Goncuoglu, M.C., 2011. Geology of the Kütahya-Bolkardağ Belt. Mineral Research and Exploration Bulletin. 142, 223-277.

GEOLOGY OF THE KÜTAHYA-BOLKARDAĞ BELT

M. Cemal Göncüoğlu, Middle East Technical University, Department of Geological Eng., Ankara

Abstract

Kütahya-Bolkardağ Belt is one of the subunits of the Tauride-Anatolite Terrane stretching from the Aegean Sea to the Hınzır Mountains. It includes numerous tectonic slices, formed during the closure of the İzmir-Ankara Oceanic branch of the Neotethys. The tectonic slices are mainly derived from three different tectonic settings: i- rocks representing the oceanic lithosphere and subduction-accretion prism of the Izmir-Ankara Ocean (ophiolites and ophiolitic mélanges), ii- flysch-type deposits that were formed in foreland-basins on the northern and passive edge of the Tauride-Anatolite platform in front of the southward advancing nappes (olistostromes with olistoliths, sedimentary mélanges), and iii- successions, in some cases with HP/LT metamorphism, representing the slope margin and external platform of the northern Tauride-Anatolite margin. Rock-units of the Kütahya-Bolkardağ Belt surround the HT/LP Menderes Core Complex and are also observed as slices or klippen in the "massif, or as nappes to the south of it.

The rocks of the Izmir-Ankara oceanic lithosphere occur as huge allochthonous bodies/tectonic slices and blocks within the mélange and olistostromes. The fossil data and geochemical data obtained suggest the following: The earliest "oceanic" volcanism commenced during middle Carnian, the generation of ocean island-type (OIB) volcanics lasted from Bajocian to Abtian, whereas the MOR-basalts spread from Aalenian to Turonian. Supra-subduction- and island-arc type basalts of Albian to Cenomanian age indicate an intra-oceanic subduction within the İzmir-Ankara Ocean. The mélanges are characterized by HP/LT metamorphism with a LP/LT overprint.

Middle Maastrichtian olistostomes with olistoliths formed in foreland basins in front of the nappes include blocks of all kind of tectonic settings mentioned above. The flysch rocks are in depositional contact with the underlying platform and/or slope rocks of the Tauride-Anatolite passive margin.

The Tauride-Anatolite slope and external platform deposits are partly affected by HP/LT metamorphism and occur as slices along the belt and as blocks within the flysch-basins. In Afyon area the Late Permian transgresses onto the Precambrian basement, whereas in Konya, more internal in regard to the platform, the Devonian carbonate platform is drowned and covered by back-arc-type sediments and volcanism of Carboniferous age. All along the belt, early Late Permian unconformably covers a slightly metamorphosed and deformed basement, attributed to a Variscan event within the Tauride-Anatolite platform. An important Early Triassic unconformity with continental clastics and alkaline volcanism mark the onset of the alpine extensional period and the initial rifting of the Neotethyan Izmir-Ankara Ocean. In the external tectonic units, the earliest deep-marine cherts are dated as Ladinian and the earliest oceanic volcano-sedimentary rocks as Carnian and younger. In the more internal platform, however, starting with Anisian platform deposition dominated. Except a Ladinian deepening, attributed to the opening of the Izmir-Ankara oceanic branch, Ladinian-Early Cretaceous is represented by thick platform carbonates. The transition from platform to slope-type deposits is in Malm in the external platform, but Abtian in more internal parts. This indicates a stepwise deepening of the platform-margin. The presence of HP/LT metamorphic platform-margin sediments is indicative for a deep subduction of the attenuated continental-crust of the Tauride-Anatolite margin.

The initial compression-slicing and nappe-emplacement must have realized prior to Middle Paleocene. Middle Paleocene-Middle Eocene in the Kütahya-Bolkardag Belt is characterized by shallow-marine or continental molasse-type deposition in the remnant basins on the platform.

Key Words: Kütahya-Bolkardağ Belt, Tauride-Anatolite, geological evolution

INTRODUCTION

Tauride – Anatolide terrane is one of the main alpine tectonic units of Turkey that was formed by opening and closure of oceanic branches of Neotethys. It represents a continental crust. In SW Greece (Gavrovo-Tripolitza zone) in Aegean Sea, together with extensions in central Iran in the east, this unit can be considered as micro-continent. It reaches today's Sumatra Island in size. Taurides are defined as an independent unit since the earliest classification of the Anatolian tectonic units. In context of plate tectonics (Şengör and Yılmaz, 1981) and previous tectonic classifications, it is divided into Tauride and Anatolide units by (Ketin, 1966).

Kütahya-Bolkardağ Belt (KBB) is one of the subunits of the Tauride – Anatolide tectonic unit that was suggested by Özcan *et al*., (1989). KBB is located in the south of İzmir – Ankara suture and extends from Karaburun to Kütahya and from there to Bolkar and Hınzır Mountains, also surrounding the Menderes Core Complex (Figure 1). Allochthonous high pressure metamorphic units in the south of Menderes Core Complex and Lycian nappes are primarily segments of KBB. Goncuoglu *et al*., (1997a) has subdivided Tauride – Anatolide terrane into three components and redefined the KBB. According to this definition, KBB is composed of various tectonic slices of continental and oceanic crust origin, displaying different type metamorphisms. These tectonic slices include:

I) Rocks representing the oceanic lithosphere and subduction-accretion prism of the İzmir – Ankara Ocean (ophiolites and ophiolitic mélange)

II) Flysch-type deposits that were formed in foreland-basins on the northern and passive edge of the Tauride-Anatolite platform in front of the southward advancing nappes.

III) Successions, in some cases with HP/LT metamorphism, representing the slope margin and external platform of the northern Tauride-Anatolite margin.

The units of KBB that surround northern and eastern margin of the Menderes Core Complex are observed as slices within and as klippen and nappes in the South of it.

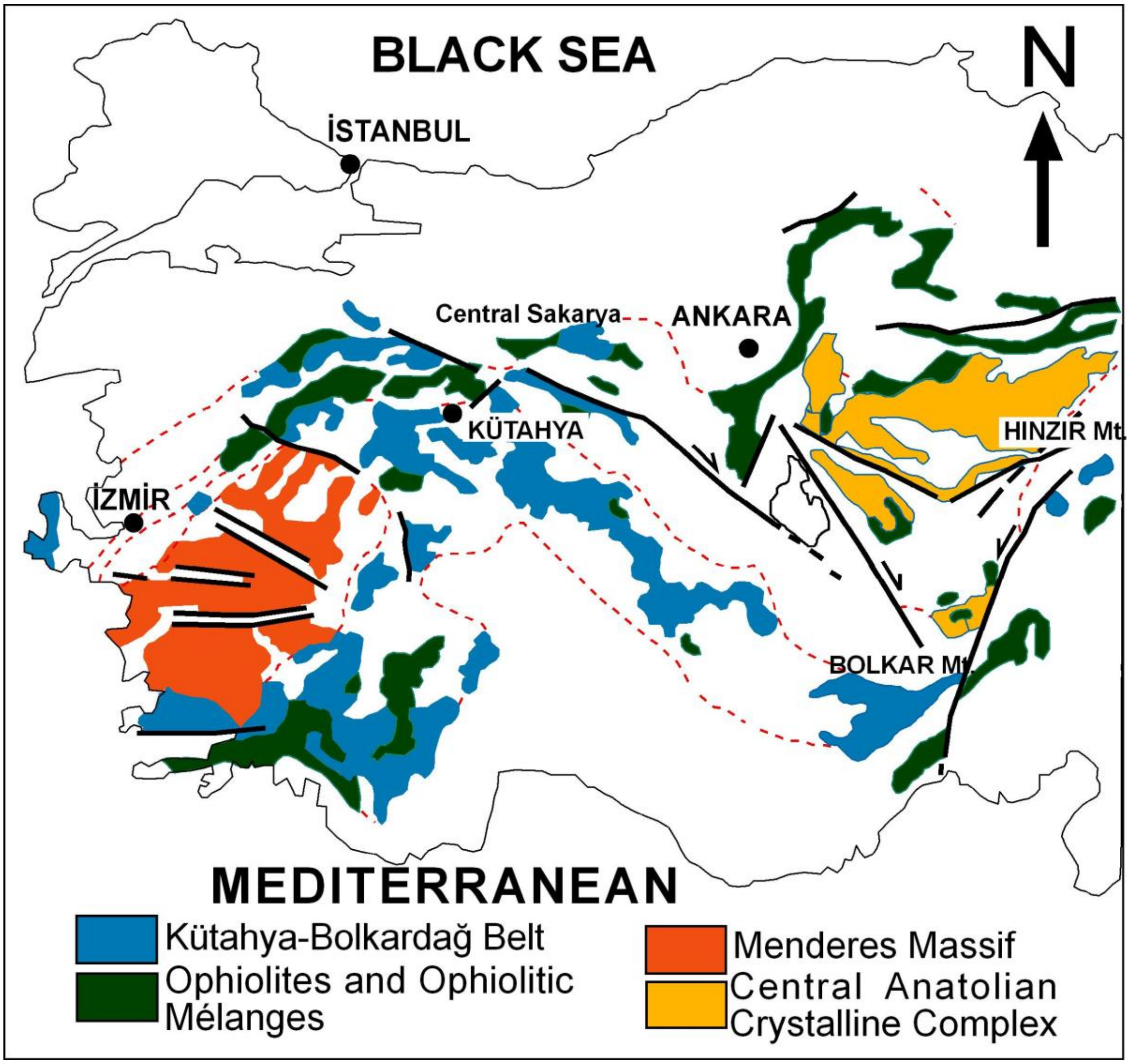


Figure 1- Location of the Kütahya-Bolkardağ Belt within the Tauride-Anatolite Unit (simplified after Göncüoğlu et al., 1997a.

Common features of the KBB and overall differences between the Tauride unit and KBB are:

I) KBB units have undergone poly-phase metamorphism. As a common feature, they are more or less affected by Alpine HP/LT metamorphism.

II) In all slices, Late Middle Permian marine transgression and/or Early Triassic unconformity are observed over a basement which was affected by Variscan deformation.

III) Mesozoic platform successions in relation to their original position in north margin of Tauride – Anatolide platform, gradually deepen during Jurassic to Low Cretaceous.

In this study, field-data provided on Kütahya-Bolkardağ Belt was obtained by projects of General Directorate of Mineral Research and Exploration in Kütahya and Konya areas between 1982 and 1987, by the Turkish Petroleum Corporation projects in the west of Tuz Lake between 1995-1996 and finally by TUBİTAK projects between 1998 and 2003.

TAURIDE – ANATOLITE CONTINENTAL MARGIN UNITS

In KBB, continental margin successions of Tauride- Anatolide terrane are partially affected by subduction. They occur as HP/LT metamorphosed tectonic slices or as huge blocks in Upper Cretaceous olistostrome deposits. In these successions, a package that starts with the Middle Permian unconformity generates the first common reference plane. Fairly monotonous Middle Permian successions are angular unconformable over various units through the belt. Second reference unit that is unconformable over several units, starts from Triassic terrestrial deposits and continues with Middle-Triassic-Cretaceous carbonate platform deposits.

After Cretaceous, transition to deep marine sediments can be seen in varying ages through the belt. At the end of Cretaceous, it can be seen that flysch deposits rest over continental margin successions of KBB and slicing commences.

Early Permian basement units

In KKB, Early Permian basement is represented by more than one unit. Lower contacts of all these units are thrust-faults.

Afyon-type Late Neoproterozoic Basement

This type of basement outcrops at the northernmost part of the belt in the East of Eskisehir on Sömdiken Mountains (Göktepe Metamorphics; Goncuoglu *et al.,* 1996, 2000a), in the South of Kütahya on Yellice Mountains (İhsaniye Metamorphic Complex; Özcan *et al.,* 1984, 1989) and in the North of Afyon in Köroğlu Mountain (Afyon Basement Complex; Gürsu and Goncuoglu, 2008).

Metamorphic rocks that constitute the lowermost visible unit in Sömdiken Mountains (Figure 2) are described by Goncuoglu *et al.,* (2000a) as Göktepe Metamorphics.

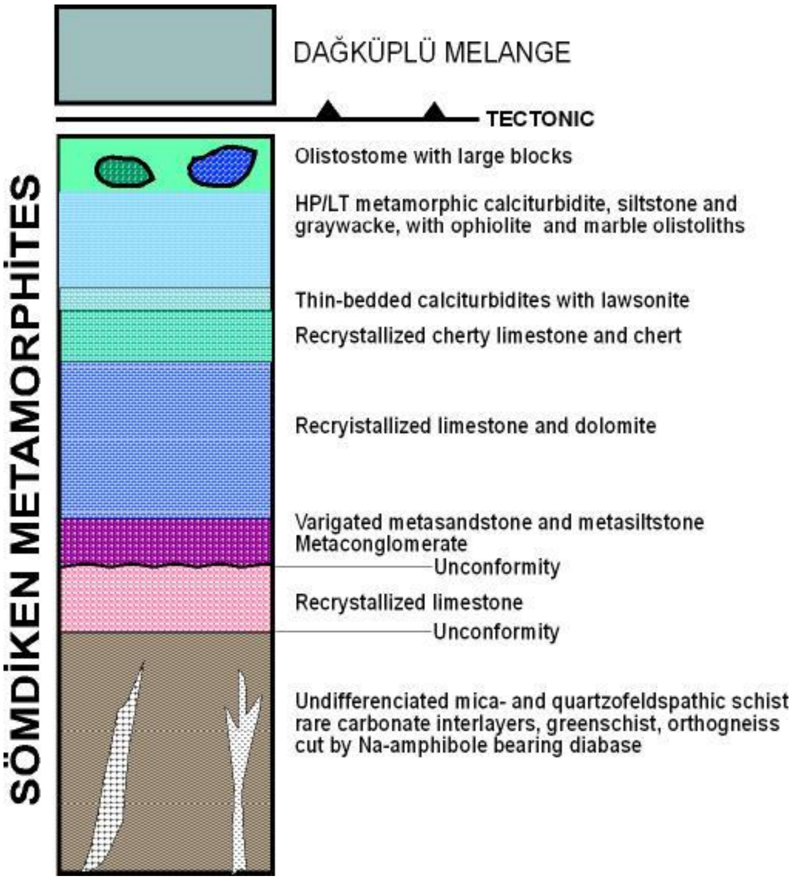


Figure 2- Stratigraphy and lithologies of the Afyon-type basement in Sömdiken Mountains to the NE of Eskişehir (simplified after Göncüoğlu et al, 2000a).

Göktepe Metamorphics is constituted by schists and orthogneisses. They also include rare marble bands, graphite schist, garnet mica schist, quartz schist; metarhyolite, meta-quartz porphyry and metabasics offer irregular outcrops. Since the unit has undergone poly-phase metamorphism and deformation, it is not possible to make detailed determinations about original successions of the unit. In the lower part of the unit, micaschists, para- and orthogneiss are common. Micaschists are described as quartz-muscovite- albite schist, quartz-muscovite-biotite schist, cholorite-muscovite-chlorite schist, biotite-albite-muscovite-quartz schist, garnet-biotite-muscovite-quartz-albite schist. Micaschists generally exhibit quite monotonous outcrops and they are probably of felsic volcanic or volcanoclastic origin. In relatively upper part of the section besides mica rich bands; thin marble bands, graphite-rich laminae and quartzite bands are observed. By considering these features it can be said that the micaschists have sedimentary origin. Orthogneiss are observed in various masses in mica schists and have blastomylonitic structure. Main constituents are quartz and feldspar porphyroclasts, muscovite and red-brown colored biotite minerals. Further constituents are sphene, tourmaline, zircon, apatite and hematite as accessory minerals. It is considered that orthogneiss are originated from granitic-rhyolitic rocks; and muscovite-rich quartzo-feldspathic gneiss is originated from aplitic-pegmatitic. In the low and middle part of Göktepe Metamorphics, in addition to mica schists and orthogneiss, 30-35 meters thick, green schist bands and lenses are commonly observed. Microscopically, various rocks like glaucophane albite-epidote-chlorite schist, glaucophane and phengite titanite-epidote-chlorite-albite schist, garnet and phengite epidote-chlorite-albite schist can be described. Glaucophanes are observed as long needle-like crystals and coarse crystals that possibly replaced coarse prismatic actinolite. Phengites occur as thin long crystals and in some sections grows within Mg-chlorite. It is considered as part of green schist forming massive lenses representing lava domes and dykes; whereas those intercalated with the mica schist represents basic volcanoclastics.

By examining macroscopic and microscopic features of Göktepe Metamorphics, it is understood that they are undergone two different metamorphic phases. In the first of these phases, parallel to dominant foliation in clastic and felsic originated rocks blastomylonitic texture and biotite + chloritoid + muscovite + garnet + chlorite + quartz + plagioclase paragenesis has been formed. As for in basic

volcanic and volcanoclastic rocks appropriate to local foliation again chlorite + actinolite + epidote + garnet + plagioclase paragenesis has been formed. This paragenesis indicates that first metamorphic phase has happened in green schist facies conditions. In the second metamorphic phase, deformation is locally effective only. In this phase, in clastic and felsic volcanic rocks: muscovite + chlorite + stilpnomelane + albite paragenesis and in basic rocks: glaucophane + phengite + stilpnomelane + chlorite + albite paragenesis has been formed. A third phase paragenesis that represented by actinolite and white mica formation overprints HP/LT metamorphic paragenesis. The same paragenesis is observed in diabase dikes that intersects Göktepe Metamorphics. The last two phases are considered as a product of Alpine HP/LT metamorphism (Goncuoglu *et al.,* 2000a). Göktepe Metamorphics are overlain by Kayapınar Marbles including a basal unit with quartz conglomerates and quartzite. This unit can be correlated with İhsaniye Metamorphic Complex (Özcan *et .al.,* 1989) or Afyon Basement Complex (Gürsu and Goncuoglu, 2008) that are going to be defined below.
In the north of Afyon between Bayat and İhsaniye, outcrops of KBB basement can be observed commonly (Figure 3).

<u>İhsaniye Metamorphic Complex</u> represents the lower part of metamorphic successions that located between Kütahya and Afyon. The unit includes mica schist and meta granitic rocks that are affected by poly-phase metamorphism and few marble, graphite-schist and quartzite in quantity (Fig. 4).
Mica schists are generally represented by garnet - biotite- muscovite and quartz - albite -muscovite schist. It is interpreted that thick schist packages having homogeneous composition were originated from magmatic rocks. In between marbles, mica schists and graphite chloritoid schists occur as thin layers. İhsaniye Metamorphic Complex, likewise the Göktepe Metamorphics, includes basic green schist intercalations of basic origin. These metamorphics of the earliest phase (Cadomian?) are overprinted by Na-amphibole-bearing phases which are products of Alpine HP/LT metamorphism (Özcan *et al.,* 1989; Candan *et al.,* 2005). İhsaniye Metamorphic Complex is unconformably overlain by Eldeş formation, or by the Lower Triassic Kıyır formation. Eldeş formation starts with quartz conglomerates and passes into fossiliferous Permian limestones. Kıyır formation includes red colored conglomerates (Özcan *et. all.,* 1989).
<u>Afyon Basement Complex</u> outcrops on first major tectonic slice that placed over non-metamorphic Tauride type units. Outcrops of this unit can be followed from Aslanapa to Bolvadin. The lowermost part of the unit comprises mica schists and metafelsic rocks as in Sömdiken and Kütahya areas (Göncüoğlu *et al.,* 2001; Candan *et al.,* 2005, Gürsu and Göncüoğlu, 2008). They include pre-Alpine (Cadomian) paragenesis in micaschists; garnet, biotite, muscovite.

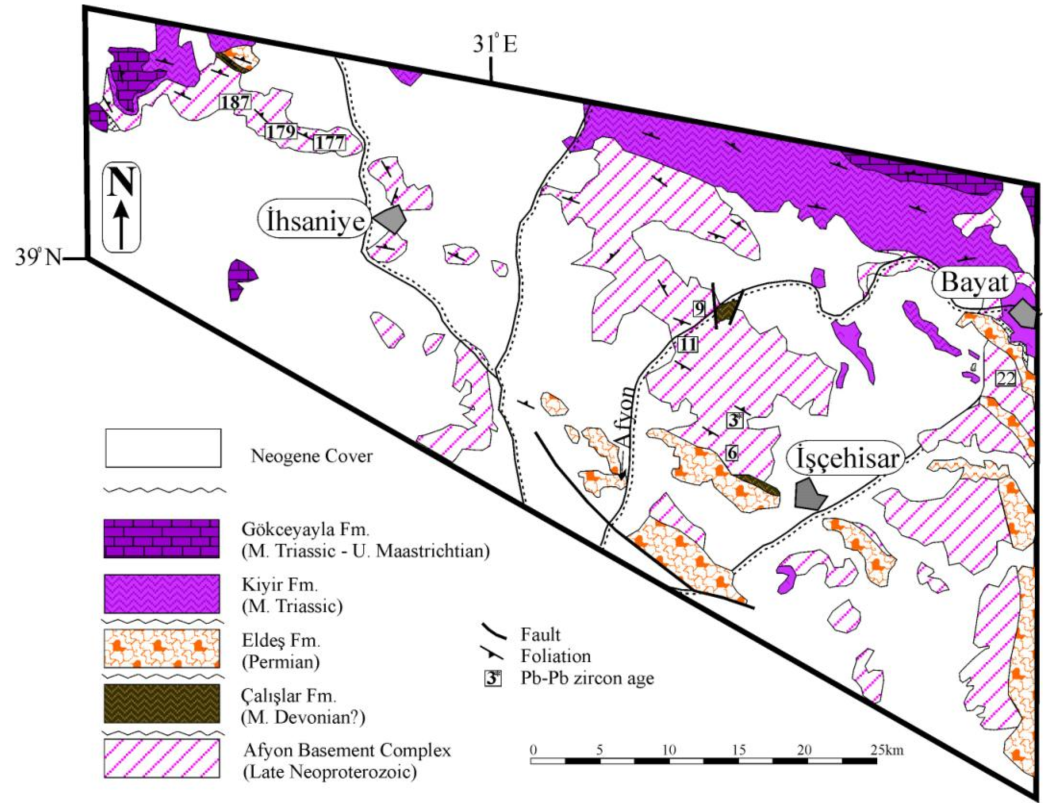


Figure 3- Geological map of the KBB units to the N of Afyon (simplified after Gürsu and Göncüoğlu, 2007).

Felsic magmatic rocks that have undergone deformation and metamorphism together with micaschists have rhyodacite–dacite composition and show blastoporphyritic texture. Zircons obtained from these felsic rocks are dated by single zircon evaporation method. The age of this intrusion is 541 + / - 4 ma (Gürsu and Göncüoğlu, 2008). This data shows that the basement of KBB is of Late Neoproterozoic age.

These Cadomian magmatics are characteristic for North of Gondwana. They constitute the basement of not only KBB, and also Taurides (Erdoğan *et al.,* 2004, Gürsu and Göncüoğlu, 2005a, 2006a, 2008), Menderes Core Complex (Dora *et al.,* 2001) and İstanbul – Zonguldak units (Ustaömer, 1999; Chen *et al.,* 2002).

In the pre-Permian basement of Afyon region, there is one more metamorphic unit that unconformably overlies the Cadomian units. This unit is named as Çalışlar formation by Gürsu *et al.,* (2004). It is composed of quartz conglomerates including deformed granite and schist pebbles, quartzite and quartz mica schists and it transgressively overlies Late Neoproterozoic basement. Locally this non fossiliferous unit has 250 m thickness. It is correlated with Devonian quartzites in Sultandağ (Gürsu and Göncüoğlu, 2008).

Konya-Type Paleozoic Basement

In the region from North of Konya (Figure 5) to Kulu area, pre-Permian low-grade metamorphosed successions are found in the basement of KBB (Özcan *et .al.,* 1987, 1990a, 1990b; Eren, 1993, 1996; Göncüoğlu *et al.,* 2000b, 2007).

This basement outcrops commonly in the tectonic slices in the Konya Bozdağ Mountains. In lower most visible part of it, quite thick meta-siliciclastic succession is found (Figure 6). Black colored meta-siltstone, black laminated lydite (Figure 7), dark gray silicified shale / tuff and nodular chert bands are included in the unit. They are cut by diabase and quartz porphyry. In the upper part of the unit there are thin and brown-black colored limestone bands. In the succession 1-2 m thick gray – black nodular chert is found locally. Göncüoğlu *et al.,* (2000b) named this unit unofficially as "Siliciclastic Turbidite Unit".

