Bull. Min. Res. Exp. (2020) 163: 47-76

Bulletin of the Mineral Research and Exploration

http://bulletin.mta.gov.tr

Oligocene molasse sedimentation in the Central Taurides: Records of the onset of extensional tectonic regime

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Research Article

Keywords:
Taurus orogeny, Orogenic collapse, Lacustrine deposits.

Received Date: 09.09.2019
Accepted Date: 26.01.2020

ABSTRACT

The lacustrine units have been deposited in the Ermenek, Bucakkışla, Korucuk and Çamlıyayla basins in the Central Taurides since early Oligocene. In this study, structural features and stratigraphical properties of Oligocene basins have been described in detail and the lacustrine units have been dated. Regional geological interpretations have been made by using tectono-stratigraphic and age data of the basins. Lacustrine Oligocene sedimentation in these basins, which were opened on the tectonic units of Taurides due to normal faults, constitute the first records of the sedimentation occurring under the extensional tectonic regime after the orogeny of the Central Taurides. All the pre-Oligocene units that had been emplaced in the region due to a north-south compressional movement in the Central Taurides, continued to be compressed until the end of Eocene, and completed their orogenic development as napped structures. The bedrock units, reaching the maximum elevation, have been subjected to "orogenic collapse" due to the strain or gravity forces as a result of an interruption or termination of the compression which lasted until the end of Eocene. Thus, "orogenic collapse" basins have started to be formed in the Central Taurides since Oligocene. The orogeny and the compressional tectonic regime forming the Taurides lasted until late Miocene in the Eastern Taurides. On the other hand, extensional basin formation since early Oligocene on the Taurus units, which had been emplaced in the region due to nappe tectonics, indicates that a new tectonic period has started in the Central Taurides.

1. Introduction

Taurides which are the southern mountain range of Turkey, consist of plate fragments amalgamated between Eurasian and Afro-Arabian plates. Triassic to Eocene geological evolution of Taurides is the result of a series of events from opening of an ocean beginning with rifting, to the closure of an ocean due to subduction, and collision. As the beginning of rifting along the northern margin of Gondwana in Early-Middle Triassic, Africa-derived microcontinents and oceanic branches between them started to be developed (Şengör and Yılmaz, 1981; Robertson and Dixon, 1984; Okay and Tüysüz, 1999). The rifted basins maintained their presence during Mesozoic –early Tertiary period (Robertson et al., 2012). The convergence between Afro-Arabian and Eurasian plates which occurred in late Mesozoic-early Tertiary period, and the closure of the Neotethyan Ocean controlled the geological development of Anatolia during this period (Şengör and Yılmaz, 1981; Robertson and Dixon, 1984; Dewey et al., 1986). Northward subduction of branches of Neotethys caused the emplacement of subduction zone ophiolite and ophiolitic mélange over Taurus

Citation info: Ilgar, A., Esirtgen, T., Türkmen-Bozkurt, B., Demirkaya, S. 2020. Oligocene molasse sedimentation in the Central Taurides: Records of the onset of extensional tectonic regime. Bulletin of the Mineral Research and Exploration 163, 47-76. https://doi.org/10.19111/bulletinofmre.681218.

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carbonate platform in Late Cretaceous (Özgül, 1976; 1977; Ünlügenç et al., 1990; Dilek and Whitney, 1997; Parlak and Robertson, 2004). This process continued during the Paleocene-Eocene period (Şengör, 1987; Clark and Robertson, 2002), thus, ophiolite and ophiolitic mélange emplacement occurred in a wide area on Taurus platform (Monod, 1977; Polat and Casey, 1995; Parlak and Robertson, 2004).

The orogeny that formed Taurides, and the resulting deformation proceeded until the late Miocene in the Eastern Taurides, and the Misis structural heights was developed by folding and thrusting (Michard et al., 1984; Kelling et al., 1987; Aktaş and Robertson, 1990; Dilek and Moores, 1990; Yılmaz, 1993; Yılmaz et al., 1993; Robertson, 2000). At the transition between the Western and the Central Taurides, the Lycian Nappes collided with the Isparta Angle until the late Miocene (Collins and Robertson, 1998, 2000; Poisson et al., 2003; Nemec et al., 2018).

In the Central Taurides which is structurally located between Isparta Angle in the west and Ecemiş Fault in the east (Figure 1a), basins started to develop due to post-orogenic extensional tectonic. However, timing of the extensional tectonics, which follow the compressional deformations related to orogeny, and the tectonic processes causing in basinal opening are controversial. According to Şengör (1987) and Clark and Robertson (2002), orogenic activities and compressional deformations in the Central Taurides lasted until the end of Eocene. Andrew and Robertson (2002) stated that the compressional tectonics indicating last movement of the nappes continued until middle Oligocene. Robertson et al. (2012) also claimed that post-collisional compressional regime lasted until the end of Oligocene.

According to Koçyiğit (1977), normal faults were formed as a result of epirogenic movements and the Mut Basin started to open in the early Miocene. These movements caused a thick sediment deposition in the basin, lateral-vertical facies changes, and forming of the tectonic structure of the region (Koçyiğit, 1977). Şafak et al. (2005) claims that, in Ermenek-Mut region, basin formation started in early Oligocene by extensional collapse following nappe emplacement. However, they report that, lacustrine detrital units (Yenimahalle formation) were initially deposited in these basins, then the lacustrine carbonates (Fakırca formation) were sedimented on these units.

A thick Neogene sequence consisting of terrestrial and marine units was deposited in the Central Taurides after the development of Taurus orogenic belt (Figure 1b). However, small intermountain molasse basins were developed in the region prior to opening of Mut Basin. These basins which started to open in Oligocene and where lacustrine depositions were occurred, formed the first products of the post-orogenic extensional tectonics. It is important to reveal the formation time and mechanism of these basins in the interpretation of regional tectonics. For this purpose, Ermenek, Bucakkışla, Korucuk and Çamlıyayla basins which were opened on the nappes due to normal faults in the Oligocene period have been the subject of the study (Figure 1b). Structural features of these basins have been defined, stratigraphic sequences have been studied in detail and the dated. Thus, structural development of the Central Taurides leading to basinal opening after orogeny has been demonstrated.

2. Regional Geology and Stratigraphy

The units defined in Taurus orogenic belt by Özgül (1976) constitute the pre-Oligocene bedrock of the Central Taurides (Figure 2). Geyikdağı Unit, among them, consists of Cambrian-Eocene aged non-metamorphosed rock units (Figures 3a, b). Geyikdağı Unit is situated beneath the other units as parautochthon. Aladağ Unit consists of carbonate and clastic rocks deposited in Late Devonian-Late Cretaceous interval (Figures 3c, d). Aladağ Unit, except for the beginning of Late Triassic, has a continuous succession. The unit is allochthonous wherever it crops out throughout the belt, and it forms sheet-like bodies on other units (Figure 3e). However, sequences of Aladağ Unit in some regions in the Taurides have been obducted by ophiolite and ophiolitic mélange. Bolkardağı Unit contains lithostratigraphic units of Middle-Late Devonian to early Cenozoic age which mainly metamorphosed under greenschist facies conditions (Figure 4a). Effect of the metamorphism varies regionally and increases with depth. The youngest metamorphic unit is Paleocene aged (Özgül, 1976). Bozkır Unit consists of a large number of blocks and tectonic slices of various age, types and sizes which can be mapped and its stratigraphy can be defined (Figures 4b, c). Mersin ophiolite and ophiolitic mélange cropping out in the southwest of Ecemiş Fault is situated in the Bozkır Unit (Figure 4d). Bozkır Unit overthrusts the other units

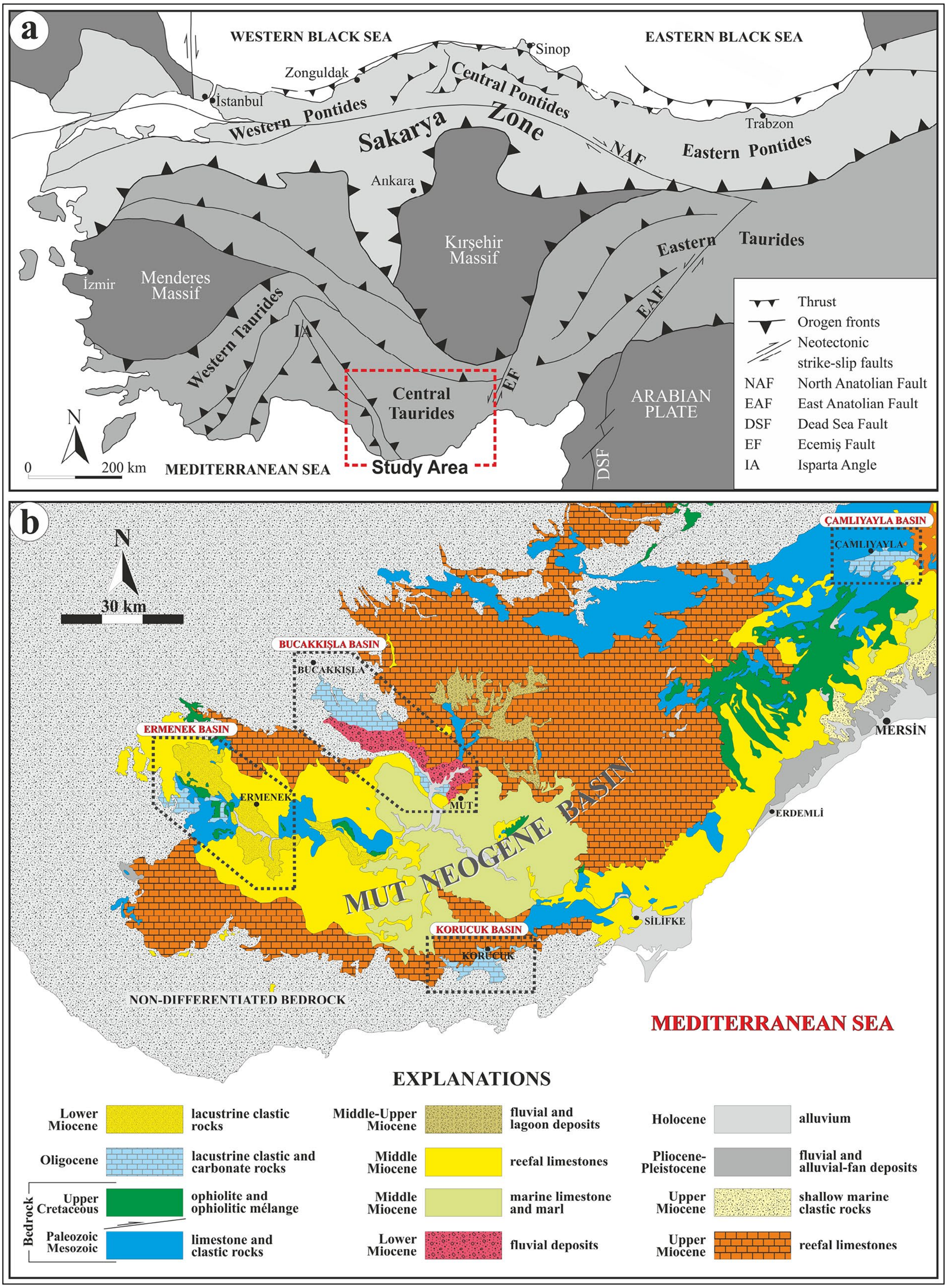

Figure 1- a) Tectonic map of the Anatolia showing Pontid and Taurus Orogenic Belts, and Menderes and Kırşehir massifs (Leren et al., 2007) and b) Simplified geological map of the Central Taurides showing Tertiary Units (modified after Şenel, 2002 and Ulu, 2002). This map shows the location and spatial distribution of the Oligocene Ermenek, Bucakkışla, Korucuk and Çamlıyayla basins and the Neogene Mut Basin.

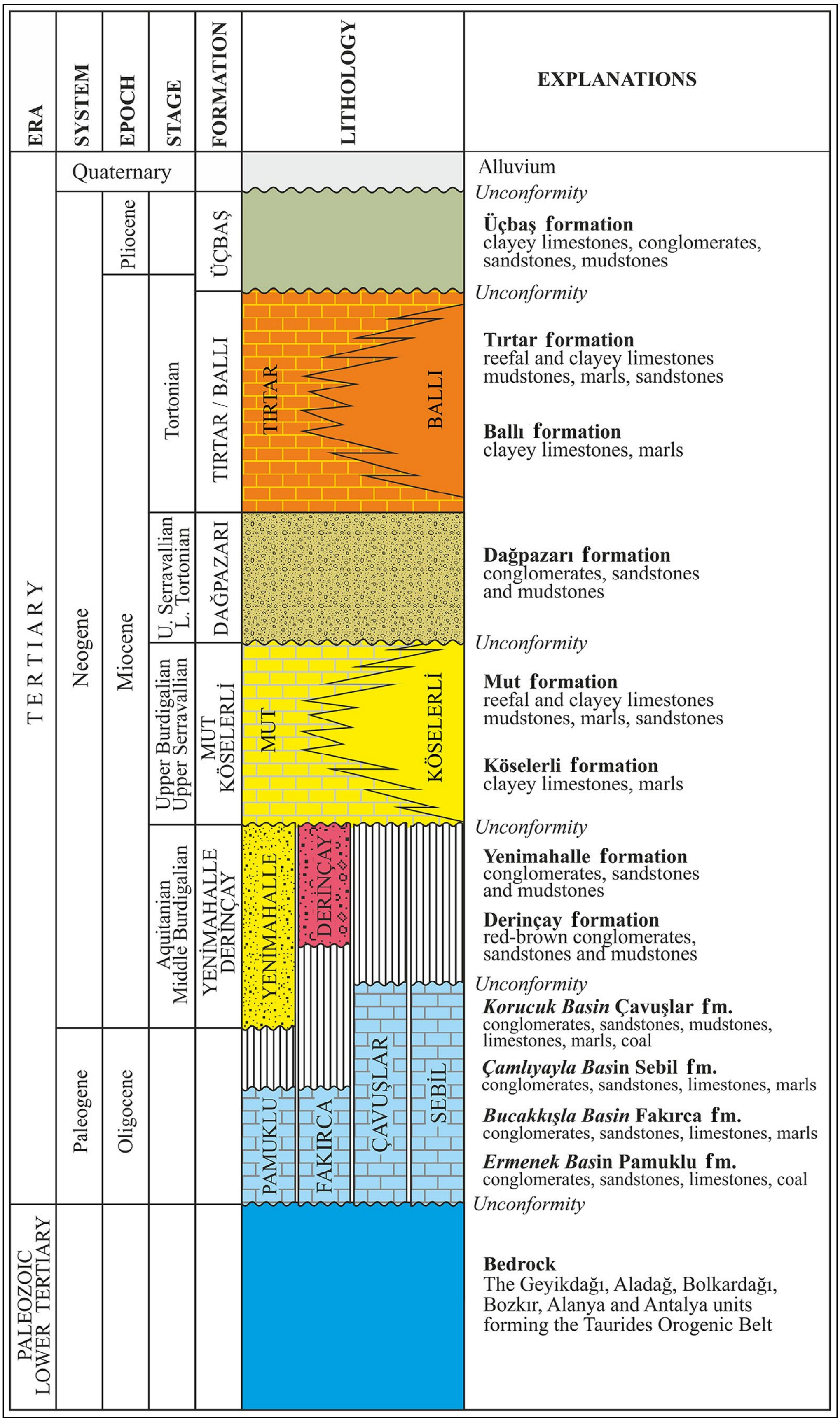

Figure 2- Generalized stratigraphic column of the Paleogene-Neogene sequence in the Central Taurides (not to scale).

