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Geology and Structural Evolution of the Tokat Massif (Eastern Pontides, Turkey)

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Abstract: The Tokat Massif consists of a pre-Jurassic metamorphic complex that crops out widely between Amasya and Reşadiye in the western part of eastern Pontides, and which can be correlated with the Karakaya Complex of the western Pontides. This complex is named the Tokat Group, and is divided into two main units, namely, the Turhal Metamorphics and Devecidağ Mélange. The Turhal Metamorphics form a volcano-sedimentary sequence in the northern part of the Tokat Massif. The lower level of the formation is made up of gneiss, amphibolite and mica schists, whereas the upper part is represented by an alternation of mica schist, phyllite, metaclastic rocks, metabasite and marble, which probably reflects an arc association. The Devecidağ Mélange is characterised by a metavolcano-sedimentary olistostrome, which forms the southern part of the massif. This unit is quite heterogeneous and reflects, in places, a subduction mélange and/or a fore-arc sequence. The Devecidağ Mélange may have formed in a setting between a subduction zone and a fore-arc. The units of the Tokat Massif can be traced along the eastern Pontides and also along the North Anatolian Ophiolitic Belt. These units have been accreted to the mélange prism as tectonic slices along the North Anatolian Ophiolite Belt before the Campanian. Some of Late Cretaceous ophiolitic mélange slices also crop out in the Tokat Group as E–W-trending tectonic slices. The ophiolites and ophiolitic mélange are believed to have been emplaced both to the north and to the south during the Late Cretaceous. The north-vergent thrusts have been later realigned into south-dipping thrusts during a neotectonic phase.

Key Words: Tokat Group, Karakaya Complex, structural evolution, eastern Pontides

Tokat Masifi'nin Jeolojisi ve Yapısal Evrimi (Doğu Pontidler, Türkiye)

Özet: Tokat Masifi, doğu Pontidler'in batı kesimini temsil eden ve Amasya ile Reşadiye arasında geniş bir yayılım sunan Liyas öncesi yaşta metamorfik bir karmaşık ile temsil edilir ve batı Pontidler'deki Karakaya Karmaşığı ile korele edilebilir. Bu kompleks, Tokat yöresinde iki temel birime ayrılabilir. Bunlar, Turhal Metamorfitleri ve Devecidağı Karışığı'dır. Turhal Metamorfitleri, masifin kuzeyini oluşturan metavolkano-tortul bir diziyi karakterize eder. Alt kesimi, gnays, amfibolit ve mika şistlerle, üst kesimi ise mika şist, fillit, metakırıntılı, metabazit ve mermerin ardaşımından oluşan bu birim ağırlıklı olarak bir yay istifinin özelliklerini yansıtır. Devecidağı Karışığı ise masifin güneyini oluşturan ve yer yer olistostromal özellikte bloklu metavolkano-tortul istifi karakterize eder. Bu birim, kimi zaman yitim karışığı, kimi zaman yay-önü istifinin özelliklerini yansıtan ve ağırlıklı olarak yitim zonu ile yay-önü arasında gelişen heterojen bir kayatürü topluluğu ile temsil edilir. Tokat Masifi'ni oluşturan metamorfik birimler, doğu Pontidler'in diğer kesimlerinde ve Kuzey Anadolu Ofiyolit Kuşağı boyunca da izlenmektedir. Bu birimler, daha güneydeki Kuzey Anadolu Ofiyolit Kuşağı'na ait ofiyolitli melanj prizmasına geç Kampaniyen öncesinde tektonik dilimler halinde eklenmişlerdir. Geç Kretase yaşlı olan ofiyolitli melanj prizmasına ait bazı dilimler de, Tokat Masifi arasında yaklaşık doğu–batı uzanımlı olarak yer almaktadır. Dolayısıyla, Tokat Masifi birimleri arasında yer alan ofiyolitler ve ofiyolitli melanjlar, ilksel yerleşim yerlerinde olmadığından bunların konumu gözetilerek kenet kuşakları çizilemez. Kuzey Anadolu Ofiyolit Kuşağı'nı oluşturan ofiyolitli melanj prizması başlangıçta hem kuzeye hem de güneye doğru yayılarak büyümüş ve kuzeydeki yani masif tarafında yer alan melanj dilimleri daha sonraki sıkışmanın güdümünde yükselip aşınmış ve kalıntı yüzeylemeler neotektonik süreçte retro-şaryajlarla terslenmiştir.

Anahtar Sözcükler: Tokat Grubu, Karakaya Kompleksi, yapısal evrim, doğu Pontidler

Introduction

The E–W-trending Pontide orogenic belt in northern Turkey, bounded to the south by the North Anatolian Ophiolite Belt (Figure 1, Ketin 1966), is commonly divided into the western, central and eastern Pontides (Y. Yılmaz *et al.* 1997a, b). In this classification, the Tokat Massif lies in the eastern Pontides. Parts of the Tokat Massif have been studied by various authors (Alp 1972; Öztürk 1979; Özcan *et al.* 1980; Bektaş *et al.* 1984; Özcan & Aksay 1996; Seymen 1991, 1993; A. Yılmaz 1980, 1981a, b, 1982a, b, 1985; Okay 1983, 1996; Okay & Şahintürk 1997). These studies have demonstrated that the Tokat Massif consists of heterogeneous pre-Jurassic rock associations. The pre-Jurassic rock association in the Tokat Massif has been subdivided into a lower metamorphic unit and an upper blocky unit (Özcan *et al.* 1980; A. Yılmaz 1980, 1982a, b). The lower unit, consisting of metaclastic and metabasic rocks, phyllite and marble is named the Turhal Metamorphics, and the overlying metavolcaniclastic unit with exotic blocks of the Devecidağ Complex; these stratigraphic names have been confirmed by the Stratigraphy Committee of Turkey (TSK 1987).

It has also been suggested that, at least, the Devecidağ Complex is the equivalent of the Karakaya Complex of the western Pontides (Bingöl *et al.* 1975), and that it represents a subduction-accretion complex (Tekeli 1981). The Tokat Massif as a whole is placed into the Sakarya Zone of the Pontides (Okay 1989; Okay *et al.* 1991; Okay & Şahintürk 1997). Y. Yılmaz *et al.* (1997a, b), who have studied the whole of the Tokat Massif, have renamed the rock-stratigraphic units without proper consideration of the previous stratigraphic nomenclature in the Tokat Massif. They claimed that an ophiolite outcrop, extending in an E–W direction in the centre of the Tokat Massif, represents an old suture, and that the rocks to the north and south of this "suture" belong to different former plates.

