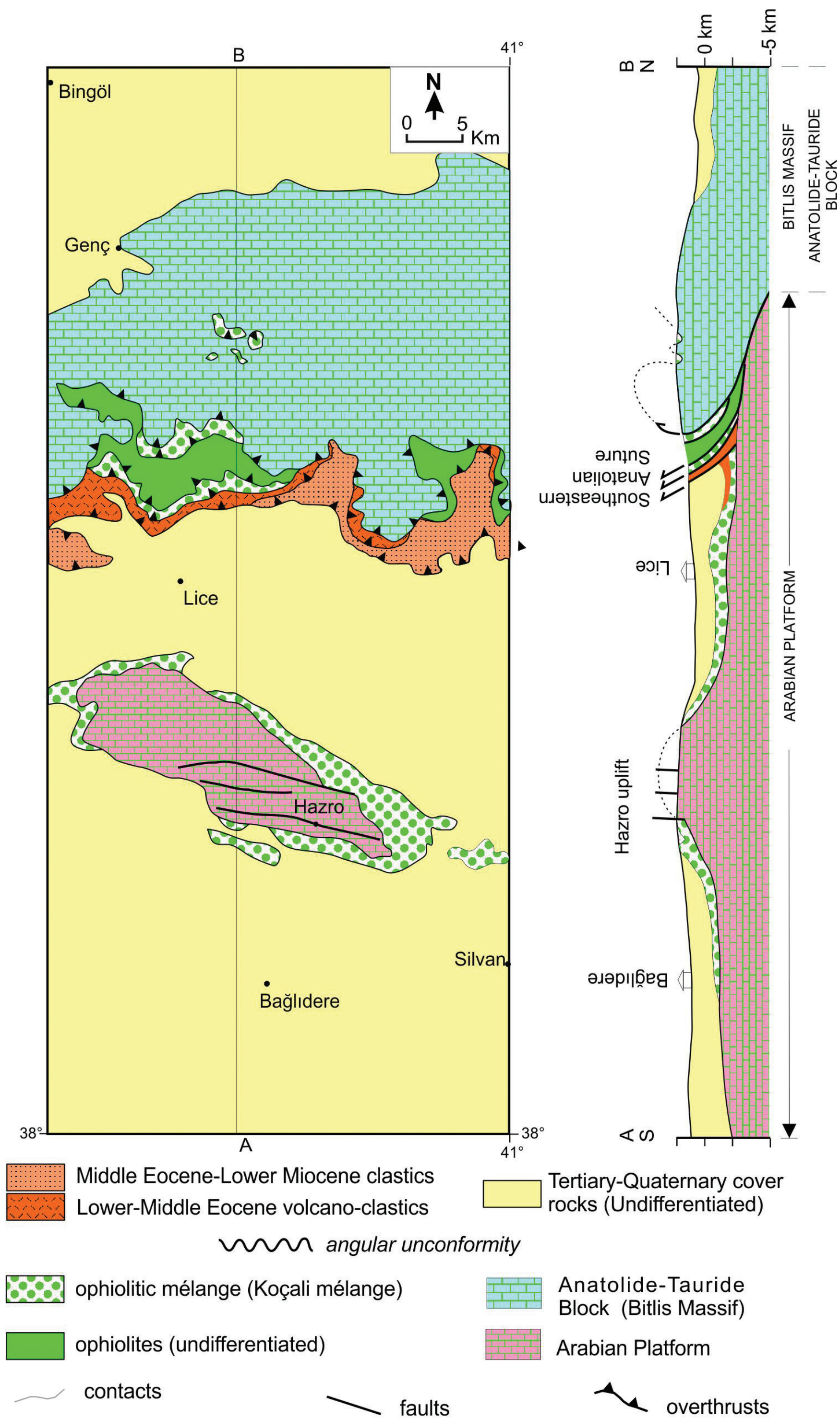

Figure 9. Simplified geological map and cross-section of the area between Bingöl and Silvan (Diyarbakır) (MTA, 2002 and new observations). See Figure 1 for location.

Şekil 9. *Bingöl ile Silvan (Diyarbakır) arasındaki bölgenin yalınlaştırılmış jeoloji haritası ve enine kesiti (MTA, 2002 ve yeni gözlemler). Yer için Şekil 1'e bakınız.*

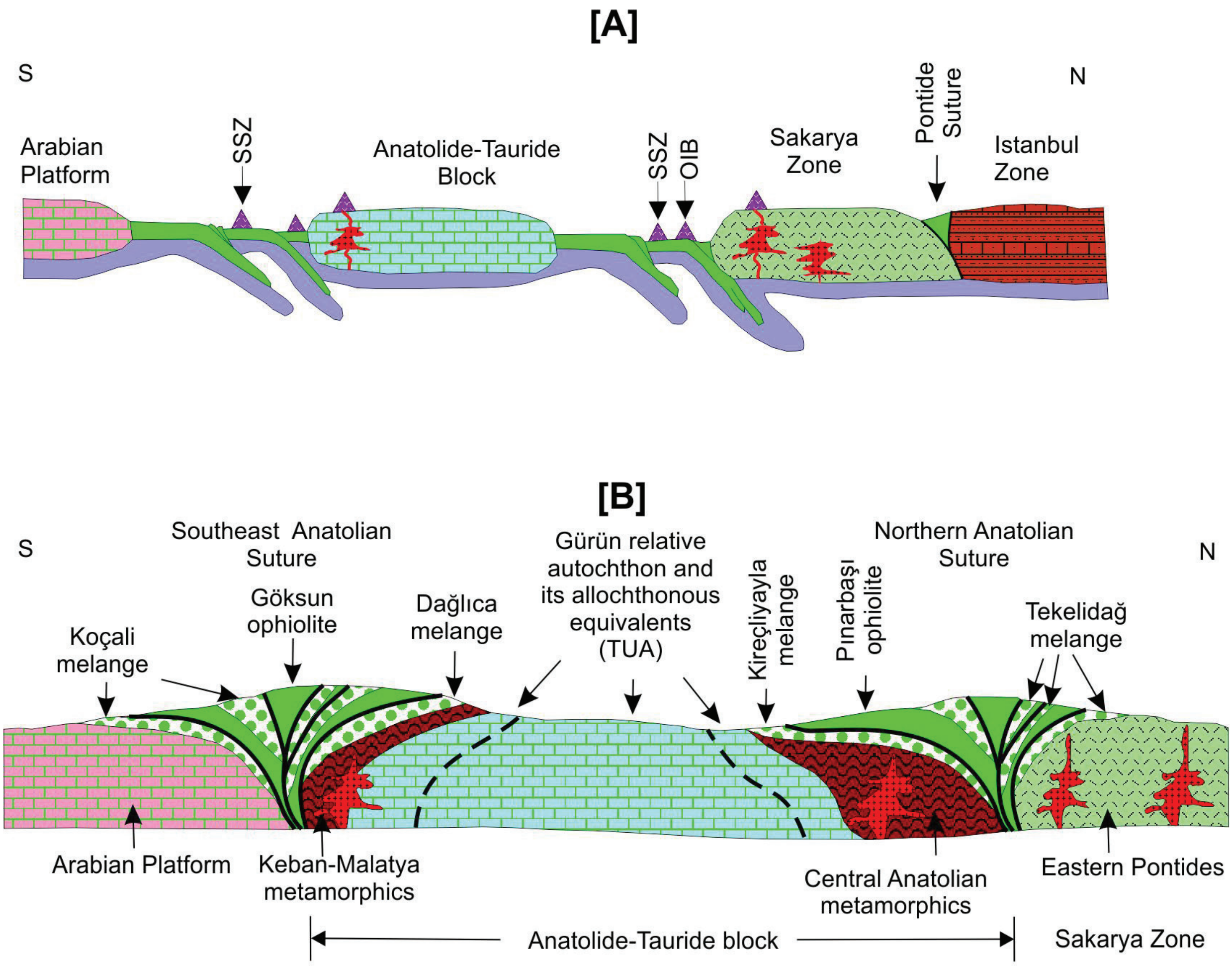

Figure 10. A probable generalized geological cross-section between the İstanbul Platform and Arabian Platform at the begining of the Late Cretaceous [A] and between the Pontide and Arabian Platform at the end of Late Cretaceous time [B]. No scale.

