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GEOLOGY OF THE TERTIARY ROCKS AROUND KEMAH-ERZİNCAN-ÇAYIRLI REGION AND THEIR SOURCE ROCK CHARACTERISTICS

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ABSTRACT.- Basement of the study area is comprised of Paleozoic rocks which are overlain by rather thick Triassic-Cretaceous Munzur limestone in carbonate facies. This unit is tectonically overlain by Cretaceous ophiolitic complex. In the region, these units are unconformably overlain by Tertiary clastic and carbonaceous deposits. The basement of the Tertiary is comprised of Paleocene clastic rocks which is conformably overlain by Eocene turbiditic deposits. In Erzincan and Çayırlı region the Eocene rocks are unconformably overlain by rather thick clastic and carbonaceous Miocene sequence. The sequence in the basin ends up with Pliocene clastic deposits. In the region, in the north of the Pülk (Balıklı) village, live oil seeps are observed. In Eocene Gülandere formation and in Kömür member of the Miocene Kemah formation, and also in different levels of the Balıklı formation bitumen and asphaltic levels are observed. Results of geochemical analyses show that these rocks do not have source rock potential considering the amount of total organic matter, maturity and type of organic matter. Biomarker analyses of the oil seep indicate that the oil was derived from an early mature clastic source rock of marine origin.

Key words: Oil seep, source rock, total organic matter, biomarker

INTRODUCTION

Neftlik oil seep in Erzincan-Çayırlı basin in Eastern Anatolia has long been known (Figure-1). The first research on this local oil seep was made by Nalifkin (1919), Lucius (1926), Petunikoff (1932), Paige (1933), Roothan (1940) and Stchepinsky (1940). Later on the seep area and the surrounding region were studied in detail from petroleum geology point of view by Kurtman (1962), Arpat (1964), Akkuş (1964), Bulut (1965), Demirmen (1965) and Pisoni (1965). Following these studies Neftlik-1, Neftlik-2, Neftlik-3 and Neftlik-4 wells were opened by the MTA but these wells were abandoned dry (Bulut and Akyol,1966; Akyol and Birgili,1966; Akyol,1968; Birgili and Yurdakul,1971; Gedik,1976). The first regional geological studies in Erzincan region were conducted by Ketin (1950). In the following years Deveciler et al. (1994), Aktimur (1986) and Aktimur et al. (1995) conducted regional studies as well. Tekin (2002) studied the source rock characteristics of the sequences located in the region. During this work, from the research conducted by Aktimur et al. (1995) was highly benefited (Figure-2). In 2000, in Kemah, Erzincan and Çayırlı regions Tur-Kan oil company conducteda geological research, measured stratigraphic sections and carried out geochemical investigations.

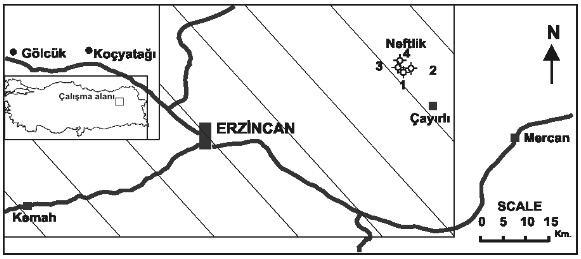

Figure-1 Study area and location map

In this study, source rock facies in the region, organic maturity, organic matter type and its maturity were investigated, also interpreted the geochemistry of the seep, seep-source rock relation and the petroleum potential of the region. Source rock analyses were made by Rock-Eva-II device. Biomarker analyses, on the other hand, were made by using GC-MS.

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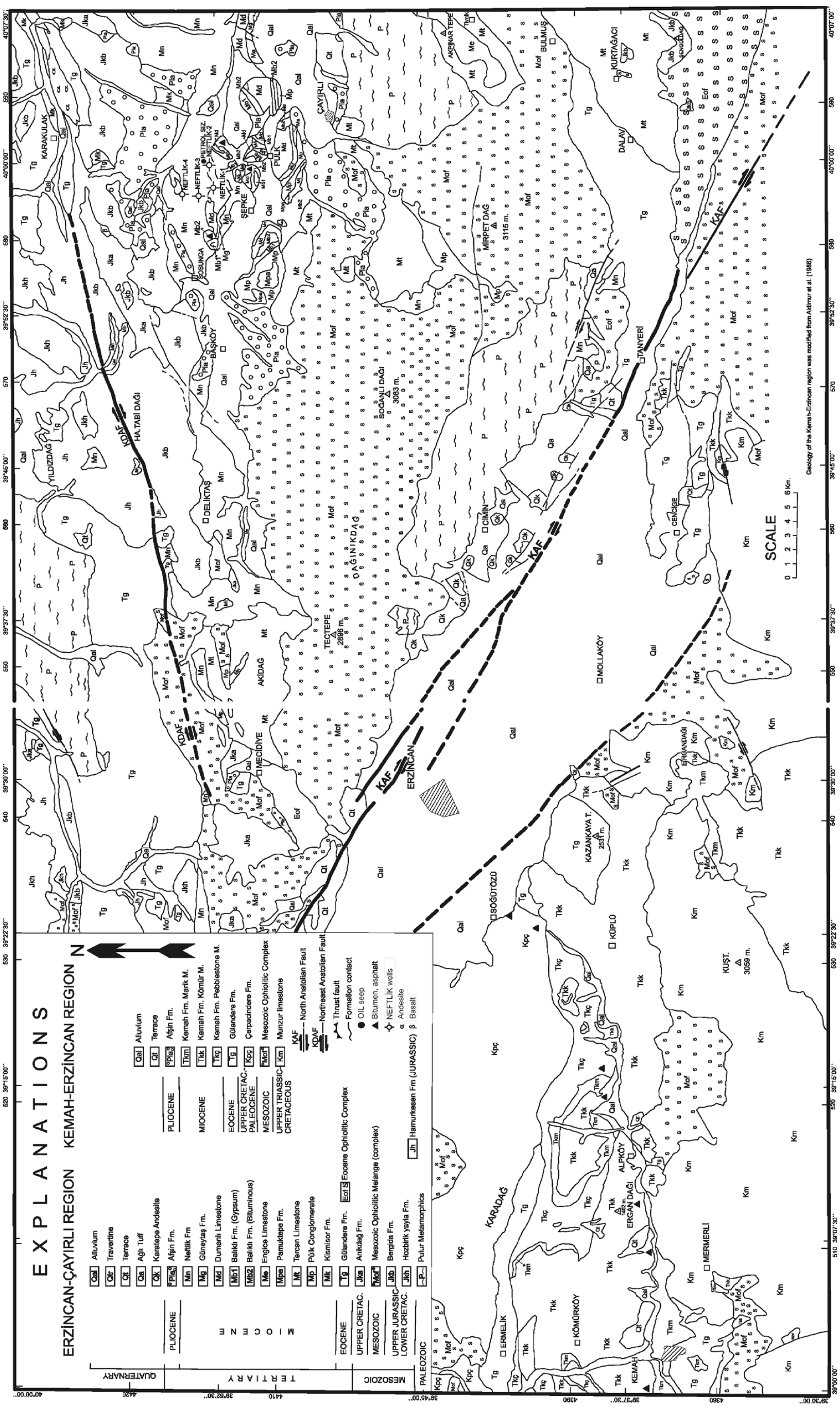


Figure-2 Geological map of the Kemah-Erzincan-Çayırlı region

GENERAL GEOLOGY

The Kemah-Erzincan-Çayırlı region which is located in the Eastern Anatolia is divided into two subbasins by the North Anatolian Fault. While Erzincan is located on the fault, Çayırlı and Kemah take place on the eastern and western sides of the fault, respectively (Figure-2).

In pre-Tertiary basement in the region there are some geological differences. The basement of the Erzincan and Kemah regions are composed of Paleozoic metamorphic rocks. This basement is overlain by rather thick Triassic-Cretaceous Munzur limestone in carbonate facies. Cretaceous ophiolitic complex is tectonically emplaced on this unit. These units are unconformably covered by Tertiary clastic deposits (Figure 3a, 3b). The basement of the Çayırlı region is comprised of Paleozoic metamorphic rocks which is tectonically overlain by Jurassic-Lower Cretaceous carbonates, Cretaceous ophiolitic melange and Upper Cretaceous clastic deposits. All these units are overlain by Tertiary clastics and carbonaceous deposits (Figure 3c). Detailed description and of the Tertiary units and the formations are given below.

Gülandere formation (Tg)

Distribution: In the north of the study area, in the north and south of the Karakulak stream, sandstones with limestone matrix and shale including *Nummulites* are observed. Besides, the formation crops out in the south of Kemah, in the east of Erzincan plain (around Çağlayan and Selepur), in Spikör, Karacaviran and Günbatur. The formation was first described by Aktimur et al. (1995).

Type Locality and Type Section: The typical section of the formation can be measured on the southern flanks of Şeyhmehmet hill in Çayırlı region. Its typical section also can be observed between Değirmendere-Bulanık which are located in the north of the Erzincan-Erzurum highway.

Lithology: The Gülandere formation is constituted of deposits having olisthostromal flysch and turbiditic flysch character. It is comprised of sandstone, claystone, conglomerate, siltstone, tuff and agglomerate succession and it includes andesitic and basaltic lavas. It also includes olisthostromal levels and blocks similar to those in an ophiolitic complex. The formation is blackish gray, brown, claret red, green in colour; it is thin-medium-thick bedded, folded, faulted and jointed. Thick conglomerates, agglomerates, andesites and basalts, thick tuff beds, intra-formational unconformities, unconformities caused by dislocational surfaces, repetitions caused by dislocations have caused the formation to have different sequences in different localities.

Contact Relations: It has gradational contact with Çerpaçindere formation in Erzincan-Kemah region and unconformably overlies Kemah formation. In Çayırlı region, the formation unconformably overlies the Anikdağ, and is unconformably overlain by Kismisor formations.

Thickness and Lateral Changes: The formation is 420 m thick around Çayırlı region. It was measured as 1020 m in Erzincan, and 1200 m in Kemah regions (Aktimur et al., 1995).

Fosil Content and Age: The formation includes *Nummulites* sp., *Discocylina* sp., *Distichoplax biserialis* Dıetrıch fossils and accordingly the age of the formation is determined as Lower-Middle Eocene.

