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STRATIGRAPHY OF THE PAN - AFRICAN BASEMENT OF THE MENDERES MASSIF AND THE RELATIONSHIP WITH LATE NEOPROTEROZOIC/CAMBRIAN EVOLUTION OF THE GONDWANA

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ABSTRACT.- The Menderes Massif, exposed in the Western Anatolia, is tectonically overlain to the north by the Afyon Zone and to the south by the Lycian Nappes. In the northwest, two high-pressure units, the Cycladic Complex and overlying the Lycian Nappes, as well as the nappes of İzmir - Ankara Zone tectonically overlay the Menderes Massif. The metamorphic rock succession of the Massif can be divided into two main units: 1-Pan-African basement (core series) and 2-Palaeozoic - Early Tertiary metasedimentary rocks (cover series). The Pan-African basement shows a stratigraphy consisting of a partly migmatized metaclastic sequence and polymetamorphic basic and acidic igneous rocks that intruded into these metaclastics. This metaclastic sequence, which is composed of paragneiss and conformably overlying schist units reaches a minimum thickness of eight kilometers and forms the oldest rocks of the Pan-African basement of the Menderes Massif. Field studies and geochronological data suggest that the protoliths of the paragneisses are predominantly clastic sediments of litharenitic composition. Frequently, the paragneisses alternate and interfinger in all directions with micaschists and biotite-albite schists, originating from mudstone and subarkosic sandstone, respectively. The paragneisses are conformably overlain by a schist unit. The originally gradual sedimentary contact is represented by a paragneiss and schist intercalation. The schists are dominated by micaschists with biotite-albite schist layers, derived from mudstone and subarkose, respectively. In the Menderes Massif, the paragneisses are generally extensively migmatized. Widespread anatectic granites occur as irregular-shaped bodies with migmatized margins. The detrital zircons of the paragneisses yielded ages scattered between 610 - 2558 Ma. Detrital zircons of the schist unit of the Pan-African basement were dated at 592 - 3239 Ma. The intrusion ages of the orthogneiss showing clear intrusive contact relationship with metaclastic sequence range from 570 to 520 Ma. The granulite facies metamorphism of the paragneiss unit was dated at 583±5.7 Ma. These geochronological evidence and the contact relationships clearly reveal that the deposition age of the protoliths of the metaclastic sequence of the Pan-African basement can be constrained to Late Neoproterozoic between ca 590 - 580 Ma. The metaclastic sequence is intruded by large granitoid bodies and gabbroic stocks. The intrusion ages of the granitic precursors now represented by orthogneisses with changed mineralogical compositions and primary textures range from 520 to 570 Ma with a major event at about 550 Ma. These granites, which can be divided into three main groups (biotite orthogneiss, amphibole orthogneiss and tourmaline leucocratic orthogneiss) are the products of a poly-phase Pan-African acidic magmatic activity that intruded the metaclastic sequence. They are syn- to post-metamorphic intrusions with respect to the Pan-African orogeny. The basic meta-igneous rocks occurring in the Pan-African basement have gabbroic to noritic composition. They display massive cores and foliated margins that consist mainly of garnet amphibolites with relics of eclogites revealing the polymetamorphic history of the Pan-African basement. Field evidence and radiometric age data indicate that the primary contact relationship

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between the Pan-African basement and the Palaeozoic cover series in the Menderes Massif was an unconformity (Supra-Pan-African unconformity) and the cover series were sourced from the Pan-African basement. The protoliths of the paragneiss and schist of the Pan-African basement were deposited on the passive continental margin of a basin occurring between East and West Gondwana during the Late Neoproterozoic time (Mozambique ocean). All the magmatic and metamorphic ages obtained from Pan-African basement coincide with the closure of this ocean and the final assemblage of the Gondwana supercontinent during Late Neoproterozoic-Cambrian time.

Key words: Menderes Massif, Mozambique Belt, Pan-African orogeny, Gondwana, Turkey.

INTRODUCTION

NE - SW trending Menderes Massif (200 x 300 km) forms one of the biggest crustal segments of the Western Anatolia. This crystalline complex is tectonically underlain by Lycian nappes to the south, by İzmir - Ankara zone and the extension of Cycladic complex in Turkey to the north and northwest. The massif is covered by Neogene sedimentary / volcanic units to the east. The Menderes Massif is divided into three sub massifs as the Demirci - Gördes sub massif (northern sub massif), the Ödemiş Kiraz sub massif (central sub massif) and as the Çine sub massif (southern sub massif) by E - W trending graben systems which is still active at present (Figure 1). In previous studies the Menderes Massif was considered as an onion shell. However, today, it is clearly revealed that the Massif tectonically has a complex internal structure defined as thrust faults produced by the Late Alpine compressional tectonism (Konak et al., 1994; Partzsch et al., 1998; Hetzel et al., 1998; Candan and Dora, 1998; Ring et al., 1999; Gessner, 2000; Candan and Çetinkaplan, 2001; Dora et al., 2001).

During studies made in the Massif for a century, prevalent evidences have been obtained indicating the presence of a Precambrian basement exposed in large areas and reshaped by Alpine event (Figure 1). The rock assemblage which is named as "core series", "Precambrian basement" or as the "Pan - African basement" is overlain by the Palaeozoic - Early Tertiary metasedimentary deposit called the "cover series". Evidences show that the primary contact relationship between these two series is an unconformity in regional scale (Supra Pan-African unconformity; Şengör et al., 1984) (Konak et al., 1987; Dora et al., 2005; Candan et al., 2006). It has been known for a long time that the basement in the Menderes Massif is affected by a polyphase metamorphism related with the Pan-African Orogeny (Candan et al., 1994, 2001, 2007; Oberhänsli et al., 1997) and consists of widespread acidic / basic magmatics associated with this period (Hetzel and Reischmann, 1996; Loos and Reischmann, 1999; Koralay et al., 2004; Candan, 1996a). In studies which aimed at establishing the general geological and tectonical structure of the Menderes Massif (Erdoğan and Güngör, 1992; Bozkurt et al., 1993), it is claimed as an opposing idea that gneisses belonging to the basement as the most typical rocks are Upper Cretaceous-Lower Tertiary intrusions (Erdoğan and Güngör, 2004; Bozkurt et al., 1995) and so, there can not be a 'core - cover' relation in the Massif.

In the light of previous studies and original new evidences / interpretations, it is considered that the analysis of basic properties of the units of the Menderes Massif which is considered as the Pan-African in age in Massif scale, and discussion of problems may guide to the investigators who will study on this topic. The article prepared within this scope aims at presenting and discussing: 1- the stratigraphy of metaclastics forming the oldest unit of the Menderes Massif, 2- the migmatization of this sequence,

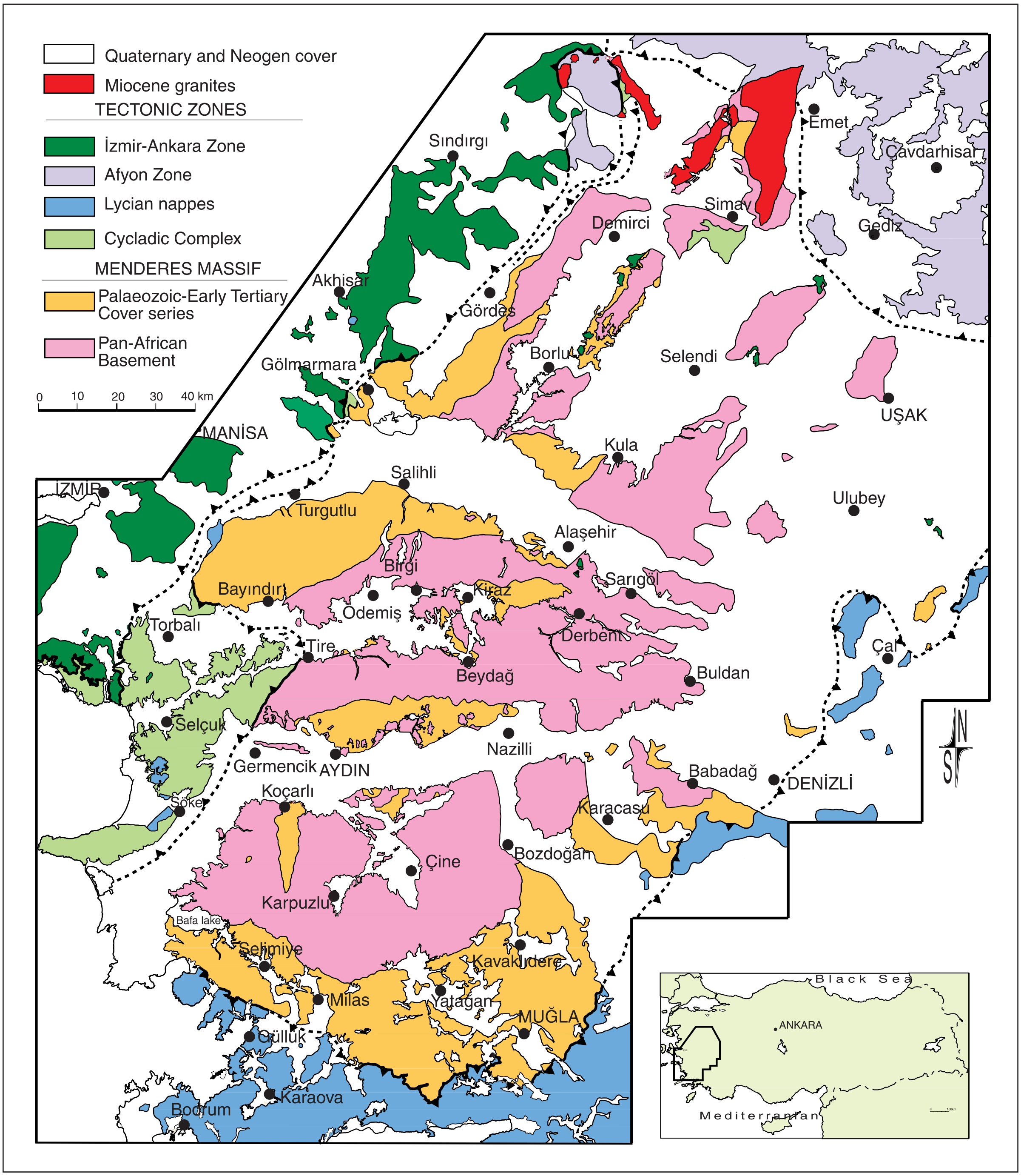

Figure 1- The generalized geology map showing the distribution of the Pan-African basement, Palaeozoic - Lower Tertiary cover series and tectonic zones surrounding the massif.

3- types of acidic / basic magmatics observed within metaclastics and their primary contact relationships with metaclastics, 4- the primary contact relationship between the Pan-African basement and cover series and 5- the temporal and spatial relations of the Pan-African base units with the stage of Gondwana in the Late Neoproterozoic time.

LITHOSTRATIGRAPHY

Recent studies made towards the tectonical structure of the Menderes Massif revealed that the original stratigraphy of the massif has largely been deteriorated by the Precambrian and the Alpine age deformations (Konak et al., 1994; Partzsch et al., 1998; Ring et al., 1999). Nowadays, in throughout the Menderes Massif, the units of the Pan - African basement exposing in large areas are shown in the form of tectonic layers strongly imbricated with Palaeozoic-Early Tertiary cover series near their internal napping. The generalized columnar section obtained by the correlation of tectonic layers made up of different Pan-African basement units is shown in figure 2.

As seen in the figure, the oldest rock units of the Menderes Massif are made up of regular and continuous metaclastic sequence. This metaclastic sequence is cut by granitoidic and gabbroic rocks which intruded at different stages of the Pan-African orogeny. The metaclastic sequence is divided into two sub units as i) paragneiss unit, and ii) schist unit from bottom to top. Rock successions of four regions belonging to northern, central and southern sub massifs are given in figure 3. These two sub units are observed as in primary contact relationships within these regions. At lower parts of the metaclastic sequence, there are gigantic granitic intrusions and / or cut by the Alpine aged thrust faults. Thus, the true thickness of primary sediments of this metaclastic sequence and by which assemblages it is underlain can not be detected. However, it is understood the minimum thickness of the sequence is 8 km, when the general stratigraphical and metamorphic properties of tectonic layers consisting the metaclastic sequence are considered throughout the Massif. The absence of carbonaceous layers is the most characteristic distinguishing feature of this thick metaclastic sequence derived from mudstone, siltstone and sandstone. The presence of emery lenses were detected only in two locations within the schist unit at the Pan-African basement.

The paragneiss unit which is the lower unit of the metaclastic sequence is formed by two lithologies that have both vertical and lateral transitions to each other. These high graded lithologies consist of sillimanite, disthene and garnet (± orthopyroxene) and are made up of schists in different compositions. Litharenitic sandstones are the predominant primary rock type in paragneiss unit. The original layer thicknesses of these sandstones which paragneisses were derived range in between 0.5 - 1 m. Thicknesses of homogenous sandstone layers which form fine grained massive paragneisses may reach 800 meters and can laterally be traced several kilometers. Paragneisses vertically and laterally grade into schists. Although there are many lithologies, the mica schist, biotite and albite schists form the dominant schist types. The protoliths of these schists are mudstone and subarkosic sandstone. Transitions into these schists originate from the lateral and vertical change of primary sand / clay ratios. The thickness of interlayers of schist generally ranges in between 300 - 500 m. However, the thickness of schists where these laterally transit into paragneisses may reach up 2 km. The widespread presence of calcsilicate rocks is another characteristic of the paragneiss unit. These fine grained, massive rocks with a zoning mineralogical composition show severe boudinage. Thickest exposures of the paragneiss unit are observed in the tectonic layer in Kula region. The 4 km apparent thickness observed in this tectonic layer can be accepted as the minimum thickness of the paragneiss unit in the massif.

There has been detected many tectonical layers consisting of the paragneiss unit with the overlying schist unit in the massif (Figure 3). Field data indicate that there is a conformable and transitional contact between these two units. The location of the contact between these two units which are fully derived from the clastic sediments is described by the latest litharenitic layer observed at the deposit. The original thickness of the related schist unit can not be interpreted, because it is present in the form of isolated layers from top and bottom and presence of probable inner nappes and isoclinal folds. For instance, 6 and 7 km apparent thicknesses were estimated in layers of Bozdağlar and Aydın Mountains, respectively. However,

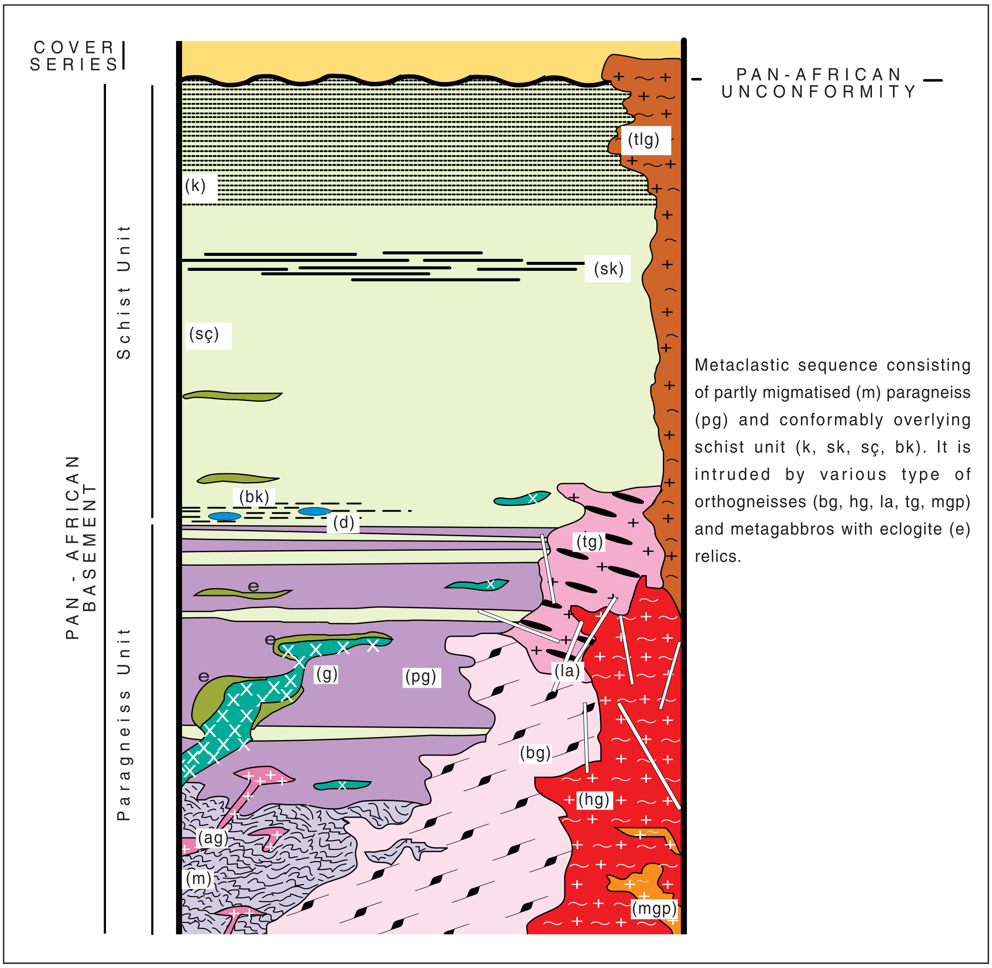

Figure 2- The generalized columnar section of the Pan-African basement of the Menderes Massif. Paragneiss (pg) which is observed partial migmatization (m) and anatectic granite (ag) and the metaclastic sequence which is made up of schists and conformably overlies it form the oldest units of the basement. Schist units are derived from subarkose - mudstone intercalations (sç) at lower layers and sandstones rich in quartz (k) at upper layers. Rare dolomite (d), lensoidal, white quartzite (bk) and black quartzite (sk) layers are observed within schist unit. Orthogneisses are derived from granites rich in biotite (bg), hornblende (hg) and tourmaline (tg) compositions and textures (la: leucocratic metaaplite, mgp: metagranite porphyry). The basement is also cut by Triassic leucocratic granites (tlg).

schists in these two tectonic units have different degree of metamorphisms (Bozdağlar: garnet, staurolite and disthene zones; Aydın Mountains: biotite and garnet zones). Therefore, it can be considered that primary thickness for the schist unit could be higher than layers indicated above. The schist unit is predominantly made up of mica schist and the intercalation of biotite - albite schists which its protoliths are equivalent of mudstone and subarkose. Black quartzite layers are also rarely observed within these schists. These graphite rich layers with a thickness of less than 0.5 m may show an intercalation within a zone of 1 km. It is considered that these quartzites are recognized at upper levels of subarkose - mudstone intercalation although their stratigraphical positions have not yet been determined. On the other hand, the schist unit composed of mica schist and biotite - albite schist intercalation at south of Çine sub massif (southwest of Bozdoğan and east of Karıncalı Mountain) is conformably and transitionally overlain by a deposition made up of muscovite schist / biotite muscovite quartz schist intercalation. These schists most probably represent the uppermost levels of schist units belonging to the Pan- African basement.

