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NEOGENE STRATIGRAPHY OF THE NORTHERN PART OF KARABURUN PENINSULA

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geochronology

ABSTRACT

The terrigenous Neogene lithology in north of Karaburun peninsula is represented by Lower-Middle Miocene rock units which are cut and bounded by NW-SE trending synthetic faults. Dominant lacustrine sedimentation (Haseki and Hisarcık formations) of Early-Middle Miocene period which was separated by upper and lower regional unconformities, and the Early Miocene mafic volcanism (Karaburun volcanites) were studied within the scope of Karaburun group. Haseki formation which reflects Early Miocene sedimentation begins with fills of alluvial fan of the Salman member and is basically formed by algal-biostromal Yeniliman limestone and lacustrine deposits of Aktepe member. With syndimentary emplacement of the 1st phase Karaburun volcanites over Yeniliman limestone platform, the dominant sequence which is micritic limestone intercalating with diatomite of the Aktepe member was deposited in environmental conditions deepening towards shore-face. The effectiveness of NW trending boundary faults which gave rise to 2nd phase of the Karaburun volcanism, shaping the western edge of Foça depression towards the end of Early Miocene has not changed the dominant depositional environment, and lacustrine sedimentation has continued with Hisarcık formation. Green and fine clastic shore-face sediments (Karabağları member) of the Hisarcık formation which deposited the latest between Early Miocene-Middle Miocene overlies Aktepe sequence with submarine parallel unconformity. Karaburun volcanism which is represented by high potassium andesitic products with calc alkaline character (pyroclastics and olivine-phyric lavas) is synchronous with sedimentation of Haseki formation and has two phases. Pyroclastic rocks which are in facies of base-surge, air-fall and ash-fall in lesser amount were emplaced before lava eruptions. K/Ar aged, 1st phase products, which are 18.2±1.0 my according to K/Ar dating, are in the position of stratigraphical reference level which separates Yeniliman limestone from Aktepe member. Second phase products are emplaced in Aktepe sequence.

1. Introduction

This study aims at reflecting the stratigraphical evolution of Early-Middle Miocene terrigenous deposits cropping out in north of Karaburun peninsula and the syndimentary mafic volcanites (Figure 1). As listed in Çakmakoğlu and Bilgin (2006), detailed geological investigations which began with Kalafatçıoğlu (1961) all around the peninsula are mainly related to pre Neogene rock

units. The main topic of the Neogene studies are the ones related with magmatism (Innocenti and Mazzuoli, 1972; Borsi et al., 1972; Türkecan et al., 1998; Helvacı et al., 2009).

The first detailed tectono-stratigraphic study related to Neogene rock units in coastal Aegean region was made by Kaya (1979). Türkecan et al., (1998) studied petrographical and mineralogical characteristics of “Yaylaköy” and “Karaburun”

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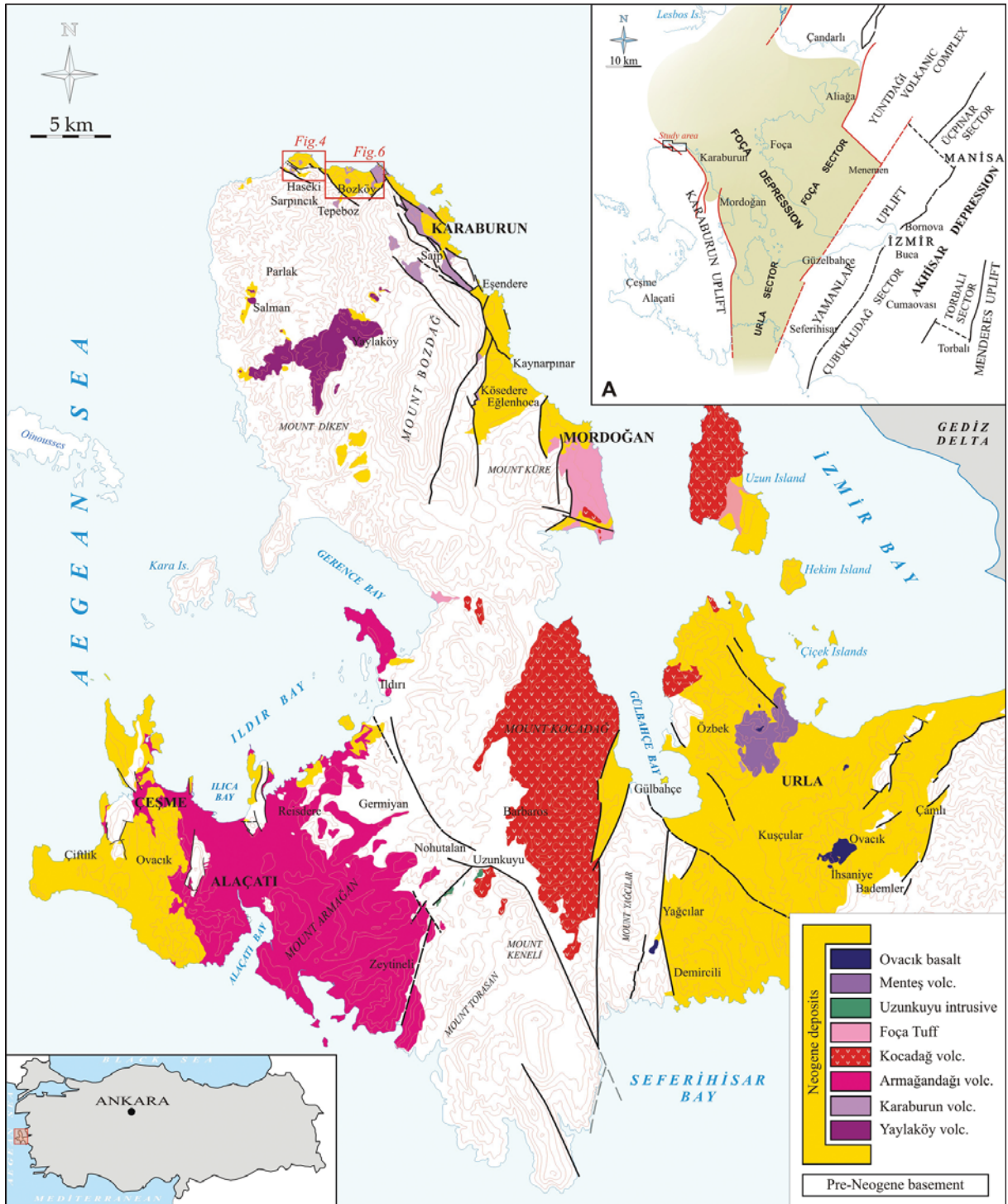


Figure 1- Location of the study area and its position within Foça Depression reflected by modifying Kaya (1979) (A).

volcanites where they were distinguished in northern part of the peninsula, and took 18.5 ± 3.1 my and 16.0 ± 0.7 my K/Ar ages from Karaburun volcanites. Helvacı et al., (2009) stated that Karaburun volcanites were formed from olivine bearing basaltic andesite and shoshonite, and took 17.0 ± 0.4 my $^{40}\text{Ar}/^{39}\text{Ar}$ age

from Yaylaköy volcanites which high potassium calc-alkaline andesite rocks symbolized. In both studies, which do not contain any stratigraphical detail, it was accepted that the generalized Neogene sedimentation and volcanism showed laterally related development thoroughly.

Major element analyses of lava samples taken from Karaburun volcanites were carried out in the Dept. of Mineral Analysis and Technology of MTA, however K/Ar analysis was performed in Tubingen University (Germany).

All stratigraphic units were named, described and mapped in 1/25 000 scale in this study the first time by dividing them into groups, formations and members in the area.

2. Stratigraphy

Pre Neogene basement rocks which propagate in north of Karaburun peninsula (Figure 2) is formed by “Küçükbahçe” (Ordovician-Cambrian?) and “Dikendağı” (Carboniferous-Silurian) formations, Camiboğazı formation (Ladinian), İzmir flysch (Late Cretaceous-Early Tertiary) which the neritic carbonates symbolize and by Yeniliman serpentine rocks (Çakmakoğlu and Bilgin, 2006). The region remained as nondepositional area starting from the emplacement of İzmir-Ankara zone to the beginning of Early Miocene sedimentation.

Neogene rock units in the study area are represented by dominant lacustrine Lower-Middle Miocene deposits which are described within Karaburun group and by Lower Miocene mafic volcanites. Haseki formation and Karabağları member forming the lower part of Hisarcık formation and Karaburun volcanites were distinguished within Karaburun group (Figure 3). Karaburun group is time stratigraphic equivalent of “Çeşme group” suggested by Göktaş (2010) in Çeşme peninsula.

2.1. Haseki Formation

Haseki formation which reflects Early Miocene sedimentation is dominantly formed by lake deposits. The unit which has taken its name from the Haseki village was studied as being separated into gravel dominant Salman member, algal biostromal Yeniliman limestone and Aktepe member represented by micritic limestone (Figure 3). Two phased Karaburun volcanites are located within lake section of the formation (Kv.I and Kv.II; Figure 3).

