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TECTONO - SEDIMENTARY EVOLUTION OF BUCAKKIŞLA REGION (SW KARAMAN) IN CENTRAL TAURIDES

Tolga ESİRTGEN[a]

[a] *General Directorate of Mineral Research and Exploration, Dept. of Geological Researches, 06800, Ankara, Turkey*

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Bozkır unit, mélange, Inner Tauride Ocean, rift volcanism, orogenic collapse.

ABSTRACT

The study area located in Bucakkışla region in Central Taurides consists of rock units of the melange which form Bozkır unit of the Tauride units and the overlying cover rocks. There are volcanic, ophiolitic and sedimentary rocks which generated in different environmental conditions. These rock groups comprise units which formed in Middle-Upper Triassic-Paleocene periods in Inner Tauride Ocean that had been opened between Tauride – Anatolide continents. Within the scope of this study, lithostratigraphic characteristics of Huğlu, Boyalı hill, Korualan nappes and cover rocks which form Bozkır Unit and tectono sedimentary evolution of the study area was built up by paleontological and structural features. Due to rifting, which started in Middle Upper Triassicin the region, the products of the rift volcanism in rifting center and the carbonate deposition on margins of basin have occurred. The continuation of extension which initiated rifting caused collapse in the basin in Middle Upper Triasic – Lower Senonian. Deep marine deposition has occurred at the center of basin, however pelagic and neritic limestones were deposited in basin margins during this time. The region has become compressed by the effect of a new tectonical regime which had been effective starting from Santonian. This compression caused new melanges to take place due to reverse faults and thrust. The formation of these melanges has continued until the end of Paleocene period. However, there has not been observed any formation depending on the compression in post Paleocene. The nappes have moved southward by the effect of compression until Eocene. But then, these nappes could not advance forward anymore so, northward back thrusts took place as basin was closured andreached the collisional stage. Sequences which had become imbricated structures by back thrusts were subjected to collapsing by the stop of compression and the gravitational effect. All sequences in the imbricated structure were cut by dip slip normal faults and lacustrine basins were formed on fallen blocks. The formation of Early Oligocene terrestrial deposits in these lakes indicates that the collapse occurred in Oligocene or immediately before this time, and this allows the dating of new tectonical period. Early Oligocene deposits to become tilted by dip slip faults show that new tectonic period in the region has also continued after Oligocene.

1. Introduction

Triassic-Cretaceous aged tectono stratigraphic units cropping out in Bucakkışla region, in Central Taurides (SW Karaman) consist of rock lithologies representing different deformation stages (Figure 1a, b). These rocks located within Bozkır Unit (Özgül, 1997) extend along the Tauride belt. The unit has a widespread mélange appearance covering blocks and slices in different sizes with lithologies such as; basic submarine volcanite, tuff, diabase, ultrabasite, serpentinite, pelagic and neritic limestone, and

* *Corresponding author : tolgaesirtgen@yahoo.com*

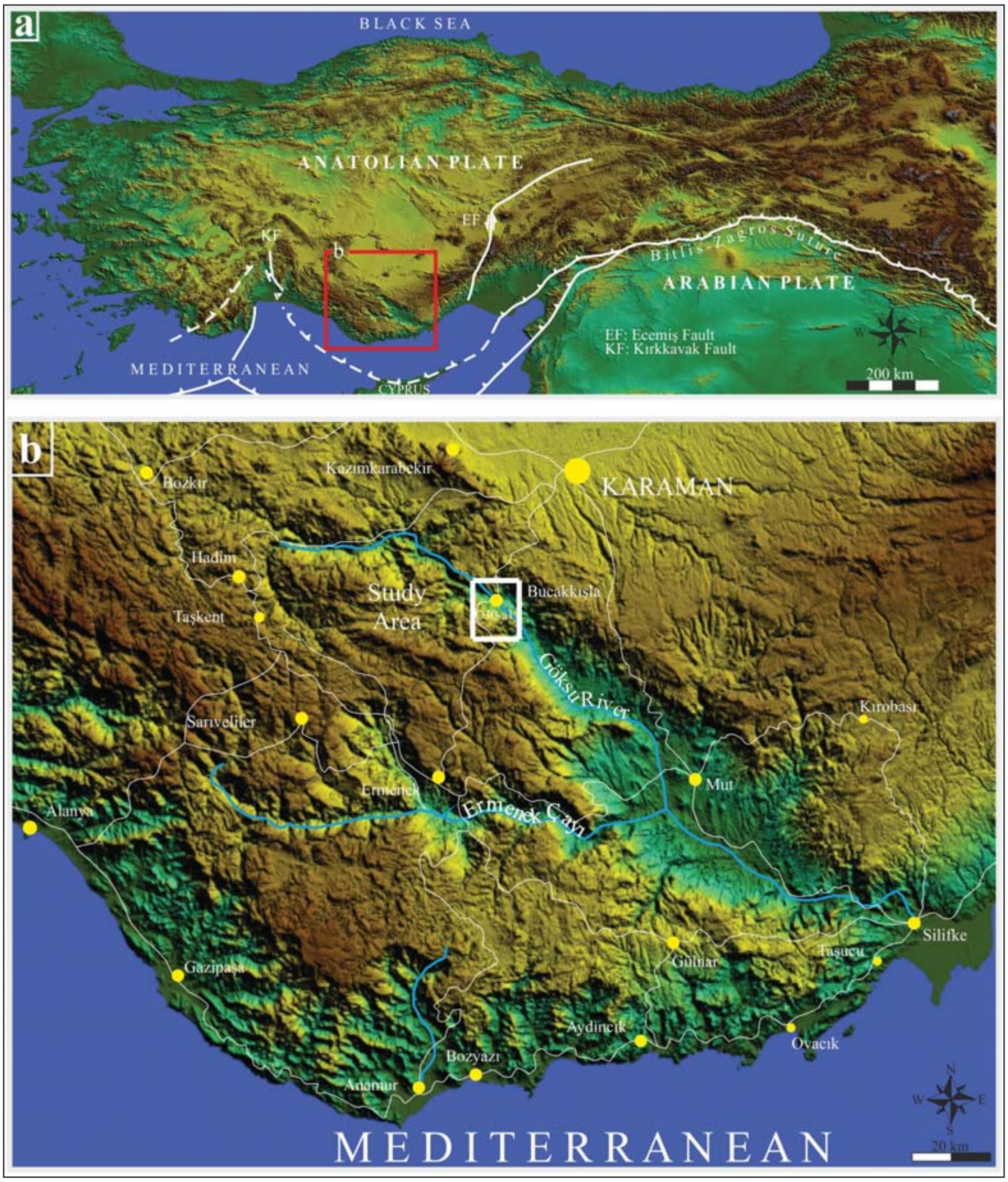

Figure 1- Location of the study area and topographic view showing main tectonic lines of Turkey; a) 90 m resolution SRTM data, Jarvis et al., (2008), b) location map of the study area.

radiolarite. These rock groups form the products of Inner Tauride Ocean defined in the region (Görür et al., 1984; Görür et al., 1998). The Inner Tauride Ocean which was formed due to Triassic rifting restricts the northern boundary of the Tauride–Anatolide platform (Robertson et al., 2012). Cover rocks which have developed since Oligocene take place over Bozkır unit. The structural and textural features of all these rocks, their components and contact relationships among them present strong evidences on the geological evolution. It ranges from rifting to obduction-subduction, from the closure of the ocean to collision and post collisional orogenic collapse which developed in the region during Triassic-Quaternary period. There are many studies which have been made both on İzmir-Ankara-Erzincan Ocean and on the southern branch of the Neotethys in literature (Robertson and Woodcock, 1981; Şengör and Yılmaz, 1981; Göncüoğlu et al., 1997; Robertson, 1998; Dilek et al., 1999; Robertson, 2000; Kelling et al., 2001; Stampfli et al., 2001; Kelling et al., 2004; Robertson et al., 2004). However, studies that have been made on the rock assemblages of the oceanic branch called "Inner Tauride Ocean" and its evolution within this period is either limited (Görür et al., 1984; Görür et al., 1998; Dilek et al., 1999; Okay and Tüysüz, 1999; Andrew and Robertson, 2002; Robertson et al., 2009;

Pourteau et al., 2010; Robertson et al., 2012) or the presence of the Inner Tauride Ocean is neglected (Göncüoğlu, 1986; 1992). The study area is located among typical regions in which the geological development of the Inner Tauride Ocean was observed. The purpose of this study is to reveal data related to different tectonical regimes of Triassic-Miocene period in the region which covers structural and stratigraphical data of all these tectonical movements in Central Taurides and to build up the geological evolution of the region.

2. Stratigraphy

The stratigraphical succession of the study area in Central Taurides consists of Huğlu, Boyalı tepe, and Korualan nappes described within Bozkır unit by Özgül (1997) and Oligo-Miocene rocks situated as cover rocks that overlie on them. Since Huğlu, Boyalı tepe and Korualan groups presents a structural relationship among them, these were defined as nappe slices and named as Huğlu nappe, Boyalı tepe nappe and Korualan nappe in the study (Figure 2). Oligo-Miocene cover rocks, formed by Fakırca and Mut formations, occurred after nappe movements and were not affected from these movements (Figure 3a, b). The ages and apparent thicknesses of basement and cover rocks were shown in stratigraphical section (Figure 4).

2.1. Huğlu Nappe

This unit was first named by Monod (1977) and crops out in southwest of the study area (NW of

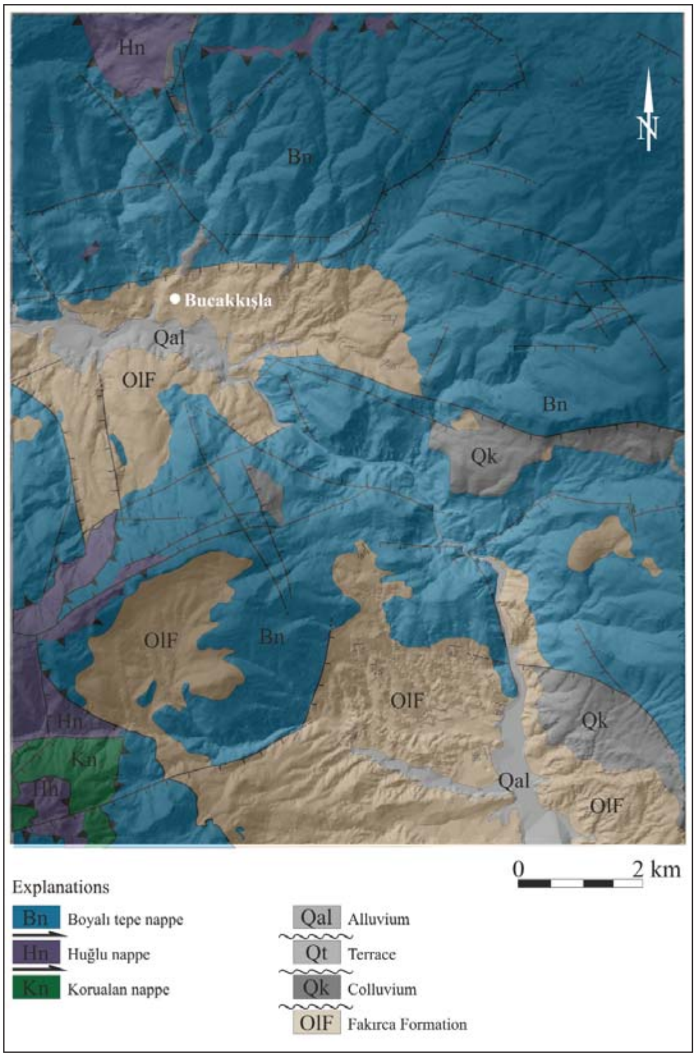

Figure 2- Map showing positionsof nappes, their relations with each other and cover units in the study area.