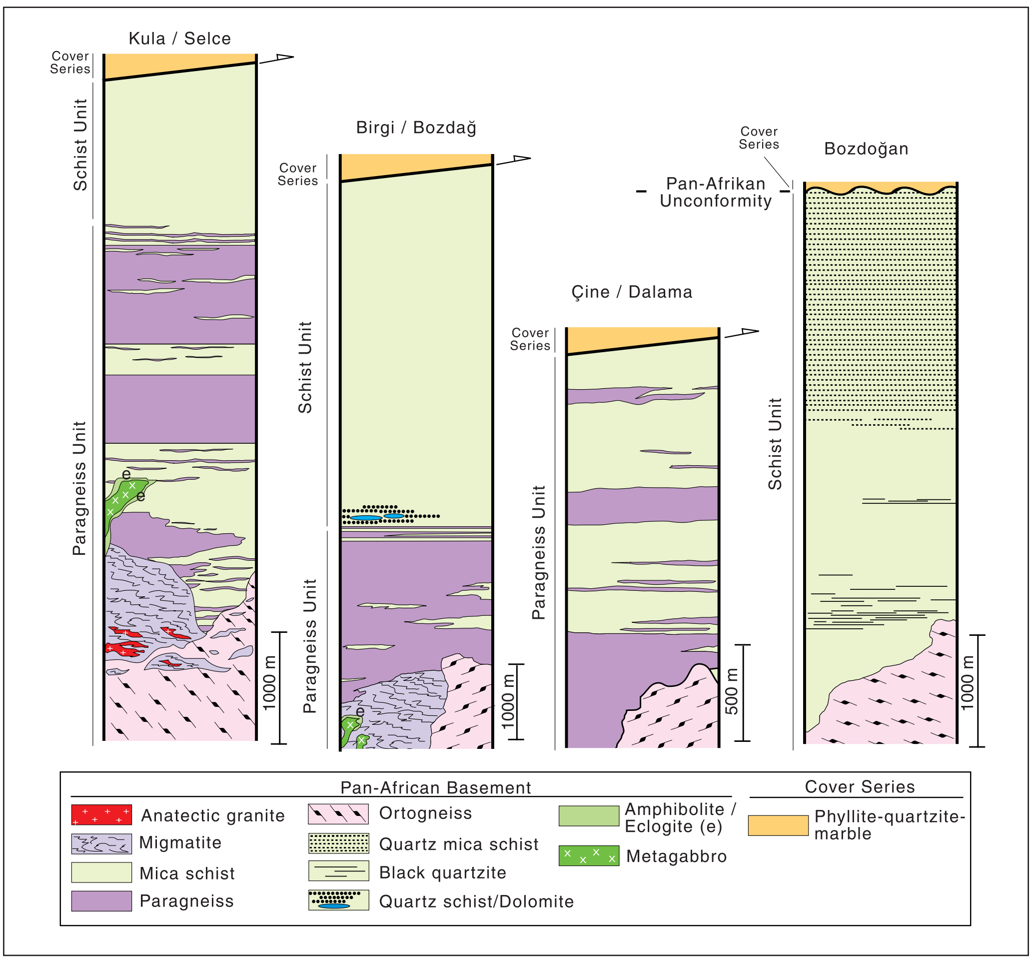

Figure 3- The generalized columnar section of metaclastics of the Pan-African basement observed in Demirci - Gördessubmassif, south of Kula, in Ödemiş - Kirazsubmassif, north of Birgi and in Çine submassif, south of Dalama and southwest of Bozdoğan.

Another quartzite / muscovite - quartz schist / mica schist intercalation within schist unit are recognized in Bozdağlar, between Birgi - Alaşehir. Within this quartz arenite / quartz rich sandstone derived intercalation, dolomitic emery lenses which are very rarely observed at the Pan-African basement take place with a dimension of 80 x 200 km. The paragneiss unit which forms the lower parts of the metaclastic sequence show widespread migmatization throughout the massif. In many places, these migmatites are accompanied by anatectic granites which are the product of partial melting. The great majority of these granites which consist of sillimanite and garnet were subjected to in situ crystallization and some of them have reached non migmatized upper levels of paragneisses.

Both schist and paragneiss units are cut by many basic magmatic rocks in vein and stock character with dimensions reaching up 1.5 km. The predominant lithology is the biotite gabbro. These are accompanied by olivine gabbro, noritic gabbro and norites. Petrological evidences show that the primary features of these extremely well preserved rocks in undeformed sections were polymetamorphosed under granulite, eclogite and amphibolite facies conditions. These so called 'eclogitic metagabbro' rocks are observed around the wall zones of gabbro stocks and show widespread transformations into garnet amphibolites. Apart from these, there are eclogites as well in the form of lenses and layers which probably derived from basaltic source rock in many locations within schist and paragneiss. In addition to these, garnet amphibolites derived from vein rocks in gabbroic composition are recognized in almost all parts of the metaclastic sequence.

Gneisses which are granitic origin form one the most prevalent rock types belonging to Pan-African basement. Orthogneisses crop out on an area of thousands of square kilometers. These are made up of plutons intruded each other with diameters reaching up tens of kilometers. Orthogneisses in the massif based on the primary textural and mineralogical compositions of its protoliths can be divided into many sub types such as; granoblastic textured biotite orthogneiss, amphibole orthogneiss, tourmaline leucocratic orthogneiss, metagranite porphyry and metaaplitic vein rocks rich in albite and quartz. These rocks can also be named as granitic, augen and banded gneiss depending on the intensity of ductile deformation. All orthogneiss types present a distinct intrusive contact relationship with paragneiss and schist units which are the oldest rocks of the Pan-African basement. These rocks can be observed as partly assimilated inclusions in orthogneisses with dimensions reaching up several kilometers. Age determinations based on the single zircon evaporation method show that the intrusional ages of granites forming the protoliths of orthogneisses are Precambrian / Cambrian (570-550 Ma; average 550 Ma).

GEOLOGY OF THE PAN-AFRICAN BASEMENT UNITS

The Pan-African basement is made up of Late Neoproterozoic metaclastics which form the oldest units of the Menderes Massif and this basement is intruded by acidic and basic magmatics associated with the Pan-African orogeny.

METACLASTIC SEQUENCE

The metaclastic sequence is divided into two sub units consisting of paragneiss and schist reflecting the facies change in the primary sedimentary rock. Basic geological properties of these partly migmatized typical lithologies of the Pan- African basement are given below.

Paragneiss unit

Macroscopic properties of Paragneisses.- Paragneisses are pinkish gray to brownish, fine grained, massif and / or coarsely foliated rocks. The pink color is originated from the homogenously distributed biotite and garnet in the rock. The primary layer thickness of litharenitic sandstones ranging between 0.5 - 1 m which paragneisses derived from, can still be recognized in paragneisses in spite of this high grade metamorphism (Figure 4a). Within a fine grained homogenous groundmass the presence of widespread mineral dwellings (speckle) ranging from several millimeters to several centimeters is the most characteristic properties of paragneisses (Kun and Candan, 1987*a*; Dora et al., 2001, 2002). In mineralogical studies these speckles were not formed from only one mineral. On the contrary, these speckles were made up of an assemblage defining high temperature (HP) conditions such as sillimanite, disthene and garnet formed by replacing of a previous porphyroblastic mineral. When evidences such as the integration of dwellings are evaluated in the evolution of the Pan-African basement, they have been interpreted as the old cordierite porphyroblasts of the product of granulite facies metamorphism (Dora et al., 2001, 2002). Speckles in paragneisses are divided into three groups based on the color and mineralogical compositions. These are; i) black, ii) green and iii) white speckles. It was identified that the discoidal black speckles reaching up 1 cm in maximum are controlled by the compositional change of the primary sedimentary rock and preferably developed on clay rich levels of the rock (Figure 4b). Much rarely observed green speckle formations could reach 4 to 5 cm and are characterized by structures of zoning composition (Figure 4c). White speckles, 4 - 5 mm in length that have homogenous distribution within a thin crystal pink groundmass (Figure 4d) have been interpreted as relic feldspar phenocrystals belonging to original porphyritic texture. Based on this, protoliths of these paragneisses were considered as volcanites in andesitic composition (Kun, 1983; Kun and Candan, 1987*a*). Whereas, detailed textural observations revealed that these were transformed from black speckles.

Widespread presence of calcsilicates is another characteristic of paragneisses (Kun, 1983; Kun and Candan, 1987*b*; Dora et al., 2001, 2002). Calcsilicates which show very intensive boudinage, are 1 x 0.4 m in dimension in discoidal form appearing several meters apart from each other sometimes (Figure 4e). These very fine grained and massif rocks have a diopsite rich green outer zone, albite rich white colored intermediate zone and pinkish core rich in garnet and zoisite (Figure 4f) (Barbol, 2005). Geochemical data show that these rocks were derived from quartzose-feldspatic levels rich in carbonate among litharenitic sandstones.

The general distributions and internal structures of paragneisses in the Massif.- The distribution of the paragneiss unit belonging to metaclastic sequence in the Pan - African basement throughout the Menderes Massif is given in figure 5. As seen, paragneisses crop out in each of three sub massifs, as being the largest exposure to be in the central sub massif.

In Demirci- Gördes sub massif the primary sedimentary internal structures of paragneisses in the Menderes Massif can clearly be observed in the southern part of Kula. This region is between Alaşehir and Kula, in dimensions of 15 x 17 km and exhibits a character of nappe pile (Figure 6). The layer which consists of the paragneiss unit is tectonically underlain by schist unit belonging to the Pan-African basement and overlain by cover series consisting of Palaeozoic-Mesozoic sequences (Candan, 1994; Dora et al., 2002). The rock succession of the tectonic layer consisting of paragneiss where all the units belonging to the Pan - African basement are observed as in clear contact relationships, is given in figure 3. Oldest units in the region are composed of metaclastics forming a continuous sequence made up of paragneiss and schist. The paragneiss unit possesses an apparent thickness of 4 km and is made up of paragneiss layers rich in sillimanite. This unit has a thickness dominantly varying between 400-600 m and a lateral continuity of 15 km. It also consists of sillimanite-garnet mica schist / sillimanite - biotite - albite schists that show both vertical and lateral transitions with sillimanite rich paragneiss layers. Sections showing the internal structures of

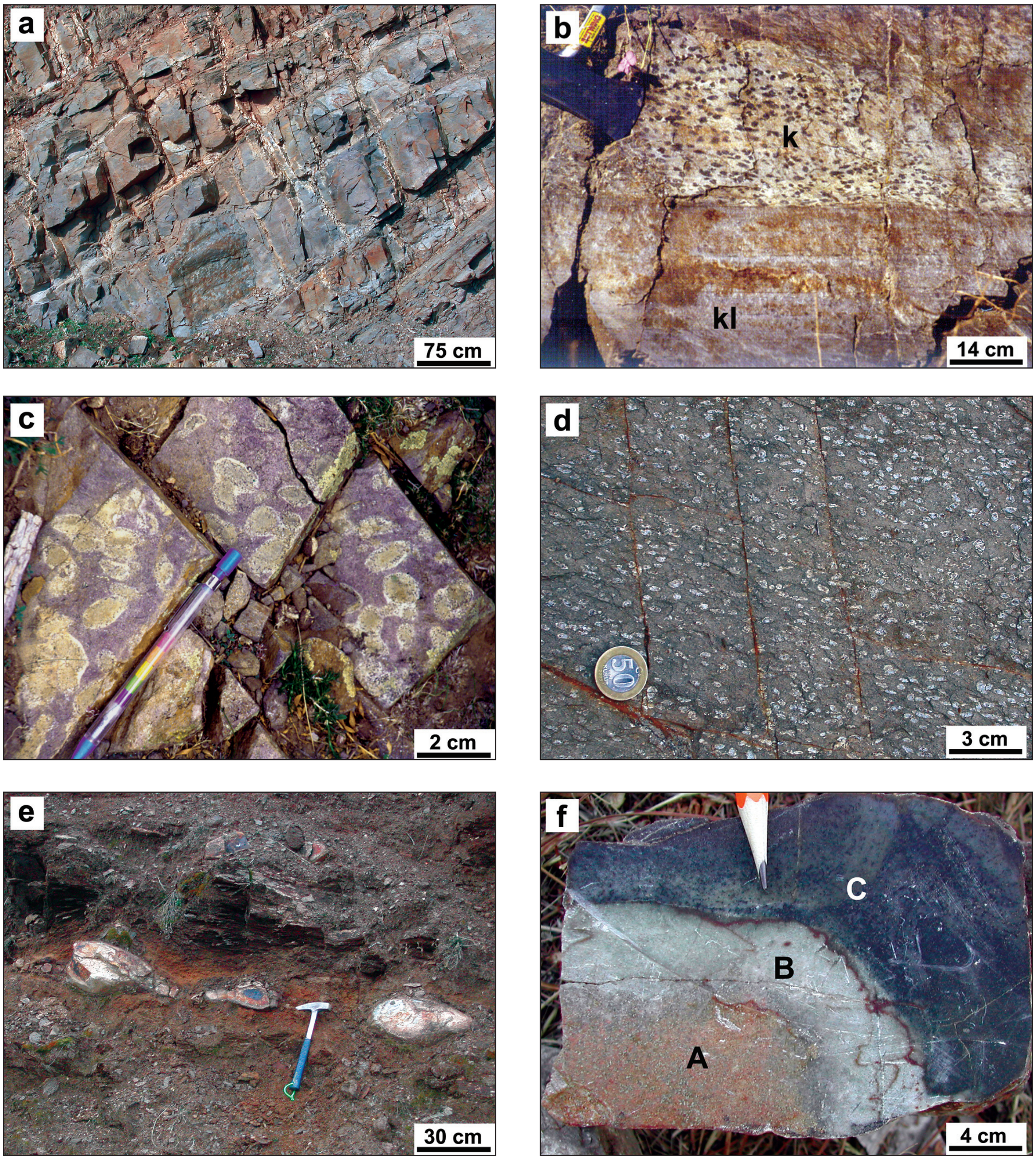

Figure 4- A: Preserved primary coarse layers observed within paragneissesin massive structure derived from litharenitic sandstones, B: Formations of black speckle derived from the probable cordierite porphyroblasts and the product of granulite facies metamorphism affecting paragneisses. Speckling markedly prefers clay rich layers of the primary sedimentary rock (k: sand rich, kl: clay rich), C: Green speckling observed in paragneisses. These speckles are derived from probable cordierite and are pseudomorphically replaced by the zoning mineral assemblage produced from high pressure metamorphism, D: White speckling formed by the formation of retrogradation of black speckles in paragneisses, E: Calcsllicate rocks characterized by boudinage, derived from carbonate rich sediments and widely observed in paragneisses, F: Mineral zoning observed in calcsilicates (A: garnet + zoisite / clinozoisite, B: quartz + plagioclase, C: Clinozoisite + plagioclase) (A - B - D: south of Kula, C: south of Alaşehir, E - F: north of Birgi).

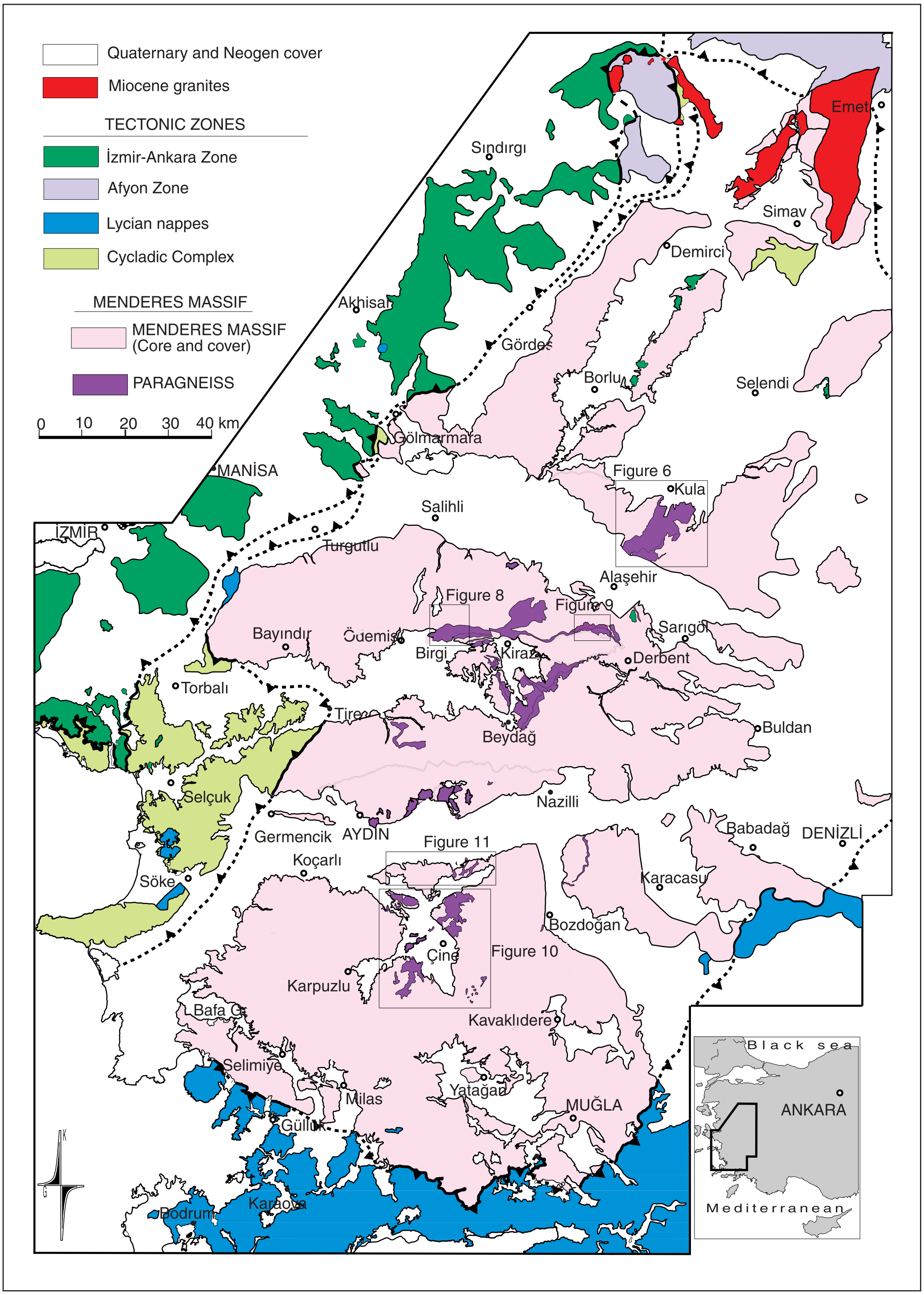

Figure 5- The distribution of paragneiss unit throughout the Menderes Massif. Paragneissic regions of which the geology maps are in detail given in the article are shown.

