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EMPLACEMENT CHARACTERISTICS OF THE GNEISSIC GRANITES IN THE MENDERES MASSIF (WESTERN ANATOLIA) AND THEIR IMPLICATIONS ON THE TECTONIC EVOLUTION OF THE MASSIF: NEW FIELD OBSERVATIONS AND RADIOGENIC AGE DETERMINATIONS

Burhan ERDOĞAN*, Erhan AKAY** and Altuğ HASÖZBEK***

ABSTRACT.- Understanding the ages and emplacement mechanism of the gneissic granites cropping out in large areas of the Menderes Massif has a critical importance in its tectonic evolution. Based on some radiogenic age data, the gneissic granites and the surrounding high-grade micaschists have been advocated to be the Precambrian "Core Succession" that was undergone high-grade metamorphism during the Pan-African Orogenesis. The micascists and marbles of Palaeozoic-Mesozoic age have been defined as the "Cover Succession" unconformably overlying the core assemblages. It has also been indicated that during the Alpine Orogenesis and by the Main Menderes Metamorphism the core and cover successions were metamorphosed together in relatively lower grade conditions. Although the Menderes succession underlies a large region in the western Anatolia and display uncovered outcrops, in nowhere structural evidences of the unconformity between Pan-African core and the Palaezoic-Mesozoic cover series has been reported. It is very difficult to expect the Alpine Orogeny to erase the older Pan-African structures to a point of undefinable state. In this study, we have new mapped and examined the boundary relations between the so-called Pre-Cambrian core and Palaeozoic-Mesozoic country succession around Dibek Mountain, Çine-Yatağan and İncirliova Dam site. In Dibek Mountain gneissic granites were emplaced, as migmatitic fronts, into the marble lenses-bearing micaschists parallel to their foliation planes. Along the Çine-Yatağan road, migmatitic syn-tectonic granitic fronts injected into and engulfed the Palaeozoic black marble, black chert and micaschist alternation. In this region, the Palaeozoic units pass upward into the Triassic metadetritals with mafic volcanic intervals and they in turn grade into the Mesozoic platform-type marble succession. In this location the granites intrude into the Palaezoic and Mesozoic series which were paleontologically dated in some other areas of the masif. Similarly around the İncirliova Dam site the augen gneisse-migmatitic granite complex intruded into a complete stratigraphic section from Palaeozoic to Triassic and the Mesozic marble succession. New field data indicate that the high-temperature-type Barrowien Main Menderes Metamorphism caused a rejuvenation in the crust and granites with large migmatitic fronts emplaced syntectonically into the entire section of the masif from thick metadetrital units below and the Palaeozoic-Mesozoic cower series above. Precambrian and Alpine zircon ages determined from the gneissic granites could be explained by the rejuvenation and migmatism during the Main Menderes Metamorphism.

Key words : Menderes Massif, granite emplacement, core-cover series relation

INTRODUCTION

Granites with augen texture cover large areas in the Menderes Massif. In the literature their emplacement age are stated to be Precambrian (540-560 Ma) based on the radiogenic ages (Candan, 1994*a*; 1994*b*; 1995; 1996; Hetzel and Reischmann, 1996; Candan and Dora, 1998; Loos and Reischmann, 1999; Candan et al., 2001; Koralay et al., 2001; Gessner et al., 2004;

* Dokuz Eylül Üniversitesi, Mühendislik Fakültesi, Jeoloji Müh. Bölümü, 35160, İzmir, Türkiye
** Dokuz Eylül Üniversitesi, Torbalı Meslek Yüksekokulu, Mermercilik Prog, 35860 İzmir, Türkiye
*** Universität Tübingen, Institut für Geowissenschaften, D-72074 Tübingen, Germany

Koralay et al., 2007). It has also been stated that the oldest succession of this metamorphic complex, named as the "Core" association, was metamorphosed under migmatitic conditions during the Pan-African Orogenesis (Schulling, 1962; Dürr, 1975; Dora et al., 1992; Candan, 1994a; 1994*b*; 1995; 1996; Candan and Dora, 1998; Candan et al., 2001; 2007). Micaschist and marble association of Palaeozoic-Early Eocene age has been named as the "Cover" and presence of a pronounced unconformity between core and cover has been inferred although in no where this boundary defined by structural evidence.

If the above mentioned core and cover definition is correct it would be assumed the core was deformed earlier under high-grade conditions, later, erroded and is overlain by Palaeozoic-Mesozoic succession. The Alpine tectonics was suggested, in earlier studies, to be caused by nappe emplacement in associate with relatively lower metamorphic conditions and without any granite emplacement (Dürr, 1975; Şengör et al., 1984; Candan, 1994*b*; 1995; Okay, 2001; Whitney and Bozkurt, 2002; Rimmele et al., 2003). In this case the unconformity between core and cover would be clearly seen and be mappable on 1/25.000 scale along the Menderes Massif which form extensive and open outcrops in the western Anatolia. Along the Taurus range in the eastern Anatolia, regionally metamorphic Bitlis Massif displays similar metamorphic characteristics to the Menderes Massif. In Bitlis Massif, the unconformable contact between the Precambrian and Palaeozoic-Mesozoic sequences is open and clearly definable by map pattern (Erdoğan, 1982; Erdoğan and Dora, 1983) although they were metamorphosed together during the Alpine Orogeny.

In some publications carried out between Bafa Lake and Yatağan region in the Menderes Massif, the core-cover boundary was defined as southerly-dipping crustal-scale detachment fault (Bozkurt, 1996; Bozkurt and Park, 1994; 1997*a*; 1997*b*; 1999; 2001; Hetzel and Reischmann, 1996; Loos and Reischmann, 1999; Bozkurt and Satır, 2000; Bozkurt and Oberhansli, 2001; Lips et al., 2001; Whitney and Bozkurt, 2002). However, Erdoğan and Güngör (2004) described and mapped that boundary as a normal intrusive boundary of a syntectonic granite as no missing part between the gneissic granites and the marble lenses bearing schists is present. Besides that, the map pattern of this boundary forms a crescent concave to the north just opposite to what would be expected to the southerly-dipping detachment zone in which case must be concave to the south (Erdoğan, 2006).

In this study, the boundary of the gneissic granites are examined and re-mapped in three different regions. To the North of Salihli, the area along western side of the Demirköprü Dam in the Dibek Mountain region is mapped on 1/25.000 scale and the boundary of the gneissic granites with the country rocks are examined in detail (Figure 1). In the Dibek Mountain region, gneissic granites emplaced into micaschists with marble lenses. The similar marble lenses-bearing country schists have also been mapped around Koçarlı, in the north of the Bafa Lake. However, in the previous studies, Precambrian core association with marble lenses has not been described in the massif.

Besides the Dibek Mountain along the southern border of the masif the second region is studied along the Çine Yatağan road (Figure 1). In this area the gneissic granites directly intruded into the well known Palaeozoic and Mesozoic successions dated by fosil content in the southern parts of the masif (Önay, 1949; Konak et al., 1987; Güngör and Erdoğan, 2001). The third area mapped is the İncirliova Dam site recently under constructionto the North of İncirliova (Aydın) (Figure 1). Along the newly opened cross-cuts of the excavation areas there are open and clealry observed outcrops between the gneissic granites and the country rocks. We mapped and examined this area on 1/10000 scale. By detailed field photographs and pre-

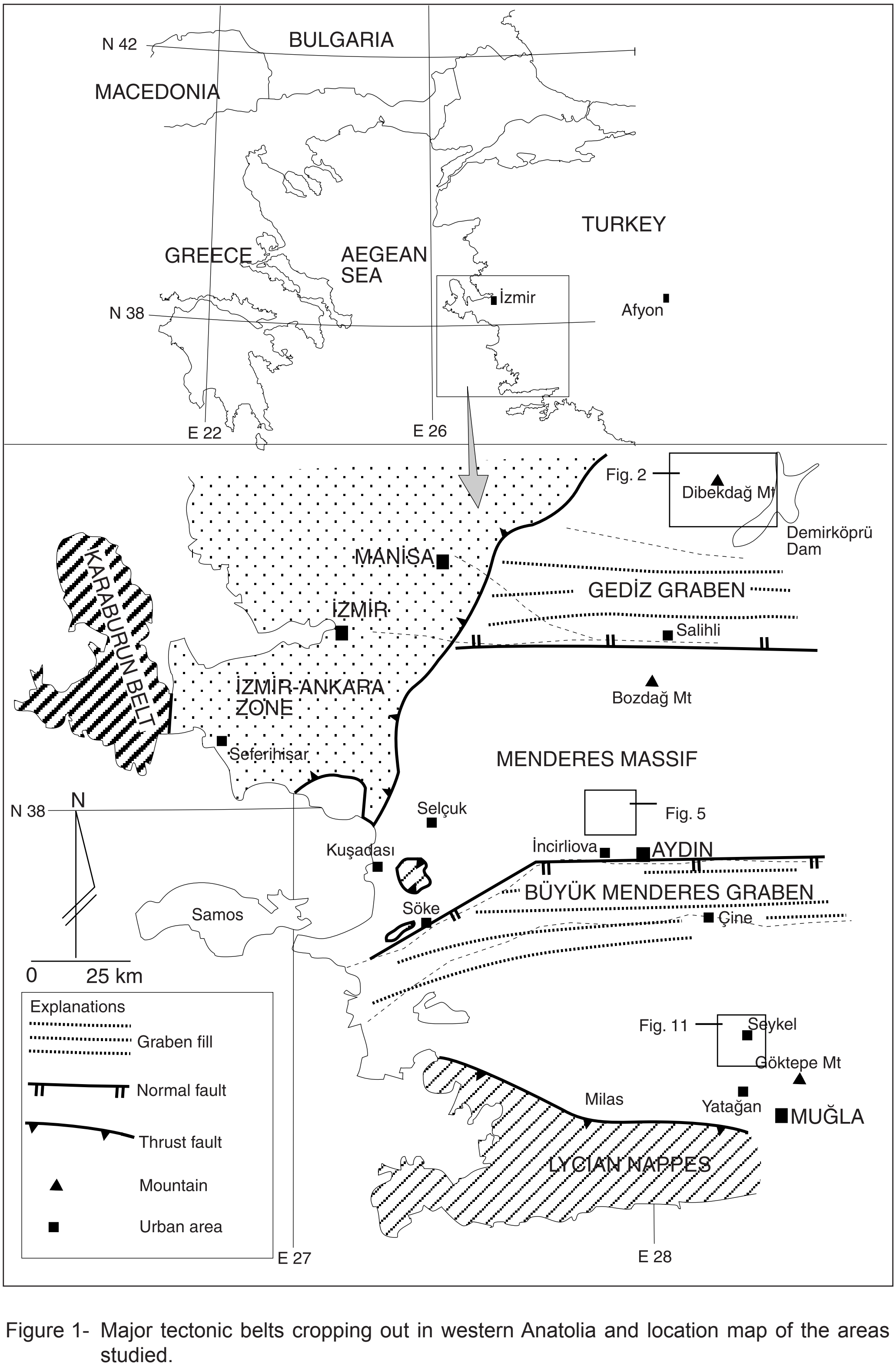

Figure 1- Major tectonic belts cropping out in western Anatolia and location map of the areas studied.

pared thin sections in these three regions both the internal structure and the boundary characteristics of the augen gneisses are described.