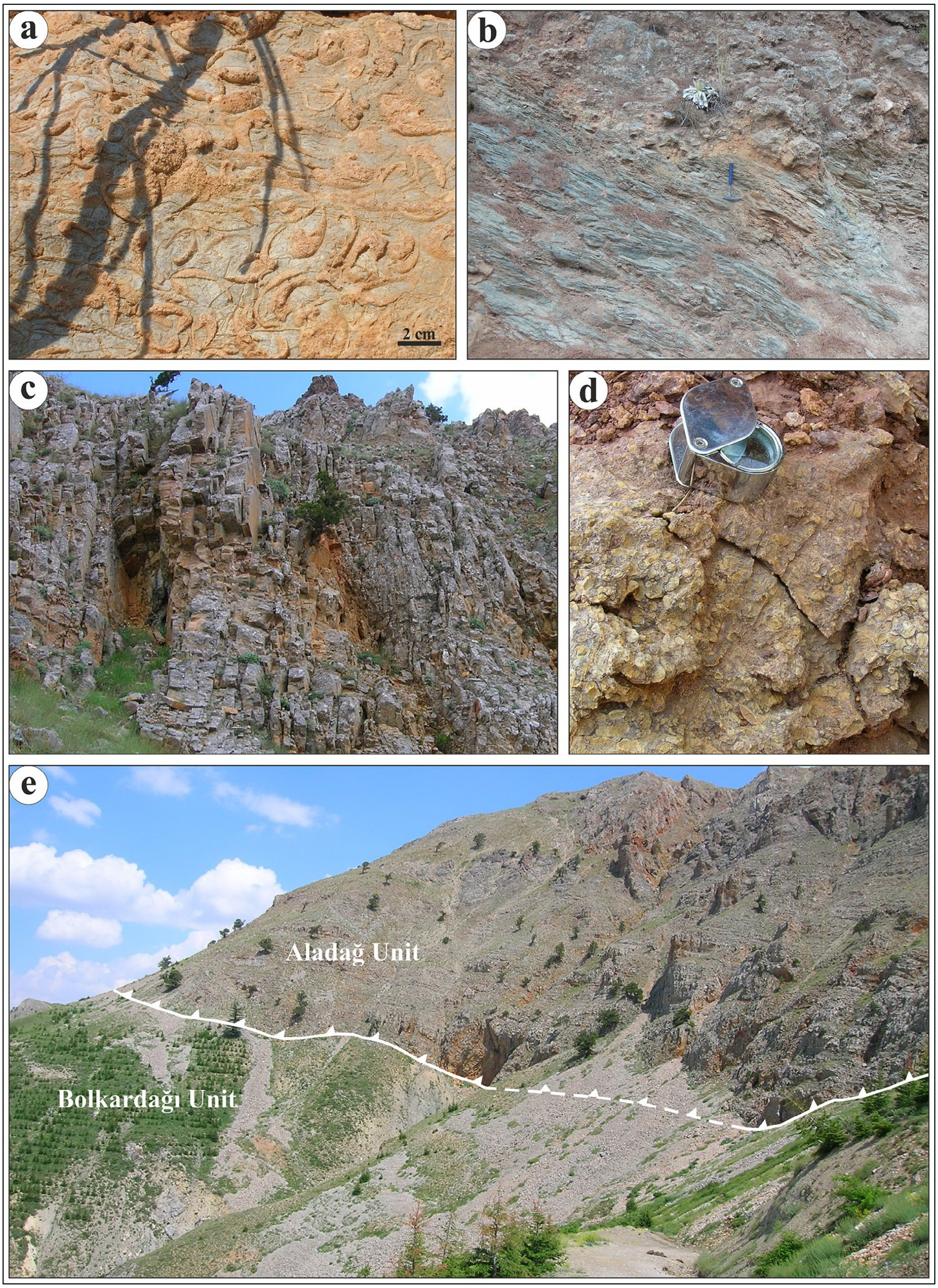

Figure 3- Bedrock of the study area consists of the rocks belonging to the Taurus units. a) Megalodon fossils observed in the Jurassic limestones of the Geyikdağı unit (N of Aydıncık), b) sandstones and conglomerates in Lutetian flysch (Mersin-Bozyazı, NW of Tekmen village) of the Geyikdağı unit, c) carbonate rocks of the Aladağ unit, d) Girvanella fossils determined in the Aladağ unit, e) Aladağ unit is allochthonous wherever it crops out throughout the belt and it is found as sheet-like bodies on other units. Note that (c), (d), and (e) images in this figure have been taken from Mersin, Cocak Valley.

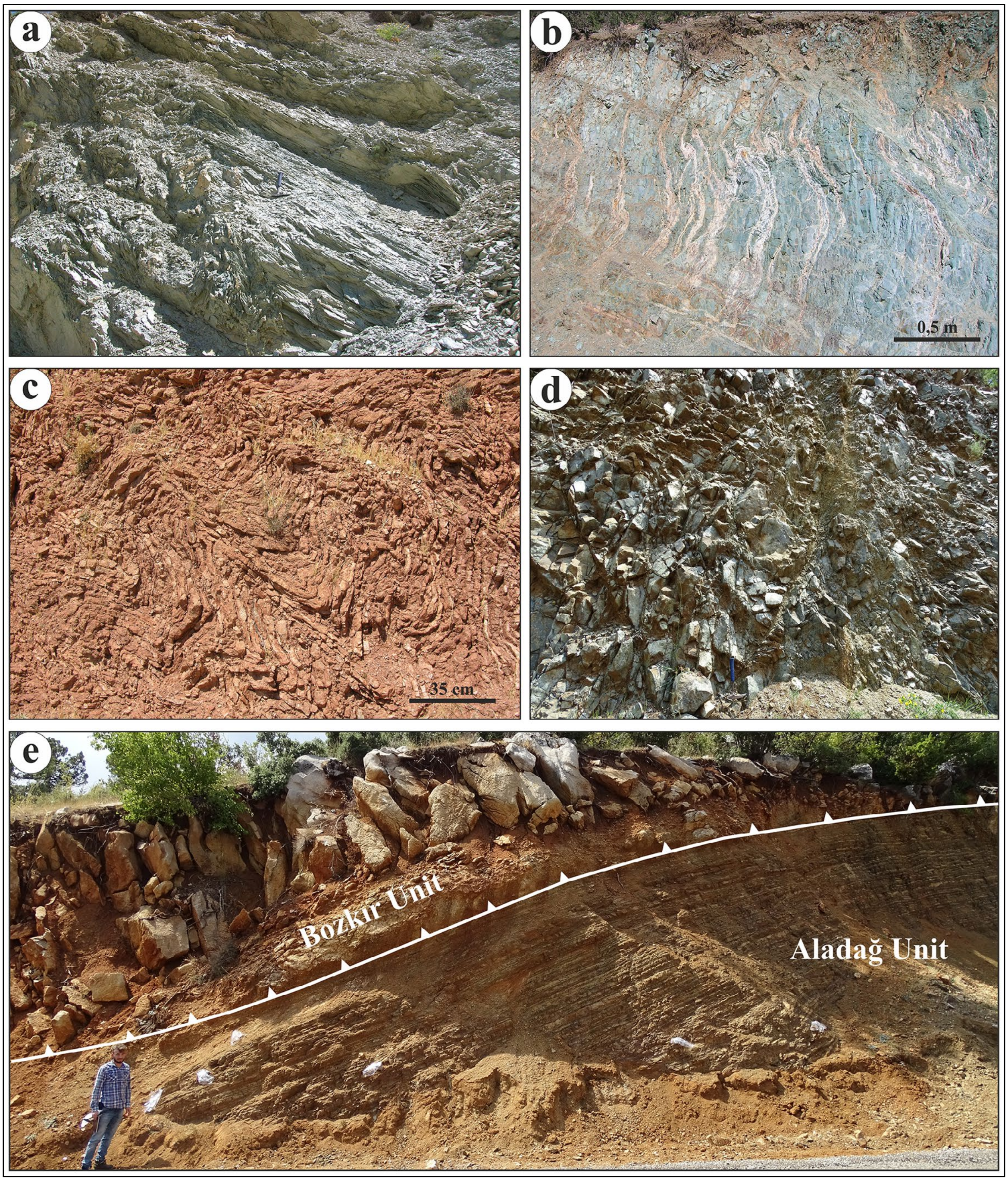

Figure 4- a) Early-Middle Triassic calcschists of Bolkardağı unit belonging to the Taurus units that constitute the bedrock (Mersin, Cocak Valley), b) Huğlu group defined in the Bozkır unit consists of green-colored thick tuffites (Karaman, S of Yollarbaşı village), c) the overlying Late Triassic-Senonian aged cherty pelagic limestone-mudstone-radiolarite alternation (Mut, Derinçay village), d) Ophiolites defined in the Bozkır unit (Mersin, Fındıkpınarı) and e) Ophiolitic mélange of the Bozkır unit which tectonically overlies Aladağ unit (Mersin, Kurudere village).

(Figure 4e). Mersin ophiolite which is the remnant of Mesozoic Neotethyan oceanic crust reflects the supra-subduction zone (Parlak et al., 1996). According to the $^{40}Ar/^{39}Ar$ hornblende ages, the initial detachment of the metamorphics from the oceanic crust during the closure of Neotethyan Ocean was occurred in late Cenomanian (Parlak et al., 1996). Metamorphism in Alanya Unit that consists of Permian, Triassic and lower Cenozoic rock units increases with depth. Lower Cenozoic rocks of this unit is transgressive and have no traces of metamorphism. This unit forms allochthonous covers on Antalya Unit in Alanya and Gündoğmuş regions. Cambrian-Upper Cretaceous Antalya Unit bears the blocks of shallow and deep marine sediments up to a kilometer scale. It contains ophiolites and the rocks of Geyikdağ Unit, and is situated on Geyikdağ Unit as allochthonous.

Lacustrine depositions were occurred in the Oligocene molasse basins which are the subject of this study and were opened on the bedrock of the Central Taurides. From the west to east respectively, lacustrine clastic and carbonate rocks of the Pamuklu formation in Ermenek Basin, of the Fakırca formation in Bucakkışla Basin, of the Çavuşlar formation in Korucuk Basin, and of the Sebil formation in the Çamlıyayla Basin have been deposited (Figure 2). These formations are described in detail below.

In early Miocene, lacustrine clastic rocks of Yenimahalle formation were unconformably deposited on the Oligocene Pamuklu formation in Ermenek Basin (Ilgar and Nemec, 2005; figure 2). In Bucakkışla Basin, fluvial sediments of Derinçay formation were unconformably deposited on the carbonates of Fakırca formation in the middle Burdigalian (Ünay et al., 2001; figure 2). The marine transgression occurring in late Burdigalian in the Central Taurides caused the Mut Basin to drown and the initiation of marine deposition in the basin during the Neogene period (Ilgar et al., 2016). Thus, the reefal limestone and platform carbonates of Mut formation, and the marls and thin-bedded limestones which constitute the offshore sediments of Köselerli formation were deposited in the Mut Basin in late Burdigalian-Serravallian period (Figure 2). Shallow marine limestones of Mut formation which shows onlapping sedimentation pattern on the bedrock towards the north due to marine transgression and offshore sediments of Köselerli formation reflect the basinal deepening in late Burdigalian-late Serravallian. Relative sea level fall in the late Serravallian period led to the shoaling of the basin, migration of the reefal limestones of Mut formation on to Köselerli formation in basinward direction and to crop out on the basin margin. Thus, incised valleys, larger than a river channel, were formed upon the reefal limestone of Mut formation (Ilgar et al., 2019). In late Serravallian-early Tortonian period, sedimentary facies of Dağpazarı formation were deposited in this incised valley (Figure 2). Early Tortonian transgression caused re-flooding of the northern parts of the Mut Basin, deposition of the reefal limestones of Tırtar formation on the basin margins and of marls to thin-bedded limestones of Ballı formation inside the basin (Ilgar et al., 2016). The marine sedimentation in the Mut Basin terminated by the isostatic uplift of the Taurides in the late Tortonian, and the basin began to expose (Cosentino et al., 2012; Ilgar et al., 2013).

3. Oligocene Molasse Basins in the Central Taurides

The Mut Basin located in the Central Taurides is one of the Neogene basins opened after the Taurus orogeny. In Mio-Pliocene period, a thick sequence consisting mainly marine and terrestrial sediments was deposited in the Mut Basin. However, small molasse basins were developed prior to opening of the Mut Basin. These basins which began opening in Oligocene and where lacustrine depositions were occurred constitute the first products of the post-orogenic extensional tectonics. Formation of the Mut Basin occurred in the advanced stage of this extensional tectonic regime. The basins which are the subject of this study have been named as Ermenek, Bucakkışla, Korucuk and Çamlıyayla from west to eastward, respectively (Figure 1b). The locations and stratigraphy of these basins are described in this chapter and their structural features in detail in the fourth section.

3.1. Ermenek Basin

Ermenek Basin, located in the SW of Ermenek and extending in NW-SE direction, is approximately 42 km long and, in the largest place, 17 km wide (Figure 5). The rocks of Aladağ and Bozkır Units constitute the pre-Oligocene bedrock of the Ermenek Basin. Opening and development of the basin were mainly controlled by NW-SE normal and oblique faults (Figure 5). Geometry of the basin and the basin floor topography were also developed under the control of these fault systems.

