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PRE - NEOGENE TECTONOSTRATIGRAPHY OF DİLEK PENINSULA AND THE AREA SURROUNDING SÖKE AND SELÇUK

Ali ÇAKMAKOĞLU*

ABSTRACT.- At Dilek Peninsula-Söke-Selçuk areas, to the western-southwestern parts of Menderes Massive, structurally related various techtono-stratigraphical units crops out. The sequence commences with the "Dipburun nappe" in the Dilek Peninsula which is probably Jurrasic to Late Cretaceous in age and composed of marble, cherty marble and metavolcanites, turbiditic marbles and phyllites depicting a flysch facies. It is overlain by the "Efes nappe" which comprises various schists and marbles of Late Paleozoic-Early Triassic age and metabauxite bearing metacarbonates of Triassic-Late Createaceous age. Around Söke-Selçuk area, The Efes nappe is tectonically overlain by the "Şirince metaflysch" comprising olistoliths or tectonic slabs of metabasic rocks, metaultrabasic rocks, eclogites, marbles, amphibolites and cherty marbles in a matrix made up of pelitic and basic schists. The Şirince metaflysch is a probable lateral equivalent of the metaflysch forming the upper levels of the Dipburun nappe. Upward, "Akçakonak unit" tectonically overlies the Şirince metaflysch. The Akçakonak unit is the equivalent of Bodrum Nappe which is a part of Lycien Nappes. It consists of metadetritics of Early-Middle Triassic age, in its lower levels and carbonates of Middle Triassic-Cenonian age in its upper levels. It is overlain by the "Izmir flysch" which is olistostromal in parts. The Izmir flysch is presented over the Efes nappe and also over and under the Akçakonak unit as tectonic slabs. All of these units are overlain unconformably by the Early Miocene-Quarternary aged formations.

Key words: Dilek Peninsula, metavolcanites, gneissic schists, metabauxit, metaflysch.

INTRODUCTION

It has been reported that the Menderes Masif, which has previously been identified in general as a "monotonous" sequence from Precambrian to Early Tertiary, is comprised of different tectonostratigraphic rock units which are overlain by various sequences of the allochthonous Lycian nappes in Dilek peninsula and surrounding region of the western Anatolia in the recent studies (related literature in the referance list). In order to differentiate the various rock units included in the Menderes Massif in Dilek Peninsula, Söke, Ortaklar, Kuşadası and Selçuk regions, 1/25 000 scale detailed geological mapping, revision, correlation and compilation studies were realized between the years 1992 - 1996 (Figure 1a). Consequently, the 1/25 000 scale map sheets of L18-c3, c4, d3 and M18-a1, a2, a3, c1, d1, d2 have completely and the sheets of M18-c2 and d3 were partially mapped in this study. The others map sheets of the region, on the other hand, have been revised and the whole work has been compiled together under the same legend.

The Neogene - Quaternary units in the study area are simplified after Göktaş (1998) (Figure 1a and 1b) and "Kösele formation - Söke formation - Dedeağaç formation - Kuşadası formation" have been defined as Neogene deposits (Nç); "Savulca formation - Ortaklar formation - Yamaçköy formation" have been defined as Plio-Quaternary units (PlQb) in the content of "Büyük Menderes Group". "Balatçık" (Nbv) and "Hisartepe Volcanics" as (Nhv)] are the Neogene volcanic units of the region.

The metabauxites which are used among the data for structural differentiation, have been known since Önay (1949) and Wippern (1963)' studies in the region.

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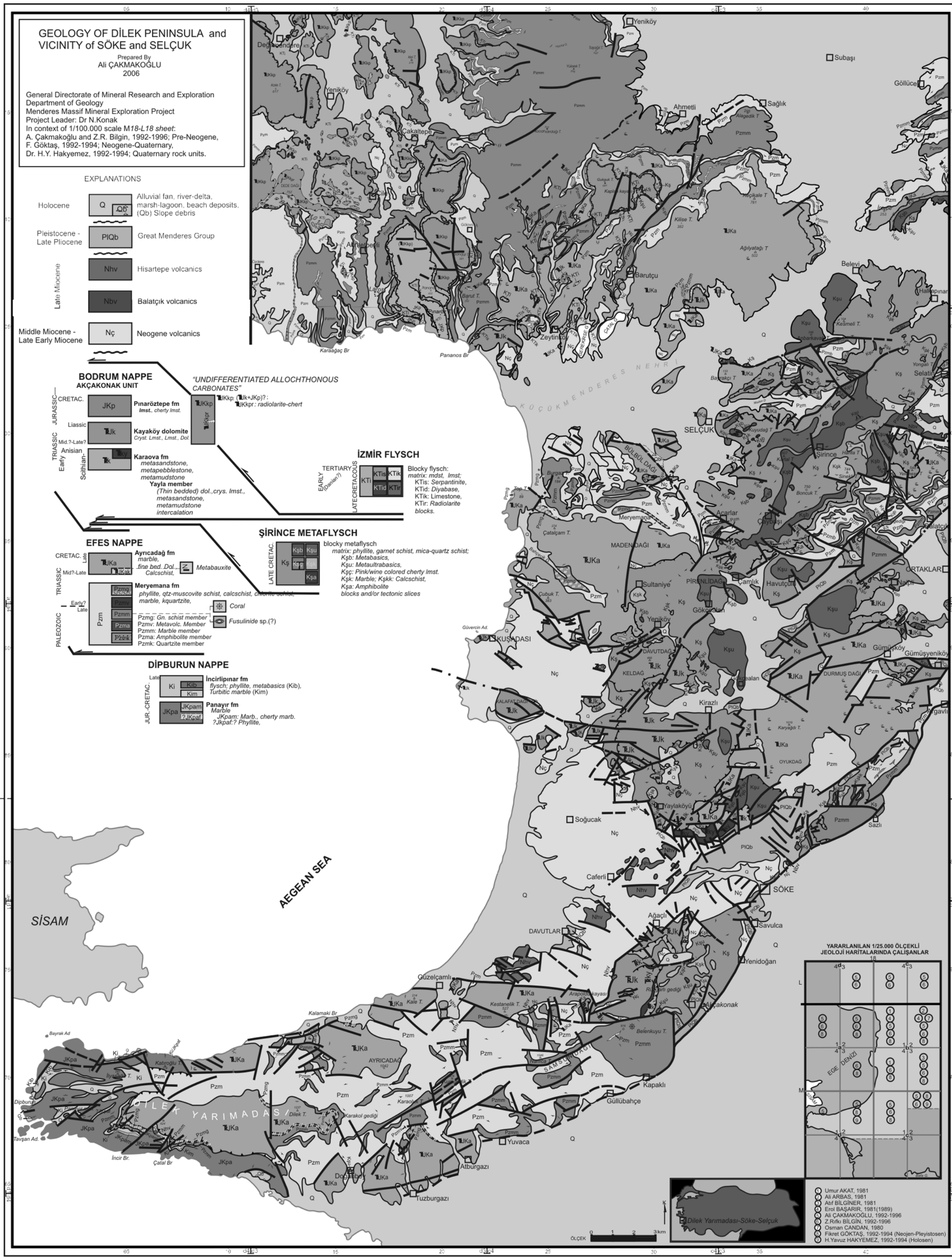

Figure 1a- Geological map of the region around Dilek Peninsula, Söke and Selçuk

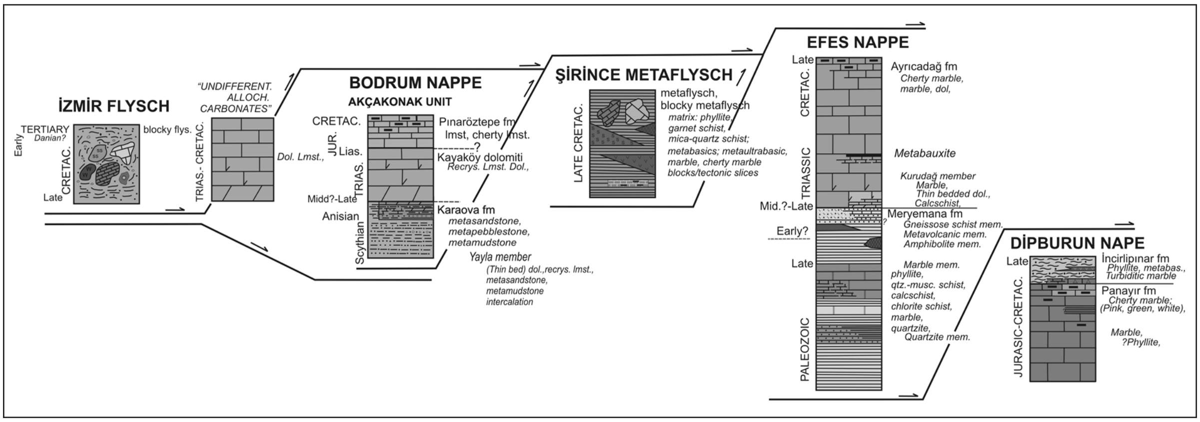

Figure 1b- Pre-Neogene tectonostratigraphic units in the study area

The studies in Menderes Massif can be dated back to 1840s; in the study area, however, geological mapping and structural - stratigraphic studies have begun in 1980s. In this study, some previous studies have been used for the discussion and evaluation of the units.

STRATIGRAPHY

The pre-Neogene rock units that have tectonic relations with each other are located as, from bottom to top, Dipburun nappe, Efes nappe, Şirince metaflysch, Bodrum nappe and İzmir flysch. Of these units, the "Dipburun nappe" is defined for the first time and its basement can not be observed in the study area. This nappe is comprised of marble, cherty marble and metavolcanics, turbiditic marble and phyllites in flysch facies and its probable age is Jurassic - Late Cretaceous. Dipburun nappe is tectonically overlain by the Efes nappe which comprises Paleozoic - Early Triassic (?) schists, marbles and Triassic - Late Cretaceous metacarbonates including metabauxite. The "Şirince metaflysch" which is tectonically located on higher levels has the characteristics of a "metaolisthostrome" with a pelitic and basic origin matrix. It contains metabasics, ultrametabasics, eclogite, marble, amphibolite and cherty marbles at various scales of blocks and/or tectonic slices. The "Akçakonak unit", one of the "Bodrum nappe" units, is tectonically located at the top. The unit is formed by Early - Middle Triassic metaclastics at the bottom and by Middle Triassic - Cenonian carbonates at the top. It is tectonically covered by olisthostromal Late Cretaceous - Early Tertiary (Danian?) "İzmir flysch" in places and moreover, interfingered as tectonic slices, The İzmir flysch overlies the Efes nappe with a tectonic contact. All of these tectonostratigraphic units are overlain by Early Miocene deposits with an angular unconformity.

DİPBURUN NAPPE

The Dipburun nappe, which is in general represented by metacarbonates (Panayır formation) at the bottom and by metaflysch (İncirlipınar formation) at the top, is observed to the west of the Dilek Peninsula. It is Jurassic - Late Cretaceous in age and the lowest observable tectonostratigraphic unit of the study area. It is partly similar to the Middle - Upper Mesozoic units of the Efes nappe and is the possible extension of the "Kerketefs unit" on the Samos Island (Papanikolaou, 1979) or "Kerketas nappe" it self (Ring et al. 1999) (Figure 2).

Panayır formation (JKpa)

This unit which is comprised of marbles and cherty marbles, is differentiated as "Panayır for-

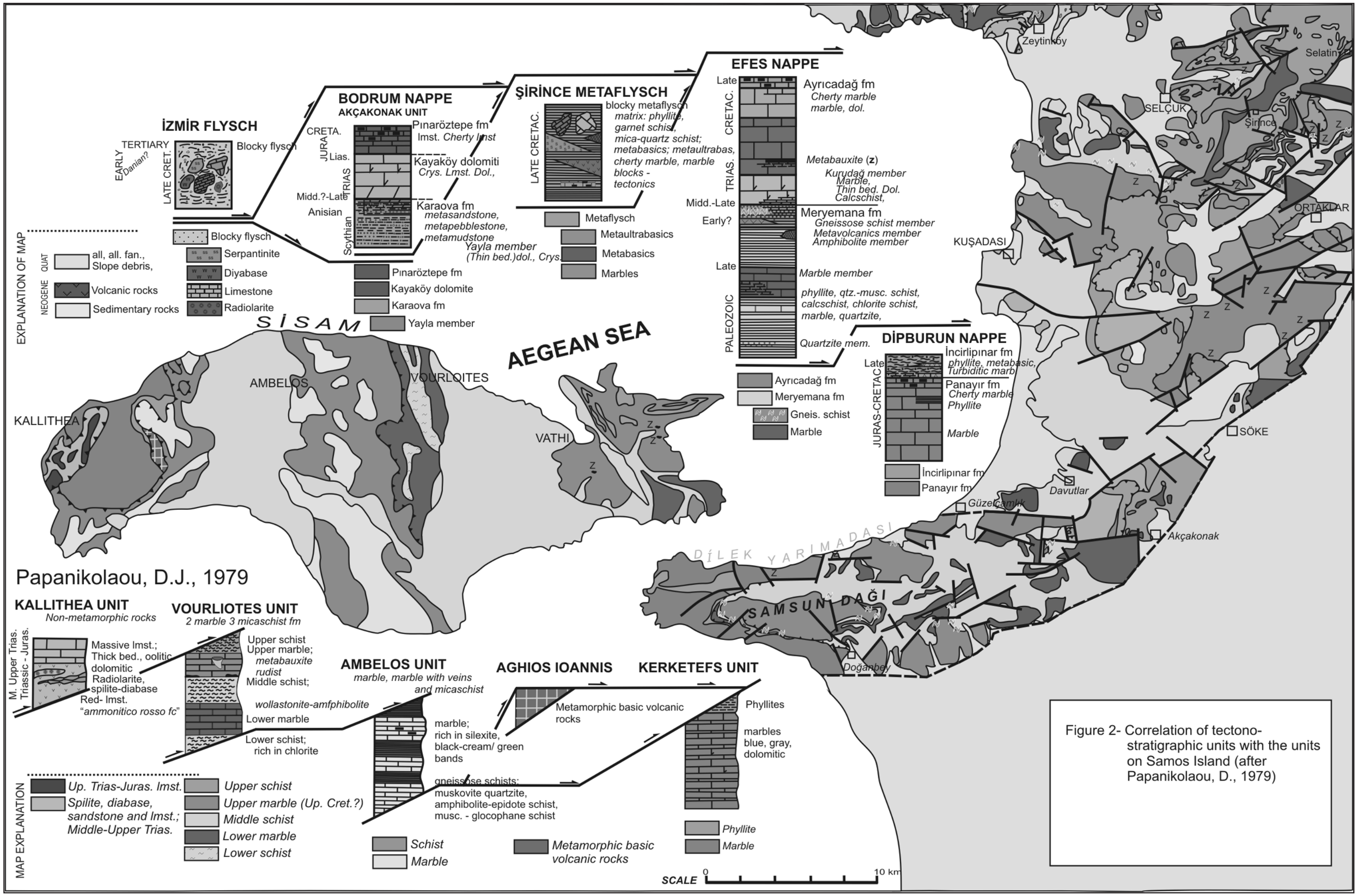

Figure 2- Correlation of the tectono-stratgiraphic units with that of Samos Island (data for the Samos Island: after Papanikolau, 1979)

mation". The medium to thick bedded marbles are dark gray, gray, bluish gray with light gray laminations, having thin to medium crystals. Towards the upper levels of the sections, local calcschist and phyllite lenses and pinkish - brown, beige colored, 1 -15 cm thick chert bands are observed. Dark green, brownish / grayish "phyllites" and yellowish Brown "calcschists" (JKpaf) are very similar to the phyllites and calcschists of the İncirlipınar formation, located at the topmost levels of the nappe (Figure 1b). Besides, the chert banded, pinkish beige / white, light wine colored marbles having thin to medium crystals and brownish yellow / pink colored calcschists are differentiated as "Pink Marble Unit" (JKpam) (Figure 1b).

The Panayır formation is 400 m thick in the study area. The marbles contained in the Kerketefs unit are reported to be at least 1000 m thick on the Samos Island (Papanikolaou, 1979).

No fossils were detected in the formation. Ring et al. (1999) reports that the Kerketas nappe is of post-Carboniferous age and ends up with a Eocene flysch. However, considering the correlative Cenonian age of the overlying İncirlipınar formation, the unit can be dated as Jurassic - Cretaceous.

İncirlipınar formation (Ki)

This is a flysch - like unit composed of phyllites and is differentiated as "İncirlipınarı formation". The formation is comprised of dark / light green, brownish beige, bluish gray colored phyllites, yellowish / pinkish, brown colored calcschists and a few m thick, green, brownish green colored metabasics and turbiditic, chert banded and clastic marbles (Figure 1b). Pinkish white, wine colored marble, cherty marble and chert banded turbiditic marbles (Kim) with marble pebbles resemble to the Campanian - Maestrichtian micritic, turbiditic limestones that are frequently observed in the western Anatolia.

A dark green, greenish -redish brown metabasic lens (Kib) of almost 4 m thick between calcschist and cherty marbles is differentiated (Figure 1b). Candan et al. (1997) discussed the presence of a "relicts of blueschist" and "glocophane + crossite paragenesis" in the extensional area of the formation which the metabasic lens (Kib) possibly reflects the same blueschist facies conditions in the study area.

No fossils were detected in the formation and based on the rock type, facies and correlations, the formation is presumed to be of Cenonian age.

EFES NAPPE

The Efes nappe which is comprised of Late Paleozoic - Early Triassic (*) schists and marbles at the bottom and Mesosoic metacarbonates at the top tectonically overlies the Dipburun nappe. Efes nappe, on the other hand, is tectonically overlain at different localities in the study area by Bodrum nappe (Şenel, 1997*c*); Şirince metaflysch (Çakmakoğlu, 2005*a, b*); İzmir flysch (Öngür, 1972; Eşder, 1988) or "undifferentiated allochthonous carbonates" (Figure 1b). The unit probably is the stratigraphical equivalent of the "Vourliotes unit" and partly "Ambelos unit" (Papanikolau, 1979) on the Samos island. The overlain Late Paleozoic - Early Triassic (?) metamorphics and the overlying Mesosoic metacarbonates are differentiated as Meryemana and Ayrıcadağ formations, respectively.

Meryemana formation (Pzm)

This unit, comprised of schist, marble and quartzites and metavolcanics and gneissose schist lenses at the upper levels, is differentiated as "Meryemana formation". In the previous studies, Meryemana formation hes been defined as Bafa formation (Akat, 1980) and Bayındır formation (Erdoğan and Güngör, 1992).

The dominant lithologies in the formation are mica schist, quartz schist, phyllite and marbles.

Especially tha marbles are observed to extend over large areas to the north of the study area. At the upper levels, calcschist intermediate levels are observed. At the upper levels of the both schists and marbles, "gneissose schists" and metavolcanics are the other prominent lithologies of the formation, even if they are not throughly continuous laterally. To the west of the Top Tepe (M18-b1) poorly sorted metapebbles made up of half rounded pebbles of marble are observed. Besides, the amphibolite (Pzma) observed 2 km east of Meryemana (M18-b1) is defined as "biotite - quartz - amphibole - epidote schist" and interpreted as the "equivalent of a heteroblastic gabbroic rock in greenschist facies" by Akat (1980). Başarır (1981, 1989), on the other hand, defines it as "amphibolite" and shows it between the "micaschists with garnet". Candan et al. (1997) advocates the presence of "chloritoide + cyanide" assemblage in Meryemana formation which locally contains garnet, biotite and muscovite. There are various lithologies defined as members of the formation.

The quartzites display very distinct morphology with thick, very thick foliation, white, yellowish / brownish beige color among the schists; they are defined as the "quartzite member" (Pzmk) to the northwest of the study area (Figure 1a, 1b). The average thickness of the quartzites vary between 20 - 30 m Especially towards gneissose schists situated at top levels, the amount of quartz increases significantly, and white, yellowish / brownish, beige colored quartzite, beige / pinkish yellow quartz schist, quartz - muscovite schists are observed.

The unit which is comprised mainly of marble including dolomite, calcschist and schist intercalations, is differentiated as "Marble member" (Pzmm). It is partly equivalent to the "Şenköy formation" (Akat, 1980) among the previous works. The marbles are in general dark gray, gray, blackish gray and white in color, and gray - white banded, mostly medium, sometimes thick / fine bedded, laminated, medium to fine crystallized. Towards the gneissose schists located at the upper levels of the formation, sometimes it includes rare silica bands, a few mm thick. Greenish yellow / light gray calcschist, brownish / whitish yellow quartz schist, dark / light gray, whitish gray colored quartz cerisite schists and blackish gray colored dolomitic marbles with thin calcite veins, medium to large crystals, graphite, and having fosil traces similar to fusulines are the other rock types of the unit.

A few meter thick "metavolcanic member" (Pzmv) located at the upper levels of the schists and at immediately below the gneissose schists are mostly mapped by exaggerating. The unit is defined as " epidot - chlorite - muscovite - quartz schist, biotite - epidote - muscovite - quartz schist" by Akat (1980). Erdoğan and Güngör (1992) discuss the presence of 20 - 30 m thick "mafic metavolcanics" lenses in "Bayındır formation"; besides, Güngör and Erdoğan (2001) reports the presence of Late Triassic clastics and "metatuffs / alkali basalts" intercalated with carbonates included in "Çaltaşı formation" as mafic metamorphic rocks. It can be accounted that the metavolcanics mark a volcanism in Lower Triassic (?) period, if we consider the stratigraphic relation and the relative age relations with gneissose schists.

In Meryemana formation, at the levels close to the lower contact of marbles containing "metabauxite" (Ayrıcadağ formation), there are metapebbless resembling gneiss/augen gneiss. The metapebbles defined as "gneissose quartz schist" by Başarır (1981, 1989) and as "gneissose schists" by Gümüş et al. (1983) were differentiated as "Gneissose schist member" (Pzmg) in this study. Gray, grayish / yellowish white colored unit is attractive with its appearance as augen gneiss. The augen structure formed by quartz resemble boudinage, however, at some observation locations [for example, North of Tuzburgazı village (M18-d2), west of Top Hill (M18-b1)] the primary rock of quartz pebbles and quartz sandstone can be differentiated (Figure 3 and 4). The

Figure 3- "Metapebblestone - metasandstone" in context of gneissose schist (Kuşadası kuzeyi, Top Tepe, M18-b1)

Şekil 4- "Metapebblestone - metasandstone" in context of gneissose schist (Kuşadası kuzeyi, Top Tepe, M18-b1)

widespread gneissose schists which can be differentiated locally (and sometimes by exaggeration) and shown symbolically, display a general association with the underlaying metavolcanics and the overlying metabauxitic marbles. The unit is mapped and defined as "gneissiques schistes" in the context of the Ambelos member on Samos island (Papanikolaou, 1979).

At almost every location the gneissose schist member is conformably overlain by the Ayrıcadağ formation. This member, however, when correlated with the Middle? - Late Triassic metapebbles and Rhetian metaclastics (Konak et al., 1987*b*) that belong to the Marçal Group (Konak et al. 1987*a*), can point out an incompatibility with Meryemana formation.

The apparent thickness of the formation in the study area is more than 500 m.

No determinable fossils were found in the unit. There are undefined coral fossils in the west of the Belenkuyu Hill - Akçakonak Village (Figure. 1a; M18-c1) and fusulin like forms (Figure. 1a; L18-c4, west of Yeniköy). Besides these, the Middle?- Late Triassic age determined at the base of the Ayrıcadağ formation which overlies the unit, implies that the age of the Meryemana formation can be Late Paleozoic - Early Triassic (?). The Permo - Carboniferous age of the similar or the other correlatable units of the Kavaklıdere group (Konak et al., 1987*a*), supports this idea. However, the ages of the metavolcanics and the gneissose schists having stratigraphical relations and located at the top of this formation have not yet been clarified. These two rock assemblages must have been of Lower Triassic rather than Upper Paleozoic.

Ayrıcadağ formation (TrJKa)

This formation, which is named as Bozdağ group (Akat, 1980) or Kayaaltı formation (Erdoğan ve Güngör, 1992), or defined as "emery bedded marbles" and silex banded marbles" (Çalapkulu et al., 1982; Gümüş et al., 1983) and "marbles / dolomitic marbles" (Başarır, 1989) in previous studies is comprised of metacarbonates in general.

The Ayrıcadağ formation begins with dirty yellow, pinkish / brownish white, beige colored, fine - very fine crystallized marble and gray, blackish gray dolomite and dolomitic marbles at the bottom. The upper levels are comprised of metabauxite containing, white, grayish / beige, white colored, medium to thick bedded marbles with granoblastic texture (Figure 1b). At its possible highest levels there are gray, grayish white, middle to thin bedded marbles containing chert bands and nodules.