Yukarı Akın and Akın villages). Although Huğlu nappe consists of the oldest unit cropping out in the study area, it is tectono stratigraphically located in the middle of succession. Huğlu nappe is formed by three formations as; Dedemli formation, Mahmut hill limestone and Kovanlık mélange. It overlies Kovanlık nappe and is underlain by Boyalı hill nappe.

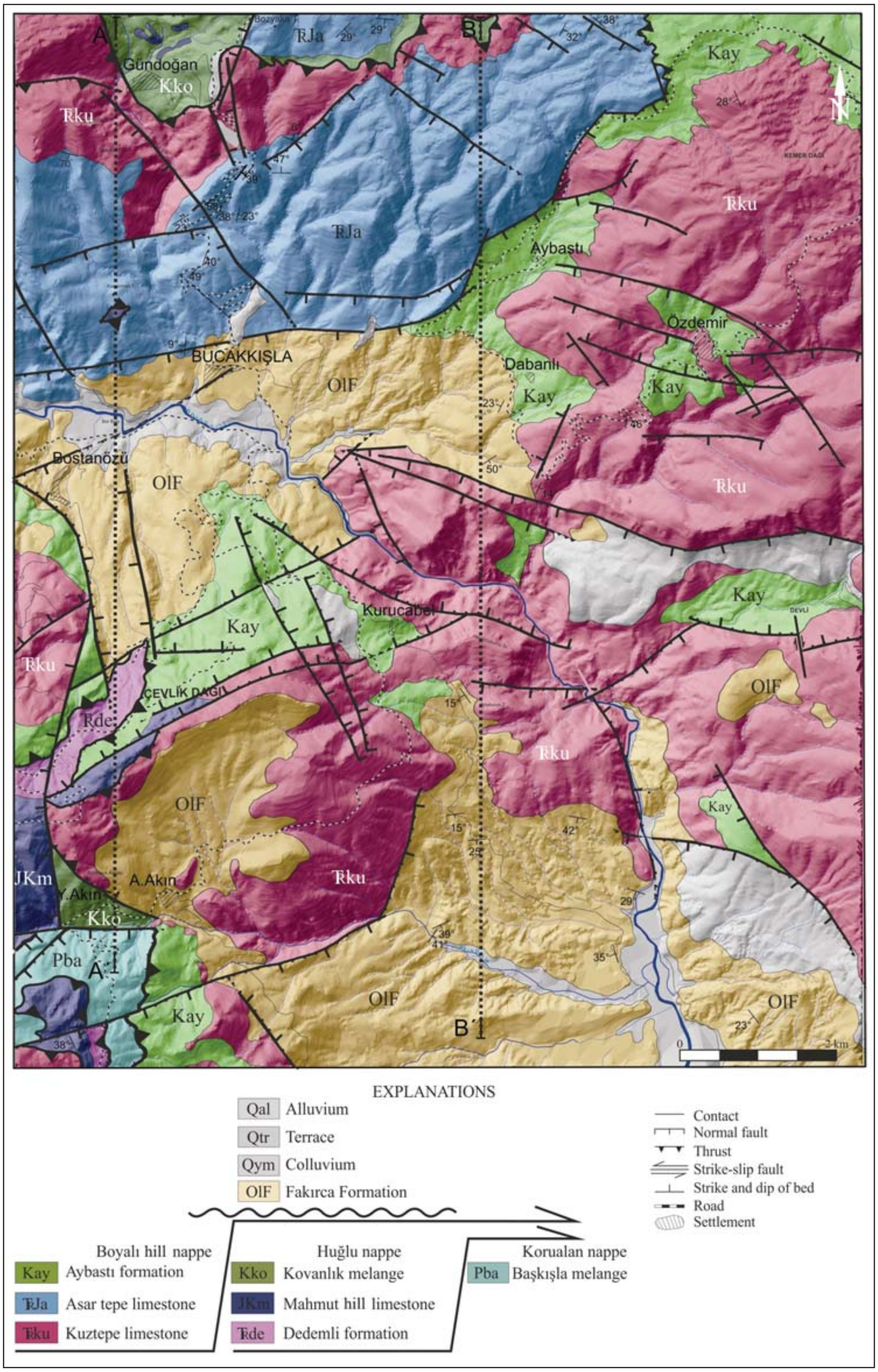

Figure 3a- Relief topography map of the study area (sheet O30-a1).

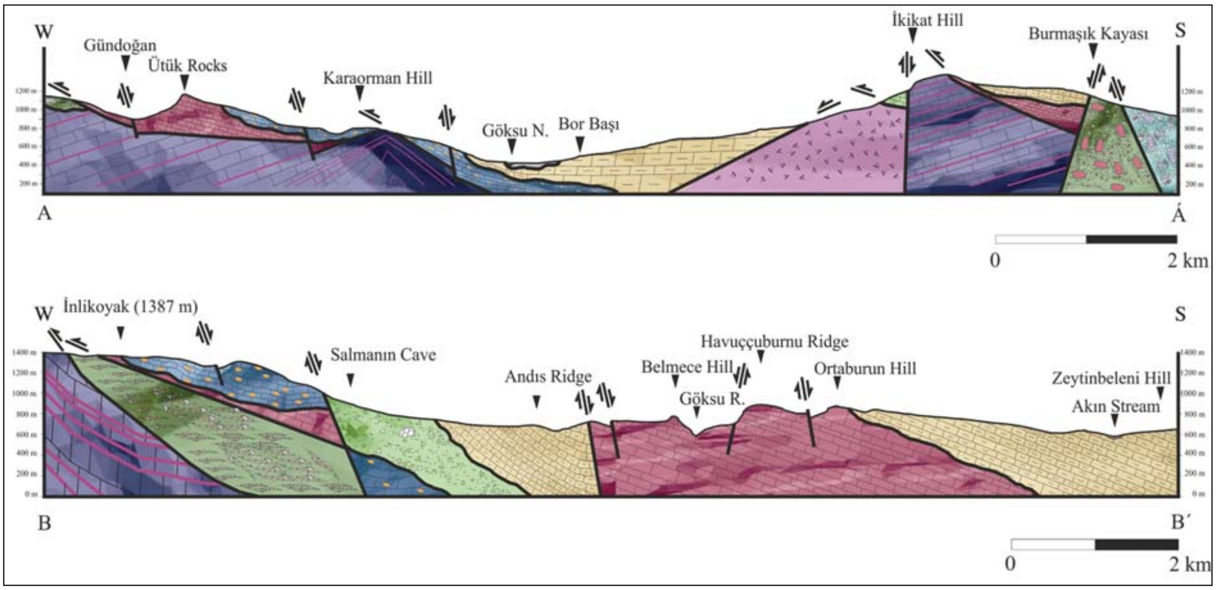

Figure 3b- N-S trending geological cross sections between A-A' and B-B'.

2.1.1. Dedemli Formation

Huğlu nappe which is located at the lowermost part of the Huğlu nappe was named by Özgül (1976) and is composed of green and brown colored, vitrified tuff, volcanites and occasionally clastic rocks (Figure 5a, b).

Tuffs are bedded, folded in varying scales and fractured. Rock compositions in thin sections are composed of glass shards, quartz, plagioclase, biotite crystals and rock clasts. Crystals located in the rock are fine grained. Quartz and biotite minerals are anhedral, however plagioclases are euhedral. Sieve texture is dominant in some of the plagioclases. Rock pieces are glassy and in porphyritic texture. These components were bonded by a binder which is formed by argillized and chloritized, altered glass shards. Intensive alteration is observed throughout the rock (chloritization and silicification). Clastic rocks are composed of quartz, plagioclase, calcite minerals and rock fragments. These rock fragments are represented by volcanic rock fragments that display microlitic, porphyritic, trachytic and glassy texture; by fine grained mica-quartz schist fragment, fine grained biotite schist fragment and by fossilliferous limestone fragments in few amounts. Clastic rocks are generally grain supported. Spatially, calcite binders are observed. Grains are angular to subangular, subrounded and medium sorted. In thin section views of these rocks, widespread vein developments are seen which are filled by secondary carbonate minerals. The rockis defined as lithic arenite.

The formation crops out on northern slopes of the Çevlik Mountain in the study area (501000E/4085500N) and has an apparent thickness of about 150 meters. Dedemli formation tectonically overlies Başkışla mélange which is in southwest of the Yukarı Akın village. The unit is transitional with the overlying Mahmut tepesi limestone. The age of the unit which is composed of volcanic rocks and clastics in few amounts could not be determined. However, the age of the formation is interpreted as Anisian-Norinian because it is transitional with Mahmut tepesi limestone (Özgül, 1997). Monod, (1977) dated blocks of debris flow deposits as Anisian which constitute the unit. However, Mahmut tepesi limestones which are in transitional contact with Dedemli formation were dated as middle Carnian (Tekin, 1999; Tekin and Bedi, 2007). Therefore, the age of the formation was accepted as Anisian–middle Carnian.

Although it is claimed that, Dedemli formation has geochemically calc alkaline character by Gökdeniz (1981), it is stated that the unit is made up of tuff and basic volcanites and have blown out submarine alkaline basalts during rifting in Middle-Upper Triassic period (Whitechurch et al., 1984; Tekin, 1999). Robertson and Dixon (1984) claim that, micro continental block of Turkey was rifted from Gondwana in Triassic period. Depending on these data, it is seen that Dedemli formation is a unit which is made up of rift environment product composed of alkali volcanic rocks.

