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NEOGENE-QUATERNARY EVOLUTION OF THE EASTERN MARMARA REGION, NORTHWEST TURKEY

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ABSTRACT.- Three main stages have been distinguished in the Neogene-Quaternary morphotectonic evolution in the East Marmara region. They are Early-middle Miocene, Late Miocene-Pliocene and Latest Pliocene-Present. Three different sedimentary sequences, each overlies the other with an angular uncomformity, have been formed in these stages. Early-middle Miocene sedimentary sequence is characterised by continental detritics whereas the Late Miocene-Pliocene rocks are represented by continental to marine transitional sediments. Terrestrial-marine sediments have been deposited since the latest Pliocene till Present. The region was transformed to denudational area by the closure of the Intra-Pontid Ocean in the end of the Oligocene and it was under the effect of paleotectonic events during the early-middle Miocene. In the end of this erosional period which lasted until the end of middle Miocene, a peneplain morphology covering large area was formed and terrestrial sediments were deposited. Neotectonics which has affected actual geology in the region, initiated in the beginning of late Miocene and occurred in two stages which differ tectonic styles. In the late Miocene-Pliocene time, the region was affected by N-S directed compressional regime and it was uplifted by NE-SW and NW-SE trending strike-slip faults with E-W lying folds as a result of this compression. During this stage, a Late Miocene-Pliocene sedimentary sequence which starts with fluvial sediments at the bottom and passes into lacustrine to marine at the top, was deposited. In the end of the period, depressions in which late Miocene-Pliocene sediments were deposited, were spread out and the region was formed as a denudational area in the late Pliocene. The second stage of the neotectonic period covers a time interval from the Latest Pliocene to Present and it begun with the occurrence of the North Anatolian Fault. Actual morphology and active tectonic frame of the Eastern Marmara region were developed in this time interval which is known with the transform character of the North Anatolian Fault. However, structural evolution of actual Marmara sea region which is related to North Anatolian Fault, initiated in Latest Pliocene.

INTRODUCTION

Many investigations related to structural and paleogeographic evolution of the sea of Marmara and its surrounding region in Neogene and Quaternary times were done (e.g. Şengör, 1979, 1980, 1982; Şengör et al., 1985; Crampin and Evans, 1986; Barka and Kadinsky-Cade, 1988; Wong et al., 1990, 1995; Görür et al., 1995, 1997; Erol and Çetin, 1995). In these studies it was thought that regional paleogeographic changes were linked and identified with the structural evolution of the North Anatolian Fault (NAF) supposed that there has been since Late Miocene (Görür et al., 1995, 1997). It was pointed out that, as proposed by Şengör et al. (1985), the geography of sea of Marmara and the surrounding region has been formed with the emergence of the NAF in Late Miocene, the whole region being under the effect of a N-S oriented extensional regime in between Western Anatolia and the NAF, and the NAF itself undergoing a structural evolution process based on its displacement and younging southward. In many research, it was agreed that, in the region the rocks of Neogene - Quaternary age including marine units were deposited in the basins developed accordingly this model of evolution (Şengör et al., 1985; Siyako et al., 1989; Erol and Çetin, 1995; *Görür* et al., 1995, 1997).

In this paper, the widely exposed Neogene-Quaternary sediments in the Eastern Marmara region are discussed (Fig.1). For this purpose, sedimentary basins considering the rocks and their stratigraphic positions, their actual morphology and the their deformations in neotectonic period were studied to provide a new perspective on the paleogeographic evolution of the region in Neogene - Quaternary based on the interrelation between tectonics, morphology and sedimentation.

STRATIGRAPHY

The pre-Neogene basement of the region consists of rock assemblages of Istanbul and Sakarya zones developed in the paleotectonic period (Şengör and

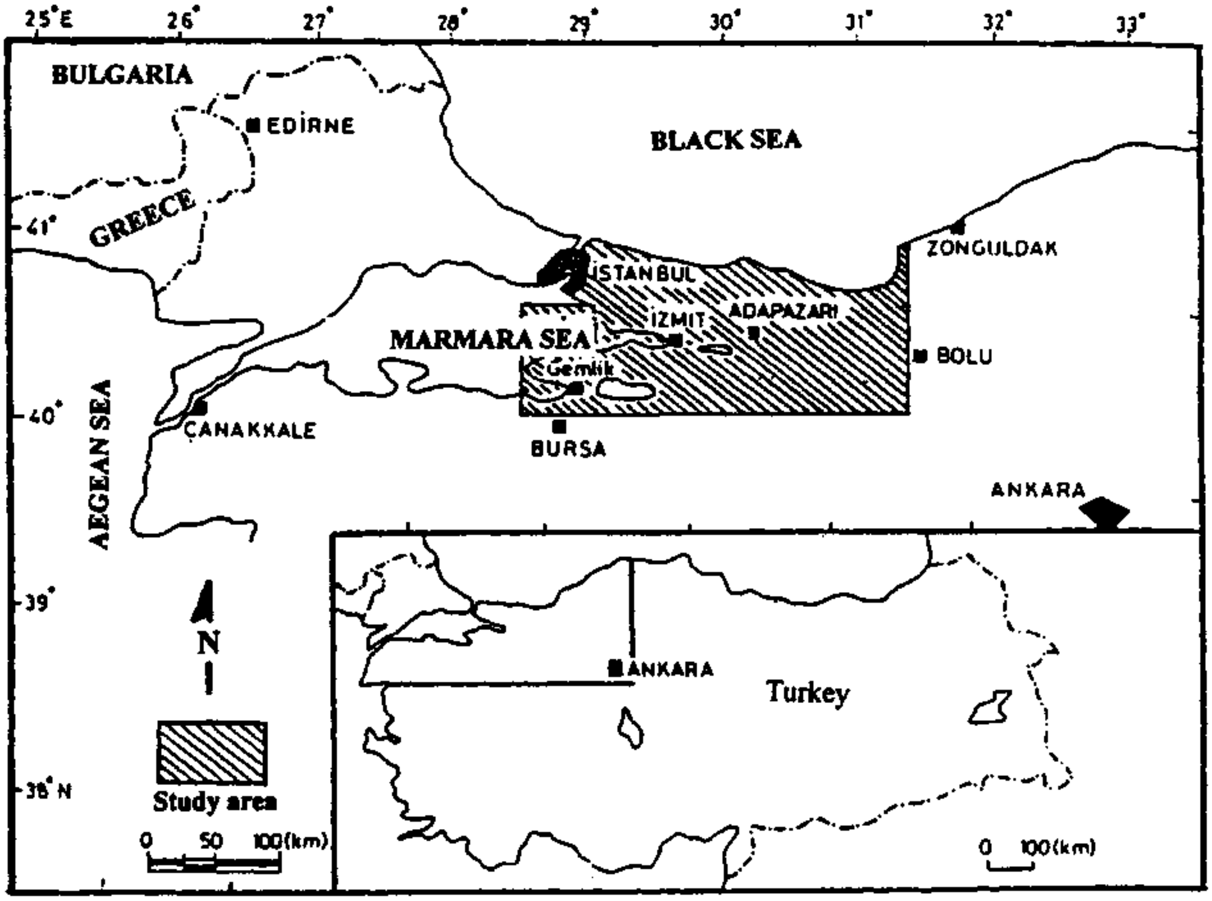

Fig. 1- Location Map of the studied area.

Yılmaz, 1981; Okay, 1989; Okay and Görür, 1995; Yılmaz et al., 1995) (Fig.2). These two zones juxtapose along the suture which formed as a result of the closure of the Intra-Pontide Ocean in Early Eocene-Oligocene where the NAF is present now (Şengör and Yılmaz, 1981; Okay, 1989; Okay and Görür, 1995). Of these, the Istanbul zone comprises the sedimentary rocks of Ordovician-Lower Tertiary age and whereas the Sakarya zone is made up of a metamorphic basement and a sedimentary cover of Jurassic - Cretaceous age (Okay, 1989; Okay and Görür, 1995; Yılmaz et al., 1995).

The Neogene-Quaternary aged rock assemblages in the region make up three different sedimentary sequence developed in different time and facies (Figs. 3 and 4). They can clearly be distinguished by angular unconformities. Of these, the oldest ones, Early - Middle Miocene aged rocks are seen in Kocaeli peninsula, the Late Miocene- Pliocene aged ones are observed in Armutlu peninsula and in Bilecik-Bursa regions, and the Latest Pliocene-Recent aged ones are seen in the basins/corridors situated along the NAF zone (Figs. 3 and 5). The recent distribution of the sediments are conformable with the age and character of the neotectonic structures in the region, and with the morphotectonic structure they formed. The above mentioned conformity is the main support of the evolution proposed in this paper. Therefore, the stratigraphy of the region is given in sub-regions each corresponding to a different morphotectonic unit. In the wide study area, the related geological units are simplified and the names of the small settlements have not been indicated (Figs. 1-6). To provide easy comprehension the stratigraphy of each region are seperately emphasized. Since the

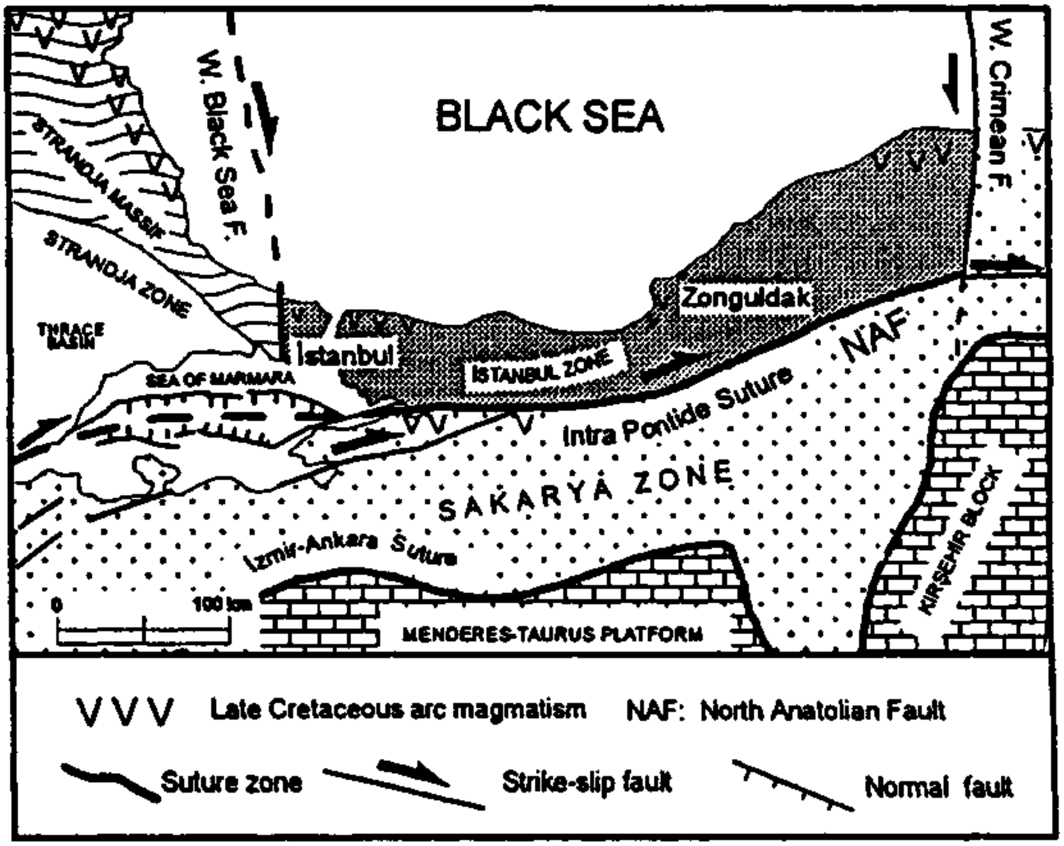

Fig. 2- Tectonic setting of the studied area (from Görür et al., 1997).

stratigraphic details are stated good enough to explain the morphotectonic evolution no stratigraphic descriptions are given.

BLACK SEA REGION

The region bounded by the NAF, sea of Marmara and the Black sea is defined under this heading. In this region the distribution of the Neogene-Quaternary sediments are limited and comprises of two rock assemblages (Figs. 3 and 4).