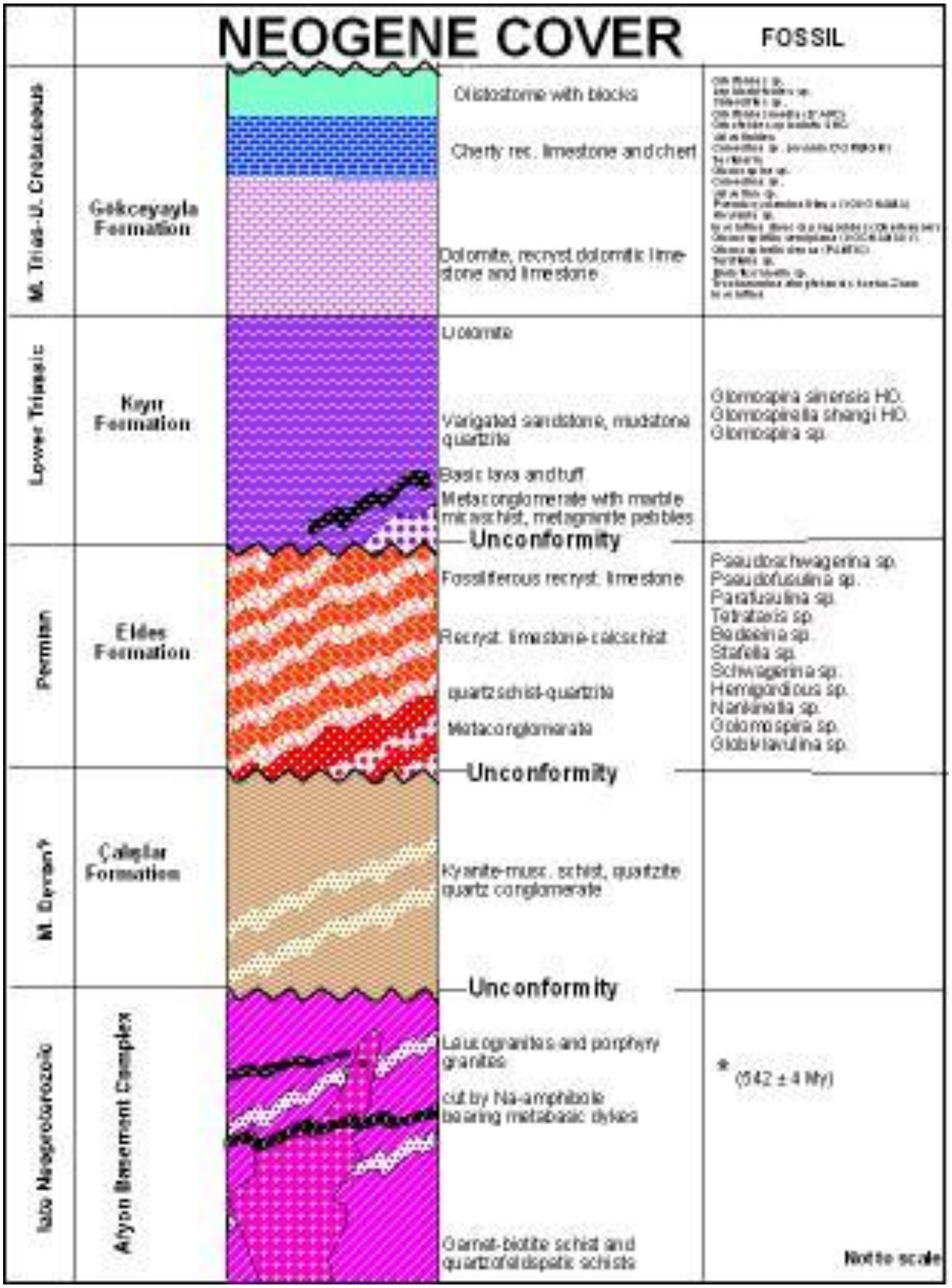


Figure 4- Generalized columnar section of the KBB units in the N of Afyon (simplified after Gürsu and Göncüoğlu, 2007).

Towards top, unit is composed of thin layered, brown-black limestone bands and 3 m thick massive black chert. Over the cherts, pink colored nodular limestone that belongs to lowermost part of the Bozdağ Limestone is found.

Besides the Middle Silurian Muellerisphaerid finding from samples collected by Kozur (1999) from nodular cherts in the middle part of the succession, sample T8-26 from thin limestone layers from top of the unit includes conodonts *Dapsilodus obliquicostatus* (Branson and Mehl), *Panderodus recurvatus* (Rhodes), *Ozarkodina excavate*, *Pseudooneotodus* beckmanni and *Panderodus* *unicostatus*. By this a Late Silurian age is given to unit. In sample T8-28 (Figure 8) conodonts such as *Coryssognathus dubius* (Rhodes), *Pseudooneotodus bicornis* Drygant, *Dapsilodus obliquicostatus* (Branson and Mehl) , *Pseudooneotodus beckmanni* (Bischoff and Sannemann) and *Papinochium sp.* (Müllerispherid) belonging to Ludlow-Pridoli (Upper Silurian) are observed. In addition, in sample T8-29 Wenlok-Pridoli (middle – upper Silurian) conodonts such as *Dapsilodus obliquicostatus* (Branson and Mehl) and *Pseudooneotodus bicornis* Drygant are determined (by Y. Göncüoğlu and H. Kozur). These findings indicate that the age of the Siliciclastic Turbidite Unit is Middle-Upper Silurian.

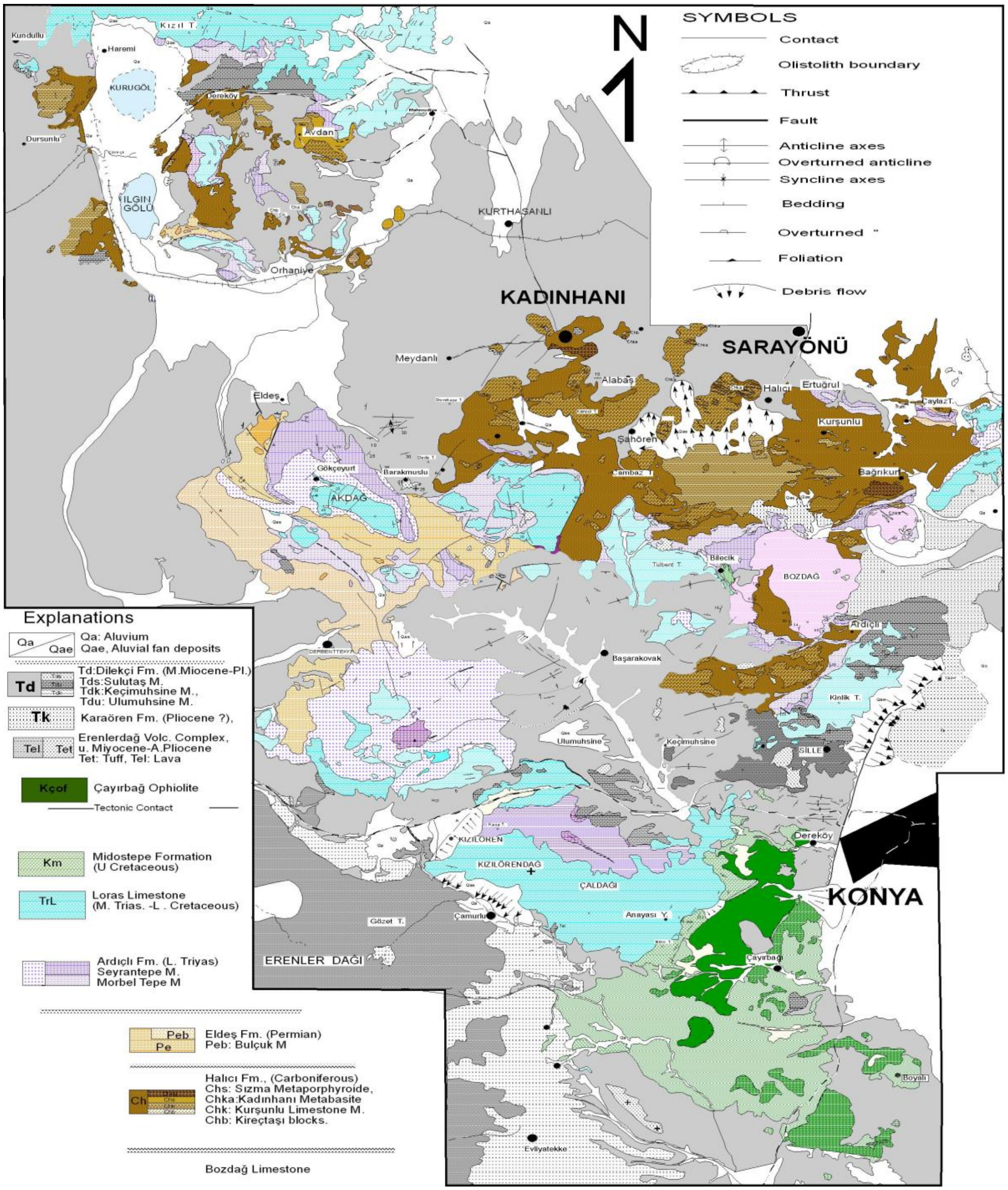


Figure 5- Distribution of the main geological units in Konya and surrounding regions (Özcan et al, 1990a) .

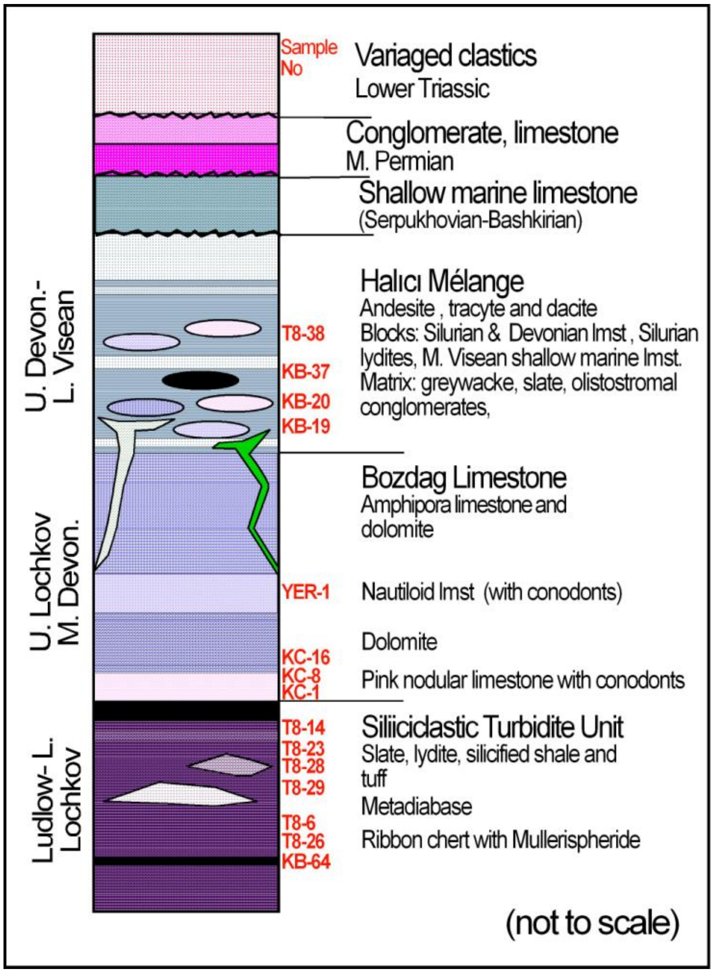


Figure 6- Stratigraphy of Konya-type basement rocks in KBB (simplified after Göncüoğlu et al, 2007).

Bozdağ Limestone, 800 m thick, is composed of recrystallized limestone and dolomites. In the lowermost part of the unit, pink colored nodular limestone is observed. After non-fossiliferous black – white colored, thin-medium layered section that is composed of dolomites, a band with 3-8 cm long nautiloid (Orthoceras) and crinoids is found.

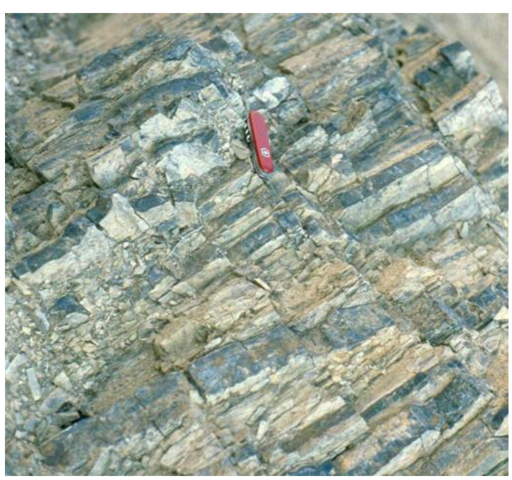
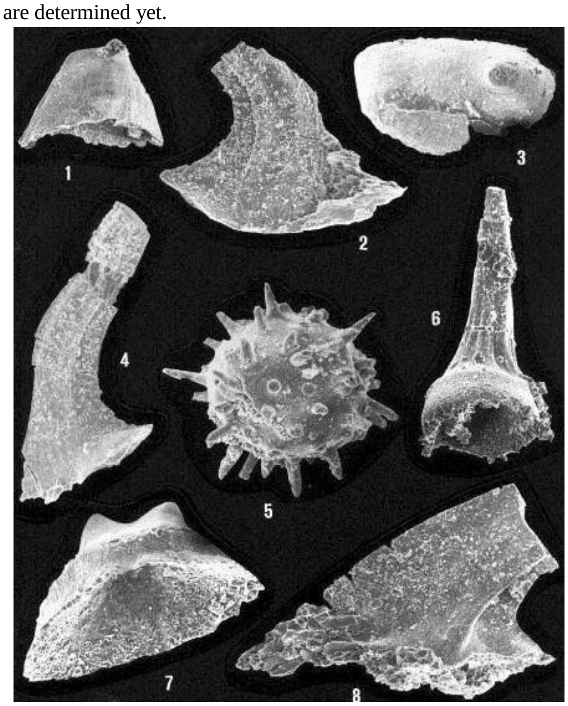


Figure 7- Lydite levels within the Siliciclastic Turbidite Unit to the N of Konya.

.Black colored massive- thick bedded limestone with Amphiphora limestone and dolomites constitutes the main body of the Bozdağ Limestone. Especially in the northern part of Bozdağ Massive, limestones are cut by diabase dikes with NE- SW extension.

Pink- black colored nodular limestones in the lower-most part of the unit, includes conodonts such as *Ancyrodelloides kutscheri* Bischoff and Sannemann, *Icriodus* sp., *Panderodus unicostatus* and *Ozarkodina* sp. (Figure 9) that belong to *A. Delta Zone* of upper Lochkovian (Lower Devonian). Also in nautiloid limestone, Early Devonian conodonts such as *Panderous unicostatus, Ozarkkodina excavate* and *Oulodus* sp. that gives Lochkovian – Pragian (Lower Devonian) are found (determined by Y. Göncüoğlu). In Amphiphora carbonates in the middle and the in the upper part of the succession, rarely solitaire corals are observed. These limestones constitute the common rock type of Middle Devonian in Taurides. In massif limestones in the upper part of the formation no fossils are determined yet.



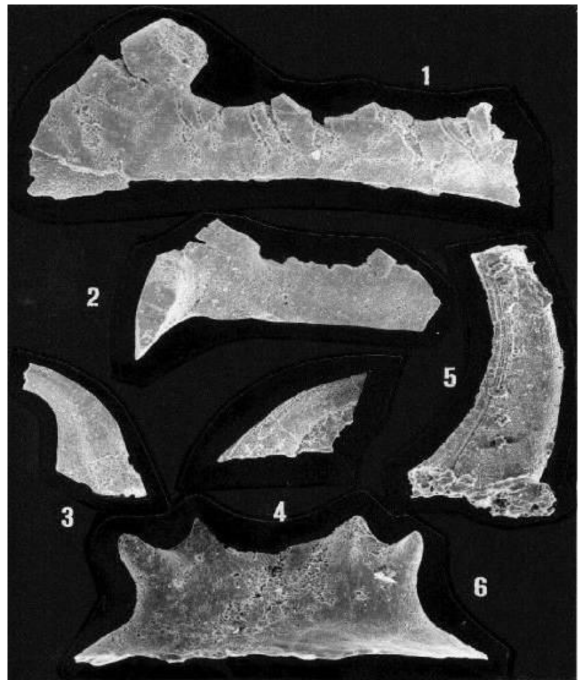


Figure 8- Conodonts and Muellerisperids from the micritic limestone-chert bands of the upper Siliciclastic Turbidite Unit: 1, 7- *Pseudooneotodus bicornis* Drygant, 2, 4, 8- *Dapsilodus obliquicostatus* (Branson and Mehl), 3- *Pseudooneotodus beckmanni* (Bischoff and Sannemann), 5- *Papinochium* sp., 6- *Coryssognathus dubius* (Rhodes)

Figure 9- Early Devonian (Lochkovian) conodonts from the lower part of Bozdağ Limestone: KC 8A 1: *Ozarkodina* sp., Sc element, 2: *Ozarkodina* sp., Sc element, 5: *Panderodus unicostatus* (Branson and Mehl), 6: (KC 8C): juvenile *Icriodus* ? sp. Age: Silurian – Early Devonian. (KC 1) 3, 4: *Panderodus* ? sp., Age: A. delta Zone, Upper Lochkovian.

Over the Bozdağ Limestone, Halıcı mélange commences with a sedimentary contact. This unit sometimes overlies karstic, cavity filling coarse siliciclastic, and mudstone and limestones. It includes olistoliths of various magnitude and olistostromal conglomerates which are products of mass flow, in the fine grained matrix that is transformed into greywacke and slate (Figure 10).

In the unit, both Siliciclastic Turbidite Unit of Silurian age and blocks of Bozdağ limestone are found as olistoliths. Apart from these, black, crinoidal Lower Carboniferous olistoliths are also observed in the unit. In the Halıcı mélange, both syn-sedimentary lava flows and olistoliths are observed. In the parts that olistoliths are not found, unit presents broken formation feature. The volcanic rocks of that unit include trachyandesite (Figure 11) and rhyolites (Bayiç, 1968; Kurt, 1996; Eren *et al.,* 2004; Göncüoğlu *et al.,* 2007) geochemically defined as sub-alkali basalts. The siliciclastics of the unit are overlain by shallow marine carbonates include Serpukhovian - Bashkirian foraminifers (determined by D. Altıner) with a sedimentary contact. In the region, no fossils are found apart from these data given. The formation is younger than Lower Carboniferous and older than the unconformably overlying late Middle Permian. By considering the geochemical and lithostratigaphic features of the volcanic rocks, it is widely accepted that unit is developed in a Carboniferous back arc basin (Özcan *et al.,* 1990a; Göncüoğlu *et al.,* 2007). Nevertheless, there is no consensus on paleogeographic position of the arc (Robertson and Ustaömer, 2009).

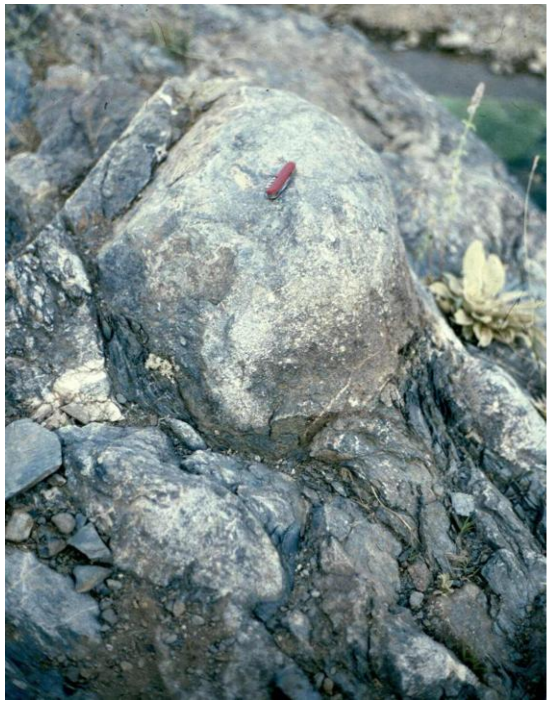


Figure 10- Crinoidal limestone blocks within the olistostromal matrix of the Halıcı Mélange to the N of Konya-Ardıçlı.

KBB units that represent similar features with Konya-type Paleozoic basement are located in Karaburun Peninsula and western Taurides. One of these, the Karaburun unit, is defined by Erdoğan *et al.,* (1995), Kozur (1998), Robertson and Pickett (2000), Rossalet and Stampfli (2002). In these studies, there is no consensus neither on their lithological features, nor their structural relations and the ages of the units.

Figure 11- Field occurrence of Sızma Metaporphyroid with large sanidine phenocrysts and well-developed trachyitic texture.

It is supposed that Tavas Nappe is one of the Lycian Nappes. It is one of the units that belong to Tauride – Anatolide platform like units of KBB (Şenel *et al.,* 1994). Halıcı mélange like Carboniferous units recently defined in Konya, are named (Kozur *et al.,* 1998; Kozur and Şenel 1999; Stampfli and Kozur, 2006) as Teke Dere Unit (Figure 12).

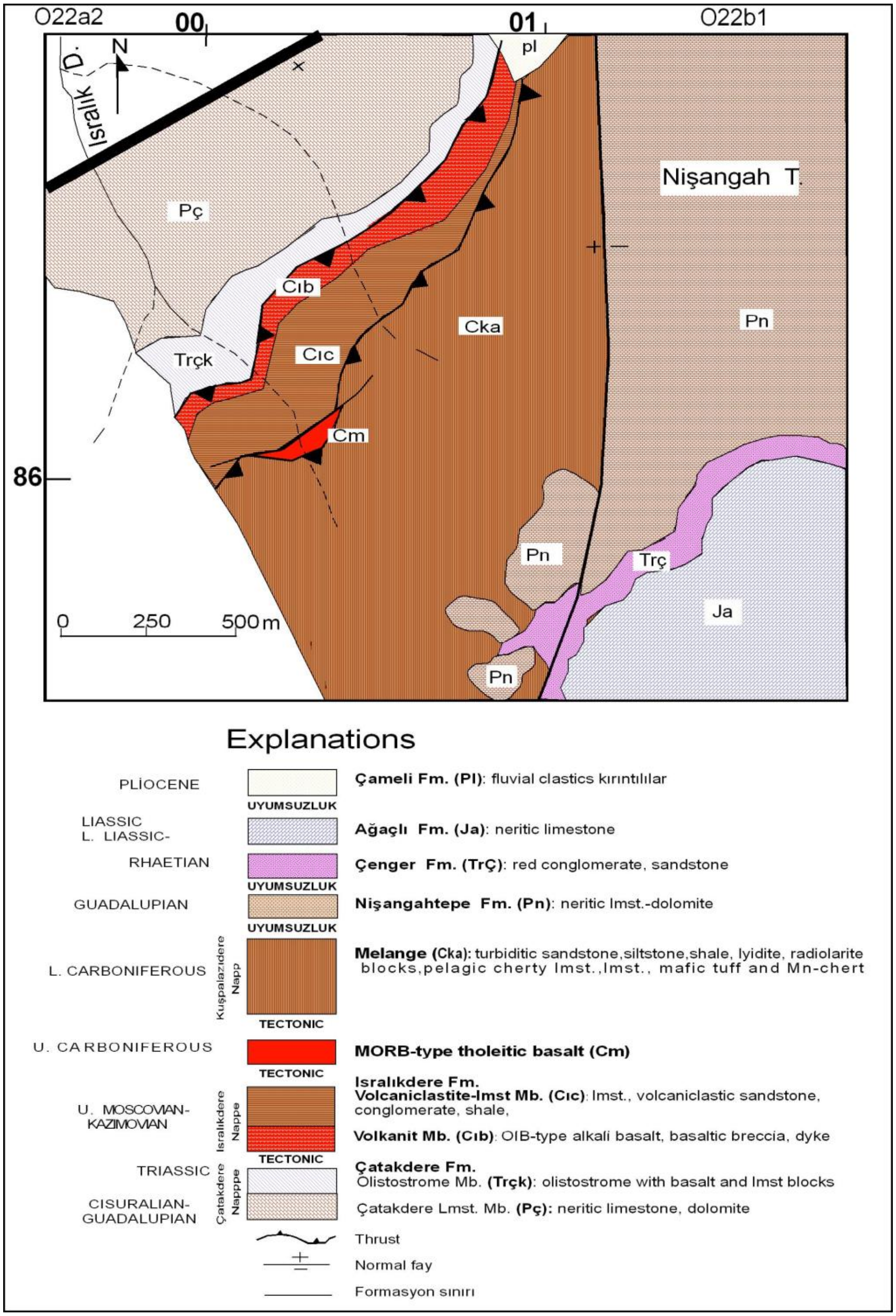


Figure 12- Geological map of the Teke Dere slice of the Tavas Nappe in KBB (Göncüoğlu et al, 2000d)

Teke Dere Unit or Teke Dere Slice of Collins and Robertson (1999) is actually composed of more than one tectonic slice. From bottom to top the slices include following units (Göncüoğlu *et al.*, 2000c):

A- Early Upper Permian limestones vertically transitional to blocky flysch (Triassic),

B- Volcano-sedimentary slice (Figure 13) starts with approximately 20 m thick pillow lava and conglomerate. Most of its pebbles were originated from volcanic rocks. Upwards follow sandstone, 1-2 m thick lava flow, brachiopod and crinoid-rich limestone, sandstone- sandy limestone, tuffite, black shale and mudstone intercalation and ends with gray-beige and pinkish, medium-thick layered vertical cliff forming limestones. The fossils that are detected in this unit were dated as Moscovian – Kasimovian (Upper Carboniferous). Geochemical analysis of alkali basalt constituting vast parts of the unit, of trachyandesite, pillow lava (Figure 14, samples T4A-H in Figure 13) which is originated from trachyte, lava breccia (Figure 14; samples T1A-B in Figure 13) and pebbles. They are forming a co-magmatic sequence and show 'oceanic island basalt (OIB)' feature (Göncüoğlu *et al.*, 2000c).