One of the data which could date Haseki formation is 18.2 ± 1.0 my K/Ar age taken from 1st phase Karaburun volcanite between Yeniliman limestone and Aktepe member in this study. And the other data is the upper age limit in which “Yeniliman small mammal fauna” was described by Saraç (2003)

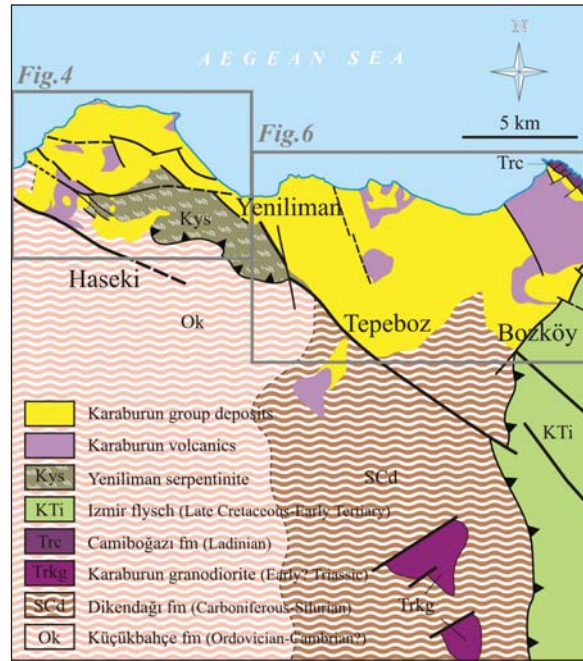


Figure 2- Geological map of Pre Neogene rock units which spreads in the study area (modified from Çakmakoğlu and Bilgin, 2006).

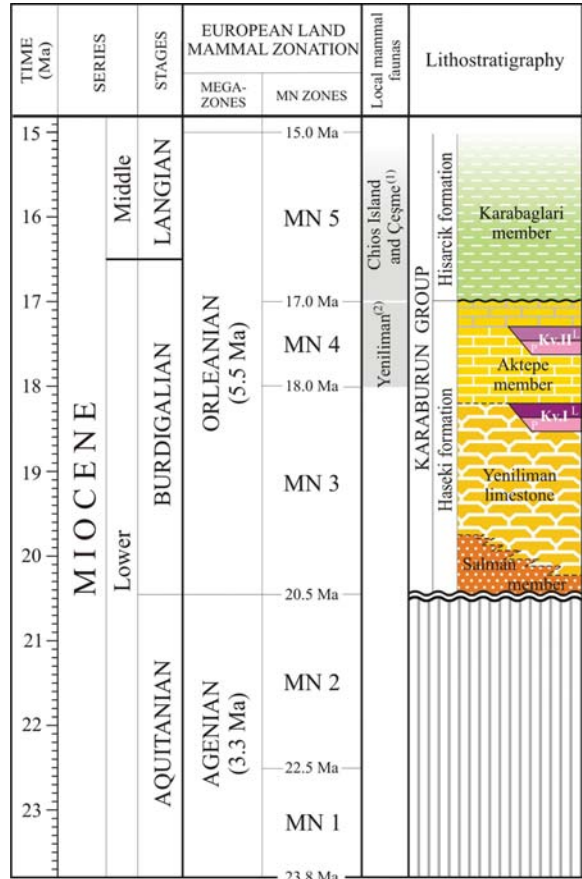


Figure 3- Generalized stratigraphic section of the study area. Time table is according to Steininger (1999). (1) Besenecker (1973), (2) Saraç (2003). Kv: Karaburun volcanites. L: Lava, P: Pyroclastic.

corresponds to 17 my in the biostratigraphy of Steininger (2000) (Figure 3). According to 21.3 K/Ar age, which Borsi et al., (1972) dated from 1st phase Yaylaköy volcanites overlying the Salman formation (Aras et al., 1999; Çakmakoğlu et al., 2013), the sedimentation might have started in Early Miocene. Though, geochronology and biochronology data in broad sense indicate Early Miocene, the sedimentation is mainly considered to have begun in late early Miocene.

“Şifne formation” (Göktaş, 2010), which evolved from alluvial to lacustrine environment in Çeşme peninsula, and Lower Miocene deposits composed of alluvial “Yeniköy conglomerate” and lacustrine “Zeytinadağ formation” (Kaya, 1979) described in Foça peninsula are regional equivalents of the unit. Lacustrine deposit which is formed by Yeniliman limestone and Aktepe member is time stratigraphic equivalent of Zeytinadağ formation. The absence of deposits which can be correlated with Haseki formation in Urla basin was explained with non-deposition (Göktaş, 2011).

2.1.1. Salman Member

The sub unit describes conglomerate dominant sequence forming the basement of Haseki formation. It is known that alluvial fan and alluvial fan deposits around Salman village and Yaylaköy (Figure 1) are represented in the name of “Salman formation” (Aras et al., 2000; Çakmakoğlu, 2008; Çakmakoğlu et al., 1999, Çakmakoğlu, 2013). The nomenclature of the unit which was reduced to member level was changed in this study.

Type location of the sub unit which shows lateral discontinuity spread between Haseki village and Bosköyis around Düdükçü Hill (Figure 4). The apparent thickness of the sequence is maximum 50 meters.

The sedimentary sequence consists of poorly bedded conglomerate, sandstone and mudstone in fewer amounts and shows a fining upward from bottom to top. Disorganized coarse gravels are located in lower part of reddish brown-paleo oxide

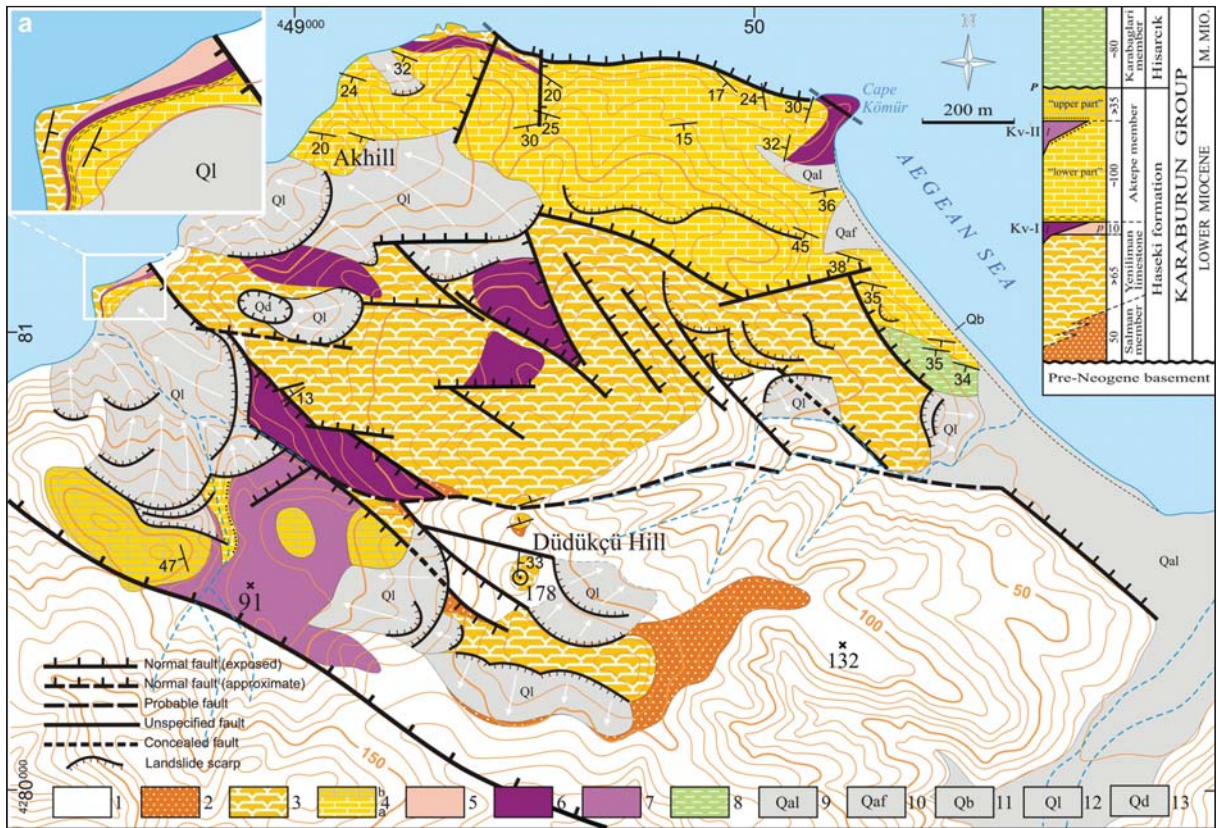


Figure 4- Geological map of north of Haseki. 1) Basement rocks, 2) Salman member, 3) Yeniliman limestone, 4) Aktepe member; a: lower, b: upper, 5) 1st stage Karaburun volcanites (pyroclastic), 6) 1st stage Karaburun volcanites (lava), 7) 2nd stage Karaburun volcanites (lava), 8) Karabağları member, 9) Alluvial, 10) Alluvial fan deposits, 11) Sand deposits, 12) Landslide debris, 13) Doline. PU: Parallel unconformity, L: lava, P: pyroclastic.

colored sequence cropping out in north of Haseki village (Figure 5).

