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DEPOSITIONAL CHARACTERISTICS AND TECTONO-SEDIMENTARY DEVELOPMENT OF THE KARGI-İSKİLİP EOCENE SUBMARINE FAN SYSTEMS (ÇORUM, N-TURKEY)

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Abstract

The Kargı-İskilip Eocene deposits located in southern part of the North Anatolian Fault are very well exposed between Kargı and Çorum settlements in N-Turkey. These Eocene deposits are observed as submarine fan and fan delta systems. Submarine fan system is characterized by clastic sediments such as conglomerate, sandstones, siltstones, greyish coloured shale and mudstone alternations. Fan delta system is represented by pebbly sandstones, siltstones and coal seams in some parts. In this study, Kargı-İskilip Eocene sediments involved in İskilip Group were examined in detail (Hacıhalil, Yoncalı and Karabalçık formations). Thus, the sedimentary facies indicating depositional environments and processes were revealed. For this research, six measured sedimentary sections (MSS) have been taken systematically and eight sedimentary facies are described and interpreted. The facies changes in vertically and laterally indicate that Kargı-İskilip Eocene deposits present as regressive character from south to north. Well outcropped sections in the studied area show that the Kargı-İskilip deposits particularly represent as flysch character (Lower Eocene) and progressively passed to the fan delta (Middle Eocene) which characterized by coarse grained clastics alternating with fine grained sediments with coal-bearing. besides, volcanic rocks outcropped as syn-sedimentary deposition with Lower Eocene marine sediments is observed commonly. In the investigated area, which formed as a piggy-back basin, syn-sedimentary growth faults also play an active role for the deepening of the basin infill.

KARGI-İSKİLİP EOSEN YAŞLI DENİZALTI YELPAZE SİSTEMLERİNİN DEPOLANMA ÖZELLİKLERİ VE TEKTONO-SEDİMANTER GELİŞİMİ (ÇORUM, K-TÜRKİYE)

Anahtar Kelimeler
Fan Delta Sistemi,
Denizaltı Fanı,
Tortul Fasiyes,
Eosen Çökelleri,
Kargı-İskilip,
K-Türkiye.

Öz

Kuzey Anadolu Fayı'nın güney kesiminde yer alan Kargı-İskilip Eosen çökelleri, K-Türkiye'de Kargı ve Çorum yerleşimleri arasında çok iyi yüzeylenmektedir. Bu Eosen çökelleri denizaltı yelpaze ve yelpaze delta sistemleri olarak gözlenmektedir. Denizaltı yelpaze sistemi; çakıltaşı, kumtaşı, silttaşı, grimsi renkli şeyl ve çamurtaşı ardalanması gibi kırıntılı çökellerle karakterize edilirken, Fan delta sistemi de, yer yer çakıllı kumtaşları, silttaşları ve kömür damarları ile temsil edilmektedir. Bu çalışmada, İskilip Grubu'na dahil olan Kargı-İskilip Eosen çökelleri (Hacıhalil, Yoncalı ve Karabalçık formasyonları) detaylı olarak incelenmiş, çökelme ortamlarını ve süreçlerini gösteren tortul fasiyesler ortaya çıkarılmıştır. Bu çalışma için, sistematik olarak altı adet ölçülü tortul kesit (MSS) alınmış ve sekiz adet tortul fasiyes tanımlanmış ve yorumlanmıştır. Dikey ve yanal yöndeki fasiyes değişiklikleri; Kargı-İskilip Eosen çökellerinin güneyden kuzeye doğru regresif karakterde olduğunu göstermektedir. İncelenen alanda iyi yüzeylenen kesitler, Kargı-İskilip çökellerinin özellikle fliş karakterinde (Alt Eosen) temsil edildiğini ve kademeli olarak, kömürlü ince taneli çökellerle ardalanmalı iri taneli kırıntılılar ile karakterize edilen yelpaze deltasına (Orta Eosen) geçtiğini göstermektedir. Ayrıca

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Alt Eosen yaşlı denizel çökellerle eşyaşlı-sedimenter çökelim olarak yüzeylenen volkanik kayaçlar da yaygın olarak görülmektedir. "Piggy-back" bir havza şeklinde oluşan inceleme alanında, eşyaşlı-sedimanter büyüme fayları da havza dolgusunun derinleşmesinde etkin rol oynamaktadır.

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1. Introduction

Eocene sub-marine basins, which might be related to each other in a large part of Turkey, mainly represent the deep-marine environment located in the southern region of Turkey (Ketin, 1983). However, Eocene basins consisting of coal-bearing sediments are generally observed in the northern part of Turkey (Çebi and Korkmaz, 2013). The study area is situated in the northeast of Çankırı-Çorum basin and widely observed between Kargı and İskilip (Çorum) settlements at the northern Turkey (Figure 1). The Çankırı-Çorum basin is surrounded by the North Anatolian Fault segments, the Ophiolitic Melange and the Sakarya Massif in the north, and the Kırşehir Massif in the south, respectively (Figure 1).

The Çankırı-Çorum Basin contains very well developed terrestrial and submarine clastics. Therefore, since the 1940s, it has a huge research area of many geological, sedimentological, stratigraphic and tectonic studies and investigations for oil exploration due to its salt content as well as a thick sedimentary deposit. The first scientific report which for the geological investigation and in the matter of petroleum leakage in the Çorum area has been studied by Lahn (1939). Later, the significant research, preparing the detailed geological map of the Çankırı-Çorum region (1/50.000 scale), was carried out by Akarsu (1959). Şenalp (1974, 1981) has investigated in succession of marine and continental sedimentary units which ranges in age from Early Eocene to Pliocene in Çankırı-Çorum Basin.

Birgili et al. (1974,1975) reported the geology and petroleum possibilities of the Çankırı-Çorum basin. Later, Tüysüz and Dellaloğlu (1992) conducted researches on the tectonic units of the Çankırı basin and the geological evolution of the basin. Moreover, in their studies, Tüysüz and Dellaloğlu (1994) found that the closing time of the Neo-Tethys Ocean was during the Maastrichtian period, at the end of this period, the region was uplifted and exposed, while the lithologies of the Sakarya and Kırşehir massifs of the Anatolides remained under shallow sea conditions. After the mid-Eocene period, they stated that this massif has exhumed and formed the Çankırı-Çorum Basin as an intermountain basin.

Generally, previous studies were mostly related with tectonic evolution and sedimentary development of this basin and surroundings (Hakyemez et al., 1986; Dellaloğlu et al.,1992; Tüysüz and Dellaloğlu, 1992; 1994; Erdoğan et al., 1996; Görür et al., 1998; Karadenizli, 1999; Kazancı et al., 1999; Kaymakçı, 2000; Kaymakçı et al., 2009; Karadenizli, 2011).