The different tectonic interpretations, outlined above, reflects the scarcity of geological data from the Tokat Massif. In this study we aim to rectify this situation by providing detailed geological data from the massif. These data include the descriptions, characteristics, distribution, contact relations, ages, depositional environments, and metamorphic grades of the rock units within the Tokat Massif. We also provide information on the little known

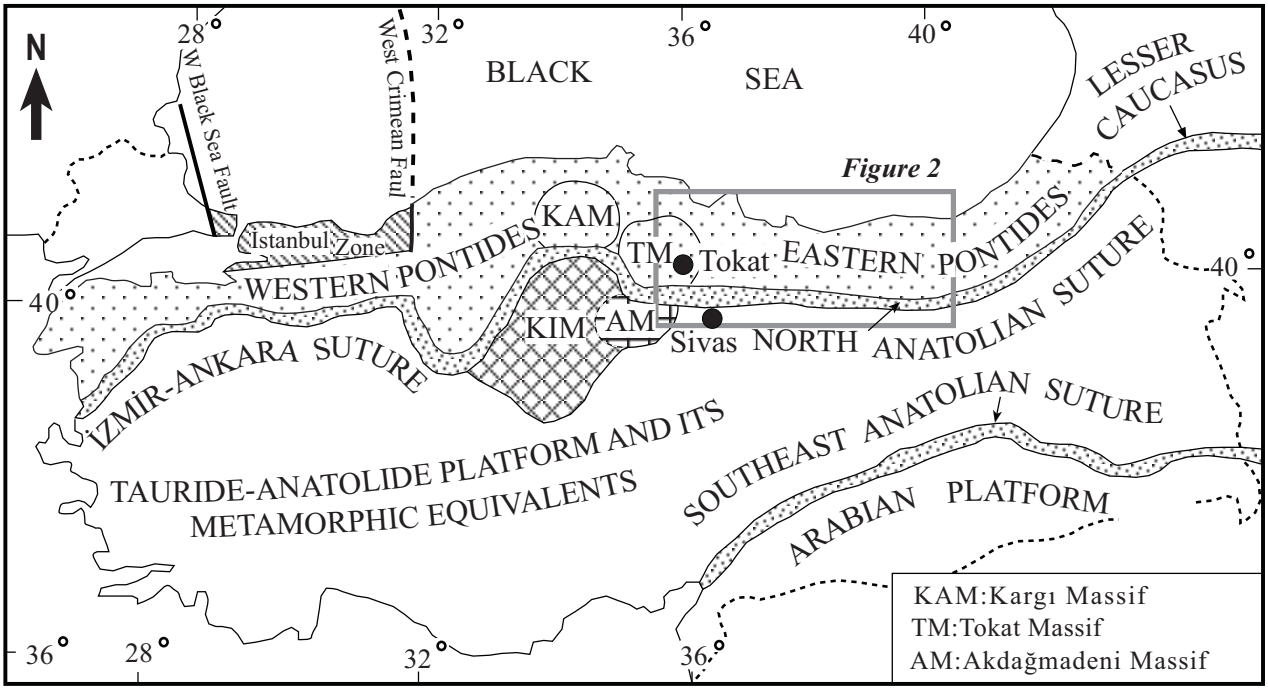

Figure 1. Simplified tectonic divisions of Turkey. The Pontides (shaded region) (after Ketin 1966 and general evaluations). Abbreviations: KAM– Kargı Massif, TM– Tokat Massif, AM– Akdağmadeni Massif. Inset shows the location of the map displayed in Figure 2 (after Okay 1989; Okay & Tüysüz 1999 and personal evaluations).

relation of the Tokat Massif to the ophiolitic belt to the south. This relationship is important for understanding the place of the Tokat Massif in the regional tectonic framework.

Regional Geology

The rocks in the Tokat Massif and in the surrounding region belong to one of the following three basic tectonic units: these are the Tokat, Yeşilırmak and Akdağmadeni groups (Figure 2; Özcan *et al.* 1980; A. Yılmaz 1980, 1982a, b). The Akdağmadeni Group, which structurally forms the lower rock association (Figure 3), is part of the Kırşehir Massif (Seymen 1985), and consists of gneiss, amphibolite, schist, quartzite and marble (Figure 3). These rocks, which are of continental crustal origin, have been regionally metamorphosed in the amphibolite facies, and later were affected by cataclastic metamorphism (Alpaslan 1993). The age of the cataclastic metamorphism, determined by the K/Ar method, falls into the Santonian–Maastrichtian (Alpaslan *et al.* 1996). This age corresponds to the period when the ophiolitic mélange prism was thrust bilaterally to the north and to the south. The metamorphic rocks of the Akdağmadeni Group, which bear traces of the Alpide orogeny (Şengör 1987), are regarded as the metamorphic equivalents of the Anatolide-Tauride Platform (A. Yılmaz *et al.* 1993). It has been suggested that the upper parts of the Akdağmadeni Group represent north-facing Atlantic-type, passive continental-margin deposits (Seymen 1985).

The Yeşilırmak Group consists of ophiolitic mélange, represented by the North Anatolian Ophiolite Belt, and of fore-arc sequences, which lie unconformably over the mélange. This belt starts in İzmir, and continues eastwards in the direction of Ankara-Erzincan and joins to the Lesser Caucasus ophiolitic belt (Zakariadze *et al.* 1983). The Upper Cretaceous ophiolitic mélange has been thrust along the North Anatolian Ophiolite Belt northward and southward over other tectonic units (A. Yılmaz 1980, 1982a, b, 1985, 1989; A. Yılmaz & Özer 1984; A. Yılmaz *et al.* 1985). In the region between Tokat and Sivas, the present structure is characterised by north-

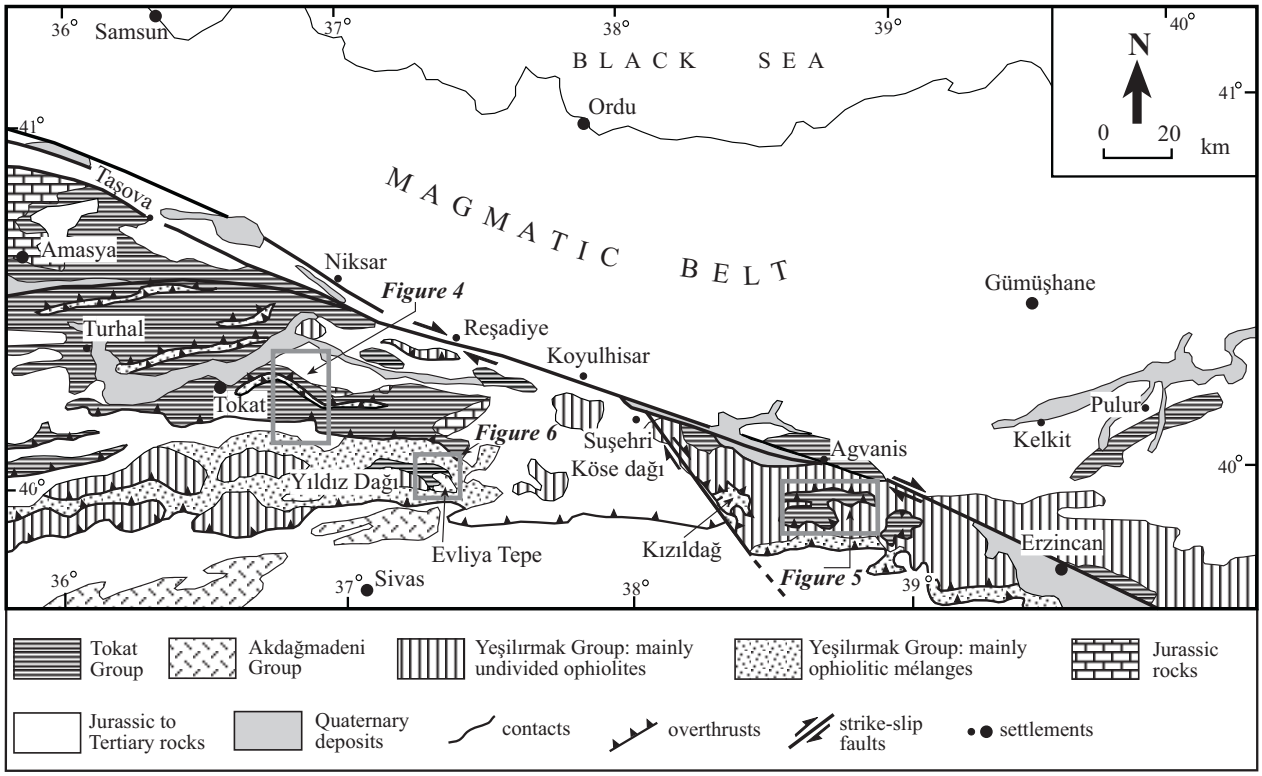

Figure 2. Simplified geological map of the area between Tokat, Sivas and Erzincan (after A. Yılmaz 1980, 1982b; Özcan *et al.* 1980; Özcan & Aksay 1996; and our own observations). Insets show the location of the maps displayed in the following figures.