EARLY MIDDLE MIOCENE

Karasu formation

Crops out along the Black sea coast in Karasu-Kefken and in the Istanbul section of the Kocaeli peninsula (Fig.3). It was defined in I: 500 000 scale geological map of Turkey (MTA, 1964) as of Plio-Quaternary age, in Aydın et al. (1987) as Örencik formation of Pliocene age and both in Baykal and Önalan (1979) and Seymen (1995) as Belgrat ormanı formation of Plio-Quaternary age. The red, yellow and brown colored formation is made up of sandstone, pebbles, siltstone and mudstone. Typical locality is Karasu region (Fig.3) where the thickness of the unit is 30-40 m cropping with angular unconformity on the pre-Neogene basement (Fig.4). At the lowermost levels, on the basement rocks, a red and brown colored paleosol layer up to 10m thick is observed overlain by an alternation of sandstone, pebbles, siltstone and mudstone. Sandstones mostly include quartz grains. Pebbles have undergone severe weathering. In these detritic levels weathering crust up to 1 m thick can be observed.

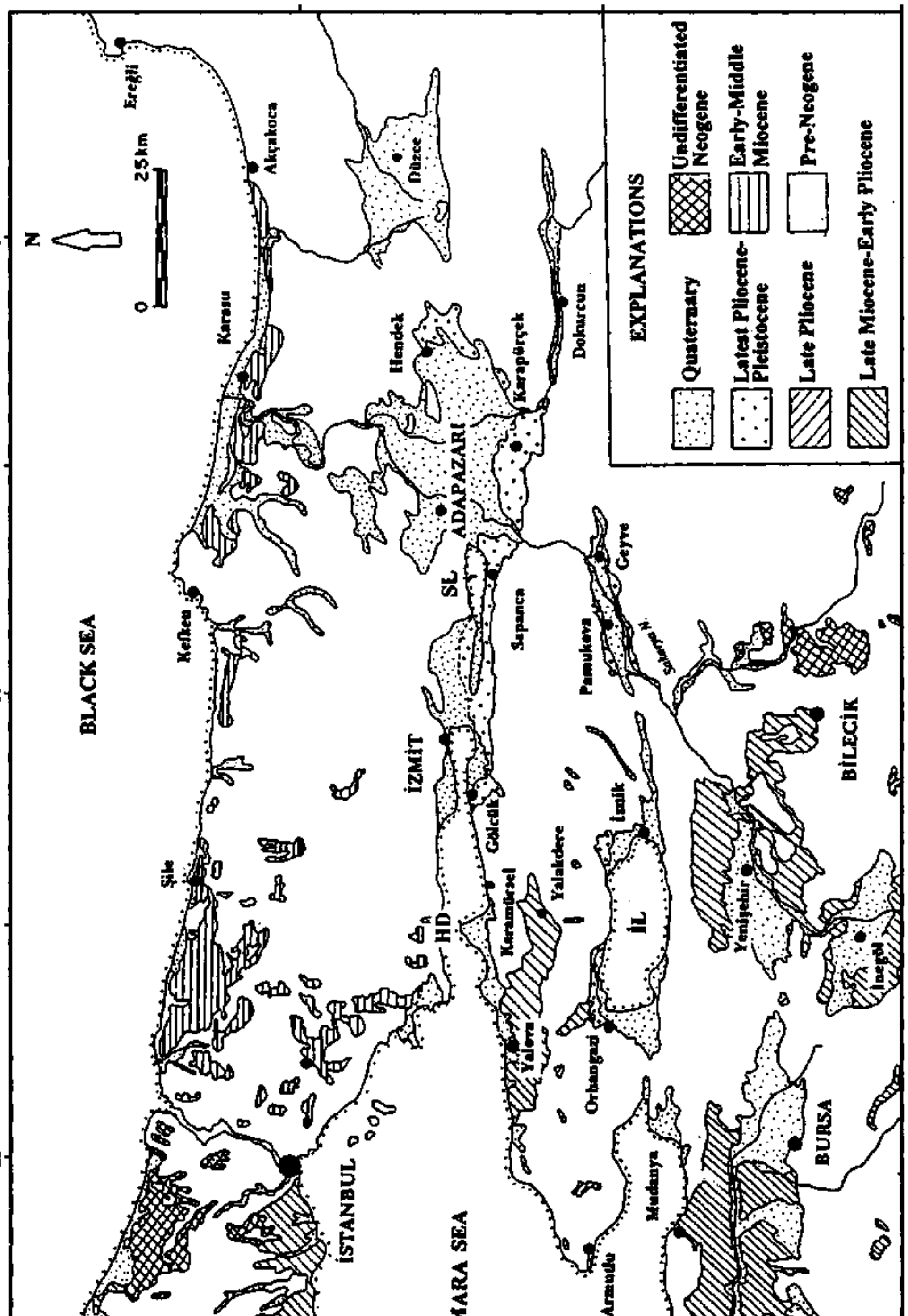

Fig. 3- Map showing the distribution of Neogene and Quaternary sediments in the eastern Marmara region. HD: Hersek Delta, SL: Sapanca Lake, İL: İznik Lake, UL: Ulubat Lake (modified from MTA, 1964).

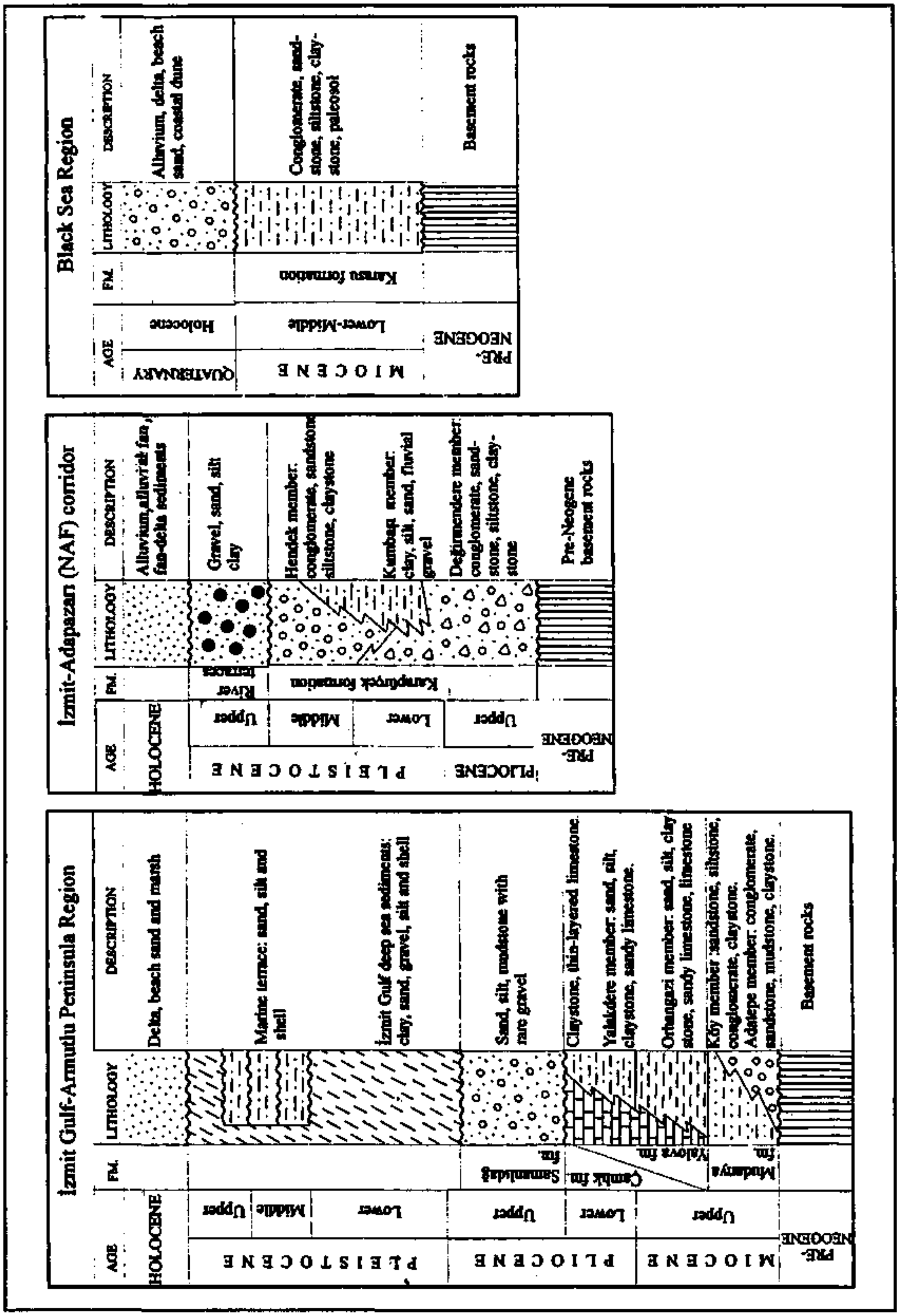

Fig. 4- Columnar stratigraphic sections of the studied area (not in scale).

No dating information was provided for this formation. It is overlain by Holocene shore sediments in Karasu area. The thick paleosol at the base, the severe weathering in pebbles and the weathering crust included indicate the unit is deposited in humid and warm climatic conditions (Wright, 1992a, 1992b; Mack et al., 1993). In Mudanya formation of Upper Miocene age in Armutlu peninsula weathered pebbles of this formation can be seen. Erol (1981) states that the regional geomorphological data indicates that the formation was deposited as terrestrial sediments of a peneplanation process took place under humid and warm climatic conditions in Early - Middle Miocene. The age of the formation, therefore, is assumed to be of Early - Middle Miocene age.

HOLOCENE

Quaternary in Black sea region is made up of Holocene aged deposits. The Holocene sediments on land comprise alluviums. On the Black sea coast, on the other hand, delta of Sakarya river, actual beach, old and new coastal dunes and back- swamp deposits were formed (Fig.4).

ARMUTLU PENINSULA - İZMİT BAY

The Neogene-Quaternary sediments in the region crops out in Mudanya-Nilüfer creek valley, in Armutlu peninsula and in the surroundings of İzmit Bay (Fig.3). The sediments here with respect to the ones in the other regions include much more time intervals stratigraphically (Fig.4). The distribution of the sediments, when examined in morphological point of view, are as follows: The Neogene aged ones are situated at the morphologic heights whereas those of Quaternary aged are observed along the depressions along the NAF zone. Except for the ones surrounding İzmit Bay, there are no data on the distribution and on the character of those take place in the eastern part of the sea of Marmara.

LATE MIOCENE

Mudanya formation

This formation cropping out in vicinity of Yalova-Yalakdere and Mudanya-Nilüfer Creek, forms the base of the Neogene sediments in Armutlu peninsula (Fig.4). The lithology of the unit is an alternation of conglomerate, sandstone, siltstone, mudstone and claystone and it is deposited in an environment of fluvial and fan-delta. The formation was named by Görmüş et al. (1997) and were divided into two members: Adatepe and Koy. In Yalova region, this unit is same as Yalakdere formation defined by Bargu and Sakınç (1989). It rests on pre-Neogene rocks with angular unconformity and its thickness varies between 100-300 m. It is transitive at the top with Yalova formation, a brackish water-marine unit.

Adatepe member.- It crops out widely in the vicinity of Mudanya-Nilüfer creek. Its relation with the basement rocks are clearly visible on the roadcuts of Yalova-Bursa road. It is red, green and brown colored and made up pf conglomerate, sandstone, mudstone with pebbles and claystone (Fig.4). At the base of the unit, on the basement rocks, a pedogenic zone rich in caliche is observed. Caliche forms interbeds and concreations inside the unit which is a characteristic feature of the formation. At the base of the formation debris flow sediments, and at the top fluvial and alluvium fan deposits are seen (Şahbaz et al., 1997). The thickness of the unit is approximately 100 m. It is laterally gradational with the Koy member which is paleontologically determined to be of Late Miocene (Sichenberg et al., 1997), therefore assumed to be of the same age (Görmüş et al.,1997).