The metabauxites, which are widespreadly observed along a belt to the South of the Menderes Masif and used as one the data in discrimination of the tectono - stratigraphic units are observed towards the lower levels of the Ayrıcadağ formation and they are accounted to be same with the "bauxites formed in time period between Liassic - Lower Cretaceous in Marçal group" (Konak et al., 1987*b*). To the west of Ahmetli (L18-c4) and to the north of Belevi (L18-c3), however, metabauxite ocurrences are observed in the Late Paleozoic marbles of the Meryemana formation. This observation is in contradiction with Mesozoic (Jurassic-Cretaceous) metabauxite findings in Menderes Massif. Here, maybe a structural and undifferentiated situation is in question rather than stratigraphic position of the metabauxites.

At the lower levels of the formation, the "Kurudere member" (TrJKak) comprises of grayish, blackish gray, grayish white dolomite, dolomitic marble and light/dark green, brownish beige phyllites and calcshists which are thick in millimeters and centimeters and pinches out laterally.

The Ayrıcadağ formation conformably overlies the Gneissose Schist member of the Meryemana formation almost everywhere. This relation, on the other hand, is questionable as discussed in "Gneissose Schist Member" section. It is tectonically overlain by the Şirince metaflysch. The upper contact is transitive according to Erdoğan and Güngör (1992), and debatable according to Candan et al., 1997). Besides, the formation is tectonically overlain by the İzmir flysch and Bodrum nappe in a few localities.

The formation is at least 750 m thick. It contains fossils indicating Middle -Late Triassic, Middle - Late Jurassic ages (Akat, 1980; N. Konak, personal comm., 1992). Rudist findings (Özer, 1993; 1998) and their probable equivalents in Samos island (Papanikolaou, 1979) yield Middle? - Late Triassic - Late Cretaceous age.

ŞİRİNCE METAFLYSCH (Kş)

In the unit the pelitic and basic schists are dominant as matrix and in the matrix, blocks or tectonic slices of metabasics, metaultrabasics, amphibolites, marbles, cherty marbles at different dimensions are found and the unit is named as "Şirince metaflysch". The unit has been presented in Late Permian - Early Triassic "Bafa formation" in the previous works (eg. Akat, 1980). The same unit has been defined also as "mica schists with garnet containing metabasic, serpantinite and marble bands - lenses" (Başarır, 1989); a "paleo - melange" (Candan and Kun, 1989); "metamorphic olisthostrome" (Candan et al., 1997, 1998); and "Selçuk formation" (Erdoğan and Güngör, 1992)

In general, the matrix made up of pelitic origin, dark / light gray, yellowish / bluish metamorphic rocks contains the dominant rock types of muscovite - quartz schist, muscovite - albite - biotite - quartz schist; muscovite - garnet - chlorite - biotite schist, calcschist, chlorite - muscovite schist. The schists with coarse grained garnets oncentrate distinctively where the Şirince metaflysch covers.

Beige, pinkish / claret reddish / greenish beige colored, thin to medium bedded, having fine to very fine crystals, marbles containing thin metachert bands are differentiated as "Cherty Marble Member" (Kşç). The metacherts brownish beige / gray in color rarely observed between phyllite and garnet schists display a dissolving cavity structure. The unit to reaches to a thickness of 10 m, as lenses locally (north Havutçulu Village, M18 - b2). Based on the lithological features and considering as the equivalent of the Cenonian units (mostly Campanian - Maastrichtian pink micritic limestones) observed in the west Anatolia frequently, the unit was differentiated by exaggerating (Figure 1a).

In Şirince metaflysch, metabasic rocks "metabasic member" (Kşb) observed as stratigraphic levels have also been mapped as well as blocks. In differentiating the brownish dark / light green, mostly foliation - displaying metabasics, in general the previous works (Candan, 1980; Başarır, 1981, 1989) have been made use of. "The metadiabase" or "the metamorphic equivalent of diabasic tuffs formed after seafloor volcanism" (Başarır, 1989), the general paragenesis of the "mafic metavolcanic" member (Erdoğan and Güngör, 1992) is given as "tremolite - albite - epidote - zoisite - garnet - sphene (leucocene) - quartz - muscovite" (Başarır, 1989; Candan and Kun, 1989), " actinolite - chlorite - quartz - albite - epidote - garnet - sphene (Erdoğan and Güngör, 1992). The albites in the unit, in places, are observed as "huge knots" typically (M. Şengün, 1993, pers. comm.).

The ultrabasic rocks that take place as blocks or as tectonic slices in the metaflysch at various dimensions and mostly showing foliation are defined as "metaultrabasic member" (Kşu). The unit of which primary rock is dunite and peridotite has undergone serpantinization by 90 - 100% (Candan and Kun, 1989); besides, in the unit, antigorite and chromite formations were observed too (Başarır, 1989; Candan and Kun, 1989). The "gabbroic originated rocks" (Akat, 1980) in the schists were mapped as "amphibolite" (Başarır, 1989) and the rocks known as "metagabbro" (Candan and Kun, 1989) were mapped as "amphibolite member" (Kşa).

There are various type and size marble blocks (Kşm) in the metaflysch. In general the marbles have saccaroid texture in gray, dirty white and beige color. No fossils have been determined in the massive marbles and sometimes dolomitic marbles. The probable age is Triassic-Late Cretaceous.

The Şirince metaflysch has tectonic relation at the bottom with Meryemana and Ayrıcadağ formations. However, Erdoğan ve Görür (1992), states that the unit has been observed, near the village Belevi, having a neat transition with the overlain Kayaaltı formation; Candan et al. (1997) states that the contact relation of these two units are controversial. On this unit, units of the bodrum nappe and İzmir flysch are located tectonically (Figure 1b).

To the east of the Selçuk where big structures are observed, the thickness of the unit at Boncuk Dağı synclinal is at least 1000 m.

The Şirince metaflysch is an equivalent of a part of "Simav metamorphics" (Akdeniz and Konak, 1979) which in Simav region includes metabasics and metaultramafics; metabasics and metaultramafics between Keçidağ and Gölmarmara metabasics and metaultramafics (Konak et al., 1980); to the north of the Çivril "Özbeyli metabasic - metaultrabasics" (Çakmakoğlu, 1986); around Tire a section of Keçidağı Group (Akdeniz et al. 1986) containing metaultrabasics; "metaflysch - like rocks" (Konak, 1994); the unit including metaserpentinites and metabasics (Konak et al., 1994); a part of "Doğanbeyburnu metamorphics" (Eşder, 1988) and Selçuk nappe (Ring et al., 1999) observed on Samos Island.

Although no fossils have been determined, it can be said that the age of the unit is Late Cenomanian according the the regional correlations.

BODRUM NAPPE

The Bodrum nappe, which is one of the structural nappes of the Lycian nappes are made up of rocks representing sometimes continental, in general shallow shelf of Lower - Middle Triassic, platform of (Middle?-) Upper Triassic - Liassic (sometimes Upper Triassic - Malm); and passive continental margin Upper Liassic - Upper Cretaceous (sometimes Cretaceous) period and is known with different names ["Köyceğiz series" (Graciansky, 1972; Bernoulli et al., 1974); "Bolkardağ unit" (Özgül, 1976); "Sandak series" (Erakman et al. 1982); "Çökelez Group" (Konak et al. 1986; Konak, 1993); "Ören Unit" (Konak et al., 1987*b*); "Çökek Group" (Şenel et al. 1989); "Çökek Nappe" (Şenel et al., 1994)] and has been re - defined by Şenel (1997*a,b,c*). The Bodrum nappe has been formed by units more or less different from each other; the representative of the Bodrum nappe in the study area has been named as "Akçakonak unit" (Figure 1b).

AKÇAKONAK UNIT

The unit is made up of metaclastics (Karaovası formation) at the bottom and metacarbonates at the top (Kayaköy dolomite and Pınaröztepe formation) and overlies the Efes nappe and Şirince metaflysch. It is of Early Triassic and Cenonian age and is overlain by Late Ctretaceous - Early Tertiary (Danian?) İzmir flysch.

Karaova formation (Trk)

It is in general made up of metaclastics and has been named as "Karaova schists" to the south of the study area by Philippson (1915), as "Karaova schist series" by Flügel and Metz (1954), as "Karaova unit (schichten)" by Brinkmann (1967), as "Karaova formation" by Akat et al. (1975), as "Karaova unit (schichten)" by Dür (1975) and as "Güllük formation" by Ercan et al. (1983, 1984). It can easily be correlated by means of its typical lithologic and stratigraphic features throughout the western Anatolia and has a widespread extension. The formation is known as "Çömlekçi formation" (Konak et al., 1980) in Akhisar and its vicinity, "Sazak formation" (Konak et al., 1986; Çakmakoğlu, 1990) in Çal - Çökelez Mountain (Denizli) vicinity, "Sorgunlu formation" (Göktaş et al., 1989) in Balkan, and to the southwest of Denizli "Karaova metasediments" (Çakmakoğlu, 1987) and "Karaova formation" (Okay, 1989; Konak, 2003). The name "Karaova formation" has been adopted for this widely extending unit and has been studied in detail.

The wide spread and typical lithologies of the formation are purple, dark gray, green, olive green, pink, gray colored, thin to medium bedded metapebble, metasandstone and metasiltstone.

Rimele et al. (2004) have determined Fe - Mg carpholite to the south of Ağaçlı (Söke) and "carpholite pseudomorphs and chloritoid" in Kirazlı (Söke) in the reddish - greenish phyllites of the formation.

Karaova formation passes into Kayaköy dolomite with the intercalation of brownish yellow calcschist, light / dark gray colored thin to medium bedded dolomite, gray, white dolomitic recrystallized limestone and metaclastics. This transition unit, which is named as "Yayla formation" in Çal (Denizli) region (Konak et al., 1986) is differentiated as "Yayla member" (Trky) in this study. It is 0 - 50 m thick and Anisian (probable) age was determined from an equivalent of this unit to the east of Karaova (Muğla) (Çakmakoğlu, 1985; Konak et al., 1987*b*).

The formation has tectonic contact with the Efes nappe and Şirince metaflysch. However, it is known that in Gökbel Mountain (Muğla) it unconformably overlies Late Permian [(Gökbel formation; Meşhur et al., 1989) Şenel, 1997*c*]. This is transitively overlain by "Kayaköy dolomite" comprising dolomite and recrystallized limestone. The formation is thought to be 100 - 150 m thick.

No age data was obtained from the clastics of the Karaova formation. Based on its stratigraphical location and correlations, the unit is assumed to be of Early - Middle Triassic (Scitian - Anisian), for Yayla member the age assumed is Anisian.

Kayaköy dolomite (TrJk)

The unit is made up of dolomite and dolomitic recrystallized limestone. Its equivalent in Muğla region is defined as "Gereme calcareous unit" first defined by Philippson (1915), however, the Middle Triassic - Liassic similar lithologies in different tectono - stratigraphic units are also named as "Gereme formation" and for this reason, the unit is re-defined as "Kayaköy dolomite" by Şenel et al. (1994). The dominant lithologies of the formation are the gray, dark / light gray, whitish beige colored, thick to medium bedded, medium to thin crystallized, dissolved recrystallized and dolomites.

The unit conformable overlies the Karaova formation and is tectonically overlain by the İzmir flysch. Its relation with the "Pınaröztepe formation" which most possibly is the upper continuation of the formation was not observed. To the south of the study area, in Muğla region, the is conformably overlain by "Göçgediği formation" (Şenel et al., 1989; Şenel and Bilgin, 1997*a,b*) comprised of cherty limestones or by "Ula marble" (Kaaden and Metz, 1954; Şenel and Bilgin, 1997*a, b*). Its maximum thickness is 300 m.

The local observations in "undifferentiated allochthonous carbonates" in L18 - c3, c4 and d3 sheets show that these units are similar to Kayaköy dolomite, besides, including the Pınarözütepe formation. However, the allochthomous clastics and carbonates appearing as the extensions of these units in the immediate west (L18 - d4) ("Sevincer Tepe sequence" and " Arpacık Tepe limestone" (Başarır and Konuk, 1981) display features of different lithologies and bio - facies characteristics, for this reason, reflect different structural units. These dolomites and limestones have been given different symbols because of the uncertainty in discrimination and for the sake of the detailed study (Figure 1a, 1b).

No fossils have been determined in the study area in the unit, therefore Middle? - Late Triassic-Middle Liassic age is assumed based on the correlations.

Pınaröztepe formation (JKp)

This unit is comprised of cherty crystallized limestones, and its metamorphic and non - metamorphic equivalents located to the south of the study area has been called as "Ula marble" (Kaaden and Metz, 1954), "Mandalya cherty limestone" (Orombelli et al., 1967), "Bodrum Unit /Schichten" (Brinkmann, 1967), "Çaldağ limestone" (Graciansky, 1972), "Çaldağ formation" (Bernoulli et al., 1974; Dürr, 1975), "Mandayla formation" (Akat et al., 1975), "Kışladağ formation" (Ercan et al., 1983, 1984) and "Göçgediği formation" (Şenel et al., 1989); however, in regional scale "Göçgediği formation" and its metamorphic equivalent "Ula marble" has been re - defined (Şenel and Bilgin, 1997*a, b*). In the study area, a section of the Göçgediği formation / Ula marble can be observed, in the other parts of the region, at the lower levels radiolarite, marl, chert, shale, nodular limestone in "ammonitico rosso" facies and Cenonian micritic limestone at the upper levels are observed. For this reason, the unit is defined and named as "Pınaröztepe formation".

The formation is made up of gray, beige - white colored, middle to thin bedded, fine crystallized limestones and includes chert bands and nodules 2 to 15 cm thick. Its upper (?) levels are turbiditic.

The 15 m thick radiolarite - chert level (TrJKkpr) exaggarated in "undifferentiated allochthonous carbonates" and cherty limestones located in the northwest of the study area are thought to be belonging to this formation.

The formation tectonically overlies (and overlain by slices of) the İzmir flysch. However, in vicinity of Karaova (Muğla) it conformably overlies Kayaköy dolomite and passes to Karaböğürtlen formation (Philippson, 1915) upwards. The thickness of the unit is 300 - 350 m.

Orbitolina (*conicorbitolina*) cf. *conica* (d'Archiac), *Salpingoporella* sp. were determined in the formation and based on these fossils, the age is assigned as Albian - Cenomanian. However, considering the stratigraphic position of the widespread Late Liassic (Toartian) - Late Cretaceous Göçgediği formation, Late Jurassic - Late Cretaceous age is envisaged for the unit.

İZMİR FLYSCH (KTi)

The unit which has a wide extension in the frame of "İzmir - Ankara Zone" (Brinkmann, 1966) has been named as "İzmir flysch formation" around İzmir where it is observed widespread (Öngür, 1972) and has been defined as a group by Eşder (1988). In general, it is made up of a matrix comprised of clastics, radiolarite and basic volcanic rocks and blocks of various size, age and lithology in this matrix. In most of the previous works, it was defined as two different formations with the names "Cretaceous flysch / Belkahve and Kavaklıdere flysch" (Parejas, 1940); "Upper Cretaceous flysch" (Akartuna, 1962); "Flysch" (Verdier, 1963; Oğuz, 1966); "Cretaceous flysch" (Brinkmann, 1966; Brinkmann and İzdar, 1971); "Bornova flysch" (Konuk, 1977); "Ulupınar formation and Erdemirçay formation" (Konak et al., 1980) and in context of "Flysch assemblages" (Yağmurlu, 1980); "Cretaceous - Paleogene flysch" (Başarır and Konuk, 1981); "Belkahve" and "Çaldağ" formations (Akdeniz et al., 1986), it was defined as "Bornova complex" (Erdoğan, 1985; 1990*a,b*; Erdoğan and Güngör, 1992). According to its distribution in the study area, it was named and defined as "Zeytinköy formation" (Akat, 1980), "blocky flysch" (Başarır, 1981, 1989).

The unit is green, brownish green, brownish yellow, pinkish beige colored and the dominant lithologies are sandstone and shale; it includes serpantinite (KTis), radiolarite (KTir), diabase (KTid) and various limestone (KTik) blocks.

The Late Cretaceous flysch / blocky flysch units present in Lycian nappes are collected under the name of "Karaböğürtlen formation" (Philippson, 1915; Şenel, 1997*a,b*). The Karaböğürtlen formation which has relations with Bodrum nappe units, especially with Göçgediği formation (Mandalya formation / Pınaröztepe formation in the study area), corresponds to İzmir flysch, stratigraphically and from extension and assemblage points of view, which is in context of İzmir - Ankara Zone (Brinkmann, 1966); however, differentiation is based on structural relations.

The unit tectonically overlies the Efes nappe and Şirince metaflysch and is tectonically overlain by the Kayaköy and Pınaröztepe formations of the Alçakonak unit of the Bodrum nappe and by the undifferentiated dolomite - limestone units (TrJKkp), and is observed as blocks in it; besides thrust slices are also observed in these units (Figure 1b).

The age of the İzmit flysch is accepted in general as Late Cretaceous based on the ages obtained from itself / blocks and from its structural - stratigraphical setting. However, the following are the other ages given to the unit: Upper Maastrichtian - Paleocene or younger (Konuk, 1977), end of Cretaceous - Paleocene (Yağmurlu, 1980), Eocene (Düzbastılar, 1980), Campanian - Paleocene (Konak et al., 1980), Turonian - Paleocene (Akdeniz et al., 1982, 1986), Paleocene - Eocene (Başarır, 1989), Campanian - Danian (Erdoğan, 1990*a,b*). According to these, the Late Cretaceous - Early Tertiary (Danian?) age can be accepted for the unit.

NEOGENE - QUATERNARY

"The terrestrial Neogene sedimentation covering Late Early Miocene - (?) Middle Miocene period in the study area begins with, from bottom to top, the Kösele formation and lacustrine Söke formation and continues with fluvial Dededağ formation which overlies the Söke formation with low angle erosional unconformity and ends with Kuşadası formation. The Miocene volcanism symbolized by dacitic Balatçık volcanics and basaltic andesite - andesite Hisartepe volcanics cuts and overlies the Kuşadası formation. The Great Menderes Group which includes the Late Pliocene - Pleistocene sedimentation related to Great Menderes graben formation is comprised of, from bottom to top, alluvial Kartaltepe formation, fluvio - deltaic and lacustrine Savulca formation, alluvial Ortaklar formation and alluvial Yamaçköy formations." (Göktaş, 1998; Ünay and Göktaş, 1999). It is made up of Holocene, alluvial fan, river - delta, marsh - lagoon and sandy deposits and slope debris.

TECTONIC

In the study area, various tectono-stratigraphic units displaying different lithofacies, environment and metamorphism characteristics overlie each other with thrust contacts. These tectonic units have most probably gained their first structural shapings during theend of Cretaceous - Early Eocene period. As a result of the tensional tectonic regime developed during the Early Miocene - Quaternary the nappes, even if local, must have moved along the thrust planes and must have gained their present day geometries by the vertical and locally oblique faults.

RESULTS

As a result of this study, some earlier works have been revised and compiled and besides, 1/250 000 scale maps in M18 sheet were completed to finalize the 1/100 000 scale geological map. The pre-Neogene rock units have been differentiated to finalize the L18 1/100 000 scale geological map.

In the study area, from bottom to top, five tectonic units, namely Dipburun nappe, Efes nappe, Şirince metaflysch, Akçakonak unit and İzmir flysch have been differentiated and their stratigraphic relations have been revealed. These tectono stratigraphic units have been correlated with the units on the Samos Island and their continuity, except for some differences, have been indicated.

It has been shown that, the "cover schists" defined in the Menderes Masif, includes different tectono - stratigraphic units in the study area; and data was provided for the units such as "Karaova formation" and "Şirince metaflysch" to study them from the southeastern corner of the masif to the east - southeast corner of the masif in various stratigraphic relations.

Along the extensional area of the probable Early Triassic basic volcanism, stratigraphic similarity between gneissose schists and marbles with metabauxites have been determined.

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THE BIVALVIA AND GASTROPODA FAUNA OF THE AMMONITICO ROSSO FACIES OF LATE SINEMURIAN-EARLY PLIENSBACHIAN OF THE KÖSRELİK REGION (NE ANKARA-TURKEY); FIRST RECORD OF ANNELID POLYCHAETE SPECIES AND THEIR PALEOGEOGRAPHIC AND PALEOECOLOGIC CHARACTERISTICS

Yavuz OKAN* and İzzet HOŞGÖR*

ABSTRACT.- The nodular limestones of the Ammonitico Rosso facies of the Ankara region of the Central Anatolia, deposited during the Early-Middle Jurassic and show similar paleontological and sedimentological characteristics to those of the red nodular limestones of the northern and southern Alps. In particular, bivalves, gastropods, annelid, crinoid, brachiopod, belemnit and other cephalopods were sampled from the Ammonitico rosso facies sediments cropping out in the northwest of the Bağlum village in the north of Ankara. The following species have been described; four bivalv taxa (*Parainoceramus bileciki* Conti and Monari 1991, *Parainoceramus nicosiai* Conti and Monari 1991, *Mytilioides* sp. and *Palaeonucula* sp), three species of gastropods (*Pleurotomaria suessii* Hörnes 1853, *Pleurotomaria* sp. and *Eucyclus* (*Eucyclus*) sp.) and annelid polycahete *Glomerula gordialis* (Schlotheim 1820). They have been identified for the first time in the Early Jurassic sequences of Turkey and their paleogeographic characteristics are discussed.

Anahtar Kelimeler: Ammonitiko rosso, Bivalvia, Gastropoda, Annelid, paleoekoloji, paleocoğrafya.

INTRODUCTION

Many Jurassic successions in the Northern and Southern Alpine region consist of red marls and noduler limestones of the type known as Ammonitico Rosso (Hallam, 1969; Galacz, 1984; Varol and Gökten, 1994; Soussi et al., 1998, 1999). Facies of Ammonitico Rosso type sedimentation are widespread in Turkey; in general, Ammonitico Rosso type outcrops are seen in the following regions in the northwest Anatolia: Halılar, Bursa-Bilecik, Mudurnu-Baypazarı and Aktaş (Altıner et al., 1991; Koçyiğit et al., 1991; Nicosia et al., 1991), from central Anatolia: Ankara region, Hasanoğlan (Alkaya, 1991), Yakacık and Bağlum-Kösrelik (Pompeckj, 1897; Gugenberger, 1929; Bremer, 1965; Varol and Gökten, 1994; Alkaya and Meister, 1995; Kuznetsova et al., 2001) (Figure 1).

Clayey and marly Ammonitico Rosso and their nodular limestones, in our study area range from Lias to Dogger. The Liassic carbonate succession, exposed around the Kösrelik region consists of conglomera, sandstones, red marls, noduler limestones, pelagic limestones from bottom to top; and disconformably overlies the Triassic metasediments (Gökten et al., 1988; Varol and Gökten, 1994). In this region, Ammonitico Rosso type sediments, and the other parts of the whole Jurassic succession contain fossils in all levels. While the densely sedimented red-marly section of the succession is especially rich in ammonites, the sandy limestones are rich in crinoids, brachiopods, belemnits, bivalus and gastropods (Varol and Gökten, 1994).