Environmental Interpretation: The Gülandere formation was deposited in a deep marine environment which is suitable for flysch deposition. Lateral movements in form of dislocations which cause repetitions in the sequence and the andesitic-basaltic volcanism are synchronous with deposition. These lateral movements have also drifted large ophiolitic blocks into the depositional basin.

Correlation: The Gülandere formation can be correlated with the Sığırcı formation observed in Bayburt region (Aktimur et al., 1995).

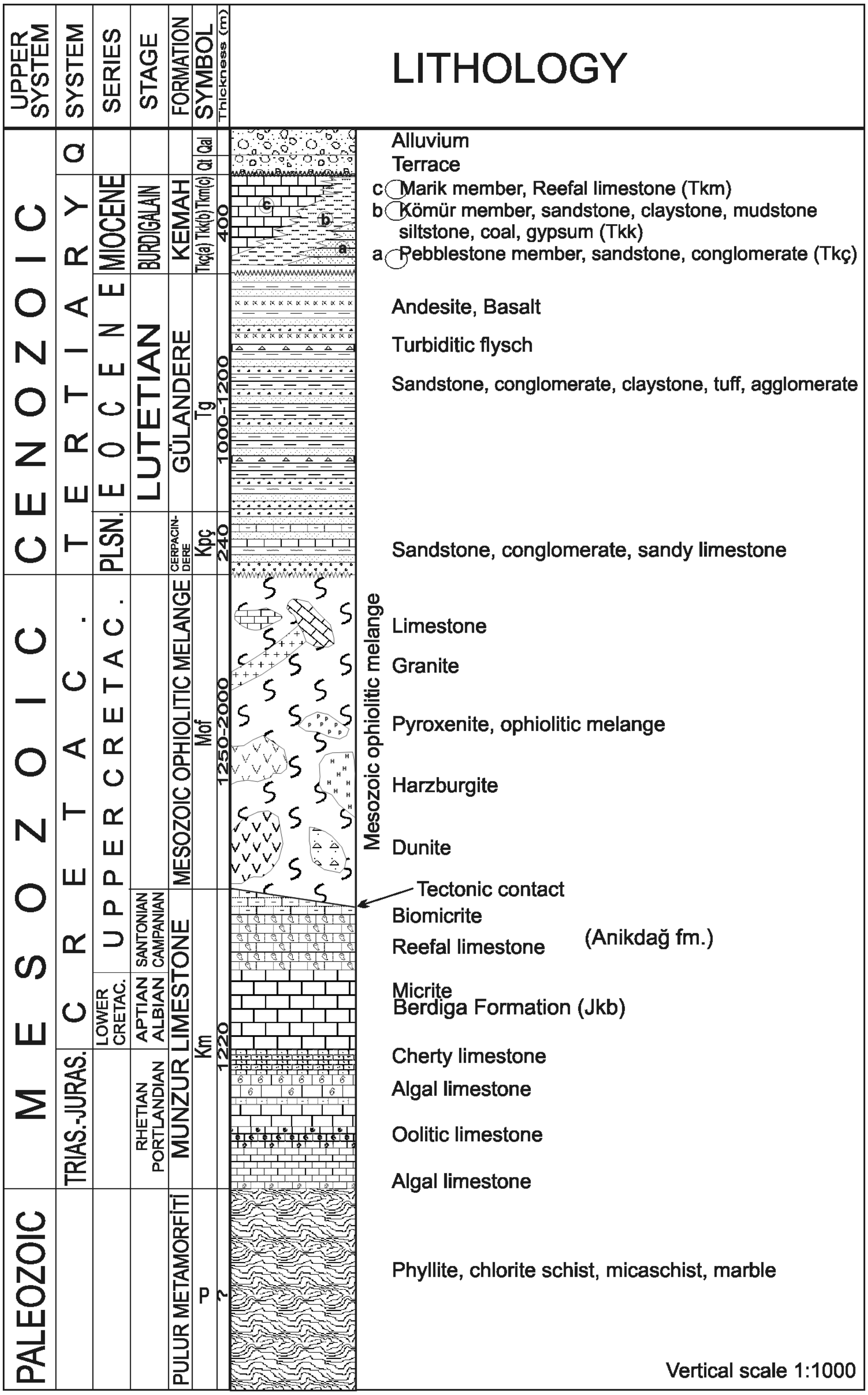


Figure-3a Generalized columnar section of the Kemah region

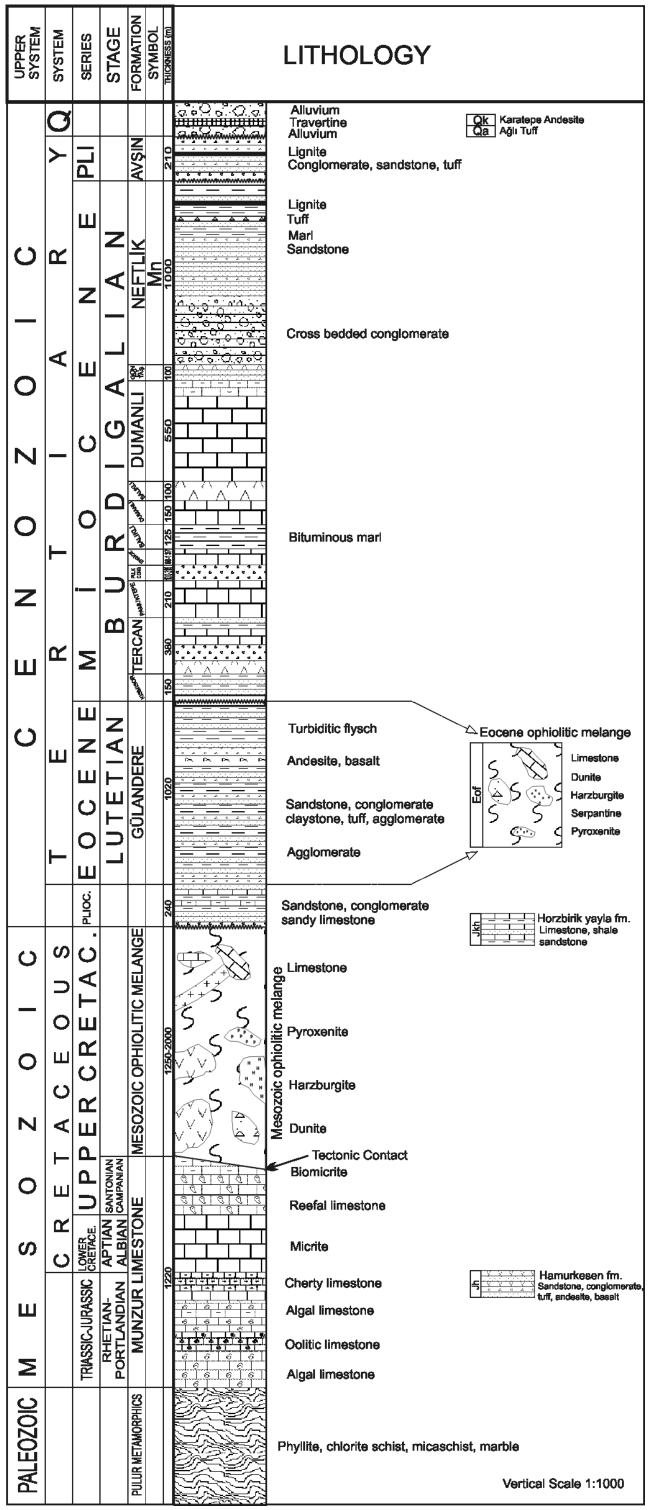


Figure-3b Generalized columnar section of the Erzincan region

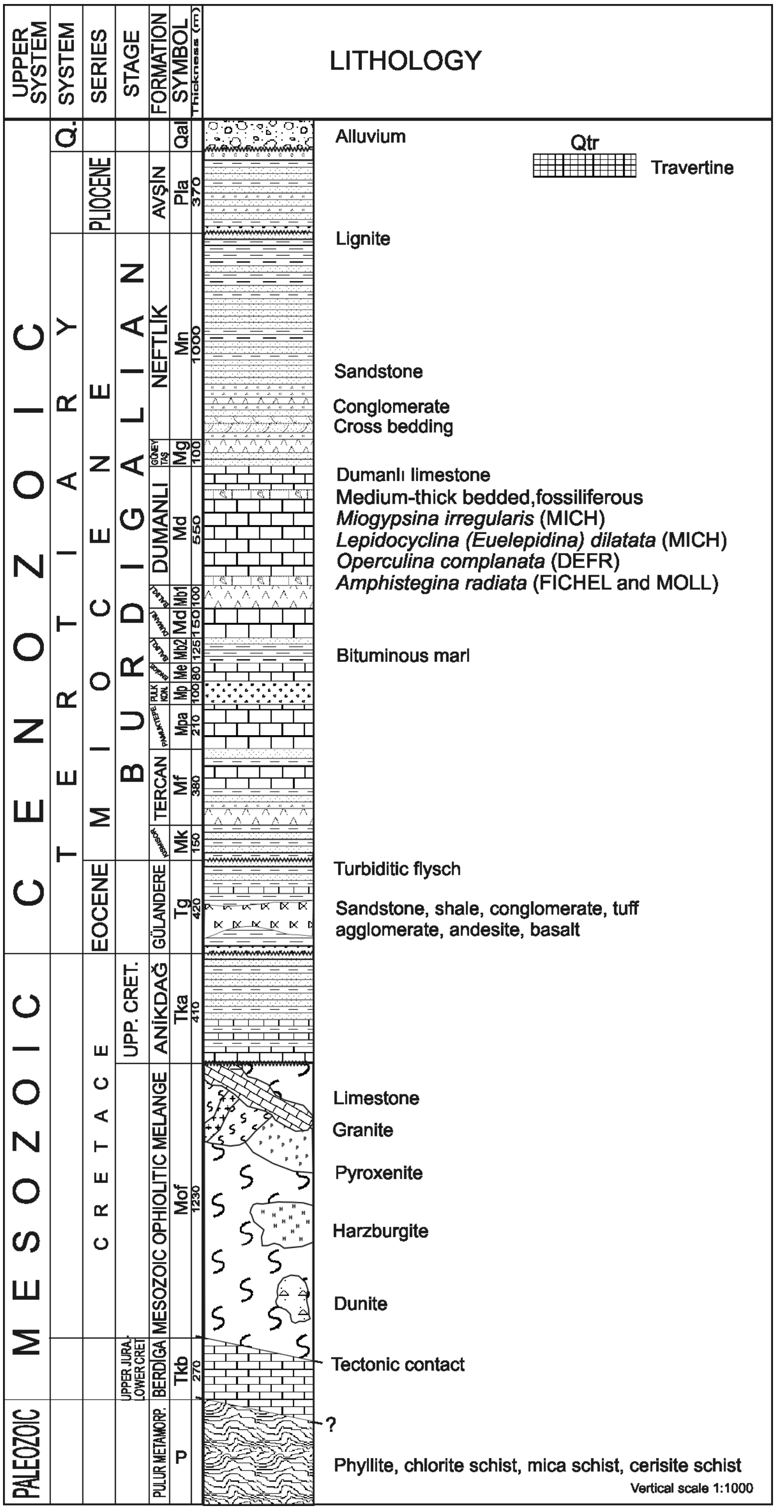


Figure-3c Generalized columnar section of the Çayırlı region

Eosen ophiolitic complex (Eof)

This complex was formed by the translation of the ophiolitic melange into the Eocene sea which crop out on the northern banks of the Fırat river and emplaced during Lower Campanian-Lower Maastrichtian interval. It displays similarities with Mesozoic ophiolitic melange. There are blocks of Çerpaçindere formation in the Eocene ophiolitic melange. The matrix of the complex is comprised of sandstone, claystone, mudstone of the Gülandere formation. According to the fossils such as Nummulites sp., Diccocyclina sp., Assilina sp. found in the matrix, the age is Eocene (Aktimur et al., 1995).

