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PRE-ALPINE AND ALPINE TERRANES IN TURKEY: EXPLANATORY NOTES TO THE TERRANE MAP OF TURKEY*

by

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INTRODUCTION

Turkey has been located at the boundary between the two megacontinents: Gondwana to the south and Laurasia to the north. It is generally accepted that during its geological history, numerous continental fragments belonging to one of these megacontinents were rifted off from the main body and amalgamated to the next, so that the Anatolian realm is made of several oceanic and continental «terranes» with different geological features. The last main orogenic event, the alpine orogeny, related to the closure of various Neotethyan branches directly controls the present distribution of these terranes.

In this paper we aim to describe the Pan-African and Hercynian and/or Palaeotethyan terranes which are represented by disrupted and metamorphosed tectonic inliers within the alpine terranes, and their alpidic evolution. The classification of these terranes will be mainly according to the alpine entities, based on published and unpublished state-of-art data.

DESCRIPTION AND CORRELATION OF THE TURKISH TERRANES

The description of the Turkish terranes will be mainly based on their the classification for the alpine period, the most prominent orogenic event which controls not only the final geographical distribution of the pre-Alpine tectonic units but has also changed their initial features. From south to north the alpine terranes are: the Arabian Plate, the northern edge of the Gondwanean Arabian-Libyan Platform; the SE Anatolian Ophiolite Belt, remnants of the southern branch of Neotethys; the Tauride-Anatolide Terrane, an alpine continental block;

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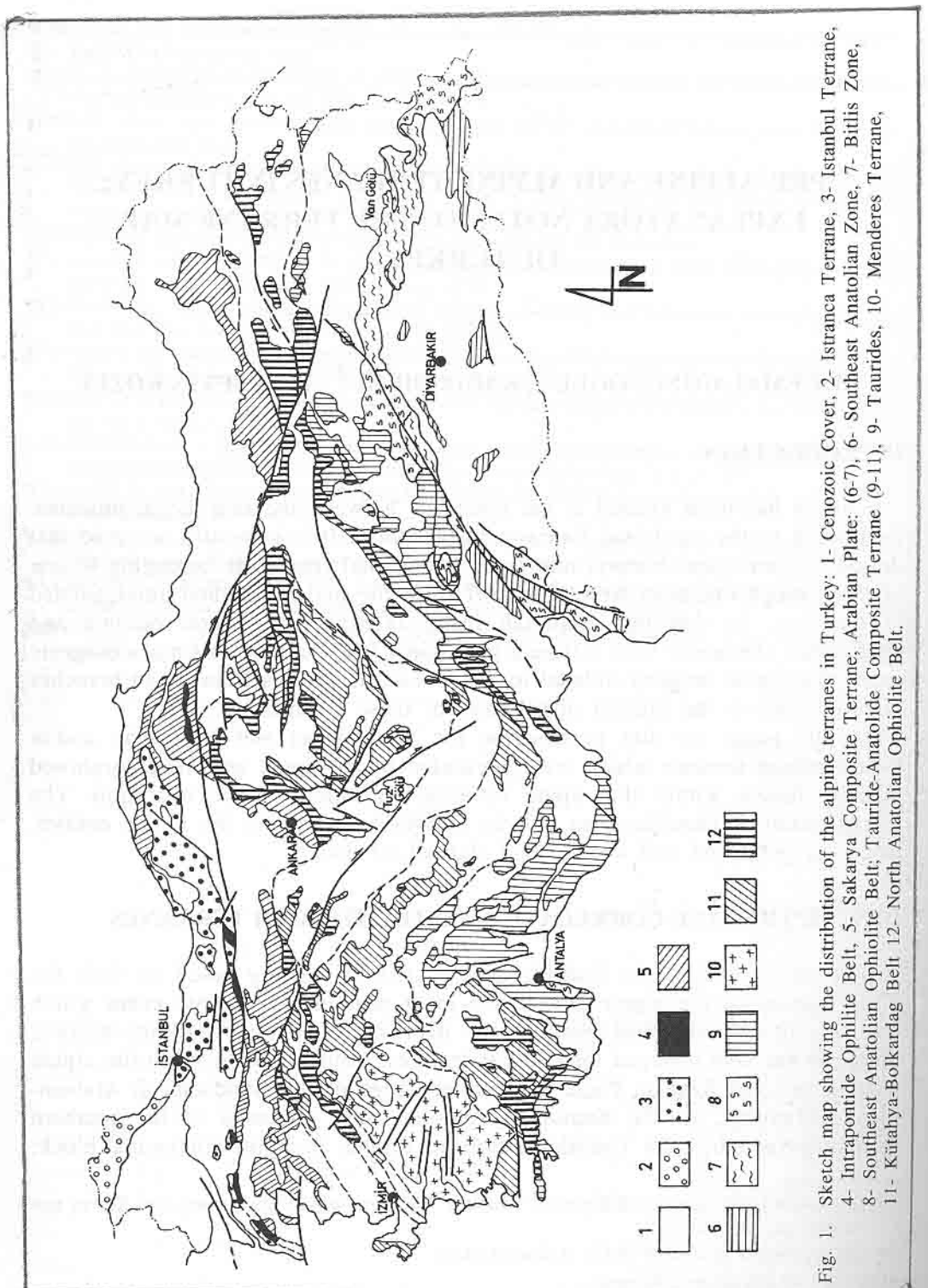

Fig. 1. Sketch map showing the distribution of the alpine terranes in Turkey: 1- Cenozoic Cover, 2- Istranca Terrane, 3- Istanbul Terrane, 4- Intrapontide Ophilite Belt, 5- Sakarya Composite Terrane; Arabian Plate: (6-7), 6- Southeast Anatolian Zone, 7- Bitlis Zone, 8- Southeast Anatolian Ophiolite Belt; Tauride-Anatolide Composite Terrane (9-11), 9- Taurides, 10- Menderes Terrane, 11- Kütahya-Bolkardag Belt 12- North Anatolian Ophiolite Belt.