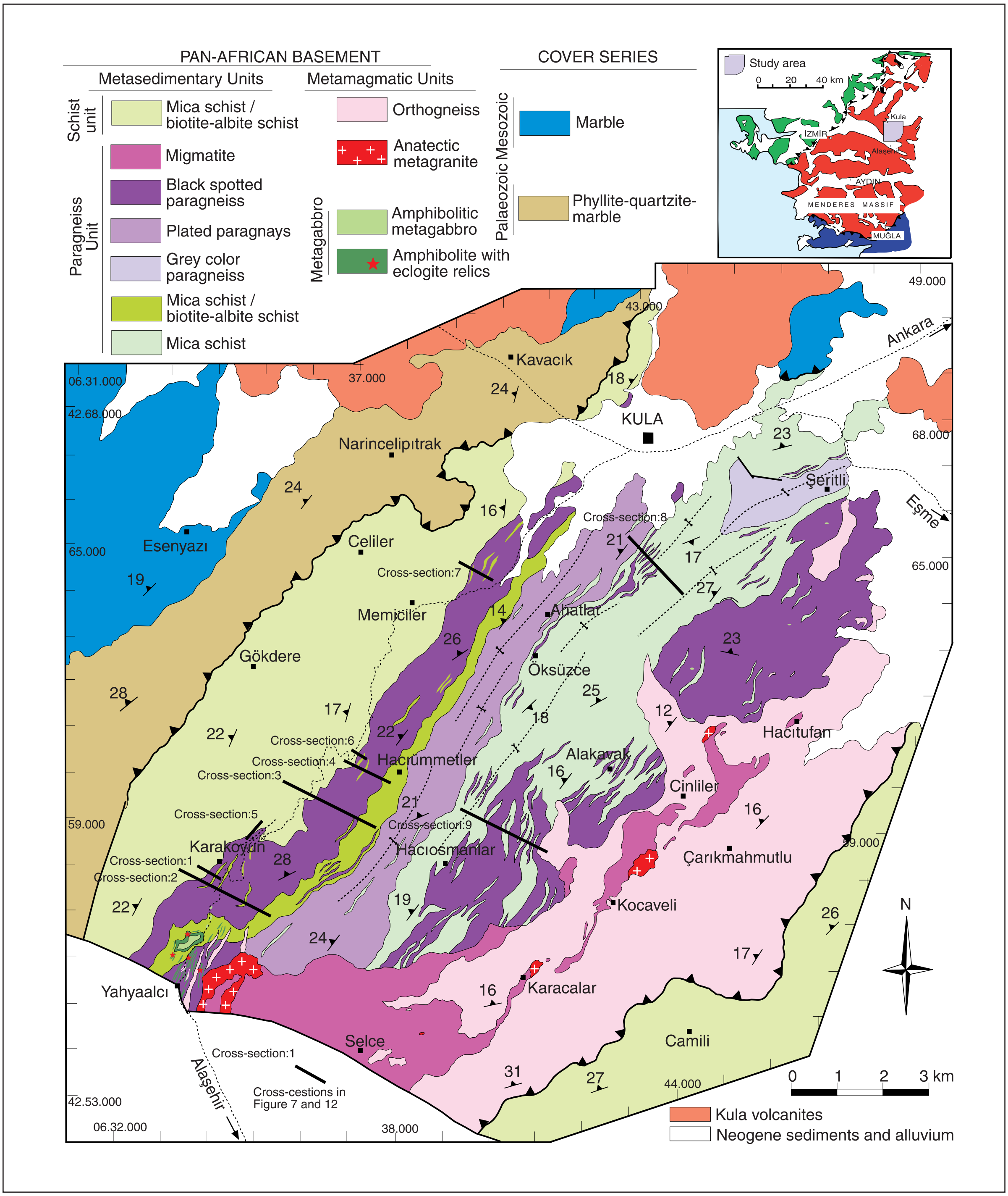

Figure 6- Detailed geology map of the metaclastic sequence of the Pan-African basement which is observed in the Demirci Gördes sub massif of the Menderes Massif, south of Kula (Location is shown in figure 5). Cross lines in figures 7 and 12 are shown on the map.

massif paragneiss layers are given in figure 7a. There are also many paragneiss layers with a thickness not exceeding several meters in schists intercalating with thick paragneiss layers (Figure 7b). In addition to these, intermediate rocks are pervasively recognized as well originating from continuous change in clay / sand ratio in the primary sediment within schists. The paragneiss unit is conformably and transitionally overlain by metaclastic schist unit. Paragneisses which were intensely migmatized at their lower parts are intruded by anatectic granites related to this migmatization. In many locations, basic magmatic rocks are present which intruded into paragneisses in stock and vein character. In amphibolitic circumferential zones of these rocks which are gabbroic in composition rarely eclogite relics are observed (Candan, 1994). The whole sequence is cut by big orthogneissic intrusions emplaced at the last stage of the Pan-African orogeny. Within the orthogneissic mass, partly assimilated migmatite and paragneissic inclusions with dimensions reaching up 2 - 3 km are extremely widespread.

In Ödemiş - Kiraz sub massif, the units of the Pan-African basement and cover series which were determined as Palaeozoic-Mesozoic in age by fossil evidences, show strong imbrication by the Alpine age compressional tectonism. When the stratigraphy of these imbricated slices are studied, it is clearly observed that paragneisses take place in only one tectonic layer in the Ödemiş-Kiraz sub massif (Figure 5). The paragneiss unit can laterally be traced 70 km in approximate and was mapped detailed in two locations, to the north of Birgi and south of Alaşehir.

The Bozdağ region, the north of Birgi is one of the rarest area which the metaclastic sequence of the Pan-African basement continuously crops out. It has been known for many years that the sequence showing regular southward dipping is overturned by stratigraphy and the degree of metamorphism (İzdar, 1971; Kun et al., 1988; Okay, 2001). The thickness of the deposits in the region reaches 8 km (Figure 8). Paragneisses in the region have homogenous internal structure and were derived from litharenitic sandstones with a thickness of 1m. Black dwellings defining old cordierite porphyroblasts are widely observed in paragneisses. Sillimanite rich paragneisses show widespread migmatization at lower parts of their primary positions. To the east of the region, the effect of the partial melting has increased and caused evolution of granitic melt largely, so numerous anatectic granite entrances into migmatites have occurred within dimensions of 6 km.

Kestane river area, the south of Alaşehir is one of the regions where the nappe tectonism in the Menderes Massif and probable Miocene-Recent extansional tectonic structures are all observed clearly (Candan et al., 2001; Gökten et al., 2001). The Pan-African aged homogenous schist unit and cover series form the lower and the upper contacts of the layer which consists of paragneiss in the region respectively (Figure 9). Cover series at the bottom begin with a thin Palaeozoic sequence composed of phyllites. These series grade into Mesozoic age platform type marbles consisting of metabauxite and rudist fossils towards upper layers. The paragneiss unit is being intercalated with schist layers that reach a thickness of 600 m. This is one of the basic properties of paragneiss unit in this area, similar to Kula region. Schists are dominantly made up of garnet mica schists derived from mudstones. Biotite - albite schists originating from feldspar rich sandstones are observed among these garnet mica schists as intermediate layers with thicknesses not exceeding 20 m. In addition to these end members, many intermediate rocks are often observed originating from an infinite change of clay / sand ratio in the primary sediment. When this intercalation is evaluated with the homogenous internal structure in Birgi region, the sight of lateral facies change in paragneisses is frequently encountered as it has been seen in Kula region as well. Purple / pink colored, sillimanite rich, massive paragneisses form the predominant schist type observed in the

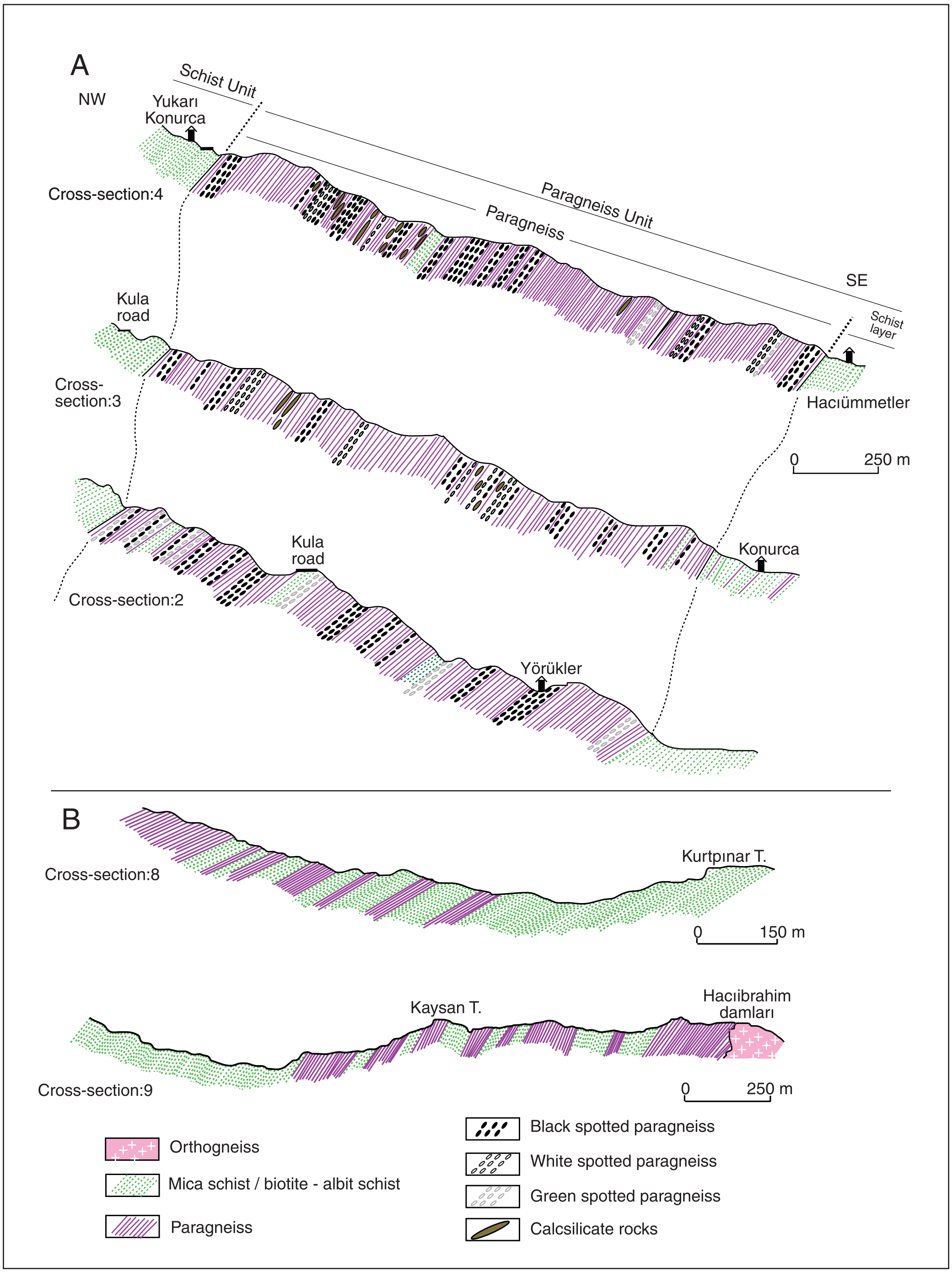

Figure7- A: Sections showing interiors of paragneiss surfaces exposed at south of Kula. B: The internal structure of schist layers within the paragneiss unit. Many paragneiss layers are observed in schistswith a thickness not more than several meters. (section locations are shown in figure 6).

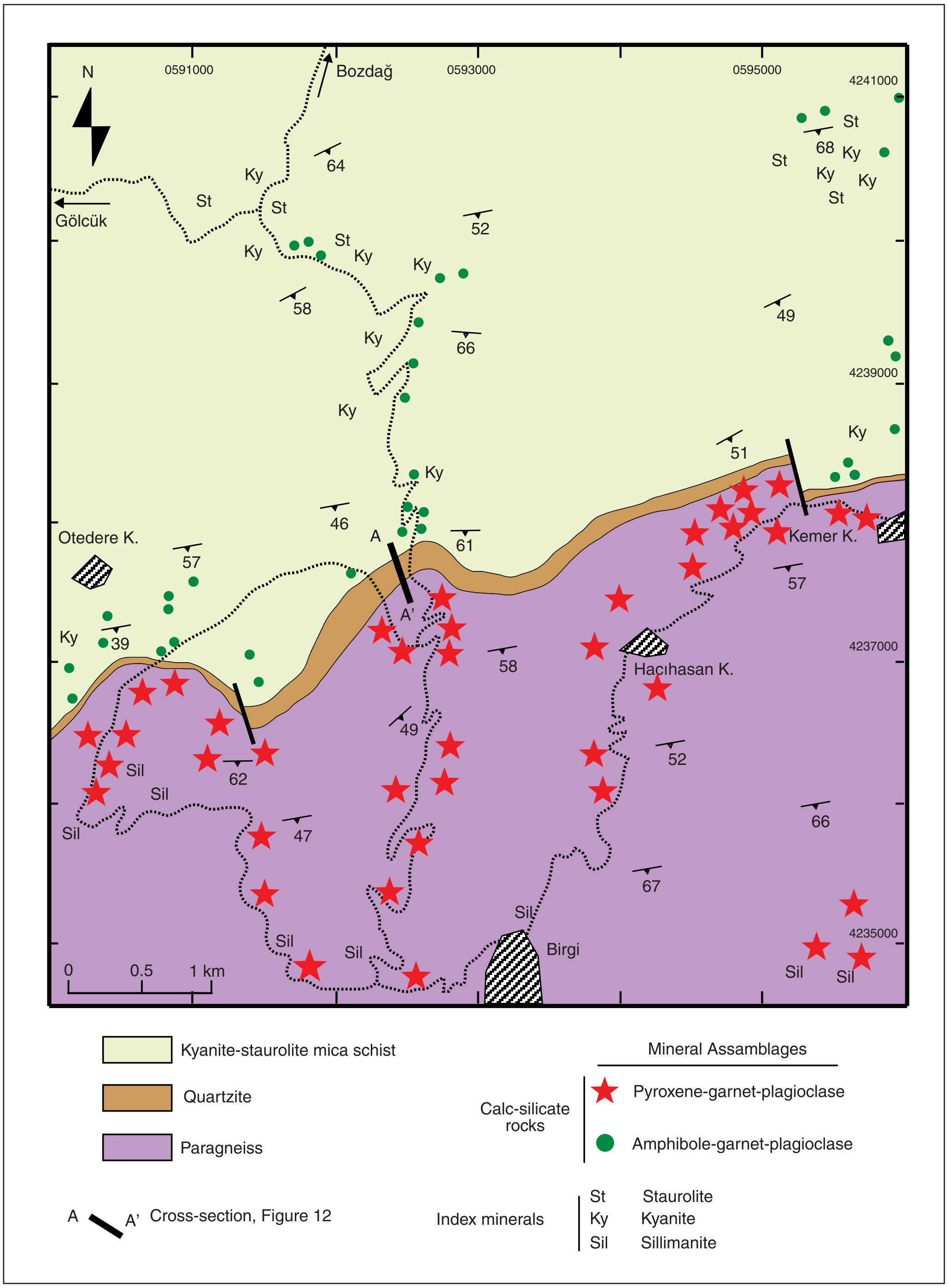

Figure 8- Geological map of Pan-African aged metaclastic sequence observed in Bozdağlar, north of Birgi. Southward dipping sequence shows an inversion in terms of both stratigraphy and the degree of metamorphism. The succession begins with garnet schists at the bottom and the degree of metamorphism reaches the degree of migmatization at uppermost layer (Dora et al., 2001) (Location is shown in figure 5).

