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The Geology and Evolution of the Tokat Massif, South-Central Pontides, Turkey[1]

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Abstract

The Tokat Massif is a major metamorphic complex of the south-central Pontides, the origin and development of which have long remained unknown. Recent detailed field-based mapping has revealed the major geological features of this complex. The Tokat Massif appears to be a tectonic mosaic composed of three major components: (1) the Yesilirmak Group; (2) the Turhal Metaophiolite; and (3) the Amasya Group. The Yesilirmak Group, which consists of a coherent lithological sequence involving Paleozoic basement and overlying Triassic units, represents a short-lived basin assemblage. The Turhal Metaophiolite consists of an ophiolitic mélange association and slices of a stratigraphically ordered ophiolite. The Amasya Group, the highest-standing tectonic unit, is represented by a lower Paleozoic clastic succession.

The different major tectonostratigraphic assemblages of the Tokat Massif record a continent-continent collision between the Laurasian Amasya Group and the Gondwanan Yesilirmak Group. The Turhal Metaophiolite, sandwiched between the two continental fragments, represents remnants of an oceanic realm that was consumed between the two continents. The three major tectonic components were assembled and underwent regional metamorphism during the Late Triassic–Liassic transition, and were later covered during the Liassic by basal detrital units.

Introduction

Turkey lies within the Alpine orogenic belt and consists of four major E-W-trending tectonic zones. From north to south, these are the Pontides, the Sakarya continent, the Anatolide-Tauride platform, and the Arabian platform (Fig. 1). These tectonic zones are separated from one another by ophiolitic sutures. The Tokat Massif is a metamorphic complex located in the south-central Pontides (Fig. 1). The

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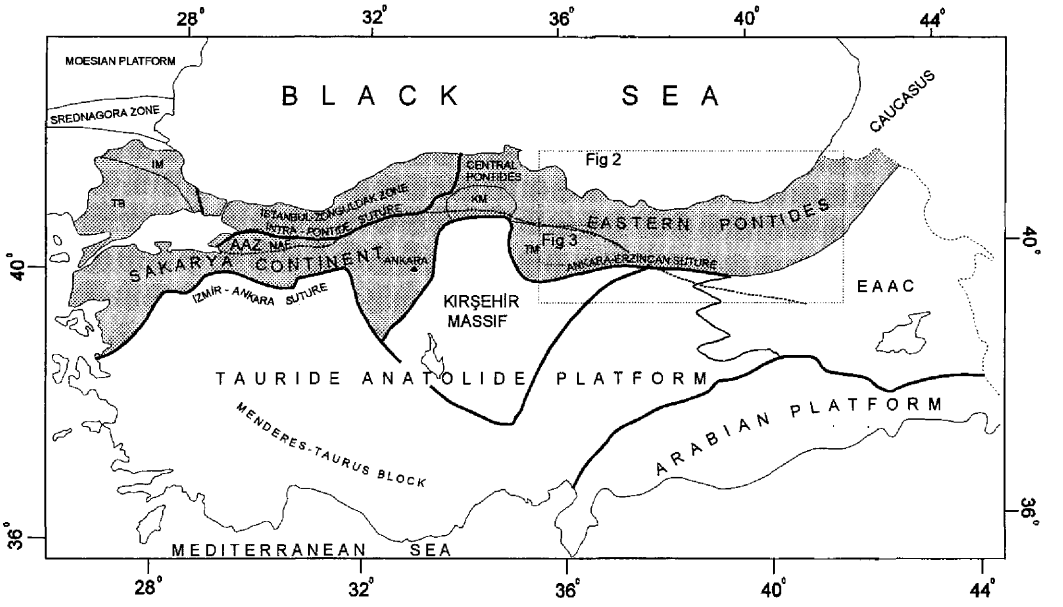


FIG. 1. Major tectonic divisions of Turkey and the Pontides (shaded region). Abbreviations: IM = Istranca Massif; TB = Thrace Basin; AAZ = Armutlu-Almacik zone; KM = Kargi Massif; NAF = North Anatolian transform fault; EEAC = Eastern Anatolian accretionary complex. Insets show the locations of maps displayed in following figures.

Erzincan-Ankara ophiolitic suture separates the Tokat Massif from a metamorphic complex to the south (the Kirsehir Massif) that belongs to the Anatolides. To the north, the Tokat Massif crops out extensively as far north as the North Anatolian fault zone; across the fault it is juxtaposed against Mesozoic and Tertiary supracrustal successions of the Pontides.

The metamorphic massifs of Turkey previously were regarded as ancient basement rocks and were referred to as the Anatolides (Arni, 1939; Ketin, 1966). However, detailed studies within the last two decades have demonstrated that some of these metamorphic massifs—particularly those occurring in central Anatolia, such as the Menderes Massif and the Kirsehir Massif—are in fact much younger (Ketin, 1966; Sengör and Yilmaz, 1981), being formed during or after the Late Cretaceous (Sengör and Yilmaz, 1981). Studies of the Kargi Massif, a metamorphic complex neighboring the Tokat Massif in the central Pontides (Yilmaz and Tüysüz, 1984; Tüysüz, 1990, Yilmaz, 1990) (Fig. 2), have demonstrated that it is a tectonic mosaic that was assembled progressively during the orogeny. This and other findings (Yilmaz, 1978; Yilmaz et al., 1993) have cast doubt on the previous assumption that the metamorphic massifs are old and represent the ancient basement of Anatolia. As a result, new research on the metamorphic massifs of Turkey was undertaken during the 1970s and 1980s. Studies of a similar nature, conducted by Y. Yilmaz and collaborators, were focused on the northern metamorphic massifs of Turkey. Metamorphic assemblages investigated include those cropping out in the Pontides, from the Armutlu Peninsula in western Anatolia to the Artvin area near the Georgian border (Yilmaz et al., 1981; Yilmaz and Tüysüz, 1984, 1991; Yilmaz et al., 1993, 1994, 1995; Genç and Yilmaz, 1995).

The Pontides represent an orogenic belt that records the Cimmeride and Alpide orogenic events (Sengör and Yilmaz, 1981). The Cimmeride orogenic phase resulted from elimination of the Paleotethys and a dependent branch known as the Karakaya marginal basin that existed during the Triassic (Sengör et al., 1984).

There is overall agreement among previous workers (Sengör and Yilmaz, 1981; Yilmaz et al., 1981; Bekta et al., 1984; Gedik et al., 1992; Korkmaz et al., 1993; Tüysüz et al., 1995; Yilmaz et al., in press) that the Pontide Range

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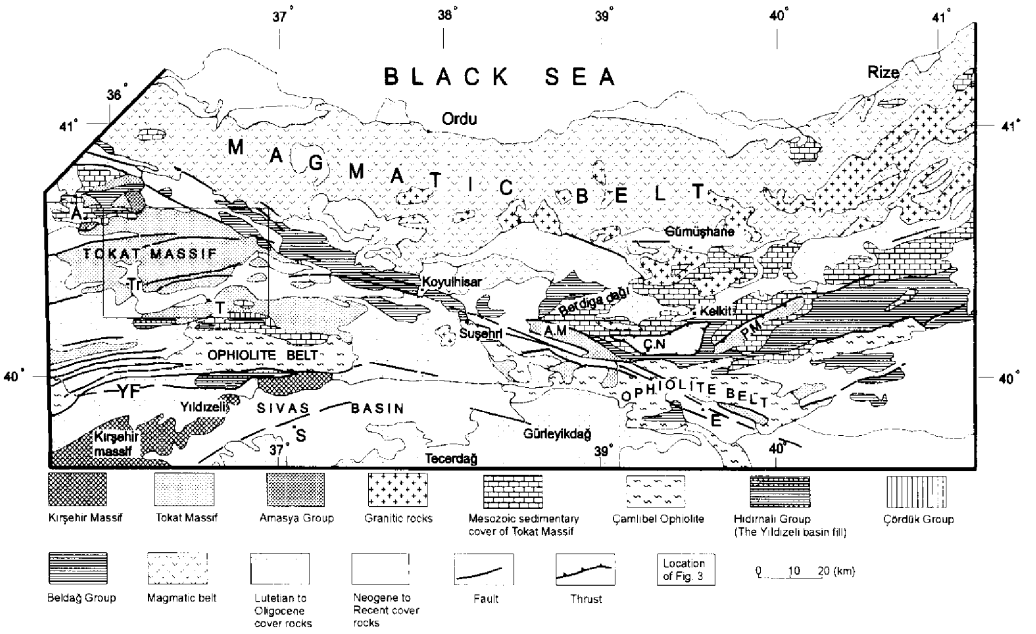