The rocks, overlying the bedrock in the Ermenek Basin, consist of lacustrine carbonates at the bottom and lacustrine clastic deposits at the top. These rocks were defined and mapped under the name of Yenimahalle formation by Gedik et al. (1979),

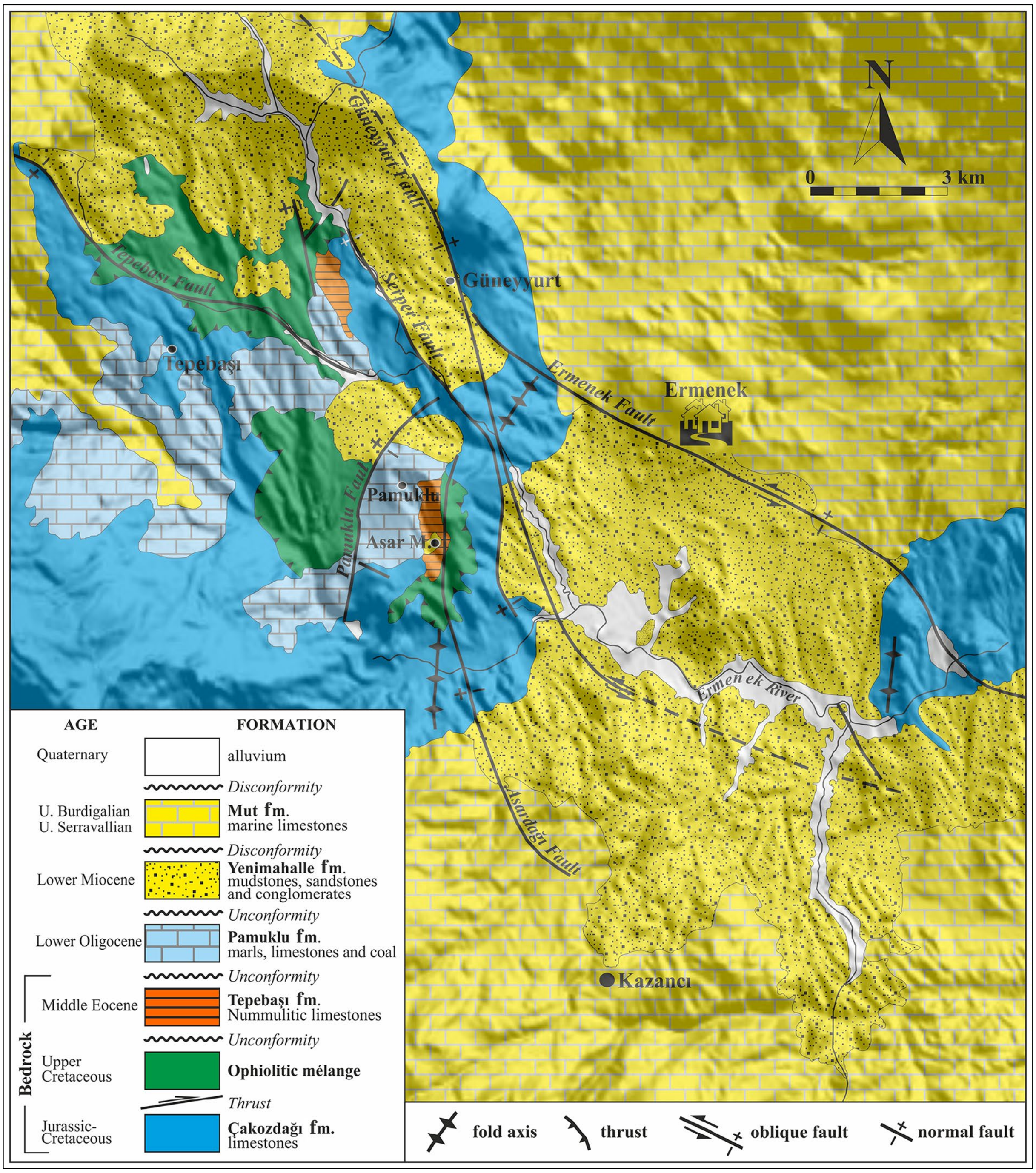

Figure 5- Detailed geological map of Ermenek Basin (Ilgar and Nemec, 2005). In this map, besides the Oligo-Miocene units, the faults that control the basin opening and development are seen.

Demirtaşlı et al. (1986), Demirel (1989). However, lithological features, age and stratigraphical position of these carbonates and their unconformable contact with the overlying lacustrine clastic rocks reveal that these carbonates had been formed and deformed before the clastic sediments. Therefore, Yenimahalle formation was divided into two formations, and the carbonates at the bottom were defined as Pamuklu formation by Ilgar (2002).

Pamuklu formation crops out in a limited area in the SW of Ermenek Basin. Location of type section of the formation is the former coal pit of the Central Coal Enterprise in Pamuklu (Cenne) coal field and its vicinity. Other outcrops of the formation can be seen in the west of Asar Mountain and in the south of Tepebaşı village.

Pamuklu formation, which unconformably overlies the bedrock in the stratigraphic section (Figure 6a) is overlain with an angular unconformity by the clastic rocks of Yenimahalle formation.

Pamuklu formation consists mainly of conglomerate, sandstone, mudstone, limestone, marl alternation and coal (Figure 6). The Pamuklu formation

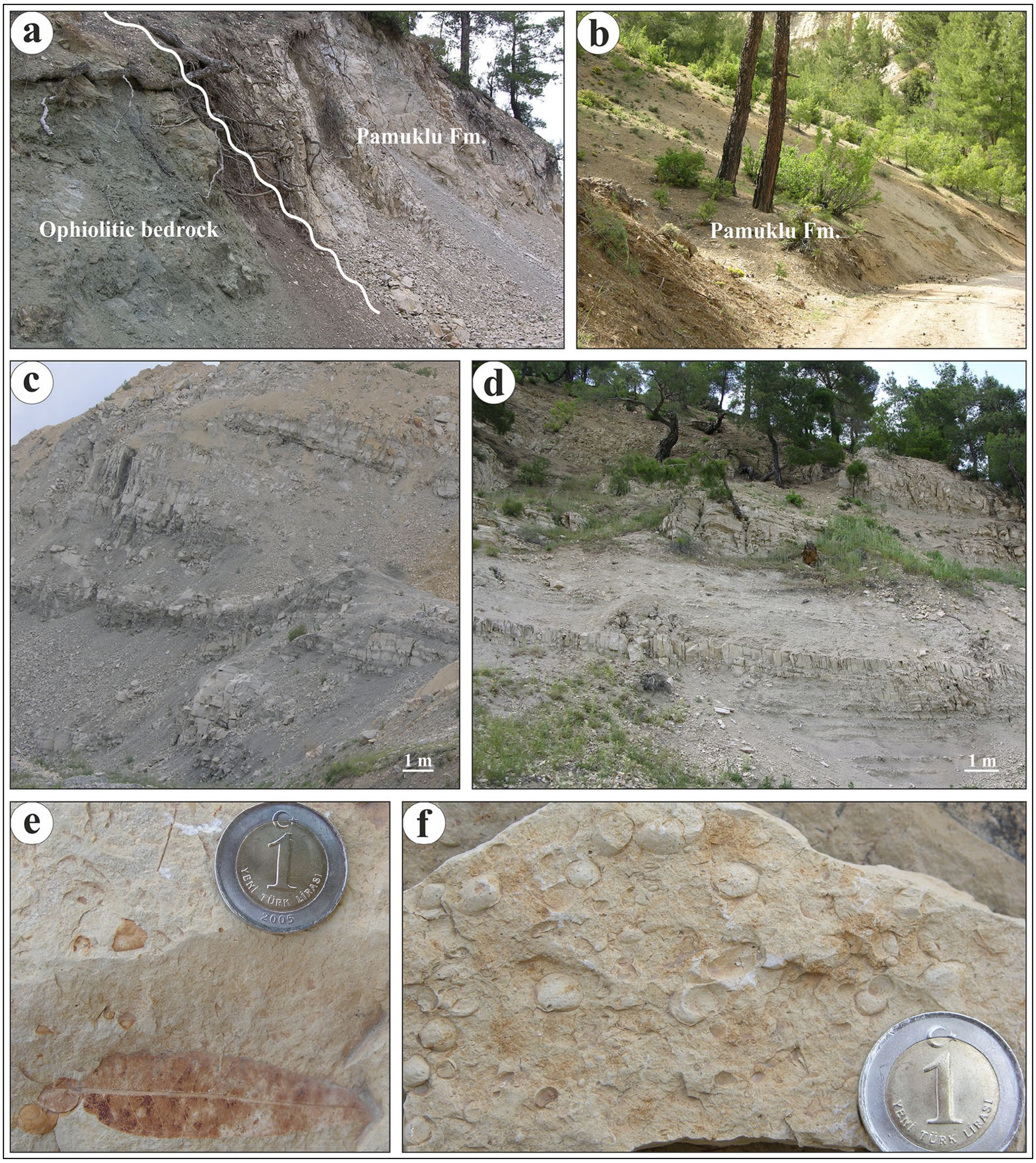

Figure 6- Early Oligocene aged Pamuklu formation which outcrops in Ermenek Basin. a) This formation unconformably overlies ophiolitic mélange of the bedrock, b) light brown colored conglomerates form the lowest levels of Pamuklu formation. There are brown-grey colored sandstones that reach several meters in thickness on the conglomerates. c) Planar-bedded sandstones pass upward into an alternation of mudstone-marl. d) Stratigraphic sequence passes upward into an alternation of thin- to thick-bedded, broken white-grey colored limestone and marl. There are (e) leaf fossils and (f) fresh-water gastropods such as *Planorbis* in the formation.

begins with a few meters thick, light brown colored, polygenic, matrix supported conglomerates with subrounded to rounded gravels on the bedrock (Figures 6a, b) Brown to grey colored sandstones that reach a few meters of thickness overlie the conglomerates (Figure 6b). Planar-bedded sandstones pass upward into an alternation of mudstone-marl (Figure 6c). There are economically operable coal deposits between these mudstone levels and their lateral continuation in the sequence. Thickness of the coal formations varies between 3 to 6 m. The thin-bedded limestone-marl alternations, 40-50 cm thick, are present between the coal bearing zones. The sequence grades upward into thin to thick-bedded, broken white-, pink-, beige-colored clayey limestones which occasionally bears leaf fossils (Figure 6d). In addition to leaf fossils, freshwater gastropods such as *Planorbis* are observed in the carbonate rocks (Figures 6e, f).

Pamuklu formation which is dispersedly situated between the paleoheights in the SW of Ermenek Basin, was significantly affected by the pre- to syn-depositional tectonism. Palynological investigations have been conducted on the samples of the formation collected from the coal pit around Pamuklu village. *Cupressacites cuspidateaformis* (ZANKL.) KRUTZS., *Tricolporopollenites megaexactus* (R.POT.) TH. and PF., *Tricolporopollenites microreticulatus* PF. and TH. in TH. and PF., *Monogemmites pseudostarius* (WEYL. and PF.) KRUTZS., *Tricolpopollenites microhenrici* (R.POT.) TH. and PF., *Pityosporites microalatus* (R.POT.) TH. and PF., *Inaperturopollenites dubius* (R.POT. and VENITZ.) TH. and PF., çok bol (% 14-20), *Caryapollenites simplex* (R.POT.) R.POT., *Tricolporopollenites cingulum* (R.POT.) TH. and PF., *Tricolporopollenites margaritatus* (R.POT.) TH. and PF., *Tricolpopollenites retiformis* PF. and TH. in TH. and PF., *Plicapollis pseudoexelsus* (KRUTZS.) KRUTZS., *Plicapollis* sp., *Arecipites* spp., bol (% 8-13), *Triatriopollenites exelsus* (R.POT.) TH. and PF., *Triatriopollenites rurensis* PF. and TH. in TH. and PF., *Triporopollenites densus* PF. in TH. and PF., *Momipites punctatus* (R.POT.) NAGY, *Triporopollenites simpliformis* PF. and TH. in TH. and PF., *Subtriporopollenites anulatus* PF. and TH. in TH. and PF., *Cycadopites* spp., *Compositoipollenites rhizophorus* (R.POT.) R.POT., *Polyporopollenites undulosus* (R.POT.) TH.and PF., *Intratriporopollenites instuructus* (R.POT. and VENITZ.) TH. and PF., *Polyvestibulopollenites verus* (R.POT.) TH. and PF., *Laevigatosporites haardti* (R.POT. and VENITZ.) TH. and PF., *Baculatisporites primarius* (WOLFF) TH. and PF., *Concavisporites concavus* PF. in TH. and PF. were determined from the samples as rare or slightly abundant (1-5%) (determination by Mine Sezgül Kayseri Özer, 9 Eylül University/İzmir, 2005).

Presence and abundance of lower Tertiary spores and pollens (*Tricolporopollenite exelsus, P. pseudoexelsus, Arecipites* sp., *Subtriporopollenite anulatus, Compositoipollenites rhizophorus* etc.) in Oligocene have been reported from various palynological studies from Turkey (Akgün et al., 1986; Akgün and Akyol, 1987, 1992, 1999; Akyol and Akgün, 1990; Akgün and Sözbilir, 2000, Akgün et al., 2002; Kayseri and Akgün, 2002, 2003). Percentage abundance of the sporomorphs tends to decrease from Oligocene to Miocene.

Age of the Pamuklu formation was assigned as early Oligocene due to the assemblage containing *Pityosporites microalatus, Inaperturopollenites hiatus, I. magnus, Triatriopollenites exelsus, Plicapollis pseudoexelsus, Caryapollenites simplex, Polyporopollenites undulosus, Compositoipollenites microechinatus, Intratriporopollenites instuructus, Compositoipollenites rhizophorus, Subtriporopollenites anulatus, Plicapollis* sp. and *Arecipites* spp. (Kayseri et al., 2006).

Age of the formation was determined as early-middle Oligocene according to the ostracod fauna containing *Lineocypris, Pseudocandona, Hemicyprideis montosa and Pokornyella limbata* obtained from the marls of Pamuklu formation, (Şafak et al., 2005). Pamuklu formation which contains leaf fossils and freshwater gastropods such as *Planorbis*, was deposited in a lacustrine basin in early Oligocene period.

3.2. Bucakkışla Basin

Bucakkışla Basin, located between Bucakkışla-Mut and extending in NW-SE direction, has a length of approximately 51 km and a width of 10 km (Figure 7). Rocks of the Bozkır Unit form the bedrocks of Bucakkışla Basin. The basin is bounded mainly by large scale NW-SE trending faults and smaller scale E-W trending normal faults. Geometry of the basin was correspondingly developed with these faults (Figure 7).

