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## EXAMPLES FROM THE FOREARC BASIN REMNANTS AT THE ACTIVE MARGIN OF NORTHERN NEO - TETHYS; DEVELOPMENT AND EMPLACEMENT AGES OF THE ANATOLIAN NAPPE, TURKEY

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**Abstract.** Based on both the detailed field and laboratory studies carried out at the north of Ankara, northwest of Amasya and south of Tokat in northern Turkey, the presence of remnants of different types of forearc basin at the active margin of Northern Neo-Tethys has been found. The forearc deposits exposed at these localities are underlain either by only subduction complex which is coloured ophiolitic mélange named as the Anatolian Nappe, or by both older rock assemblages named as the Karakaya Nappe and the Anatolian Nappe. Based on the bottom boundary relationships of the forearc sequences, the forearc basins observed in northern Turkey are of two main types, namely, accretionary and constructed forearc basins. On the other hand, the paleontological data coming from the lowermost part of the forearc basin sequences suggest that the development age of the Anatolian Nappe as a subduction complex at the active margin is pre-Middle Campanian. However, its emplacement age on the passive continental margin ranges in Late Maastrichtian to Late Pliocene time interval.

### I. INTRODUCTION

Depending on the tectonic setting, the basins are classified into two major groups: [1] Intraplate basins, and [2] Interplate basins. Intraplate basins occur either on continental crust or on oceanic crust. However, the interplate basins occur at (A) divergent margins where ocean floor is created, (B) convergent margin where lithosphere is consumed, and (C) conservative margins where lithosphere is neither created nor destroyed, but the motion between two plates are strike-slip. On the other hand, the basins formed at convergent margin are of five major types: (a) outer slope basins, (b) trench, (c) inner slope basins, (d) forearc basins, and (e) backarc basins [1].

Although numerous examples of interplate basins occurred at convergent margin are known from different parts of world [1-6], the similar structures in Turkey could not be sampled and defined well till now. In this present paper, the tectono-stratigraphical characteristics, natures and types of forearc basin remnants at the active margin of Northern Neo-Tethys in Turkey will be discussed. Various geological characteristics and boundary relationships of forearc basin deposits have been studied in detail at three different domains in northern Turkey. (Fig. 1)

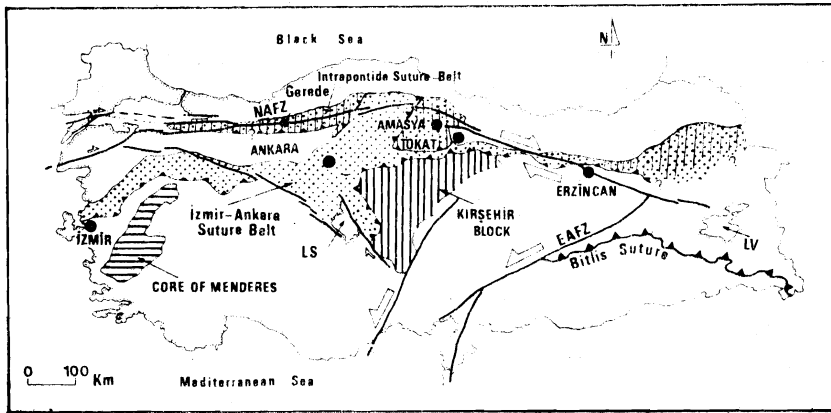


Figure 1. Simplified map showing the distribution of Anatolian Nappe and İzmir-Erzincan Suture Belt, and main neo-tectonic structures of Turkey.

## II. TECTONIC SETTING

The site of an ancient collision zone between the Eurasian plate to the north and Gondwana to the south is represented by an E-W trending suture zone, İzmir-Erzincan suture [7] (Fig. 1). Due to the convergence between these two plates, remnants of both oceanic crust and subduction complex of the North Neo-Tethyan Ocean have been transported tectonically on diverse thrust planes for many kilometers. After the Late Cretaceous closure of the North Neo-Tethyan Ocean, the progressive deformation across this collision zone has been lasted till Late Pliocene, accordingly the ophiolitic units (remnants of oceanic crust and subduction complex) have been brought into their present positions, where they are either klippean or olistostromes. The Neo-Tethys-derived ophiolitic units exposed in İzmir-Erzincan suture zone have been

named as the Anatolian Nappe [8]. In places, within the İzmir-Erzincan suture zone, the subduction complex on the ophiolitic mélange has a sedimentary boundary relationship with the overlying forearc sequences, which have also been transported passively together with the underlying subduction complex into their present positions. Three of these domains, where some well-preserved forearc sequences expose, are located 8 km north of Ankara, 10 km northwest of Amasya, and 15 km south of Tokat (Fig. 1).

### III. TOKAT DOMAIN

It is located in the eastern segment of the İzmir-Erzincan suture zone. In this domain, the type locality of the forearc sequence is the Killik village, which is situated approximately 15 km south of Tokat (Fig. 2).

*Stratigraphy.* In the Killik region, four basic units crop out. From the oldest to the youngest, these are the Anatolian Nappe [8-9], Çördük olistostomes, Tekneli and Çobanlı formations [10]. The Çobanlı formation is composed of fluvial clastics of Pliocene age, and forms a cover, therefore it is out of the scope of this paper. The Çördük olistostomes and the Tekneli formation are the deep marine deposits, and they represent a forearc type of depositional setting. Their various characteristics have been described in detail below. The Anatolian Nappe, that was stacked up as a subduction complex at the active margin of the North Neo-Tethyan Ocean before the collision of Gondwana Land with the Eurasian plate, forms the basement of the forearc deposits in the Killik region.

*Basement rocks.* In Tokat domain, the basement rocks are represented by two tectonic units. The oldest one is the Karakaya Nappe. It is composed of a triple rock assemblages such as shallow marine carbonates, volcano-sedimentary sequence and wildflysch with the tectonic intercalations of high-grade metamorphics [9]. The second tectonic unit is the Anatolian Nappe, which is an ophiolitic mélange composed mostly of spilitic basalt, diabase, spilitic olistostomes, peridotite, pelagic cherty limestone of Cenomanian age, and Jurassic to Lower Cretaceous shallow-marine carbonate blocks embedded in a sheared pelitic matrix.

Both the Karakaya Nappe of Norian age and the Anatolian Nappe of Late Maastrichtian to Late Pliocene age display a southward verging imbricate structure in the E-W trending zone between Ankara to the

west and Erzincan to the east as well as in Killik region. Just north of Killik region, the subduction complex of the Anatolian Nappe gradually passes into the overlying forearc sequences (Çördük olistostromes and the Tekneli formation). In the same region, the ophiolitic mélangé thrusts onto the Pliocene fluvial conglomerates, by which it is transversely overlain.

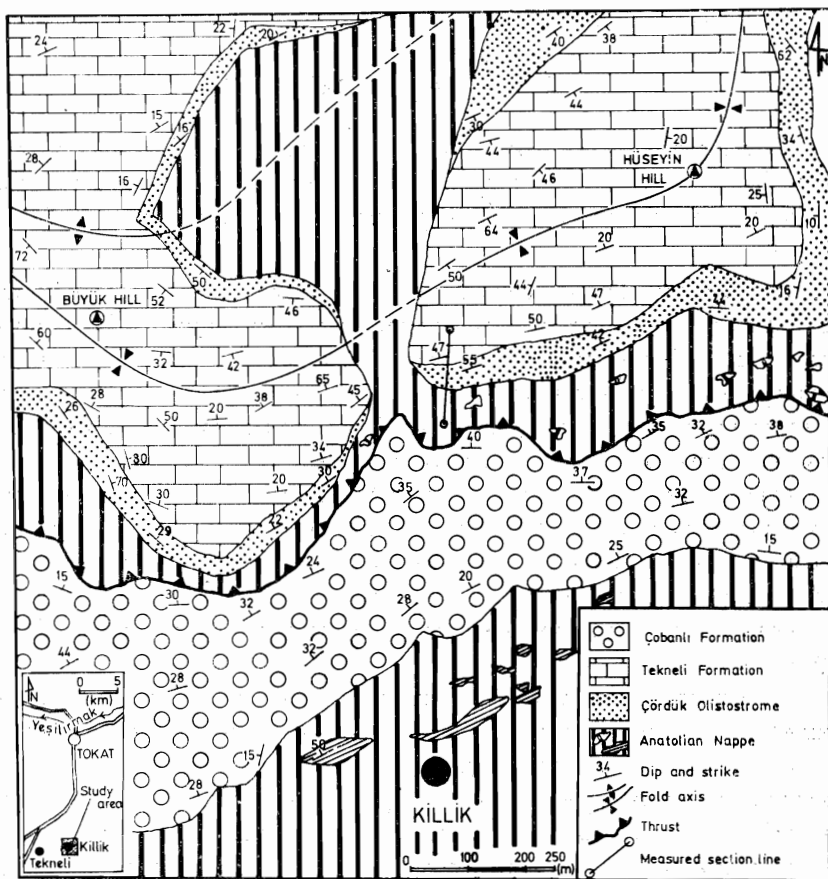


Figure 2. Location and geological map of the Killik area.