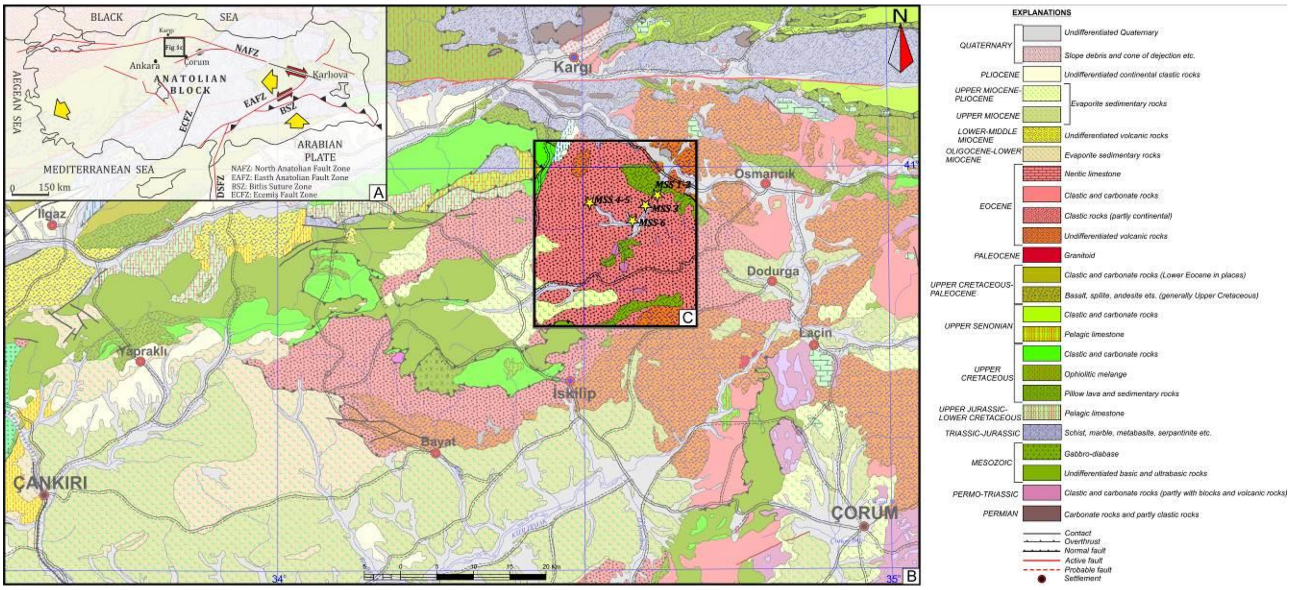


Figure 1. (A) Location map of the study area; (B) Simplified geological map of the Çankırı-Çorum Basin and (C) The satellite image of the investigated area with points of measured sedimentological sections (MSS) obtained from the north of İskilip town (1/500.000 scaled MTA was drawn from Sinop maps, Uğuz et al., 2002).

In addition, palaeoenvironmental, palaeoclimatic reconstruction of basin development based on mammal and palynological findings have been studied and thus, the Oligocene and Mio-Pliocene boundary in the Çankırı-Çorum Basin have been highlighted (Birgili et al., 1975; Akyürek et al., 1980, 1982; Yoldaş, 1982; Ünalan ve Harput, 1983; Hakyemez et al., 1986; Rögl, 1999; Besbelli, 2001; Saraç, 2003; Karadeniz et al., 2004; Oyal, 2016; Kayseri-Özer et al., 2017; Oyal et al., 2017; Gürsoy et al. 2019).

Geophysical studies were also conducted in this area based on palaeomagnetic and seismotectonic investigations by several researchers (Platzman et al., 1994; Piper et al., 1996; Taymaz et al., 2007; Bilim and Ateş, 2007; Bilim and Demir, 2010; Ateş et al., 2012; Aslan et al., 2013). Bilim and Demir (2010) implied that the Çankırı Basin was separated by a possible fault or thrust fault, which are NE-SW trending and forming palaeotopographic high, according to the gravity anomalies they examined. In addition, they created 3-D model of basin and calculated the thickness of sediments. Ateş et al. (2012) also defined the Çankırı-Çorum Ophiolitic Complex (CCOC) from the maximum positions determined from the horizontal gradient of the pseudogravity anomalies of the aeromagnetic data.

In this research, it has been focused on Eocene submarine deposits in Kargı-İskilip area which belongs to Çankırı-Çorum Basin. Although there are several researches on the Çankırı-Çorum Basin, in this study particularly important to be described and interpreted in detail on submarine fan system and its depositional processes with lateral and vertical changes during the Eocene. For this reason, all facies description and depositional systems illustrated in this compact work, it could be strongly good work for who volunteer to research in this notable region.

2. Material and Method

The fieldworks, geological mapping and sedimentological investigations were carried out in this study. Geological mapping was made by using the scale 1:25.000 topographic map. Totally, six stratigraphic sections have been measured in particular where sandstone-mudstone intercalation with sedimentary structures and thick conglomeratic units are best exposed within deltaic and marine facies. The sedimentary structures have been determined in the field study. For description and interpretation of facies and depositional processes which occurred from deltaic to sub marine environments have been used Mutti and Lucci Ricci, 1972; Reineck and Singh, 1975; Walker, 1978; Miall, 1984; Pickering et al., 1986; Miall, 1988, and Stow, 1994.

3. Geological Settings

3.1. Regional Geology

The Çankırı-Çorum Basin is a post-collisional basin formed on the İzmir-Ankara-Erzincan suture zone between these two continents as a result of the collision of the Sakarya Massif in the north and the Kırşehir Block in the south at the end of the Upper Cretaceous.

The Kargı-İskilip Eocene deposits, constituting the subject of the study, which are located in the north of the Çankırı-Çorum basin. These Eocene sediments are observed in a NE-SW trending basin extending between the settlements of Bayat-İskilip-Kargı-Oğuzlar and Osmancık (Çorum) (Figure 1B). The basin is surrounded by segment components belonging to the North Anatolian fault zone and lithologies of the Ilgaz metamorphic massif in the north, a Cretaceous aged ophiolitic mélange in the west and Eocene volcano-sedimentary rocks in the east (Figure 1B). The volcanics in this region are mainly composed of basalt, andesitic basalt and the accompanying agglomerates.

The basements of the study area comprise of metadetritics and ophiolithic melange which are belong to Sakarya-metamorphic massif and Ankara-Erzincan suture zone, respectively (Seymen, 1981, 1984; Tüysüz and Dellaloğlu, 1992; Erdoğan et al.,1996; Kaymakçı, 2000). Sakarya metamorphic massif is characterized by medium to low grade Palaeozoic metamorphic rocks and granitic intrusions (Tüysüz and Dellaloğlu, 1992). The ophiolithic melange is belong to İzmir-Ankara-Erzincan suture zone and located mainly in the south of Sakarya and Ilgaz massifs. The Ilgaz metamorphic massif geologically meets the extension of the Sakarya massif in the east. The Ilgaz massif, located in the northern part of the study area, is composed of medium to low grade metamorphic rocks such as slates, phyllites and quartz schists and associated mafic meta-volcanics. Ophiolitic rocks, defined as Kösedağ ophiolitic melange, mainly consist of serpentinized peridotites, gabbro, diabasic volcanics, chert, chert-limestone, radiolarite and related allochthonous blocks (Özçelik and Öztaş, 2000). The ophiolitic melange is well observed in the southwestern parts of the investigated area (Figure 2).

The sedimentary fill forming the Çankırı-Çorum basin was formed in different sedimentation stages. The Upper Cretaceous-Upper Palaeocene period commenced with volcanoclastics and continued with shallow marine deposits, reddish clastics and carbonates. The Upper Palaeocene-Middle Eocene period began with a marine fine-clastic flysch succession and was characterized by coarse clastic, massive conglomeratic clastics. During the beginning of the Eocene, marine transgression covered all area and with the retreat of the Eocene sea towards to the end of Eocene period transitional environments (such as lagunal) become common in this region (Akarsu, 1959). With the regression of the Eocene sea, which is a strong result of regional tectonic activity, the Oligo-Miocene terrestrial sediments began to deposit (Akarsu, 1959; Karadenizli, 1999; Karadenizli, 2011). In the Upper Eocene, Oligocene and middle Miocene, there were terrestrial sediments that basically cover a large part of the basin surface. The Upper Miocene period was represented by clastics alternating with evaporites which formed under fluvial-lake conditions. Plio-Quaternary alluvial fan deposits and alluviums can be observed along the rivers extending in the region.

3.2. Stratigraphy

The lithostratigraphic units in the study area and its surroundings are divided into three different groups such as Upper Cretaceous-upper Paleocene, Upper Paleocene-middle Eocene and post-Middle Eocene (Kaymakçı, 2000; Kaymakçı et al., 2001; Tokatlı et al., 2006; Kaymakçı et al., 2010). The Upper Cretaceous-Upper Paleocene deposits consist of serpentinized ultramafic rocks of the oceanic crust, chert, clayey limestone, radiolarite, basaltic lavas, tuffs, tuffites and agglomerates which originating from the accretion prism formed during the subduction of the northern branch of Neo-Tethys. Clastic sediments consisting of clayey limestone, marl and siltstone were included in this accretion and were deposited as pre-and and inter- arc sediments (Kaymakçı, 2000,2001; Özçelik and Öztaş, 2000).