Kismisor formation (Mk)

Distribution: The formation crops out along the Karakulak stream valley, around Kismisor village, on the ridges of Söğütlü and in the west of Mirzaoğlu in the map of İ44 a1 sheet.

Lithological Features: The formation is comprised of red and purple coloured clay, marl, sandstone and conglomerates. It was named by Arpat (1964).

Contact Relations: In the west of Mirzaoğlu, the Kismisor formation overlies the Eocene units with angular unconformity. It is gradationally transitive to the Miocene units at its upper contact.

Thickness and Lateral Changes: The thickness of the formation is 150 m.

Fosil Content and Age: No fossils were collected in the unit. It was assumed to be of Miocene age since it overlies the Eocene units.

Environmental Interpretation: According to its lithological features, the Kismisor formation must have been deposited in shallow sea conditions.

Correlation: The Kismisor formation is similar to the Hürrübaba formation in Erzurum-Tekman basin. There is no bitumen in this formation. The age of the formation is Oligocene according to Arpat (1964). Pisoni (1965) defines the formation as Lakoğlu formation (Deveciler et al., 1994).

Tercan limestone (Mt)

Distribution: The colour of the formation is light yellow, grayish white. It includes foraminifera, lamellibranch, echinides, gastropoda and algae. The formation was named by Pisoni (1965). It crops out around Pülk mountain, Sırataş hills and Engice mountain.

Type Locality and Type Section: The type section of the formation was measured in Babanın Şenliği located in the south of Çayırlı (Figure-4).

Lithological Features: In the section measured in the south of Çayırlı, at the bottom limestone, marl and claystone succession, and at the top white coloured, medium bedded limestone with bioclast intercalations and at the topmost calcarenite including lamellibranches were observed.

Contact Relations: It overlies the metamorphic rocks and ophiolites with angular unconformity in Gelinpertek village located in the south of Çayırlı. It is overlain by Pülk conglomerate with gradational transition.

Thickness and Lateral Changes: The thickness of the formation was measured as 125 m in Babanın Şenliği section. The average thickness of the formation is 150 m.

Fossil Content and Age: The formation includes *Miogypsinoides* sp., *Miogypsina* sp., *Lepidocyclina* sp., *Amphistegina* sp., *Tarbellastraea reussina* (Edwards ve Haıme), *Favites neglecta* (Mıchelottı) fossils and the age of the formation is Burdigalian-Early Miocene accordingly.

Environmental Interpretation: According to the lithological and paleontological features of the

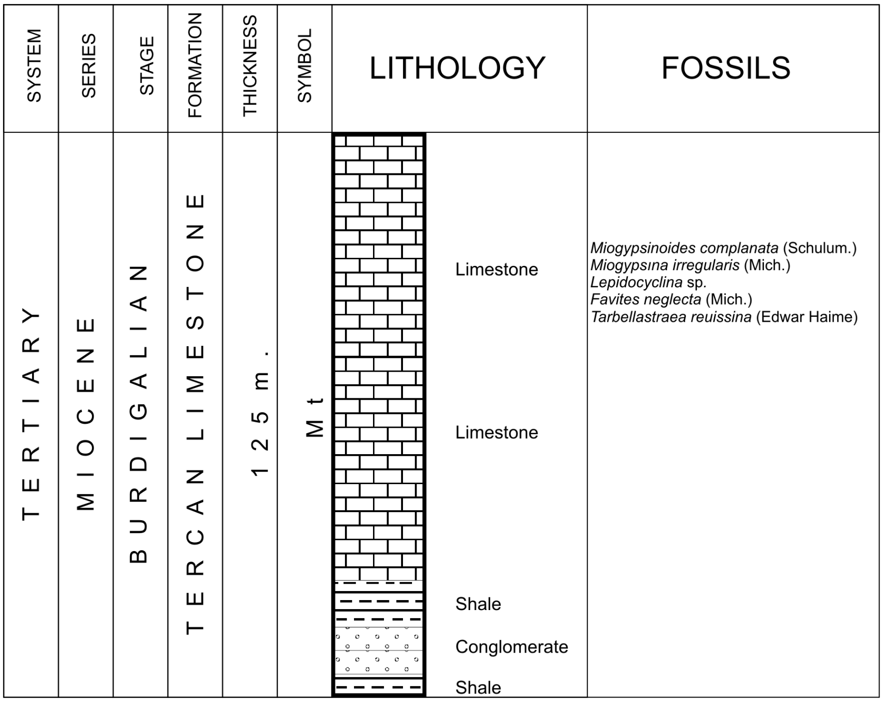


Figure-4 Measured stratigraphic section of Tercan limestone

formation, it must have been developed in an environment affected by high energy conditions. The coral reefs indicate that the environment has reefal characteristics (Deveciler et al., 1994).

Correlation: The formation can be correlated with the Haneşdüzü limestone observed in Erzurum-Pasinler, Tekman, Hınıs regions.

Pülk conglomerate (Mp)

Distribution: This unit crops out in the south of Çayırlı. In the east of the study area, the same unit was named as Lakoğlu formation. It is reddish, purplish in color and comprised of sandstones and mudstones with rounded, semi-rounded pebbles. It has conglomeratic features. The unit was defined by Arpat (1964).

Type Locality and Type Section: The typical localities of the unit are Pamuktepe, Pülkdağı and Pülkdağı hill around Çayırlı.

Lithological Features: The sequence is comprised of purplish, reddish, conglomerate with rounded, semi-rounded pebbles, reddish sandstone and mudstone. Conglomerates are thick bedded and lenticular, with erosional basements. The sandstones are medium bedded and locally display cross beddings. They have good porosity. The mudstones are brick coloured and thin bedded; they include sundry cracks and thin gypsum beds.

Contact Relations: The unit is gradually transitive on the Tercan limestone in Babanın Şenliği section. It is also gradually transitive to the Balıklı formation in Pamuktepe section and in Pülkdağı hill, and with Engice limestone in Pülkdağı and in Kızılkayalar sections. Its base is gradationally transitive on the Tercan limestone in Babanın Şenliği and Pamuktepe sections only.

Thickness and Lateral Changes: Thickness of Pülk conglomerates is 270 m at Pülk hill, 316 m in Pamuktepe hill ve 98 m at Pülkdağı (Figure 5).

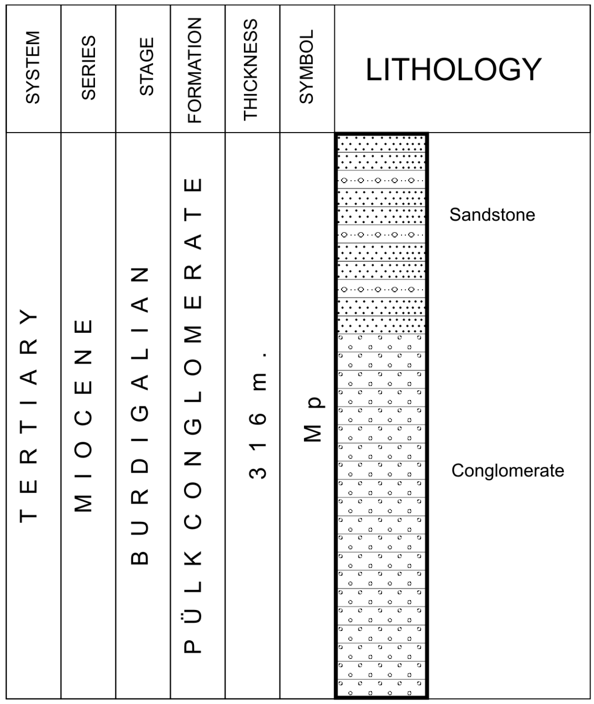


Figure-5 Measured stratigraphic section of Pülk conglomerate

Fosil Content and Age: No fossils were collected in the Pülk conglomerates. Because of its stratigraphic position, by overlaying the Tercan and underlaying the Engice limestones, the age of the unit is assigned as Early Miocene.

Environmental Interpretation: The Cross bedded sandstone lenses, and conglomerates indicate debris flows low energy and shallow stream deposits. The unit was deposited in upper-medium alluvial fan environment. Pebbles that form the conglomerate are of metamorphic and ophiolitic rock origin; this indicate that ophiolitic and metamorphic rocks are present in the source area.

Correlation: The unit can be correlated with Hürrübaba conglomerates in Erzurum-Tekman basin.

Pamuktepe limestone (Mpa)

Distribution: The unit crops out in the west of Çayırlı (İ43 b3) only. It was first defined by Arpat (1964).

Type Locality and Type Section: The type locality of the unit is Pamuktepe.

Lithological Features: The unit has light gray coloured, hard, well bedded sandy limestones in the lower levels, in the central sections it comprises white coloured, brittle, fossiliferous, sandy and clayey limestones. The unit has yellowish grey coloured, thin bedded, laminated and fossiliferous limestones in the upper levels.