Köy member.-This member, cropping out to the south of Yalova, Karamürsel and Bursa-Mudanya regions is made up of gray, yellow, beige colored sandstone, siltstone, conglomerate and grayish green claystone (Fig.4). It was deposited in fan delta environment and is vertically and horizontally gradational with Adatepe member at the lower contact. To the southwest of Mudanya, it is observed to have gradational transition with Çamlık formation at the upper contact (Sahbaz et al., 1997; Görmüş et al., 1997). At a roadcut outcrop at 10th km of Mudanya-Bursa road, marine siltstone and carbonates of Yalova formation observed to conformably overlie the unit. It bears the pebbles of Karasu formation in vicinity of Yalova. Near Yörükali village, Mudanya, *Amebeledon* sp. ("frincki" typ), a mammal fossil of Upper Miocene age was found in this unit (Sichenberg et al., 1975). These data indicate that Köy member and Mudanya formation were deposited in Late Miocene.

LATEST MIOCENE-EARLY PLIOCENE

Yalova formation

The Neogene sediments widespread in Eastern Marmara and deposited in brackish water - fresh water, brackish water and open sea fades in different localities are called Yalova formation in this paper. The different levels of the formation were called Kılınç and Yalakdere formations in previous papers (Bargu and Sakınç, 1989). However, the Yalakdere formation made up of fluvial and fan delta sediments described by Bargu and Sakınç (1989) is as equivalent of the Mudanya formation in vicinity of Yalova. The formation forming a transgressive sedimentary sequence is transitive with the Mudanya formation at the bottom (Görmüş et al., 1997). The formation in the research area is made up of siltstone, claystone, carbonate sandstone, marl and limestone (Fig.4). In the areas where the Mudanya formation can not be observed at its bottom, it overlaps the pre-Neogene rock assemblages. In Yalova-Karamürsel region it is overlain with angular unconformity by Altınova and Kaytazdere marine terrace sediments of Pleistocene age (Bargu and Sakınç, 1989). Its thickness reaches up to 400 m and has two members, Orhangazi and Yalakdere.

Orhangazi member.- It crops out in Orhangazi region to the northwest of lake İznik. It is made up of silt, sand, sandy limestone and limestone. It is thin to medium bedded and dirty white, white, gray and yellowish in color. It rests on pre- Neogene basement rocks with angular unconformity in Orhangazi region. On the other hand, at a roadcut outcrop at 10th km on Mudanya-Bursa road it conformably overlies the deltaic deposits of Mudanya formation. On the section here, the unit with a 10 m thickness passes upwards into the clays bearing coal seams and deposited in lagoon environment. These clay levels bearing coal seams were observed on the roadcuts along Orhangazi-Yalova road. However, here, the lower levels of the clays bearing gastropoda shells and alternating with limestones cannot be observed.

This member is the first marine unit deposited in eastern Marmara in Neogene. Its typical section is seen at Orhangazi-Yeniköy roadcut. It bears mollusk shells characterizing brackish water environment. *Pseudocatillus pseudocatillus* Sinzov, *Pseudocatillus* sp., *Dreissena* cf. *tenussima* Sinzov, *Dreissina* sp. were found in the samples taken from this fauna. This assemblage is similar with the Pontian fauna of Paratethys. The same fauna was met in Serres and Chalkidiki basins in North Aegean (Jacobshagen, 1986). The Latest Miocene-Early Pliocene fauna in the North Aegean is of Mediterranean origin and takes place in a transgressive sedimentary assemblage (Jacobshagen, 1986). This similarity results in deducing that the first marine water entrance may be from Mediterranean Sea.

Yalakdere member.- Crops out in vicinity of Yalakdere (Fig.3). Its typical locality is the roadcut at the 2nd km of the Yalakdere-İznik road. This member, named by Bargu and Sakınç (1989) corresponds to the Karasu limy sandstone member of Yalakdere formation. On the other hand, the Yalakdere formation defined by these authors corresponds to Mudanya formation. It is yellow, beige, white and gray in color. It is made up of sand, claystone alternated with silt, limestone and carbonate sandstone. The bottom of the unit was not observed. However, in Yalakdere region, because of the colluvium cover the contact can not be clearly traced and in a short distance fan delta sediments of the Mudanya formation starts. This member where the E-W folds have developed is overlain with angular unconformity by marine terrace deposits of Pleistocene age in Karamürsel region (Bargu and Sakınç, 1989).

Some levels of the Yalakdere member includes abundant large shells. *Pontalmyra* sp., *Dreissena* ex. gr. *rostriformis* Deshayes, *Dreissena* sp. which indicate brackish water environment are found in between them. This mollusk fauna shows similarity with Cymmerian in Paratethys. This stage covering 5.3-3.5 million years corresponds Early Pliocene in Mediterranean chronology.

Çamlık formation

Widely crops out on Bursa-Karacabey road and in Nilüfer creek valley. The dominant rock type is white, beige colored, thin to medium bedded limestone and gray-green colored claystone alternating with it. In limestones there are two facies determined: at the bottom dolomitic and developed in deep brackish water environment, and at the top shallow and reflecting fresh water environment (Varol et al.,1997). It is gradationally transitive with Mudanya formation at the bottom (Görmüş et al.,1997). In some places it onlaps the basement rocks. In Armutlu Peninsula, on the roadcuts of Yalova-Orhangazi road the unit alternates with gastropoda bearing claystone and limestone.

No paleontologic dating was obtained from the unit. However, its lower levels reflecting deep brackish environment is transitive with Late Miocene aged Mudanya formation (Görmüş et al., 1997). Considering the contact relations, Çamlık member assumed to be of Late Miocene-Early Pliocene age.

Samanlıdağ formation

This formation comprises the old alluviums (Fig.3) situated on top of Samanlıdağları (Armutlu Peninsula) mass (Fig.6) which is bounded in the north and south by the NAF. The lithology of the brown, yellowish and reddish unit is mudstone with scarce pebbles, silt and sand (Fig.4). In places it includes debris and its thickness is 30-40 m. It is typically observed in Adliye, west of Pamukova and in Sultaniye, west of Armutlu Peninsula, on the old valley floors. It rests on pre-Neogene rock assemblages with angular unconformity and no unit overlying the formation has been observed.

No dating information is available for the unit. The old valley forms in which the unit was deposited in Yalakdere region were observed to have formed on the Yalova formation of Late Miocene-Early Pliocene age. In the İzmit-Adapazarı corridor, the oldest rock assemblage deposited along the NAF zone cutting the drainage pattern in which these deposits were developed is Karapürçek formation of Latest Pliocene-Pleistocene age. Therefore, it is assumed that the formation is of Late Pliocene.

Marine terraces

In the area surrounding İzmit bay marine terraces of Pleistocene age crops out (Chaput, 1936; Erinç, 1956; Göney, 1964; Akartuna, 1968; Bargu and Sakınç, 1989; Sakınç and Bargu, 1989; Paluska et al., 1989). These sediments which are widespread between Karamürsel-Yalova, to the south of the bay, are found at three different morphometric levels. The sequence-is called as Altınova formation in vicinity of Karamürsel (Bargu and Sakınç,1989). Their being at different morphologic levels and being tilted, at some places have led the interpretation that they took that step-like position because of tectonic movements (Erinç,1956; Sakınç and Bargu, 1989).

Faunal content and radiometric datings indicate that these three terrace fillings have deposited during different sea levels. The oldest terrace deposits are seen in southwest of Karamürsel, 60-90 m above the present sea level (Paluska et al., 1989). They rest on the Mudanya formation of Late Miocene age with angular unconformity. The fauna of this deposit developed in lagoon environment includes *Mytilus galloprovincialis* Lamark, *Ostrea lamellosa* Brocchi, *Chlamys opercularis* Linne, *Venerupis calverti* Newton, *Cerastoderma edule* Linne, *Loripes lacteus* Linne and *Cerithium* spp. the dating result, 260 000 years B.P., obtained with Tl method corresponds to Early Tyrrhenian (Paluska et al.,1989).

The other two terrace deposits crop out along Bursa - İzmit road, in the immediate east of Karamürsel (Sakınç and Bargu, 1989). Here, the terrace surface situated morphologically, upper is 20-25 m higher above the sea level and rests on the Eocene rocks with angular unconformity. Its bottom is 10 m high above the sea level. It includes sand bearing shell fragments and Mediterranean fauna, silt and pebbles and also includes ostrea banks (Sakınç and Bargu.1989). The U/Th dating by Paluska et al. (1989) has yielded 130.000 years from the samples collected from these banks.

The morphologic surface of the lowermost terrace is 10-15 m high above the sea level. The bottom of this terrace was not observed. Its typical outcrops are seen in Kaytazdere region. This terrace bears richer mollusk fauna than the upper one.

Bottom sediments in İzmit bay

The deep drillings have shown the existence of a thick sediment sequence in the bay (Meriç, l995). The deepest of these drillings was made in Hersek delta, south of the bay and samples were taken from 118m. Yet, the bottom of the sequence was not reached but levels bearing clay, sand, pebbles, silt and shell fragments were cut. This sequence was investigated in many different ways (Meriç, 1995; Meriç et al., 1995; Çetin et al., 1995; Ediger and Ergin, 1995; Gülen et al., 1995; Toker and Şengüler, 1995; Taner, 1995). The source area of the sediments is of terrestrial origin. The most apparent of these is Hersek delta.

İzmit bay is a tectonic corridor developed upon the formation of the NAF (Emre et al.,1997d). Therefore, the sediments situated at its base have the same age with the NAF. During the Hersek drilling it was observed that the sedimentation was continuous under different conditions since Latest Pliocene (Meriç, 1995). At the bottom of the sequence *Discoater brouweri* zone was determined which indicates the most Latest Pliocene (Toker and Şengüler, 1995). Meriç et al., (1995) state that the sediment assemblage was deposited at four different environments in four different stages. Accordingly, during Latest Pliocene anoxic marine, in Lower-Middle Pleistocene deep and brackish water, in the beginning of Upper Pleistocene brackish water, delta and terrestrial, and in the end of Upper Pleistocene - Holocene marine cpnditions were dominant (Meri9,1995).

The Latest Pliocene- Middle Pleistocene section of the sediments are the marine equivalent of the Karapürcek formation situated to the eastern part of the NAF corridor (Fig.4). The marine terraces around the bay corresponds to the Middle Pleistocene section of the sequence.

HOLOCENE

Holocene sediments are observed in the beach, swamp and delta areas around the bay. The deltas having sources from the south have greater fans. Hersek delta is the largest sedimentary body developed in the bay (Fig.3). There are lagoons on the delta. To the west of the bay swamps are widespreadly situated.

İZMİT - ADAPAZARI (NAF) CORRIDOR

This region includes the NAF segment in between the İzmit bay and Karapürçek. The Neogene-Quaternary sediments here are divided into three stratigraphic units (Figs. 3 and 4).

Karapürçek formation

In Sapanca-Karapürçek-Hendek area, this formation bounds the Adapazarı plain in the south, and also observed in between Sapanca-İzmit bay (Fig.3). It comprises alluvial fan and fluvial fillings. Its bottom is not observed but in NAF zone, it rests on the pre-Neogene rocks with angular unconformity. Its apparent thickness is 150 m and is unconformably overlain by Late Pleistocene aged terraces and Holocene fillings of the Sakarya river. It is divided into three members having vertical and horizontal transitions (Fig.4).

Değirmendere member.- Forms the base of the formation. It crops out in between Sapanca and Karapürçek, south of Adapazarı plain, and in the south of G6Iciik. It comprises alluvial fan deposits. Rock types are poorly sorted gray, beige yellowish pebblestone, gray, blackish, yellow and brown colored sandstone, siltstone and dark gray, black, green and bluish claystone (Fig.4).

These are transitive with each other. Pebblestones and sandstones have well exposed outcrops in Akçay creek valley. Here the sandstones and pebblestones include levels cemented with carbonates. Siltstones and claystones taking place in the distal sections of the fans are typically observed in Değirmendere valley. There are levels among them bearing gastropoda fragments and vertebrate fossils. Its bottom can not be observed. This member is the oldest unit deposited in NAF morphology. The alluvial fans forming the depositional environment for the unit have their source areas in the heights situated to the south of the NAF. However, the layers have tilted up to 25° towards south and southwest because of the normal faults of the Adapazarı pull-apart basin. It is transitive with the Kumbaşı member of the formation and is unconformably overlain by the Hendek member at the top.