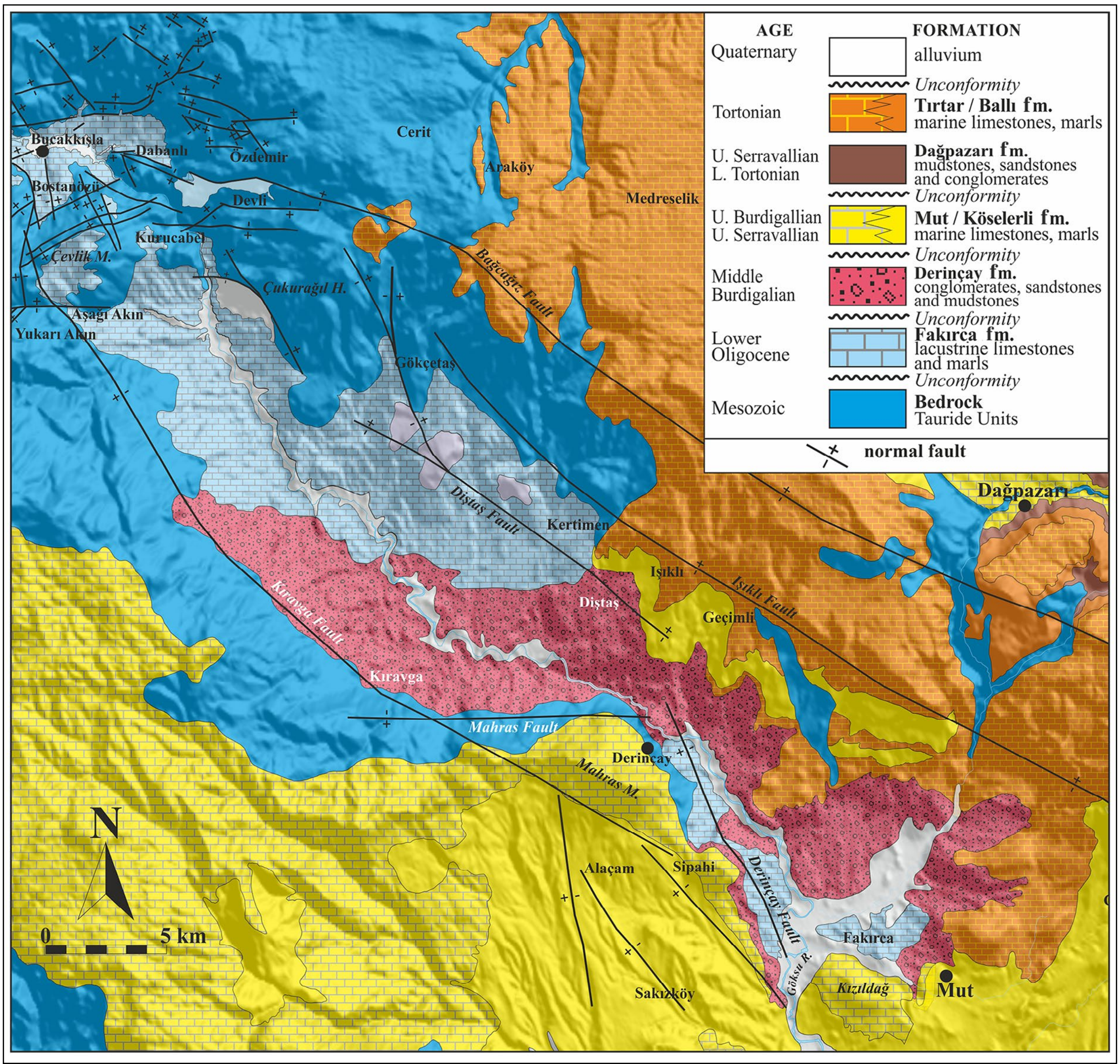

Figure 7- Detailed geological map of Bucakkışla Basin. In this map, besides the Oligo-Miocene units, the faults that control the basin opening and development are seen.

The conglomerate, sandstone, shale, marl assemblage overlying the Mesozoic bedrock with an angular unconformity in the Bucakkışla Basin, was named as Derinçay formation by Gedik et al. (1979). The shales and marls that are defined in this unit and outcropped in the Fakırca region in the NW of Mut are defined by the same researchers as the Fakırca member of the Derinçay formation. As being products of the terrestrial deposition systems, these sequences have been examined as two distinct formations depending on different facies features, relative stratigraphical position and erosional unconformity between the units. The rock assemblage, overlying the bedrock and consisting generally of lacustrine deposits, has been named as Fakırca formation. Fluvial deposits which overlie the Fakırca formation with an angular unconformity have been defined as Derinçay formation (Figures 2, 8a). Fakırca formation outcrops in a large area between Bucakkışla and Fakırca villages (Figure 7).

Fakırca formation begins with reddish conglomerates, sandstones and mudstones on the bedrock to the south of Derinçay village (Figures 8a, b). Conglomerates consist of rounded to surrounded gravels of serpentinite, limestone, chert and radiolarite. These conglomerates with clast-supported texture are massive or crude stratified. Sandstones that consist of medium to coarse grain size are planar-parallel stratified, planar-cross stratified and trough-cross stratified, and graded bedded in less proportions (Figure 8c). This sequence, having a 20-50 m thickness in the basin margin, grades into marls and clayey limestones. Carbonized plant fragments and mudstones rich in organic matter are also observed in these levels.

Fakırca formation begins with thick-bedded sandstone-mudstone alternation in its type section located in Fakırca village. Sandstones with fine to medium grain size are planar parallel stratified. Claret red-colored thick mudstones are crude stratified. A thin-bedded rock assemblage consisting of marl-mudstone-clayey limestone and limestone alternation, with a thickness of 15 m, overlies these thick-bedded rocks (Figure 8d). The rocks constituting this assemblage are grey-colored and planar parallel stratified. Undulated and hummocky-cross stratified limestones are also present in different levels of the sequence (Figure 8e). The thickness of this rock assemblage increases towards the upper level of the

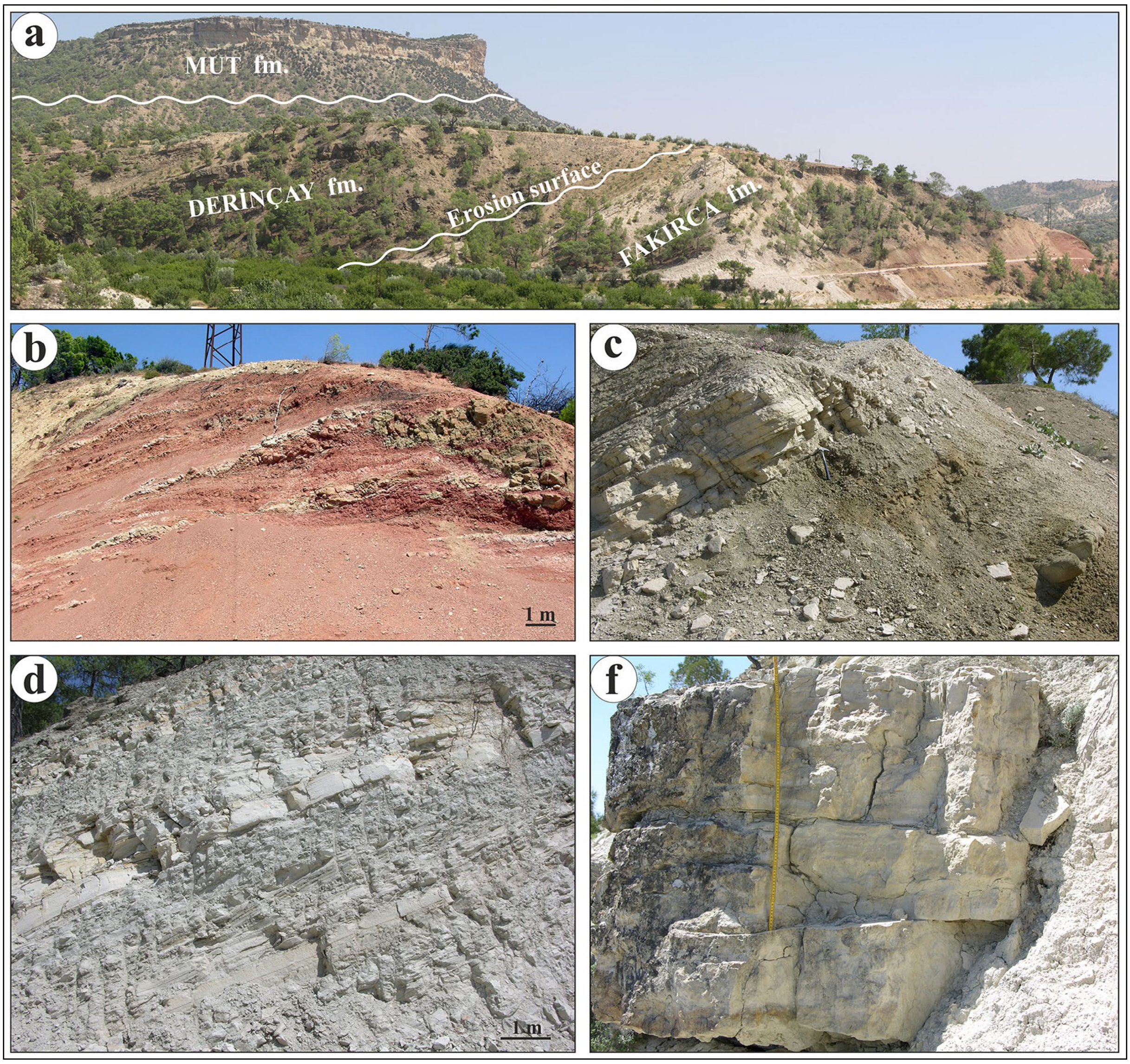

Figure 8- Oligocene aged Fakırca formation which outcrops in Bucakkışla Basin begins at the base with (a, b) reddish conglomerate, sandstone and mudstone on the bedrock. c) Overlying khaki sandstones are planar-bedded, planar-parallel stratified and locally normal-graded. This sequence grades into marls and clayey limestones. d) The formation in its type section located in Fakırca village, begins with thick-bedded sandstone-mudstone alternation and passes upward into an alternation of thin-bedded marl-mudstone-clayey limestone-limestone. e) Limestones defined in the sequence are generally planar-bedded or undulated.

sequence. There are occasionally very thick-bedded sandstones in this assemblage reaching approximately 35 m thickness. These limestones are generally planar parallel stratified, but occasionally hummocky-cross stratified and rippled-cross stratified. The hummocky-cross stratified sandstones are amalgamated and crudely normal-graded. Desiccation cracks are present at the base of some limestone beds.

The palynological investigations have been conducted on the samples collected from mudstones of Fakırca formation in Bucakkışla Basin, and results have shown that:

Pityosporites microalatus species is abundant,

Triatriopollenites coryphaeus, Momipites punctatus, Subtriporopollenites simplex, Tricolpopollenites microhenrici, Tricolpopollenites densus, Tricolporopollenites megaexactus species are regularly low,

Pityosporites libellus, Inaperturopollenites hiatus, Inaperturopollenites dubius, Spinizonocolpites prominatus, Spinizonocolpites echinatus, Triatriopollenites exelsus, Subtriporopollenites anulatus nanus, Polyporopollenites undulosus, Polyvestibulopollenites verus, Slowakipollis hipophäeoides, Tricolpopollenites retiformis, Tricolporopollenites microreticulatus, Tricolporopollenites margaritatus, Tetracolporopollenites sapotoides species are irregularly low. According to the obtained data, age of Fakırca formation outcropping in the Mut Basin is early Oligocene (determination by Mine Sezgül Kayseri Özer, 9 Eylül University/ İzmir, 2005).

The rock assemblage, situated at the base of Fakırca formation and consisting mainly of reddish conglomerate, sandstone and mudstone, constitutes the alluvial fan deposits. Massif or crude stratified conglomerates defined in these sediments reflect debris flow products. Medium to coarse-grained cross stratified sandstones, accompanying these rocks, indicate the bar deposits in active distributary channels within the alluvial fan. It is thought that, carbonized plant fragments and coal formations observed in relatively upper parts of the sequence indicate swamp environments occurred in floodplain or playa lake.

Thick-bedded, planar parallel stratified and wave rippled-cross stratified sandstones defined in Fakırca formation were deposited in the shoreface environment on the normal wave-base (Clifton, 1976; Walker and Plint, 1992; Ainsworth and Crowley, 1994). In addition to these deposits, amalgamated hummocky cross stratified sandstones in the sequence indicate a deposition within the shoreface environment due to storm processes.

Thin-bedded rock assemblage of marl-mudstone-clayey limestone and limestone alternation situated in the middle-upper parts of the sequence was deposited in the offshore- transition environment between the normal wave-base and the storm wave-base. Sand- and clay-sized materials were transported into the environment which has the calm water environment in the fair weather conditions and in which mud sedimentation occurred as from the suspension. The undulated and hummocky cross-stratified clayey limestones with sharp base defined at these levels of the sequence constitute the tempestites deposited due to storm processes (Dott and Bourgeois, 1982; Hunter and Clifton, 1982; Walker and Plint, 1992; Ainsworth and Crowley, 1994).

There are no fossil records suggesting a biogenic origin in planar-bedded marls and limestones that have gradational transition with mudstones. Despite having no isotopic data, these carbonate rocks are thought to be formed by inorganic precipitation due to gradational transition with mudstones. The absence of evaporitic sediments and the presence of *Planorbis* fossils in Fakırca formation reflect freshwater conditions. In this case, the waters that supply the lake have been enriched with calcium ions and hardened by probably passing through the limestone-rich rocks. As a result of the removal of CO_2 from the environment by photosynthesis of phytoplankton and picoplankton whose abundance level increased in the sedimentary environment, the pH of the water in the environment increased and $CaCO_3$ precipitation occurred (Kelts and Hsü, 1978; Wright, 1990; Talbot and Allen, 1996). Amount of the clastics that concurrently transported into the basin were also decreased in that period.