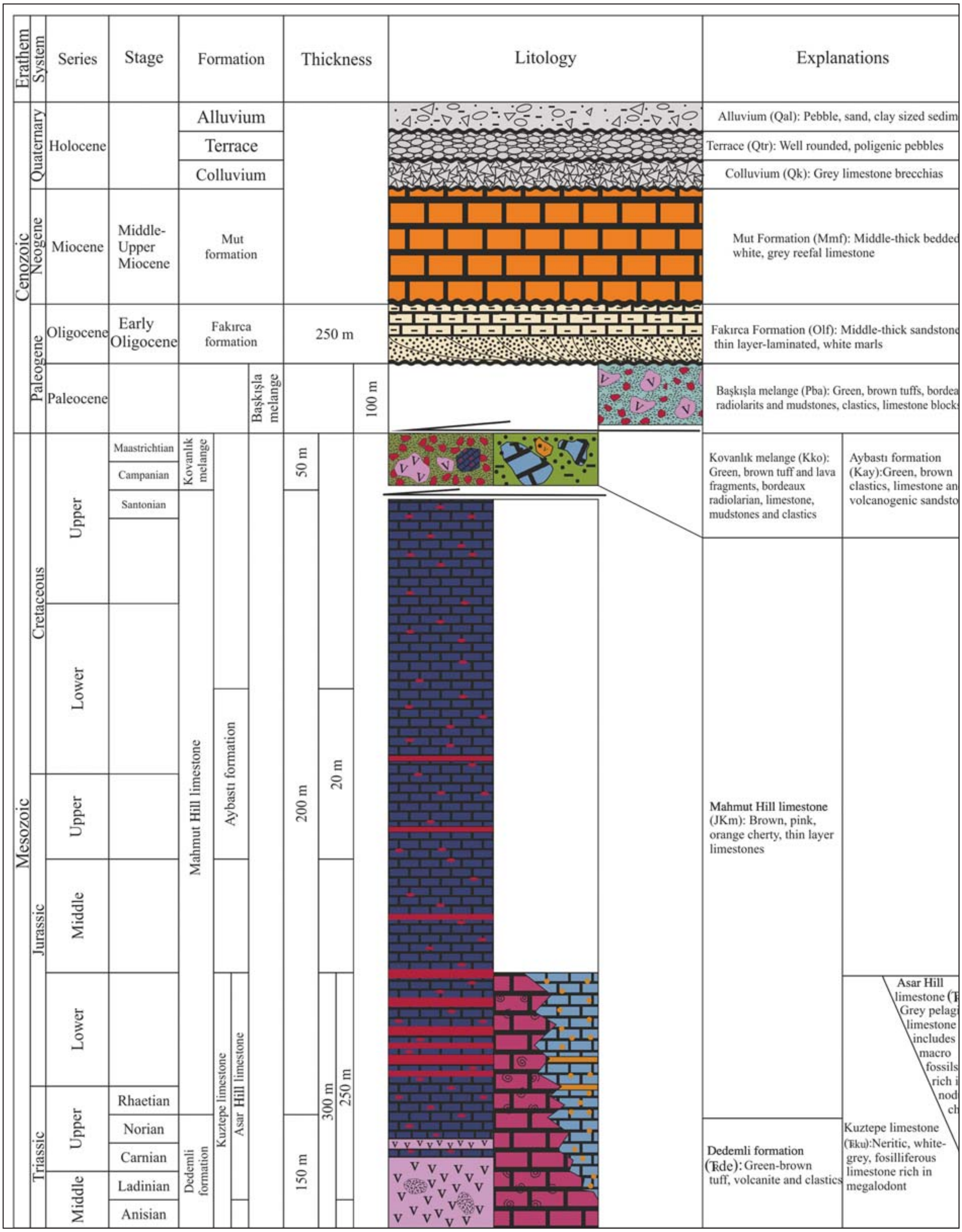

Figure 4- Unmeasured column section showing the general stratigraphy of the units in the study area.

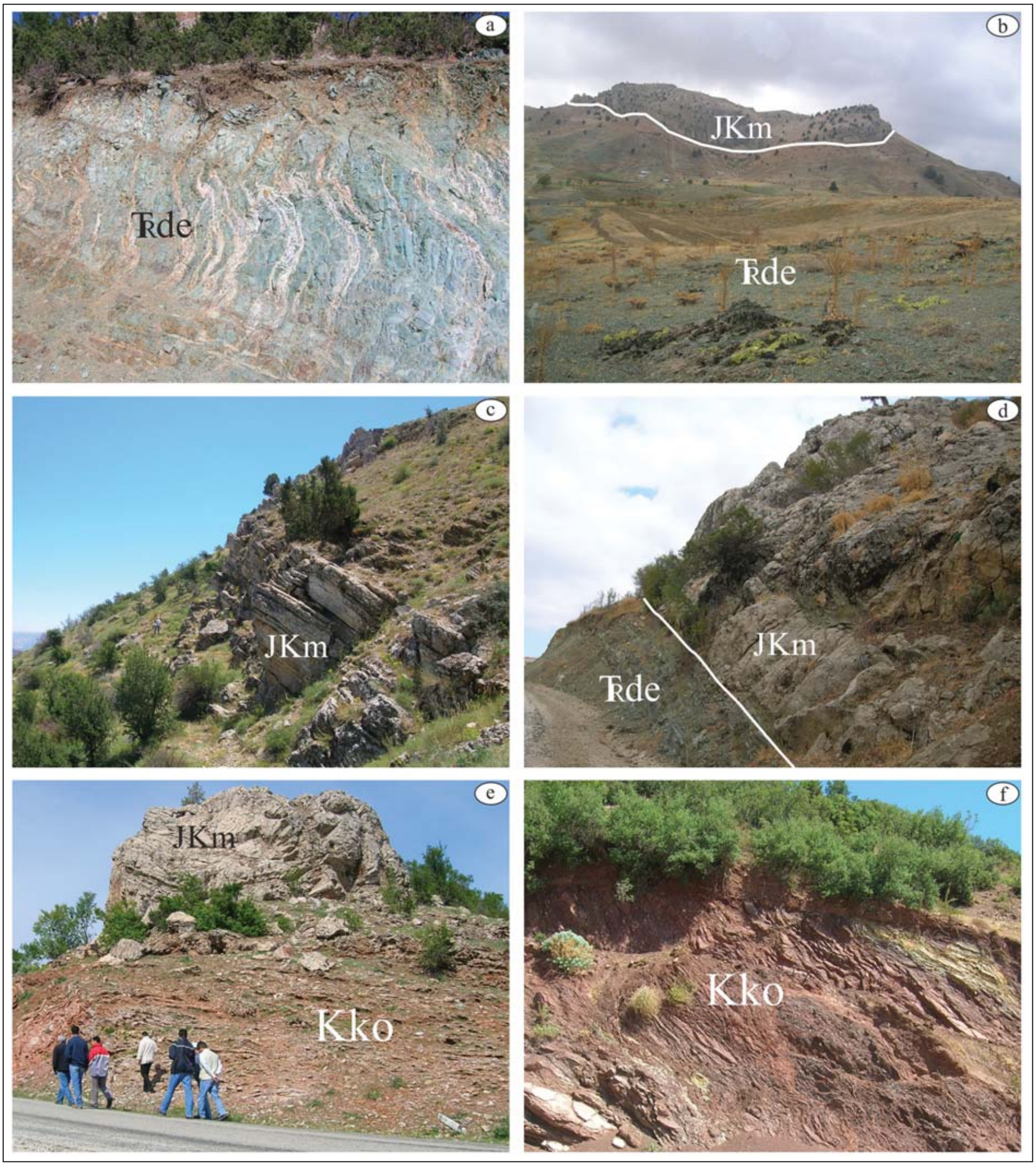

Figure 5- a) Folded tuffs of the Dedemli formation, b) Dedemli formation and transitional Mahmut Hill limestone, c) Thinly bedded, folded limestones of the Mahmut Hill limestone, d) Transitional contact relationship of Mahmut hill limestone with Dedemli Formation, e) Kovanlık melange and the Mahmut hill limestone block within, f) Folded, thin radiolarite-mudstone alternation of the Kovanlık melange.

2.1.2. Mahmut Hill Limestone

The nomenclature of Mahmut hill limestone was given by Özgül (1997). The unit is composed of brown, orange, pink colored, cherty, fine bedded and folded pelagic limestones (Figure 5c,d). It crops out on northwestern slopes of the Çevlik Mountain, north of Yukarı Akın village (500500E/4083000N) in the study area. The deposition of the unit begins with volcanites of Dedemli formation transitionally and is most probably unconformably overlain by Kovanlık mélange. Mahmut hill limestones are represented by different ages in different parts of the Central Taurides and have been deposited in a broad time period ranging from Middle–Late Triassic to early Senonian (Özgül, 1977). In latter studies, Middle Carnian age was obtained from radiolarians in cherty limestones constituting the unit (Tekin, 1999; Tekin et al., 2001; Tekin and Bedi 2007). The age of the unit was accepted as middle Norian-Santonian. It has an apparent thickness of about 200 meters and presents a continuous succession which does not display any definite facial change during deposition. This formation which forms a dense succession is considered that it has a limited material transport from land and as deposited on a pelagic environment that has a very low depositional rate.

2.1.3. Kovanlık Mélange

Kovanlık mélange was first named by Özgül (1997) and is a unit in which rock fragments with different sizes, types and ages are located within red-bordeaux matrix altogether. Pink-bordeaux colored, radiolarite-mudstone alternation is composed of green-brown colored tuff and lava fragments, limestone blocks and other clastic rocks. Mafic rock fragments are also observed in the unit though less (Figure 5e, f). The apparent thickness of the unit which crops out in the vicinity of Yukarı Akın and Gündoğan villages (502000E/4094400N) is around 50 meters in the study area. Kovanlık mélange begins with alternation of radiolarite-mudstone over Mahmut tepesi limestone and continues with conglomerate consisting of Pebble-size tuff, lava, limestone and radiolarite fragments. There is not observed any definite bedding which dips or grades in the unit. These characteristics indicate deposits of massive debris flow product. Petrographical studies of the rocks which form the unit according to Streckeisen (1976) show that, limestones are composed of biomicrite, and mafic rocks are composed of gabbro and serpentinite (Figure 6a, b, c, d, e, f ,g, h ,i, j).

Biomicrites which constitute the mélange consist of much radiolarian microfossils filled with silica within crypto-microcrystalline carbonate crystals. Fractures which are observed in various thicknesses and large amounts were filled up by micro-meso crystalline carbonate minerals. These fractures were generally stained by ironoxides and hydroxides. Grains that constitute gabbro minerals are subhedral and granular in texture. The rock which is coarse grained is mainly composed of plagioclase, clinopyroxene, orthopyroxene and olivine minerals. Plagioclase minerals are subhedral, anhedral with poiklitic twinning and are intensively altered. In most plagioclases; sericitization and argillization (in occasion) and zeolitization are observed. Most mafic minerals constituting the rock are composed of clinopyroxene minerals and orthopyroxene in minor amounts. Pyroxenes which are mainly subhedral and anhedral were not altered unlike plagioclases. Some clinopyroxene minerals consist of orthopyroxene in the form of exsolution lamellae. Olivine minerals are totally transformed into serpentine minerals. Serpentine minerals which form serpentinite display sieve texture. It is made up of crysotile minerals that display vertical arrangement on edges and antigorite minerals among them. Magnetite was detected as the widespread opaque mineral type in thin section studies of opaque minerals. Less chromium and millerite minerals in trace amounts are also observed as opaque mineral. Talcose characteristic is present occasionally.