FIG. 2. Geological map of the eastern Pontide Range. Inset shows location of the map displayed in Figure. 3. Abbreviations: A = Amasya; E = Erzincan; S = Sivas; T = Tokat; AM = Agvanis Massif; CN = Cimendag nappe; PM = Pulur Massif; Tr = Turhal; YF = Yildizeli fault.

became the site of Andean-type mountains during the closure of Tethys, and remained a volcanic chain until the latest phase of collision of the arc with continental lithospheric fragments situated in the south (i.e., the Taurides and the Kirsehir Massif). The collision occurred during Late Cretaceous–Early Eocene time. During this period the Tokat Massif was elevated and played an active role in the geological evolution of the Pontides (Yilmaz et al., in press). Little was known about the major geological problems related to the origin, generation, and evolution of the Tokat Massif, because of the lack of detailed previous work, with the exception of some local studies such as metamorphic rock descriptions from selected areas (Özcan et al., 1980; Seymen, 1993). A four-year field-based project was carried out from 1992 to 1994 for the purpose of finding answers to the major problems outlined above, and the entire Tokat Massif and the surrounding areas were mapped. As a result, 35 geological map sheets at a scale of 1:25,000 were produced. The main findings of this research are outlined below, and the major geological problems related to the Tokat Massif and the surrounding region are discussed.

Stratigraphy

The Tokat Massif is a metamorphosed tectonic mosaic in which three distinctly different tectono-stratigraphic assemblages are recognized. The contacts among them are thrusts. The different metamorphic assemblages are overlain collectively by Liassic clastic sedimentary rocks (Figs. 2 and 3). However, the Liassic rocks are severely sheared in places, penetratively deformed, and cataclastically metamorphosed. The three major components of the Tokat Massif are the Yesilirmak Group, the Amasya Group, and the Turhal Metaophiolite.

The Yesilirmak Group

The Yesilirmak Group is the dominant rock group of the Tokat Massif, cropping out extensively from Corum in the west to Resadiye in the east (Fig. 2). It covers an area of ~75 × 20 km. The Yesilirmak River cuts across the Tokat Massif between Tokat and Amasya, providing good exposures along the river valley.

The Yesilirmak Group displays regional metamorphism, well-developed, penetrative schistosity, and polyphase deformation. Despite

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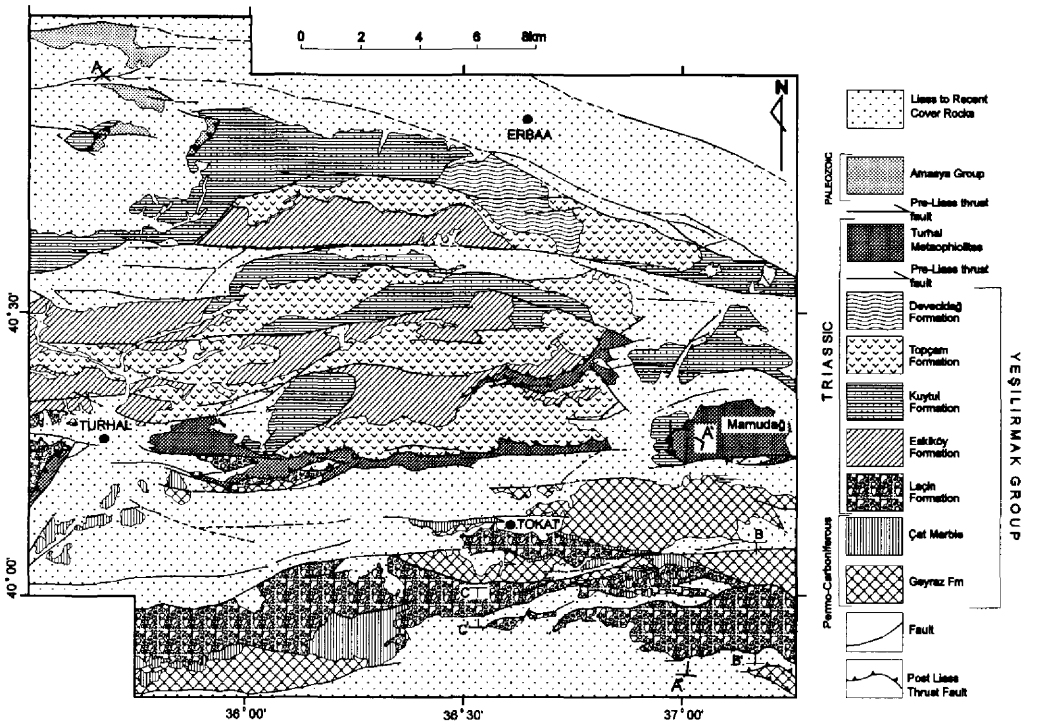


FIG. 3. Simplified geological map of the Tokat Massif and the surrounding regions. A-A'-A" = cross-section direction in Figure 6; B-B = cross-section direction in Figure 9; C-C = cross-section direction in Figure 10.

metamorphism extending into the epidote-amphibolite facies, constituent rock units have been differentiated through detailed field work, establishing the stratigraphic sequence prior to the regional metamorphism. The generalized stratigraphic section of the Yesilirmak Group is illustrated in Figure 4. Ages of deposition were identified from fossil assemblages obtained from the metasedimentary rocks and their local and regional stratigraphic correlations. The metamorphic grades encountered in the Yesilirmak Group decrease gradually upward. Thus the upper units of the sequence are only slightly metamorphosed, displaying primary sedimentary and volcanic features.

The stratigraphic units of the Yesilirmak Group include, from bottom to top (Fig. 4), the The Geyraz Formation, the Cat Marble, the Laçin Formation, the Eskiköy Formation, the Kuytul Formation, the Topçam Formation, and the Devecidag Mélange.

The Geyraz Formation. The Geyraz Formation is the lowermost unit exposed in the core of a regional anticline in the southern part of the Tokat Massif, where the unit displays well-developed schistosity dipping at high angles to the north and south. The best outcrops of the Geyraz Formation can be observed along the Yesilirmak River valley. This unit consists primarily of pink to brown meta-semipelitic and pelitic rocks, represented by metaquartzite at the bottom, schists and phyllites in the middle, and recrystallized limestone lenses alternating with the phyllites at the top. The formation is cut in places by granitic veins and dikes.