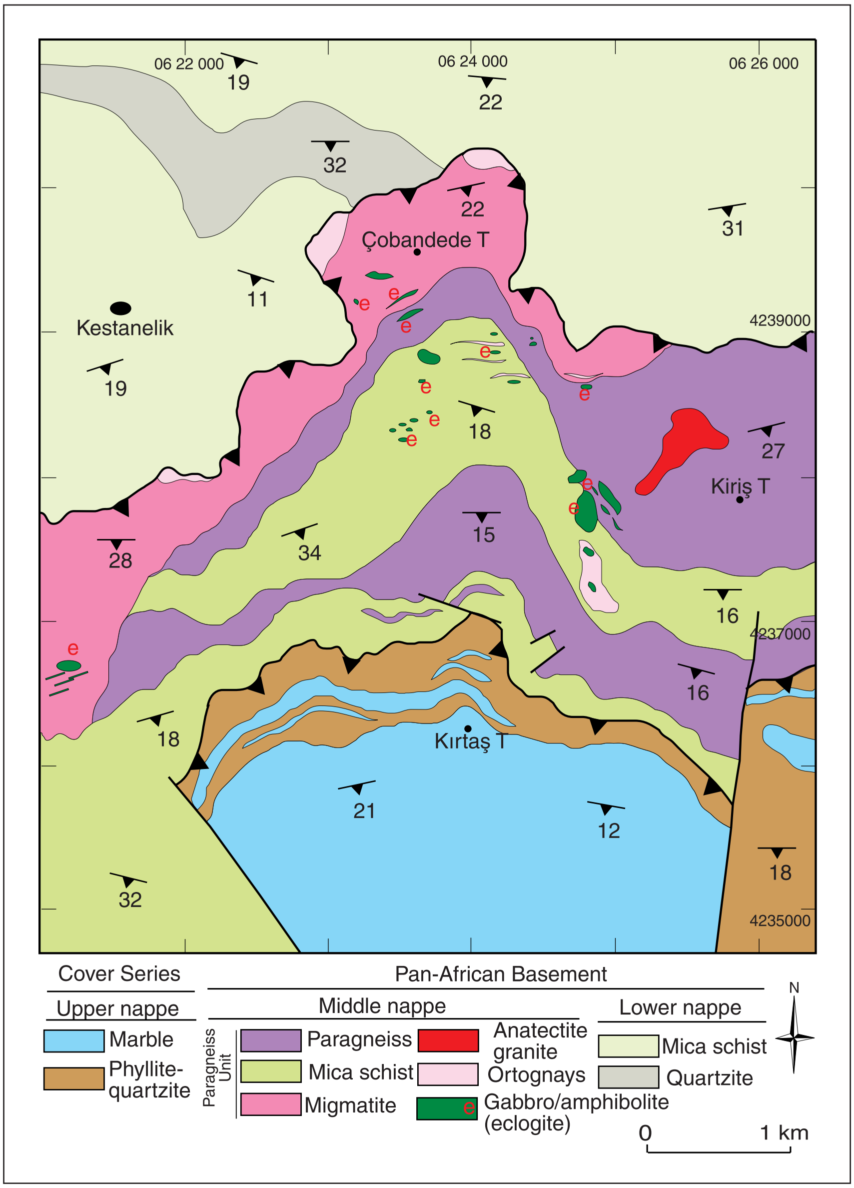

Figure 9- Geological map of paragneiss unit made up of eclogitic lens paragneiss - schist intercalation observed in Kestane River, south of Alaşehir (location is shown in figure 5).

region. Similar to other region, black and green speckles are widely encountered in paragneisses. Lower parts of the paragneiss unit were widely migmatized and cut by the intrusion of anatectic granitic masses associated with these. It is difficult to recognize these structures since migmatitic levels have been subjected to intense ductile deformation. Both in paragneiss and schist layers, there are basic intrusive rocks in vein and stock character. These are gabbroic and noritic in composition with dimensions reaching 300 meters. It was detected that related basic magmatics were transformed into eclogites along their wall zones in more than 20 locations (Candan et al., 2001).

Çine sub-massif is characterized by the presence of big sized granites transformed into augen and banded gneisses at present. Paragneisses do not crop out along the southern border of Bafa - Denizli region of this submassif. Many paragneiss exposures are observed at central and northern parts of the Massif. Paragneisses in this region are in the form of inclusions within dimensions of 7 - 8 km which floats in very big sized orthogneissic masses. On the other hand, the intensive migmatization observed in these rocks cause difficulty in gathering information about the primary internal stratigraphy of Pan-African aged metaclastic sequence (Figure 10).

To the east of Eski Çine, around Ovacık village there are many inclusions dominantly made up of schists. These schists have lateral and vertical transitions into paragneisses (Başarır, 1975). Paragneisses are observed in schists as layers with thicknesses not exceeding several hundreds of meters. However, the dimensions of inclusions within orthogneisses may reach up 6 to 7 km at southwest of Çine. These inclusions are generally formed by high grade migmatized paragneisses. Especially at east of Çine, granitic masses with sizes of 1 km are encountered within migmatites. These fine grained and massif granites consist of garnet and sillimanite and have many inclusions related to paragneisses where these granites were derived from. Dalama region located at the north-eastern part of Çine submassif is the best region which the paragneiss / schist intercalation is clearly observed (Çolak, 1985; Dora et al., 2002; Şengül et al., 2006). The region is made up of paragneiss in which orthogneiss intrusions took place, the overlying Pan-African basement made up of schist unit and of tectonically overlying Palaeozoic - Mesozoic aged cover series (Figure 11). Purple / pink colored paragneiss unit which rarely bears black speckles crops out at south of Dalama. Paragneisses consist of schist layers in variable thicknesses ranging from several meters to several hundreds of meters. Schists are transitionally in contact with paragneisses and are predominantly made up of mica schists derived from mudstones. These are accompanied by horizons of biotite plagioclase schist derived from subarkoses similar to other regions of the Menderes Massif.

Contact relationships between paragneiss and schist units.- As described above, the metaclastic sequence which is the oldest units of the Pan-African basement is divided into two sub units as paragneiss and schist units. Schist horizons are encountered in paragneiss unit as well and these two lithologies show both lateral and vertical transitions due to facies change in the primary sediment. The protoliths of schist layers within paragneiss unit and rocks in schist unit mentioned above show a great similarity. So, it makes difficult to determine the character and to find the position of the contact between these two sub units of the metaclastic sequence in many places of the Massif. Despite all these problems, this contact relationship on either regions of the Menderes Massif is clearly observed. The first of these is the region between Kula - Alaşehir. The contact between paragneiss and schist units show a lateral continuity of 15 km (Figure 6) and can be recognized in many locations. The contact between two units is defined by the latest litharenitic sandstone layer observed at the deposition. Four measured sections taken along this contact are given in figure 12a. As seen in figures, the gradation from paragneiss to schist occurs in intermediate zones of maximum 100 meters. Within this zone there is a distinct increase in intermediate schist levels. In addition, intermediate rocks which can neither be defined as paragneiss nor as schist are frequently encountered. After the latest paragneiss level, schist units are encountered with a transition defined by the gradational increase in mica schist in a narrow zone less than a meter. After this contact, it is not observed any layer which

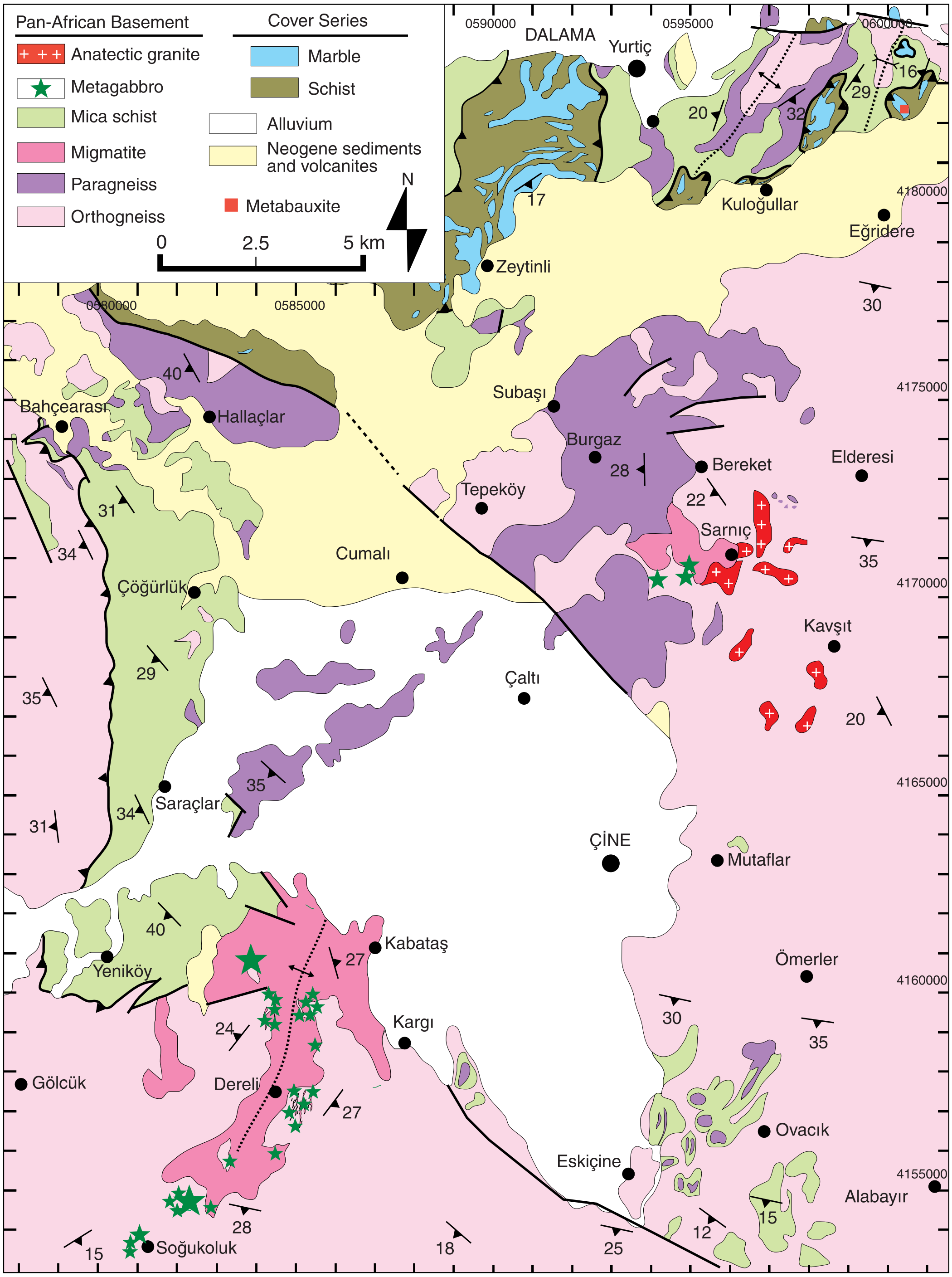

Figure 10- The general distributions of migmatizedparagneisses. These are exposed in the form of large and small inclusions in granitic gneisses at the middle and northern part of the Çinesubmassif (the map was compiled from Schulling, 1962; Başarır, 1975; Kun, 1983; Çolak, 1985; Candan, 1996*a-b*; Candan and Dora, 1998 and Şengül et al., 2006) (location is shown in figure 5).

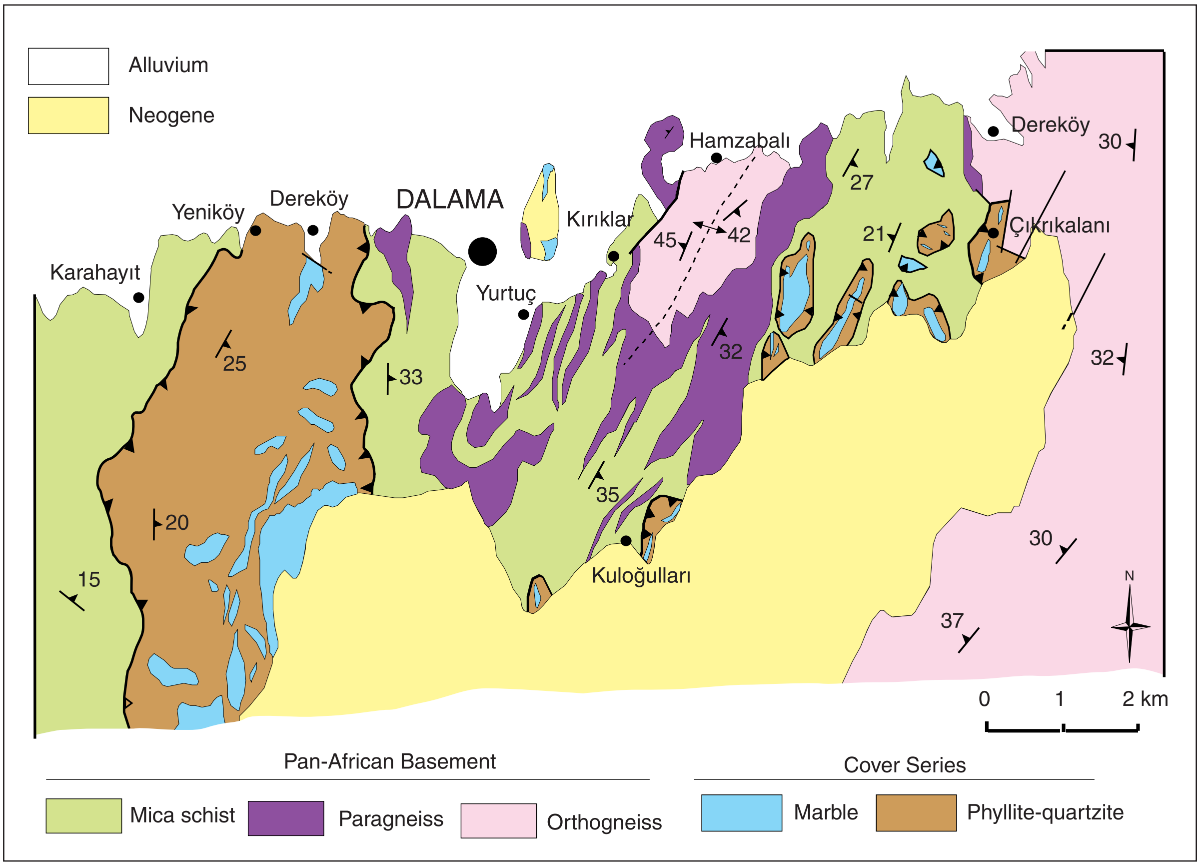

Figure 11- The geological map of Dalama surround where the paragneiss unit is observed at the northern part of Çine submassif (modified from Çolak, 1985; Dora et al, 2002; Şengül et al., 2006).

might be defined as paragneiss within the schist unit having a thickness of 2 km's in the region.

The second region where the contact relationship is markedly observed is the northern part of Birgi (Figure 8). The contact relationship in this region was previously defined by Dora et al. (2001). The contact between the two units can be traced approximately 2 km's. The distinct relationship between two overturned units can clearly be observed at a section where Bozdağ - Birgi road cuts the contact (Figure 12b). The contact is conformable and transitional in this region and consists of some differences than in Kula region. The transition from paragneiss that have homogenous internal structure with a thickness of 2.5 km into schist occurs at 20 m zone. This zone is described by widespread presence of intermediate rocks in addition to frequent intercalations of schist - paragneiss horizons. After the latest paragneiss layer 80 m homogenous schist is traversed and begins an intercalation of metaquartzite - quartz schist - mica schist. This intercalated zone is defined by white colored, pure metaquartzite layers (0.5 - 5 m in thickness). It has a maximum thickness of 170 m and can laterally be traced about 35 km up to Alaşehir. Besides, amphibolitic layers and metaaplitic sills are encountered within this intercalating sequence. In addition, emery lenses are present in quartzites in two locations in dimensions of 70 x 150 m. These rare carbonate lenses at the Pan-African basement of the Menderes Massif are located at north of Birgi, in Yılanlı Kale

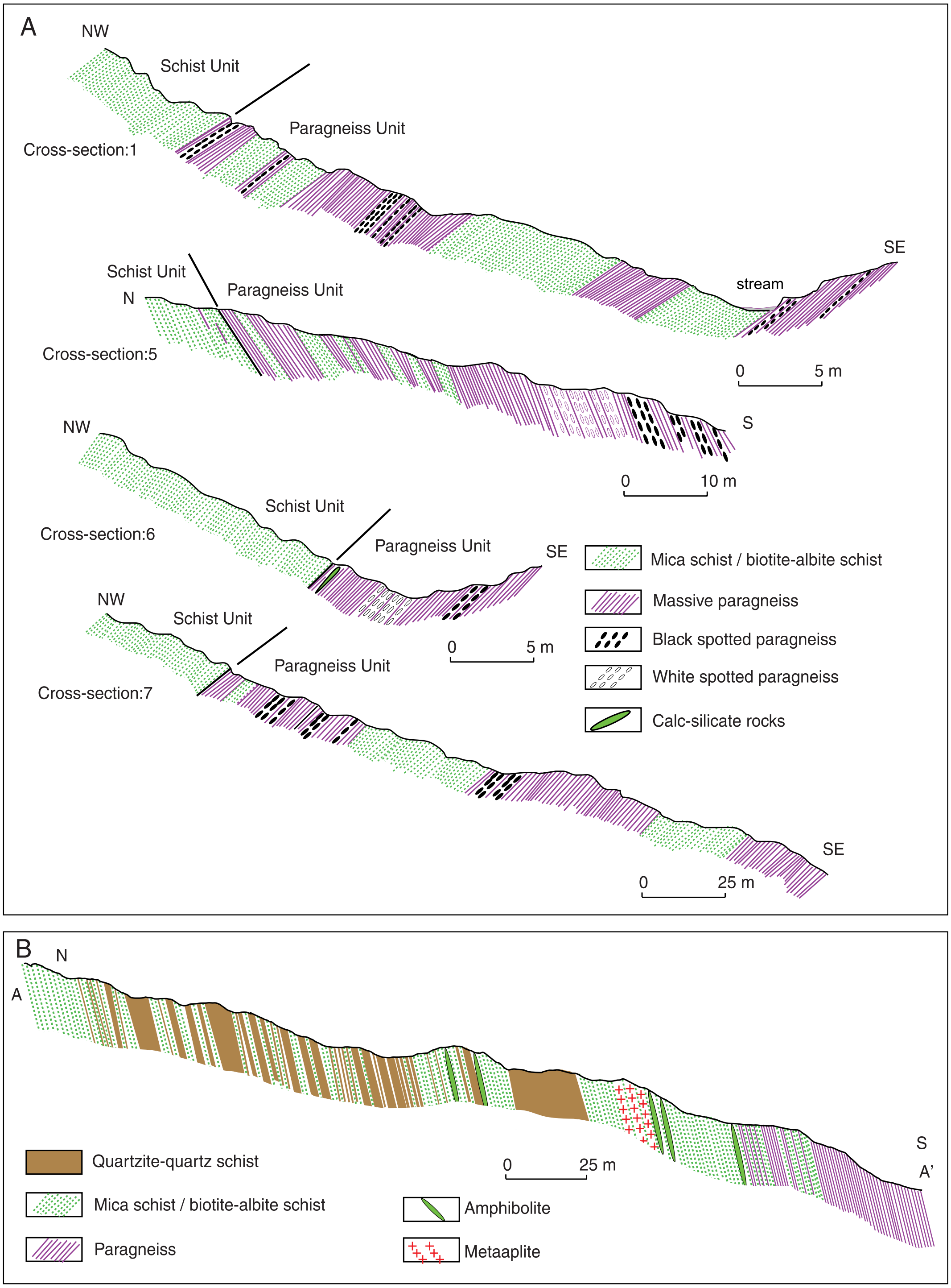

Figure 12- Geological cross sections showing conformable and transitional contact relationship between paragneiss and schist units forming the metaclastic sequence belonging to the Pan-African basement. A: south of Kula, B: north of Birgi (locations are shown in figures 6 and 8).

and at south of Alaşehir / Azıtepe. This intercalating sequence is overlain by disthene - staurolite schists derived from subarkose - mudstone intercalation that have a thickness of 6 km.

