GEOLOGICAL EVOLUTION AND BASIN MODELS DURING NEOTECTONIC EPISODE IN THE EASTERN ANATOLIA

Fuat ŞAROĞLU* and Yücel YILMAZ**

ABSTRACT. —In the Eastern Anatolia, neotectonic regime beginning in Middle Miocene has considerably affected the geological evolution of the region. During the neotectonic episode, compressional tectonic regime, characteristic for the region, resulted in formation of folds, thrust and strike-slip faults, and large-scale extentional fractures. Under the control of all these structural elements, basically two types of basins (intermountain and pull-apart) are formed. Among these, Muş, Ahlat-Adilcevaz and Karayazı-Tekman basins are the intermountain basins. Kağızman-Tuzluca basin, however, has been evolved as a pull-apart type. The Erzurum-Pasinler-Horasan is another type of intermountain basin which was also affected by strike-slip faults. The general features of the new episode deposits are to be in nonmarine facies and with the coeval volcanites their accumulation in separate basins.

INTRODUCTION

This paper is an attempt to introduce the main affects of the neotectonism to geological evolution of the Eastern Anatolia. The Eastern Anatolia is a tectonic region that is characterized by unique deformational style during neotectonic episode (McKenzie, 1972; Şengör, 1980; Şaroğlu and Yılmaz, 1984). The area, which is here introduced under the name of the Eastern Anatolia region, is to the further east of the intersection point (around the east of Karlıova) of North and South Anatolian Faults (Allen, 1969; Apart and Şaroğlu, 1972; Şengör, 1979). As in Figure 1, the Eastern Anatolia lies between the Pontides on the north, folded and thrust belt on the south, and extends to the Turkish-Iranian and Turkish-Russian state boundary to the east (Ketin, 1966).

Some earlier works have been carried but dealing with the general features of the neotectonism in the Eastern Anatolia. These works primarily discussed the structural, morphological and volcanic events in the region (Şaroğlu et al., 1980; Şengör, 1980; Şaroğlu and Güner, 1981; Yılmaz, 1984; Şaroğlu and Yılmaz, 1984; Yılmaz et al., 1986; Şaroğlu, 1985). These studies have also provided information on the tectonically related structures and their subsequent deformational geometries that are shaped up in the period between the last change in tectonic regime and the present time.

Depending on the closure of Neotethys, this neotectonic evolution is the result of the continent-continent collision that is evident along the Bitlis suture belt (Şengör et al., 1979). The continent-continent collision initiated a new tectonic episode mainly characterized by compressional tectonic regime in the Eastern Anatolia. During this new episode, folds, thrust and strike-slip faults, and large-scale pull-apart type of extentional fractures are formed. These structures led to the narrowing and subsequent widening of the region in N-S and E-W directions, respectively. These structures also caused the thickening of continental crust, thus subsequent uplifting of the region.

In general, synclines and anticlines trend east-west in the region. They correspond to and are overlain by east-west trending basins and elongate ridges. Different type of basins are also formed along the north-south trending extentional fractures and in areas where strike-slip faults step up in en-echelon character. The young volcanism in the region has displayed some changes depending on the evolution of the continental crust. Eruptions have mostly followed the extentional fractures and chose them as paths to get out. N-S trending deep valleys and E-W trending meandering rivers are among other features formed during this neotectonic episode.

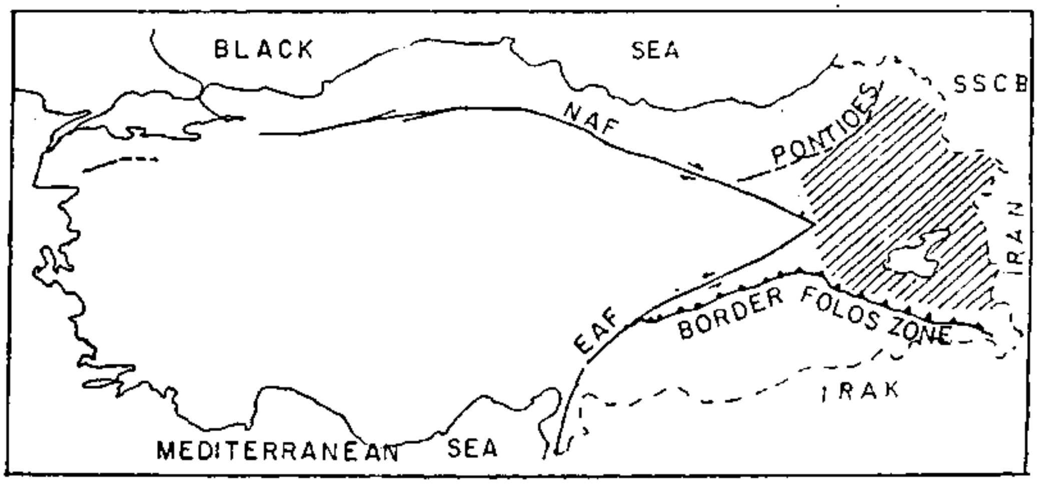

Fig. 1 - Location map for the study area.

In the region, sedimentary rocks and coeval volcanites cover very wide areas. In this paper, first the stratigraphy of new episode will be introduced, and then, to a great extent, the geological evolution of the region will be discussed under the light of the stratigraphic relations.

GENERAL ASPECTS OF THE STRATIGRAPHY OF THE NEOTECTONIC EPISODE IN THE EASTERN ANATOLIA

Geological evolution of the Eastern Anatolia can be analized in four structural stages (Şaroğlu and Güner, 1981; Şaroğlu and Yılmaz, 1984). From oldest to youngest these can be arranged as in the following.

The first stage covers the Palaeozoic to Lower Mesozoic metamorphic rocks that are the oldest strata in the region (Boray, 1975; Perinçek, 1980; Perinçek and Özkaya, 1981; Yılmaz et al., 1981; Göncüoğlu and Turhan, 1983; Çağlayan et al., 1983). The second stage rocks consist of ophiolitic melange type of strata that was structurally pushed over the first group in Upper Cretaceous (Demirtaşlı and Pisoni, 1965; Ketin, 1977; Yılmaz et al., 1981). The third stage rocks cover a sequence of Eocene to Lower Miocene sedimentary rocks. They unconformably overlie the first and second group strata. The fourth stage strata consist of the Upper Miocene to present day deposits. They are nonmarine in character and are strongly affected by both volcanism and neotectonism. The last stage sediments unconformably sit on the all of these older rocks and have some diastems and stratigraphic onlaps. These are the products of neotectonic episode.

Overall, the tectonic evaluation (including paleotectonic) of the Eastern Anatolia was earlier presented by Şengör and Yılmaz (1981). This paper, however, only deals with the tectonic events that has occured during the neotectonic episode.

First, the stratigraphy will be introduced within the eight areas where the sediments of the neotectonic episode have very widespread distribution. Second, the stratigraphic units will be considered in terms of time and space. Third, on the basis of facies, facies changes and distributions in each basin, an attempt will be made to explain the evolution of the entire region. Among these areas, first the ones that are on the south and then, the ones on the north will be introduced. These areas are in turn, (1) Karlıova-Bingöl, (2) Muş, (3) Ahlat-Adilcevaz, (4) Karayazı-Tekman, (5) Hınıs, (6) Zırnak, (7) Erzurum-Pasinler-Horasan, and (8) Kağızman-Tuzluca. Among them, there are several small and large basins, as well. Along with the 8 areas, evolution of the other basins will be considered eventhough their stratigraphy is not included in this paper.

Bingöl-Karlıova area

A very large area, between Muş basin and the East Anatolian strike-slip fault, is covered with widespread volcanites (Fig. 2). Here, Tertiary deposits are exposed at several localities. The stratigraphic relations between the Tertiary rocks and underlying basement strata are well discernable. Such relations are important because they lead us to know the areal distribution of the Tertiary sediments deposited following the paleotectonic events. The Lower Miocene strata are primarily overlying the older rocks thin to the west.

In the Bingöl-Karlıova area, the Lower Miocene consists of Adilcevaz limestone. The Adilcevaz unconformably overlies the basement strata and have sandy limestones at its very base. The Adilcevaz limestone is exposed at very small localities along the North Anatolian fault. Fossils found in the limestones are characteristic for Burdigalian. Very lower portion of the Adilcevaz can be designated to Aquitanian (Seymen and Aydın, 1972). Solhan volcanites, showing very wide distribution in the area are Upper Miocene in age. They are intercalations of lavas that are continental in origin. Well exposed outcrops of the Solhan volcanites are on the both sides of the East Anatolian fault. In the lower portion of the Solhan volcanites, gravels collected from the conglomerate have fossils thought to be Upper Miocene in age. Zırnak formation is another stratigraphic unit with widespread distribution in the area. It is Pliocene in age. Samples collected from coal layers of the Zırnak formation have fossils of Middle-Upper Pliocene (Nakoman, 1968). The lower contact with the underlying Solhan volcanites is probably unconformable. Quaternary in Bingöl-Karlıova area comprises Boran formation, landslides, travertine and unnamed ancient and modern alluvial deposits (Fig. 3). The Boran formation bears the characteristics of alluvial fan deposits with a lateral extend limited to the Karlıova plateau. The Boran formation is old Quaternary, thus is assumed to be Pleistocene in age.

As inferred from the overall sequence, the area of Bingöl-Karlıova has become continent after the Lower Miocene. The oldest strata of the neotectonic episode is the Solhan volcanites. They are intercalated with nonmarine deposits. The presence of Pliocene Zırnak formation on both sides of the East Anatolian fault indicates that faulting occured after the deposition of Zırnak formation. Presence of the Pliocene Boran formation indicates the opening of the Karlıova basin.

Muş area

The area of Muş is in the southeast portion of the study area. This area is interesting because age relations between the widespread Tertiary deposits can clearly be seen. The Muş area, with an approximate east-west extention is bordered in the south by Bitlis mountain, in the east by Nemrut volcano, and in the north by Bingöl volcano and Hamurpet uplift (Fig. 2). The stratigraphy in the area is showrt; in Figure 4. The Lower Miocene Adilcevaz limestones have gradual contact with underlying Aquitanian Abulbahar formation (Ünal, 1970), and has very widespread distribution in the northern part of the Muş plain. The Adilcevaz is dominated by limestones in the west, clayey and sandy limestones in the east of Muş plain. The limestones of the Adilcevaz characterize the Burdigalian.