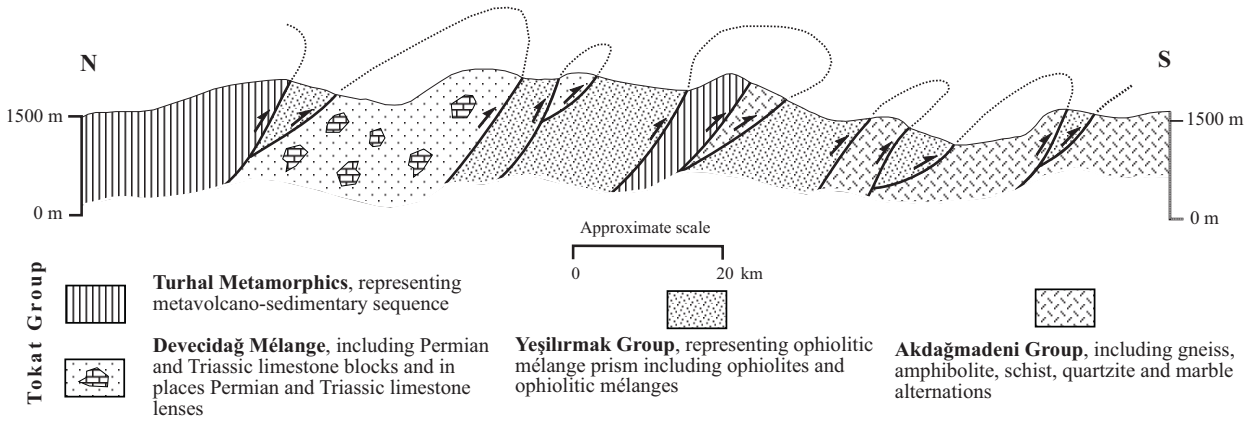

Figure 3. Columnar section indicating structural relationships between Yeşilırmak group, Tokat Group and Akdağmadeni group.

dipping thrusts. This may be related to the rotation of the earlier south-dipping thrusts, or later backthrusting as a result of continuing contraction following the emplacement of the ophiolitic mélange.

The Tokat Group, which constitutes most of the Tokat Massif (Blumenthal 1950), consists of a lower coherent metamorphic sequence and an upper blocky volcano-sedimentary series. It has undergone low-grade greenschist facies metamorphism, and bears imprints of the Alpide and Cimmeride orogenies (Şengör 1987).

The Pre-Jurassic Units of the Eastern Pontides, and the Tectonic Setting of the Tokat Group

The pre-Liassic basement of the eastern Pontides consists of various units with different lithologies and tectonic features. These include high-grade metamorphic rocks, Lower Carboniferous granitoids, Upper Carboniferous–Lower Permian shallow marine to terrigeneous deposits, and Permo–Triassic low-grade metavolcano-sedimentary rocks. The relations between these units are poorly known because of the overlying Mesozoic–Tertiary cover, and because of the interference of the Alpide orogeny.

The Permo–Triassic low-grade metavolcano-sedimentary rock association between Amasya and Suşehri is known as the Tokat Massif. Figure 2 shows the outcrops of the Tokat Massif, and the neighbouring metamorphic massifs that can be correlated in part with the Tokat Group. In the Pulur Massif, two metamorphic rock associations, separated by a tectonic contact, have been differentiated. The Cenci Group shows metamorphism in the granulite facies, whereas the Hasso Group is represented by greenschist-facies metavolcano-sedimentary rocks, and has been correlated with the Ağvanis and Tokat massifs (Okay 1996). The Upper Carboniferous–Lower Permian shallow-marine to terrigeneous sedimentary sequence in the Pulur region (Akdeniz 1988) contains well-rounded clasts derived from the Cenci Group of the Pulur Massif, and represents a molasses-type deposition at the end of the Hercynian orogeny (Khain 1975; Okay & Leven 1996; Çapkınoğlu 2003). Similar lithologies and contact relations are observed in the Greater Caucasus and in the Khrami Massif of the Lesser Caucasus (Adamia *et al.* 1982, 1983; A. Yılmaz 1989; Okay & Leven 1996). A further important pre-Jurassic rock association in the eastern Pontides is the Lower Carboniferous Gümüşhane and Köse plutons (Zankl 1962; Y. Yılmaz 1974; Bergougnan 1987). The presence of pre-Liassic ophiolites has long been claimed in the Tokat Massif and along the North Anatolian Ophiolite Belt (Blumenthal 1950; Koçyiğit 1991a; Seymen 1991, 1993; Y. Yılmaz 1997a, b). This short discussion illustrates that the pre-Jurassic basement of the eastern Pontides forms a complex mosaic, with the Tokat Massif having a key role in our understanding of the pre-Jurassic evolution of the region.

The Tokat Group

In this study, the name Tokat Group (Özcan *et al.* 1980; A. Yılmaz 1982a, b) has been used for the pre-Liassic

low-grade metavolcano-sedimentary rocks. Although similar pre-Liassic units have been studied and named in more detail in the western Pontides, the outcrops around Tokat are large and distinctive enough to warrant a different name. The Tokat Group has been divided into two formations: the Turhal Metamorphics and the Devecidağ Mélange (Figure 4).

Lithological Features

The Turhal Metamorphics is a volcano-sedimentary sequence metamorphosed in the greenschist facies. The rocks consist of an alternation of phyllite, schist, metasiltstone, metasandstone, metatuff and metabasite. In the lower parts of the section, these rock types are accompanied by gneiss, amphibolite, mica schist and quartzite, and in the upper parts by calc-schist and marble.

The Devecidağ Mélange is made up of exotic blocks, including Silurian to Triassic limestone, and ophiolite blocks, in a metaclastic and metavolcanic matrix. It differs from the Turhal Metamorphics by the presence of the exotic blocks. When examined in detail, the Devecidağ Mélange can be observed to locally have an olistostromal or strongly mylonitised, sheared character. In areas of strong mylonitisation, the primary relationships between different rock types have been completely destroyed. The ophiolite blocks in the Devecidağ Mélange, mainly serpentinised peridotites, are interpreted as remnants of a pre-Liassic oceanic crust. It has also been suggested that at least parts of the Devecidağ Mélange represents a pre-Liassic accretionary complex (Tekeli 1981).