Comparing the Menderes succession with the various parts of the Tauride-Anatolide Platform is importent in understanding the tectonic evolution of the masif. In this study, the Menderes successions are compared with the Tauride successions in Sandıklı (Afyon) region and the Bitlis Massif in Avnik (Bingöl) region.

BOUNDARY RELATIONS BETWEEN THE GNEISSIC GRANITES AND THE COUNTRY ROCKS IN DİBEK MOUNTAIN

Dibek Mountain where the three-dimentional forms of the gneissic granites form open outcrops, is located in the western side of the Demirköprü Dam and forms the eastern limp of the NE-SW-trending antiform (Figures 2, 3). In this region gneissic granites were emplaced as NE-SW-trending and SE-dipping granites zones paralel and concordantly into the foliation planes of the hosting mica schists (Figures 2, 3). The core and the limp of the antiform are made up of quartz mica schists and biotite muscovite schists. In the metadetrital succession there are white marble lenses with lengths and thickness of mappable on 1/25.000 scale. One of these marble lenses shown on figure 2 and 3, was engulfed by the gneissic granites along its northern extension and converted into coarse grained calcite marble with 3-4 mm- large crystals. The map pattern, cross section characteristics, structural properties and diffuse boundary relations are typical granitic emplacement as migmatitic fronts. Toward the migmatitic fronts and close to the boundary, up to 2-3 km in distance to gneissic granites, micaschists become cleaved and shiny with 3-4 mm-large biotite flakes and red transparent almandine porphyroblasts. Kyanite and sillimanite accompany with this paragenesis in some places. In the field along road cuts almandine biotite schists include 1-2 cm-long quartzofeldspatic lenses and augens. As the granitic bodies approach eastern, their numbers and thickness increase and become septums parallel to the foliation of the biotite schists. After the contact and inside the granitic body, there are numereous biotite schist restites partly to completely assimilated. Eastward, toward the Demirköprü Dam these restites decrease in number and homogenous augen textured granites become dominant (Figures 2, 3). The foliation of the granites and the country schists are completely conformable to each other. During the granite emplacement in situ assimilation of the country schists caused this conformable relation of centimeters to outcrops scale. The migmatitic gneissic granite fronts, in places, cover an area of several 1/25.000 scale topographic sheets. In situ assimilation of the country schists caused gradational changes from leucocratic granites to biotite-rich melanocratic gneisses and into biotite schists. Geological map patterns, relations in the third dimension in cross-sections, and structural concordance with the country schists are typical for the emplacement mode and mechanism of the granites in the Menderes Massif and are repeatedly observed in differenet regions (Bozdağ, Kiraz) in western Anatolia.

In some rare areas of the massif such as Bafa Lake region, an intrusive contact between the gneissic granites and the country schists is found along which enclaves from the schists are found in the granites. These rare and very narrow intrusive parts might be shallower regions in the crust that the melt formed in deeper parts, moved upward and formed injections in the shallower parts. The Bafa Lake region of the Menderes Massif is an exeptional area where the gneissic granites do not display the typical geometry of the migmatitic syn-tectonically emplaced granites.

THE ÇİNE-YATAĞAN ROAD

The Çine-Yatağan road is one of the rare areas were the gneissic granites are in a close contact with the Palaeozoic-Mesozoic succes-

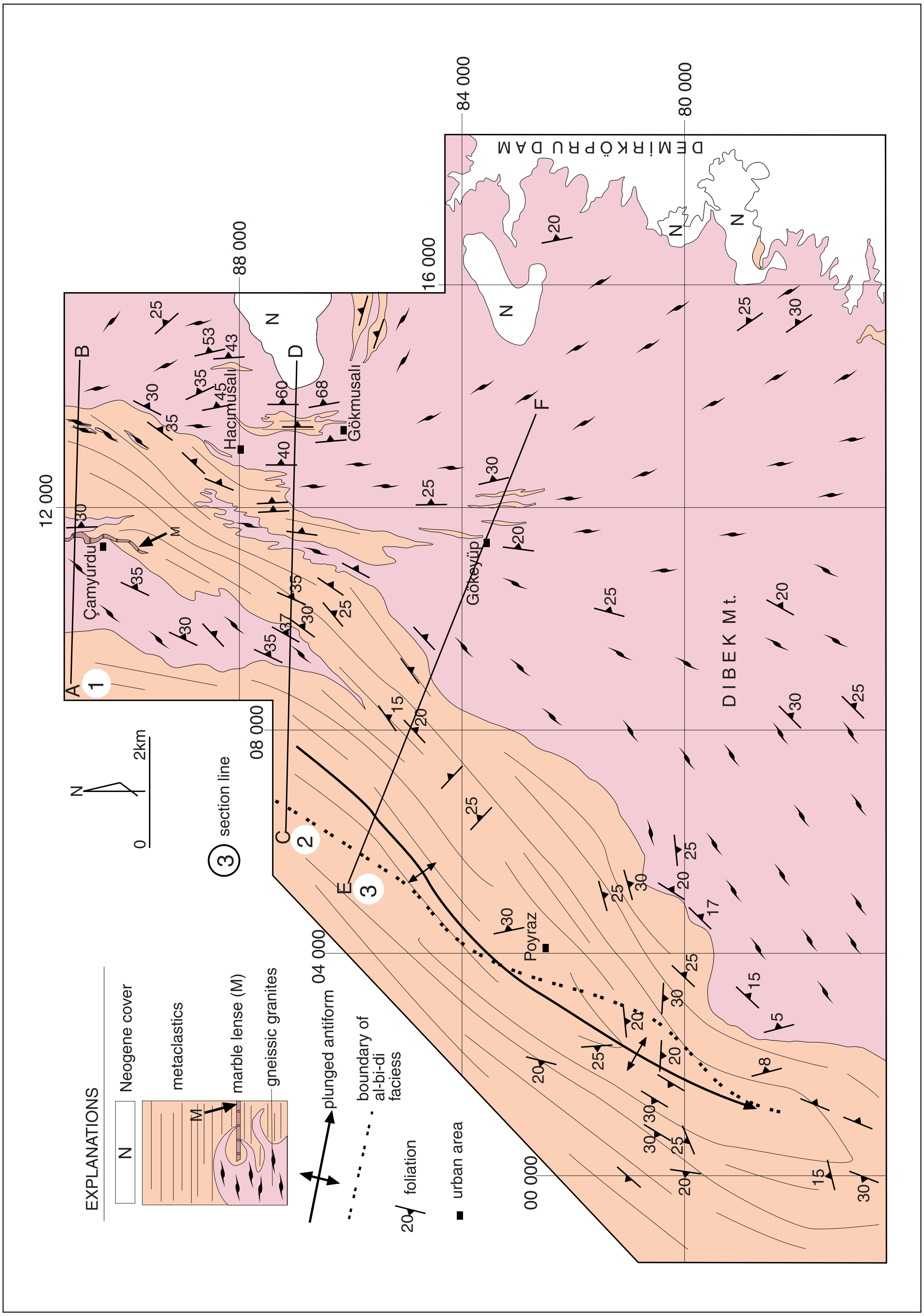

Figure 2- Geological map of the Dibek Mountain area.

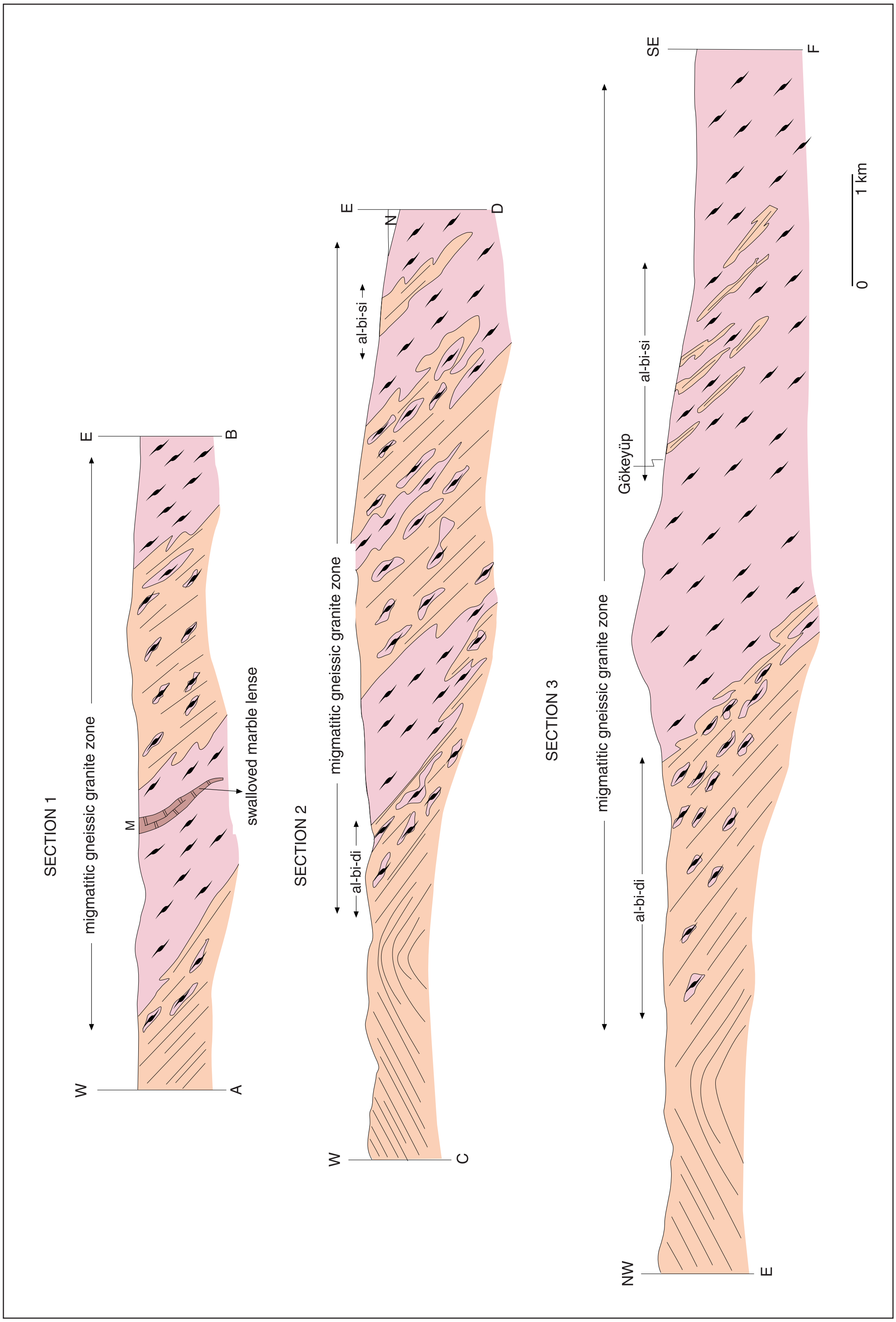

Figure 3- Cross-sections showing the contact relations between the gneissic granites and marble-bearing mica schists in Dibek Mountain Area (for section lines see figure. 2, al: almandine, bi: biotite, di: kyanite, si: sillimanite).

sions of the massif. To the South of Yatağan region the Palaeozoic and Mesozoic series were only metamorphosed under low-grade conditions and they were paleontologically aged (Önay, 1949; Konak et al., 1987; Güngör and Erdoğan, 2001). In the map area around Kafacakaplancık, Irmadan and Seykel villages (Figures 1, 5) the gneissic granites intrude into this Palaezoic-Mesozoic succession which named previously as "the Cover"

Along the road, gray phyllite, black chert and metaquartzite intercalations are in contact with the gneissic granites (Figure 5). This intercalation is known around Göktepe forest fire lookout tower with fossil content of fusulinids, corals and crinoidal fragments as Carboniferous-Permian in age and named as Göktepe Formation (Önay, 1949; Konak et al., 1987). The fosil-rich Göktepe Formation has been mapped and found to extend to the map area along the Çine-Yatağan road (Önay, 1949; Konak et al., 1987; Güngör and Erdoğan, 2001). In the map area, to the South, this Palaeozoic unit is overlain by an intercalation of yellow marbles, metadetritals and mafic metavolcanics. Around the Göktepe region their age is determined as Triassic by their fossil content (Güngör and Erdoğan, 2001).