Contact Relations: The unit overlies the gypsum unconformably. It is overlain by Miocene Neftlik formation.

Thickness: Pamuktepe limestone is 210 m thick (Figure-6).

Fossil Content and Age: The following fossils collected from the unit indicates Burdigalian age: *Miogypsina irregularis* (Mish), *Amphistegina radiata* (Fichtel ve Moll), *Operculina complanata* (Defr).

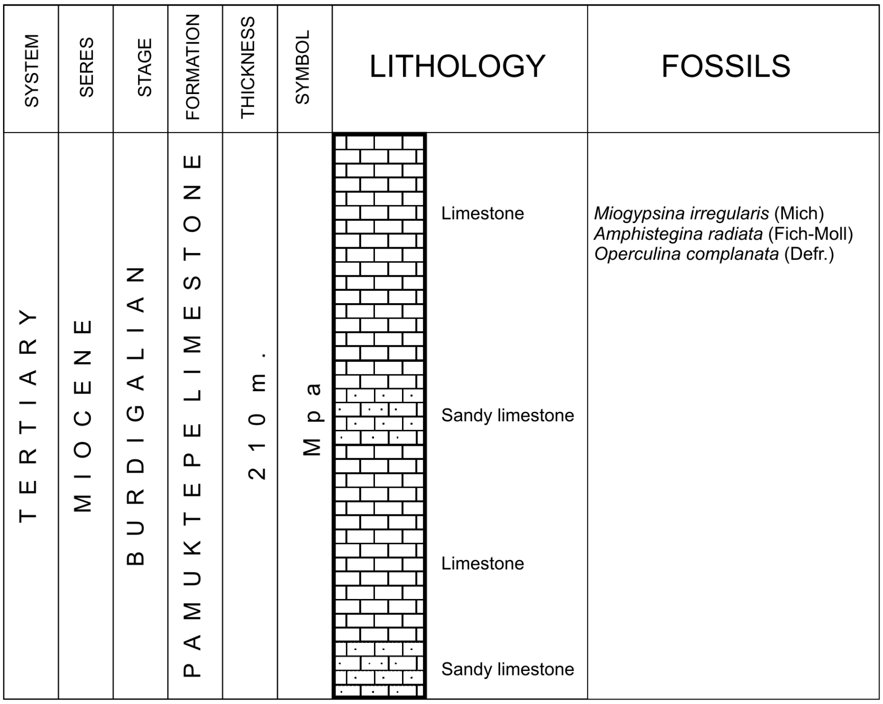


Figure-6 Measured stratigraphic section of Pamuktepe limestone

Environmental interpretation: According to lithological and paleontological features of the unit, it was deposited in a shelf environment of a warm sea.

Correlation: Pamuktepe limestone can be correlated with the Haneşdüzlü limestone observed in Erzurum-Tekman, Karayazı, Pasinler basins.

Engice limestone (Me)

Distribution: The unit crops out in the Pülk mountain, Kızılkayalar, Mırcıgataşı hill, Engice mountain and Şahinkalesi hill in the study area. Engice limestone which is comprised of light red -pink coloured, fossiliferous limestones was defined by Arpat (1964).

Type locality and type section: The type sections of the sequence were measured at Pülk mountain, Kızılkayalar and Engice mountain.

Lithological features: The Engice limestone which overlie the Pülk conglomerate in Pülk mountain is white coloured and includes large shell fragments and crinoid fragments; however, in Kızılkayalar it is a red - pink coloured, well sorted calcarenite with coarse sand and includes terrigenous clastics derived from ophiolites, lamellibranch and shell fragments. Silicium and ophiolitic pebbles are found in limestones around Şahinkalesi hill. The 1-1.5 cm sized pebbles are ill-sorted and medium-well rounded. They are thick bedded. In the south of Mırcıga village, Pülk conglomerates with large blocks (marbles of 80 cm in diameter, serpantines of 50 cm in diameter, andesite, granite blocks of 20 cm in diameter) are located below the red limestones.

Contact relations: Pülk conglomerates are located below the Engice limestone. In the upper contract, it is transitive to Balıklı formation.

Thickness and lateral changes: The average thickness of the Engice limestone is 80 m. The unit is 64 m in Pülk mountain, 125 m in Engice mountain and 137 m in Kızılkayalar. Thickness gradually decreases in the west of Pülk mountain (Figure-7).

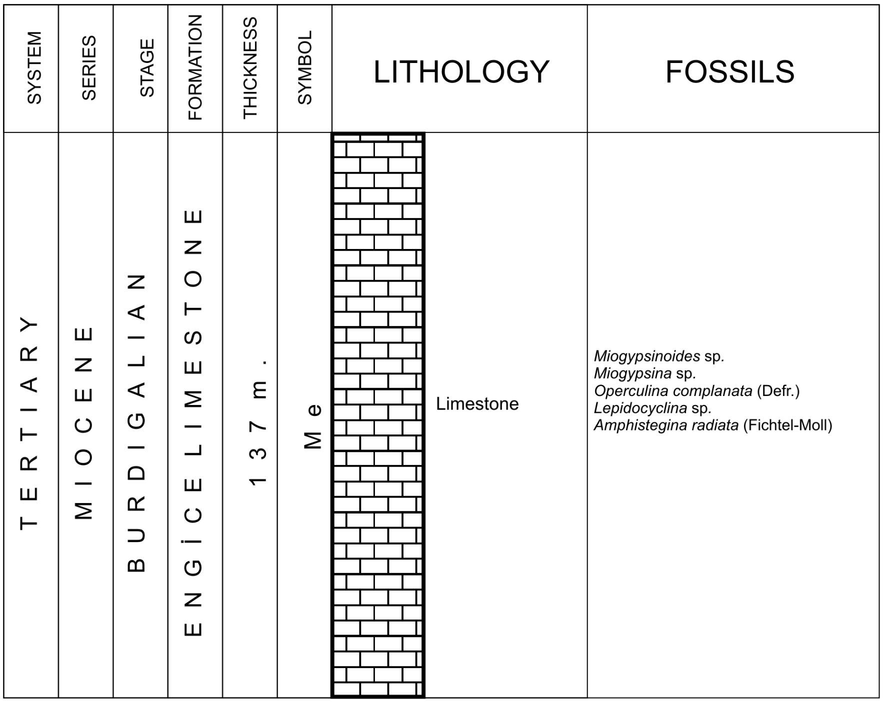


Figure-7 Measured stratigraphic section of Engice limestone

Fossil content and age: The age of the unit is Burdigalian according to the following fossil assemblage: *Miogypsinoides* sp., *Migypsina* sp., *Amphistegina* sp., *Lepidocyclina* sp., *Lithothamnium* sp., *Operculina* sp., *Elphidium* sp., Bryozoa, corals, gastropoda, echinoides.

Environmental interpretation: The fossils stated above indicate marine environment between 0-50 m and indicate that the section of the Engice limestone with coarse grains, including shell fragments, sandy, pebbly sections were formed in high energy sea shore environments. Fine grained, massive or thick bedded calcarenites indicate deposition in deeper environments by the fossils pointing the conditions below the wave base. In general, The Engice limestone is in clastic limestone facies; it was formed in clastic and carbonaceous seashore environment. It is transitive in lateral and vertical directions.

Correlation: The unit can be correlated with Haneşdüzü limestone observed in Erzurum-Pasinler-Karayazı, Tekman basins.

Balıklı formation (Mb1, Mb2)

Distribution: Balıklı formation which crops out in Çayırlı region is comprised of bituminous marl and gypsum. The gypsum is indicated on the map by Mb_1 and the bituminous marl is indicated by Mb_2. The sequence was defined by Arpat (1964). It overlies the Engice formation and is comprised of clay, marl and limestone levels with clastic elements. The limestones include bitumen.

Lithological features: The sequence is comprised of a marl, shale and claystone succession and gypsum levels gradually thickening and thinning and after a thin limestone level.

Contact relations: The unit is laterally and vertically transitive to Engice limestone in the lower contact and to Dumanlı formation in the upper contact. It is below the Neftlik formation in Neftlik-4 well.

Thickness and lateral changes: The unit is 220 m in Pülk mountain section, 121 m in Kızılkayalar, 222 m in Pamuktepe, 1050 m in Neftlik-4 well (Figure-8, 12).

Fossil content and age: The following fossils indicate that the age of the Balıklı formation is Burdigalian (Arpat, 1964): *Miogypsina* spp., *Gyroidina neosoldanii* Brotzen, *Uvigerina longistriata* Perconıg, *Nonion pompilioides* (Fıcht-Moll), *Nonion boueanum* (D'orb) and *Pyrgo depressa (D'orb).*

Environmental interpretation: Evaporites such as gypsum, anhydrite and halite were formed by the primary deposition at the bottom of the lagoon and between tidal flat environment which resemble the Holocene sabhkas.

Dumanlı limestone (Md)

Distribution: Dumanlı limestones crop out in Pülk mountain, Sırataştepe, Kırklartepe and Güneytaştepe. The general lithology is limestone. In the study area it crops out in Çayırlı region and was first defined by Arpat (1964).

Type locality and type section: The typical locality of the sequence is Pamuktepe, Pülkdağı and Kızılkayalar.

Lithological features: The lower levels of the Dumanlı limestone are comprised of conglomerates and limestones with shell fragments. This limestone is gray-white, yellowish in color, hard, with abundant fossils, and includes large shell fragments, echinides and lamellibranch fragments in some levels. It is medium to thick bedded and its upper levels include fine grained limestones. It is sandy in general.

Contact relations: The unit is gradationally transitive onto the Balıklı gypsum and Balıklı claystone. It also is gradationally transitive to Güneytaş formation in the upper contact.