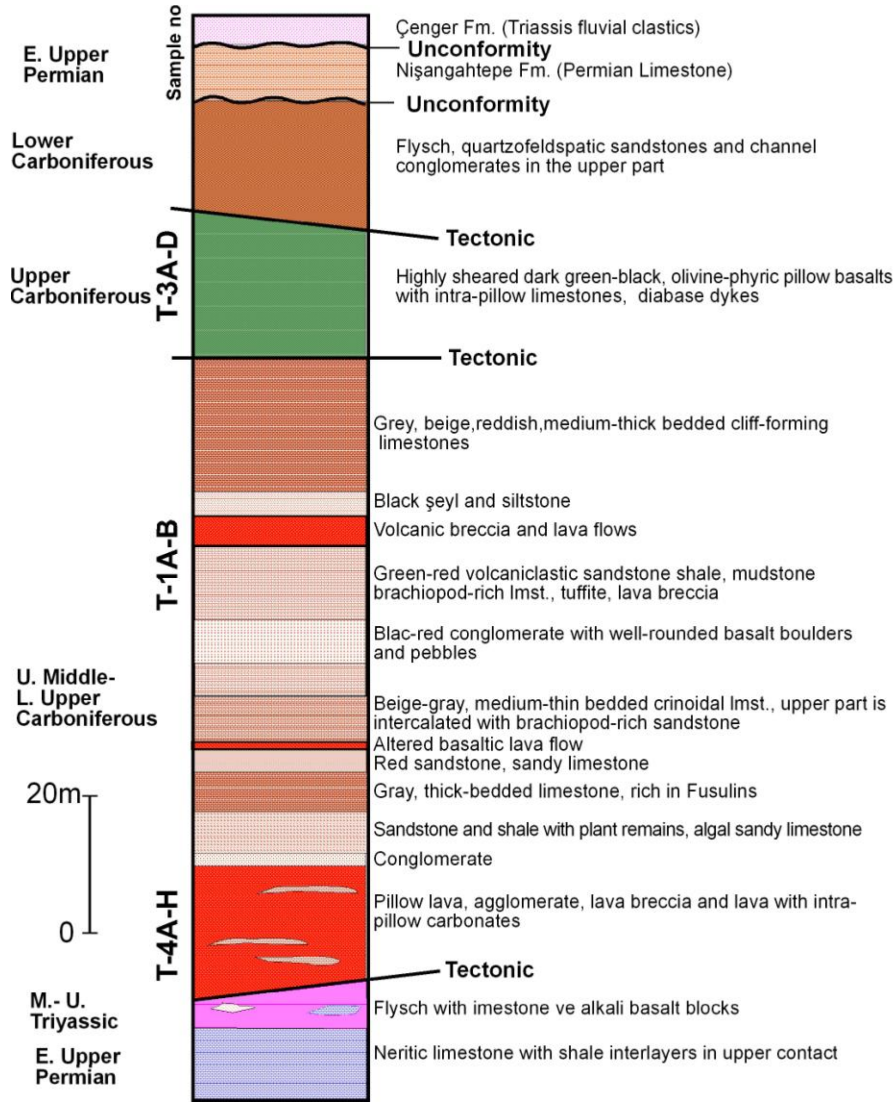


Figure 13- Generalized stratigraphic sections and fossil locations of Teke Dere slice of the Tavas Nappe.

C- Approximately 20 m thick lavas, from time to time with pillow-structure is cut by diabase dikes, intra pillow carbonate filled olivine basalt slice. In this slice, Middle – Late Carboniferous, badly preserved fossils in carbonate and chert intra-pillow fillings are detected. Samples that are taken from this unit display Mid-Oceanic Ridge Basalt (MORB) character (Göncüoğlu *et al.,* 2000c).

D- Shallowing upward successions with sandstone- siltstone and shale with the appearance of a flysch is unconformably covered by Upper Permian limestone and variegated terrestrial siliciclastics of Triassic Çenger Formation. In the flyschoidal unit that constitutes lower part of the slice, conodonts of Lower Carboniferous (Visean) are found by Kozur *et al.,* (1998).

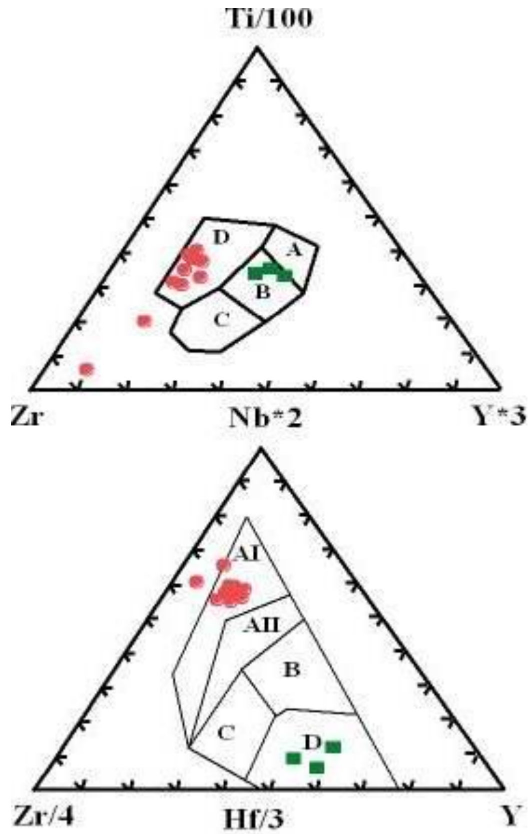


Figure 14- Tectono-magmatic classification of the volcanic rocks in different slices of the Tavas Nappe in Teke Dere. Circles are OIB lavas that alternate with Fusulina limestones; squares represent MORB lavas from olivine basalt slices (Göncüoğlu et al., 2000d).

The Carboniferous 'oceanic island' and 'mid-oceanic ridge' type volcanic rocks together with Carboniferous distal flysch within the Tavas Nappe are evaluated together with the coeval back arc basin units found in Konya. It is claimed that these units are related with the Variscan event that occurred in pre-Permian at the Northern margin of Paleozoic Tauride-Anatolite platform (Göncüoğlu, 1989).

Middle Permian Cover

All along the KBB, middle Permian units overlie the older units defined above with an angular unconformity. Considering Tauride Units that are defined by Özgül (1976) this unconformity is the characteristic feature. Early Upper Permian is a common unit that overlies various units in different regions of KBB by transgression. This transgressive unit in some places (ex. North of Afyon) overly a variably eroded substratum that may reach down to the Neoproterozoic basement. This erosion is related with a rapid rising phase of Tauride-Anatolite Platform before Upper Permian and it is evaluated as representative of the Variscan event (Özcan *et al.,* 1989)

In the bottom of the Permian successions always quartz rich conglomerates or white, cream or black colored quartzites with quartz – pebbles are observed. Pebbles are mostly composed of well rounded quartz, quartzite, mica schist, meta-quartz porphyry grains. The succession continues with light gray, greenish gray, beige-light brown colored quartzite that shows lamination, and cross bedding. Towards top it is composed of calcschists and medium-thin layered sugary textured recrystallized limestone bands. Upper part of the succession is represented by medium-thick-bedded, gray, white and black colored, Crinoid, Mizzia and Fusulina- bearing limestones. Slices in the north only include deformed Fusulina and Mizzia where the internal structures are erased because of recrystallization. On the other hand in the south Konya region (Figure 15) *Tetrataxis* sp., *Staffella* sp., *Hemigordius* sp., *Nankinella* sp., *Globivalvulina* sp., *Verbeekina* sp., *Neoschwagerina* sp., *Kahlerina* sp., and algae (*Pseudovermiporella* sp.) are determined. *Verbeekina* sp., *Neoschwagerina* sp., and *Kahlerina* sp, are of Wordian – Capitanian (Guadalupian) age. By referring these data it is claimed that the unit is deposited in late Middle Permian (revised data from Özcan *et al.* ,1989, 1990a by Dr. C. Okuyucu; Eren, 1993; Göncüoğlu *et al.*, 2003, 2007)

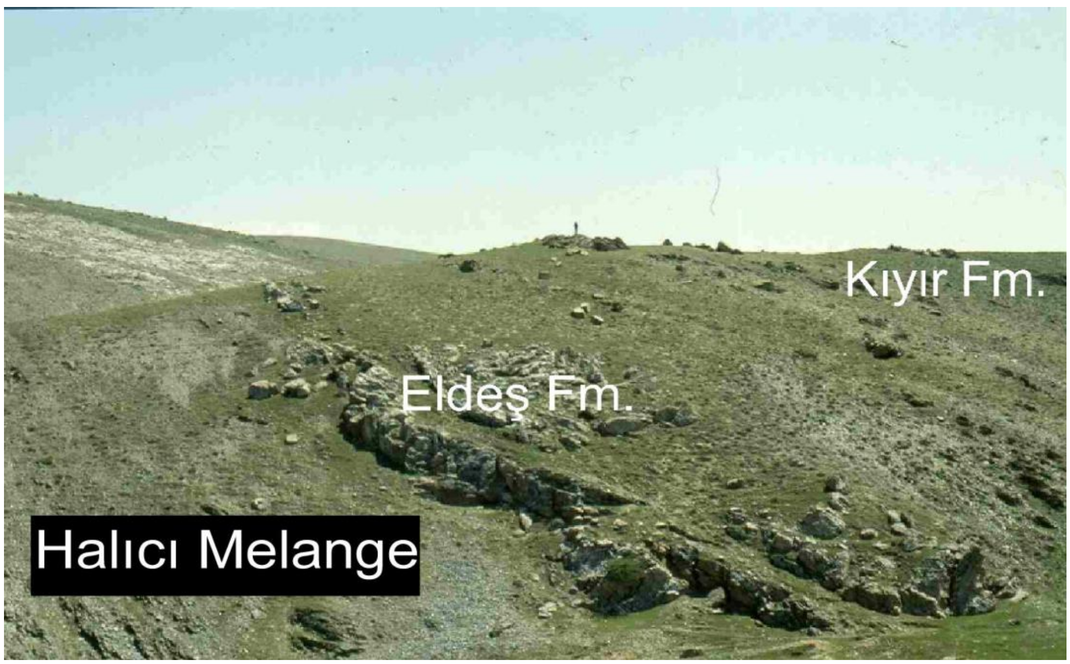


Figure 15- View showing the Permian and Early Triassic unconformities in Çaylaz Dere NE Konya.

In the NE of Konya the Permian unit has a special position in KBB; it is determined as one of the slices of KBB by Özcan et al., (1989), on the other hand Eren (1993) determined it as Gökçeyurt Group. It exhibits similar metamorphic features to KBB but differs from them in its stratigraphy. This difference is observed especially in lithostratigraphy and relations of Permian and Triassic successions. In typical KBB successions, between Permian carbonates and Triassic continental successions there is an important unconformity but in this area relation of these two units are conformable, as in Aladağ Unit of Özgül (1976). Because of that, interpretation (Eren 1993, 1996) that Gökçeyurt Group belongs to another Tauride Unit is more realistic.

Mesozoic Platform Successions

Mesozoic successions are the most fundamental units of KBB. They overlie different type basements and can be correlated easily in every slice. In these successions from bottom to top pretty thick sediments are deposited. Lower Triassic starts with continental clastics and passes to platform carbonates in Middle Triassic and Jurassic, in different slices between end of Jurassic and Early Cretaceous successions are transitional to slope-type pelagic sediments and followed in Late Cretaceous by thick, ophiolite-bearing flysch-type sediments (Figure 16).

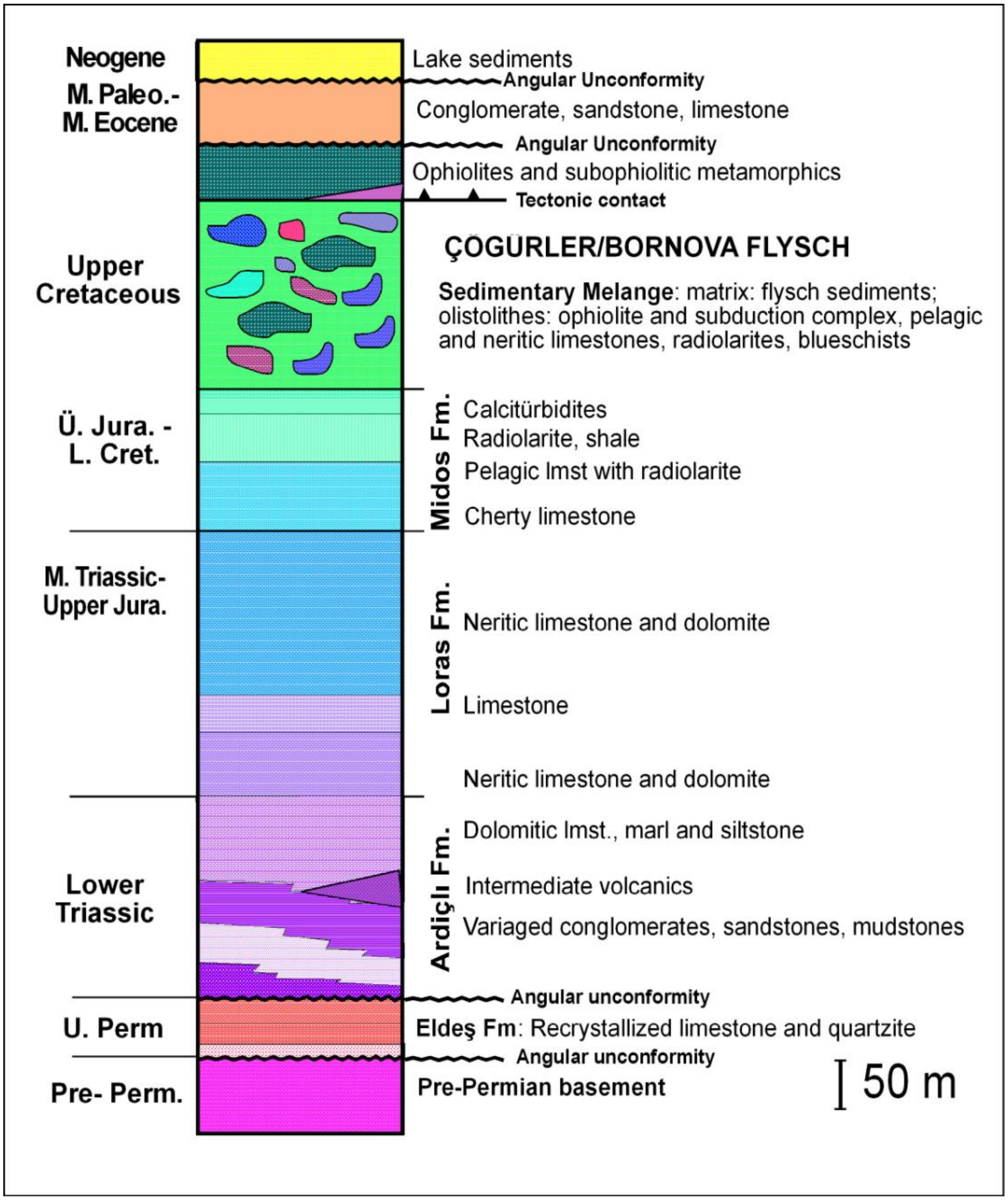


Figure 16- Generalized Mesozoic columnar sections in KBB (Göncüoğlu et al, 2002).

Lower Triassic Terrigenous Units

Lower Triassic rocks that are characteristic with their variegated colors in all tectonic slices of KBB are named as Kıyır formation (Özcan *et al.,* 1989; 1990a, b; Göncüoğlu *et al.,* 1992) in Kütahya region (Figure 17), Ardıçlı formation (Özcan *et al.,* 1990a; Göncüoğlu *et al.,* 2003) in Konya region and, Otluk Metaclastite (Göncüoğlu *et al.,* 1996, 2000a) in Central Sakarya region (Figure 18).

Name of the Kıyır formation will be used in terms of priority all along the belt. The formation includes Morbel Tepe and Seyrantepe members which are commonly observed in Konya region (Özcan *et al.,* 1990b, 1992).

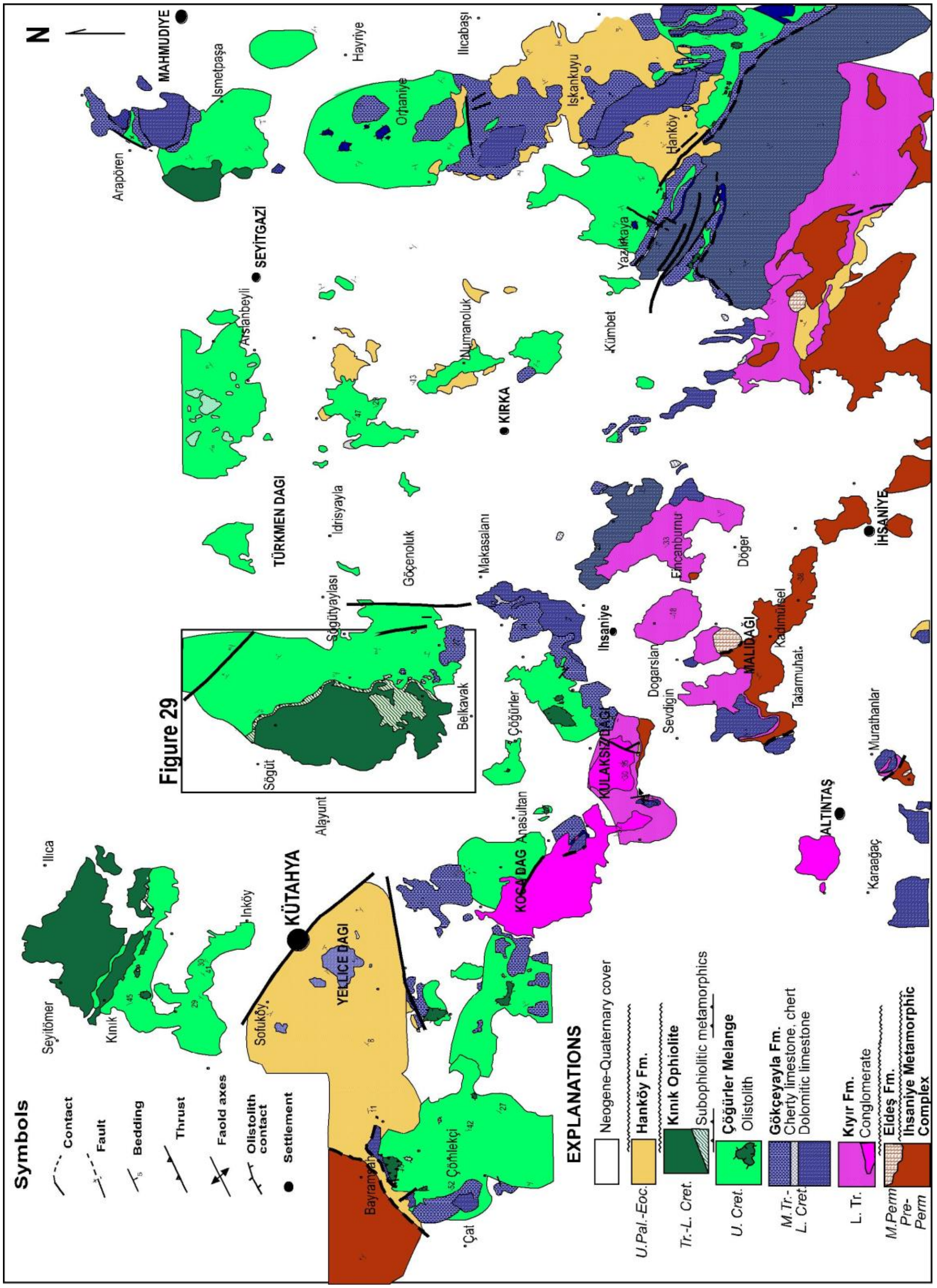


Figure 17- Geological map of Kütahya area (simplified after Özcan et al, 1989). Inserted field shows the locality of Figure 29.

Morbel Tepe member is composed of red, purple, pink, violet conglomerate, sandstone and mudstone. In the unit, rarely dirty yellow colored dolomitic interbeds are noticed. Places where Morbel Tepe member reaches its maximum thickness are: SW of Kütahya Kocadere, and NE of Afyon Kıyırderesi. The reference sections of this unit are located in Afyon-Altıntaş antique marble quarry exposures, north of Sevdiğin Village on the southern slope of Kulaksız Mountain and Meydan Village located 32 km NNE of Konya. Morbel Tepe member overlies pre-Triassic units with an angular unconformity. In the lower part of the unit, the thickness of the basement conglomerate from time to time exceeds 100 meters. It includes red-brown colored, grain supported, subrounded- rounded-angular pebbles.

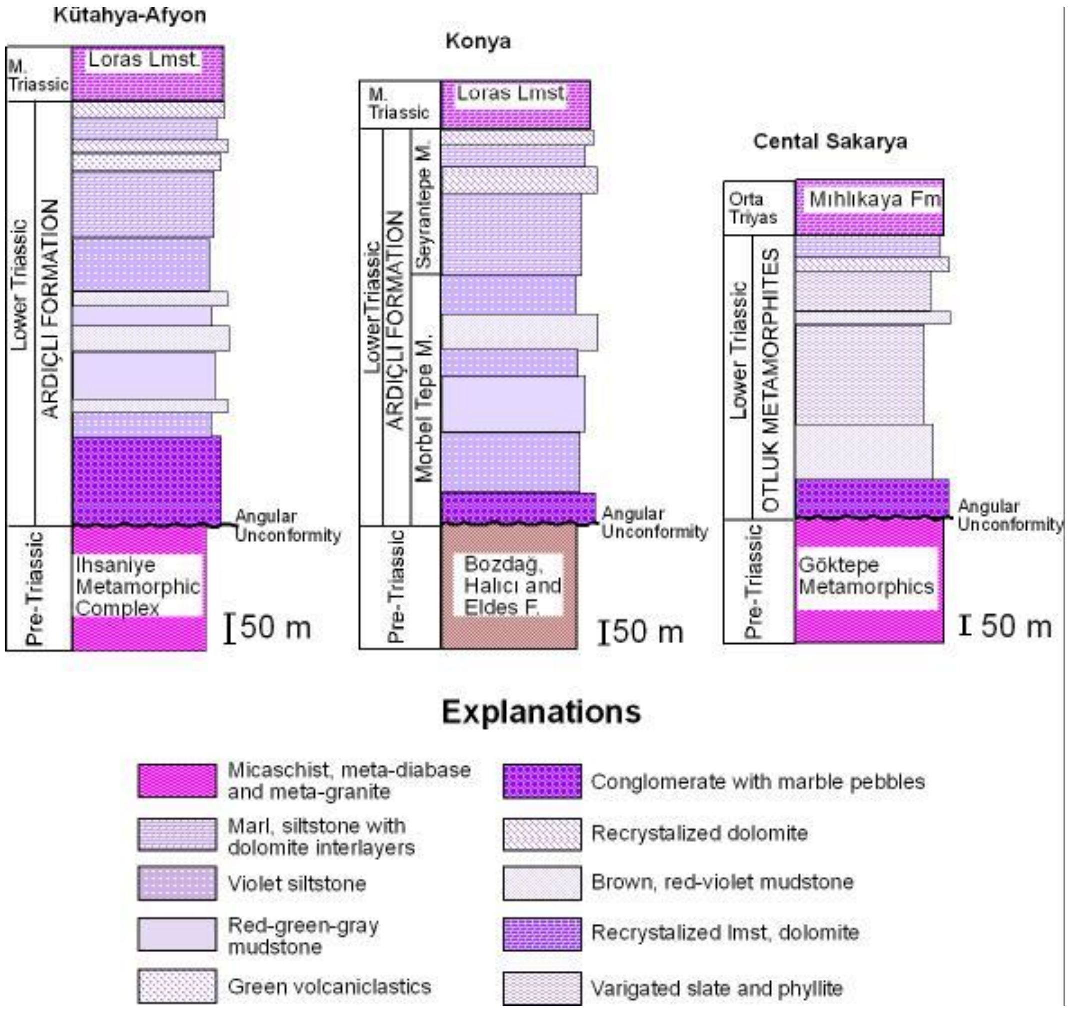


Figure 18- Lithology and correlation of the Triassic rock-units in KBB (Göncüoğlu et al, 2003).