In the study area the Triassic metadetrital succession passes into the Mesozoic massif white marbles including emery lenses in the upper parts. Upward, these platform-type marbles are overlain by thin, red laminated pelagic marble, and metaserpentinite blocks-bearing metadetritals in ascending order which are known in various parts of the massif as Campanian-Meastrichtian in age (Konak et al., 1987; Güngör, 1998; Güngör and Erdoğan, 2001; Özer et al., 2001). Therefore along the Çine-Yatağan road the Entire Palaeozoic-Mesozoic succesion crops out.

In the northern part of the map area around Irmadan and Seykel villages the gneissic granites cut the Palaeozoic units. A serious of photographs show, both on the map and cross-section (Figures 5, 6, 7, 8, 9), that the gneissic granites are injected as migmatites into the foliation planes of micaschist and marble intercalation. Along the boundary zone between the marble lenses and and the migmatitic granites, the preserved magmatic texture is observed in thin sections although the entire boundary zone is strongly deformed (Figure 9). At the contact zone in the black marbles large almandine-bearing calc-schists are common. Along the road of Seykel village granitic seams are found both above and below the black marble lenses (Figure 10).

The boundary zone is several kms wide in the Dibek Mountain region whereas between Irmadan and Seykel the same zone is only 100 m in width. But similar to the Dibek Mountain area granitic seams and surrounding foliation are always conformable and in situ melting along the boundary of the granitic seams are common. The numbers of quartzo-feldspatic seams increase northward approaching to the granitic body and finally graduated into the homogenous granites. In the granitic body strongly assimilated mica schist restites with a length of several meters are common.

Formation of foliation in the country rocks and emplacement of the granites occured together. So that the entire boundary zone display regional foliation. This relation has been wrongly interpreted as a crustal-scale detachment zone by Bozkurt (1996), Bozkurt and Park (1994; 1997*a*; 1997*b*; 1999; 2001), Hetzel and Reischmann (1996), Loos and Reischmann (1999), Bozkurt and Satır (2000), Bozkurt and Oberhansli (2001), Lips et al. (2001), Whitney and Bozlurt (2002) and into the shear zone leucocratic granitic seams have been suggested to injected (Bozkurt and Park, 1994; 1997*a*; 1997*b*). On the other hand, the foliation is not restricted a particular zone but the entire granitic body and the country rocks are deformed and attained penetrative foliation. In situ melting along granitic seams in the marble-schist intercalation is recognized as diffuse, centimeter- to

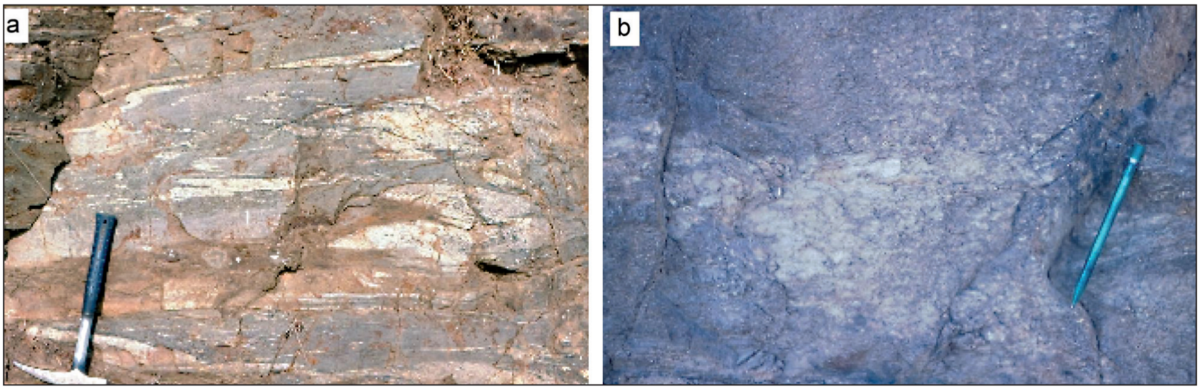

Figure 4- Field photographs showing the gradational diffusive contact relations between the gneissic granites and mica schists formed by in situ melting: a) Toward the gneissic granites mica schists include granitic seams in increasing number and thickness. b) Close-up view of granitic seams in mica schists.

milimeter-scale gradational passes from granitic texture to quartzo-feldspatic layers to surrounding schists.

İKİZDERE DAM SITE

Five km far and in the north of İkizdere town (Aydın), along the recently opened cuts, the intrusive boundary relation between the gneissic granites with pronounced augen texture and the Palaeozoic-Mesozoic succession is observed (Figure 11). The Palaeozoic unit consist of black cherts, quartz mica schists, black phyllites and dark gray marbles (Figure 12). Above this intercalation yellow marble, mica schist and quartz metaconglomerate (Figure 12) association is present and in the uppermost parts there are thick, white massive marbles. Black chert and black marble associaiton is lithologically similar to the Palaeozoic parts of the Menderes Massif and yellow marbles, quartz metaconglomerates and overlying white marbles are the Triassic units of the masif. Only difference with the Triassic sections are the absence of mafic volcanic intervals in the İkizdere dam site. But the Triassic units show lateral facies changes in large area of the masif as described by Güngör (1998). Neogene conglomerates, sandstones and claystones overlay the metamorphic complex unconformably in the map area.

In the İkizdere Dam site along two seperate outcrops the gneissic granites lay inside the Palaeozoic and Mesozoic parts of the masif. In the SW corner of the map (Figure 11) the granites display augen texture with K-Feldspar porphyroblasts of 2-3 cm length. These augen gneisses intrude both the Palaeozoic and Mesozoic units (Figure 11). The augen gneiss - country rock boundary, starting from the spillway of the dam, intruded into the Palaeozoic units and westward into the Mesozoic white marbles (Figure 11).

Along the spillway cuts, granitic seams, ranging from centimeters to meters in thickness, injected conformably into the black cherts and black marbles (Figure 13). In thin sections in some areas granitic texture are stil recognized in the foliated gneisses (Figure 14). These granitic seams are rich in tourmaline crystals and texturally similar to the augen gneisses in the SW corner of the map area (Figure 13a and b).

In the E-NE corner of the map area, there is another gneissic granite body (Figure 11). A NE-SW trending derivation tunnel, excavated for the dam, starts in the north from the granites and after about 200 m it enters into the Palaeozoic black marble, calcschist, mica schist intercalation

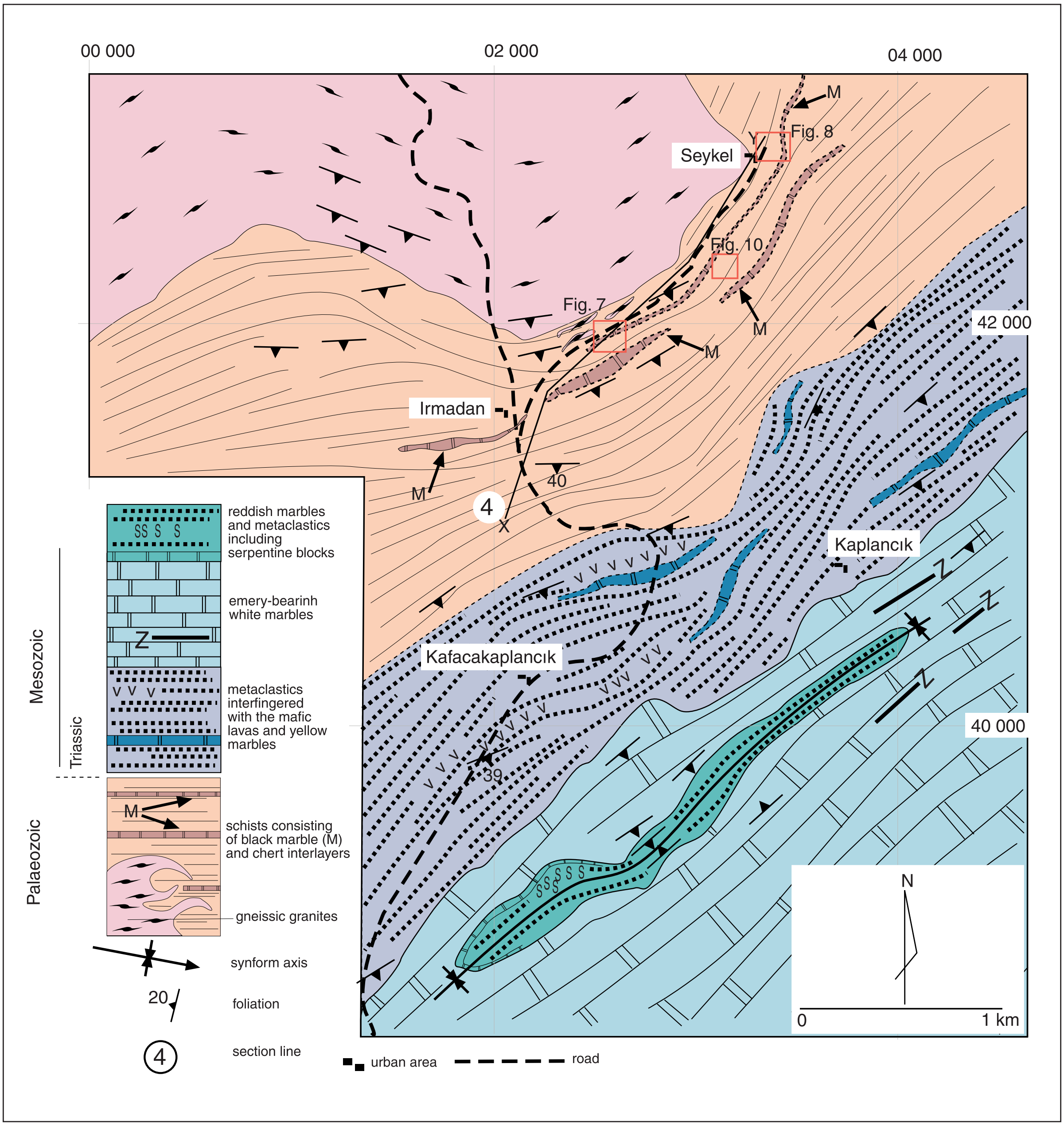

Figure 5- Geological map of the Çine-Yatağan road.