Conglomerate is in degree of low textural maturity, intercalated with badly sorted, pebbly-coarse sand, blocky in varying amounts and is unbedded. The ratio of coarse components, as dense as it could be grain supported, with respect to matrix is generally very high (Figure 5a). Less distinctive, cross layered, conglomerate-pebbly sandstone layers gradually increase towards the upper layers of deposit. Conglomerate is formed by single or multilayered lateral discontinuities. It is generally made up of small gravels and grains or intra material supported (Figure 5b). Pebbles, which are angular to sub spherical, have elongated and sheet like shapes. Sandstone is generally coarse to very coarse sand sized, consists of small cobble and pebble, grain supported, and is medium to badly sorted. All rock type components forming the sedimentary sequence were derived from Küçükbağçe and Dikendağı formations (Figure 2) and formed by shale, greywacke and vein quartz in the order abundance.

Lateral intertongue of LLH-SH (Laterally Linked Hemispheroid-Stacked Hemispheroid) morphotype stromatolith which is the lateral continuity of Yeniliman limestone and red colored small conglomerate-sandstone-sandy mudstone levels are observed around Bozköy (Figure 5c and d).

The sub unit which overlies Küçükbağçe and Dikendağı formations and Yeniliman serpentine with angular unconformity forms Early Miocene basin bottom. It also reflects the beginning of continental Neogene sedimentation. The relationship is lateral intertonguing from bottom to top in the generalized stratigraphical section.

The burial of boundary faults which separates Haseki formation from basement rocks with post sedimentary vertical activities and the Salman member, which gives a limited observation because of Yeniliman limestone cover, reflects time transgressive alluvial fan deposit which developed Early Miocene basin margins. Disorganized coarse gravels which form the lower section of the deposit

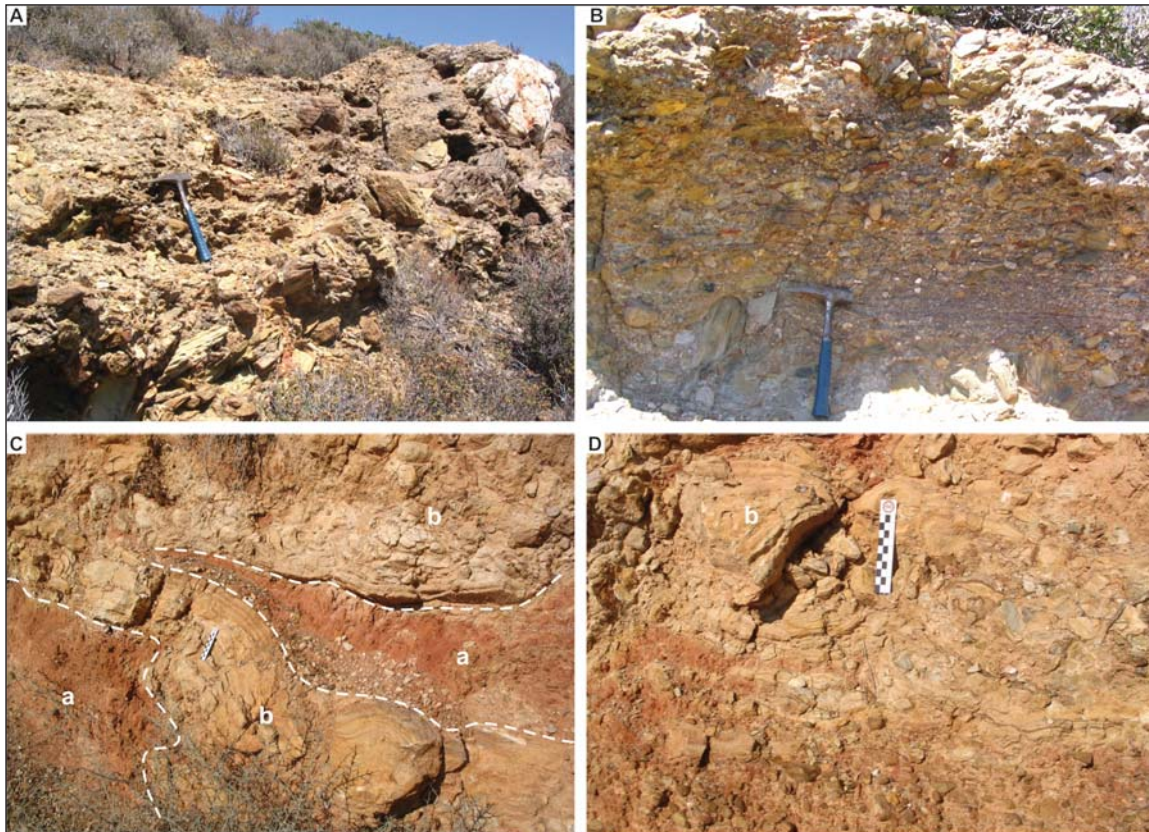


Figure 5- Sediment facies of the Salman member. A) Debris flow facies, B) Braided stream channel fill facies, C) Lateral intertongue between LLH type stromatolith horizons of alluvial deposits of the Salman member (a) and the overlying Yeniliman limestone (b) are observed as autochthonously grown around deposited pebbles. Hammer size 33 cm, scale 10 cm.

are in debris flow facies and describe the proximal fan deposition. Cross bedded conglomerate and pebbly sandstone layers which increase towards upper parts are channel and bar deposits of the braided rivers developed on fans.

Salman member can be correlated with Yeniköy conglomerate in Foça peninsula because of their positions at the beginning and of similar environmental characteristics. The sub unit is the equivalent of non-systematically described Bozköy formation by Helvacı et al., (2009). The presences of its conjugates which are not exposed in Çeşme peninsula were confirmed by drilling data (Göktaş, 2010).

2.1.2. Yeniliman Limestone

The sequence consists of algal biostromal-biohermal limestone from bottom to top and was first distinguished in this study in the name of “Yeniliman member”. The type locality is the Yeniliman district of the Salman village. The apparent thickness of the sequence which mainly crops out between Yeniliman and Bozköy is higher than 120 meters (Figures 4 and 6).

The sequence dominant in algal limestone which was formed by organisedimentary structures that stromatolites symbolize seldom consists of green,

massive sandstone interlayers and lenses of diagenetic chert. The biostromal limestones which were formed by in-situ growing stratiform stromatolites are dominant in the sequence. According to textural classification of Dunham (1962), the limestone in “algal boundstone” facies is medium to coarse crystalline and is generally very hard. The decomposition surface is in dark gray or yellowish gray and fresh rock is in beige color. It is generally thick (100-30 cm), occasionally medium (30-10 cm) or very thick (>100 cm), tabular parallel layered and is algal laminated (Figures 7a and b). Within biogenic limestone sequence; “undulated and parallel laminated” stromatolites are abundant (Figures 7c and d) however, the ones that are “tabular and parallel laminated” are in minority. Fenestral cavities parallel to algal laminae become widespread in some places (Figure 7e). According to geometrical classification of Logan et al., (1964), LLH morpho type stromatolites are widespread, but LLH-SH morpho types are seldom observed (Figure 7f). Thin branched species which are seldom observed have been post mortem reworked and formed biosparitic levels among algal laminated sections.

A stromatolite bioherm different than widespread algal was observed in the uppermost part Yeniliman limestone sequence which is 6 m thick (Figure 4a) cropping out 600 meters away from SW of Aktepe. Algal mass, which its decomposition surface is

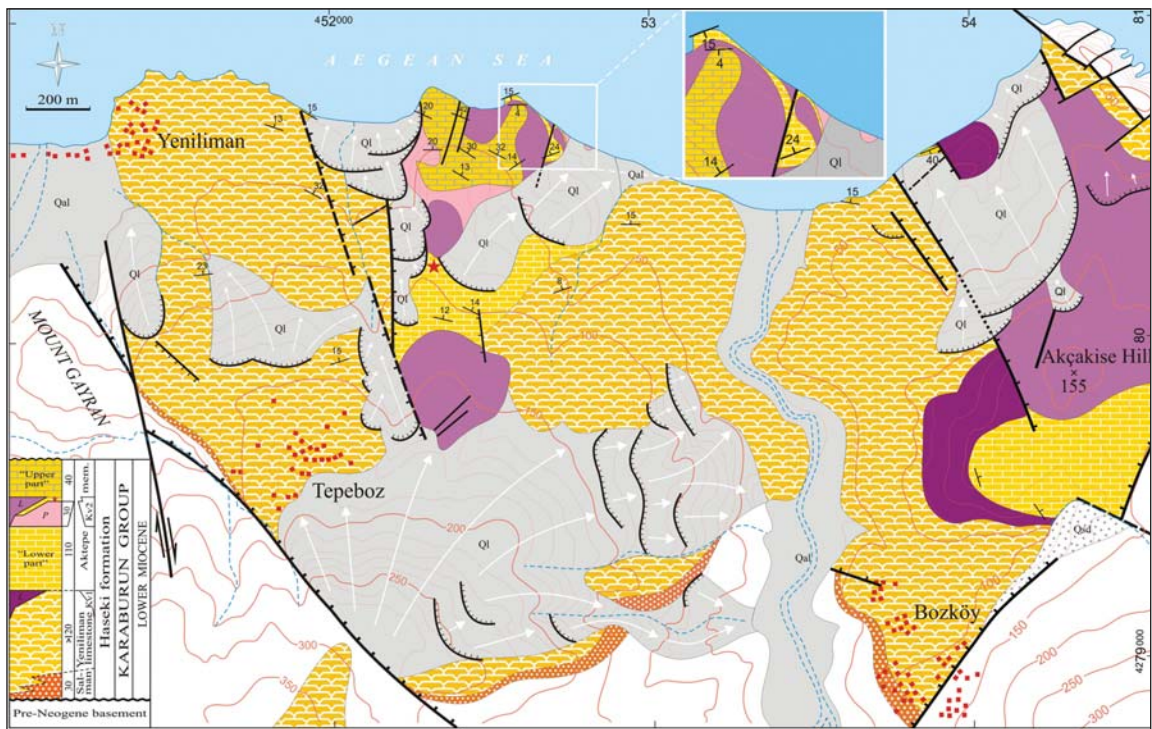


Figure 6- Geological map of Tepeboz-Bozköy surround. Red star denotes for finding locality of MN+ mammal fauna.

