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EVOLUTION OF THE POST-COLLISIONAL CRATONIC BASINS IN EASTERN TAURUS

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ABSTRACT. — A number of cratonic basins developed as a result of continent—continent collision in Eastern Taurus. During this collision, some changes in the rate of continental convergence considerably affected the evolution of these cratonic basins. Following the Late Eocene collision, the Oligocene transgression started as a result of a decrease at the rate of continental convergence. The weaker effect of the convergence rate during the Middle—Late Oligocene resulted in lithospheric deformation forming some troughs and uplifts. Further decrease in the effect of the convergence rate during the Uppermost Oligocene, caused the widespread Early Miocene transgression. During Langhian, a sudden increase in the effect of the convergence rate gave rise to the uplifting of the whole region above the sea level. In Serravalian—Tortonian, continental and marine transgressions took place, due to the relatively decreasing effect of the convergence rate. However, convergence rate which was considerably effective in the Uppermost Tortonian, played an important role in the formation of Anatolia. A partial decrease in the convergence rate during the Early—Late Pliocene provided the deposition in continental basin conditions. In the Uppermost Pliocene, the convergence rate increased again and as a result of this, the tectonic lines representing the Uppermost Tortonian phase were displaced. The effect of convergence rate which was relatively low during the Early—Late Pleistocene provided restricted continental depositional conditions. Increasing effect of convergence rate from the Late Pleistocene to the present—day is responsible for the active faults. This evolutionary scheme of the post—Eocene basins proves that the collision has been continuing since Late Eocene.

INTRODUCTION

Up to the present—day, some investigations were made on the geodynamic evolution of Eastern Taurus (Baştuğ, 1980; Dewey et al., 1986; Şaroğlu et al., 1980; Şaroğlu, 1985; Şengör, 1980; Şengör and Yılmaz, 1983; Y.Yılmaz et al., 1987). Eastern Taurus is bounded by the East Anatolian Fault(EAF) in the west and the Southeastern Anatolian overthrust in the south. The interpretation of the results obtained from the detailed stratigraphic and tectonic studies of the Muş Tertiary basin (Akay et al., 1989) with the other previous investigations in. Eastern Taurus and palaeomagnetic data obtained from Taurid belt, led to the reconstruction of the post-Eocene geodynamic evolution of Eastern Taurus.

GENERAL GEOLOGICAL CHARACTERISTICS OF EASTERN TAURUS IN PRE-OLIGOCENE

In Eastern Taurus, the various units showing different stratigraphic, lithological, tectonic and metamorphic features came together in pre—Oligocene. Of these units, the Bitlis massif is made up of Palaeozoic—Mesozoic rock assemblages which underwent metamorphism in pre—Maastrichtian and an ophiolitic unit which was emplaced in the Late Cretaceous (Baştuğ, 1980; Göncüoğlu and Turhan, 1983, Çağlayan et al., 1983). On the other hand, the northern part of the massif is made up of an accretionary prism (Şengör and Yılmaz, 1983).

The Munzur mountain is made up of platform type rock assemblages which span from Triassic to Campanian and overlain by an ophiolitic melange which was emplaced in the Late Cretaceous (Özgül and Turşucu, 1983). On the other hand, the Keban platform has greenschist character and comprises rock units which were deposited in a period ranging from Permian to Upper Cretaceous (Özgül and Turşucu, 1983; Yazgan, 1983). The rock assemblages of Malatya metamorphic platform resemble to those of the Keban metamorphic platform (Yazgan, 1983).

POST-EOCENE GEODYNAMIC EVOLUTION

Before we consider the tectonic events which happened in a time interval from Oligocene to the present—day, we will briefly describe some events before and during the Eocene. Şengör (1980) claims that the Southeast Anatolian suture zone formed as a result of the continent—continent collision, during the Middle Miocene. However Michard et al. (1985) puts forwards two hypothesis concerning the region. According to the first hypothesis, in a part of Eastern Taurid belt which is baunded by the Ecemiş, fault, the continent-continent collision took place in the Uppermost Cretaceous. Afterward, until Eocene, melting of the subducting oceanic crust remnants gave rise to a volcanism. The Arabian continent plunged northwardly underneath the Anatolides in a time interval of Eocene to the Middle Miocene and as result of this, a volcanism took place. The continent—continent collision has been continuing up to the present—day. According to the second hypothesis, in Eastern Taurus, the northward dipping subduction of the oceanic crust, lasting until Eocene gave rise to a calc—alkaline volcanism. Afterwards, the volcanism which took place in a period lasting until Miocene, is caused by either melting of the remnants of the oceanic crust as a result of subduction or melting of the lithosphere as a result of deformation.