Şekil 10. *Geç Kretase başlangıcında İstanbul Platformu ve Arap Platformu arasının genelleştirilmiş olası bir enine jeoloji kesiti [A] ve Geç Kretase sonunda Pontitler ve Arap Platformu arasının genelleştirilmiş olası bir enine jeoloji kesiti [B]. Ölçeksiz.*

As a result, it is thought that the ophiolites and ophiolitic mélanges of the Southeast Anatolian Suture may have risen and been emplaced due to collision between the Anatolide-Tauride block to the north and the Arabian Platform to the south. The ophiolites associated with ophiolitic mélanges spread to both north and south as flower structures (Figs. 9, 10 and 11) and were eroded following the Late Maastrichtian. The present setting and distribution of the ophiolites with ophiolitic mélanges in the area is a result of erosion and the formation of a Tertiary foreland basin (Yılmaz et al., 2010).

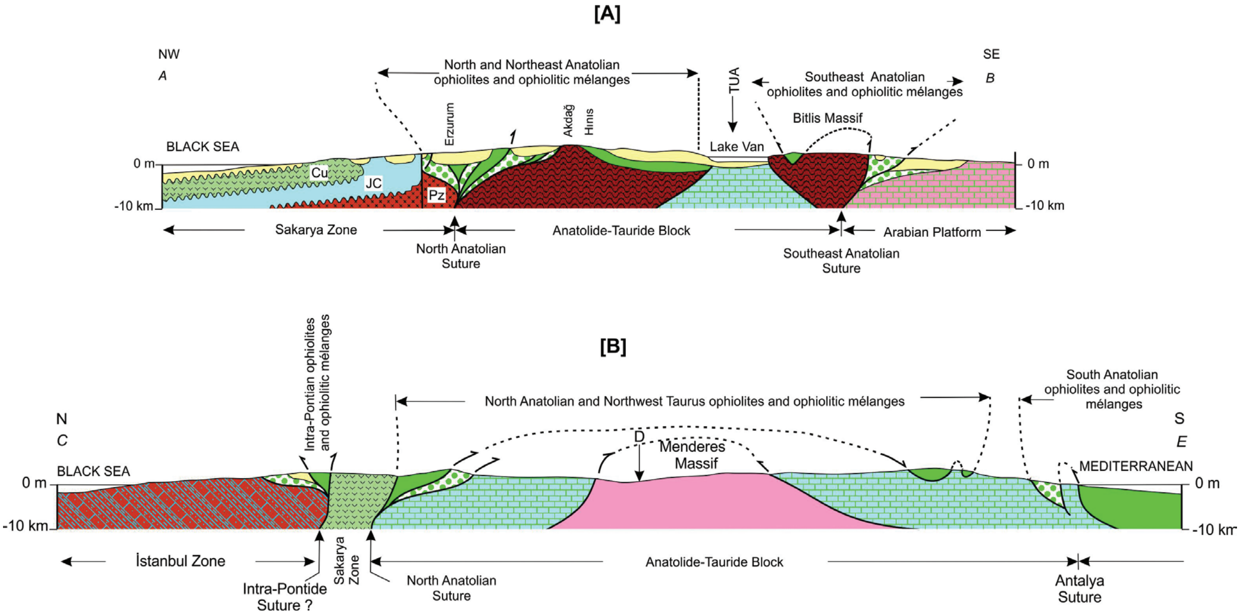

Figure 11. Simplified recent geological cross-sections of the eastern (A-B) [A] and western (C-D-E) [B] parts of Turkey: Paleozoic (Pz), Jurassic-Cretaceous (JC) and Upper Cretaceous (Cu) levels have been differentiated in the eastern part of Pontide-Transcaucasus continent-arc system. See Figure 1 for location.

Şekil 11. *[A] Türkiye'nin doğu kesimi (A-B) ile [B] batı kesiminin (C-D-E) yalınlaştırılmış enine kesitleri: Pontid-Kafkasya kıta-yay sistemi'nin doğu kesiminde, Paleozoyik (Pz), Jura-Alt Kretase(JC) ile Üst Kretase (CU) yaşlı düzeyler ayırt edilmiştir. Kesit yerleri için Şekil 1' e bakınız.*

Geological age

On the basis of geochronological evaluations of the Antalya ophiolite, the age of the ultramafic cumulate is 122 Ma, the cumulate gabbro 50 ± 10 or 68 ± 5.5 Ma, and the diabase 55 ± 3 Ma or 69 ± 4 Ma, whereas the age of the mélange is Late Cretaceous (Yılmaz, 1982). Robertson and Woodcock (1982) and Robertson (1993) reported a Late Cretaceous age from pelagic carbonate rocks interbedded with mafic volcanic rocks, and also suggested that the oceanic crust of the region was created during Late Cretaceous time, associated with submergence and onset of pelagic carbonate deposition on platform areas. On the basis of evidence set forth by Robertson (1993) and Bağcı et al. (2006), regional compression in Antalya area began in the latest Cretaceous (Maastrichtian) and led to subduction-accretion, as evidenced by volcanic-sedimentary mélange. Suturing was completed during the Late Paleocene-Early Eocene, resulting in collision and imbrication of the carbonate platform.

K-Ar analyses of rocks from the Mersin ophiolite yield an age of 93.4 ± 2.2 Ma, recording the initial detachment of the oceanic crust (Parlak et al., 1995).

The fossil contents of the volcano-sedimentary unit of the ophiolites in the Göksun (Tarhan, 1982, 1984; Yılmaz et al., 1993a) and Kızıldağ areas indicate an age of Jurassic-Late Cretaceous (pre-early Maastrichtian) (Tinkler et al., 1981; Tekeli et al., 1983). The age of volcanic sequences of the Koçali complex between Malatya and Adıyaman has been assigned to late Triassic based on the radiolarian data from the associated pelagic rock units (Varol et al., 2011) and late Jurassic-early Cretaceous (Sungurlu, 1974; Uzuncimen et al. 2011)). K/Ar radiometric dating of the biotites from granodiorites associated with the İspendere-Kömürhan meta-ophiolites yielded ages of 75 ± 2.5 Ma (Yazgan, 1983). In addition, paleontological and radiometric means of dating ophiolites along the SAOB yield Jurassic to Late Cretaceous ages (90-145 Ma) (Dilek and Moores, 1990). Granitoids associated with the ophiolites exhibit an age range from 82 Ma to 85 Ma, based on $^{40}Ar/^{39}Ar$ analyses (Rızaoğlu et al., 2009).

However, the ophiolitic mélanges of the SAOB yield only Late Cretaceous ages. For instance, the Dağlıca mélange of the Göksun area comprises Late Cretaceous and unmetamorphosed Upper Maastrichtian clastic rocks, including blocks of ophiolites and metamorphic rocks that unconformably overlie the ophiolitic sequence in the Bitlis area (Perinçek 1980; Göncüoğlu and Turhan, 1984). This relationship indicates that the emplacement age of the Gevaş ophiolite in the Bitlis area is pre-late Maastrichtian. Sungurlu (1974), Perinçek (1979a, 1979b, 1980) and Aktaş and Robertson (1984) also suggested that the ophiolites of SE Turkey were emplaced during latest Cretaceous time

On the other hand, the matrix of the Koçali mélange typically yields Late Cretaceous ages (Yılmaz et al. 1993b; Uzuncimen et al., 2011). However, the geological age of the Cilo ophiolite is Late Mesozoic, having been emplaced onto the Arabian Platform during the Late Cretaceous (Perinçek, 1990). Therefore, it may be said that the mélanges of this region developed during emplacement of the ophiolites.

The Elazığ Igneous Complex comprises an imbricated Maastrichtian-Early Eocene island arc and young marginal-basin terrain which evolved until the Middle Eocene (Hempton, 1985). In addition, the Eocene Maden mélange and the Miocene Çüngüş mélange (Özkaya, 1982), along with other rock associations such as the Maden complex (Perinçek 1979a, 1979 b, 1980; Sungurlu et all 1984; Perinçek 1990; Yiğitbaş and Yılmaz, 1996), may be materials reworked from the Koçali mélange.