The upper Palaeocene -middle Eocene deposits in the investigated area and surroundings, which were known as İskilip Group, compose of six different formations. These formations are Hacıhalil, Yoncalı, Karabalçık, Bayat, Osmankahya and Kocaçay, respectively (Kaymakçı, 2000; Kaymakçı et al., 2001, 2010; Gürsoy et al., 2019). The Hacıhalil formation, named by Birgili et al. (1974), consists of locally reddish brown conglomerates containing fine coal seams and grayish colored thick bedded sparsely fossiliferous and brownish sandstone-shale alternation. The Yoncalı formation which named by Birgili et al. (1974, 1975) was formed in flysch character facies. This formation consists of dark greenish-gray colored, planar cross-bedded sandstones and dark grayish colored, thin to medium bedded (10-100 cm) shale alternations included shell fragments. These sandstone-shale alternations were accompained by conglomerates in the northern part of the basin and pelagic limestone in the eastern part (Özçelik, 1994; Demirer et al. 1992, Kaymakçı, 2000). The conglomerates observed in the flysch facies generally consist of components derived from radiolarian chert, serpentinite, micritic limestones, basalt and tuffs as well as ophiolitic rocks. The age of Yoncalı formation is reported as Lower-middle Eocene and the formation is observed in transitionally with the Hacıhalil formation at the lower. Moreover, other formations which belong to the İskilip group (Karabalçık, Bayat, Osmankahya and Kocaçay) are observed as lateral and vertical transitions with the Yoncalı formation (Figure 2).

The Karabalçık Formation is mainly represented by intercalations of sandstone and shale conglomerate and tuff-tuffite. The formation is well-developed in the NNE and SSW of the İskilip-Kargı Eocene basin, and it is locally observed by channel-like conglomerates unconformably overlying on the Yoncalı Formation or on ophiolitic mélanges. The age of Karabalçık formation is reported as middle Eocene (Birgili et al.,1974). The Middle Eocene aged Bayat formation is named by Ayan (1969) and the formation is characterized by a series of volcano-sedimentary deposits widely observed in the NE and SE parts of the Kargı-Iskilip Eocene basin (Figure 2). The Bayat Formation consists of two different lithologies. The lower part consists of alternation of marl, sandstone, conglomerate and tuff. The upper part of the Bayat Formation consists mostly of various volcanics interbedded with tuffy marls. The middle Eocene aged Osmankahya Formation is described by Birgili et al. (1974, 1975) and the formation is generally characterized by continental reddish clastics. Lithologically, the conglomerate consisting entirely of grayish-reddish ophiolitic pebbles consists of alternations of coarse grained sandstone and siltstone. In some parts of the basin, it is characterized by very thick polygenic conglomerates, cross-bedded sandstones and reddish mudstones interbedded with fine grained tuffy beds.

The middle Eocene aged Kocaçay Formation is named by Birgili et al.(1974, 1975) and the formation is characterized by nummulitic limestones and sandy limestones. Lithologically, at the bottom, thin-bedded marl and thick-bedded nummulitic limestones. Later, at the upper part, brownish dark green, medium bedded nummulitic limestones and fineg rained tuffy sandstone-shale and marl alternations are observed.

In the study area, three formations belonged to İskilip Group are significantly observed. Kargı-İskilip area is entirely cropped out Hacıhalil, Yoncalı and Karabalçık formations and they presented transitions (vertically and laterally) with each other.

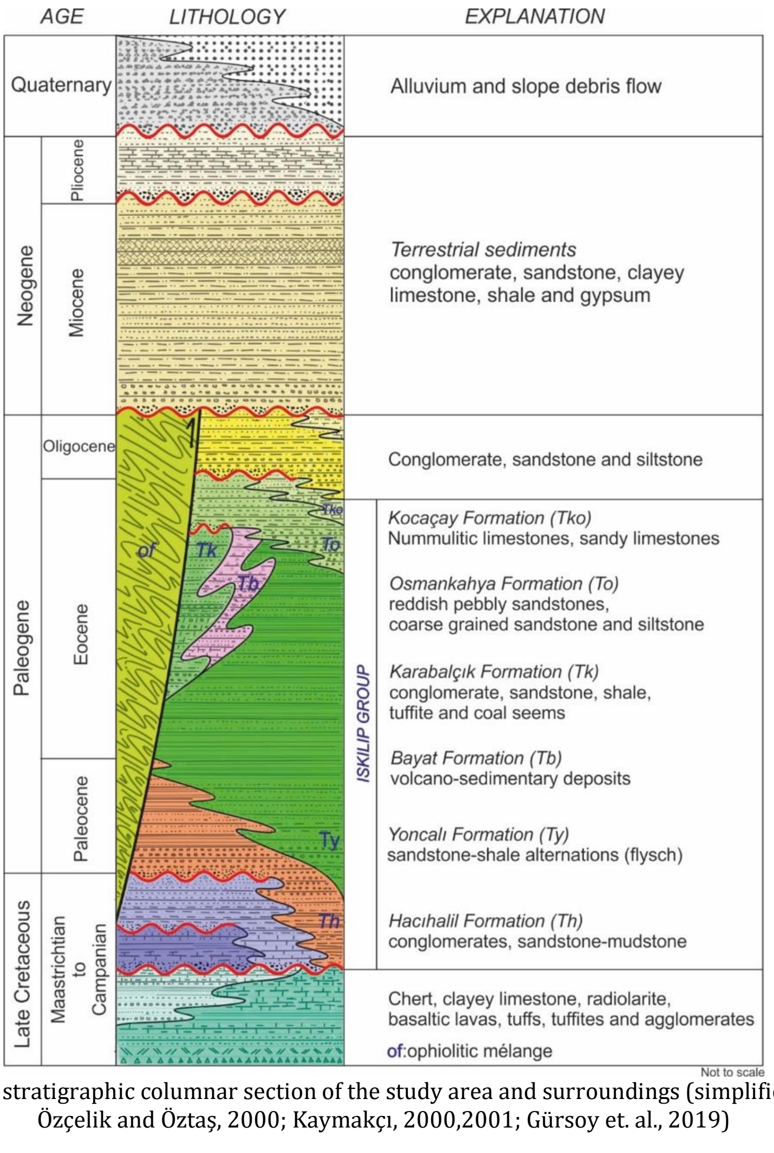


Figure 2. Generalized stratigraphic columnar section of the study area and surroundings (simplified and modified from Özçelik and Öztaş, 2000; Kaymakçı, 2000,2001; Gürsoy et. al., 2019)

4. Results

The Early-Middle Eocene aged sediments in the Kargı-İskilip area are represented by two different sedimentary depositional systems. From north to south: (1) Fan-delta system included delta plain, distributary channel and prodelta and (1) Submarine fan system consists of conglomeratic slope/apron fan, channel fill, sand lobe and basin plain deposits (Fig. 3). For facies interpretations and facies codes used in this depositional system have been referenced by Reineck and Sing (1975) and Miall (1984).