As mentioned above, the geodynamic evolution of Eastern Taurus which is questionable in the period ranging from Oligocene to the present—day was tried to be reconstructed under the light of some evidences such as the geometry of the basins in the region, time of the basin formation—closure, time of the basin, deformation, type and age of volcanism.

Uppermost Eocene-Late Oligocene depositional period

In a section of Muş Tertiary basin, where the sediments representing this period are the thickest (Akay et al., 1989), the approximately 1000 m. thick fluvial sediments of the Uppermost Eocene Ahlat formation are found at the base. The approximately 500 m. thick marine sediments of Lower Oligocene Norkavak formation overlie them conformably. These marine sedimepts are conformably overlain by the approximately 3500 m. thick Yazla formation of Middle—Upper Oligocene which was deposited below the wave base. In eastern part of the basin, the thickness of the fluvial sediments belonging to the Ahlat formation is unknown (assumed to be very thick). In this section, the 170 m. thick limestone beds of the Lower—Middle Oligocene Gerisor formation, which were deposited within the wave base, rest conformably on these fluvial sediments (Ahlat formation). These limestones are overlain by the 60 m. thick sediments of the Upper Oligocene Yazla formation, which were deposited below the wave base. The thickness of the sediments which were deposited below the wave base, considerably decreases to the east of the Muş, basin. On the other hand, a westward decrease in the thickness of the same sediments is also assumed to be considerable.

In the Hınıs basin, located to the north of the Muş, basin (A.Yılmaz et al.,1988), the unit corresponding to the Uppermost Eocene fluvial sediments of the Muş, basin is 1200 m. thick. It is transitionaly overlain by about 300 m. thick Oligocene marine sediments which are interbedded with andesite in the upper levels.

In the vicinity of Palu, the Middle—Upper Oligocene sediments, composed of detritic rocks at the bottom and carbonates at the top, overlie the basement with an angular unconformity (Sirel et al., 1975).

The Lower—Upper Oligocene carbonates which were deposited on the continental shelf show transition into the underlying Upper Eocene marine carbonates, around Elazığ (Sirel and Gündüz, 1979).

On the other hand, the Lower—Upper Oligocene marine sediments show transition into the underlying Upper Eocene marine sediments in the Kahramanmaraş Tertiary basin (Uysal et al., 1985).

Consequently, a post-collisional restricted eratonic basin which was extending from the Kahramanmaraş, basin to the Hınıs basin or further to northeast