The age of Kovanlık mélange was given as early Senonian (Özgül, 1997) as it overlies Mahmut hill limestone and consists of fragments belonging to these limestones. Tekin (1999) emphasized that the age of Mahmut hill limestone which he named as Huğlu limestone was limited by Santonian. The age of Kovanlık mélange should be Santonian to post Santonian as it consists of Mahmut hill limestones.

Kovanlık mélange which has different origin rock types is an ophiolitic mélange. Ophiolitic rocks defined within this mélange are described as SSZ type ophiolites “supra-subduction zone type”. These rocks are based on geochemical contents like Lycian, Beyşehir, Divriği and Mersin ophiolites which are located in the same belt (Şengör and Yılmaz, 1981; Şengör, 1984; Robertson and Dixon, 1984; Dercourt et al., 1986; Parlak et al., 1996a, 1996b; Okay and Tüysüz, 1999; Barrier and Vrielynck, 2009; Robertson et al., 2012). This unit is tectonically overlain by Boyalı Hill nappe.

2.2. Boyalı Hill Nappe

Middle Triassic-Lower Jurassic limestones with megalodonts in western Taurides were first decribed by Gutnic and Monod (1970) called the “Boyalı hill”. The same unit which crops out as well in Central Taurides was studied by Özgül (1997) in the name of Boyalı tepe group. The same rock groups cropping out in the study area were investigated under the name “Boyalı hill nappe”, too. Boyalı hill nappe consists of three formation as Kuztepe limestone, Asar hill limestone and Aybastı formation in the study area (Figure 7a, b, c, d, e, f).

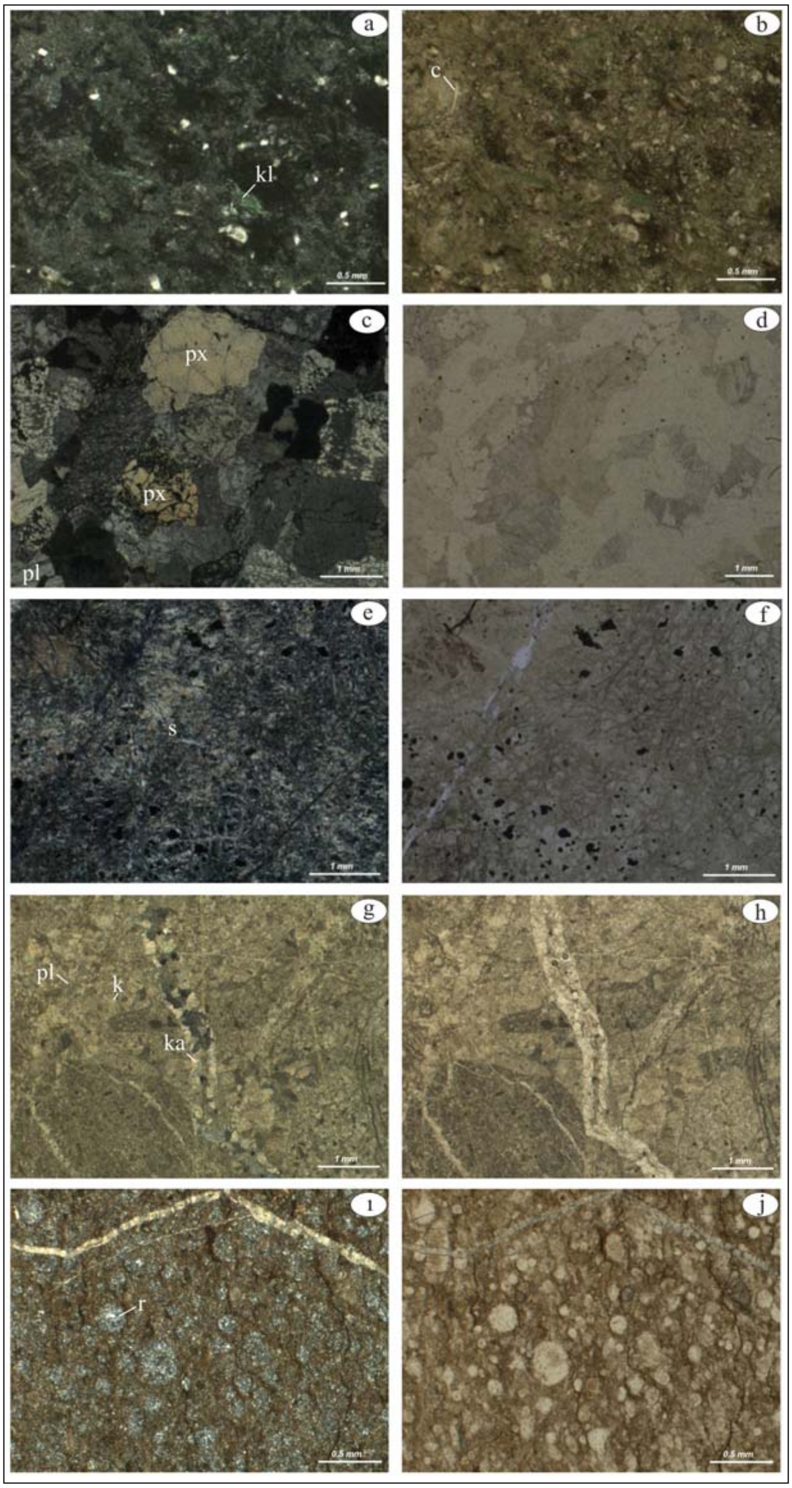

Figure 6- Petrographical views belonging to different lithologies which form the Kovanlık Melange; a) lithic arenite, b) silicified, chlorite glassy tuff, c) biomicrite, d) gabbro, e) and f) serpentinite.

2.2.1. Kuz Hill Limestone

This unit is composed of white, occasionally gray, much megalodont fossilliferous limestone and was described and named as Kuz hill limestone by Özgül (1997) on Kızıltepe ridges located in southeast Aslantaş of Bozkır. It has an apparent thickness of about 300 meters in the study area and is exposed at southeast of Bucakkışla village (505500E/ 4088300N), at north of Yukarı and Aşağı Akın villages and in vicinities of Kurucabel and Bostanözü villages. The primary basal contact of the unit is not observed. Kuz hill limestone tectonically overlies all units that form Huğlu and Korualan nappes and gradually passes into Asar hill limestones in the upper boundary of the succession. According to

Figure 7- a) Megalodont fossils of Upper Triassic Kuz hill limestone, b) thick bedded neritic limestones of the Kuz hill limestone, c), d) articulated, dark brown pelagic limestones with chertnoddles of the Asar hill limestone, e) clastics of radiolarite and limestone collected from different units in Aybastı formation, f) spherical deformation in volcanic material sandstones in Aybastı formation.

petrographical studies, Kuz hill limestones have the characteristics of biomicrite and micritic limestone (Figure 8a, b). Giant crystal growths (Figure 8c) and dolomitizations (Figure 8d) are observed in the form of fracture fills within limestones. Brecciation, fracture growth, veins with carbonate fillings and iron stains in occasion are probable. Late Noran-Rhaetian (Late Triassic) ages were taken from *Aulotortus* gr. s*inuosus* Weynschenk, *Aulotortus communis* (Kristan), *Aulotortus* cf. *tenius* (Kristan), *Aulotortus* spp., *Auloconus* sp., *Thaumatoporella parvovesiculifera* (Raineri) fauna in Kuztepe limestones. *Aulotortus* sp., *Turriglomina* sp., *Ammobaculites* sp., *Frondicularia* sp., *Ophthalmidium* sp., *Cetates* sp., Lamellibranch shell sections andsponge spicules fauna gave the age of Ladinian-Carnian (Middle-Late Triassic). According to *Ophthalmidium*sp., pelagic pelecypoda sections, *Ophthalmidium* sp. fauna Late Triassic-Liassic? ages were determined. Based on all these findings, the age of the Kuztepe limestone was determined as Ladinian-Liassic? (Figure 9a, b, c, d).

It is considered that Kuztepe limestones that had been formed widely by the benthic foraminiferas and in micritic limestone facies were deposited in a relatively low energy neritic environment. Gradual deepening is observed in the depositional environment towards upper parts of the succession which forms Kuztepe limestones. This deepening in the basin becomes distinctive in Asar tepe limestones. Deepening begins towards the end of Rhaetian and reaches the maximum in Liassic and grasps slope-basin conditions (Ekmekçi et al., 2007).

2.2.2. Asar Hill Limestones

This unit, which is composed of much cherty, macro fossilliferous, gray pelagic limestone was first defined by Özgül (1976) in Asar Hill (south of Bozkır county) and named as Asar Hill limestone. Layer thicknesses are planar generally ranging in between 10 to 60 cm in limestones. Cherts are observed within limestones in the form of independent, yellow-brown colored, nodular cherts with various frequencies with