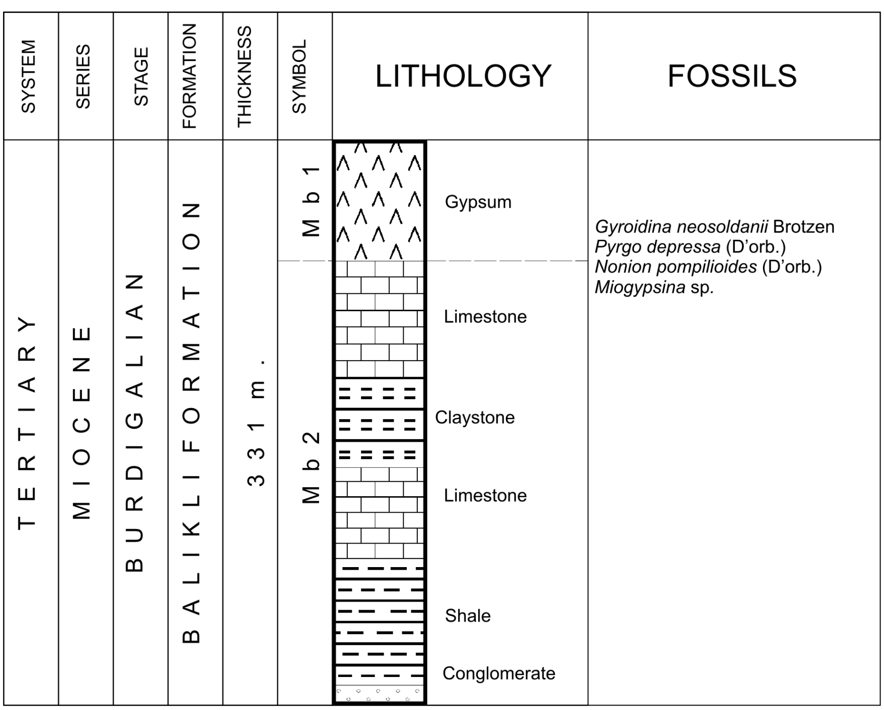


Figure-8 Measured stratigraphic section of Balıklı formation

Thickness and lateral changes: The unit is 345 m in Pülkdağ, 452 m in Kızılkayalar, 193 m in Neftlik-1 well and 550 m in the west of Çayırlı (Figure-9).

Fossil content and age: The following fossils collected in the unit indicate Burdigalian: *Miogypsina irregularis* (Mıch), *Miogypsina* sp., *Lepidocyclina* sp., *Amphistegina radiata* (Fıchtel and Moll), *Rotalia* sp., *Elphidium* sp., *Operculina complanata* (Defr.)

Environmental interpretation: Coarse grains, shell fragments, sand and pebble content of the Dumanlı formation indicate that the formation was deposited in a high energy marine condition.

Correlation: The formation can be correlated with the Lower Miocene Haneşdüzü formation in Erzurum basin.

Güneytaş formation (Mg)

Distribution: The formation crops out at Güneytaştepe and Sırataştepe hills located in the north of the Pülk village. It is comprised of white coloured marl, red sandstone, clay and gypsum. The formation was defined by Arpat (1964).

Type locality and type section: No typical sections were measured.

Lithological features: The sequence is comprised of white coloured marls, red coloured sandstones, clay and gypsum succession. It uncludes abundant ostrea

Contact relations: The lower contact of the formation is unconformable with Dumanlı limestone while the upper contact is gradationally transgressive to Neftlik formation.

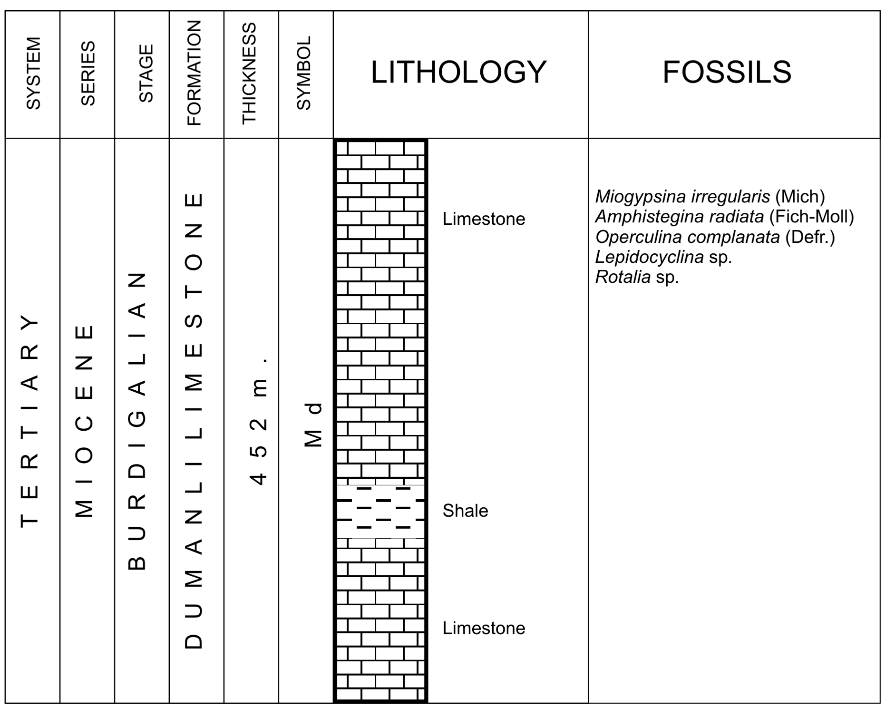


Figure-9 Measured stratigraphic section of Dumanlı limestone

Thickness and lateral changes: The thickness of the formation is 110 m.

Fossil content and age: The following fossils were determined in the formation and accordingly the age of the formation is Burdigalian: *Miogypsina* sp., *Rotalia* sp., *Elphidium* sp., *Operculina* sp., *Ostrea* sp.

Environmental interpretation: The formation was deposited in a shallow marine environment.

Neftlik formation (Mn)

Distribution: The succession of conglomerate, sandstone, claystone and sandy marl observed in the study area is named as Neftlik formation. It crops out in wide areas in İ44 a_1 and a_4 sheets. It was first described by Arpat (1964).

Type locality and type section: The typical section of the unit was measured on the roadcuts between Çayırlı-Karakulak and Neftlik mountain. Besides, it can be mesured at Kenetaşı hill in İ44 a_3 sheet.

Lithological features: The lower sections of the Neftlik formation was comprised of red coloured conglomerate with abundant magmatic pebbles. In the central parts sandstones and in the upper parts marls are dominant. Between the thick conglomerate levels white coloured tuff beds are observed. Thickness of the lower conglomerate level is 280 m. Conglomeratic levels become rare upwards and sandstones become dominant in general. Thickness of the sandstones is 420 m. The upper levels of the Neftlik formation is comprised of white-yellow, green coloured clays and marls. There are two tuffaceous levels which display clay mineralization.

Contact relations: The lower contact of the Neftlik formation is gradationally transitive with Dumanlı limestone and Güneytaş formation whle the upper contact is unconformable with Afşin formation.

Thickness and lateral changes: Thickness of the Neftlik formation is 1050 m. 986 m of the formation was cut in the Neftlik-4 well (Figure-12).

Fossil content and lateral changes: The following fossils were determined in the unit and accordingly the age of the formation is given as Burdigalian *Miogypsina* sp., *Lepidocycüna* sp., *Heterostegina* sp., *Elphidium* sp., *Operculina* sp., Miliolidae.

Environmental interpretation: The formation was deposited in underwater delta platform and was buried under the floodplain with alluviums of which deltaic ceiling is advancing. Grain size of the conglomerates, erosional bottom contacts and the cross beddings indicate that the formation was deposited in high energy flow beds (Deveciler et al., 1993).

Correlation: The formation can be correlated with Yastıktepe formation located in Horasan, Pasinler (Erzurum) region.

Kemah formation (Tkç, Tkk, Tkm)

Kemah formation crops out in the south of the North Anatolian Fault between Kemah town and Erzincan and on the north and south of the Erzincan-Kemah road. Three members were differentiated in the formation. These three members are laterally and vertically transitive to each other: Pebblestone member (Tkç), Kömür member (Tkk) and Marik limestone member (Tkm).

Pebblestone member (Tkç)

Distribution:The sequence crops out in the core of the Kömürtuzlası anticline, in Kömür village and around Tortan, Mazerik, Zikri, Arbos and Sürek regions.

Type locality and type section: No typical sections were measured.

Lithological features: The Pebblestone member is comprised of reddish, locally grayish, gren

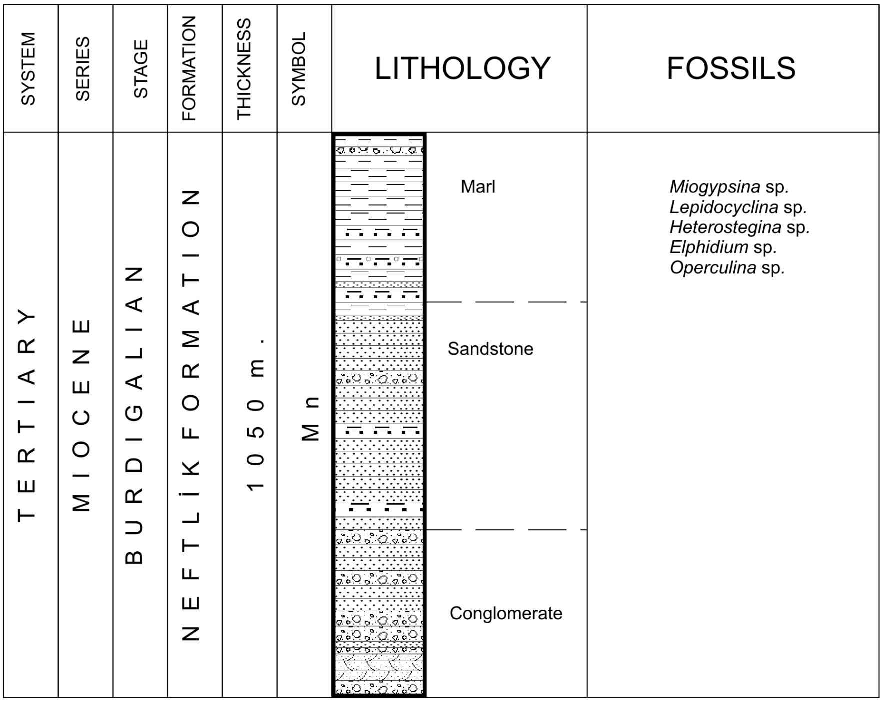


Figure-10 Measured stratigraphic section of Neftlik formation

coloured, medium to thick bedded, well sorted pebblestones and sandstones with clayey and carbonaceous matrix. It crops out in the core of the Kömürtuzlası anticline and in the north of the Kemah-Erzincan road. It can easily be differentiated from the other red coloured formations.

Thickness and lateral changes: Thickness of the Pebblestone member of the Kemah formation is 400 m. It is laterally and vertically transitive to the Kömür member.