Distribution

The Tokat Group has a wide distribution to the south, east and southeast of Tokat (Figure 2). The outcrops of the Tokat Group in the Amasya and Turhal regions (Özcan *et al.* 1980), west of Koyulhisar, and immediately south of the North Anatolian Fault are those of the Turhal Metamorphics. Furthermore, the outcrops north of Ağvanis, and parts of the Pulur Massif can be assigned to the Turhal Metamorphics (Okay 1983, 1996). All the outcrops in these regions consist of greenschist-facies metamorphic rocks without exotic blocks. In regions south of Tokat, and in the Refahiye area south of Ağvanis, pre-Liassic metavolcanic rocks crop out as tectonic slices with the North Anatolian Ophiolite Belt (Figure 5).

This discussion shows that the Tokat Group extends eastward as far as the Pulur region. Furthermore, the dyke complex in the Yusufeli region, and the metavolcanic rocks in the Khrami Massif can easily be correlated with the Bayburt-Pulur region (A. Yılmaz 1989; Okay & Leven 1996). In the northern parts of the eastern Pontides, in the region of Giresun, small outcrops of pre-Liassic metamorphic rocks have been mapped (S. Yılmaz & Boztuğ 1996). These outcrops of mica schist, phyllite and calc-schist, extending in a NE–SW direction south of the Dereli village of Giresun, are correlated with the Turhal Metamorphics. Were it not for the Mesozoic–Tertiary cover of the eastern Pontides and the Transcaucasus, the Tokat Group would have most probably been seen to extend north to the Dizi series of the Greater Caucasus (Adamia *et al.* 1982; A. Yılmaz 1989). However, because of the presence of the Mesozoic–Tertiary cover, the isolated pre-Liassic outcrops have been interpreted differently (Şengör 1987), although they in fact are part of the same tectonic unit. In conclusion, the Tokat Group has a very wide distribution in the eastern Pontides and in the Caucasus.

Contact Relations

The basal stratigraphic contact of the Tokat Group is not observed anywhere. It is unconformably covered by a sedimentary sequence of Liassic to Cretaceous age (Özcan *et al.* 1980; Seymen 1991, 1993). The Turhal Metamorphics of the Tokat Group crop out generally in the north, and structurally at a lower position than the Devecidağ Mélange, which crops out in the south. The contacts between these two formations are generally tectonic, and only locally gradational. The Tokat Group shows tectonic relations with the granulite facies metamorphic rocks of the Pulur Massif. These two different metamorphic units probably were amalgamated during the Cimmeride orogeny (Okay 1996). The Tokat Group also lies tectonically over the metamorphic rocks of the Akdağmadeni Group, as observed in the region of Evliya Tepe north of Sivas (Figures 2 & 6). This tectonic contact is unconformably covered by Eocene clastic rocks. This shows that the oceanic lithosphere between the Tokat and Akdağmadeni groups was completely subducted by the Eocene.

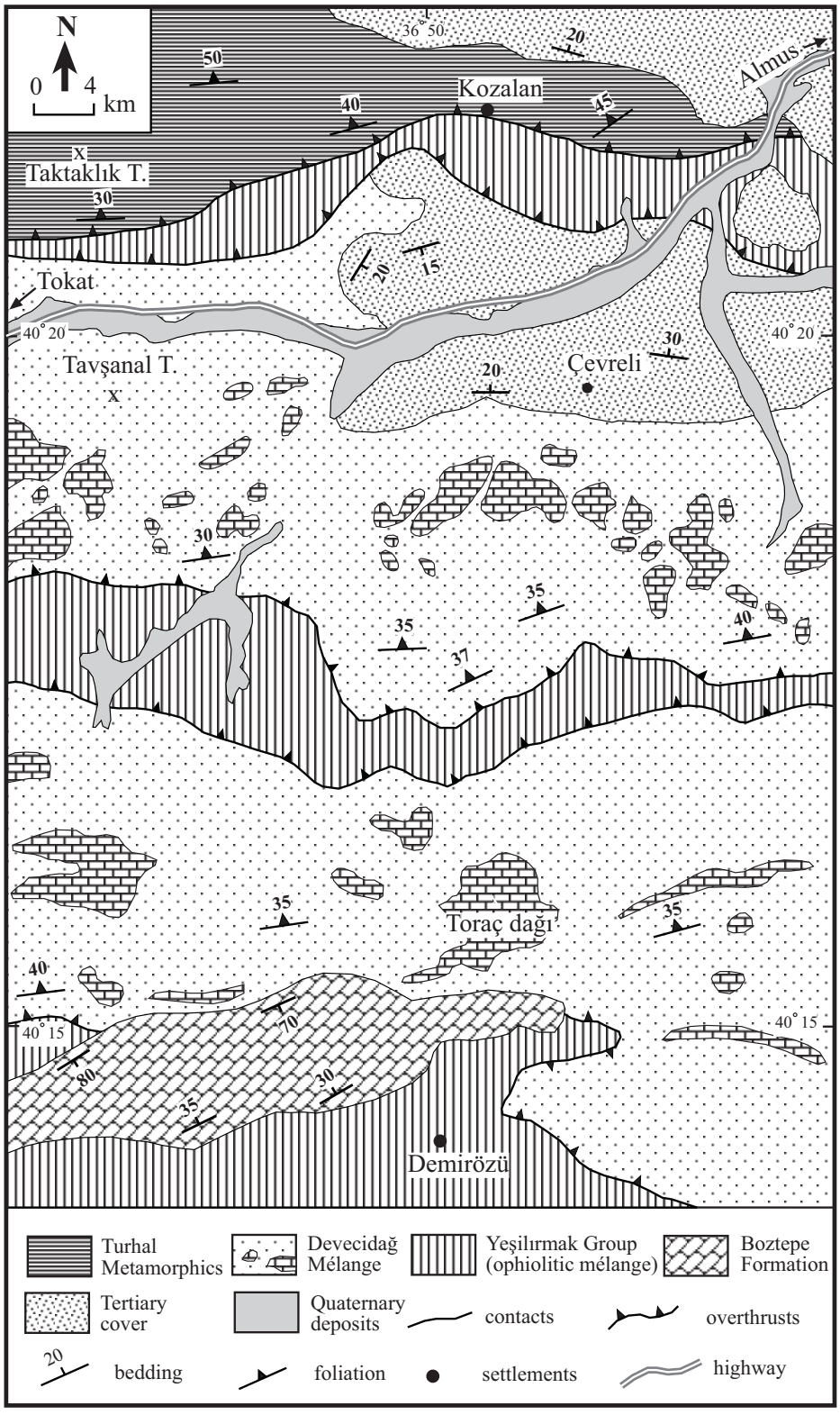

Figure 4. Geological map of the area between Tokat and Almus (after A. Yılmaz 1980, 1982b; Özcan & Aksay 1996; and our own observations). For the location see Figure 2.