The Cat Marble. The Cat Marble consists of fine-grained marbles and recrystallized limestones that crop out extensively around the village of Cat and the surrounding area, south of the city of Tokat (Fig. 3). This unit is readily distinguished in the field since it comprises resistant hills and cliffs. The thickness of the Cat Marble varies from a few meters to 300 m. Such a large variation is related mostly to lateral facies changes (pinching), possibly the result of the more resistant nature of the marble with respect to the surrounding pelitic rocks. The unit displays a variety of contact relationships

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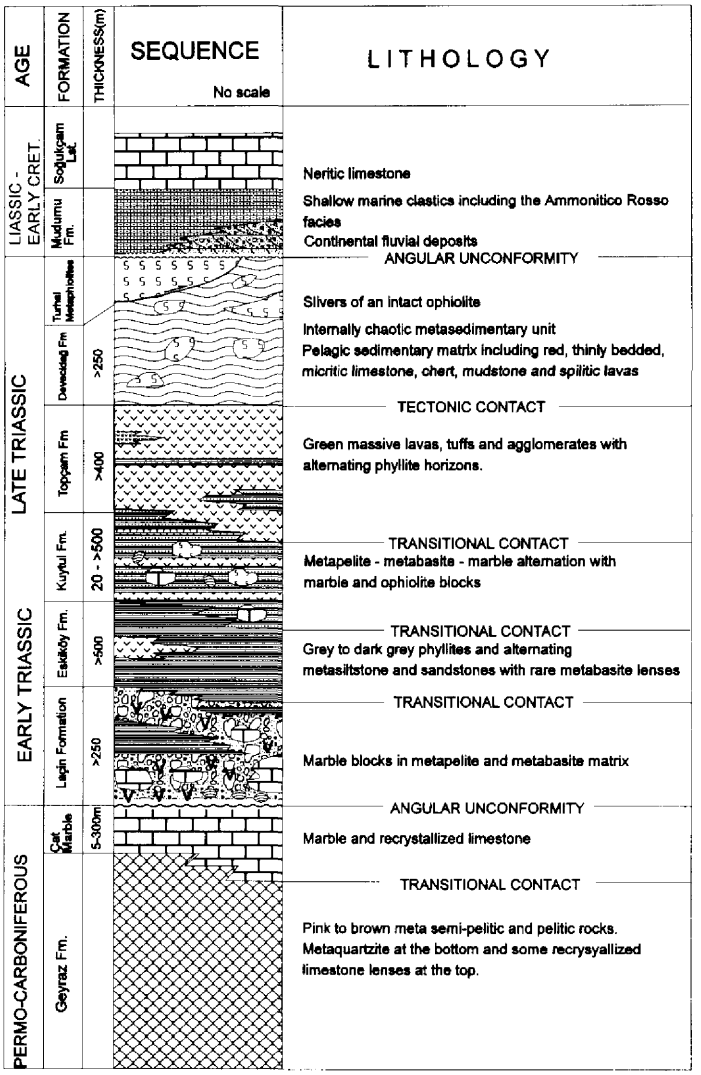


FIG. 4. Generalized stratigraphic columnar section of the Yesilirmak Group.

with the overlying and underlying metasedimentary rocks. Some thin, precursor limestone horizons with similar lithological features to those of the Cat Marble are observed locally, but commonly the marble rests unconformably on the underlying units, beginning with a thin (<10 m thick) quartzitic sandstone layer at the base of the unit. At the top, recrystallized limestone horizons interbed with metamudstone and shale-siltstone-micritic limestone alternations. A basal conglomerate rests unconformably on the marble. Pebbles in the conglomerate were derived from the underlying marble and are cemented by a pink mud matrix. The conglomerates give way to a megaconglomerate unit known as the Laçin Formation.

The lower part of the Cat Marble is grey and medium bedded. Some beds are dolomitic and bituminous. Others are fossiliferous, containing abundant fusulinid fauna. The following fossils were identified in the area surrounding the village of Cat: *Hemigordius* aff. *renzi*, *Baisehina pulchre*, Schwagerinidae, *Hemigordius* sp., *Kamurana* cf. sp., Stafellidae, Paleotextularia sp., and *Agathammina* sp. According to this fossil assemblage, the unit is Late Permian

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in age. The upper part of the formation is grey, with thin chert horizons and nodules. Collectively the Cat Marble succession is indicative of a progressively deepening marine environment. This is evidenced by the neritic carbonate sequence at the bottom, which gradually gives way to pelagic cherty limestones at the top.

The Laçin Formation. The Laçin Formation commonly is a chaotic unit consisting of abundant blocks trapped in a metapelitic and metavolcanic matrix. The blocks are dominantly derived from the underlying Cat Marble succession. The unit displays relatively better ordering at the bottom and the top, but is mostly chaotic in the middle; its thickness varies from 100 to 500 m. The Laçin Formation crops out extensively in an approximately E-W–trending belt from Hanpinari, through Teknecik-Semerci, to Toraç Mountain (Fig. 3). The unit is well exposed on the Inçali hill, the Hanpinari dam lake, and the Kavakdere stream valley.

At the base of the Laçin Formation, the matrix consists of alternating dark lavas, siltstones, quartzites, and metatuffs including ignimbrites. Within these layers a number of lenses of fluvial conglomerate wedge out within short distances. At the top, the matrix gradually grades into purple shales, graywackes, and alternating red mudstone, limestone, and chert. Basalt lava layers alternating with the lower metasedimentary sequence are commonly amygdaloidal, whereas basalts intercalating with sediments at the top of the succession display deformed pillow structures aligned parallel to the schistosity.

Light grey, fossiliferous recrystallized limestone beds interbedded with the metagraywackes and metasiltstones occur at the bottom of the sequence. The limestones that outcrop around the village of Cat between Inçali hill and Üçtepeler contain the following fauna: *Frondicularia woodvordi*, Trochamminidae, *Involutina* spp., *Ammodiscus* spp., *Opthalmidium* spp., Amodiscina, and Nodosariidae.

According to this fossil assemblage, the Laçin Formation is Middle to Late Triassic in age. At the top of the sequence, the formation gradually grades into a metasedimentary unit known as the Eskiköy Formation.

The Eskiköy Formation. The Eskiköy Formation is a metaflysch sequence consisting of grey to dark grey phyllites of alternating metasiltstone and sandstone origin. The formation is one of the dominant rock units of the Tokat Massif, displaying good exposures around the villages of Eskiköy and Sirçali, and along the valley of the Keten stream. The unit displays well-developed, closely spaced slaty cleavage and crenulation cleavage. In this unit, large- and small-scale folds are common. As a result of tight folding and S-vergent thrusting, which repeat the succession, the exact thickness of the unit is difficult to establish. The apparent thickness is more than 500 m.

Metasandstone layers of the Eskiköy Formation commonly display primary sedimentary features such as parallel and convolute laminations, bottom marks, gradings, and slump structures. Within the shale- and phyllite-rich layers are intraformational fragments entrapped in a matrix of similar rocks. Euhedral, coarse, cubic pyrite porphyroblasts also are common within the fine-grained phyllitic matrix. An ophiolitic mélange slice that was tectonically wedged into the Eskiköy Formation as a result of the S-vergent thrusting is present in the Tekmezar area. The phyllite-dominated succession of the Eskiköy Formation gradually passes into green foliated metalavas, alternating with white calcschist toward the top of the sequence. This overlying lava-sediment alternation is differentiated as the Kuytul Formation.

The Kuytul Formation. Along the Keçeci stream valley north of Tokat, and around the villages of Kuytul and Bayat, outcrops of the Kuytul Formation are well exposed. This unit consists of a metapelite-metabasite-marble alternation that forms a matrix encompassing blocks of marbles and ophiolitic rocks. The metapelites are composed essentially of phyllites, semi-schists, schists, and marbles. The protoliths of the metapelites apparently are a sedimentary succession that consisted essentially of a fine-to-coarse clastic alternation. The marbles occur mostly as lenses ranging in thickness from a few meters to 100 m. The metavolcanic rocks are mainly well-foliated, green lustrous metalavas in which rounded, white albite porphyroblasts and the surrounding chlorite-actinolite–rich matrix may be distinguished readily. Locally the metalavas display pillow structures. In places, some tuff layers also can be recognized. With an increase in the amount of blocks, the unit becomes internally more chaotic.

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The thickness of the Kuytul Formation varies from a few meters to 500 m, and it is cut by a number of basic and felsic magmatic dikes and veins. The dikes apparently were formed before regional metamorphism, as evidenced by the metamorphic structures and textures that cut across the contacts of the dikes within the host rocks. Despite this, a relatively well preserved diabase texture is preserved locally in the dikes. The Kuytul Formation passes laterally and vertically into the Topçam metavolcanic association.