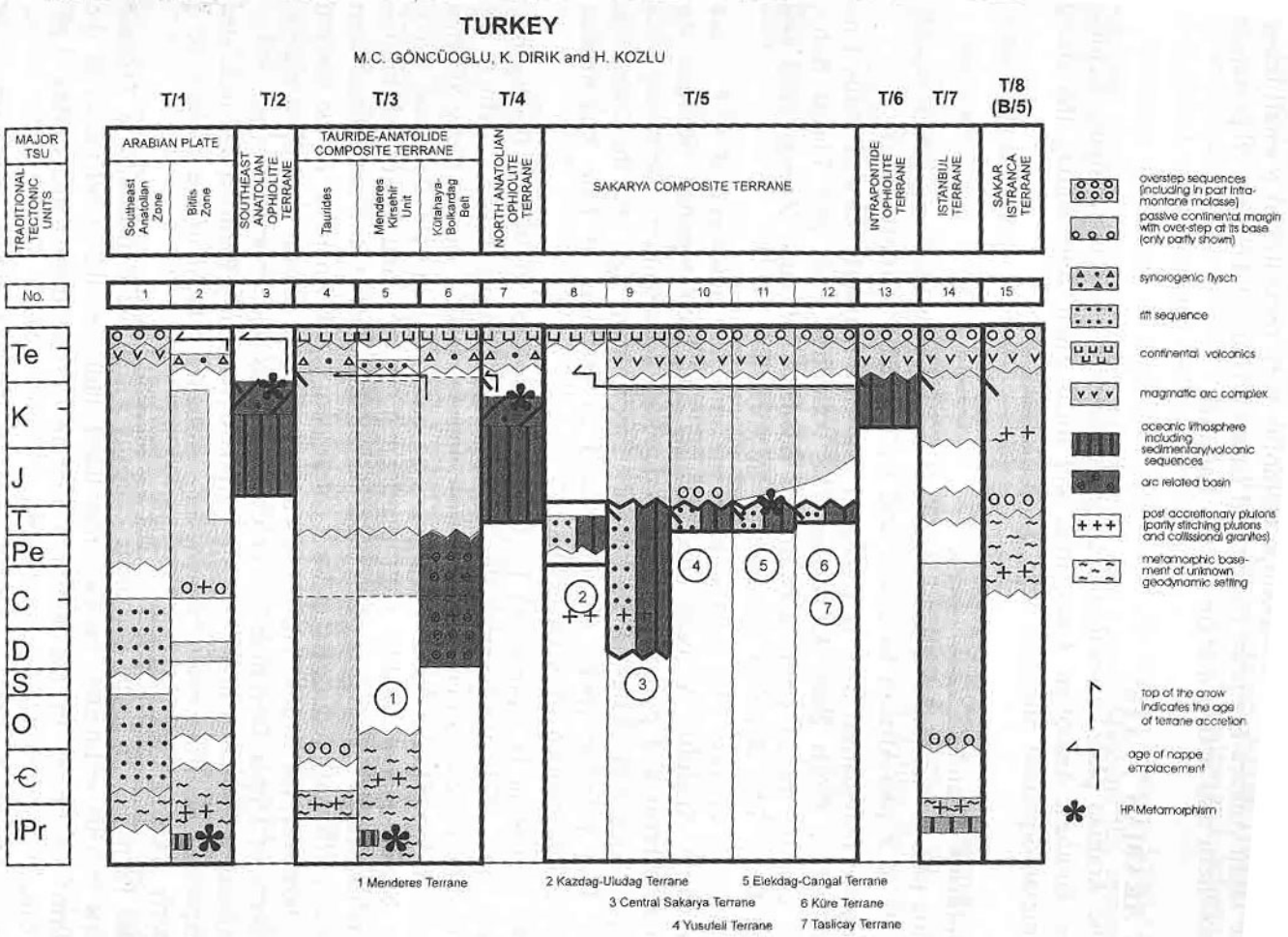

Fig. 2. Accretionary diagram of Turkey.

North Anatolian Ophiolite Belt, the allochtonous oceanic assemblages of the Neotethyan Izmir-Ankara-Erzincan Ocean; Sakarya Composite Terrane, another alpine continental block; Intrapontide Ophiolite Belt, remnants of a small branch of the Izmir-Ankara-Erzincan Ocean and Istranca/Istanbul Terranes, representing the southern and active margin of the Laurasia.

THE ARABIAN PLATE

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

A-Southeast Anatolian Zone (SAZ):

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

Terrane boundaries: SAZ is separated from the northerly located Bitlis Unit by an active thrust zone, known as «SE Anatolian Fold and Thrust Belt», which can be traced south-eastward for hundreds of kms (Zagros Fold and Thrust Belt). The thrusting commenced in Miocene.

Pre-alpine history: The pre-Cambrian metamorphic basement of SAZ is not observed in Anatolia. A local unconformity has been reported between the submarine lavas and pyroclastics of intermediate composition, alternating with red epiclastics and shales of presumably Precambrian age and the Paleozoic cover. The volcanic rocks are interpreted as products of Late Pan-African arc-related volcanism (SENGÖR, 1991).

The Cambrian is represented by fluvial-deltaic type clastics at the bottom, grading into shelf type carbonates and shallow marine clastics, which are followed by Ordovician coastal to shallow marine clastics. During Early Silurian a regional depositional break occurred. The Late Silurian-Late Devonian deposition began unconformably with continental clastics and restricted marine sediments, which was followed by tidal-dominated clastics and terminated with regrassive (fluvial) sediments in the central part of SE Anatolia. In the eastern areas, however, the Ordovician clastics are overlain by coastal to shallow marine sediments of Upper Devonian-Lower Carboniferous age (PERINÇEK *et al.*, 1991). A regional depositional break of Late Carboniferous-Early Permian age indicates an important uplifting event, which very probably related to the closure of a northerly located Late Paleozoic oceanic basin.

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

Alpine history: The alpine cycle in SAZ commenced with the Middle Triassic rifting (ALTINER, 1989) and opening of the «Southern Branch of Neotethys (SENGÖR and YILMAZ, 1981) «between Arabian and the Tairide Platforms. The

deposition on SAZ up to the Early Cretaceous is characterized by platform carbonates.

During Late Cretaceous a flip to foreland deposition and arrival of northerly derived ophiolitic nappes is recorded. Bi-modal volcanism (ERLER, 1984), related to the opening and southward propagation of foreland basins and deformation of foreland sediments are further features.

Overstep sequences in SAZ are represented by Upper Maastrichtian-Lower Miocene shallow marine sediments. During late Lower Miocene the second set of allochtons were emplaced onto the SAZ.

B-Bitlis Zone (BZ):

BZ consists of a large number of northward diping slices of metamorphic and sedimentary rocks. It represents the northernmost edge of the Arabian Platform, which has been deformed and metamorphosed during the closure of the Southern Branch of Neotethys.