Fossil content and age: No datable fossils were found in the red, variegated coloured conglomerates, sandstones and shales beds of the member.

Environmental interpretation: The Peblestone member of the Kemah formation, cross bedded sandstone and shale beds were deposited in underwater fan delta environment.

Correlation: The unit can be correlated with the Lakoğlu formation located between Tercan-Aşkale.

Kömür member (Tkk)

Distribution: This member crops out on the northern and southern banks of the Fırat river between Erzincan and Kemah.

Type locality and type section: No typical sections were measured.

Lithological features: The units in general is comprised of a succession of sandstone, claystone, mudstone, clayey limestone, siltstone. It includes red, yellow, white, gren coloured, thin-medium-thick bedded, folded, jointed, locally overturned levels including fine carbonates, coal and gypsum.

Contact relations: It is laterally and vertically transitive to the overlain Pebblestone member and Marik limestone. Locally the unit unconformably overlies some other older units.

Thickness and lateral changes: Thickness of the unit is 400 m, however it can observed thicker in some places. It is laterally and vertically transitive to Marik limestone.

Fossil content and age: Based on the following fossils the age of the member is determined as Burdigalian: *Cyclammina latidossata* (Born), *Singmoilina miocenica* Cushman, *Margulina* cf. *incerta* (Egger), *Discorbis* cf. *orbicularis* (Terquem).

Environmental interpretation: The Kömür member was deposited in a terrestrial, lagoonal and shallow marine environment (Aktimur et al., 1995).

Correlation: The unit can be correlated with Hürrübaba formation located in Tekman-Erzurum regions.

Marik limestone member (Tkm)

Distribution: Marik limestone member crops out in Kemah, Zoga, Marik, Tavginer and Acemsuyu regions.

Typical locality and typical sections: No typical sections were measured.

Lithological features: The unit is white, yellowish coloured in general and is medium to thick bedded with calcite veins and joints. It is sandy and in some places it is observed as clayey limestone. It includes algae, micro and macro fossils.

Contact relations: The lower contact of the sequence is transitive to Pebblestone member and in places it is transitive to Kömür member. In general the Marik limestone member is located at the topmost. It unconformably overlies the older units.

Thickness and lateral changes: Thickness of the Marik limestone member is 400 m. It is laterally and vertically transitive to Kömür and Pebblestone members.

Fossil content and age: Based on the following fossils and algae and shell fragments collected in the Marik limestone member the age of the member is determined as Burdigalian: *Miogypsina irregularis* Mich, *Miogypsina saitoi* Yabe ve Hanzawa, *Miogypsina* sp., *Lepidocyclina* sp., *Amphistegina* sp.

Environmental interpretations: Marik limestone member has abundant fossils, it was deposited in a warm and shallow marine environment.

Correlation: The unit can be correlated with Haneşdüzü formation located in Pasinler-Tekman-Hınıs regions.

Avşin formation (Pla)

Distribution: This unit which forms slightly rough, rounded hills in the region by conglomerate with hard matrix and sandstone with coarse-medium size grains. It crops out around Kirazdağ and Kazburnu hills in the map of İ44 a_1 sheet and Avşin and Aşağı Avşin in İ44 a_3 sheet. It was first described by Akkuş (1964).

Type locality and type section: Type locality of the Afşar formation is in the south of Avşin stream located between Yukarı Avşin and Aşağı Avşin villages.

Lithological features: Avşin formation is comprised of a succession of conglomerate with hard matrix and sandstone with coarse-medium size grains. Th epebbles at the upper levels are not consolidated. Thickness of the pebblestone levels is 50-75 cm. The pebbles were derived from serpentines, radiolarites, Mesozoic and Miocene limestones. Large scale cross beddings are observed. At the upper levels of the Avşin formation marl, swamp deposits with coal and tuff beds are located. The beds are horizontal or have dips varying between 10°-25°.

Contact relations: Avşin formation unconformably overlies the older units. It is unconformably overlain by the Quaternary terraces and alluviums.

Thickness and lateral changes: Thickness of Avşin formation is 370 in Çayırlı region and 210 m in Kemah region. In DSİ Pekeriç drillings the thickness of the formation is measured as 235 m.

Erzincan volcanics

The young volcanic rocks cropping out in the eastern side of the Erzincan plain have formed in two phases. These are Ağlı tuff (Qa) and Karatepe andesite (Qk).

Ağlı tuff (Qa): This is unit is comprised of tuff, perlite and pumice. The name of the unit is after Ağlı. It crops out around Üzümlü in the eastern sections of the Erzincan plain. The tuffs are white - gray coloured, thin to medium bedded, jointed, faulted. The age of the unit is Plio-Quaternary and it unconformably overlies the older units and is unconformably overlain by the alluviums and alluvial cones.

Karatepe andesite (Qk): The unit is comprised of rocks such as andesite, trachyandesite, rhyolite, rhyodacite and trachyte. It was named after Karatepe. It crops out around Üzümlü, in vicinity of Erzincan-Pülümür highway, and around Güneyli. They include andesine, augite, hornblende and biotite crystals.

Travertines

In Kismisor stream valley, along Başköy reverse fault travertines were formed. Recent travertine formations stil continue in the region. Besides, in southeast of Erzincan, travertine formations can be observed around Çağlayan and Brastik villages.

Alluviums (Qal) and alluvial terraces

Alluvial terraces cover large areas in the study area. The Mans and Pülk streams joining to Karasu river have formed their own beds on the hanging alluviums. The terraces lithologically include flat or angular pebbles, sandstones, sands, pebbles and clay successions. Pebbles are generally derived from basic and ultramafic rocks. They are partly well rounded and ill sorted. Clay levels are dark coloured (Aktimur et al., 1986). The younger alluviums are mostly found in stream beds and in valleys and can easily be differentiated from the older terraces.

STRUCTURAL GEOLOGY

Folds

In the north of the study area, there is a 1-3 km wide folded zone which extends between Pülk and Çığaloğlu bridge. In this zone, there are anticlines and synclines in Miocene sequences. These folds continue in the east of Pülk village. The largest anticlines and synclines are located in the north of Pülk mountain. The axis of the anticline which is located in the south of the Bozağa village extends in E-W direction for 10 km. Pülk mountain, Kırklar hill, Sırataş hills and Engice mountain forms the southern flank of this anticline. Pülk mountain is a double plunging syncline and its axis extends in E-W direction. Jurassic-Cretaceous, Late Cretaceous, Eocene and Oligocene formations have folded in E-W, NE-SW directions. Miocene deposits have formed wider folds and plunging anticlines and synclines. The irregularity in the folds of the gypsums are mainly for this reason.

Thrusts

In the north of the Karakulak and Başköy, it was observed that ammonites, belemnites bearing Upper Jurassic-Early Cretaceous (Jkb) Bedirga limestone is located on the Eocene Gülandere formation and the abnormal contact has very little dip and the thrust was developed from north to south. In the south of Kismisor village the Upper Jurassic-Early Cretaceous Berdiga limestone and Neftlik formation has an abnormal contact with right angle and reverse fault.

Westward the fault becomes a fault with right angle. The Neftlik fault which traverses the area where the Neftlik oil seep is observed continues westward with increaisng slip rate. This fault is the most important fault in the region since it affects the oil prospect of the area. The oil seep is located on this fault which cuts the northern flank of the anticline. The slip of this fault decreases in the west of the oil seep and disappear in İ43 b_2 sheet. The fault plane is vertical.

In Kemah region, around Cirzini and Kürkentli, the older units have thrusted onto the Early Miocene units. This thrust continues for kilometers in the east. As a result of these thrusts the northern flank of the Miocene Kemah formation was overturned and overturned synclines were formed. In Tanyeri-Bulanık region, along an E-W line of 25 km long, older units were observed to thrust onto Gülandere and Miocene Kemah formation.

Normal Faults

In the study area, the North Anatolian Fault (NAF), the Northeast Anatolian Fault (NEAF) and small scale normal faults joining these faults under certain angles are located.

North Anatolian Fault (NAF)

The North Anatolian Fault zone traverses the Erzincan region in SE-NW direction. The fault which has caused many earthquakes in historical times and recently form a 10-15 km wide zone in Erzincan basin. The right-lateral strike-slip North Anatolian Fault is comprised of two segments in the region. The first segment is located around Yarbaşı village in the south of Üzümlü and is 30 km long. The second segment begins in the west of Üzümlü and follows the line along Geçitköy and Yalnızbağ. The North Anatolian Fault which is active on the northern border of the Erzincan basin recently was active in the southern border of the basin in the past.

East Anatolian Fault (EAF)

The Northeast Anatolian Fault which joins to the North Anatolian Fault just outside the study area, traverses along the line passing 2.5 km south of Spikör, Köroğlu, north of Hatabi mountain and the region around Büyükgelenç. It is a left-lateral strike-slip fault and its length in the study area is about 30 km.

SOURCE ROCK INVESTIGATIONS

The oil seep in Çayırlı-Neftlik region and the signs of presence of oil in the shales and marls in Balıklı formation indicates that the region has importance from the oil occurrence point of view and oil was formed here (Figure 11). Organic geochemical features of the sequences in the basin and the geochemical features of the oil seep were analyzed (Table 1). Depending on these analyses, the type and amount of total organic matter and its maturity were determined and the hydrocarbon potential of the sequences were interpreted. The source of the oil seep was investigated making use of the source rock-oil analyses. The analyses were conducted in the TPAO Research Laboratories. The pyrolysis analyses are given in table 2.