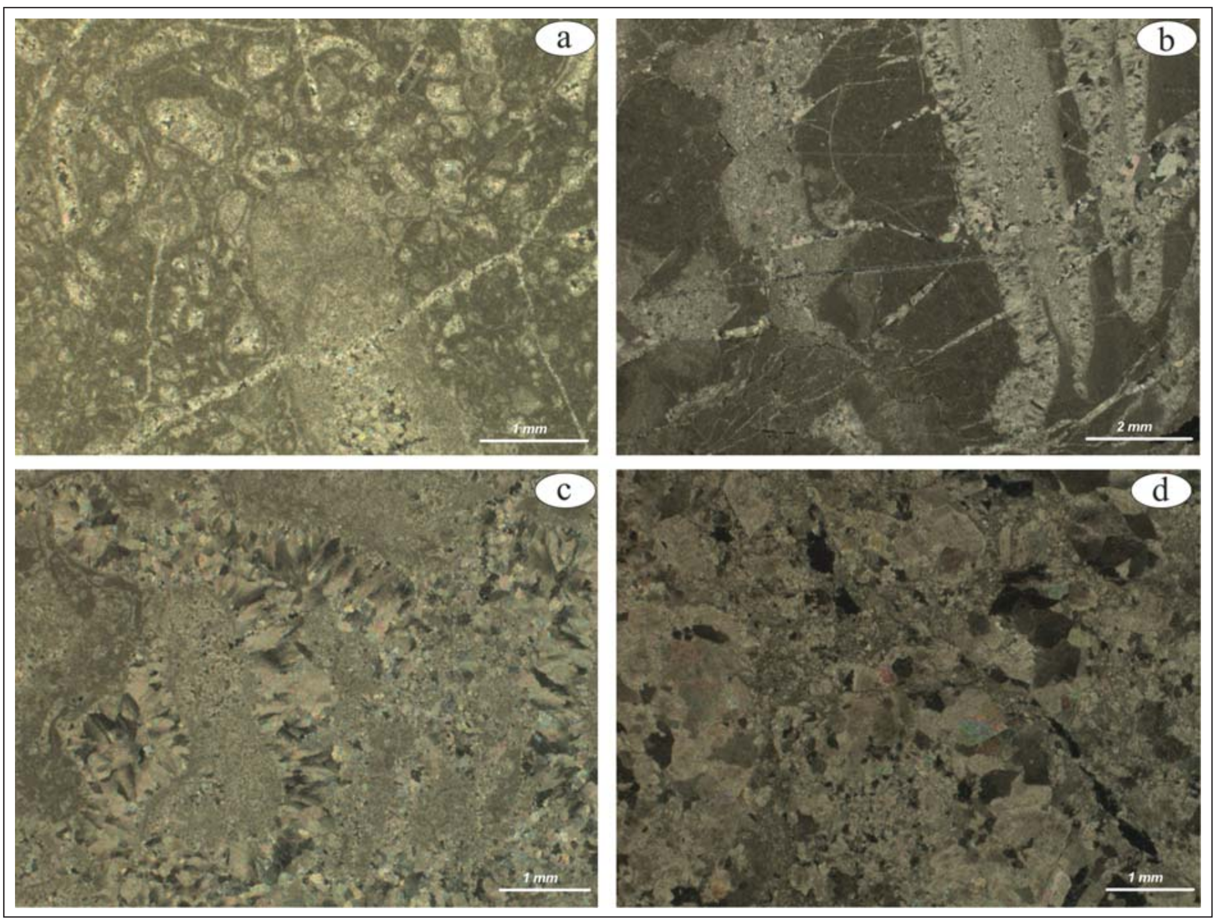

Figure 8- Tectonical effects in thin sections of petrographical samples belonging to different lithologiescollected in Kuz hill formation, a) biomicrite, b) micritic limestone, c) limestone, d) dolomite.

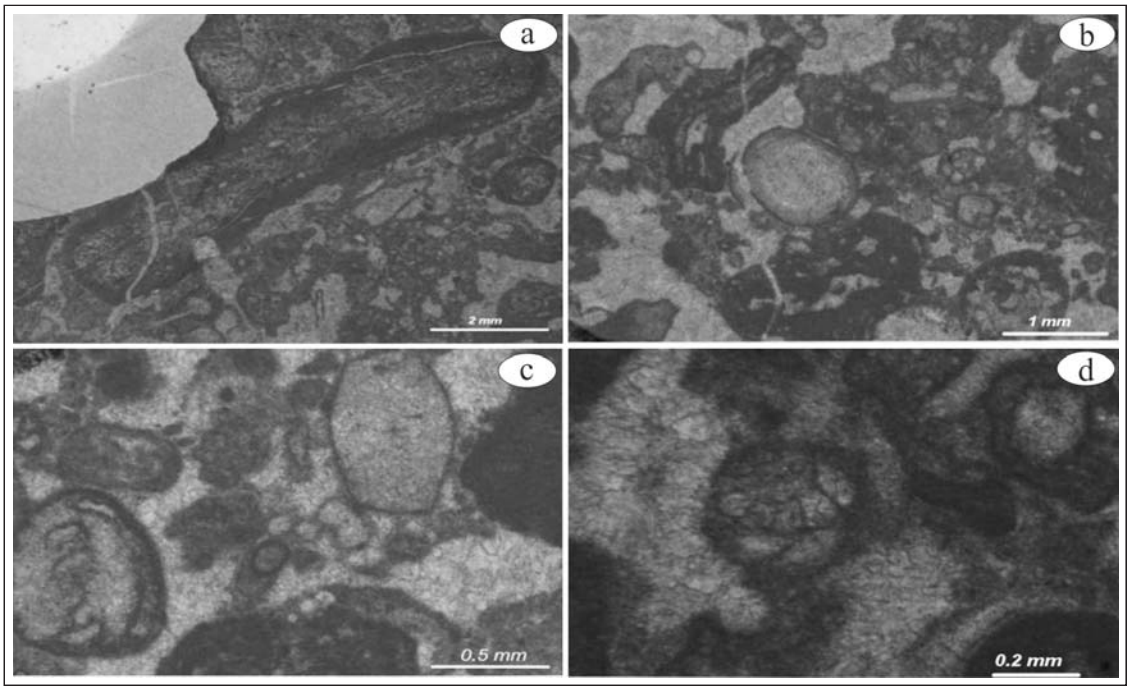

Figure 9- Fossil content of the Kuztepe limestone; a) *Griphoporellacurvata,* b) *Aulotortus* sp., c) *Aulotortussinuosus,* d) *Trochammina* sp.

a diameter size of 5-10 cm. The unit extensively crops out in NW of the study area (502500E/4091700N) and has an apparent thickness of about 80-100 meters. Asar hill limestones which makes a gradual transition into Kuz hill limestones at the bottom are unconformably overlain by the clastics of Aybastı formation in Aybastı village in north of the study area. Silicified dolomitic limestone (Figure 10a) and biomicrite (Figure 10b) determinations were made in petrographical studies of limestones.

According to paleontological studies performed in Asar Hill limestones *Aulotortus* sp., *Turriglomina* sp., *Ammobaculites* sp., *Frondicularia* sp., *Ophthalmidium* sp., *Cetates* sp., lamellibranch shell sections and sponge spicule fauna Ladinian-Carnian (Middle-Late Triassic) ages were obtained; *Aulotortus* sp., *Endothyra* sp. fauna gave Late Triassic age, and from shell sections of radiolaria and pelagic pelecypoda Carnian-Liassic age was detected (Figure 11a, b, c). The age of the formation was given as Ladinian to Early Jurassic based on fossil determination.

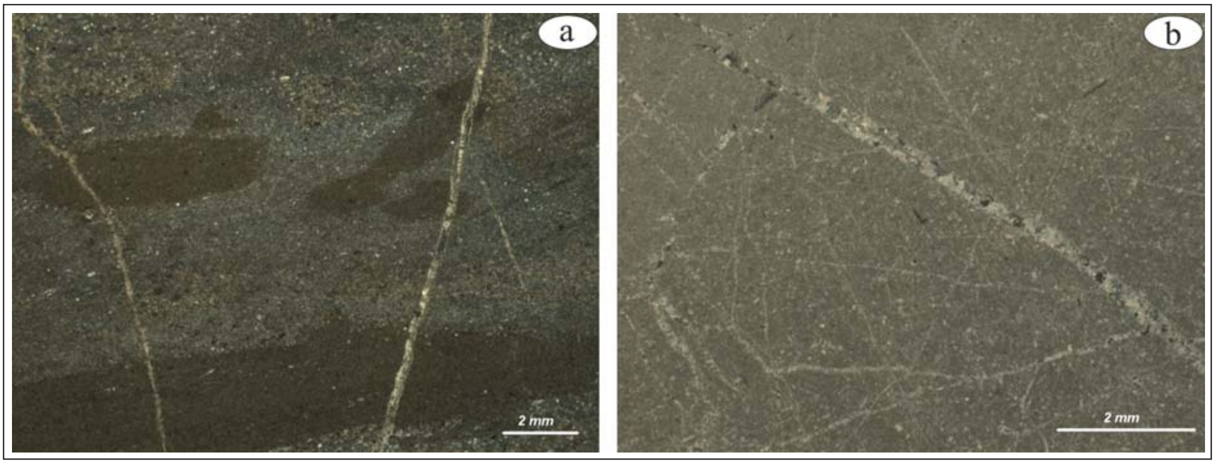

Figure 10- Lithologies defined on petrographical studies of Asar hill limestone, a) silicified dolomitic limestone, b) biomicrite.

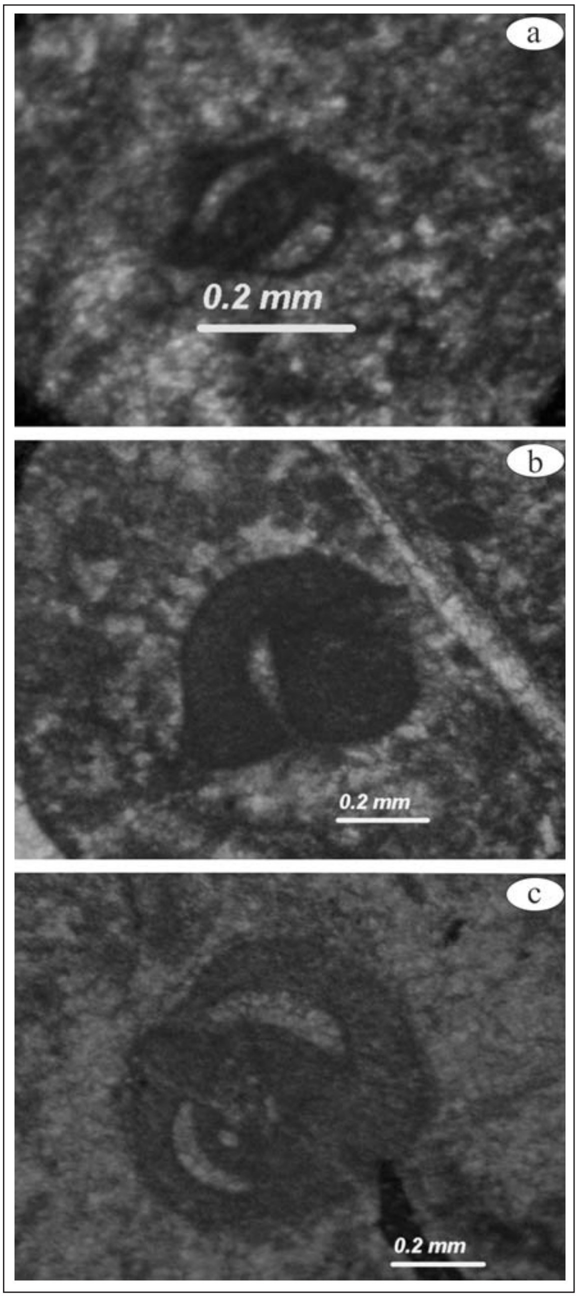

Figure 11- Fossil content of the Asar hill limestone, a) *Ophthalmidium* sp., b) *Galeanellapanticae,* c) *Galeanellapanticae*.

2.2.3. Aybastı Formation

Aybastı formation was first defined by Esirtgen (2009) in the vicinity of Bucakkışla and it takes its name from Aybastı village in NE of Bucakkışla. The formation is a unit in which rock fragments have various sizes, types, and ages are located within brown colored matrix together. This formation is composed of yellow to brown colored chert, bordeaux mudstone, green to brown colored tuff and lava fragments, limestone blocks, and brown colored volcanic sandstone and conglomerates. It is considered that angular limestone blocks of which their sizes reach few meters occasionally belong to Kuztepe limestones. Conglomerates are generally observed in the form of chaotic mixture of volcanic blocks. Spherical deformations in volcanoclastic sandstones are widespread.