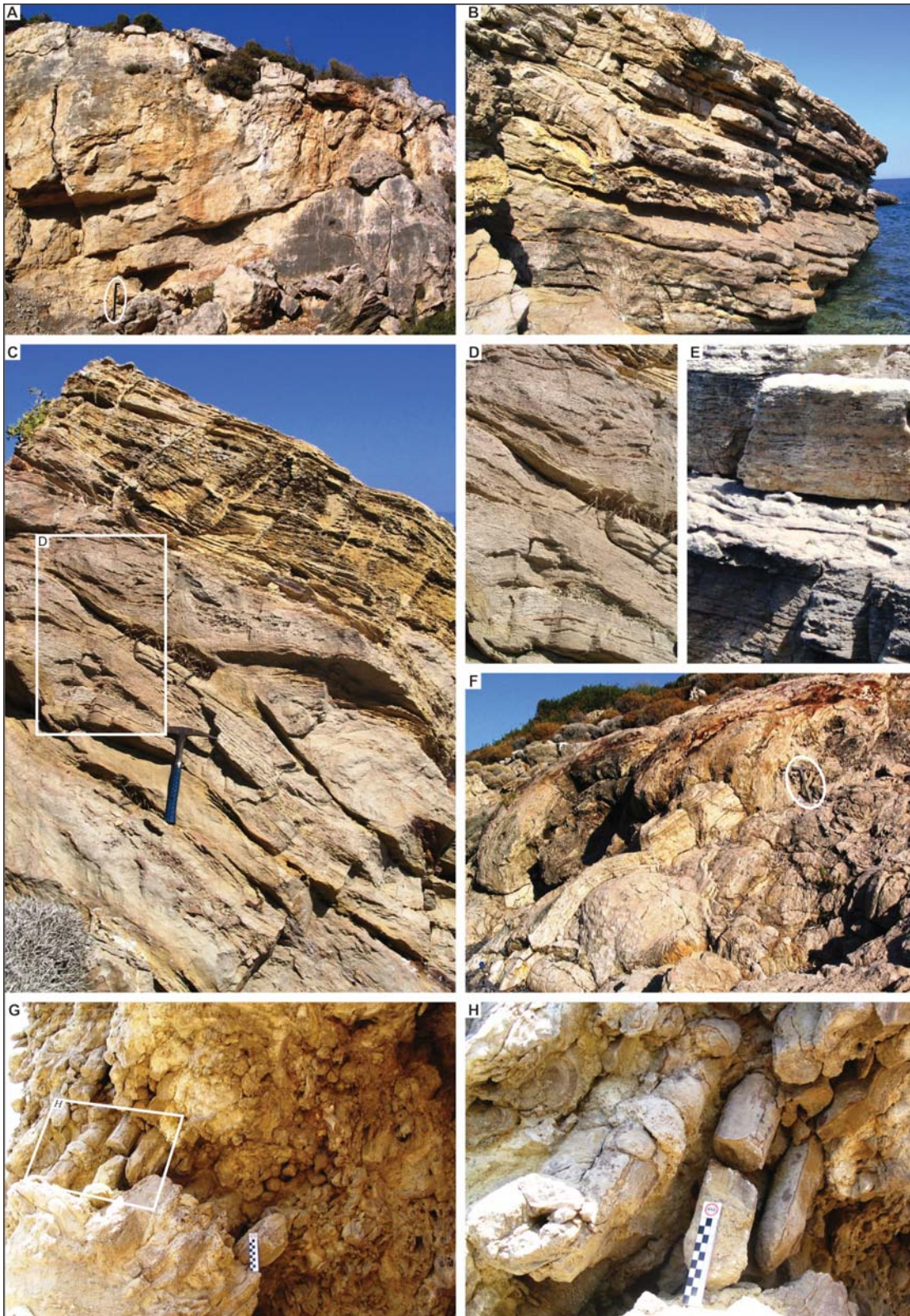


Figure 7- Specific rock type facies of the Yeniliman limestone. A) very thick undefined bedding, (Jacob stick 140 cm.); B) Planar, parallel, medium-thick bedding; C, D) stromatolith bioherm made up of undulated parallel alg laminae (hammer size 33 cm); E) fenestral spaces developed parallel to algal laminae; F) stromatolith bioherm with LLH morphotype; G, H) bioherm which columnar stromatoliths formed (scale 10 cm).

yellowish brown and fresh surface is dark brown, is formed by the columnar stromatolites with diameters exceeding 10 cm. Textural features such as; grain supported packaging without inter material and cementation with spar calcite indicates rudstone facies of Dunham (1962) (Figures 7g and h).

Yeniliman limestone rests on basement rocks by means of transgressive basement clastics in places where it laterally overcomes Salman alluvial deposits. NW trending faults that activated post sedimentation or re-activated around Bozköy and Tepeboz, have formed a contact between Yeniliman limestones and basement rocks burying Salman alluvial deposits. The first phase products of Karaburun volcanism (in spread areas) distinguish Yeniliman limestone from Aktepe member. Algal limestones within close vicinity of volcanic centers have been braided by pyroclastic rocks in base-surge and air-fall facies which emplaced before lava eruptions or by lava flows. In places, where the first phase volcanism is not available, the continuity of lake sedimentation is clearly observed between Yeniliman limestone and Aktepe member.

Algal limestone deposits have been formed by autochthonous stromatolites which developed on coastal part of the Lower Miocene perennial lake. Not to encounter oncoids (spheroidal stromatolites) which are mobile algal solvation products within the deposit reflects low energy conditions in which transportation or wave solvation has not sufficiently developed.

2.1.3. Aktepe Member

The sequence which is formed by tabular, parallel, fine to medium layered micritic limestone consists of algal limestone and diatomite interlayers (Figure 8a). The member took its name from Aktepe (N of Haseki village) (Figure 4).

Type locality is Aktepe vicinity and the thickness of the sedimentary sequence is more than 100 meters. The Aktepe sequence which forms the vertical continuation of Yeniliman limestone is distinguished by diatomite intralayers which occurred after the first phase Karaburun volcanites had intervened. The proportional relation between micritic limestone and diatomitic layers is variable within deposit. In addition to limestone dominant sections which bears diatomitic intralayer in decimeter thicknesses, there are limestone-diatomite alternations or diatomitic layers that have thin limestone layers-laminae (Figure 8b).

The sequence, which rests on first phase lava flow with transgressive overcome in SW Aktepe, begins with gray colored sandstone layer which is massive and carbonate cemented. Medium-coarse grained sandstone layer consists of white and thin mollusk gastropods, specifically in millimeter size. The overlying, pale yellow, disintegration colored massive mudstone sequence consists of tabular parallel, fine to medium layered, micritic limestone interlayers (Figure 4a). There is a 3 meter thick, red-yellow-green zoning, poorly consolidated, massive and laterally discontinuous mudstone layer at the bottom of sequence which overlies the first phase lava flow in NE Aktepe (Figure 4). The bottom section of the 7 meter thick sedimentary sequence cropping out Kömür Burnu surround is made up of siltstone-micritic limestone alternation (Figure 4). Limestone and diatomite intercalations made up of laminated stromatolites are observed in lower parts of fine to medium layered sequence which is dominant in micritic limestone which developed following fine clastic layers in mentioned localities. Algal limestone layers which become rare towards the upper parts are reddish brown and are distinctively medium to thick layered. Horizontal bands made up of branched algal fragments in millimeter and centimeter sizes, completely silicified layers and chert bands in thicknesses varying in between 5-15 cm are observed within horizontal layers. Diatomite facies is mostly laminated, with chert lenses as arranged parallel to lamination in centimeter size, and is white colored, poorly consolidated clayey in variable ratios (Figure 8b). White colored chert lenses in millimeter thicknesses are widespread in fine to medium layered micritic limestone facies which become dominant towards upper sections of the deposit.

Aktepe sequence which is observed in west of Düdükçü Tepe is relatively divided into lower and upper layers by the lava flow belonging to second phase of the Karaburun volcanism (Figure 4). Fluvial pebbles made up of small pebbles take place at the contact of lower limestone deposit with overlying lava flow. However, the bottom of upper limestone deposit ends with medium to fine layered limestones with whitish, pale gray, disintegration surface. At the bottom of this sequence, there is a massive, intensely bioturbated, yellowish pale brown, high carbonate cemented, fine to medium grained, transgressive sandstone layer with a thickness of more than 1 meter.