In the member, in Şükriye and Değirmendere locations small mammal fauna is found. In Değirmendere large mammal fauna are found, too. The small mammals are *Microtus* sp. and *Kalymnomys* sp. which indi-

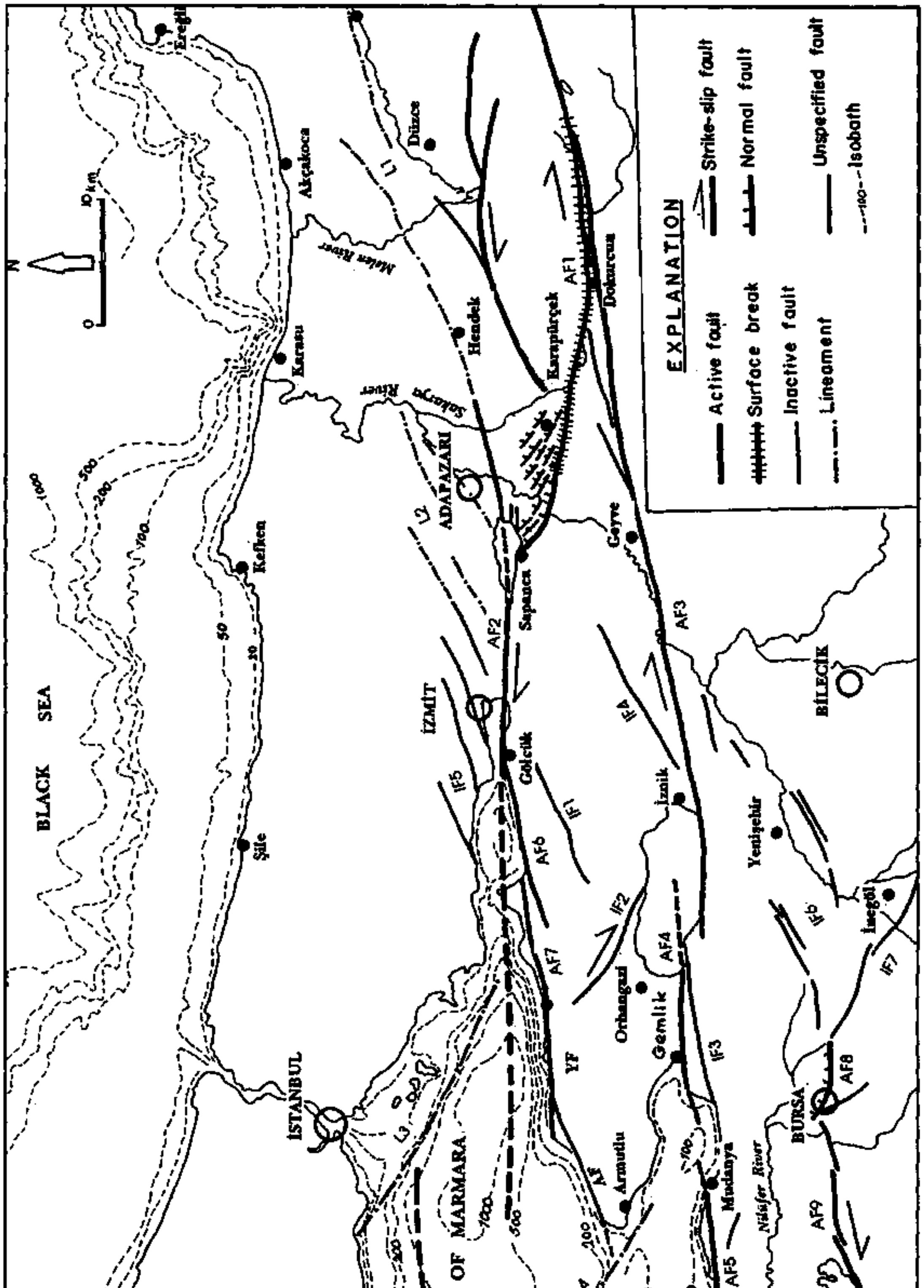

Fig. 5- Neotectonic period faults in the eastern Marmara region. Key: 1. Active faults: NAF Zone. AF 1, Dokurcun segment, AF 2, İzmit-Adapazarı segment, AF 3, İznik-Geyve segment, AF 4, Gemlik segment, AF 5, Zeytinbağı segment, AF 6, Gölcük fault (probably active), AF 7, Yalova fault (probably active), AF 8, Bursa fault, AF 9, Ulubat fault, AF 10, Düzce fault, 2. Inactive faults: IF 1, Yalakdere fault, IF 2, Orhangazi fault, IF 3, Gençali fault, IF 4, Adliye fault, IF 5, İzmit fault zone, IF 6, Yenişehir fault zone, IF 7, İnegöl fault, IF 8, Karacabey fault. 3. Lineaments: L 1, Hendek-Yığılca lineament, L 2, İzmit-Karasu lineament L 4, İmralı lineament.

cates Late Villanian and Early Biharian. Therefore, the age of the Değirmendere member is Latest Pliocene-Early Pleistocene. This member may assumed to be terrestrial equivalent of the Latest Pliocene-Early Pleistocene aged unit which is found at the base of the drilling in İzmit bay (Toker and Şengüler, 1995) and of the sediments dated 817 000 ± 105 000 years by Çetin et al. (1995).

Kumbaşı member.- The river bed and flood plain deposits seen along the Sakarya river to the south of Adapazarı plain are called as Kumbaşı member. Its typical section can be seen in the quarry next to Kumbaşı village. It is made up of gray, beige colored pebblestone, dark gray, black and greenish claystone alternation. The thickness of the pebbles dominant at the top reaches up to 30 m. The thickness of the beds are between 0.5-4 m. Erosional based and lenticular pebblestones are of river bed, silt and clays are of flood plain origin.

The thickness of this member reaches up to 60 m. Its base can not be observed. It is transitive with the Değirmendere formation which is evaluated as the old sediments of the Sakarya river and also overlain by Hendek member. *Kalymnomys* sp. was found in the typical locality of the member and it is assumed that the age of the Kumbaşı member is Early Pleistocene.

Hendek member.- It crops out between Sapanca-Karapürçek-Hendek region and İzmit bay-lake Sapanca. It has 80 m thickness in Balıklıdere valley where it is well observed. It is made up of alluvial fan deposits. It has a very distinctive color: red, brown and yellowish. Its lithology is poorly sorted, loose.pebblestpne, sandstone, mudstone and siltstone. This member is less effected by the tectonics created by the Adapazarı pull-apart basin than the ofher units in the south. It rests on Değirmendere and Kumbaşı members with erosive contact and is overlain by river terraces of Late Pleistocene and Holocene with angular unconformity. According to these contact relations, the unit is assumed to be of Middle Pleistocene age.

Terraces of Sakarya river

The river terraces cropping out to the west of Sakarya river, south of Adapazarı (Bilgin, 1984) forms two morphometric levels. The upper levels of the terraces are made up of brown, yellowish colored flood deposits whereas the lower levels comprise sand and well rounded pebbles. These terrace fillings are not observed along the Sakarya river in the north of the line between Adapazarı and Hendek. They overlie the Karapürçek formation with angular unconformity and are overlain by Holocene aged flood plain deposits. According to these relations the terrace fillings are of Late Pleistocene age.

HOLOCENE

The actual river bed fillings of the Sakarya river comprise flood plain deposits and alluvium fans. The bottom sediments of the lake Sapanca are included in this category (Figs. 3 and 4). On the southern shores of the lake Sapanca fan delta forms are observed. The thickness of the Holocene at the base of the Adapazarı plain exceeds 100 m.

MORPHOLOGY

The study area is one of the rare places in Anatolia where paleotectonic and neotectonic morphology can be observed. Paleotectonic relief group, where the primary morphology is preserved, forms the lowest topography except for the tectonic depression areas. The morphology of this period, in the north of the sea of Marmara and along the shores of Black sea, corresponds to the underwater shelf areas (Fig.6). The relief of the neotectonic period, on the other hand, are as high mountain belts, depressions along the fault zones, tectonic depression basins in between the faults and as hollows (Figs. 5 and 6).

Neotectonic landscape reflects two different stages of tectonics (Fig.7). The morphotectonic prolongations not affected or dissected by the NAF are aligned in NE-SW or in NW-SE directions. The landscape groups developed in NAF zone, on the other hand, cut them in E-W direction and form morphologic discordance which are reflected in distribution of Upper Miocene-Quaternary deposits. The Upper Miocene-Pliocene deposits, except for along the NAF zone, can also be observed on high morphologies. On the contrary, Quaternary sediments are bounded with the basin-corridor shaped

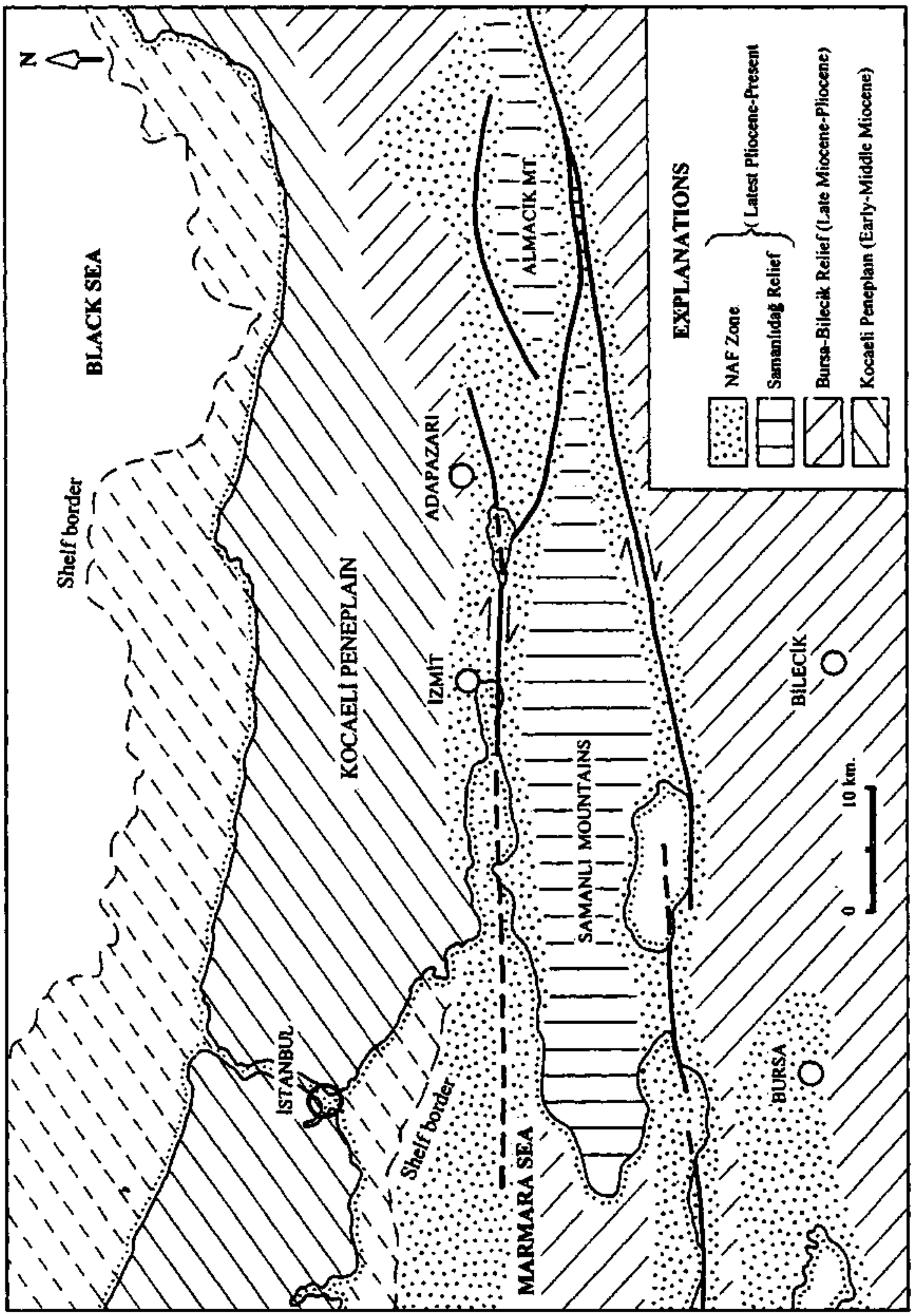

Fig. 6- Morphotectonic units of the eastern Marmara region.

depressions and with the base of the depressions eroded and emptied (Figs. 3 and 5).