Microscopic properties of paragneisses.- Fine grained, purple colored paragneisses without speckle form the most prevalent paragneiss type in the Menderes Massif. These rocks are generally massif and gain a platelet structure in ductile shear zones. Massif structured paragneisses are characterized by their fine to medium crystalline granoblastic - polygonal textures. In petrographical studies, related paragneisses are divided into three subgroups based on the contents of sillimanite and orthopyroxene. Non sillimanite massif paragneisses composed of 'biotite + plagioclase (±orthoclase) + garnet + quartz ± muscovite ± rutile ±zircon ± opaque mineral (ilmenite)' and derived from aluminum poor sediments present a polygonal textural structure in a way to characterize the high temperature metamorphism. Fine to medium grained, dark brown biotite crystals within a groundmass of euhedral garnet and quartz (+ plagioclase) crystals show a random distribution in these paragneisses. The ratio of sillimanite may reach up 15% in massif paragneisses consisting of sillimanite. Sillimanites in these rocks could be observed in two different positions. Sillimanites which were developed by the pseudomorphic replacement of biotite crystal form the prevalent type of sillimanites. Other sillimanite formations are the fibrolitic sillimanite crystals developed at two feldspar or feldspar / quartz contacts. In these formations thin sillimanite crystals present a comb texture located at the contact of two minerals. Foliation planes developing in samples of this type which were subjected to ductile deformation are defined by needlelike sillimanite crystals showing parallel growth to each other (Figure 13 a). Orthopyroxene bearing massif paragneisses are the most rarely observed type. In orthopyroxene paragneisses extremely complex textural relations reflecting the polymetamorphism were observed. These rocks are extremely rich in sillimanite with a ratio of up to 20%. Sillimanites are generally observed in the form of pseudomorphic dwellings developed by replacement of coarse biotite crystals (Figure 13b). In addition to these, fibrolitic sillimanites are also widely observed which were developed in the form of comb between the contacts of two feldspars (Figure 13c).

Speckle bearing paragneisses are divided into three groups based on the composition of speckles. Black speckled paragneisses form the most prevalent type. These are made up of a groundmass composed of fine grained crystals and speckle structures presenting zoning composition changes in it. The general mineral paragenesis of the groundmass consisting 70% of the rock is 'biotite + plagioclase + quartz + garnet ± sillimanite (± disthene) ± muscovite ± orthoclase ± rutile ± zircon'. Speckles on the other hand are made up of 'biotite + sillimanite + garnet + quartz + muscovite'. Hundreds of thin sections were prepared and a relic that could directly define primary mineral in dwellings was encountered in none of them. It is suggested that these speckles have been derived from cordierite porphyroblasts characterizing an earlier metamorphism by their macroscopic pictures, the rarely seen primary crystal forms avoided from deformation, and the speckles developed in granulite facies conditions during multiphase metamorphic evolution of the Pan-African basement. The zoning mineral composition is the most typical properties of black speckles (Figure 13d). In this structural type, there is a euhedral garnet crystal at the center of dwelling. Garnets are also encountered as in the form of crystal assemblages showing interstitial growth. The central part is made up of garnet which is surrounded by an intermediate zone with a composition of 'biotite + sillimanite + (± disthene) + quartz'. Sillimanites in this zone are made up of extremely thin fibrolitic crystals. Since crystal sizes are very small, it is often too difficult to make a distinction between disthene - sillimanite. In some samples, the presence of late stage muscovites in thin crystals was encountered. These muscovites are thought as crystals retrograded from sillimanite which is the product of overlying retrograded metamorphism. At the outermost part of the speckle, there is a white / gray colored circumferential zone composed of 'sillimanite + quartz'.

The green speckled paragneisses are characterized by ellipsoidal speckles in 7-8 cm dimensions presenting a homogenous distribution in a fine-grained groundmass as similar to the ones with black speckles. The general mineral paragenesis of the groundmass forming the 60% of the rock is made up of 'biotite + plagioclase + quartz + garnet ± disthene ± sillimanite ± muscovite ± rutile ± zircon'. Speckles are composed of 'biotite + disthene + (± sillimanite) + garnet + quartz'. As clearly seen in figure 13, a zonal replacement texture is observed in green speckles. The main body of this structure is made up of green colored 'biotite + disthene + garnet + quartz (±muscovite)' with a homogenous distribution. The homogenous ensemble forming the main body is surrounded by a partly developed intermediate zone made up of a coarse single biotite crystal. This biotite zone can easily be distinguished from other fine grained biotites forming the body with its dark red colors. In macroscopic observations, it is markedly seen that speckles are surrounded by a white colored outer zone. Although it can not be discriminated by distinct borders, this mica poor outer zone originates from relative enrichment of quartz and feldspar.

White speckled paragneisses are described by the formations of ellipsoidal shaped, white colored speckles with dimensions of 0.5 cm within a pink colored fine grained groundmass. In addition to biotite, the muscovite is also encountered in fine grained matrix. The mineral composition of the matrix that has distinct foliation is 'biotite + quartz + muscovite + plagioclase (± garnet)'. White colored dwellings are made up of 'muscovite + quartz + garnet + (± sillimanite ± biotite)'. At centers of white dwellings garnet takes place made up of one or two crystals (Figure 13f). In subhedral garnets diffuse quartz inclusions are encountered. In some dwellings one or two biotite crystals may rarely accompany garnets. The rest of the dwelling is made up of fully quartz and muscovite. In some dwellings the presence of irregular sillimanite patches was determined. Textural data indicate that white colored mineral dwellings are formed by the replacement of the muscovite with sillimanites in former black speckles, as a result of the overlying low temperature metamorphism.

Schist unit

As explained above, the metaclastic sequence is formed by paragneiss with schist intercalation and the overlying schist unit. Schists within these two units show big similarities with each other in terms of source rock and mineral compositions. Therefore, to avoid repetition, the all schists in metaclastic sequence were considered under one title.

Macroscopic properties of Schists and their general distributions.- Schists form the predominant rock type in the Pan African basement. Almost all parts of NE-SW trending Gördes Demirci highlands with dimensions of 60 x 10 km are made up of partly migmatized schists in Demirci Gördes sub massif at north. In distant sections of schists from migmatization, the disthene, staurolite and garnet porphyroblasts reaching 4 - 5 cm in dimensions are pervasively encountered (Candan and Dora, 1993). The size of disthene crystals reach up 40 - 50 cm in quartz rich pegmatoids that show parallel growth to foliations of schists. It is considered that these pegmatoids were formed by the emplacement of Si and Al which were migrated from the country rock along the foliation plane during metamorphism (Candan, 1991). Sillimanites accompany these minerals at lowermost parts of schist series. These biotite and muscovite rich schists were dominantly derived from claystones.

Ödemiş - Kiraz sub massif is made up of tectonic layers belonging to Pan African core and cover series overlapped on each other. The layer

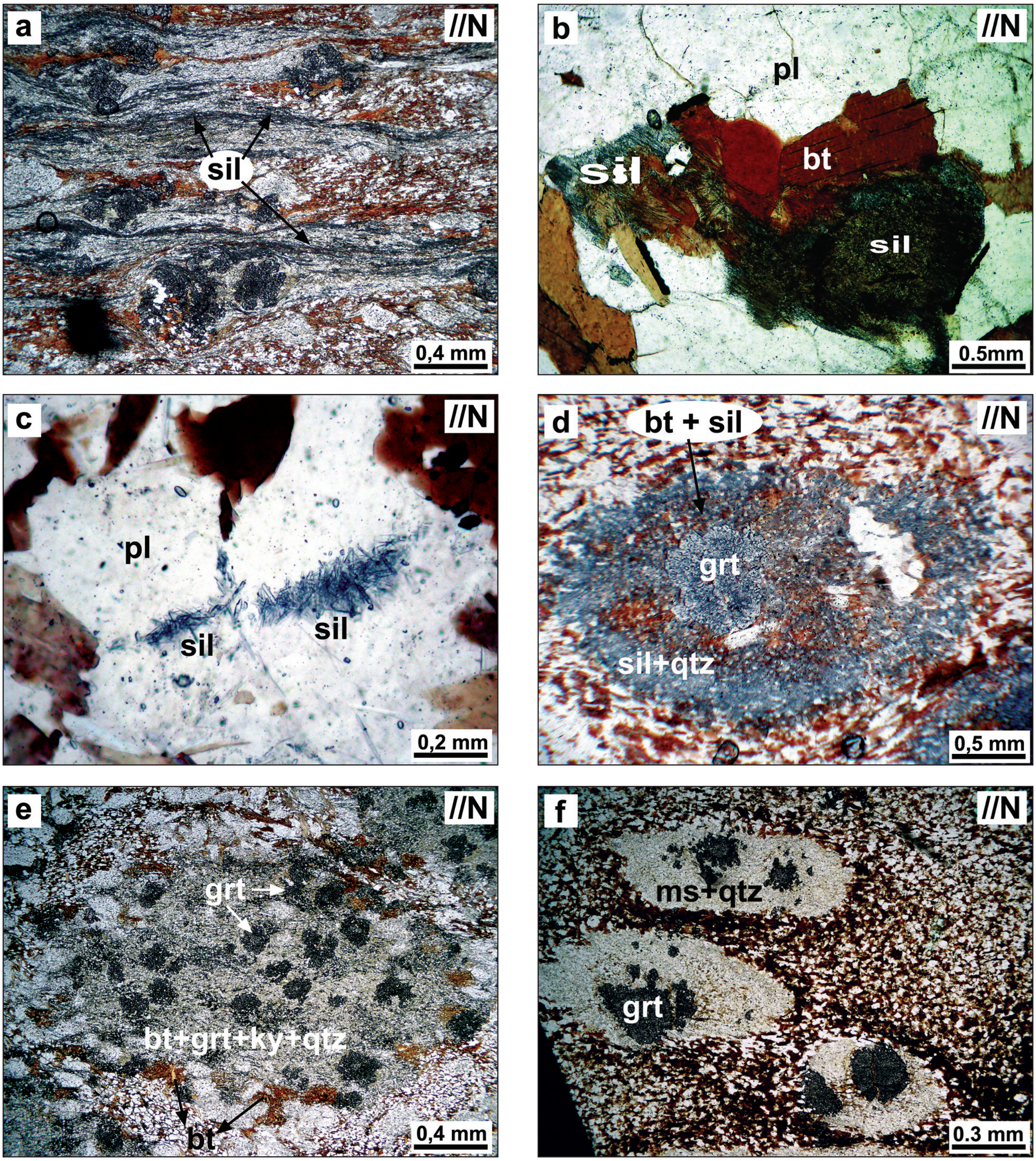

Figure 13- A: Sillimanite rich paragneissessubjected to ductile deformation. Foliation plane is defined by sillimanite needles. B: Sillimanites developed by rthe replacement ofbiotite crystals, C: Sillimanite crystals developing at walls of feldspar. D: Black speckles made by the assemblage of upper amphibolite facies that present mineralogical zoning and replaced cordierite porphyroblastswhich is the granulite facies product. E: Zonal interior structures of dwellings in green speckled paragneisses. F: Microscopic views of white speckles derived by the replacement of sillimanite in black speckles by muscovite (Bt: biotite, sil: sillimanite, pl: plagioclase, grt: garnet, qtz: quartz, ms: muscovite, ky: disthene).

which is observed in Aydın Mountains crops out in a region of 15 x 90 km and is fully composed of schists. This schist sequence has homogenous internal structure and was derived from the intercalation of mudstone - subarkosic sandstone. The most characteristic lithology of the schist unit, the biotite - albite schists were produced from subarkosic sandstones. These are also defined by the presence of single and coarse biotite crystals showing homogenous distribution within a white colored quartz feldspatic groundmass. Petrographical / petrological data indicate that this sequence which is composed of biotite and garnet schists is in overturned position in terms of the degree of metamorphism (Okay, 2001). Bozdağlar which form the northern part of Ödemiş - Kiraz submassif is made up of paragneisses and of conformably overlying schist units (Figure 3). This schist series are derived from a source rock similar to that of Aydın Mountains. However, these schists consist of disthene and staurolite minerals defining lower - middle amphibolite facies conditions. Petrographic data show that schist series as well are in overturned position (İzdar, 1971; Dora et al., 2001). The abundant presence of layers composed of 'hornblende - garnet - quartz - plagioclase' is one of the most characteristics of schist unit. Barbol (2005) stated that these layers which are described by the presence of amphibolites were transformed into boudinaged calcsilicates consisting of pyroxene within paragneisses as a result of the increasing degree of metamorphism.

Pan African units within Çine submassif are made up of metaclastics cropping out in narrow areas and of gigantic orthogneisses intruding into them. Schists belonging to metaclastic sequence observed in Dalama and to the west of Karıncalı Mountain are generally composed of garnet - mica schist and biotite albite schist (Kun, 1983; Şengül et al., 2006). Despite that, schists located at west of Karacasu and south of Bozdoğan consist of rarely observed lithologies in the remnant part of the Menderes Massif. These rocks define the uppermost levels of the schist unit and present a regular schist deposit at south of Bozdağ (Figure 3). At upper levels of schists derived from the subarkose - claystone intercalation black colored quartzite interlayers are observed. These quartzite layers which have variable thickness in 5 - 50 cm are intercalated with mica schists in a 1 km zone and can laterally be traced 3 km's. Similar black quartzite layers are encountered at south of Tire and south of Adagide as well. This deposit is conformably and transitionally overlain by quartz rich schists. These rocks form uppermost layers of schist unit reaching a thickness of 2 km. These are silver to white in color and have varying muscovite / quartz ratios. These rocks were derived from quartz and / or clay rich sediments and were made up of muscovite schist and muscovite - biotite - quartz schists with vertical and lateral transitions in cm scale. In addition to these, schist unit of the Pan-African basement lies as a thin line along the contact of orthogneiss - schist of Çine submassif between Bafa Lake and Yatağan. These schists show an intrusive contact relationship with orthogneiss and are predominantly made up of biotite - albite schists derived from subarkosic sandstones.

Microscopic properties of Schist unit.- As also described above, primary sediments of schists of the Pan-African basement can be divided into 3 main lithologies although these consist of continuous interlayer. These are; 1) subarkosic sandstones, 2) quartz rich sandstones and 3) mudstones.

Rocks originating from subarkosic sandstones form 'biotite - albite schist' and 'sillimanite - garnet - biotite - albite schists'. The general mineral composition of these plagioclase rich rocks was determined as 'quartz + plagioclase (albite) + biotite + garnet ± muscovite ± sillimanite ± rutile ± ilmenite ± zircon'. A continuous schistosity, made up of homogenously distributed coarse individual biotite crystals, is observed in these rocks (Figure 14a). Garnets in biotite - albite schists are generally in the form of subhedral small crystals. Rocks which show lateral transitions with paragneisses consist of very fine crsytalline fibrolitic sillimanite developed between the two feldspar contacts.

Quartz rich sandstones were transformed into 'muscovite schist / garnet muscovite schist' and 'muscovite - biotite - quartz schist' as these sandstones had been metamorphosed under conditions of upper greenschist facies. Main components of these rocks are quartz and muscovite. Muscovite and quartz ratios in these rocks vary between 30 - 60% and 40 - 70%, respectively. Besides, biotite, garnet and hornblende are observed in these rocks as well. Hornblendes form porphyroblasts with size of 3 cm and show poikiloblastic texture because of dense quartz inclusions.

Mica schists originating from mudstones are the most widespread schist type in the Massif and show quite different compositions as a function of degree of metamorphism. These schists consist of ensembles of Barrowian type medium pressure metamorphism and define development conditions extending from biotite to sillimanite. Biotite schists which are observed at south of Aydın Mountains and forming the lowest graded rocks of the deposit are composed of 'quartz + plagioclase + biotite + muscovite ± zircon'. By the addition of garnet to this assemblage, it is passed through the most prevalent schist type which is garnet mica schists. These rocks are composed of 'quartz + plagioclase + muscovite + garnet + biotite ± zircon'. Polyphase growing structures are pervasively observed reflecting the polymetamorphic stage in garnets (Figure 14b,c). Staurolite which defines the transition into almandine - amphibolite facies conditions is widely observed in Bozdağlar and around Demirci - Gördes. These rocks are 'quartz + plagioclase + staurolite + garnet + biotite + muscovite ± zircon ± apatite' in composition and majority of staurolites are in syn tectonic structure (Figure 14d). Disthene schists are appeared in ensembles in which staurolite disthene accompanies and staurolite disappears (Figure 14 e). The general mineral composition of these rocks can be given as 'quartz + plagioclase + disthene + garnet + biotite + muscovite ± zircon ± apatite'. Disthene crystals which might reach 5 - 6 cm in size give a characteristic porphyroblastic texture. Schists which intercalate especially with paragneisses include sillimanite. The ratio of these minerals is less than 1% and observed in the form of thin, fibrolitic crystals between the contacts of two feldspars. The mineralogical contents of these rocks are 'quartz + plagioclase + garnet + biotite + sillimanite ± zircon ± apatite'.

Migmatization and anatectic granite.- The metaclastic sequence of the Pan African basement consist of prevalent data related to partial melting and the development of anatectic granite in many places of the Massif. Schists with disthene that belong to schist unit cropping out in large areas at north, around Gördes - Simav region has been known for many years (Ayan, 1971; Dağ and Dora, 1991; Akdeniz and Konak, 1979). These rocks are defined as layered migmatites and are intruded by many pegmatites and granites. However, in central and southern parts of the Menderes Massif, all migmatized rocks were derived from the intercalation of paragneiss - schist which corresponds to lower layers of the metaclastic sequence (Figure 15a). The relation of migmatization - granite development is best observed in region between Alaşehir - Kula (Figure 6). The migmatitic front in the region obliquely cuts primary stratigraphy of paragneiss unit. Migmatization begins with ptigmatic leucocratic zones and continues until the development stage of anatectic masses with dimensions of 1- 2 km's. Great majority of these granites makes transitional contacts with migmatites in a way that shows in situ crystallization. It is still possible to observe partly assimilated relics of migmatite even at highest graded melted parts of these masses. Various migmatite types are widely observed in the region. Masses formed by the ensembles of migmatite and / or migmatite - anatectic granite may be seen as non assimilated inclusions with dimension of 6 km, in gigantic orthogneiss intrusions (Figure 6).