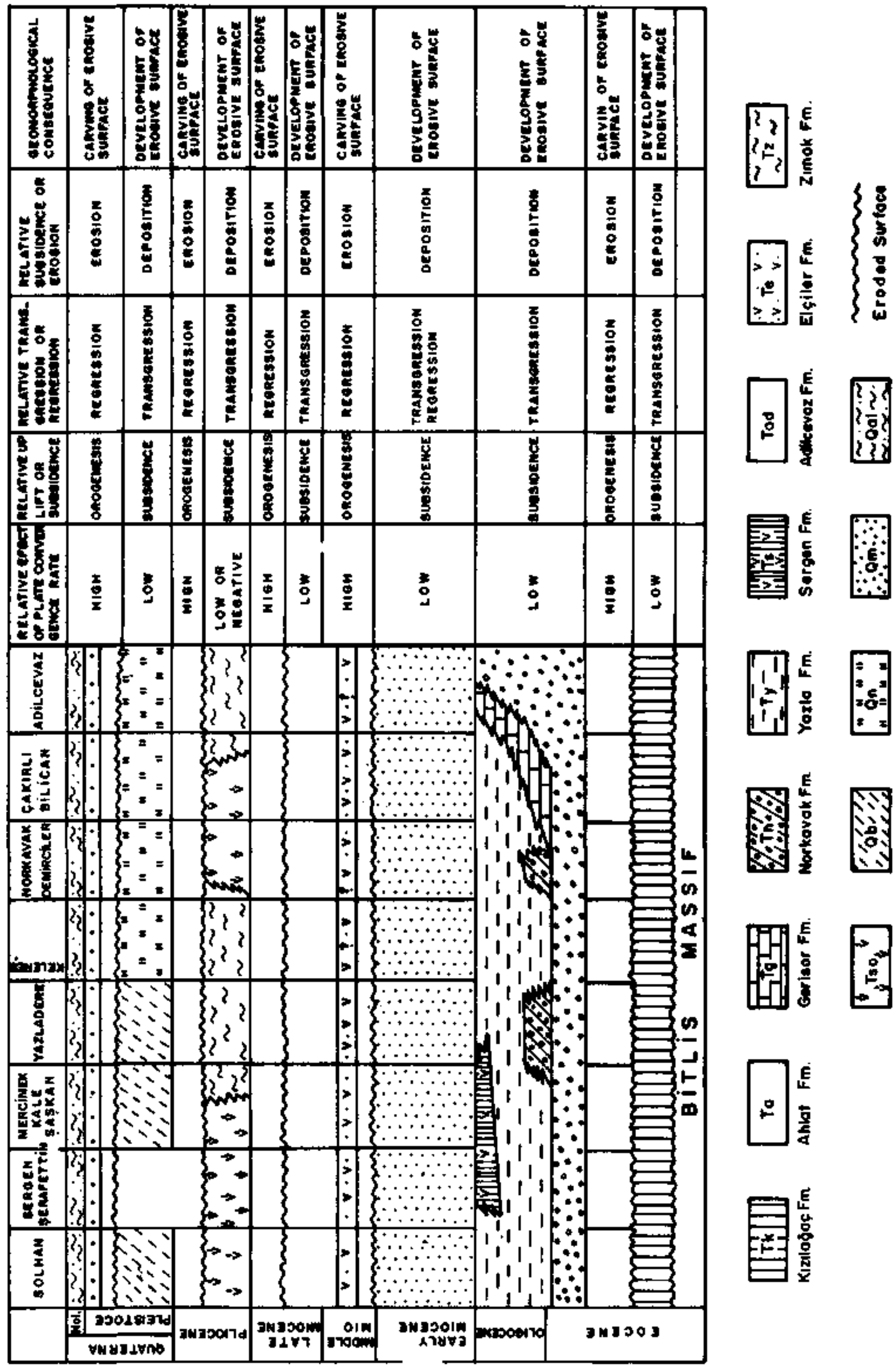

Fig.1 Table of comparative composite columnar sections of Muş Tertiary basin (Akay et al., 1989) and geodynamic events coinciding with periods at the table.

and lying more or less along the present East Anatolian Fault, had existed in the Oligocene.

In the Muş Tertiary basin (Akay et al., 1989), the marine claystone—siltstone beds of the Upper Oligocene Yazla formation show transition into the rhyolitic volcanic rocks of the Sergen formation. These beds are nonconformably overlain by the Miocene sediments (Fig-1).

Livermore and Smith (1983) further reported that the Anatolia has been undergoing continuous compression about in N—S direction during the Oligocene—Quaternary. On the other hand, according to Dercourt et al. (1986), the rate of continental convergence suddenly decreased at the boundary between Eocene and Oligocene and this decrease continued during the Oligocene. Due to the high rate of continental convergence during the Late Eocene. The Arabian and northern continents juxtaposed and as a result of this, an orogenic belt developed. Afterwards, decreasing rate of continental convergence during the period of Late Eocene to the end of Early Oligocene gave rise to deposition of fluvial sediments of the Muş—Hınıs basin and the overlying sediments which were deposited within the wave base, the fluvial sediments of the Adilcevaz area (Demirtaşlı and Pisoni, 1965) and the shelf carbonates of Elazığ—Palu area. The effect of compressional forces was slightly weak and continuous during the Middle-Late Oligocene and as a result of this, lithospheric deformation developed. The fact that the thickness of the sediments which were deposited below the wave base in the Muş basin, decreases from 3500m. to 60 m. at a distance of 30 km., can be explained by this event. The litosphere underwent an intensive deformation in the Late Oligocene, while as the sediments of the basins were not deformed. The deformation induced melting of the litosphere led to the development of rhylotic volcanic rocks in the Muş basin (Akay et al., 1989), quartz porphyries in the vicinity of Palu (Sirel et al., 1975) and andesitic lavas in the Hınıs basin. On the other hand, shelf depositional conditions prevailed in the vicinity of Elazığ—Palu during the Early—Late Oligocene while the fluvial sediments were deposited in the vicinity of Adilcevaz. The East Anatolian Fault,which is now oblique to that compression direction, can be the present-day continuation of a fault system which has been active since that time. Also it is very likely that the Ecemiş fault which is assumed to have moved mainly during the Late Eocene (Akay and Uysal, 1987) and the ancestor of the East Anatolian Fault moved together within the same system in the late phase of the Late Eocene collision. Meanwhile, a fault which is about in the eastern extension of the North Anatolian Fault should have operated as an conjugate of the East Anatolian Fault.

Aquitanian—Burdigalian depositional period

The Early Miocene transgression took place over a very extensive area in Anatolia.