3.3. Korucuk Basin

Korucuk Basin, located in the W of Silifke in the S of Central Taurides and extending in E-W direction, has a length of approximately 22 km and a width of 10 km (Figure 9). Limestones of the Aladağ Unit, ophiolites and the mélange of Bozkır Unit form the

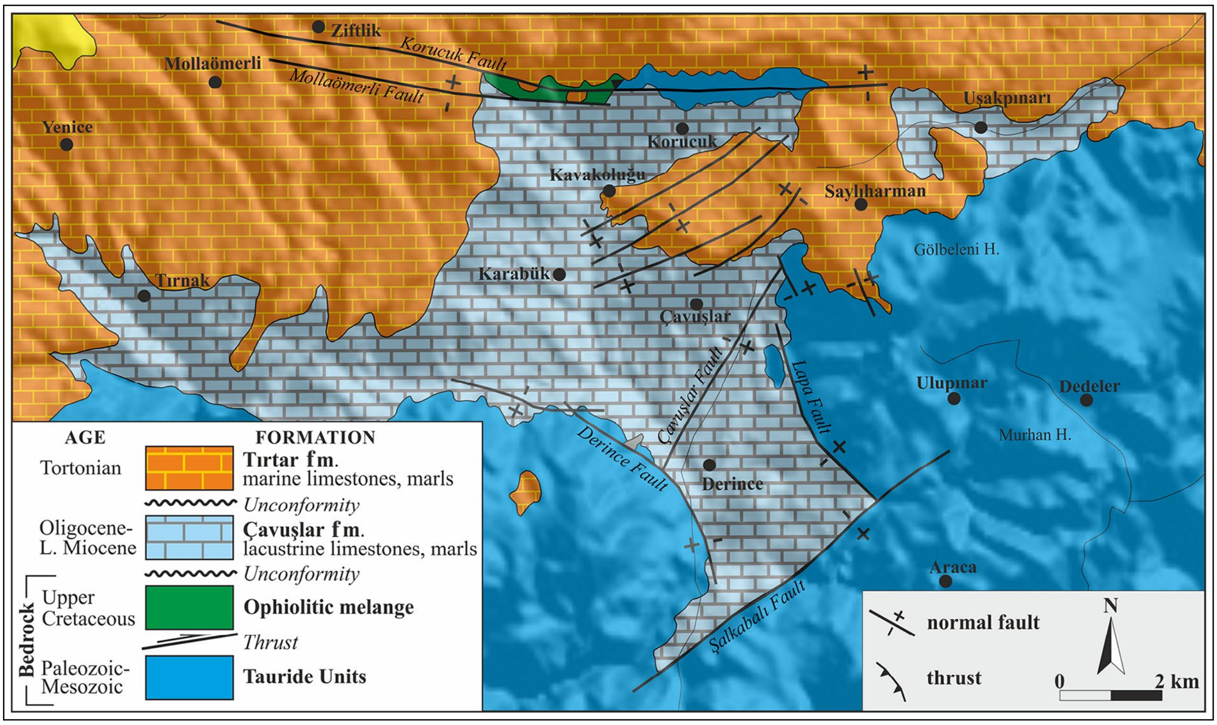

Figure 9- Detailed geological map of Korucuk Basin. In this map, besides the Oligo-Miocene units, the faults that control the basin opening and development are seen.

bedrocks of the Korucuk Basin. The basin has an irregular geometry and basin floor topography owing to being opened between faults developed in different directions (Figure 9).

Lacustrine sediments of Çavuşlar formation (Demirtaşlı, 1984) were deposited with an angular unconformity on the Mesozoic bedrock in the Korucuk Basin. Çavuşlar formation crops out in the vicinity of Bozağaç, Korucuk, Uşakpınarı, Kavakoluğu, Çavuşlar and Derince villages in the SE of Gülnar (Figure 9). Type section of the formation is located in the Kavakoğlu and Çavuşlar villages, and the reference section is in Korucuk village.

Çavuşlar formation, having approximately 100-400 m of thickness, unconformably overlies the Cretaceous limestones in the Korucuk village in the north (Figure 10a). In the west of Korucuk village, it unconformably overlies ophiolites. In the south, the formation overlies the Cretaceous limestone with an angular unconformity in Fıstık River in the vicinity of Derince neighborhood. Çavuşlar formation is overlain by late Miocene Tırtar formation with an angular unconformity between Kavakoğlu and Çavuşlar villages (Figure 10b).

Çavuşlar formation consists mainly of thin-bedded sandstone, mudstone, limestone, marl alternation (Figures 10c and d) and, in lesser proportions, conglomerate and coal. Yellow-, light-brown colored sandstones, consisting mainly of very fine to medium grain size, have bedding thickness varying between 1 to 20 cm. Normal grading, planar parallel stratification (Figure 10c), and sparse wave- and current ripples constitute the sedimentary structures of the sandstones which have laterally widespread planar bedding. Çavuşlar formation, in central and southern parts of the basin, consists mainly of the alternation of marl, mudstone, clayey limestone and limestone (Figure 10d). Marls and limestones of the formation are beige, and the mudstones are greyish-green colored. Planar-bedded mudstones are massif, and the limestones are generally planar parallel stratified and occasionally rippled-cross laminated. Coal formation is located in the immediate south of the E-W trending normal fault in the northern margin of the basin.

Conlomerates and pebbly sandstones observed in the northern margin of the basin consist of basinward inclined tabular beds towards the south (Figure 10a). Horizontally bedded conglomerates and pebbly sandstones overlie the tabular inclined beds (Figure 10a). Basinward inclined rocks and the

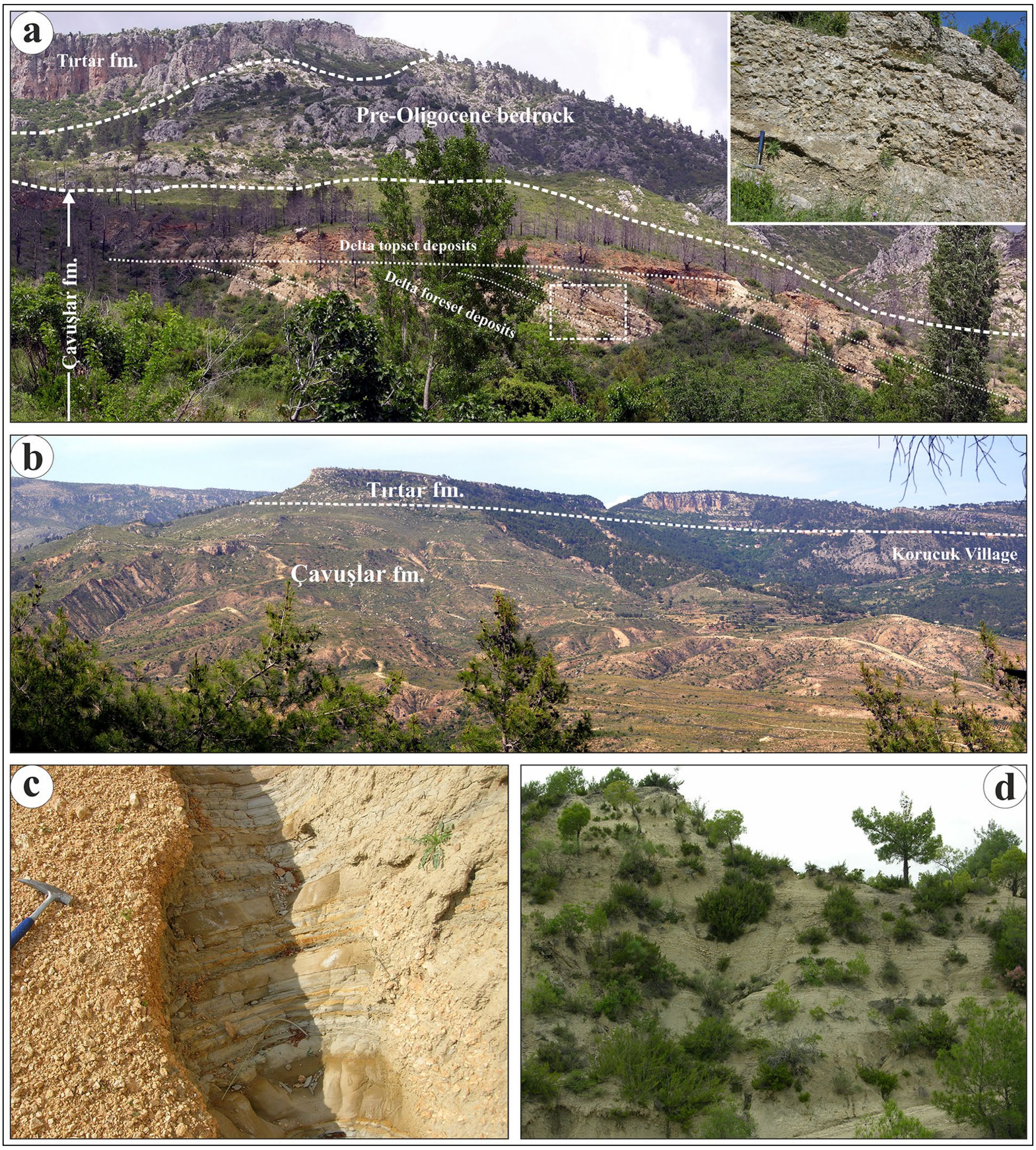

Figure 10- Oligocene-early Miocene aged Çavuşlar formation which outcrops in Korucuk Basin a) unconformably overlies the bedrock. Gilbert-type delta deposits, consisting of conglomerate and sandstone, crop out in front of the normal faults that limit the basin to the north of the basin. In this figure, besides the delta topset and delta foreset deposits which form the delta, there is also a close up view of the delta foreset deposits. b) Çavuşlar formation is overlain by the late Miocene Tırtar formation with an angular unconformity between Kavakoğlu and Çavuşlar villages. c- d) Çavuşlar formation consists mainly of thin-bedded sandstone, limestone, marl alternation.

overlying horizontally bedded sediments constitute the delta foreset and delta plain deposits that are typical for Gilbert-type delta (Barrell, 1912; Colella, 1988; Postma, 1990). These delta deposits have approximately 25 m of thickness.

Delta foreset deposits: Delta foreset deposits consist mainly of basinward inclined (<25°) conglomerates, and sandstones in less proportions (Figure 10a). Conglomerates that consist of granule to coarse pebble size grains are generally

15-120 cm thick, and planar-bedded. Cobbles, up to 15 cm in size, occur scattered in conglomerates. Grains are subrounded to rounded in these deposits which have clast-supported texture. The grains were mostly derived from Mesozoic limestones of the bedrocks. Intergranular cement consists of sand and granule sized grains that are well sorted. Massif conglomerates, showing generally no gradation or reverse grading, are planar shaped in longitudinal sections and mound-shaped in transverse sections. These have been interpreted as noncohesive debris flow deposits (Nemec and Steel, 1984; Nemec, 1990). Sandstones are commonly found in the lower parts of delta foreset deposits. Planar bedded, fine to very coarse grained sandstones have 10-30 cm of bedding thickness, and alternate with granule conglomerates. Planar parallel stratified sandstones show either normal grading or no gradation. Planar parallel stratified sandstones and granule conglomerates show the sediment transportation and deposition resulted from hyperpycnal turbidity currents (Bornhold and Prior, 1990; Nemec, 1990). Hyperpycnal turbidity currents indicate river-derived low-density turbidity currents (Lowe, 1982).

Delta topset deposits: The topset deposits, which are horizontally bedded on the delta foreset deposits, consist of fine-coarse pebble conglomerates and coarse-grained sandstones. These deposits form fining upward bedsets that have erosional bottom surfaces. The bedsets stacked upon one another and have a few meters wide, form the channel-fill deposits of braided stream (Miall, 1985; Collinson, 1996). Planar parallel-stratified and cross-stratified conglomerate and sandstone beds defined in the channel deposits, 10–45 cm thick, reflect the longitudinal and transverse midchannel bar deposits (Miall, 1985; Nemec and Postma, 1993).

Çavuşlar formation, containing coal and freshwater gastropods such as *Planorbis* in its marls and limestones, was deposited in a fault-controlled lacustrine basin. Coal deposition occurred due to normal faulting at the northern margin of the basin. Depending on the sediment transport carried from the north in a period that the basin was relatively deepening, Gilbert-type delta deposition was also developed in the northern margin.

According to the palynological investigations conducted to date lacustrine Çavuşlar formation, latest Oligocene-early Miocene (Burdigalian) age was assigned based on the findings of *Pinus indet* (for taxonomy see Benda, 1971), *-haploxylon-*group, silvestris group, *Picca*-type, *Cedrus*-type, *Magnus-dubius* group, *Taxodiaceaepoll.* hiatus (R.POT) KREMP, *Sequoiapoll. polyformosus* Thierg, Ineperturopoll. *emmaensis* (Murr. and pF.).pF, *Quercoidites* henrici (R.POT) R.POT., TH. and THIERG, *Quercoidites* microhenrici (R.POT) R.POT., TH. and THIERG, *Rhoipites dolium* R.POT, *Caprifoliipites microreticulatus* (Pf. and Th) R.POT, *Nyssoidites roddorensis* Thierg, Trivestibulopoll. betuloides PF., *Myricoides-bituitus-rurensis-*group, *Subtriporopoll simplex* (R.POT) Pf. and Th., *Alni-poll verus* R.POT, *Gramineae, Cyperaceae, Cicatricosisporites* corogeresis R.POT. and Gell, of Osmundaceae spores (Uğuz, 1989). Bilgin et al. (1994) accepted the age of Çavuşlar formation as early Oligocene-early Miocene (Burdigalian). In this study, the age of Çavuşlar formation has been accepted as Oligocene-early Miocene considering previous studies.

3.4. Çamlıyayla Basin

Çamlıyayla Basin, located in the eastern side of the Central Taurides and extending in the NE-SW direction, has a length of approximately 17 km and a width of 7 km (Figure 11). Bedrocks of the Çamlıyayla Basin are the rocks of Aladağ Unit and the ophiolite and mélange of Bozkır Unit. In the north of the basin, Eocene carbonate rocks of Kaleboynu formation are also found in the bedrock with a very limited distribution. Çamlıyayla Basin is bounded mainly by large scale NE-SW trending parallel faults and smaller scale E-W trending faults. Basin geometry was developed under the control of NE-SW trending fault systems (Figure 11).

The rock assemblage consisting mainly of sandstone, mudstone, marl, limestone and, in less proportions, conglomerate and coal deposited in Çamlıyayla Basin has been named as Sebil formation in this study. Sebil formation crops out between Çamlıyayla, Sebil, Boğazpınar and Korucuk villages in the south of Çamlıyayla (Figure 11). Sebil formation overlies the Jurassic to Cretaceous aged limestones and the Eocene aged nummulitic limestones with an angular unconformity around Çamlıyayla and Sebil. The formation is unconformably overlain by limestones of Mut formation and clastic rocks of Dağpazarı formation in the south of Çamlıyayla.