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

Pre-alpine history: The basement rocks of the BZ comprises various para-gneisses, migmatites, amphibolites, micaschists and orthogneisses. Bands and lenses of kyanite eclogites are found as minor intercalations within the gneisses (OKAY *et al.*, 1985). Petrographic data indicate to a plurifacial HT/HP event in the basement (GÖNCÜOGLU and TÜRHAN, 1984). The pre-Lower Paleozoic age of the metamorphism in the basement is clearly documented by the presence of HT/HP metamorphic clasts in the basal micro-conglomerates of the Lower Paleozoic cover. Rb/Sr isochrone ages about 450my from the basement (HELVACI and GRIFFIN, 1984) confirm the geological data. A pan-African age has been assigned to the metamorphic basement complex.

The basement is unconformably overlain by a Low Grade metamorphic sequence of Lower Paleozoic age, where Givetian-Frasnian fauna could be documented in the recrystallized limestones. This lower part of the sequence is followed by olistostromal felsic metavolcanic/volcanoclastic rocks with blocks of recrystallized limestones and intruded by granitiods of Carboniferous age (GÖNCÜOGLU, 1984). Permian-Lower Triassic platformal carbonates unconformably cover these rocks. The regional Permian unconformity and the presence of Carboniferous granitoids strongly suggests to a Hercynian event in BZ.

Alpine history: In BZ, the initiation of the alpine cycle is characterized by the Middle Triassic metavolcanics and volcanoclastics, which are related to the rifting and opening of the «Southern Branch of Neotethys». These volcanic rocks are conformably overlain by a condensed series, mainly consisting of metapelites interlayered with basic metabolcanics, metacherts and metatuffs of Upper Triassic-Lower Cretaceous age. This sequence is interpreted as the

northern slope deposits of the Arabian passive margin. Ophiolites and ophiolitic olistostromes of Upper Cretaceous age are observed as thrust sheets on the metamorphics.

The metaclastics of the alpine cover sequence contain paragenessis that indicate to an alpine LOW GRADE metamorphic event. This alpine overprint is documented by geological and radiometric data (YILMAZ, 1975; YAZGAN, 1984).

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

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

SOUTHEAST ANATOLIAN OPHIOLITE BELT

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

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

Alpine history: In the tectonic slivers with almost complete ophiolitic sequences (Guleman Ophiolites), the relative abundance of peridotites versus lherzolites, abundance of podiform cromites and plagiogranites and a deplated mantle composition are the striking features indicating to a supra-subduction setting.

Further metaophilitic slivers intruded by dioritic-granodioritic bodies of Upper Cretaceous age (Kömürhan Metaophiolites; YAZGAN and CHESSEX, 1991) and its volcanic cover (Yüksekova Complex; PERINÇEK and KOZLU, 1984) are interpreted as ensimatic arc complexes (YILMAZ, 1993). Slices of HP/LT metamorphosed basalts are reported from eastern part of the belt (GÖNCÜOGLU and TÜRHAN, 1984). The paleontological data from the pelagic sediments of the epi-ophiolitic rocks suggest that the age of the ophiolitic unit is Jurassic-Upper Cretaceous.

Ophiolitic lithologies of the Southeast Anatolian Ophiolite Belt very probably represents a variety of supra-subduction zone type tectonic settings and can be correlated with the Oman Ophiolites in the east.

TAURIDE-ANATOLIDE COMPOSITE TERRANE

Tauride-Anatolide Composite Terrane represents the continental platform between the Neotethyan Izmir-Ankara-Erzincan Ocean to the north and the

Southern Branch of Neotethys to the south. It comprises three groups of structural units. From north to south these are Kütahya-Bolkardag Belt, representing the northern margin of the platform, Menderes Terrane, representing the metamorphic central part and Tauride Belt, a package of mainly non-metamorphic nappes.

A-Taurides:

Taurides or the Tauride Belt is represented by a pre-Cambrian basement and its non-metamorphic Paleozoic-Mesozoic cover made of platformal sediments. The Late Cretaceous closure of the northern and southern branches of Neotethys gave way to a double-verging napped structure, which consists of a number of tectono-stratigraphic units with distinctive stratigraphic and structural features characterizing different depositional environments of the platform. Based on Özgül's (1976) palinspatic restoration these units are arranged from north to south as: Bozkir Unit, Bolkar Dagi Unit, Aladag Unit, Geyikdagi Unit, Antalya Unit and Alanya Unit.

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

Pre-alpine history: Limited outcrops of mildly metamorphosed Precambrian rocks are reported from different parts of the Taurides. The relatively well studied areas are located in Karacahisar Dome, Sandikli Area, Anamur-Silifke Region in Central Taurides and Feke Area in Eastern Taurides. The Karacahisar Unit is represented by strongly deformed monotonous pelitic and psammitic rocks, which are interpreted as distal turbidites (KRÖNER and SENGÖR, 1990). Locally, sills and dikes of diabase and volcanoclastic intercalations are reported from the upper parts of the unit. Early Middle Cambrian sedimentary rocks overlie the Karacahisar Unit with a gentle unconformity. On the basis of «partial illite recrystalization» KRÖNER and SENGÖR (1990) suggest that the metamorphism was at very low grade. Detritial single zircon ages and paleontological data suggests that the age of the metamorphic/deformational event is pan-African (KRÖNER and SENGÖR, 1990). In the Sandikli area highly sheared and mylonitized porphyroids, unconformably covered by Early Middle Cambrian clastics and limestones yielded xenocryst single zircon ages about 550 my which also suggests the presence of a late pan-African igneous activity.

An almost complete Paleozoic sequence with platform-type deposition can be well correlated with the Southeast Anatolian Paleozoic sequences, thus indicating that Taurides and the Southeast anatolian Zone formed together the northern part of a huge platform contiguous to the Gondwanaland. The absence of late Paleozoic sediments, an important regional unconformity during Early Upper Permian and the presence of Carboniferous pyroclastics in the northern tectonostratigraphic units on the other hand suggests a Late Paleozoic event to the north of the Tauride Platform. The Permian sequence represented by epicontinental carbonates is followed in the south and north of the platform

by rift related Lower-Middle Triassic sediments and volcanics which indicate to the opening of Neotethyan basins and thus the beginning of the alpine cycle.