Type locality of the formation is the section between the east of Bucakkışla village and the south of Aybastı village in the study area (506000E/4091000N). Aybastı formation has an apparent thickness of about 20 meters and unconformably overlies Kuz hill and Asar hill limestones, and unconformably underlies Fakırca formation. The thickness of the formation thins out towards north of Aybastı village. Aybastı formation can be correlated with Kemaliye formation defined by Özgül et al. (1978) in Munzur mountainous territory of Eastern Taurides.

For paleontological determinations of samples collected from the formation Malm?-Neocomian? age was determined according to *Quinqueloculina* sp., *Ophthalmidiidae, Miliolidae, Nodosariidae,* Brachiopoda fauna (Figure 12a, b). However, the age of the unit was accepted as late Campanian-early Maastrichtian (Özgül et al., 1978) due to insufficient paleontological data.

2.3. Korualan Nappe

It crops out in southwest corner of the study area, around Yukarı Akın, Aşağı Akın villages and was first defined by Özgül (1997) as Korualan group. These rock assemblages display a nappe structure with Huğlu nappe and Boyalı tepe nappe, and are named as “Korualan nappe”. Only the Başkışla mélange among rock assemblages which form Korualan nappe crops out in the study area.

2.3.1. Başkışla Mélange

Başkışla mélange was first defined by Özgül (1997) in Central Taurides. It is formed by the chaotic mixture with clastics of limestone, radiolarite, debris flow, volcanites and green tuffs (Figure 13a, b).

The type locality of the mélange is Başkışla village in southwest of the study area and forms the youngest unit defined in nappe slices. The only locality wherethe mélange can be seen is the south of Yukarı Akın village (501300E/4082500N). Başkışla

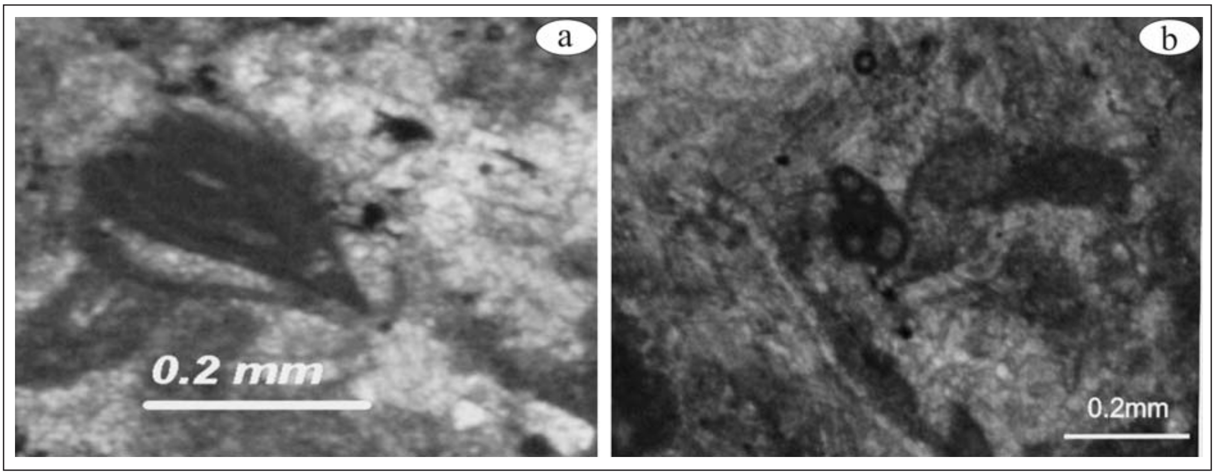

Figure 12- Fossil content of the Aybastı formation, a) *Ophtalmidiiade*, b) *Miliolidae*

mélange possesses an apparent thickness of about 100 meters in the study area and rock units in the mélange show similarities with other units forming other nappe slices. Green tuff and volcanites resemble to Dedemli formation, however thin bedded limestones with radiolarite resemble to Mahmut hill limestone and Kuz hill limestone. Özgül (1997) emphasizes that the age of formation of the mélange should be late and post Senonian considering the age intervals of blocks which the mélange consists of. However, the minimum age should be Paleocene as the unit consists of materials belonging to Kovanlık mélange. Both lower and upper boundaries are tectonically in contact with other nappe slices. Mélange was influenced from compressional regime which has begun in Late Cretaceous and continued until Late Eocene. Kuz hill limestone is located as thrusted extending from south to north over Mahmut hill limestone in south of Yukarı Akın village. This tectonic slice which is formed by Kuztepe and Mahmut hill limestones thrusts over Başkışla mélange. These three units again tectonically overlie Mahmut hill limestones in the northernmost part of the area. Başkışla mélange is made up of debris flow products of different rock lithologies and displays a chaotic view. It also is considered as a product of basin which was opened in front of nappes. Rock groups were most probably subjected to the same deformation due to the compression that continues in the region.

2.4. Fakırca Formation

Lacustrine deposits located over Mesozoic basement rocks in Mut basin was first named by Atabey et al. (2000) as Fakırca formation dedicated to Fakırca village in northwest of Mut. The formation which begins with the deposition of conglomerate, sandstone and mudstones is generally composed of thin bedded, cream white colored, limestone-marl

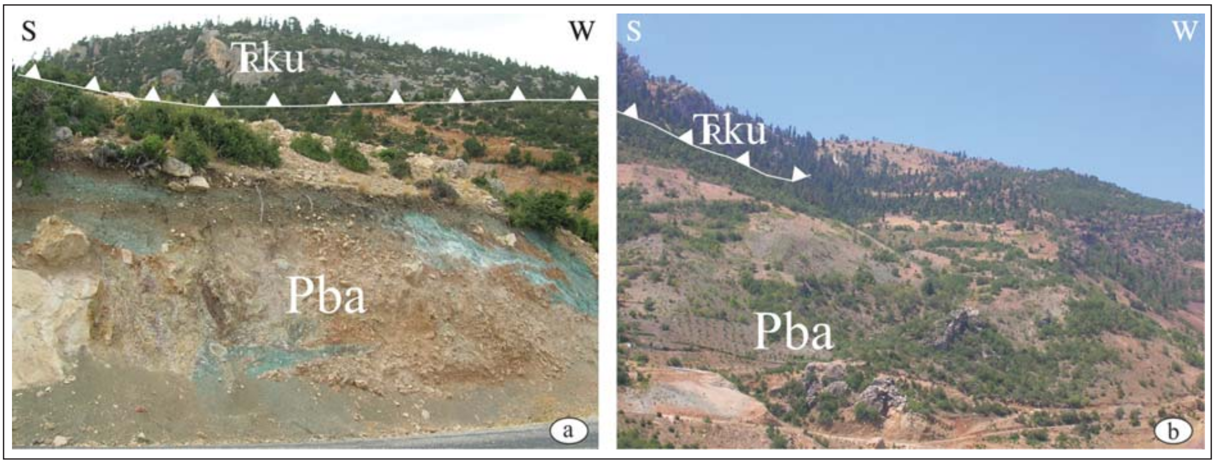

Figure 13- a), b) Tectonical relationship between Başkışla melange and Kuz hill limestone of the Boyalı hill nappe which overlies the melange in N-S directions.

alternation (Figure 14a, b). The apparent thickness of Fakırca formation is about 250 meters and its type locality is in the vicinity of Topalhacı farm in Göksu valley (508000E/4081800N).

The formation has definite angular unconformity with Mesozoic units at the bottom. It again displays an angular unconformity with the overlying Mut formation. The Fakırca formation was dated as; Burdigalian by Gedik et al., (1979); Oligocene-Lower Miocene by Bilgin et al., (1994); Upper Oligocene-Akitanian by Tanar and Gökçen (1990); Akitanian-Burdigalian by Özdoğan (1999); Akitanian–Lower Burdigalian by Atabey et al., (2000), and as Early Oligocene by Kayseri et al., (2006). Conglomerate, sandstone and mudstone succession deposited at the bottom of Fakırca formation indicate alluvial fan deposits. And the overlying, planorbis type gastropoda fossil bearing, marl-limestone alternation shows a fresh water lacustrine environment (Ilgar et al., 2010).

2.5. Mut Formation

Miocene limestones of the Mut formation are located with an angular unconformity over Fakırca formation in near eastern part of the study area (Figure 15a, b).

All Miocene limestones cropping out in Mut basin and its vicinity were named as Mut formation by Gedik et al., (1979). The formation is composed of medium to thick bedded, white, gray reefal limestones. Mut formation represents reef accumulations that formed in transgressive stage of the marine (Atabey et al., 2000). Mut basin was submerged due to marine transgression that developed in Late Burdigalian time in the basin.

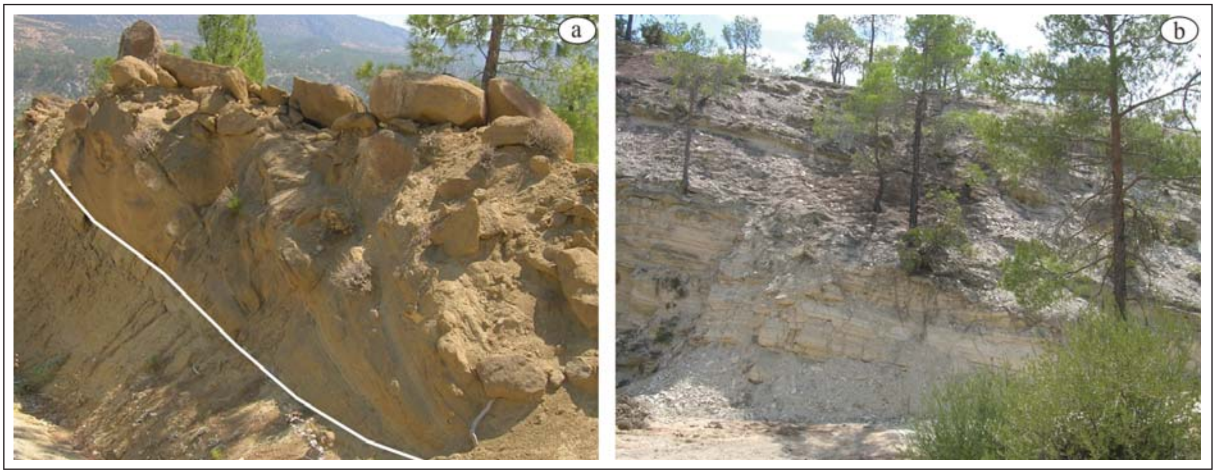

Figure 14- a) Tangential sandstone-mudstone alternation at the bottom of Fakırca formation, b) Laminated marl-limestone alternation of the Fakırca formation.