SYSTEMATIC PALEONTOLOGY

Middle Jurassic bivalve and gastropod faunas are well recorded in the related literature, but Lower Liassic bivalve and gastropods faunas have rarely been mentioned. The informations about the Liassic bivalve and gastropods of the Alpine and Mediterranean regions, have been given by the more recent papers of Damborenea (1987*a*, 1987*b*), Szabo (1979, 1984, 1995), Conti and Monari (1991), Szente and Vörös (1992)

*Ankara Üniversitesi, Mühendislik Fakültesi, Jeoloji Mühendisliği, 06100, Tandoğan, Ankara.
E-posta: Yavuz.Okan@eng.ankara.edu.tr

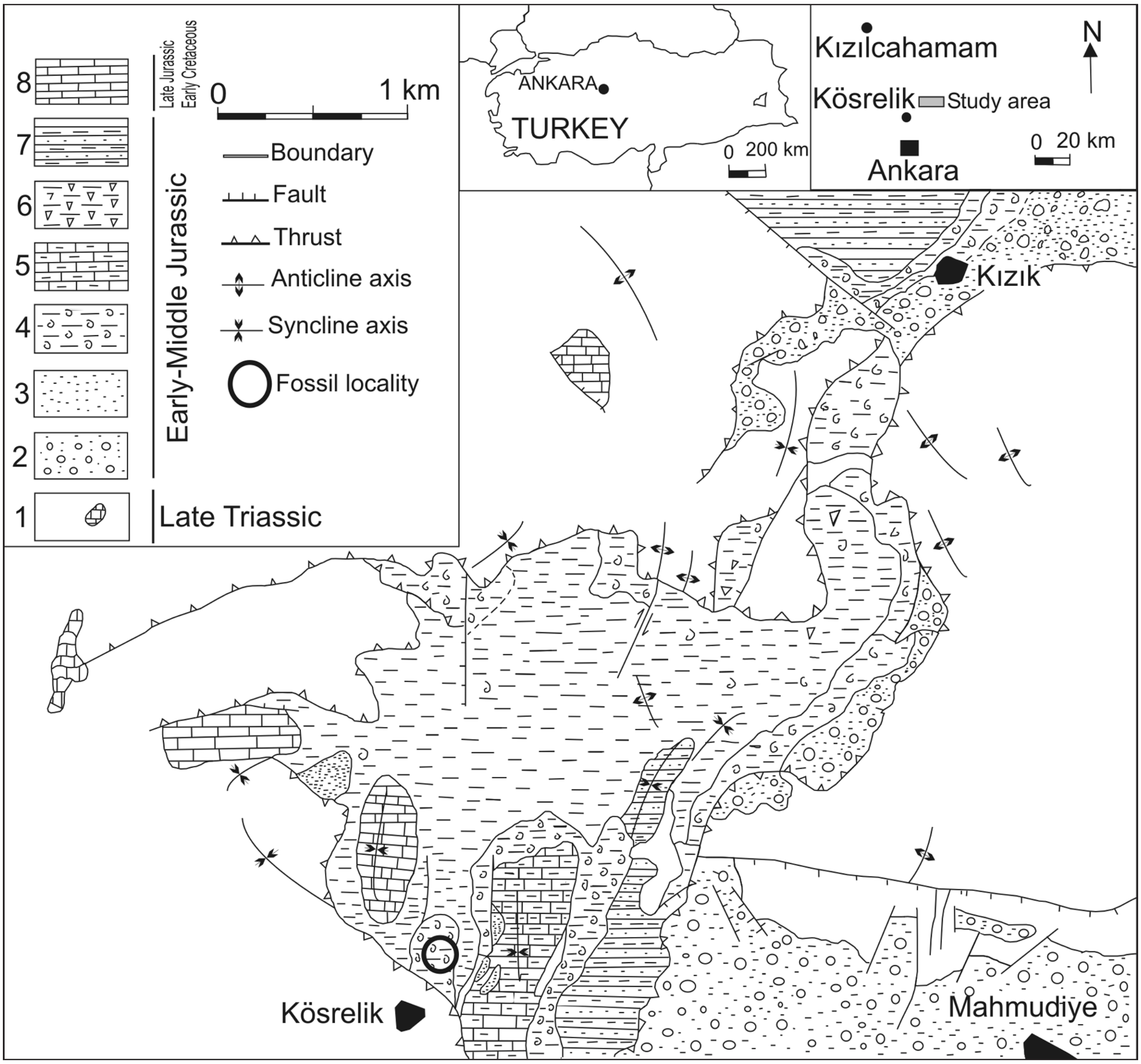


Figure 1 - Geological map of the study area, 1- Metasediment, 2- Conglomerate, 3- Sandstone, 4- Red marly limestone, 5- Nodular limestone, 6- Red and grey marly limestone, 7- Turbiditic sediment, 8- Pelagic limestone (modifeid from Varol and Gökten, 1994).

and Valls et al. (2004). Classification of the bivalv species in this study follows that of Bieler and Mikkelsen (2006) and the gastropods species follows that of Wenz (1938-44) and Knight et al. (1964). In the classification of the *Eucyclus* (*Eucyclus*) sp. the Hickman and McLean (1990)'s study have been taken in to consider in this study. The superfamily name was proposed by Golikov and Starobogatov (1975). Cossmann (1916) and Wenz (1938) established the Amberleyidae and Littorinidae families where *Euscyclus* is only a subgenus of *Amberleya*. Golikov and Strobogatov (1975) recognized that inclusion of *Eucyclus* as a subgenus in *Amberleya* is erroneous, and that is why they proposed usage of Eucyclidae as family name

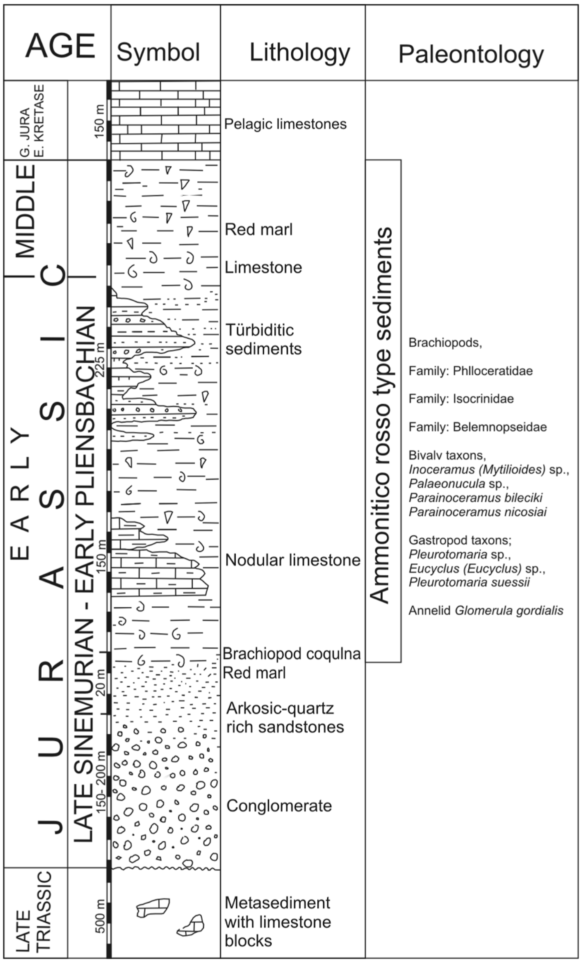


Figure 2 - General stratigraphic column of the Ammonitico-bearing Jurassic sequence, Kösrelik area (modifeid from Varol and Gökten, 1994).

and Eucycloidea Koken as superfamily name respectively (Hickman and McLean 1990; Szabo, 1995; Conti and Monari, 2001). Our fauna consisting of bivalves and gastropods have very similar to the species described from the Lower Jurassic of the Bilecik area (Conti and Monari 1991).

The annelid of the genus *Rotularia* is a common element of Jurassic to Early Tertiary shallow marine faunas but their palaeoecologic and stratigraphic significance have rarely been subjected in the related studies. The polychaete annelids species have been reported first time from the Early Eocene of the Çankırı Basin by Hoşgör and Okan (2006). In this study, the polychaete annelids species from the Lower Jurassic of the study area have been determined and the characteristics have been studied by electron microscope (SEM). Classification of the annelids in this study follows that of Nielsen (1931), Regenhardt (1961) and Radwanska (2004).

Class : Bivalvia Linne, 1758
Subclass : Palaeotaxodonta Korobkov, 1954
Order : Nuculoida Dall, 1889
Superfamily : Nuculoidea Gray, 1824
Family : Nuculidae Gray, 1824
Genus : *Palaeonucula* Quenstedt, 1930

Palaeonucula sp.
Plate-1, figure 1, 1a

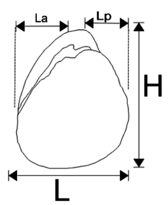
Description.- Small-sized shell, subtrigonal-quadrangular in shape, quite inflated and with umbones posteriorly placed. Anterior region elongated, ornamentation formed by a slightly growth striae. (Measurements, see Figure. 3).

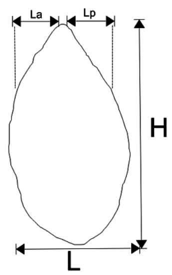
Remarks.- The Hungarian species *Palaeonucula* Quenstedt (Szente 1995, p. 60, pl. 6, figures 1-2) and the Jurassic from Bilecik species (Conti and Monari 1991, p. 247, pl. 1, figures3-4) are a similar species described from the study area. *Nuculoma* Cossmann (Cox et al., 1969, p. 231, figure A3-6) is a very similar species. It is differentiated from *Palaeonucula* Quenstedt by an elongated posterior margin and heavily growth striae.

Paleoecologic and Paleogeographic implications.- Palaeonucula forms have probably evolved many strategies of life behaviour from the Triassic to Late Jurassic. The main trophic groups of this species include infaunal detritivores. Many Palaeonucula species described from the Triassic to Jurassic of Asia, North America, Jurassic Eurapean localities (Germany, Hungary, Frace and Span) (Cox et al., 1969;

Bivalvia

Family Nuculidae **Family Inoceramidae**





Dimensions (mm)

Palaeonucula sp.

Specimen	H	L	La	Lp
AJK AU 01	11	9	4	3

Inoceramus (Inoceramus) sp.

Specimen	H	L	La	Lp
AJK AU 02	11	9	4	3

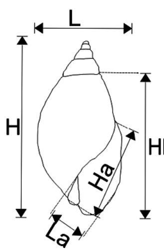
Parainoceramus bileciki

Specimen	H	L	La	Lp
AJK AU 03	39	24	10	5
AJK AU 04	29	19	7	3
AJK AU 05	-	26	-	-
AJK AU 06	-	19	6	4

Parainoceramus nicosiai

Specimen	H	L	La	Lp
AJK AU 07	35	25	6	5
AJK AU 08	29	19	8	6
AJK AU 09	18	12	7	3

Gastropoda



Pleurotomaria sp.

Specimen	H	L	Hl	Ha	La
AJK AU G1	5	7	2	-	-

Pleurotomaria suessii

Specimen	H	L	Hl	Ha	La
AJK AU G2	9	11	4	3	2

Eucyclus (Eucyclus) sp. s

Specimen	H	L	Hl	Ha	La
AJK AU G3	-	14	-	-	-

Figure 3 - Measurements taken from the bivalvs and gastropods species, H- Height, L- Length, La- Length of the anterior margin, Lp- Length of the posterior margin, Hl- Height of the last whorl, Ha- Height of the aperture, La- Length of the aperture.

Szente, 1995; Fürsich et al., 2001; Delvene, 2003), and from the Turkey, Liassic of Bilecik-Günören (Conti and Monari, 1991).

Order : Pterioida Newell, 1965
Suborder : Pteriina Newell, 1965
Superfamily : Pterioidea Gray, 1847
Family : Inoceramidae Giebel, 1852
Genus : *Inoceramus* Sowerby, 1814
Subgenus : *Mytiloides* Brongniart, 1822

Inoceramus (*Mytiloides*) sp.
Plate-1, figure 2

Description.- Medium-sized shell, inequilateral, mytiliform, moderately inflated with maxiumum inflation placed in the dorsal half of the valve below the rounded umbonal area. Anterior margin quite elongated, posterior margin weakly convex. Ornamentation formed by about a strongly concentric plicae (Measurements, see Figure 3).

Remarks.- This species does not well show generic characters well. The species merely exhibits some general likeness with *Inoceramus hamadae* Hayami 1960 (p. 302, pl. 15, figure 14) from Japan of the Middle Jurassic. It is differentiated from *Inoceramus* (*Mytiloides*) sp. by a large shell, narrow ligamental area and strongly concentric plicae.

Paleoecologic and Paleogeographic implications.- Species of *Inoceramus* (*Mytiloides*) sp. are epifaunal suspension feeders and lives on sandy bottom. (Fürsich, 1977; Fürsich et al., 2001; Delvene, 2003). *Inoceramus* (*Mytiloides*) sp. species described from the Early Jurassic-Late Cretaceous of European, and from the Turkey, Liassic of Bilecik-Günören (Conti and Monari, 1991).

Genus: *Parainoceramus* Voronetz, 1936

Parainoceramus bileciki Conti and Monari, 1991
Plate-1, figure 3, 3a

1991 Parainoceramus bileciki Conti and Monari, p. 251-252, pl. 3, figures. 5-10.

Description.- Small-sized shell, equivalve, elongated with ventral direction, umbonal area narrow, beaks curved (Plate 1, figure 4a), anterior margin elongated and straight than posterior margin, ornamentation formed by about a slightly concentric plicae (Measurements, see Figure 3).

Remarks.- This species was first described from from Turkey, the Liassic of Bilecik-Günören (Conti and Monari, 1991). It is a very similar species described from the Liassic of the Bağlum-Kösrelik region. Additionally, the main similiar character between these species is the ligamen area with elongated posterior teeth.

Parainoceramus bileciki Conti and Monari are very similar to *Parainoceramus pinnaeformis*= *Gervilla pinnaeformis* (Dunker, 1851) (p. 179, pl. 25, figures 10-11) a German species of the Early Liassic age. But our sipecies has extreme ligamental area.

Paleoecologic and Paleogeographic implications.- Species of *Parainoceramus bileciki* Conti and Monari are epifaunal suspension feeders and lives on sandy bottom. (Fürsich, 1977; Fürsich et al., 2001; Delvene, 2003). In Turkey it occurs in the Liassic of the Bilecik-Günören (Conti and Monari, 1991).

Parainoceramus nicosiai Conti and Monari 1991
Plate-1, figures. 4, 4a, 5

1991 *Parainoceramus nicosiai* Conti and Monari, p. 253-254, pl. 2, figures. 4-10.

Descirption.- Species of small size, equivalve, mytiliform, shell wall of reduced thickness. Umbonal area narrow, inflated, slightly curved beak, anterior margin straight and slightly more elongated than the posterior margin. External surfaces commonly smooth with slightly concentric plicae (Measurements, see Figure. 3).

Remarks.- This is the first record of species from Bilecik-Günören, where it is the most characteristic umbonal area of the Liassic. *Parainoceramus altineri* Conti and Monari 1991 (p. 250-251, pl. 2, figures. 11-17) is a very similar species first described from the Jurassic of Bilecik. It is differentiated from *Parainoceramus nicosiai* Conti and Monari by narrow-sharp umbonal area. Most of the English Jurassic species have been assigned to Pseudomytiloides dubius (Sowerby) (Cox et al., 1969, p. 320, figure C49 2). The main distinguishing character between these species is the more concentric plicae of *Parainoceramus nicosiai* Conti and Monari and its less convex shell.

Paleoecologic and Paleogeographic implications.- Species of *Parainoceramus nicosiai* Conti and Monari are usually considered byssally attached suspension feeding, a part of some Jurassic Inocemid groups that could have developed as free-resting on the sandy bottom (Fürsich, 1977; Fürsich et al., 2001; Delvene, 2003). In Turkey it occurs in the Liassic of the Bilecik-Günören (Conti and Monari, 1991).

Class	: Gastropoda Cuvier, 1797
Subclass	: Prosobranchia Edwards, 1848
Order	: Archaeogastropoda Thiele, 1925
Suborder	: Pleurotomariina Cox ve Knight, 1960
Superfamliy	: Pleurotomarioidea Swainson,1840
Family	: Pleurotomariidae Swainson, 1840
Genus	: *Pleurotomaria* Defrance, 1826

Pleurotomaria sp.
Plate-1, figure 6

Description.- Shell with gradated spire, trochoid forms, number of whorls about 4-5, sunken sutures, slightly high spire, subquadrangular whorl section (Measurements, see Figure 3).

Remarks.- The shell shape and position of the trochoid-selenizone are typical of the genus *Pleurotomaria*, due to the lack of the whole shell morphologic characters. *Pleurotomaria* sp., (Conti and Monari, 1992, p. 264, pl. 5, figures. 14-15) is a very similar species from the Jurassic of Bilecik. It is differentiated from our species by high trochoid-selenizone form.

Paleoecologic and Paleogeographic implications.- Species of *Pleurotomaria* sp., are epifaunal suspension feeders (Fürsich, 1977; Fürsich et al., 2001; Delvene, 2003). *Pleurotomaria* sp., species described from the Early Jurassic (France and Spanin) and Early Cretaceous (Aptian) of European (Knight et al., 1969; Fürsich et al., 2001), and from the Turkey, the Liassic of Bilecik-Günören (Conti and Monari, 1991).

Pleurotomaria suessii Hörnes 1853
Plate-1, figure 7, 7a

1853 *Pleurotomaria suessii* Hörnes, Hauer, p. 762.

1911 *Pleurotomaria suessii* Hörnes, Gemmellaro, p. 213, pl. 10, figure 10-12.

1991 *Pleurotomaria*? cfr. *suessii* Hörnes, Conti and Monari, p. 263, pl. 5, figure 1-4.

Description.- Shell small with depressed spire, number of whorls about 3-4, sunken suture, section of the whorl differentiated from the last whorl with elevation (Measurements, see Figure 3).

Remarks.- In the specimens we posses the collabral with literatures, and our specimen are very similar to those coming from Gemmellaro (1911). Our meterial is represented by at a low whorl number, but *Pleurotomaria* cfr. *platyspira* Eudes-Deslongchamps (Conti and Monari, 1991, p. 263, pl. 4, figure 12-15) is a very similar species from the Jurassic of Bilecik.

Paleoecologic and Paleogeographic implications.- Species of *Pleurotomaria suessii* Hörnes 1853 are epifaunal suspension feeders (Fürsich, 1977; Fürsich et al., 2001; Delvene, 2003). *Pleurotomaria suessii* Hörnes 1853 species described from the Early Jurassic of Italy (Gemmellaro, 1911), and from Turkey, Liassic of Bilecik-Günören (Conti and Monari, 1991).

Suborder : Trochina Cox and Knight, 1960
Superfamily : Eucycloidea Koken, 1897
Family : Eucyclidae Koken, 1897
Subfamily : Eucyclinae Koken, 1897
Genus : Eucyclus Eudes-Deslongchamps, 1860
Subgenus : Eucyclus Eudes-Deslongchamps, 1860

Eucyclus (*Eucyclus*) sp.
Plate-1, figure 8

Description.- Shell medium size, high spire, number of whorls about 4-5, whorl convex and separared by deep channel of suture (Measurements, see Figure 3).

Remarks.- Eucyclus (*Eucyclus*) sp., (Szabo, 1995; p. 68-71, pl. 7, figures. 4-6, 10-13, Conti and Monari, 2001; p. 190-199, pl. 6, figures. 6-26) is a very similar species from the Jurassic, due to the lack of the last whole shell morphologic characters.

Paleoecologic and Paleogeographic implications.- Species of *Eucyclus* (*Eucyclus*) sp., are epifaunal suspension feeders (Fürsich, 1977; Fürsich et al., 2001; Delvene, 2003). In Europe it occurs from the Triassic to Oligocene of the Germany and Hungary (Szabo, 1995).

Class : Polychaeta Grube 1850
Order : Sedentaria Lamarck 1818
Family : Serpulidae Rafinesque 1815
Subfamily : Filograninae Rioja 1923
Genus : *Glomerula* Nielsen 1931

Glomerula gordialis (Schlotheim 1820)
Plate-2, figure 1, 2, 2a

1831 *Serpula gordialis* Schlotheim, Goldfuss, p. 234, pl. 69, figure 8.

1931 *Glomerula gordialis* (Schlotheim), Nielsen, p. 88, pl. 1, figures 9-11.

1956 *Serpula* (Cycloserpula) *gordialis* (Schlotheim), Parsch, p. 214, pl. 20, figures 15-16.

1961 *Glomerula gordialis* (Schlotheim), Regenhardt, p. 26, pl. 1, figure 2.

1965 *Glomerula gordialis* (Schlotheim), Nestler, p. 74, pl. 4, figures 6, 8-10.

1968 *Glomerula gordialis* (Schlotheim), Bignot, p. 18, pl. 1, figure 1; pl. 2, figures 1-4.

1973 *Glomerula gordialis* (Schlotheim), Pasternak, p. 9, pl. 1, figures 3-5.

1983 *Glomerula gordialis* (Schlotheim), Jager, p. 26, pl. 2, figures 1-18.

1987 *Glomerula gordialis* (Schlotheim), Jager, p. 40, pl. 1, figures 17-20.

2004 *Glomerula gordialis* (Schlotheim), Radwanska, p. 38-39, pl. 1, figures 1-10.

2006 *Cycloserpula gordialis* (Schlotheim), Zitt et al. figure 15 I.

Description.- The solitary tube attached to the substrate is composed of few whorls. The tube is either regularly coiled planispirally. The outer surface of the tube is sculptured by bioerozion (Plate 2, figure 1).

Remarks.- Most of the jurassic polychaete species have been assigned to *Glomerula gordiali*s. The main generic character of this species is the solitary tube and its joining with another tube.

Paleoecologic and Paleogeographic implications.- Species of *Glomerula gordiali* are semiinfaunal suspension feeders on the sandy bottom of shallow water condition (Hoşgör and Okan, 2006). *Glomerula gordialis* is a stratigraphically and geographically widely distributed species. In Turkey, it exists in the Early Jurassic of the Ankara region. It is also described from the Jurassic to Early Tertiary of Europe, for example, from the Early-Middle Jurassic of Germany (Parsch, 1956), from the Middle-Late Jurassic of the Germany, Poland and central Rusia (Goldfuss, 1831; Radwanska, 2004; Ippolitov, 2007), the Late Cretaceos of the Germany (Regenhardt, 1961; Nestler, 1965; Pasternak, 1973; Jager, 1983, 1987), Denmark (Nielsen, 1931), and the Czech Republic (Zitt et al., 2006) and, the Early Tertiary (Danian) of the Denmark (Nielsen, 1931).

DISCUSSION AND CONCLUSIONS

The nodular limestones and red marls of the Bilecik and Ankara regions, deposited during the Early to Middle Jurassic are known as Ammonitico Rosso facies. Many Jurassic successions in the Alpine-Mediterranean region consist of ammonitico rosso and are subdivided into the following two types; calcareous ammonitico rosso and marly ammonitico rosso. The facies and depositional environments of the ammonitico rosso are confined to seamount topographies in the Mediterranean region. Similar conditions have also been reported for the sequences of Jurassic. (Şengör and Yılmaz, 1981; Görür et al., 1983; Galacz, 1984; Nicosia et al., 1991; Koçyiğit and Altıner, 2002).

This is the first description of Early Jurassic (Late Sinemurian-Early Pliensbachian) bivalves, gastropods and one species of polychaete faunas from Kösrelik, central Anatolia. Four species of bivalves, *Parainoceramus bileciki* Conti and Monari 1991, *Parainoceramus nicosiai* Conti and Monari 1991, *Mytilioides* sp. and *Palaeonucula* sp., three species of gastropods, *Pleurotomaria suessii* Hörnes 1853, *Pleurotomaria* sp. and *Eucyclus* (*Eucyclus*) sp.,and one species of polychaete, *Glomerula gordialis* (Schlotheim 1820) are described from the Kösrelik region and its paleogeographic characteristics discussed.

Opening of the northern branch of the Neotethys affected large areas in the Mediterranean, except its southern and eastern coasts by the early Jurassic time, however Tekin et al (2004) proposed a Late Triassic opening for the northern branch of the Neotethys. Environmental analysis of the Liassic deposits in the Pontides show that the Bilecik to Ispir regions were characterized by rapidly subsiding seamounts (Şengör, 1979; Görür et al., 1983). The topography determined the tectonic characteristic of the northern margin of the Neotethys and controlled the sedimentation durin the Early-Middle Liassic time . So many different facies have been developed around the Mediterranean area. (Hallam, 1969; Görür et al., 1983; Galacz, 1984; Nicosia et al., 1991).

Finally, in the Early Jurassic time the Kösrelik fauna is very similar to the faunas of Bilecik. So the environmental conditions must have been essentially the same too.

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PLATES

PLATE I

Figure 1- *Palaeonucula* sp., left valve, AJK AU 01.

Figure 1a- *Palaeonucula* sp., ligamental area view, AJK AU 01.

Figure 2- *Inoceramus* (*Mytilioides*) sp., left valve, AJK AU 02.

Figure 3- *Parainoceramus bileciki* Conti and Monari 1991, right valve, AJK AU 03.

Figure 3a- *Parainoceramus bileciki* Conti and Monari 1991, right valve, AJK AU 04.

Figure 4- *Parainoceramus nicosiai* Conti and Monari 1911, left valve, AJK AU 07.

Figure 4a- *Parainoceramus nicosiai* Conti and Monari 1911,ligamental area view, AJK AU 07.

Figure 5- *Parainoceramus nicosiai* Conti and Monari 1911, left valve, AJK AU 08.

Figure 6- *Pleurotomaria* sp., dorsal view, AJK AU G1.

Figure 7- *Pleurotomaria suessi* Hörnes 1853, apertural view, AJK AU G2.

Figure 7a- *Pleurotomaria suessi* Hörnes 1853, apical view, AJK AU G2.

Figure 8- *Eucyclus* (*Eucyclus*) sp., dorsal view, AJK AU G3.