along a sharp contact (Personal communication with A. Rıza Özdemir, 2007). In the SE part of the map in Figure 11, at Ballıkaya site, metamorphic succession consists of yellow marbles and meta-conglomerates that are overlain by white massif Mesozoic marbles. In this Mesozoic section, there are numerous granitic seams and where the marbles are in contact with these granitic seams, marbles are turned into calc schists with large garnet porphyroblasts. Around the İncir-

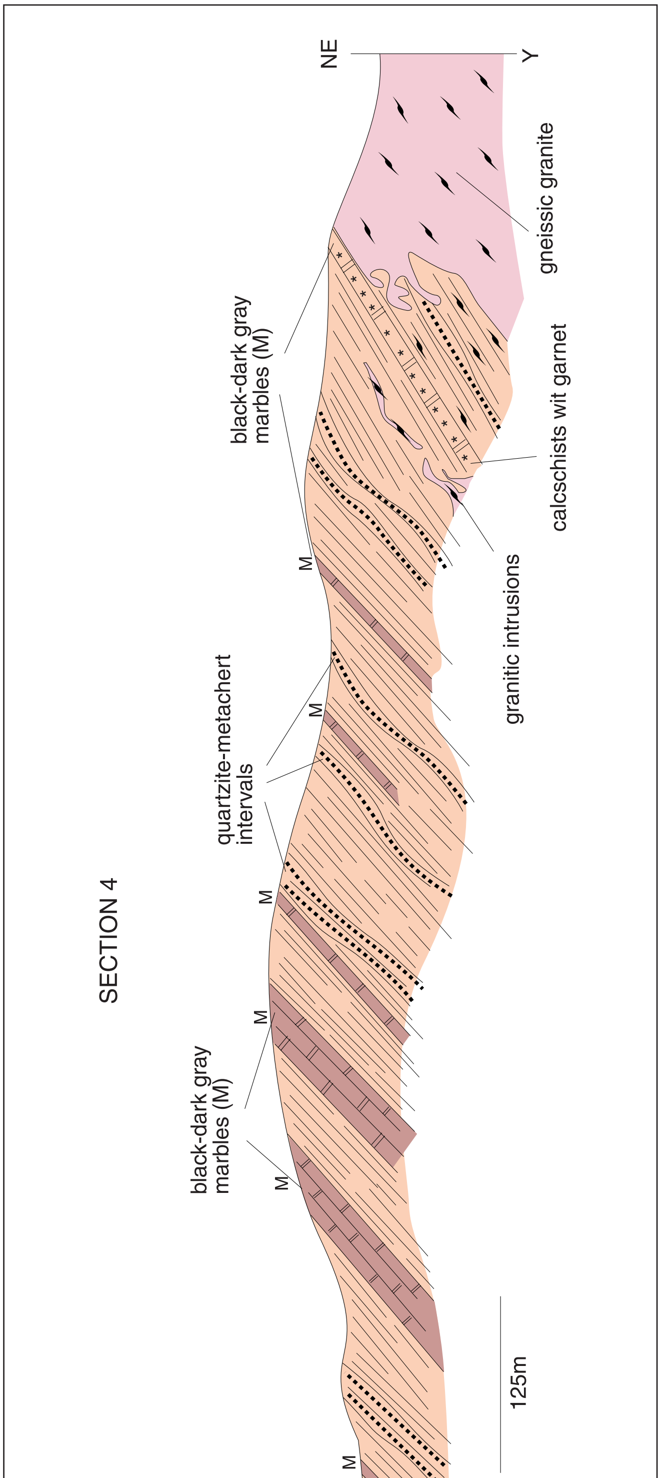

Figure 6- Cross-section showing the relation between gneissic granites and metadetritals in Çine-Yatağan road-Seykel area. For section line see figure 5.

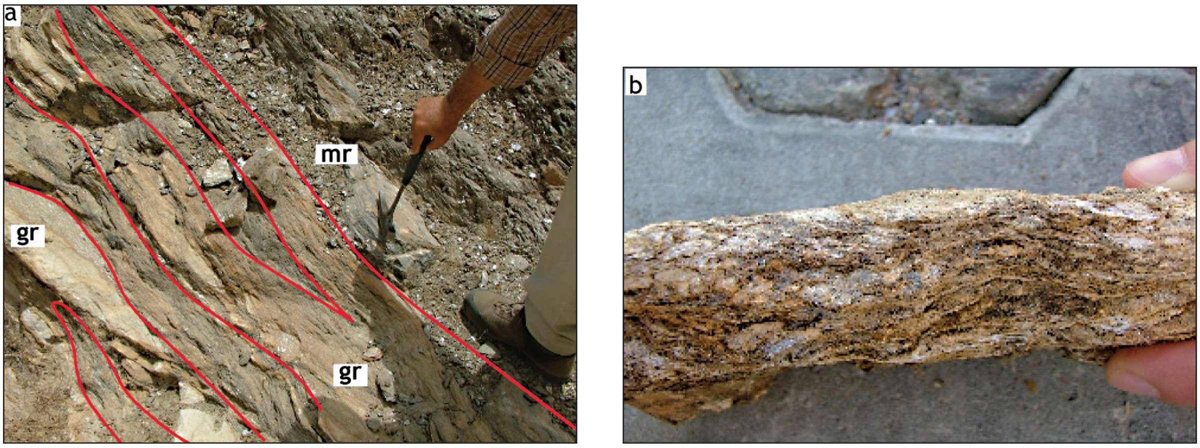

Figure 7- Granitic seams in Palaeozoic schists at Seykel village (Figures 1, 5) road cuts: a) Granites in different thickness emplaced parallely along the foliation planes of marble lenses-bearing schists, b) Just below the marble lenses, typical magmatic texture with quartz and feldspars is seen in granitic seams. Photomicrograph taken from this handspecimen is given in Figure. 9 (Dotted lines: contacts, solid lines: foliation. Mr: marble, gr. Granite, for location of photographs see Figure. 5, UTM 602564 / 4141888).

liova Dam site, both the map pattern and close-up views of the gneisses and country rocks indicate that they were emplaced into the Palaeozoic-Mesozoic succession during formation of their foliation.

COMPARISON OF THE MENDERES SUCCESSION WITH THE PALAEOZOIC AND PRECAMBRIAN UNITS OF THE TAURUS BELT

The western part of the Tauride-Anatolide Platform in the Menderes Massif and eastern side in the Bitlis Massif were metamorphosed during the Alpine Orogeny. But large parts along the Taurus range were not affected by this metamorhism. The oldest parts of the platform crop out around the Sandıklı region and they are not metamorphic (Erdoğan et al., 2004). In the Sandıklı region there is the Kocayayla Group of more than 3 km in thickness in the lowermost part of the succession (Figure 15). In the lowermost parts, the Kocayayla Group consists of quartzite and phyllite association and passes upward into the mudstones and rare limestone intercalations-bearing detritals with felsic lava and pyroclastics. In the mudstones, there are trace fossils that have yielded Early Cambrian age. The Kocayayla Group ends in its upper parts with quartzite and phyllite association. The Early Cambrian Kocayayla Group is unconformably overlain Hudai quartzites passing upward into the Çaltepe formation of dolomite and nodular limestones. The Çaltepe formation contains abundant trilobite and conodont fosil assemblage of Middle-Late cambrian age (Gedik, 1977; Dean and Özgül, 1994). Above the Çaltepe formation there is the Late Cambrian-Early Ordovician Seydişehir formation of thick mudstone succession. In the Sandıklı region a platform succession starting from the detrital Triassic unit to Eocene carbonates overlays unconformably the older units. Thick metaquartzite, mica schist and rare marble succession cropping out in extensive areas in the Menderes Massif that have been mapped and defined as the Pan-African core association (Dora et al., 1992; Candan, 1994*a*; 1994*b*; 1995; 1996; Hetzel and Reischmann, 1996; Candan and Dora, 1998; Loos and Reischmann, 1999; Candan et al., 2001; Koralay et al., 2001; Gessner et al., 2004; Koralay et al., 2007; Bozkurt, 1996; Candan et