Alpine history: The Middle Triassic-Lower Cretaceous time interval in the central part of the platform was dominated by neritic carbonates, while in the northernmost margin, facing the Izmir-Ankara-Erzincan Ocean pelagic conditions continued. During the Senonian the oceanic basins to the south and north of the platform started to close. Ophiolitic as well as marginal sequences were thrusted from north onto the more external parts of the platform, the resulting crustal thickening generated a metamorphic zone (Menderes and Kütahya-Bolkardag units) to the north of it. The arrival of these external nappes onto the Taurides is Early Eocene.

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

The tectonostratigraphical units of the Tauride Belt can be well correlated with the non-metamorhic platformal nappes (Pre-Apulian, Plattenkalk, -onian, Tripoliza and probably Almyropotamos Units) of the external Hellenides. A more detailed correlation of these units is out of the scope of this outline.

The most crucial unit of the Taurides for the correlation with the Hellenides is the Bozkir unit, consisting of Triassic-Cretaceous pelagic sediments interlayered with basic volcanics and slices of ophiolites, which are interpreted as oceanic crust-starved slope-margin sequences. This unit is observed as a nappe-pile on the platformal carbonates of the Taurides. The lithology and the structural position of these nappes is very similar to Pindos Units, which are assumed to be the remnants of a medial oceanic basin, between Pelagonian and the external Hellenide Platform. The Bozkir Unit, however, is interpreted as allochtonous assemblages of the Izmir-Ankara Ocean, which have been tectonically transported ca 300km toward south, passing on the internal platform units such as Kütahya-Bolkardag and Menderes. So that in contrast to the western areas, and relying only on the structural position of these oceanic units we do not suggest an oceanic basin between Menderes/Pelagonian and Taurides/external Hellenides.

B-Anatolides:

The Anatolides represent the metamorphic northern margin of the Tauride-Anatolide Platform, separated from the Sakarya Composite Terrane by the Neotethyan Izmir-Ankara Suture. The Anatolides consist of two huge crystalline complexes: the Menderes Massif to the west and the Central Anatolian crystalline Complex to the east. The Kütahya-Bolkardag Belt represents the northern and less metamorphic peripheral belt of the Menderes Massif and also corresponds to the allochtonous units such as Bozkir and Bolkar Dag Unit of ÖZGÜL (1976) which are observed as nappes on the northern flank of the Taurides.

a- Menderes Terrane (MT): This metamorphic core-complex forms the

western nuclei of the Anatolides. Its petrographic features have been relatively well studied by various authors (e.g. DORA *et al.*, 1991). The Menderes Terrane comprises a pre-Alpine «gneissic core» and an alpine «schist and marble envelope» where also evidences of a Late Paleozoic event is hidden.

Terrane boundaries: The northern boundary of MT is a tectonic zone, where less metamorphosed slices of Kütahya-Bolkardag unit are thrusted onto the former.

Pre-alpine history: The core of the Menderes Unit consists, in ascending order of migmatites, para- and orthogneisses (leptites), amphibolites, granulites and eclogites. It is generally accepted that the «core» of MT was effected at least by two progressive metamorphic events. SENGÖR *et al.* (1984b) suggest a sedimentational age of 680my for the protoliths of the «core»-gneisses. The first metamorphic event in the migmatized gneisses, evidenced by a Rb/Sr whole rock isochrone age of 500my is regarded by the same authors as the age of the pan-African High Grade Metamorphism. DORA *et al.* (1991) confirm this data by additional Rb/Sr data. This event has probably led to the formation of the anatectic granitoides, which yield a Rb/Sr whole rock isochron age of 470my (SENGÖR *et al.*, 1984b). Recent work (CANDAN, 1994) suggests the presence of relict granulitic and eclogitic metamorphisms of pan-African age in the core series, thus suggesting a complex pan-African history.

The core is unconformably covered by the schist unit, which starts with metaconglomerates and consists mainly of kyanite+staurolite+garnet schists and garnet-mica schists with minor intercalations of metaquartzites and garnet amphibolites.

Calc-schist and phyllite interlayers increase towards the top of the unit. Based on sparse paleontological data KONAK *et al.* (1987) suggest a Paleozoic age for this sequence. A post-pan-African/pre-alpine metamorphic event accompanied by granite intrusions during Late Paleozoic in northern Menderes is suggested by SENGÖR *et al.* (1984b).

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

Recent work suggests that during the Neotectonic period the Menderes Unit has been effected by extensional tectonic and represents a «core complex» (BOZKURT *et al.*, 1993).

PAPANIKOLAOU and DEMIRTASLI (1987) assume that correlateble units in the Hellenides are buried below the nappes of the blueschists and the internal Hellenides, including the allochtonous Pelagonian basement rocks.

b-Kütahya-Bolkadag Belt (KBB): This unit represents the northernmost edge of the north-facing passive margin of the Tauride-Anatolide Platform and thus the northern periphery of the Menderes Unit. KBB constituents two alpine

subunits: a northern and discontinuous HP/LT metamorphic belt (Tavsanli Zone of OKAY, 1985) characterizing the subducted slope of the passive margin and KBB proper.

Terrane boundaries: KBB is overthrusted by ophiolites of the North Anatolian Suture Belt.

Pre-alpine history: The lower part of KBB consist of olistostromal meta-clastics (mainly greywackes) alternating with felsic-intermediate meta-volcanics and volcanoclastics, black slates and lydites. Olistolites of Devonian-Lower Carboniferous neritic limestones, meta-porphyroides and microgranites are very common. Biostratigraphic data suggests a Late Carboniferous depositional age for this part of the sequence. ÖZCAN *et al.* (1988) and GÖNCÜOGLU (1989) atrributed these lithologies to a Hercynian back-arc deposition. The metaclastics of this basement exhibit mineral paragenesis which correspond to a pre-alpine Low Grade Metamorphism. The alpine event is represented by a retrograde overprint in the basement rocks.

This lower sequence is paraconformably covered by microconglomerates and recrystallized limestones of Early Upper Permian.

Alpine history: Rift related continental red clastics of Scytian age representing the opening of the alpine Izmir-Ankara-Erzincan Ocean and thus, the separation of the Tauride-Anatolide Platform from the Sakarya Terrane, unconformably cover the metamorphic basement. The Middle Triassic-Lower Cretaceous deposition is characterized by continous platform-type carbonates, which is followed by Upper Cretaceous pelagic micrites and radiolarian cherts. The Upper Maastrichtian is represented by a sedimentary melange/olistostrome with huge ophiolite, blueschist and neritic limestone blocks. Oceanic lithologies of the Izmir-Ankara Ocean are observed as pieces of a discontinuous nappe on this melange.