(scale: 10 mm)

PLATE - I

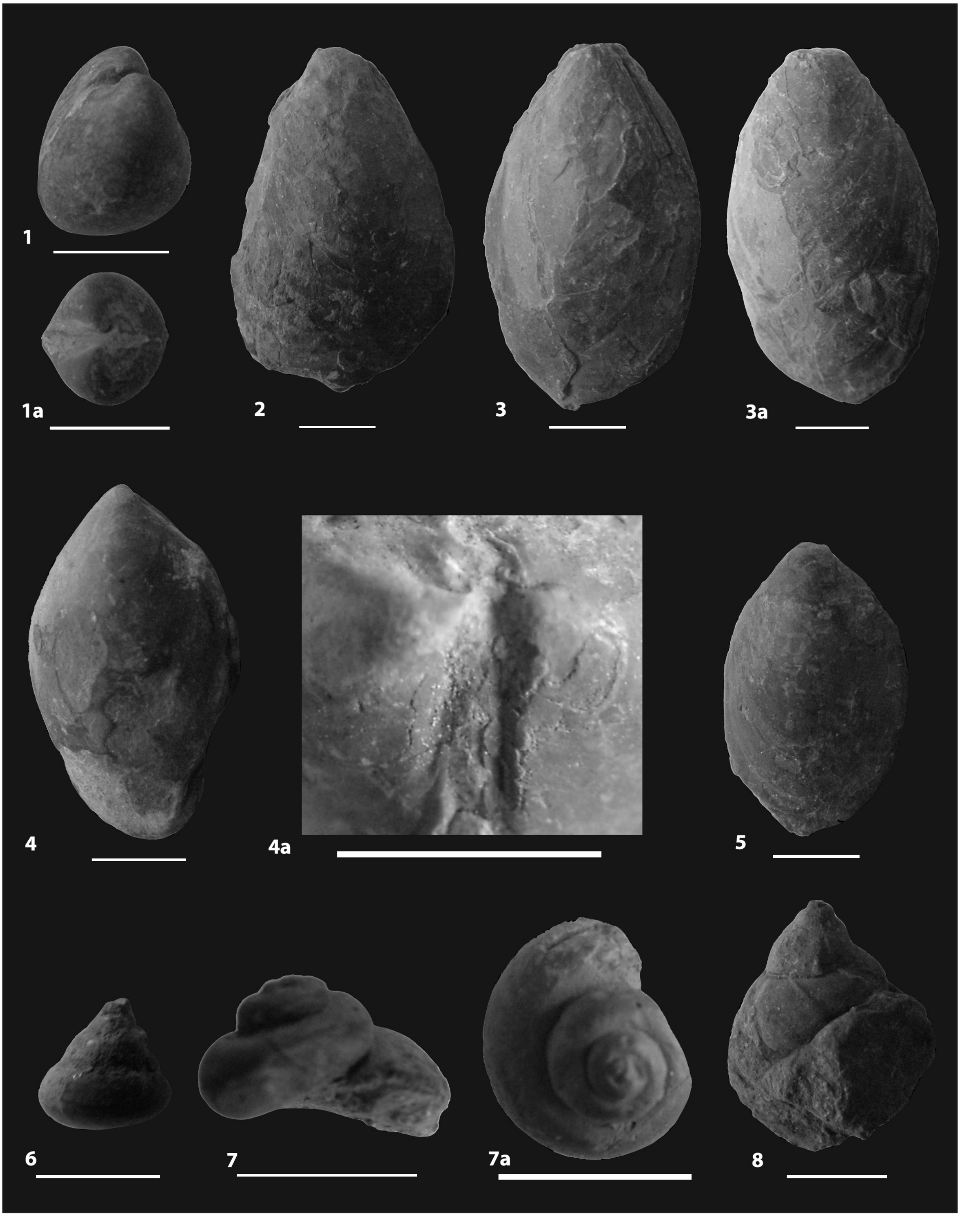


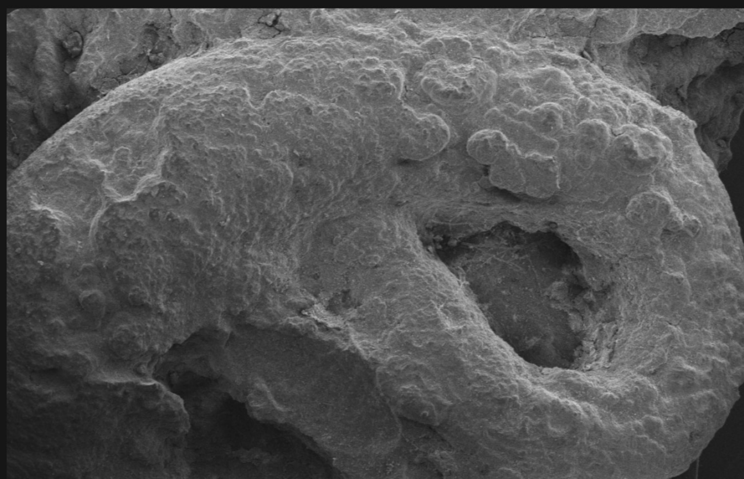
PLATE II

Figure 1- *Glomerula gordialis* (Schlotheim 1820), top view, to show the bioerosion of the solitary tube. (scale: 200 μm)

Figure 2- *Glomerula gordialis* (Schlotheim 1820), top view, the solitary tube and its joining with another tube. (scale: 200 μm)

Figure 2a- *Glomerula gordialis* (Schlotheim 1820), the solitary tube and its joining with another tube. (scale: 100 μm)

PLATE - II



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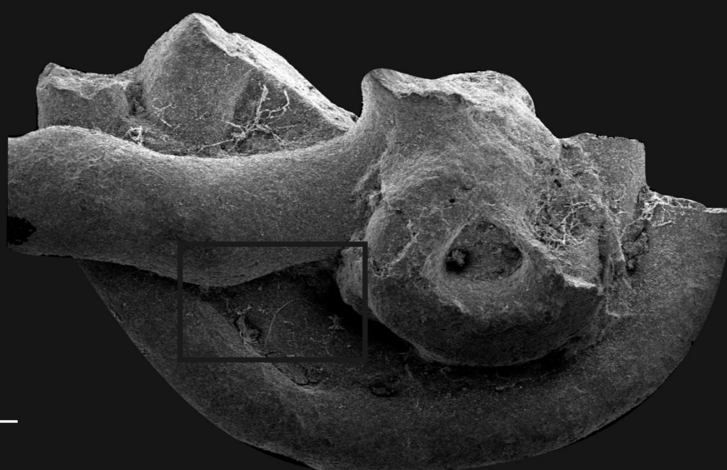

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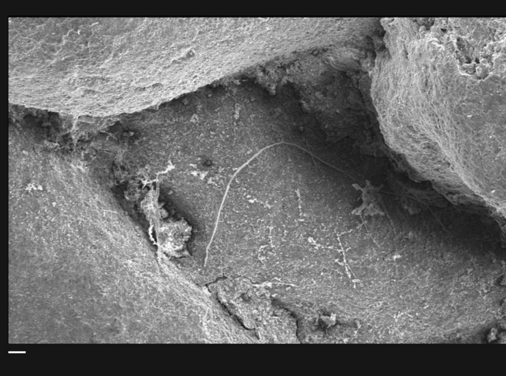

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Mineral Res. Expl. Bull., 135, 31-44, 2007

AN IMPORTANT CHABASITE OCCURRENCE IN CENTRAL ANATOLIA AND ITS MINERALOGICAL FEATURES

M. Bahadır ŞAHİN*

ABSTRACT.- The Lower - Middle Miocene Aktepe Formation cropping out to the south of Ankara (Central Anatolia) is comprised of volcano - sedimentary lacustrine deposits. In the formation mainly three zeolitic tuffaceous layers including dominant chabasite were determined. Based on the data obtained from XRD and SEM investigations, it was determined that the authigenic zeolite minerals are chabasite, erionite and clinoptilolite, and minor smectite in some samples. Where the clinoptilolite is dominant, at a location, it has been observed that K-feldspar enters into the mineralogical composition. The main mineral assemblages in zeolitic tuffs are determined as "chabasite + erionite + clinoptilolite" and "chabasite + erionite + clinoptilolite + K-feldspar".The first data obtained points out that the Aktepe Formation has deposited in a saline - alkaline lacustrine environment. It can be said that, the zeolitic tuff occurrences in which chabasite is abundantly present, has economical potential.

Key words: Chabasite, zeolite, Central Anatolia, Lower - Middle Miocene, volcano sedimentary rocks.

INTRODUCTION

In Central Anatolia, according to the studies carried out by Temel and Gündoğdu (1996) around Cappadocia, chabasite mineral is found in zeolitic tuffs which are known to be wide-spread in this region. The first chabasite occurrence that have economical potential, however, has been found in Lower - Middle Miocene volcanosedimentary - lacustrine deposits to the 80 km south of Ankara (Figure 1) in the scope of a project realized by MTA in Central Anatolia.

The zeolite occurrences located in the study area corresponds to the "closed basin zeolites" proposed by Sheppard and Simandi (1999). In this region, during the previous geological investigations on the basis of the formations (Aktepe Formation), it has ben stated that the lacustrine deposits contained volcanic intercalations and various tuff layers (Uğuz et al., 1999). However, no information on the mineralogical compositions of the tuffs and zeolite occurrences was given in this study (Uğuz et al., 1999).

During the studies explained in this paper, pre-sence of zeolitic occurrences and their mineralogical compositions have been revealed for the first time. The field work carried out on the Ak-tepe formation cropping out near Akviran-çarsak Village, which is comprised of a volcanosedimentary lacustrine sequence including three main zeolitic tuff layers. The distance between the tuff layers, of which thickness is about 20 cm - 1.5 m, varies between 1.5 - 4 m. The dips of the beds vary (25°-90°) based on tectonic effects. The samples collected from these beds have been studied by using the XRD and SEM methods and the mineralogical and textural features of the zeolite minerals (chabasite, erionite, clinoptilolite) have been revealed.

TECTONIC SETTING

The study area is located in about 80 km south of Ankara on a subduction zone separating the deposits of active and passive continental margin, called Sakarya continent and Central Anatolian Metamorphic Massifs (Görür et al., 1984; Dellaloğlu et al., 2001; Figure 2). The basement rocks cropping out in Central Anatolia, in general, are defined as a micro-plate surrounded by branches of Neo-Tethys during Mesosoic - Paleocene period (Şengör et al., 1984).

* Maden Tetkik ve Arama Genel Müdürlüğü, Maden Etüt ve Arama Dairesi, 06520 Ankara

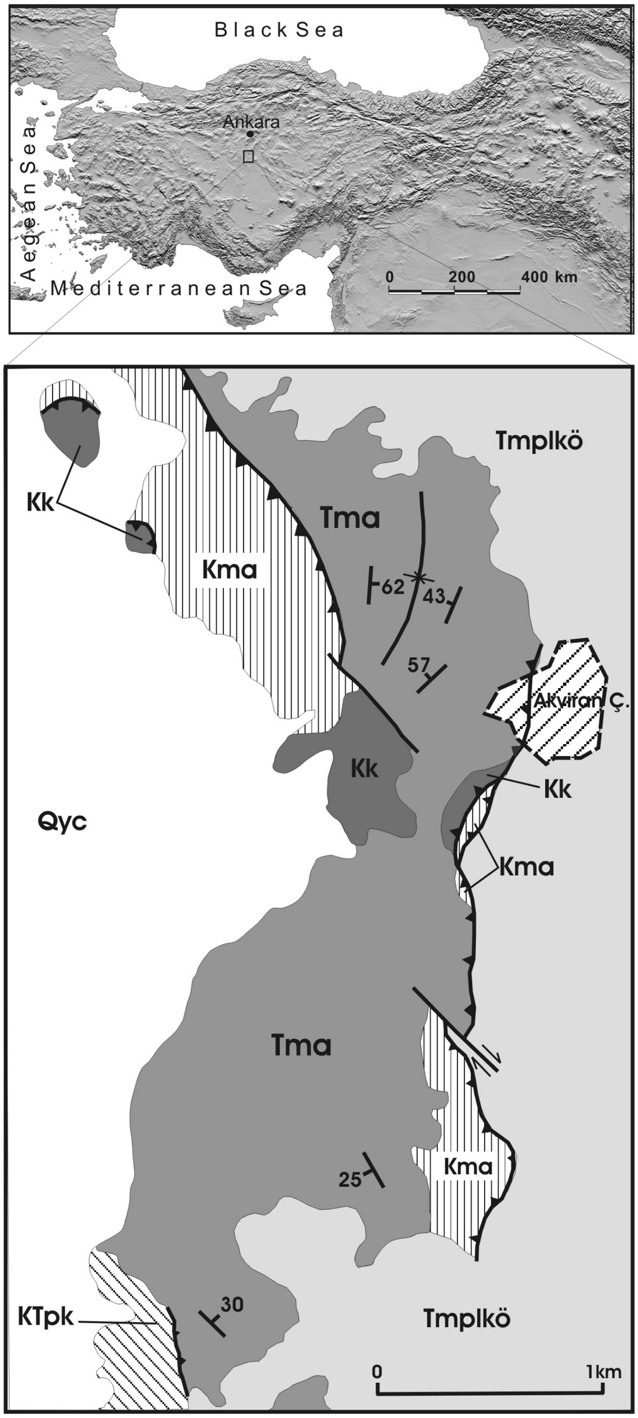

Figure 1- Location and simplified geological map of the study area (after Uğuz et al., 1999).

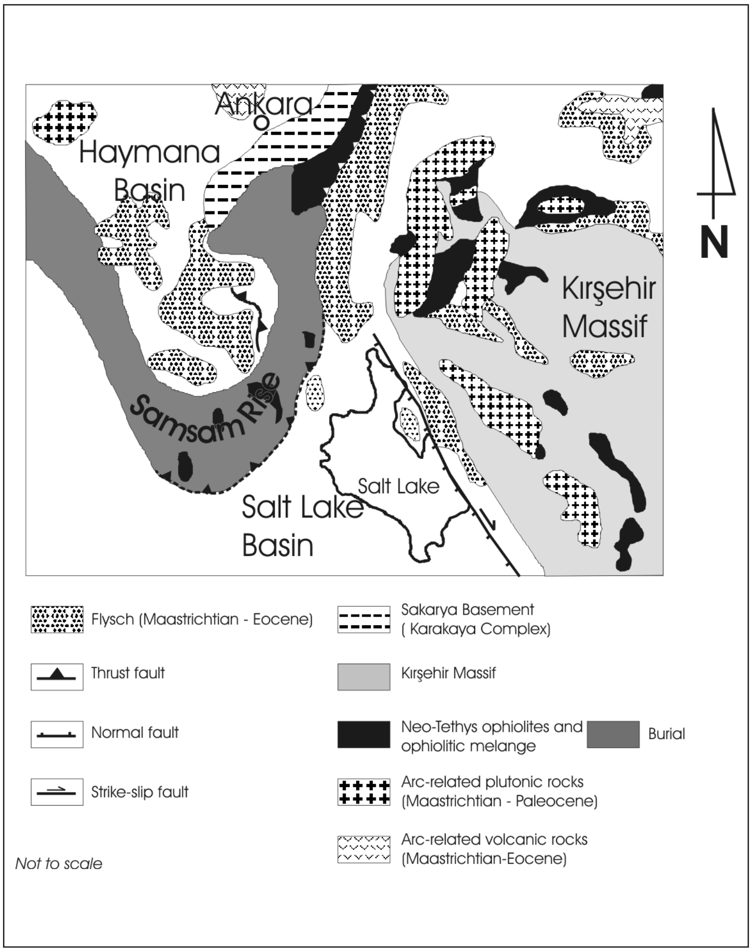

Figure 2- Simplified geological map of the Lake Tuz Basin and the sur rounding regions (Görür et al., 1984).

As a result of the continental collision (Kırşehir Block - Sakarya Continent) during Late Maastrictian - Late Paleocene, Haymana and Salt Lake basins have formed, on the other hand, the ophiolitic melange known as Ankara Melange has emplaced. This ophiolitic melange, which separates the Haymana and Salt Lake basins with a structural rise namely Samsam rise (Görür et al., 1984) on which the study area has been developed (Figure 2).

While the lacustrine deposits are comprised of Neogene clastics and evaporites overlying the Eocene marine deposits and the ophiolitic melange, in certain regions have volcanic products as well. The volcanic series which are comprised of tuff and lavas in general, are laterally transitive to lacustrine deposits mainly dominated by carbonates and clastics. The ophiolitic melange of the Samsam Rise and the overlying volcanic and / or volcanoclastics are widespreadly observed, and at the basement, marine units of the Haymana Basin take place.

GEOLOGICAL CHARACTERISTICS

The formation in which zeolitic tuff occurrences are included in the study area is the Lower - Middle Miocene Aktepe formation (Uğuz et al., 1999). This is a widespread formation in Central Anatolia and typically crops out around Çankırı where it is called Hançılı Formation by Akyürek et al. (1984).

Aktepe formation is stratigraphically located on the Ankara Melange, however, it is observed that Ankara Melange tectonically overlies Aktepe Formation in the study area. The Upper Miocene -Lower Pliocene terrestrial deposits of the Kömüşini Formation (Uğuz et al., 1999) unconformably overlies the Aktepe formation (Figure 1).

Aktepe formation is a volcano - sedimentary sequence made up of siltstone, mudstone, bituminous shale, zeolitic siltstone and zeolites. These series corresponds to a lacustrine depositional environment that has developed during Lower - Middle Miocene and is observed in relation to the Karacadağ Volcanics comprising basaltic - andesitic lava, tuffs and agglomerates (Uğuz et al., 1999).

In the study area, mainly three different zeolitic tuff layers were differentiated: layer 1: average thickness= 40 cm, layer 2: average thickness= 65 cm and layer 3: average thickness= 80 cm (Figure 3). Chabasite bearing zeolitic tuff lenses of 10 - 20 cm thick in average accompanying these layers also exist in the area.

METHODOLOGY

For mineralogical studies, samples were collected from three tuff layers as well as the other lithological units.

The samples selected are outcrop, trench and core samples. On these samples XRD and SEM analyses were carried out and the results were compared.

The mineralogical compositions of the samples were first determined at the XRD Laboratory (Philips, PW 1830: Cu-K , 30 k$_\alpha$V, 40mA,

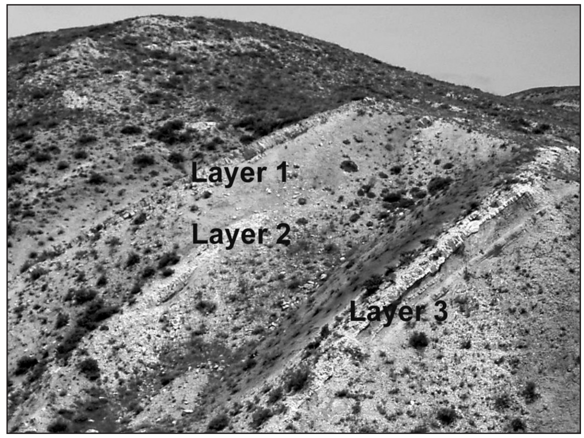

Figure 3- Zeolitic tuff layers bearing chabasite (from older to younger: Layer 3, Layer 2 and Layer 1).

2 θ :2.5°-70°, 6°/dk.) of the Mineralogy - Petrography Laboratory of MTA, later on, the same samples were investigated at the SEM Laboratory of the Hacettepe University (Zeiss, EVO 50-EP: scanning conditions are shown on the photographs).

During the SEM investigations especially the textural features of the samples were revealed as well as their mineralogical contents.

MINERALOGY

XRD INVESTIGATIONS

Whole rock XRD analyses of the samples were performed in order to determine the mineralogical compositions of the zeolitic tuffs. When notice to the mineralogical compositions of the representative samples given in table 1, it can be seen that the dominant zeolite mineral is chabasite. Presence of the erionite and clinoptilolite at various amounts indicate the existence of the "chabasite + erionite + clinoptilolite" paragenesis. Glassy material (volcanic glass) is mostly observed in accompanying to this assemblage. It can be said that the amounts of the minerals vary respectively depending on layers and locations, and that the amount of the chabasite is sufficient to be evaluated as an industrial raw material, and finally that the erionite is in less amounts in the-

Table 1- Mineralogical compositions according to XRD investigations.

Sample No	Layer No	Thickness (cm)	Chabasite	Erionite	Clinoptilolite	Smectite	Amorphous material
GA-158	2	60	dominant	very few	-	-	very few
GA-159	3	65	dominant	very few	-	very few	very few
GA-188*	3	65	dominant	-	-	-	-
GA-192	2	60	dominant	very few	very few	-	very few
GA-193	2	50	dominant	very few	few	-	-
GA-197	2	60	dominant	-	few	-	very few
GA-199	2	150	less	very few	dominant	-	few
GA-200	3	100	dominant	few	very few	-	few
GA-202	1	55	dominant	very few	very few	-	few

GA-188 is core sample. Its thickness is 65 cm, and is taken from a depth of 32 m.

assemblage and clinoptilolite is dominant mineral in only one sample.

By the XRD analysis of the sample taken from Layer 1 (GA-202: Layer 1, Figure 4), it was seen that the zeolite mineral is dominantly chabasite and less amounts of erionite and clinoptilolite are accompanied to the chabasite (Figure 5). Very little amount of amorphous materials were also observed as relict material (Table 1). Thickness of the Layer 1 which is stratigraphically at the top varies betwen 20 - 60 cm.

When the mineralogical composition of the 65 cm thick layer 2 (Figure 6), is investigated according to the results of XRD analyses, it was seen that the dominant zeolite mineral was chabasite in many samples (GA-158, GA-192, GA-193, GA-197) collected from different locations of this layer, and erionite, clinoptilolite and amorphous material are included in different amounts (Table 1, Figure 7a, b, c, d). To the north of the area the thickness of the layer increases from 60 cm to 150 cm; similarly, the mineralogical composition also changes (GA-199, Table 1, Figure 7e). Clinoptilolite is dominant zeolite in sample no. GA-199, and in XRD analyses, reflections of chabasite minerals can not be observed clearly.

The stratigraphically lowest Layer 3 (Figure 3, 4 and 8) is a 65 - 100 cm thick layer where it crops out, and chabasite is the dominant zeolite mineral (GA-159, GA-188, GA-200) in this zeolitic tuff layer. According to the XRD analysis of the samples collected from the surface, erionite, clinoptilolite and amorphous materials (volcanic glass) are presented in minor amounts (Table 1, Figure 9a, b). The XRD anaysis of the core sample (GA-188: thickness=65 cm) taken from this layer does not reflect the other components except chabasite.

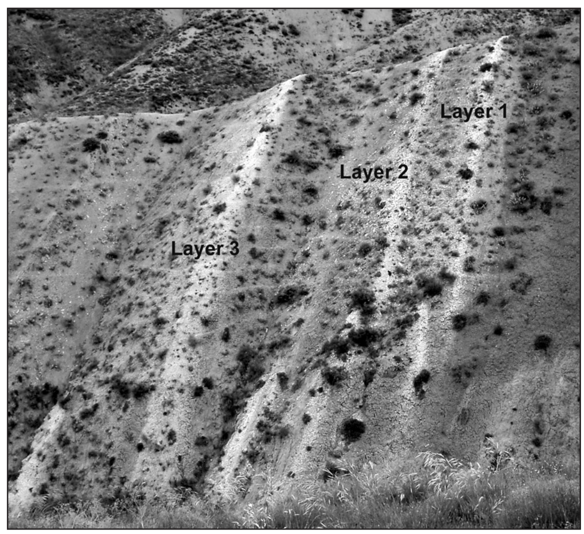

Figure 4- Chabasite bearing upstanding zeolitic tuff layers (GA-202: chabasite dominant; collected from layer 1; thickness: 55 cm)

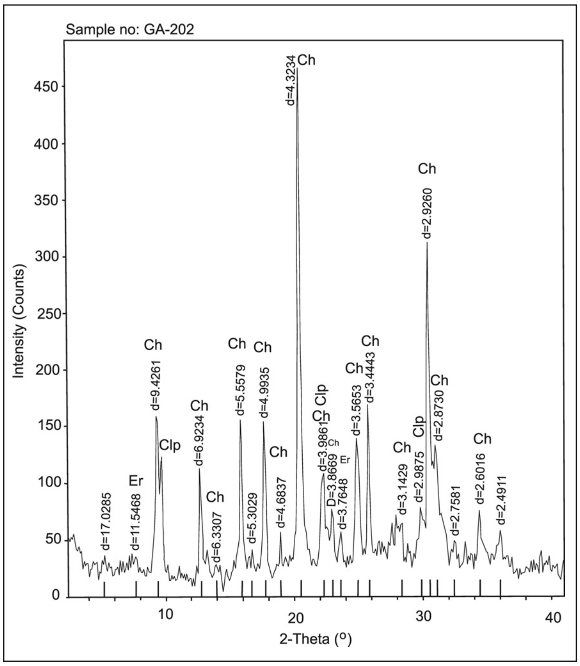

Figure 5- XRD diffractogram of sample no. GA-202; Ch: chabasite, Clp: clinoptilolite, Er: erionite.

Figure 6- Zeolitic tuff layer bearing abundant chabasite (Layer 2, GA-197: Chabasite dominant, thickness of chabasite: 65 cm).

SEM INVESTIGATIONS

The components, crystal sizes, morphologies and grain relations of the zeolitic tuff samples of which mineralogical components were determined by XRD analyses have been defined by scanning electron microscope (SEM).

The minerals taking place in Table 1 and observed through SEM investigations in the samples of which mineral compositions were determined by XRD analyses are given in table 2.

Chabasite

Chabasite is the dominant zeolite mineral found in all of the samples studied. Its rhombohedral grain sizes varying betwen 0.5 - 4 μm are typical (Figure 10). Especially the crystallizations developed in between the pores and voids are eye - catching; besides, local aggregations or clusterings of chabasite crystals are also observed (Figure 11a, b, c). Well developed twinnings of the minerals in such occurrences are common.