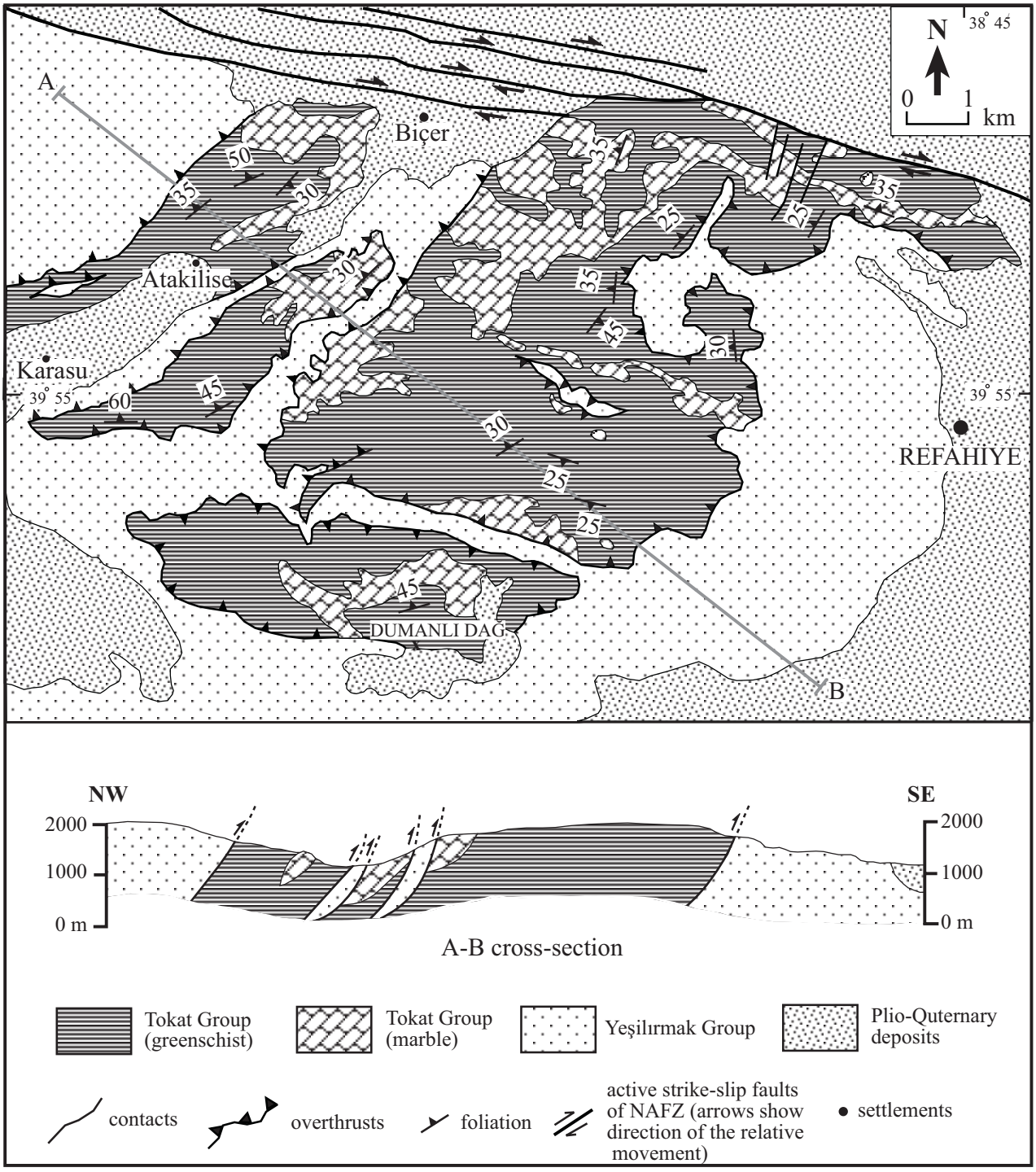

Figure 5. Geological map of Dumanlı Dağ of Refahiye area (after A. Yılmaz *et al.* 1985b). For location see Figure 2.

In several localities, the Tokat Group lies tectonically over the ophiolite or ophiolitic mélange (Figures 2 & 3), or over the Jurassic to Tertiary cover sequence (Figures 2 & 4). Of these tectonic contacts, those west and north of Tokat are young neotectonic thrusts. In the Refahiye region, the Tokat Group occurs as a tectonic slice in the

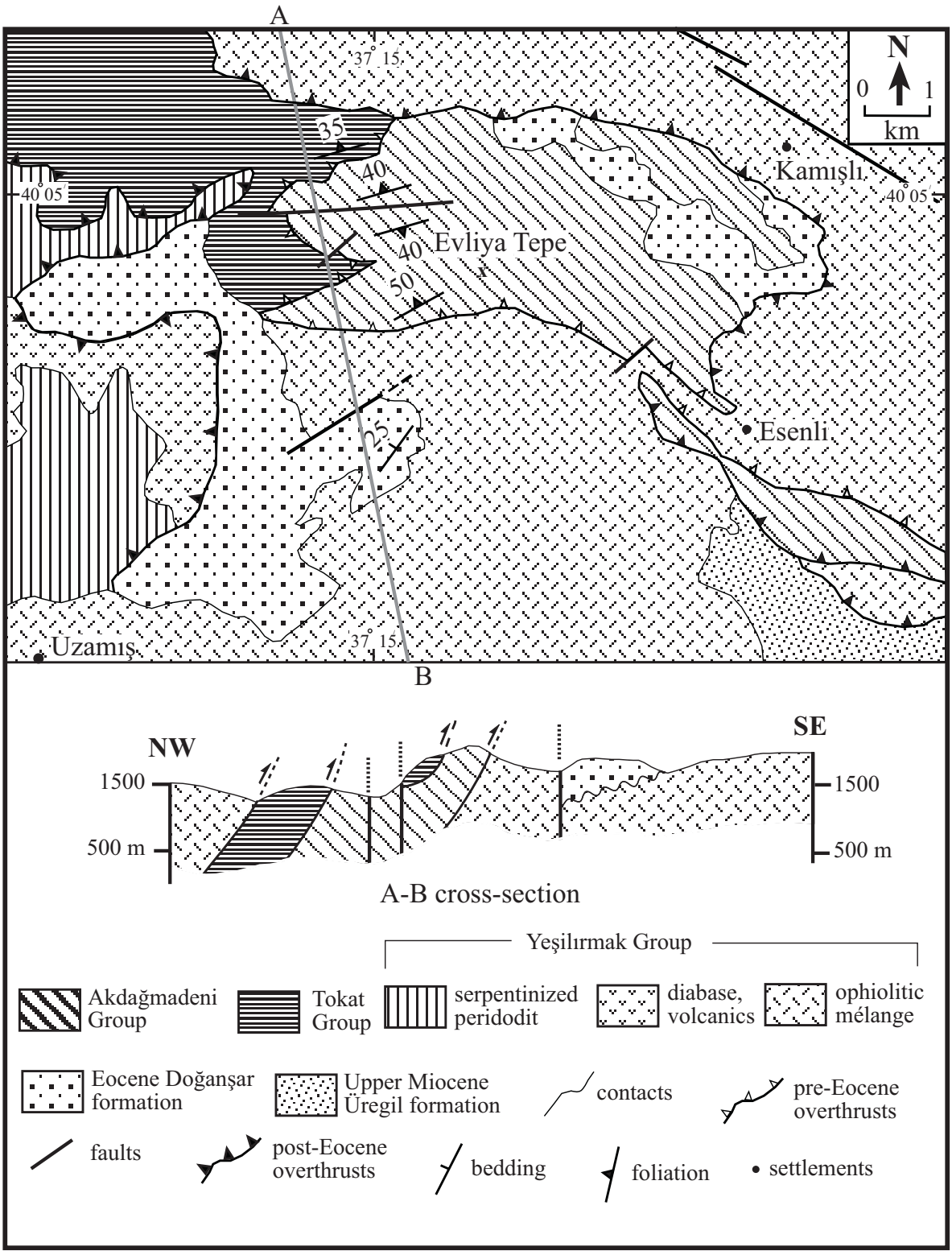

Figure 6. Geological map of the Evliya Tepe area showing relationship between Tokat Group, Akdağmadeni Group and Yeşilırmak Group (after A. Yılmaz 1982b). For location see Figure 2.