In north of Tepeboz village (Figure 6), with the emplacement of pyroclastics which the second phase Karaburun volcanism had produced, the depositional

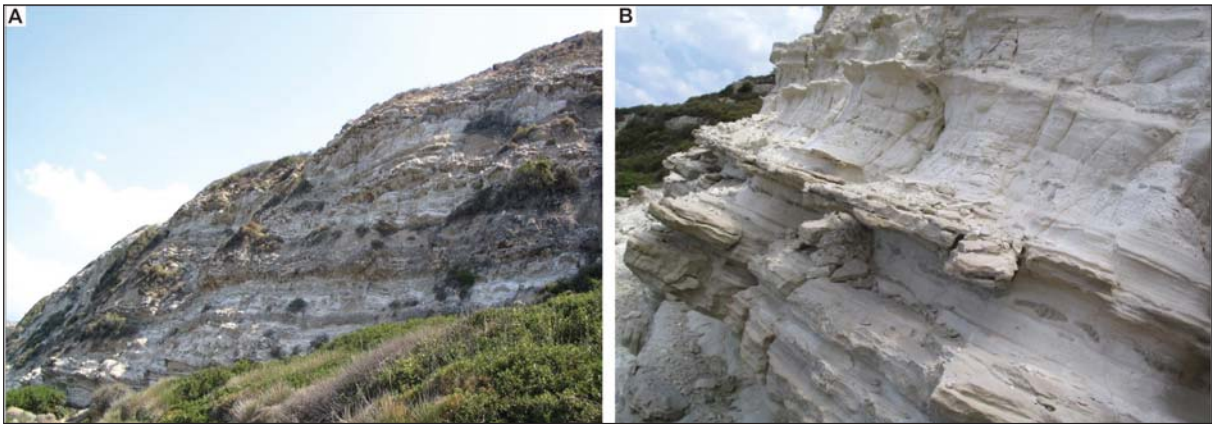


Figure 8- Aktepe member. A) General view, B) micritic limestone intercalations and clayey diatomite horizons covering chert lenses.

environment of the Aktepe limestone has become shallow and fine clastics between pyroclastics and the overlying lava flows have been deposited. The sequence of which its 3 meters can be observed consists of small mammal remnants belonging to MN4 biozone (*Cricetodon* sp., *Democricetodon* cf. *gracilis*, *Megacricetodon* cf. *bavaricus*) described by

Saraç (2003). This biozone is also composed of coarse sandstone-pebblestone intercalations, traces of bioturbation, nodular-laminar caliche formations, and claystone and siltstone layers bearing organic material in varying proportions (Figure 9). The pyroclastics of small volume lava eruptions which remain outside the spread area are overlain by

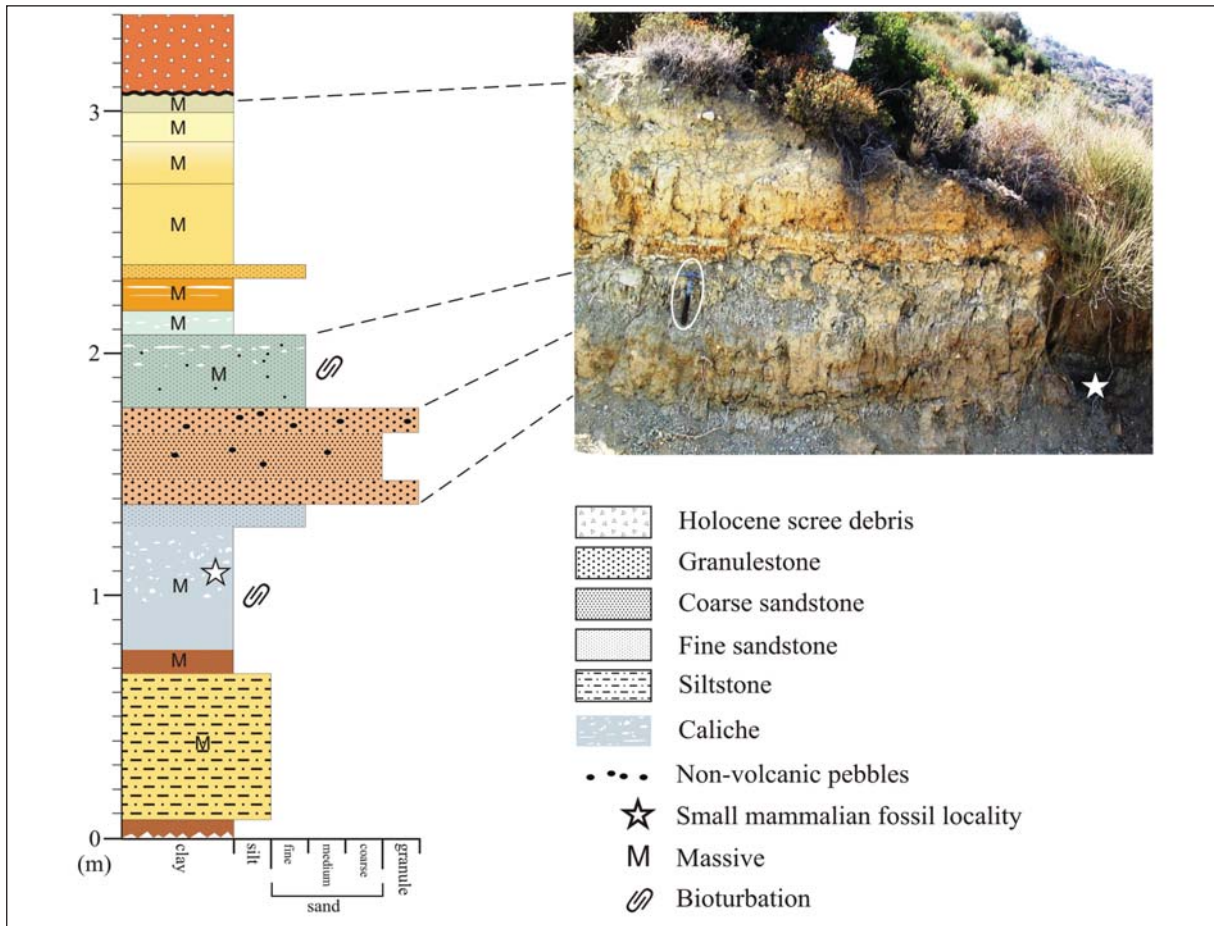


Figure 9- Measured section of the succession containing small mammal remnants belonging to MN4 biozone within Aktepe Member.

lacustrine deposits of the upper section of the Aktepe member. The upper part begins with silicified limestones which deformed by the fine to medium

layered and algal laminated diagenetic silica emplacement following the diatomite layers with green claystone intercalations (Figures 10b and c).

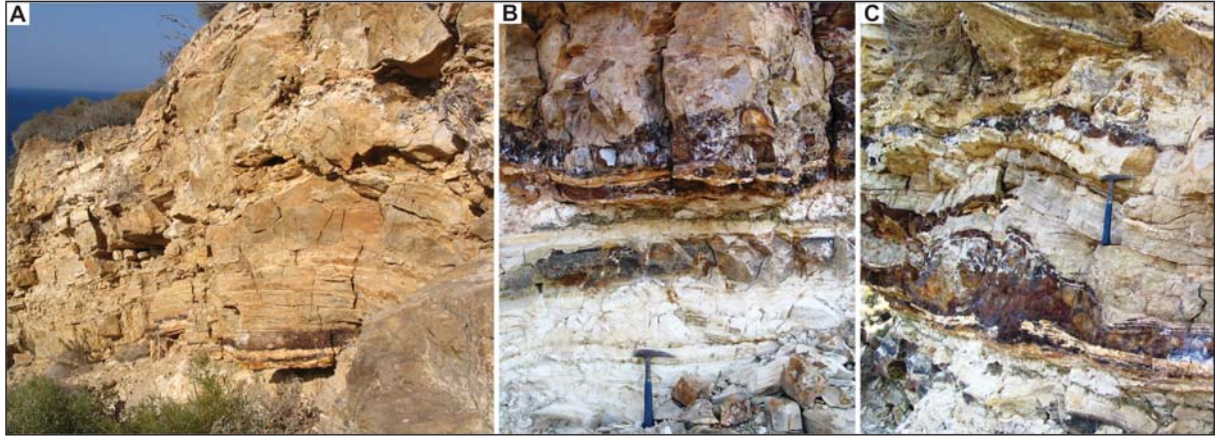


Figure 10- A) Upper section of the Aktepe member; B, C) at the bottom section of the upper part, chert bands in decimeter scale which caused diagenetic deformation in laminar stromatolithic limestones over cherty diatomite horizons take place.

During extensional phase which caused the occurrence of first phase Karaburun volcanism the basin was relatively deepened and Aktepe sequence was deposited in slowly changing environmental conditions from shallow areas where Yeniliman limestone had been deposited towards shoreface. The silica increase in medium which was approved by diatomite formation is related with volcanic exsolutions.

The sedimentary sequence can be correlated with Ovacık formation in Çeşme peninsula, defined by Göktaş (2010) in terms of general rock type composite consisting rock stratigraphic location and diatomite.

2.2. Hisarcık Formation

The unit is composed of claystone–siltstone dominant sequence intercalating with sandstone in bottom and limestones on top. Typical exposures of the sedimentary sequence reflecting Middle Eocene lacustrine deposition extends along the shoreline between NE Bozköy and Eşendere port which is outside the study area (Figure 1). The name of the formation was taken from Hisarcık district which is approximately 2 km’s to the northwest of Karaburun county center (Göktaş, 2014). The lower part of the sedimentary sequence of which its upper section had been eroded was studied within Karabağları member in the study area (Figure 4). The unit is the equivalent of “Çiftlik formation” which was described by Göktaş (2010) in Çeşme peninsula.