It is composed of pebbles from the Neoproterozoic basement and boulders of the metasedimentary (quartz-mica schist, chlorite-muscovite schist) and metaigneous (meta-quartz porphyry, metarhyolite, metabasic) basement rocks. Black lydite, sandstone, quartzite, Mizzia bearing recrystallized limestone clasts are considered as transported from the Paleozoic basement (Figure 19). In a marble quarry in Altıntaş, pockets and 1 m thick vertical fillings are observed. These pockets are formed by the same material inside the paleokarstic cavities of Permian limestones that located in the basement of the unit. Same images are also seen in south of İşçehisar, where Permian recrystallized limestone is excavated under the name “Afyon marble”.

Red, green, gray colored quartzarenite as intercalations with conglomerate and some mottled mudstone are seen. Over this unit, fining upward, cyclic, brown-red-purple colored, medium-coarse grained, laminated sandstone-siltstone-mudstone packages are placed. The top of each cycle, mud cracked and bioturbated purple mudstone intervals are characteristic. In the uppermost part of the unit, greenish-brown and pinkish gray colored dolomites, dolomitic limestones, and oolitic limestones are found as discontinuous bands and lenses. They are oosparites and oomicrites and include undetermined bivalves.

Figure 19- Polymictic basal conglomerates of Kıyır formation.

By considering its depositional characteristic and the absence of marine fossils, it is claimed that lower and middle part of this member are formed in fluvial environment (Özcan *et al.,* 1984). In more detail, the conglomerate dominated lower part formed in proximal alluvial fan and flood plain, whereas intercalated variegated siliciclastics represent meandering river sediments alternating with flood plain and beach sediments. The upper part of the unit represents subtidal and intertidal environment in oscillating platform margin. It is also claimed that dolomitic and oolitic limestones are sabhka sediments (Göncüoğlu *et al.,* 2003).

Five km north of Afyon-Altıntaş between İncebel Tepe and Obruk Tepe, first limestone bands overlying the varigated clastics include *Glomospira sinensis* HO and *Glomospirella shengi* HO. In the section between Tepecik Hill – Sızma, located 15 km NNW of Konya, first limestone bands and lenses in the outskirts of Gökçeyayla Village, 13 km SW of Konya-Ilgın also include *Glomospira sinensis* HO, *Glomospirella shengi* HO, *Glomospira sp., Meandrospira pusilla* HO, *Nodosinella sp., Earlandia sp.,*algae and gastropods. According to these data, Mobel Tepe member was deposited in Early Triassic (Induan-Olenekian) and before. By considering sedimentary features of the unit, conglomeratic levels present fluvial facies and sandy, silty, muddy sections present meandering river facies. Banded and lensoidal mudstone-siltstone levels present flood plain and coastal beach. Towards the top of the unit, laminations, cross laminations, wavy lamination and bioturbation indicate intratidal sediments, and shallow marine affect. In general terms, this unit presents an environment that starts with fluvial and passes to shallow marine conditions.

The upper member of the formation, composed of carbonates, is named as the Seyrantepe member (Özcan *et al.,* 1990a). This member from bottom to top includes greenish brown colored, medium-thick bedded, dolomitic limestone, oolitic limestone, dolomite, rarely marl, calcarenite, and siltstone intercalations (Figure 20). In these rocks recrystallization is common. Around İşçehisar -Afyon in between and under the limestones, altered lava flows and volcanoclastics as discontinuous bands are observed together with mudstones. Thickness of this unit varies from 10 m to 200 m. It is vertically and laterally transitional with Morbel Tepe member. These volcanic rocks are attributed to Jurassic by Candan et al. (2005) without any evidence. Petrographically limestones are defined as bioclastic grainstone and oolitic grainstone and it is claimed that they are deposited between tidal barriers (Wilson, 1975) in shelf margin (Özcan *et al.,* 1990a). Towards top, where thick carbonates dominate, bioturbated bioclastic wackestone represents transition to marginal platform facies belt. Fossils obtained from this part indicate that its age is Lower Triassic as the Morbel Tepe member. Seyrantepe member passes to the thick carbonates of Middle Triassic (Loras formation) through the top of the section.

Figure 20- Transition of the Kıyır formation into Gökçeyayla (Loras) formation in Afyon Gökçeyayla valley.

Ardıçlı formation, which is defined in Konya region, is affected less by metamorphism than the KBB units in the north. In this area KBB successions in N and NE of Konya, display a distinct Lower Triassic disconformity. On the other hand, in Aladağ area (NW of Konya) more different Lower Triassic succession crop out. This unit sometimes has been correlated with the Halıcı complex by mistake (1993). However, its Triassic age is provided by foraminifera and conodonts.

In Central Sakarya region where northernmost outcrops of KBB are seen, metamorphic equivalents of the Kıyır formation are named as Otluk metaclastite (Göncüoğlu *et al.*, 1996, 2000a). The basement of this formation starts with red-purple colored, thick bedded metaconglomerates. It is composed of orthogneiss, micaschist and marble pebbles. Through top, after variegated metaclastic intercalations, recrystallized carbonates comprise the dominant rock type. This part of the formation reaches to 160 m thickness and it is overlain by Loras-type massive limestones.

Around Konya, in the N and NE of Bozdağlar massive, typical successions of KBB which are defined in Afyon and Kütahya regions crop out commonly. In Aladağlar, NW of the massive, more different successions are observed (Eren, 1993). In these successions, in contrast with other slices of KBB, the distinctive Lower Triassic angular unconformity is not observed. In this area, over the carbonates of Eldeş formation, after a hard ground section, a succession starting with oolitic and algal limestone and passing into red-purple-green colored siltstone and mudstone, are observed. Towards top, this succession is overlain by cream- gray colored medium bedded, Middle Triassic (Anisian)-Jurassic limestones (Eren, 1993, 1996). Most significant feature of this unit is the presence of algal and oolitic limestones in the lower part of the Triassic units. In this unit, also in contrast to other KBB units, no volcanic-volcanoclastic and olistostromal Carboniferous; but shales, quartz-arenites and Girvenella-bearing limestones are found below the Permian quartzites. These successions are found also in NW of Konya and North of Ilgın and corresponds to Özgül (1976)'s Aladağ unit as defined by Eren (1993) correctly. This Aladağ-type unit includes Lower Triassic mottled siliciclastics, dolomite and dolomitic limestones of various thicknesses, and volcanic-volcanoclastic (Akal *et al.*, 2003) intercalations. In NW of Konya (Uzunyayla Stream), limestones have blocky appearance because of folding and rupture. In these limestones conodonts, such as *Neogondolella balcanica, N. oerti* and *N. polignathiformis* are detected and it is evidenced that the carbonate sedimentation reaches to Middle Triassic.

It is evident that the KBB contains not only Bolkar Dağı-type rocks (sensu Özgül, 1976), but includes also tectonic slices which were deposited in the more internal parts (e.g. Göncüoğlu *et al.,* 2007) of the Tauride-Anatolite platform (e.g. Aladağ unit, sensu Özgül, 1976).

Middle Triassic – Lower Cretaceous platform carbonates

The most distinctive unit of KBB is platform carbonates that cover a large portion of Mesozoic. In Kütahya region this unit is described as Gökçeyayla formation also covering the Midos Tepe formation which bears slope sediments (Özcan *et al.,* 1986). In Central Sakarya region, recrystallized limestones are named as Mıhlıkaya metacarbonate (Göncüoğlu *et al.,* 1996). They have the same lithostratigaphic position as the Gökçeyayla formation.

Limestones are the most dominant rock type in the unit. In the lower part of the succession, the formation is in transition with dolomitic limestones, and it is composed of gray colored, thin medium bedded micrites. Just above these, middle – thick bedded, gray-beige colored, algal and oolitic, pelecypod shell bearing limestone is observed. Overall in KBB, the carbonates are dolomitized and intensively affected by deformation and recrystallization. Because of this deformation and tectonic slicing the observed thicknesses of the unit varies between 200 – 700 m in different parts of the belt. The type section of the unit is on the road between Bayat and Gökçeyayla to the E of Afyon. Reference sections are in Loras Mountain, Konya; West of Kütahya in Kocasu Stream and in the West of Bayat.

In terms of microfacies, the lower part of the unit is protected from dolomitization. It is composed of ostracod and algae bearing, pelletoidal limy mudstone and stomatoporitic limy wackestone. According to Wilson (1975) these are deposited in low circulated, shallow marine conditions. They are overlain by Megalodont-bearing micritic packstone. It shows rarely dolomitic and fine-coarse intraclastic wackestone-packstone-pelletic limestone-mudstone characteristics and may have been deposited in low circulated, shallow marine conditions with limited faunal development. Above these formations, the succession continues with packstone-boundstone-grainstone-algal- pelletic packstone and dolomitic limestone. This part represents back reef sedimentation in limited shallow marine environment. In North of Altıntaş, just above this unit mass flow-type, purple colored micrites including intraformational conglomerate levels are observed. They are Late Ladinian – Early Carnian in age. (Kaya *et al.,* 1995). Over these levels, again pelletic grainstone, calcisphere limestone, algal dolomite, crystalline limestone is observed. It is interpreted that this part deposited in restricted marine facies belt of Wilson (1975). After this level the affect of dolomitization increases. In rare isolated areas, presence of fine intraclastic dolomite and dolostone indicates restricted shelf belt deposition. As approaching uppermost levels of the unit, chert bands (Figure 21), micrite pockets and shale laminations increase.

Figure 21- Occurrence of the cherty limestones of Loras formation.

In summary, it is suggested that the unit started with tidal environment conditions. It progressively changed to restricted shelf and finally to open shelf conditions (Özcan *et al.,* 1989). Thereafter, deposition of siliciclastics, pink, violet and green micrite, radiolarian micrite and chert are increased and the unit passes into slope sediments, as described below.

The age of the unit is introduced by the help of foraminifers (determined by Ahmet Işık and Ayşe Turşucu) and conodonts (determined by Asuman Keskin and Heinz Kozur). Samples are taken from various sections and points from West of Kütahya to East of Konya (Göncüoğlu *et al.,* 1992). According to these data the age of the succession starts with Anisian. In various part of the KBB the age ends with Upper Jurassic and Lower Cretaceous. Within the succession each stage starting from Anisian to Malm are determined. After this interval, because of heavy dolomitization the age determination could not be done properly. However, any findings that may correspond to a considerable hiatus or erosion could not be observed in this formation.

Middle Triassic - Lower Cretaceous platform carbonates constitutes the basement of unit which is named as Bornova Mélange (Erdoğan, 1990) or Bornova Flysch Zone (Konuk 1977; Okay and Siyako, 1993, Okay *et al.,* 1996). This unit is located at NW of the Menderes Core Complex (Figure 22).

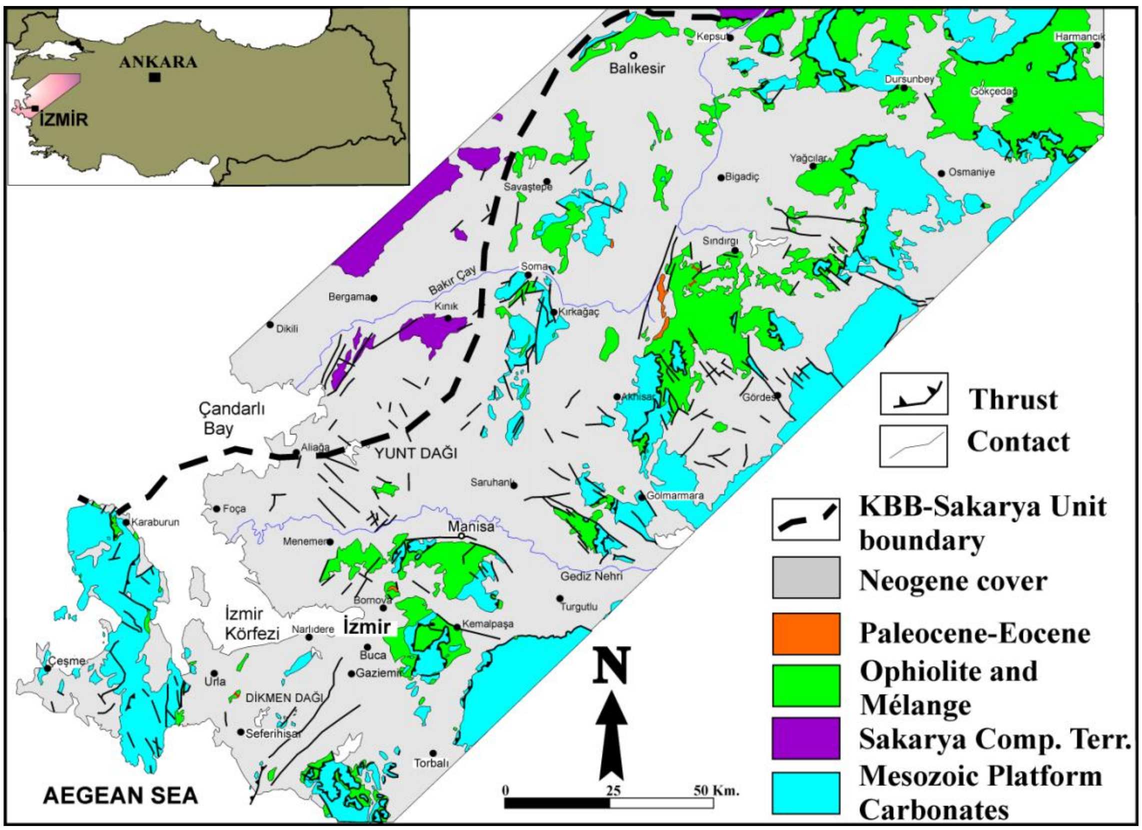


Figure 22- Simplified geological map of Bornova Flysch Zone and sample locations. A. Paleozoic-Mesozoic carbonates of the Tauride - Anatolide Platform, B. Sakarya Composite Terrane, C. Ophiolite and ophiolitic mélange, D. Eocene carbonates and clastics, E. Post-Eocene units, F. Boundary between Sakarya and Tauride-Anatolide units, G. Normal contact, H. Fault, I. Thrust, J. rivers, K. localities of studied sections, (simplified after MTA, 2002)

In Manisa – Akhisar and Simav regions as seen in generalized stratigraphic section (Figure 23) Akdeniz and Konak (1979), Akdeniz *et al.,* (1980), Akdeniz (1985) the thick Mesozoic carbonate succession including Gökbel, Hasköy, Kocakır, and Görenez formations equalizes the carbonates of KBB. Lower Cretaceous recrystallized neritic limestones of Görenez formation in the uppermost part of the unit is transitional first to slope-type pelagic limestone and chert and then to the turbiditic successions of "Bornova Flysch" (Yalınız *et al.,* 2005; Tekin *et al.,* 2006), as in the Kütahya region.

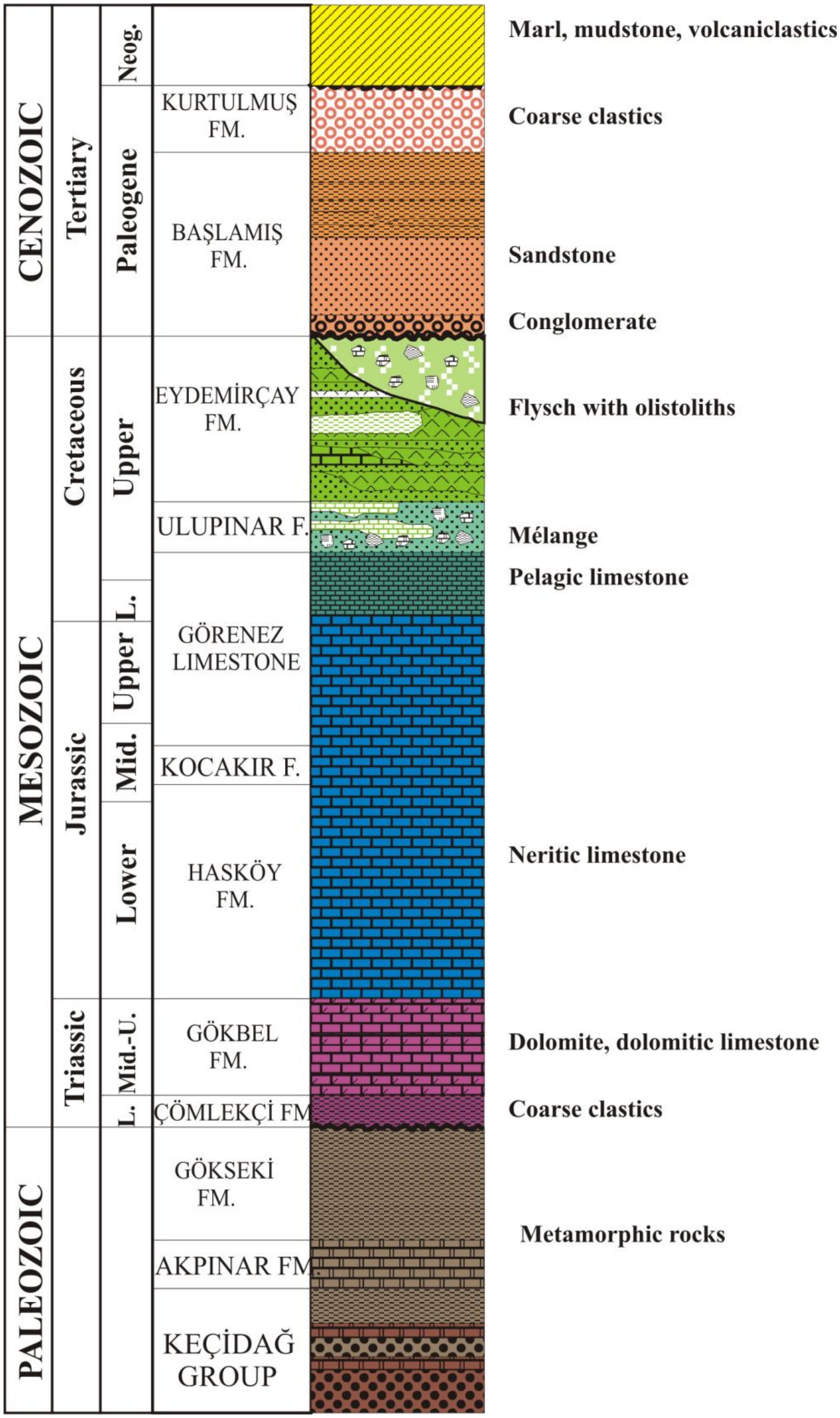


Figure 23- Generalized stratigraphic section of Bornova Flysch Zone (after Akdeniz et al, 1980; Akdeniz, 1985)

Upper Cretaceous Slope Sediments

Successions that transitionally overlie the platform carbonates of KBB are named as Midos Tepe formation in Konya region. The formation is accepted as a member of Gökçeyayla formation in Kütahya-Afyon region and Mıhlıkaya formation in Central Sakarya. It starts with reddish-pink colored, thin bedded and lensoidal semi-pelagic limestones with chert nodules. From time to time it continues with an intercalation of chert-micritic limestone and pelagic fossil bearing red mudstone-radiolarite. In Bayat region the unit starts with 5 m thick quartzarenite and continues with shale-micrite-chert alternation. In this zone radial/prismatic calcite after aragonite is a typical feature of carbonates (Özcan *et al.,* 1989; Candan *et al.,* 2005) which were generated because of HP/LT metamorphism. In Tavşanlı – Ovacık region, Midos Tepe formation from bottom to top includes the following rock types: micrite, pelletoidal-fossiliferous packstone, calcisphere Orbitoid-bearing micrite, mylonitic, ostrocod-bearing wackestone, ostracod-pellet-calcisphere bearing wackestone, limy mudstone, recrystallized fossil rich (radiolaria) micrite, radiolarian chert, radiolarite, and shale (Figure 24). According to the microfacies analyses, Midos Tepe formation is in general deposited in continental slope facies belt of Wilson (1975), but its uppermost part presents typical characteristics of continental slope-oceanic basin facies.

Figure 24- Occurrence of Midostepe formation in Konya İpekler section.

In East of Konya, in Koçkaya tectonic slice (Figure 25) - the most characteristic HP/LT slice of KBB - thin layered pink micrites and radiolarian cherts of Midos Tepe formation was metamorphosed to fine grain marble and Mn-silicate bearing quartz-schists (Özgül and Göncüoğlu, 1997; Floyd *et al.,* 2003). Deposition of Midos Tepe formation in different slices of KBB commences in various times. In its type locality, deposition of the unit starts in Barriasian-Valanginian and continued until Upper Campanian – Lower Maastrichtian. It includes all stages of Cretaceous without a considerable gap. On the other hand in East of Yunak the deposition started in middle Malm (Göncüoğlu *et al.,* 1997b). In Midos Tepe formation towards top, calciturbiditic and clayey sandstone intercalation increases. Then, it passes to foreland sedimentary mélange in late Cretaceous.

Late Cretaceous Foreland Sedimentary Complexes

KBB slope sediments are overlain by olistostromes by a primarily transitional contact. It includes material from the İzmir-Ankara Ocean, sand-size clasts to giant (> 10 km) blocks. Locally, it is olistostromal and turbiditic, sometimes tectonically mixed, sometimes in classical occurrence of a proximal flysch. A non-genetic term “complex (mélange)” is applied to this unit. In order to differentiate these from metamorphic units produced by tectono-sedimentary processes in an accretion prism, the name “sedimentary complex” is preferred. In these units the main process is mass-flows and slides related with sedimentation. As their generation is realized in a compressional environment after their sedimentation, folding, faulting and rupture by shearing is common. As these formations were subsequently incorporated together with their continental crust into the subduction and metamorphosed, they sometimes display similarities to the subduction-accretion prism of the İzmir-Ankara Ocean. During the geological mapping campaign from Bornova to Konya, and then to Bünyan and Hızır mountains, the main criteria used for differentiation was: a) transitional contact between platform-slope successions and ophiolite bearing olistostrome, b) metamorphism.

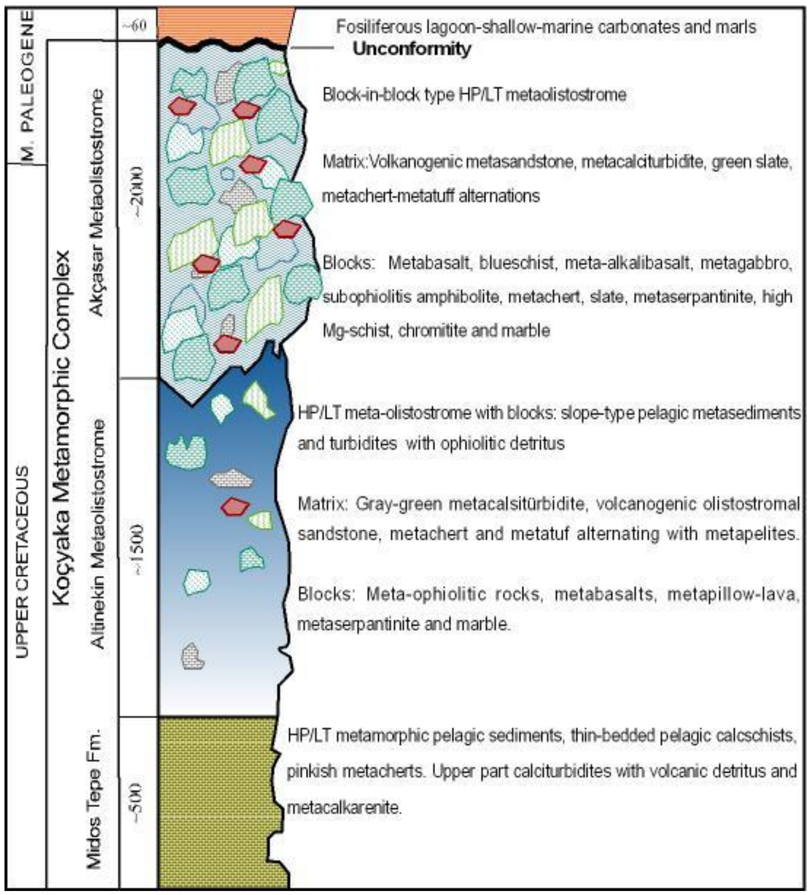


Figure 25- Generalized stratigraphy of the Koçyaka slice (after Özgül and Göncüoğlu, 1999)

First criteria can be used in every distinctively metamorphic (e.g. Koçkaya in the NE of Konya (Figure 25, 26) and Girdopdere in Central Sakarya) or non-metamorphic (Çakmak and Çöğürler in Kütahya region, Yüreğil in N of Emirdağ, Hanköy section in the N of Bayat, Figure 27) slice of KBB.