Amount of Organic Matter

The Total Organic Carbon (TOC) analysis was made to determine the amount of the organic matter in the rock (Table 1). The total organic matter amount is equal to the addition of the hydrocarbons present in the rock freely and the organic carbon related to kerosene (Tissot and Welte, 1984; Barker, 1986; Jarvie, 1991). The TOC value of the sample collected from the Upper Cretaceous Anikdağ formation is zero, that means this formation does not include organic matter. The TOC value of a sample collected from the Gülandere formation is zero, however, that of another sample collected from the same formation is 0.48. According to these values, the Gülandere formation has weak

Table 1- Pyrolysis analyses of source rocks of Kemah-Erzincan-Çayırlı region and the calculated parameters

AGE	Formation Name	Sample No	TOC (weight%)	S_1 (mg HK/g rock)	S_2 (mg HK/g rock)	S_3 (mg CO_2/g rock)	T_{max} (^oC)	Genetic Potential (S_1+S_2) (mg HK/g rock)	Transformation Rate [$S_1/(S_1+S_2)$]	HI (S_2/TOK) (mg HK/g TOC)	OI (S_3/TOK) (mg CO_2/g TOC	Residual Carbon (%)
Miocene	Kemah (Kömür Mem.)	200997	0.33	0.02	0.27	0.16	436	0.29	0.070	81	48	0.31
	Kemah (Kömür Mem.)	200999	0.01	0.02	0.05	0.25	466	0.01	0.333	50	2500	0.01
	Neftlik	200995	0.02	0.02	0.02	0.77	-	0.04	0.500	100	3850	0.02
	Neftlik	200994	0.00	0.03	0.00	0.89	-	0.03	1.000	-	-	-
	Balıklı	200998	1.43	0.03	1.07	0.41	434	1.10	0.030	74	28	1.34
	Balıklı	200992	0.49	0.25	0.64	2.10	374	0.89	0.280	130	428	0.42
	Kismisor	201001	0.00	0.01	0.23	-	-	0.01	0.000	-	-	-
Eocene	Gülandere	201000	0.00	0.01	0.00	0.11	-	0.01	0.000	-	-	-
	Gülandere	200996	0.48	0.01	0.21	0.33	452	0.22	0.050	43	68	0.47
Upper Cretaceous	Anikdağ	220993	0.00	0.01	0.00	0.20	-	0.01	0.00	-	-	-

Table 2 - Rock-Eval Analyses (Çayırlı-Erzincan)

FORMATION	Sample Pyrolysis No	TOC %	S1	S2	S3	Genetic Potential (S1+S2) mgHK/g rock	Tmax	Hydrogene Index (Iıı)	Oxygene Index (Io)	Transformation Rate S1/(S1+S2)	RC
Balıklı Fm. Miocene	200992	0,49	0,25	0,64	2,10	0,89	374	130	428	0,280	0,42
Balıklı Fm. Miocene	200998	1,43	0,03	1,07	0,41	1,10	434	74	28	0,030	1,34
Neftlik Fm. Miocene	200994	0,00	0,03	0,00	0,89	0,03	-	0	0	1,000	-
Neftlik Fm. Miocene	200995	0,02	0,02	0,02	0,77	0,04	-	100	3850	0,500	0,02
Söğütlü Village Gülandere Fm. Eocene	200996	0,48	0,01	0,21	0,33	0,22	452	43	68	0,050	0,47
Kemah Fm. Kömür Mem. Miocene	200997	0,33	0,02	0,27	0,16	0,29	436	81	48	0,070	0,31
Kemah Fm. Kömür Mem.	200999	0,01	0,02	0,05	0,25	0,01	466	50	2500	0,333	0,01
Anikdağı Fm. Upper Cretac.	200993	0,00	0,01	0,00	0,20	0,01	-	0	0	0,000	-
Gülandere Fm. Eocene	201000	0,00	0,01	0,00	0,11	0,01	-	0	0	0,000	-
Kismisor Fm. Miocene	201001	0,00	0,01	0,00	0,22	0,01	-	0	0	0,000	-

source rock characteristics. The TOC values of the selected samples of four Miocene formations were measured. Accordingly, the TOC value of the Kismisor formation iz zero, it can not be considered as a source rock. The TOC values of the two samples collected from the Balıklı formation are 1.43 and 0.49, the average value is calculated as 0.96. These data indicate that the Balıklı formation has source rock features at medium level. The samples collected from Neftlik formation either does not include organic carbon or include very few; therefore this formation can not be accounted for as a source rock. The TOC values of the samples from the Kemah formation are measured as 0.01 and 0.33, the average value is calculated as 0.17. Accordingly, the Kemah formation is a weak source rock.

Type of Organic Matter

In order to determine the kerosene types of the samples from the Kemah, Gülandere and Balıklı formations, HI-Tmax kerosene type diagram (Mukhopadhyay et al., 1995) was used. According to this diagram, the samples from the Kemah, Gülandere and Balıklı formations fall into the Type III kerosene area (Figure 12). Only one single sample from the Kemah formation was observed to fall on Type II - Type III boundary. The Type III kerosene indicate that these formations include terrestrial organic matters that have the capability to produce gas only.

Maturity of Organic Matter

Maturity of the organic matter is defined as the process of formation of hydrocarbon com-

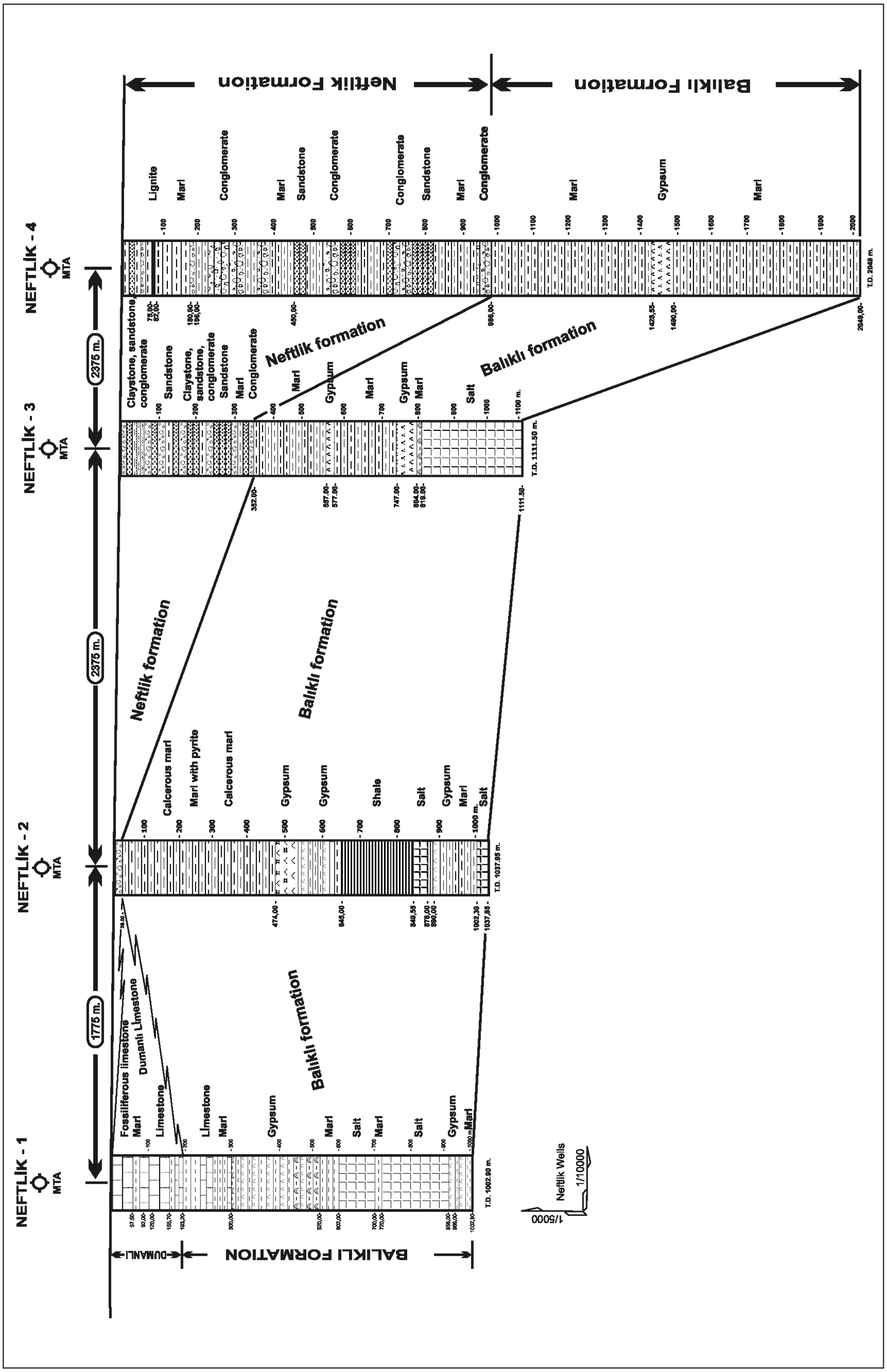


Figure-11 Correlation of the Neftlik-1, Neftlik-2, Neftlik-3, Neftlik-4 wells

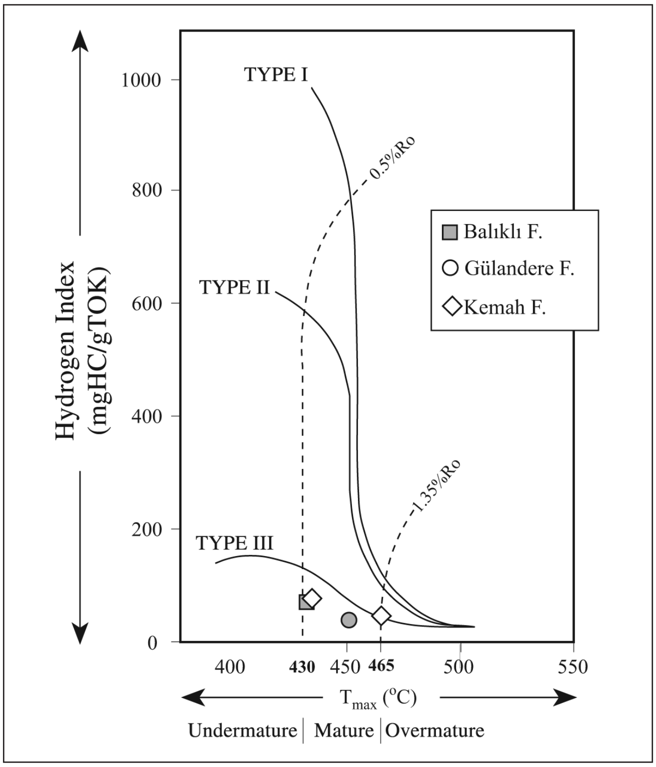


Figure-12 HI-Tmax diagram of the Gülandere, Balıklı, Kemah Formation Kömür member

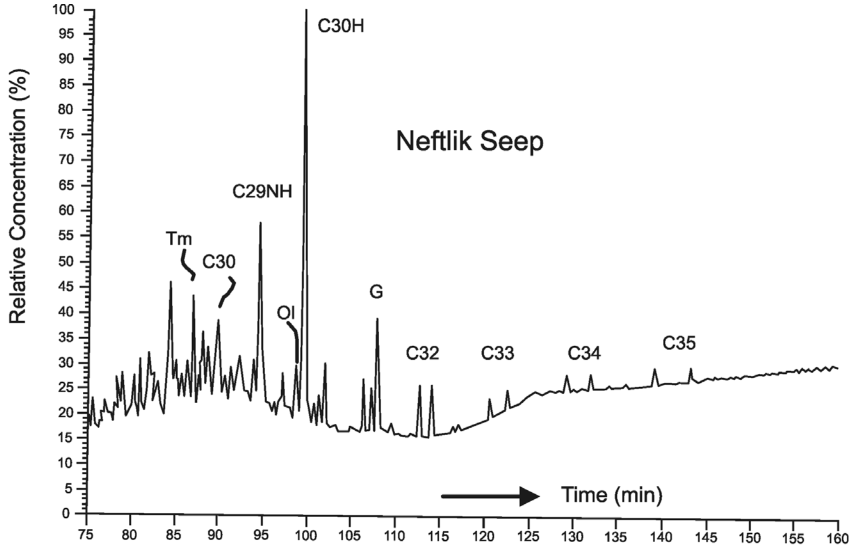
pounds by physicochemical changes under factors such as temperature, pressure, burial and time. Thermal development of the organic matter changes many physical and chemical feature of the matter and by determining these features maturity of the organic matter can be measured (Tissot and Welte, 1984, Hunt, 1995).