MORPHOTECTONIC UNITS

Four different morphotectonic belts having different relief characteristics were observed in the investigation area (Fig.6). These, from north to south, are Kocaeli peneplain, Samanlıdağ and Bursa-Bilecik reliefs and NAF zone (Fig.6). The three relief groups displaying uplift morphology have been separated from each other with a sharp morphologic discordance, E-W trending depressions and hollows developed on the northern and southern branches of the NAF. Kocaeli peneplain reflects the morphology of paleotectonic era while the others have developed in neotectonic era (Fig.7).

Kocaeli peneplain

This is the relief group of the Kocaeli peninsula situated in the west of Sakarya valley. There is a peneplain surface on the peninsula with an average elevation of 150-200 m (Fig.6). Monadnocks are typical landforms on this north inclined surface. The inclination between İzmit and Karasu is higher because of tilting. Sea bottom topography makes one think that Black sea shelf is the prolongation of the peneplain under the water. Northern shelf of the sea of Marmara on which the Prince Islands are situated reflect the same characteristic features with the peneplain (Fig.6). The present watershed-line is very close to the sea of Marmara and NAF zone. In the watershed, along north oriented old drainage forms, hanging valleys and captured streams can be observed.

On the peneplain, Karasu formation is situated (Figs. 3 and 6) which is deposited during the process of peneplanation. The paleosol at the base and the weathering zones included are the indicators for humid and warm climatic conditions of the time of peneplanation. This climatic condition is known to prevail during Lower-Middle Miocene in Anatolia (Erol, 1981). On the other hand, in Armutlu peninsula and in Bursa region the pebbles of Karasu formation were observed in Mudanya formation of Late Miocene age. The rock assemblages of Latest Miocene-Early Pliocene are known to situate on a paleotopography having peneplain character (Emre et al.,1997c). This discordance surface which appears locally by the unveiling of the sediment cover most probably corresponds to Kocaeli peneplain. All these data indicate that Kocaeli peneplain was formed in Early-Middle Miocene and covered widespread areas before the neotectonic period in sea of Marmara region.

Except for tilting northward, Kocaeli peninsula is the only place where the peneplain preserves its shape very close to its original situation. Basement geology of the area corresponds to the Istanbul zone which belongs to paleotectonic era (Okay and Görür, 1995) (Fig.2). Peneplain morphology is preserved on the west of the Adapazarı-Karasu line. Istanbul zone, in the east of the line, displays a high mountain morphology where folds and thrusts are seen (Aydın et al., 1987) (Fig. 6). The southern boundary of the peneplain is marked by the NAF which in paleotectonics corresponds to Intra-Pontide suture (Şengör and Yılmaz, 1981; Okay and Görür, 1995) (Figs. 2 and 6).

These data show that Kocaeli peninsula (western sector of Istanbul zone) bounded by the NAF zone and Adapazarı-Karasu line (Fig. 5) reacted against the deformations arising from neotectonic period as a rigid mass, and these deformations could only happen as doming and tilting/warping and therefore the peneplain morphology that developed in Early-Middle Miocene could be preserved until present time (Fig.7).

Bursa-Bilecik relief

It comprises the landscape between east of Bursa and Sakarya valley (Figs. 3 and 6). The main elements of this landscape are İnegöl and Bursa depressions, plateaus and mass-like blocks in the region. All these high terrain has been dissected by the Sakarya river and its drainage.

İnegöl and Yenişehir depressions lie in NW-SE and NE-SW directions, skew to each other. Their bases are filled with Quaternary alluviums. Around them, Upper Miocene-Pliocene aged sediments, their base corresponding to Mudanya formation and in the upper levels changing into lacustrine sediments crop out (Genç, 1986; Erendil et al., 1991). These sediments can also be observed in the SE slopes of Uludağ and on the Bilecik plateau. The directions of paleocurrents in the old alluvial fan deposits here show that their source area is on the north of the NAF (Emre et al., 1997c) A watershed line separates the NAF zone and Yenişehir depression at present.

Upper Miocene-Pliocene aged sediments on the Bilecik plateau are observed in paleo-karst depressions as relicts of denudation. Here, the plateau surface is tilted towards the Yenişehir and İnegöl depressions. The surface of the plateau corresponds to the paleotopography (surface of unconformity) which unveils from the sediment cover. It also corresponds to Kocaeli peneplain in the region.

In the plateaus surrounding the depressions valley forms as relicts from an old drainage are observed. In the bases of these valleys Samanlıdağ formation crops out. In the north of the NAF, in Armutlu peninsula, the same valley forms are also seen. They are hanging valleys between the peninsula and the NAF zone dividing Bursa- Bilecik relief. Quaternary incisions of Sakarya river are buried in this valley system. However, along the NAF zone between Gemlik and Geyve this system is cut off and deformed.

Bursa-Bilecik relief is made up of lineations in NE-SW and NW-SE directions in the same direction with the faults of neotectonic period. The data show that the region displayed peneplain morphology in Early-Middle Miocene which later on, in Late Miocene, underwent tectonic deformation and in the basins formed fluvial and lacustrine sediments were deposited. In the later stages of the deformation the region was uplifted and the faults in NE-SW and NW-SE directions became dominant. During the uplift, sedimentary basins also were deformed and some parts of them reached up to the elevation of the present day mountains. On the high relief developed in this way, in Late Pliocene, the drainage system of Sakarya river was set and along the vallet Samanlıdağ formation was deposited. Together with the emerge of the NAF, between Gemlik and Geyve the morphologic relation between the Armutlu peninsula and Bursa-Bilecik relief was cut off. As a result of the rapid dissection in Pleistocene the Sakarya river drainage was deepened and along the river canyon-like valleys were formed. The Upper Miocene-Pliocene deposits taking place along the NW-SE and NE-SW directions were transferred with erosion giving birth to Yenişehir and İnegöl erosive depressions. In Holocene the bases of these depressions were filled again and formed present days plains.

Samanlıdağ unit

This unit comprises the Samanlıdağ relief between the northern-and southern strands of the NAF (Fig.6). The section of Samanlıdağ between Gemlik and İzmit bays, prolonging towards sea of Marmara forms Armutlu peninsula. It lies between Dokurcun valley and Armutlu in E-W direction and approximately is 165 km in length. In the eastern and western terminations it gets narrower, and appears in form of a shuttle (Fig. 6). This high relief has been isolated by the corridors of the NAF in the north from Kocaeli peneplain and in the south from Bursa-Bilecik relief. The mass is cut in east by Geyve gorge in which Sakarya river flows and in the west by Orhangazi-Yalova trough in N-S direction. Except for the steps to the south of Yalova, Samanlıdağ displays a massive height and has plateau character with an average elevation of 700-1000 m.

The high relief comprises generally the pre-Neogene rocks (Akartuna, 1968; Bargu and Sakınç, 1989; Erendil et al., 1991; Yılmaz et al., 1995). In its central parts, in Yalova - Yalakdere - Orhangazi regions, sediments of Late Miocene-Early Pliocene (Mudanya and Yalova formations) crop out (Figs. 3 and 4). In the old valley floors fluvial deposits of Late Pliocene (Samanlıdağ formation) take place.

There are two different drainage systems with different characteristic features on the mass. On the plateaus, a northward flowing drainage pattern in wide valley floors and with less energy and bearing sediments of Late Pliocene (Samanlıdağ formation) is dominant. In places this drainage system is deformed. On the other hand, in parts close to the NAF zone, the second drainage system with short streams and "V" shaped valleys is seen. This drainage which developed in Quaternary is linked with the older drainage system through backward erosion and in places, has changed

<table>
<tr><th rowspan="3" colspan="2">AGE</th><th rowspan="3" colspan="2">TECTONISM</th><th colspan="5">MORPHOTECTONIC REGIONS</th><th rowspan="3">PROCESSES</th></tr>
<tr><th colspan="3">NAF ZONE</th><th rowspan="2">BURSA BİLECİK</th><th rowspan="2">BLACK SEA</th></tr>
<tr><th>İzmit-Sapanca Trough</th><th>Adapazarı Basin</th><th>Samanlı Mountains</th></tr>
<tr><td rowspan="2">QUATERNARY</td><td>Holocene</td><td rowspan="5">NEOTECTONIC PERIOD</td><td rowspan="2">NAF Stage</td><td rowspan="2">Strike-slip deformation</td><td rowspan="2">Subsidence (Pull-apart mechanism)</td><td rowspan="2">Uplift (positive flower structure)</td><td rowspan="2">Erosion</td><td rowspan="2">Tilting to the North</td><td rowspan="6"></td></tr>
<tr><td>Pleistocene</td></tr>
<tr><td rowspan="2">PLIOCENE</td><td>Late</td><td rowspan="3">N-S Compressional Stage</td><td rowspan="3" colspan="4">NAF
Regional (en-block) uplift due to folding and strike-slip faulting</td><td rowspan="3">Ondulation</td></tr>
<tr><td>Early</td></tr>
<tr><td rowspan="2">MIOCENE</td><td>Late</td></tr>
<tr><td>Early-Middle</td><td>PALEOTECTONIC PERIOD</td><td>Stabil</td><td colspan="5">PENEPLAINATION</td></tr>
</table>

Fig. 7- Table showing the stages of morphotectonic evolution.

the course of the older system by abstractions. The mature drainage systems on the mass are observed as hanging valleys along the NAF zone both on the northern and southern strands. They indicate Samanlı mountains were in the same drainage system with Kocaeli peneplain and Bursa-Bilecik region. In the watershed line between Kocaeli peneplain and the NAF zone in İzmit-Adapazarı area, the northward directed old valley troughs show that the Samanlıdağ drainage, in pre-NAF period, was towards the Black sea.

Samanlı mountains is an E-W trending, active fault bounded morphotectonic unit. Contrarily, in the physiographic structure of the surface of the mass NE-SW and NW-SE trending lineations are dominant and the surface morphology displays a blocky structure which is consistent with the conjugate fault systems lying in the same direction. These are inactive faults and the physiographic structure controlled by them were cut by the NAF in E-W direction (Fig. 5). Of these conjugate faults, the NW-SE trending Orhangazi fault is a right lateral strike-slip fault (Erendil et al., 1991). Some of the others in NE-SW direction give clues of being left lateral strike-slip fault (Bargu and Sakınç, 1989). In Mudanya and Yalova formations cut by these faults roughly E-W trending folds were developed (Bargu and Sakınç,1989). These data indicate that, Samanlı mountains, in pre-NAF periods, were under N-S compressional tectonic regime.

The data on pre-Late Miocene morphology of the Samanlı mountains are limited. The morphology of the region in post-Upper Miocene was determined with tectonic processes. On the other hand, in the surface morphology of the mass there is an erosional plain inconsistent with these tectonic processes. The above mentioned older drainage forms were buried in this erosional surface which is cut by NW-SE and NE-SW trending faults and possibly corresponds to Kocaeli peneplain.

Samanlıdağ height forms a positive flower structure displaying a fault wedge geometry between the northern and southern strands of the NAF. The data indicate that, in the first stage of the neotectonic period this region had the same morphotectonic features with Bursa-Bilecik region. Together with the emerge of the NAF, in Latest Pliocene, Samanlı mountains have uplifted as pressure ridge and isolated from Kocaeli peninsula and Bursa-Bilecik relief and formed a different morphotectonic unit. Samanlı mountains, when compared with Kocaeli peninsula in morphometric terms, can be said to be uplifted averagely 700-800 m from the beginning of the neotectonic period.

NAF zone

In the research area, consistent with the structural prolongation of the NAF, there are two morphologic troughs as corridors in E-W direction along the northern and southern strands (Figs. 5 and 6). Of these, the northern one can be called İzmit-Adapazarı whereas the southern one can be as Gemlik-Geyve. These two corridors in the east gets closer to each other but in the west they fall apart. In İzmit and Gemlik Bays the corridors are invaded by the sea of Marmara. Westward, at the bottom of the sea, they lie apart from each other. The northern corridor, on which the deep depressions were formed at the bottom of the sea, joins the Saros-Gaziköy fault making a concave turn southward. The southern one terminates in Bandırma bay (Emre et al., 1997c).