*Forearc sequence.* In Tokat domain, the forearc deposits are represented by a thick coarsening-upward sequence of Campanian to Early Paleocene age. It mostly has a transitional sedimentary boundary with the subduction complex of the underlying Anatolian Nappe,

while the erosional contact with the Karakaya Nappe. The forearc sequence is composed of three different levels. From bottom to top, they are the olistostrome-dominated pelagic biomicrite, flysch and shallow marine to neritic carbonates. The first level and the lowermost part of the second level have been measured and examined in detail in the Killik region (Fig. 3), where the remnant of a subduction complex is conformably overlain by the red, thin bedded (2–5 cm), fossiliferous, pelagic biomicrite dominated by the polygenic olistostromes. This lowermost level previously named as the Çördük olistostrome [11] starts with a polygenic olistostrome of 20 m thickness at the bottom, and is succeeded by a red, pelagic biomicrite with abundant olistostromal intercalations (Fig. 3). The individual olistostrome is composed of diverse-sized angular clasts derived from the underlying subduction complex, and embedded within a red, pelagic limy matrix. The most common clasts are red to green radiolarite, spilitic basalt, diabase, serpentinite, peridotite, chert, white colored Jurassic to Cretaceous carbonate. The sizes of these clasts range from a portion of mm to 15 cm in diameter. Olistostromes are lense-shaped, and their lateral extensions range from 1 m to 150 m, while they are 10 cm to 1.7 m in thickness. The total thickness of the Çördük olistostrome is 16 m in the Killik measured section (Fig. 3).

Both the limy matrix of the olistostromal levels and the intervening regularly bedded pelagic biomicrites are very rich in especially *Globotruncana*. The study of the faunal content of the thin sections and washed samples revealed the presence of *Globotruncana linneiana* (d'Orbigny), *Globotruncana arca* (Cushman), *Globotruncana bulloides* Vogler, *Heterohelix* sp., *Hedbergella* sp. and *Globigerinelloides* sp. Based on this fossil assemblage, an Early Campanian to Middle Maastrichtian age has been assigned to the lowermost level of the forearc sequence (Çördük olistostromes) (Fig. 3).

After the sixteenth meter of the Killik measured section, the Çördük olistostromes disappear, and the forearc sequence converts into a flysch facies that was named as the Tekneli formation [10] It is composed of cream–yellow–pinkish colored, fossiliferous biomicrite, turbiditic sandstone with abundant pelagic biomicrite clasts, scarce but large-scale ophiolitic olistostromes of 10 to 30 m thickness and 50 to 250 m length, shale and marl alternation. It is also characterized by growth faults and slumps. The total thickness of the flyschoidal part of forearc sequence is about 700 m, but its only lowermost 11.4 m has been measured (Fig. 3). The pelagic

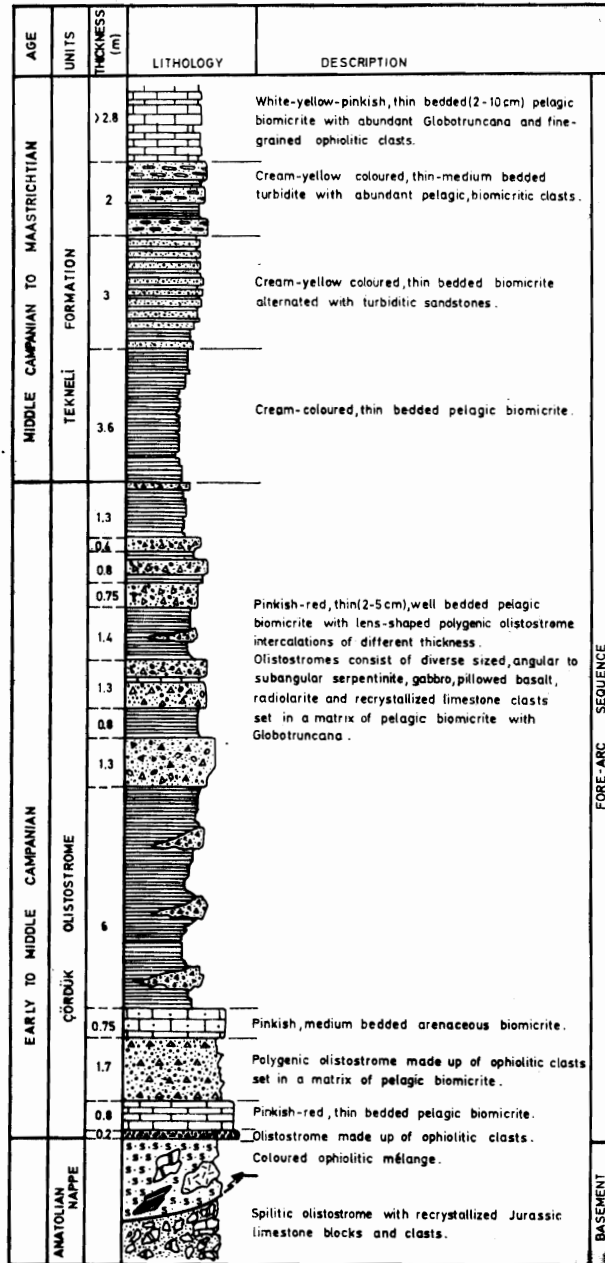


Figure 3. Killik measured stratigraphical column.

biomicrites of the Tekneli formation are also rich in *Globotruncana*. The following fossils have been identified: *Globotruncana linneiana* (d'Orbigny), *Globotruncana arca* (Cushman), *Globotruncana bulloides* Vogler, *Globotruncanita stuartiformis* (Dalbiez), *Hedbergella* sp. Based on this fossil assemblage, the second level of the forearc sequence (Tekneli formation) has been also dated as Middle Campanian to Late Maastrichtian.

The third and the uppermost part of the forearc sequence laid down in a shallow marine to neritic environment, and of Early Paleocene age does not crop out in and around the Killik region, therefore it was not described here.

#### IV. AMASYA DOMAIN

It is located at the northern part of the central segment of İzmir–Ankara–Erzincan suture. In this domain, the type locality of the forearc sequence is the 1 km southwest of Ağıl district, that is situated approximately 8 km northwest of Amasya and at the southern margin of the Merzifon depression (Fig. 4).

##### Stratigraphy

In the Ağıl region, five basic units crop out. These are, from the oldest to the youngest, the Anatolian Nappe, Geyiközü, Fındıklı, Deveboynu formations and the Quaternary alluvial deposits. The Quaternary alluvial deposits are represented by the fine-grained Quaternary plain deposits, coarse to fine-grained alluvial/apran deposits and talus breccias. The Deveboynu formation of Eocene age is composed of fluvial to lacustrine sediments characterized by the sandstone and marl alternation with gypsum intercalations. These first two units unconformably rest on both the forearc sequence and the basement rocks, and form a veneer, so they are out of the scope of this paper, and were not described in detail. The Fındıklı and Geyiközü formations represent the forearc sequence and consist of diverse lithofacies of Early Campanian to Late Maastrichtian age. As in the Tokat domain, the basement rocks in the Ağıl region are also dominated by the Anatolian Nappe, therefore, it was not described again.