2.2.1. Karabağları Member

The sedimentary sequence is generally composed of green claystone-siltstone-sandstone-conglomerate. The name of the sub unit was taken from Karabağları location which is 1 km away from NE of Karaburun county center (Göktaş, 2014). The measured thickness of the sequence which is represented by a small outcrop is approximately 80 meters in the study area (Figure 4).

Karabağları member consists of claystone-siltstone-sandstone of which their relative proportions vary irregularly and conglomerate lithofacies in few amounts in the study area. Claystone and siltstone which forms the dominant rock type assemblage is generally green colored, carbonated, massive or tabular parallel, fine to medium layered and laminated. Sandstone interlayers are seldom encountered in decimeter thickness. Sandstone is mostly coarse grained, grain supported, well sorted and medium to fine consolidated. Trough like cross bedded, pebble stone and sandstone layers crop out in front of NW trending normal fault which is in contact with Yeniliman limestone (Figure 4). Main components are well rounded small pebbles and coarse grained sands.

Mammal faunas defined in Azmakdere member, which is the equivalent of the sub unit in Çeşme peninsula (Göktaş, 2010) and in equal horizons in Chios (Keramaria unit: Besenecker, 1973) belong to

MN5 biozone and are dated to 15 my (Besenecker, 1973; Bonis et al., 1998; Koufos, 2006). According to biochronological data based on lithostratigraphical correlation, it was accepted that sedimentation of Karabağları member had begun in Early Miocene the latest and mainly developed in Middle Miocene (Figure 3).

The contact between Aktepe member and the overlying Karabağları member is sharp and conformable. There was not observed any gap in deposition between the two consecutive shore-face sequences. It is clear that depositional conditions have suddenly changed and continental derived sediment transportation increased with the activation of boundary faults. Therefore, it was considered that the relation between the two units could be explained with paraconformity that had developed in submarine. The sedimentary sequence has decreased by erosion that had continued until today.

Green claystone-siltstone dominant sequence of the Karabağları member was deposited in lacustrine shore-face environment. Sandstone layers which take place among suspension layers and reflect deposition in high energy conditions indicate transportation by wave and currents, and reworking. Trough like, cross bedded sandstone-conglomerate assemblage that have paleoreduction colors were interpreted as the products of river transportation in submarine sections of delta fans flowing into lake.

2.3. Karaburun Volcanites

Pyroclastics of calc alkaline volcanism which were identified as evolved lithostratigraphically in two phases during Late Early Miocene and small scale lava flows were distinguished and studied under "Karaburun volcanites" title (Figure 11). The name "Karaburun volcanites", which was first given by Türkecan et al., (1988), was also embraced in this study as it had been in used in the study of Helvacı et al., (2009).

Karaburun volcanism which developed in Early Miocene basin formed synchronous products with lacustrine sedimentation within Haseki formation (Figure 12). Each phase shows a binary facies association mainly as pyroclastics at bottom and as lavas on top. The hydrovolcanic origin of the base-surge facies which symbolizes pyroclastics and this facies to contain limestone pieces which subjected to plastic deformation tells that the volcanism has started in submarine. The lavas can be correlated with mafic lava layers (Sarıyer member) distinguished by Kaya (1979) in lacustrine Zeytindağ formation which

is located in Foça peninsula. The timestratigraphic equivalent of first phase volcanites in Çeşme peninsula which is defined as early period product of the Armandağı volcanism (Türkecan et al., 1988) is the rhyolitic "Alaçatı tuff" (Göktaş, 2010).

Major element data related to 8 samples collected from Karaburun volcanites (Table 1) were plotted on TAS diagram of Le Bas et al., (1986). Hence, it was observed that 6 of them were in andesite region and 2 samples were in basaltic-andesite area (Figure 13a). All sub alkaline samples are calc alkaline in character. Samples which were studied in K_2O vs SiO_2 diagram of Le Maitre et al., (2002) cumulate in high potassium, basaltic andesite area (Figure 13b).

Textural and petrographical characteristics of lavas investigated are similar. The main phenocryst is olivine in samples that have hypocrystalline porphyritic texture (Figure 14a). Most of olivine phenocrysts and microphenocrysts were calcified (entirely in some places) starting from fractures and edges (Figure 14b). Plagioclase minerals are generally prismatic and show polysynthetic twinning. Pyroxene group minerals which are generally observed as microlites in the groundmass are brownish, of some are twinned and glomeroporphyritic in texture. The groundmass, which generally shows pilotaxitic and interstitial textures, is composed of plagioclase (Figures 14c and d), pyroxene and olivine microlites that are irregularly distributed or have less defined flow direction, and seldom volcanic glass components. Quartz crystals which are magmatically corroded, observed in most samples were surrounded by microlite and microcrystals of pyroxene (Figures 14e,f, g and h).

2.3.1. First Phase Volcanites

The first phase volcanites which are in the position of lateral discontinuity reference layer separating Yeniliman limestone and Aktepe member from each other in the generalized stratigraphy indicates the beginning of Neogene volcanism in Karaburun peninsula (Figures 4 and 12). A few meters thick pyroclastics which emplaced before lava eruptions are mainly in base surge and air fall facies. As a result of K/Ar radiometric dating analysis, 18.2 ± 1.0 my total rock age was determined in lavas (Table 2).

Yellowish gray, pale brownish-yellow colored pyroclastic sequence, which is observed over Yeniliman limestone in NW Aktepe, is about 5

Neogene Stratigraphy Of The Northern Part Of Karaburun Peninsula

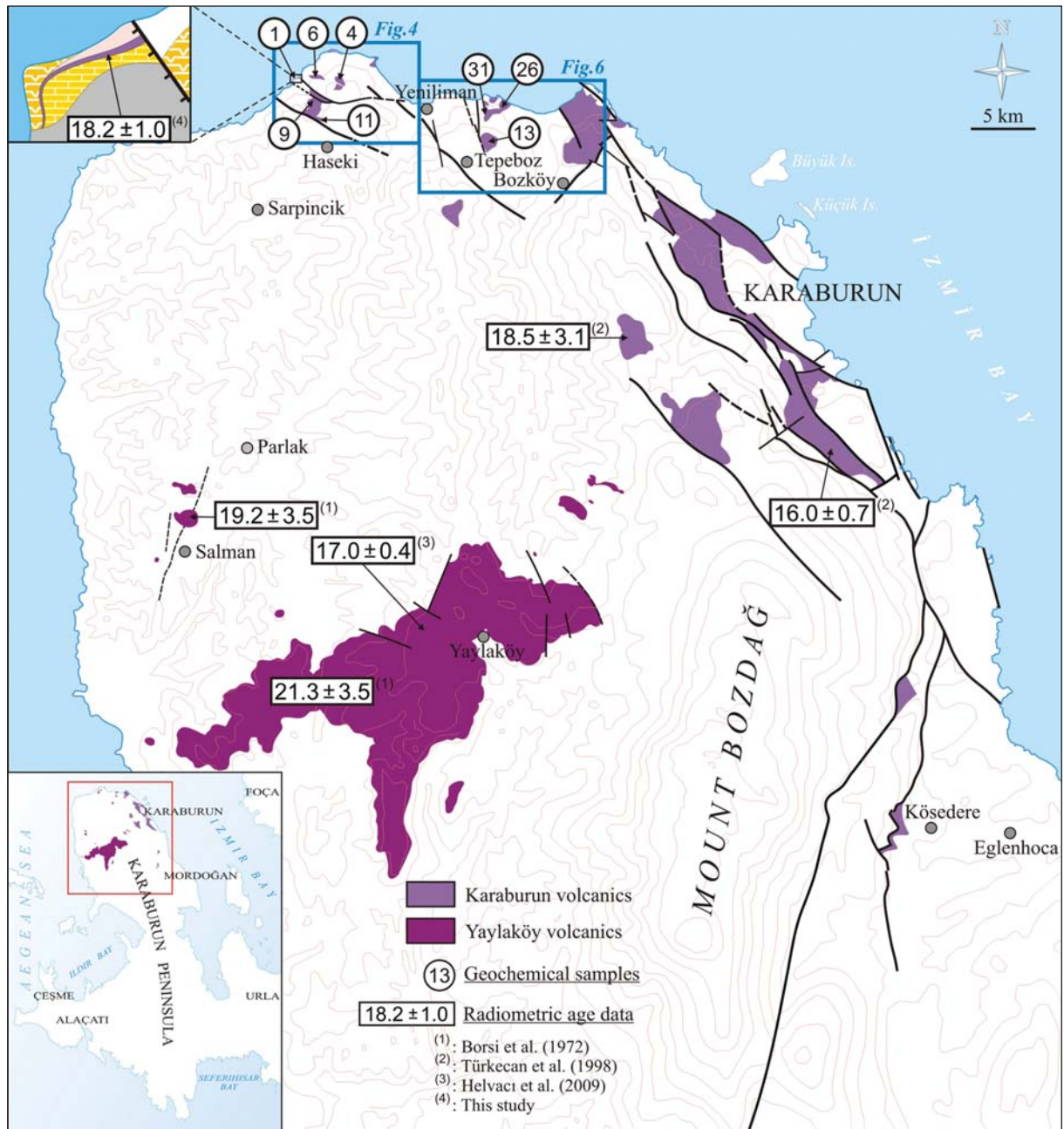


Figure 11- The distribution of mafic volcanites in northern section of the Karaburun peninsula.