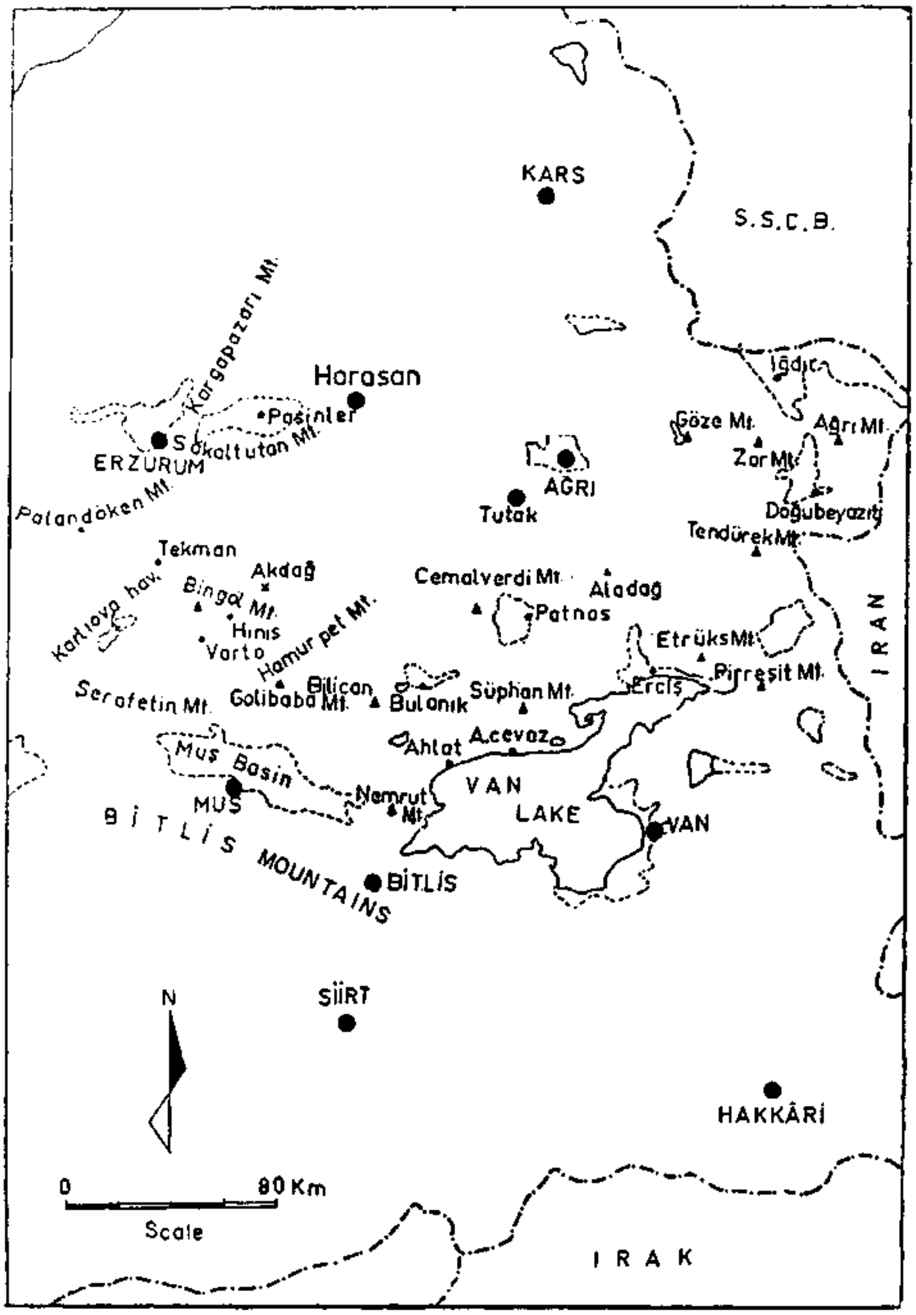

Fig. 2 - Simplified map for locating the basins and areal distribution of Quaternary rocks in the Eastern Anatolia.

The Solhan volcanites, unconformably overlying the Adilcevaz limestones, have wide distribution in the western part of the area (Yılmaz et al., 1986). Type sections for the Solhan volcanites are along the both sides of the Murat river valley. Lower Miocene gravels have been found in the lower portion of the Solhan volcanites. The Solhan volcanites are different from the Middle Miocene sediments of the Ahlat-Adilcevaz area, thus the Solhan volcanites are thought to be Upper Miocene in age.

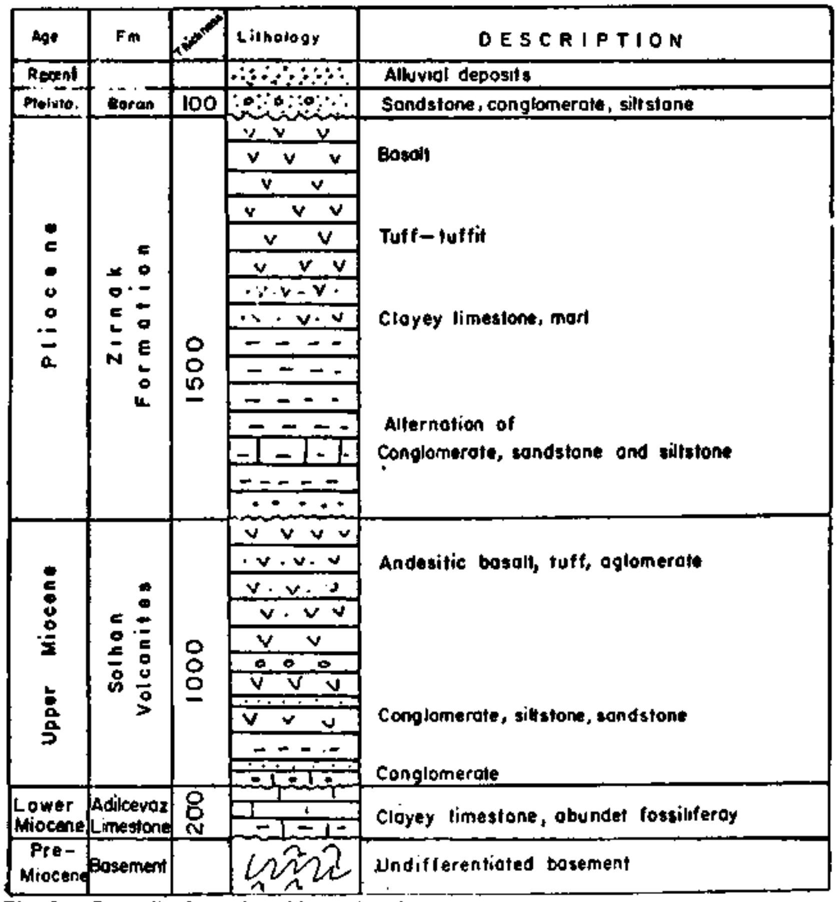

Fig. 3 - Generalized stratigraphic section for Bingöl-Karlıova area.

The Zırnak formation, lying in the Solhan volcanites with possible unconformity, has a widespread areal distribution in the northern part of the Muş basin. The Zırnak is deposited in non-marine environment and has some limestone interbeds that are characteristic for lake deposits. Fossils collected from different layers of the Zırnak formation are designated to Upper Miocene to Pliocene time span.

The Anzar formation, which was formed in the boundaries of today's Muş basin (Yılmaz et al., 1986), consists mainly of deposits of a lake, that was present at the beginning of Quaternary. The possible age for the Anzar formation is Pleistocene.

Ignimbrites, whose distribution is conformable with the drainage pattern of the Murat river and adjacent streams, are thought to be Pleistocene in age. Basalts, tuffs and dasites of Nemrut volcano are designated to Quaternary (Güner, 1984).

According to the overall sequence of strata, the present sea regressed from the area towards the end of the Lower Miocene. Middle Miocene strata has not been found in the area. There is an angular unconformity between the strata of neotectonic and paleotectonic episode. The presence of widespread volcanites in the area, and the unconformity between the Solhan volcanites and overlying Zırnak formation indicate that the tectonism had a great effect in neotectonic episode.

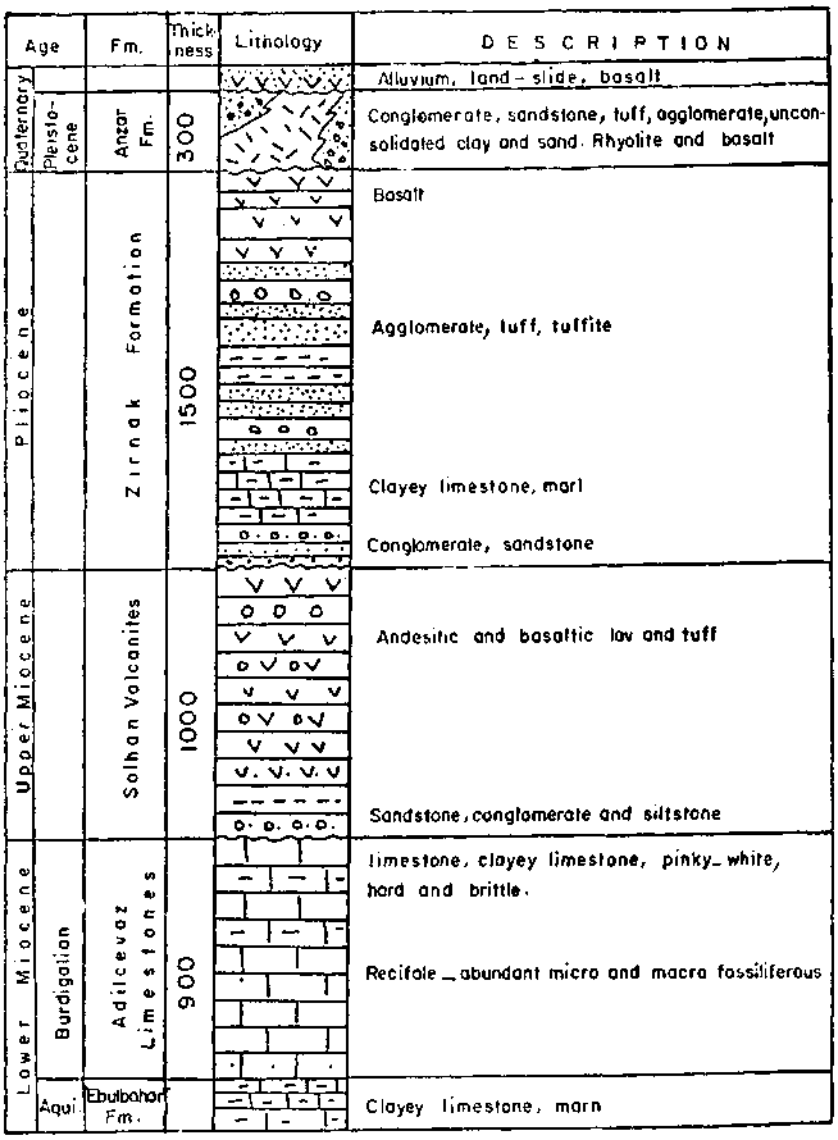

Fig. 4 - Generalized stratigraphic section of Muş area (adapted from Yılmaz et al., 1986).