The Topçam Formation. The Topçam Formation crops out widely along the crests of the E-W-trending mountain ranges situated north of Tokat. This unit is essentially a metavolcanic association consisting of an alternation of lavas with pyroclastic rocks. The common lithologies are green, massive lavas, tuffs, and agglomerates. They alternate with some rare, buff-to-brown, well-foliated phyllite horizons. Around the Tepeyurt, Tekmezar, Kemikbeli, and Gavurçukuru areas, some pelagic sedimentary horizons—such as manganiferous cherts, radiolarites, and mudstones—are intercalated with the pillow lavas. The Topçam metavolcanic association also is cut by basic and felsic dikes.

The major mineral constituents of the metavolcanic rocks are euhedral brown garnet, white porphyroblastic albite, pale-green epidote, needle-like, dark-green actinolite, and fibrous chlorite, which are easily recognized in the field. The metalavas display relatively well preserved pillow structures with the long axis ranging from 15 to 60 cm. Interpillow pelagonite tuffs, radial cracks, and glassy rims are identified locally. In the succession, in addition to the metapyroclastic rocks, volcanic mud flows, lahar breccias, and autoclastic lava breccias also are present. The metapyroclastic rocks have well-developed and closely spaced foliation planes.

The Devecidag Formation. The Devecidag Formation is a metamorphosed olistostrome that occurs widely in the Devecidag area. This unit often is spatially associated with the Turhal Metaophiolite and commonly is tectonically underlain by the ophiolite nappe. The Devecidag Formation comprises blocks including serpentinized peridotite, gabbro, basalt, and epi-ophiolitic sedimentary rocks—i.e., manganiferous shale, red limestone, and chert. Some of the blocks are marbles and recrystallized limestones. The matrix of the unit is a weakly metamorphosed flysch-wildflysch succession including calciturbidites with interbedded shales and tectonized olistoliths in a tectonized matrix. The formation has been pervasively mixed by sedimentary processes modified locally by tectonic processes. The age of the Devecidag Formation is Late Triassic, because it contains blocks of the underlying units up to Middle to Late Triassic age and is overlain transgressively by Liassic sandstones.

Age, metamorphism, and evolution of the group. The Yesilirmak Group may be divided into two coherent subgroups, the Lower Units and the Upper Units, separated by a major unconformity. The Lower Units are represented by the Geyraz Formation and the Cat Marble, which collectively form the basement beneath the overlying rocks of the Upper Units. The age of these rocks is Paleozoic, reflecting the Late Permian age obtained from the Cat Marble. The overlying rocks of the Upper Units include a continuous sequence whose members are laterally and vertically transitional (Figs. 3 and 4). This sequence is Triassic, as indicated by paleontologic data. The Middle to Late Triassic ages are determined from the middle part of the section, but it is assumed that the sequence also includes Lower Triassic rocks, since there is a thick succession under the Middle Triassic rocks from which no fossils have been obtained.

The Devecidag Formation includes blocks of the Lower and Upper units that were incorporated into the olistostrome by sedimentary processes. The rocks of the two units of the Yesilirmak Group are collectively blanketed by Liassic basal conglomerates and sandstones.

The metamorphic history of the Yesilirmak Group is more complicated than is suggested by the stratigraphic data outlined above, because the angular unconformity dividing the Lower and Upper units also separates two rock groups of different metamorphic histories; the Lower Units display polyphase metamorphism reaching amphibolite facies, whereas the highest grade of metamorphism in the Upper Units extends only to middle greenschist facies. The different metamorphic histories of the Upper and Lower units are further supported by the following evidence. (1) A post-tectonic, high-level granitic pluton was emplaced into high-grade metamorphic rocks of the Lower Units during the Carboniferous; the granite is 298 Ma

by U/Pb dating (Cogulu, 1975) and 360 ± 2 Ma by $^{87}Sr/^{86}Sr$ dating (Bergougnan, 1987). The metamorphic rocks as well as the granite are stratigraphically overlain by Upper Permian Cat Marbles. This indicates that the Lower Units already were regionally metamorphosed before the intrusion of the granite during Carboniferous time. Pebbles of the schists and the granite are common in the basal arkosic and quartzitic conglomerates of the Triassic succession. (2) The Lower Units exhibit a more complicated history of deformation; two more folding phases are recorded in rocks of the Lower Units than in the Upper Units. This has also been reported previously by Seymen (1991, 1993).

In light of the above, the following geological evolution may be envisaged for the Yesilirmak Group. The rocks of the Lower Units underwent regional metamorphism before the Carboniferous; the granitic post-tectonic pluton intruded the metapelitic rocks during the Carboniferous. A new marine transgression occurred and deposited the basal sandstone, followed by the limestone succession, above this basement during the Permian. Subsequently, a new transgression occurred above a regionally developed surface of an angular unconformity. This transgression is associated with the opening of a new basin during the Triassic, which is represented by the Upper Units. The lower and upper subgroups collectively underwent severe tectonism and a new phase of regional metamorphism by the beginning of the Liassic.

The Turhal Metaophiolite

The Turhal Metaophiolite is a metamorphosed ophiolite nappe that overlies the Yesilirmak Group. Three different tectonic units, after tectonic mixing, formed the metaophiolite: (1) an ophiolitic mélange; (2) an internally chaotic sedimentary assemblage (an olistostrome); and (3) a slice of a stratigraphically coherent ophiolite. The ophiolite slices commonly occur as thin thrust sheets wedged into the other tectonic units. The matrix of the mélange commonly consists of sheared serpentinites and spilitic lavas; however, in places the matrix is composed of tectonized shales and mudstones.

The Turhal Metaophiolite outcrops extensively in a narrow belt from the Turhal area in the west to Mamudag and Tozakli Dag in the east (Fig. 3). The best outcrops of the disrupted ophiolite can be seen in Mamudag and to the south of Turhal. The ophiolitic mélange is exposed mostly north of Günevi and between the villages of Sirçali and Boyali.

The Turhal Metaophiolite may be regarded as a subduction-accretion mélange that was mixed by both sedimentary and tectonic processes. This view is further supported by a glaucophane-bearing greenschist-facies metamorphic overprint, which is encountered in a variety of places, including the Kurudere area east of Tokat. The Turhal Metaophiolite tectonically overlies all the members of the Yesilirmak Group and in turn is underlain either by the nappe of the Amasya Group or by basal clastic rocks of Liassic age.

The Amasya Group

Among the major components of the Tokat Massif, the Amasya Group is present as only a few scattered inliers of limited size around the town of Amasya (Figs. 2 and 4). Original sedimentary features of the metasedimentary succession, such as cross-bedding, graded bedding, and flute casts, are easily identified in these outcrops. Despite the preservation of the latter features, the rocks apparently have undergone a regional compressional deformation accompanied by incipient crystallization, as evidenced by the porphyroclastic and foliated textures that developed to varying degrees. The textural rearrangements are more extensive than the development of metamorphic minerals, which are restricted to the formation of sericite and chlorite.

Outcrops of the Amasya Group begin at the bottom with quartzitic metaconglomerates and sandstones (Fig. 5). Among the quartzitic sandstones are a few thin (10 to 30 cm) limestone horizons. The lower clastic rocks are medium to coarse grained, hard, resistant, and dark colored. The sandstones are commonly well sorted. The conglomerates are poorly sorted and pinch out laterally within the quartzitic sandstone hosts; the main components of the conglomerates are granitic and metamorphic rocks. The quartzitic sandstones consist essentially of quartz and feldspar grains.