Table 1- Results of major element analyses related to lava samples taken from Karaburun volcanites.

Sample	Coordinate	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MgO	CaO	Na ₂ O	K ₂ O	TiO ₂	P ₂ O ₅	MnO	SrO	BaO	L.O.I
1K	0448690E/4281115N	53.6	14.4	6.8	3.4	9.4	3.0	2.1	0.7	0.2	0.2	0.08	0.08	5.85
4K	0449415E/4281065N	56.4	16.4	7.1	5.2	6.5	3.4	2.1	0.7	0.3	0.2	0.08	0.08	1.45
6K	0449072E/4280155N	54.9	15.8	7.6	6.0	7.2	3.3	1.8	0.7	0.3	0.1	0.07	0.08	1.60
9K	0449088E/4280757N	53.5	14.9	6.9	2.8	9.3	3.0	2.2	0.7	0.3	0.1	0.08	0.08	5.80
11K	0449140E/4280285N	53.4	14.7	6.9	3.3	9.3	2.9	2.2	0.7	0.2	0.1	0.08	0.08	5.80
13K	0452355E/4279932N	55.4	16.4	7.2	4.2	8.1	3.2	2.1	0.6	0.2	0.1	0.07	0.07	2.05
26K	0452715E/4280655N	54.8	16.4	7.5	5.3	7.6	3.2	2.0	0.7	0.2	0.2	0.07	<0.01	1.85
31K	0452320E/4280265N	56.4	16.2	6.9	3.2	7.2	3.6	2.3	0.6	0.3	0.1	0.09	0.11	2.60



Figure 14- Microphotos reflecting mineralogical and petrographical characteristics of Karaburun volcanites. A) Hypocrystalline porphyric texture in which olivine phenocrysts and oriented plagioclase microliths are observed; B) Calcification in euhedral olivine phenocryst; C, D) orientation and glomeroporphyritic texture in plagioclase microliths and microphenocrysts (C: cross nicol; D: planenicol); E, F, G, H) Quartz crystals which subjected to magmatic corrosion were occasionally surrounded by radiate acicular or anhedral pyroxene microliths.

meters thick and composed of base surge at bottom (3 m) and air fall deposits (2 m) on top (Figure 15). The base surge layer is made up of tuff layers by which pyrogene material in centimeter to decimeter thicknesses with a size of coarse ash-lapilli was formed and seldom consists of blastic lava clasts (Figure 16a). Lapilli size components forming air fall layer that has indefinite bedding are angular and grain supported. Lava flow with a thickness of 7 meters located on the sequence has widespread gaseous voids. Calcite and chalcedony infillings are observed in some voids which display flow oriented lensoidal sections.

The volcanic sequence in NE of Aktepe begins with about 3 meters thick pyroclastics. The uppermost section of the pyroclastic sequence is composed of air fall layers in decimeter thicknesses. Along the 1 meter thick bottom section of the overlying lava flow, typical red colored, agglutinated spatter lava layer is located because of thermal oxidation. Lava fragments in decimeter size have dense gas voids. However, the overlying blackish lava flow has a flow foliation (Figure 16b).

2.3.2. Second Phase Volcanites

The second phase volcanites which were emplaced as synchronous with the sedimentation into Aktepe member is composed of pyroclastic at bottom and lava layers on top (Figures 4 and 12).

The pyroclastic sequence which is formed by base surge, air fall and ash fall facies is thicker compared to previous phase. Type locality is about 1 km away from NE of Tepeboz village (Figure 6). Fine clastic sequence which is 3 meters thick located in between pyroclastics and the overlying lava flow reflects volcanic inactivity between the pyroclastic

emplacement and lava eruption (Figure 12b). Yellowish, pale gray colored pyroclastic sequence is formed by the tabular, parallel, and fine to medium layered, coarse ash tuff-lapilli tuffassemblage (Figure 17A). The thickness of thin ash-tuff layers in ash fall facies reducing down to 1 cm. pyroclastic flow structures in base surge deposits are seldom observed (Figure 17b). Lapilli tuff layers, consisting of angular to sub angular, centimeter sized porous/non-porous mafic pyroclastics were interpreted as air fall deposit. Air fall deposits varyin between 10 to 60 cm, completely massive and are specifically grain supported (Figure 17c). However, ballistic lava fragments are seldom (Figure 17d and e). Beside homogenous lava clastics, fragments transferred from previously emplaced pyroclastics and hydrated limestones are observed. The plastic deformation observed in the fragments of silicified limestone which was subjected to thermal oxidation (Figure 17f) supports that pyroclastic emplacement is synchronous with sedimentation. Both physical and petrographical characteristics of second phase lavas resemble to previous phases.

3. Stratigraphical and Paleogeographical Evolution

In studies related to mammal biostratigraphy carried out in Lower Miocene basin fills within scope of Aegean collapse, the faunal assessment below MN3 biozone was not made (according to Steininger, 1999; between 18-20,5 my) (Manisa-Beydere fauna: Dönmez et al., 1993; Menemen-Bozalan fauna: Saraç, 2003; Bornova-Sabuncubeli fauna: Bruijn et al., 2006). Borsi et al., (1972) took K/Ar ages (21.3-19.2 my) from mafic lavas which cut as syn sedimentary and overlie deposits of Salman formation around Yaylaköy. These data not only make a specific approach to the beginning of

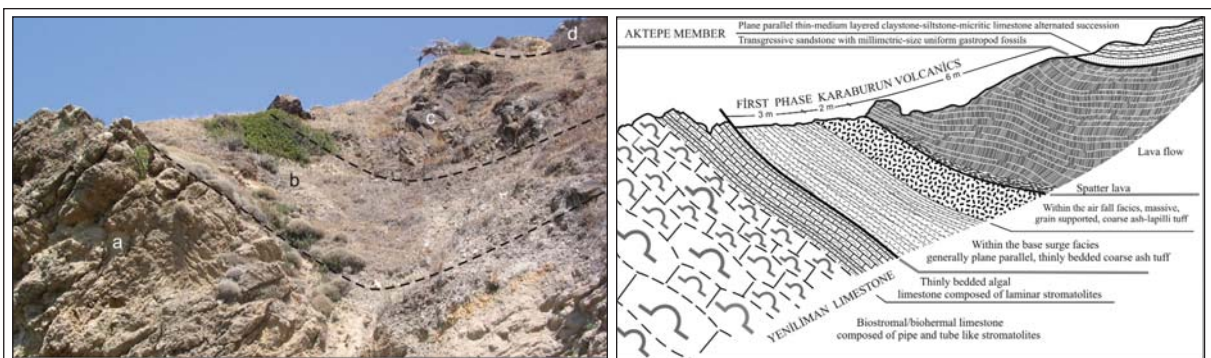


Figure 15- First stage Karaburun microliths located between Yeniliman limestone and Aktepe member. a) Yeniliman limestone, b) pyroclastic deposit, c) lava, d) Aktepe member.

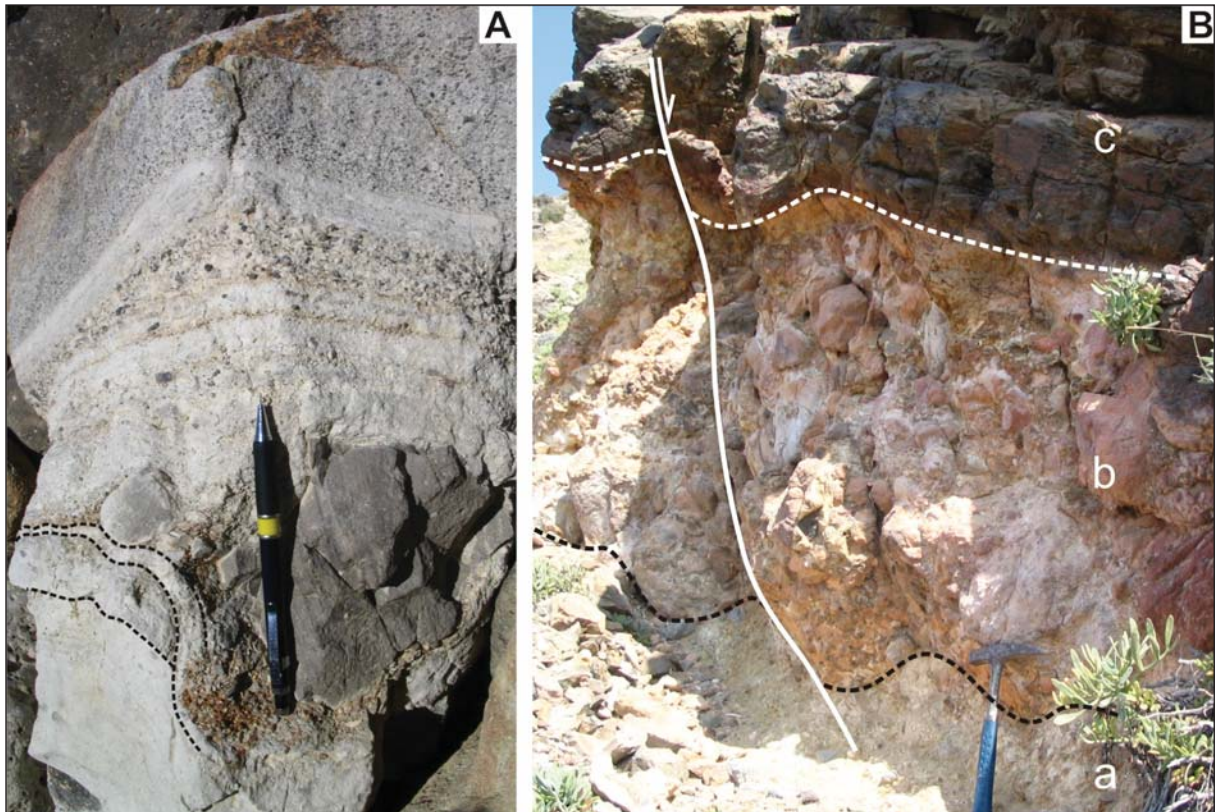


Figure 16- First stage Karaburun volcanites exposing in NE Aktepe, A) ballistic lava clasts observed in base surge deposits; B) vertical order of volcanic facies' developed from explosion stage to lava flow stage: a) back fall deposits. B) spatter lava horizon which lava fountain generated, c) Flow layered lava horizon.