On the basis of the age interval mentioned above, it may be concluded that the age of SAOB ophiolites is Mesozoic, in general and the age of mélanges is Late Cretaceous, at least pre-Maastrichtian. In southeastern Turkey, ophiolites and mélanges were emplaced southward onto the Arabian Platform in latest Cretaceous (Campanian) time (Sungurlu 1974; Perinçek 1979b, 1980; Sungurlu et al., 1984; Robertson, 2000, 2002). In addition, the Jurassic-Cretaceous ophiolites, in general, are MORB-type, whereas the Upper Cretaceous ophiolites are SSZ-type ophiolites (Robertson, 1994; Parlak et al., 1996; Dilek et al., 1999).

DEFINING SUTURE BELTS IN TURKEY

The relationship between suture belts and ophiolitic associations has been discussed for a long time. Burke et al. (1977) pointed out that there is a link between the global distribution of sutures and the sites of former oceans. In addition, the ophiolites have been interpreted as indicators of the geodynamic evolution of the oceans (Knipper et al., 1986). Accordingly, it is necessary to demonstrate the relationships between the Tethyan oceans and ophiolitic associations.

In fact, there is no a consensus on the classification of the Tethyan realms. For instance, Paleotethys has been regarded as an oceanic basin along the Greater Caucasus (Belov, 1981; Adamia et al., 1982) and also along the Lesser Caucasus (Gamkrelidze, 1982). In the present study, the classificaton of Şengör and Yılmaz (1981) has been adopted for using as a general framework.

Without entering into a detailed description of ophiolitic complexes, it is impossible to review the different geodynamic environments in which ophiolites have developed, evolved and were later accreted to continents. In this respect Turkey is a place of critical importance, for here it is possible to demonstrate the relationship between suture zones and the ophiolitic association.

Thus, in this context, it is proposed to define the suture zones and related ophiolitic associations of Turkey. Figure 11 gives simplified cross-sections of the eastern [A] and western [B] parts of Turkey. In these cross-sections, it is possible to see the exact locations of root zones of the sutures and the distribution of ophiolites, with mélanges. As is seen in Figures 10 and 11, the metamorphic equivalents of the Anatolian-Iranian Platform are situated as tectonic windows beneath the ophiolites of the eastern and western Anatolian regions. The tectonic setting of the Central Anatolian Metamorphic Complex may be similar to a tectonic window as well. Figure 12 illustrates the sutures of Turkey and surroundings as a whole. In this presentation, it is also possible to correlate the sutures of Turkey and surrounding areas.

On the basis of explanations presented above, three main sutures have been defined. These are the Intra-Pontide Suture in the northwest, the North Anatolian Suture in the middle of the country, and the Antalya Suture with the Southeast Anatolian Suture in the south (Figure 12).

In this context, following correlation of the tectonic units, a new classification of the continental fragments may be suggested. For instance, the İstanbul zone can be correlated with the Moesian and Scythian Platforms. The Sakarya zone is located between the Intra-Pontide Suture and the North Anatolian Suture. The Anatolide-Tauride block can be separated from the Arabian Platform (and also the African) by the Antalya and Southeast Anatolian sutures. This simple classification reflects the actual situation of the continental fragments of Turkey and surrounding areas better than previously suggested classifications.

Today, southeastern Turkey records a post-collisional setting, whereas areas to the southwest of Turkey are experiencing the incipient collision of the Arabian and Turkish plates (Robertson, 2000).

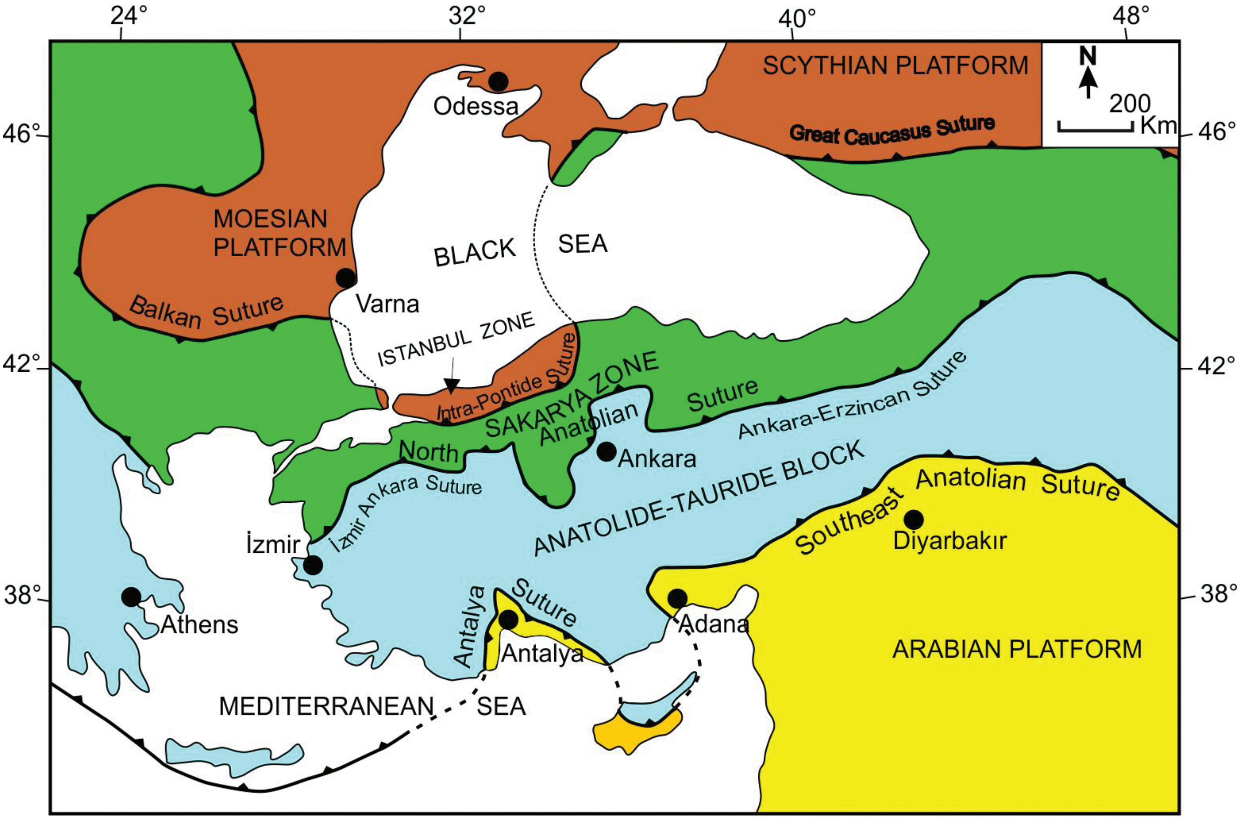

Figure 12. Simplified tectonic units and suture belts of Turkey and surrounding regions.
Şekil 12. *Türkiye ve yakın dolayının yalınlaştırılmış tektonik birlikleri ve kenet kuşakları.*

The Intra-Pontide Suture

Şengör and Yılmaz (1981) called Intra-Pontide Suture as the suture of the northern branch of Neotethys which seperated the Rhodope-Pontide fragment from the Sakarya continenet. Then this suture was used to denote the suture seperating the Paleozoic of the İstanbul and Karakaya complex of the Sakarya zone (Okay, 1989). However, this suture coincides with the North Anatolian Fault Zone (Barka, 1992), as well. Pre-Alpine ophiolites and mélanges cropout along the suture; accordingly, these ophiolitic associations have been interpreted as products of Paleotethys (e.g., Yiğitbaş et al., 1999). In this framework, the Intra-Pontide suture is the best candidate for the Palaeo-Tethyan suture in Turkey (Okay, 1989).