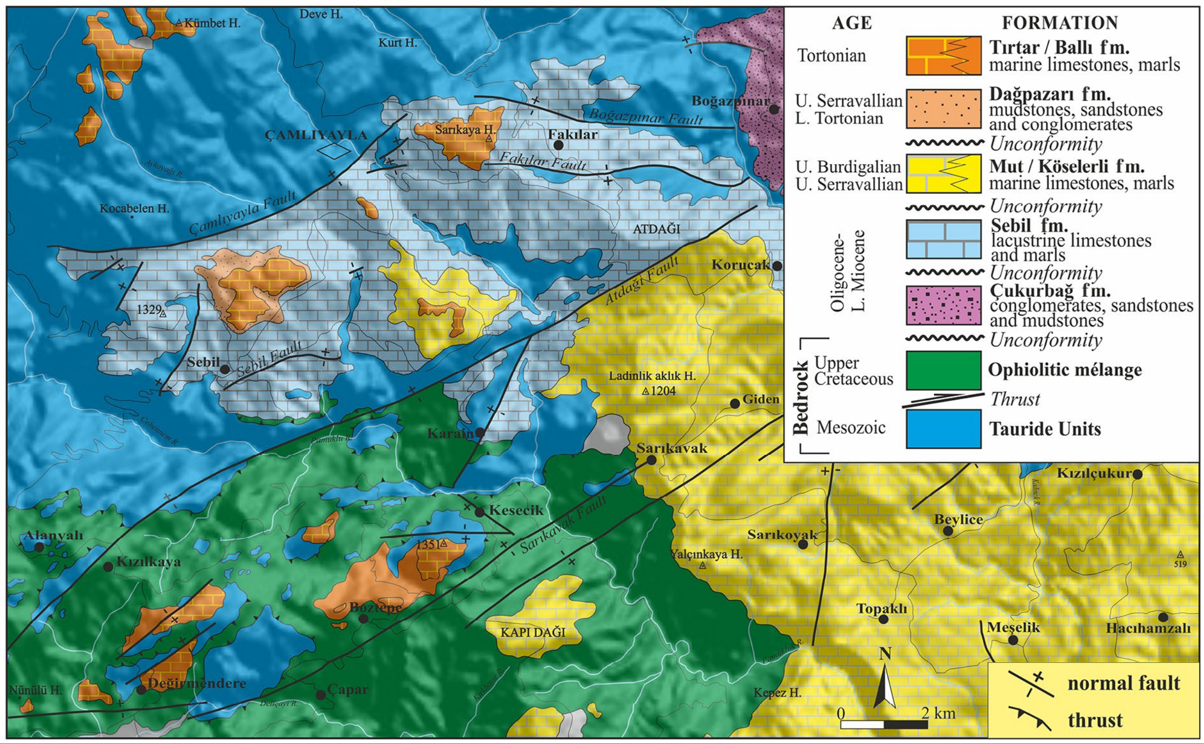

Figure 11- Detailed geological map of Çamlıca Basin. In this map, besides the Oligocene-Miocene units, the faults that control the basin opening and development are seen.

This formation consists of cream-light yellow colored sandstone, limestone, marl, mudstone alternation, coal and conglomerates in the vicinity of Sebil village (Figure 12). The sequence begins with the alternation of mudstones and marls at the bottom. Thin-bedded coal-bearing deposits that reach 150 cm in thickness, and organic matter-rich mudstones overlie these sediments (Figures 12a, b). The coal-bearing zones grade upward into an alternation of clayey limestone-marl. Thin-bedded, laterally continuous clayey limestones are overlain by fine-medium grained, planar bedded sandstones which reach 250 cm in thickness (Figures 12 a, b, c). Well sorted sandstones are planar parallel stratified, wave rippled and occasionally hummocky cross-stratified. Pebbly sandstones and fine pebble conglomerates, reaching 1 m in thickness, are present between these sandstones (Figure 12d). Well sorted and well-rounded conglomerates are planar parallel stratified. The sequence continues with the thin-bedded mudstone-sandstone alternation which reaches 4 m in thickness. These sandstones and mudstones have thickness varying between 5-20 cm. This sandstone-mudstone alternation continues upward with the alternation of marl, limestone and occasionally dark grey colored mudstone. These thin-bedded and laterally continuous sediments have an approximate thickness of 7 m. In the uppermost part of the sequence, there is an alternation of mudstone-sandstone. Sebil formation, which consists of clastic rocks as conglomerate, sandstone, siltstone in the basin margin, passes basinward into an assemblage of marl and limestone. Leaf fossils and freshwater gastropods such as *Planorbis* are present in the marls and limestones.

Planar parallel stratified and wave rippled-cross stratified sandstones defined in Sebil formation were deposited in the shoreface environment on the normal wave-base (Clifton, 1976; Walker and Plint, 1992; Ainsworth and Crowley, 1994). Hummocky cross-stratified sandstones defined in this sequence reflect the storm processes which occurred in the shoreface environment. Well sorted, planar parallel stratified conglomerates, accompanying the shoreface sandstones, indicate beach environment (Bluck, 1967, 1999; Clifton, 1973; Postma and Nemec, 1990). Marl, mudstone, clayey limestone, limestone alternation defined in different levels of the sequence were deposited in the offshore-transition environment

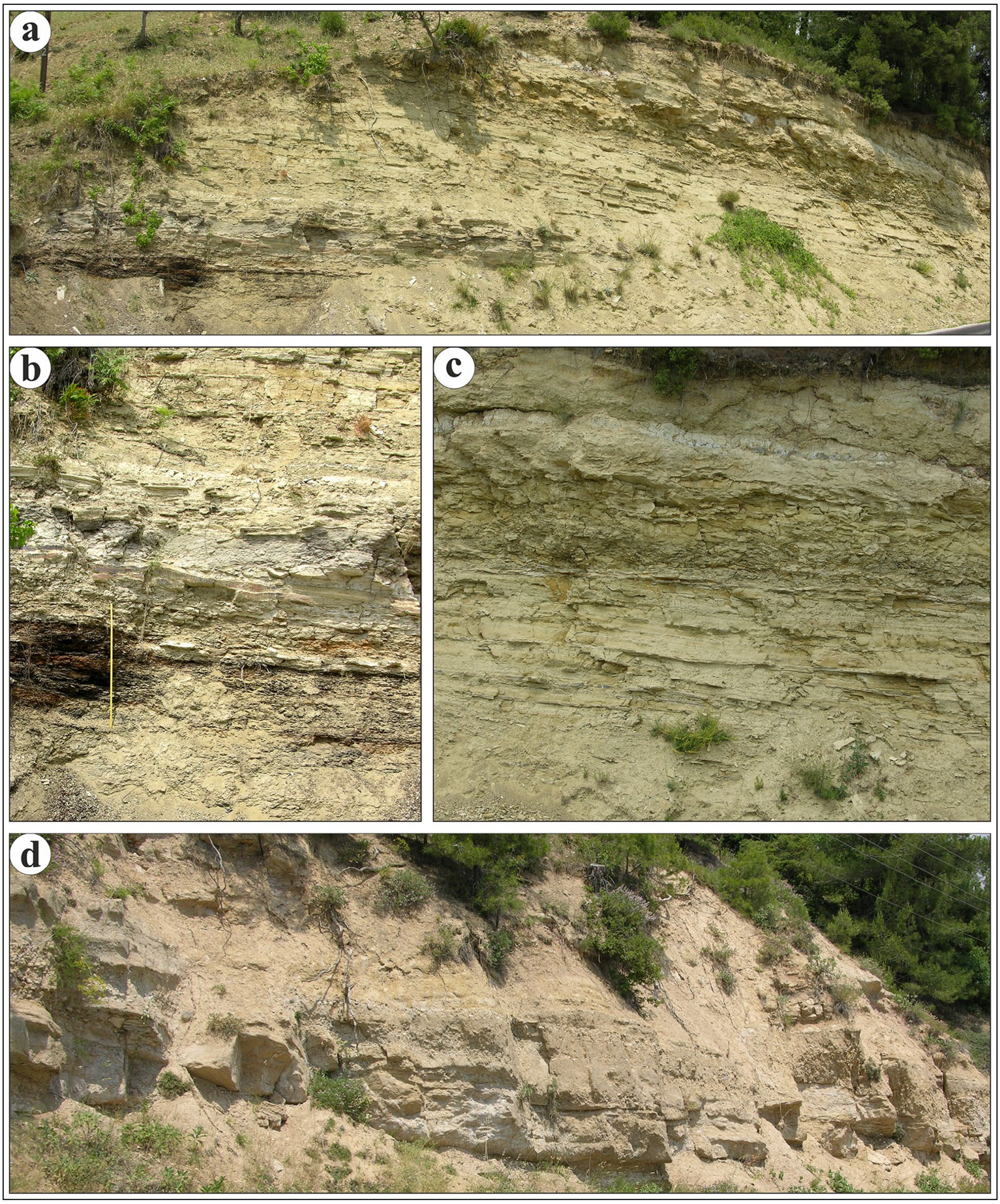

Figure 12- Oligocene-early Miocene aged Sebil formation which outcrops in Çamlıyayla Basin a) consists of cream-light yellow colored sandstone, limestone, marl, mudstone alternation, and coal and conglomerates. b) Coal-bearing zones and mudstones rich in organic matter grades upward into the alternation of clayey limestone-marl. c) There are fine to medium grained, planar-bedded sandstone on the limestones. d) Planar-parallel stratified, well sorted and well-rounded conglomerates and pebbly sandstones are seen between the sandstone beds.

between the normal wave-base and the storm wave-base. In this environment, while mud sedimentation occurred as from the suspension in the fair weather conditions; sand- and silt-sized materials transported into the environment depending on the storm processes, and were deposited in offshore-transition environment (Dott and Bourgeois, 1982; Hunter and Clifton, 1982; Walker and Plint, 1992; Ainsworth and Crowley, 1994).

No age data has been obtained from the mudstone samples collected from Sebil formation. However, based on its stratigraphical position between the Eocene Kaleboynu formation and the reefal limestones of late Burdigalian-late Serravallian Mut formation, and its close stratigraphical similarities with Fakırca formation defined in the Bucakkışla Basin, age of Sebil formation is thought to be Oligocene-early Miocene.

4. Structures and Deformations of Oligocene Basins

4.1. Ermenek Basin

Ermenek Basin, which is located in the SW of Ermenek and has a longitudinal geometry in NW-SE direction, is a tectonically controlled basin. There are faults of various sizes on the NE and SW margins of the basin and inside of the basin. NE margin of the Ermenek Basin is bounded by Ermenek fault which strikes N63W and dips 54ºSW (Figures 5 and 13a). Starting from Güneyyurt village towards the SE, trending of this 17 km long fault rotates in the east of the basin, and continues as striking N26W with dip of 62º SW. Slickenlines with +64º rake are present on the slickenside (Figure 13a). Trending of the 18 km long Tepebaşı fault, which is located in the NW margin of the basin, changes between N33W/60ºNE and N74W/65ºNE (Figure 5). Serper fault observed in the NW of the basin, bounds the bedrock and the

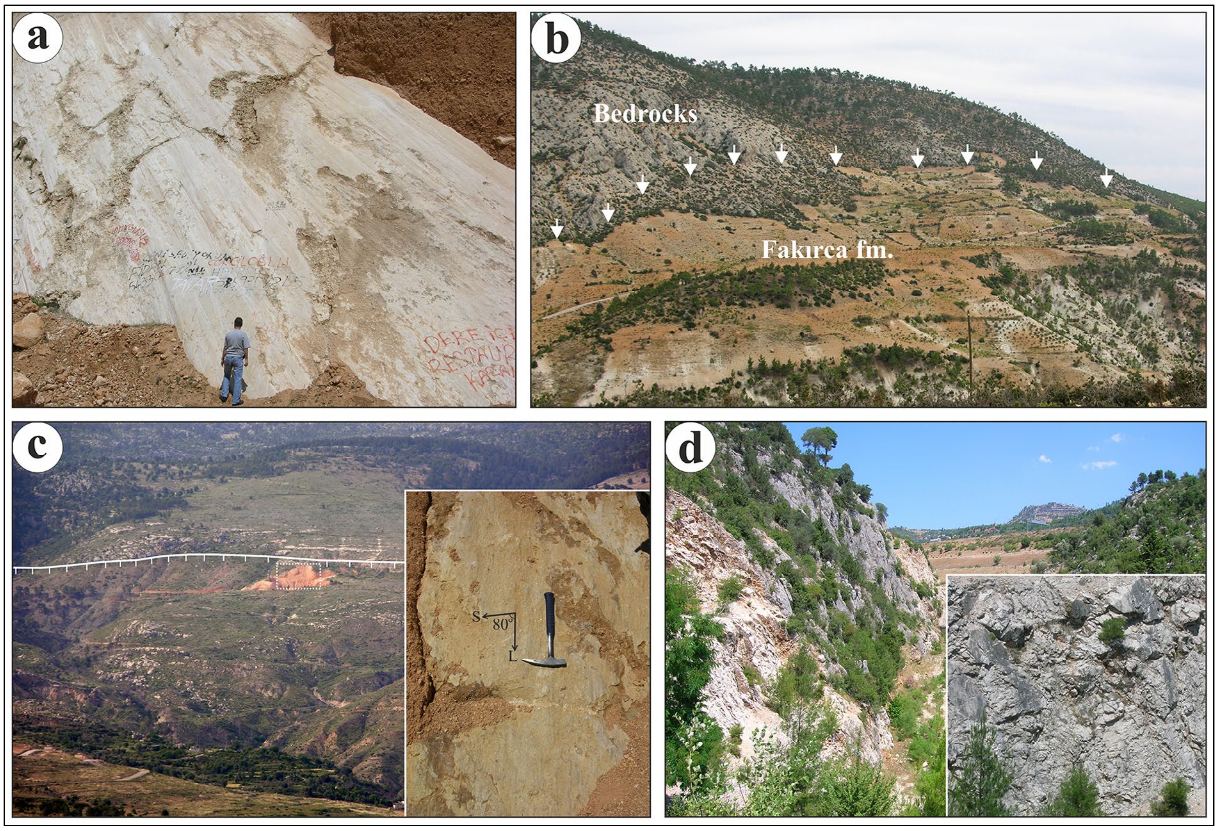

Figure 13- Examples of normal faults that limit the Oligocene basins in the Central Taurides. a) Ermenek fault which starts from Güneyyurt village in Ermenek Basin and extends 17 km towards the SE by limiting the NE margin of the basin. Note that the slickenlines are present on the fault planes. b) Diştaş fault defined in the Bucakkışla basin, is a N60W striking and 82ºSW dipping fault. Fault plane forms a border between Oligocene Fakırca formation and the bedrock. c) Korucuk normal fault which limits the northern margin of Korucuk Basin. d) Atdağı normal fault, cutting the bedrock and Oligocene Sebil formation and Miocene Mut formation, is a fault defined in Çamlıyayla Basin.

early Miocene lacustrine deposits. This fault has a length of 10 km between the trending N32W/73ºNE and ~N-S/70ºE (Figure 5). Pamuklu fault, forming a boundary between the bedrock and the Oligocene lacustrine deposits in the west of Pamuklu village, has a total length of 8 km. Trending of the Pamuklu fault changes between N34E/55ºSE and N08E/58ºSE. Asardağı fault, 11 km long and located in the middle of the basin, extends along trends between the N-S/72ºE and N18W/68ºNE. Güneyyurt fault, a 28 km long oblique-slip fault, extends from the NW of the basin towards the SE along the trends N34W/66ºSW, N17W/73ºSW, N67W/64ºSW. Slickenlines with +57º rake are present on the slickenside.