serpentinised Cretaceous peridotites (Figure 5). In this region, actinolite in the metabasic rocks of the Tokat Group shows replacement by sodic amphibole along a tectonic contact north and northeast of Alakilise (A. Yılmaz 1985). The oldest rocks, which cover the tectonic contacts between the Devecidağ Mélange of the Tokat Group, and the ophiolitic mélange, make up the Boztepe Formation (Figure 4). The pelagic foraminifera determined from the Boztepe Formation by Ercüment Sirel include *Globotruncana linneiana* (De LAPP.), *Globotruncana* cf. *arca* (CUSH.), *Globotruncana* cf. *calcarata* (CUSH.) *Globotruncana* cf. *coronata* BOLLİ, *Globotruncana* cf. *tricarinata* (QUE), *Globotruncana* sp., and indicate a Late Campanian age. Farther west, the Boztepe Formation also lies unconformably over the Cretaceous ophiolitic mélange. The Boztepe Formation consists predominantly of pelagic limestones but also includes turbiditic clastic rocks, and olistostromes with ophiolitic detritus. The Boztepe Formation is interpreted as a fore-arc basin developed on the ophiolitic mélange. Similar fore-arc basins have been described in detail by Koçyiğit (1991b). The stratigraphic position of the Boztepe Group, both above the Tokat Group and above the ophiolitic mélange, indicates that at least part of the tectonic interslicing between the Tokat Group and the ophiolitic mélange occurred in pre-late Campanian time during formation of the ophiolitic mélange.

In the Tokat region, where the Tokat Group has extensive outcrops, the ophiolitic mélange occurs as thin thrust sheets within the Tokat Group (Bozkurt *et al.* 1997). In contrast, in the south in the North Anatolian Ophiolite Belt, rocks of the Tokat Group occur as thin thrust sheets within the ophiolitic mélange. In all these regions, the thrusts trend E-W, parallel to the North Anatolian Ophiolite Belt, and dip N. In conclusion, the rocks of the Tokat Group were probably injected as tectonic slices in the mélange prism during the formation of the ophiolitic mélange.

Age

There is no concrete data on the age of the Turhal Metamorphics of the Tokat Group. The recrystallised limestone levels in the upper parts of the Turhal Metamorphics have speculatively been correlated with Triassic and Permian carbonates in the Devecidağ Mélange. The Devecidağ Mélange comprises limestone blocks of Silurian, Devonian, Carboniferous, Permian and Triassic in age (Alp 1972; Özcan *et al.* 1980; Çapkınoğlu & Bektaş 1999) implying that the Devecidağ Mélange is Triassic in age. However, to the east of Toraç Mountain, south of Tokat, south of the Develiçalı Hill (Figure 4), stratigraphic intercalation of limestone lenses occur within the Devecidağı Mélange. In Figure 4, these limestone lenses are exaggerated. These limestone lenses make up a few distinct stratigraphic levels and are folded with the intervening metaclastic horizons. Samples from these limestone intercalations contain a Permian fauna as determined by Ahmet Işık and Ercüment Sirel: *Pachyphlio* sp., *Glomospira* sp., Nodariidae, Staffelliidae, Lagenidae, and Fusulininae. There is no unconformity between the levels with the Permian limestone lenses, and the overlying series with Triassic limestone blocks. These data indicate that the Devecidağ Mélange has an age range of Permian and Triassic.

The high-grade metamorphic rocks, which make up part of the Pulur Massif, and those into which the Gümüşhane and Köse granitoids were emplaced are considered outside the definition of the Tokat Group. On the basis of the geochronological data and stratigraphic relations with the Upper Carboniferous–Lower Permian molasse units, these metamorphic rocks are Early Carboniferous in age.

Depositional Environment

Different depositional environments have been proposed for the rocks of the Tokat Group and its equivalents in the western and central Pontides. The equivalents of the Tokat Group in the western Pontides have been interpreted as deposits of a fore-arc or intra-arc basin (Okay *et al.* 1996). Similar units in the central Pontides have been considered as products of a marginal back-arc basin opened above the southward subducting Palaeo-Tethys ocean (Şengör & Yılmaz 1981; Tüysüz & Yiğitbaş 1994). Equivalents of the Devecidağı Mélange have been interpreted as deposits of a marginal basin (Özcan *et al.* 1980), or of a back-arc basin (Koçyiğit 1991a), or a fore-arc basin (Okay *et al.* 1997) or that of a subduction zone (Tekeli 1981). The various interpretations on the depositional setting of the Tokat Group are the result of strong post-depositional tectonism, and the lack of age and primary sedimentary data.

The lithologies of the Turhal Metamorphics and the matrix of the Devecidağ Mélange are fairly similar.

Therefore, the depositional setting of the Tokat Group can be considered as a whole. Lithologically, the Turhal Metamorphics are dominated by metaclastic sedimentary and volcaniclastic rocks. Basic lavas and other sedimentary intercalations are rarely observed. Therefore, a palaeo-arc depositional environment can be assigned to the Turhal Metamorphics. A more accurate depositional setting can be assigned to this formation after the geochemistry of the volcanic rocks is known.

A fore-arc or a back-arc depositional setting, or a combination of the two, is probably more appropriate for the Devecidağ Mélange. The presence of both blocks and sedimentary intercalations of Permian and Triassic limestones argues for a back-arc setting, whereas intense deformation suggests a fore-arc to subduction-zone setting.

Considering that an inactive fore-arc basin may contain blocks and intercalations, a fore-arc depositional setting can be preferred for the Tokat Group. The locally strongly sheared matrix of the Devecidağ Group, and the local presence of ophiolite blocks, indicate the presence of a subduction complex beneath the fore-arc basin.

Considering that the outcrops of the Turhal Metamorphics are mainly in the north, and those of the Devecidağ Mélange are mainly in the south (Figures 2, 4 & 7), an arc through fore-arc to subduction zone depositional setting can be envisaged for the pre-Liassic time. This implies a system with the subduction zone in the south and the arc in the north, contrary to the presently accepted view.

Metamorphic Grade

The Tokat Group as a whole has undergone regional metamorphism in greenschist facies (Özcan *et al.* 1980; A. Yılmaz 1980, 1982a, b). The mineral paragenesis suggests a metamorphic pressure of 3 to 6 kbar, and a temperature of 300–500 °C, indicating burial to a depth of 10–18 km (Y. Yılmaz *et al.* 1997a). However, it is claimed that some outcrops of the Devecidağ Mélange have undergone metamorphism in blueschist, greenschist and to amphibolite facies (Tekeli 1981). Especially in localities where ophiolites lie tectonically over the greenschists, a change towards the glaucophanitic greenschist facies has been observed, for example, to the north of Alakilise in the region of Refahiye (A. Yılmaz 1985).