Nevertheless, the ophiolitic associations of the Intra-Pontide oceanic basin are also dated as Late Cretaceous and interpreted as the products of a branch of Neotethys (Yılmaz et al., 1995; Robertson and Ustaömer, 2004; Göncüoğlu et al., 2008). On the other hand, Göncüoğlu et al. (2008) suggested that MORB-type basalts were generated in the Intra-Pontide Ocean during the Late Jurassic, and that the ocean existed at least between the Late Bathonian to Santonian based on paleontological and geochronological data. In addition, the preliminary observations on the melange suggest its formation in Late Cretaceous during the closure by obduction of an oceanic basin originated in Middle to Late Jurassic time span between the Eurasian plate and Sakarya microplate (Ellero et al., 2012).

In this framework, the Intra-Pontide Suture can be interpreted as a relict not only of the long-lived Paleotethys but also Neotethys and/or the Late Cretaceous ophiolitic associations may be reworked materials from the Paleotethys.

There are no data regarding the age of opening and for the well-recognized passive margin sequences of the Intra-Pontide Ocean. The İstanbul zone may represent a northern passive margin of the paleo-ocean. The age of its closure, generally based on the appearance of the first transgressive sediments, is either placed in the Paleocene-Eocene (Şengör and Yılmaz, 1981) and Eocene-Oligocene (Okay et al., 1994), Late Cretaceous (Yılmaz et al., 1995), or the Cenomanian (Tüysüz, 1999). It is well known that Upper Cretaceous-Tertiary series in the region between the Black Sea and Bursa indicate pre-Santonian juxtaposition of the İstanbul and Sakarya zones (Özcan et al., 2012). Data related to the original location and setting of the suture was obliterated during formation of the North Anatolian Fault and, consequently, this situation resulted in the duplication of major suture zones (Stampfli and Borel, 2004).

As a result, it may be emphasized that the opening and closing ages of the oceanic basin and also the polarities of the subduction zone are highly speculative and controversial. Therefore, the opening and closing of Paleotethys and/or the northern branch of Neotethys in this region remains an important question.

The Balkan Suture (Yanev and Adamia, 2010) may be the northwestern extension, whereas the Great Caucasus Suture may be northeastern extension of the Intra-Pontide Suture. In this framework, the İstanbul zone and the Moesian and Scythian platforms were periodically the main parts of the East European Platform (IGC, 1984).

North Anatolian Suture

The North Anatolian Suture separates the Sakarya Zone to the north from the Anatolide-Tauride block to the south (Figs. 11, 12). The western part of this suture is known as the İzmir-Ankara-Erzincan suture (Şengör and Yılmaz, 1981; Okay, 1989; Rice et al. 2009), which is linked to the Vardar suture (eg. Zelic et al,. 2010). The Eastern part of the suture is known as the North Anatolian-Lesser Caucasus suture (Yılmaz, 1989; Yılmaz et al., 2000, 2010).

It is known that the eastern Taurus belt of Turkey may be correlative to the Sanandaj-Sirjan belt of Iran (Yılmaz and Yazgan, 1990). Thus, the Anatolian-Iranian Platform (AIP) has been defined within a regional framework, and the southern edge of the eastern Taurus belt with the Sanandaj-Sirjan belt has been re-interpreted as the southern passive margin of the AIP (Yılmaz et al., 2010).

This suture zone is generally accepted as being the major Tethyan suture in Turkey and characterized by widespread ophiolitic slices with accretionary mélange units. The ophiolitic slices generally consist of peridotite massifs, lacking a complete ophiolitic sequence.

The opening age of the western part of the northern branch of Neotethys originally was suggested to be Late Triassic (Göncüoğlu et al., 2006), and for the eastern part of the northern branch of Neotethys was suggested to be Early Liassic (Görür et al., 1983). However, there are also pre-Liassic ophiolites in the Erzincan area (Koçyiğit, 1990, 1991) and Paleozoic ophiolites along the Lesser Caucasus Ophiolitic Belt (Zakariadze et al., 1983), which represents the eastern continuation of the North Anatolian Suture. In this framework, it is not possible to explain the existence of old ophiolitic units well along the suture.

It is suggested that the ophiolites obducted in the east before the Late Coniacian (Gasanov, 1986), at least before Paleocene (Sosson et al., 2010). $^{40}Ar/^{39}Ar$ ages of the units along the Lesser Caucasus suture give insights for the subduction and collage from the Middle to Upper Cretaceous (95-80 Ma) (Roland et al., 2009, 2011).

On the other hand, blueschists dated at 100-90 Ma are recorded in NW Turkey (Okay et al., 2006). Although Rice et al. (2009) suggest that Late Paleocene-Eocene clastics are the oldest unit unconformably overlying the Upper Cretaceous melange in the Erzincan area, reworked materials of ophiolites and melanges have not been separated from the Upper Cretaceous accretionary prism in this study. Akdeniz et al. (1994) and Yılmaz and Yılmaz (2006) suggested that Late Campanian-Maastrichtian clastic units overlied unconformably the ophiolitic units. In this framework, it can be said that subduction was dominanat, in general during Cretaceous.

On the other side, the ophiolitic outcrops of this belt are scattered to the north and south of the suture. Due to young basin-fill cover, it is not possible to examine the relationships between the scattered outcrops as well. Thus, the ophiolitic associations of this belt have been divided into two sub-belts: northern and southern. The northern sub-belt represents the NAOB directly, and the southern sub-belt represents tectonically transported ophiolitic units of the NAOB..

Most of ophiolitic associations in Turkey are believed to have originated from the North Anatolian Suture. Both Alpine and pre-Alpine ophiolitic associations crop out along the suture. The opening age of the northern branch of the ocean is, therefore, not well-established and is quite controversial.

Numerous tectonic models have been suggested for the evolution of the NAOB. A single northward-dipping subduction zone (Şengör and Yılmaz, 1981), two northward-dipping subduction zones (Tüysüz, 1990), southward-dipping subduction, followed by reversal of subduction direction (Okay and Şahintürk, 1997), single northward-dipping subduction with the genesis and emplacement of a marginal basin (Ustaömer and Robertson, 1997), northward-dipping subduction followed by southward-dipping subduction (Rice et al., 2009) are some of the suggested tectonic models. The main reason of different models is the the lack of data, mainly about ophiolites and melanges.

In spite of lack data, it is possible to suggest some constraints for the Late Cretaceous time. For instance, along the North Anatolian Suture, MORB- and SSZ-type ophiolites crop out together, and north- and south-facing overthrusts are widespread. Structural studies indicate that the ophiolitic complexes and/or assembled accretionary prisms were emplaced northward onto the Pontides of the Eurasian margin and also southward onto the Taurides of the Gondwana margin during Campanian-Maastrichtian time (Yılmaz, 1985b; Rice et al., 2009) in the Erzincan area. In this framework, a new model for Late Cretaceous (Figure 10) has been suggested to explain the setting of two northward-dipping subduction zones with emplacements of ophiolites like a flower structure. All other data also indicate that the setting of the obducted ophiolitic units resembles a flower structure, as defined in the area between Tokat and Sivas (Yılmaz and Yılmaz, 2004a).

In NW Turkey, the collision between the Tavşanlı zone of the Anatolide-Tauride Zone and the Sakarya Zone of the western Pontides began before Paleocene and Eocene magmatism, interpreted to have developed in a post-collisional setting (Okay and Şahintürk, 1997; Okay et al., 2010). For NE Turkey, Rice et al. (2006) suggested that the incipient 'soft' collision along the suture was followed by widespread Paleocene-Early Eocene sediments on deformed and emplaced melange, arc and ophiolitic units. Final closure 'hard' collision of the Northern Neotethys occurred during the Mid-Eocene.

On the other hand, Yılmaz (1985a) pointed out that Eocene clastic materials overlie the older tectonic units unconformably along the upper Kelkit River, and Topuz et al. (2011) suggested that Eocene magmatism represents post-collisional adakite-like activity within the Agvanis Massif. In addition, sedimentary sequences on both sides of a suture are expected to show similar depositional characteristics on the continental margins. In this respect the collision between the Pontides and the Anatolide-Tauride block should be at least pre-Middle Eocene.