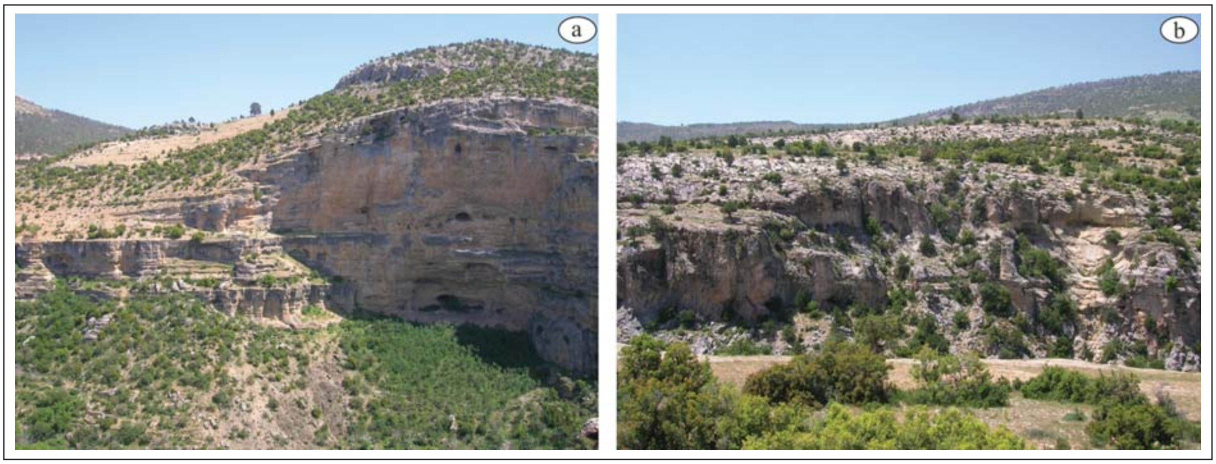

Figure 15- a) Reef flank which forms the Mut formation, b) limestones showing the geometry of the reef core.

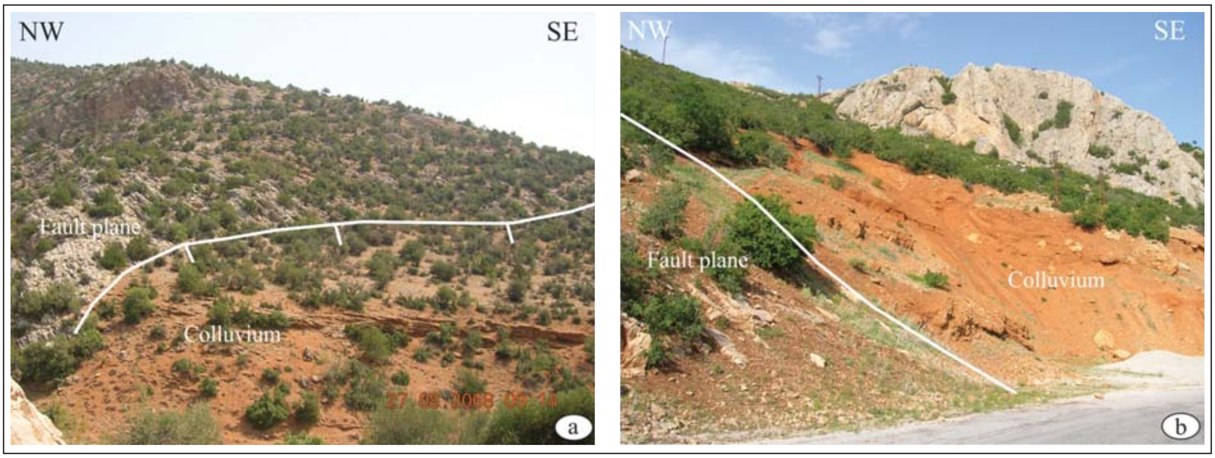

Figure 16- a) Colluvials in front of the normal fault cutting Asar hill limestone, b) colluvials in front of the normal fault cutting Mahmut hill limestone.

Hence, carbonate platform, patch and bornier reefs and lagoonal deposits of he Mut formation have started to deposit on bedrock and Fakırca formation in the basin starting from this time (Ilgar et al., 2010). The age of the Mut formation was determined as Upper Burdigalian-Tortonian (Atabey et al., 2000).

2.6. Plio-Quaternary Deposits

Colluivals, terraces and alluvials form Plio-Quaternary deposits cropping out in the study area. Colluvials are formed by deposits which consist of brick colored, pebble-sand size angular grains in valley margins and fault scarps which show bedding due to granular arrangement (Figure 16a, b).

These deposits have often spaces among grains. Terraces are observed in the form discontinuous outcrops at 4-5 meter above the valley bottom in Göksu valley and consist of very well rounded, well sorted polygenic pebbles (Figure 17).

Figure 17- Field view of terraces along the edges of Göksu River.

These are located on both sides of the Göksu valley at the same levels. There is not observed any effect of active tectonism in terraces which are above the bottom due to stream cutting. Alluvials are generally located inside and on margins of the Göksu valley (502500E/4089650N).

Alluvials which are composed of polygenic material with much pebbly limestone and pebbly chert in occasions have few meters thicknesses and are the youngest unit.

3. Tectonic Evolution and Discussion

Taurides are formed by 6 tectonic units with characteristic features which can be traced almost along the belt (Özgül, 1976). The Geyikdağı unit, which is paraautochthonously located below other units, covers rock units deposited between Cambrian-Tertiary periods of time. This unit is tectonically overlain by Bozkır, Bolkardağı and Aladağ units in north and by Alanya and Antalya units in south. Bozkır unit which is the subject in this study extends from Milas to Munzur Mountains along the Tauride belt. This unit is known as western Lycian nappes around Fethiye-Köyceğiz (Graciansky, 1967; Brunn et al., 1971), as eastern Lycian nappes around Korkuteli (Brunn et al., 1971) in western Taurides; as Beyşehir-Hoyran nappe around Beyşehir-Seydişehir in Central Taurides (Gutnic et al., 1968), as ophiolitic series around Hadim-Bozkır (Özgül, 1971) and as schist-radiolarite formation in Karaman region (Blumenthal, 1956). The unit is formed by different rock groups defined as Huğlu, Boyalı hill and Korualan nappes. Basic submarine volcanite, tuff, diabase, ultrabazite, serpentinite, pelagic and neritic limestone and radiolarites constitute rock groups which represent Triassic-Cretaceous times. It has a mélange characteristic because of its internal structure. Triassic-Quaternary geological evolution of this mélange and the rock units covering the mélange are successively mentioned below.

3.1. Rifting Stage

Due to rifting in Triassic in north of Gondwana, numerous oceanic basins have been opened, and these basins located among continental blocks have continued their presences during Mesozoic-early Senozoic periods (Robertson et al., 2012). Data related to this rifting and opening are widely observed in southern Mediterranean Sea. Depending on rifting of Tauride-Anatolide continent in Triassic, oceanic basin called “Inner Tauride Ocean” was opened in the region (Görür et al., 1984, Görür et al., 1998). Dedemli formation which is known as the lowermost unit of Huğlu nappe is considered to have formed as the product of rift volcanism that had occurred during rifting of Inner Tauride Ocean in Anisian-middle Carnian periods. These units, which form the Bozkır nappe, can be correlated with Alihoca and Mersin mélanges which consist of siliceous deposits such as Triassic aged alkaline lava and radiolarian located within the same belt (Dilek and Whitney, 1997; Parlak and Robertson, 2004; Robertson et al., 2012).

While on one hand, tuff, tuffite, volcanic glass, alkali basic volcanic rocks and lavas originating from the mid-oceanic volcanism have been deposited, on the other hand clastic rocks that generated due to sediment transportation from platform margin have accompanied to this volcanism (Figure 18a).

3.2. Subsidance Stage

Kuz hill limestone which was formed by thick bedded limestones and deposited in a neritic environment is vertically and laterally transitional with Asar hill limestone which is composed of pelagic deposits (Figure 18b). Asar hill limestone among rocks which was deposited during Ladinian-Early Jurassic periods transforms into limestones with chert nodules in middle–upper sections of the succession and grades into bedding layers consisting cherts. This change, which is observed towards middle-upper sections of the succession, is interpreted as the deepening of depositional environment in time and as the condition in deposition of environment has descended below calcite compensation depth (CCD). Deepening and transgression in the basin can be related to eustatic sea level rise and/or to collapse in the basin. In middle Carnian-Santonian period pelagic, cherty limestones were deposited which form Mahmut hill limestones over Dedemli formation in deep marine environmental. The basin margin of this ocean, which is located on the northern part of the Tauride carbonate platform and composed of passive margins, had subsided during Jurassic-Early Cretaceous (Reed, 1982; Andrew and Robertson, 2002; Robertson et al., 2012). Mahmut hill limestones have a transitional contact relationship with Dedemli formation. The presence of Mahmut hill limestones which were deposited on Dedemli formation consists of rift volcanism products and indicates that the volcanic activity and rifting in the basin starting from middle Carnian has ended.