Erionite

In the SEM studies, it was seen that erionite is the zeolite mineral which accompanies the chabasite mineral in all samples. While mostly observed as bundles of acicular crystals (Figure 12), erionite crystals in form spicules or filaments can also be observed. Its crystal size may reach up to 15 - 20 μm.

According to XRD analyses, it occurs in little amounts or does not exist as in the sampes numbered GA-188 and GA-197. SEM studies, however, reveal the existence of erionite in both samples (Figures 11c, 13). Failure in determination of erionite in these samples may be explained by its minor ratio in the mineralogical composition.

Clinoptilolite

Clinoptilolite minerals are found in the forms of well developed laminated crystals, inwhich crystal size may reach up to 50 μm. Although it is not observed in all of the samples, when presented, it accompanies to the chabasite and erionite minerals.

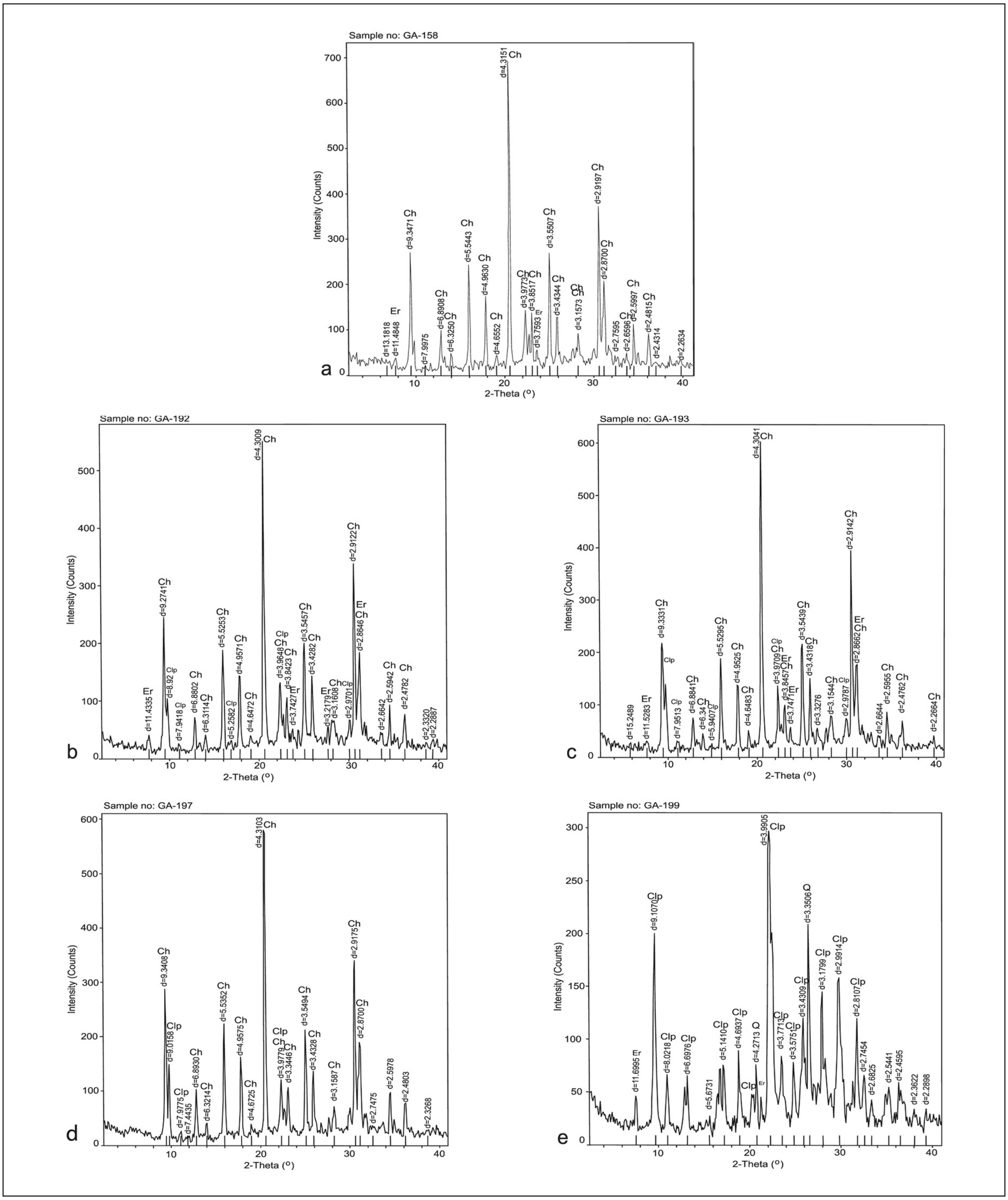

Figure 7- XRD diffractograms of samples taken from Layer 2; Ch: chabasite, Er: Erionite, Clp:Clinoptilolite Q: Quartz; (a: GA-158), (b: GA-192), (c: GA-193), (d: GA-197), (e: GA-199).

Table 2- Mineralogical compositions according to SEM investigations

Sample No	Layer No	Thickness (cm)	Chabasite	Erionite	Clinoptilolite	Smectite	Amorphousf material	K-feldspar
GA-158	2	60	+	+	+	-	+	-
GA-159	3	65	+	+	-	+	+	-
GA-188*	3	65	+	+	-	-	+	-
GA-192	2	60	+	+	+	-	+	-
GA-193	2	50	+	+	-	-	+	-
GA-197	2	60	+	+	+	-	+	-
GA-199	2	150	+	+	+	-	+	+
GA-200	3	100	+	+	+	-	+	-
GA-202	1	55	+	+	+	-	+	-

GA-188 is core sample. Its thickness is 65 cm, and is taken from a depth of 32 m.

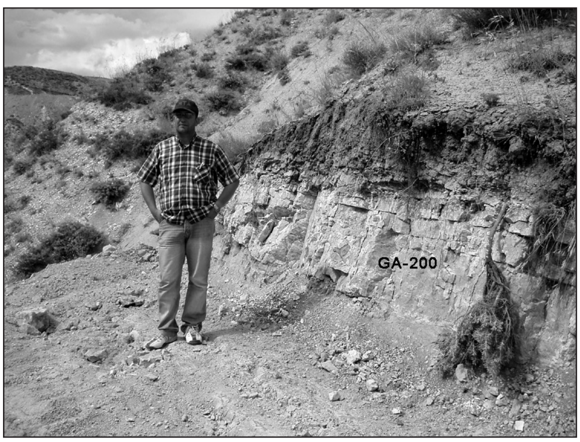

Figure 8- The stratigraphically lowermost zeolitic tuff layer (Layer 3, GA-200, chabasite dominant, thickness 100 cm).

It is mostly observed in less amounts in most of the samples, only in sample no. GA-199, while the chabasite is in less amount, clinoptilolite is the dominant zeolite mineral.

It forms the "chabasite+erionite+clinoptilolite" assemblage when presented in rocks (Figure 14).

K-feldspar

K-feldispat is observed in one of the samples (GA-199) taken from chabasite bearing zeolitic tuff layers. Well developed K-feldspar rhombohedrals are typical. Grain size varies between 1-15 µm (Figure 15).

In sample GA-199 where the "K-feldspar + clinoptilolite + erionite + chabasite" assemblage is observed, and the amount of chabasite is less while clinoptilolite is dominant according to XRD analysis.

Volcanic glass and clay minerals

Volcanic glass is abundant in all samples and it is a starting material for crystallization. It displays reflections of amorphous materials in XRD analyses and are found less.

Smectite is a clay mineral observed in a few samples of chabasite bearing zeolitic tuffs as minor minerals through XRD analyses. In SEM investigations well developed crystals of smectite are not found.

PARAGENETIC RELATIONS

In the studies made by Eyde et al. (1987) on chabasite bearing zeolitic tuffs in Bowie, it has been especially pointed out that the paragenetic relations between zeolites and smectites (Hay, 1966) are different than the zeolite occurrences in saline, alkaline lakes defined by Sheppard and

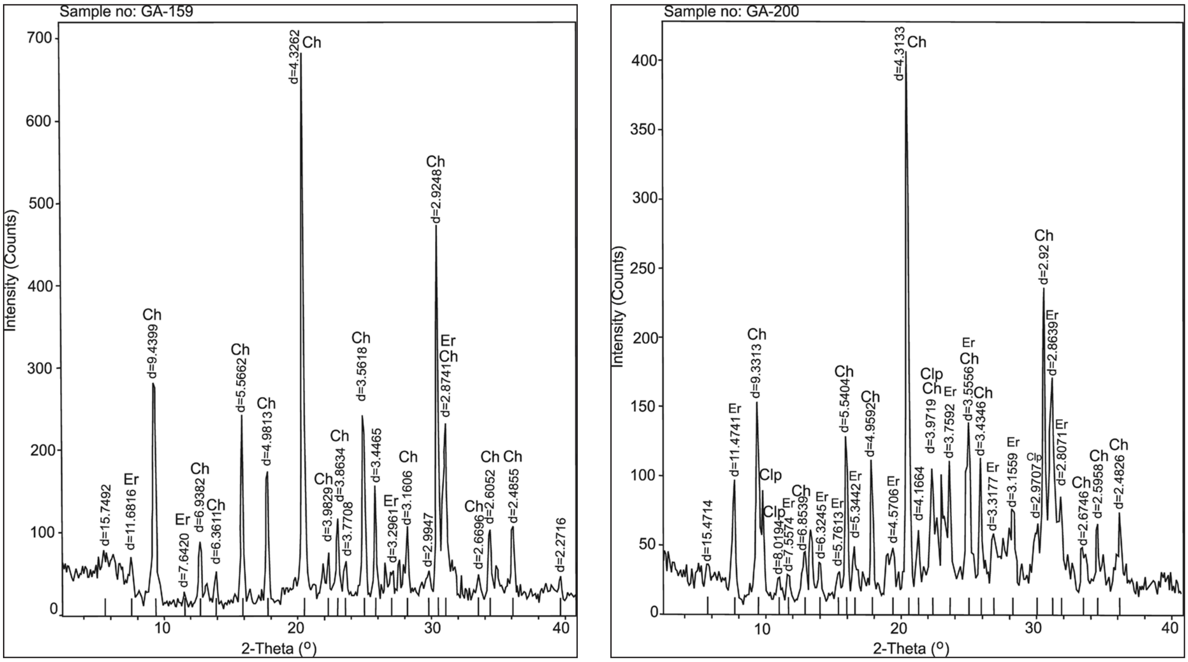

Figure 9- XRD diffractograms of the samples taken from Layer 3; Ch: chabasite, Er: Erionite, Clp:Clinoptilolite Q: Quartz; (a: GA-159), (b: GA-200).

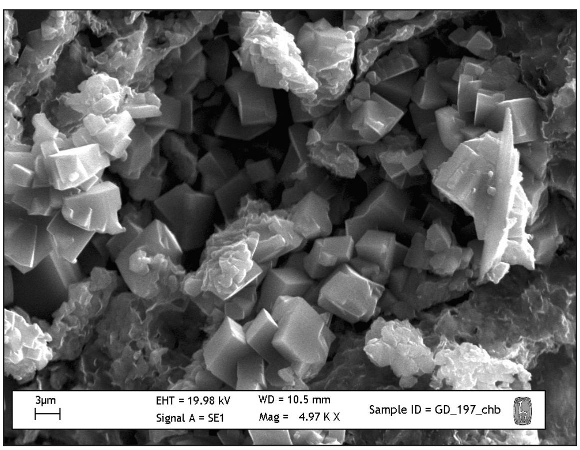

Figure 10- Rhombohedric chabazite minerals (GA-197, Layer 2).

Gude (1968, 1973). The SEM investigations made during this study showed that, here, smectite is not the first forming authigenic mineral (Eyde et al., 1987). It has been expressed that, in Bowie, the first forming authigenic minerals are chabasite and erionite and the latter is observed on poly - crystalline chabasite laminates and most possibly formed after chabasite. Chabasite and erionite minerals taking place in partly or wholly altered zeolites are observed to be coated by smectite, on the other hand, the clinoptilolite minerals crystallized after chabasite and erionite are not coated by smectite, therefore, it can be claimed that they formed after smectite and the other zeolites (Eyde et al., 1987).

The SEM investigations of the samples collected from the study area display paragenetic relations similar to that in Bowie zeolites. It has been observed that zeolite minerals are formed by the alteration of silicic volcanic glass, and many samples include relict silicic glass in less amounts. In only one sample, it has been thought that smectite, which is found in less amounts, is not the first forming authigenic mineral as it was in Bowie. The acicular erionite crystals developed on chabasite minerals imply that probably

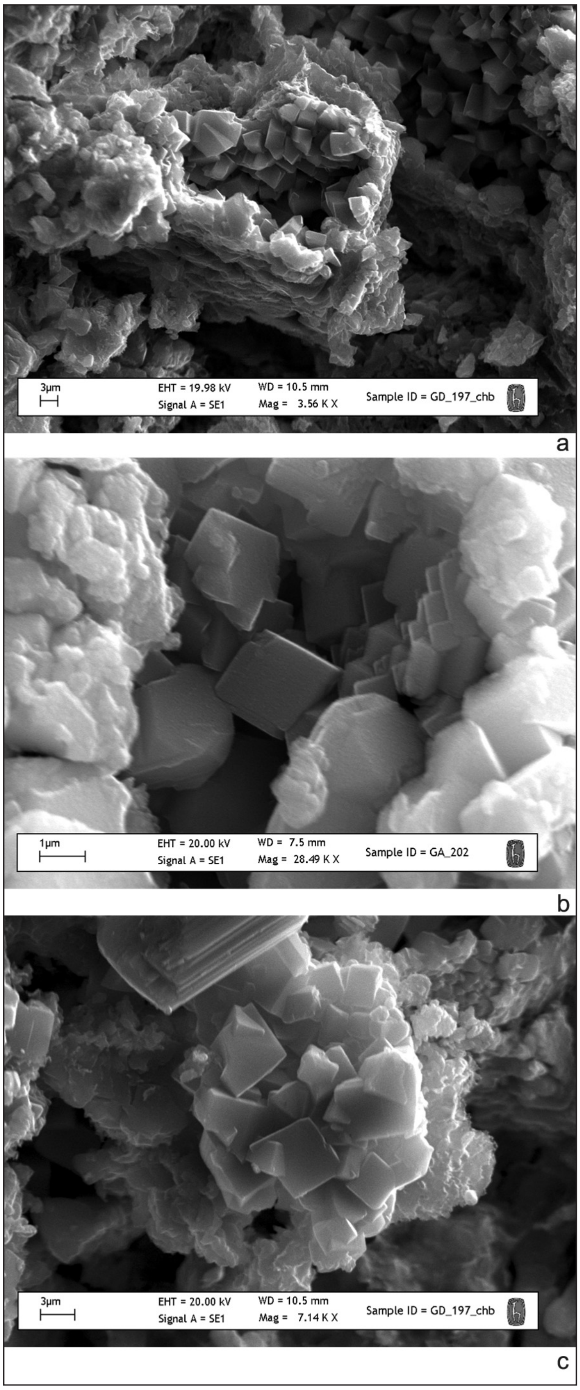

Figure 11- Rhombohedral chabasite developed in pores and voids (a: GA-197-Layer 2; b: GA-202- Layer 1), aggregations formed by chabasite minerals having well developed twinnings (c: GA-197-Layer 2).

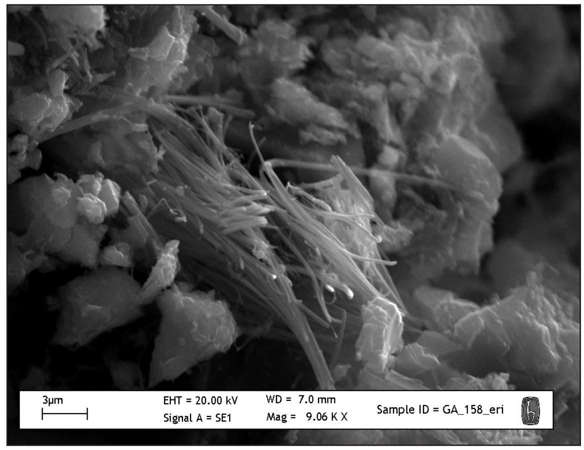

Figure 12- Bundles of acicular erionite minerals (GA-158).

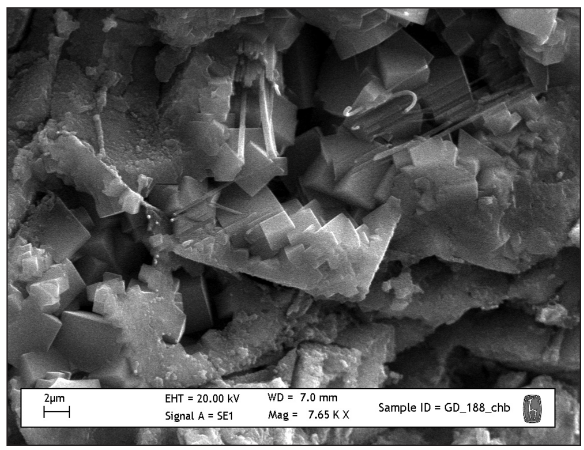

Figure 13- Acicular erionite crystals developed on chabasite minerals (GA-188).

chabasite formed before (Figure 13). In Figure 14, it has been understood that, the clinoptilolite developed at the center of a void, of which inner walls are coated by chabasite, formed before clinoptilolite.

In the study area, in some samples where "chabasite + erionite + clinoptilolite" assemblage is observed, it was thought that the order of formation of zeolite minerals probably is, as it was in Bowie, (1) chabasite, (2) erionite, and (3) clinoptilolite (Figure 14, 16).

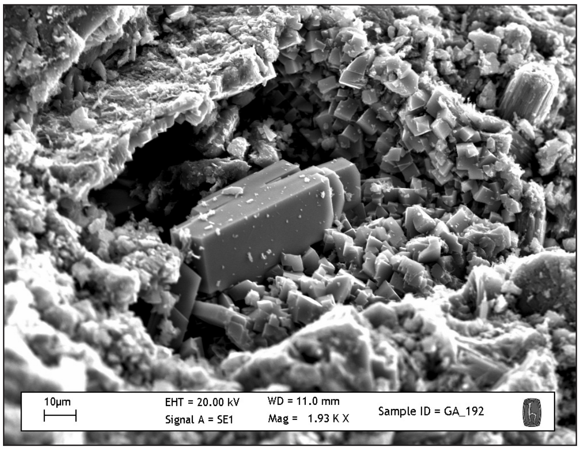

Figure 14- Well developed laminated clinoptilolite minerals and "chabasite + erionite + clinop tilolite" assemblage (GA-192).

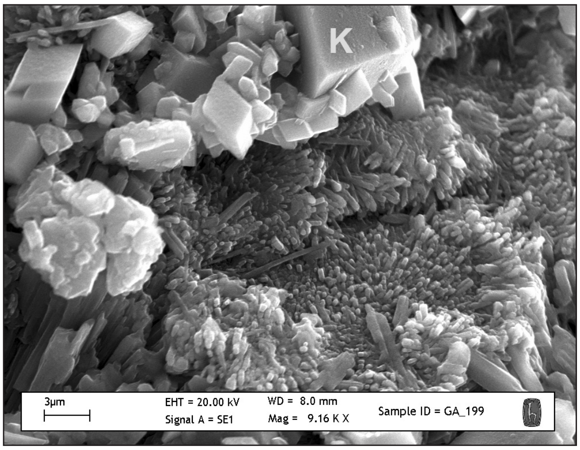

Figure 15- Well developed K-feldspar rhomboids found together with erionite and chabasite (GA-199).

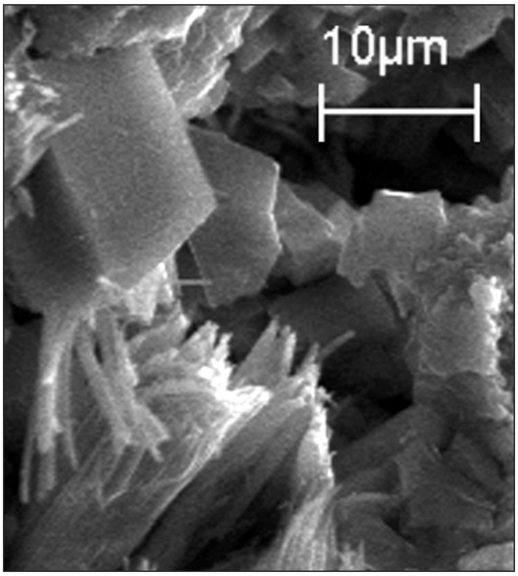

Figure 16- Erionite bundles developed after the formation of chabasite and clinoptilolite that have formed later (GA-197).

DISCUSSION AND CONCLUSIONS

During this study which reflects some part of the data collected during a project to search the industrial raw materials implemented by the General Directorate of MTA, mineralogical findings on some important chabasite occurrences in Central Anatolia were presented.

In the context of the project, it has been determined that the chabasite mineral which has importance for its economical value and areas of use, shows an economical potential in the study area after the Bowie field where the most of the production in the world for chabasite was made. Such zeolite occurrences especially have close relations with economical evaporitic minerals such as borates and trona and since they can give hints on the formation conditions, have great special importance.

According to studies made by Eyde et al. (1987) in Bowie field, paragenetic series of authigenic minerals can provide information on the salinity and alkalinity of the lake water. In the model put forward for Bowie field, it was claimed that when the first volcanic ash is deposited, the lake water is too much alkaline for the formation of smectite, for this reason, before the dissolving of silicic glass, crystallization of chabasite and clinoptilolite took place (Eyde et al., 1987).

In sections where alkalinity and salinity dropped, smectite was formed and later on, upon reaching to the same alkalinity and salinity conditions clinoptilolite was crystallized (Eyde et al., 1987).

In most of the samples collected from the study area chabasite is dominant which indicates that, as in the case of Bowie, the medium here is alkaline and saline. The minor amount of chabasite in "K-feldspar + clinoptilolite + erionite + chabasite" assemblage determined in one sample collected from the north of the study area can be explained by an increasing in the alkalinity in these sections. Detailed investigation of K-feldspar mineral, however, and study of its extension and origin will conclude this assessment.

Zeolites which are mentioned above and are the subjects of this paper, have close relations with the formation of the economical evaporitic mineral beds located in boron basins in Western Anatolia and Beypazarı trona basin in Central Anatolia.

Helvacı et al. (1983) established the relation between the borate minerals and authigenic silicates in Late Miocene intracontinental basins in the northeastern Mediterranean. During this project carried out in the Bigadiç, Sultançayırı, Kestelek, Emet and Kırka basins which are the productive borate basins, the tuffs are found together with borates as intercalations and rich in authigenic silicate minerals such as zeolites, K-feldspar and opal-CT. In borate basins, presence of evaporites themselves and authigenic silicate minerals such as clinoptilolite, analcime, K-feldspar indicate the prevalence of saline - alkaline conditions (Helvacı et al., 1993).

During the study on zeolites in the lacustrine Neogene basins bearing borate in Western Anatolia (Bigadiç, Emet, Kırka basins), paragenesis of clinoptilolite - dominant mineral have been determined, inexistence of silica -rich sodic zeolites (mordenite, erionite, chabasite and philipsite) in this field has also been determined and therefore the zeolite occurrences correspond to saline lacustrine basins (Gündoğdu et al., 1996). Although, it was indicated that, such sodic zeolites occur in the Cenozoic formations like Lake Tecoba, Barstow and Big Sandy (Western USA) mostly together with clinptilolite and these are said to be in important amounts in saline - alkaline lacustrine deposits (Lake Tecoba) which include trona and gaylussite (Sheppard and Gude 1968, 1969, 1973; Surdam and Sheppard 1978; Hay 1978).

Gündoğdu et al. (1996) explain the reasons why silica rich sodic zeolites and trona did not occur in the basin during the presence of non - alkaline conditions and the low activity of sodium in the lake water (Wagon Bed and Chalk Hills Formations; Boles and Surdam, 1979; Sheppard, 1991).

Kırka, Emet and Bigadiç basins and Lake Tecoba where trona beds are located and in Beypazarı basin, during the diagenetical transfer of rhyolitic glass to smectite and clinoptilolite, very important chemical changes do occur; inside the pore solution, together with the Na, K and Mg ions, concentrations of the elements such as B and Li increase (Gündoğdu et al., 1996). During the compaction of the pyroclastics, pore solutions preserved in brine are added to lake waters and consequently, under suitable depositional conditions, evaporitic mineral occurrences in these basins are observed (Gündoğdu et al., 1996).

During the studies in the Beypazarı trona bed, extensive zeolitization, dolomitization and chloritization were observed in trona bed and it was determined that the accompanying rocks and tuff fractions were dominantly zeolites such as analcime, waikerite, natrolite and clinoptilolite (Helvacı, 1998). As for the source of the occurrence of trona, weathering of the granites and Paleocene - Cretaceous volcanics are given; extraction of extensive tuffs are shown to be the main resource for the trona and the other sodium carbonate salts (Helvacı, 1998).