Antalya and Southeast Anatolian Sutures

The Antalya suture (or the Pamphylian suture of Okay and Tüysüz, 1999) is situated between the western Taurus Platform and obducted ophiolites (Figure 7), whereas the Southeastern Anatolian Suture separates the Anatolian-Iranian Platform to the north from the Arabian Platform to the south (Figure 9). Along the SAOB, Jurassic-Lower Cretaceous MORB- type ophiolites and Upper Cretaceous SSZ-type ophiolites occur, and these ophiolites were accreted to the Upper Cretaceous mélange prism during the Late Cretaceous. MORB- and SSZ-type ophiolites are widespread in the Antalya, Mersin and southeastern Anatolian regions.

The Southeast Anatolian Suture (Yılmaz et al., 1993b) and/or Assyrian and Zagros sutures (Okay and Tüysüz, 1999) separates the Anatolide-Tauride block to the north from the Arabian Platform to the south (Figs. 11 and 12). The Antalya Suture may be a western continuation of the Southeastern Anatolian Suture.

The Alpine ophiolites and mélanges of eastern Turkey are believed to have originated from the Southeast Anatolian Suture. These rocks are products of the southern branch of Neotethys, and the products of this suture may be separated from the Northern and Northeastern Anatolian Alpine Ophiolitic Belt (NAOB) by the TUA of the Tauride-Anatolide block (Figure 1).

The ophiolitic outcrops of this suture are also scatterred to the north and south of the suture. Therefore, the location of the suture is still under discussion. For instance, some suggest that the suture lies to the south of the Bitlis and Pütürge Massifs (Şengör and Yılmaz, 1981; Yılmaz et al., 1993b), while others argue that the suture is located to the north of the massifs (Yazgan, 1983; Michard et al., 1984). However, on the basis of data given in Figures 8 and 9, and scenarios given in Figure 10, the location of the suture should be to the south of the Bitlis Massif, but north of the Pütürge Massif. The Keban-Malatya Metamorphics and the Bitlis Massif have similar stratigraphic sequences and represent the southern metamorphic edge of the Tauride-Anatolide block (Yılmaz et al., 2010). However, the Pütürge Massif is dissimilar from these two metamorphic units due to its relatively high metamorphic grade.

The opening age of the southern branch of Neotethys was Triassic (Perinçek, 1980; Şengör and Yılmaz, 1981). However, the Alpine cycle of the southeast Anatolian region was initiated with Late Permian-Middle Triassic rifting (Altıner, 1989). $^{39}Ar/^{40}Ar$ dating of white mica in different parageneses from the Bitlis comlex reveals a 74-79 Ma (Campanian) date of peak metamorphism and rapid exhumation to an almost isothermal greenschist stage at 67-70 Ma (Maastrichtian) (Oberhänsli et al., 2012).

All data show that subduction along the suture is dominant mainly during Late Cretaceous (Robertson et al., 2007). However, the collision of the Arabian margin below the Bitlis Massif is still debated. For collision, it has been proposed as Maastrichtian (Yazgan, 1983), Mid to late Eocene age (Hempton, 1985), a late Eocene to Oligocene (Yılmaz, 1993), Early- Middle Miocene (Robertson et al., 2007) and before the Late Miocene (Şengör and Kidd, 1979; Dewey et al., 1986; Şengör et al., 2003). In addition, uplift of the final exhumation of the Bitlis Massif range by 18-13 Ma (Middle to Late Miocene) is documented on the basis of apatite fission track dating (Okay et al., 2010). Late Miocene molasse deposits overlie the older tectonic units unconformably from north to south throughout the region. Therefore, the collision may have been ended before Late Miocene along the suture.

Along the Southeast Anatolian Ophiolitic Suture (SAOB), south-facing overthrusts predominate. However, north-facing overthrusts and active faults are recognized along the northern contacts of the ophiolitic units. On the basis of these data, structures delineating the ophiolitic units show both south- and north-facing overthrusts.

Consequently, it is thought that the ophiolites and mélanges of the Southeast Anatolian Suture may have been uplifted during collision between the Anatolide-Tauride block to the north and the Arabian Platform to the south. The ophiolites associated with ophiolitic mélanges then spread like a flower structure to the north and south, *en masse*, and later eroded prior to the Late-Maastrichtian. The present-day configuration of the ophiolites and ophiolitic mélanges of the area is a result of erosion and the formation of new basins (Yılmaz et al., 2010).

In addition, on the basis of existing exotic blocks derived from the south Taurides, it appears that Turkey underwent large lateral displacements in a roughly E-W direction; this movement resulted in duplication of major suture zones (Stampfli and Borel, 2004). Major strike-slip movements during the Variscan orogenic cycle produced the first juxtaposition of terranes (Moix et al., 2008). The present juxtaposition of these terranes is far from their original locations. For instance, Moix et al. (2008) suggested that the Anatolian terrane was detached from Eurasia, which was accreted to the Taurus-Cimmerian domain in the Late Triassic and then moved together with Gondwana. Therefore, the geological history of the southern branch of Neotethys is relatively complex and needs more detailed study.

If we correlate the suture zones as a whole, it is clear that all of the suture zones in Turkey are characterized by ophiolitic mélanges and by both MORB-type and SSZ-type ophiolites. It may be suggested that the North Anatolian and Southeast Anatolian sutures were double north-dipping subductions during emplacement of the ophiolitic associations.

In conclusion, a preferable tectonic model for the Southeastern Anatolian Suture should involve northward subduction including MORB- type ophiolites and SSZ-type ophiolites together. Subduction is dominant during Late Cretaceous- Early Tertiary, the collision along the suture may have occurred before Late Miocene. Recent emplacement of ophiolites shows a flower structure, because of the north-facing and south-facing overthrusts.

COMPARISONS OF THE OPHIOLITIC BELTS IN TURKEY WITH SURROUNDING REGIONS

On the basis of definition and distribution, stratigraphical features, ophiolite geochemical signature and tectonic setting and geological age, it is possible to compare and/or correlate the ophiolitic belts of Turkey with surrounding regions for pre-Alpine and Alpine stages.

Pre-Alpine Stage

For instance, the Paleotethyan ophiolites located to the south and southeast of the İstanbul zone may be correlated to the ophiolites of the Greater Caucasus (Adamia et. al., 1978, 1991, 2004, 2011) and the Balkans (Haydoutov, 1987; Von Quadt et. al., 1998). The ophiolitic rocks of the Caucasus and Balkans have also MORB and SSZ signatures and developed during the evolution of Paleotethys (Yanev and Adamia, 2010; Adamia et al., 2011).

In conclusion, although data is lacking with regard to some aspects of the pre-Alpine ophiolites of Turkey, it can be suggested that they developed in a tectonic setting which changed from MORB-type to SSZ--type within the Precambrian-Triassic interval, as defined in the Greater Caucasus and Balkans, as a product of Paleotethys.

The Karakaya Complex represents a part of Sakarya Composite Terrane (Göncüoğlu et. al., 1997) and can be correlated to a part of the Rhodope terrane of the Balkans (Yanev and Adamia, 2010) to the northwest and to pre-Liassic complexes of the Pontian-Transcaucasus continent-arc system (Yılmaz et al., 2010) to the east and northeast. This unit developed in a tectonic setting that changed from a rift to a subduction zone during the Permian-Triassic time interval within the framework of the evolution of Paleotethys. However, there are also local Late Cretaceous mélanges along the Intra-Pontide suture.

In this region, therefore, the pre-Liassic Karakaya Complex and local Late Cretaceous mélanges may be intermixed and/or the Late Cretaceous mélanges may be reworked materials derived from the Karakaya Complex.

In fact, it is accepted that Paleotethys was a Paleozoic-Early Mesozoic ocean and that the Karakaya Complex may be a closing product of Paleotethys (e.g., Bozkurt and Mittwede, 2001, and references therein). However, there is no consensus on the polarity, geological age, and paleogeographic locations of the opening and closing of Paleotethys during the Cimmerian Orogeny.

Alpine Stage

The NAOB can be correlated to the Lesser Caucasus Ophiolitic Belt (Zakariadze et. al., 1983) in the east and the Innermost Hellenic Ophiolitic Belt of the Vardar Zone (Smith, 1993) in the west.