Each of these sections is composed of different rock types. However their common feature is the presence of well-developed calcitubidites. In the metamorphic slices (Girdopdere and Koçkaya) these rocks are transformed into aragonite marble that contain Na amphibole bearing mafic rock fragments. In slices that display low-grade metamorphism, they include mafic and ultramafic rocks that belong to mélange, red chert and rock fragments. Sandstones are the most dominant rock types of the unit. The sandstone includes clasts of basalt, diabase, blueschist, green and red chert, red-purple micritic limestone and serpentinites. They have rounded pebbles -reaching 20-25 cm size- and mass flow deposits. They also contain black, purple and pink colored mudstone and clayey limestone bands. The complex includes olistoliths of various sizes: few meters to 10 km. They are incorporated into the clastic matrix by mass gliding and include rock types as: recrystallized Mesozoic limestones of the platform margin and slope, all units of ophiolite sequence and their equivalents that have undergone blueschist metamorphism, mélange blocks affected by blueschist metamorphism, amphibolites and andesitic-dacitic volcanics (Göncüoğlu *et al.,* 2000a). In slices that do not show distinct foliation and metamorphism, greywackes and sandstones include clasts of distinctively foliated glaucophane- lawsonite bearing blueschist pebbles. They indicate that some fragments of the mélange have undergone subduction and subsequently transported into the foreland basin. Moreover, limestone blocks reaching a few kilometers in size are equivalents of the Tauride-Anatolite platform. This also indicates that platform-margin/slope units are also transported into the basin by gravity sliding. Locally, not only the blocks but the matrix itself is also affected by deformation and metamorphism.

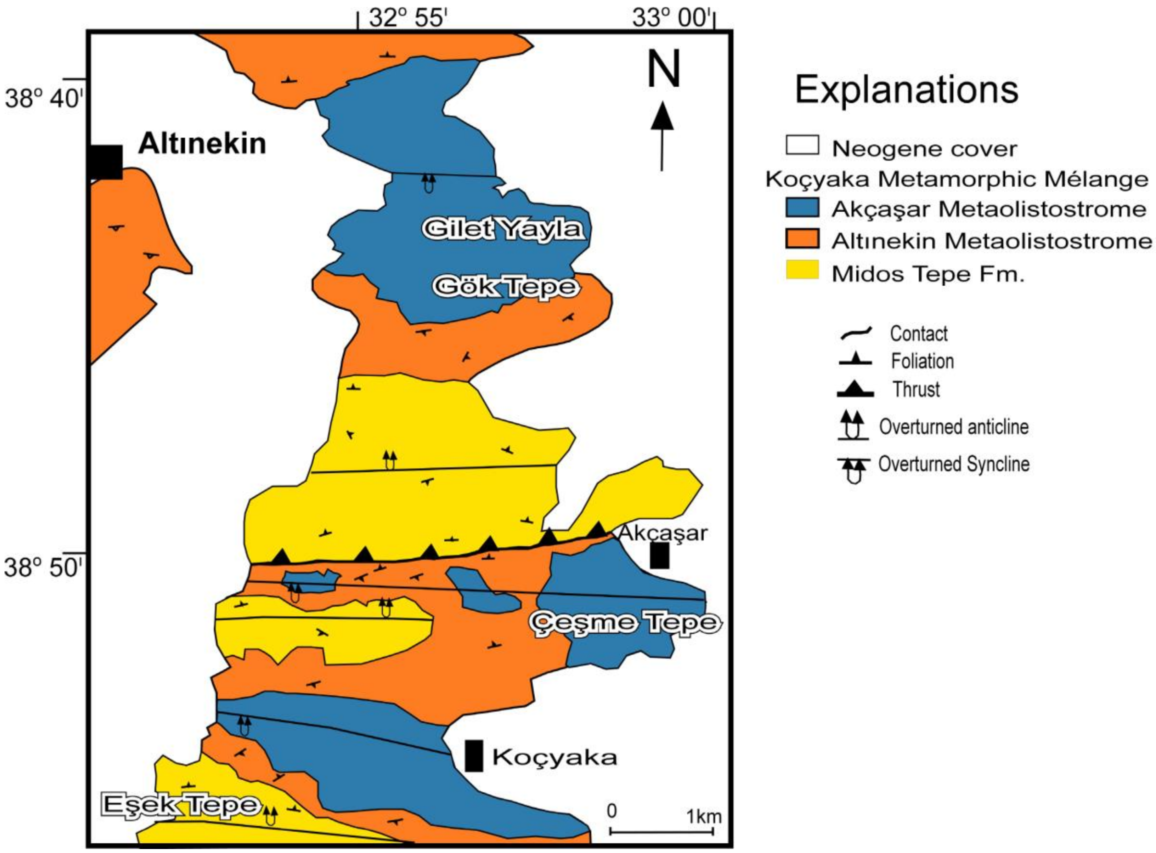


Figure 26- Geological map of the type-locality of Koçyaka slice to the NE of Konya.

The thickness of the unit is more than 3000 m in Kütahya region (Özcan *et al.,* 1989) and 5000 m in Bornova region (Yalınız *et al.,* 2005; Tekin *et al.,* 2007).

In Kütahya – Yüreyir and Tavşanlı – Ovacık areas, in the lower part of unit Middle-Upper Maastrichtian fossils: *Globotruncana* cf. *conica, G. linneinae, G.* aft. *gannseri, Hedbergella* spp. (determined by Dr. T. Çoruh) are found (Özcan *et al.,* 1989). On the other hand, the youngest blocks are dated as Turonian-Campanian. The oldest units that unconformably overlie the unit in Konya region yielded Thanetian fossils (Göncüoğlu 1992; 1997b). According to these data the age of the unit is post Campanian – pre Thanetian (Göncüoğlu *et al.,* 1997b).

In the easternmost edge of the belt the foreland units are defined as "Yeşiltaş Yayla Complex" by Erkan *et al.,* (1978). The characteristics features of the succession and the transition facies to siliciclastics are very similar to the Western areas (Figure 28). In northern slope of Hızır Mountain, in Göktaşlıyurt and Büyükbileyik areas recrystallized limestones of Hınzırdağı Metamorphics also occur as olistoliths reaching a few kilometers in size. They are embedded in a matrix composed of green colored mudstone (Göncüoğlu *et al.,* 1994). Sometimes, the matrix is calciturbiditic and alternate with olistostromal sandstones and conglomerates. Within the matrix, blocks and clasts of limestone, serpentinized ultramafics, radiolarian mudstone and HP/LT metabasic rocks are included. The fossils obtained from pelagic limestone blocks are indicative for Campanian. By this a post-Campanian formation age is evidenced.

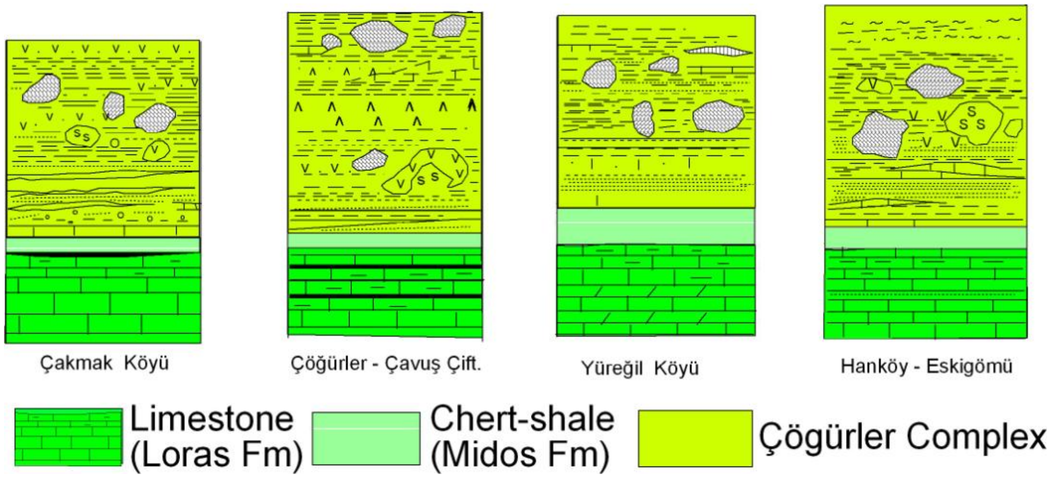


Figure 27- Sections with transitional contacts between platform slope and olistostromal flysch sediments in: A-Kütahya-Çakmak, B-Kütahya-Çöğürler, C- Emirdağ -Yüreğil and D- Bayat-Hanköy (simplified after Özcan et al, 1989).

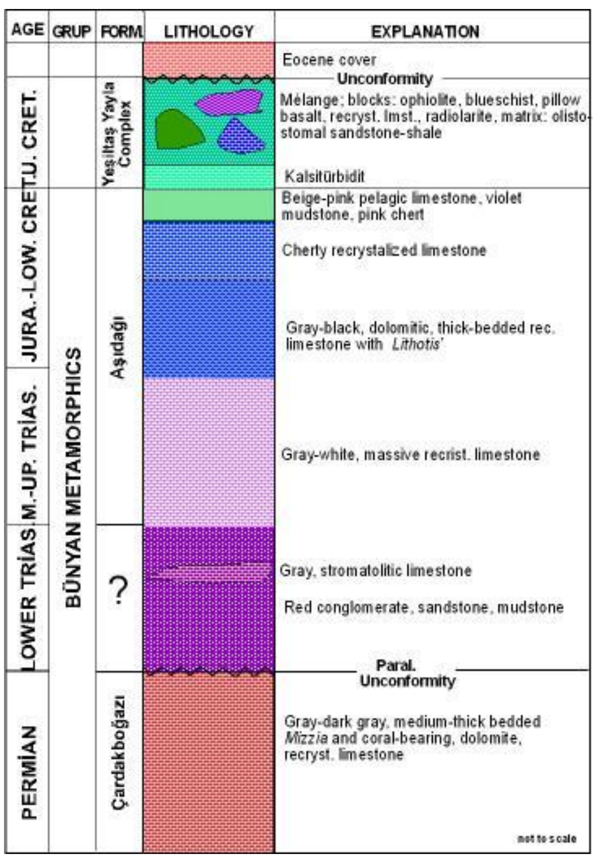


Figure 28- Generalized stratigraphy of the Hınzır Dağı Metamorphics and their relations with the ophiolite-bearing mélanges (Göncüoğlu et al 1994)

Subduction-Accretion Complexes and Ophiolites of the İzmir-Ankara Ocean

Ophiolite Slices

This unit differs from ophiolite blocks within the mélanges by their structural position and by including partial sections of an ordered ophiolite sequence. The ophiolites tectonic slices are of a few kilometers in size, and represent dismembered successions of the oceanic lithosphere. Ophiolitic massifs of Bursa-Orhaneli (e.g. Tankut, 1991), Bursa-Harmacık (Manav *et al.*, 2004), Kütahya-Dağardı (Bacak *et al.*, 2003), Central Sakarya-Dağküplü (Asutay *et al.*, 1989; Göncüoğlu *et al.*, 1996), Ankara-Edige/Kalecik (Tankut, 1984) are relatively well-known units. These massifs include mostly metamorphic tectonites and partially cumulate sections. They are generally highly serpentinized and intersected by isolated dykes.

Dağküplü Ophiolite is located in Central Sakarya area. The name is used by Şentürk and Karaköse (1981) for describing an ophiolitic slice which is supposed to have pre-Liassic age. Peridotites with chromites are the most common rock types. Through shear zones they are highly serpentinized and intersected by rodengitic dykes. The unit includes pyroxenite bands and lenses in some places. In the lower part of the unit typical metamorphic texture is observed. In addition to dunite and harzburgite, orthopyroxenite with large (ca 3 cm long) orthopyroxene crystals and phlogopite-bearing peridotite are observed. In this massif, from bottom to top following tectonic slices were determined by Asutay *et al.*, (1989): gabbro, clinopyroxenite, mafic and ultramafic cumulates and tectonites.

In Orhaneli and Harmancık ophiolitic slices are generally thrust over the HP/LT subduction-accretion prism units. Their visible thickness is a few thousand meters. In regions like Sakarya, Yunak and Konya, beneath the ophiolite slices different units of the mélange complexes are found.

Subophiolitic Metamorphic Rocks

Throughout KBB, metamorphic rocks are found in the basement of ophiolite slices. They are described in North of Kütahya Başdeğirmen and Kaynarca (Göncüoğlu 1990; Figure 29), Central Sakarya (Göncüoğlu *et al.*, 2000a) and Konya Altınekin (Özgül and Göncüoğlu, 1999). In both areas in the Kütahya region, metamorphic rocks outcrop as a single slice but sometimes they have more than one slice.

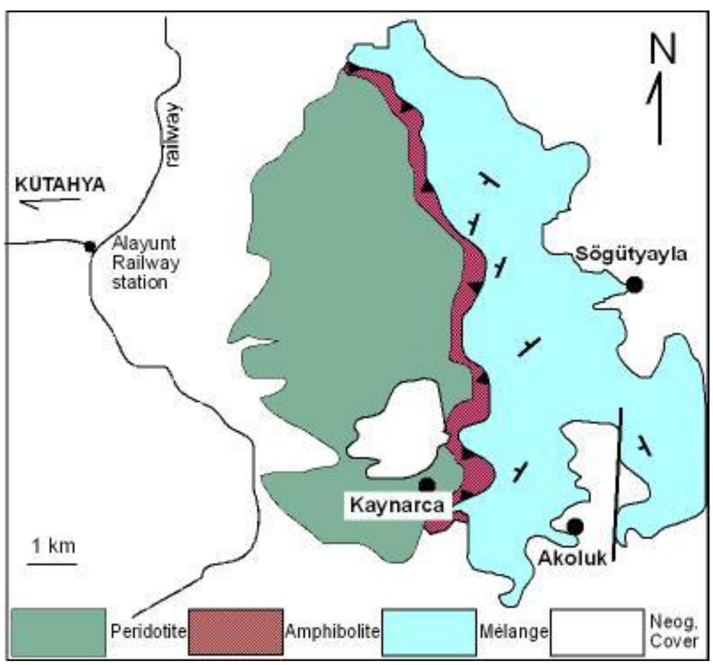


Figure 29- Structural setting of the sub-ophiolitic rocks and mélange units with the ophiolite to the N of Kütahya-Kaynarca. The location of the map-area is shown in the regional map in Figure 17.

They are attached to the basement of the metamorphic ultramafics and their thickness varies between 10 m and 150 m. Rock types of these metamorphics and their structural relations in Kaynarca area are shown in Figure 30. Generally the ophiolite is composed of peridotite intersected by micro gabbro dikes, serpentinized harzburgite and dunite. At the ultramafic-mélange contact, 30 meters thick, black colored, well foliated amphibolites are observed (Figure 31 a, b).

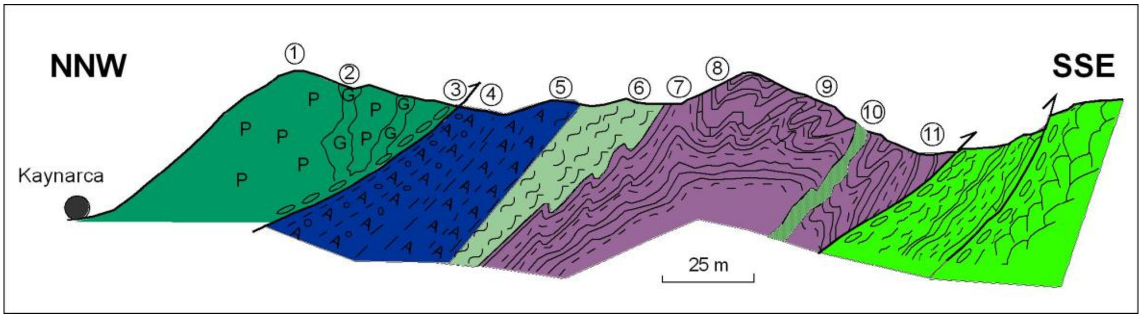


Figure 30- Contact relations of the ophiolitic units with the underlying subophiolitic amphibolites.

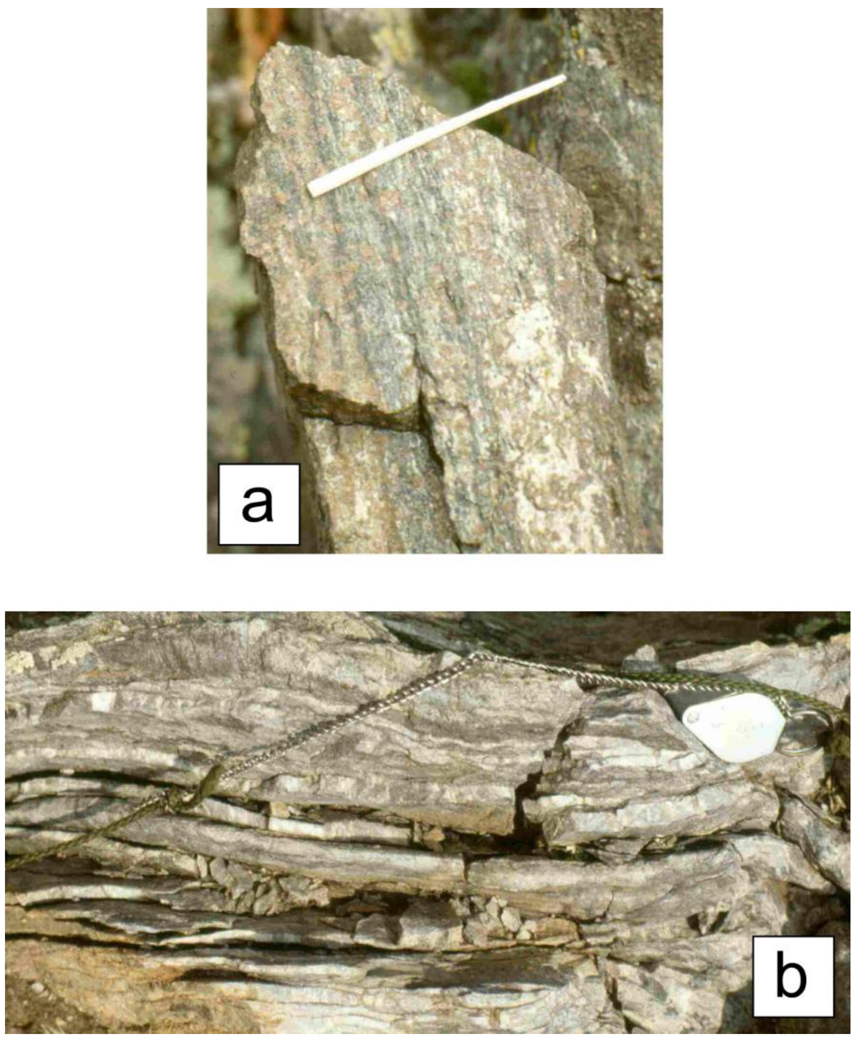


Figure 31 a- Garnet amphibolites from the Kaynarca subophiolitic metamorphics, b- greenschist metamorphic pelagic sediments (more resistant meta-radiolarite bands alternating with recrystallized micritic limestones).

The minerals of the unit are: hornblend + garnet + sphene and secondary Mg-chlorite and epidote. Away from the contact diopside – green amphibole-plagioclase-sphene schist; actinolite-biotite-oligoclase schist, pinkish fine crystallized, thin bedded marble intercalated with rutile-Mn-garnet-piemontite muscovite quartzite are observed. It is suggested that the rocks in that last part represent micritic limestones and Mn- rich cherts. The 30 meters thick lowermost slice that overlies mélange unit comprises greenschists showing less deformation and partly preserved basaltic texture and pillow structure; fine grained recrystallized limestone intercalations, Mn-rich radiolarian chert, slates and quartz-schists are observed. It is concluded that this slice includes the same rock types as the overlying slice. The overlying slice includes metabasics that are metamorphosed to garnet-bearing amphibolite. It is argued that these metavolcanic and metasedimentary successions represent oceanic sediments. During intra-oceanic subduction they came into contact with the hot lithospheric mantle and affected by high temperature metamorphism (Göncüoğlu 1990; Önen and Hall, 1993). In both slices HP/LT Na-amphiboles partly replace brown and green amphiboles which are product of HT metamorphism. This shows that the sub-ophiolitic rocks were also subducted and affected by HP/LT metamorphism (Özcan *et al.*, 1989).

Subduction-Accretion Mélanges

Apart from more or less uniform ophiolitic slices that belong to the İzmir – Ankara oceanic lithosphere, most of the oceanic material that belongs to this ocean, is mixed or accreted in subduction zone.

In this mélange, units that belong to the upper mantle and oceanic crust, oceanic islands and their platforms and slope sediments that related with them, island arc and related pyroclastics, fore-arc and back-arc oceanic crust fragments or basin sediments developed in this conditions, various rocks that belong to slope of the continental crust or transitional rocks between continental-oceanic crust units and their tectonically mixed equivalents that were affected by HP/LT or medium P- LT are observed.

As different from the foreland sedimentary complexes, subduction-accretion mélange units always display moderate to high deformation and metamorphism. These units are mostly tectonically mixed. Even primarily accumulated by sedimentary processes and show characteristics of mass flow and olistostromal features, they are variably sheared. So that their deformed matrix is represented by disordered alternation of green- gray- red colored conglomerate-sandstone-siltstone. Sandstones are the most common rock types. They are generally green and gray colored, fine- medium grained and thin-medium bedded. They include microscopic grains – pebbles- blocks of ophiolitic lithologies. The grains are subrounded and non-graded. In places where sandstones are green, basic volcanic grains are dominant. In places where sandstones are yellow and red, radiolarite and marble clasts are dominant. Siltstones and mudstones are generally highly sheared. Dark gray – green and yellow colored siltstones are thin bedded and laminated.

All units of mélange show metamorphism. Metamorphism sometimes erased all sedimentary and magmatic textures, and completely eliminated the original mineral compositions. So, the rocks have commonly gained schistose texture. As it can be seen in the microscopic analysis of incipiently metamorphosed metavolcanics with poorly developed planar fabrics, the new metamorphic minerals are formed in the veins or replace primary minerals along cleavage planes.

Blocks

In KBB the mélange includes several blocks with variable sizes: ultramafics, gabbros, basalt, dolerite dike fragments, radiolarite, pelagic limestones, mafic tuffs, blueschists and recrystallized limestone blocks.

Mafic-Ultramafic Rocks are observed as large allochthonous masses or blocks within the mélange. They include all members of a dismembered ophiolite sequence.

Amphibolites are 5-20 m long blocks and observed in outcrops extending from Bornova to East of Konya. They are massive-weekly foliated and banded. Under microscope the rock includes hornblende, plagioclase, rare garnet and epidote.

Blueschist Blocks and Slices occur either as olistoliths that were incorporated into the accretion prism material by tectonic or sedimentary processes. They include differences in terms of their metamorphism and matrix. Slices are homogeneous HP/LT metamorphosed rocks that are traceable laterally through several kilometers within a proper belt with several slices. No matter what rock type is included, they present sheared contacts with their surrounding units. Their character as a tectonic sliver is obvious by differences in metamorphism with surrounding units. So, although they are integral parts of the mélange, they can be handled separately as “blocks” and “slices”. Blueschists are common blocks of mélange. They form outcrops from few ten cm to several hundred meters in size. These blocks are mostly composed of basic volcanic and volcanoclastic rocks. They include rocks with different HP/LT metamorphic paragenesis. Original magmatic texture of basic rocks in some of the blocks is preserved. Only in veins, prismatic lawsonite and needle like Na-amphibole is generated. On the other hand, in some blocks basic rocks are well-foliated. Some minerals like glaucophane and lawsonite reached textural equilibrium. In the most common blueschists the first metamorphic phase has variably erased the original mineral composition and parallel to the S1 plane, chlorite-epidote- albite and actinolite are formed. In the rock the remnant texture and relic pyroxene can be still preserved. In the second phase, blocks less affected from metamorphism/deformation include needle-like Na amphibole crystals. In blocks where textural equilibrium is established, typical violet glaucophane phenocrysts are formed parallel to S2 plane. Blueschist metamorphism is not limited to rocks of basic volcanic origin blocks. It is also seen in coarse grained gabbros, serpentinites, and cherts.

