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NEOGENE STRATIGRAPHY AND PALEO GEOGRAPHIC EVOLUTION OF THE KARABURUN AREA, İZMİR, WESTERN TURKEY

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ABSTRACT

Keywords:
Karaburun Peninsula,
Neogene stratigraphy,
Neogene volcanism,
paleogeography,
K/Ar geochronology.

The western margin of the Foça Depression (FD) is located in the NE of the Karaburun Peninsula. Terrestrial Neogene sediments in the study area which partly representing the western margin of the FD and the mafic volcanics have NW-SE directions towards İzmir bay and are separated from the basement rocks by synthetic normal faults. During the Miocene deposition the basin's boundaries became structurally narrower and two main sedimentary successions have been defined namely the Karaburun group and the Eşendere group which have been separated with angular unconformity in regional scale. The Karaburun group is represented with dominantly lacustrine deposition in Early-Middle Miocene period that includes Haseki and Hisarcık formations and Karaburun volcanics. The Lower Miocene Haseki formation is represented by the Salman member developed in the alluvial fan environment and lacustrine deposits of algal-biostromal Yeniliman limestone and micritic limestone dominated Aktepe member. NW trending basin margin faults which formed a boundary between Karaburun high and the FD and caused the effective second stages of mafic volcanism did not interrupt the lacustrine deposition at the beginning of the Early Miocene. But it caused relative deepening of the basin, changed depositional conditions and lacustrine sedimentation continued with the Hisarcık formation. The activity shaping the FD from the western part and partly coinciding with the Early Miocene basin margin faults has been documented with the unconformity showing no time gap between Haseki and Hisarcık formations. Hacıhüseyintepe member has unconformity with the lavas that represent the second stage of Karaburun volcanics and laterally passes into the Karabağları member. The Karabağları member consists of green coloured lacustrine shoreface sediments which lie on the Aktepe succession with sublacustrine paraconformity. Değirmentepe limestone transitionally lies on the top and it is the last member of the Karaburun group. Eşendere group lies on the Hisarcık formation with regional scale angular unconformity and presents the Late Miocene-early Early Pliocene(?) sedimentation grading from alluvial fan deposits of the Saip formation to lacustrine Çukurcak limestone. Calc-alkaline Karaburun volcanism which is represented with potassium rich andesitic products has three stages that laterally connected with the Early Miocene-early Middle Miocene deposition. The first two stages have dual facies namely, pyroclastics at the base and lavas on the top. The first stage products are laterally discontinuous reference level that is separating Yeniliman limestone and Aktepe member. Second stage products are in/on the Aktepe member. The third stage lava flows are dated as K/Ar 16.0±1.3 Ma age which is thought to be located at the bottom of the Değirmentepe limestone that is the last member of the Karaburun group.

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1. Introduction

The purpose of this study was to prepare 1/25000 scale geological map and study the stratigraphic and paleogeographic evolution of the terrestrial Neogene sediments and volcanics along the NE margin of the Karaburun Peninsula (Figure 1). In the study area

there has not been any previous work dealing with the same topic but there have been numbers of previous work. Some important of these previous geological work as it has been listed in Çakmaköğlu and Bilgin (2006) are mainly related to the Pre-Neogene rock units. Previous work for Neogene units are, for magmatism (Innocenti and Mazzuoli, 1972;