Upward in the section, the sandstones alternate with shales and siltstones. Following this gradual transition, the fine-grained detrital

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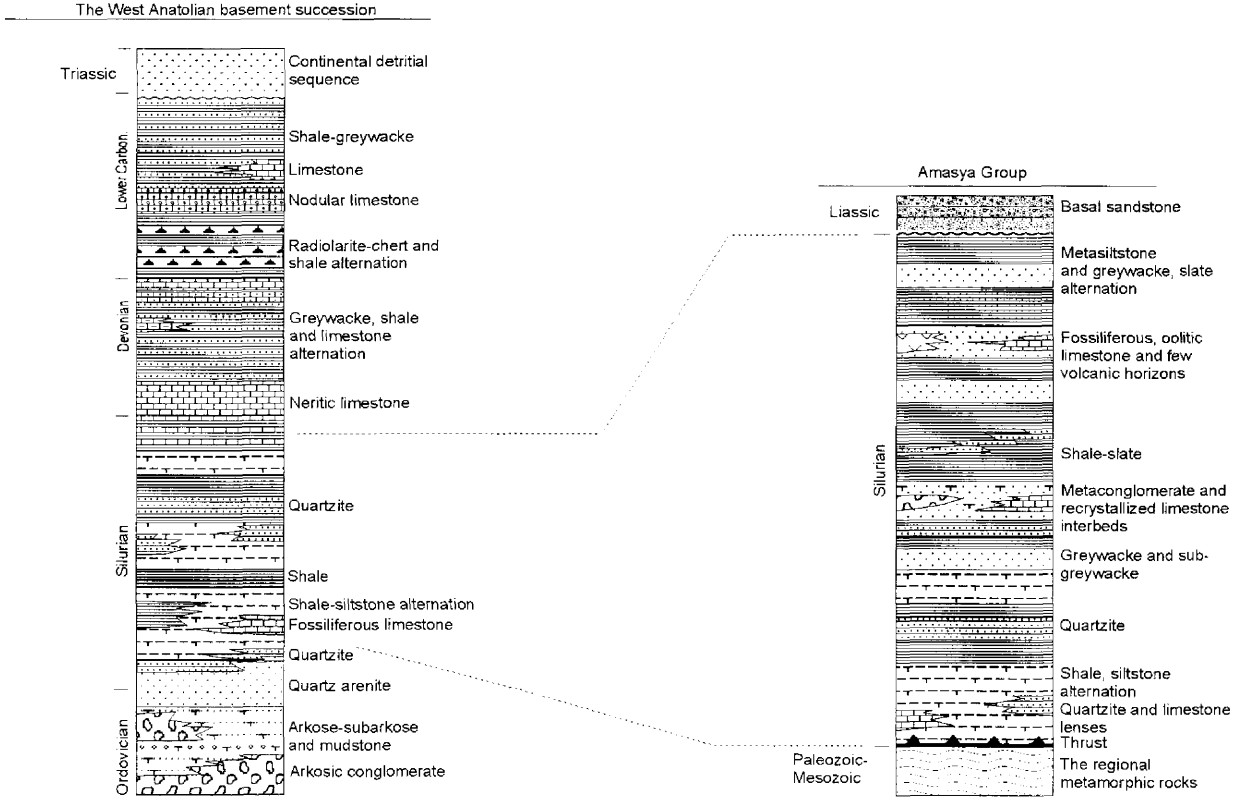


FIG. 5. Comparative stratigraphic sections of the west Anatolian basement and the Amasya Group.

rocks become dominant. Consequently, the sequence is represented by dark, brittle, well-bedded, locally well-foliated, slightly metamorphosed subgraywackes and shales. In places they gradually grade into a slate-phyllite association in which the development of sericite and chlorite gives the rocks a lustrous appearance. Among the fine-detrital successions also are thin, fossiliferous and dark-colored limestone beds. Alp (1972) identified the following Silurian fauna from the upper layers of the sequence: *Harricoceras* sp., *Euorthoceras* sp., and *Leurocycloceras* sp.

The metamorphic grade of the Amasya Group is low, rarely extending to the lower limit of the greenschist facies. However, in places the metasedimentary succession displays intense cataclasis, as evidenced by well-developed shear zones that increase in intensity toward the main contact of the Amasya Group with the underlying rocks. This corresponds to the thrust surface, above which the Amasya Group rests tectonically on metalavas and metapelitic rocks of the Yesilirmak Group. The thrust contact is exposed between Turhal and Amasya. The metamorphic grades differ significantly across the thrust boundary; the Amasya Group displays zeolite- to lowermost greenschist-facies metamorphism, whereas glaucophane-bearing greenschist-facies assemblages are identified in the underlying rocks of the Turhal Metaophiolite.

In the Amasya area, the Amasya Group is stratigraphically overlain by the Liassic basal sandstones and conglomerates. A good section of the sediment cover is exposed in the Karasenir area (Fig. 2).

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Metamorphism of the Tokat Massif

The mineral assemblages of the three major components of the Tokat Massif are outlined below.

The Amasya Group

This group displays a metamorphic transition between diagenesis and regional metamorphism. The metamorphic mineral assemblages encountered in these rocks include:

quartz + albite + chlorite + sphene, in the graywackes (prehnite occurs only in the altered graywackes); quartz + albite + muscovite + stilpnomelane + pumpellyite, in the slates of metasandstone parentage; and quartz + albite + muscovite + chlorite, in the pelitic phyllites.

These assemblages indicate that the metamorphic grade exceeded the lower limit of the greenschist facies.

The Yesilirmak Group

In this group, a complete transition is seen from high-grade well-foliated schists, occurring at the bottom of the sequence, to slightly metamorphosed metavolcanic and metasedimentary rocks, in which primary structural and textural features are well preserved, near the top of the section.

The mineral assemblages encountered in these graywackes, sandstones, and lavas are listed below, in order of increasing grade of metamorphism.

A. Metapelitic-semipelitic rocks:

muscovite + chlorite + quartz + albite, muscovite + chlorite + albite + quartz + stilpnomelane ± hematite, quartz + muscovite + chlorite + albite + biotite ± epidote, quartz + muscovite + chlorite + albite + biotite + garnet ± epidote.

B. Metavolcanic rocks:

albite + chlorite + muscovite + quartz ± epidote ± calcite, albite + epidote + chlorite + actinolite + sphene ± quartz, chlorite + actinolite + albite + sphene ± biotite ± quartz ± epidote, epidote + chlorite ± glaucophane ± albite + calcite, albite + actinolite ± hornblende (blue-green) ± sphene ± epidote.

C. Metacarbonate rocks:

calcite + quartz, dolomite + calcite + quartz.

The mineral paragenesis listed above covers almost the entire range of the Barrovian-type greenschist facies (Will et al., 1990). The absence of minerals such as zeolite, prehnite, and pumpellyite distinguishes these metamorphic facies from the zeolite and prehnite-pumpellyite facies. Also, the absence of lawsonite, jadeite, and omphacite indicates that the limits of the glaucophone-lawsonite facies were not exceeded.

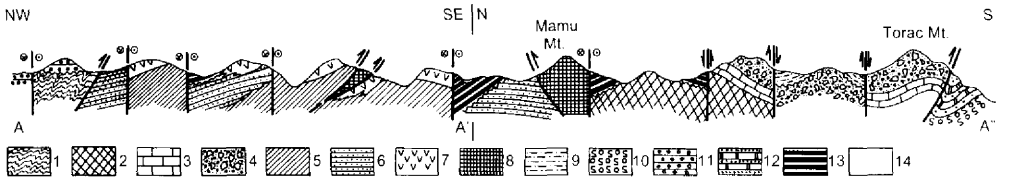


FIG. 6. Geological composite cross-section across the Tokat Massif. See Figure 3 for cross-section direction (A-A'-A''). Legend: 1 = Amasya Group (western Pontide basement); 2 = Geyraz Formation; 3 = Cat Marble; 4 = Laçin Formation; 5 = Eskiköy Formation; 6 = Kuytul Formation; 7 = Topçam Formation; 8 = Turhal Metaophiolite; 9 = Liassic to Lower Cretaceous sedimentary rocks; 10 = Upper Cretaceous ophiolitic mélange; 11 = Upper Cretaceous detrital rocks (Belda Group); 12 = Upper Cretaceous olistostrome and micritic limestone succession; 13 = Middle Eocene detrital rocks; 14 = Plio-Quaternary deposits.