As a consequence of the pyrolysis (Rock-Eval) analysis, the Tmax values of the samples from the Kemah, Gülandere and Balıklı formations were determined as 404 °C which indicates non-mature source rock (Figure 13, 14; Table 2) The average Tmax values of the samples from the Miocene Kemah formation were measured as 451 °C which indicates a mature source rock. The Tmax values of a sample from the Eocene Gülandere formation were measured as 452 °C, this value indicates a mature source rock, too.

Biomarker

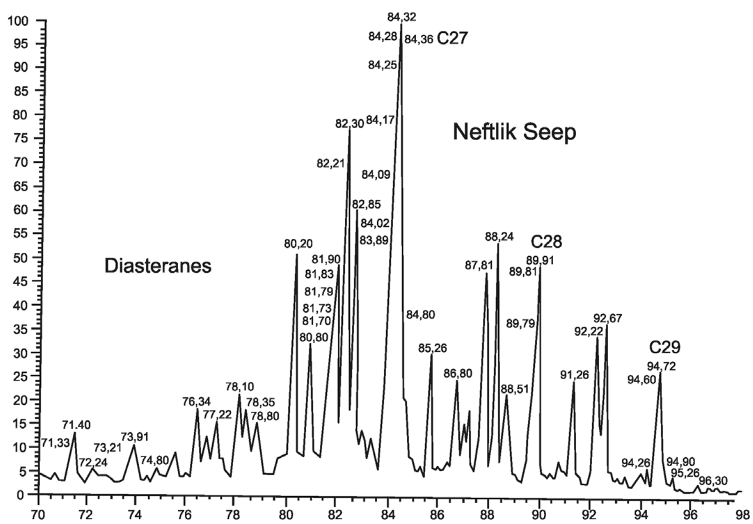
The organic compounds of which carbon structures are directly related to the organic molecules of the live organism from which they were formed and are indicators for the live organisms they were derived are called biomarkers (Tissot and Welte; 1984; Waples and Machihara, 1991, Peters and Moldowan, 1993; Hunt, 1995). Because of these features, biomarkers are known as geochemical fossils. In this study, steran and terpan biomarkers of Neftlik oil seep in turn were determined and interpreted in m/z 217 and 191 mass chromatograms.

The biomarker distributions vary depending on the organic facies and depositional environments. By determining these variations type of organic facies, depositional environment and



Neftlik Seep	$C_{29}NH/C_{30}H$	Tm/Ts	C_{35}/C_{34}	Gam/C_{30}	C_{32} 22S/22 S+R	NOTE
	0.37	2.4	1.00	0.26	0.50	Oleanane +(Ol)

Figure-13 GC-MS m/z 191 terpan fragmentogramme of the Neftlik oil seep and its parameters



Seep	% C 27	% C 28	% C 29	C 29 20S / 20S+R	% Iso steran	% Normal steran	% Diasteran	NOTE
Neftlik	55	29	16	0.44	43	40	43	4- met. Steran+

Figure -14 GC-MS m/z 217 steran fragmentogramme of Neftlik oil seep and its parameters some features of the depositional environments can be known. Besides, some biomarker transformations are controlled by the underground temperature and the exposure time to this temperature. By determining these transformation ratios, it is possible to make interpretations on the maturity.

In m/z 191 mass chromatogram of the Neftlik oil seep, the C_{27}, C_{28} and C_{29} steran ratios were determined as 55, 29 and 16%, respectively. Huang and Meinschein (1979) stated that the relative ratios of the C_{27}-C_{29} regular sterols are related to specific environments and sterans can provide significant paleo-environmental information. Almost all of the high plants include C_{29} as dominant sterols and the cases where the C_{29} sterans are dominant indicate terrestrial organic matters (Huang and Meinschein,1979; Robinson, 1987). Dominant C_{27} sterans indicate dominance of marine phytoplanctons (Huang ve Meinschein, 1979). The C_{28} steran is the rarest of these three steran groups and when they are rather abundant, presence of intensive lacustrine algae is indicated (Waples and Machihara, 1991). According to the steran distribution of the Neftlik oil seep the most dominant steran is C_{29} and the lowest steran is C_{27}. This distribution indicates that the input of the terrestrial organic matter is less and the organic matter determined is of marine origin. No C_{30} sterans which indicate marine contribution were recorded in m/z 217 mass chromatogram. Although the presence of C_{30} sterans indicate marine origin, it is not the reverse case when they are not present. Besides in m/z 217 mass chromatograms widespread diasterans were recorded. It was observed that the diasterans are widespread in clay rich clastic sediments and the diasteran/steran ratio is used widely for differentiang the carbonaceous - clastic rocks. Abundance of diasterans in Neftlik oil seep indicate that the source rock is a clastic rock. Besides, it was pointed out that the C_{29} hopan recorded in m/z 191 mass chromatogram has an atypical value in carbonates and evaporites (Waples and Machihara, 1991) and C_{29}/C_{30} ratio can be used as a criteron for carbonate content (Riva et al., 1989). Any value larger than 1 correspond to carbonates. The C_{29}/C_{30} of Neftlik seep in m/z 191 mass chromatogram was determined as 0.37, which indicate a clastic source rock. Besides, Ts is more dominant with respect to Tm in m/z 191 mass chromatogram. It was found that the Ts/Tm ratio is low in carbonate rocks and contrarily high in shales (McKirdy et al., 1983; Rullkötter et al., 1985). Therefore, the Ts and Tm values indicate that the source rock is not a carbonate rock. In m/z 191 mass chromatograms high gamaseran amount was recorded and the Gamaseran/C_{30} hopan ratio was calculated as 0.26. Gamaseran is characteristic for lacustrine and marine sediments with high salinity (Waples and Machihara, 1991; Connan, 1993; Peters and Moldowan, 1993). Significant amount of gamaseran indicate that the source rock was deposited in a saline environment. Oleanan is a biomarker which was assumed to be derived from terrestrial sources especially from the angiosperms of the plants and is an indicator for terrestrial organic matter input (Peters and Moldowan, 1993; Hunt, 1995). This biomarker has not been observed in a source rock younger than Cretaceous and its presence indicates Cretaceous or younger times (Waples and Machihara, 1991; Peters and Moldowan, 1993; Hunt, 1995). Oleanan was recorded in less amounts in m/z 191 mass chromatograms. This indicates that the Neftlik seep comes from a source rock of Cretaceous or younger and has very little terrestrial organic matter input.

Some biomarker transformations change with maturity and is used for the interpretation of the maturity. In this study, 20S/(20S+20R) (McKenzie et al., 1980; Spiro, 1984; Seifert and Moldowan, 1981, 1986; Waples and Machihara, 1991; Peters and Moldowan, 1993) and $\beta\beta/(\beta\beta+\alpha\alpha)$ (Peters and Moldowan, 1993; Hunt, 1995), steran (C_{29}), 22S/(22S+22R) homohopan (C_{32}) (Waples and Machihara, 1991; Hunt, 1995; Seifert and Moldowan, 1986) ratios which increase with maturity were calculated. The

20S/(20S+20R) and $\beta\beta/(\beta\beta+\alpha\alpha)$ C_{29} steran ratios of the Neftlik seep were calculated as 0.44 and 0.55, in turn. Besides, the 22S/(22S+22R) C_{32} homohopan ratio is determined as 0.50. According to these values an early maturity feature is observed.

CONCLUSIONS

In Kemah-Erzincan-Çayırlı region, rather thick Tertiary sedimentary sequences comprised of carbonaceous sediments crop out on the pre-Late Cretaceous basement. In this study lithological features, extensions, contact relations and ages of these sequences were described and the depositional environments were interpreted. Oil seeps and the levels including bitumen and asphalt in Tertiary sequences were also studied and the hydrocarbon potential was investigated.

The Late Cretaceous Anikdağ formation does not include any organic matters and therefore is not a source rock. According to its TOC content, the Eocene Gülandere formation is a weak source rock. The Miocene Kismisor and Neftlik formations do not have the characteristic features of a source rock. The Miocene Balıklı formation is a medium level source rock while the Kemah formation is a weak source rock.

The organic matter types of the Kemah, Gülandere and Balıklı formations are determined as Type III according to the results of pyrolysis analyses. The Balıklı formation is not a mature formation based on its Tmax value. On the other hand, the Kemah and Gülandere formations are mature formations.

Widespread diasteran content of the sample from the Neftlik oil seep and its C_{29}/C_{30} hopan ratio calculated to be less than 1 and high Ts/Tm ratio indicates that it seeped from a clastic source rock. Gamaseran indicates that the source rock from which the oil seep was derived was deposited in an environment with high salinity. Presence of the oleanan point out a source rock of Cretaceous age or younger and also the input of terrestrial organic matters. According to the maturity data calculated from the steran and terpan distributions in the oil seep, an early maturity was assigned.

When evaluated with all these geochemical data, it was concluded that there was no good source rock in the basin and consequently the basin does not have oil potential.

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