In the Muş basin (Akay et al., 1989) the Lower Miocene Adilcevaz formation (Fig. 1),shows transitions into the underlying Oligocene Yazla formation in marine conditions in the eastern part of river Murat and in continental conditions in the western part of river Murat. The Lower Miocene formations consisting of carbonates and clastic rocks are generally 1000 m.thick. These formations which were deposited within the wave base show regressive character with respect to the underlying Oligocene sediments. In the Hınıs basin, the Lower Miocene sediments sometimes show transition into the underlying Oligocene sediments and sometimes transgressively rest upon the basement (A.Yılmaz et al., 1988). In the vicinity of Adilcevaz, the Adilcevaz formation shows transition into the red fluvial sediments of the underlying Ahlat formation (Akay et al., 1989) and is 500 m. thick. The Lower Miocene sediments show transition into the underlying Oligocene sediments, as shelf sediments around Elazığ—Palu (Sirel et al., 1975; Sirel and Gündüz, 1979). The Lower Miocene sediments overlie the Upper Eocene sediments with angular unconformity to the northwest of Malatya (Örçen, 1986). In the Kahramanmaraş, basin, the Oligocene sediments show transition into the Lower Miocene sediments (Uysal et al., 1985). The transgressive limestone and sandstone beds over the basement rocks to the north of lake Van which yield Aquitanian and Burdigalian ages are a few hundred meter thick and probably have an age reaching the Lower Langhian (Gelati, 1975). The Early Miocene transgression took place not only in this region but in the Adana (Yalçın and Görür, 1984), Antalya and Beydağları basins (Akay et al.,1985). Therefore, it is concluded that the existing post collisional cratonic basin became wider.

Which mechanism gave rise to this widening of the basins during the Early Miocene and why?

In this period regressive sediments were deposited in marine basins and transgressive-regressive sediments in continental basins. It is apparent that the continuous slow compression resulted in lithospheric deformation. The phenomenon which happened during the Early Miocene can be explained by the fact that the effect of continental convergence rate which had resulted in this deformation, considerably decreased during the Uppermost Oligocene (Dercourt et al., 1986). As a result of this, the subsidence of continental uplifts gave rise to transgression, while the uplift of subsided basins gave rise to regression.

More or less invariable thickness of sediments and the lack of volcanic intercalations in the Early Miocene basins, indicate that the effect of continental convergence rate is much weaker or lacking, as reported by Dercourt et al. (1986). On the other hand, the development of D I erosive surface described by Erol (1983) coincides with this period (Fig. 1).

Langhian folding period

The Miocene depositional period was interrupted probably during the Lower Langhian to north of lake Van (Gelati, 1975). The depositional period ended in the Muş basin (Akay et al., 1989), Hınıs basin (A.Yılmaz et al., 1988), Elazığ-Palu basin (Sirel et al., 1975; Sirel and Gündüz, 1975) at the end of Lower Miocene and in the Kahramanmaraş, basin (Uysal et al., 1985) in Middle Miocene. On the other hand, a considerable overthrusting is apparent over the Lower Langhian se: diments in the Beydağları basin (Akay et al., 1985). This phenomena coincides with the end of depositional period in Eastern Taurus. In the vicinity of Şarkışla—Gemerek, the Miocene continental depositional conditions ceased in the lower stage of Middle Miocene (Sümengenetal., 1987). ;

In the area between Bilican mountain—Muş—Bingöl, the volcanic rocks of the Elçiler formation, consisting generally of andesites were (Akay et al.,1989) formed after the Lower Miocene depositional period.

In the Hınıs basin, the Lower Miocene sediments forming E—W trending folds, are overlain by the Pliocene sediments with an angular unconformity (A.Yılmaz et al., 1988). The same position is seen in the vicinity of Çakırlı—Yünören within the Muş basin (Akay et al., 1989). The folds effecting the Lower Miocene sediments, strike NE—SW in the Palu basin. These sediments are overlain by the Pliocene sediments with an angular unconformity (Sirel et al., 1975).

In the Misis—Andırın basin, the rock units belonging to the basement are embedded in the Middle Miocene sediments as giant blocks (N.Turhan, 1988, oral communication).

Y.Yılmaz et al. (1988) claimed that a continuous compression from Oligocene—Early Miocene to the Middle Miocene gave rise to the closure of the Miocene basin in the vicinity of Kahramanmaraş. If it is so the regressive beds which formed in the northern nappe area must be older and the beds in the southern nappe area must be younger. However, the regressive beds in the northern nappe area are of at least Middle Miocene age. The regressive beds of the Miocene basin are of Middle Miocene age around Kahramanmaras.. On the other hand, the contact between the Lower Miocene Aslantaş formation and the Middle Miocene Karataş formation is conformable in the vicinity of Andırın This indicates that no considerable deformation took place in the region until the formation of the Middle Miocene regressive beds. Therefore, the effect of continental convergence rate which is assumed to be low in Eastern Taurus during the Early Miocene, must also be low or even much lower in this region. Therefore the closure of the Miocene basin around Kahramanmaraş was caused by the Langhian compressive regime whose traces can be observed everywhere in Anatolia, but not by a series of continuous events occured during the Early—Middle Miocene.