The Turhal Metaophiolite

Within the different rock varieties of the Turhal Metaophiolite, the following mineral assemblages are observed.

A. Metabasites:

albite + chlorite + glaucophane, albite + muscovite + epidote + quartz + actinolite + glaucophane.

B. Metacherts:

quartz + albite + epidote, quartz + hematite + epidote + glaucophane (or riebeckite), quartz + stilpnomelane + glaucophane (or riebeckite).

C. Metagraywacke:

quartz + albite + chlorite + muscovite + stilpnomelane + calcite.

D. Metapelite:

muscovite + chlorite + albite + quartz + stilpnomelane.

In the metaophiolite association, typical glaucophane-lawsonite-facies mineral assemblages—such as jadeite, lawsonite, aragonite, and typical prehnite—are not found. The rocks of highest metamorphic grade of the Tokat Massif contain the hornblende + plagioclase association. Despite this, the metamorphic grade rarely exceeds the upper limit of the greenschist facies, because the plagioclase composition is commonly within the albite range. However, the presence of glaucophane in some rocks indicates that the pressure was relatively high in places, but not high enough for the glaucophane-lawsonite assemblage to develop. The metamorphic mineral paragenesis listed above collectively indicates that these rocks were metamorphosed under P-T conditions varying from 3 to 6 kbar and 300 to 500°C, indicating that the rocks were buried to depths of 10 to 18 km during metamorphism.

The petrological data obtained across the contacts of the three major components of the Tokat Massif are inadequate to state conclusively whether the grade of metamorphism across the thrust planes is or is not continuous. This is partly the result of the Late Cretaceous post-metamorphic structural rearrangement of the Tokat Massif, during which most of the initial tectonic positions of the major tectonic units were rearranged. However, it is clear that the metamorphic grade decreases steadily from the bottom of the metamorphic pile to the top of the sequence.

Discussion

As outlined above, the Tokat Metamorphic Massif is a tectonic mosaic composed of the Amasya Group, the Yesilirmak Group, and the Turhal Metaophiolite. The three major components differ significantly from one another in age, lithology, metamorphism, and tectonic setting. The Amasya Group represents the highest-standing tectonic unit and rests on top of the other tectonic units as a nappe (Figs. 3, 5, and 6). The Paleozoic rocks of the Amasya Group are weakly metamorphosed, mostly as a result of intense semibrittle to ductile cataclasis. These rocks are assumed to have formed during nappe emplacement, because the arrangement of the structures as expressed by vorticity indicators, such as the attitudes of small-scale folds, cleavage planes, and deformed pebbles, all are

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consistent with a single stress field, and collectively suggest that they were formed by SE-directed tectonic transport (Yilmaz et al., 1993).

The Amasya Group is lower Paleozoic in age, as indicated by fossils obtained from graywackes and interbedded limestones. The stratigraphic section that crops out in the Amasya area, although limited in extent and thickness, compares closely with the Silurian and underlying rocks widely exposed in the basement of the western Pontide Range (Yilmaz et al., in press). This basement is known to have originally belonged to Laurasia, inasmuch as it contains Laurasian fauna (Dean et al., 1993). Given this similarity, the Amasya Group may be regarded as a weakly metamorphosed equivalent of the western Pontide basement, which was deformed and metamorphosed during its transportation as a nappe onto the other tectonic units in the Amasya area.

The Yesilirmak Group, the lowermost tectonic unit of the Tokat Massif, is much younger than the Amasya Group. The ages obtained from this unit range from middle through late Paleozoic to Late Triassic. This tectonic unit is commonly shown on the regional geological maps of Turkey (see, e.g., Gattinger, 1962) as a separate tectonic entity, possibly because it is bounded to the north by the eastern Pontide Range, across the North Anatolian transform fault, and to the south by the Izmir–Erzincan ophiolite suture. However, the Tokat Massif is similar in lithological ordering, age, and metamorphism to the Agvanis, Pulur, and Gümüshane metamorphic massifs that crop out farther east in the eastern Pontide belt (Fig. 7) (Okay, 1983; Akdeniz, 1988; Koçyigit, 1991; Yilmaz et al., 1993, 1994). These metamorphic massifs form the basement metamorphic assemblages of the eastern Pontide Range beneath the Mesozoic and younger cover rocks. Sengör (1990) compared and discussed data derived from basement rocks of the Pontides and neighboring regional tectonic units along the extension in the Caucasus and Iran with the Gondwanan sections. Sengör concluded that this range was attached to the northern edge of Gondwana until the Triassic. If this view is correct, then the Tokat Massif also may be regarded as originally belonging to Gondwana.

The rock-stratigraphic units of the Yesilirmak Group form two coherent groups of rocks: an old metamorphic basement assemblage and an overlying Triassic succession (Fig. 4). In the old metamorphic assemblage, three rock units are distinguished: (1) Paleozoic schists and associated metamorphic rocks; (2) a Carboniferous post-tectonic intrusive granite; and (3) a Permian neritic limestone succession. In the Triassic sequence, although rapid vertical and lateral transitions are observed, three major rock groups also may be distinguished. (1) The lower rock units consist of basal clastic rocks and intercalated basaltic lavas; this unit contains abundant blocks and olistostromes from the underlying metamorphic rocks. (2) The middle rock unit is represented by deep-sea sedimentary rocks and associated pillow basalts. (3) The upper rock unit is a flysch sequence enveloping various blocks and olistostromes; the blocks and fragments were mostly derived from an ophiolite association. The contacts between the lower, middle, and upper rock units are transitional, suggesting that the entire sequence was formed during the progressive stages of basin development.

When evaluated collectively, the Triassic sequence may be interpreted as follows. During the Early Triassic, a marine transgression occurred over the Paleozoic rocks of the region, depositing basal clastic rocks, followed by fine-grained detrital rocks and carbonates (the Cat Marble). Permian limestones were incorporated into the Triassic lower clastic succession as blocks and olistostromes. During the same time, basaltic lavas were extruded and intercalated with the clastic rocks. All of these data may be interpreted as reflecting the initiation of basin opening associated with an episode of normal faulting. This possibly corresponds to the early stages of continental breakup, because during this period, internally chaotic clastic units accompanied by possible rift-type basaltic lavas were formed (the Laçin Formation). The clastic rocks gave way to an increasingly deeper sea section as rifting progressed, as indicated by the gradual upward transitions from clastic rocks to radiolarian and manganiferous cherts, shales, and micritic limestones (the Eskiköy Formation). During this phase, internally chaotic sedimentary units were gradually replaced by more orderly successions. The sediments were accompanied by basaltic pillow lavas (the Topçam Formation). This assemblage may be