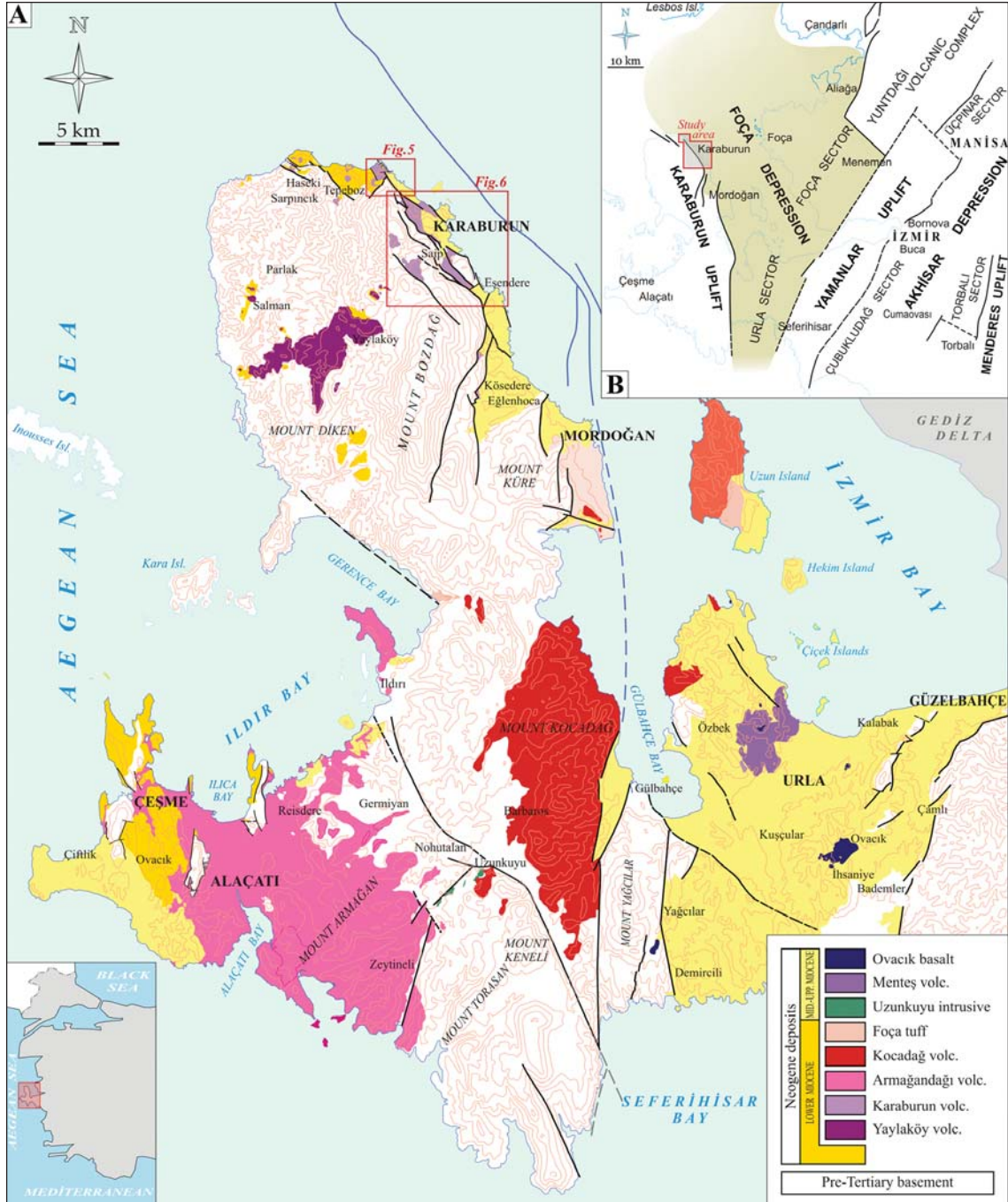


Figure 1- The location of study area (A) and its position in the Foça depression (B; modified from Kaya, 1979). The submarine faults at the east of Karaburun Peninsula are taken from Aksu et al. (1987).

Borsi et al., 1972; Türkecan et al., 1998; Helvacı et al., 2009; Agostini et al., 2010), for tectono-stratigraphy (Kaya, 1978; 1979; 1981) and for Cenozoic structural evolution of the region (Uzel et al., 2013) (Figure 2). Aras et al. (1999) and Çakmaköğlü et al. (2013) studied economic potential of the Early Miocene clays in the northern part of the peninsula around Salman village. They studied and mapped preliminary products of Early Miocene sedimentations, Yaylaköy volcanics and their lithostratigraphical connections. Türkecan et al. (1998) and Helvacı et al. (2009) proposed a generalized stratigraphic column. In this succession it was indicated that Neogene sedimentations and the volcanics in the Karaburun Peninsula show lateral connected developments from base to the top. In these studies, lithostratigraphy was not studied in detail and sedimentary rock units and their lateral-vertical relations with the multi stage volcanics were also not studied enough, the relative stratigraphic connections have been re-constructed with the radiometric age data.