In conclusion, the effect of continental convergence rate which was very low or lacking during the

Early Miocene, considerably increased during the Langhian, and as a result of this, the lithosphere underwent a deformation, inter-mountain basins developed and the Arabian continent was forced to plunge underneath the northern continent. The andesitic volcanic rocks such as the Elçiler formation (Akay et al., 1989) resulted from these events. The northward overthrusting determined by Şengör et al. (1985) by means of seismic profile, cuts the Oligocene— Lower Miocene sediments in the southern part of Muş plain. This overthrust should have moved also during the Middle Miocene phase.

Additionaly. the fracture system which is oblique to N-S trending compressive forces and assumed to be ancestor of the East Anatolian Fault and thought to have moved probably during the Oligocene, should have also moved in this period.

Serravalian—Tortonian depositional period

The Langhian compressional period was followed by a relaxation period whose traces are observed in the neighbouring areas, but not in the region. As a result of this, the Middle Late Miocene marine transgression in the north of lake Van (Demirtaşlı and Pisoni, 1965), Tortonian marine transgression in the vicinity of the Adıyaman (Meriç, 1987), Tortonian continental-marine transgression in the Misis Andırın basin (N.Turhan, 1988, oral communication), Tortonian marine transgression in the Adana basin (Yalçın and Görür, 1984), Tortonian marine transgression in the southern part of iskenderun (Y.Yılmaz et al., 1988), continental transgression starting in the lowermost stage of Late Miocene in the Şarkışla-Gemerek basin (Sümengen et al., 1987) and Serravalian -Tortonian marine transgression in the Antalya basin (Akay et al., 1985) took place. This period represents a transition from the period of deposition in pre-existing, post-collisional marine eratonic basin to the period of deposition in inter-mountain basin. On the other hand, the formation of D II erosive surface described by Erol (1983) coincides with this period (Fig.l).

Uppermost Tortonian compressional period

Akay and Uysal (1987) suggested that the 11 km. long westward overthrust in the Antalya basin probably developed by the westward movement of the portion between the North Anatolian Fault and East Anatolian Fault, following the formation of these faults. For this reason the effect of continental convergence rate during the Uppermost Tortonian is maximum in Eastern Taurus. At the same time, the sediments in Adana (Yalçın and Görür, 1984), Antalya (Akay and Uysal, 1987), Misis—Andırın (N.Turhan, 1988, oral communication) marine cratonic basins and inter-mountain basins in Eastern Taurus were deformed. On the other hand, the fact that the Late Miocene sediments and Pliocene sediments show transition into each other in the Şarkışla—Gemerek basin (Sümengen et al.. 1987) indicates that the region was well-preserved as inter-mountain or extensional basin in this period. During the initial stage of the Uppermost Tortonian phase, the region and its surroundings were affected firstly by an approximately N—S trending compression and then the East Anatolian Fault moved again and the arc-like shape of the North Anatolian Fault formed in the late phase of compression.

There is an overthrust which developed during the Uppermost Pliocene in the northern margin of Muş plain (Soytürk, 1973; Akay et al., 1989). This overthrust probably moved during the Uppermost Tortonian, because the lower level of the Pliocene sediments underlying the overthrust consists completely of pebbles derived from the Oligocene formations and these pebbles indicate a transportation from north. Hence, if the present uplift in the north of Muş, plain formed during the Uppermost Pliocene compressional period, a probable overthrust might have formed an uplift and caused the formation of Muş basin as an inter-mountain basin originally during the Uppermost Tortonian. Therefore the clastic materials derived from this uplift were transported into the inter-mountain basin in the south. Afterwards, due to the decrease of compressional effect during the Pliocene relaxation period, the sediments derived from the Bitlis massif were deposited, which rest conformably on the underlying beds and overlapping this uplift. This type of other basins probably developed in Eastern Taurus. On the other hand, a buried fault in the northern part of Bitlis massif, which is assumed to have moved during the

Langhian compressional period might have moved essentially during this period.

Furthermore, the structures which formed during the Langhian were deformed again during this period.