The researches mentioned above show that occurrence of the evaporite mineral beds and the zeolitization ocurred in the same setting as to be closely related. Salinity and alkalinity in the closed lake basins are important factors as well.

According to the mineralogical findings presented in this paper, in the formation of the zeolites (chabasite, erionite and clinoprilolite) taking place in the Aktepe Formation, the origin material is the glassy tuff that have deposited in a lacustrine environment. It was observed that, in many samples the pores or the voids have been filled by zeolite minerals (Figs. 11a, b, 14). This situation is especially typical with chabasite mineral and means that zeolite minerals have been crystallized by the dissolution of the volcanic glass by alkaline - saline pore water during the sedimentation process.

The zeolite occurrences located in the Aktepe Formation, correspond with the "Closed - Basin Zeolites" (Sheppard and Simandi, 1999) by their lithological, mineralogical and the other geological characteristics and their depositional environment has the characteristics of saline - alkaline lacustrine basins.

With these qualifications and upon the detailed studies to be realized in future, Aktepe Formation is going to gain importance for eveporitic mineral beds such as borates and trona.

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This study covers some data collected in scope of the project "Search for Industrial Raw Materials - Central Anatolia" implemented by the General Directorate of Mineral Research and Exploration (MTA). I would like to thank İnciser GİRGİN (MTA) for her contribution during XRD determinations and Prof. Dr. Erkan AYDAR, Prof. Dr. Abidin TEMEL, Orkun ERSOY, İnan ULUSOY and Gökhan ATICI (HÜ) for their contributions during SEM investigations. I also thank to the coworkers of the project.

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

DISCOVERY OF A NEW GEOTHERMAL FIELD BY GEOLOGICAL, GEOPHSICAL AND GEOCHEMICAL METHOD ÜÇBAŞ - ŞAPHANE - KÜTAHYA

Musa BURÇAK*, Fatma SEVİM** and Ömer HACISALİHOĞLU***

ABSTRACT.- The basement rock of the studied area have represented by Paleozoic aged core rocks which composed of flaser gneiss, migmatitic gneiss which covered by surrounding Upper Paleozoic-Lower Mesozoic aged cover rocks which are composed of schist, marble crystallized limestone belong to Northern margin of the Menderes Massive. The rocks of the Menderes massive are overlain tectonically by Dağardı Ophiolithic Melange which is composed of serpentinized mafic and ultramafic rocks, limestone olistoliths and blocks. All these rocks units are covered by Miocene to Pliocene aged lacustrine sediments interlayer volcanic levels. Geological remote sensing, detail geology, hydrothermal alteration, aerial photo studies, hydrogeology (hydrochemistry and isotope hydrology), geophysical (magnetotelluric and resistivity); drilling, well logging studies have been carried out in the study area from 2003 to 2006. Gediz geothermal area is one of the medium enthalpy geothermal areas in the Western Anatolia. The hot spring temperature is 70-76 °C in the area. The main aims of this study by means of getting data from Gediz-Abide field and collected other region to simulate each other to detect whether or not presence of promising area as buried geothermal system around there. At the and geology, hydro geochemistry and isotopic studies it has been found out a promising area which is covered under thick sediments near Şaphane-Üçbaş area at 5km northern part of the Gediz-Abide field. There is no manifestation in around the Shaphane-Üçbaş buried geothermal area at the surface. Geophysical (Magnetotelluric and resistivity) studies have shown two anomalies at Gediz-Abide and promising area. These anomalies have evidently low resistivity under the thick cover rocks and supported by geological hydrogeolgical and tectonical mapping. These two anomalies have been found also through the west along two profiles. Geothermal well (KŞÜ-1), have been drilled at 1330 m depth in 2006 at Şaphane-Üçbaş promising area. Geothermal fluid which have 40 l/s, flow rate and 90 °C were produced from the well using compressor test. 105.5 °C temperature has been measured end of 56 hours waiting after circulation at the bottom of the well. and 109 °C static temperature have been measured. KŞÜ-1 drilling thermal water is $Na\text{-}SO_4\text{-}HCO_3$ type and similar chemical composition to Gediz-Abide drilling hot waters. It can be suitable district heating (equivalent 1150 dwellings), heating green houses and thermal bath facilities.

Key words: Şaphane-Üçbaş, geothermal field, water chemistry, hydrological isotope, magnetotelluric, resistivity, geothermal well.

* MTA Genel Müdürlüğü Enerji Hammaddeleri Etüt ve Arama Dairesi, 06520, Ankara burcak@mta.gov.tr
** MTA Ege Bölge Müdürlüğü, Bornova-İzmir
*** MTA Doğu Karadeniz Bölge Müdürlüğü -Trabzon

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A KEY STUDY FOR SEISMIC REFLECTION APPLICATION; GEOLOGICAL INTERPRETATION OF THE COALIFEROUS NEOGENE SEQUENCE IN AFŞİN-ELBİSTAN

Yahya ÇİFTÇİ* and C. Ertan TOKER*

ABSTRACT.- High-resolution shallow seismic reflection profiles were collected along three lines in Afşin-Elbistan basin, lignite-bearing sequence. Two of these lines are east to west oriented whereas the other is north to south. Collected data were processed first in MTA, then in TPAO and the 2D Seismic Lines were obtained. Stratigraphical and sedimentological data were correlated using well-log data located along the seismic lines. Afterwards, the information was tied to the seismic lines and the contents of the seismic reflection packages were interpreted. High amplitude reflection surface between 300 and 400 msec was described as the bottom of the Neogene-aged coal-bearing sequence. Other reflections between this bottom reflection and the surface were identified as different sedimentary units correlating to the well-log data due to their internal structures and different reflection patterns. This experimental study revealed that high resolution seismic reflection studies would provide useful geophysical data to interpret the coal-bearing sequences in Neogene aged coal-bearing basins. It is proved that high-resolution seismic reflection lines are the most useful geophysical data for stratigraphy and geological interpretation in sedimentary basins.

Keywords- Afşin-Elbistan, coal seams, High-resolution seismics.

INTRODUCTION

The study area is located between Afşin and Elbistan districts of K.Maraş (Figure 1). This coal-bearing zone is still run by TKİ and lignites are used at the thermal power plant. At this coal-bearing zone, drilling reserve development studies are conducted again by MTA separately. The geological data used in this study were provided by MTA Energy Department.

The base depth, lateral continuity and perpendicular seismic resolution of the coal-bearing zone were tested along a total of three seismic profiles two parallel pieces of which had lengths of 1,5 kms and 1,75 kms and a separate one with a length of 1 km intersecting these (Figure 2) in accordance with the drilling plan located on the field. The clay and coal levels, the seismic resolution of which decreased due to close values exhibited by the densities of the clastic rocks and coal levels found in the neogene sequence, were investigated at a frequency band of 25 - 250 Hz of the energy resource.

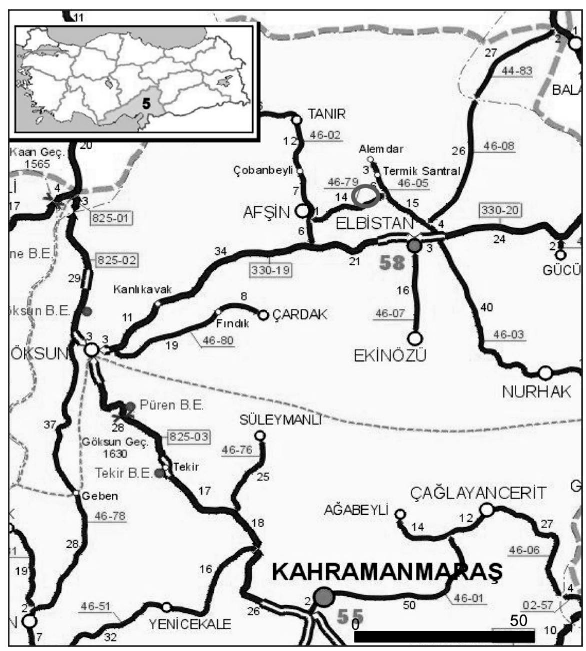

Figure 1- The location map of the Afşin-Elbistan (K.Maraş) coaliferous Neogene Basin.

These lines were processed as high resolution shallow seismic cross-sections in order to be

* Maden Tetkik ve Arama Genel Müdürlüğü, Jeofizik Etütleri Dairesi, Sismik Birimi, Ankara.

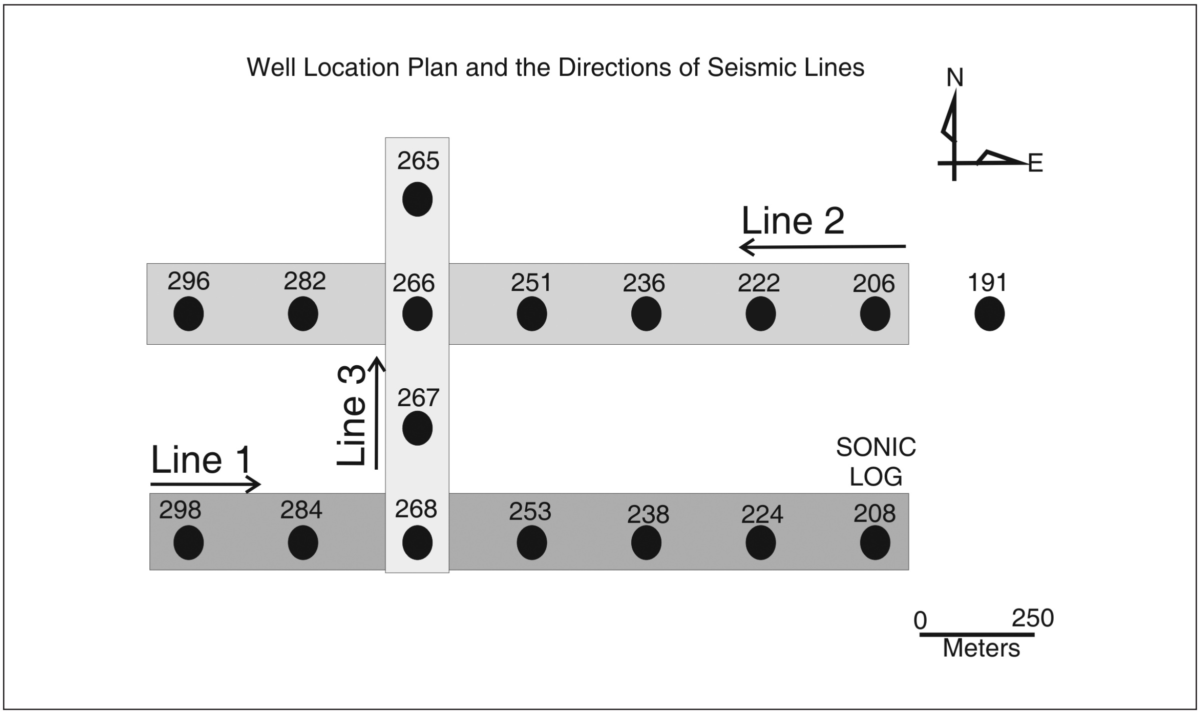

Figure 2- The line geometry of the seismic lines and the location map of the wells.

able to identify geological changes and to establish a correlation along lateral distances; and thus, certain reflection signs that are thought to reflect the inner changes of formations with a strong reflection surface the apex of which reaches up to 200 ms were obtained. The interpretation and lateral correlations of these motifs on each line can be traced on the final cross-sections.

STUDY METHODS

This study was conducted in three stages as seismic data collection on the field, data processing and geological interpretation of seismic cross-sections.

Data Collection

The record parameters used in the study are given in table 1.

During the field study, while shooting priority belonged to the recorder, after the existing canals were laid (66 canals) the profile was completed by advancing on the line sweep the 48 channels that were alive by use of Rollalong. As the advancing method, Off-End (Shooting at the

Table 1 - Shooting geometry practiced in the seismic reflection study and record parameters.

Recorder:	Strawiev 48 channels	Group distance:	5 meters
Geophone:	14 Hz	Shooting distance:	5 meters
Energy Resource:	MiniVib II	Sweep type:	Logarithmic
Sampling Interval:	1 msn	Sweep length:	6 sn
Recording Duration:	1024 msn	Taper:	1 sn symmetrical
Close Offset	15 mt	Pilot Trace	1^{st} Channel

back, geophones in the front, by shifting) method was used in the study (Sakallıoğlu, 1995; Krug, 2004).

Data processing

The processing of the seismic data collected was performed in accordance with the conventional data-process scheme used by TPAO and shown in figure 3 (Yılmaz, 1987; Us, 1993). To this end, SUN work station within the body of MTA Marine Researches Coordination Unit was used. Once the general and routine processes using FOCUS data-process software were performed at that work station, for more detailed (high resolution) processes, TPAO data-process possibilities were made use of. Within this scope, the related profiles were re-processed using Promax data process software. This seismic cross-sections obtained as a result of this second process were of quality that could represent the geological milieu of the field in a high resolution manner.

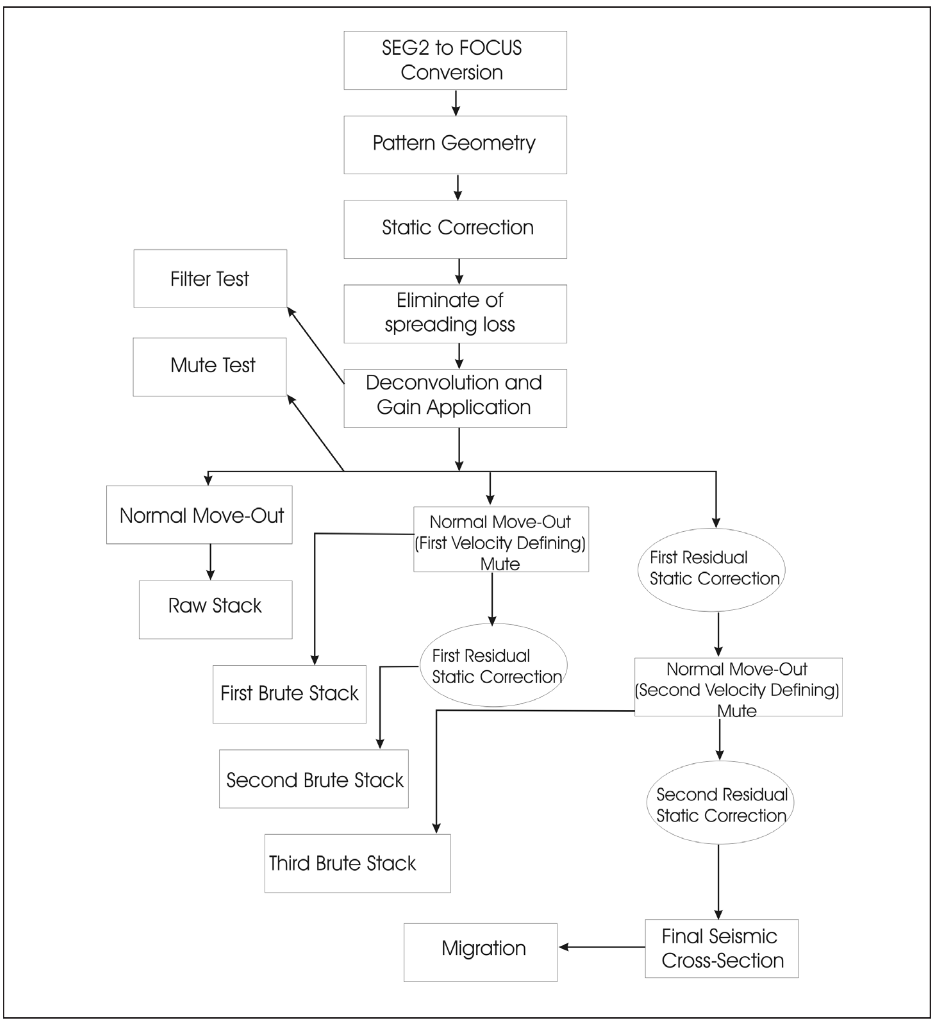

Figure 3- The process flow-chard of Afşin-Elbistan seismic data.

Geological interpretation

On the seismic cross-sections obtained as a result of the processing of the seismic data obtained, geological interpretation studies were conducted in order to both determine the depth and the geometry of the base rock and make lateral correlations relating to the inner structure of Neogene sequence. The geological interpretations on the seismic cross-sections were made using real well information provided by General Directorate of Mineral Research and Exploration (MTA) Energy Department. For this purpose, first, lateral correlations of the wells that remained on the seismic lines were made; and then, in order to be able to understand the evolution of the base morphology of the deposition basin for the Quaternary base, the wells were hung at certain DATUM levels before, during and after the deposition of coaliferous series and general geomorphologic and tectonic characteristics belonging to the deposition areas of the coaliferous level at the related period were tried to be understood. At the final stage, well information was carried onto the seismic lines and their correlations with seismic traces were made. Since the actual coordinate values of the well locations did not overlap with the coordinates of the seismic lines, their locations on the seismic lines were accepted as approximate.

At the second stage, interval speed values for each of the geological formations were calculated based on sonic log speed information. The seismic speed for alluvium and underlying silty clay layers from top to bottom was found to be 1600 m/sec; the seismic speed value for green clay layers (top clay) was found to be 1800 m/sec; the seismic speed value for coal horizon was found to be 2000 m/sec; and the seismic speed value for mudstone - marl layers at the bottom of the coal horizon was found to be 2300 m/sec. The seismic speed value of the formations at the bottom of the Pliocene series was taken as 3750 m/sec. From these values and by the help of Dix (1955) formula, RMS speeds and thus, stack speeds were found and seismic reflection cross-sections were obtained.

The base level of the coal horizon corresponds to 100 to 120 ms TTT (Total Travel Time) time values. When these values are converted to TWT (Two Way Travel Time) on the seismic reflection cross-section, approximately twice as much values of time are obtained. The depth equivalent of this time value is about 200 meters. In the same way, when the geological correlations of the lines are considered, it is seen that the base level of the coal horizon usually remains between 180 and 220 meters. The time values below are given in TWT.

GEOLOGY

Comprehensive geological researches covering basin as well are found in literature (Staesche, 1972; Tarhan, 1984, 1986; Perinçek and Kozlu, 1983). Besides, specifically MTA and TKİ reports are the most significant sources for the evaluation of the geology of this basin and coal formations (Koçak et al., 2002; MTA Collection Reports: Atay, 1981; Aydoğan, 1978; Barkurt et al., 1991; Baydar, 1975; Bilgin, 1982; Karlı, 1983; Mengeloğlu, 1999; Özcan, 1981; Uysal, 1985).

In the first extensive studies conducted on the basin, it is stated that the basin-fill rocks are formed of limnic and fluviatill facies rocks (Staesche, 1972; Gökmen et al., 1993). The generalized stratigraphic column cross-section of the basin is given in figure 4.

Perinçek and Kozlu (1983) state that Senozoic sequence in the Afşin - Elbistan region began with the Miocene aged Kuzgun formation, and upon this, Pliocene and Quaternary series began to subside (Figure 5). The same researchers considered the young terrestrial sediments in the region in two sets as Pliocene and Plio-Quaternary - Quaternary. It is stated that the Pliocene sediments, which constitute the main subject matter of this study, began with conglo-

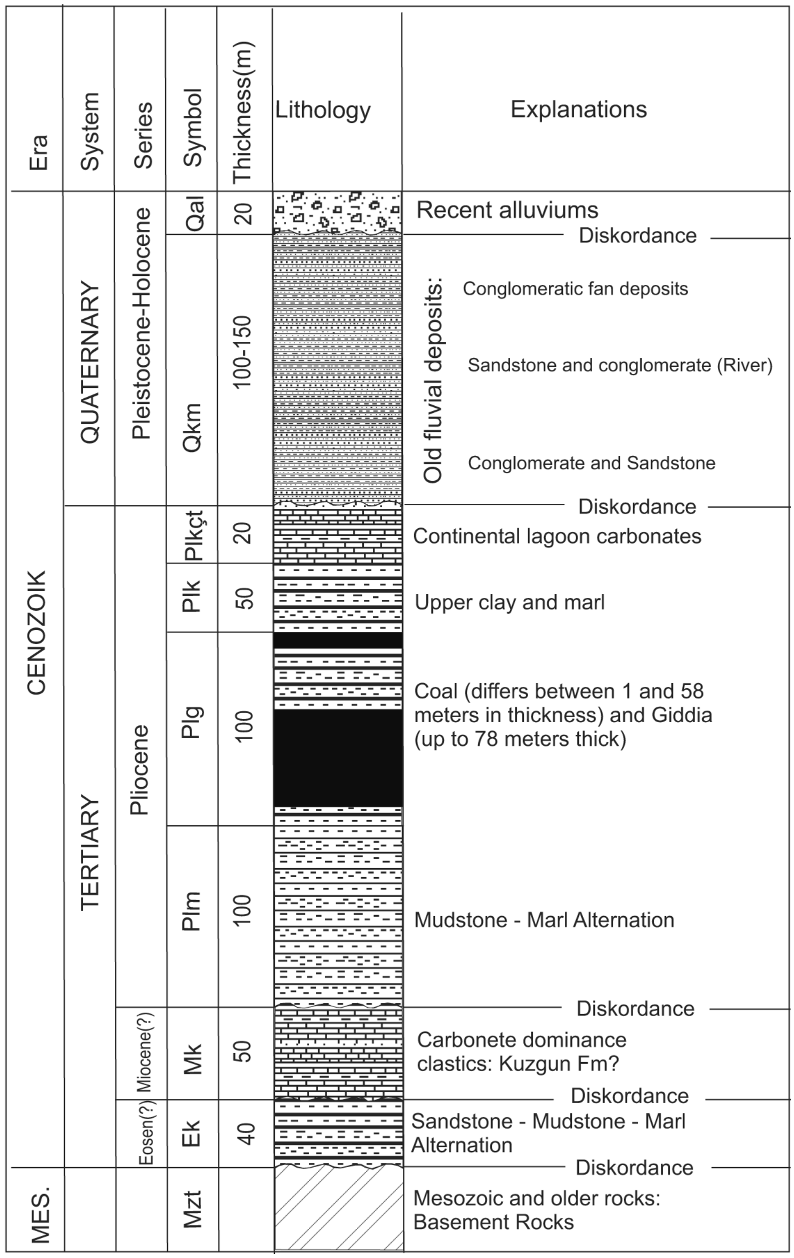

Figure 4- Generalized stratigraphic column-section of the Afşin-Elbistan basin (No Scale).

merate or gravely limestone on the base, and continued with claystone and mudstone upwards. As for Tarhan (1984), he names the Pliocene aged sequence including sandstone, claystone, marl, lagoonal limestone, conglomerate, tuffite, mudstone and coal levels (Afşin lignite) as Nadir formation. This formation is represented by black-red polygenic conglomerates in the SW of Afşin - Elbistan basin around Göksun (Yümün and Kılıç, 2002).

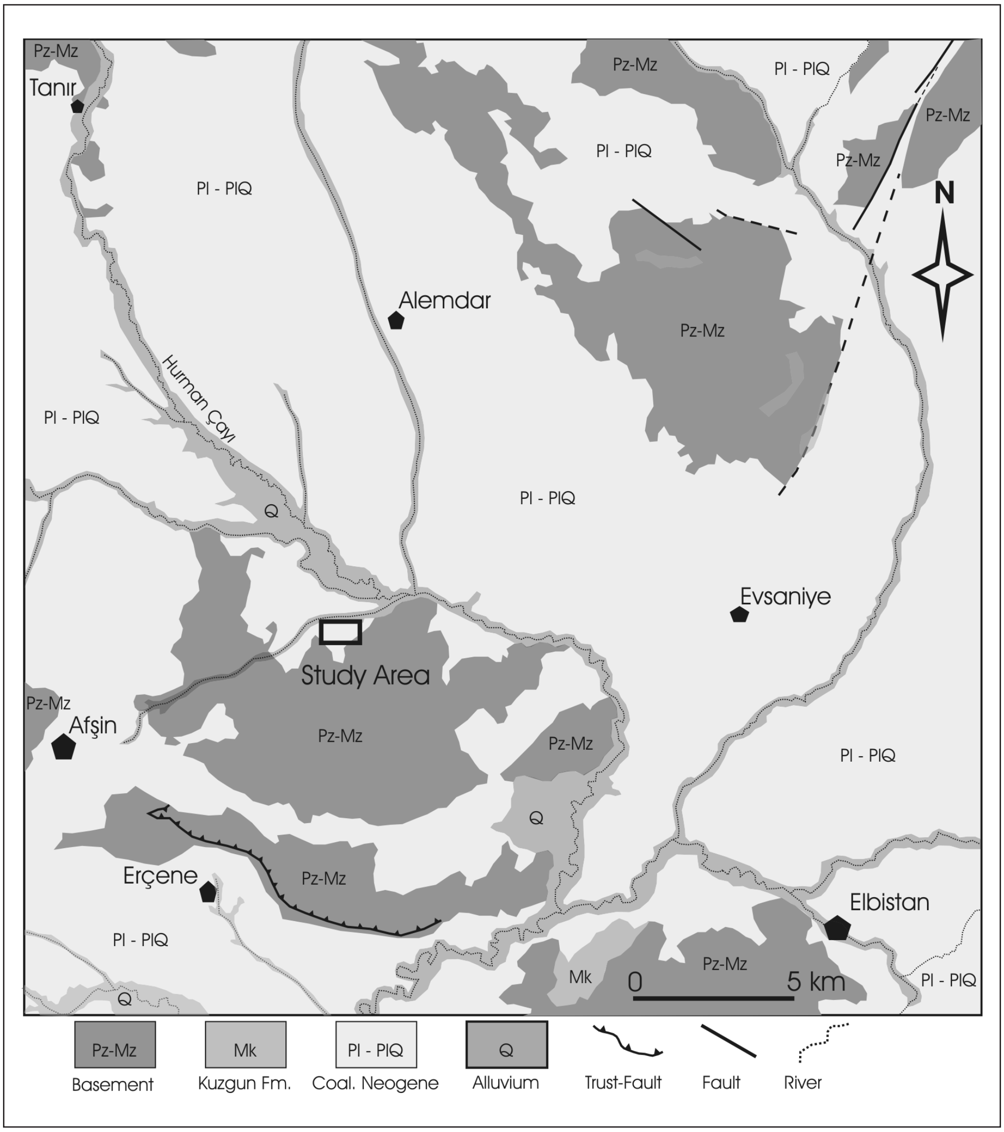

Figure 5- Geological map of Afşin - Elbistan Basin (Simplified from Perinçek and Kozlu, 1983).