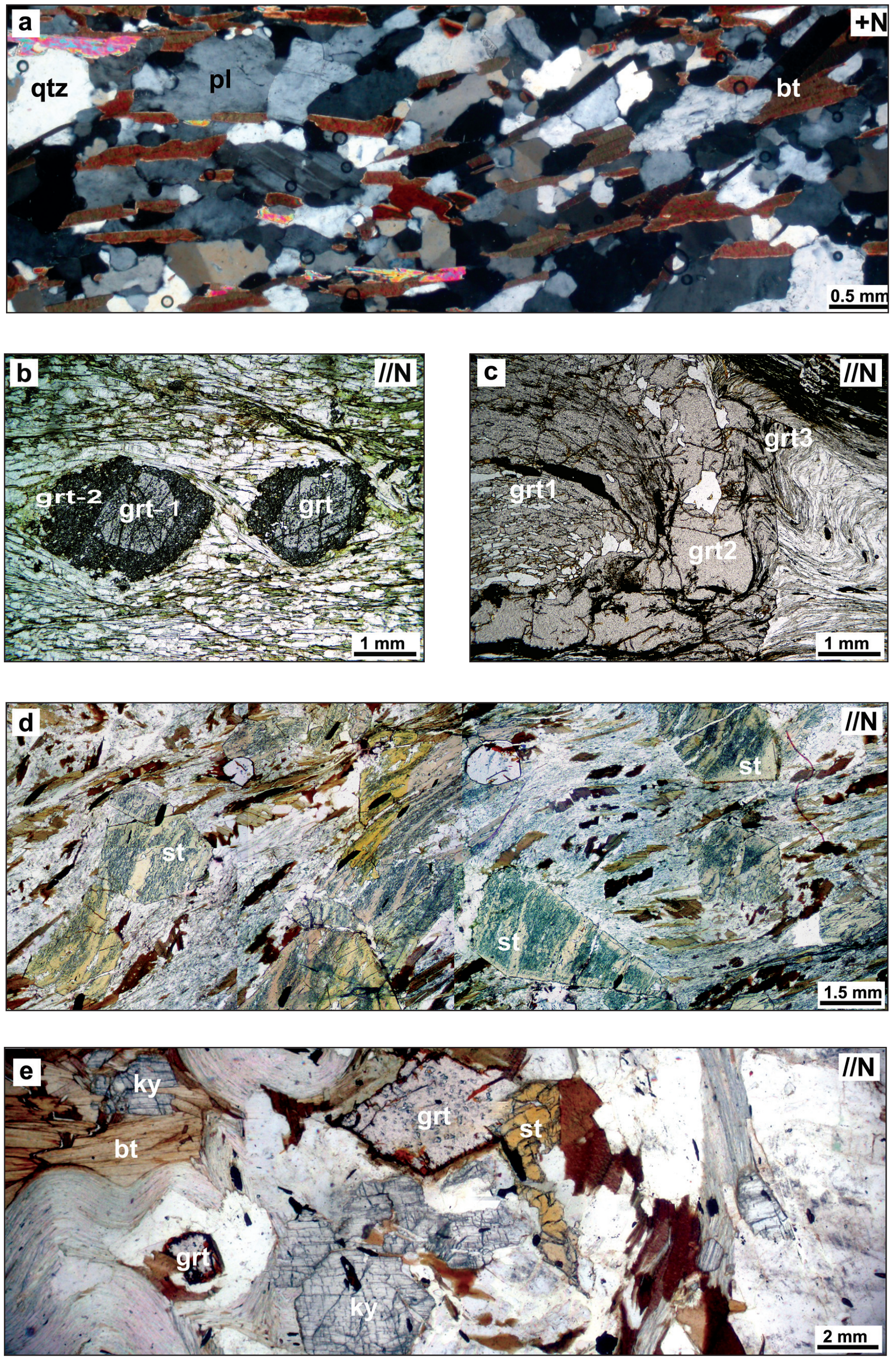

Figure 14- A: biotite - albiteschists made up of homogenously distributed single biotite crystals within a quartz and feldspar rich groundmass, B-C: Zoning garnet crystals defining polyphase growth and recognized by the change in quartz inclusion proportions, D: Stauroliticporphyroblasts showing syntectonic growth in schists, E: Assemblage of 'staurolite + disthene + garnet' in mica schists (grt: garnet, st: staurolite, ky: disthene, bt: biotite, qtz: quartz, pl: plagioclase).

Migmatites and associated granites are pervasively observed in Ödemiş - Kiraz submassif as well. These cropping out rocks around Ödemiş - Kiraz towns are only observed in tectonic layer consisting of metaclastic sequence of the Pan-African basement within the napped structures of this submassif. The migmatization generally occurs at lower parts of the paragneiss unit. It exposes as in broken focals with a lateral continuity not exceeding 7 - 8 km's, since the deposit is cut by thrust faults. Very different structural types were developed in migmatites similar in Kula region. Migmatites are accompanied by big masses of anatectic granites and more than 10 masses of granite were determined in this region. The biggest one of these granitic masses is located between Birgi - Kiraz within a size of 6 x 3 km's. This fine grained, rock in granoblastic texture, largely shows a massif structure (Figure 15b). Despite that, this rock shows a high graded mylonitization along rarely ductiled shear zones which cut the mass within thicknesses ranging from one to tens of meters. These granites microscopically consist of garnet crystals with a size of 4 cm in addition to sillimanite content (Figure 15c). However, some granitic masses at the southern part of Kiraz were completely transformed into strongly lineated and foliated ultra mylonites (Figure 15d).

Great majority of paragneiss exposures show high graded migmatization in Çine sub massif. These migmatites are best observed at south / north of Çine and at south of Karpuzlu. Migmatites which are accompanied by masses of anatectic granite with a size of 1 km are observed in the form of inclusions generally floating in intrusions of gigantic orthogneiss. The size of these inclusions reach up 5 km's (Candan, 1996b). Both migmatite and granites associated with them have structural, textural and compositional properties in a way that reflects a common origin similar to Ödemiş, Kiraz and Kula regions.

Metamagmatic rocks

Partly migmatized metaclastic sequence belonging to Pan-African basement of the Menderes Massif is intruded by widespread acidic / basic magmatics associated with the Pan-African Orogeny. The distinguishing features of these magmatics are summarized below.

Acidic metamagmatics

In a broad sense, orthogneisses which are the well known rocks of the Menderes Massif have been described as 'augen' or as 'granitic' gneiss in many studies. Besides, the same rocks have been named in different ways in order to define the degree of metamorphism (sillimanite gneiss), properties of deformation (mylonitic gneiss) and source rocks (orthogneiss). Evidences obtained in recent years have shown that these intrusions can be gathered in to 3 groups based on mineralogical compositions (Bozkurt, 2004; Dora et al., 2005). The type and the amount of the mafic mineral form the main parameter in this classification. Within this scope, orthogneisses can be classified as; 1- biotite orthogneisses, 2- amphibole orthogneisses and 3- tourmaline leucocratic orthogneisses. These rocks are the differentiation products of the same Pan-African aged magmatic activity following each other. The structural, textural and mineralogical properties of these are given below.

Biotite orthogneisses.- This type is the widely observed orthogneiss type in the Menderes Massif. These coarse crystalline rocks can be divided into 2 sub types according to primary textural properties of the granite which these were derived from. The most prevalent type is the porphyritic granite in porphyry texture which was originated from 6-7 cm euhedral orthoclase crystals within a medium to fine grained groundmass. This groundmass is made up of quartz and plagioclase. These rocks traverse into blastomylonitic, augen / banded orthogneisses showing strong foliation and lineation developed

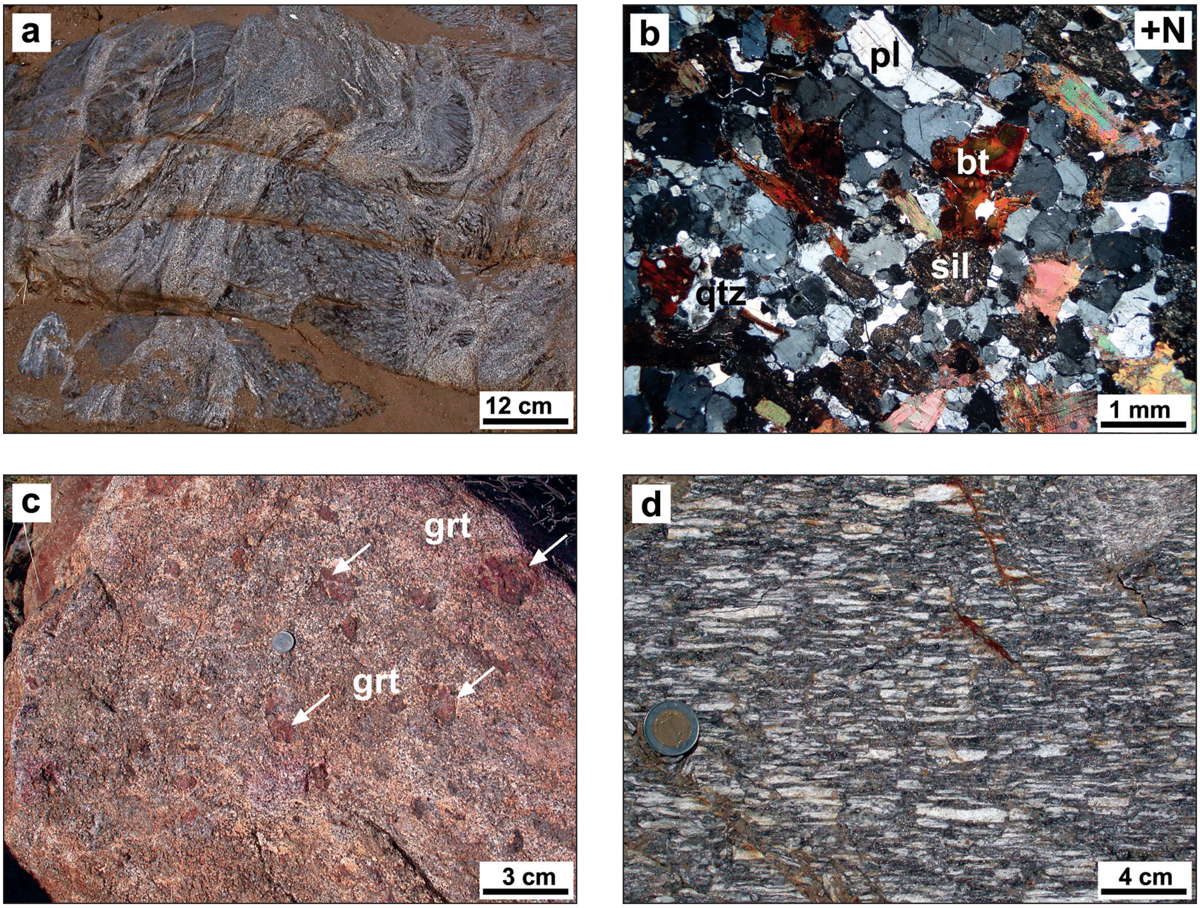

Figure 15- A:migmatites derived from paragneisses observed in Kula / Selce area, B: granoblastic texture observed in anatectic granites associated with migmatites, C: garnet porphyroblasts observed in anatectic granites (Çine), D: biotite and feldspar lineations in anatectic granites which were subjected to ductile deformation in Kiraz (pl: plagioclase, sil: sillimanite, grt: garnet, qtz: quartz).

along the shear zones under ductile deformation. Shear bands in this deformation prefer especially equally sized quartz rich groundmass whereas, coarse orthoclase porphyroblasts transform into porphyroclastics surrounded by recrystallized orthoclase zones (Figure 16a). The second type of these rocks is medium to coarse crystalline, granoblastic in texture, equally sized granites. These are described as granitic gneiss in undeformed sections. However, these rocks turn into banded gneisses in ductile deformation zones. The ratio of biotite in both types varies in between 15 - 25 %. Blastomylonitic type of these rocks is easily recognized with its strong biotitic lineation. These orthogneisses are observed in the form of plutons that have intruded each other with diameters of 8 - 10 km in the Massif. Country rock fragments widely observed in orthogneisses clearly reveal intrusive character of intrusive contacts of these rocks (Figure 16b).

Amphibole orthogneisses.- These are granoblastic in texture and fine to medium crystalline massif rocks described by the presence of hornblende and garnet porphyroblasts. These rocks are observed only in Karıncalı Mountain and around Buldan area located at north, in the Menderes Massif. These masses are stock in character within diameters of 500 - 600 m and have been intruded into augen gneisses and schists of the Pan-African Basement. Dark green colored and non oriented amphibole crystals have a homogenous distribution in massif orthogneiss. These crystals have a ratio of 20% and a dimension of 1 - 2 cm (Figure 16c). Rocks have been transformed into ultra mylonitic gneisses that could be named as gray to silver colored hornblende schist along internal shear zones and the walls of masses.

Tourmaline leucocratic orthogneisses.- In studies performed around Çine submassif, it has been established that gray to white colored leucocratic orthogneisses consisting of tourmaline (±biotite) as mafic mineral spreads in very large areas (Bozkurt et al., 2006; Dora et al., 2005). These rocks are completely white in color and the ratio of tourmaline may reach up 20%. Tourmalines are generally in the form of individual crystals having a size of 2 - 3 mm and as dispersed in the texture. In addition to this, tourmalines may be observed in the form of nodules as 6-8 cm in length and tourmaline minerals as 2 - 3 cm in length which is the characteristics of these orthogneisses. Leucocratic orthogneisses show variable contact properties ranging from transitional to sharp intrusive relationship with biotite rich augen / granitic gneisses. These leucocratic rocks can be divided into 3 groups among them based on the shape of their masses, textural properties and mineralogical compositions. These are; 1) tourmaline leucocratic orthogneisses observed in the form of plutons, 8 - 10 km in diameter, 2) leucocratic porphyritic metagranites derived from vein or stock like small intrusions and 3) leucocratic metaaplites defining the latest stage which shows distinct vein character.

Tourmaline leucocratic orthogneisses are distinctive with their marked white colors and relatively more massif structures. These are characterized by high tourmaline (10 - 20 %) and muscovite contents especially despite the non presence of biotite (max. 5%). Leucocratic orthogneisses may show some textural differences due to magmatic facial changes in them. These are; 1) leucocratic orthogneisses with a mealy view, defined by gray colored heaps made up of muscovite (±tourmaline) heaps, 2) tourmaline leucocratic orthogneisses, granoblastic in texture made up of equally sized feldspar crystals (Figure 16d) and 3) porphyritic leucocratic orthogneisses consisting of coarse orthoclase phenocrystals within a gray colored, relatively fine grained quartz feldspatic groundmass. Leucocratic orthogneisses are observed in very large areas especially between Bafa - Bozdoğan, in Çine submassif in the form of gigantic plutons interferencing with each other. Leucocratic orthogneisses show distinct intrusive contact relationship with schists (Figure 16f) both derived from biotite rich, augen orthogneisses (Figure 16e) and subarkosic sandstones. These belong to the schist unit of the Pan-African basement forming the country rock at all points along 150 km gneiss - schist contact. On the hand the related granitic intrusions are emplaced in schist and biotite rich augen gneisses in the form of stocks reaching up 3 - 4 km in size. These rocks are located at 100 - 150 km to the north of this region, south of Koçarlı, the northern part of Karıncalı Mountain, south of Kula and north of Sarıgöl. This data show that intrusions of leucocratic orthogneiss can not be restricted with any region of the Massif.

Leucocratic porphyritic metagranites are exposed in the form of amorphous masses, 50 - 150 meters in dimension or in lensoidal structures within leucocratic orthogneiss intrusions. It is considered that fine grained, white colored rocks which are transitionally in contact with tourmaline leucocratic orthogneisses were stock / vein type products of the leucocratic magmatic activity in many places. The pervasive presence of tourmalines in many samples supports that these have a primordial relationship with tourmaline leucocratic orthogneisses.

Leucocratic metaaplites form the latest stage of the Pan-African age acidic magmatic activity. These rocks are substantially composed of 'albite + quartz + (± tourmaline ± rutile) and are generally observed in the form of veins not exceeding several meters in thickness. These rocks are in white color and have also distinct or transitional contacts with tourmaline leucocratic orthogneisses. Despite that, thicknesses of these vein rock types which are managed as albite deposits in Çine sub massif may reach 100 meters in thickness and 4 - 5 km in length. These vein rocks can be observed in a very large region from Selimiye-Bafa surround at the south, to Karpuzlu at the north and to the Karıncalı Mountain at the east. Leucocratic metaaplites are described by; 1) consisting of tourmaline nodules in zonal structure (Figure 16 g,h), 2) their fine granularity, 3) being completely white in color, 4) consisting of pink colored titanium rich zones made up of rutile and sphene around the circumference of many veins throughout the Massif.

Basic metamagmatics

The presence of basic metamagmatics in the Menderes Massif (metagabbro - metanorite) has been known since Schuiling (1962). In the following years, around Çine, Ödemiş-Tire and at south of Kula, the widespread presence of similar composite basic magmatics have been determined (Kun, 1983; Kun and Candan, 1991; Candan, 1992, 1994, 1996*a,b*). The basic geological properties of these rocks closely related with eclogites (Candan et al., 1994, 2001; Oberhänsli et al., 1997) are given below within the framework of sub massifs.