Early—Late Pliocene depositional period

Related to the sudden decrease in the effect of continental convergence rate or reversal in some regions during the Uppermost Tortonian, andesitic—basaltic volcanic rocks of the Solhan formation and terrigenous sediments of the Zırnak formation were deposited together in subsided areas (Fig. 1). These formations show lateral transition into each other in the Muş Pliocene basin (Akay et al., 1989). The volcanic rocks of the Solhan formation which has been considered to be of Late Miocene age at first and the volcanic rocks of the Zırnak formation which is assumed to have formed in an immediate period following the Late Miocene (Y. Yılmaz et al., 1987) are interpreted to be contemporaneous according to Early—Late Pliocene ages obtained from the sediments showing lateral transitions into both of them. Early and Late Pliocene ages have been obtained in the Hınıs (A.Yılmaz et al., 1988) - Muş (Akay et al., 1989) basin.

Y.Yılmaz et al. (1987) reported that the volcanic rocks of the Solhan formation are the initial products of the neomagmatic period and later the volcanic rocks of the Zırnak formation an Sergen rhyolite developed, respectively. Since the volcanic rocks of the Solhan and Zırnak formations are contemporaneous and the rhyolitic magmatism of the Sergen formation is of Oligocene age, the neomagmatic period needs to be rewieved.

In the Muş—Hınıs basin, no deformation wok place during the depositional period ranging from the lowermost stage of Lower Pliocene to the uppermost stage of Upper Pliocene. This situation disagrees with the hypothesis of Barka (1987) that the movement of the North Anatolian Fault is maximum during the Early Pliocene. On the contrary, it is likely -that the fault might have moved reversely in a short distance, as a result of the removal or extreme lessening of the force which caused the formation of the fault.

On the other hand, the marine transgression belonging to the same period in the Adana (Yalçın and Görür, 1984) and the Antalya basins (Akay et al., 1985) supports a regional event which occured during the relaxation.

Atalay (1983) mentioned about three different erosive surfaces which formed in different levels, in Bitlis mountains to the south of Muş plain. These erosive surfaces one of which is at the altitude of 2250 m. formed during the Oligo—Miocene and the other is at the altitudes of 2000-2050 m formed during the Mio-Pliocene are shown as a single erosive surface in the geomorphological map. However, the Pliocene Solhan formation constitutes the Kozmadağı mountain at the altitude of 2100 m. located to the south of the western margin of Muş plain (Akay et al., 1989). This altitute approximately corresponds to the above mentioned two erosive surfaces. Thus, both erosive surfaces developed during the Pliocene (Fig. 1). The correlan deposits on this surface belong to the Pliocene basin (Fig. 1). On the other hand, the formation of I) 111 erosive surface described by Erol (1983) coincides with this period.

Uppermost Pliocene compressional period

The traces of this period can be observed in the basins located to the north of Bitlis mountains. The approximately SE—NW trending overthrusts and folds developed in the Muş basin (Akay et al., 1989). At first, the Muş plain and its surrounding formed as an inter-mountain basin as a result of compression during the Uppermost Tortonian. Afterwards the uplifts in the north of the inter-mountain basin subsided due to the subsidence during the Pliocene depositional period and took part in to the depositional basin. The inter-mountain basin was formed again by the effect overthrusting in the north of the plain during the Uppermost Pliocene (Akay et al., 1989). The Pliocene sediments dip northward at an angle of 10° in the westernmost part the southern margin of the plain. The dips of these strata increase eastwards. On the other hand, a buried fault extending along the southern margin of the plain, which is assumed to have moved slightly during the Langhian compressional period and considerably during the Uppermost Tortonian, might have been thrusted over northwards without affecting the strata in the western part of the plain during this period. Furthermore, in the Hınıs basin to the north of the region, folding axes in the eastern part of Zırnak strike in NE—SW direction, where those in the western part of Zırnak extend in NW—SE direction (K. Sulu, 1988, oral communication).

The volcanoes such as Nemrut, Süphan, Tendürek and Ağrı which are assumed to have erupted along the N—S trending fractures produced by the N—S trending compressive forces (Şaroğlu et al., 1980; Güner, 1984) are seen in a NE—SW trending line. This line represents a fracture zone which developed probably during the Uppermost Pliocene and which is responsible for the formation and of these volcanoes.

On the other hand, Şaroğlu and Yılmaz (1987) further reported that the East Anatolian Fault and North Anatolian Fault, cutting this formation were formed during the Late Pliocene time on the basis of Early Pliocene age obtained from the Zırnak formation. The Middle—Late Pliocene age was obtained from the regressive strata of the Muş Pliocene basin (Akay et al., 1989). In the same way, the Middle of Late Pliocene age was obtained from the regressive strata of the Pliocene sediments in the Antalya basin (Akay et al., 1985). Hence, this orogenic phase is synchronous everywhere in Anatolia and has been occured during the Uppermost Pliocene.