2. General Geology

Terrestrial Tertiary sedimentation and volcanism in the Karaburun Peninsula are represented with Neogene rock units. It is considered that the area has been subjected to deformations and erosions during the time interval between tectonic emplacement of the İzmir flysch (Öngür, 1972; Eşder, 1988; Çakmaköğlü ve Bilgin, 2006) and the development of the Early Miocene basin. In the study area Çakmaköğlü and Bilgin (2006) defined the Carboniferous-Silurian Dikendağı formation, Ladinian Camiboğazı formation, Rhaetian-Carnian, Güvercinlik Formation and Late Cretaceous-Early Tertiary İzmir flysch basement rocks (Figure 3). They all have angular unconformity contact relations with the Miocene sediments. In general the faults which developed or became active after sedimentation have marked the present day lithological boundaries. In the NE part of the peninsula Miocene sediments and volcanics have extended in a step faulting zone with NW-SE, 50°-80° NE trend. Ersoy et al. (2006) and

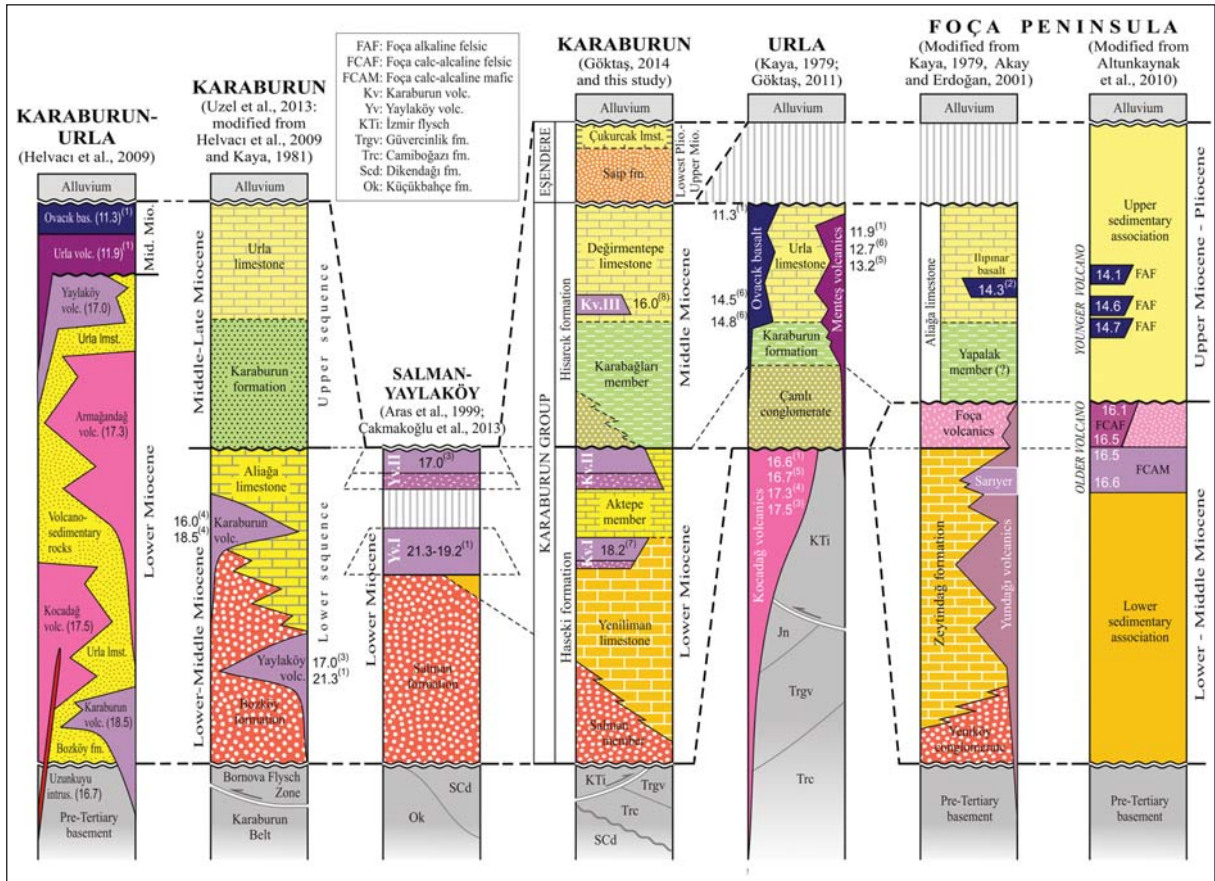


Figure 2- Correlation of generalized Neogene stratigraphies proposed for Foça Depression and Karaburun Uplift. ⁽¹⁾Borsi et al. (1972), ⁽²⁾Ercan et al. (1997), ⁽³⁾Helvacı et al. (2009), ⁽⁴⁾Türkecan et al. (1998), ⁽⁵⁾Karacık et al. (2013), ⁽⁶⁾Göktaş (2011), ⁽⁷⁾Göktaş (2014), ⁽⁸⁾This study.

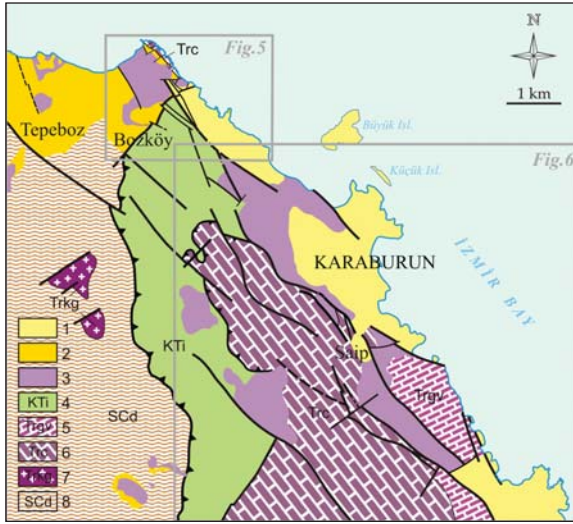


Figure 3- Geological map of the pre-Tertiary rock units in the study area (modified after Çakmakoğlu and Bilgin, 2006). 1) Middle-Upper Miocene deposits, 2) Lower Miocene deposits, 3) Karaburun volcanics, 4) İzmir flysch, 5) Güvercinlik fm., 6) Camiboğazı fm., 7) Karaburun granodiorite, 8) Dikendağı fm.