These corridors lying along the NAF zone separates the other morphotectonic units from each other (Fig.6). The floors of the corridors in which İznik and Sapanca lakes are situated were filled with Latest Pliocene-Recent sediments. The morphology observed in them reflects the active tectonics of the region. The development process of the erosive landforms in both zones are similar with each other. These landforms are known with deep valleys with steep morphology intruded into the other morphotectonic units. On the other hand, the landforms having depositional origins are different in both corridors from the formation processes point of view. For example, although marine terraces were developed along the shores of the İzmit bay (Erinç, 1956; Göney, 1964; Akartuna, 1968; Bargu and Sakınç, 1989; Sakınç and Bargu, 1989; Erol and Çetin, 1995), in Gemlik bay they are not present. The situation is vice versa when comparing the lakes. It is known that there are terraces of Pleistocene age on the shores of the lake İznik (Ardel, 1954; Bilgin, 1968; Akartuna, 1968; Ikeda et al., 1991) whereas none on the shores of Sapanca lake. This example shows the difference in between the morphotectonic development in northern and southern corridors of the NAF. The characteristic localities of the fault is briefly given below:

- The NAF zone forms an approximately 150 km long morphologic corridor between Geyve and Gemlik (Figs. 3 and 6). The western continuation of this corridor corresponds to the bottom topography of the sea of Marmara in Gemlik and Bandırma bays. Between Geyve and Bandırma the segments of the NAF are İznik-Geyve, Gemlik, Zeytinbağ and Bandırma (Emre et al.,1997c). These are en echelon and transtensional segments complementing each other. Where the en echelon structures are seen, pull-apart basins have formed corresponding to lake İznik, Gemlik and Bandırma depressions in sea of Marmara (Barka,1992; Barka and Kuşcu,1996).

- The depositional surfaces observed around lake İznik are lined up as terraces (Fig. 3). The terraces, mostly seen on the north and west parts of the lake as four levels (Bilgin,1968) and mostly comprise fan delta deposits. The lowest terrace filling has yielded 18 000 years by C_{14} method (Ikeda et al.,1991). Fan deltas to the north were deposited in front of the young valleys capturing the Late Pliocene valleys on the Samanlıdağ mass. These data indicate that lake İznik was formed in Pleistocene.

- The NAF is a single line between İznik-Geyve (Fig. 5). Right lateral strike-slip fault morphology is dominant at the depression developed along the fault. This depression divides Bursa-Bilecik relief and Samanlıdağ mass (Fig.6). Along the zone, the Late Pliocene drainage on the heights have been preserved as hanging valleys. The Pamukova depression situated in the east, was opened on the NAF, in the beginning due to erosive processes of Sakarya river, but later on was filled with the alluviums of the same river. Around the basin, fluvial-lacustrine sediments of Pleistocene are observed as terraces. In the western end where the river enters to the depression terrace deposits include deltaic sections. On the floor of the depression flood plain deposits of Holocene age are seen. The sediments imply that Pamukova depression from time to time gained a lacustrine basin character. The 22 km right lateral offset the river at the floor of the depression (Fig. 5), at the first glance, may be interpreted as the movement of the NAF (Şaroğlu et al., 1987; Koçyi-(Jit, 1989), but, since the southern strand of the fault corresponds to a fault of paleotectonic period (Yılmaz et al., 1995) it is difficult to argue that the offset is totally because of the NAF.

- İzmit-Adapazarı corridor lying between the sea of Marmara and Dokurcun valley separates the Kocaeli peneplain and the Samanlıdağ height (Fig. 6). On this trough there are sedimentary basins having different features such as Adapazarı plain, lake Sapanca and İzmit bay (Fig. 3). Adapazarı plain which is situated in a transtensional region in between the Dokurcun and İzmit-Adapazarı segments of the NAF was developed as a pull-apart basin (Fig. 5). Düzce fault also effects the morphology of the basin. Pull-apart morphology is quite apparent in the south of the basin. Between Dokurcun valley and Sapanca, this basin is separated from the Samanlıdağ mass by a morphologic discordance corresponding to the NAF. Starting from Karapürçek region where the fault enters the basin, together with its right lateral strike-slip character, the fault also displays normal slip component and in between Sakarya river and Sapanca it totally becomes a normal fault (Fig. 5). Between the NAF and the floor of the basin, in Karapürçek-Sapanca region, there many normal faults in NW-SE direction (Fig. 5) displaying step-like morphology. On the surfaces of the blocks between the faults cutting the Karapürçek formation of Latest Pliocene-Pleistocene age, southward tiltings of 20°-25° can be seen. The amount of tilting and the offset of the faults decrease in NE direction. The younging of the fans here is also in the same direction. Besides, the bed migration in Sakarya river is from west to east. No normal faults in the NE of the basin were observed. These data indicate that Sakarya plain is a pull-apart basin developed as a half graben and younged in NE direction.

- The morphology of the corridor between lake Sapanca and İzmit bay is controlled by strike-slip movement. The floor is filled with Pleistocene and Holocene aged sediments. The youngings at the fans are in vertical direction in Sapanca region, whereas in the bay region they are as lateral onlaps. This difference indicates that the offset of the fault increases from west to east. As a matter of fact, on the Pleistocene fans to the west of lake Sapanca, right lateral offsets reaching up to 10 km can be seen (Emre et al., 1997d). Lake Sapanca is situated just on the trace of the NAF. No terrace is observed around it. The floor of the lake, most probably formed as erosional fault valley during the last glacial age. Due to the alluvium accumulation in Sakarya plain in Holocene the east end of this valley was blocked and the basin of the lake was formed.

- Western termination of the corridor is under the waters of İzmit bay (Fig. 6). Shore morphology of the bay is jagged with two depressions at the bottom (Fig. 5). Because of the structural features of the NAF, this morphology was intended to be explained with pull-apart basin models (Barka and Kadinsky-Cade, 1988; Barka, 1992; Barka and Kuşcu, 1996). At present, the fault comprises only one single trace in the bay (Fig. 5). The NE-SW trending faults on land represent the structures in the first formation stage of the NAF and now are inactive. They are responsible from the jagged appearance of the shore. The closed depression situated to the east of the bay is due to Hersek delta. The fan of this delta has divided the NAF corridor into two, morphologically, and has caused the formation of the closed eastern depression (Figs. 3 and 5).

- The first sediments deposited in the İzmit-Adapazarı corridor in NAF morphology are of Latest Pliocene and Early Pliocene aged. On the other hand, Late Pliocene drainage situated on the Samanlıdağ mass and draining towards Black sea via Kocaeli peneplain was cut and deformed by the fault. In Geyve-Gemlik corridor there are no deposits older than Pleistocene in NAF morphology. All these data indicate that the NAF emerged in Latest Pliocene.

DISCUSSION AND RESULTS

THE STAGES OF NEOTECTONICS

The neotectonics in Anatolia begins with the continent to continent collision between African and Anatolian plates in the end Middle Miocene-Upper Miocene (McKenzie, 1972; Şengör, 1979, 1980, 1982; Şengör and Kidd, 1979; Şengör and Yılmaz, 1981; Jackson and McKenzie, 1984). Through this process took place under N-S compression tectonic regime, since the continental crust thickening in East Anatolia was not taken up by folding, thrusting and strike-slip faulting exceedingly, two long transform faults, the NAF and EAF (Eastern Anatolian Fault) was formed and the western escape of the Anatolian plate, the neotectonic framework of Turkey was set (Şengör, 1979, 1980; Şengör et al., 1985; Şaroğlu, 1985). The authors mostly have emphasized that the emergence of the NAF and the EAF and therefore the western escape of Anatolian plate started in Upper Miocene.

In the beginning of the neotectonic period, the eastern part of Anatolia was inundated and the western part was displaying peneplain morphology (Erinç, 1953,1955; Şengör, 1980; Şengör et al., 1985; Şengör and Yılmaz, 1981; Erol, 1981; Şaroğlu and Güner, 1981; Şaroğlu, 1985). This paleomorphology, through the structural processes in neotectonic period has undergone changes by inversions in E-W and N-S profiles and the hypsographic curve of the land has shown tendency to increase from west to east (Erinç, 1953, 1955, 1973; Şengör, 1980; Şengör et al., 1985; Erol, 1981; Şaroğlu and Güner, 1981; Şaroğlu et al., 1983, 1987). In this process of change East Anatolia was uplifted, Central Anatolia was turned into inner depressions and in West Anatolia, horst and graben structures were developed. Tauride and Pontide belts have changed into border fold mountains by uplifting.

In papers about Marmara region, it is mostly accepted that the neotectonism started in Middle-Upper Miocene with the emergence of the NAF, and the region took place in between the NAF zone and West Anatolian graben system and the Neogene-Quaternary sediments were deposited in the structures developed under these conditions (Şengör, 1979, 1980, 1982; Şengör et al., 1985; Barka and Kadinsky-Cade, 1988; Barka, 1992; Wong et al., 1990, 1995; Taymaz et al., 1991; Straub, 1995; Görür et al., 1995, 1997).

The data collected during this study is roughly parallel with the above outlined structural evolution model of neotectonics of Anatolia. However, the character of neotectonic events, timing and the geochronologic order of the morphotectonic changes do not match with the proposed models.

The neotectonic structures of the Marmara can be grouped into two (Fig. 5). The faults showing the large scale morphotectonic prolongations are in E-W direction in east Marmara, whereas in NE-SW in west Marmara and Biga peninsula (Şaroğlu et al., 1987, 1992; Emre et al., 1997c). These are active neotectonic structures (Fig. 5). The second group faults are in NW-SE and NE-SW directions and are conjugate with each other (Fig. 5). Most of these are inactive. The NAF zone lies in E-W direction, incompatible to them. The morphotectonic prolongations developed by these conjugate systems are cut by the NAF.

The findings have revealed that the neotectonic framework of the Marmara (Fig. 5) developed in two stages which reflect different tectonic styles. These stages are divided into two: Late Miocene-Pliocene and Latest Pliocene-Recent. Of these the first one is of compressional tectonic regime, and the second is, represented by the NAF, the stage of vertical tectonic movements with transform character.

North-South compression stage

The first neotectonic deformations in the region were started in Upper Miocene (Fig. 7). They were as large scale ondulations and the peneplain morphology resting on the basement rocks were deformed and ondulated due to. Mudanya formation which is transitive with the Yalova formation at the top and is the first deposit of neotectonic period was deposited in the basins developed due to these deformations. The first depositional basins correspond to wide synclines, in structural sense.

Late Miocene-Early Pliocene sediments, recently are observed at the floor of the depressions bounded by the faults in NE-SW and NW-SE directions and on the surrounding high topography. In these sediments folds in E-W directions are seen. In fault zones, more deformation on these can be observed. Findings indicate that the NE-SW and NW-SE trending faults have developed after the deposition of Mudanya and Yalova formations and these depositional basins were cut by them. These units in present day geology are observed as erosive relicts in the troughs in between the faults (Figs. 3 and 5).

Both the deformational structures in the fault zones and their morphologic features, show that the faults complementing each other in NE-SW and NW-SE directions are of strike-slip nature. Of these, the ones in NW-SE, as in the case of Orhangazi fault (Erendil et. al., 1991), are right lateral (Fig. 5). However, the faults in Yalakdere region the faults in NE-SW direction are of left lateral (Bargu and Sakınç, 1989) which are being accompanied by folds and reverse faults in E-W direction. These structural data show that the region in Late Miocene-Pliocene was under N-S compression and was deformed due to. The peneplain morphology developed in Early-Middle Miocene is observed in high mountainous and plateau areas and are tilted, blocked and domed due to compression and uplift. Another data for rising morphology is the presence of Mudanya and Yalova formations in morphometrically high areas as seen in Bilecik and Yalakdere regions.

Most of the conjugate faults developed under the N-S compressional tectonic regime in Late Miocene are inactive. The active faults of the Marmara are seen in the NAF zone lying in E-W direction (Fig. 5). This relation with the strike and the activity of the faults show that the tectonic regime in which the above mentioned strike-slip faults developed ended in Latest Pliocene with the emergence of the NAF.

The N-S trending compression may be defined as the first stage of the neotectonics in Marmara (Fig. 7). The faultings related to this tectonics can not be observed in Kocaeli peninsula, situated in the north of the Intra-Pontide suture belt where presently the NAF takes place (Figs. 2 and 5). The deformations here are as warping and doming (Fig. 7). Contrarily, all the structural elements related to compressional regime were developed in the south of the suture belt. The morphotectonic character of the Armutlu peninsula, in the compressional stage, shows that it had the same behaviour with the Bilecik-Bursa region situated in the of this rise (Fig. 7).