*Forearc sequence.* In the Amasya domain, the forearc sequence is characterized by a thick and upward-fining volcano-sedimentary sequence. It has a widespread distribution and shows two different types of boundary relationships with the older basement rocks. One

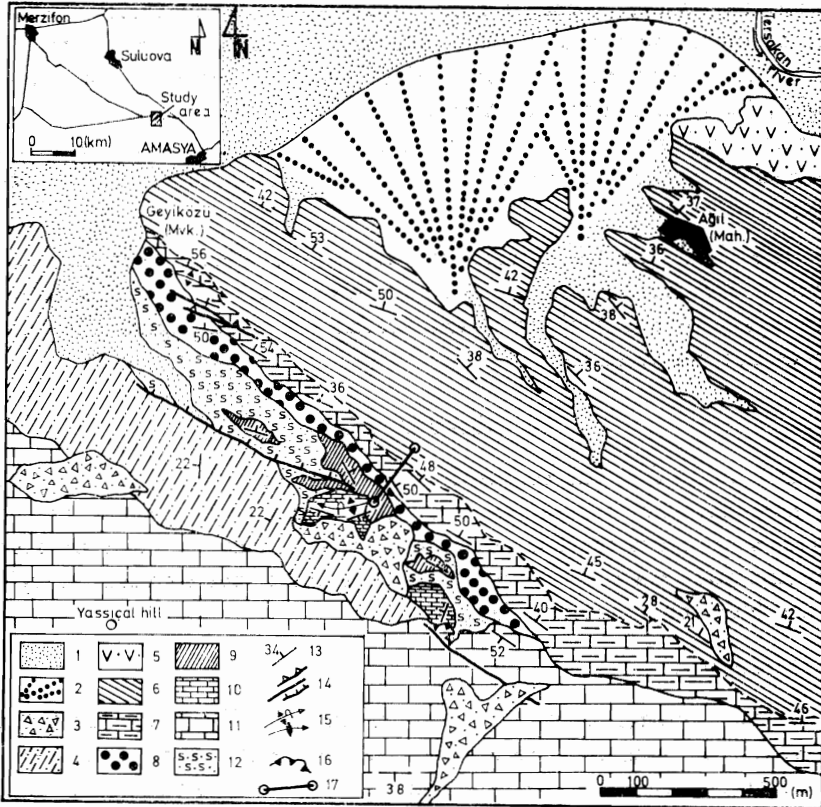


Figure 4. Location and geological map of the Ağıl area. 1. Quaternary plain deposits; 2. Alluvial fan deposits; 3. Talus breccia; 4. Deveboynu formation of Eocene age; 5. Fındıklı formation of Late Cretaceous age; 6., 7. and 8. Geyiközü formation of Late Cretaceous age; 9. Radiolarite; 10. Pelagic cherty limestone; 11. Jurassic to Lower Cretaceous limestone; 12. Ultrabasics; 13. Dip and strike; 14. Diverse faults; 15. Fold axes; 16. Overthrust; 17. Measured section line.

of them is the transitional sedimentary boundary. It is seen well in the highland between the Vezirköprü to the north and the Merzifon depression to the south where the forearc sequence conformably overlies the subduction complex (Anatolian Nappe) of the North Neo-Tethys. The second type of boundary relationship is a local erosional surface, which is seen well at the southeastern margin of the Merzifon depression where the forearc sequence unconformably overlies the underlying Anatolian and Karakaya Nappes.

At the type locality, the forearc sequence consists of three different facies of over 1 km thickness. From bottom to top, these facies

are fluvial clastics, neritic carbonates and volcano-sedimentary sequence of flysch character. In the further east of the type locality, around Koyulhisar region, the top level of the forearc sequence gradually passes into the Early Paleocene continental sequence made up of red marl, shale, fine to coarse grained sandstone and conglomerate alternation with the evaporitic intercalations, whereas in the north of Amasya, the top of the forearc sequence is overthrust by the older basement rocks (Anatolian and Karakaya Nappes), in places.

Only the lowermost 58.8 m of the forearc sequence have been measured and examined in detail at the type locality (Fig. 4,5) where the basal part of the forearc sequence starts with a red, polygenic, fluvial conglomerate and breccias resting unconformably on the erosional surface of the underlying Anatolian Nappe. These fluvial clastics are composed mostly of well to subrounded clasts of Jurassic to Lower Cretaceous limestone, radiolarite, spilitic basalt, diabase, ultrabasics, metamorphics and quartz. They also contain red sandstone intercalations in places. Towards the top of these coarse clastics, the grain size gradually decreases and they grade into red sandstone level of 2.8 m thickness. The total thickness of these basal part is 36.8 m. The fluvial clastics are succeeded by the alternation of marl and neritic limestones. The total thickness of this alternation is 22 m. The rest part of the forearc sequence is composed of the volcano-sedimentary sequence of the deep marine flysch character.

In the upper marine part of the Geyiközü formation, the following fossils have been identified: *Globotruncana cf. arca* (Cushman), *Globotruncana linneiana* (d'Orbigny), *Globigerinelloides* sp., *Heterohelix* sp., *Hedbergella* sp., *Rosita* sp. Based on these fossils, the Early Campanian to Middle Maastrichtian age has been assigned to the Geyiközü formation, which constitutes the lower half of the forearc sequence in the Ağıl district (Fig. 5).

## V. ANKARA DOMAIN

It is located at the central segment of the İzmir-Ankara suture zone (Fig. 1). In this domain, the type locality of the forearc sequence is the Teşrekayla district that is situated in the area between Orhaniye and Memlik villages, approximately 8 km northwest of Ankara (Fig. 6).

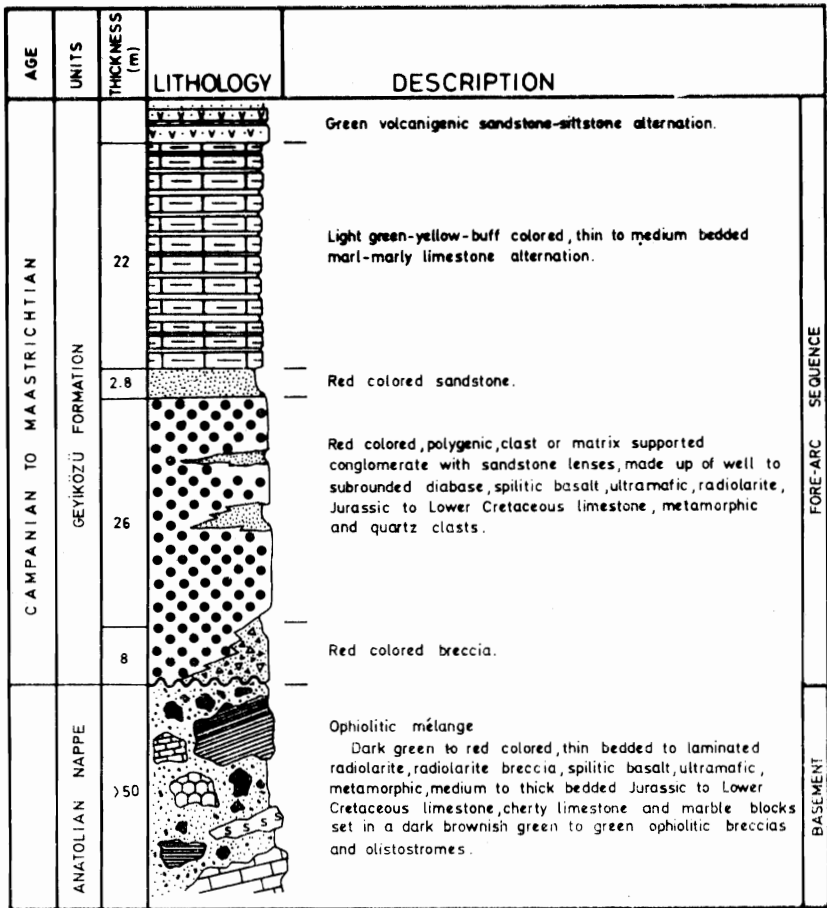


Figure 5. Ağıl measured stratigraphical column.