Ahlat-Adilcevaz area

In the northern part of the Van lake, there are widely distributed volcanites of neotectonic episode (Fig. 2). Tertiary deposits interstratified with these volcanites are well exposed at some localities between Ahlat and Adilcevaz. From bottom to top, the lithostratigraphic units in the area are the Lower Miocene Adilcevaz limestone, Middle-Upper Miocene Develi formation with Aktaş conglomerate at its very base, Pliocene Çukurtarla limestone and unnamed volcanites (Fig. 5). Age of the Pliocene for the Çukurtarla limestone is still debateble. The stratigraphic units in the area were first named by Demirtaşlı and Pisoni (1965).

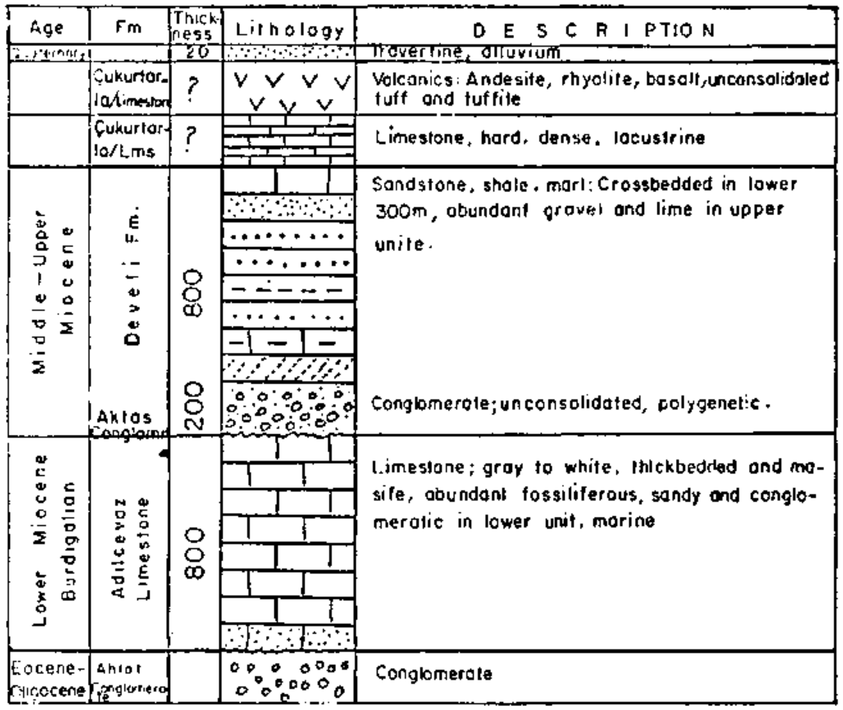

Fig. 5 - Generalized stratigraphic section of Ahlat-Adilcevaz area (modified from Demirtaşlı and Pisoni, 1965).

The Adilcevaz limestone is exposed at the outcrops in the south portion of the area. It is in marine fades and shows the same fades characteristics around Erciş, in the east, and Muş, in the west. The Aktaş conglomerate, which comprises the lowest portion of the Adilcevaz formation, do not have any fossil to designate it to a particular age. The Aktaş contains the gravels of the underlying Adilcevaz limestone, thus it is younger than the Lower Miocene. Owing to gradual contact between the conglomerate and the overlying Middle-Upper Miocene Develi formation, the age for the Aktaş conglomerate should be older than Middle Miocene. With respect to the fossils found in the Develi formation, it is Middle Miocene in age. The Develi formation gradually pass upward into Çukurtarla limestones. The Çukurtarla limestone is in lake facies and has distribution in the north of the basin. Along with the overlying volcanites, the Çukurtarla limestones are thought to be Pliocene in age. In terms of facies characteristics, the Çukurtarla limestone resembles the Zırnak formation of the Muş basin.

The present sea regressed from the Ahlat-Adilcevaz during the Middle-Upper Miocene time. The facies gradation from marine deposits of the Develi formation up into lake limestones of the Çukurtarla formation indicates that the marine environment was gradually replaced by the lake environment. Such a regression is probably related to the local uplifting resulted from neotectonic events.

Karayazı-Tekman area

The Karayazı-Tekman basin nearly extends from east to west. It is bounded in the north by an east-west trending ophiolitic ridge, in the south by Akdağlar, that is made up of the metamorphic basement rocks, in the west by volcanites of neotectonic episode. In the east, the basin opens up into Zırnak basin. The basin has a different position among others because of the unconformity between different stratigraphic units, widespread existence of the deposits of neotectonic episode and presence of definitive basin boundaries in the north and south at the beginning of neotectonic episode. Figure 6 represents the observed strata in the basin.

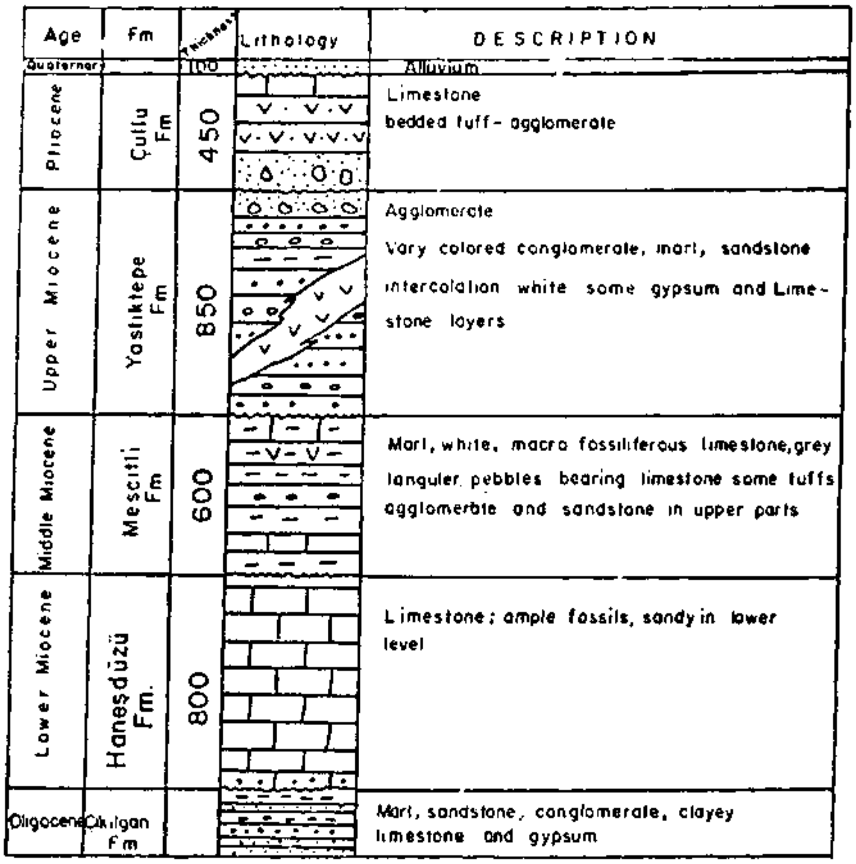

Fig. 6 - Generalized stratigraphic section of Karayazı-Tekman area (adapted from İlker, 1966 *b*; Erdoğan, 1966 and Tanrıverdi, 1977).

In the Karayazı-Tekman area, the Lower Miocene is characterized by Haneşdüzü formation. The name «Haneşdüzü» which unconformably sits on the Çığılgan formation, was firts used by İlker (1966b). It consists of marly, marine limestones with some breccia and has characteristic fossils of Burdigalian. The Haneşdüzü is unconformably overlain at the top by Mescitli formation. The Mescitli appears to have features of the lake deposits and has intercalations of volcanites towards its top. Fossils collected from the Mescitli formation are designated to Middle Miocene. Up in the section, Mescitli formation is conformably overlain by Yastıktepe formation that consists of conglomerate, with varigated color, sandstones and marl interbeds. The name «Yastıktepe» was first used by Akkuş (1965). The upper portion of the Yastıktepe formation is intercalated with the volcanoclastic rocks. Fossils of Upper Miocene are found in the Yastıktepe formation. Yastıktepe deposits were thought to be accumulated in lagoonal environment, following the regression of the Lower Miocene sea.

Pliocene in the area is characterized by the Çullu formation that conformably lies on the Yastıktepe formation. The Çullu formation consists of interbedded agglomerate, tuff and limestones. The limestones show the characteristics of the lake deposits. At some localities, Quaternary rocks of alluvium and basalt lavas are present.

In the area, general regression probably occured in Middle Miocene because the shallow marine sediments of the Lower Mescitli pass upward into shallower lagoonal sediments. The Lower Miocene Haneşdüzü formation is present in basins on the north and south. This indicates that the basin boundary was not definite in the Lower Miocene; on the other hand, the formation of Upper Miocene-Pliocene strata in the Karayazı-Tekman basin, but not in the adjacent basins indicates that the Karayazı-Tekman basin was present in the Upper Miocene.

Hınıs area

The area of Hınıs, which is located in the north of the Muş basin, is bounded in the west by Bingöl volcano, in the north by Akdağ metamorphics, in the south by Hamurpet uplift (Fig. 2). Within these boundaries, the Hınıs is a seperate basin and directly opens up into the Zırnak basin in the east. In the Hınıs basin, the stratigraphic relations between neotectonic strata and underlying paleotectonic strata are well seen. This basin has a seperate importance in terms of establishing the relations between the Muş basin in the south and the Karayazı-Tekman basin to the further north.

Neotectonic episode deposits of the Hınıs basin disconformably overlie the Lower Miocene marine carbonates of Güzelbaba limestone (Fig. 7). The Güzelbaba limestone gradually passes downward into Oligocene Aktuzla marls. On the south part of the Hınıs basin, the exposures of the Güzelbaba limestone are at the near Niftlik area around the Hamurpet uplift and Divanhüseyin village along the Hınıs-Varto state road.

The first deposits «Alibonca formation» of the neotectonic episode consist mainly of conglomerate, sandstone, tuff and mudstone. These deposits with marine character also include basalts and trachytic lavas. The gravels in the conglomerates have fossils of the Lower Miocene, thus the Alibonca formation should be Upper Miocene in age.

The Alibonca formation is unconformably overlain by the Pliocene Zırnak formation. Up in the section, the Zırnak formation is covered by unconsolidated Quaternary deposits. The Zırnak formation with various lithology mainly consists of marl, limestone, tuff, tuffite, basalt and andesite lavas. These basalts and andesites are thought to be products of Bingöl and Golibaba volcanoes.

Zırnak area

The Zırnak area is not a seperate from the Hınıs basin. But, because of the very widespread extention of the Hınıs basin to the east, both the area and the stratigraphy of the Zırnak will be considered seperately, Such a way of introduction will perhaps help better understanding the lateral changes in the stratigraphic units. The Zırnak basin is bounded in the north by Akdağ, in the east by Cemalverdi mountain, in the south by Bilican mountain (Fig. 2). The type section of the Zırnak formation, with the characteristic, fossils, is in this area.

In the Zırnak area, Aquitanian Aktuzla formation at the base gradually pass upward into the Burdigalian Güzelbaba limestones with marine character. There are andesites on the Güzelbaba limestones exposed at the outcrops in the northeast and southwest Zırnak basin (Fig. 8).