The Lesser Caucasus Ophiolitic Belt includes some magmatic rocks in a serpentinite mélange, and to these can be assigned a Precambrian age; for example, pegmatitic gabbro of the Sevan-Akera subzone yields a K-Ar age of 583±30 Ma (Belov et. al., 1978; Belov, 1981). In addition, the radiometric ages obtained from tonalities (160±4 Ma; Zakariadze et al., 1990) and gabbros (165.3±1.7 Ma; Galoyan et al., 2009) of the Sevan ophiolite suggest that oceanic crust formation continued during the Batonian-Callovian. Radiolarian ages for the sedimentary cover of the Sevan ophiolite indicate late Middle Jurassic (Asatryan et al., 2010). In addition, the age of the Sevan-Akera and also Vedi ophiolites is constrained by $^{40}Ar/^{39}Ar$ dating that has provided a magmatic crystallization age of 178.7±2.6 Ma

(Roland et al., 2010). Jurassic-Neocomian MORB-type and Cenomanian-Early Coniacian island-arc-type ophiolites have been identified along this belt (Zakariadze et. al., 1983). Late Coniacian clastic rocks overlie the ophiolitic units unconformably, which were obducted both northward (Sevan-Akera) and southward (Vadi) along the suture zone (Knipper and Khain, 1980; Sosson et al, 2009).

On the other hand, Vardar Zone boninites of the Kopaonik area (southern Serbia) represent only suprasubduction ophiolites and the melange occurred in the Early Cretaceous (Marconi et al., 2004). The Innermost Hellenic Ophiolitic Belt includes both sub-ophiolitic and supra-ophiolitic mélanges. The sub-ophiolitic mélange contains blocks of ophiolitic material and continental fragments, and represents a subduction-accretion complex. However, the supra-ophiolitic mélange and overlying Tithonian-Valanginian flysch deposits and Barremian-Upper Cretaceous neritic limestone rest unconformably on the ophiolites and platform carbonates. The ophiolites of the Mirdita area of Albania show a transition from MORB to IAT (Island Arc Tholeiite) and boninitic affinities from west to east and structurally upward (Beccaluva et al, 1994; Dilek et. al., 2005). The basalt samples of the Dinaric-Helenic Chain show a N-MOR affinity and are associated with latest Bajocian- early Batonian radiolarian cherts (Nirta et al., 2010). The stratigraphic and structural dataset presented by Zelic et al. (2010) shows complex tectonic history of the Vardar zone, as well.

In conclusion, it can be said that the NAOB and its eastern and western extensions have not only similar but also different stratigraphic features, age and tectonic setting. For instance, although a great deal of the NAOB comprises Alpine ophiolites, there are also pre-Alpine ophiolitic outcrops which have been accreted tectonically to the NAOB and include Jurassic-Cretaceous MORB-type and Late Cretaceous SSZ-type ophiolites. In this respect, there are similarities between the SAOB and Lesser Caucasus, but differences from the Vardar Zone. In addition, the ophiolitic mélange of the NAOB is Late Cretaceous (locally pre-Maastrichtian) in age. Along the ophiolitic belts, where NAOB and SSZ-type ophiolites occur, respectively, the tectonic setting of ophiolites with mélanges is characterized by north-facing and south-facing overthrusts; hence, it may be suggested that the ophiolites with mélanges developed and rose as a flower structure, and then eroded during the collisional and post-collisional processes. Therefore, isolated and scattered outcrops of these units along both sides of the North Anatolian Ophiolitic Suture Zone are not observable at present.

The SAOB consists of relatively complex, undeformed, Triassic (Perinçek, 1980; Uzuncimen et al., 2011) and Jurassic to Late Cretaceous ophiolites with Late Cretaceous ophiolitic mélanges.

The ophiolites and mélanges in the Antalya and Mersin areas may be correlated to similar units of the External Ophiolitic Belt (Bortolotti et al., 2004 and Zelic et al., 2005) of the Dinaric-Hellenic region, from the standpoint of tectonic setting and geological age. Although the ophiolites along the External Ophiolitic Belt range in age from Triassic to Jurassic, and the ophiolites along the southern Taurus belt from Triassic-Jurassic to Cretaceous, both belts include MORB-type *and* SSZ-type ophiolites. However, the timing of the onset of rifting on both sides may be similar.

In addition, the Antalya Complex has affinities to the Mamonia Complex of western Cyprus and is a critical piece in tectonic interpretations of the easternmost Mediterranean during Mesozoic and Tertiary time (Robertson, 1998).

The SAOB of the southeastern Anatolian region is a product of a north-dipping subduction zone, whereas the SAOB of the southern Taurus region in the Antalya and Mersin areas may be a product of a south-dipping subduction zone (Figs. 7, 8 and 9). However, the ophiolites of the SAOB of the southeastern Anatolian region were uplifted and emplaced to the north and the south as a flower structure. Subsequently, north-facing structures were overturned and became south-facing, young structures during the collision between the Anatolide-Tauride Platform and the Arabian Platform in the southeastern Anatolian region.

The ophiolites of the SAOB in the southeastern Anatolian region may be correlated with the ophiolites between Iran and Iraq (Adib and Pamic, 1980; Adamia et al., 1980; Alavi, 1994; Babaei et al., 2005) and the Semail Ophiolite in the mountains of northern Oman (Welland and Mitchell, 1977; Searle et al., 1980) on the basis of similar characteristic features, geotectonic setting and age. For instance, the Neyriz Ophiolitic Complex occurs along the NW-SE-trending Main Thrust Zone in the Zagros Range, which is the equivalent of the Arabian Platform of Turkey, and the Sanandaj-Sirjan Belt (Alavi, 1994), which is the eastward extension of the Bitlis Massif (Yılmaz and Yazgan, 1990), that is a part of the Anatolide-Tauride block. It is believed that emplacement of the Neyriz Ophiolite occurred in the Late Cretaceous and this ophiolite may be a product of island-arc and/or MORB-type setting; furthermore, uppermost Cretaceous (probably Maastrichtian)-Paleocene clastic rocks contain fragments of ophiolite-radiolarite materials, indicating subaerial weathering of the ophiolitic rocks (Alavi, 1994; Babaei et al., 2005).

According to Shirdashtzadeh et al. (2011) geochemical data of the Nain and Ashin-Zavar ophiolites point to an island arc tholeiitic affinity for the amphibolitic rocks and to a MORB nature for the pillow lavas and sheeted dykes that are related to a back-arc basin. The suture of the ophiolites located between the Sanandaj-Sirjan zone and the Central-Easts Iranian microcontinent before Middle Eocene. This suture may represent eastern continuation of the Bitlis suture (Şengör and Yılmaz, 1981) of Turkey.

On the other hand, the ophiolites of the Kermanshah area represent MORB type and SSZ type ophiolites together and emplaced along the suture between the Zagros belt and Sanandaj-Sirjan zone (Allahyari et al., 2010). This suture represents eastern continuation of the Southeast Anatolian Suture directly.

In addition, amphibolite units - representing the sole detachments of the ophiolites - have been reported in Turkey (e.g., Dilek et al., 1999), in the Neyriz area of Iran (Babaei et al., 2005), and in Oman (Hacker et al., 1996). Lanphere and Pamić (1983) dated a sample of pargasite-schist from below the peridodite using the $^{40}Ar/^{39}Ar$ technique and determined a 94.9 ± 7.6 Ma age for the amphibolite. For instance, in Turkey, as mentioned above, K-Ar analyses of the Mersin ophiolite yield an age of 93.4 ± 2.2 Ma, representing the initial detachment of the oceanic crust (i.e., the Mersin ophiolite) (Parlak et al., 1995).

Based on the data presented above, it is clear that the SAOB continues to the east, along the border between Iran and Iraq and as far as Oman. Discussions on the setting of the sutures in southeast Turkey are valid for the southwest of Iran.

CONCLUSIONS

Ophiolites and ophiolitic mélanges are the main indicators of the geodynamic evolution of the oceans, and thus elucidate the overall evolution of a region. Accordingly, the ophiolites and mélanges of Turkey have been reviewed. After eliminating controversial topics related to the ophiolitic associations, it is advisable to suggest a new classification of the continental fragments in order to better understand the geology of Turkey and surrounding areas (Figure 12). In that figure, a simplified picture of the large continental blocks and the sutures separating them is illustrated. The İstanbul zone represents a southern promontory salient of the East European Platform. However, the promatory salient affected the shape of the southern continental fragments, such as the Sakarya zone and the Anatolide-Tauride block together and also the sutures separating them (Figure 12).