### Stratigraphy

At and around the type locality, ten different rock units crop out. From the oldest to the youngest, these are the Anatolian Nappe, Kızılkaya, Teşrekayla, Kartal, Uzunçarşılı formations, Orhaniye syenite, Akpınar, Mezgit, Memlik and Kuşkonan formations (Fig. 6). The Mezgit, Memlik and Kuşkonan formations, that are characterized different continental deposits of Late Tertiary age, unconformably rest and form a cover on the older rock units, therefore they are out of the scope of this paper. Except the Anatolian Nappe and the Or-

haniye syenite, the rest of these ten units constitute the forearc sequence. Both the Anatolian Nappe and at least the lower half of the forearc sequence (Kızılkaya, Teşrekayla, Kartal and Uzunçarsı formations) are intruded by the Orhaniye syenite (Fig. 7).

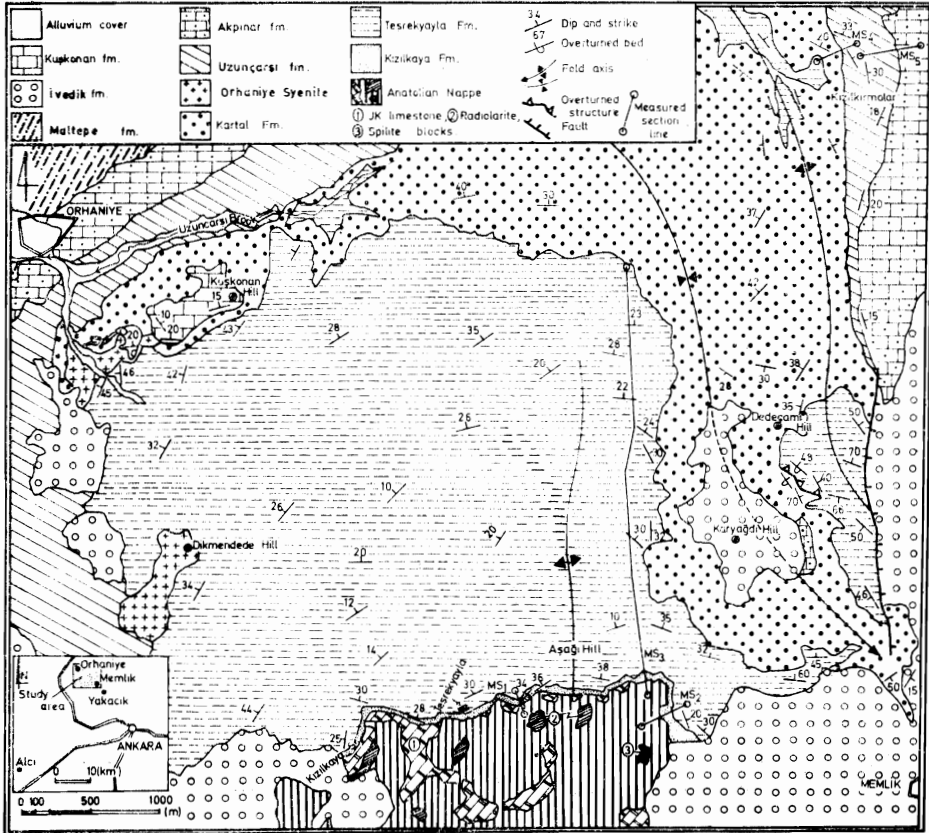


Figure 6. Location and geological map of the Orhaniye-Memlik (Ankara) area.

**Basement rock.** As in the above-mentioned two domains, the basement rock of the forearc sequence in the Ankara domain is also the Anatolian Nappe. It is a chaotic tectono-sedimentary mixture of various blocks of different age, origin and facies set in an intensely sheared, "semischistose" or milonitized fine-grained matrix composed of ophiolitic sandstone, i.e., the sandstone containing dominantly de-

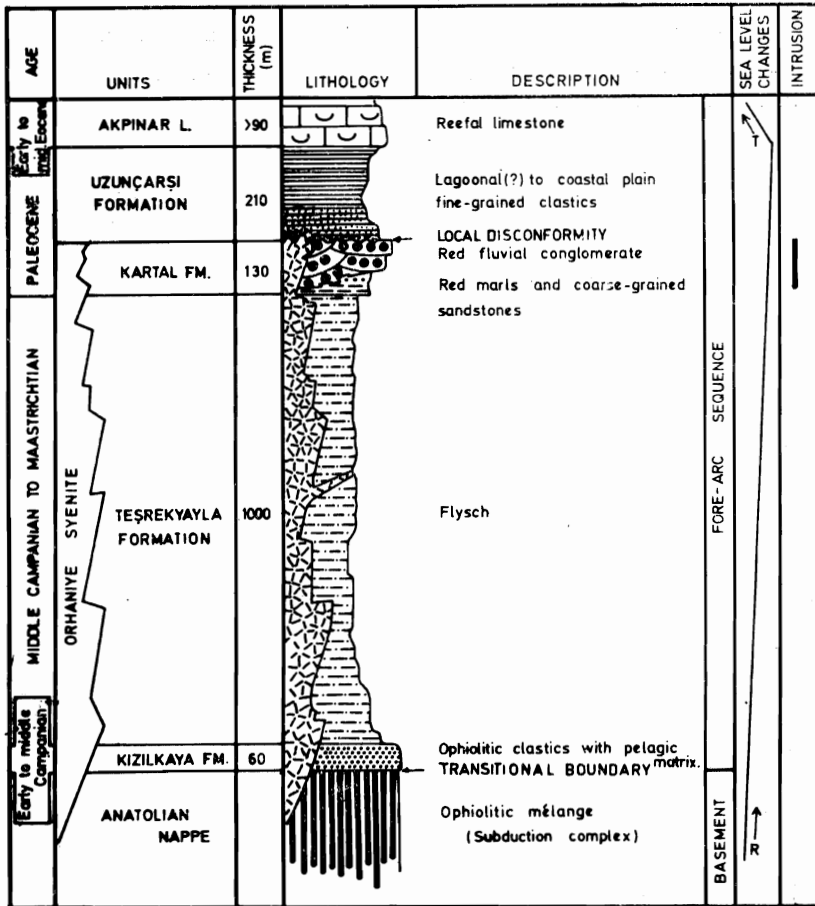


Figure 7. Generalized stratigraphical column of the forearc sequence in Orhaniye-Memlik (Ankara) area (MS<sub>1, 2, 3, 4, 5</sub> in Fig. 6). R. Regression; T. Transgression.

trital ophiolitic material, shale and pelagic mudstone. In other words, it is a well-preserved remnant of the subduction complex accreted at the active margin of North Neo-Tethys. The rock type, facies, size and age of components constituting this subduction complex or ophiolitic mélangé of pre-Campanian age slightly differ from place to place. However, it is composed of blocks derived from three basic sources. These are the oceanic crust, epiophiolitic pelagic sediments, and the active continental margin sediments deposited, deformed and incorporated into subduction complex during the reversal period of

the North Neo-Tethys. The widespread components derived from these three sources of the Anatolian Nappe are chromite-bearing peridotite, serpentinite, gabbro, spilitic pillow basalt, manganese-bearing siliceous rocks, radiolarite, olistostromes of diverse origin and composition, and flyschoidal broken formations of Albian to Early Campanian age (D. Altiner, 1987, personal communication). The latter component of the Anatolian Nappe which represents the turbiditic flyschoidal slope sequence deposited and deformed at the time of subduction, has been well-preserved in a SW-NE trending belt between Bahkuyumcu to the southwest and Bağlum to the northeast in Ankara domain.

On the contrary of the structure in both Amasya and Tokat domains, a well-developed and preserved imbricated structure, which is very conclusive character of the subduction complex underlying the forearc sequence, is observed in the basement rocks exposed in the northwest of Ankara, where thin but long lens-shaped tectonic slices of the basement rock have been stacked up in a NE-SW trending and southward verging imbricated zone (Fig. 9).