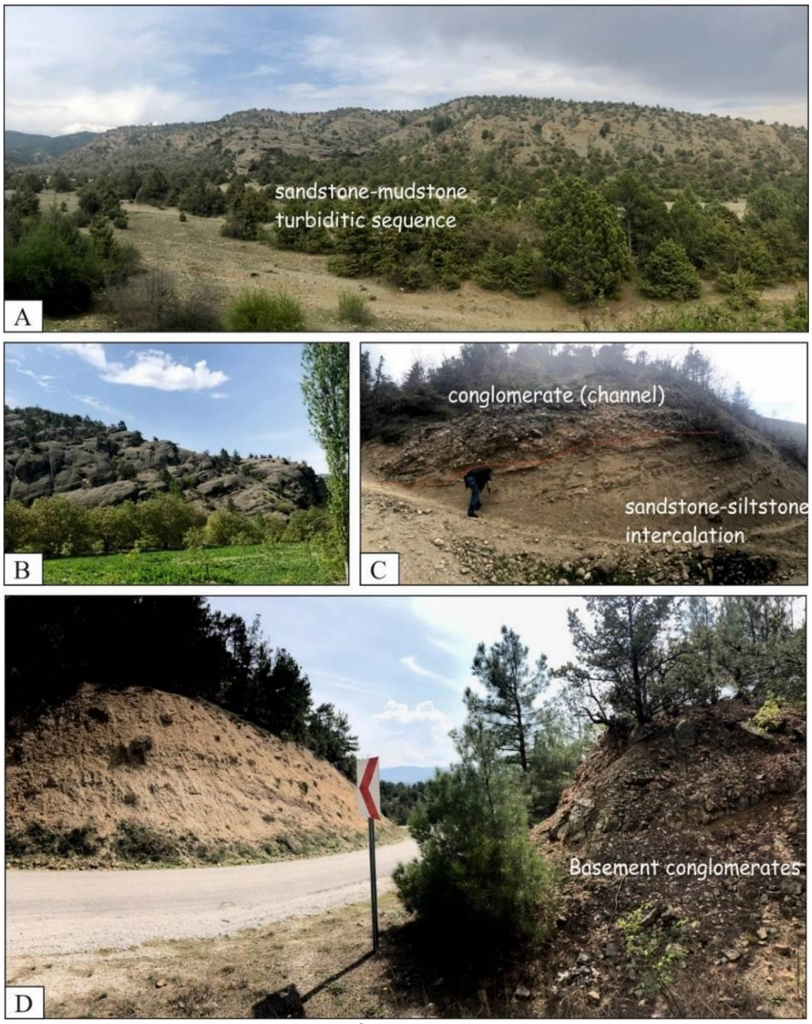


Figure 3. Outcrop photos from Kargı-İskilip area and Eocene submarine fan systems.
(A) The panoramic view of turbiditic sequence; (B) Conglomeratic slope/apron fan; (C) Gravel-rich channel-fill deposits erosional basement with fine-grained sediments; (D) Basement conglomerates which contacted with pre-Eocene basement rock assemblages

4.1. Fan Delta System

The sediments of the deltaic system are widespread in the northern part of the study area (Figure 1B). The low-grade metamorphics rocks of the Ilgaz metamorphic massif and their accompanying ophiolites form as basement rocks. The sedimentary deposits that are formed in the deltaic system unconformably overlie on the basement rocks with an erosive contact. Regolithic occurrences of terrestrial origin, which can be defined as the base conglomerate and composed of clastic sediments, are observed locally in the incompatible contact zone.

The detrital sediments of the fan delta system are composed of claystone, mudstone, sandstone and conglomeratic channel fillings. Non-economic coal seams are located in the upper part of the delta sequence within the organic matter-rich mudstones. The fan delta system which obtained measured sedimentological sections (MSS-1 and MSS-2) is made up of a clay rich topset deposits, delta front with distributary channels, and prodelta deposits. This regressive deltaic system is characterized by Karabalçık formation which included in the Lower to Middle Eocene aged in İskilip Group. The Karabalçık formation laterally grades into the Yoncalı formation which represented mudstone-shale alternation at centre of the study area (Figure 4).

4.1.1. Delta plain deposits

Description

The delta plain deposits are chiefly consist of siltstone, organic-rich mudstones (F7) and coal (F8) intercalations (Figure 4). Mudstones are mainly observed as thin-bedded and horizontal laminated. Generally, this facies association is accompanied by very fine to coarse sandstones (F4 and F6) (Table 1; Figure 4). The sandstone and pebble levels contain reworked nummulitic fossil fragments at the upper part of the clastic deposits.

Interpretation

The fine detrital clastic-dominated facies association is most probably subaerial topset deposits of delta plain (Table 1). The delta plain represents swamp deposits, organic clays and peat. Coal seams with mudstones form in the poorly drained swamps (Reineck and Sing, 1975). This facies is commonly observed in the higher up the Karabalçık formation which located at the northern part of the study area (Figure 4).

4.1.2. Distributary Channel

Description

The distributary channel facies association is composed of stratified gravel (F2), coarse pebbly sandstone (F4) and fine to coarse grained sandstone (F5) facies varieties (Table 1; Figures 4 and 5). The channel filling conglomerates (F2) of the distribution channels are commonly observed in the field upper part of the fine grained delta plain deposits (Figure 4). The conglomerates are mainly thick-very thick-bedded, medium to well sorted. The component pebbles are mainly derived from low-grade metamorphic rocks forming the Ilgaz massif and ophiolitic rocks. The intercalations of sandstone and mudstone are observed locally within the conglomerates. The sandstones (F4) are mostly composed of well-developed, thick to medium bedded, changeable grain sizes (from fine to coarse) with pebbly in some parts, cross-stratified and erosive base. Sand percentages are approximately above 50%. Coarsening-upwards sequences were generally observed in this facies association. Sandstones are mainly associated with thin layer mudstones and siltstones (Figure 4). The mudstone (F7) and coal seams (F8) are intercalated with massive sandstones (F3).

Interpretation

The clastics deposits from gravel to fine sand represent distributary channel according to description in above (Figure 4). Observing fining upward, and cross-stratification are common sedimentological structures in the channel fill formations of the distribution channels. The sand-dominated facies association was probably deposited in a delta plain of fan delta setting (Table 1; Figure 4). Gravel-rich, cross-stratified pebble to cobble coarse-grained sediments with erosive basement are represented very well in distributing channel of fan delta (Figure 4). The sub-marine feeder channels in the studied area are to be directed fed from this facies association (fan delta deposits).

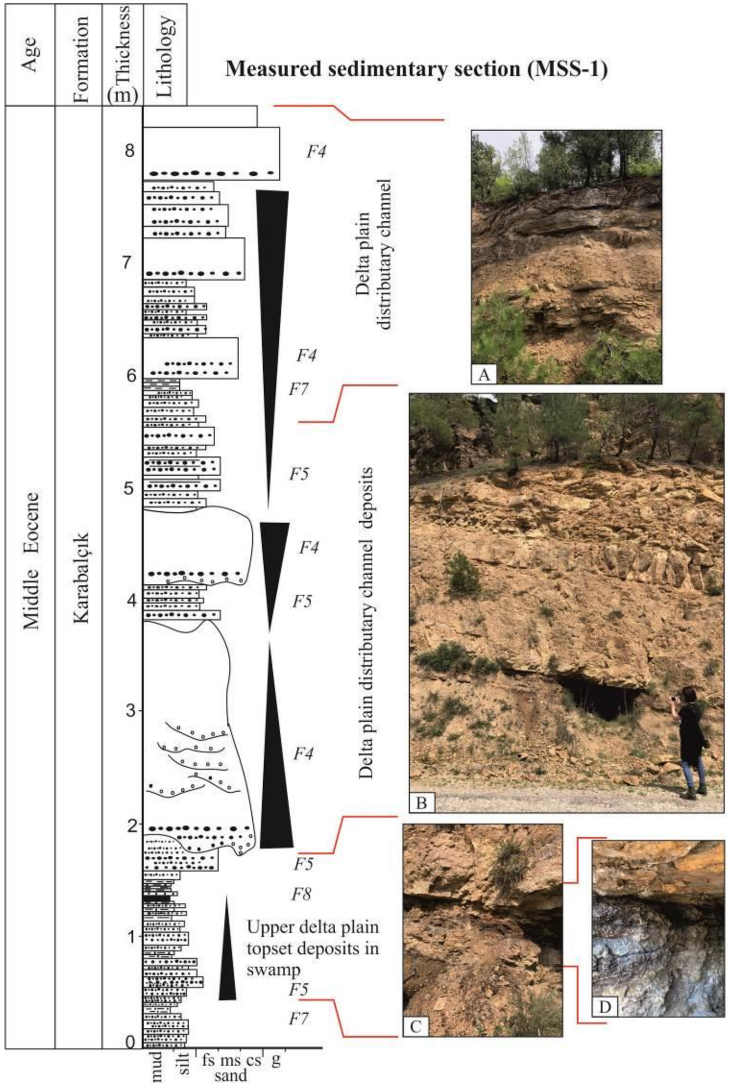
4.1.3. Prodelta Deposits

Description

The facies consists of claystone, mudstone (F7) and fine grained sandstone (F5). These fine-grained detritals forming the bottom-set are mostly medium to dark grayish, medium to weakly bedded. The bioturbation traces of sandstone and organic matter rich claystone are common. The fossil remains, consisting mainly of Nummulites, are widely observed in mudstones.

Interpretation

The fine-grained deposits forming the delta base are graded to the top of the relatively coarse-grained sediments that may belong to the prodelta sub-environment. The bioturbation and shell fragments in fine-grained clastics (silt, silty clay and mud) characterize bottom set deposits. These deposits are product of the slow deposition of suspended sediments (Reineck and Singh, 1975). Bioturbation is most common structure in the prodelta deposits.