The NAF stage

The neotectonic regime effective in the area has changed style in the Latest Pliocene with the emergence of the NAF. The N-S compressional tectonics in Late Miocene-Pliocene has left its place with the formation of this fault to the lateral shears and displacements (Fig. 7). The structures of this stage is well marked with the faults forming the transform NAF in east Marmara (Fig. 5). The same process is valid for the Biga peninsula and west Marmara. In these regions, the fault, changing its general trace of E-W starting from Bandırma to westward, has caused the formation of new faults (Şaroğlu et al., 1987, 1992; Emre et al., 1997c). The structures of this period forms the NAF between sea of Marmara and Saros bay (Şengör, 1979; Şengör et al., 1985). Biga peninsula, in this period, has been dissected by the NE-SW trending faults (Şaroğlu et al., 1987, 1992; Emre et al., 1997a, *b, c).*

The NAF, between Karlıova and Dokurcun valley is made generally up of lineer faults (Şengör, 1979; Şengör et al., 1985; Şaroğlu et al., 1987, 1992; Barka and Kadinsky-Cade, 1998; Barka, 1992). This structure of the NAF changes starting with Dokurcun valley and towards west, it is made up of two strands diverging each other (Fig. 5). The prolongation of the southern strand between Bandırma and Dokurcun is concordant with that of east of Dokurcun (Fig. 5). This zone comprises of short, single fault segments, shortening more westward, such as İznik-Geyve, Gemlik, Zeytinbağı and Bandırma (Emre et al., 1997c). In this section the fault has replaced an old fault zone of Cretaceous (Yılmaz et al., 1995). Between the segments where transtensional overlaps are seen pull-apart basins have formed (Barka, 1992; Barka and Kuşçu, 1996).

Northern strand of the NAF developed in Intra-Pontide belt (Şengör and Yılmaz, 1981) displays a more complex structure than the southern strand (Figs. 2 and 5). Here the fault has two segments, Dokurcun and İzmit-Adapazarı. Dokurcun segment, which in its eastern termination lies in NE-SW direction, changes it trace towards Adapazarı plain and runs in NW-SE direction (Fig. 5). In vicinity of Karapürçek where it enters Adapazarı depression it gains normal component. Between Sakarya river and Sapanca, it totally displays normal fault features (Fig. 5). On the other hand, Adapazarı segment, starts in the east as a continuation of Hendek-Yığılca lineation, a former paleotectonic period fault which later on moved in the first stages of the neotectonic period (Aydın et al.,1987) (Fig. 5). It changes its direction to E-W in the west of Sapanca which is NE-SW in the east. Along this zone, between Adapazarı and Yalova, there are inactive faults in NE-SW direction (Fig. 5). These en echelon faults, defining the border morphology of İzmit bay in the north and south are cut by the NAF (Fig. 5). These structures accompanying the active trace of the NAF most probably represent the shear zone in the first stages of the formation of the fault. The right lateral offset on the fault reaches up to 10 km (Emre et al., 1997d).

Between the segments in the northern strand Adapazarı pull-apart was developed. The normal faults responsible for the formation of this basin lie in NW-SE direction diagonal to the main trace of the fault (Fig. 5). Its offset is verified by the fault plane solution of the after shocks of the 30.7.1967 earthquake (McKenzie, 1978; Jackson and McKenzie, 1984).

At this stage, due to the NAF, two large pressure ridges were formed where the fault bifurcates. These ridges, reaching mountain scales morphologically, form Samanlıdağı and Almacıkdağı masses (Fig. 6). The downcutting of the Sakarya river bed in an antecedant gorge implies the Samanlıdağ ridge is uplifting.

PALEOGEOGRAPHIC DEVELOPMENT PERIODS

Three distinctive periods of structural processes in the geomorphologic evolution of the East Marmara region in Neogene-Quaternary were differentiated (Fig. 7). These periods are also defined with three sedimentary sequences with angular unconformity (Fig. 4). Of these, the first one corresponding to Early-Middle Miocene represents a technically quiescent period and reflects the morphology of the paleotectonic period. Neotectonic period is represented by Late Miocene-Recent. The morphologic structure reflects two different tectonic styles (Fig. 7). The following paleogeographic evolution is based on the events in these three morphotectonic periods.

Early-Middle Miocene: Paleotectonic period

Istanbul and Sakarya zones, in the end of the Oligocene, have joined along the suture zone as a result of the closure of Intra-Pontide ocean (Fig. 2) and emerged. The region therefore has turned into terrestrial erosion area (Okay and Görür, 1996; Görür et al., 1995, 1997).

During the Early-Middle Miocene, a peneplanation period was observed under warm and humid climatic conditions on this land mass (Fig. 7). By the end of Middle Miocene, the area covering today's sea of Marmara and the shelf of Black sea has gained a mature peneplain morphology. The relief today observed on Kocaeli peninsula is a relict of that. The presence of a thick paleosol cover indicates the long period of peneplanation and the lack of tectonic effect on the formation of this landscape (Brown and Kraus, 1987; Retallack, 1990; Wright, 1992a, *b* ; Kraus and Asian, 1993; Mack et al., 1993). The Early-Middle Miocene peneplain, except for Marmara, has developed in whole Western Anatolia and in Strandja (Pamir, 1938; Erinç, 1955; Erol, 1981; Erol and Çetin, 1995).

The fluvial, lacustrine deposits of the peneplanation period are observed both in Biga peninsula and in Thrace basin (Sümengen et al., 1987; Siyako et al., 1989; Yaltırak, 1995; Görür et al., 1995, 1997). On the other hand, in SE Marmara they are not seen. This situation explains the increasing height of the peneplain morphology from west and north to SE Marmara and this section was an erosional area.

Late Miocene-Pliocene: N-S compression stage of Neotectonic period

Great morphological changes happened in Marmara region as seen in whole Anatolia together with the initiation of neotectonics in the end of Middle Miocene-Early Late Miocene (Şengör 1979,1980,1982; Şengör and Yılmaz, 1981; Şengör et al., 1985; Barka and Kadinsky-Cade, 1988; Barka, 1992; Görür et al., 1995, 1997; Erol and Çetin, 1995; Emre et al., 1997a,b,c). The region together with the neotectonism started compressing in N-S direction and uplifting and the peneplain morphology got deformed. The first deformations took place as great ondulations. As a result of this change in the relief, the first deposit of the neotectonic period, Mudanya formation, began depositing. The caliche zones in and at the base ofthe formation reflect the dry climatic conditions of Late Miocene. The reddish mudstone at the base were deposited as pediment deposits. These mudstones, most likely represent the accreation of thick soil cover at the floor of the basins situated at the surface of the deformed and uplifted Early-Middle Miocene peneplain. They upwards pass into the alluvium fan deposits bearing pebbles of basement rock which indicates the tectonic origined uplifting is increasingly continuing.

Together with the neotectonics initiated in Late Miocene the region began morphologically uplifting (Fig. 7). The negative uplifting areas corresponding to synclines have formed the depositional basins. Deformations have taken place mostly as folds and the faults have not had any important role in the formation of the development of the basins.

Towards the end of the Late Miocene fluvial-lacustrine environments in the region have spread over, and the alluvial fans and the fan deltas of Mudanya formation began developing. In vicinity of Mudanya the paleocurrent directions indicate that their source area was in the north (Şahbaz et al., 1997) and therefore some parts of the sea of Marmara were erosional areas.

The first marine water entrance to the East Marmara was in the end of Late Miocene. This sea has transgressed over the fluvial, lacustrine basins and the other morphologic depressions where Mudanya formation deposited and therefore has led the deposition of Yalova formation. The marine conditions in the area continued by the end of the Early Pliocene (Cymmerian). As a result of the above mentioned transgression, the morphologic depressions developed as intermontane basins (Şaroğlu and Güner, 1981) under the effect of N-S oriented compressional tectonic regime have gained marine basin character. The paleogeographic extension of this marine basin is not concordant with the NE-SW and NW-SE trending faults developed in neotectonic period and with the direction of the NAF (Figs. 3 and 5).

As a result of the continuing N-S compression and therefore the regional narrowing and uplifting, towards the end of the Early Pliocene, the marine areas began to spread out and close and underwent the effect of terrestrial processes. The transition of the dolomites of Çamlık formation defining the deep brackish water environment to the limestones reflecting the shallow fresh water environment (Varol, 1997) may be explained by spread of seas and change into lakes.

The morphologic change resulting with the closure of marine basins was provided by the NE-SW and NW-SE trending faults apart from the folds (Fig. 5). This deformational stage under the dominance of strike-slip faulting is the maximum uplifting stage of East Marmara. As a result of the relief inversion occurred by this deformation, as in Mudanya and Yalakdere regions, the floors of marine basins of Late Miocene-Early Pliocene have reached up the peaks of mountains.

The Late Pliocene morphology including east part of the present day sea of Marmara where terrestrial erosional conditions were effective have led an increasing trend from Black sea to south. On this morphology which was technically controlled except for the Kocaeli peninsula a drainage pattern which could be assumed to be the ancestor of the present day Sakarya river was set and the whole region began to drain towards Black sea (Figs. 3 and 5).

The Latest Pliocene-Recent: The NAF stage

This time interval is a period of large scale morphologic changes due to style changes in neotectonics. The present day morphotectonic framework was mainly set in this interval with the emergence of the NAF. To the north of the Dokurcun, the fault has bifurcated into two independent faults with different structural developments. The southern strand has placed on an old fault developed in the paleotectonic period (Yılmaz et al., 1995) and the faults here has developed as single traces. In the en echelon regions between the segments forming the zone subsidence areas of pull-apart nature was formed and lake İznik and in Gemlik and Bandırma bays sea of Marmara has invaded these structures.

The faults on the northern strand of the NAF were developed in the second stage of the neotectonics. Here, the NAF has appeared as a shear zone in the beginning, as seen in the east (Şaroğlu, 1988) and in this first stage en echelon NE-SW trending shear faults were developed (Fig. 5). In the later stages of this break up, the main fault breaks representing the active tectonics today appeared and the fault gained its transform character.

In the east of the NAF zone, the depression between İzmit-Adapazarı and Dokurcun segments was formed as a pull-apart basin and Sapanca-İzmit bay section has gained a corridor morphology. In this context, in the east terrestrial, and in the west marine sediments began depositing. The sediments in the bay indicate that there are four major level changes in sea of Marmara in Late Pliocene-Holocene (Meriç, 1995). The fauna and the features of the environment show a very intense tectonics in Middle Pleistocene (Meriç, 1995). The same findings were met in the east of the corridor. The deformational structures in the Karapürçek formation deposited in Adapazarı basin are mostly of Middle Pleistocene-age. Therefore it can be said that the maximum activity of the NAF was in Middle Pleistocene.

With the emergence of the NAF, in Late Pleistocene, the uplifting morphologic structure from Black sea towards Samanlıdağ mass was deformed and the mass in between the two strands of the fault was heaved as a positive flower structure (pressure ridge) and isolated from the surrounding morphology. The surface of the Kocaeli peninsula, on the north of the NAF was tilted northward (Fig. 7). The absence of marine terraces on the shores of the Black sea, opening of Sakarya river into a deep submarine canyon (Fig. 5) indicate that the shore areas of the present day shelf, in that period, was not invaded by water. In the south, in vicinity of Bilecik, together with the initiation of the NAF regime erosional processes increased and the region was dissected by the drainage of Sakarya river.

By the end of the Late Pleistocene (the latest glacial age) the erosional processes reached a maximum in the area during the sea level decrease in Black sea and sea of Marmara, and together with tectonics some other processes controlling the morphologic development prevailed. As aresult of that the rivers dissected their beds and the morphologic dissection in the region was reached its maximum. İnegöl and Yenişehir basins in the south, Pamukovası, Sapanca trough and Adapazarı plain shaped as erosive depressions. After the sea level increase in Holocene these erosive morphologies were filled with sediments and present day's alluvium plains were formed. During the process of filling with alluvium, Sapanca trough which opened on the NAF as a fault valley was blocked and the basin of the Sapanca lake was formed. The earthquakes indicate that today's landscape forming is due to the NAF.