The Güzelbaba formation is unconformably overlain by the Upper Miocene Alibonca formation. The Alibonca formation consists of alternated beds of clayey limestones, conglomerate, mudstone and basalts. The name «Alibonca» was first used by İlker (1966a) in this area. There is no fossil in these nonmarine strata. Inferred age for the Alibonca is probably the Upper Miocene.

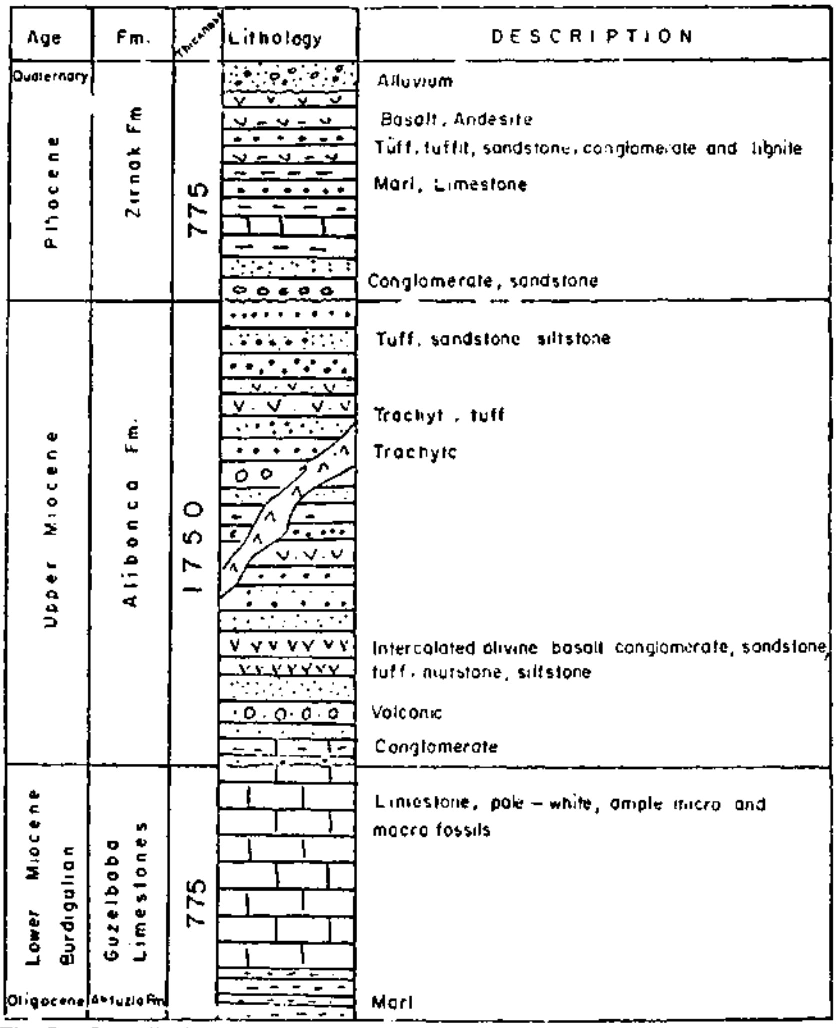

Fig. 7 - Generalized stratigraphic section of the Hınıs area (collected from Tütüncü, 1967; Özcan, 1967; Erdoğan, 1967 and Sungurlu, 1967).

As seen in the other areas, the Zırnak formation starts at the lower portion with the same lithology of sandstone, conglomerate and clayey limestone, and continue upward with sandstones and clayey limestones with coal layers. The very upper portion of the Zırnak formation is dominated by conglomerate, limestone and travertine-like limestones. The name «Zırnak» was also first used by İlker (1966a) for such deposits whose type section is around the Zırnak village. The limestones in the Zırnak formation are in lake facies and include the characteristic fossils of Pliocene (Dacian). The Pleistocene Karaali formation, which consist of conglomerate and sandstone, was also first named by İlker (1966a) in this area.

Erzurum-Pasinler-Horasan area

In the Eastern Anatolia, the Erzurum-Pasinler-Horasan basin is the northeastern basin where the deposits of the neotectonic episode are present. Nearly the east-west extending basin of the Erzurum-Pasinler-Horasan is bounded in the north by Kargapazarı mountains. Today, Erzurum, Pasinler

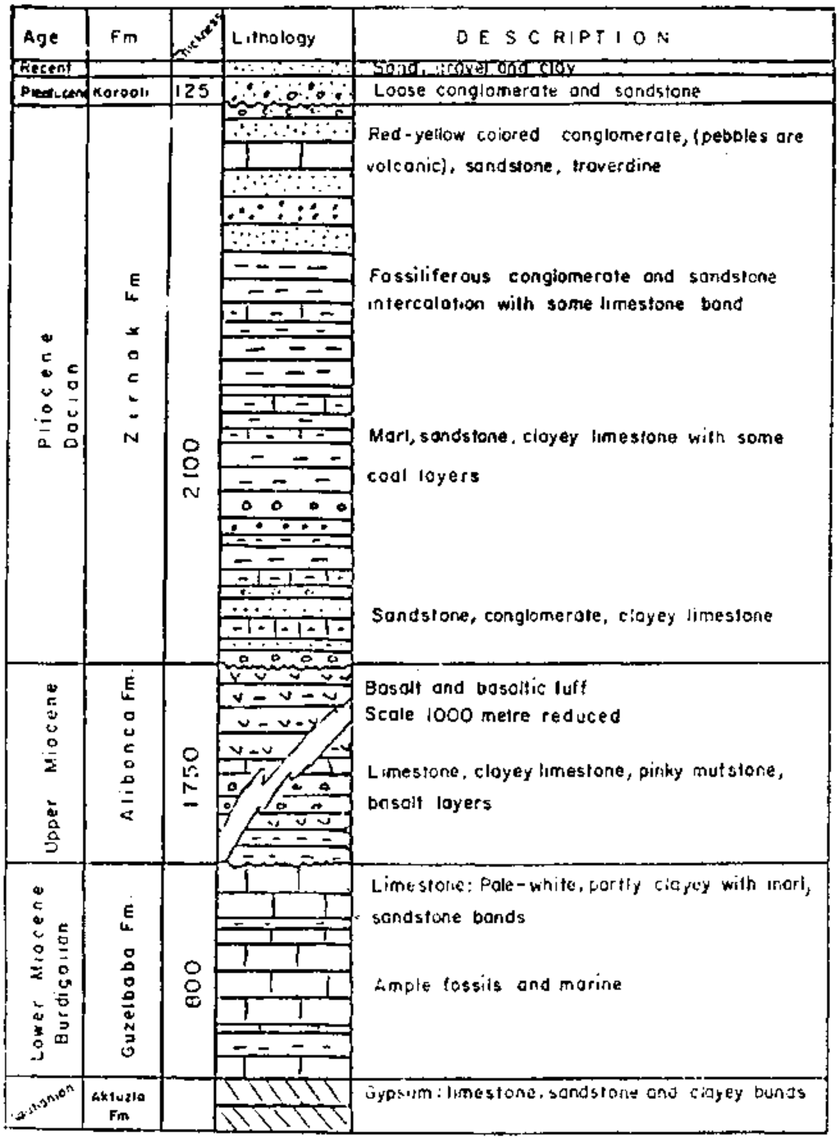

Fig. 8 - Generalized stratigraphic section of the Zırnak area (collected from Birgili, 1968; Şenalp, 1966 and İlker, 1966*a*).

and Horasan are seperate basins, however, there are strong evidences that they were interconnected at the beginning of neotectonic episode. As a result of effective neotectonic deformation and neovolcanism, these basins were become seperated. Because they have a similar neotectonic evolution, here these three basins are analized together (Fig. 2).

The stratigraphic sequence in this area is as in following (Fig. 9); Oligocene Çığılgan formation at the base is unconformably overlain by marine limestones of the Haneşdüzü formation that gradually passes upwards into the Mescitli formation. The Mescitli formation was subdivided into two members of marl and agglomerate. The Mescitli formation is Middle Miocene in age and is unconformably overlain by nonmarine deposits of Upper Miocene Yastıktepe formation. Pliocene in this area is characterized by Horasan formation that unconformably lies on the underlying units. The Horasan formation consists mainly of repetafive beds of sandstone, conglomerate, clayey mudstone and marls. The name «Horasan» was first used by Rathur (1966). Time stratigraphic equivalent of the Horasan formation in the area is the Gelinkaya formation. The Gelinkaya consists of tuff, tuffite, basalt lavas and interbeds of lime to clayey rocks. The youngest strata in the area is the Plio-Quaternary Karatepe volcanites characterized by basalt lavas.

As inferred from the overall stratigraphy in the area, the present sea probably regressed in the Middle Miocene. The present nonmarine deposits of the Upper Miocene are related to the neotectonic episode but Pliocene deposits are not because the Pliocene deposits are different from those in other basins, therefore they are unique to the Erzurum-Pasinler-Horasan basin. This indicates

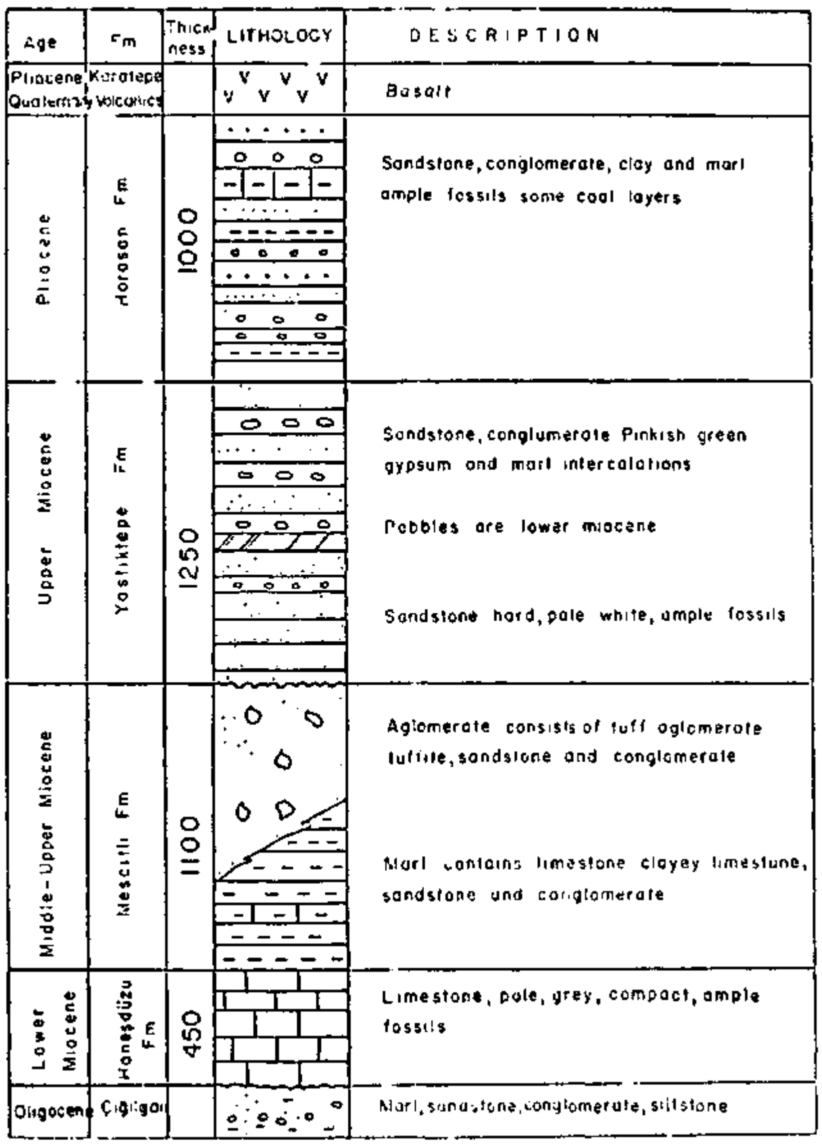

Fig. 9 - Generalized stratigraphic section of the Erzurum-Pasinler-Horasan area (Akkuş, 1965; Toker, 1965; Rathur, 1966 and Tütüncü, 1966).

that the marginal area of the basin was probably uplifted thus the connection between the Erzurum-Pasinler-Horasan and other basins were cut. Upwards in the section, sediments alternated with lavas do not have widespread areal distribution. This probably indicates that the basin was more effected by the compressional stress that resulted in subsequent narrowing of the basin.