In the Antalya basin, there is a 11 km.long westward overthrust which developed during the Tortonian phase. However, the Pliocene strata, dipping at an angle of 40° maximum, generally dip 5°—10° (Akay and Uysal, 1985). If the Uppermost Tortonian and Uppermost Pliocene phases gave rise to deformations in the same way (it must be so), the first phase was 11 times more effective than the second phase.

As is seen on a 1:60,000 scale aerial photograph, at the west of Bilican mountain there are 4 different terraces whose altitudes varying from 1550 m. to 1700m. The present dip of slope increases more and more above 1700 m. These terraces developed during the regression of the Pliocene lake in Eastern Anatolia due to the Uppermost Pliocene deformation. On the other hand, the base of the Pliocene sediments are seen at the altitude of 1950 m.further to the north of Muş plain. When the thickness of sediments is taken into consideration, the phenomenon indicates that uplifts of at least 500 to 600 m.occured in the region.

The present morphology and drainage affecting the morphology started to form after the Uppermost Pliocene compressional period in Eastern Taurus and its surroundings, even all over Anatolia.

On the other hand, the erosive surfaces which developed during the Lowei—Upper Pliocene depositional period have been carved as a result of the uplifting of the region.

Early-Middle Pleistocene depositional period

Following the Uppermost Pliocene compressional period, a relaxation period during which the effect of continental convergence rate decreased, took place in the Early—Middle Pleistocene. This period is less important than the Early—Late Pliocene relaxation period. As a result of this the further subsidence of intermountain basins which developed during the Uppermost Pliocene compressional period led to the deposition of sedimentary rocks of the Bulanık formation (Fig.l). Late Pleistocene age was obtained from the upper level of these sediments in Muş plain (Akay et al., 1989). The coarse grained sediments were deposited in the margins of the basins, whereas the fine grained sediments were deposited in the central parts of the basins. These sediments are 200 m. thick maximum and consist generally of sandstone, siltstone and claystone. The sandstones are different from the sediments belonging to upper and lower depositional periods, because they contain abundant white small fragments of lamellibranchiata and are cross-bedded. These sediments are observed also around Hınıs—Tutak—Ağrı (K. Sulu, 1988, oral communication).

The NE—SW trending fracture which had developed during the Uppermost Pliocene and activated Nemrut, Süphan, Tendürek and Ağrı volcanoes, partially moved during this period and gave rise to the development of volcano-sedimentary deposits around the volcanoes.

Erol (1983) reported that the D IV erosive surface formed during the Early Pleistocene. The erosive surfaces at the altitude of 1500 - 1800 m in the north and at the altitude of 1750 - 1800 m.in the south of Muş plain (Atalay, 1983) formed during the Early-Middle Pleistocene (Fig.l). The erosive surface in the north the plain is sometimes covered by ignimbrite—tuffite, being final products of the Nemrut volcano (Özpeker, 1973). On the other hand, the same ignimbrites are found on the floor of the Bitlis valley. This valley developed prior to the formation of ignimbrites which formed in the first stage of the Late Pleistocene (Akay et al, 1989).

Maxon (1936) considered the Bitlis valley as the extension of the ancient river Murat. He suggested that the Bitlis valley and its surroundings were filled up by the volcanic rocks of Nemrut and as a result of this lake Van developed. Özpeker (1973), Şaroğlu and Güner (1981), Güner (1984) supported this hypothesis. However, the floor of the Bitlis valley, which is made up of metamorphic rocks is at the altitude of at least 1700 m. The deepest site of the Van basin which didn't contain any water 100,000 years ago (Wong and Finslch, 1978) is at the altitude of 1200 m. The meandering river sediments of the Middle Pleistocene are at the altitude of 1250 -1300 m.in the Muş basin. If it is supposed that the compressive regime lasting from the Late Pleistocene to the present day did not disturb the settings of the rocks in this area, it is unlikely that the Middle Pleistocene meandering river and the other rivers reaching lake Van which did not contain any water at this time, drained by Bitlis creek. Consequently, the Bitlis creek should be the present extension of a river which was active prior to the Early—Middle Pleistocene depositional period and probably during the Early—Late Pliocene.

The Muş plain and basin of lake Van are inter-mountain basins which were formed and disturbed by the Uppermost Tortonian tectonic regime first and than formed again by the Uppermost Pliocene compressive regime, but not by Pleistocene tectonic regime as reported by Şaroğlu and Güner (1981). These two basins were joint during the initial volcanism of Nemrut. Afterwards, these basins were seperated by the Nemrut volcanic rocks.

The subsidence-deposition during the Early-Middle Pleistocene indicates that the effect of continental convergence rate was slightly low. Meanwhile, it is probable that the movements of North Anatolian Fault and East Anatolian Fault decreased, stopped or were reversed.