Slickenlines and corrugation axis trends on the abovementioned faults are perpendicular or nearly perpendicular to the strike of the faults. In addition to the slickenlines and the corrugation axis trends, chatter marks also indicate normal faulting. Besides, two different normal faults with left lateral strike-slip component are seen in the north and inside of the basin.

Bedrock of the Ermenek Basin which consists of Jurassic-Cretaceous aged limestones, ophiolites, Eocene aged limestones were cut by normal faults. Ermenek, Güneyyurt, Tepebaşı, Pamuklu faults form boundaries between the bedrock and the Oligocene-early Miocene aged lacustrine deposits. Onlapping geometry is observed on fault planes in lacustrine depositions occurring along the faulted contacts. This depositional geometry indicates that normal faulting was occurred before the deposition.

While the faults bounding the NE of the basin dip to the SW, the faults located in the SW margin dip to the NE. Data obtained from stereographic projection analysis of the faults which limit the basin show that the Ermenek Basin was opened as being cut by normal faults under the effect of NE-SW directed stress after the Taurus Orogeny (Figure 14a).

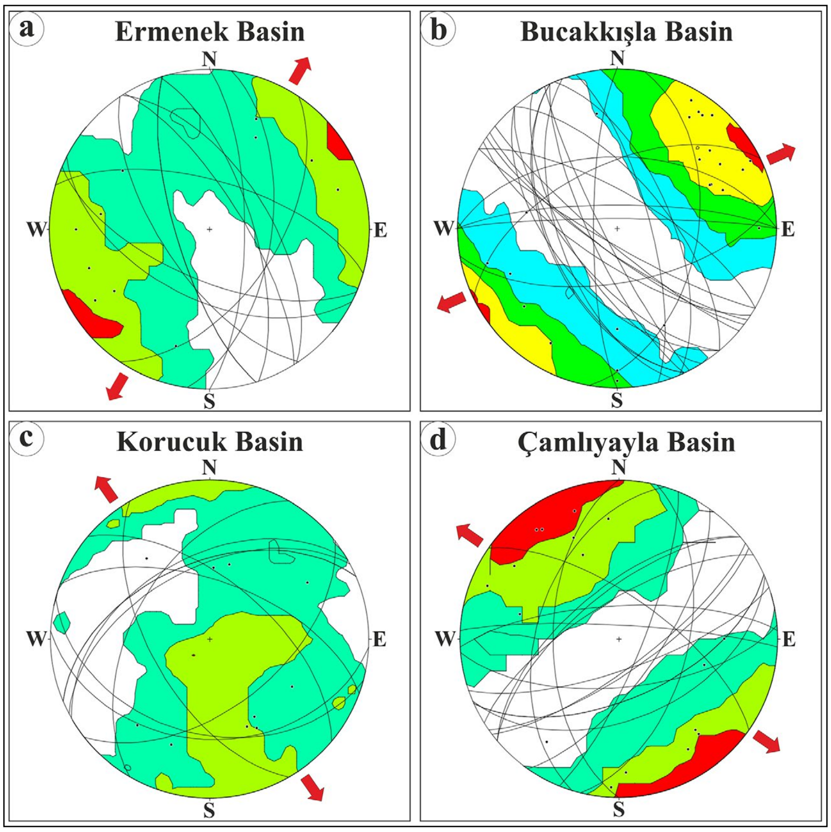

Figure 14- Lower hemisphere projection showing data of strain forces and faults that caused the opening of Ermenek, Bucakkışla, Korucuk, Çamlıyayla basins in the Central Taurides and later on affected the Tertiary marine sediments. Dataset including strikes and dip angles of faults, and the plots have been generated by using Stereonet 9.5 program (Allmendinger et al., 2013).

Ermenek Basin, which began opening in Oligocene and infilled with mainly lacustrine carbonates of Pamuklu formation, has continued to develop under the control of normal faults. In early Miocene period, lacustrine clastic rocks of Yenimahalle formation were deposited in this basin. While the lacustrine clastic rocks of early Miocene Yenimahalle formation are generally in almost horizontal or slightly inclined position, early Oligocene aged lacustrine carbonates have been tilted at angles between 20º to 25º. The angular unconformity observed between the early Oligocene and the early Miocene units have been interpreted as deformations occurred due to an ongoing basin formation under the gravity effect in late Oligocene.

4.2. Bucakkışla Basin

Bucakkışla Basin which is located in the NW of Mut and has a longitudinal geometry in NW-SE direction, is bounded by Bağcağız and Işıklı faults in the NE and by Kıravga and Derinçay faults in the SW (Figure 7). In addition to these major faults, there are large number of minor faults with various sizes both in the basin interior and in the margin. There are large number of faults with 1 to 5 km of lengths particularly in the NW edge of the basin (Figure 7). Bağcağız fault, which is a 51 km long fault and limits the NE margin of the basin, strikes N57W and dips 72º SW. Işıklı fault, which is another fault located in the northeast of the basin and runs parallel to Bağcağız fault, strikes N53W and dips 78ºSW, and has 33 km in length (Figure 7). Widespread colluvium cones have been developed in front of these faults. Kıravga fault which has a trending of N40W/65º NE in the region between Bostanözü and Sipahi villages and is located in the west of the basin, has 27 km of length (Figure 7). Derinçay fault, which limits the western margin of the basin and has 13 km of length, strikes N23W and dips 62º to NE. Mahras fault which limits the basin in the north of the Mahras Mountain, is 12 km in length, strikes E-W and dips 78ºN. Diştaş fault defined in the basin, has an approximate length of 12 km. This fault strikes N60W and dips 82º SW, and bifurcates into two branches towards the northwestern end. Another fault bifurcated from Diştaş fault strikes N25W and 76ºSW in the west of Gökçetaş village (Figures 7 and 13b).

Bucakkışla Basin forms a depression area between the faults bounding the basin to the NE and to the SW margins. Slickenlines and corrugation axis trends on the fault planes of Bağcağız, Işıklı, Kıravga, Mahras, Derinçay faults, which limit the depression area, are perpendicular or nearly perpendicular to the strike. While, as such in Ermenek Basin, the faults limiting the NE of the basin dip to the SW, the faults located in the SW margin dip to the NE. These faults, in many locations along the boundaries of the basin, forms a border between the bedrock and the Oligocene lacustrine sediments. The lacustrine sediments of Fakırca formation deposited upon the fault planes as onlapping geometry (Figure 13b). The onlapping geometry observed along the faulted contacts of the basin shows that normal faults which thought to have controlled the basinal opening had developed prior to the deposition. Data obtained from the stereographic projection analysis of the faults that limit the basin reveals that Bucakkışla Basin was opened as being cut by normal faults under the effect of NE-SW directed stress after the Taurus Orogeny (Figure 14b).

Lacustrine carbonates of Oligocene Fakırca formation deposited in the Bucakkışla Basin are overlain by the fluvial deposits of early Miocene Derinçay formation with an angular unconformity. In addition to the tectonic deformations, Fakırca formation is observed as being deeply eroded by fluvial processes in the basin. Fluvial erosion indicates the exposure of Bucakkışla Basin at the end of Oligocene and a fall in the base level. Tilting occurred after deposition in the units of Fakırca formation shows that tectonism, which leads to basinal opening due to normal faulting under the gravity effect, maintained its activity in also post-Oligocene period (Esirtgen, 2014).

4.3. Korucuk Basin

Korucuk Basin was opened in the S of Central Taurides between the faults with different strikes and dip directions (Figure 9). It is a smaller basin comparing with the Ermenek and Bucakkışla basins. Although the basin does not present a regular basin geometry, it generally has E-W trending. Northern margin of the Korucuk Basin is bounded by the south-dipping Korucuk and Mollaömerli faults which have 15 and 7 km of length, respectively. Korucuk fault which strikes N87W and dips 37ºSW in the south of Ziftlik village, continues in E-W trending down from the NW of Korucuk village (Figures 9 and 13c). On the other hand, Mollaömerli fault strikes N75W and dips 40º SW (Figure 9). Southern margin of the basin is limited by ~8 km long Şalkabalı fault which strikes N67E and dips 50º NW. Lapa fault, striking N32W and dipping 58ºSW, is located in the east of the basin, and has approximately 5 km of length. In the west of the basin, 5 km long Derince fault which strikes N48W and dips 63º NE is situated. This fault continues towards the NW in 3 km distance as striking N69W and dipping 60º NE. Çavuşlar fault, striking N30E and dipping 54º NW, is approximately 5 km long and is located between Çavuşlar and Derince villages in the middle of the basin (Figure 9). Kavakoğlu faults, 4-5 km long and running parallel to each other, are seen between Çavuşlar and Korucuk villages. These faults are observed as in following trends: N60E/47º NW, N62E/53º NW, N67E/50ºNW from north to the south, respectively. Besides this, Saylıharman fault which strikes N52E and dips 54º SE is located in the NW of Saylıharman village.

Slickenlines and corrugation axis trends on the fault planes of Korucuk, Mollaömerli, Şalkabalı, Lapa and Derince faults which lead Korucuk Basin to opening and also limit the basin, are perpendicular or nearly perpendicular to the strike of the faults. Korucuk Basin was formed in front of these faults. Chatter marks on the fault planes indicate also normal faulting.

Coal deposition has been occurred in front of Mollaömerli fault under the control of normal faulting in the northern margin of the basin. A Gilbert-type delta has also been deposited under the control of particularly Korucuk fault in the northern margin of the basin. The development of Gilbert-type delta architecture on the northern margin of the basin is important in terms of showing the activities of the faults opening the basin during sedimentation. The dip slip magnitude on the Korucuk fault and the basin deepening allowed the drainage system from the north of the basin to develop Gilbert-type delta instead of the shallow water delta.

In addition to the Gilbert-type delta development in the fault-controlled basin margins, onlapping depositions, as in Ermenek and Bucakkışla basins, occurred on the bedrock cut by normal faults.

The faults in the northern margin of the basin are inclined towards the south, while the faults located in the east and south of the basin are inclined towards the NW. Data obtained from the stereographic projection analysis of the faults which led the Korucuk Basin to be opened, reflect that Korucuk Basin was opened as being cut by normal faults under the effect of NW-SE directed stress after the Taurus Orogeny (Figure 14c) and also that the development of an extensional tectonic regime was occurred following nappe emplacement.

4.4. Çamlıyayla Basin

Çamlıyayla Basin, which is located in the south of Çamlıyayla and has a NE-SW trending, is bounded mainly by large scale NE-SW trending faults and smaller scale E-W trending faults (Figure 11). These faults, cutting the bedrock and running nearly parallel to each other, have been developed as step faults. The NW margin of the basin is limited by Çamlıyayla fault. Çamlıyayla fault, striking N35E and dipping 69º SE in the south of Çamlıyayla, strikes E-W towards the west. Çamlıyayla fault forms a border between bedrock and Sebil formation. Boğazpınar and Fakılar faults are located in the NE margin of Çamlıyayla Basin (Figure 11). The fault which extends for 6 km between the SW of Boğazpınar village and the NW of Fakılar village, strikes N73W and dips 47º SW. Fakılar fault, which is located in the south of Fakılar village and is 6 km long, strikes almost E-W and dips 56º N. Atdağı fault, which is located in the south of the basin and extends from the NE of Atdağı towards the SW for approximately 17 km, cuts the ophiolite and mélange belonging to the Bozkır Unit, Oligocene aged Sebil formation, and Miocene Mut formation (Figures 11 and 13d). Atdağı fault is a N67E striking and 73º SE dipping fault. Sarıkavak fault, running almost parallel to Atdağı fault, is observed between Sarıkavak village and the SW of Çapar. This fault, striking N66E and dipping 59º SE, has 10 km of length. There are two other faults, running parallel to Sarıkavak fault, with 8 and 3 km lengths and with dip angles 50º - 55º in the south of Sarıkavak village. In addition to these larger faults, there are also N26E striking and 62º SE dipping Karain fault in the east of Karain village, and some other small-scale faults around Sebil village and in the SE of Çamlıyayla village in the basin.

Slickenlines and the corrugation axis trends on the fault planes defined in Çamlıyayla Basin are perpendicular or nearly perpendicular to the fault strikes so as indicating normal faulting.

The faults, which causes the Çamlıyayla Basin to be opened by cutting the bedrock and limits the northern and southern margins of the basin, are inclined towards the S and the SW. The NE-SW trending faults which are thought to have controlled basin opening and the development, have been developed as forming stair-stepping pattern from the NW towards the SE. Çamlıyayla Basin has been developed as a half-graben in front of these faults. Stereographic projection analysis of the faults which controlled the development of Çamlıyayla Basin has revealed that these faults were formed under the effect of NW-SE directed stress (Figure 14d). This data shows that Çamlıyayla Basin was opened as being cut by normal faults after the Taurus Orogeny.

5. Discussion

5.1. Pre-Oligocene Orogenic Development of the Central Taurides

Taurides, which is situated in the Eastern Mediterranean section of the Alpine-Himalayan mountain range and constitute the southern parts of Turkey, consist of both oceanic and continental plate fragments amalgamated between Eurasian and Afro-Arabian plates. Pre-Oligocene geological development of the Central Taurides is the result of a series of events that occurred in Triassic-Eocene time interval. This includes, from rifting to the collision, following events: opening of an ocean, obduction of ophiolites and ophiolitic mélanges, and mountain-building events depending on the closure, collision, and compressions.