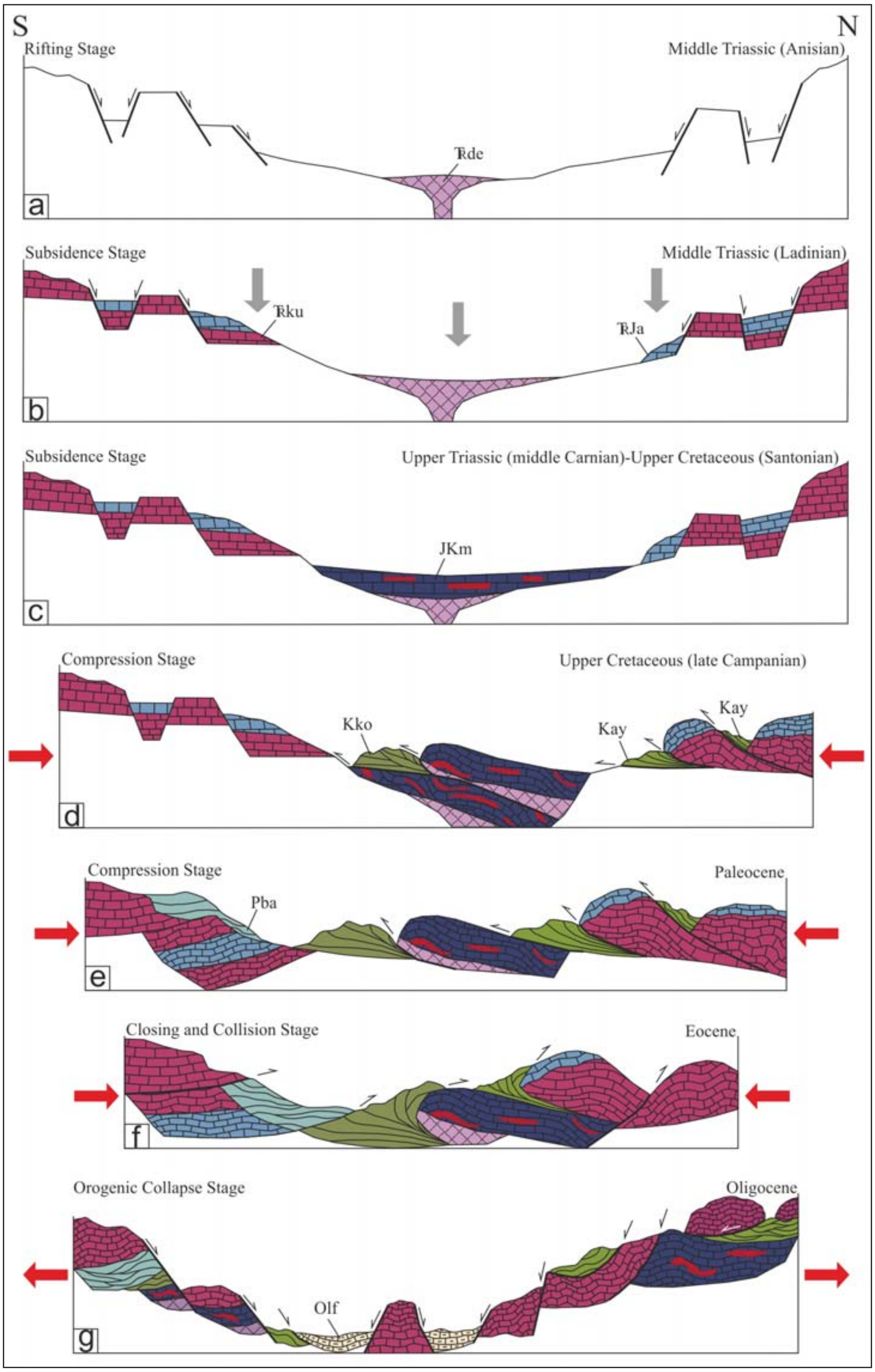

Figure 18- Middle Triassic-Oligocene period geological evolution of the study area: a) the rift volcanism in Anisian, b) the deposition of pelagic limestones in deep and the deposition of neritic limestones in shallow sections of the basin in Ladinian, c) the closure of rift volcanism and the deposition of pelagic, cherty limestones in Middle Carnian-Santonian, d) the beginning of compressional stage in late Campanian, the formation of Kovanlık mélange and Aybastı formation, e) the continuation of the compressional stage and the formation of Başkışla Melange in Paleocene, f) the formation of collision and back thrusts in Eocene, g) the formation of post collisional orogenic collapse in Oligocene the formation of lagoonal basins and the lagoonal deposition of Fakırca formation in Oligocene.

As Mahmut hill limestones were deposited in deep sections of the basin (Figure 18c), Kuz hill and Asar hill limestones continued to deposit on platform margins of the same basin.

3.3. Compressional Stage

The location of Kovanlık mélange to be over Dedemli and Mahmut tepesi formations in rift center, its formation by picking up fragments from those units and this mélange to consist of SSZ type ophiolites were geochemically interpreted as the beginning of compression and of the subduction-obduction process in the region (Figure 18d). When Santonian age of Mahmut Hill limestone is taken into consideration which was determined by Tekin (1999), the age of Karanlık melange could be Post Santonian.

The beginning of compression and subduction-obduction stages with Kovanlık mélange means at the same time that the tectonic regime prevailing in the region has changed, so this period was dated as post Santonian. The formation of SSZ type ophiolites and the ophiolitic mélange during this period of time developed due to northward subduction of Inner Tauride Ocean in Late Cretaceous (Robertson et al., 2012). The units belonging to Kovanlık mélange due to this subduction-obduction began to occur and move northward in time.

As Kovanlık mélange was formed in inner parts, the Aybastı formation was formed in late Campanian-early Maastrichtian period on Kuztepe and Asar tepe limestones of the marginal basin by taking materials from these units (Figure 18d). The unconformable location of Aybastı formation on Kuztepe and Asar tepe limestones reflects non-depositional period that developed between middle Jurassic–early Campanian age intervals. It indicates that the upper sections of the succession formed by limestones were removed from environment by tectonical and/or erosive processes.

Başkışla mélange, according to Özgül (1997), gives the view of chaotic mélange of blocks which their sizes reach hundreds of meters and have similarities with rock units belonging to other slices of the Bozkır unit (probably derived from them). Green tuff and tuffites in the unit resemble to volcanites of Dedemli formation, the radiolarite and cherts resemble to Mahmut tepesi formation and Kovanlık mélange and limestones resemble to Kuztepe limestones of the Boyalı tepe group. Başkışla mélange probably began to occur in Paleocene by taking material from all units that had generated earlier (Figure 18e). The youngest unit which is older than this formation is Kovanlık mélange. Başkışla mélange is formed by units belonging to Kovanlık mélange and blocks of Kuztepe limestone. This situation was interpreted that the subduction-obduction processes that generate Kovanlık mélange continued, and formed Başkışla mélange in latter stages also including Kuztepe limestones into its body. Hence, Bozkır nappe overlain the northern margin of the Anatolide-Tauride platform starting from Campanian-Maastrichtian period (Bergougnan, 1975; Dürr, 1975; Ricou et al., 1975; Özgül, 1976; Özgül et al., 1978; Şengör and Yılmaz, 1981). Rocks belonging to Bozkır unit not to display any metamorphism or significant deformation support the opinion that this unit was emplaced into the region by the closure of Inner Tauride Ocean.

3.4. Closing and Collisional Stage

The Southern branch of Neotethys partly remained open during Paleocene-Early Eocene period. Forever the inner Tauride Ocean was largely closed and entered into uplifting Subarial period (Koçyiğit, 1983; Robertson, 2000; Robertson et al., 2012). Marine Lutetian sedimentation in Central Taurides is represented only by clastics in olistolith and olistostromal flysch facies in successions belonging to Geyikdağı unit. Olistoliths located within this flysch belong to Bolkardağı and Aladağ units and were transported into Lutetian basin and were included into deposition (Özgül, 1997; Andrew and Robertson, 2002). Bolkardağı and Aladağ units overlie Geyikdağı unit in the next stage. Bozkır mélange, which forms Kovanlık and Başkışla mélanges too, continued to emplace towards south, like Bolkardağı and Aladağ units (Alan et al., 2007, Robertson et al., 2009).

The structural relationships of Huğlu, Boyalı tepe and Korualan nappes which constitute Bozkır unit in the study area, are seen in the form of thrusts onto each other towards north (Figure 18f). Huğlu nappe is the lowermost nappe and successively Korualan, Huğlu and Boyalı tepe nappes are located on it. Başkışla mélange remains between the two Huğlu nappes in south of the study area. However, Başkışla mélange is younger than the units of Huğlu nappe. Besides, Huğlu nappe overlying Başkışla nappe is tectonically overlain by Boyalı hill nappe. Boyalı hill nappe consists of Kuztepe limestone which is older than its units.

This structural relationship shows that nappe slices which emplaced towards south during the closure of Inner Tauride Ocean had moved in the opposite direction during collisional stage and completed its formation advancing northward in the form of back thrusts. The units has taken their recent positions with these back thrust movements.

3.5. Orogenic Collapse Stage

The characteristic of the tectonic movement investigated in Central Taurides in post Eocene is still in debate and it is claimed that post collisional compressive movements continued, and erosion and terrestrial deposition occurred in Oligocene too (Kuşçu et al., 2010). Kaymakçı et al. (2010) pointed out that the second deformational phase occurred as a result of the convergence of Africa-Eurasia in southwestern Anatolia during Late Eocene-Oligocene. However, Oligocene time both in Bucakkışla region and in Ermenek, Mut, Silifke and Çamlıyayla regions is represented by lacustrine clastic and carbonate deposits (Bilgin et al., 1994; Ilgar, 2004; Ilgar and Nemec, 2005; Ilgar et al, 2010). All depositional environments in which these lacustrine depositions had occurred were restricted by dip slip normal faults and fault controlled sedimentation developed in these areas.

All pre Oligocene units which have developed in the region depending on NS trending compressional movement in Central Taurides have been compressed until Late Eocene and become imbricated and completed their orogenic evolutions. The units, which had reached its maximum height,was then collapsed due to a pause or end in compression after orogeny, or due to extension and gravity effect that had developed in the region (Figure 18g). Based on this orogenic collapse event, units that form nappes were cut by dip slip normal faults, so small lacustrine basins were formed in front of faults on falling blocks. The first unit that deposited on these lagoons is the Fakırca formation.

The lower age of the unit to be Early Oligocene indicates that, orogenic collapse event had occurred just in and/or before Oligocene. Early Oligocene deposits are as well inclined southeast in Bucakkışla region. The inclination of the Fakırca formation shows that tectonic lines that caused orogenic collapse and the formation of negative areas have not lost its activity during and after Early Oligocene period.

These depositional areas which formed based on dip slip normal faults were interpreted as the end of compressive movements which began in early Senonian in regional scale and a new tectonical regime started which caused Oligocene deposition in central Taurides.

4. Results

Bozkır unit which crops out in Bucakkışla region consists of basic submarine volcanite, tuff, diabase, ultrabzite, serpentinite, pelagic-neritic limestone and radiolarites and has a giant mélange appearance that covers blocks and slices in various sizes. These rock units has been formed in Inner Tauride Ocean that restricts the north of Tauride-Anatolide platform. In the region, rifting, collapse, compression, closure and collisional events and tectonostratigraphical sequences have occurred during Triassic-Eocene time periods. The study area has been subjected to orogenic collapse and lagoonal deposition has developed in this collapse region. These evolutionary stages were summarized below;

Rifting in north of Gondwana which occurred in Middle-Upper Triassic and the Dedemli formation consisting of tuff and alkali volcanic rocks as rift volcanism product was formed during this time period.

Kuz hill and Asar hill limestones were deposited on basin margins in Ladinian-Early Jurassic period.

Mahmut hill limestones which developed on rift volcanics indicate that the volcanic activity and rifting in the basin ended starting from middle Carnian.

Pelagic Asar tepe limestone to turn into chert nodular limestone towards the upper parts of the succession during Ladinian-Early Jurassic time periods was interpreted as the deepening of depositional environment in time and as the decrease of conditions in depositional environments to a level lower than calcite compensation depth (CCD).

The beginning of compression and subduction-obduction stages with Kovanlık mélange also mean that tectonic regime effective in the region changed and this period was dated as post Santonian.

The lithology of Paleocene aged Başkışla mélange and its stratigraphical position show that compression in the region continued.

During Paleocene-early Eocene period, Inner Tauride Ocean has been largely closed and Bozkır unit has continued to emplace southward. However, recent locations of Korualan, Huğlu and Boyalı tepe nappes which constitutes Bozkır unit in the study area indicate that nappe slices moved during collisional stage in reverse direction and completed its formation advancing northward in the form of back thrusts.

Lacustrine Oligocene deposits which developed over nappe slices and restricted by dip slip normal faults show that compressional regime in the region has ended. Early Oligocene units to incline depending on dip slip faults indicate that the tectonic process which caused Oligocene basin to open have also continued after Oligocene.

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