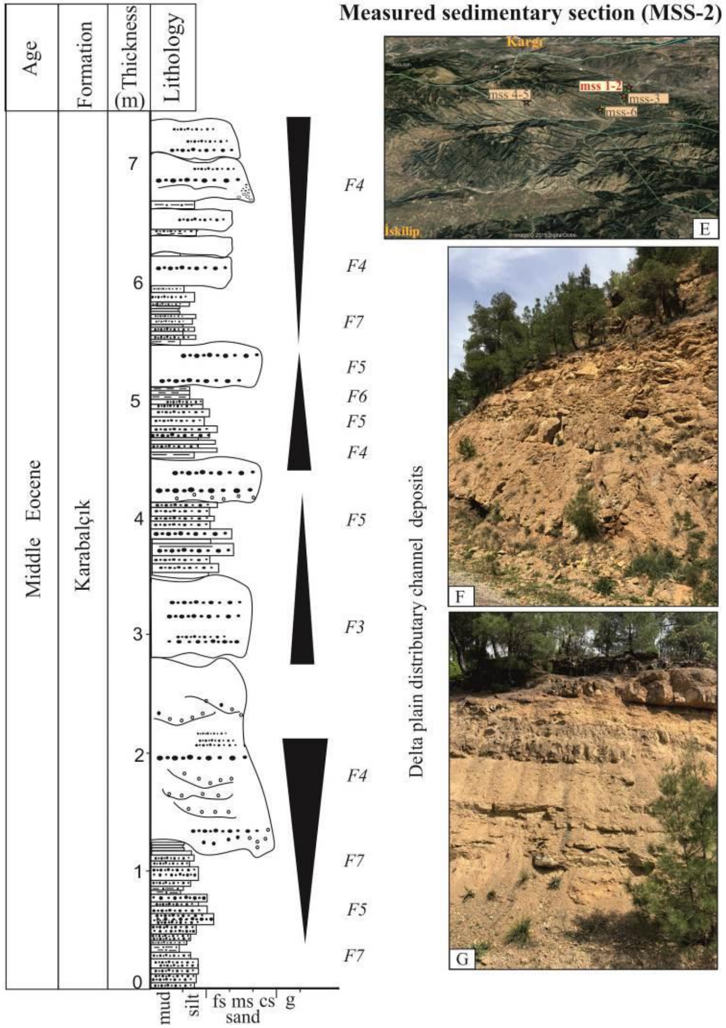


Figure 4. The measured sections which contain coal bearing fine grained sediments intercalated with sand-dominated channel deposits (MSS-1; photos from A to D) and gravel-rich distributary channel deposits (MSS-2; photos F and G). Locations of measured sections are indicated in E.

4.2. Sub-marine Fan System

The sediments of the sub-marine fan system are widespread in the central part of the study area (Figure 1B). They are composed of thick massive conglomerates, pebbly sandstones and fine grained mudstone-shale alternations. In the study area, measured sedimentological sections (MSS-3, MSS-4 and MSS-5) show that sub-marine fan system progressively deeper from north to the south (Figures 5 and 6). This transgressive sequences which represented by thick conglomerates, sandstones and thin bedded mudstone-shale alternations as flysch character (Figures 5, 6 and 7). In this investigated area, sub-marine fan system consists of conglomeratic slope, channel fills, sand lobes and basin fill deposits. These marine deposits are presented by Hacıhalil and Yoncalı formations.

4.2.1. Conglomeratic Slope-Apron Fan

Description

Thick bedded conglomerates are highly concentrated, moving a large volume of deposits included gravel to boulder conglomerates (F1) as debris flow (Figure 3B). These thick-bedded successions are mainly composed of highly erosive pebbly to cobble, sandy matrix-supported conglomerates dominantly interbedded with pebbly sandstones. Massive, disorganized conglomerates show progressively changes in thickness. The thicknesses of conglomerate beds are nearly up to 4 meters and total thickness range between 450 to 1200 meters. Clasts are well rounded, poorly sorted, coarse sandy matrix-supported and massive (F1). The maximum clast size is up to approximately 22 cm. Clasts are mainly derived from ophiolitic rock fragments and commonly oriented. The main sedimentary structures are imbricated clasts (to the south) in some places (Figure 4E). This facies typically are very well exposed by upper part of the Hacıhalil formation (Figure 5).

Interpretation

The thick conglomeratic unit was occurred from deposition by coarse sandy to gravelly high-density flow currents and debris flows (Lowe 1982; Miall, 1984; Mutti and Normark 1987; Stow, 1994; Shanmugam 2000). The disorganized conglomerate beds are generally thought to deposit rapid, detrital sedimentation on steep slope and could be related to submarine fan systems. Shelf-apron conglomeratic fan most probably was triggered by seismic activity and/or slope over steepening or overloading. In this case, seismic activity could affect overload sediments to move through the slope as debris flow. The disorganized, chaotic, thick-bedded and no graded conglomerates pass to the fan system (to the south).

4.2.2. Channel Fill Deposits

Description

The channel-fill deposits compose of mainly coarse-grained, matrix-supported, cross stratified, poorly sorted, sub- to well-rounded pebble to gravels (F2). It is dominated by pebble to cobble grain size conglomerates intercalated with pebbly sandstones (F3). Pebbles are grayish blue and green coloured and mainly derived from ophiolites and limestone fragments of Kösedağ ophiolitic melange. Clast size is up to 13 cm and imbrication is also observed (Figure 6). Scours and load casts at the bottom of the bed are the main sedimentary structures. This facies is well observed in Hacıhalil formation at the nearly centre of the study area. The facies transitionally passes to the fine grained mudstone-shale alternations (Yoncalı Formation) and has progressively gradations to the fan deltaic sediments (Karabalçık Formation).

Interpretation

The facies assemblages, composed of conglomerate and sandstone, present long-distance transport by high concentration turbidity currents (Table 1). The facies association characterizes channel fill deposits in the proximal fan of the submarine system.