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ABSTRACTS OF THE PAPERS PUBLISHED ONLY IN THE TURKISH EDITION OF THIS BULLETIN

QUATERNARY FRESHWATER FAUNA OF THE KILBASAN AREA, NORTHERN KARAMAN

Ümit ŞAFAK* and Güler TANER**

ABSTRACT.- Clastic units exposing around the Kılbasan village at north of the city of Karaman contain the relicts of a dry lake basin. In this basin, the presence of an extensive fauna even detectable with necked eye is noticeable. Seven of wash samples collected as point sampling from the basin were subjected to detail works. As a result of examinations on the fauna, a number of 3 ostracods, 4 gastropods and 1 pelecypod species characteristic for typical freshwater environment were determined.

STRATIGRAPHIC AND TECTONIC FEATURES OF MIOCENE BASIN SOUTH OF İMRANLI AND HAFİK (SİVAS)

Yavuz ÇUBUK*** and Selim İNAN****

ABSTRACT.- Basement of the autochthonous units cropping out in the south- southeast of İmranlı (Sivas) and south-southwest of Hafik (Sivas), comprises the Refahiye ophiolitic complex, whose time of emplacement is Late Cretaceous-Early Eocene. This basement is overlain unconformably by the Middle Eocene Bozbel formation, composed of marine sediments with occasional volcanic components. The Bozbel formation is overlain again unconformably by the Oligocene Selimiye formation, comprising shallow marine (possibly lagoonal) sediments. Chattian-Burdigalian aged Ağılkaya formation, which is composed of red colored aluvial fan-sabkha-limited cycle sediments, overlyes transgressively the Selimiye formation. The Ağılkaya formation crosses gradually into the Lower Miocene Karayün formation of red colored fluviatile-playa sediments. The Karayün formation and Ağılkaya formation are overlain unconformably by the Lower-Middle Miocene age Sarıhacı formation, which comprise green colored mudstone, with shallow marine sandstone-limestone interlayers. All these units are overlain by the Upper Miocene-Pliocene Eğerci formation, comprising fluviatile sediments. Sivas Tertiary basin, whose evolution started in Early Eocene, has been subject to the influence of N-S trending compressive regime in Late Eocene. Chattian-Aquitanian gypsum deposits have caused the first period of salt uprisal which shaped the recent structural units of the basin in Early Miocene. This salt tectonics has been effective in the basin up to Late Pliocene. In this epoch, abundantly salt uprisals and related folds and overthrust have been developed in the basin.

GEOLOGIC AND MINERALOGIC INVESTION OF THE NORTHERN KONYA LACUSTRINE UNITS

Zehra KARAKAŞ** and Selahattin KADİR*****

ABSTRACT.- Neogene lacustrine sediments of Northern Konya consist of limestone, clayey limestone, claystone, mudstone, marl, sandstone and conglomerate. Widely observed limestones are fine grained, white-beige-cream coloured and contain remnants of the plant root. Brecciation, calcretion, drying cracks and dissolution voids are also common. Laminates are widely seen in claystone and sandstone. Ooid, pellet, intraclast and ostracod are the main components of limestones. Ooids and intraclasts are surrounded by meniscus type cement which represents a vadoze environment. SEM studies indicate that hexagonal and rhombic type calcite and dolomite minerals of meniscus cement are covered by sepiolite and palygorskite clay fibre. XRD analyses show that sepiolite and palygorskite minerals are associated with smectite, chlorite, feldspar, illite and quartz minerals. Carbonate units of Neogene lacustrine of Konya area are alternated and intercalated with conglomerate, sandstone and mudstone lenses. These indicates that, from time to time, the lacustrine area is fed by flowing water. Considering the mineral paragenesis and their textural features of the study area, precipitation was occured due to continuous changes in climate conditions. Climate conditions changes the lacustrine water chemistry and thus facilitating precipitation of carbonate and detrital units. Because of continuous climate changes, sepiolite and palygorskite were formed as a result of calichification of carbanate units.

EARLY DEVONIAN CONODONTS FROM LIMESTONE OLISTOLITHS WITHIN THE KARASENIR FORMATION OF THE KARAKAYA COMPLEX

Şenol ÇAPKINOĞLU* and Osman BEKTAŞ*

ABSTRACT.- Limestone olistoliths of different size are commonly observed in the elastics of Karasenir formation (Amasya) which is unconformably overlain by the Liassic deposits. In two of these olistoliths, conodont faunas belonging to eurekaensis, delta and Pesavis zones of early Devonian (Lochkovian) were determined. Typical Permian algaes (Gymnocodiacea) were described in thin sections of a dark gray limestone olistolith. Since it contains early Devonian and Permian olistoliths and unconformably covered with the Liassic units, the age of Karasenir formation is believed to be Triassic. Including of underlying metamorphic rocks to the Karakaya complex necessities also including of Karasenir formation as their stratigraphic continuation.

BENTHIC FORAMINIFERA (HOLOCENE) PALEOBIOFACIES OF BOSPHORUS (GOLDEN HORN - SARAYBURNU - ÜSKÜDAR): A NEW APPROACH TO MEDITERRANEAN-BLACK SEA WATERWAY

Mehmet SAKINÇ**

ABSTRACT.- Young sediments in the shelf areas in the sea of Marmara have some faunal signs of Mediterranean transgression, Flandrian, developed following the Vürm period. The evolution of locally tectonic-controlled foraminifera paleobiofacies formed as a result of this transgression 7.5-3.5 thousand years before present in the triple junction between entrance of Bosphorus in Northern Marmara Shelf-Mouth of Golden Horn-Üsküdar indicates that Mediterranean-Black Sea connection in late Quaternary was accomplished over Bosphorus as a result of tectonic-transgression association.

DETECTION OF POTENTIAL AQUIFER USING REMOTE SENSING DATA AND DIGITAL ELEVATION MODEL, SADRAZAMKÖY, THE TURKISH REPUBLIC OF NORTHERN CYPRUS

Kenan TÜFEKÇİ***

ABSTRACT.- The Turkish Republic of Northern Cyprus (T.R.N.C.) is under the Mediterranean climatic conditions and there is fairly water trouble due to insufficient rainfall and incorrect irrigation methods. For this reason, the investigations have been carrying out by The General Directorate of Mineral Research and Exploration (MTA) and also have been supporting by remote sensing methods. In this application, Landsat 5 TM's thermal IR band, which is the date 28.06.1994, 176/35-36 path/row and 30x30 m resolution, was evaluated and the temperature analysis of the sea surface along the T.R.N.C. shorelines was processed and the cold areas which can be interpreted as ground water outputs were detected in the surrounding of the Cape Koruçam (NW of Cyprus). The relation between these data from the satellite image and the land was researched by both aerial photographs and field observations. It is found that the paleokarstification was developed on the Upper Pliocene-Pleistocene aged bioclastic limestones and also a probably calcerous crust covering this formation in the surrounding of Sadrazamköy. It is understood that the bioclastic limestones and the karstic areas formed under the humid climatic conditions and morphometrically located at same levels as the sea terrace levels can be thought as a potential aquifer area.

GEOLOGY OF THE GÜZELSU CORRIDOR AND ITS NORTHERN PART IN THE CENTRAL TAURIDES

Mustafa ŞENEL*; Halil DALKILIÇ*; İbrahim GEDİK*; Mualla SERDAROĞLU*; Sait METİN*; Kadri ESENTÜRK*; A. Sait BÖLÜKBAŞI**; Necdet ÖZGÜL***

ABSTRACT.- Anamas-Akseki autochthon, Antalya nappes and Alanya nappe are observed in the study area which is situated to the southwest of Central Taurus mountais. The Anamas-Akseki autochthon, in the region, is represented by outcrops of dolomites and limestones of Upper Norian?-Rhaetian age (Menteşe dolomite, Leylek limestone), conglomerate, sandstone and mudstones of Rhaetian-Lover Liasic age (Üzümdere fm), limestones of Middle Liassic-Cenomanian age (Kurucaova fm) + dolomite and limestones of Liassic-Dogger? age (Hendos dolomite, Alıçbeleni fm.), limestones of Dogger-Malm age (Çamkuşağı fm), limestone of Malm age (Akkuyu fm, Karlığın fm.), limestones of Malm-Lover Cretaceous age (Belalan fm.), limestones of Lower Cretaceous age (Akseki limestone), limestones of Berriasian age (Susuzkır fm.), limestones of Campanian-Maasrichtian age (Seyrandağı fm., Dumanlı fm), Danian age olisthostrome of Upper Paleocene-Lower Eocene age (Çetmi limestone) and sandstones and conglomerates of Middle Eocene age (Gümüşdamla fm). The Antalya nappes, cropping out in a narrow approximately east-west trending corridor between Anamas-Akseki autochthon and Alanya nappe, according to its structural and stratigraphic features are subdivided into nappes as given below: Çataltepe nappe represented by Aygırdere (Kasımlar formation, Karasay limestone, Kepezbeleni formation) and Güzelsu (Kasımlar formation, Kayabükü formation, Gören formation, Keçili formation) sequences; Alakırçay nappe represented by rocks ot Lower Triassic-Upper Cretaceous age, Alakırçay (Akıncıbeli formation, Çandır formation, Keçili formation) and Hocaköy (Halobia bearing limestone, Hocaköy radiolarite, Keçili formation) sequences; and Tahtalıdağ nappe represented by rocks of Upper Kambrian-Upper Cretaceous age, Katrandağı (Çukurköy formation, Akıncıbeli formation, Günlük formation, Katrandağı kireçtaşı, Keçili formation), Kavzandağı (Seydişehir formation, Güneyyaka formation, Çukurköy formation, Akıncıbeli formation, Günlük formation, Kavzandağı formation, Keçili formation) and Gündoğmuş (Seydişehir formation, Bozşehir formation, Güneyyaka formation, Kızılbağ formation, Akıncıbeli formation, Sinektepe formation) sequences. In general, during Mesozoic, Çataltepe nappe represented passive confinental margin, whereas Alakırçay nappe and Tahtalıdağ nappe represented basin and offshore platform, respectively.

RESERVOIR ROCK PROPERTIES OF MIDDLE EOCENE SANDSTONES IN NORTHERN THRACE BASIN

Nurettin SONEL**** and Aynur (Geçer) BÜYÜKUTKU****

ABSTRACT.- Değirmencilik and Yeniköy formations at north of Thrace basin were examined by means of detailed sedimantalogic and petrographic studies. In this study, reservoir rock features of sandstones were studied with thin section, sonic well log, core, and scanning electron microscope (SEM) works. Results of laboratory analysis yield that sandstones of Değirmencik and Yeniköy formations have a reservoir rock potential for oil. Petrographic studies indicate that dissolution of carbonate and feldspars together with pressure dissolutions facilitate widening of secondary pores in sandstones providing development of diagenetic traps.

VOLCANO-STRATIGRAPHY OF COLLISION-RELATED VOLCANICS ON THE ERZURUM-KARS PLATEAU AND EVOLUTION OF VOLCANISM IN THE LIGHT OF NEW K/Ar AGE DETERMINATIONS, NE ANATOLIA TURKEY

Mehmet KESKİN*****

ABSTRACT.- In north-eastern Anatolia, the area between Erzurum and Kars consists of a plateau which is 2.5 km above sea level. This high land, named the Erzurum-Kars Plateau, has gained its characteristic present-day morphology by means of crustal thickening resulted from collision between the Anatolian and Arabian plates after elimination of the south branch of Neotethys ocean. A great portion of the plateau is covered by lavas and pyroclastic units which are genetically related to collision event. Volcanic activity initiated in the region with basic lavas at around 11 Ma shortly after regional uplift, attained a climax between 5 and 7 Ma and continued until 2.5 Ma, producing volcanic successions that, reach over 1 km in thickness in places. The magma generally reached to the surface via fissures located in areas of local extension in strike-slip fault systems which are the predominant elements of neotectonics of the region. A significant portion of volcanic material generated was deposited in nearby pull-apart basins which were also controlled by these strike-slip fault systems. The period between 6 and 11 Ma was represented by a bimodal volcanism which is composed predominantly of widespread felsic pyroclastics/domes and basic lavas. Intermediate porfiritic lavas which had experienced fractional crystallisation of amphibole as a mafic phase at depth erupted onto the surface producing domes around 5-6 Ma. The period between 2.7 and 5 Ma was dominated by olivine-bearing basic lavas which covered large areas as plateau-forming horizontal lava sheets. New K/Ar dating results revealed that volcanic activity migrated from west to east, becoming more basic during the course of time. This may be resulted from a gradual eastward increase in local extension in strike-slip fault systems.

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