Initiation of the rifting along the northern margin of Gondwana in Early-Middle Triassic provided the derivation of African-originated microcontinents and development of the oceanic branches between these microcontinents (Şengör and Yılmaz, 1981; Robertson and Dixon, 1984; Okay and Tüysüz, 1999). These oceanic braches maintained their existence during Mesozoic-early Tertiary interval (Robertson et al., 2012). Rock units such as limestone, cherty limestone, sandstone, mudstone, radiolarite and rift volcanism products belonging to the Taurus Units have been accumulated in these basins. These units which were deposited in shelf, slope, and deep marine environments, are vertically and horizontally transitional and reflect the deepening and the shallowing occurred in the basin (Esirtgen, 2014).

The convergence between Afro-Arabian and Eurasian plates which occurred in late Mesozoic-early Tertiary interval, and the closure of the Neotethyan Ocean dominated the geological development of Anatolia in this period (Şengör and Yılmaz, 1981; Robertson and Dixon, 1984; Dewey et al., 1986). Northward subduction of the branches of Neotethyan Ocean caused the subduction-zone ophiolites and the ophiolitic mélange to have been obducted over the Taurus carbonate platform in Late Cretaceous (Dilek and Whitney, 1997; Özgül, 1997; Parlak and Robertson, 2004). The compression between Eurasian and Afro-Arabian plates continued also in Paleocene-Eocene period, thus widespread ophiolite and mélange emplacement over the Taurus platform occurred. The subduction that began at the end of Mesozoic, and the compression which continued during early Tertiary caused forming of the napped structure in Taurus Units (Figures 3e, 4e, 15a, b) and the development of Taurus orogenic belt. The orogeny in the Taurus orogenic belt which had been shaped by subduction, collision and compressional movements, and had created napped structure, has been ended by the thickening of continental crust.

5.2. Formation of the Oligocene Molasse Basins in the Central Taurides

Although the depositions occurred in Oligocene on the Taurus orogenic belt in the Central Taurides have limited lateral extent, they host very important data in revealing regional tectonic changes. Signs of changing in regional tectonic manifest firstly itself by the opening of Oligocene basins. Lacustrine sedimentations within the Ermenek, Bucakkışla, Korucuk and Çamlıyayla basins, which were opened due to normal faulting upon the Taurus Units, constitute the first records of the depositions occurred under the extensional tectonic regime following the Taurus Orogeny. The Central Taurides have been shaped by the depositions occurred under this new tectonic regime which began in Oligocene and continued during Neogene.

Different basin models developed based on the compressional or extensional tectonism can be proposed for the Oligocene lacustrine basins defined in this paper within the Central Taurides. However, considering that the basins defined in the region are situated on the Taurus Units and were opened in front of normal faults under extensional tectonic conditions

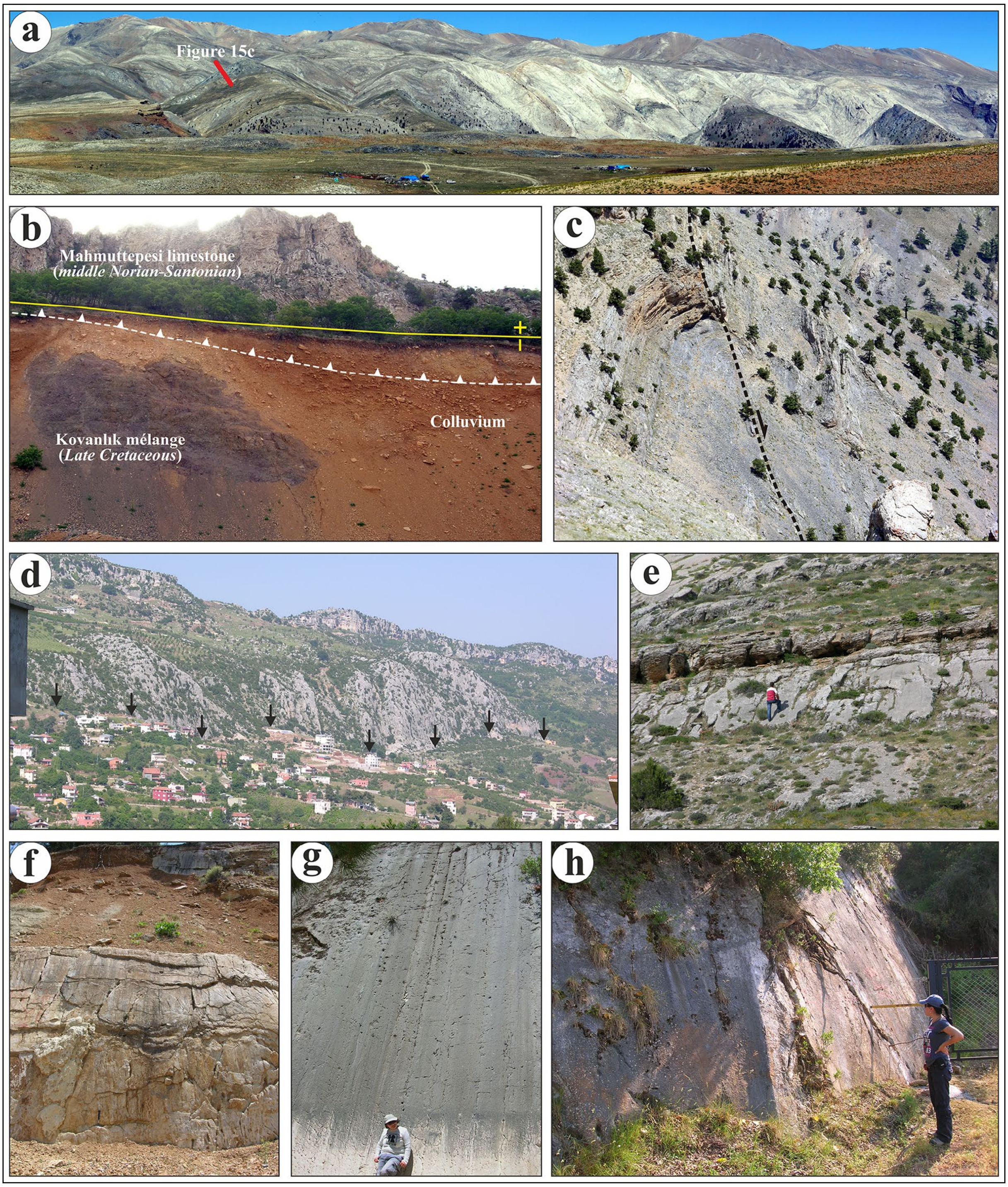

Figure 15- a, b) All the pre-Oligocene units in the Central Taurides gained a napped structure by the compression that lasted until the late Eocene due to Taurus Orogeny, and completed their orogenic developments (a- Mersin, Cocak Valley; b- Karaman, NE of Afgan Village). b, c, d) These units have been subjected to orogenic collapse as from Oligocene as a result of interruption or termination of the compression and have been cut by dip-slip normal faults (c- Mersin, Cocak Valley; d- Mersin, Bekiralanı Village). e, f, g, h) Normal faulting in the region continued after Neogene and the units deposited in the Neogene period were also cut by the larger normal fault systems (e- Mersin, NW of Çömelek Village; f- Mersin, S of Zeyne; g- Mersin, Sarıkavak, S of Gündüzler Village; h- Mersin, W of Ayvagediği).

and are absent of deformation data that reflect the compressional tectonism; it has been inferred that the compressional deformation and the basin development due to compressional regime have not been active in the region since Oligocene.

Mut Basin at regional scale is thought to be formed as a result of orogenic collapse developed in the extensional back-arc of Cyprus-arc located in the south (Kempler and Ben-Abraham, 1987; Robertson, 2000; Kelling et al., 2001; Ünlügenç et al., 2001). According to Le Pichon and Angelier (1981) and Gautier and Brun (1994), extensional tectonic regime was occurred as a consequence of northward-subducting Hellenic arc to migrate towards the south via back-arc spreading. However, the time discrepancy between the extensional tectonics beginning in late Oligocene-early Miocene within the Western Anatolia and the southward migration of subducting plate in middle Miocene-early late Miocene interval make the proposed models improbable (Seyitoğlu and Scott, 1996). Vertical uplift of the Central Taurides in the late Miocene (late Tortonian) (Cosentino et al., 2012; Ilgar et al., 2013) indicates that the formation of the Oligocene basins could not be related to vertical uplift of the Taurides. Kelling et al. (1995) suggested that this structural development was developed as a result of the orogenic collapse. The continental crust, overthickened in Eocene period, has caused basin opening by gravity effect due to disappearance of compression (Gautier et al., 1999; Dilek and Whitney, 2000).

All the pre-Oligocene units which had been emplaced in the region depending on the N-S compression in the Central Taurides, gained a napped structure by compression that lasted until the late Eocene, and completed their orogenic developments (Figures 3e, 4e, 15 a, b). These mountain ranges where the thickening of continental crust and the structural heterogeneity developed, are the post-orogenic extensional regions (Dewey, 1988; Seyitoğlu and Scott, 1996). Gravity collapse is expected to be occurred in the subduction zones where the crustal thickening observed and in the continent-to-continent collision regions. Gravitational collapse of the continental crust is a process which follows the crustal thickening. Inıtiation of the collapse is resulted from changes in the balance of forces that, during conversion and collision, generate crustal thickening and stabilize this thickness (Rey et al., 2001).

Pre-Oligocene units, reaching maximum elevation in the Central Taurides, have been subjected to strain or gravitational forces occurred in the region in consequence of interruption or termination of compression that lasted until the end of Eocene. Thus, the units which constitute nappes were cut by dip-slip normal faults due to orogenic collapse (Figures 15b, c, d), and in front of the faults, Ermenek, Bucakkışla, Korucuk, Çamlıyayla basins began to form upon the hanging wall blocks.

The fact that the Taurus orogenic belt has a napped structure and the presence of ophiolites and ophiolitic mélange in the Bozkır Unit have contributed significantly to the basin opening after the nappe emplacement. Nappe tectonics, at first, has caused the Taurus orogenic belt to be overthickened. The decrease in the horizontal compressional force that caused the crustal thickening allowed the orogenic collapse and a rapid basin formation under the effect of gravity. Besides, the nappe tectonics has caused the Taurus orogenic belt to have a heterogeneous structure and the development of weak zones between the nappes/thrusts. These weak zones have caused reduction of the basal shear stress between nappes and thrust sheets (Rey et al., 2001). It is thought that the reduction of the compressional force that creates orogeny and the re-activation of weakness zones in the form of normal faults or detachment planes under the effect of gravity facilitates the basin development due to extensional tectonics.

According to Robertson et al. (2012), Oligocene period in the Central Taurides is represented by the post-collisional compressional regime. However, the formation of Ermenek, Bucakkışla, Korucuk and Çamlıyayla basins, which take place in the form of grabenization, reflect the post-orogenic molasse basin development. The fact that the clastic and carbonate rocks deposited in the molasse basins in the Central Taurides are Oligocene aged indicate that the post-orogenic collapsing and basin formation occurred in the early Oligocene, just after collision and compression.

Formation of the basins related to extensional tectonics upon the units emplaced in the region due to nappe tectonics in the Central Taurides indicates that a new tectonic period has started in the region. This new period shows that the compressional tectonic regime did not have any effect in the region in early Oligocene, but on the contrary, a new tectonic regime that could lead to basin development began to develop. It is observed that the Oligo-Miocene basins located in the Central Taurides, at first, began to open as independent small basins due to the orogenic collapse in the Oligocene period and lacustrine sedimentation was developed in these basins. The marine transgression that occurred in the Central Taurides during the late Burdigalian period caused the drowning of Mut Basin and marine sedimentation in this basin in the Neogene period. As a result of the migration of the northward-subducting Cyprus plate towards the south as from the end of the middle Miocene, the orogenic collapse continued in the extensional back-arc, and the units deposited in the Neogene period were cut by normal fault systems (Figures 15e, f, g, h).

6. Conclusions

In this study, four Oligocene lacustrine basins, namely Ermenek, Bucakkışla, Korucuk and Çamlıyayla basins, have been defined in the Central Taurus Mountains. Structural features and stratigraphic sequences of these basins have been studied in detail and the basins have been aged.

The tectono-stratigraphic and age data of the basins have been evaluated together, and the timing of formation of the basins and the tectonic processes controlling the basin opening have been discussed at the scale of Central Taurides.

The Oligocene lacustrine sediments deposited in Ermenek, Bucakkışla, Korucuk and Çamlıyayla basins reflect the first sedimentary sequences deposited on the Taurus Units. These units constitute the first records of deposition occurred under the extensional tectonic regime following the Taurus Orogeny in the Central Taurides.

Extensional basin formation on the Taurus Units which had been emplaced in the region due to nappe tectonics indicates the "orogenic collapse basins" developed under the effect of strain or gravity forces at a regional scale.

In previous studies, it was interpreted that Mut Basin was opened as a result of orogenic collapse in extensional back-arc of the Cyprus subduction arc in the south, or as the back-arc spreading as a result of migration of the northward subducting Cyprus plate towards the south. However, the time discrepancy between the southward migration of the subducting-plate in the late middle Miocene-early late Miocene interval and the basin opening that began in Oligocene in the Central Taurides makes the suggested models controversial.

The orogeny that built Taurides and the compressional deformation lasted until late Miocene in the Eastern Taurides. In the Central Taurides, extensional basin formation as from the early Oligocene on the Taurus Units that had been emplaced in the region due to nappe tectonics indicates a new tectonic period has started in the region.

Acknowledgements

This study was carried out in the scope of "*Geology and Paleogeographic Development of the Neogene Rocks in Adana-Mut Basin*" project conducted between 2009-2012 by the Department of Geological Research of the General Directorate of Mineral Research and Exploration (MTA). Palynological investigations were conducted by Assoc. Prof. Dr. Mine Sezgül Kayseri Özer. The first draft of the manuscript was reviewed by Prof. Dr. Cihat Alçiçek, Dr. Volkan Özaksoy, Dr. Oktay Parlak and Ali Ergen. Prof. Dr. Yaşar Eren, Prof. Dr. Ulvi Can Ünlügenç and Assoc. Prof. Dr. Serkan Üner made valuable contributions. We would like to thank to the Referees for carefully reading our article and for giving such constructive comments which substantially helped improving the quality of the paper.

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