Kağızman-Tuzluca area

The Kağızman-Tuzluca basin with approximate east-west extend is in the northeastern part of the Eastern Anatolia. It lies between Kars plateau in the north, Tendürek and Ağrı mountains in the south (Fig. 2). This basin is characterized by very thick Pliocene strata. Absence of the Lower Miocene marine deposits is important because that assist to identify the paleogeographic boundaries at the beginning ofthe neotectonic episode. The Kağızman-Tuzluca basin has also another importance because it is a pull-apart type of basin that began to evolve in the neotectonic episode and is still effected by the active strike-slip faults.

The youngest strata of the paleotectonic episode in this basin is Eocene in age and consist of conglomerate, sandstone, marl, siltstone, and limestone. The deposits of neotectonic episode are in Pliocene in age and comprise at the lower portion repetative beds ofsalt, gypsum and mudstone, and in the upper portion conglomerate and sandstone.

The Pliocene Tuzluca formation was first named by Şenalp (1969). Şenalp (1969) suggested that some beds in the Tuzluca formation can be assigned to shallow marine or lake deposits. The Tuzluca formation in this basin is overlain by unnamed Pliocene volcanites of mainly tuff, tuffite and basalts. As seen from overall sequence of Eocene-Pliocene, this area has stayed as a land on which no sediment was deposited. During the Lower Miocene the northern boundary ofpresent peneplaine did not reach to the Kağızman-Tuzluca area. In the Pliocene, abundant volcanoes were present and divided the basin into its components. At the very beginning of the Pliocene, Gürbulak and Kağızman-Tuzluca basin were together but they were become seperated by volcanoes such as those above (Fig. 10).

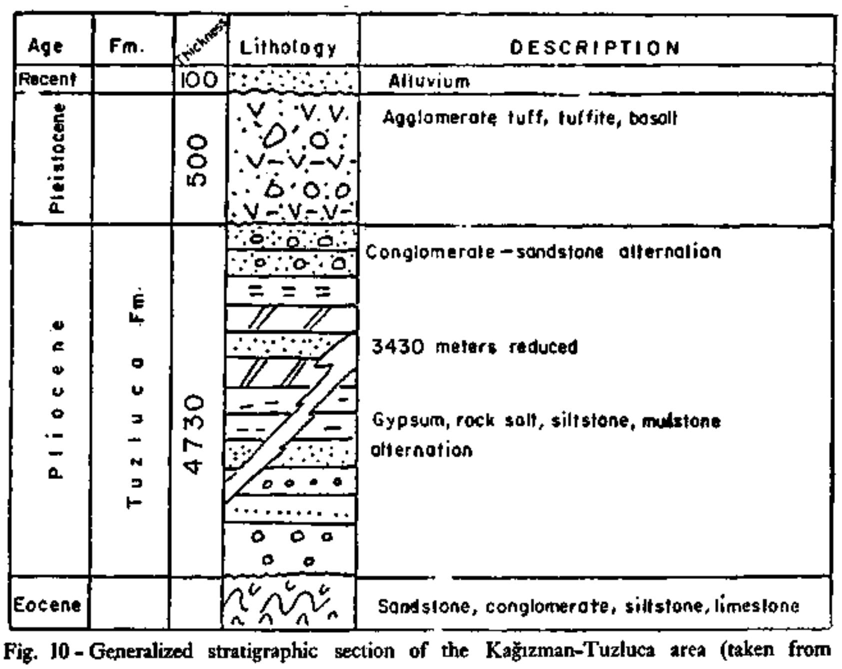

Fig. 10 - Generalized stratigraphic section of the Kağızman-Tuzluca area (taken from Havur, 1968; Şenalp, 1969 and Yurdakul, 1971).

GENERAL FEATURES OF REGIONAL STRATIGRAPHY

On the basis of stratigraphy in different areas or basins, the general stratigraphic features of the Eastern Anatolia will be introduced below. In this chapter, in order f6r the better understanding of neotectonic stratigraphy, the top unit of paleotectonic episode will be described first

Lower and Middle Miocene

In the Eastern Anatolia, the deposits of the latest paleotectonic episode are the Lower Miocene in age, and show the characteristics of the marine strata in the region. They generally bear features of a reef environment and have characteristic fossils for Burdigalian. The sedimentation is continuous from Oligocene up to Aquitanian. But in many areas, the Lower Miocene strata unconformably sit on the underlying units. The main lithology types for the Lower Miocene strata are generally the limestones and the clayey limestones. Towards the northern Anatolia, elastics associated with the limestones are also present and from place to place elastics are predominant. In such places, interbeds of evaporites are also seen. The Lower Miocene sea regressed from the region towards the end of the Lower Miocene.

In the Eastern Anatolia, Middle Miocene strata are found in restricted areas. They are in marine facies and show the characteristics of a regressive sequence. Regression beginning towards the end of the Lower Miocene finally led to the deposition of lagoon sediments. The Middle Miocene strata consist mainly of clayey limestone, marl, sandstone and siltstone. Fossils are rare in the Middle Miocene deposits, thus characteristic fossils are not found. The Middle Miocene has a pradual contact with the underlying Lower Miocene.

Despite the Lower-Middle Miocene strata is well laced with marine facies, their nonmarine equivalents are not found yet. The evaporite-bearing nonmarine type of deposits are present in northern part of the region (these deposits are shown as Oligocene on the geologic map of the Kars section with scale of 1:500 000). Some parts of these deposits are considered as Miocene strata, and if so, they correspond to the Miocene marine deposits. There are also coavel volcanites associated the Lower-Middle Miocene deposits. They mainly consist of lavas and pyroclastic rocks. Within these volcanites, basalt, trachyte, andesite and pyroclastic rocks are predominant. They should be the Lower Miocene in age because in localities between Patnos and Tutak, these volcanites are interstratified with the Lower Miocene limestones. This is true because on the south of Taşlıçay town of Ağrı, and on the north of Aladağ, from place to place these volcanites underlie the Lower Miocene limestones. In also some places they cook the very bottom portion of limestones and causes them to alter. They are mostly overlain by Middle Miocene deposits; thus reexistance of these volcanites has probably continued until the end of the Lower Miocene. The Lower Miocene volcanites cannot be distinguished across the region, thus their detailed analysis have not been done yet. However, under the light of regional tectonic, these volcanites are assigned to the island-arc type of volcanites in origin (Şengör and Yılmaz, 1981). The morphological features of the Lower Miocene volcanites are eroded, therefore no relict morphologic features are well seen. The trends of the faults are not parallel to the general trend of the volcanoes, instead they cut across the volcanoes. Such evidences show theexistance of volcanoes before the neotectonic activities.

Upper Miocene

In the Eastern Anatolia, the Upper Miocene strata begins with sandstone, siltstone and conglomerate, and upward continues with clayey limestone, tuff, agglomerate and volcanic lavas. The Upper

Miocene rocks unconformably sit on the underlying strata. The followings are the evidences that show the presence of such an unconformity: (a) the presence of the basal conglomerate at the very base of the Upper Miocene, (b) an angularity between the conglomerate beds and the underlying Lower-Middle Miocene strata, eventhough it is not very discernable, and (c) the presence of the Lower Miocene fossils in the gravels of these conglomerate, (d) without Lower-Middle Miocene in the most localities, the Upper Miocene directly sits on the older strata. However in some places, the Upper Miocene conformably overlie the Lower Miocene strata. But the Middle Miocene is not determinate in between. Therefore, there should be an hiatus between the Upper Miocene strata and those of the underlying units. The Lower Miocene strata shows the characteristics of the marine facies whereas the Upper Miocene units are in nonmarine facies. In addition, the Upper Miocene volcanites are different from those of underlying units.

Fossils in the Upper Miocene are rare, and none is characteristic for age determination; the present ones are lamellibranch, gastropoda and plant fragments. The age of the Upper Miocene is not definite, thus stratigraphically inferred.

Pliocene

In the Eastern Anatolia, Pliocene strata consist mainly of sandstone, siltstone, marl, conglomerate, tuff, tuffite, agglomerate and lake limestones. The limestone beds contain very fossilliferous levels; some beds contain large amount of shells thus the term «coccina» may be appropriate for such limestones. Fossils collected from these limestones are characteristic for Pliocene (Dacian). There are some economically important coal layers interbedded with the Pliocene deposits. The age of Pliocene was also supported by determined spors in the samples from these coals. The present volcanic rocks in the Pliocene are the basalts, andesites or trachy-andesites. They unconformably lie on the underlying units.

Pleistocene

Pleistocene in the Eastern Anatolia is characterized by nonmarine deposits with mostly lake or fluvial in character. Along with the unconsolidated clay, sand and gravels, well indurated sandstone, gravelstone and siltstone are the main deposits. Eventhough some fossiliferous levels are present, there is no characteristic fossil present in the Pleistocene rocks. The configuration of the Pleistocene rocks reflects the drainage pattern of ancient lake and streams. The Pleistocene strata contain the gravels of older rocks and unconformably overlie them. Depending up on the type of extrusive materials scattered around the volcanoes. The Pleistocene strata can contain tuff, tuffite, agglomerate, basalt, andesite and rhyolite lavas. In addition, Ağrı, Tendürek, Süphan and Nemrut volcanoes showed activities in the past and acted as a seperate source for the Pleistocene rocks. In places where there was not any fossils, age determination was made with respect to stratigraphic position of the strata in the section.