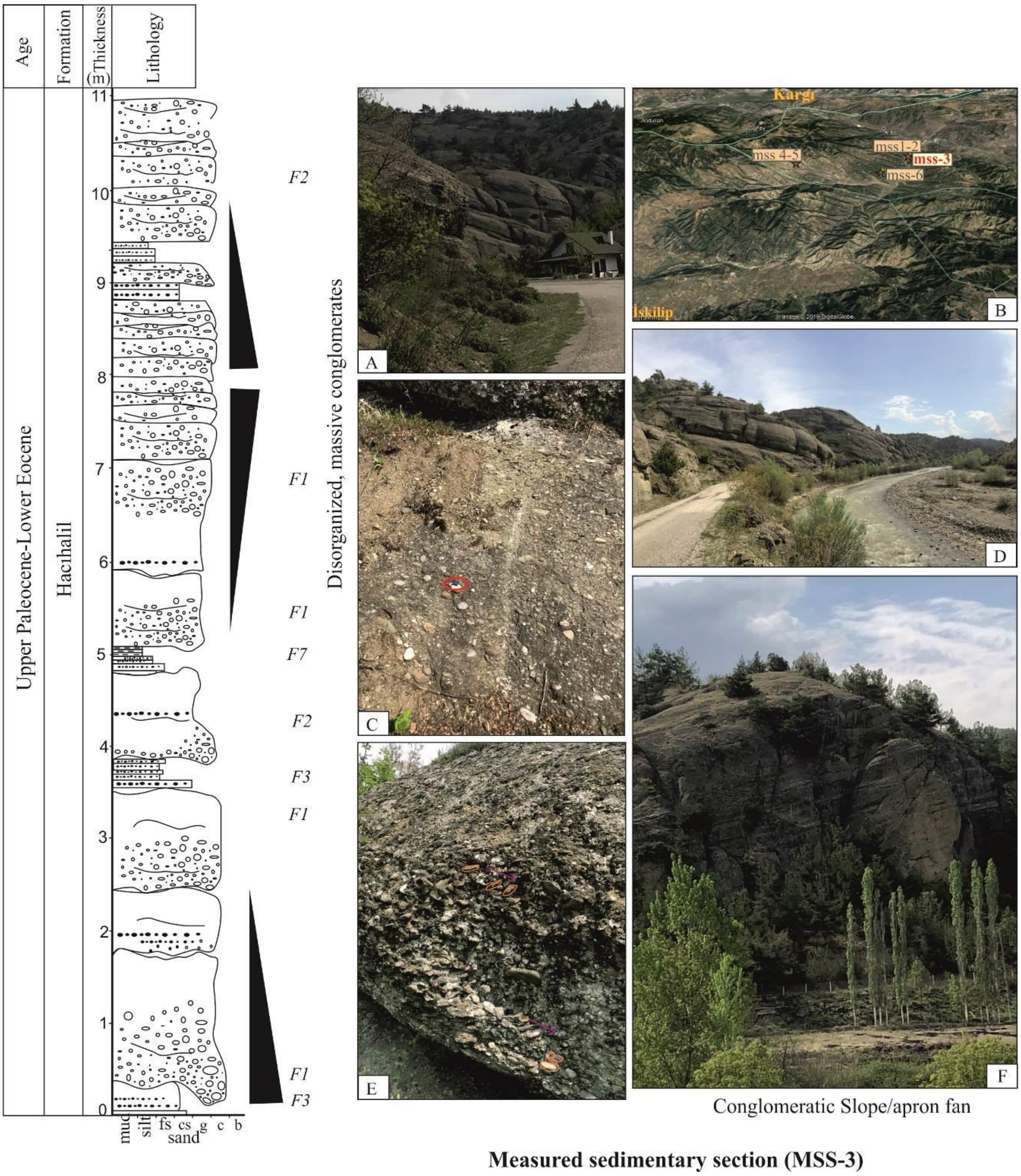


Figure 5. The measured sedimentary section which expose disorganized thick conglomerate occurrences as a debris flow (MSS-3; photos A to E). Photos: A-D and F, the general field view of thick disorganized massive conglomerate sequences; B, indicating mss-3 location; C and E, closer view of matrix- supported conglomerates and imbrications (with purple arrows) are commonly observed in some places.

4.2.3. Sand Lobe

Description

The depositional sand lobe facies is consisted of medium- to coarse-grained, thick-bedded, parallel stratified, non-channelized, thickening-upward sandstones (F3) with some soft-sediment deformations indicating loading and slump structures (Figure 6A). The sand/shale ratio is 9:1 and associated with distributary channel deposits (Table 1). These thick-bedded sandstones with pebbly might be represented by classical Bouma (1962) sequences but complete Bouma (1962) sequences are absent. Most of the sandstone beds consist of Ta-b Bouma (1962) sequences, whereas the Tc, Tab, Tbc divisions are rarely observed. This facies are well represented in Hacıhalil formation situated at the central part of the study area (Figure 6C).

Interpretation

The abundance of inversely graded, massive or normally graded sandstones with floating clasts has been interpreted to be the result of high density turbidity currents (Lowe 1982; Postma 1986; Postma et al. 1988). Slump and sliding structures are also evidence of the fast flowing which is most probably triggered by tectonic activity in the region.

Moreover, the distributary channels are associated with non-channelized sandy deposits. Generally, these deposits would suggest a channel-lobe transition or proximal lobe environment. Sandstone lobes form increasingly associated with finer-grained lobe fringe and fan fringe deposits suggesting a more distal part of the deep-marine system.

4.2.4. Basin Fill Deposits

Description

The facies association is mainly dominated by moderately thin bedded sandstone, siltstone (F6), parallel laminated mudstone (F7) and shale alternations. The thickness range is between 0.5 and 4 cm. The shales are dark gray to green, variable thickness (from thin to thick). Distinctly shale-dominated deposits occur in association with channel, lobe and lobe fringe deposits. They are typically composed of thin-bedded, fine-grained F6 to F7 facies and associated with F5 (Figure 6). These fine-very grained clastic alternations are typically represented by Yoncalı Formation.

Interpretation

The shale-dominated this sequence represent the distal lobe fringe in submarine system. This flysch character deposits might be formed by low velocity, low-concentration turbulent flows far from channel sources as a basin fill (Bouma 1962; Stow et al. 1996; Einsele 2000).

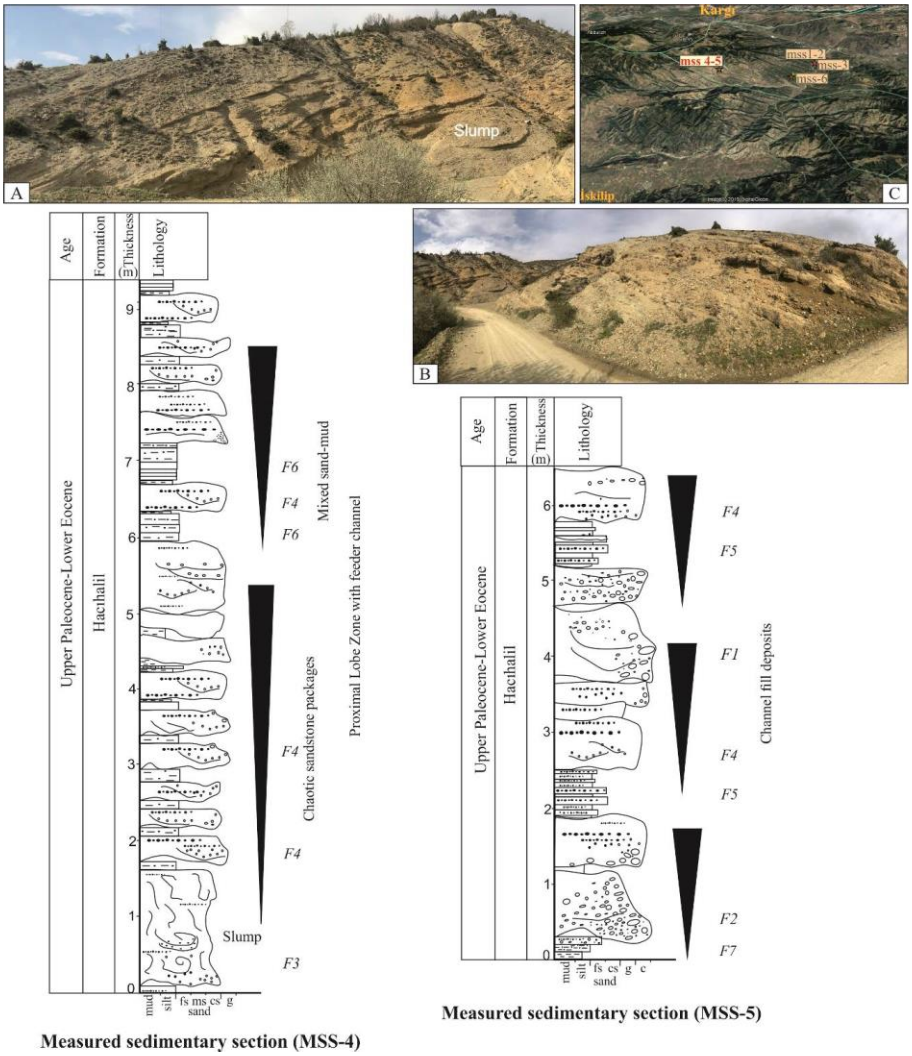
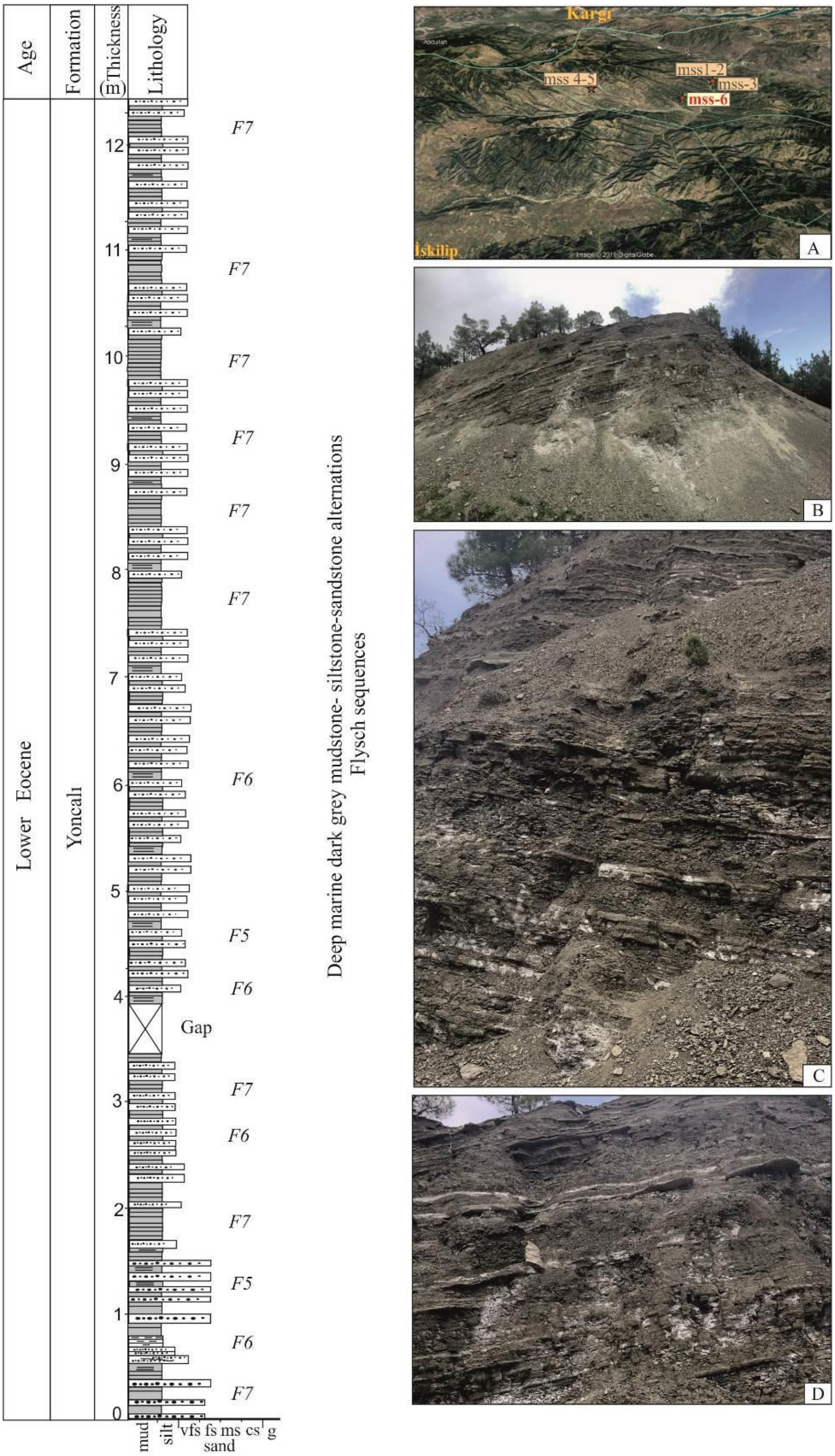