Correlation

The Tokat Group and its Mesozoic–Tertiary cover can confidently be correlated with the Sakarya Zone of Okay *et al.* (1996). However, there are problems in the correlation of the pre-Liassic units between the eastern and western Pontides. Some of the problems arise because the pre-Liassic units in the eastern Pontides have not been studied in as much detail as in the western Pontides. The different names given to the same unit by different geologists also create problems in correlation.

The Tokat Group is the equivalent of the Tozanlı Complex, Akdağ Formation and the Karakaya Mélange of Seymen (1975, 1991, 1993). In more detail, the Turhal Metamorphics correlate with the Tozanlı Complex and the Akdağ Formation, and the Devecidağı Mélange with the Karakaya Mélange. With limited data, Yılmaz *et al.* (1997a, b) claimed that the different rock units in the Tokat Massif represent different geotectonic environments; for example, the Turhal metaophiolite, which extends through the centre of the Tokat Massif, was claimed to represent a palaeo-suture. The presence of Palaeozoic ophiolites in the Tokat region (Blumenthal 1950; Koçyiğit 1991a; Y. Yılmaz *et al.* 1997a) and along the North Anatolian Ophiolite Belt (Tatar 1978; Zakariadze *et al.* 1983; A. Yılmaz 1989) has long been claimed. However, these ophiolite slices have been accreted to the Upper Cretaceous ophiolitic mélange prism. In a similar manner, the ophiolites mapped by Y. Yılmaz *et al.* (1997a) between Turhal and Mamodağı belong to the Upper Cretaceous ophiolitic mélange with Upper Jurassic limestone blocks (Özcan *et al.* 1980).

As shown in Figures 2 & 4, the Tokat Group comprises several E–W-trending Upper Cretaceous ophiolite mélange slices. In the view of Y. Yılmaz *et al.* (1997a, b) this would require several sutures within the Tokat Massif. In conclusion, ophiolites of various ages occur in the Upper Cretaceous ophiolitic mélanges of the North Anatolian Ophiolite Belt or within the Tokat Massif. However, especially the ophiolitic mélanges in the northern part of the Tokat Massif do not represent sutures.

The Ilgaz-Kargı and the Devrekani massifs in the central Pontides (Tüysüz & Yiğitbaş 1994; Ustaömer & Robertson 1997) can be correlated with the Tokat Massif, and hence with the Tokat Group. The Permo–Triassic volcano-sedimentary sequence with exotic blocks

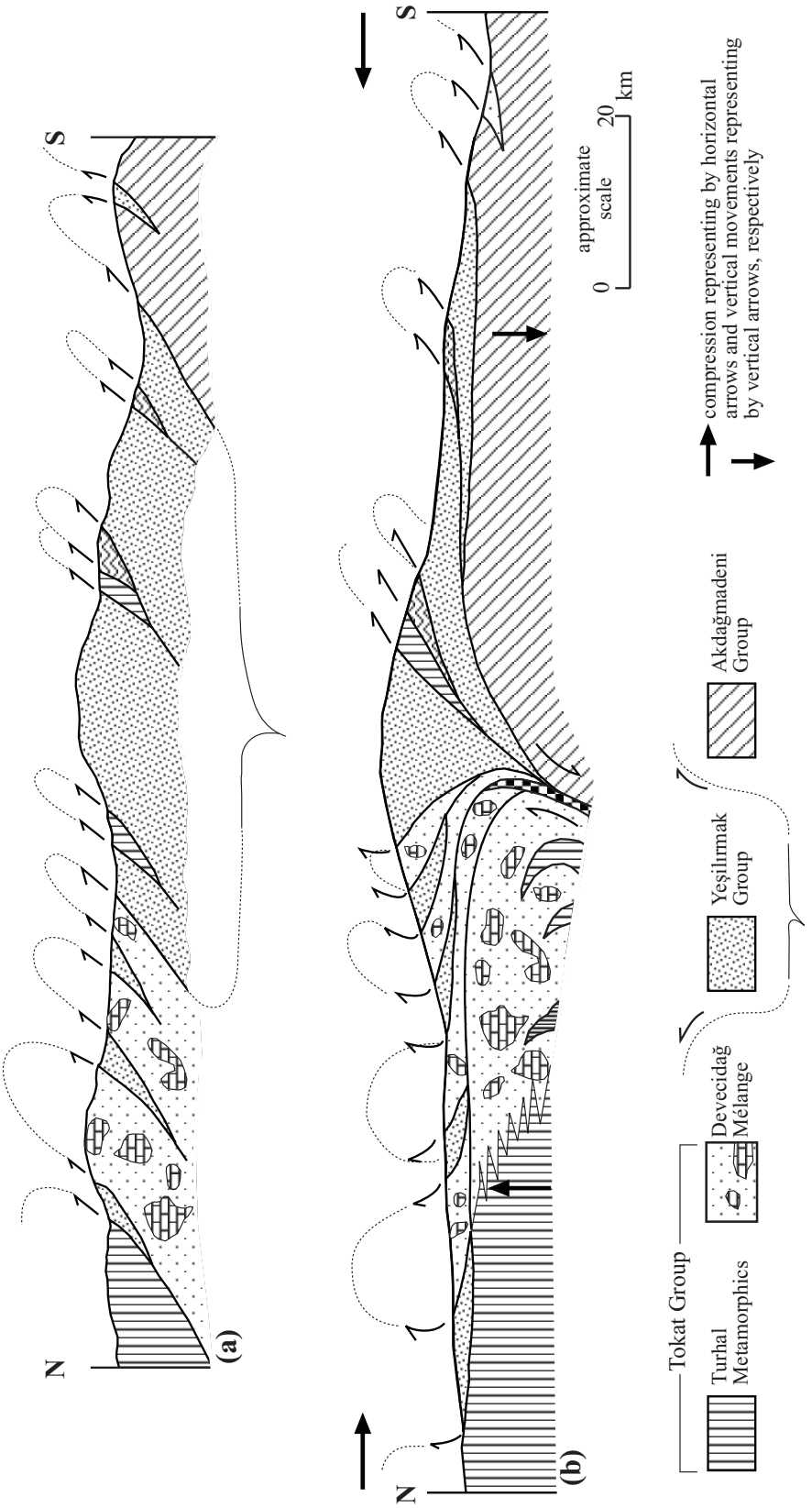

Figure 7. Cross-sections depicting structural relationships between Yeşilırmak Group, Tokat Group and Akdağmadeni Group (A– Recent, B– end of Late Cretaceous and/or earlier). Compression is represented by the horizontal arrows and vertical movements by the vertical arrows, respectively.

in the Ilgaz-Kargı Massif has even been named the Karakaya Unit (Tüysüz & Yiğitbaş 1994).

The main problem in correlating the Tokat Group with equivalents in the western Pontides lies in the fact that the pre-Liassic rocks have not been studied in as much detail as in the western Pontides. The Karakaya Formation as defined by Bingöl *et al.* (1975) can be correlated with the Tokat Group. However, a more detailed study of the Karakaya Formation has resulted in a change of the name to the Karakaya Complex (Şengör *et al.* 1984; Okay *et al.* 1996). Therefore, the Tokat Group can be used as the equivalent of the Karakaya Complex. In a more detailed study of the Tokat Massif, it would be possible to map the equivalents of the Nilüfer, Çal and Hodul units, and the Orhanlar Greywacke, which are defined on the Biga Peninsula in the western Pontides. The correlation between the western and central Pontides becomes even easier when only the blocky and coherent pre-Liassic units are considered. In this case, the Turhal Metamorphics correlate with the Nilüfer Unit, and the lower parts of the Çal and Hodul units, and the Devecidağ Mélange correlates with the upper parts of the Çal and Hodul units, and the blocky part of the Orhanlar Greywacke.