The Anzar formation was attributed to the Pleistocene in the Muş basin where the Pleistocene rocks give one of the best exposures. The Anzar is about 300 m thick in the Muş basin. In the Hınıs-Zırnak area, however, the Karaali formation forms the Pleistocene strata, and is in the order of 125 m thick. In the localities around the Doğubayazıt-Kars area, unnamed Pleistocene is 500 m thick. In the Tutak-Patnos area and around Van lake, Pleistocene show the characteristic of the lake deposits. 200 m thick Pleistocene deposits in the Tutak-Patnos basin was earlier attributed to the Lower Quaternary.

Holocene

Holocene strata mainly covers modern stream and lake deposits. Minor amount of landslides, glacier deposits and morens are also present in the Holocene strata. From place to place the modern deposits generally has gradual contact with the Pleistocene deposits. At some outcrops, the Holocene deposits are not even be distinguished from the Pleistocene deposits. At such localities, flood plain are assumed to be the boundary between the Holocene and Pleistocene deposits.

THE RELATIONS BETWEEN STRUCTURAL ELEMENTS AND THE BASINS FORMED IN THE NEOTECTONIC EPISODE

In the Eastern Anatolia, folds, reverse faults, large-scale extentional fractures, right and left lateral strike-slip faults are formed in the neotectonic episode (Fig. 11). As in Figure 11, in places where strike-slip faults step up in en echelon character, there are some volcanoes existed as a result of the effective tectonism. The major structural features on the neotectonic map of the Eastern Anatolia are the east-west extending folds, reverse faults, north-south striking extentional fractures, left (northeast-southwest striking) and right lateral strike-slip (northwest-southeast striking) faults (Fig. 12). In the region, pull-apart type of basins are formed between strike-slip faults. Another different type of basins in the Eastern Anatolia are the intermountain basins which generally extend east-west and correspond to the synclines (Fig. 13). Such basins can be bounded on one side by a trust fault. Along with these two major type of basins, there are also basin-like localities between compressional features or along the extentional fractures. But these are relatively small in scale. Thus the basin types in the Eastern Anatolia can be summarized as two types; (a) pull-apart, and (b) intermountain.

As we glanced over the volcanism during the neotectonic episode (Fig. 14), there is a number of volcanoes existed in different time. The existence of these volcanoes is related to the structural elements of the Eastern Anatolia. The nature of the volcanism, however, has changed with time as continental crust has been evolved by the persistent tectonic effect (Yılmaz et al., 1986).

GEOLOGICAL EVOLUTION OF NEOTECTONIC EPISODE

The stratigraphy in each basin, stratigraphic correlation between the basins (Figs. 3,4,5, 7,8,9), present volcanic activities and major structural elements are considered together and combined to analize the geologic evolution of the Eastern Anatolian region.

Towards the end of the Lower Miocene the Eastern Anatolia had a peneplain-like paleomorphologic feature. This peneplain was lying between Bitlis mountain on the south and Tuzluca-Kağızman-Tortum line on the north (Fig. 2). The east and west boundaries of this peneplain were outside of the region. Over the Middle Miocene, the region was compressed under the influence of north-south directed tectonism. This led to the flactuation of the peneplain, subsequent formation of the folds and fractures. Thus the peneplain, covering very large area, was turned into high mountainous area. As a result of this uplifting, the, present sea began to regress from the region. The

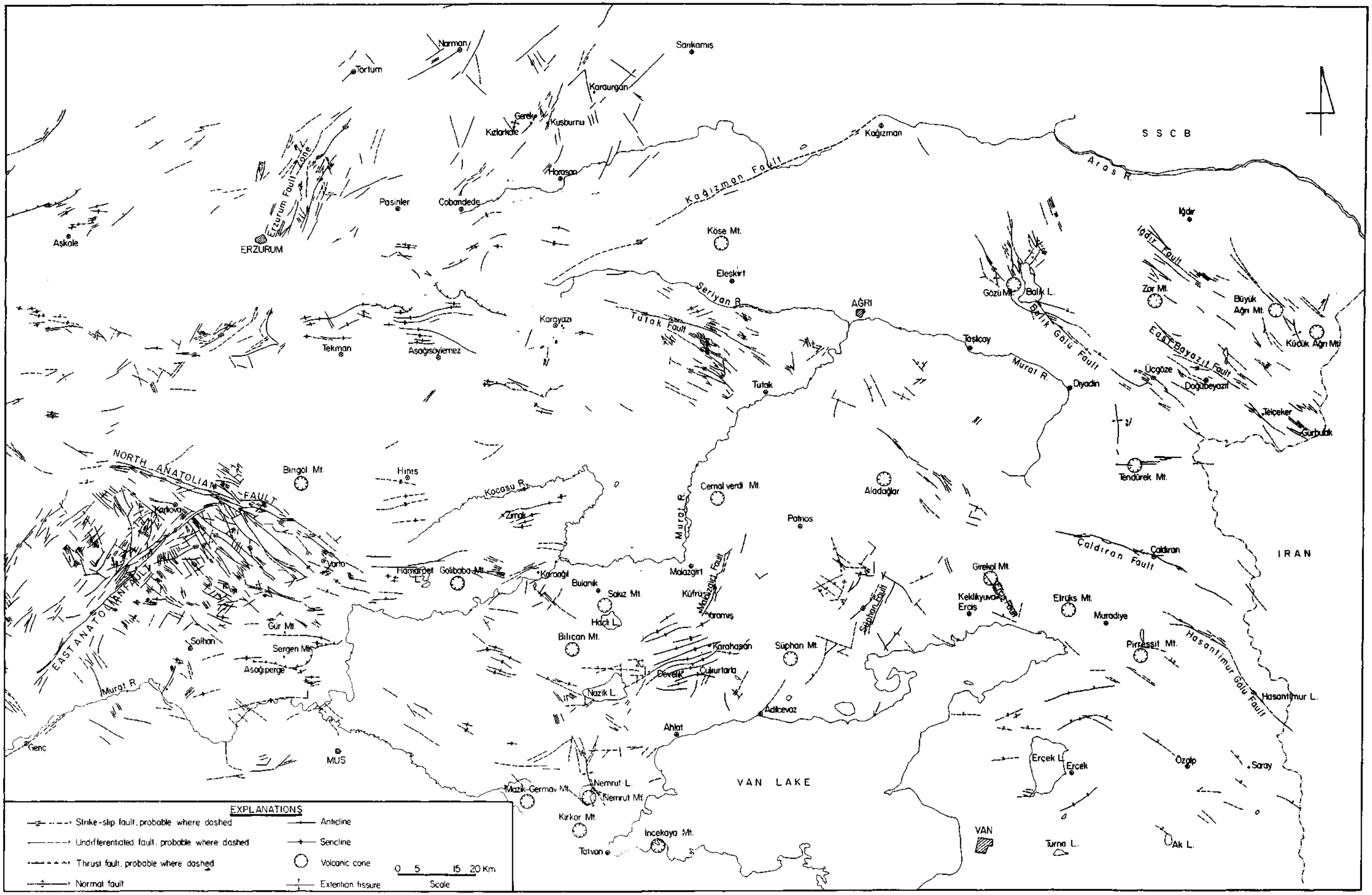

Fig. 11 - Neotectonic map of the Eastern Anatolia.

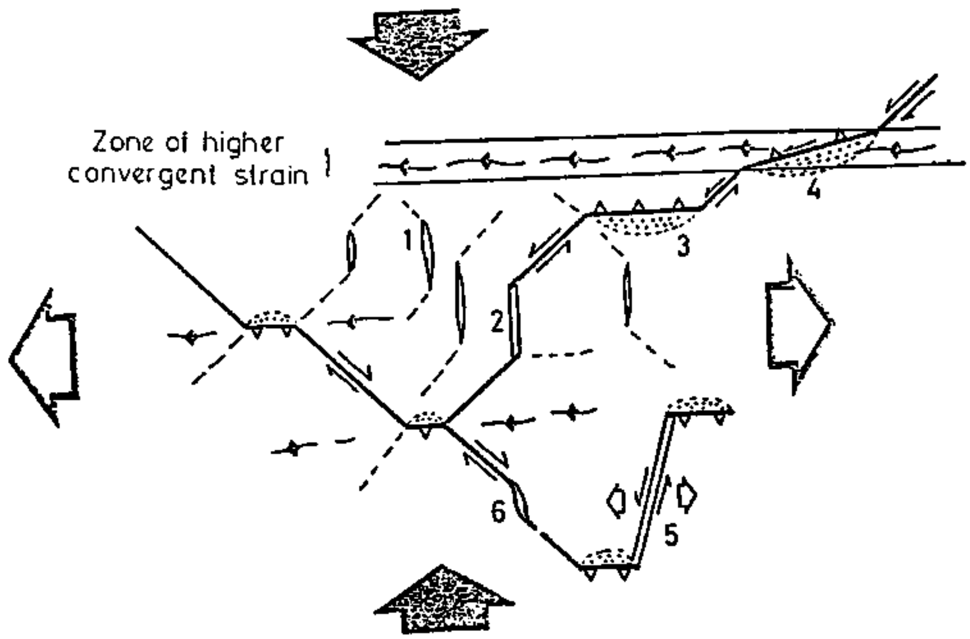

Fig. 12 - Schematized diagram showing the deformational features along the narrowing area in the Eastern Anatolia. Numbers show the basin types evolved in the region. 1-Extentional fracture; 2 and 6-Intermountain basin; 4 and 5-Other basins formed under the control of more than 1 structural effect (Şengör et al., 1985).