Upper Paleocene sediments in KBB represent the post-tectonic cover (GÖNCÜOGLU *et al.*, 1992a). We suggest that the KBB was imbricated during Late Cretaceous and emplaced first onto the Menderes and subsequently as huge nappes onto the Taurides during the Middle Eocene.

The stratigraphy of the Tavsanli zone, which lies with a low-angle tectonic contact on the Upper Cretaceous sedimentary melange of the KBB is similar to the latter. The well developed HP/LT metamorphism of alpine age (KULAKSIZ and PHILLIPS, 1985) in this zone is attributed to the subduction of the passive margin sediments prior to the collision of the Tauride-Anatolide Platform with the Sakarya Terrane (OKAY, 1985).

The basement of KBB can be correlated with the Flambouron Unit, representing the basement of the Almopia Unit in the Internal Hellenide Platform. The stratigraphy of Almopias, in turn is similar to the Mesozoic platform deposits of KBB.

The HP/LT Tavsanli Zone on the other hand can be well correlated with the Ambelakia Unit in Northern Cyclades.

c-Central Anatolian Crystalline Complex (CACC): This unit forms the eastern

continuation of the Anatolides. It has been separated from the main trunk of the Anatolides by the Tertiary Tuzgölü Basin.

Terrane boundaries: CACC is bounded to the north by ophiolitic slivers of the North Anatolican Suture Belt. Its southern boundary is covered by Tertiary sediments of Tuzgölü, Ulukisla and Sivas Basins.

Pre-alpine history: The lowermost unit of CACC is composed of sillimanite-cordierite bearing gneisses, pyroxene gneisses, micaschists, amphibolites, bands and lenses of marbles/calc-silicate marbles and migmatites. The earliest event in CACC is represented by zircon Pb/Pb model ages and Rb/Sr whole rock isochron ages (450my) from the gneisses of the basement (GÖNCÜOGLU, 1982), thus suggesting a pan-African generation.

Alpine history: a thick quartzitic band, probably representing a pre-metamorphic transgression, is followed by an alternation of marbels, sillimanite gneisses, amphibolites, calc-silicate amphibolites and quartzites. The upper unit of CACC consists of a thick sequence of marbles passing upwards into cherty marbles and finally into cherts and amphibole schists. Correlating these carbonates with those in the Kütahya-Bolkardag Belt, GÖNCÜOGLU *et al.* (1992b) suggests a Triassic-Lower Cretaceous age for this upper unit of the metamorphic sequence. This carbonate sequence is transitional to an ophiolite bearing metaolistostrome and has been overthrusted by ophiolites. The metamorphics as well as the ophiolites are intruded by syn/post metamorphic collision-type granitoides (GÖNCÜOGLU and TÜRELI, 1994). The alpine metamorphism is supported by Rb/Sr and K/Ar mineral ages, which range between 74 and 78my (GÖNCÜOGLU, 1982, 1986). Non-metamorphic Upper Maastrichtian-Paleocene clastics unconformably overlie the CACC.

It is suggested that the pre-metamorphic stratigraphy of CACC is very well correlatable with the further Anatolide units and that CACC had been part of the Tauride-Anatolide Platform during the alpine period. The southward emplacement of the ophiolitic nappes and related crustal thickening during the closure of the Izmir-Ankara-Erzincan branch of Neotethys has been the cause of the high grade metamorphism in CACC units. The main difference from the MT is that the ophiolite emplacement, crustal thickening and thus the metamorphism is earlier than the former but coeval with the KBB. We use this data to join CACC to the Kütahya-Bolkardag Belt.

NORTH ANATOLIAN OPHIOLITE BELT

The North Anatolian Ophiolite Belt (NAOB) represents allochtonos assemblages of the Neotethyan Izmir-Ankara-Erzincan Ocean, which were emplaced southward onto the Tauride-Anatolide Platform during Late Cretaceous.

Terrane boundaries: In the NW, Anatolia units of Sakarya Composite Terrane tectonically overlie the ophiolites. In Central and East Anatolia, the ophiolites are thrusted along steep basement-thrusts onto Tertiary basins.

NAOB consists of huge bodies of almost complete ophiolitic sequences and

tectonic melanges of the accretionary complex. The ophiolites display characteristic features of supra-subduction zone-type ophiolites (GÖNCÜOGLU and TÜRELI, 1993). An incipient blueschist metamorphism is reported from the mafic volcanics (OKAY, 1983). Pelagic limestones and radiolarites in the melange yield ages that range from Upper Triassic to Late Lower Cretaceous, suggesting the creation of the oceanic crust lasted until Late Cretaceous. This data is further confirmed by radiometric ages (79-85my) from the gabbros. Subophiolitic metamorphic soles of Albian-Campanian age (ÖNEN and HALL, 1993) indicate that it had been started to be consumed in an intra-oceanic subduction zone. The main subduction, however, is beneath the Sakarya Composite Terrane giving way to the formation of the Late Mesozoic-Tertiary Pontide Magmatic Arc. Ophiolites of the NAOB can be correlated with the Northern Cycladic ophiolites.

SAKARYA COMPOSITE TERRANE

The Sakarya Composite Terrane is no alpine unit which is bounded by the Izmir-Ankara Suture to the south and the Intrapontide Suture to the north. It is a 100-200km wide east-west trending belt covering almost the entire northern Anatolia. The pre-Jurassic basement of this composite terrane constitutes numerous tectonic assemblages, about which quite contrasting interpretations are offered.

The pre-Jurassic tectonic assemblages can be attributed to the following groups: Central Sakarya Terrane, Uludag-Kazdag Terrane, Elekdag-Cangaldag Terrane, Küre Terrane and Yusufeli Terrane.

A- Uludag-Kazdag Terrane: Both, Kazdag and Uludag units occur as tectonic windows in NW Anatolia.

The Kazdag Unit is located in the eastern part of the Biga Peninsula. The gneiss, amphibolite and marble that make up the core of the Kazdag Mountain are studied by BINGÖL *et al.* (1975). A metaophiolite sequence of metadunite, metaharzburgite and metagabbro (Tozlu Metaophiolite). This metaophiolite sequence overlies a thick marble horizon and shows the same deformation and metamorphism along with the rest of the Kazdag Group. The Kazdag Group is tectonically overlain by the units of the Central Sakarya Terrane. In the west and north it is overthrusted by the alpine ophiolitic melange (OKAY *et al.*, 1991) of the Intrapontide Ocean. PAPANIKOLAOU and DEMIRTASLI (1987) correlate the Kazdag Group with the Rhodope Massif, however we prefer to correlate it with the Serbo-Macedonian Terrane, where migmatitic gneisses and marbles of Kerdilion Unit, similar to those, in Kazdag, occur as tectonic slivers. The metaophiolites, consequently, may have a similar tectonic setting to those in Therma-Volvi-Gomati Complexes described by Dixon and Dimitriadis (1984).