Gabbroic rocks in Çine sub massif are densified at southwest of Çine and around Karıncalı Mountain. Hundreds of metagabbroic exposures have been determined at southwest of Çine (Kun, 1983; Candan, 1996a). Great majority of these rocks are approximately in dimensions of 2 x 30 m and are in vein or lensoidal masses. The sizes of stock type masses rarely reach 300 meters. The country rock is made up of migmatized paragneiss and augen / granitic gneisses. Metagabbros show quite different textural features ranging from fine grained ophitic texture (crystal sie 2-3 cm) to holocrystalline granoblastic texture (Figure 17a). It is extremely difficult to observe metamorphic characters of these massif rocks on the field. Only in their peripheral zones and rarely in their internal shear zones, transformations into amphibolites not exceeding 20 - 30 meters in thicknesses can be observed (Figure 17b). Garnet occurrences and replacement of pyroxenes by amphibole widely develop along these zones (Figure 17c). These rocks are made up of biotite gabbro and olivine gabbro and their general mineral composition is 'plagioclase + clinopyroxene + biotite + ilmenite (± olivine) (Figure 17d).

Basic magmatics around Karıncalı Mountain consist of more widespread metamorphic effects than in Çine region. Hundreds of vein rocks have been determined in the region not exceeding 50 m in size. The size of masses may very rarely reach 1 km. Basic rocks in the region are predominantly formed by garnet amphibolites. Dark green colored garnet porphyroblasts may reach 0.5 cm in size and are composed of 'hornblende + plagioclase + epidote / zoisite + sphene ± garnet'. Small sized vein rocks have totally been transformed into amphibolite. These formations in big masses whereas, densify around peripheral zones. Basic magmatics in the region in undeformed zones have completely preserved coarse crystalline holocrystalline textures and have statically been recrystallized. These rocks are named as amphibolitic metagabbro and while primary clinopyroxenes were consumed by hornblende the plagioclases were consumed by clinozoisite too.

The most dense gabbro formations are observed at the north of Birgi (Candan, 1996*b*) south of Kiraz (Candan et al, 2001) and at the southwest of Tire in the Ödemiş - Kiraz submassif. The presence of eclogite zones in their

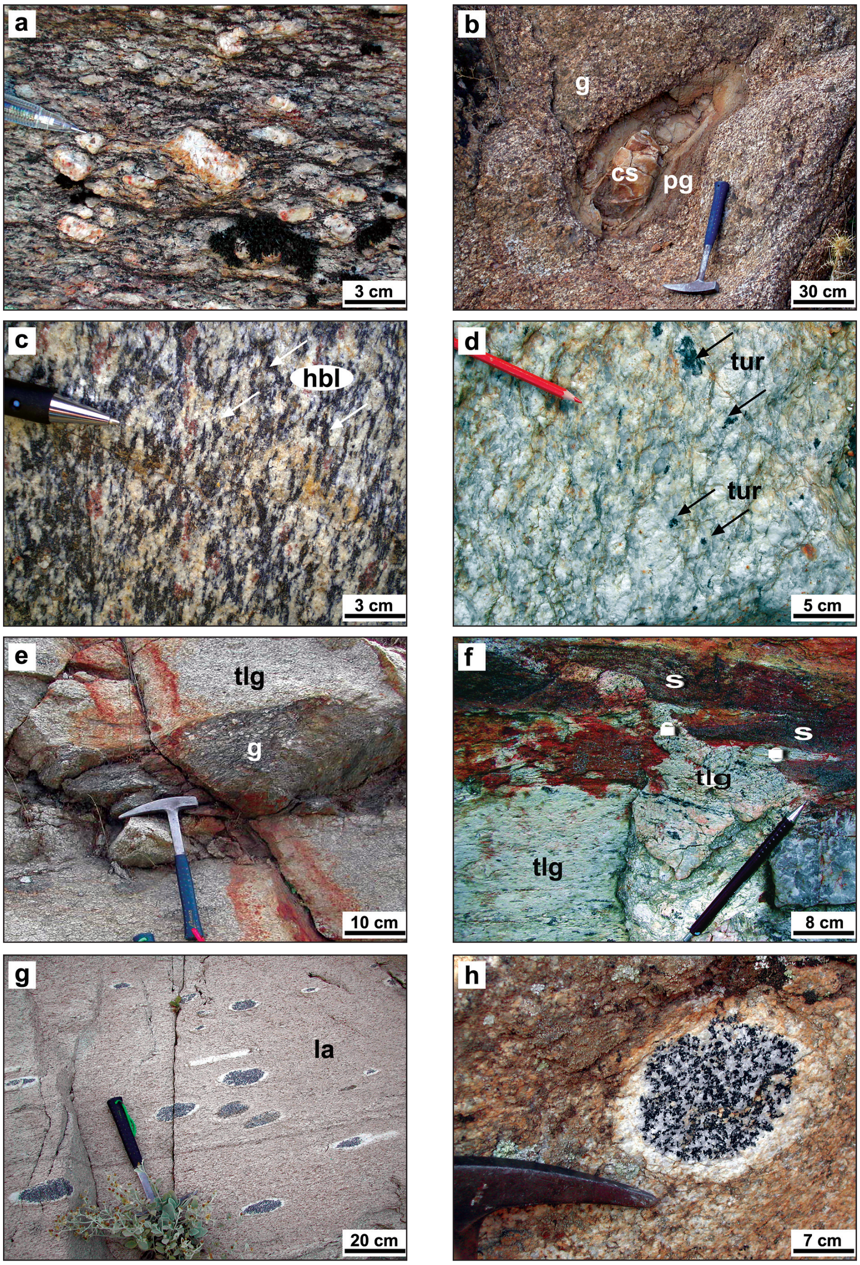

Figure 16- A: Blastomyloniticbiotiteorthogneiss forming by the ductile deformation of source granitic rock with porphyroblastic texture (Çine - Selce), B: paragneiss and calcsilicate inclusions within biotite-orthogneisses (Alaşehir / Karacalar), C: Amphibole orthogneisses enriched by hornblende crystals, D: Equidimensional, granoblastic textured, tourmaline rich leucocratic orthogneisses (Karıncalı Mountain), E: Distinct contact relationship between biotite rich orthogneiss and tourmaline leucocratic orthogneisses (Çine - Selce), F: Preserved primary intrusive contact relationship between tourmaline leucocratic orthogneiss and schist, G: Leucocratic metaaplites made by zoning tourmalinite nodules within fine grained quartz feldspatic groundmass (north of Selimiye), H: Close up view of tourmalinite nodules (Çine - Selce) (g: biotiteorthogneiss, cs: calc silicate, pg: paragneiss, tur: tourmaline, la: leucocratic aplite, hbl: hornblende, s:schist, tlg: tourmaline leucocratic orthogneiss).

circumferences is the basic characteristics of metagabbros. To the north of Birgi, around Cevizalan village 3 stocks with a size of 1.5 km and many vein rocks are observed. In one of them, relics of eclogite have been detected around circumferential zones of amphibolite and along internal shear zones (Candan, 1996*b*). Inner parts of stocks have been very well preserved thus, it is macroscopically impossible to detect the effects of metamorphism. Rocks in the region are made up of olivine gabbro and have a mineralogical composition of 'olivine + plagioclase + clinopyroxene + ilmenite ± biotite'. In sections where gabbros were subjected to ductile deformation the mylonitic texture has been developed widely (Figure 17e). The metamorphism effects in these sections can be described by formations of garnet and multi coronal structures developed around olivine crystals. In southeast of Tire numerous metagabbro stocks have been determined in a clippe, 5 x 5 km in size reflecting metamorphism under lower crust conditions (Çetinkaplan, 1995). Sizes of these stocks are 300 x 500 m and around these stocks well preserved eclogitic - metagabbroic zones are observed (Candan et al., 2001). Metabasic rocks in the region have a composition varying in between gabbro - norite. The mineralogical compositions of norites and gabbros are 'plagioclase + orthopyroxene + biotite + ilmenite' and 'plagioclase + clinopyroxene + olivine + biotite + ilmenite' respectively.

The biggest metagabbroic mass is observed at north of Alaşehir, in Yahyaalcı village in Demirci Gördes submassif (Candan, 1994). This stock is in a size of 300 x 200 m and is accompanied by many vein rocks. Towards the center of stock continuous textural and mineralogical variations are observed related to polyphase metamorphism. Badly preserved eclogite relics are present within the amphibolitic circumferential zone of the stock. At the center, gabbro has been statically recrsytallized and primary holocrystalline texture has totally been preserved in low tensile regions. Transformations of pyroxenes into amphibole, the consumption of plagioclase by clinozoisite and partial garnet coronas around magmatic phases are the fundamental metamorphic effects.

THE CONTACT RELATIONSHIP BETWEEN THE PAN-AFRICAN BASEMENT / COVER SERIES

Many investigators have emphasized that there should be an unconformity between the Pan-African basement and Palaeozoic - Early Tertiary cover series in the Menderes Massif (Pan-African unconformity) (Şengör et al., 1984; Dora et al., 1995). Objective evidences towards this problem have been obtained around Mesken village at north of Yatağan (Konak et al., 1987; Dora et al., 2005; Candan et al., 2006). In the map prepared around Mesken village, it was determined that the unconformity plane is defined by muscovite-quartz schists derived from quartz arenite and the presence of meta conglomerates in character of channel fills among them has been established. These conglomeratic channel fills are in the form of crop outs broken from each other and can be traced 35 km towards Bozdoğan at the east. Conglomerate bearing quartz schist unit has a minimum thickness at north of Mesken village but reaches maximum thickness of 1.5 km towards the south. Quartzite forming the lowermost part of Palaeozoic cover series resides on different units such as orthogneiss and schist which belong to the basement in such a way to describe a deep abrasion. Quartzites are overlain by probable Carboniferous black phyllites with a transitional contact. The conglomerate layers are best observed in Gökçen River and Kale Tepe at the north of Mesken. This meta-conglomerate layer is laterally traced 7 km approximately and is important in order to determine especially the source rock of cover series. The compounds of conglomerates are made up of fully leucocratic in character, tourmaline rich granite, aplite and quartzite pebbles. The primary rock of this conglomerate has an intermediate sandy material. In these conglomerates black tourmalinite pebbles are also encountered.

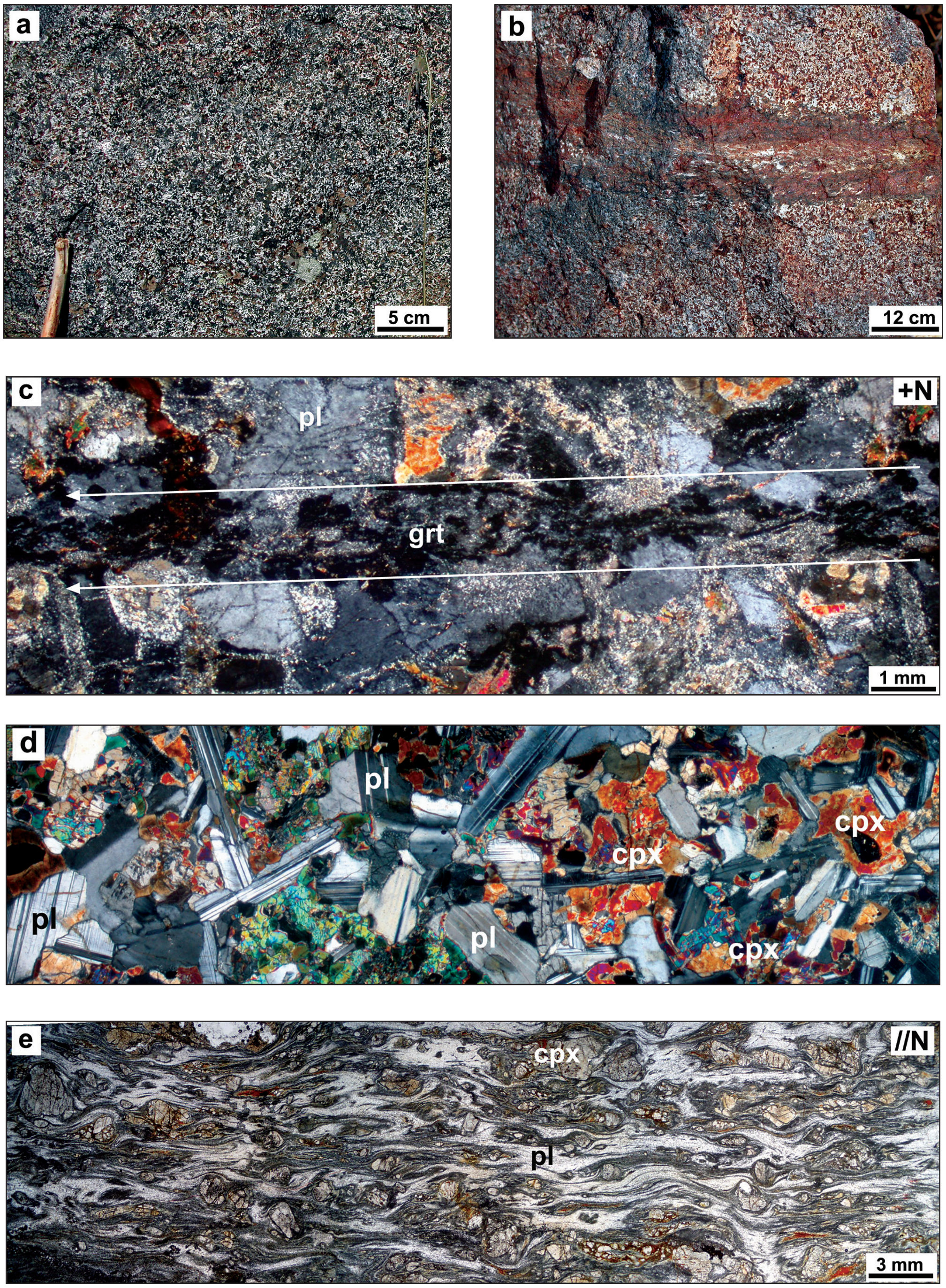

Figure 17- A: Primary ophitic texture of gabbros in sections preserved from metamorphism (BirgiCevizalan), B: amphibolite transformations forming along shear zones cutting gabbros (Birgi), C: garnet crystals forming along ductile shear zones cutting gabbros, D: microscopic view of primary ophitic texture in gabbros which were preserved from metamorphism, E: Mylonitic texture in gabbros subjected to ductile deformation (pl: plagioclase, cpx: clinopyroxene, grt: garnet).

The unconformity between the Pan-African basement and Palaeozoic cover series is clearly observed in N-S directed cross section passing through Kale Tepe (Figure 18a,b). Here, tourmaline leucocratic orthogneiss and porphyritic metagranites forming the basement show a clear intrusive contact relationship with muscovite schists which belong to metaclastic sequence forming the country rock (porphyritic metagranite sample taken here gave an intrusion age of 551.5 ±2.9 Ma (Dora et al., 2005). Palaeozoic deposit begins with 60 m thick quartzites in homogenous structure derived from coarse quartz sandstones. Quartzites are overlain by 30 m thick conglomerates made up of huge blocks at lower parts. Above meta-conglomerate layer, 18 m thick muscovite quartz schist layer takes place. Above quartzites Carboniferous black colored garnet - chloritoid phyllites / calcschist intercalation is recognized with a distinct contact. The matrix of conglomerate layer is made up of green, coarse muscovite crystals which can easily be recognized on field. Porphyritic metagranite, leucocratic orthogneiss, quartzite, aplite and tourmalinites are the main rock types forming metaconglomerate pebbles. Porphyritic meta-conglomerate pebble taken here and from the bedrock that has similar textural / structural, mineralogical and geochemical features was dated as 550.4 ± 2.6 Ma (Dora et al., 2006; Candan et al., 2006). The other composites forming conglomerates as well present very similar properties with that of magmatics at the basement in such a way that it supports the unconformable character of the contact.

DISCUSSION

During the last 20 years many ideas have been put forward towards the stratigraphy of the Pan-African basement and source of protoliths of main lithologies in the Menderes Massif.

The source, primary depositional age and provenance of paragneisses

These rocks were distinguished as a distinct unit by Schuiling (1962) in Çine sub massif of the Menderes Massif and named as 'fine grained gneiss in basic character'. In the following years, similar rocks in the southern part of the same region were named as 'hornfels like rocks' by Başarır (1975). The first study directly towards the source of paragneisses was made by Kun (1983). The investigator named these rocks in Çine region as 'leptite'. Kun (1983) interpreted these rocks as 'island arc volcanites, composed of rhyolite - andesite and calcalkaline in character'. In the following years, the presence of rocks that have similar mineralogical, petrographical and geochemical features was detected around Ödemiş - Kiraz (Kun and Candan; 1987a; Kun et al., 1988; Candan and Kun, 1991; Candan, 1996*a,b*), in Nazilli Karıncalı Mountain regions (Kun and Candan, 1991) in Çine, Yenipazar (Çolak, 1985; Şengül et al., 2006), at southern slopes of Aydın Mountains (Candan et al., 1992), at north of Alaşehir (Candan, 1994), at south of Tire (Candan, 1995) and at north of Çine Kun (1983) and these were interpreted as high graded metamorphic derivatives of continental volcanites in accordance with the data obtained by Kun (1983). The formation of white speckles within the fine grained groundmass in paragneisses was wrongly interpreted as relic hypocrystalline porphyritic texture belonging to old volcanites and that has been effective in this opinion. Dora et al. (1988, 1990) interpreted related rocks as continental volcanites developed on the Precambrian basement in the following metamorphism stage of core series within the metamorphic stage of the Menderes Massif.