Important units that are described as slices are: Yenişehir (Okay, 1980, 1986), Sivrihisar (Çetinkaplan *et al.,* 2008), Yunak and Koçkaya HP/LT. It is possible to see similar metamorphism features in units around Menderes Core Complex (e.g. Rimmele *et al.,* 2005). Koçkaya slice (Figure 25 and 26) has typical feature among them. It is examined by Floyd *et al.,* (2003) and Droop *et al.,* (2005).

Andesite and Dacite blocks are not very common in the mélange. Their size varies from pebble size to 60-70 meters. Blocks are placed in a volcanoclastic matrix. It has green-yellow color, and contains conglomerate-sandstone intercalation mostly with grains of volcanic origin. In hand specimen andesites are green, mylonitic and include large plagioclase phenocrysts. Under the microscope the rock includes plagioclase, biotite and hornblende phenocrysts in a highly altered and sheared matrix. Along shear planes metamorphic phengites are formed. Dacitic rocks look like andesites but they include corroded quartz in phenocrysts phase.

Radiolarian Chert and Mn-Cherts are the most common block types which are very distinctive with their red-green-purple-black colors and bedded-laminated structures. Chert blocks reach their maximum size in North of Akhisar and Central Sakarya. Radiolarian cherts include purple-pink-green colored shale interlayers. In smaller blocks deformation is observed distinctively. Under the microscope, radiolarian cherts are composed of very fine grains of quartz and opaque minerals. In deformed blocks, foliation is distinctive because of presence the white mica flakes.

Radiolarian cherts found in the mélange units have been studied comprehensively in the last few years (Bragin and Tekin, 1996; Rojay *et al.,* 2001; Tekin *et al.,* 2002; Tekin and Göncüoğlu, 2007; Göncüoğlu et al.*,* 2006; Tekin *et al.,* 2006; Tekin and Göncüoğlu, 2009). Provided information shows that in İzmir-Ankara Basin the deposition of radiolarian cherts first start in Upper Carnian. As it can be seen in Figure 32, apart from a gap in Jurassic, radiolarian chert deposition continued up to Upper Cretaceous.

Massive and Pillow Lavas are together with the radiolarian cherts, the most common rock types of KBB. These rocks constitute blocks -few centimeters to 100 meters in size- in mélange. In areas where the matrix of the mélange is visible, blocks are surrounded with an olistostromal matrix. Lava clasts and pebbles of are the dominant ingredients of the matrix. In areas of block-block contact, rocks and contacts are sheared. Blocks of lava are different in terms of their appearance (pillow lava, lava breccia, massive flow, pillow breccia etc.), pillow size (10-80 cm), amygdale distribution, metamorphism and most importantly chemical properties. In numerous studies done through the belt (Göncüoğlu et al.*,* 2006; Aldanmaz et al., 2008 and references in here) it is noticed that the geochemical character of the pillow lava changes from normal mid oceanic ridge belt (N-MORB), enriched mid oceanic ridge belt (E-MORB), oceanic island belt (OIB), island arc tholeiites (IAT), supra subduction zone (SSZ) types (Figure 33). The SSZ types further include fore-arc (FABB) and back-arc (BABB) subgroups. In Figure 34 the geochemical characterization together with the age of volcanism is presented. In the light of data obtained from the blocks in the mélange, it is suggested that the earliest oceanic crust formation in İzmir-Ankara Ocean started in early Late Triassic. It continued to spread in late Early Cretaceous and started to close by intra-oceanic subduction from then on.

Recrystallized Limestones are also common constituents of the mélange and represented by a great variety of properties. The most common blocks are gray-black colored, medium-thick bedded recrystallized limestones. These blocks may form 200-300 meters long to 70-100 meters large outcrops. Another frequently outcropping recrystallized limestone block type is gray-yellow-pink colored, thin bedded, and well-foliated pelagic limestones.

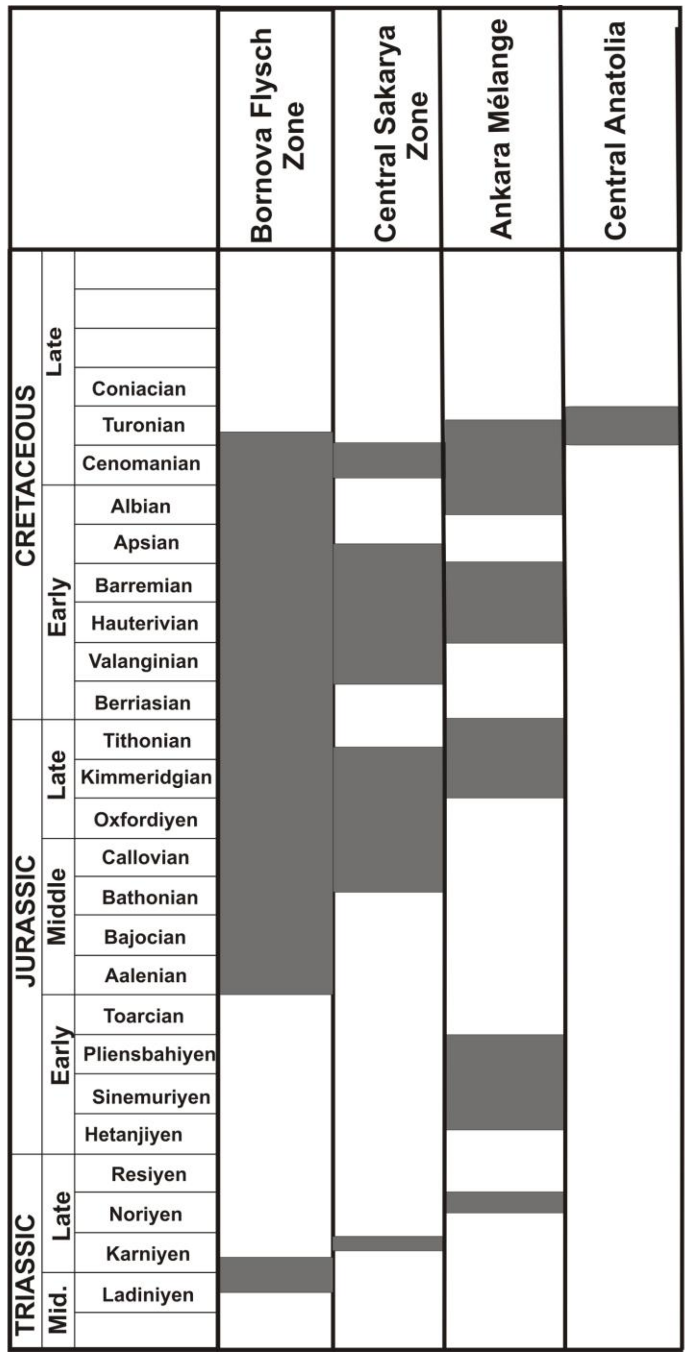


Figure 32- Radiolarian ages obtained from different parts of the KBB (for data see text).

Similar lithologies to these limestones are observed in the upper part of the platform successions. Generally these limestones are recrystallized and include badly preserved Lower Cretaceous pelagic fossils. Micritic limestones and radiolarian cherts are in many cases associated with basalts and yielded foraminifers in chert intercalations. In previous work, Upper Cretaceous (Campanian) (Erdoğan 1990), Upper Santonian- Maastrichtian (Akdeniz et al., 1986) ages are determined by using planktic foraminifers in these lenses. Samples from different parts of the matrix in the mélanges of the Bornova Flysch Zone yielded

Campanian, Maastrichtian-Danian (Erdoğan 1990; Akdeniz et al., 1986) ages. By this, it is proposed that the deposition in this basin is Maastrichtian-Early Paleocene (Erdoğan 1990; Akdeniz et al., 1986).

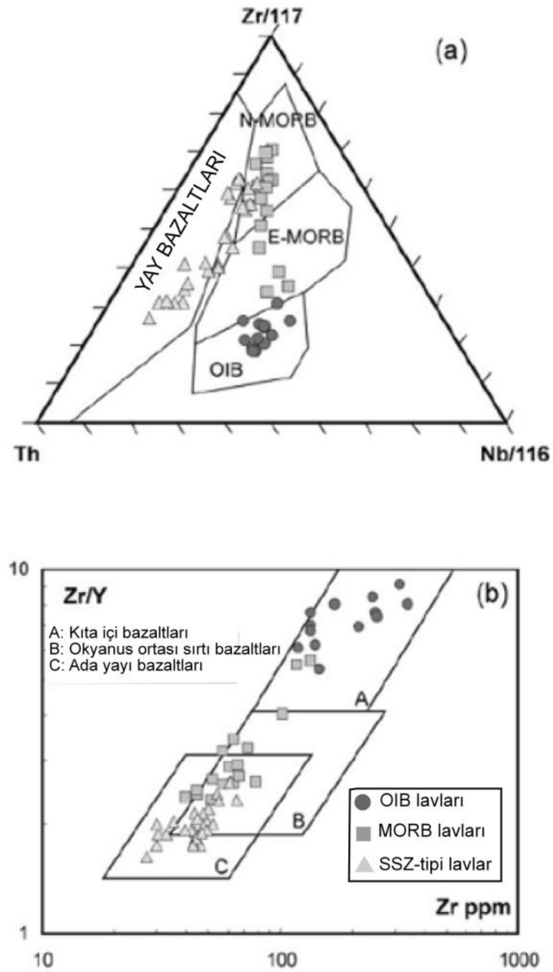


Figure 33- Tectono-magmatic discrimination of volcanic rocks from the KBB mélange, flysch and ophiolitic nappe. (for data see Göncüoğlu et al, 2006b.

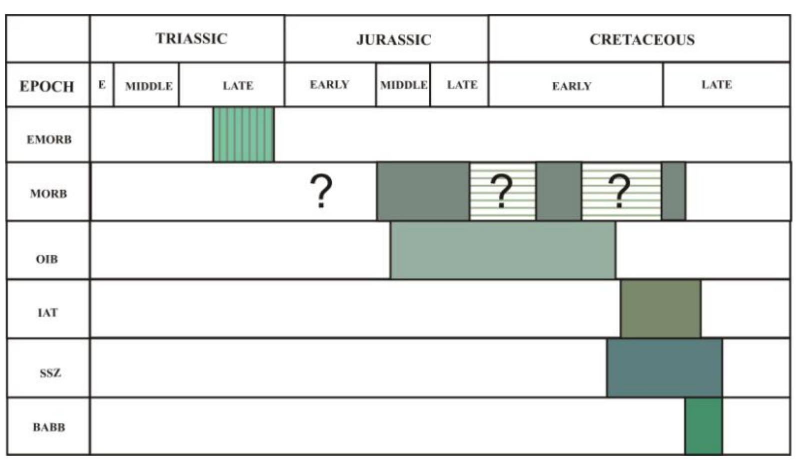


Figure 34- Evolution of the volcanism within the İzmir-Ankara ocean through time (after Göncüoğlu et al, 2006a).

PALEOSEN-EOSEN COVER UNITS

The oldest overstep sequence disconformably covering products of the Late Cretaceous ophiolite emplacement and related tectonic imbrication is described as Kızılçay Group in Central Sakarya and Kartal formation in NE of Konya (Göncüoğlu et al., 1997b; Çemen et al., 1999). Both of these formations are composed of dark maroon-red, locally green-yellowish-green colored, thick bedded, non-graded or badly graded conglomerates with rounded – sub angular pebbles. Compounds of the conglomerate ranging from pebble to block in size are quartz, red-black chert, quartzite, andesite, monzonite, gabbro, gray limestone, white recrystallized limestone, red chert, and metamorphic rock fragments. Towards the top conglomerate-sandstone alternation is more distinctive.

In the North of Altınekin (Figure 35) the cover unit starts with red colored conglomerate overlying highly sheared serpentinites of the Koçkaya Metamorphic Complex. Locally the pebbles reach to block size. They are dominantly derived from the radiolarite, pelagic limestone, gabbro and rarely syenites of the underlying mélange rocks. In lower part pebbles are cemented with carbonate cement. In the cement, plenty byrozoa and algae (*Melobesia*) fragments are found. Above, macrofossil rich gray colored clayey limestones, and conglomerates with limestone and radiolarite pebbles are deposited. In some of these pebbles, *Globotruncana* rich limestones of Cenonian age are found. Limestones of this age and fossil content are also noticed in the mélange of the basement. In clayey limestones constituting the matrix of Kartal formation plenty of algal flocs, corals, *Haddonia* sp., and *Planorbulia create* (determined by Dr. E. Sirel); *Micocodium* sp., *Planorbulina* sp., *Ethalia* sp., *Milliolidae* and *Discorbidae* (det. S. Erk) are found. By this, the age of the unit is given as Danian- ?Lower Tanesian. Towards top in marly sections fossils like *Chiasmolithus bidens, Fasciculithus tympaniformis, Fasciculithus involutus, Ellipsolithus macellus, E. distichuc, Discoaster multiradiatus, D. Aster, D. mohleri, Neoschiastozygus perfectus, Sphenolithus anarrhopus, Zygodiscus herlynii* ve *Coccolithus* sp. were determined. The age of this level is accepted as Thanetian. Here and also in the neighbouring Tuz Lake basin, upper level limestones that probably deposited in lagoonal environment and include the fossils *Laffiteina* sp., *Broeckinella* cf. *Arabica, Glomalveolina primaeva,* Alveolinidae, *Asterigerina* spp., *Hottingerina* cf. *lucasi, Mississippina* spp., *Ethelia* sp., Corallinacea, Dasycladacea, *Distichoplax biserialis.* The age of this limestone level is also Thanetian (Dr. E. Sirel, oral communication).

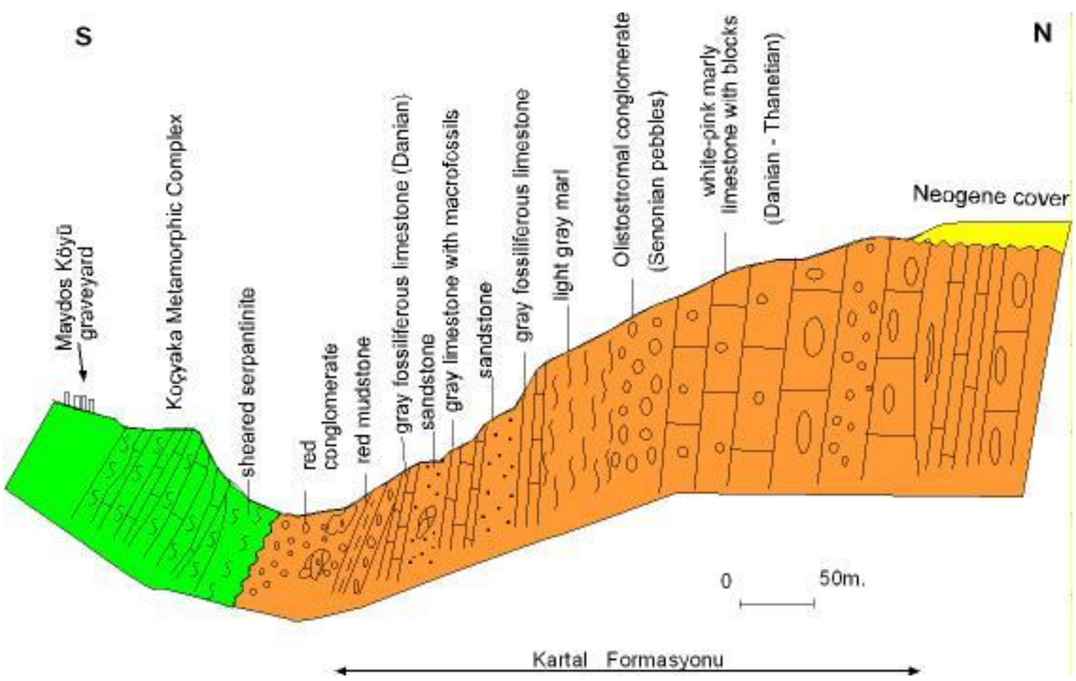


Figure 35- Cross-section of the Upper Paleocene cover of the melange units to the N of Altınekin (Göncüoğlu et al, 1997b)

In NW of Cihanbeyli, in Sülüklü-Sarıkaya area another cover succession starts with a sedimentary breccia with angular fragments (ophiolite, radiolarite, Loras- and Midos-type recrystallized limestones) from the basement over the Loras-type limestones. Its includes 5-10 meters thick intervals of purple-red- brown sandstones, carbonate cemented limestones, marls, evaporites (sabkha sediments) and conglomerates. The pink and gray colored algal limestones in this succession yielded Danian fossils.

The Early Tertiary cover rocks are encountered in Afyon-Bayat and in its North (Fig. 17). They are the oldest rocks we found yet covering several thrust slices with an angular unconformity. These rocks are defined as the Hanköy formation by Özcan et al. (1989). The lithostratigraphic features and fossiliferous levels of this formation in N KBB are shown on Figure 36. In the lowermost part of the successions in several sections algae (*Melobesia*) rich sabkha-type carbonates are found within red colored fluvial clastics. *Alveolina*-bearing samples taken from carbonate-dominated parts indicate a Upper Paleocene age.

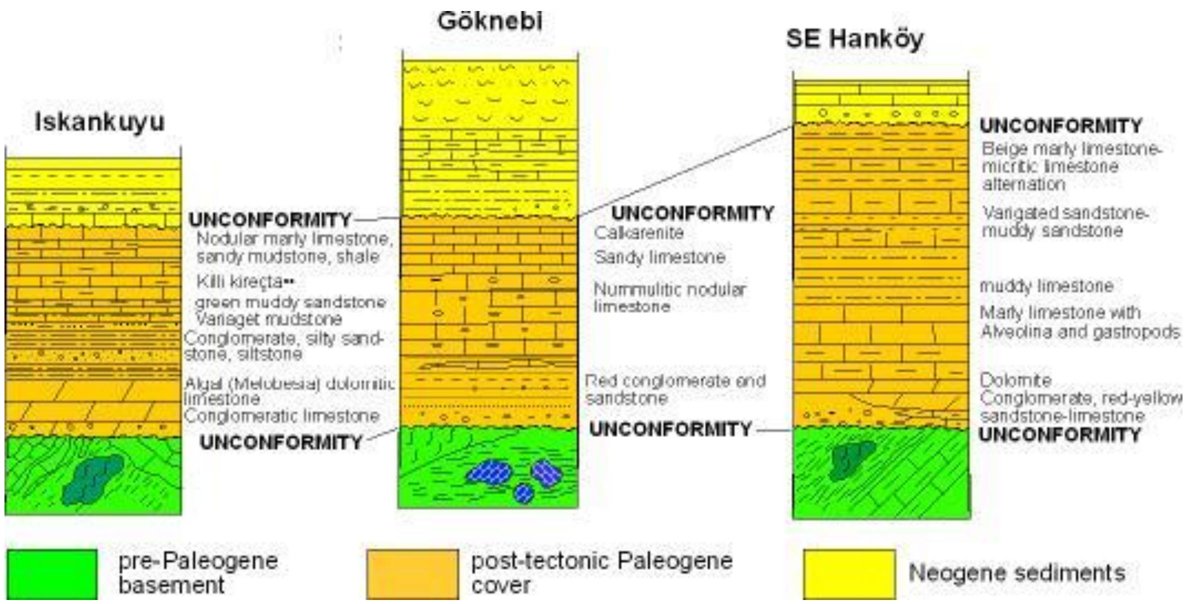


Figure 36- Stratigraphic features of the Hanköy Formation in Kütahya area.

Also in the Bornova Flysch Basin, Tertiary sediments overlie the Upper Cretaceous flyschoidal sediments with an angular unconformity. They are named as Başlamış formation by Konak et al. (1980). The unit starts with red conglomerates. The overlying shallow sandstones and limestones of brackish water environment include Upper Paleocene fossils.

In Central Sakarya region, the first unconformable unit over the ophiolitic rocks and mélange units are pink colored algal carbonates. Towards top, red colored mudstone-sandstone and carbonate alternation is correlated with the Upper Paleocene rock units (Göncüoğlu et al., 1997b) in the S. In this area the Paleocene as well as the Eocene (Bartonian, Goncuoglu et al., 2000) cover sediments are sliced with the underlying mélange units during the Miocene compressional events.

In terms of their depositional environment, Paleocene units have the characteristics of alluvial fan deposits that reach a very shallow lagoon. Considering the blocky character and the internal order, they were probably formed in front of a rapidly uplifting block.

The Eocene units are transgressively covering a peneplained topography, sometimes even truncating the Paleocene units. They start with few meters thick carbonate-cemented, green-cream colored marine conglomerates-sandstones and continue with cream colored, medium bedded locally nodular limestones. Towards top volcanic rocks as domes and volcanoclastic material is observed in carbonate-clastic successions. All along KBB in samples taken from the lower part of the unit, Middle Eocene (Lutetian) fossils are determined (e.g. Konak et al., 1980; Özcan et al., 1987, 1989; Göncüoğlu et al., 1997b).

After the Middle Eocene no marine deposition is reported yet in KBB. The Eocene sediments, especially in the north of KBB are incorporated in Miocene tectonic slices (e.g. Central Sakarya area).

The formation of the Neogene basins and related volcanism and the evolution of the region in the Neotectonic period are beyond the scope of this present review but can be found in several recent publications (e.g. Özsayın and Dirik, 2008).

GEOLOGICAL EVOLUTION

Geological evolution of KBB in a way includes the geological evolution of Tauride-Anatolide Platform and Menderes Core Complex. This evolution will be examined in the frame of major geological events and data obtained from the KBB.

Pan-African/Cadomian Period

The Precambrian units are commonly represented by low grade metamorphism in the Taurides. In Anatolides they include rocks of ortho- and para origin and their outcrops of proven age are found in Menderes Core Complex, and in KBB. Afyon-İhsaniye Basement Complex, their equivalents -Sandıklı Basement Complex in the S and Göktepe Metamorphics in North in Sömdiken Mountains have similar properties. Considering Afyon and Sandıklı units, it is observed that a clastic-dominated unit with rare carbonates is intersected by post-collisional felsic magmatic rocks (Gürsu and Göncüoğlu, 2008). Zircon U/Pb ages (542 my) obtained from this unit are coherent with the age of the core gneisses of Menderes Core Complex (Koralay et al., 2004; Candan et al., 2005a). Göncüoğlu (1997) and Gürsu and Göncüoğlu (2005a, 2006a) propose that this magmatism was formed in northern margin of Gondwana (Figure 37), above the southward subducting oceanic lithosphere.

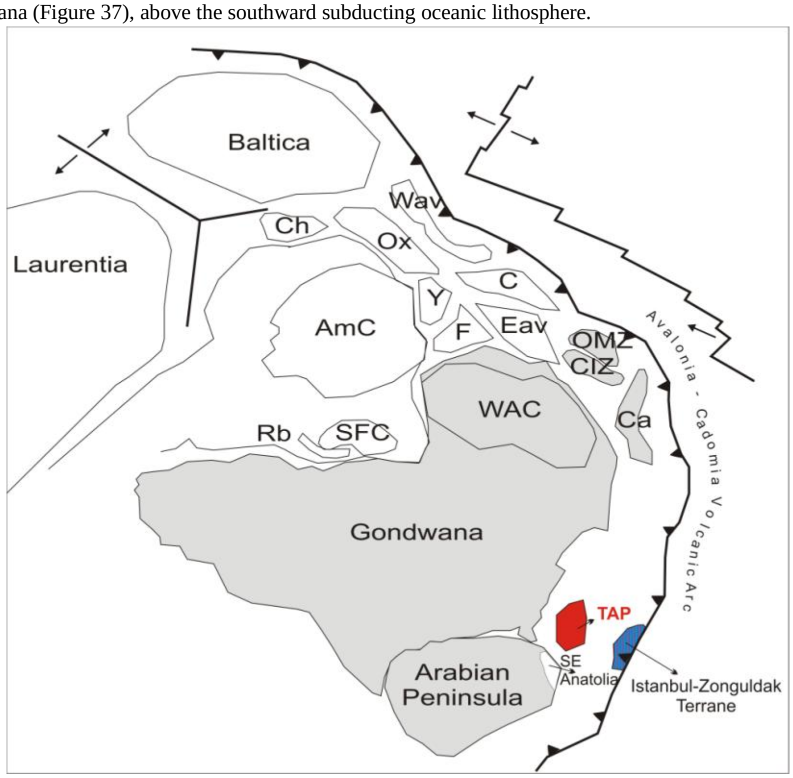


Figure 37- Paleogeographic setting of the Tauride-Anatolide Platform during the Late Neoproterozoic. AmC: Amazonia Craton, C: Carolina, Ca: Cadomia, Ch: Chortis Block, CIZ: Central Iberian Zone (Iberia), Eav: D Avalonia, F: Florida, OMZ: Ossa-Morena Zone (Iberia), Ox: Oaxaquia, Rb: Ribeira, SFC: San Fransisco Craton, WAC: B Africa Craton, Wav: West Avalonia, Y: Yukatan. (Gürsu and Göncüoglu, 2006b).