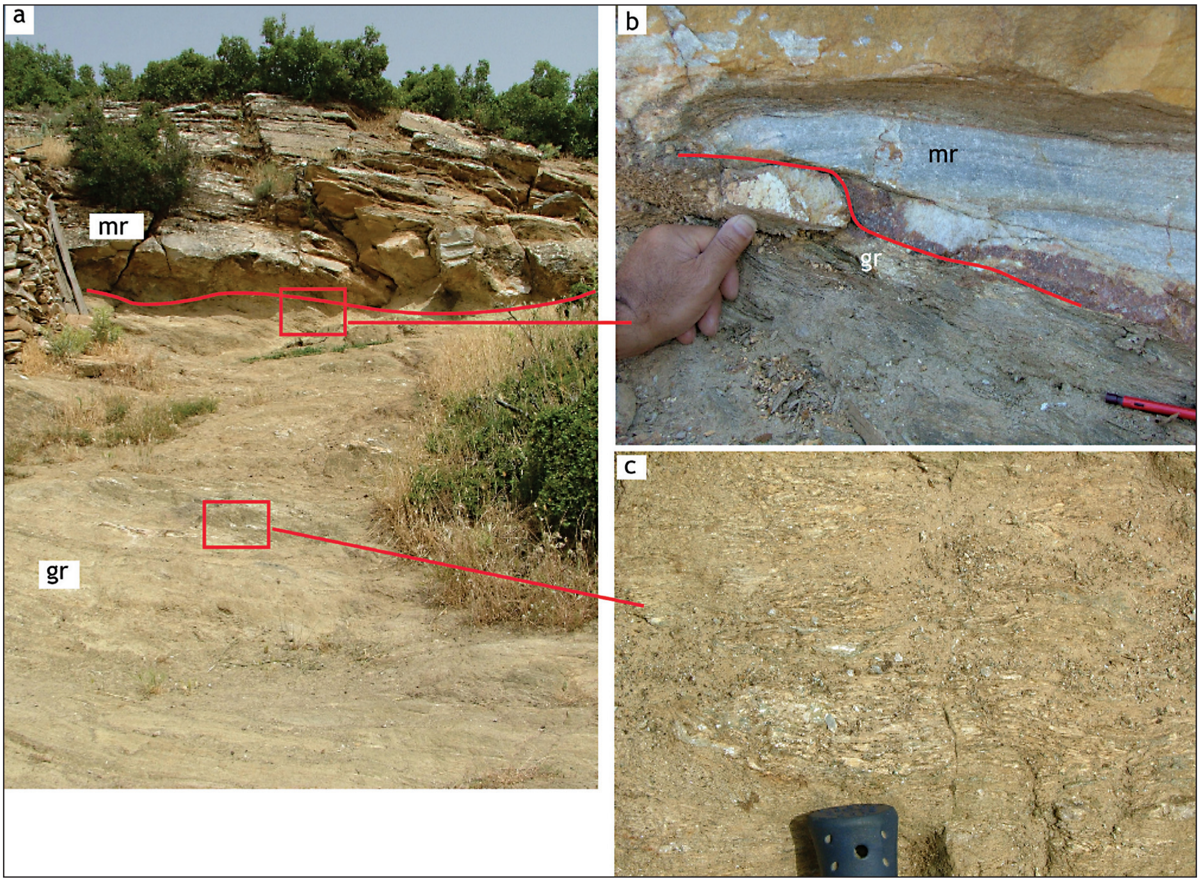

Figure 8- Near Seykel village (Figures. 1, 5) main granitic body engulfes the marble lenses where partly migmatized schists and granitic seams are in contact with the marbles including garnet porphyroblasts of 0,5-1 cm in length. a-b) Marble lenses intercalating with the schists which are engulfed and assimilated by migmatitic granites (in Figure b, finger shows gneissic granite seam touching marble lense). c) Gneissic granites with magmatic texture in schists. In situ migmatization is seen in the upper part of the hammer (Dotted line: contact, mr: marble, for location of photographs see figure. 5, UTM 603656 / 4142751).

al., 2006; 2007) resemble in facies and thickness to the Kocayayla Group and might be Early Cambrian in age.

The eastern part of the Tauride-Anatolide Platform had been metamorphosed as the Menderes Massif and forms the Bitlis Massif. In the north of Selvi town and around Avnik village (Bingöl), the Bitlis metamorphics consist of Lower and Upper associations (Figure 16a). The Upper association is represented by 2 km-thick white and gray marble succession of Palaeozoic-Mesozoic age characterizing the platform of the Taurus range. Below the platform marbles there is more than 1 km-thick lithologically uniform garnet mica schists unconformably overlying the Lower association along a thin metaquartzite basal level. These uniform mica schists resemble to the Ordovician-Silurian Seydişehir formation of the Taurus range.

The Lower association is more than 2,5 km in thickness around Avnik village and consists of mafic volcanics, amphibolites and leucocratic

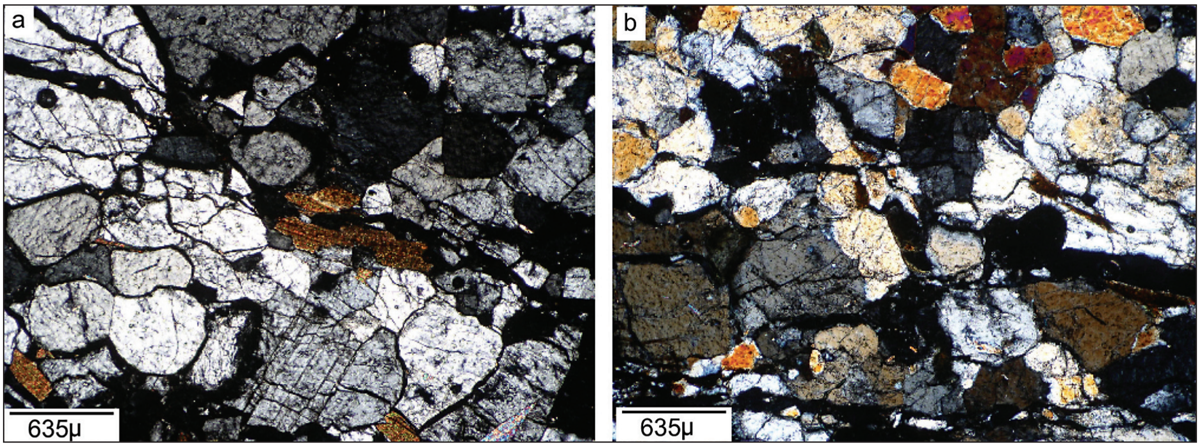

Figure 9- Typical magmatic texture and mineral assemblage are seen in granitic seams along the Seykel Village road (Figures 1, 5). (Hand specimen: Figure. 7b. Photographs were taken in cross-polarized light. This sample was collected below the marble lense shown in map).

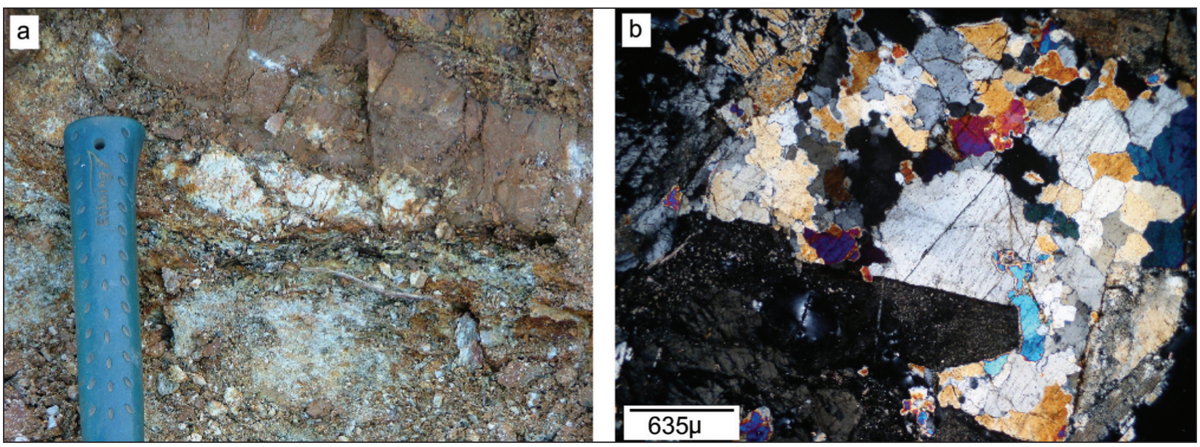

Figure 10- Along Seykel village (Figures. 1, 5) granitic seams are found also above the marble lense. Deformation did not errased the granitic texture. a) Field view, b) Deformed granitic texture in thin sections (For location of photograph and thin sections, see figure. 5, UTM 603003 / 4142130, photomicrograph was taken in cross-polarized light).

gneisses (Figure 16a, b). In the metavolcanic succession there are laterally contunious banded iron formations. Apatite-bearing banded iron formations in the north of Avnik village along the Mur valley (Figure 17) interlayered with the metatuffs, mafic and felsic metavolcanics and formed as lenses paralel to the original stratigraphic layers in the volcano-sedimentary succession (Erdoğan et al., 1981; Erdoğan, 1982). The Lower association is cut by migmatitic leucocratic and fine grained Avnik granitoid. The heterogenous pile of the Lower association, cropping out below the Ordovician-Silurian Upper association and separated from it by a pronounced unconformity, has been interpreted as the Precambrian in age (Erdoğan et al., 1981; Erdoğan, 1982). Banded volcanostratigraphic iron formations are characteristics in the Precambrian units all around the world (Bankes, 1973; Goodwin, 1973; Banerji, 1977; Kimberley,