Figure 6. The measured sedimentary sections (MSS-4 and MSS-5) which exposed sand lobe with slump structure (MSS-4; photo A) and channel-fill deposits in Proximal zone in marine environment (MSS-5; photo B). Locations of measured sections are indicated in photo C.



Measured sedimentary section (MSS-6)

Figure 7. The measured section exposes fine to very fine, thin bedded mudstone-siltstone- sandstone alternations (MSS-6; photos B to C). Locations of MSS-6 is indicated in A.

Table 1. Lithofacies description and environmental interpretation of the Eocene submarine fan system in the Kargı-İskilip area (Facies codes are referenced from Mutti and Lucci Ricci, 1972; Walker, 1978; Pickering et al. 1986).

Facies	Facies Description	Sedimentary Structures	Associations	Depositional Processes	Environment
F1 (Massive conglomerates)	Massive, poorly sorted, sandy matrix supported gravel to boulder size, max. clast size 22 cm., sub-rounded, erosive base, thick bedded	Clasts are commonly oriented, in some places imbricated	F2, F3, F4	Rapid deposition, Debris flow deposits	Slope/apron fan
F2 (stratified conglomerate)	Gravel stratified	Trough crossbedding, imbricated	F1, F4	High concentration, turbidity currents	Proximal fan, Distributary channel
F3 (massive sandstone)	Sand, very fine to coarse, pebbles are also present, yellowish gray, medium-thickly bedded, Sand/shale ratio: 9:1	Massive medium to thick bedded, slump-slide structures	F1, F4, F7	High velocity, high-density turbidity currents, slump	Sub-marine sand lobe deposit, Proximal fan; Canyon subaqueous slopes in Sub-marine fan
F4 (cross stratified sandstone)	Sand, very fine to coarse, some part with pebbly	Cross stratified, erosive base	F1, F2, F8, F9	Bed load transported	Delta plain; Distributary Channel
F5 (laminated sandstone)	Sand, fine to coarse grained	Horizontal laminated, bioturbation, sharp contact base	F2, F4, F3	Medium velocity, medium to low deposition,	Prodelta fan and marine deposits
F6 (laminated shale, clay, silt)	Fine silt and clay, shale	Laminated to massive	F5, F7	Low velocity, low density turbidity currents, suspended sediments	Mid-distal sub-marine fan fringe
F7 (laminated mudstone)	Mudstone, siltstone	Laminated, thin bedded, reworked nummulite fragments	F5, F6, F8	Subaerial condition, lower energy	Upper Delta plain, swamp
F8 (Coal, coaly mudstone)	Coal, carbonaceous mud	Plants, mud lenses	F7	Low energy, subaerial	Poorly drained swamp, subaerial delta topset

5. Discussion

5.1. Depositional Modelling of the Kargı-İskilip Eocene Deposits

Throughout the Eocene, the depositional settings continued to vary from fan delta to sub-marine fan environments in the studied area. The transgression during the Eocene covered the metamorphic basement rocks that had previously been affected by compressional force and raised. According to field observation and detailed sedimentological investigations indicate that northern part of the studied area represents a fan delta system composed of both subaerial and subaquatic facies associations (Figure 7). Coal-bearing mudstone-siltstone intercalations at the base are characterized by flood plain deposits in a swamp which is the submarine part of the delta (Figure 7). Thick- medium bedded sandstone-siltstone which coarsening upward sequence indicate that distributary channel in delta plain. The sediment accumulation varies considerably along the lateral direction and changes to the prodelta deposits consisting of shell fragments and bioturbated sandstone- siltstones.

As shown on the block diagram given in Figure 7, the bathymetric structure of the Kargı-İskilip area and the sedimentary lithofacies in this basin are mostly controlled by fault systems extending from East to West. These fault systems also correspond to weakness zone between the pre-Paleogene basement rocks and Eocene deposits. Thus, the Eocene deposits unconformably overlie on basement rocks which composed of metamorphic rocks of the Ilgaz massif and complex rock assemblage forming the ophiolitic mélange (Figure 8). While metamorphic rocks are mainly exposed in the north of these faults, ophiolites mostly spread in the southern part of the study area (Figure 8). In addition, these syn-sedimentary faults, showing growth fault characteristics, controlled the thickness, spreading, and lithofacies features of the sediments filling in the basin.

Fan delta and accompanying neritic facies are dominant in the northern part of the growth fault, submarine fan channels and accompanying turbiditic facies are more dominant in the southern part. According to previous researches and in this work, submarine fan channel fills pass laterally transitional to turbidic sediments which composed of thin bedded mudstone-siltstone alternations. Conglomerate intercalations, which may belong to fan channel fillings, are observed in places within the turbiditic sedimentary sequence. Accordingly, Kargı-İskilip Paleogene-Neogene deposits show deepening marine lithofacies from north to south. Slide-slump structures are clearly seen large scale in sandstones and formed by the effect of high-density currents are occur in the proximal fan at the southwest of the basin (Figure 5; MSS-4).

However, it should be emphasized here that the thick succession consisting of fine-grained, gray coloured mudstone-siltstone alternation in flysch character was deposited in the Early Eocene (Yoncalı formation). Towards the middle-late Eocene period, the basin gradually became shallower and showed transitionally to the fan delta deposits (Karabalçık and Hacıhalil formations). In this context, thick, massive, matrix-supported, medium/well-rounded conglomerates are observed as debris flow in the slope /apron fan system towards from north to the south of the study area (Figures 1 and 5). This shallowing in the northern part must be strongly related to the tectonic uplift in the region.