The Uludag Unit consists of high grade gneisses and amphibolites covered by marbles and cherty marbles (KETIN, 1983). The depositional and metamorphic age is unknown. It is overthrusted by the Karakaya Complex. Considering its thick carbonate cover, the Uludag Unit can be speculatively correlated with

the Anatolide Units. The correlation with the Rila-Rhodope Unit (PAPANIKOLAOU and DEMIRTASLI, 1987) in Macedonia is even more speculative and could not be justified only by the presence of similar lithologies, described by BIRK (1970).

B-Central Sakarya Terrane (CST): The Central Sakarya Terrane is subdivided into two variably deformed, metamorphosed and imbricated assemblages called the Central Sakarya «Basement» and the «Karakaya Complex», respectively. Both of them are unconformably overlain with a major unconformity by Liassic clastics. Views on the structural setting, ages of deposition and metamorphism are still controversial.

Terrane boundaries: The southern boundary of CST is an alpine thrust. Further pre-Jurassic Terranes are either sliced with or have been thrusted onto CST.

Pre-alpine history: Rock units of the «Basement» are exposed as E-W trending discontinuous tectonostratigraphic units representing a Late Paleozoic (Hercynian) orogen (GÖNCÜOGLU, 1989). The structurally lower part (Sogut Unit) comprises amphibolites, ortho and paragneisses, felsic to mafic metavolcanics with rare marble interlayers and discontinious blocks of metaophilites. The relatively upper unit (Inegöl Unit), however consists of metabasics, metatuffs, metaclastics with thin pelagic metacarbonate and metaradiolarite interlayers along with blocks of metaophiolites. Calcalkaline granitoides intruded both the Sogut and the Inegöl Units. K/Ar data on the granitoids intruding the basement (290 my, COGULU *et al.*, 1965) indicates that the deposition and metamorphism of the unit should be pre Early Permian. The depositional age is suggested as post Devonian, however, is mainly based on regional correlation and is therefore highly speculative. The pre-Alpine metamorphism of the Sögüt Unit corresponds to medium-high grade (YILMAZ, 1990). The Inegöl Unit is characterized by LOW GRADE metamorphism. GÖNCÜOGLU (1989) interpreted these basement units as fore-arc and arc assemblages of a southward subducting late-Paleozoic ocean (Southern Hercynian Ocean).

The Karakaya Complex, unconformably overlying the Hercynian basement includes a thick greywacke section with Devonian, Carboniferous and Permian limestone olistoliths, intercalated with abundant basic lava, volcanoclastics and pelagics of Triassic age (BINGÖL *et al.*, 1975). The metamorphism is generally in HP greenschist conditions, the deformation is semi-brittle, giving a broken formation character to the unit (KAYA, 1988). The depositional age of the Karakaya Complex is Triassic so far documented by paleontological data.

The deformation and accompanying metamorphism of the Karakaya Complex is post Upper Triassic - pre Liassic.

The Karakaya Complex is interpreted by OKAY *et al.* (1991) as Permo-Triassic intra-oceanic fore-arc deposits, sliced with Late Paleozoic-Triassic accetionary complexes of the Paleotethyan active margin, which was located to the south of the Central Sakarya Terrane. SENGÖR and YILMAZ (1981), however, suggest that the Karakaya Complex has formed as a marginal basin within the Hercynian

Sakarya Microplate which was located to the south of the southward subducting Paleotethys.

Alpine history: The deformed units of the CST are unconformably covered by continental-shallow marine sediments of Lower Jurassic age (e.g. ALTINER *et al.*, 1991). These clastics are discordantly succeeded by Middle to Upper Jurassic platform-type neritic carbonates, Lower Cretaceous pelagic limestones and Upper Cretaceous turbidites, representing the carbonate platform between the Intrapontide and Izmir-Ankara Oceans. During the Late Cretaceous ophiolites of the former were emplaces on this platform.

The basement of the CST can be correlated with the Kerdilion and Vertiskos Units of the Serbo-Macedonian Unit, whereas the Karakaya Complex is quite similar to the units of Circum-Rhodope Belt except that the deposition in the latter continued during Early Jurassic (Svoula-Flysch of KOCKEL, 1977).

C-Yusufeli Terrane: This tectonostratigraphic unit consists of the Yusufeli and the Tuzluca Complexes. YILMAZ and SENGÖR (1985) interpret the ultramafic-mafic assemblages and associated sediments of the Yusufeli Complex together with its epi-ophiolitic cover as the easternmost representatives of the Küre Unit and thus as Paleotethyan ophiolites. The late Jurassic sediments overlie the oceanic assemblage of the Yusufeli Terrane with sharp angular unconformity (SENGÖR *et al.*, 1980).

Terrane boundaries: The boundaries of Yusufeli Complex is covered by alpine sequences.

Pre-alpine history: KONAK *et al.* (1991) described at least four NE-SW trending tectonic slivers (Harsdere, Demirkent, Narlik, and Kisla Zones) with major differences in lithology and metamorphic conditions in the Yusufeli Complex.

The Harsdere Zone consists essentially of gneisses, micaschists and migmatitic gneisses. The Demirkent Zone comprises serpantinized ultramafics, meta-gabbros, meta-diabases, amphibolites and amphibole gneisses. Blastomylonitic granitoids and syenites intruded this metamorphic complex, which is interpreted as an ensimatic island-arc. The Narlik Zone consists of tholeiitic volcanics interlayered with slates, tuffs and cherts, grading upwards into black, turbiditic sandstones and siltstones with graphite bearing slate interlayers. The Kisla Zone is represented by low-grade assemblages such as quartz-muscovite schists and muscovite-chlorite schists.

The rock-units of the Yusufeli Complex are correlatable with the Artvin-Bonisi block of the South Transcaucasian Terrane of ADAMIA *et al.* (this volume). The most important limitation, however, is that the latter is ascribed to a Variscan event, supported by numerous radiometric data from the igneous complexes.