On the basis of the data presented herein, the age and tectonic setting of the pre-Alpine ophiolites and mélanges remain controversial. Due to a relative paucity of data, it is not possible to present a detailed model for the Intra-Pontide Suture and the evolution of Paleotethys in Turkey. In spite of this, it may be said with confidence that relicts of Paleotethys exist along the Intra-Pontide and North Anatolian sutures.

The North Anatolian suture is one of the main and most important ophiolitic sutures of Turkey. It separates the Sakarya zone from the Anatolide Tauride block. Along the NAOB, Paleozoic and Mesozoic MORB-type and Upper Cretaceous SSZ-type ophiolites occur, and these ophiolites were accreted to the mélange prism in Late Cretaceous time. The eastern Anatolian ophiolites may have been derived from the North Anatolian Suture. However, it is important to point out that the basement of eastern Anatolia does not represent an ophiolitic mélange prism; rather, it comprises equivalents of the Anatolide-Tauride block.

During emplacement of the ophiolites, north- and south-facing overthrusts developed, forming a flower structure during the collision of the Sakarya zone and the Anatolide-Tauride block. The present-day tectonic setting of the ophiolites with ophiolitic mélanges along the NAOB is a result of erosion and facilated the formation of new basins.

The emplacement mechanism for ophiolites along the SAOB is similar to the mechanism for those along the NAOB. Along the North Anatolian Suture, $^{40}Ar/^{39}Ar$ ages give insights for the subduction and collage from the Middle to Upper Cretaceous (95-80 Ma), whereas along the South Anatolian suture, Upper Cretaceous (74-71 Ma) ages exhibit subduction of the southern Neotethys and these data have been interpreted as a subduction jump from the northern to the southern boundary of the Anatolide-Tauride block at 80-75 Ma (Roland et al., 2010, 2011). The TUA is the only line (crustal unit) that separates the NAOB ophiolitic associations from the SAOB ophiolitic associations (Figure 1).

In addition, the Inner Tauride suture (Görür et al., 1984; Koçyiğit, 1990; Dilek et al., 1999; Pourteau et al., 2010), the Bitlis suture (or the Assyrian-Zagros Suture) (Hall, 1976; Yazgan, 1983, Çağlayan et al., 1984; Yılmaz et al., 1993b, Şengün, 2006) and a suture between Bursa and Balıkesir, which separates the Rhodope-Strandja Massif from the Sakarya Zone (or Intra-Pontide Suture), have been suggested as means to interpret the evolution of other Neotethyan branches. However, there are insufficient data supporting the existence of these sutures as well as passive margins along both sides of the sutures. In addition, it is not necessary to define a suture zone, wherever the ophiolitic outcrops can be seen.

After review of the main geological characteristics, tectonic setting and age of the ophiolitic associations, the following interpretations should be emphasized:

1. It is possible to provide an overall definition of the main suture zones of Turkey in so far as all of the recognized suture zones have characteristic features. For instance, they all include MORB- and SSZ-type ophiolites of various ages. The style of emplacement of the ophiolites and mélanges of the sutures are similar and, in many cases, result in flower structures due to the north-facing and south-facing overthrusts. However, it is not possible to see the whole flower structure in the present day because of younger deformation and erosional processes.
2. The rock associations of these suture zones mainly comprise ophiolite, ophiolitic mélange, fore and ensimatic-arc units, being a complete subduction system. The ophiolitic associations of the Intra-Pontide suture zone, the North Anatolian Suture and the Southeast Anatolian Suture were all initially emplaced with south- and north-vergent imbricated structures.
3. It may also be suggested that collision of continental fragments initially developed in the north and, subsequently, collisional events developed progressively from north to south, reaching into southeastern Anatolia.
4. Another important finding of this study is that the northern and southern branches of the Neotethyan ocean were not integrated into the eastern Anatolian region, as seen from the profiles, there is continental crust beneath the obducted ophiolitic units and overlying cover, and this crustal structure has been defined as the Anatolide-Tauride block by Okay and Tüysüz (1999).

As indicated by Moix et al. (2008), vast areas of eastern Turkey, Iraq and western Iran are still under-explored; more thorough investigation of these regions is necessary to go further in understanding the central Tethyan realm.

In future investigations of the ophiolitic associations, it will be necessary in Turkey to separate the mélanges of subduction zones near continental margins from the mélanges related to ensimatic arcs. Subsequently, the primary and secondary settings of the ophiolites and mélanges should be studied; accordingly, mélanges *sensu stricto* and reworked mélanges should be distinguished in detail. After further investigation, it may be possible to make better correlations and to locate suture zones more exactly.

GENİŞLETİLMİŞ ÖZET

Birçok ofiyolitik kened kuşağı içermesi nedeniyle Türkiye, Doğu Akdeniz bölgesinde yer alan kıtasal blokların jeolojik ilişkilerinin incelenebileceği önemli bir bölgedir. Bu bölgede kenet kuşaklarının yeri, konumu ve yaşı konularında kapsamlı bir çalışmaya gereksinim duyulmaktadır. Bu çalışmanın amacı Türkiye ofiyolitleri ile ofiyolitik karışıklarına dair bilgileri derlemek ve bu birimlerin özelliklerini gözeterek bölgenin jeolojik evrimine yönelik sınırlamalara bir ışık tutmaktır. Ofiyolitlerin yaş ilişkileri ve coğrafik dağılımlarıyla birlikte derlenen verilere göre Türkiye'deki ofiyolitik topluluklar üç ana grup halinde sınıflandırılabilir.

***Birinci grup** İstanbul Zonu'nun güneyinde ve güney kenarında yer alan pre-Alpin ofiyolitleri ve ofiyolitik karışıkları kapsar. Almacık dağı?, Elekdağ, Çele ve Küre metaofiyolitleri ve Karakaya Karmaşığı bu döneme ait oluşuklardır. Paleotetisin bu kalıntıları Intra-Pontit Kenedini temsil eder. Ofiyolitler en azından Jura öncesi* *(kimileri olasılıkla Proterozoyik ya da Alt Paleozoyik) yaşta olan ofiyolitik dizilerden oluşmaktadır. Ne varki Türkiye'nin başka yerlerinde de, örneğin Erzincan yöresinde ve hatta daha doğuda ve aynı kuşakğı temsil eden Küçük Kafkasya'da da pre-Alpin ofiyolitlerinin bazı kalıntılarına rastlanmaktadır. İstanbul Zonu ile ilişkisi izlenemeyen bu ofiyolitlerin hangi okyanusa ait olduğu ve günümüzdeki konumlarına hangi mekanizmalarla yerleştiği hala tartışma konusudur.*

Türkiye'nin pre-Alpin ofiyolitleri genel çerçevede yaşları ve konumları açısından KD' da Büyük Kafkasya ve KB' da Balkanlardaki pre-Alpin ofiyolitlerle deneştirilebilirler.

Karakaya kompleksi ise pre-Alpin ofiyolitik karışıkları temsil eder ve bu birim pre-Alpin ofiyolitlerinin yerleşimi sırasında oluşmuştur. Paleotetisin Türkiye'de açılma ve kapanma yaşları ile polaritesi esas olarak çözülememiş bir konudur. Ancak, İstanbul Zonu üstünde gelişmiş olan yay istifleri ile Pontidler'in Üst Kretase yaşta olan yay istiflerinin benzerliği gözetildiğinde, bu kenedin Üst Kretase öncesinde tümüyle kapanmış olabileceği, ve kimi pre-Alpin ofiyolitlerin Üst Kretase sırasında yeniden aktarılarak günümüzdeki konumlarına yerleşmiş olabileceği de gözardı edilmemelidir. Karakaya kompleksi esas olarak Kuzey ve Kuzeydoğu Anadolu Ofiyolit Kuşağı'nın kuzeyinde yer almaktadır.