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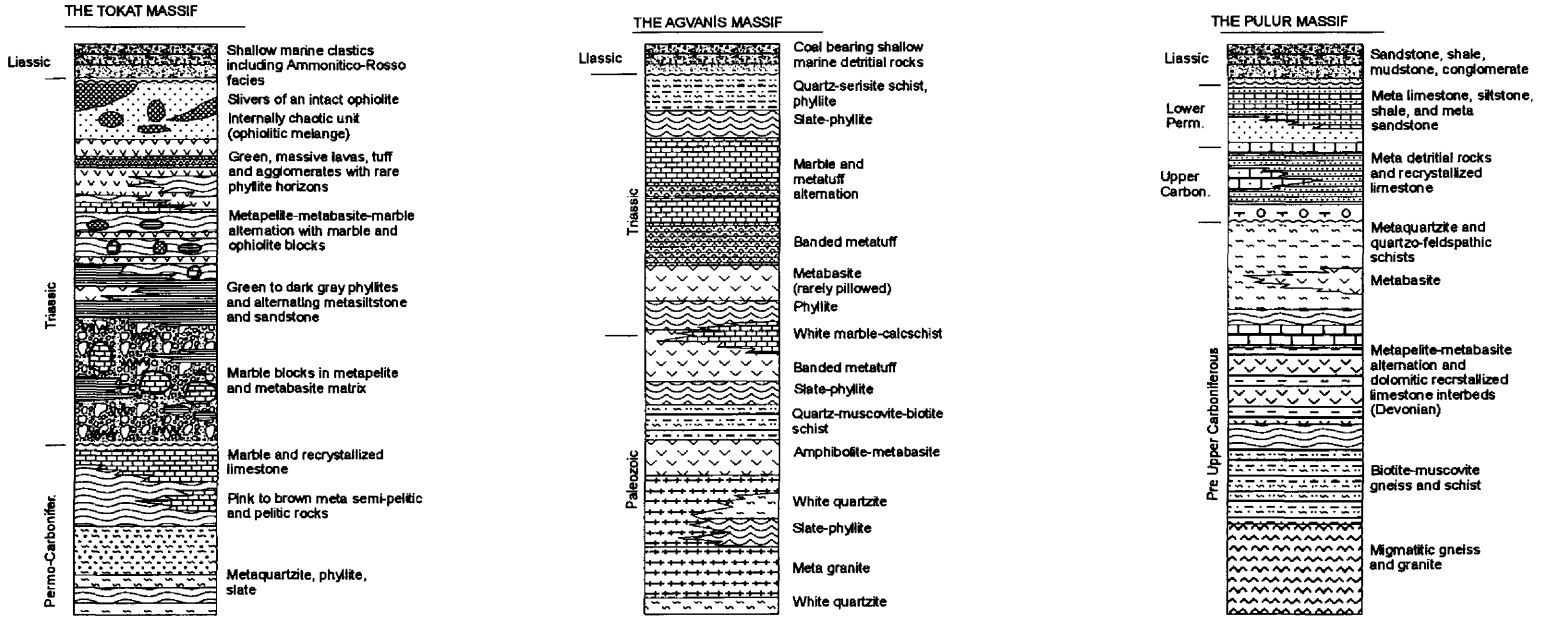


FIG. 7. Comparative stratigraphic sections for the Tokat, Agvanis, and Pulur massifs.

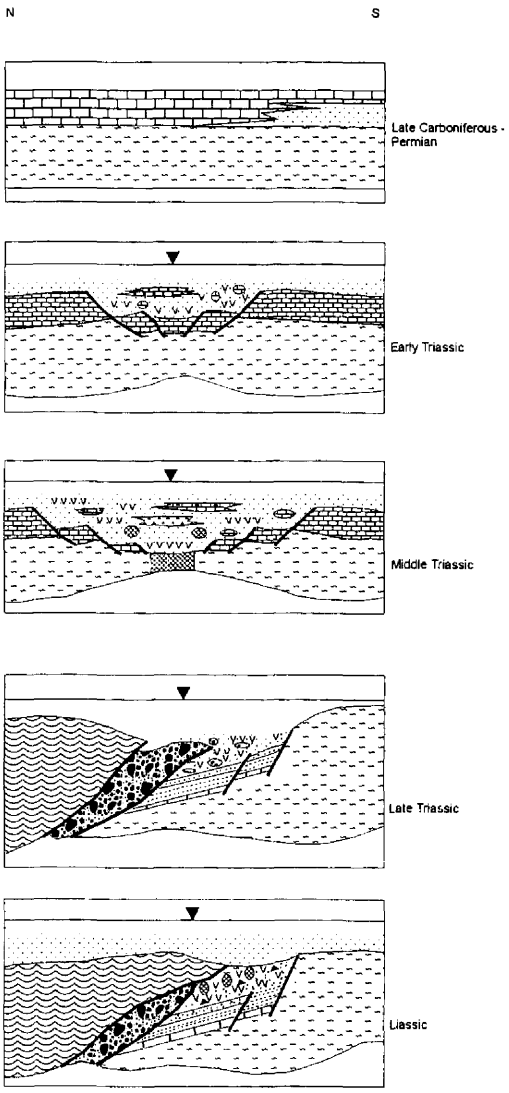


FIG. 8. Consecutive stages of the geological evolution of the eastern Pontide metamorphic basement rocks.

considered a passive continental margin association. The passive margin probably was collapsing into the oceanic environment, as indicated by the Turhal Metaophiolite. The ophiolitic blocks intermixed with pelagic rocks consist of fragments of the Turhal Metaophiolite. The upper association is represented primarily by a flysch deposit (the Kuytul Formation). The blocks and olistostromes that increase in amount and proportion upward through the sequence can be regarded as syntectonic sediment deposition (the Devecidag Formation) formed in association with the emplacement of the ophiolite.

The Triassic succession as a whole indicates development of a short-lived rift basin (Figs. 8A–8E). During early stages, the basin evolved into an oceanic environment, which later closed before the Lias, as suggested by the presence of Liassic basal clastic rocks deposited on different components of the Tokat Massif (Fig. 4). During the closing stage, an ophiolitic mélange including slivers of an intact ophiolite (the Turhal Metaophiolite) was tectonically emplaced on the continental-margin succession of the Triassic basin (the Kuytul and Topçam formations).

The Triassic succession and the underlying Paleozoic sequence of the Yesilirmak Group closely resemble the basement association of northwestern Anatolia, where the Triassic tectonic units are referred to as the Karakaya complex (Bingöl et al., 1973; Sengör and Yilmaz, 1981; Okay et al., 1991; Koçyigit, 1991; Genç and Yilmaz, 1995). This similarity was previously noticed by Seymen (1991, 1993). The Karakaya complex is considered to be the product of a short-lived marginal basin formed behind a more northerly oceanic realm, the Paleotethys (Sengör and Yilmaz, 1981; Sengör et al., 1984).

In light of the close similarity between the Yesilirmak Group and the Karakaya complex, the Turhal Metaophiolite also may be considered to belong to the Karakaya Basin. The main difference between the basement associations of northwestern Anatolia and the Tokat Massif is that northwestern Anatolia lacks metamorphic tectonic units similar to those of the Amasya Group, which in aggregate represents the highest-standing nappe of Laurasian origin. A Paleozoic nappe of similar nature also is observed within the neighboring Kargi Massif of the Central Pontides (Yilmaz and Tüysüz, 1984; Tüysüz, 1990; Yilmaz and Tüysüz, 1991), where western Pontide basement rocks known as the Devrekani metamorphics tectonically overlie the Karakaya marginal basin as well as remnants of the Paleotethys ocean (Yilmaz and Tüysüz, 1984; Tüysüz, 1990; Yilmaz et al., in press). The Karakaya marginal basin closed before the Lias. On the other hand, the Paleotethys ocean is known to have existed from the Paleozoic to the end of the Liassic period, possibly extending into the Dogger (Sengör and

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Yilmaz, 1981; Sengör et al., 1984; Aydin et al., 1986).

According to the data outlined above, a critical unsolved problem arises concerning the origin of the Turhal Metaophiolite—whether it originally belonged to Paleotethys or to the Karakaya marginal basin. Discussions regarding the paleogeologic position and significance of and the relationship between Paleotethys and the Karakaya marginal basin are provided elsewhere (Sengör et al., 1980, 1984; Tüysüz and Yigitbas, 1994; Genç and Yilmaz, 1995; Yilmaz et al., in press) and will not be repeated here. However, on the basis of field data obtained from the central and eastern Pontides, Yilmaz and Tüysüz (1984) and Yilmaz et al. (in press) suggested that these two basins were intimately connected in time and space during the Triassic, particularly in the Tokat-Kargi areas of the central Pontide region, where remnants of two separate oceanic environments are difficult to distinguish.