*Forearc sequence.* In the Ankara domain, in general, the forearc sequence is represented by the Upper Cretaceous to Eocene flysch sequence of the Haymana basin [12-13]. But the type locality at which we focused our studies is located at the north-northwest margin of this basin.

All over the Ankara domain, the forearc sequence shows two different boundary relationships with the basement rock. One of them is a local erosional contact which can be seen well around Alcı village, 40 km southwest of Ankara, where the forearc sequence composed of fluvial clastics at the bottom and patch reef at the top, unconformably overlies the Anatolian Nappe (Fig. 8). The second and widespread boundary relationship between the forearc sequence and the basement rock is a transitional sedimentary contact. It is seen well at the type locality of this study (Fig. 6, 7, 9, 10) where the forearc sequence is represented by a thick and coarsening-upward sequence succeeded by a thin and fining-upward sequence (Fig. 7). 1/25,000 scaled geologic map has been carried out, and several stratigraphical columnar sections have been measured in order to identify precisely the boundary relationship, facies changes and age of the forearc sequence in the area between Orhaniye and Memlik villages in the north of Ankara (Figs. 6, 7, 9, 10).

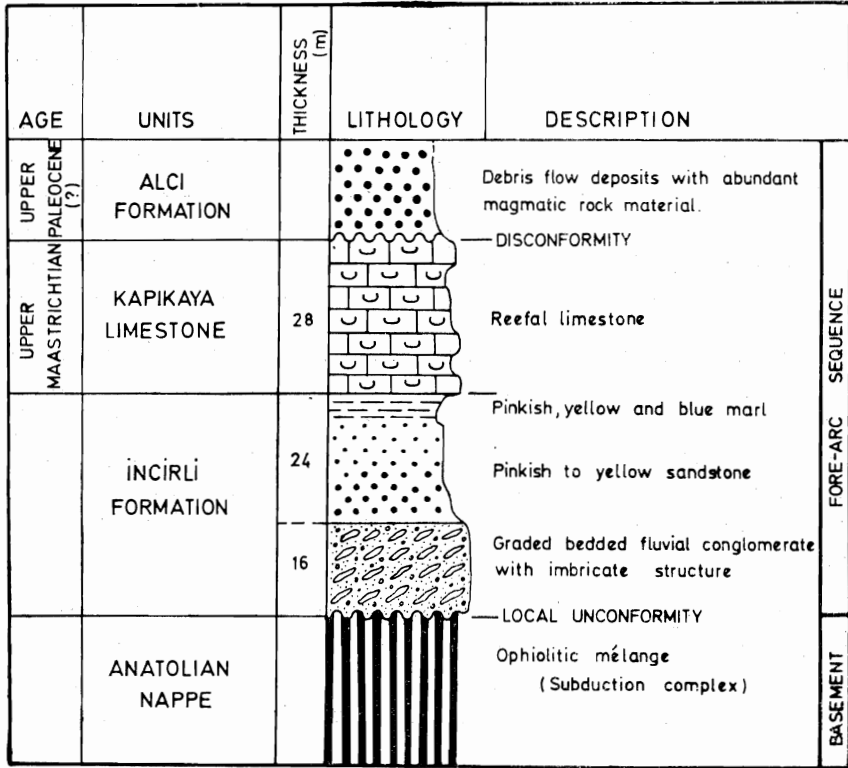


Figure 8. Kapıkaya measured stratigraphical column (Modified from Koçyiğit and Lünel [14]).

In the area between Orhaniye and Memlik villages, the forearc sequence occurs in a large-scale folded structure with the NNW-SSE trending axes, and is divided into five rock-stratigraphic units (Figs. 6, 7). From bottom to top, these are the Kızılkaya, Teşrekayla, Kartal, Uzunçarşılı, and Akpınar formations. The lowermost part of the forearc sequence crops out to the north of the study area, through Kızılkaya, Teşrekayla and Aşağı Hill, and is represented by the Kızılkaya formation. It conformably overlies the underlying basement rock, and is made up of an olistostromal transitional zone in which various pelagic facies are alternated with the subduction complex-derived olistostromes of different thickness and compositions (Figs. 9, 10). Within the pinkish silty marls of the Kızılkaya formation, the following fossils have been identified: *Globotruncanita elevata* (Brotzen), *Globotruncana bulloides* Vogler, *Globotruncana rugosa* (Marie), *Globotruncana orientalis*

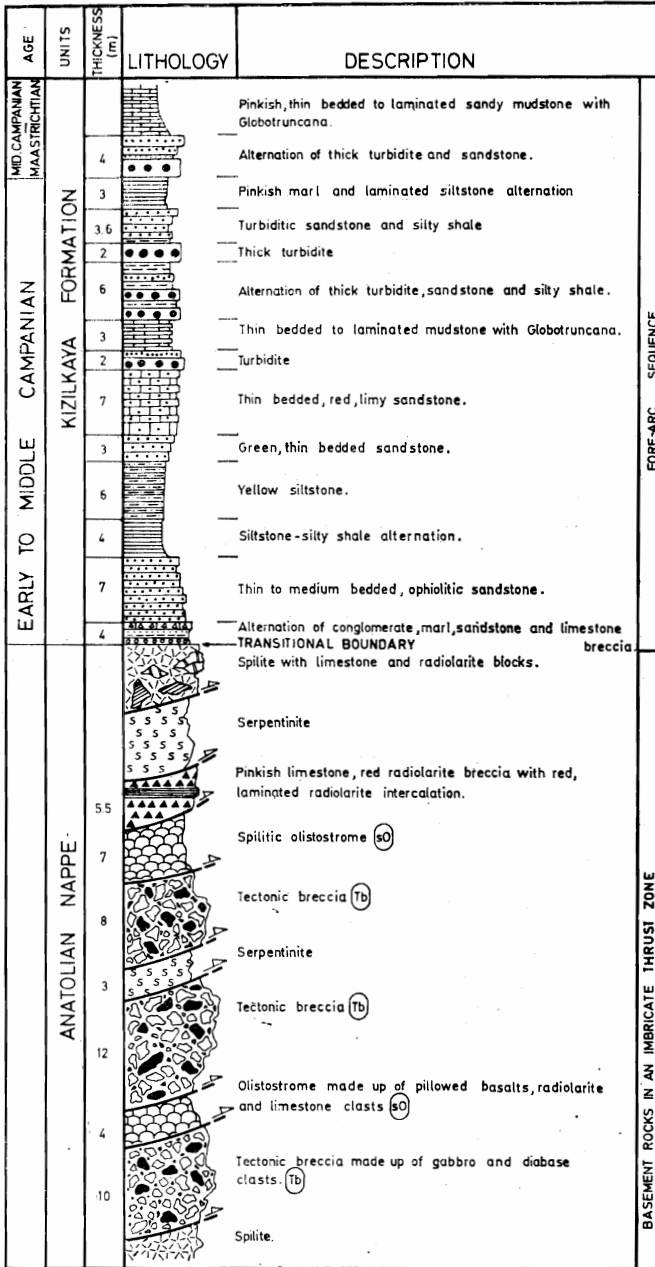


Figure 9. Aşağı Hill measured stratigraphical column (MS 2,3 in Fig. 6).