The Tuzluca Complex at the Iranean border is a relatively less known structural element, which consists of a Pre-Cambrian? crystalline basement, covered by non-metamorphic Paleozoic (Devonian-Permian) sequences. Similar litholigies are observed as allochtonous blocks within the alpine East Anatolian

Accretionary Complex and Pulur Massif. Tuzluca Complex corresponds to the Nahcevan Block in northwestern Iran.

Alpine history: The orogenic complex of Yusufeli is unconformably covered by Lower Jurassic terrestrial and shallow-marine sediments grading upwards into the arc-related volcanics and volcanoclastics of Upper Mesozoic-Tertiary age. This alpine cover is the common overstep sequence in the whole northern edge of the Sakarya Composite Terrane. It is generally accepted that this magmatic event should be related to the northward subduction of the Izmir-Ankara-Erzincan Ocean. This alpine cover can be followed in the Adjara-Trialeti and Talesh Zones of the South Transcaucasian Terrane (ADAMIA *et al.*, this volume).

D-Elekdag-Cangaldag Terrane: The Elekdag-Cangaldag Terrane is characterized by imbricated thrust sheets of volcanic-arc type metabasic and metafelsic rocks, metamorphic subduction/accretion complexes and an ophiolitic basement (Cangal Dag Ophiolite and Elekdag Ophiolite) which is made up sliced basic lavas, sheeted dykes, mafic- and ultramafic cumulates and serpantinised peridotites (EREN, 1979; YILMAZ, 1983; SENGÖR *et al.*, 1984a; USTAÖMER and ROBERTSON, 1992). Non-metamorphic Malm clastics unconformably seal the imbricated contacts of these tectono-stratigraphic units.

Terrane boundaries: The Unit is overthrusted by the Istanbul Terrane and tectonically overlying the equivalents of the Karakaya Complex.

Pre-alpine history: The Cangal Dag Ophiolite consists mainly of metagabbro, metadiabase, metaspilite and occasional serpantinite bodies. Towards south Eren (1979) reports a HP/LT assemblage. In the Cangal Dag area the ophiolites and the overlying metavolcanics are intruded by Mid-Jurassic granitoids (YILMAZ and BOZTUG, 1986) and unconformably overlain by Late Jurassic sediments indicating a pre-Mid Jurassic age for the Cangaldag Terrane.

The immobile trace element geochemistry of the basic volcanics within the Cangaldag Terrane indicates a volcanic -arc type tectonic setting and thus the unit is interpreted as remnants of a Paleotethyan ensimatic arc, that had developed on a supra-subduction type oceanic crust (USTAÖMER and ROBERTSON, 1992).

A rather complete and intact ophiolite is preserved in the Elekdag area at the south of Cangal Dag. Elekdag Unit is in the form of a nappe with bands and lenses of eclogites and overlies an ophiolitic melange along a sharp tectonic contact. The Cr/Cr+Al ratio of the Cr-spinels of the ultramafics is >0.8 and hence suggests a supra-subduction setting (USTAÖMER and ROBERTSON, 1992). The basla melange complex was metamorphosed to glaucophane-bearing greenschist facies. An Upper Carboniferous-Liassic age is suggested for the Elekdag Unit.

The Elekdag-Cangaldag forms a mosaic of various imbricated tectonostratigraphic units. Based on geochemical data, USTAÖMER and ROBERTSON (1992) suggest that the basements of the Küre and Cangaldag Terranes are of the same origin. This correlation, however, is mainly based on very general

assumptions, affected by a large amount of uncertainty and is completely speculative.

Alpine history: The alpine evolution of this terrane is similar to further terranes of the Sakarya Composite Terrane, except the presence of extensive volcanic and volcanoclastic rocks of Upper Mesozoic and Tertiary age.

E-Küre Terrane: The Küre Terrane is an imbricated unit, comprising slices of Early Mesozoic clastics within a dismembered ophiolitic assemblage (Küre Ophiolite, GÜNER, 1980; AYDIN *et al.*, 1987; USTAÖMER and ROBERTSON, 1992). SENGÖR *et al.* (1984) argued that the Küre Terrane represents the remnants of Paleotethys.

Terrane boundaries: The Küre Terrane is tectonically overlain by the Istanbul Terrane. To the south, the Küre Terrane is in tectonic contact with two further subterranes of the Sakarya Composite Terrane.

Pre-alpine history: The Küre unit contains disrupted ophiolites, basic volcanics with Cyprus-type massive deposits, deep-sea sulfide radiolarites, turbidite sequences and flyschoidal sequences including olistostromes. OKAY (1986) suggests a Mid Triassic-Early Jurassic depositional age for the flyschoidal sequences, which he correlates with the Karakaya Complex. Immobile major and trace element data on volcanic rocks indicate MORB and VAB-type characteristics and strongly suggest that the Küre Terrane was generated in a supra-subduction-type tectonic setting (USTAÖMER and ROBERTSON, 1992).

Pre-alpine history: The Küre Terrane is unconformably overlain by undeformed conglomerates and sandstones of Middle Jurassic age, passing upwards to Late Jurassic-Early Cretaceous limestones representing the alpine platform of the Sakarya Composite Terrane. A post-Early Cretaceous southward thrusting is reported from the Central Blacksea area (DERMAN, 1993, personal communication).

The Küre Terrane has been compared with the Lipacka Flysch and the Diabase-phyllitoid Complex of the Strandja Unit in Bulgaria (SENGÖR *et al.*, 1984).

INTRAPONTIDE OPHIOLITE BELT

The Intrapontide Ophiolite Belt is composed of imbricated structural units representing oceanic assemblages generated in a northern branch of Neotethys which is believed to be located between the Sakarya Composite Terrane and Istranca and Istanbul continental slivers.

Terrane boundaries: The oceanic assemblages of the Intrapontide ophiolite Belt are thrusted southward onto Upper Cretaceous flyschoidal sequences of the Sakarya Composite Terrane. To the north the ophiolites are overthrusted by the Istanbul Terrane (GÖNCÜOGLU and ERENDIL, 1990).

Alpine history: Large bodies of ultramafic and volcanosedimentary rocks, basic lavas, radiolarian cherts and allochtonous blocks of Jurassic-Lower Cre-

taceous neritic-pelagic limestones are the main constituents of the unit, (OKAY *et al.*, 1991). The overstep sequence starts with Lutetian shallow-marine sediments.

The Intrapontide Ophiolite Belt can be correlated with the ophilites observed on the Lesbos Island or with the Eastern Rhodopian Ophiolites of PAPANIKOLAOU (1989).