In the Tokat Massif, the Turhal Metaophiolite was sandwiched between two different lithospheric fragments. The lower tectonic unit, the Yesilirmak Group, represents the eastern Pontide basement, and the upper tectonic unit, the Amasya Group, represents the western Pontide basement. The Turhal Metaophiolite represents the remnant of an ocean that once separated the two continents (Fig. 8C), which collided during the Late Triassic following the elimination of the oceanic environment. The accretionary mélange association (the Turhal Metaophiolite), which displays glaucophane-bearing greenschist-facies metamorphism, was formed as a result of the elimination of the oceanic lithosphere.

The Late Triassic–Early Liassic time interval corresponds to deep burial and subsequent metamorphism of the Yesilirmak Group. Burial may have been caused by progressive stacking of ophiolite nappes and the western Pontide basement nappe during their southeasterly transportation (according to the present structural configuration) onto the eastern Pontide basement. During this tectonic phase, the autochthonous as well as the allochthonous units were penetratively deformed and underwent polyphase metamorphism accompanied by ductile deformation. Thus the metamorphic grade increases downward in the nappe pile. Following regional metamorphism, the metamorphosed assemblage was elevated and formed the Tokat Massif.

The oldest sedimentary rocks that were deposited on major components of the Tokat Metamorphic Massif and the thrusts that separate them are detrital units that formed during the region-wide Liassic transgression (the Bayirköy and Mudurnu formations). These units show rapid lateral facies changes, from continental fluvial units that crop out in the Amasya area to shallow-marine clastic units, including the Ammonitico Rosso facies observed in the Taslidag and Ladik areas. These units are regarded as having been formed in a tectonically active environment that produced a horst-and-graben system (Yilmaz, 1972; Görür et al., 1983; Nicosia et al., 1991; Yilmaz et al., 1993).

The basal detrital rocks are overlain by a thick neritic limestone succession passing rapidly upward into a pink, white micritic limestone of Late Jurassic age. The Jurassic limestones are overlain by Early Cretaceous cherty and thinly bedded white limestones (e.g., the Ladik area and the village of Seyfe). These limestones pass upward into a reddish pelagic limestone-radiolarite-mudstone unit of Cenomanian–Turonian age (Seyfe village and Tepe upland pasture areas). Following this, the uniform and continuous Cretaceous pelagic limestone succession was replaced by a flysch sequence. Blocks, olistostromes of older units, and fragments of ophiolitic mélange are included within the flysch succession. Following incorporation of the olistostromes and blocks, the region underwent intense southerly compressional deformation. This corresponds to the southerly transportation of the nappes, when the Tokat Massif was thrust onto the cover sedimentary succession (Fig. 9). During this period, parts of the region were subsequently elevated and eroded down to basement (Fig. 7). Following this episode, the Upper Cretaceous ophiolitic mélange was backthrust onto the region from the south (Yilmaz et al., 1993). During compressional deformation, the sedimentary cover was detached from the underlying metamorphic basement and transported as a décollement, as indicated by the development of a wide (>500-m) semibrittle-ductile shear zone along the contact of the lowermost nappe (Fig. 10). Along this zone, the transgressive contact of the massif with the overlying rocks is locally

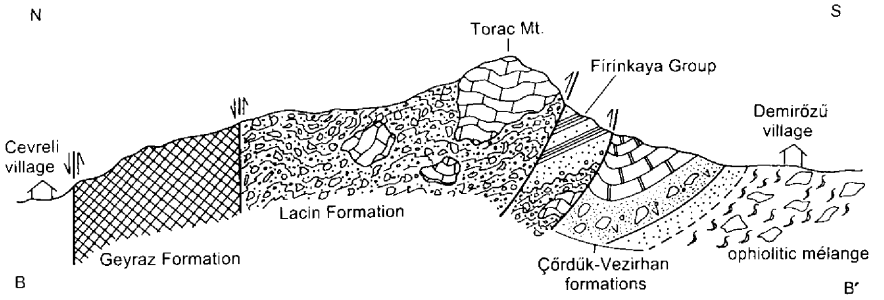


FIG. 9. Geological cross-section from Cevreli to the Demirözü region showing the post-Late Cretaceous thrusting. See Figure 3 for cross-section direction (B-B').

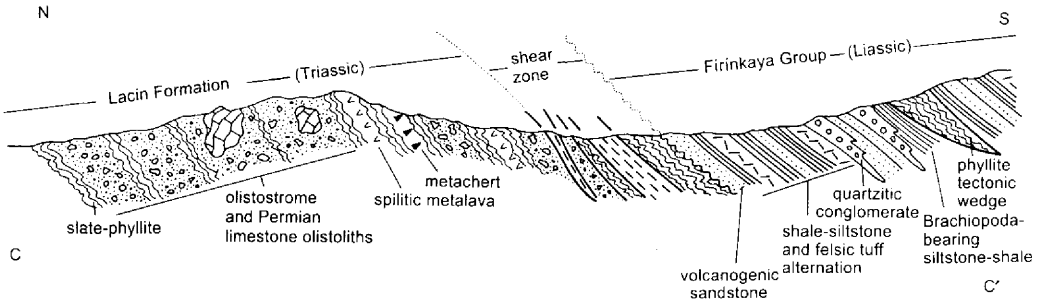


FIG. 10. Geological cross-section showing the semibrittle-ductile shear zone observed along the contact between the Yesilirmak Group and the Liassic sedimentary succession. See Figure 3 for cross-section direction (C-C').

obscured because of the development of an intense zone of cataclasis. The result is a tectonic transition between the metamorphic rocks of Tokat Massif and the overlying Liassic detrital rocks. Consequently, the Tokat Massif was reactivated during this period. The imbricated pile then was covered by Maastrichtian sedimentary rocks.

Conclusions

The Tokat Massif is a regionally metamorphosed tectonic entity situated in the south-central Pontides. It is a tectonic mosaic composed of three main components. (1) The Yesilirmak Group constitutes the dominant unit in the Tokat Massif, consisting of a Paleozoic metamorphic core and an overlying Triassic cover sequence. The core rocks consist mainly of schists and phyllites and an intruding post-tectonic granitic pluton radiometrically dated at 298 to 360 ± 2 Ma. The Triassic rocks and the underlying basement collectively underwent regional thermodynamic metamorphism during the Late Triassic. (2) The Turhal Metaophiolite consists of an ophiolitic mélange and slivers of an ordered ophiolite, which underwent glaucophane-bearing greenschist-facies metamorphism and represent a subduction-accretion complex resting tectonically on the Yesilirmak Group. (3)The Amasya Group is a Silurian sedimentary succession that forms the highest-standing nappe, resting over the other tectonic units. The three major components of the Tokat Massif were assembled during the latest Triassic and collectively were blanketed by Liassic sediments.

The Amasya Group represents the basement of the western Pontide Range and originally belonged to the Laurasian continent. The Yesilirmak Group constitutes the basement of the eastern Pontide Range and originally was part of Gondwana. The Triassic sequence of the Yesilirmak Group represents the development of a short-lived basin that reached an oceanic stage; the Turhal Metaophiolite is interpreted as the remnant of this ocean that once separated the Amasya and the Yesilirmak groups. The gradual elimination of the ocean floor created a subduc-

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tion-accretion mélange complex known as the Turhal Metaophiolite, and led to continent-continent collision. Subsequently, the collided package was buried and metamorphosed, then elevated prior to a new transgression during the Lias.

A thick pile of sedimentary rocks was deposited on the Tokat Massif throughout the Mesozoic. During the Late Cretaceous, a severe, southerly compressional regime affected the region. Under the southerly transported nappe pile, the cover sedimentary rocks were detached from the metamorphic basement and moved as a décollement, producing a thick semibrittle mylonitic zone along the detachment surface.

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