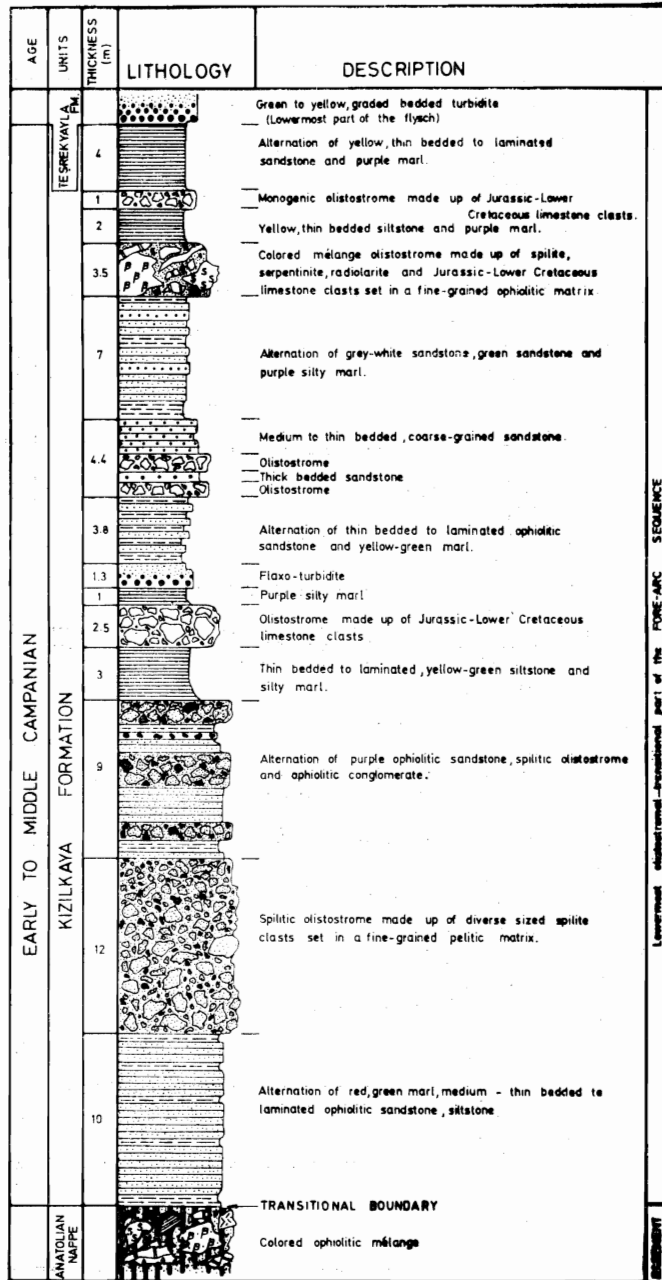


Figure 10. Teşreykayla measured stratigraphical column (MS<sub>1</sub> in Fig. 6)

El-Naggar, *Globotruncana linneiana* (d'Orbigny), *Globotruncana arca* (Cushman), *Heterohelix* sp., Ostracoda and some benthonic Foraminifera. Based on this fossil content, the Early-Middle Campanian age has been assigned to the Kızılkaya formation. The total thickness of the Kızılkaya formation determined in different measured sections is about 60 m (Fig. 6 MS<sub>1</sub>, MS<sub>3</sub>; 9, 10).

The Kızılkaya formation is conformably succeeded by the Teşrekyayla formation. It starts with a thick bedded turbiditic sandstone with the lower Bouma units on the Kızılkaya formation and continues upward as a deep marine flysch facies characterized by the repeated alternations of the siltstone, shale, marl, pelagic limestone and turbiditic sandstone. The individual lithology of the flysch is composed mostly of ophiolitic materials. Within the flysch, some syndepositional structures such as graded bedding, flute casts, slump folds, growth faults and large-scale olistostromes are very common, and they indicate an unstable environment at the time of deposition. At the uppermost part, the flysch gradually passes into coarse-grained, yellow sandstone with lense-shaped conglomeratic intercalations. The measured thickness of the Teşrekyayla formation at the type locality is about 1000 m. At different levels of the Teşrekyayla formation, almost the same fossil assemblage has been identified: *Globotruncana linneiana* (d'Orbigny), *Globotruncana arca* (Cushman), *Globotruncana orientalis* El-Naggar, *Globigerinelloides* sp., *Heterohelix* sp., *Hedbergella* sp. Based on this fossil content, a wide age range between Middle Campanian to Late Masstrichtian has been assigned to the Teşrekyayla formation (Fig. 7).

The Kartal formation conformably overlies the Teşrekyayla formation, and begins with either red marls or yellow-gray, pebble-supported, coarse-grained sandstone with abundant plant debris at the top of the underlying Teşrekyayla formation. It continues upward as the repeated alternations of pebble-supported, coarse-grained gray sandstone; red, unsorted, polygenic conglomerate; thin to medium bedded, red to yellow sandstone, and massive to thick bedded (75 cm-3 m), yellow-red, unsorted, polygenic conglomerate. Consequently, in the measured section, the Kartal formation is dominated by a red, mostly unsorted, polygenic conglomerate, but it scarcely displays a thick graded and large-scale trough like cross-bedding. The size of the components ranges from 1 mm to 1 m in diameter. These characteristics of the Kartal formation can be attributed to the braided to meandering rivers and debris flow fan environments. The total thick-

ness of the Kartal formation in the measured section (Fig. 6, MS<sub>4</sub>) is about 130 m (Fig. 7).

At the topmost of the Kartal formation, a gradual change in both the grain size and color takes place, and then the Kartal formation is conformably overlain by a dark green fine clastics named as the Uzunçarşılı formation (Figs. 6, 7). It starts with the yellow to green marl and cross-bedded to laminated fine-grained sandstone alternation with the green conglomerate lenses at the bottom, and goes upward into the green marl and laminated siltstone alternations with cream to white limestone, white and hard quartz sandstone, and yellow, well-rounded conglomerate intercalations (Fig. 6, MS<sub>4</sub>, MS<sub>5</sub>). These fine-grained clastics are very rich in both organic materials and plant debris, therefore, they are dominated by a dark green color. The measured total thickness of the Uzunçarşılı formation is 210 m. Although no fossil could be found in both the Kartal and Uzunçarşılı formations, they are conformably underlain by the Teşrekyayla formation of Early Campanian to Late Maastrichtian age, and overlain by the Akpınar formation of Early to Middle Eocene, therefore, their age has been accepted as Paleocene (Fig. 7). On the other hand, the Teşrekyayla, Kartal and Uzunçarşılı formations have been intruded by the Orhaniye syenite. This relation can be seen well approximately 1 km SSE of Orhaniye village (Fig. 6) where the cross-cutting relationship between the Teşrekyayla formation and the Orhaniye syenite is very obvious. Therefore, the Orhaniye syenite can not be interpreted as a lava flow in the form of sill. According to its composition, texture, ultramafic xenoliths in itself and the boundary relationships observed in the field, it has been interpreted as a shallow-seated intrusion located in a somewhere below the subduction complex [14].

The topmost unit of the forearc sequence in Ankara domain is the Akpınar limestone (Fig 7). It conformably overlies the fine-grained continental clastics of the underlying Uzunçarşılı formation, and is made up of white-yellow to pinkish, medium to well bedded, fossiliferous sandy limestone with abundant macrofossils and foraminifers. Among macrofossils corals, sponges, algae, pelecypods, gastropods and brachiopods can be mentioned. The foraminifers identified in thin sections are mostly *Alveolina (Alveolina) elliptica* Nuttall, *Nummulites* sp., *Orbitolites* sp. and Miliolidae. Based on this fossil content, the Early to Middle Eocene age has been assigned to the Akpınar limestone. Its lithofacies and the fossil content indicate that the Akpınar limestone was deposited as a reef in an agitated shallow marine depositional setting.

## VI. TYPES OF BASINS

As explained in detail in the foregoing chapter, the bottom boundary relationships, structure, lithofacies and the basin sizes of the forearc sequences exposed at three different domains (Tokat, Amasya and Ankara) led us to conclude that these sequences have been deposited in two basic types of forearc basin: (a) constructed forearc basin (Fig. 11A, 2), and (b) accretionary forearc basin or innerslope basin (Fig. 11A, 1). In the Tokat domain, the forearc sequence has a transitional sedimentary contact with the underlying subduction complex, but erosional unconformable contact with the older arc massif rocks (Karakaya Nappe), in other words, it has been deposited on both the arc massif and subduction complex. Therefore, the type of the basin in Tokat domain is the constructed type of forearc basin [5]. In the Amasya domain, the forearc sequence has both the transitional and erosional sedimentary boundaries with the underlying subduction complex, but an erosional unconformable contact with the older arc massif rocks (Karakaya Nappe). Therefore, the type of the basin in the Amasya domain is also constructed type of forearc basin. The constructed forearc basin, however, in the Amasya domain differs from that in the Tokat domain for two respects: [1] at the time of forearc sedimentation, some parts of the basement rocks (subduction complex) were emerged and supplied material into the forearc basin; [2] in general, the forearc sequence in the Amasya domain is dominated by volcanic arc-derived volcanics. This latter indicates that the constructed forearc basin in the Amasya domain was adjacent to the volcanic arc, while it was away from the volcanic arc in the Tokat domain.