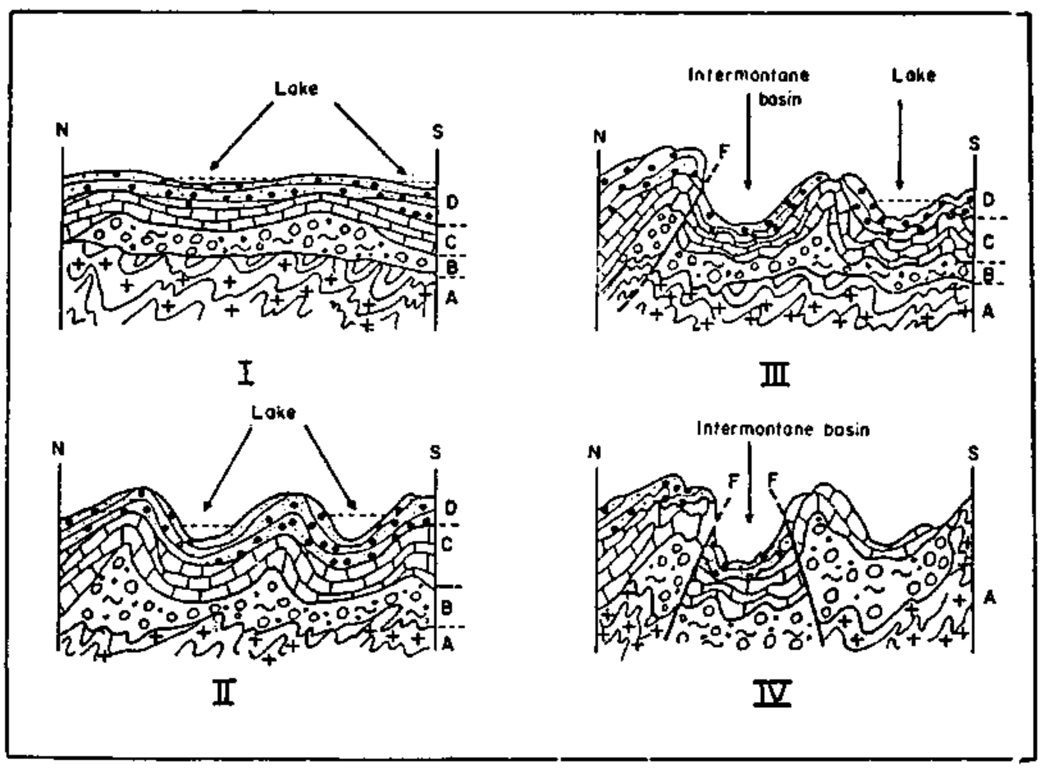

Fig. 13 - Schematized cross section showing the evolution of the intermountain basin in the Eastern Anatolia.

elongated ridges, that formed as response to the uplifting, led to the basins to form in between. The Develi formation in the Ahlat-Adilcevaz, Yastıktepe formation in the Erzurum-Pasinler-Horasan and Mescitli formation in the Karayazı-Söylemez basin are the stratigraphic units deposited right after the formation of the basins. In the Upper Miocene, the present sea completely regressed from the region. As parallel to the regression, the volcanoes started errupting through the extentional fractures. The lakes and streams were also existed at this time. The Solhan volcanites on the south, the Alibonca formation in the Hınıs-Zırnak area, Yastıktepe formation between the Erzurum-Pasinler-Horasan-Tekman-Karayazı are the products of the Upper Miocene and include intercalated materials. The Akdağ and the Sakaltutan mountain ridges played as dividing highs between described basins. New morphologic features, formed at the end of the Upper Miocene, led to the existence of lakes covering very large area in the region. The lake deposits have volcanoclastic materials derived from the Aladağ, the Bingöl and the Pirreşit volcanoes. The lake on the south dies among Bitlis mountain, Akdağ, Ahlat-Erciş and Bingöl-Karlıova. The Zırnak formation in this lake, the Çullu formation between the Akdağ-Sakaltutan mountains on the further north, the Horasan formation between Sakaltutan and Kargapazarı mountains, the Çukurtarla limestone in the Ahlat-Adilcevaz area were deposited. As a result of the compression and the subsequent folding, the continental crust were thickened. This led to the formation of strike-slip faults. As response to this type of faulting, in the northeast part of the region (area surrounded by Tuzluca-Kağızman-Iğdır-Doğubayazıt-Gürbulak) a new basin was formed under the control of obliquely displaced fault blocks. The Tuzluca formation was deposited in this basin. At the same time, Etrüsk, Bilican, Cemalverdi, Gözü, Zor, Köse and Sakız mountain volcanoes were existed. Thus by these volcanoes, present large basins were divided into smaller ones; while Bilican and Sakız together divided Muş-Varto area from the Ahlat-Adilcevaz; Cemalverdi mountain seperated the Patnos-Tutak basin from Malazgirt in the north. First Gözü, later Zor mountains divided Kağızman-Tuzluca from Doğubayazıt-Gürbulak and Iğdır basins. Persisting tectonic regime led to the narrowing of previously compressed basins. Tectonic regime also caused the present ridges to gain more relief. Such an uplifting was associated with the volcanic activities that resulted in more subdivision of mentioning basins. Towards the Middle Pliocene, strike-slip faults are become important structural elements of the region. On the west, Northern and Eastern Anatolian faults were merged. As a result of that, Karlıova and on its further south Bingöl plains were existed. On the north, however, in the Kars area where strike-slip faults come to a proximal position, intensive volcanism caused the formation of Kars plateau. Nearly at the same time, Hamurpet and Şerafettin mountains were existed and gave way to the formation of the new basins in between. Muş-Van basin was shaped up in the Upper Pliocene. Towards the beginning of Quaternary Ağrı, Süphan, Nemrut, Tendürek volcanoes were existed and helped the basins to gain today's configuration. At the beginning of the Quaternary, the Anzar formation in Muş basin, Boran formation in Karlıova, the Karaali formation in the Zırnak area and other unnamed units were deposited. As proved via earthquakes, today's morphologic features have still been altered to a great extent.

As the basins are analized under the light of the major structural elements in the Eastern Anatolia, they may be classified as follows: The Muş-Ahlat-Adilcevaz and the Karayazı-Tekman basins appear to be intermountain type. The Tuzluca-Kağızman-Iğdır-Doğubayazıt-Gürbulak basin, which was first divided by Gözü, second by Zor and third by Ağrı mountain, can be considered as the pullapart types. The Erzurum-Pasinler-Horasan basin is an intermountain basin that was formed under the supplementary influence of the left lateral strike-slip faults. The Karlıova-Bingöl basin was formed under the control of both left lateral (Eastern Anatolia) and right lateral (Northern Anatolia) strikeslip faults. In fact, the Hınıs and the Zırnak area, each of which is a seperate basin but together, it is a wide basin formed under the control of several structural elements.

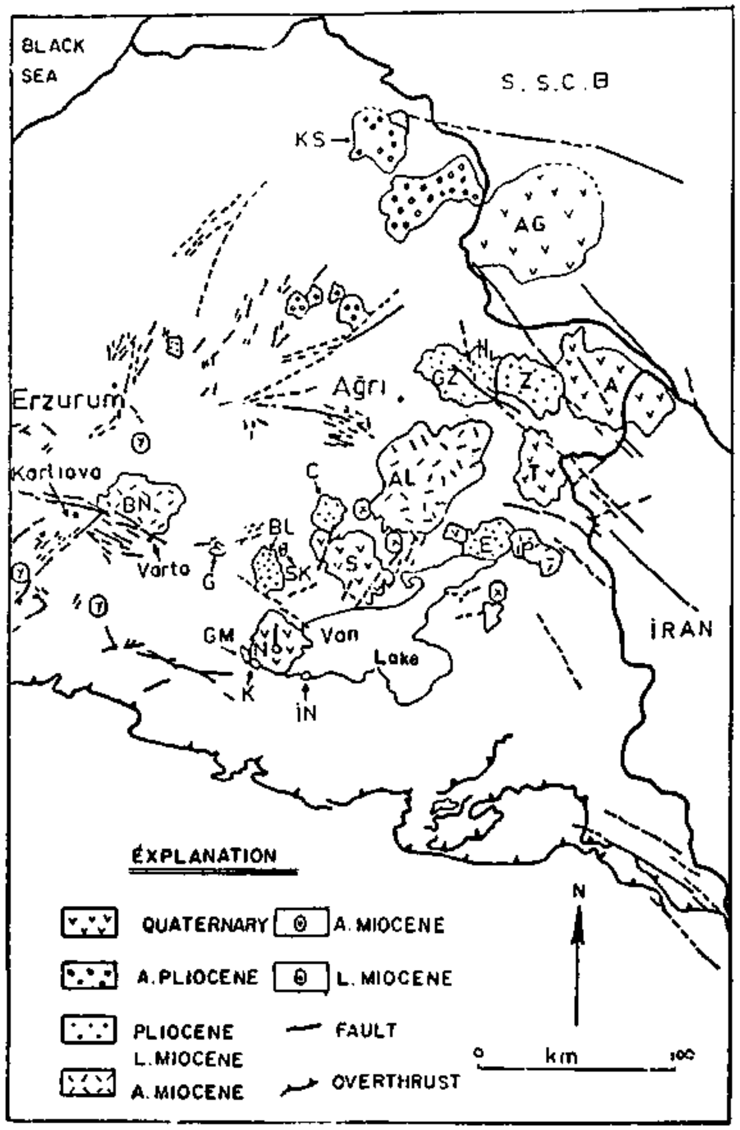

Fig. 14 – Existed volcanoes during the neotectonic episode in the Eastern Anatolia. AG- Alagöz mountain; KS- Kısır mountain; BN- Bingöl mountain; T- Tendürek mountain; A- Ağrı mountain; AL- Alagöz mountain; İN- İncekaya mountain; C- Cemalverdi mountain; P- Pirreşit mountain; E- Etrüsk mountain; S- Süphan mountain; SK- Sakız mountain; BL- Bilican mountain; G- Golibaba mountain; GZ- Gözü mountain; GR- Germav mountain.

This study covers very large area in the Eastern Anatolian region. In a gross sense, an attempt was made to define the position, type and evolution of the basins. In this respect first opinions and approaches that were made up to this point can be a guide for detailed works will probably be made in the future.

THE RELATIONS BETWEEN THE GEOLOGIC EVOLUTION AND THE PETROLEUM POTENTIAL OF THE REGION IN NEOTECTONIC EPISODE

In the Eastern Anatolia, at some localities some oil seepages have been known to us. Such oil seepages are the main reason for many workers to initiate investigations in the region. In preceding chapters, most unpublished reports and cite references are about these works made in the Eastern Anatolia. There are some wells drilled to test the determined structural trapsin the region. Well site reports are not present, thus it is obvious that there is no opportunity for us to make a detail evaluation about the reached results. However we know that in all these drilling projects, the deposits of the paleotectonic episode, especially the Lower Miocene limestones were the main target but the deposits of neotectonic episode were not considered to have potential for oil production. In nowadays, petroleum potential of the Eastern Anatolia has been discussed to a great extent. Some tectonic results derived from this study will be presented below so that we think they may help better understanding the problems of the petroleum-related studies. In some places of the Eastern Anatolia there are five thousand meter thick neotectonic deposits. This fairly thick sediment is due to effective tectonism and volcanism. It is known that during the neotectonic episode, the thermal conductivity was very high in the continental crust (Dewey et al., 1986). This value should be higher around the mouth of the volcano. Also the lavas are both thermally conductive and has a potential to be cap rock. Within the Pliocene rocks some intervals are rich in fossils. Some petroleum seepages are from the deposits of the neotectonic episode or related to them. Within the Pliocene strata, there are some layers of bituminous shale. These direct or indirect evidences show that the deposits of the neotectonic episode in the Eastern Anatolia have a tendency to generate the petroleum. If this idea was correct, the basins developed during neotectonic episode should be taken into account in terms of having a potential for petroleum.

RESULTS

1. The youngest deposits of the paleotectonic episode in the Eastern Anatolia are the Lower Miocene in age. The shallow marine limestones characteristic for the Lower Miocene are widespread in the entire Eastern Anatolia.

2. The neotectonic episode in the Eastern Anatolia began in the Middle Miocene.

3. Middle Miocene is characterized at the lower portion by marine, towards the top by nonmarine deposits. The regressive sequence of the Middle Miocene is related to the compressional tectonic, thus the uplifting of the region.