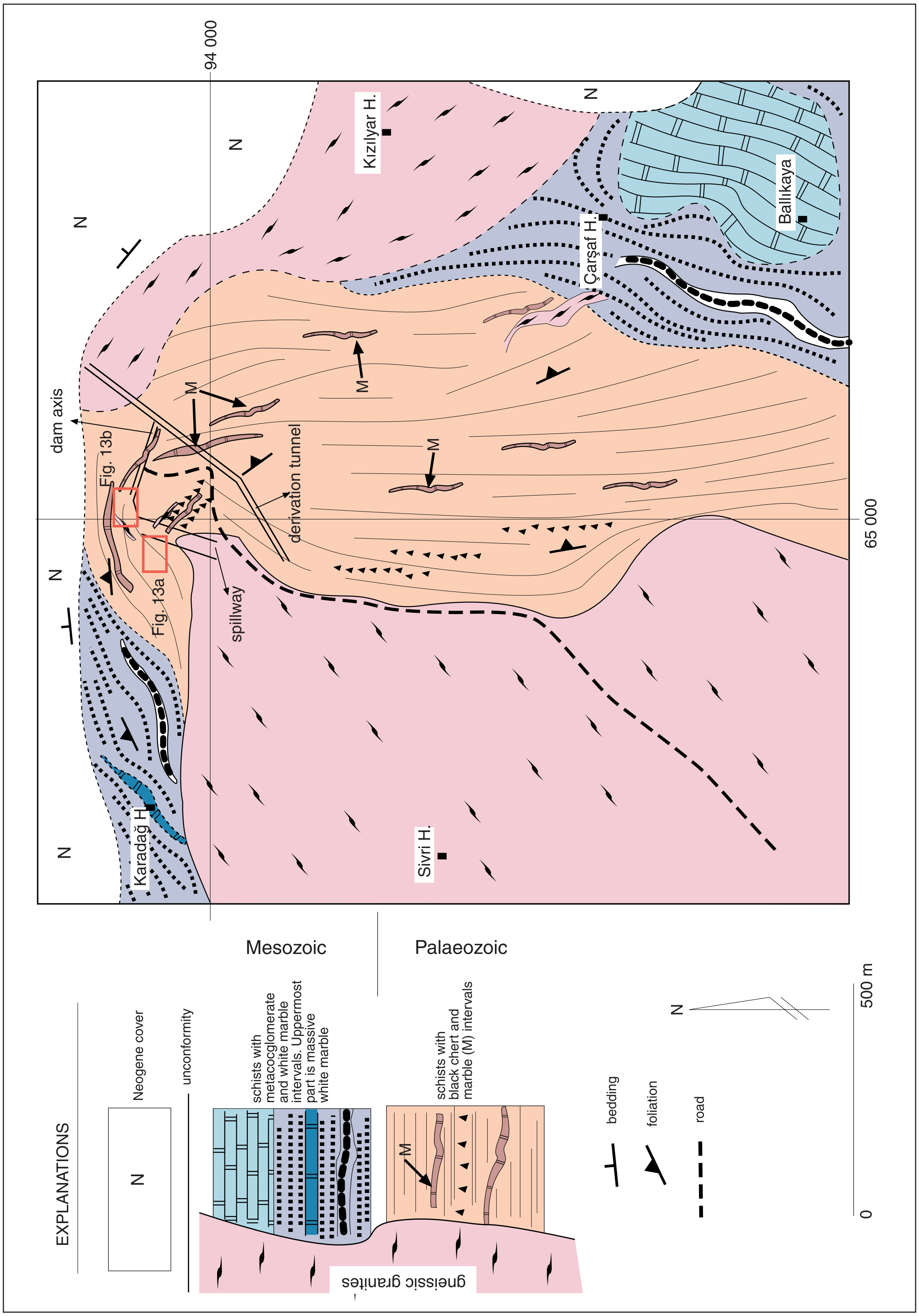

Figure 11- Geological map of the İkizdere Dam site

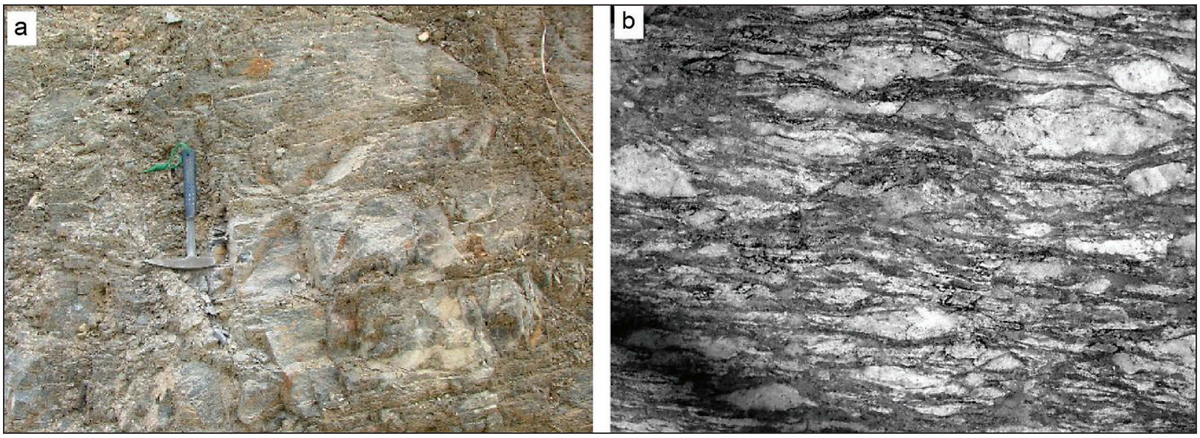

Figure 12- Characteristics of the Palaeozoic-Mesozoic sequence around İkizdere Dam site. a) Black chert s (UTM 564972 / 4193988), b) Conglomerate intercalations in Mesozoic units overlying the Palaeozoic succession (UTM 564591 / 4194107) (Lines on photographs show foliation).

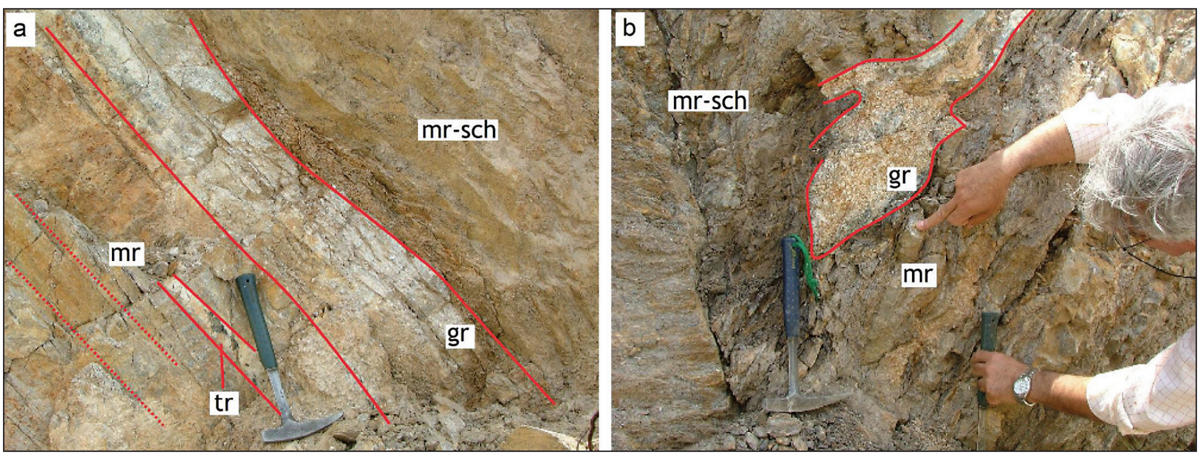

Figure 13- a-b) At the spillway cuts of the İkizdere Dam, granites with tourmaline crystals emplaced into the marbles parallely to the foliation. In these outcrops quartz and feldspar-bearing mineral association and magmatic texture are clear in granitic seams. Tourmaline layers are found (Dotted lines: foliation, solid lines: contacts, mr: marble, gr. granite, tr. tourmaline, for location of photographs see Figure 11. a: UTM 565038 / 4194140, b: UTM 565038 / 4194156)

1978; Gole, 1981). In the core-succession of the Menderes Massif, however, there is no economically important banded iron formations and besides that they are almost devoid of any metallic mineralizations. For this reason the thick metadetrital succession of the Menderes which is considered to be Pan-African basement do not have any resemblance with internally continuous banded iron and apatite-bearing thick Pre-cambrian metavolcanic succession of the Bitlis Massif.

In the Bitlis Massif the Lower association is cut by migmatitic granites and deformed. The

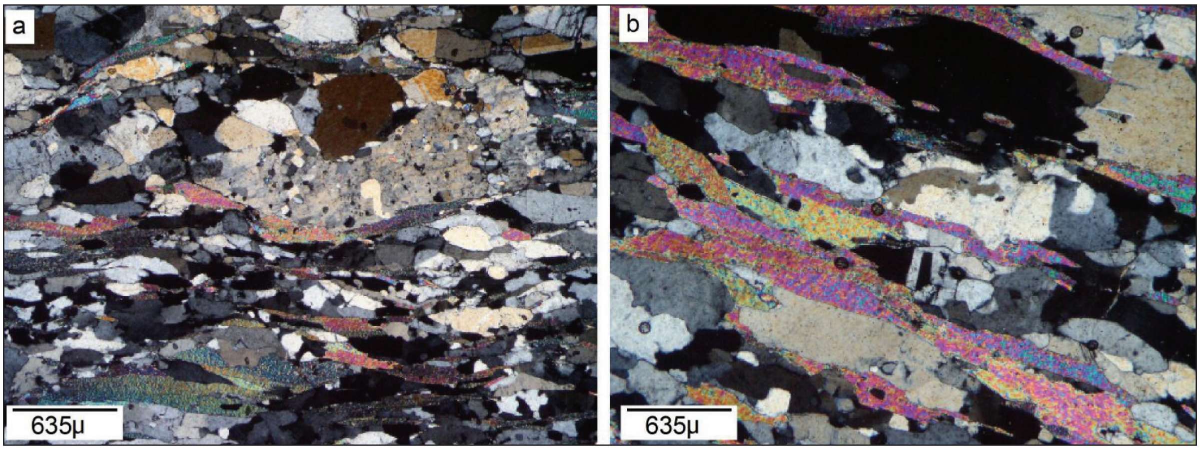

Figure 14- Granitic texture is clealrly determined in thin sections from gneissic granites in marble-gneissic granite alternation. Granites are made up of quartz, feldspar and biotie (Photomicrographs are cross-polarized in light).

Upper association unconfomably overlies these units. Later during the Alpine Orogeny, both groups deformed and metamorphosed. However, the unconformity between the Precambrian units and the Palaeozoic Upper association is still clearly definable and mappable. Along the unconformity surface (shown on Figure 16a by arrows) the basal quartzites of the Upper association directly overlay different units of the Lower association.

Stereographic projection of the mesoscopic fold axis which were measured on a relatively not complicated area covering both the Upper and Lower associations in the North of Avnik Village is given in figure 18. In the Upper association prominent fold axis is N40-50W/30-60 NW in setting. In the Lower association though, two different groups of fold axis are plotted, one is conformable with those found in the Upper association coinciding the Alpine deformation, and the other (EW/10-30W) is inherited from the older deformation before the Ordovician-Silurian unconformity. Although the region had experienced strong Alpine deformation and metamorphism the old deformation were not errased and stil recognizable.

DISCUSSION AND CONCLUSIONS

In the Dibek Mt, Çine-Yatağan and İncirliova regions the gneissic granites emplaced into the surrounding rocks syntectonically and display wide migmatitic zones. The granites and the country rocks deformed together attaining concordant foliation. On regional-scale foliation zones channalized migmatitic fronts form quartzofeldspatic augens and septums in thickness ranging from cm to map scale. Along these three regions there are always transitional passing from the country rocks into the granitic bodies. In the direction to the granitic bodies grade of metamorphism increases and almandine biotite kyanite sillimanite paragenesis appears in shiny biotite quartz mica schists. In the biotite schists with red clear almandine porphyroblasts, quartzofeldspatic lenses are observed in the field. These granitic seams and augens increase in number and thickness toward granitic bodies in the migmatitic fronts. There are abundant partly or completely engulfed and digested restites of biotite schist as it is entered into homogenous granitic bodies in which sillimanites join into almandine-biotite-kyanite paragenesis. The sillimanite-bearing restites display polygonal texture under microscope suggesting partial melting and