According to this model, the Late Proterozoic subduction and related arc magmatism that had began at 600-575 my. It stopped between 575-550 my by collision of North margin of Gondwana – arc-trench collision. A new magmatic phase has started in between 550-525 my because of post collision and/or back arc extension. The products of this succession of events are generally attributed to the late events of the Pan-African Orogeny (e.g. Şengör et al., 1984). However a number of Late Neoproterozoic magmatic/metamorphic events in the Avalonian, Southern European and North African terranes, seem to be unrelated to the Pan-African events in terms of time and space. Because of these differences such events were ascribed to a proper igneous-metamorphic event, named as Cadomian Magmatism (Murphy, 2002). Göncüoğlu (1997) pointed out that this magmatism in North Gondwana between 600-550my has not only affected the Avalonian-S European-N African active margin but also the Tauride-Anatolide and İstanbul-Zonguldak terranes (Figure 37).

Detailed clay mineralogical studies (Bozkaya et al., 2006) performed on the Precambrian sediments in the Sandıklı area proved that these Cadomian events are not limited with magmatism but affected the pre-Tommotian (< 530 my) metasediments and the granitoids intruding them by low grade metamorphism.

Variscan Period

Except the undated quartz-rich clastics of İhsaniye Metamorphic Complex (Gürsu et al., 2004) no Lower-Middle Paleozoic sediments are described from the KBB and hence from the northern part of the Tauride-Anatolide platform. In the inner part of the Paleozoic platform, however, disregarding the deepening characterized by the Silurian ribbon-cherts in Konya, the deposition between Cambrian to Devonian is represented by platform-type siliciclastics and carbonates. Within this platform, outcrops of an Early Carboniferous back-arc basin extents from Konya to Karaburun (Özcan et al., 1990b). The within-plate alkaline magmatism represented by intensive dike-swarms cutting the Devonian platform carbonates are interpreted as an evidence of continental extension that were formed at the first step of this basin opening. By considering the geological features of Halıcı mélange in the North of Konya together with the petrographic character of bi-modal volcanic rocks, Göncüoğlu et al., (2007) claimed that the opening of these basins may be due to southward subduction of Paleotethys as marginal or more probably as a back-arc basin (Figure 38) in the North of Tauride-Anatolide platform.

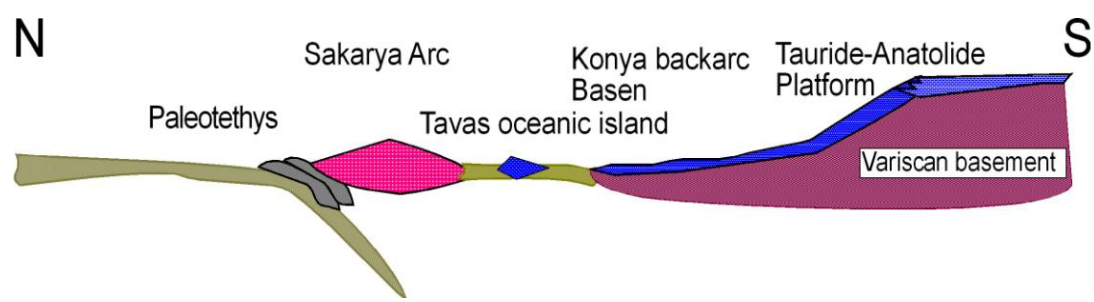


Figure 38- Carboniferous reconstruction of the Tauride-Anatolide northern margin (Göncüoğlu et al, 2004)

The presence of such an oceanic basin could also explain the Middle Carboniferous oceanic rocks observed in the Tavas Nappe (Göncüoğlu et al., 2000c). As mentioned above, in this nappe, also Middle Carboniferous MOR-basalts and representatives of a Moscovian-Kasimovian oceanic island is discovered., Considering that İzmir-Ankara Ocean has not been opened yet during this period and that Lycian Nappes are originated from the northern margin of the Tauride-Anatolide platform, the source of this oceanic crust material must be Paleotethys or more probably a basin to the South of it. What led the closure of this basin is arguable (Robertson and Pickett, 2000; Göncüoğlu et al., 2007; Moix et al., 2008). However it is clear that this closure accompanied by deformation of Variscan time (Göncüoğlu, 1989). In northern part of KBB, Middle Permian clastics are transgressively overlying various units with a weak angular unconformity. The Permian transgression (Figure 39) generally starts with deposition of shallow-marine quartzites. Locally the deposition continued with thick platform carbonates. The fact that Middle-Upper Permian platform deposited unconformably over both the Tauride-Anatolide Units and the Sakarya Composite terrane, indicates that both units were affected by the same tectonic regime in Middle Permian.

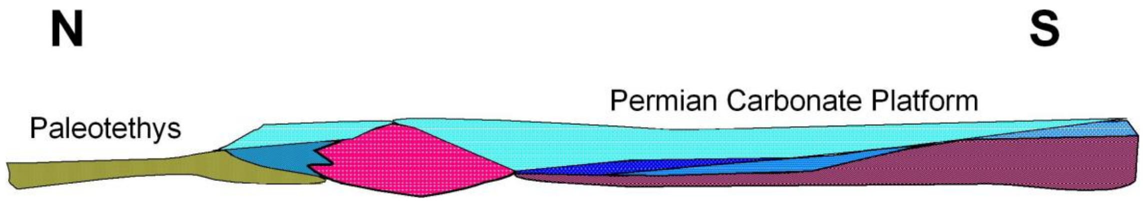


Figure 39- Middle Permian reconstruction of the Tauride-Anatolide northern margin (after Turhan et al, 2004)

Alpine Period

The first step of the Alpine cycle in KBB is generated by Early Triassic continental deposition. The fluvial clastics of Kıyır formation overlie the KBB units with angular unconformity. In some slices this unit was deposited only in Permian, in some others, it disconformably overlies the Late Neoproterozoic basement, indicating deep erosion that removed a very thick sedimentary pile of Paleozoic rocks. This is evaluated as an important indicator of extension and uplifting in Tauride-Anatolide Platform that resulted in rifting and subsequent opening of the İzmir-Ankara Ocean at the end of Middle Triassic (Göncüoğlu et al., 2003; Mackintosh and Robertson, 2008). This interpretation is confirmed by late Ladinian (Tekin et al., 2007) and Carnian (Tekin and Göncüoğlu; Tekin et al., 2002) radiolarian ages obtained from intra-pillow cherts of the İzmir-Ankara Ocean. Also the Triassic age (Koralay et al., 2007) obtained from granitoids intruding Menderes Core Complex and its cover, must be related with the crustal melting related to this uplifting. In the internal Tauride platform, traces of this event are lavas, intercalated with the Middle Triassic fluvial sediments (Candan et al., 2005) and Ladinian (Kaya et al., 1995) olistostromes in shallow platform carbonates, that indicate the role of extension in this deepening .

In most parts of the Tauride-Anatolide Platform during Middle Triassic (Anisian) to Late Jurassic- Early Cretaceous restricted platform, open platform, and finally slope environments respectively dominated (Figure 40). In different tectonic slices, lateral facies changes related to depositional environment and their ages show some differences. Deepening of the platform-margin generally increases from North to South in time. This leads to differences in the age of contacts of lithostratigraphic units. For example, transition to deeper pelagic sediments (Midos formation) from platform carbonates (Loras - Gökçeyayla formations) is of Malm age in the external platform. In the inner platform however, this transition is during the Abtian.

During the Middle Triassic- Cretaceous time interval, in North, between the Sakarya Continent and Tauride-Anatolide Platform, İzmir-Ankara Ocean is evolved (Figure 41). Although the oldest transitional type volcanism in this oceanic basin started in Carnian, the earliest Mid Oceanic Ridge basalts dated yet are late Early Jurassic – beginning of Middle Jurassic in age. Formation of MORB and hence sea-floor spreading in Izmir-Ankara Ocean continued until the end of Cretaceous without any interruption. Ocean island type volcanics of different ages may indicate the presence of mantle plumes under the İzmir-Ankara oceanic lithosphere since Triassic.

At the end of late Early Cretaceous – Late Cretaceous (Turonian-Campanian) slope sediments of KBB facing to İzmir-Ankara Ocean should have replaced by oceanic basin sediments. In the same time period in İzmir-Ankara Oceanic important changes are taken place. Yet, starting from Albian in general “supra subduction zone (SSZ)”, specifically “island arc” and “back arc basin”-type volcanic rocks were formed (Göncüoğlu et al., 2006a). These formations indicate that İzmir-Ankara oceanic lithosphere started to break and subduct along an intra-oceanic subduction zone (Figure 41). The fact that the youngest products of the SSZ volcanism are of Cenomanian age, this intra oceanic subduction has been continuing at least since the early Late Cretaceous. Another data for the age of the intra-oceanic subduction is derived from the sub-ophiolitic amphibolites that are found in mélange units and in basement of ophiolite slices. These amphibolites of ocean island origin are metamorphosed in contact with the mantle rocks in such intra-oceanic subduction zone. The radiometric ages obtained from the amphibolites range from Albian to Campanian (Önen and Hall, 1993) that are in accordance with other findings on the initiation of intra-oceanic subduction. .

The common feature of Kaynarca, Beşdeğirmen and Koçkaya amphibolites is that they are overprinted by HP/LT metamorphism. It has been proved by Sherlock et al., (1999) that in Tavşanlı area this HP/LT metamorphism occurred in about

80 my. In this case, subduction in İzmir-Ankara Ocean and related accretion prism generation (Figure 42) must have happened at the end of Cretaceous.

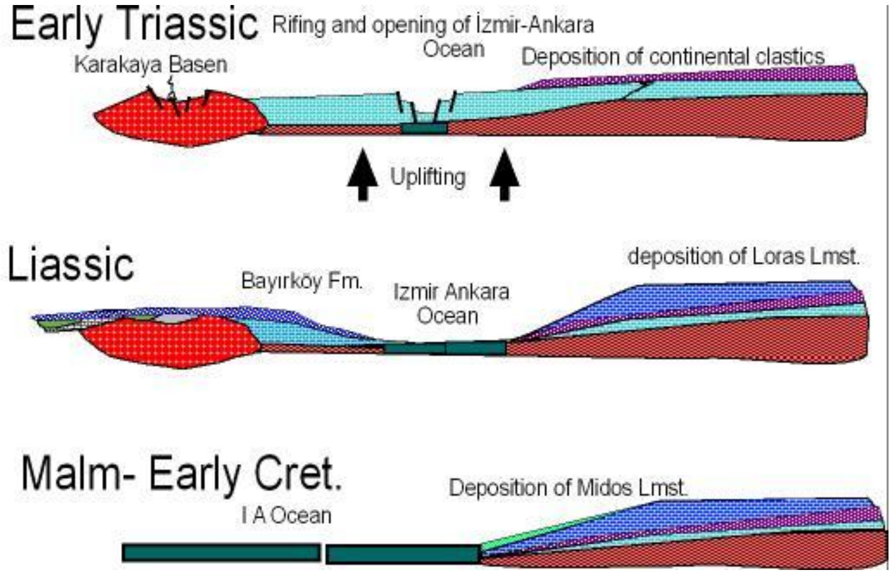


Figure 40- Triassic- Early Cretaceous reconstruction of the Tauride-Anatolide northern margin.

Blueschist metamorphosed blocks and lawsonite-glaucophane clasts are found in Maastrichtian foreland sediments. Therefore all these events related to closure were realized in about 10 my between the middle Campanian and middle Maastrichtian. HP/LT metamorphism is observed in all slices including Tavşanlı (Okay, 1980), Sünnüce Mountain (Göncüoğlu et al., 2000a), Yunak (Yeniyol, 1982), Koçyaka (Özgül and Göncüoğlu, 1999) and also the relatively thin continental crust slivers representing the northern margin successions of the Tauride-Anatolide platform margin. It shows that these continental units were also deeply subducted and obducted onto the platform margin, together with the subduction-accretion prism material and foreland basin deposits by forming a structural complex with allochthonous bodies derived from different tectonic settings. By this, the geographic subdivision of the KBB in a HP/LT metamorphic northern belt (Tavşanlı Zone) and a MP/LT metamorphic southern belt (Afyon Zone) by Okay (1980) contradicts with the available geological data.

The limited data yet obtained on the initial emplacement of ocean-derived material on Tauride-Anatolide continental margin is Maastrichtian in age. This data is obtained from the oldest ophiolite-bearing olistostromal sediments in Kütahya region. However by new data this age could be changed into an older age. The progression of the emplacement of oceanic crust, accretion prism and thin continental crust slices into the flyschoidal foreland basins could be continued in Early Paleocene. The first common cover of foreland, mélange and ophiolite slices is Middle-Upper Paleocene. According to this data the Alpine compression, slicing and nappe emplacement in KBB should have stopped before Middle Paleocene. During the Middle Paleocene – Middle Eocene period in remnant basins on the Tauride Anatolite Platform, terrigenous and shallow marine molasse- type sediments are deposited. The fact that the basal units are thrust over the Middle Eocene carbonates indicates another compressional episode through the belt.

RESULTS

The Neoproterozoic basement of KBB, similar to other parts of the Tauride-Anatolide Platform, includes sedimentary and volcano-sedimentary rocks and post-collisional felsic magmatic rocks that intrude them. These units are affected by deformation and low grade metamorphism prior to Lower Cambrian. The Lower – Middle Paleozoic units are not preserved in the northern KBB. They are represented by discontinuous outcrops through W Central Anatolia in Konya, İzmir –Karaburun and in Tavas nappes.

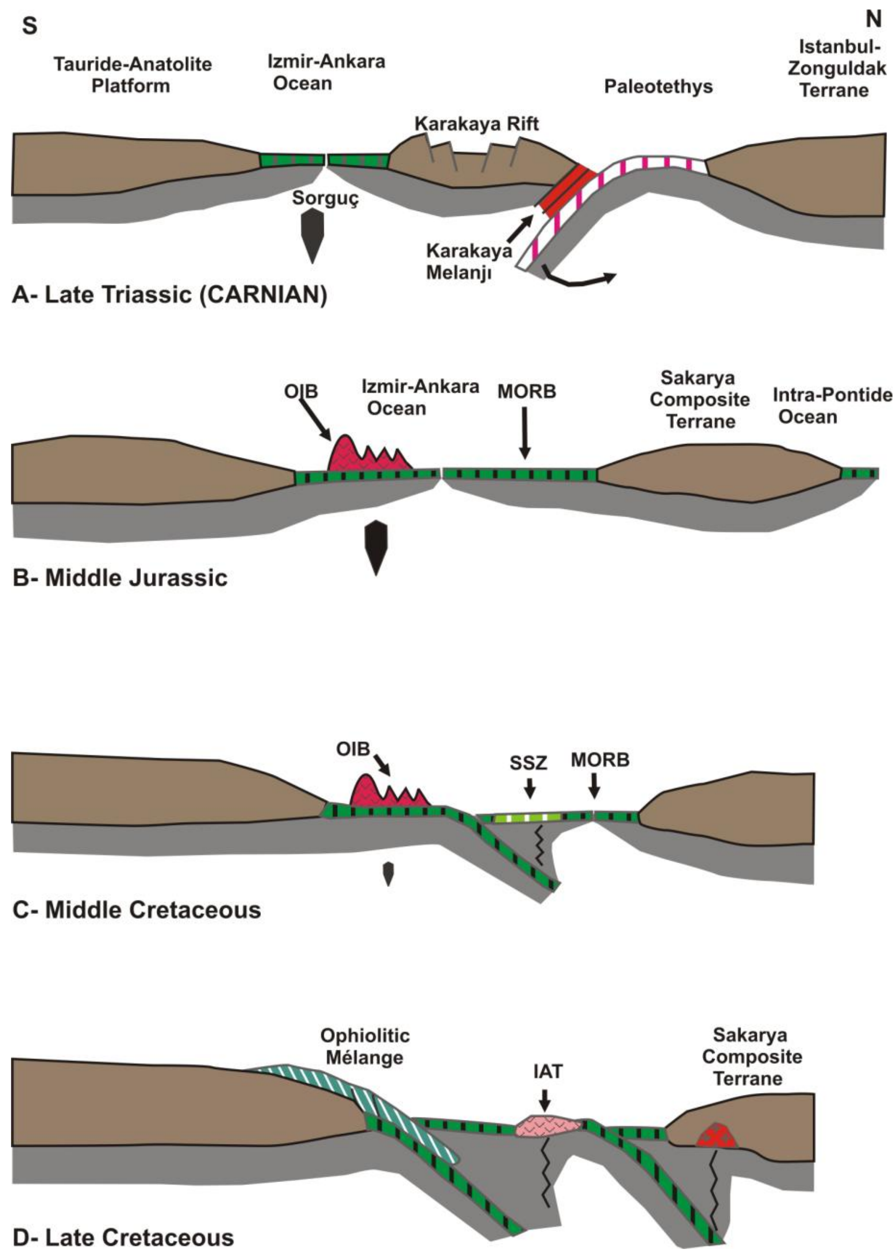


Figure 41- Mesozoic evolution of the İzmir-Ankara Ocean (simplified after Göncüoğlu et al, 2006a).

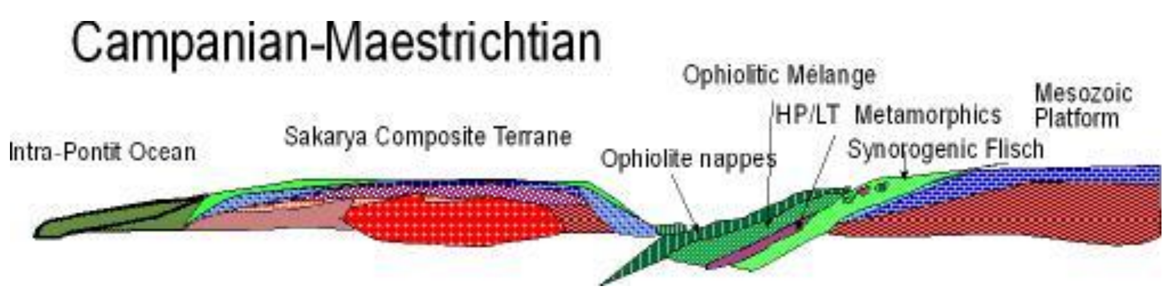


Figure 42- Late Cretaceous evolution of KBB.

They include volcanic and sedimentary remnants of a marginal/back-arc basin which opened in the North of the Tauride – Anatolian Platform in Carboniferous. Regional Middle Permian transgression observed through the belt, indicates restoration of an extensive carbonate platform by closure of this Carboniferous basin. In KBB the onset of the Alpine cycle is characterized by rapid uplifting of the basement rocks and deposition of fluvial clastics with volcanics during the Early Triassic. At the end of Middle Triassic rifting of Sakarya microcontinent from the Tauride – Anatolide platform and opening of the İzmir Ankara Ocean followed this uplifting. On the platform margin during the Middle Triassic - Early Cretaceous interval typical passive continental margin development has occurred. At the same time-interval the İzmir Ankara Ocean must have continued to spread by generating MORB-type volcanics. At the end of Early Cretaceous this convergence is replaced by divergence giving way to a N-directed intra-oceanic subduction. This subduction resulted in formation of subduction/accretion prisms, HP/LT metamorphisms, supra-subduction-type volcanism, etc. Emplacement of these oceanic material on the N margin of the Tauride – Anatolide Platform, formation of peripheral foreland basins, their closure by ongoing compression , napping and slicing of all these units and their emplacement towards S onto the southern Anatolides above what is today the Menderes Core Complex should have happened in Late Cretaceous – Early Paleocene interval. The oldest late/post orogenic overstep sequence is represented by terrigenous sediments of Middle Paleocene age.

In conclusion, KBB represents a napped/sliced belt generated by the closure of the İzmir Ankara Ocean and collision of the northern margin of Tauride – Anatolian Platform with the Sakarya continent. Rock-units of this belt surround Menderes Core Complex from North, East and South. They also constitute the pre-Miocene structural cover of Menderes. In NW Anatolia, tectonic units of KBB are known as: Bornova Flysch Zone, Tavşanlı Zone, Afyon Zone, Lycian Nappes, Cycladic Nappes etc. KBB is obviously not affected or partially affected from the exhumation of the Menderes Core Complex as a core complex in the Neotectonic period. So, its structural order and successions provides first hand data for understanding the alpine compressional period on the Tauride – Anatolide Platform. Thus, detailed studies that will be done on these units would shed light to the evolution of the High-grade metamorphic "massifs" such as Menderes and Central Anatolian crystalline complexes.

Acknowledgements

Field studies upon which this review is based was realized by a large group of colleagues including A. Özcan, N. Turhan, K. Şentürk, Ş. Uysal, late A. Işık, Prof. Dr. K. Yalınız, L. Özgül, Prof. Dr. S. Altıner and Prof. Dr. U.K, Tekin. Prof. Dr. E. Gökten, and Prof. Dr. A.İ. Okay are acknowledged for their constructive comments. Mr. Sinan ….. is acknowledged for his efforts for the translation of the manuscript.

REFERENCES

Akal A., Candan O., Koralay E., Chen F., Oberhaensli R., Satır M. and Dora O.Ö., 2003. Geochemistry, geochronology and metamorphism of the Early Triassic metavolcanics in the Afyon Zone. TÜBITAK Report, 59s (unpublished).

Akdeniz, N., 1985. Akhisar – Gölmarmara – Gördes – Sındırgı arasının jeolojisi. İstanbul Üniversitesi Fen Bilimleri Enstitüsü, PhD theses, 254 s. (unpublished).

Akdeniz, N. and Konak, N. 1979. Simav, Emet, Tavşanlı, Kütahya dolaylarmm jeolojisi. MTA Report No. 6547 (unpublished).

Akdeniz, N., Konak, N. and Armağan. F., 1980. Akhisar (Manisa) güneydoğusundaki Alt Mesozoyik kaya birimleri. Türkiye Jeoloji Mühendisliği Kongresi Bülteni, 2, 77- 90.

Aldanmaz, E., Yalınız, M.K., Güçtekin, A. and Göncüoğlu, M.C. 2008. Geochemical characteristics of mafic lavas from the Tethyan ophiolites in western Turkey: implications for heterogeneous source contribution during variable stages of ocean crust generation. Geol. Mag., 145, 37-54.

Asutay, H.J., Küçükayman, A., and Gözler, Z., 1989, Dağküplü (Eskişehir Kuzeyi) Ofiyolit Karmaşığının stratigrafisi, yapısal konumu ve kümülatların petrografisi. MTA Bulleten, 109, 1–6.

Bacak, G., and Uz, B., 2003, Dağardı güneyi (Kütahya) ofiyolitinin jeolojisi ve jeokimyasal özellikleri. İstanbul Teknik Univ. Bulleten, 2, 86–98 .

Bayiç, A., 1968. On the metaporphyroids of the Sızma region, province of Konya. MTA Bulleten, 70, 142-156.

Bragin, N.Y. and Tekin, U.K. 1996. Age of radiolarian chert blocks from the Senonian ophiolitic mélange (Ankara, Turkey). Island Arc, 5, 114-142.

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

Candan, O., Cetinkaplan, M., Oberhansli, R., Rimmele, G. and Akal, C. 2005. Alpine high-P/low-T metamorphism of the Afyon Zone and implication for the metamorphic evolution of Western Anatolia, Turkey. Lithos, 84, 102–124.

Chen, F., Siebel, W., Satır, M., Terzioğlu, N. and Saka, K. 2002. Geochronology of the Karadere basement (NW Turkey) and implications for the geological evolution of the Istanbul zone. International Journal of Earth Sciences, 91, 469-481.

Collins, A.S. and Robertson, A.H.F. 1999. Evolution of the Lycian Allochthon, western Turkey, as a north-facing Late Palaeozoic to Mesozoic rift and passive continental margin. Geological Journal, 37, 197-138.

Çemen, I., Göncüoğlu, M.C. and Dirik, K., 1999, Structural evolution of the Tuzgolu (Salt Lake) basin: evidence for Late Cretaceous extension and Cenozoic inversion in Central Anatolia, Turkey. Journal of Geology, 107, 693-706.

Çetinkaplan, M., Candan, O., Oberhänsli, R. and Bousquet, R. 2008. Pressure-temperature evolution of lawsonite eclogite in Sivriihisar; Tavsanli Zone-Turkey. Lithos, 104, 12-32.