Late Pleistocene present day compressional period

No remarkable deformation is observed in the Lower—Middle Pleistocene sediments. The strata dip at an angle of 3°-5° or horizontal over an area extending from Muş to Ağrı However, in some places where the strata lean against the mountains, angles of 15°-25° can be measured (K. Sulu, 1988, oral communication). On the other hand, the Değirmen stream draining into the Muş plain carved its bed for 70 m. following the depositional period in which the Bulanık formation developed (Akay et al., 1989). The bottom of tuffites on the erosive surface which developed during the Early-Middle Pleistocene, on the sides of Norkavak and Çaksor streams draining into the Muş plain was carved for 200 m. maximum by the streams. The similar examples are seen in northern edge of the Bitlis massif. On the other hand, the terrace systems described by Erol (1983) probably developed in this period.

Consequently, the effect of continental convergence rate increased again following the partial relaxation during the Early—Middle Pleistocene. As a result of this, the region was slightly uplifted but no effective deformation took place yet. All the active faults in Eastern Taurus were activated in this period. Additionaly. the sediments such as the Muşovası formation (Akay et al., 1989), were deposited as inter-mountain basin sediments in the region; following the slight erosion related to the uplifting. On the other hand, the recent eruptions of Nemrut and the other volcanoes, which had started to erupt in the Uppermost Pliocene along the NE—SW trending fractures are controlled by the N—S trending fractures formed as a result of the N—S trending compression which is still effective, as reported by Şaroğlu et al. (1980).

The age of the water of lake Van was determined to be 60,000 years on the basis of major element content but argued to be of 100,000 years (Wong and Finckh, 1978). On the other hand, the deepest site of the lake is at the altitude of 1200 m. If it is supposed that the Bitlis creek whose highest site is at the altitude of 1700 m.on the metamorphic rocks was not subjected to any change in structural setting, it is unlikely that this creek was drained by the rivers reaching lake Van which did not contain any water during the Upper Pleistocene. As discussed in the Early—Middle Pleistocene depositional period, it is also impossible that the Bitlis creek was drained by the rivers in Muş plain in this period. On the other hand, the fact that no terraces resembling to those of on the side of lake Van are found in the margin of Muş plain, indicates that the Van-Muş basins were not joint in this period.

The Muşovası formation was carved (Akay et al., 1989) as a consequence of the final lowering of sea-level and partly by the effect of tectonics, but later, these troughs are filled up by the Holocene (actual) sediments related to the rising of sea-level again.

CONCLUSIONS

Şengör et al. (1985) and Dewey et al. (1986) report that the Eastern Anatolia has been undergoing a shortening of the continental lithosphere as a result of the continent-continent collision since the Late Serravalian. However, stratigraphic data obtained by Gelati (1975) indicate that the compressive regime probably lias been taken place since the Langhian. On the other hand, Michard et al. (1985) claims that the continent-continent collision took place during the Late Eocene. The facts that the Oligocene basin did not develope widespread, the geometry of sediments belonging to this basin frequently changes due to the lithospheric deformation, very limited acidic volcanism took place in the final phases of the basin and syncronous occurrence of the Early Miocene transgression in the both southern and northern parts of Southeast Anatolian suture zone (Baştuğ, 1980; Meriç., 1987) supports the Late Eocene collision. Therefore, the neotectonic period started in the Late Eocene. The shortening of continental lithosphere has been continuing since Late Eocene. In the region, the changes in the fate of continental convergence gave rise to the formation of depositional basins and chains of uplifts. The relative rate of continental convergence can be deduced depending on whether these formations developed widespread or not. This rate was maximum during the Uppermost Tortonian, and lower during Late Langhian, Uppermost Pliocene, Early—Middle Pleistocene, Serravalian—Tortonian, Early—Late Pliocene, Oligocene, Early Miocene in a decreasing order. The rate of continental convergence must be considerably high from Late Pleistocene to the present-day.

The frequent occurrence of basin uplifting indicates that the continental crust has been progressively thickening since Langhian.

On the other hand, the neomagmatic period which is assumed to have started in the Late Miocene by Y.Yılmaz et al. (1987) has been continuing since the Late Oligocene volcanism.

Although Şaroğlu and Güner (1981) dated the Late Miocene lithologies and Pleistocene lithologies in the Muş basin without any fossil evidence, they reported that the Muş inter-mountain basin gained its characteristics in the Pleistocene in one place and at the end of Pliocene in another place. However, the Muş inter-mountain basin firstly developed during the Uppermost Tortonian compressional period and was disturbed during the Early—Late Pliocene depositional period and gained its present characteristics during the Uppermost Pliocene compressional period. It underwent no remarkable structural change in the Quaternary.

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