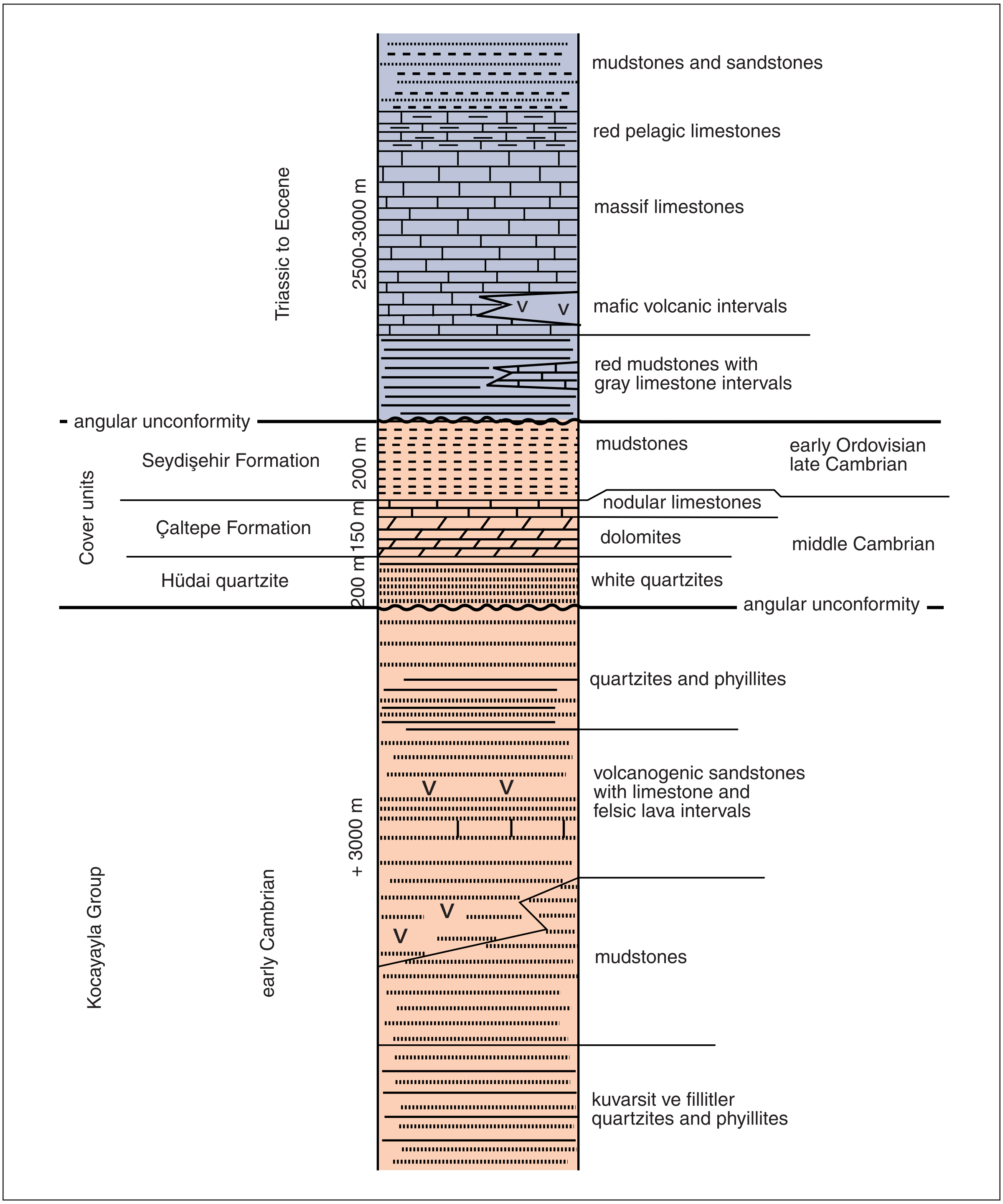

Figure 15- Generalized stratigraphic column of the Sandıklı region (After Erdoğan et al., 2004). Palaeontologically aged Palaeozoic units are lithologically resemble to the metadetrital units of the Menderes Massif.

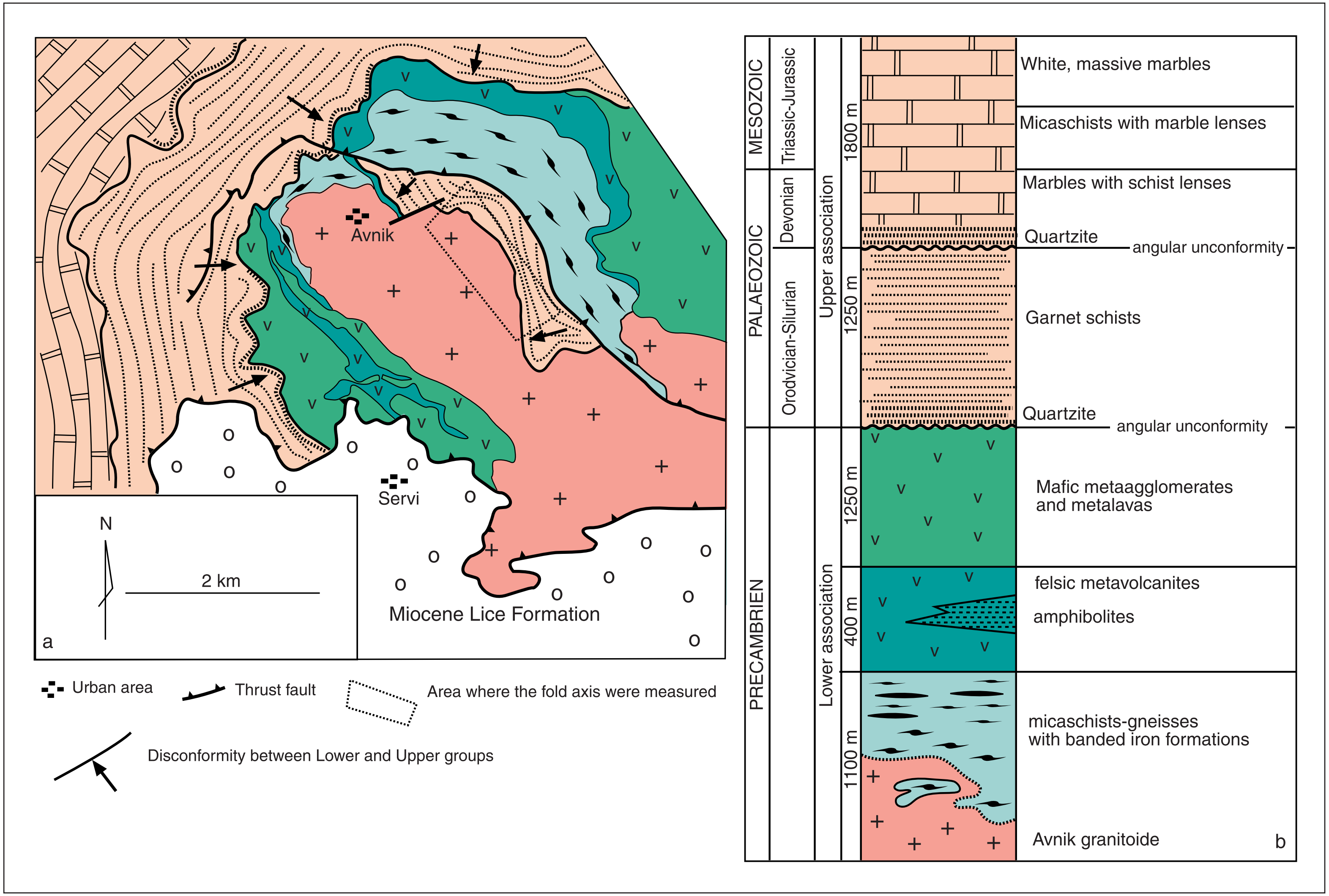

Figure 16- a) Geological map of the Bitlis Massif around Avnik Village (Bingöl). Unconformity between the precambrian and Palaeozoic-Mesozoic units is definable and mappable although the Alpine metamorphism (Arrows in map show the unconformity surface). The mesozcopic fold axis given in figure 17 were measured in the squarred area (For explanations of map, see figure 16b) b) Generalized stratigraphic column of the Avnik region. Lateral equivalents of the Precambrian units are not found in the Menderes Massif (Simplified after Erdoğan, 1982 and Erdoğan and Dora 1983).

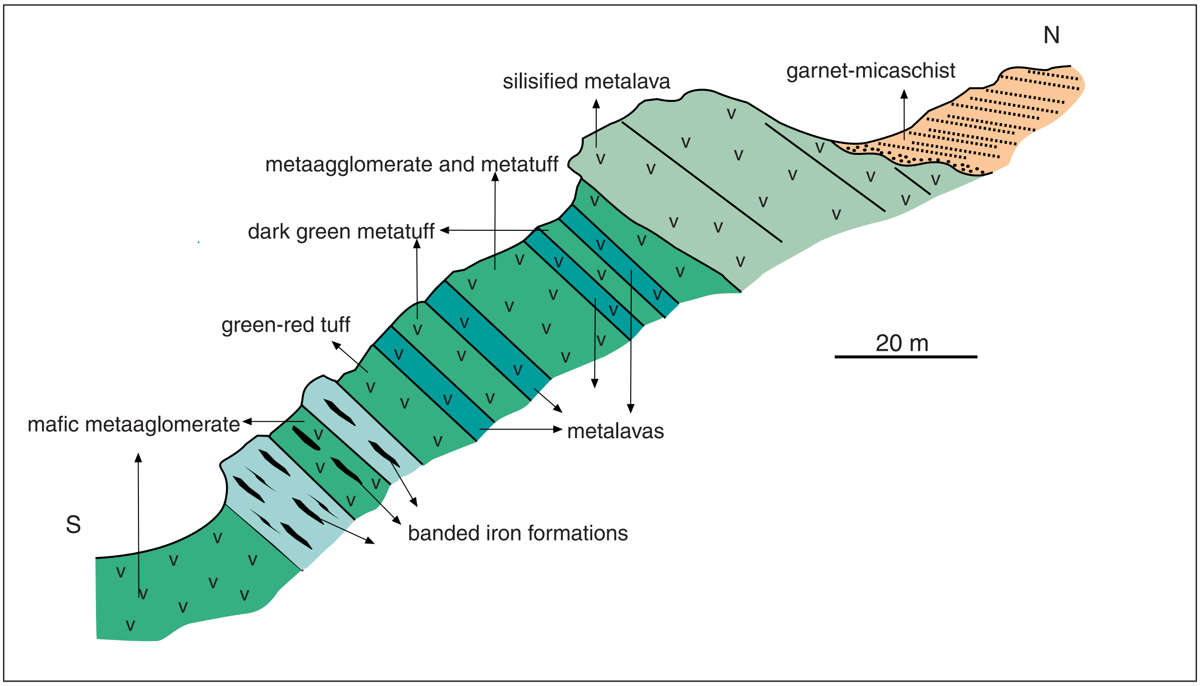

Figure 17- Cross-section showing stratigraphy of the Precambrian units in the Bitlis Massif along Mur valley (north of Avnik) (After Erdoğan et al., 1981). Banded iron formations are found concordant intercala tions in mafic metacolcanics.

they are common in gneissic granites in various parts of the masif and mapped as leptite gneisses in previous works (Dora et al., 1988; 2001).

In the previous studies based on the dips of foliation and an assumption that the gneisses would always be structurally lower attitude, the boundaries with foliation dipping toward the migmatitic fronts were interpreted as thrust faults. Besides, increase in grade of metamorphism along the dip of foliation toward migmatitic granites were wrongly interpreted as overturned limbs. On the other hand, in the map areas the country schists were melted in situ and strongly assimilated during the formation of foliation and the foliation surfaces channalized the migmatization (Figure 4). So that while foliation was forming on a regional scale migmatization fronts prefered the shear surfaces that caused in situ melting. Dibek Mt region is an example of this type of syntectonic emplacement of migmatitic fronts. In the direction of increase in metamorphic grade it is gradually entered into migmatitic front where lithologically homogenous but still strongly foliated granitic bodies crop out. Thus, the central parts of large granitic bodies would be a magmatic realm. During such a syntectonic granite emplacement gneissic granites structurally overlying the mica schists do not mean an overturned sequence or tectonic imbrication. Around Ödemiş and Kiraz region small diabasic or gabbroic dykes and stocks are found completely digested in the magmatic realm. These strongly assimilated and digested ghosts of diabasic rocks were defined as eclogite or granulites and interpreted as the older metamorphic phases (Candan, 1994*a*; 1994*b*; 1995; 1996; Candan and Dora, 1998; Candan et al., 1998; 2001). Defining metamorphic phases and granites in magmatic centers of the gneissic granitic fronts would lead us wrong conclusions