In this study, the local stratigraphic sequence in the area which is covered by seismic reflection profiles bears importance in terms of geological correlation. According to the drilling information obtained at the basin, the base of the research field is formed of Mesozoic and more aged limestone - marble - schist etc. rocks (Pz-Mz). On the base, a series formed of sandstone - mudstone - marl alternation which is probably Eocene aged, clastic and with an average thickness of 40 meters comes discordantly (Ek). The carbonate-rich clastic series which comes over this clastic series is probably Miocene aged and has an average thickness of 50 meters (Mk). This series was first named by Çağlayık (1970) and was accepted as Kuzgun Formation by Perinçek and

Kozlu (1983) (Figure 5). The Plio-Pleistocene aged coaliferous series comes over this base series from the discordantly and begins with gravely to sandy levels on the base and contains clay, coal, marl and limestone levels upwards.

This coaliferous series is formed of mainly four separate levels.

Tertiary

Base Level Clay and Marls (Eocene (?) - Miocene (?) - Lower Pliocene) (Plm)

In the study field, the base of Plio-Pleistocene is in the form of clay marl alternation as dominant lithology. It is formed of sandy clay and gravely clay levels towards the base. It is bluish green in color. These formations that are not appear at the outcrop are identified in the wells. According to the location of the coal, this base level begins from various depths in the basin. This level found on the base of the coal can easily be identified thanks to its typical color and the carbonate lumps it contains and its thickness can go up to 200 meters. This sequence comes over the other base rocks that are more aged with direct discordance.

Coaliferous giddia (Pliocene) (Plg)

A level formed of giddias is found on the base clay and marl level and it contains lignite veins. Although the thickness of the giddia level is 10-15 meters below the coal vein, it can go up to 30-40 meters over the coal vein. These limnic formations that do not appear at the outcrop can only be identified from the cores of the wells in the basin. The total thickness of the coaliferous levels and giddias can reach up to 100 meters in places and the giddia levels contain an ample amount of decomposed gastropod shell fragments especially on the upper sections of the sequence.

The coal vein found in this unit is more monotonous in the west of the basin and is in the form of a single vein the thickness of which can go up to 40-45 meters. The coal veins in the east portions of the basin form a zone of 70-80 meters with the clay inter-layers. The total thickness of all these coal veins goes up to 50-60 meters.

Ceiling level clay and marl (Plio-Pleistocene) (Plk)

In this level that is found over the coaliferous giddia level, the dominant lithology is clay and silty-sandy-clay alternation. The unit which contains silt and sand bands in places is little fossiliferous. The thickness of the unit is around 20-30 meters.

Fresh Water Limestone (Plio-Pleistocene) (Plkçt):

These formations that are seen on the surface of the basin fill are the final horizontal layered limmnic sediments. They are rich in terms of gastropod fossils. They are white in general and rarely grey and brown. These formations can be defined as shore front shallow lake carbonate shelf (Scholle e al., 1983) and their thickness does not exceed 20 meters.

Quaternary

Quaternary aged sediments are found in two series in the basin: the old stream sediments found on the base are identified in the drills and they do not appear. The actual alluvial sediments cover the whole series with an angled discordance (Figure 4).

Gravel-conglomerate (Qkm)

The old stream sediments are represented by conglomerate-sandstone on the base, stream sediments in the mid sections and conglomeratic fan sediments on the top (Figure 4). Gravel series are seen in many sections of the basin. Gravel dimensions become smaller from the shore of the basin towards the centre of the basin. The sizes of the gravels vary between 2 - 20 centimeters in the rim sections of the streams flowing into the basin and in the centre of the basin, tiny grain sand is dominant. This clastic material is formed of the limestone, quarsit and radiolarite gravels on the sides of the basin, and they are cemented with some carbonated cement. With the drillings performed, it has been determined that the thicknesses of these sediments go up to 150 meters in places.

Recent Alluviums (Qal)

Actual alluviums are seen only along Hurman Creek. This main drainage canal that covers the study field in the NW-SE direction has left actual alluvium on a wide area. The thicknesses of these actual sediments are around 20 meters.

Thes geological units described above were interpreted as five units in the seismic cross-sections and geological correlations were made. These units are as follows: 1) Marbles at the basement of the basin, 2) overlying basin fill sediments, 3) clayey-coal horizon, 4) clay-marl alternated cover series, and 5) Recent alluvial deposits.

GEOLOGICAL CORRELATIONS OF THE WELLS

The study was conducted on a total of three seismic reflection lines (Figure 2). Two of these lines (LINE 1 and LINE 2) are E-W directional and parallel to each other and their lengths are 1500 meters and 1750 meters, respectively. The horizontal gap between the lines is about 500 meters. The third line (LINE 3) is selected as perpendicular to these two lines in the N-S direction and its length is approximately 1000 meters. There are wells on each of the three seismic reflection lines. The geological correlation of these wells that are drilled with intervals of 250 meters is made and in the geological correlation, the stratigraphic sequence given in Figure 4 is complied with. The locations of some guide levels shown on the lithological stamps of the wells are arranged according to the core information.

Establishing a correlation between the stratigraphic sequence and the seismic cross-sections constitutes the main objective of this study. Besides, the known main stratigraphic and structural elements are defined and matched on the seismic reflection cross-sections produced.

One of the most important parameters during seismic data processing is to collect seismic speed information from formations directly and to ensure real depth conversion by applying these speeds to related levels during data processing. For this purpose, well geophysics was applied to well no. S-222 found on Line 2 and sonic log was obtained. When this sonic log is examined, it is observed that the seismic speed values of Pliocene series vary between 1600 and 2300 m/sec. In addition, seismic refraction studies reveal that the seismic wave speed of the uppermost layer is about 650 m/sec. During seismic data processing, the average seismic speed for the entire seismic recording was selected as 1500 m/sec considering the low seismic wave speed zone at the shallow surface. After this selection, the stratigraphic log data and the major reflection surfaces of seismic cross-section was tied at around 270 meters. According to this seismic speed information, the average depth of the reflection surface of the base of the basin and that occurred on the seismic reflection cross-sections were calculated as 250 to 300 meters. On the other hand, wells drilled in the basin so far do not generally go deeper than 180-220 meters except for the few number of pilot wells, and they do not reach the bottom of the basin. In this case, for the deeper units, the wells and the seismic cross-sections do not overlap one to one and this causes difficulties in the geological correlation of the more aged units.

When the generalized stratigraphic column cross-section of the basin is considered, it is seen that below the coaliferous horizon, there is a series with an approximate thickness of 100 meters forming the base of the Neogene sequence and that consists of mudstone - marl alternation (Figure 4). Since the reserve development wells drilled in the basin are programmed mainly for the determination of the change in the thickness of the coaliferous horizon, lithologies that are accepted as basic rock in well lithology stamps and the basin base rocks that are identified at seismic-cross sections as 'Seismic Basement' most probably do not overlap. Since the wells in the basin are usually ended when they enter the mudstone-marl sequence (Plm) found on the base of the coaliferous horizon, the lithologies below this zone are not reflected on the well correlation cross-sections. Yet, when the seismic cross-sections are considered, it is observed that high resolution seismic reflection data are obtained up to approximately 400 milliseconds (TWT: Two Way Travel Time). When an average seismic speed of 1500 m/sec is applied to these seismic cross-sections, 200 milliseconds (OWT) time depth corresponds to an approximate depth of 300 meters. Thus, since the coal horizon goes down to an average depth of 200 meters, the sequence found below this horizon can be distinguished on the seismic reflection cross-sections but it can not be correlated geologically.

According to figure 4, on the base of the mudstone - marl (Plm) sequence, there are probably Miocene aged clastic rocks with an approximate thickness of 50 meters and that are very rich in terms of carbonate (Mk; Kuzgun Formation), and on the base of this sequence, there are probably Eocene aged sandstones (Ek) with an approximate thickness of 40 meters but these geological units are not represented in seismic cross-sections. All thes units have deposited on Paleozoic-Mesozoic aged basement rocks with an angular unconformity (Figure 4, Figure 5). The newly constructed borehole numbered as S-222 reaches to the seismic basement rocks at the 271-meter depth. This borehole also revealed that the Pliocene-aged coaliferous sediments have been deposited directly on the seismic basement rocks (marbles) onconformably.

Since the mudstone - marl and sandstone type litologies found on the base of coaliferous horizon do not have a great speed contrast with the coaliferous horizon; these series do not display strong reflections. But physically, a speed jump in transitions from this mudstone - marl - sandstone sequence to metamorphic rocks, specifically to marbles would be expected. In the same way, according to the sonic log of S-222 borehole the seismic wave speed dropped from 3750 m/sec to 2300 m/sec. So, the reflections observed on the base along the seismic cross-sections (300 - 350 milliseconds TWT) and forming the dome-like structure belonging to the basement rocks (limestone - marble) point to the presence of a paleo-basic high in this location.

While there is no sufficient geological data available about the beginning and development process of this paleo - basic high; a general approach about the tectonic development of the basin can be provided with the palinspastic analysis of the stratigraphic levels of the geological cross-sections obtained with the correlation of the wells. Within this scope, the sequence was hung up in the coaliferous horizon from a selected characteristic surface and the base geometry of the basin during coal deposition was determined palinspastically (Figure 6). When this figure is examined, it is understood that at the period when coal deposition occurred, possible block faulting could have developed in the basin and in the depression areas that were formed, coaliferous series deposited. The same process was made for Lower-Middle Pliocene, Upper Pliocene and Quaternary base and the base morphological evolution of the basin was tried to be interpreted from Pliocene to our day (Figure 7). In Figure 7, from the shape of the (B) curve, it can be understood that at the period when the coaliferous horizon almost completed its formation, (Middle) Pliocene paleo-topography was in a location that was in harmony with the dome-like morphological structure that occurred in the actual seismic cross-sections and the base of the basin was rather undulated. What attracts atten-

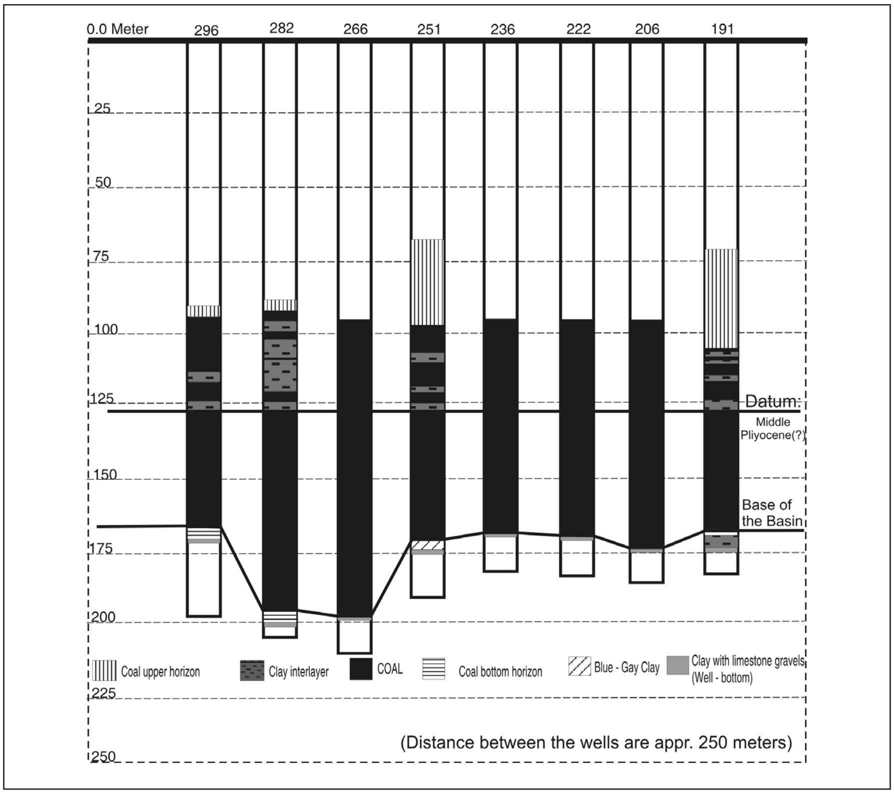

Figure 6- The basin morphology and stratigraphic correlation of the Early-Middle Pliocene deposits according to the Datum that selected from middle section of the coal section in Line Two.

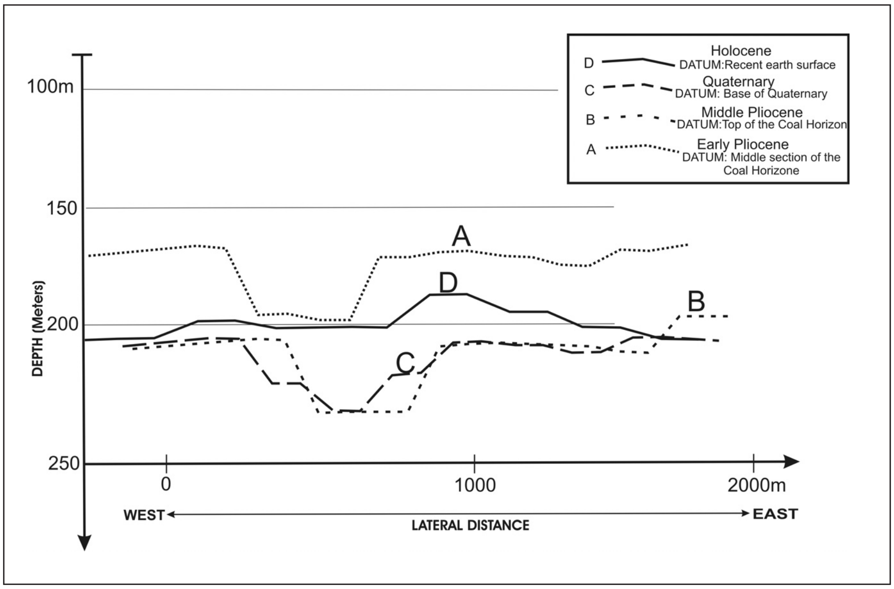

Figure 7- The tectonic evolution of the Afşin-Elbistan Coaliferous Basin from Early Pliocene to the Recent.

tion in the (C) curve in the same figure is that in lateral distances, the depth of the basin exhibits much sharper changes. In the same way, when geological correlations are considered, it is observed that while carbonated sediments are formed at regions that are very close to each other, in other sections, silty clay type litologies are formed. When this section is compared to today's geological location (Figure 8, 9 and 10) it is understood that only along Quaternary do the vertical replacements exceed 25 meters in places in the basin. The sections where these alluvium fills are formed can also be interpreted as incised valleys. When interpreted such, it is found that a rapid elevation or a rapid water discharge has developed in the basin.

When the coaliferous horizon is hung up from a typical interface on Line 2, the geomorphologic structure of the period when the basin was formed can approximately be understood (Figure 6). In the cross-section prepared accordingly, it can be observed that the west region of the basin is relatively deeper in the deposition period, and after some time, (after the hung-up surface deposits) the basin is tilted towards the east (Figure 7, A Curve). When the same process is applied from the base of the upper coal horizon, the geometry and the geomorphologic structure of the basin in the period when the cover series began to deposit can be better understood (Figure 7, B Curve). Accordingly, it again comes to light that the basin does not have a homogenous depth distribution and there is a certain undulation. This case is more clearly observed on the Quaternary base (Figure 7, C Curve).

When Figure 7 is examined, it can also be seen that after Early Pliocene, a depression of approximately 50 meters has occurred in the basin, and from Middle Pliocene on, the basin has started to elevate as a block.

According to geological data, the correlations on the seismic lines are listed below:

LINE 1; Geological Correlation of the E-W Directional Seismic Line

The lateral correlation of the well lithological stamps belonging to the wells on Line 1 (Figure 2) is given in figure 8. There are seven wells cutting coal on this line. Geophysical log (sonic log) was recorded in well no. 208 located on the very east of the line. According to this sonic log, the average seismic speed of the formation is 1850 m/sec. When this sonic log is examined, it can be seen that a great speed contrast is not formed in the transitions of the formations. That the seismic speeds are so close to each other has been related to the closeness of the lithological characteristics of the formations to each other. Because of the physical parameters were not found as reliable values, a new borehole was constructed near the nr. 222 borehole located on the Line 2. This borehole (S-222) represents the whole Pliocene sequence and the phisical parameters were accepted as reliable for the seismic cross-sections.

The coaliferous series in the wells found on Line 2 seismic reflection line was hung up from the base of the upper horizon (DATUM) and thus, the basin geometry for the depression period of this series was set forth (Figure 6). The same process was applied for the Quaternary base, and by arranging the developments in the basin morphology during geological periods, the lines were compared. For interpretations on this issue, Line 2 was used.

LINE 2; Geological Correlation of the E-W Directional Seismic Line

The total length of the line is 1750 meters (Figure 2). Total nine boreholes located onto this line includet the newly constructed S-222 borehole. The gap between the wells is around 250 meters but the S-222 borehole is located between the 222 and 206 numbered boreholes. The thickness of the coal horizon varies between 50 - 100 meters. The highest thickness is 100

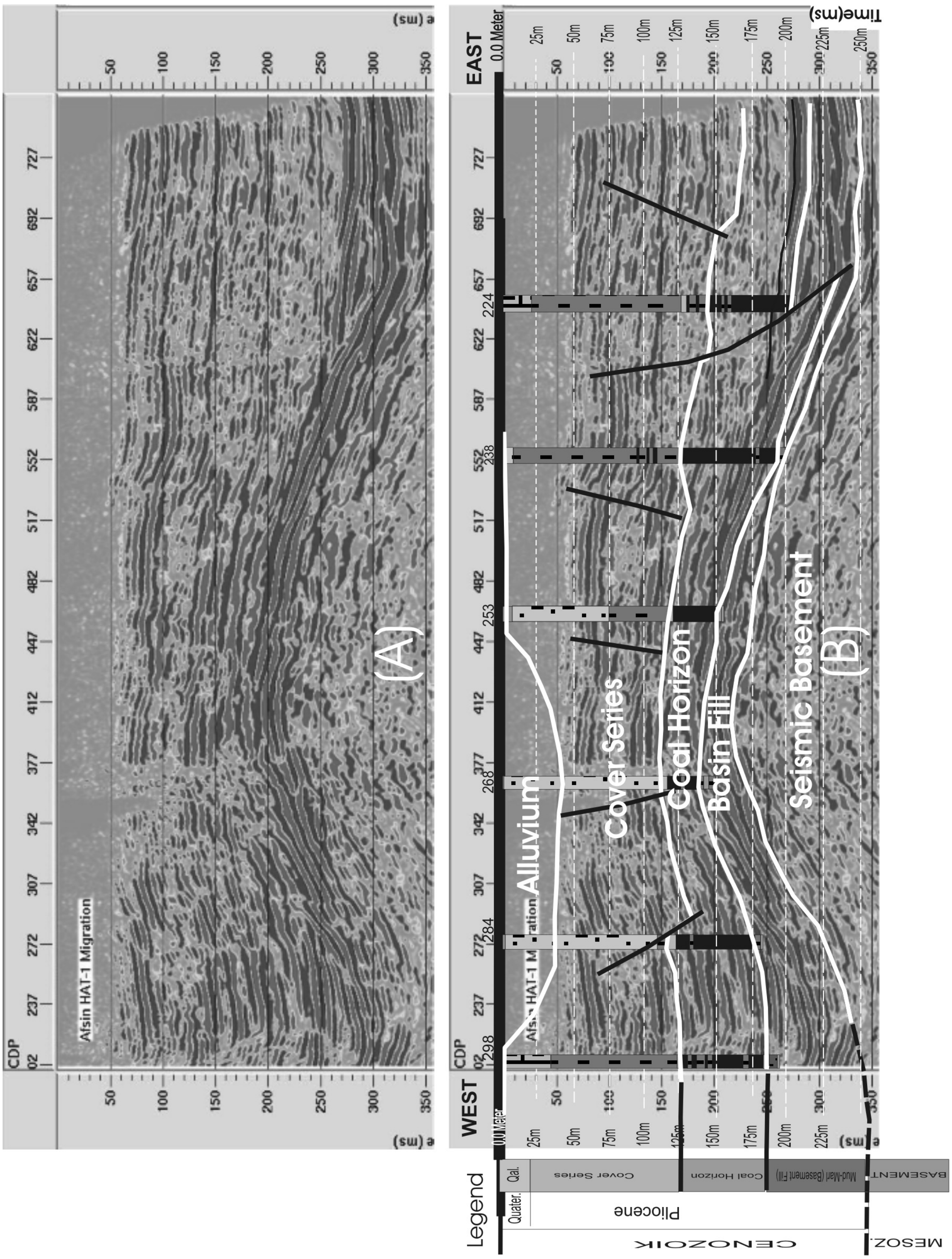

Figure 8- The raw (A) and interpreted (B) seismic cross-sections of Line-One: correlation of the coal section (the lateral distance between the wells are 250 meters).

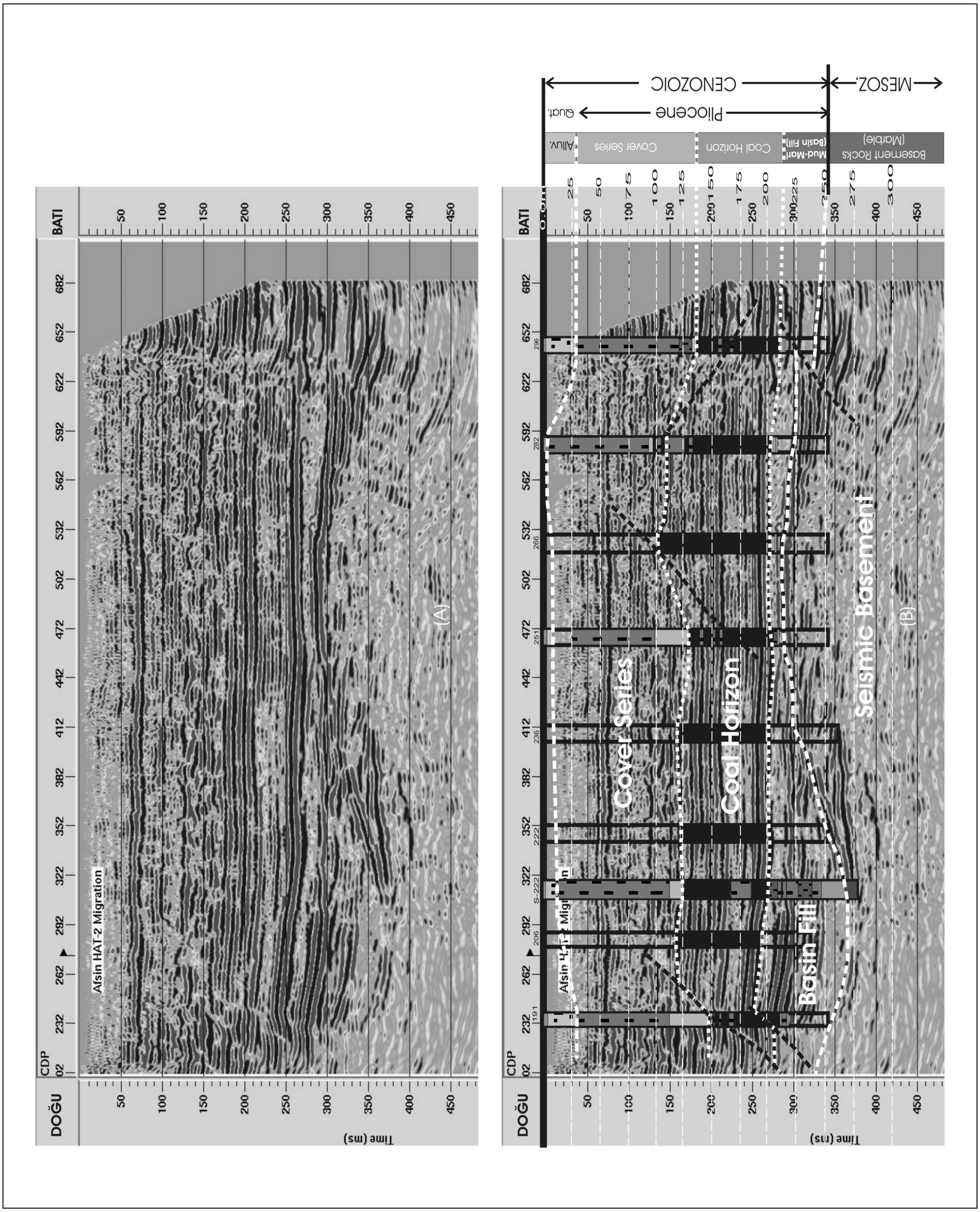

Figure 9- The raw (A) and interpreted (B) seismic cross-sections of Line-Two: correlation of the coal section (the lateral distance between the wells are 250 meters).