Dora, O.Ö. Candan, O., Kaya, O., Koralay, E. and Dürr, S. 2001.Revision of "Leptite-gneisses" in the Menderes Massif: a supracrustal metasedimentary origin. International Journal of Earth Sciences, 89, 836-851

Droop, G.R., Karakaya, M., Eren, Y. and Karakaya, N., 2005. Metamorphic evolution of blueschists of the Altınekin Complex, Konya area, south central Turkey. Geological Journal, 40, 127–153

Erdoğan, B., 1990. İzmir-Ankara Zonu'nun, İzmir ile Seferhisar arasındaki bölgede stratigrafik özellikleri ve tektonik evrimi.Türkiye Petrol Jeol. Der. Bülteni, 2/1, 1-20.

Erdoğan, B., Güngör, T., Özer, S. and Altıner, D., 1995. Stratigraphy and deformational style of Karaburun Belt and Izmir–Ankara Zone., Int. Earth Sci. Cong. Aegean Regions 1995, Gezi Kitabı, pp. 1–31.

Erdoğan, B., Uchman, A., Güngör, T. and Özgül, N. 2004. Lithostratigraphy of the Lower Cambrian metaclastics and their age basen on trace fossils in the Sandıklı region, southwestern Turkey. Geobios, 38, 346-360.

Eren, Y, 1993. Konya kuzeybatisinda Bozdağlar Masifinin otokton ve örtü birimlerinin stratigrafisi. Geol. Bulleten Turkey, 36, 7-23.

Eren Y. 1996. Structural features of the Bozdağlar Massif to the south of Ilgın and Sarayönü (Konya). Geol. Bulleten Turkey 39, 49–64.

Eren, Y., Kurt, H., Rosselet, F. and Stampfli, G.M. 2004. Palaeozoic deformation and magmatism in the northern area of the Anatolide block (Konya), witness of the Palaeotethys active margin. Eclogae geol. Helv. 97, 293–306.

Erkan, E., Özer, S., Sümengen, M. and Terlemez, İ., 1978, Sarız-Şarkışla-Gemerek-Tomarza arasının temel jeolojisi: MTA Report Nr: 6546, 121p.

Floyd, P.A., Özgül, L., Göncüoğlu, M.C., Yalınız, M.K., and Winchester, J.A., 2001. Konya HP Belt Metabasalts: aspects of petrology and geochemistry. 4.Int. Geol. Symposium, 24-28 September, 2001, Adana. Abstracts, 95.

Floyd, P.A., Özgül, L. and Göncüoglu, M.C, 2003, Metabasite blocks from the Koçyaka HP-LT metamorphic rocks, Konya, central Anatolia: geochemical evidence for an arc—back-arc pair?. T. Jr. Earth. Sci., 12, 157-174.

Göncüoğlu, M.C., 1989, Structural framework of the Anatolian Hercynides: 28th Int.Geol.Congress, Washington, Abstracts, 1, 563-564

Göncüoğlu, M.C., 1990a, Sub-ophiolitic metamorphics at the Kütahya-Bolkardağ Belt: Northern Margin of the Menderes Massif, NW Anatolia. Int. Earth Sci. Cong. Aegean Regions, İzmir, Abstracts, 61-62.

Göncüoğlu, M.C., 1990b, Mesozoic Platform evolution of the northeastern edge of Menderes Massif, Kütahya Region, NW Anatolia: Int. Earth Sci. Cong. Aegean Regions, İzmir, Abstracts, 162-163.

Göncüoğlu, M.C., 1997. Distribution of Lower Paleozoic Units in the Alpine Terranes of Turkey: paleogeographic constraints. In: Göncüoğlu, M.C. and Derman, A.S.(Eds), Lower Paleozoic Evolution in northwest Gondwana, Turkish Assoc. Petrol. Geol., Spec. Publ.No:3, 13-24, Ankara.

Göncüoğlu, M.C., 2000, Restoration of an alpine foreland-thrust belt: Kütahya-Bolkardağ Zone of the Tauride-Anatolide Platform, NW Turkey. Geology 2000, Wienna, April 14-17, 2000, Terra Nostra, Schriften der Alfred Wegener Stiftung, 2000/1, p 47.

Göncüoğlu, M.C., Özcan, A., Turhan, N. and Işık, A., 1992a, Stratigraphy of the Kütahya Region. Guide Book: A Geotraverse Across Suture Zones In NW Anatolia, 3-8, MTA Publication, Ankara.

Göncüoğlu, M.C., Özcan, A., Turhan, N., Şentürk, K. and Uysal, Ş., 1992a, Pre-alpine events at the northern edge (Kütahya-Bolkardağ Belt) of the Tauride-Anatolide Platform: 6th Geological Congress of Greece, Athens, 25-27 Mayıs 1992, Abstracts, 13-14.

Göncüoğlu, M.C., Erler, A., Dirik, K. and Yalınız, K., 1994, Sivas Baseninin batısındaki temelin jeolojisi ve basen birimleri ile ilişkisi. TPAO Report Nr: 3535, 135 p.

Göncüoğlu, M.C., Turhan, N., Sentürk, K., Uysal, Ş.,Özcan, A. and Işık, A., 1996b, Orta Sakaryada Nallihan-Sarıcakaya arasindaki yapısal birliklerin jeolojik özellikleri MTA Report Nr: 10094, 173 p.

Göncüoğlu, M. C., Dirik, K. and Kozlu, H. 1997a. General characteristics of pre-Alpine and Alpine Terranes in Turkey: explanatory notes to the terrane map of Turkey. Annales Ge´ologiques des Pays Helle´nique, 37, 515–536.

Göncüoğlu M.C., Dirik K., Erler A.,Yalınız, K., Özgül, L., and Çemen I., 1997b. Tuz Gölü Havzası batı kesiminin temel jeolojık sorunları: TPAO Report Nr: 3753, 114p.

Göncüoğlu, M.C., Turhan, N., Özcan, N., Şentürk, K., Uysal, Ş., Göncüoğlu, Y., Işık, A. and Kozur, H.W., 1998, Kütahya-Bolkardağ Kuşağında (Konya Kuzeyi, Orta Anadolu) Alpin öncesi olaylar: Cumhuriyetin 75. Yıldönümü Yerbilimleri ve Madencilik Kongresi, 2-6 Kasım 1998, Ankara, Abstracts, 45-46.

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

Göncüoğlu, M.C., Turhan, N. and Göncüoğlu, Y., 2000b. Vestiges of Late Paleozoic (“Variscan”) events within the Tauride-Anatolide Belt, Turkey: Implications for the Paleotethyan evolution in NW Peri-Gondwana. ESF Europrobe Meeting, 30 Sept-2 Oct., 2001, Ankara. Abstracts, 24-26.

Göncüoğlu, M.C., Kozur, H., Turhan, N., and Göncüoğlu, Y., 2000c, Stratigraphy of the Silurian-Lower Carboniferous rock units in Konya area (Kutahya-Bolkardağ belt, Central Turkey). VIII International Meeting of IGCP 421, Evora, 12-14 Oct., 2000, Abstracts, 227-228.

Göncüoğlu, M.C., Yalınız, M.K. and Floyd, P.A., 2000d, Petrology of the Carboniferous volcanic rocks in the Lycian Nappes, SW Turkey: implications for the Late Paleozoic evolution of the Tauride-Anatolide Platform. Int. Earth Sci. Cong. Aegean Regions 2000, Izmir, Sept.25-29, 2000, Abstracts, 213.

Göncüoğlu, M.C., Tekin, U.K. and Turhan, N. 2001, Geç Kretase yaşlı Orta Sakarya Ofiyolitli Karmaşığı (KB Anadolu) içerisinde yeralan Geç Karniyen yaşlı radiyolaritli basalt bloklarının jeolojik anlamı. Jeo 2000, Proceedings, CD-54-56, 6s.

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

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

Göncüoglu, M.C., Yalınız, K. and Tekin, U.K., 2006a. Geochemistry, tectono-Magmatic discrimination and radiolarian ages of basic extrusives within the Izmir-Ankara Suture Belt (NW Turkey): Time constraints for the Neotethyan evolution. Ofioliti 31, 25-38.

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

Göncüoğlu, M.C., Çapkınoğlu, Ş., Gürsu, S., Noble, P., Turhan, N., Tekin, U.K., Okuyucu, C. and Göncüoğlu, Y., 2007. The Mississippian in the Central and Eastern Taurides (Turkey): constraints on the tectonic setting of the Tauride–Anatolide Platform. Geologica Carpathica 58, 427–442.

Gürsu, S. and Göncüoğlu, MC. 2005. Early Cambrian back-arc volcanism in the western Taurides, Turkey: implications for rifting along the northern Gondwanan margin. Geol. Mag. 142, 617-631.

Gürsu, S. and Göncüoğlu, M.C., 2006a. Petrogenesis and tectonic setting of Late Pan-African meta-felsic rocks in Sandıklı area (Western Turkey). Int. Journ Earth Sci, 95, 741-757.

Gürsu, S. and Göncüoğlu, M.C., 2006b. Batı Torosların (Sandıklı GB'sı, Afyon) Geç Neoproterozoyik ve Erken Paleozoyik yaşlı birimlerinin jeolojisi ve petrografisi. MTA Bulleten, 130, 29-55.

Gürsu, S. and Göncüoglu, M.C., 2008. Petrogenesis and geodynamic evolution of the Late Neoproterozoic post-collisional felsic magmatism in NE Afyon area, Western Central Turkey. In: The boundaries of the West African craton. In: ENNIH, N. and LIE´ GEOIS, J.-P. (eds) The Boundaries of the West African Craton. Geological Society, London, Special Publications, 297, 409–431.

Gürsu, S., Göncüoğlu, M.C. and Bayhan, H., 2003, KB Gondwana'da izlenen yay-gerisi volkanizmaya bir örnek: Sandıklı (Afyon GB'sı) yöresinde yüzeylenen Erken Kambriyen yaşlı mafik volkanitlerin petrolojisi ve petrojenezi. Süleyman Demirel Üniv, Müh-Mim Fak 20.Yıl Jeoloji Semp., 14-16 Mayıs. 2003, Proceedings, 107-108.

Gürsu, S., M. Göncüoğlu, M.C. and Turhan, N. 2005. Geology and petrology of Cadomian felsic magmatism in Afyon Area (NW), Western Central Turkey. Int. Earth Sci. Cong. Aegean Regions 2005- Abstracts, 46-47.

Gürsu, S., Göncüoğlu, MC, Turhan, N. and Kozlu, H. 2004. Characteristic features of Precambrian, Paleozoic and Lower Mesozoic successions of two different tectono-stratigraphic units ın the Taurides in Afyon area, western Central Turkey. Chatzipetros, AA and Pavlidis, SB. (eds) Proceed. 5. Int Symp. Eastern Medit. Geol., Thessaloniki, 14-20 April 2004, 80-83.

Gürsu, S., Göncüoglu, M.C., Kozlu, H., and Besbelli, A., 2005. Toros- Anatolit Platformu'nda Kambriyen yaşlı meta-magmatik kayaçların petrografisi, petrolojisi ve petrojenez özelliklerinin belirlenmesi. MTA Report Nr: 10759, 72.s.

Gürsu, S., Göncüoğlu, M.C., Kozlu, H. and Turhan, N., 2006a. Toros-Anadolu Kıtacığı ve yakın çevresinin Geç Neoproterozoyik evrimi. Proceedings 59. Geol. Congr, 48-50.

Gürsu, S., Göncüoğlu, MC., Kozlu,H., and Turhan, N., 2006b. Toros Kuşağında Geç Neoproterozoyik-Erken Kambriyen yaşlı birimlerin litolojik özellikleri. Türkiye Stratigrafi Kom. 6. Workshop Proceedings, 4-5.

Kaya, O., Saadeddin, W., Altiner, D., Meric, E., Tansel, I. and Vural, A., 1995. Stratigraphic and structural setting of the anchimetamorphic rocks to the south of Tavsanlı (Kutahya, western Turkey): relation to the Izmir-Ankara Zone. MTA Bulleten, 117, 5-16.

Ketin, I. 1966. Türkiyenin tektonik birlikleri. MTA Bulleten, 66, 23-34.

Koralay, E., Candan, O., Dora, O., Satir, M., Oberhansli, R. and Chen, F. 2007. Menderes Masifi'ndeki Pan-Afrikan ve Triyas yaşlı metamagmatik kayacların jeolojisi ve jeokronolojisi, Batı Anadolu. Menderes Masifi Colloqium İzmir, 18−24.

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

MTA, 2002, 1/500.000 ölçekli Türkiye Jeoloji Haritası, İzmir Paftası, Düzenleyen: Neşat Konak, MTA Publications.

Konak N., Akdeniz N. and Armagan F., 1980. Akhisar – Golmarmara –Gordes - Sindirgi dolaylarının jeolojisi. MTA Genel Müd. Report Nr: 6916, 177p (unpublished)

Konuk, T., 1977. Bornova Filişinin yaşı hakkında. Ege Üniv. Fen Fakültesi Bulleten, B 1, 65-74.

Koralay, E., Dora, O. O, Chen, F., Satır, M. and Candan, O. 2004. Geochemistry and geochronology of orthogneisses in the Derbent (Alaşehir) area, eastern part of Ödemiş–Kiraz submassif, Menderes Massif: Pan-African magmatic activity. Turkish Journal of Earth Science, 13, 37–61.

Kozur, H., 1998. The age of the siliciclastic series ("Karareis Formation") of the western Karaburun peninsula, western Turkey. Paleontologia Polonica 58, 171–189.

Kozur, H.W, 1999, A review of the systematic position and stratigraphic value of Mullerisphaerida. Boll. Soc. Paeont. Ital., 38, 197-206.

Kozur, H.W., Şenel, M., 1999. Carboniferous oceanic sequences in the Lycian nappes of southern Turkey. XIV ICCP, International Congress on the Carboniferous–Permian, Calgary, p. 79.

Kozur, H.W., Şenel, M., Tekin, K., 1998. First evidence of Hercynian Lower Carboniferous flyschoid deep-water sediments in the Lycian Nappes, southwestern Turkey. Geologia Croatica 51 (1), 15–22.

Kurt H., 1996. Geochemical characteristics of the metaigneous rocks near Kadınhanı (Konya), Turkey. Geosound, 28, 1-22.

Kurt, H. and Arslan, M. 1999: Geochemistry and petrogenesis of Kadınhanı (Konya) K-rich metatrachyandesite: The evolution of Devonian (?) volcanism. Geol. Bulleten Turkey, 41, 57–69

Manav, H., Gultekin, A.H., and Uz, B., 2004, Geochemical evidence for he tectonic setting of Harmancık ophiolites, NW Turkey: Journal of Asian Earth Sciences, 24, 1–9.

Mackintosh, P.W. and Robertson, A.H.F. 2008. Structural and sedimentary evidence from the northern margin of the Tauride platform in south central Turkey used to test alternative models of Tethys during Early Mesozoic time. Tectonophysics, 473, 149-172

Murphy, JM. 2002. Cadomian Orogens, peri-Gondwanan correlatives and Laurentia Baltica connections. Tectonophysics, 352, 1-9.

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

Okay, A.I., and Siyako, M., 1993. The new position of the Izmir-Ankara Neo-Tethyan suture between İzmir and Balıkesir. In: (S. Turgut ed.) Tectonics and Hydrocarbon Potential of Anatolia and Surrounding Regions, Proceedings of the Ozan Sungurlu Symposium, Ankara, 333-355.

Okay, A.I., Satır, M., Maluski, H., Siyako, M., Metzger, R and Akyüz, S. 1996. Paleo and Neo-Tethyan events in northwest Turkeey: geologic and geochronological constraints. In: Yin A. and Harrison T. M. (eds.). The Tectonic Evolution of Asia, Cambridge University Press, 420-441.

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

Özcan, A., Turhan, N., Göncüoğlu, M.C., Şentürk, K., Işık, and Keskin, A., 1984, Kütahya-Çifteler-Bayat-İhsaniye yöresinin temel jeolojisi. Türkiye Jeol.Kur. 38. Bilimsel ve Teknik Kurul.Abstracts, 135-136.

Özcan, A., Göncüoğlu, M.C., Turhan, N., Uysal, Ş. and Şentürk, K., 1987, Late Paleozoic evolution of the Kütahya-Bolkardağ Belt: Melih Tokay Geology Symposium, Ankara, Abstracts, 23-24.

Özcan, A., Göncüoğlu, M.C., Turhan, N., 1989, Kütahya-Çifteler-Bayat-İhsaniye Yöresinin Temel Jeolojisi: MTA Report Nr: 8974(8188), 142 s.

Özcan, A., Göncüoğlu, M.C., Turhan, N., Şentürk, K., Uysal, Ş. and Işık, A., 1990a, Konya-Kadınhanı-Ilgın Dolayının Temel Jeolojisi: MTA Report Nr: 9535, 132 p.

Özcan, A., Göncüoğlu, M.C., Turhan, N., Uysal, Ş. and Şentürk, K., 1990b, Late Paleozoic evolution of the Kütahya-Bolkardağı Belt. METU Journal of Pure and Applied Sciences, 21/1-3, 211-220.

Özcan, A., Turhan, N. and Göncüoğlu, M.C., 1992, Field Guide to Kütahya Region. A Geotraverse Across Suture Zones In NW Anatolia, 9-11, MTA Publication, Ankara.

Özgül, N., 1976. Torosların bazı temel jeoloji özellikleri. Geol. Soc. Turkey Bull., 19, 65–78.

Özgül, N. and Kozlu, H. 2002. Kozan-Feke-Mansurlu arasındaki bölgenin stratigrafisi ve tektonigine ait yeni veriler. Turkish Aqssoc. Petrol. Geol. Bull., 14, 1-36.

Özgül, L. and Göncüoğlu, M.C., 1997, A HP/LT Neo-Tethyan sliver in the Northern Central Taurides, Turkey: Koçyaka Metaophiolitic Complex; remnant of a subducted passive continental margin: Çukurova Univ. 20th Anniv. of Geol. Educ., 30 April-3 May 1997, Adana, Abstracts, 3-4.

Özgül, L. and Göncüoğlu, M.C., 1998, Geology and petrology of HP/LT metamorphic rock units in Koçyaka Metamorphic Complex, Altınekin Area, Konya: a HP/LT Neotethyan sliver in the northern Central Taurides. 3. Int.Turkish Geology Symposium, 31 August-4 September, 1998, Ankara, Abstracts, 277.

Özgül, L. and Göncüoğlu, M.C., 1999, Kocyaka metamorfik kompleksinin metamorfik evrimi: Batı Orta Anadoluda YB/DS metamorfizmalı bir tektonik birim. 52. Turkiye Jeol. Kur. Abstracts, 279-286.

Özsayin, E. and Dirik, K., 2008. Quaternary activity of the Cihanbeyli and Yeniceoba fault zones: İnönü-Eskişehir fault system, Central Anatolia. Turk. Journ Earth Sci., 16, 471-492

Rimmelé, G., T. Parra, B. Goffé, R. Oberhänsli, L. Jolivet, and O. Candan (2005), Exhumation paths of high-pressure-low-temperature metamorphic rocks from the Lycian Nappes and the Menderes Massif (SW Turkey): a multi-equilibrium approach. Journal of Petrology, 46, 641-669.

Robertson, A.H.F. and Ustaömer, T., 2009. The Palaeozoic–early Mesozoic development of the Konya Complex, south central Turkey: testing of alternative subduction/accretion versus intra-continental marginal basin settings. Tectonophysics 473, 113–148.

Robertson, A.H.F., Pickett, E.A., 2000. Palaeozoic–early Tertiary Tethyan evolution in the Karaburun Peninsula (western Turkey) and Chios Island (Greece). In: Buzkurt, E., Winchester, J.A., Piper, J.D. (Eds.), Tectonics and Magmatism in Turkey and the Surrounding Area: Geological Society, London Special Publication, 173, 25–42.

Rojay, B., Yaliniz, M.K., Altiner, D., 1995. Age and origin of some spilitic basalts from 'Ankara Mélange' and their tectonic implications to the evolution of northern branch of Neotethys, Central Anatolia. Int. Earth Sci. Cong. Aegean Regions Abstracts, Izmir.

Rosselet, F., and Stampfli, G., 2002, The Karaburun Units, a remnant of the Paleotethys fore-arc basin, in 1st International Symposium of the Faculty of Mines (ITU) on Earth Sciences and Engineering, 2002, Istanbul, Turkey.

Sherlock, S., Kelley, S.P., Inger, S., Harris, N., Okay, A.I., 1999. 40Ar–39Ar and Rb–Sr geochronology of high-pressure metamorphism and exhumation history of the Tavşanlı Zone, NW Turkey. Contribution to Mineralogy and Petrology 137, 46–58.

Stampfli, G.M., Kozur, H.W., 2006. Europe from the Variscan to the Alpine cycles. In: Gee, D.G., Stepherson, R.A. 2006. European Lithosphere Dynamics, Geological Society, London, Memoir 32, 43–56.

Şenel, M., Akdeniz, N., Öztürk, E.M., Özdemir, T., Kadınkzın, G., Metin, Y., Özal, H., Serdaroğlu, M., Örçen, S., 1994. Fethiye (Muğla)-Kallkan (Antalya) ve kuzeyinin jeolojisi.-MTA Report Nr: 9761 (Unpublished).

Şengör, A.M.C. and Yılmaz, Y. 1981. Tethyan evolution of Turket: a plate-tectonic approach. Tectonophysics, 75, 181-241.

Şengör, A.M.C., Satır, M. and Akkök, R. 1984. Timing of tectonic events in the Menderes Massif, western Turkey: Implications for tectonic evolution and evidence for pan-African basement in Turkey. Tectonics, 3, 693-707.

Şentürk and Karaköse 1981. Orta Sakarya bölgesindeki Liyas öncesi ofiyolitlerin ve mavişistlerin oluşumu ve yerleşmesi. Geol. Soc. Turkey Bull., 24, 1-10.

Tankut, A. 1984. Basic and ultrabasic rocks from the Ankara Melange, Turkey. Geological Society of London, Special Publications, 17, 449-454.

Tankut, A., 1991, The Orhaneli masif, Turkey.Ofioliti, 61, 702–713.

Tekin, U.K. 1999. Biostratigraphy and systematics of Late Middle to Late Triassic radiolarians from the Taurus Mountains and Ankara region. Geologisch-Paläontologisch Mitteilungen, 5, 297p.

Tekin, UK, and Göncüoğlu, M.C., 2002, Middle Carnian radiolarians from the Intra-pillow limestones of the Turunc Unit, within the Gülbahar nappe (Lycian nappes, Marmaris, S Turkey: geodynamic implications, 1.Int Symp. Fac. of Mines (ITU) on Earth Sci. and Eng.16-18 May, 2002, Istanbul, Abstracts, 84p.

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

Tekin, U.K. and Göncüoğlu, M.C. 2009. Late Middle Jurassic (Late Bathonian-Early Callovian) radiolarian cherts from the Neotethyan Bornova Flysch Zone, Spil Mountains, Western Turkey. Stratigraphy and Geological Correlation, 17/ 3, 298–308.

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

Tekin, U.K., Göncüoğlu, M.C., Yalınız, M.K. and Altıner-Özkan, S., 2006. Neotetis Volkanitlerinin Planktonik Fosil Faunası (Radyolarya ve Planktonik Foraminifera) ile Yaşlandırılması, Bornova Filiş Zonu, KB Anadolu. Final Report TUBITAK Project 103Y027, 229p.

Turhan, N., Gürsu, S. and Göncüoğlu, M.C., 2003, Afyon yöresinde Prekambriyen temel ve Üst Paleozoyik-Alt Mesozoyik örtüsünün Stratigrafisi ve Jeolojisi. M.Ü. 10.Yıl Semp., Abstract, 26-27.

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

Ustaömer, PA. 1999, Pre-Early Ordovician Cadomian arc-type granitoids, the Bolu Massif, West Pontides, Northern Turkey: Geochemical evidence. Int. Journ. Earth Sci., 88, 2-12.

Wilson, J.L., 1975. Carbonate facies in geologic history. Springer Verl., NewYork, 265s.

Yalınız, MK. and Göncüoğlu, MC., 2005. Bornova Fliş Zonu ve doğusunda yer alan ofiyolitik birimlerin petrojenezi. Final Report TUBITAK Project 199Y100, 74p.

Yalınız, K., Göncüoğlu, M.C., and Floyd, P.A., 1998, Geochemistry and geodynamic setting of basic volcanics from the northernmost part of the Izmir-Ankara branch of Neotethys, Central Sakarya Region,Turkey. 3. Int.Turkish Geology Symposium, 31 August-4 September, 1998, Ankara, Abstracts, 174.

Yeniyol, M., 1982, Yunak (Konya) magnezitlerinin oluşum sorunları, değerlendirilmeleri ve yöre kayaçlarının petrojenezi. *İstanbul Yerbilimleri*, 3/ 1–2, 21–51.