The Structural Evolution of the Tokat Group

In order to understand the structural evolution of the Tokat Group, it is necessary to study its contact relations with the North Anatolian Ophiolite Belt and the Akdağmadeni Group. The North Anatolian Ophiolite Belt represents a suture zone between the Pontides in the north and the Anatolide-Tauride Block in the south, formed as a result of the closure of the northern branch of Neotethys (Şengör & Yılmaz 1981). The North Anatolian Ophiolite Belt comprises Upper Cretaceous mélanges, which include several different block lithologies. The blocks in the north are largely derived from the Tokat Massif, whereas those in the south from the Akdağmadeni Group (A. Yılmaz 1982a, b). Thin tectonic slices of Upper Cretaceous ophiolitic mélange occur within the Tokat Group (Figures 2 & 3). In contrast, in the North Anatolian Ophiolite Belt in the south, thin tectonic slices of the Tokat Group are found in the Upper Cretaceous mélanges. As shown in Figures 4, 5 & 6, the tectonic slices and the thrusts dip to the north.

Tectonic slices belonging to the Akdağmadeni Group, and consisting of amphibolite-facies metamorphic rocks, are observed in the North Anatolian Ophiolite Belt south of Yıldız Dağ and at Evliya Hill (Figures 2 & 6; A. Yılmaz 1982 a, b). Furthermore, serpentinised peridotite and gabbro slices occur within the Akdağmadeni Group or above them (A. Yılmaz 1980; A. Yılmaz *et al.* 1995). When the sizes and thicknesses of these tectonic slices have been studied, it has been found that the Akdağmadeni slices are thin in the North Anatolian Ophiolite Belt, whereas the ophiolitic mélange slices are thin in the main outcrop area of the Akdağmadeni Group (Figure 3). The relation between the Tokat Group and the Yeşilırmak Group, which is the local name for the North Anatolian Ophiolite Belt, is shown in a cross-section in Figure 3. As seen in this section, and also in Figure 6, the rocks of the Tokat Group and the Akdağmadeni Group are locally in tectonic contact. A similar relation has also been described from the Kızıldağ region (A. Yılmaz 1985; A. Yılmaz *et al.* 1985).

Eocene clastic rocks lie unconformably over the Tokat Group in the north and over the Akdağmadeni Group in the south, and also cover the tectonic contact between these two groups (Figure 6). This suggests that the collision between these plates and the complete consumption of the oceanic lithosphere between these two groups occurred before the Eocene. The tectonic contact between the Tokat Group and the ophiolitic rocks of the Yeşilırmak Group is unconformably covered by the upper Campanian Boztepe Formation, as shown in Figure 4. Therefore, the accretion of the various metamorphic rock slices to the ophiolitic mélange occurred before the late Campanian, possibly during the formation of the ophiolitic mélange.

As stated above, all the present-day tectonic contacts dip to the north. It has been established that the thrusts in the south have had a northward dip at least since the Late Cretaceous – since the formation of the ophiolitic mélange – and have preserved their northward dips during Eocene movements (A. Yılmaz & Özer 1984). In addition, thrusts in the Tokat region are known to be rather young, and possibly active in a neotectonic phase. For example, the extension of the thrusts north of the Çevreli village in Figure 4 have been studied northeast of the Almus reservoir lake, and it has been found that the Lower Miocene clastic and carbonates in the footwall of the thrusts are inverted (Terlemez & Yılmaz 1980).

In conclusion, an investigation of the tectonic relations between the metamorphic units and the ophiolitic mélange suggests that initially the ophiolitic mélange was emplaced both northward and southward over the Tokat and Akdağmadeni groups (Figure 7). The south-vergent structure in the Tokat region developed later in a neotectonic episode. If the initial tectonic picture had been preserved, one would have expected a folded structure with the Akdağmadeni and Tokat groups below and the ophiolitic mélange above, as illustrated in Figure 7b. Such a mechanism provides an explanation as to why the thickness of the ophiolitic mélange slices decreases as one goes to the north and to the south.

Conclusions and Discussion

In the future, more detailed studies of the rocks of the Tokat Group, which make up the Tokat Massif, would allow a more thorough testing of theories concerning the genesis and structure of this Massif, including that by Y. Yılmaz *et al.* (1997a) regarding the evolution of the Tokat Massif. However, at present it can be said that this model does not take into proper account some of the previous data (Özcan *et al.* 1980; Tekeli 1981; A. Yılmaz 1980, 1982 a, b, 1985, 1989). For example, the presence of pre-Jurassic metaophiolite in the Tokat Massif does not necessarily indicate that the Massif is divided by a Palaeozoic suture. The presence of pre-Jurassic ophiolites is known from the North Anatolian Ophiolite Belt, and even from the Lesser Caucasus (Blumenthal 1950; Tatar 1978; Zakariadze *et al.* 1983; A. Yılmaz 1989; Koçyiğit 1991a). However, these ophiolites are accreted to the Upper Cretaceous ophiolitic mélange of the North Anatolian Ophiolite Belt, which represents a suture zone of the northern branch of Neotethys. This belt does not represent a pre-Liassic suture.

Y. Yılmaz *et al.* (1997a) have described a series from the Tokat region consisting of Carboniferous–Permian metapelites at the base, overlain by marble, and overlain unconformably by the blocky Triassic sequence. They assigned this series to Gondwana. However, no such sequence is known from Gondwana. Furthermore, it is questionable as how representative this series is for the regional geology. Figure 4 shows one of the regions where this series has been described. Detailed mapping in this area has shown that the Geyraz Formation and the Çat Marble, which have been described as the lowermost Gondwanian units, are in fact allochthonous within the Permo–Triassic blocky series (A. Yılmaz 1980). Furthermore, this blocky series also crops out north of the metaophiolite between Tokat and Mamodağı (Özcan *et al.* 1980). Therefore, this metaophiolite belt – with similar sequences to the north and to the south – does not represent a suture zone.

The presence of north- and south-dipping thrusts along the North Anatolian Ophiolite Belt and the Lesser Caucasus, developed during Late Cretaceous ophiolite obduction, are widely reported (Zakariadze *et al.* 1983; A. Yılmaz 1985; Okay *et al.* 1996; Okay & Şahintürk 1997). However, because of subsequent deformation related to the North Anatolian Fault Zone, north-vergent structures cannot be seen clearly in the Tokat Massif. As shown in the model in Figure 7, in the Tokat region the ophiolitic mélange was initially thrust both to the north and to the south. The north-vergent thrusts were modified during a later period.

This study has shown that the Turhal Metamorphics of the Tokat Group crop out mainly in the north, whereas the overlying Devecidağ Mélange crops out in the south. The Tokat Group formed in pre-Liassic time, probably during the Permian and Triassic in – from north to south – an arc through fore-arc to subduction-zone setting, and this subduction complex was accreted to the ophiolitic mélange prior to the late Campanian.

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