The palaeocurrent directions show unimodal current vector in locally and the current axes indicate towards to the south of the basin. The succession of the turbidite sequences indicates that the basin is deepened and mudstone-siltstone-sandstone alternation as flysch character, which is several km in laterally, is observed in the southern part of the study area as a distal basin of a submarine (Figure 8).

Similarly, submarine fan systems have been observed in south of the Turkey. For instance, Aksu and Manavgat Basins located in southern part of the Isparta Angle are good examples for turbiditic submarine fan systems. Several studies on fan delta sediments and submarine fan channels accompanied with turbiditic deposits have been investigated by many researchers in detail (Akay et al. 1985; Çiner et al., 2008; Flecker et al., 1998; Glover and Robertson, 1998; Karabıyıkoğlu et al. 1997,2000 and Poisson et al. 2003). They emphasised that the Paleogene-Neogene deposits, which filled into these basins, and accompanied with sediments have been controlled by syn-sedimentary growth faults systems.

In addition, the Kusuri Formation, composed of turbiditic sandstone-mudstone alternations, which are located in Sinop-Boyabat Basin (N-Turkey) have occurred during the Early-Middle Eocene obtained from micropaleontological analysis (Aydın et al., 1995; Leren, 2003). Moreover, the Eocene deposits which occurred at the NW-Turkey and Eastern Thrace basin fill could be also given as another example for similar outcrops. The Ceylan shale, located in the lower part of the Eastern Thrace basin, has the characteristics of petroleum source rock due to its high organic matter content (Keskin, 1974).

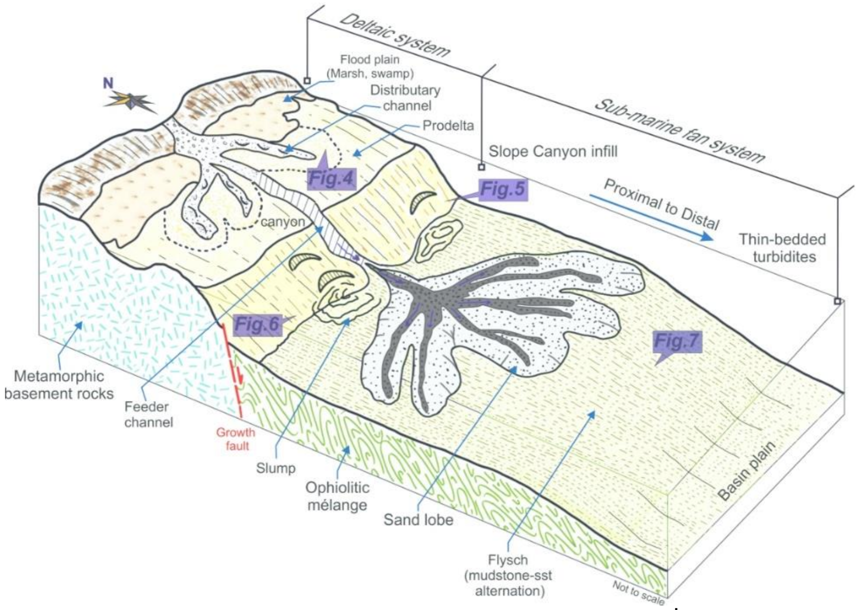


Figure 8. Schematic block diagram showing depositional environments of the Kargı-İskilip basin during the Eocene period

At almost all these examples given, it is noteworthy that they are quite important basins in terms of hydrocarbon potential. Moreover, there are also several examples from all around the world which show from fan delta to turbiditic sequence in submarine systems during the Eocene period. Particularly, the Ainsa (proximal) and Jaca (distal) Basins which are located in southern Pyrenean (Spain) are good examples which forming from fluvio-deltaic to deep-marine systems during the Early-Middle Eocene (Heard, 2007; Dal Gupta, 2008; Dal Gupta and Pickering, 2008).

Furthermore, in the western and eastern regions of the study area, the Late Eocene volcanic, which are mostly composed of andesite, basalt and andesitic basalts and associated pyroclastics and dykes, are widespread. These volcanic, which extend in the study area and in the east of the basin, also form part of the Late Eocene volcanic belt which is widespread in North Anatolia. Ercan (1992), Şengör and Yılmaz (1981) stated that most of the Late Eocene volcanic in the northern part of Anatolia are calc-alkaline. They also emphasized that these volcanic started to form as a result of the closure of the Inner Taurus Ocean and the Maden Basin, which forms the northern branch of the Tethys Ocean, from the beginning of the Eocene. The authors stated that the Late Eocene volcanism with calc-alkaline composition was formed under island arc conditions occurring in the north of the subduction zone developing from south to north.

5.2. Paleogeography and Tectonic Control of the Basin infill

Generally, submarine clastic systems located on active margins are greatly influenced by tectonics. Tectonic activity controls basin topography, sediment moving ways, sources and fan developments (Mutti and Normark 1987; Bouma, 2000).

Taking a look at the paleogeographic evolution of the study area and surroundings according to the palaeotectonic model developed by Şengör and Yılmaz (1981) reveals the impact of events on the northern branch of the Tethys ocean. According to this model, the Inner Taurus Ocean and the Maden Basin, which form part of the northern branch of the Tethys Ocean, had been closed from the beginning of the Eocene. Correspondingly, the marine basins which shows marginal sea character were formed in the northern part of Turkey.

Due to the closure of the northern edge of the ocean during the Upper Cretaceous-Upper Eocene period, a complex tectonic model (compressive and extensional) was formed.

The study area and its surroundings developed under the control of the compression regime during the Upper Paleocene-Lower Eocene, and later (Tüysüz and Dellaloğlu, 1992, 1994), an extensional regime occurred after the stress regime in the Miocene period (Seyitoğlu et al., 1997, 2000,2009).

At the beginning of the Eocene, marine transgression covered the whole area, and towards the end of the Eocene period, transitional environments (such as lagunal) became widespread in this region with the retreat of the Eocene sea (Akarsu, 1959). With the regression of the Eocene sea, which is a strong result of regional tectonic activity, Oligo-Miocene terrestrial sediments commenced to deposit (Akarsu, 1959; Karadenizli, 1999; Karadenizli, 2011).

In this study, it has been clearly seen that Kargı-İskilip deposits are very well outcrop for Eocene basins in the marginal sea that emerges north of the subduction belt. The pre-Eocene basement rocks, which form the basement of the basin, are predominantly composed of Paleozoic metamorphics and ophiolitic rocks that overlie them tectonically.

The boundary between two basement rock units must be strongly related with thrust faults which controlling to be formed as a piggy-back basin (Figure 7). Moreover, syn-sedimentation due to subsidence under the control of the east-west trending growth faults that confine the Kargı-İskilip sediment fillings basin has revealed the depositional processes which getting deeper towards the south.

6. Conclusion

Kargı-İskilip area (N-Turkey) has been deposited in different sedimentary environments from north to south through the Eocene period. All data obtained from field observations and detailed sedimentological analysis in this study are given in the following items respectively.

I. Considering the facies analysis revealed eight lithofacies have been identified and interpreted according to their sedimentary structures and characteristic of lithological features. They represent two different depositional systems such as fan delta system composed of the delta plain, distributary channels and prodelta deposits and submarine fan system composed of conglomeratic slope/apron, channel fill, sand lobe accompanied with submarine slip-slump structures and shale dominated turbiditic sequence (distal turbidite). Non-economic coal seams within the organic matter-rich mudstones are clearly observed in the lower part of the deltaic sequence as topset deposits.

II. The palaeocurrent data obtained from clastic sediments filling the Kargı-İskilip deposits reflects the existence of feeding from north to south. The sediments of the deltaic facies located to the north of the basin are graded to the south of the basin, in a short distance to the massive sandstone and conglomerate of the submarine channel filling facies. This situation is important in terms of reflecting the existence of syn-sedimentary growth faults, which are probably in the east-west direction and located at the northern edge of the basin.

III. In this region, such a study was carried out for the first time on the Eocene sediments. Detailed studies on turbiditic unit which have potential source rock properties and porous sandstones which thought are to be reservoir rock for hydrocarbon exploration are required.

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Conflict of Interest

No conflict of interest was declared by the authors.

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