ISTRANCA TERRANE

The Istranca Terrane is characterized by a complex of poorly known metamorphic assemblages unconformably overlain by Early Upper Cretaceous clastics. It represents the eastern part of Sakar Zone in Bulgaria.

Terrane boundaries: The terrane boundaries of the Istranca terrane is covered by the Tertiary deposits of the Thracian Basin.

Pre-alpine history: The metamorphic rock units in this area are described as the Istirance Group, which is made up of two metamorphic subunits, separated by an erosional surface. The lower subunit consists of amphibolites and amphibole-schists with monor intercalations of metapelites. The protholites of the lower subunit is interpreted as clastics by AYDIN (1974). This lower sequence is intruded by 244 my old (Hercynian) granitoides with blastomylonitic textures.

The upper subunit, unconformably overlying the amphibolites starts with meta-conglomerates, which contain deformed clasts of the basement rocks (CAGLAYAN *et al.*, 1992). Quartzo-feldspatic schists, metagreywackes and phyllites of Triassic age are the main rock-types, calcschists and marbles are observed as subordinate bands and lenses.

Alpine history: A thick sequence of recrystallized fossiliferous limestones of Jurassic age unconformably cover the metamorphics. The lower and upper subunits are intruded by post metamorpic calcalkaline granitoids of Lower Cretaceous age. Senonian volcanoclastites represent the non-metamorphic cover units in this area.

The pre-Triassic basement of the Istranca Terrane in Turkey may be well correlated with the pre-Cambrian and Hercynian basement units of the Sakar and Dervent subunits of the Bulgarian Strandzides (GOCHEV and YANEV, this volume). The threefold subdivision of the Triassic Nappes (Sub-Balkanide, Veleka and Topolovgrad Subunits of CHATALOV, 1988), related to the closure of the Paleotethys and thus to the Cimmerides, however, this has not yet been established in the Turkish part of the terrane.

ISTANBUL TERRANE

The Istanbul Terrane consists of a pre-Cambrian basement, unconformably covered by a well-developed sequence, extending without any major break from Cambrian to the Upper Carboniferous.

This anchimetamorphic Paleozoic section, representing a passive continental margin is unconformably overlain with Lower Triassic continental clastics,

which pass upwards to an alpine-type Triassic sequence and finally unconformably covered by Upper Cretaceous - Paleocene carbonates.

Terrane boundaries: The Istanbul Terrane is separated from the Sakarya Composite Terrane in the South by the Intrapontide Ophiolite Belt. OKAY *et al.* (1994) suggest that a pre-Eocene stike-slip fault constitutes the boundary with the Istranca Terrane.

Pre-alpine history: Limited outcrops of meta-gabbros, ortho-amphibolites and amphibole-gneisses are reported from basement of the unit (ARPAD *et al.*, 1978). Thin horizons of biotite gneisses and biotite - amphibole schists of para origin are observed as thin interlayers. Blasto-mylonitic alkali-feldspar granites and quartz-monzonites are common intrusive constrituents of the Basement Complex.

In the central part of the Istanbul Terrane Cambro-Ordovician variegated shales and sandstones with Trilobites and primitive Brachipods rest with an angular unconformity on the Basement Complex (AYDIN *et al.*, 1987). The Ordovician is characterized by red terrigenous clastics overlain by white, clean quartzites which are followed by Lower Silurian shales and siltstones. The Devonian is represented by crinoidal and nodular limestones with shale, silty shale and siltstone interlayers, passing conformably into Lower Carboniferous radiolarian cherts. Most of the Carboniferous in the south and southwest parts of the unit is represented by a thick sequence of greywacke and shale with some lidites and cherty limestones. In the northeast part (Zonguldak area), however, the well-known non-marine, coal bearing units of the Carboniferous are exposed. Continental clastics of Scytian age lie unconformably over the deformed Palaeozoic Sequence in western and central parts. The easternmost outcrops of the Paleozoci sequence, are transitional to Permo-Triassic molasse - type deposits and intruded by granitoides of Middle Jurassic age (YILMAZ and BOZTUG, 1986). SENGÖR *et al.* (1984a) has related the Carboniferous deformation of the Istanbul Terrane in the western areas to the closure of Hercynian ocean.

Alpine history: The pre-Alpine assemblages of the Istanbul Terrane are unconformably covered by the alpine cover sequences, which start with a well developed alpine-type Triassic and continue with Jurassic carbonates and Cretaceous shallow-marine clastics and volcanoclastics.

The Istanbul Terrane can be correlated with the southern zone of the Moesian Platform and/or the Balkan Terrane in Bulgaria.

CONCLUSIONS

Pan-African terranes in Turkey are characterized by continental crust material intruded by collisional to arc-type magmatics (pre-Cambrian units of Menderes and Central Anatolian Massifs, Taurides and Southeast Anatolia) as well as ophiolitic lithologies (basement of Istanbul Terrane).

Hercynian and/or Palaeotethyan terranes lie mainly within the accreated terranes of northern Turkey. In this zone Late Paleozoic platformal (Istanbul

Terrane), arc-related or oceanic (Sakarya Composite Terrane) units are imbricated with Early Mesozoic ophiolites and island-arc volcanics (Küre, Cangaldag-Elekdag and Yusufeli Terranes) or riftarc volcanics (Küre, Cangaldag-Elekdag and Yusufeli Terranes) or rift-related sequences (Karakaya Complex).

Correlations of the Turkish terranes with those in the adjacent areas show in general a striking lateral continuity of the main tectonic units. The major differences, especially with those in the western areas is mainly based on disagreements on the geodynamic concepts or models, which may be smoothed out by the «Alpine-Himalayan Terrane Map» and the new data accumulated within IGCP No: 276.

ABSTRACT

The Turkish orogenic collage can andivided into a number of tectono-stratigraphic units or terranes trending in E-W direction. These units, corresponding with various tectonic settings, such as active and passive continental margins, arc and suture complexes, were generated as a result of the closure of three main oceanic areas: Pan-African, Hercynian and/or Palaeo-Tethyan and Neo-Tethyan. The terranes related to the Pan-African and Hercynian and/or Palaeotethyan cycles are represented by disrupted/metamorphosed tectono-stratigraphic units within the alpine terranes.

In this paper, we will discuss the lithologies, tectonic settings and assemblage of these terranes, correlate them with the adjacent areas and try to re-organize the pre-alpine tectonic classification of Turkey

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