In the Ankara domain, the forearc sequence has both the transitional and local erosional sedimentary contacts with only the underlying subduction complex (Anatolian Nappe). Therefore, the type of the basin is the accretionary type of forearc basin or innerslope basin [1,5]. The local erosional boundary relationship between the forearc sequence and the subduction complex is seen at the northern margin of the basin, while the boundary is transitional where the forearc sequence was deposited away from the northern margin. These boundary relationships imply that the basement rock was emerged locally at or near the northern margin, while the forearc sedimentation was going on in areas away from it.

## VII. EVOLUTION OF FOREARC BASIN IN ANKARA DOMAIN

Except the Ankara domain, the data obtained from other two domains, the Tokat and Amasya domains, are insufficient to explain the geotectonic evolution of the forearc basins. Therefore, the development of the accretionary forearc basin in only the Ankara domain has been described (Fig. 11).

The Haymana accretionary forearc basin whose southern part was first introduced as the Haymana forearc basin by Görür *et al.* [13] is located between the Kızılcahamam magmatic arc in the north and Kırşehir block to Lake Salt in the south. The sequence of the Haymana accretionary forearc basin displays a number of diverse-sized and discontinuous outcrops in a NE–SW trending belt between the Polatlı to the southwest and Kalecik to the northeast [12–14, 15–19].

In the Ankara domain, except one or two short-term gaps, a thick and continuous sedimentary sequence deposited at the North Neo-Tethys margin in the Late Hettangian to Albian time interval crops out. In contrast, the Cenomanian to uppermost Santonian marginal sediments of the same oceanic basin could not be found as a single, complete and continuous sequence up to now. But it is possible to obtain a combined marginal sedimentary sequence of Cenomanian to Late Santonian age by putting the local measured stratigraphical sections of the sedimentary rock outcrops scattered as the broken formations and matrix in the Anatolian Nappe, in especially Ankara region. These broken formations and their shaly matrix together have been reported as “Blocky unit” by Ünalán [18]. In fact, they are the Cenomanian to Late Santonian marginal sediments which were synchronously deposited, deformed and mixed with the trench sediments and tectonic slivers of oceanic crust as a subduction complex or *mélange* at the active margin of the North Neo-Tethyan ocean in the Cenomanian to Late Santonian time interval.

Till the beginning of Early Campanian, this subduction complex was tectonically stacked up, locally emerged at or near the volcanic arc, and gained a certain morphology (Fig. 11B, b). Afterward, an accretionary type of forearc basin started to develop on its top. The forearc sedimentation started with the fluvial clastics on its locally emerged top surface nearby the magmatic arc, and led to the formation of a local erosional sedimentary contact between the underlying subduction complex and the lowermost part of the overlying forearc sequence (İncirli formation) (Fig. 11B, c) On the other hand, in the

marine environments, the forearc sedimentation lasted on the subduction complex without any break and resulted in a transitional sedimentary contact between the underlying subduction complex and lowermost unit (Kızılkaya formation) of the overlying forearc sequence. (Figs. 9, 10 11B, d) The lowermost transitional unit of the forearc sequence is dominated by the repeatedly alternating ophiolitic clastics and olistostromes which indicate that the tectonic stacking up of the underlying subduction complex was still going on at the time of initial forearc sedimentation. A continental sedimentation near the magmatic arc and a marine sedimentation of flysch facies away from the magmatic arc continued up to Late Maastrichtian. As a result of the marine sedimentation, an approximately 1000 m thick flysch sequence (Teşrekyayla formation) made up of thick turbidite, marl and shale alternations and structured by growth faults and slump folds formed. During Late Maastrichtian, the previously emerged part of the subduction complex was submerged and the fluvial clastics deposited by both the braided and meandering rivers were conformably overlain by a reefal build up (Kapıkaya limestone) formed in the shallow marine waters invading the northernmost part of the forearc basin (Fig. 11B, e). At the end of Late Maastrichtian, the whole of the northern margin of the forearc basin was uplifted again above the sea level, and the sedimentation lasted in different continental environments such as flood plain, fan-delta and lake (Fig. 11B). As a result of this continental sedimentation lasting through Paleocene, various continental sequences (Alcı, Kartal, and Uzunçarşılı formations) were deposited (Figs. 11B, i, k, l). During the same time interval, the southern parts of the forearc basin were still under the influence of both the shallow and deep marine conditions [12-13]. As a result of the shallow marine sedimentation nearby the emerged areas, reefal buildups (Çaldağ limestone) were deposited, while a thick flyschoidal sequence (Kırıkavak formation) was being deposited in the southward deepening part of the forearc basin through Paleocene (Fig. 11B, g,h). Another important geologic event taking place in Paleocene was the microsyenitic intrusion, that was resulted from a magma chamber located in a somewhere below the subduction complex at the uplifted and emerged northern margin of the forearc basin [14]. All of the forearc sequence deposited up to at least Late Paleocene were intruded by this syenitic intrusion (Fig. 11B, j). The cross-cutting relationships, ultramafic xenoliths and thermal effects of the syenitic intrusion can be seen well along the

boundaries between the Orhaniye syenite and the Teşrekayla formation exposed at 1 km southeast of Orhaniye village (Fig. 6).

At the end of Paleocene or beginning of Eocene, the most parts of northern margins of the forearc basin were submerged and invaded once more by shallow marine waters, and a new reefal buildup (Akpınar limestone) was deposited in the areas nearby magmatic arc, while the flyschoidal deep marine sedimentation was lasting in the southern part of the forearc basin (Fig. 11B, m, n). Both the shallow and deep marine sedimentation continued in a coarsening upward character up to the end of Lutetian, and then, the whole of the forearc basin was emerged, and the forearc sequences were unconformably overlain by the Late Tertiary continental deposits dominated by evaporites [13]. Consequently, in the Early Campanian to Middle Eocene time interval, an accretionary type of forearc basin was developed on the subduction complex at the active margin of North Neo-Tethys. In general, the northern magmatic arc side margin of this forearc basin is characterized by the thick pile of continental sequence with the intervening thin, shallow marine, reefal buildups, while the southern margin is dominated by a thick and coarsening-upward deep marine sequence. This asymmetrical sedimentation can be attributed to the southward migration of the forearc basin due to the northward subduction of the North Neo-Tethys. Southward younging thrusts and the large scale monoclinical structures with the steep south limbs are the distinctive and conclusive evidences of this event and the asymmetrical forearc sedimentation.

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Figure 11. A. Sketch cross-section showing the tectonic setting of the constructed (2) and accretionary (1) types of forearc basin (After Dickinson and Seely [5]); B. Tentative block diagram illustrating the Haymana accretionary forearc basin and its facies distribution in both the time and space (Modified from Koçyigit and Lünel, [14]). a. Arc massif (Karakaya Nappe); b. Subduction complex (Anatolian Nappe); c. İncirli formation (fluvial clastics of pre-Late Maastrichtian age); d. Teşrekayla and Haymana formations of Early Campanian to Late Maastrichtian age; e. Kapıkaya limestone and Asmaboğazı formation of Late Maastrichtian age; f. Yeşilyurt formation of Montian age; g. Kırkkavak formation of Early-Middle Paleocene age; h. Çaldağ limestone of Early-Middle Paleocene age; i. Kartal formation; j. Orhaniye syenite of pre-Late Paleocene age; k. Alei and Karacihan formations of Late Paleocene age (?); l. Uzunçarşı formation of Late Paleocene age (?); m. Akpınar limestone of Early-Middle Eocene age; n. Eskipolath formation of Late Paleocene-Early Eocene age; fç. Feeder channels of Kızılcahamam volcanics of Late Maastrichtian to Tertiary age; o. Disconformity; T1, T2, T3. Time lines corresponding to Early Campanian, Paleocene and Eocene, respectively; R. Coarsening-upward sequence of Early Campanian to Middle Paleocene age, and T. Fining-upward sequence of Late Paleocene to Middle Eocene age.