sedimentation but also is not sufficiently reliable as it consists of high error margin (± 3.5 my). K/Ar dating obtained (17.0 my) by Helvacı et al., (2009) from the same lavas in the area probably reflects the second phase of Yaylaköy volcanism (which is known as 2 phased from previous studies). First phase Karaburun volcanites in which K/Ar age was taken as 18.2 ± 1.0 my in this study shows the beginning of calc alkaline Neogene volcanism in NE Karaburun volcanites (Figure 11).

In the study area, Early Miocene deposition begins with alluvial fan deposits of the Salman member which was emplaced with an angular unconformity over basement rocks. This deposit is defined by the algal biostromal Yeniliman limestone. Organosedimentary limestone sequence deposited in the vicinity of a “stable” and “open” lacustrine was formed by spreads of stromatolitic algal. Lateral and vertical continuities of autochthonous stromatolites reflect shallow and low energy depositional environments of the shore-line with routine bathymetry. The shore-face and off-shore of the lake or open lacustrine deposits are partly observed in

Foça peninsula but are mainly submerged in the Aegean Sea.

During the extensional phase, the development of syn-sedimentary emplacement of the first phase Karaburun volcanites over algal limestone platform has occurred. During this phase, the depositional environment (from off-shore to shore-face) has become relatively deeper and Aktepe member has conformably and transitionally been deposited over Yeniliman limestone during continuous lacustrine deposition. Diatomitic interlayers were deposited depending on the increase in volcanogenic silica as algal limestone interlayers in the dominant fine layered/laminated, micritic limestone of the Aktepe member becomes less in upward direction.

Early Miocene basin spreaded over much larger areas than Foça depression in which Haseki formation and regional equivalences had been deposited (Kaya, 1979). Over structural blocks which limit the depressional area (Karaburun height on west and Yamanlar height on east), relatively Lower

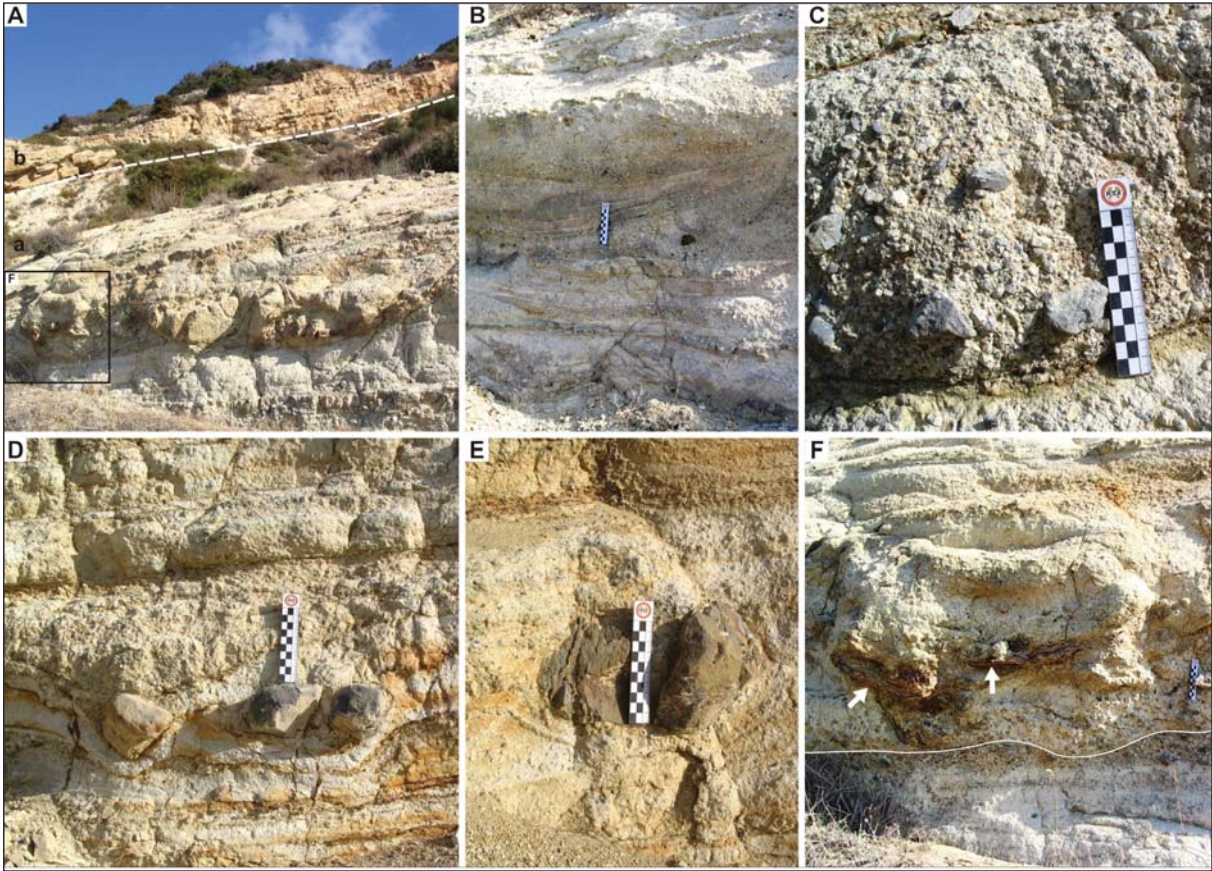


Figure 17- Second stage pyroclastics, A) General view; a) pyroclastic deposit, b) Aktepe member “upper section”, B) sections which display pyroclastic flow structure of base surge deposits; C) back fall deposit; D, E) Ballistic lava clasts; F) Limestone pieces which subjected to plastic deformation.

Miocene erosion residual deposits are located (Aras et al., 1999; Çakmakoglu et al., 2013; Dönmez et al., 1993). As it is understood from the distribution of alluvial and lacustrine deposits in Karaburun peninsula, the Bozdağ which rises in Great Early Miocene Lake in coastal Aegean region (Figure 1) was as in similar position as today. Probably; towards the end of Early Miocene, the Foça depression that occurred in Early Miocene basin by remodeling of Karaburun and Yamanlar heights has then transformed into a basin in which Middle Miocene lacustrine deposition had developed. In other words, Early Miocene lacustrine deposition has continued during Middle Miocene following the unconformity related with the formation of Foça depression.

4. Results

Continental Lower-Middle Miocene deposits and Lower Miocene volcanites in the north of Karaburun peninsula, which had not been previously investigated, were distinguished the first time.

Lithofacial characteristics were described within generalized stratigraphic order classifying sequences as group, formation and member, and their environmental characteristics were studied. In doing so, the regional correlation of these rock units was tested.

It was determined that, the Early-Middle Miocene sedimentation which was divided into 2 formations within the scope of Karaburun group, began to deposit with alluvial fan deposits and developed dominantly in lacustrine environment. It was also detected that; small size, first products of the Karaburun volcanism were emplaced between algal biostromal Yeniliman limestone deposited on the shore of Early Miocene lake and on the micritic limestone dominating shore-face sequence of Aktepe member. It was interpreted that, the silica which formed diatomite and cherts in Aktepe member was originated from this volcanism. It was suggested that the lacustrine sedimentation against disconformity between the shore-faces of Aktepe member and the

overlying Karabağları member were not interrupted and continued at least during Middle Miocene.

Karaburun volcanism which developed during the deposition of Haseki formation was activated in two phases and each phase was formed by pyroclastic facies at bottom and by lava facies at top. The first phase reflecting the beginning of Neogene volcanism in Karaburun peninsula was dated as 18.2 ± 1.0 my by K/Ar method. Hydrovolcanic pyroclastic rocks in base-surge facies which quotes lava eruptions and reflects that the volcanism has begun in submarine was first described and distinguished as a member on map scale. Petrographical and geochemical analyses of lavas which are outside the area in previous studies were carried out. Olivine-phyritic textured lavas were named as andesite based on total alkaline-silica contents and it was shown that they took place within high potassium calc alkaline series.

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