***İkinci grup** kuzey ve güney alt kuşakları olmak üzere iki alt kuşağa ayrılabilen Alpin ofiyolitleri ve ofiyolitli karışıkları içermekte olup Kuzey ve Kuzeydoğu Anadolu Ofiyolit Kuşağı (KAOK) ile temsil edilir. Bu kuşaktaki ofiyolit toplulukları daha güneyde yer alan Güney ve Güneydoğu Anadolu Ofiyolit Kuşağı'ından Torosların metamorfik olmayan göreli otoktonu ile ayrılırlar ve bir bütün olarak Neotetis'in kuzey koluna ait olabilirler. Kuzeyde yer alan alt kuşağın ofiyolit topluluklarının Kuzey Anadolu Ofiyolit kenedi ile ilişkisi tartışmaya yer vermeyecek kadar açıktır. Ne varki güneyde yer alan alt kuşağa ait ofiyolit topluluklarının Kuzey Anadolu Ofiyolit kenedi ile ilişkisi tartışmalıdır. Bu nedenle kimi araştırmacılar tarafından bu ofiyolitlerin başka sütür zonlarına ait olabileceği öne sürülmektedir.*

***Kuzeydeki alt kuşak,** İzmirden doğuya doğru sıra ile Eskişehir, Ankara, Tokat-Sivas arası, Refahiye-Erzincan, Kop Dağı ve Oltu'dan Küçük Kafkasya Ofiyolit Kuşağı'nın Sevan-Akera alt kuşağına bağlanır. Kuzey Anadolu'nun bu alt kuşağı, Neotetisin kuzey kolunu ve Türkiye'nin ana kenet kuşağını doğrudan temsil eder. Bu alt kuşağın ofiyolitleri Mezozoyik yaşta MORB ve Jura- Geç Kretase yaş aralığında SSZ türde parçalanmış ofiyolitik dizilerle temsil edilir. Ofiyolitler genel olarak Üst Kretase yaşta olan ofiyolitli karışıkların içinde ya da daha güneyde yer alan Toroslar'ın metamorfik eşlenikleri (yani metamorfik masiflerin) üzerinde tektonik dokanaklarla yer alırlar.*

***Güneydeki alt kuşak,** Marmaris yöresinden doğuya doğru, sıra ile Hadim, Aladağlar, Tecer-Divriği, Erzurum, Kağızman yörelerinde devam ederek Küçük Kafkas Ofiyolit Kuşağı'nın Vedi alt kuşağına bağlanır. Hınıs yöresindeki ve Van Gölü'nün kuzeydoğusundaki ofiyolitik yüzeylemeler dahil Doğu Anadoluda dağınık olarak izlenebilen ofiyolitik yüzeylemeler, KAOK topluluğunun güneyindeki alt kuşağın en güneyindeki uc ürünleri olabilirler. Güney alt kuşağının ofiyolitleri ve karışıkları kayatürü, jeolojik yaş ve jeo-tektonik ortam açısından kuzey alt kuşağın ofiyolitlerine ve karışıklarına benzer özellikler sunarlar. Ayrıca bu topluluklar, Toros Platformu'nun üzerinde ilksel bir ilişki ile gelişmiş olistostromal bir düzeyin üzerinde yer almaktadırlar. Dolayısıyla bu ofiyolitlerin,* *Neotetis'in kuzey kolunda yer alan ofiyolitlerin tektonik olarak güneye taşınması sırasında çökel süreçlerin de eşlik ettiği bir aktarılmanın ürünleri olduğu kabul edilmektedir.*

Yapılan çalışmanın sonucu olarak, Neotetisin kuzey kolunun açılmasının Türkiye'nin batısında Triyas'ta, doğusunda Jurasik'te başladığı bir ölçüde kabul edilebilir. Ancak Neotetisin kuzey kolunun kapanmasının Geç Kretase'de başladığı ve Orta Eosen öncesinde sona erdiği benimsenmektedir.

Üçüncü grup *Jura-Kretase ve Geç Kretase yaşta olan düzenli ofiyolitli dizileri ve ofiyolitli karışıkları içeren Güney ve Güneydoğu Anadolu Ofiyolit Kuşağı (GAOK) ile temsil edilir. Batıda Antalya'dan başlayıp doğuya doğru, sıra ile Mersin, Göksun, İspendere-Kömürhan, Guleman, Kızıldağ, Gevaş ve Cilo dağlarında yüzeylenen birbirinden kopuk olan ofiyolitik masifler ve GD Anadoluda yaygın olan Koçali Karışığı GAOK'un tanımlanmış olan bileşenleridir. Bölgede egemen olan ofiyolitli karışık, Jura-Kretase yaşta olan MORB ve Üst Kretase yaşta olan SSZ türde ofiyolitlerin yerleşmesi sırasında oluşmuştur.*

Güneyde ve Güneydoğu Anadolu'da Neotetisin güney kolunun Permiyen sonu-Triyas başı dönemde açıldığı, kapanmasının ise Geç Kretasede başladığı ve Geç Miyosen öncesi dönemde sona erdiği kabul edilmektedir.

İkinci ve üçüncü grup Alpin ofiyolitler ve karışıklar birbirlerinden Anadolu-Toros Bloku'nun metamorfik olmayan ve göreli otokton olarak izlenebilen ekseni ile ayrılırlar. Bu eksen Gürün ile Van Gölü arasındaki bölgede genç havza çökelleri nedeniyle izlenememektadir. Van'ın batısında ve İran'ın batısında (İran Platformu olarak bilinir) ise bu platforma ait bazı yüzeylemeler izlenebilmektedir. Ayrıca, Anadolu-Toros Bloku'nun metamorfik olmayan ekseni, yani geniş anlamıyla Toros Platformu varlığını Alt Eosen'e kadar sürdürürken Alpin döneme ait ofiyolitlerin Jura Kretase, karışıkların yaşı ise Üst Kretase'dir. Dolayısıyla, Türkiye'de batıdan doğuya kadar yer yer kesikli bir biçimde de olsa izlenebilen bu eksen Alpin ofiyolitleri ve karışıkları (yani Neotetis'in kuzey kolu ile güney koluna ait ofiyolitik birimleri) ayıran en önemli bir eşiktir.

Alpin ofiyolitler genel olarak Jura-Kretase sırasında gelişen MORB ve SSZ türlerde jeotektonik ortamların ürünüdürler. Ofiyolitli karışıkların yaşı ise Üst Kretase'dir. Ayrıca, Üst Kretase sırasında Pontidler'in ve Toros Platformu'nun güney kenarının da aktif yapılar olduğu gözetildiğinde, bu ofiyolitlerin ancak kuzeye dalımlı yitim zonları boyunca yerleşmiş olabilecekleri öne sürülebilir. Yani ofiyolit topluluklarının aynı yaştaki MORB ve SSZ türlerdeki ofiyolitleri birlikte içerdiği gözetilirse, Neotetis'in her iki kolunun da , kuzeye dalımlı çift yitim zonları boyunca oluşan karışığa eşlik ederek yerleşmiş olabileceği öne sürülebilir. Neotetis'in iki koluna ait ofiyolitlerin uzanımı ve bunların yerleşimden sonraki yayılımlarına bakıldığında, bu iki kolun Türkiye'de değil, İran'da birleşmiş olabileceği kabul edilebilir.

Tektonik unsurların egemen olduğu karışıklar, ağırlıklı olarak Alpin kenetlerine yakın yerlerde, olistostromal karışıklar ise kenet kuşaklarının kuzey ya da güney kesimlerinde yer alırlar. Örneğin Toros Platformu'nun metamorfik olmayan eksenine, yani göreli otoktona yakın olan yerlerde olistostromal karışıklar ve aktarılmış olan ofiyolitler egemendir. Buna göre, Alpin ofiyolitik birimlerin yerleşme mekanizması, söz konusu kenet kuşakları boyunca kimi yerlerde kuzeye ve güneye bakan bindirmelerin varlığı gözetildiğinde bir çiçek yapısını gösterir. Ancak daha sonra gelişen deformasyona ve erozyona ilişkin süreçler nedeniyle günümüzde bu çiçek yapısının tümünü görmek mümkün değildir.

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Makale Geliş Tarihi : 15 Nisan 2013
Kabul Tarihi : 4 Haziran 2013

Received : 15 April 2013
Accepted : 4 June 2013