Loos (1995) determined the presence of abrasions of crystal face and distinct roundness' to show the detritic origin in zircon which he picked in paragneisses. Besides, these zircons were dated as ranging between 585 - 1871 Ma by means of the single zircon evaporation method supporting the detritic origin. Using these evidences, Dora et al. (1995) stated that these leptites could be sedimentary in origin. In the following years, many studies towards the determination of source rocks of paragneisses have been made and to the contrary of volcanic origin,

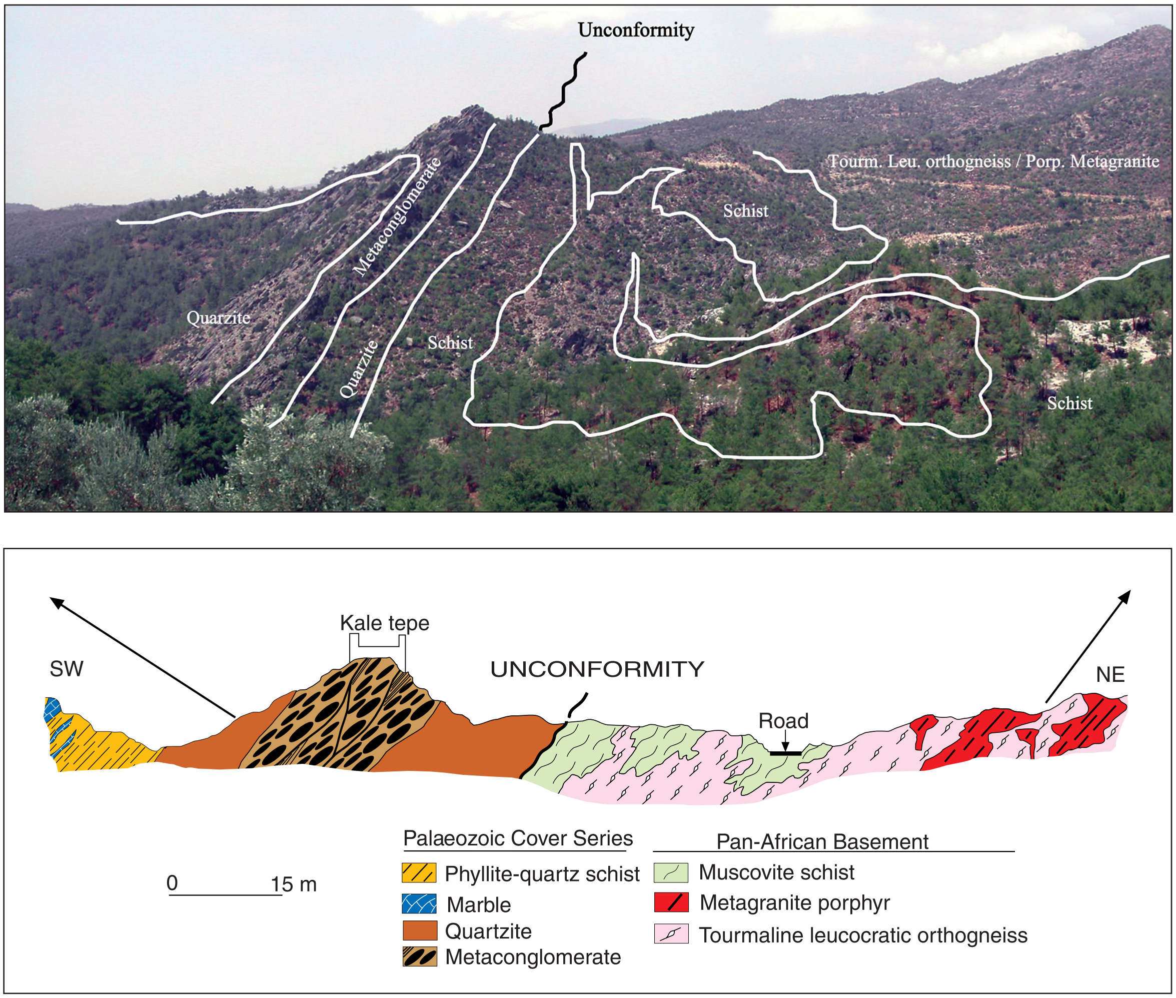

Figure 18- A: Field view and B: Geological section of unconformable contact relationship between the Pan-African basement and Palaeozoic cover series in the Menderes Massif.

new evidences indicating that these were derived from clastic sedimentary rocks have been obtained (Dora et al., 1998, 2000, 2001, 2002; Koralay et al., 2002, 2003). Investigators stated that the data such as; i) the presence of no textural data to be preserved belonging to the primary volcanics, ii) the absence of clastic facies' such as lava, agglomerate and tuff in different compositions that might be found in a volcanic sequence at this thickness and iii) the non visualization of structures such as dyke and dome that could be observed in a volcanic complex in this size decreases the probability of volcanic source in these rocks. Despite that, evidences such as; i) the constitution of the mica - schist unit of the Pan-African basement a conformable and continuous sequence with the paragneiss unit, ii) the case of schists derived from mudstone and subarkosic sandstone layers in the paragneiss unit are gradually transitional with paragneisses both in vertical and lateral directions, iii) the widespread occurrence of intermediate rocks which can not be defined as mica schist and paragneiss that originated from continuous changes in ratio of clay / detritic grain in primary sedimentary rock within paragneiss unit,

iv) the presence of mica or quartz (+feldspar) rich layers originating from the rhythmic compositional change of the primary clactic sediment in paragneisses which are the equivalent of clay and sand rich layers at millimeter - centimeter thickness and v) zircons in the paragneiss containing abrasioned crystal faces or their presence to be as fully rounded grains, and their scattered age data support feeding from a cratonic field which clearly reveal the sedimentary source of paragneisses according to the investigators (Dora et al., 2001, 2002; Koralay et al., 2002).

In order to determine the depositional age of primary clastic sediments which paragneisses derived from, zircon clastics were picked and dated from paragneisses at each of three sub massifs. On single heating step, zircon ages ranging between 613 - 2558 Ma were obtained from these samples. Only one zircon grain was detected as 587 Ma which is not robust (Dora et al., 2002; Koralay et al., 2002, 2003, 2005). The crystallization age of primary granites in orthogneisses that have intrusive contact relationship with paragneisses were dated as 549.3 ± 13.4 Ma in Karacalar Village, north of Alaşehir. On the other hand, ages of zircon clastic of schists belonging to Pan-African basement in Çine submassif were dated as 592-3239 Ma (Dora et al., 2005). The metaclastic sequence to be a continuous deposit made up of paragneiss and schist units foresees a time range of 590-550 Ma as for the depositional age of primary sediments of these metaclastics forming the oldest units of the Menderes Massif (Dora et al., 2002; Koralay et al., 2005; Candan et al., 2007). When it is considered that the intrusional age of primary granites of orthogneisses vary between 570 - 520 Ma (Loos and Reischmann, 1999) throughout the Massif and schists forming country rocks with the age of 570 Ma belong to metaclastic sequence, the depositional age lies between 590-570 Ma (Late Neoproterozoic). On the other hand, it is known that core series of the Menderes Massif were affected by the polyphase metamorphism associated with the Pan-African Orogeny (Candan et al., 2001). The granulite facies metamorphism affecting paragneisses and forming the first stage as well was dated as 583 ± 5.7 Ma by Koralay et al. (2006). The time interval for the depositional age of primary sediments is foreseen as 590-580 Ma when all these geochronological data are evaluated for the metaclastic sequence forming the oldest rocks of the Menderes Massif. According to Dora et al. (2002) paragneiss unit derived dominantly from litharenitic sandstone, bears the character of grain flow of shoreline drift with high energy. According to investigators, provenance conditions are suggested as 'planar, humid - arid climate, gneisoid - granitoid rock in composition and gradually uplifted as an example structural behavior everywhere'.

The source and formation age of protoliths of gneisses

In studies made for more than 50 years, different opinions have been put forward about protoliths of gneisses which are the most characteristic of the Massif. These opinions can be gathered in three groups; 1- gneisses were formed under high graded metamorphism of sedimentary rocks (Schuiling, 1962; Şengör et al., 1984; Akkök et al., 1984; Dora et al., 1990; Satır and Friedrichsen, 1986), 2- gneisses in both the sedimentary and magmatic in origin are observed in the Massif (Başarır, 1970, 1975; Scotford, 1969; Graciansky, 1965; Konak, 1985; Konak et al., 1987) and 3- all gneisses were formed as a result of metamorphisms of magmatic rocks in granitic composition (Erdoğan, 1992; Bozkurt, 2004; Bozkurt and Park, 1994; Bozkurt et al., 1995, 2006; Loos, 1995; Dora et al., 1995, 2005; Hetzel and Reischmann, 1996; Dannat, 1997; Dannat and Reischmann, 1998; Loos and Reischmann, 1999; Gessner et al., 2001, 2004; Koralay et al., 2004, 2007; Erdoğan and Güngör, 1992, 2004). The solution of this problem lies under the assessment of field data and geochronological / geochemical evidences together. Recent studies have revealed that these rocks were derived from a granitic source rock due to basic properties of gneisses. These properties are as follows; i) gneisses have homogenous internal structure, ii) the preserved holocrystalline structure peculiar to protolith can be observed, iii) gneisses show clear intrusive contact relationship with schists forming the country rock, iv) gneisses diffusively have zircon peculiar to magmatic rocks describing the crystallization from a melt, v) these zircons give extremely close results describing magmatic crystallization and vi) source rock diagrams in geochemical analyses clearly define a magmatic rock (Erdoğan and Güngör, 1992; Bozkurt and Park, 1994; Bozkurt et al., 2006; Dora et al., 2005; Hetzel and Reischmann, 1996; Dannat, 1997; Loos and Reischmann, 1999; Gessner et al., 2004; Koralay et al., 2004).

Ideas about the ages of orthogneisses in the Menderes Massif can be gathered in to two groups except for different ideas on source rock. These are; i) Precambrian - Cambrian and ii) Upper Cretaceous / Tertiary. In this article, this problem will be explicated as a brief summary since detailed data were given by Koralay et al. (in this ıssue) regarding the geochronology of orthogneisses. So far, many different groups have estimated the intrusional age of primary granites for orthogneisses in laboratories based on total rock, single zircon evaporation, classical zircon and SHRIMP methods and obtained age of Precambrian / Cambrian (Schuiling, 1973, 548 Ma; Dora, 1975, 490 ± 90 Ma; Satır and Friedrichsen, 1986, 502 - 471 Ma; Hetzel and Reischmann, 1996, 546 Ma;, Dannat and Reischmann, 1997, 540 Ma; Koralay et al., 2004, 560 - 570 Ma; Loos and Reischmann, 1999, 520 - 570 Ma; Gessner et al., 2004, 541-566 Ma; Dora et al., 2005, 545 - 552 Ma). The idea of orthogneisses to be young however, is based on field data and deformational properties (Erdoğan, 1992; Erdoğan and Güngör, 1992, 2004; Bozkurt and Park, 1994, 1997*a,b*, 1999; Bozkurt and Park, 2001; Bozkurt, 2000; Bozkurt et al., 2006). Investigators who supported this idea interpret that all the dated zircons in orthogneisses are relic zircons.

The age of gabbros

The first data related to the presence of basic magmatic rocks in the Menderes Massif are seen in Schuiling (1962). These rocks located in the Çine submassif were interpreted as Miocene aged post metamorphic intrusions following vertical tectonic lines by Kun (1983). In following years, presence of gabbros has been detected in other parts of the Massif as well and these rocks have similarly been assessed as young plutons (Dora et al., 1988, 1992; Kun and Candan, 1991). However, as an opposition to those opinions new field data and petrological studies were clearly revealed that gabbros are not young and were not affected by polyphase metamorphism (Candan, 1994, 1996*a,b*; Candan et al., 1994, 2001; Oberhänsli et al., 1997, 2010; Dora et al., 2001; Çetinkaplan, 1995).

The relative Precambrian age was suggested for gabbros in articles which the metamorphic character of these rocks was first defined (Candan, 1994, 1996 *a,b*). Gabbros are only located in the Pan-African basement and do not cut cover series by intrusion. These data were used as basic geological features. K/Ar ages estimated from micas in gabbros were dispersed much and gave geologically meaningless results (Candan, 1996). Oberhänsli et al. (2010) performed a study on a sample which was well preserved from metamorphic effects and dated zircons in magmatic origin as 540 ± 3.5 Ma. This age is compatible with basic geological data and was interpreted as the crystallization age of gabbro by investigators.

The primary contact relationship between the Pan-African basement and cover series

Many of the articles regarding the general geological structure of the Massif confirm that the contact between the Pan-African basement and the overlying cover series accepted as Palaeozoic - Early Tertiary in age is an unconformity plane which traces were greatly erased by latter metamorphisms (Schuiling, 1962; Graciansky, 1965; Başarır, 1970; Dora, 1975, Şengör et al., 1984; Dora et al., 1988, 1990, 1995; Konak et al., 1987). Many investigators define and name this unconformity plane as the 'Pan-African unconformity'. First objective data on this subject were obtained by Konak et al. (1987). The unit which was defined as basal conglomerate in some studies by investigators and as channels fills in cover series (Erdoğan and Güngör, 2004; Bozkurt et al., 2006) was retreated and studied by Dora et al, (2005). Investigators claim that units of the Pan-African basement is unconformably overlain by a deposit of cover series (Pan-African unconformity) (Dora et al., 2005; Candan et al., 2007, 2010) that begins with quartzite / conglomerate, continues with phyllite - quartzite - marble. These are based on evidences given below.

i) The main components of conglomerates are made up of tourmaline rich, granite, leucocratic in character and of tourmalinites, ii) tourmaline rich granites that have the same mineralogical composition, textural feature and chemical composition with these pebbles are pervasively observed in the Pan-African basement, iii) granite pebbles and their equivalents give identical ages (Pebble: 552 ± 3.1 Ma, Basement: 551.5 ± 2.9 Ma), iv) quartzites containing conglomerate layers cover different units of the Pan-African basement, v) probable Late Devonian aged quartzite / conglomerate unit is placed at the lowermost part of the Palaeozoic cover series.

The Palaeogeographical position of the Pan-African basement in Late Neoproterozoic time

The Pan-African Orogeny comprising the events of the integration of Gondwana ranges in between 950 - 450 Ma (Kröner, 1984). The distribution of continents in Neoproterozoic time indicates that East and West Gondwana lands were separated by an ocean named the Mozambique Ocean (Stern, 1994; Wilson et al., 1997; Daiziel, 1991). This ocean is as big as the Pacific Ocean and is considered as it was formed by the disintegration of Rodinia Super Continent 800 - 850 Ma ago. The closure of this ocean and collision of east and west Gondwana lands with each other caused the formation of orogenic belt extending in N-S directions along the eastern margin of the African continent. This orogenic belt which is also defined as the 'Mozambique belt' was named as the East African Orogeny by Stern (1994).

In the final integration stage of Gondwana in the Latest Neoproterozoic time, it is considered that Anatolia was located at the northeast of the African-Arabian peninsula and at the northernmost part of Mozambique belt (Stern, 1994; Wilson et al., 1997). Şengör et al. (1984) states that the northern continuity of suture belts associated with the closure of this ocean can be traced with the Pan-African events in Bitlis and Menderes Massifs. Similar paleogeographic position is foreseen by different investigators based on various geological data and correlations (Dora et al., 1995, 2002; Stampfli and Borel, 2002; Gessner et al., 2004; Gürsu et al., 2004; Monod et al., 2003; Neubauer, 2002; Koralay et al., 2005; Candan et al., 2007; Oberhänsli et al., 2010).

Within this context, it is seen that assemblages of units belonging to the Pan - African basement of the Menderes Massif could be associated with Mozambique belt from Egypt, Red Sea and Arabian Peninsula to South Africa along East Africa. Thus, it can be concluded that the metaclastic sequence made up of paragneiss and schist units forming oldest units of the Pan-African basement were deposited on the passive continental margin of Late Neoproterozoic Mozambique Ocean that is in between East and West Gondwana lands. In this issue of the periodical, the original relation between the Late Neoproterozoic evolution of the Mozambique Ocean and the polymetamorphic evolution of the Pan-African basement in the Menderes Massif is being discussed in the article given by

Candan et al. (in this issue). In this study it is emphasized that the Mozambique belt was defined by the metamorphism of granulite facies with ages of 715-650 Ma and 620-520 Ma (average 550 Ma) (Stern, 1994) and besides, rare 530-500 Ma aged eclogites were observed in Malawi as well (Ring et al., 2002). Investigators claim that age of granulite (583.0±5.7 Ma; Koralay et al., 2007) and eclogite (529.9±22 Ma; Oberhänsli et al., 2010) facies metamorphisms in the Menderes Massif show big similarity with the metamorphisms and events in the Massif could be associated with closure of the Mozambique ocean and with final collisional stage of East and west Gondwana lands. On the other hand, again in issue, Koralay et al. (in this issue) interprets that Late Neoproterozoic / Cambrian aged granitic intrusions within the Pan-African basement of the Menderes Massif ranging between 570-520 Ma (average 550 Ma) (Loos and Reischmann, 1999) are syn to post African intrusives associated with the closure of this ocean. Finally, data obtained from the Pan-African basement indicate that sedimentary, magmatic and metamorphic stages of core series of the Menderes Massif could be associated with final integration period of the Gondwana Continent resulted by closure of the Mozambique Ocean and collision of East and West Gondwana lands. Exposures belonging to the Pan-African Orogeny in Anatolia by plate tectonics in Palaeozoic and Mesozoic times were napped with younger units and acquired their present positions in the form of isolated tectonic layers.

RESULTS

The stratigraphy of the Pan African basement of the Menderes Massif obtained by the studies in recent years and the results related to properties of main lithologies are given below:

1- The Pan-African basement consists of a thick metaclastic sequence and numerous acidic / basic magmatics that have intruded into the basement.

2- The metaclastic sequence begins with a litharenite dominant sequence at the bottom (paragneiss unit) and continues with sandstone - mudstone intercalation sequence (schist unit).

3- The thickness of this metaclastic sequence reaches 8 km and the depositional age of primary sediments occurred in a time interval of 590 - 580 Ma.

4- This metaclastic sequence was migmatized at the last stage of the Pan- African orogeny and pervasive development of anatectic granite took place associated with this event.

5- Orthogneisses in the Massif derived from a granitic source rocks that have various textural / mineralogical features and have an intrusive primary contact relationship. Orthogneisses which are the differentiation products of the same magmatic activity can be divided into three groups as; i) biotite orthogneiss, ii) tourmaline leucocratic orthogneiss and iii) amphibole orthogneisses.

6- Geochronological and petrological evidences indicate that rocks of which have an intrusion age ranging between 570 - 52 Ma (averaging at 550 Ma) could be granites synchronous with the Pan-African orogeny and have intruded in the following stage.

7- Gabbros which are observed only in the Pan-African basement are Precambrian / Cambrian aged intrusions and consist of polyphase metamorphic data associated with the Pan-African orogeny.

8- The sedimentary, metamorphic and magmatic evolutions of the Pan-African basement in the Menderes Massif are associated with closure of the Mozambique Ocean in Late Neoproterozoic - Cambrian and with the collision period of East and West Gondwana which results in the final assemblage of the Gondwana super continent.

9- The primary contact relationship of the Pan-African basement - Palaeozoic - Early

Tertiary cover series which was reshaped by the effect of Alpine age compressional and the following extensional tectonism are unconformable (Upper Pan-African unconformity). The unconformity is described by (?) Upper Devonian quartzite metaconglomerate sequence.

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