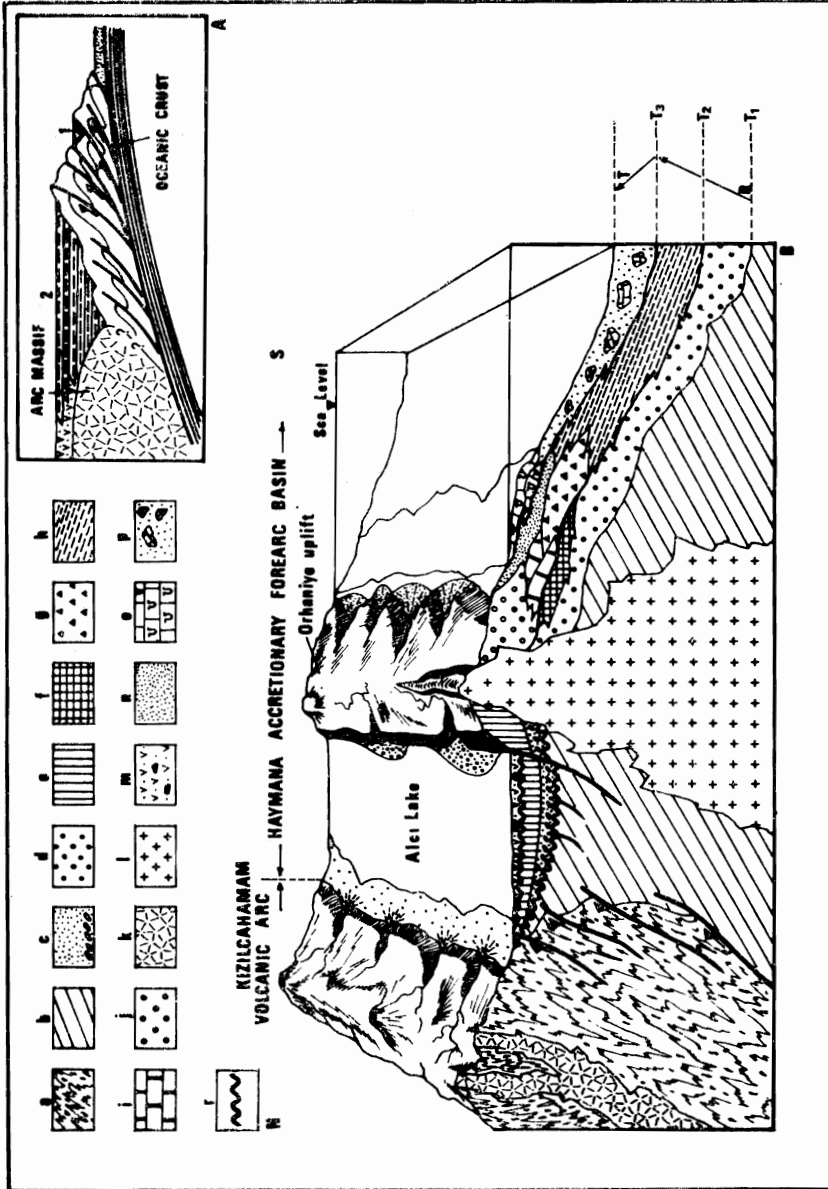


Figure 11 A B and B. Explanation on preceeding page.

### VIII. DISCUSSION AND CONCLUSION

When the 1/500.000 scale geological map of Turkey is examined closely, some Upper Cretaceous flysch outcrops scattered in the ophiolitic *mélange* (Anatolian Nappe) exposed at the İzmir-Erzincan suture belt are seen. In order to solve some geologic problems associated with these Upper Cretaceous flyschoidal sequences and the surrounding ophiolitic *mélange*, three type localities have been chosen. Under the light of recent data obtained from both the detailed field studies carried out at these three localities, Tokat, Amasya, Ankara, and the laboratory studies of samples, the natures, litho- and biofacies, boundary relationships, tectonic setting and ages of both units have been discussed again in detail, and the followings have been concluded: [1] the basement rocks of the flyschoidal to molassic sequences are only a subduction complex or both the subduction complex and older arc massif (Karakaya Nappe); [2] in Ankara domain, the age of matrix of the subduction complex or ophiolitic *mélange* (Anatolian Nappe) is the Late Santonian to Early Campanian [18]; (D. Altner, 1987, personal communication); [3] the ages of the flyschoidal sequences range between Early Campanian to Middle Eocene in the Ankara domain, Early Campanian to Late Maastrichtian in the Tokat domain, and Early Campanian to Paleocene in the Amasya domain; [4] in both the Tokat and Amasya domains, the flyschoidal to molassic sequences have an erosional unconformable contact with the underlying older arc massif, while they have both erosional and transitional boundary relationships with the subduction complex; [5] in the Ankara domain, the flyschoidal to molassic sequence displays both local erosional and transitional sedimentary boundary relationships with only the subduction complex [13-14, 18]; [6] in both the Tokat and Ankara domains, there is an approximately 60 m thick transitional level between the underlying subduction complex and overlying flysch to molassic sequence, and it is characterized by a fine-grained ophiolitic clastics with pelagic mud matrix and olistostrome intercalations; [7] in Tokat, Ankara and Amasya domains, the thickness of the flyschoidal to molassic sequences ranges between approximately 600 m and 2000 m; [8] at these three localities, sequences are structured by growth faults, slumps, and made up of thick turbidites, shale, marl and olistostromes; [9] in the Ankara domain, the flyschoidal to molassic sequence is intruded by an Early to Middle Paleocene syenitic intrusion; [10] in also

the Ankara domain, the subduction complex has been built up by the tectonic thickening and stacking up of the Cenomanian to Late Santonian marginal sediments and tectonic slivers of oceanic crust; [11] the flysch sequence in these three domains is composed mainly of both the subduction complex- and magmatic arc-derived materials; [12] in general, these sedimentary sequences are in a coarsening-upward sequence character, and also their upper levels are molassic facies.

Consequently, based on above-mentioned findings, these Early Campanian to Early Tertiary flyschoidal to molassic sediments are the remnant forearc sequences deposited in a constructed type of forearc basin in both the Tokat and Amasya domains, but in an accretionary type of forearc basin in the Ankara domain, at the active margin of North Neo-Tethys. In the same way, the upper limit of the development age of the subduction complex is Late Santonian to Early Campanian, but its emplacement age as the Anatolian Nappe on the passive continental margin ranges between Late Maastrichtian to Late Pliocene.

## ÖZET

### KUZEY NEO-TETİS'İN ETKİN KİTA KENARINDAKİ KALINTI YAYÖNÜ HAVZALARINDAN ÖRNEKLER : ANADOLU NAPİ'İN YERLEŞİM YAŞI, TÜRKİYE

Kuzey Türkiye'de Ankara kuzeyi, Amasya kuzeybatısı ve Tokat güneyinde yapılan saha ve laboratuvar çalışmaları sonucu, kuzey Neo-Tetis'in etkin kıta kenarına ait değişik tür yayönü havzasının kalıntıları saptanmıştır. Bu yörelerde yüzeyleyen yayönü havzası istifleri ya yalnızca, Anadolu Napı olarak adlanan yitim karışığı (renkli ofiyolitli mélanj tarafından, ya da Karakaya Napı olarak adlanan daha yaşlı kaya topluluğu ve Anadolu Napı tarafından birlikte altlanır. Yayönü havzası istiflerinin taban dokunak ilişkilerine göre, kuzey Türkiye'de gözlenmiş olan yayönü havzaları iki türdür. Bunlar yığışım türü ve yapım türü yayönü havzalarıdır. Diğer taraftan, yayönü havza istiflerinin taban kesimlerinden elde edilen paleontolojik verilere göre, Anadolu Napı'nın kuzey Neo-Tetis'in etkin kıta kenarında bir yığışım prizması olarak oluşum ve büyüme yaşı Orta Kampaniyen önceci, pasif kıta kenarına bir nap olarak yerleşim yaşı ise Geç Maastrichtiyen- Geç Pliyosen zaman aralığıdır.