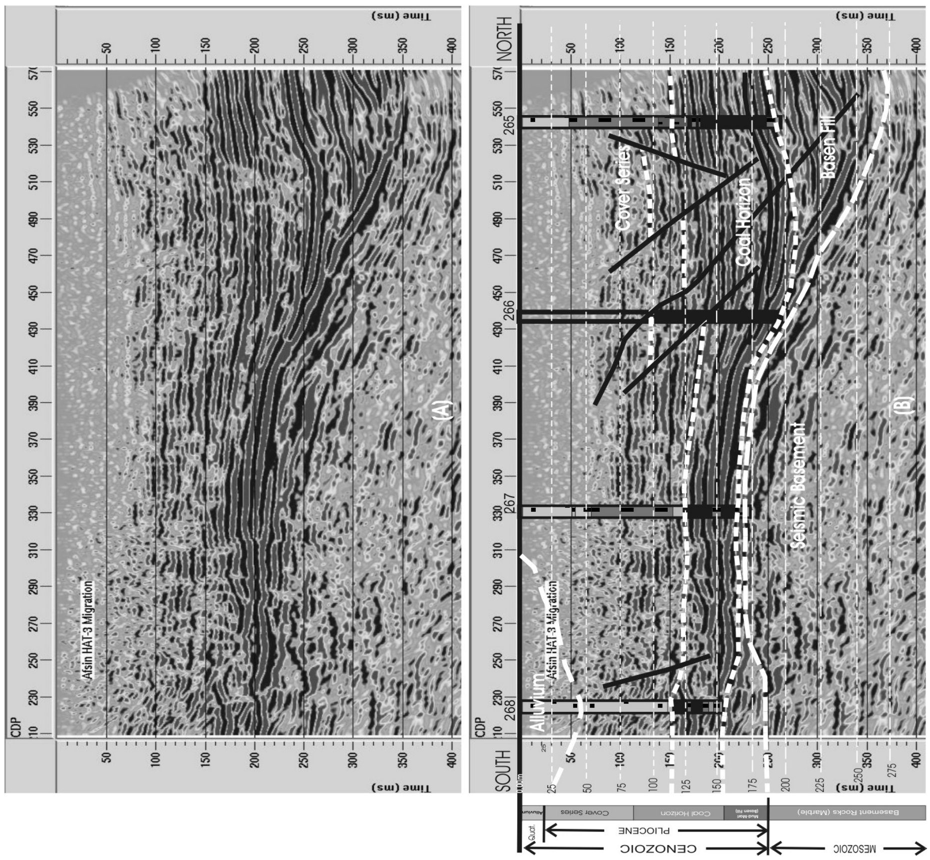

Figure 10- The raw (A) and interpreted (B) seismic cross-sections of Line-Three: correlation of the coal section (the lateral distance between the wells are 250 meters).

meters and it pertains to well no. 266, and the lowest thickness is 50 meters and it pertains to well no. 191. When the correlation curve on the line is examined, it is observed that the thickness value decreases towards the east (Figure 9). Besides, as mentioned in the text above, the coal horizon both becomes thinner and bifurcates with thin coal-layers when headed towards the east. Despite this, on the western portion of the basin, the coal horizon is relatively thicker and demonstrates an integrated structure. When the correlation curve is examined, another factor that draws attention is the undulation on the top and bottom boundaries of the coal horizon. While the upper limit begins at a depth of about 100 meters on the west of the basin, the depth of this zone increases when headed towards the east and becomes 150 meters in well no. 191. When it is considered that coal formation is depressed into a state close to horizontal in a shallow, stable and still basin, it is known that Neogene sediments are deformed, bent and broken in the period following the coal formation (Atay, 1981; Gökmen et al., 1993; Staesche, 1972). In the same way, on the seismic reflection cross-sections, fault systems that have caused significant shifts can be identified in places. A seismic reflection line that exhibits this deformation can be much more clearly observed on the base of Figure 10. After using the sonic log values of the

S-222 borehole located onto this line, the speed /depth conversions were made and the boreholes were tied onto the seismic profiles. The calculated seismic speed walues are given in previous section.

The dome-like reflection surface that offers clear reflection at an approximate level of 300 ms (TWT) on the seismic cross-section is the high of the paleo-basic on the base of the basin and identified as the base level.

LINE 3; Geological Correlation of the N-S Directional Seismic Line

Both on Line 1 and Line 2 seismic lines, the changes in the coal horizon were identified in E-W direction. There are not enough wells on Line 3 to make a detailed evaluation. Making an evaluation about the North-South directional changes of the basin using a total of four wells can yield misleading results. But still, by taking the truth above into consideration, it might be appropriate to make a limited assessment.

Line 3 is laid perpendicular to Line 1 and Line 2 in the direction of North - South (Figure 2). There are four coal cutting wells on the line. From among these, well no. 266 is at the same time on Line 2 seismic line, and well no. 268 is at the same time on Line 1 seismic line. The horizontal distance between Line 1 and line 2 seismic lines is 500 meters. Well no. 267 inspects this distance. The well which is on the very north of Line 3 is well no. 265. Therefore, the coal horizon changes between Line 1 and Line 2 seismic lines can be traced up to maximum 250 meters towards north and the portion between the lines can be inspected from exactly the mid section of the lines.

The geological correlation cross-section belonging to this line was hung up from two stratigraphic levels (DATUM) and the paleo-geographical milieu of the related periods was examined. The first characteristic surface in the coal horizon was selected as the base plane of the coal upper horizon. According to this cross-section, the coal horizon in the basin becomes thinner towards the south at a significant rate. The north portion of the cross-section is probably a depression zone controlled by again an E-W directional perpendicular fault system in regions where Line 1 pass. In the same manner, the coal horizon has significantly become thicker in this section. This depression zone which is understood to be of the same age with the sedimentation of the coal horizon has deposited in contrast to other sections of the basin that are gradually elevating and the swamp environment conditions required for coalification were preserved. In the period when deposition of coal horizon was completed and the covering layers began to deposit, the depression in this region stopped and the entire basin began to shallow. In the same way, the milieu first became stream-delta-lake and then entirely transited to terrestrial environment; and the sediments that are the products of stream sediments filled the basin.

The same seismic line was examined after being hung up once again from the Quaternary base above (DATUM) and here again, it was understood that the basin went through a quite active tectonic period during the Quaternary period and perpendicular movements of about 25-30 meters were developed (Figure 7).

THE GEOLOGICAL INTERPRETATION OF SEISMIC REFLECTION CROSS-SECTIONS

The reflection cross-sections that were produced reflect the general structural and stratigraphical state of the basin to levels of 350 - 400 ms (TWT) quite well. In the seismic reflection cross-sections, fairly high resolution seismic reflection values from about 50 ms were obtained. There is a regular reflection package that continues between 50 and 100 ms; and this regular structure disappears after 100 ms. It is seen that this weak reflective chaotic zone that appears at 100 and 150 ms levels represent the clay-marl alternation of the cover series. These strong reflection values that occur again between 150 ms and 250 ms are resulted from the clayey coal horizon. The weak reflections below these levels represent the basin-fill sediments, consisting of clay-marl alternation. Finally, strong reflections starting from 350 ms represent the seismic basement rocks.

The basin fill sediments are deposited directly onto the Mesozoic-aged marbles unconformably thus big thickness changes have been ocurred. This reveals that the deposition of the Pliocene series were tectonically controlled. The coal horizon, however, was deposited under relatively stable tectonic conditions but after their deposition regional tectonic processes were reactivated. Number of non-described faults in seismic lines the most important evidence of this idea.

CONCLUSION

Researching of coal beds using high resolution shallow seismic reflection method started to become widespread in the 80ies (Greanhalgh et al., 1986; Gochioco and Cotten, 1989). These studies became more widespread in the 90ies (Gochioco, 1991; Henson and Sexton, 1991; Kragh et al., 1991), and even a patent was received from USA Patent Service (US Patent No: 4298967). Today, the developments both in the measuring and data processing and interpretation fields made the applicability of this method possible not only in coal areas but also in mine beds with all kinds of layers. The methodologies of this method were set forth especially in coal searching (Kamkar-Rouhani, 2007). While there are numerous coaliferous Neogene zones in our country, coal searching using seismic reflection method has not been conducted yet. This paper is the first study which shows that this method can be applied to coal beds in our country.

Since the formation in Neogene lagoonal basins deposited in depositional environments which do not have sudden depth differences in general and fed by streams, they consist of series that are laterally and perpendicularly transitive with each other, clastic and sometimes carbonated. Except for the thick carbonated surfaces, the geophysical characteristics of these clastic sediments are similar to each other. Since the physical changes of the formations are not sharp, it is generally difficult to produce detailed seismic reflection cross-sections the perpendicular resolution of which is high in such basins. But again, at the end of this study it is understood that when the shot pattern and frequency interval on the field are selected properly, it is possible to obtain high resolution. In this study, the sediment packages suited to the general stratigraphic sequence of the basin were allocated on seismic reflection cross-sections and their lateral correlations were made. Specifically, when the detailed speed and age data of the formations constituting the aged base are provided, the sequencing in the basin and stratigraphic and seismic stratigraphic studies can be examined more easily.

Using softwares designed to make geological interpretations on the seismic reflection cross-sections, these 2D seismic reflection data can be made usable for real coal study purpose; top, mid and bottom levels of the coal can be mapped separately and the structural analysis can be reflected onto these maps.

Consequently, though they are not representatives of the entire basin, when the seismic reflection cross-sections and the well's geological correlations were taken into consideration as a whole, it was set forth with seismic studies as well that the base of this basin started to acquire a shape tectonically before the Neogene sediments determined by use of geological data. The influence of the Paleo-basic high on coalification can be seen clearly. Structural deformation continued its course during Neogene period and the deposition in the basin must have been kept under tectonic control continuously. In the same way, it is understood that the same perpendicular movements continued during Quaternary as well. With the determination of the underground geometry and the distribution characteristics of coal more exactly, it will be possible to study the open operational conditions in sections where stream sediments, the thicknesses of which reach up to 150 meters in places during Quaternary, are found and to consider the slope stability calculations once again. Application of high-resolution shallow seismic methods to coals may ensure more exact determination of the cover thickness of coal horizon, the type of the cover rocks or sediments and the changes in depth and may contribute in the preparation of operational plans in a more carefully considered manner.

It has been determined that seismic reflection method is appropriate as a rapid and reliable research method for such studies, supported by geological data and physical parameters collected from representative boreholes. We are hopefull that this key study would give a different opinion to the researchers for their ongoing or futur geological studies.

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BOZCAADA' DA (ÇANAKKALE) SOĞUCAK FORMASYONU' NDA SAPTANAN YENİ PALEONTOLOJİK VE SEDİMANTOLOJİK BULGULAR

Baki VAROL*, Ercüment SİREL*, Turhan AYYILDIZ* ve Meltem BAYKAL**

GİRİŞ

Trakya ve yakın çevresinde havza kenarı karbonatları olarak geniş alanlarda yüzlekler veren Orta Eosen yaşlı kireçtaşları Soğucak Formasyonu olarak adlandırılmış ve haritalanmıştır (Holmes, 1961; Sümengen ve diğerleri, 1987). Ayrıca, Siyako ve Huvaz (2007) tarafından diğer Eosen birimleri ile birlikte bu formasyonun Trakya havzasındaki konumu ve stratigrafik pozisyonu detaylı bir şekilde tanıtılmıştır. Önceki çalışmalarda Bozcaada' da yüzeylenen Soğucak Formasyonu, Trakya havzası genelinde olduğu gibi Orta Eosen olarak yaşlandırılmıştır (Temel ve Çiftçi, 2002; Kesgin ve Varol, 2003; Siyako ve Huvaz, 2007). Buna karşın formasyona verilen bu zaman aralığının tüm havza ölçeğinde süreklilik göstermediği yer yer Alt Eosen-Oligosen aralığında değiştiğine dair veriler de mevcuttur. Önal (2002) 'de Gelibolu yarımadasında Soğucak Formasyonu'na eş değer olarak ayırdığı ve tanımladığı Başoğlu üyesini Erken Eosen olarak yaşlandırmıştır. Baykal ve diğerleri (2007) ise, Kuzeybatı Trakya havzası genelinde bu formasyon içerisinde yaygın bir Oligosen çökelim sürecini ortaya koymuştur. Bu veriler, Soğucak Formasyonunun Trakya havzasında daha geniş bir yaş aralığında çökelmiş olabileceğini işaretlemektedir.

BULGULAR

Fıçıtepe Formasyonu: Bölgede yaklaşık 60 metrelik kalınlık oluşturan Fıçıtepe Formasyonu aşağıda tanımlanan iki fasiyes grubu ile temsil olunur (Şekil 1).

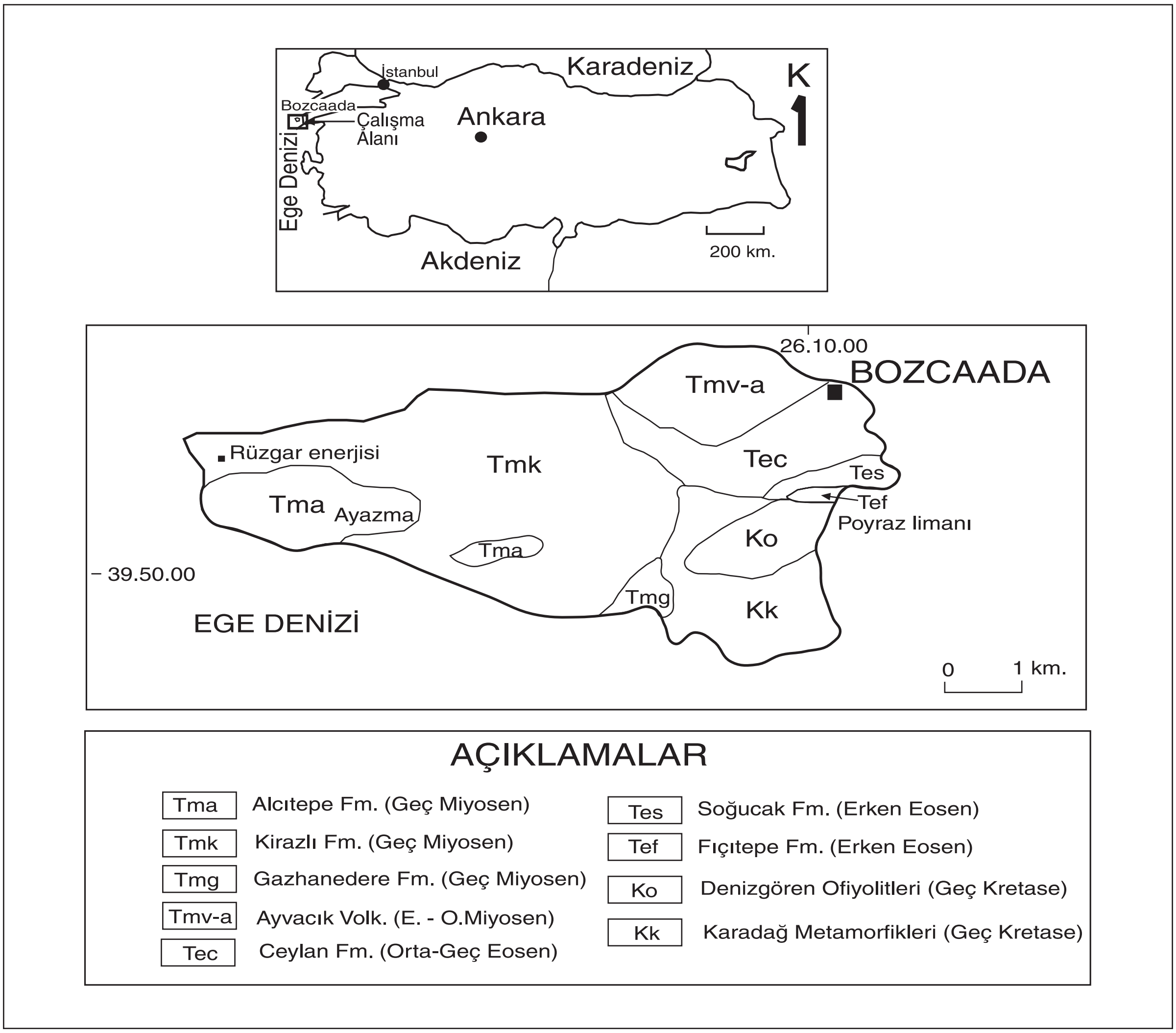
Bunlar; çapraz tabakalı kırmızı-bordo renkli çakıltaşı kumtaşı (F1) ve mikroresifli gri kumtaşı-çakıltaşı (F2) fasiyeslerdir. Ayrıca, F2 fasiyesin en üst bölümünde, çakıllı ve bloklu zeminde büyüyen mercanların oluşturduğu 50-100 cm boyutunda mikroresifler görülür (Şekil 2). F1 fasiyesi depolanma dinamiği açısından örgülü akarsu-havza kıyısı aluviyal yelpaze; F2 fasiyesi ise yüksek enerjili sahil kuşağı karbonatlı konglomeratik kum barları şeklinde yorumlanmıştır.

Soğucak Formasyonu: Fıçıtepe Formasyonunun silisiklastik fasiyesleri üzerine gelen karbonat ağırlıklı bu formasyon içerisinde alttan üste doğru 3 fasiyes ayrılmıştır.

Bu fasiyesler; Alg yumrulu kireçtaşı (F3), makrofosilli kumlu kireçtaşı (F4) ve bentik foraminiferli kireçtaşı (F5)' dır (Şekil 2). F3 fasiyesi algli karbonat gelgit düzlüğü, F4 fasiyesi sınırlı denizel ortam (Ostrea sp.) - silisiklastik sahil birlikteliği; F5 ise bank tipi (*Alveolina* sp. ve *Nummulites* sp.) karbonat yığışımları şeklinde depolanmıştır.

Bu çalışmaya konu olan Erken Eosen yaşını belirleyici fosil toplulukları ölçülü kesitin taban-orta üst bölümünü içine alan yaklaşık 60 metrelik kısmında yoğunluk kazanmaktadır (Başlangıç Koordinatı: 354205130D, 4408800K; Bitiş Koordinatı: 3542089D, 4408758K). Yukarıda ifade

* Ankara Üniversitesi Mühendislik Fakültesi Jeoloji Mühendisliği Bölümü, 06100, Ankara, varol@eng.ankara.edu.tr, sirel@eng.ankara.edu.tr, ayyildiz@eng.ankara.edu.tr,
** Maden Tetkik Arama Genel Müdürlüğü Genel Jeoloji Dairesi, 06658, Ankara, meltembaykal@mta.gov.tr



Şekil 1- Bozcaada' nın basitleştirilmiş jeoloji haritası (Kesgin ve Varol (2003)' den alınmıştır)

edilen bu aralıklar içerisinde yaş belirleyici türler aşağıda verilmiştir.

Alveolina canavarii Checchia Rispoli,1905.KUİZİYEN

Nummulites sp. (grup partschi)

Alveolina pasticillata Schwager, 1883........İLERDİYEN

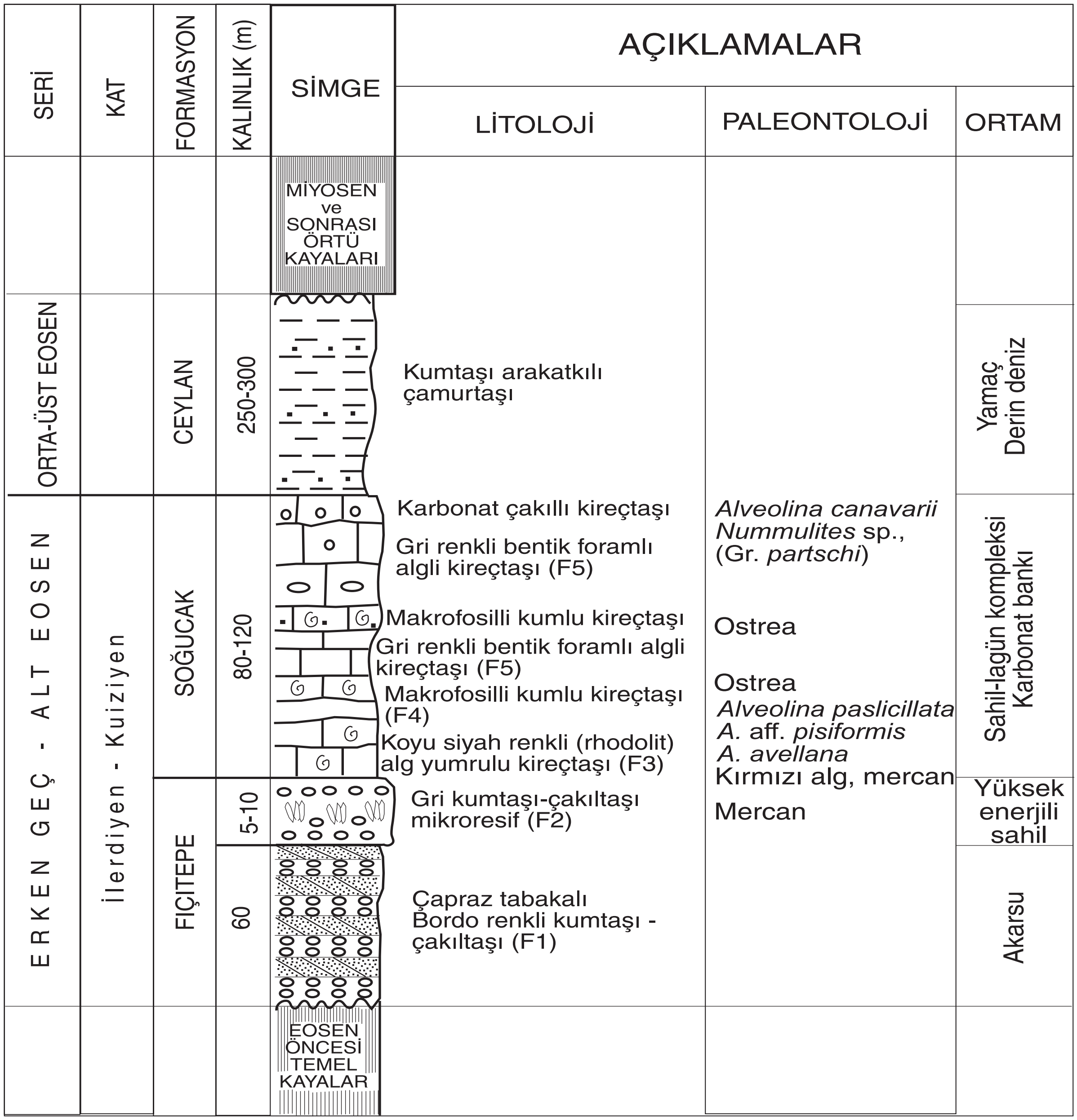
Alveolina aff. pisiformis Hottinger, 1960

Alveolina avellana Hottinger, 1960

SONUÇLAR

Bozcaada Eosen istifini temsil eden Fıçıtepe ve Soğucak Formasyonları için bugüne kadar bilinen özellikleri dışında aşağıdaki yeni bulgular elde edilmiştir.

1) Fıçıtepe Formasyonu karasal bir depolanma sistemi dışında en üst bölümünde mikro resifli denizel bir ortama geçiş göstermektedir.



Şekil 2- Bozcaada Eosen stratigrafisi için önerilen stratigrafik kolon kesit

2) Soğucak Formasyonu tabanda yer alan Fıçıtepe Formasyonu ile geçişlidir

3) Fosil içeriğine göre Soğucak Formasyonu kireçtaşları Bozcaada' da Erken Eosen'de çökelmiştir.

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