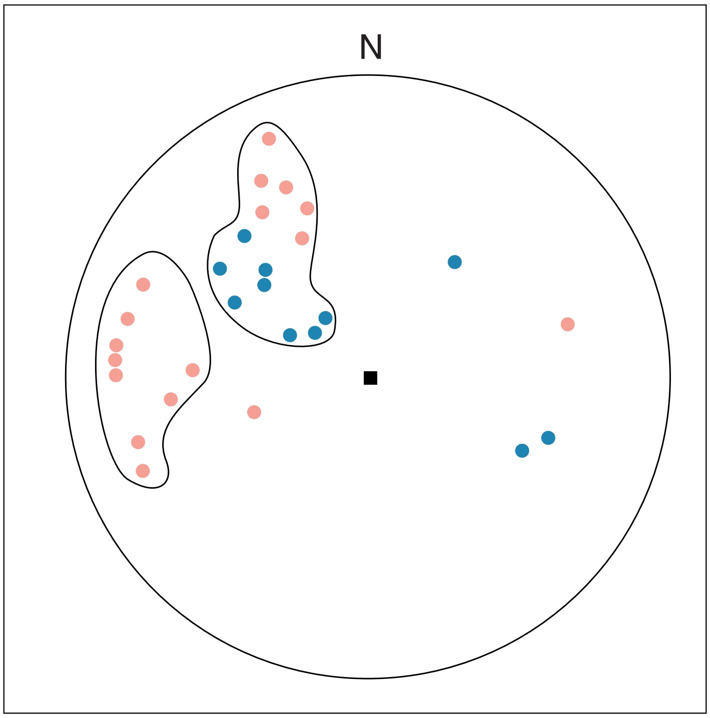

Figure 18- Stereographic projection of the Mesozcopic fold axis measured from both the Lower and Upper associations in Avnik region (Red dots: axis measured from the Lower association, blue dots: axis measured from the Upper association)

and be carefully accepted. In earlier studies under microscope magmatic phases with charnockites were defined in central parts of magmatic fronts (Candan, 1995). They would also be accepted carefully.

At the border zones of the gneissic granite bodies there are various magmatic phases and types of granites. For example near Bafa Lake there are aplitic dykes, muscovite-rich granites, biotite-rich phases, tourmaline-bearing leucocratic gneissic granites and metagranites. These different phases, on the other hand, show close geochemical similarity on nomenclature geochemical character and tectonic phase diagrams (Erdoğan and Güngör, 2004) (Figure 19). In this area granites varying from leucocratic to melanocratic character also form a single geochemical association. They are S-type and Syn-Collisional in character (Figure 19) and compared to the alkalines they are all rich in Al content indicating that the different phases were evolved from one parent magma and do not differ in phase and formation as stated by Bozkurt and Park (1994; 1997*a*; 1997*b*) some phases injected into the detachment zone.

As described in the Dibek Mt these various phases ranging from leucocratic to melanocratic granites were formed in the deep crustal environment by partial to complete assimilation of country schists inside the migmatitic fronts without any spatial relation with extensional shear zones. Clearly intrusive contacts with mica schist enclaves in the gneissic granites, on the other hand, are rare in the Menderes Massif and might

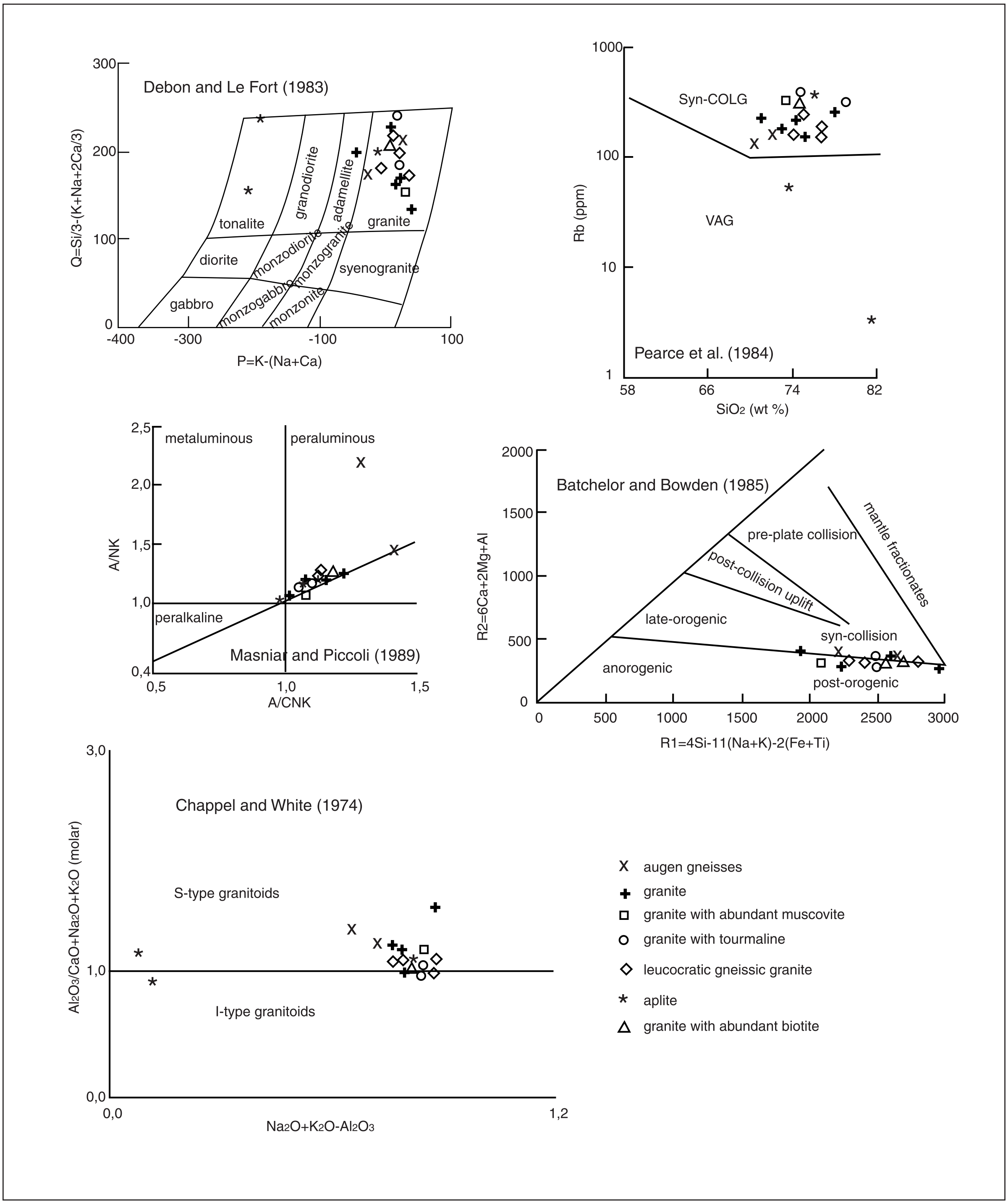

Figure 19- Geochemical nomenclature and tectonic discrimination diagrams of different-phase gneissic rocks from the Bafa Lake region. Different-phase gneisses show similar geochemical characteristics (After Erdoğan and Güngör, 2004).

correspond the shallower parts of the granite emplacemet.

Along Çine-Yatağan road and near İkizdere Dam, the gneissic granites injected directly into the well-known Palaeozoic and Mesozoic succession during the Main Menderes Metamorphism as concordant syntectonic granites. Along their boundaries no structural unconformities are present. The marble intercalations at the contact zone were inverted into calc-fels with garnet porphyroblasts.

The gneissic granite emplacement occured during the Alpine Orogeny. 500-560 Ma Precambrian radiogenic ages reported in some earlier publications are not in accord with the structural and geological data. In recent years metagranites, emplaced structurally concordant to the gneisses, have been mapped along the northern border of the Menderes Massif (Akay, 2009) and 30 Ma zircon ages have been determined in these metagranites (Hasözbek et al., 2010*a*). The Alpine metagranites and leucogranites from different parts of the masif were also documented in the literature (Bozkurt and Satır, 2000; Bozkurt and Park, 2001). These metagranites geochemically and structurally resemble to the gneissic granites (Figure 19; Erdoğan and Güngör, 2004). 550 Ma upper intercept points obtained from the zircons in gneissic granites, beside, indicate that the Alpine metagranites were originated from the older granites in the crust (Hasözbek et al., 2010*a*).

New field mapping and radiogenic studies indicate that during the Alpine orogeny the crust was strongly melted and rejuvenated. Remobilized magma, almost completely, assimilated the Precambrian-Palaeozoic unconformity and directly injected into the cover succession. The Precambrian ages from the rejuvenated Alpine migmatites would inherited from the parent rocks. In the Çine-Yatağan region in the structurally lowermost parts of the granitic terrane from probable remobilized leucocratic granites we are presently trying to do new radiogenic age determinations and expecting to obtain Alpine traces of remobilization.

Evirgen (1979; 1981), Evirgen and Ashworth (1984) to the north of Ödemiş city examined and mapped the facies characteristics of the Main Menderes Metamorphism and defined a high-temperature Barrowian-type metamorphism as represent by appearence of sillimanite. Erdoğan and Güngör (2004) tried to explain this high-temperature by southward dipping subduction zone along the northern magrin of the Menderes Platform. On the other hand metamorphic facies of the extensive tectonic zones that were defined along the northern edge of the Menderes Massif by Okay et al. (1996; 2005); Candan et al. (2005); Okay (2007), indicate northward diving of the platform edge up to the 80 km in Tavşanlı and Afyon Zones. Therefore, from the northern border any southward dipping subduction would not be valid. In recent years we mapped southery imbricated thrust packages along the northern side of the massif (Hasözbek et al., 2010*b*) which also preclude the model of Erdoğan and Güngör (2004). But it is stil a problem to explain high-temperature-type Barrowian metamorphism and migmatitic emplacement of granites during the Alpine Orogeny. Burried by tectonic slices would not be able to explain this controversy and needs a better explanation.

In this study we compared the Menderes succession with the Taurus Range in two different areas; one is metamorphosed during the Alpine Orogeny and the other is not. In the Sandıklı region there is a thick detrital sequence (Kocayayla Group) which is Early Cambrian in age. The metamorphic equivalent of this unit would be the thick metadetrital succession around Ödemiş-Alaşehir examined by Evirgen (1979; 1981) and Evirgen and Ashworth (1984).

The Bitlis Massif around Avnik region is similar to the Menderes Massif and affected by Alpine metamorphism. There is a thick mafic-felsic volcanic succession with banded iron formation of probably Precambrian age around

Avnik and is overlain by Palaeozoic-Mesozoic platform succession along an unconformity. The Alpine metamorphism was as high as that of the Menderes Massif but still the Palaeozoic unconformity and old deformations are recognizable and can be easily discovered by mapping on 1/25000 scale. The Precambrian succession of the Bitlis Massif is completely different with thick mafic-felsic volcanic succession and including banded iron formation of economic size that are characteristics of the Precambrian successions in other parts of the world.

As a conclusion the Precambrian outcrops are either completely engulfed by gneissic granites or limited in areal extend. They would be searched in areas of below the Palaezoic schist sequence and away from the granitic fronts.

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