4. The deposits of the neotectonic episode are continuous from the Lower Miocene to present. They show the characteristic of the nonmarine facies and are formed in intensive tectonic regime associated with volcanism. Local unconformities, lateral gradations and hiatus are usual.

5. In the Eastern Anatolia the peneplain, formed at the beginning of neotectonic episode, is bounded on the south by Bitlis mountain, on the north by Tuzluca-Kağızman-Karaurgan-Tortum. Eastern and western boundaries of the peneplain are the outside of the region.

6. Among the basins formed in neotectonic episode, Muş Ahlat-Adilcevaz and the Karayazı-Tekman basins are intermountain in type; whereas, Kağızman-Tuzluca, Doğubayazıt-Gürbulak and Iğdır basins are pull-apart type. Erzurum-Pasinler-Horasan basin is another type intermountain basin that was also effected by strike-slip faults. Hınıs and Zırnak basins have been stayed under the control of various structural elements. The Karlıova-Bingöl basin, however, was opened under the effect of the strike-slip faults.

ACKNOWLEDGEMENTS

The study was carried out under the project of «Turkey Neotectonic and active fault mapping» conducted by the General Directorate of Mineral Research and Exploration Institute. We thank Directorate of Mineral Research and Exploration for giving us this opportunity to study. We also thank to O. Sungurlu, Y. Güner and A.M.C. Şengör for their appreciable advise and comments.

Manuscript received May 7, 1986

REFERENCES

Akkuş, M.F., 1965, Pasinler havzasının 1:25 000 ölçekli detay petrol etüdü raporu: MTA Rep., 4087 (unpublished), Ankara-Turkey.

Allen, C.R., 1969, Active faulting in northern Turkey: Contr. 1577, Div. Geol. Sciences, Calif., Inst. Tech., 32 pp.

Arpat, E. and Şaroğlu, F., 1972, Doğu Anadolu Fayı ile ilgili bazı gözlemler ve düşünceler: MTA Bull., 78, 44-50, Ankara-Turkey.

Birgili, Ş., 1968, Muş bölgesi 1:25 000 ölçekli Karaköse J48-d3-d4 ve Muş K47 b2 paftalarının detay petrol etüdü hakkında rapor: MTA Rep., 1707 (unpublished), Ankara-Turkey.

Boray, A., 1975, Bitlis dolayının yapısı ve metamorfizması: TJK Bull., 18/1, 81-84.

Çağlayan, M.A.; İnal, R.N.; Şengün, M. and Yurtsever, A., 1983, Structural setting of Bitlis Massif; International symposium, edt., Tekeli and Göncüoğlu, Geology of the Taurus belt, 245-254.

Demirtaşlı, E. and Pisoni, C., 1965, Ahlat-Adilcevaz bölgesinin jeolojisi (Van Gölü kuzeyi): MTA Bull., 64, 22-36, Ankara-Turkey.

Dewey, J.S.; Hempton, W.R.; Kidd, W.S.; Şaroğlu, F. and Şengör, A.M.C., 1986, Shortening of continental lithosphere: the neotectonics of Eastern Anatolian-a young collision zone: Collision Tectonics, edt., Coward ve Ries, Geological Society Special Publication, 19, 3-36.

Erdoğan, T., 1966, Erzurum-Karayazı bölgesi I47-C_2, 147-C_3, I48-d_4 paftalarına ait jeolojik rapor: MTA Rep., 4193 (unpublished), Ankara-Turkey.

———, 1967, Erzurum-Hınıs bölgesi 1:25 000 ölçekli -Erzurum J47-d_1 ve J47-d_2 paftalarının detay petrol etüdü: MTA Rep., 4340 (unpublished), Ankara-Turkey.

Göncüoğlu, M.C. and Turhan, N., 1983, Geology of the, Bitlis metamorphic belt: International symposium, edt., Tekeli O. and: Göncüoğlu, C., Geology of the Taurus belt, 237-244.

Güner, Y., 1984, Nemrut yanardağının jeolojisi, jeomorfolojisi ve volkanizmasının evrimi: Jeomorfoloji Bull., 12, 23-65.

Havur, E., 1968, Kötek-Kağızman, (Kars) çevresinin 1:25 000 ölçekli detay petrol etüdü raporu: MTA Rep., 4271 (unpublished), Ankara-Turkey.

İlker, S., 1966a, Erzurum-Muş bölgesinde Karaköse J48-a_4 ve J48-d1 paftalarının 1:25 000 ölçekli detay petrol etüdü hakkında rapor: MTA Rep., 4177 (unpublished), Ankara-Turkey.

———, 1966b, Erzurum bölgesinde 147-c1, I47-C4, 147-d2 ve I47-d3 paftalarının detay petrol etüdü hakkında rapor: MTA Rep., 4236 (unpublished), Ankara-Turkey.

Ketin, İ., 1966, Anadolu'nun tektonik birlikleri: MTA Bull., 66, 23-34, Ankara-Turkey

———, 1977, Van gölü ile İran sınırı arasındaki bölgede yapılan jeoloji gözlemlerinin sonuçları hakkında kısa bir açıklama: TJK Bull., 20/2, 79-85.

McKenzie, D.P., 1972, Active tectonics of the Mediterranean region: Geophys. J.R. Asr., Soc., 30, 109-185.

Nakoman, E., 1968, Karlıova-Halifan linyitlerinin sporo-pollinik etütleri: TJK Bull., XI/1-2, 68-90.

Özcan, A., 1967, Erzurum-Hınıs bölgesinde Erzurum J47-a3-a4 paftalarının detay petrol etüdü: MTA Rep., 4128 (unpublished), Ankara-Turkey.

Perin9ek, D., 1980, Bitlis metamorfitlerinde volkanitli Triyas: TJK Bull., 23/2, 201-211.

———and Özkaya, I., 1981, Arabistan levhası kuzey kenarı tektonik evrimi, Yerbilimleri, 8, 91-101.

Rathur, Q_., 1966, Pasinler-Horasan (Erzurum) sahasına ait genel jeolojik rapor: MTA Rep., 4168 (unpublished), Ankara-Turkey.

Seymen, İ. and Aydın, A., 1972, Bingöl deprem fayı ve bunun Kuzey Anadolu Fay Zonu ile ilişkisi: MTA Bull., 79, 1-8, Ankara-Turkey.

Sungurlu, O., 1967, Erzurum-Hınıs bölgesinde 1:25 000 ölçekli Erzurum J47-b3-b_4 paftalarına ait jeolojik detay petrol etüdü raporu: MTA Rep., 4176 (unbpulished), Ankara-Turkey.

Şaroğlu, F., 1985, Doğu Anadolu'nun neotektonik dönemde jeolojik ve yapısal evrimi: İstanbul Üniversitesi Fen Bilimleri Enstitüsü Doktora tezi (unpublished), Ankara-Turkey.

———; Güner, Y.; Kidd, W.S.F. and Şengör, A.M.C., 1980, Neotectonics of Eastern Turkey: New evidence for crustal shortening and thicening in a collision zonu: EOS, 51, 17, 360.

———and Güner, Y., 1981, Doğu Anadolu'nun jeomorfolojik gelişimine etki eden öğeler: Jeomorfoloji, tektonik, volkanizma ilişkileri: TJK Bull., 24, 39-50.

———and Yılmaz, Y., 1984, Doğu Anadolu'nun neotektoniği ve ilgili magmatizması: Ketin simpozyumu bildirileri, 149-162.

Şenalp, M., 1966, Erzurum-Muş bölgesi 1:25 000 ölçekli Erzurum J47-a_2, J47-b1 ve Karaköse J48-c1, c2, a3, c_4, J48-b3 paftalarının detay petrol etüdü: MTA Rep., 4288 (unpublished), Ankara-Turkey.

———, 1969, Tuzluca (Kars) havzasının 1:25 000 ölçekli detay petrol etüdü raporu: MTA Rep., 4084 (unpublished). Ankara-Turkey.

Şengör, A.M.C., 1979, The North Anatolian transform fault: its age, offset and tectonic significance: Jour. Geol. Soc. 136, 269-282, London.

———, 1980, Türkiye'nin neotektoniğinin esasları: TJK Pub.

———; White, G.W. and Dewey, J.F., 1979, Tectonic evolution of the Bitlis suture, southeastern Turkey: Implications for the tectonics of eastern Mediterranean: Rapp. Comm. Int. Mer Medit., 25/26-2a, 95-97.

———and Yılmaz, Y., 1981, Tethyan evolution of Turkey: A plate tectonic approach: Tectonophysics, 75, 181-241.

———; Görür, N. and Şaroğlu, F., 1985, Strike-slip faulting, and related basin formation in zones of tectonic escape: Turkey as a case study; strike-slip deformation, basin formation and sedimentation, edt, Biddle and Christie-Blick, Society of Economic Paleontologists and Mineralogists Special publication, 37, 227-264.

Tanrıverdi, K., 1971, Erzurum (Söylemez) yöresinin jeolojisi ve petrol olanakları: MTA Rep., 6239 (unpublished), Ankara-Turkey.

Toker, S., 1965, Erzurum-Hasankale bölgesi, Erzurum I46-b2, Tortum H46-c_3 paftalarına ait jeolojik rapor: MTA Rep., 4118 (unpublished), Ankara-Turkey.

Tütüncü, K., 1965, Erzurum ovası kuzey ve güneyinin genel jeolojisi ve petrol imkanları: MTA Rep., 4297 (unpublished), Ankara-Turkey.

———, 1967, 1:25 0000 ölçekli Erzurum J47-c_1, c_2, c_3, c_4 paftalarına ait genel jeoloji ve petrol imkanları: MTA Rep., 4120 (unpublished), Ankara-Turkey.

Ünal, A., 1970, Muş bölgesi 1:25 000 ölçekli Erzurum J47-c_4 Muş K47-b4-c_1-c_2 paftalarının detay petrol etüdü raporu: MTA Rep., 4754 (unpublished), Ankara-Turkey.

Ürgün, S., 1961, Muş-Nazik gölü-Murat nehri arasındaki sahanın detay jeolojisi: MTA Rep., 4730 (unpublished), Ankara-Turkey.

Yılmaz, Y., 1984, Türkiye'nin jeolojik tarihinde magmatik etkinlik ve tektonik evrimle ilişkisi: TJK Ketin simpozyumu bildirileri, 63-81.

———; Dilek, Y. and Işık, H., 1981, Gevaş (Van) ofiyolitinin jeolojisi ve sinkinematik bir makaslama zonu: TJK Bull., 24/1, 37-44.

———; Şaroğlu, F. and Güner, Y., 1986, Initiation of neomagmatism in the Eastern Anatolia (in press).

Yurdagul, M., 1971, Kağızman doğusunun (Kars H50-c_1 paftası) jeolojisi ve petrol olanakları: MTA Rep., 4828 (unpublished), Ankara-Turkey.