Uzel et al. (2013) defined this zone as ‘Karaburun fault zone’. They are normal faults with oblique displacements and have over 75° dip angles (Mean rake is 60° W).

The calc-alkaline ~16-18 Ma volcanism in the Karaburun Peninsula is represented with “Karaburun” (olivine bearing andesites and shoshonites), “Yaylaköy”, “Armağandağı”, “Kocadağ” (high potassium bearing andesites, dacites and latites) volcanics.

3. Neogene Stratigraphy

In the study area wide spread Early-Middle Miocene lacustrine deposits and laterally associated mafic volcanics have been defined as the Karaburun group. Eşendere group from base to top consists of alluvial fan and lacustrine deposits and overlies the Karaburun group with angular unconformity. Eşendere group represents Late Miocene-early Early Pliocene(?) sedimentations (Figure 4).

3.1. Karaburun Group

Karaburun group is the chronostratigraphic equivalent of the Çeşme group (Göktaş 2010) in Çeşme Peninsula. Karaburun group consist of Haseki and Hisarcık formations and Karaburun volcanics

(KV). The Lower Miocene Haseki formation and Middle Miocene Hisarcık formation have been separated by an uncoformity which has not caused sedimentation interruption. As they deposited in the same basin in a superimposed manner so they were included into the Karaburun group. As Haseki formation have been explained in detail in the Göktaş (2014), here details of the Hisarcık formation and Eşendere group will be given.

3.1.1. Haseki Formation

Haseki formation starts with alluvial fan/delta deposits (*Salman member*) and predominantly consists of lacustrine deposits of Yeniliman limestone and Aktepe member (Göktaş 2014). First two stages of the Karaburun volcanisms (KV1 and KV2) are within the lacustrine sediments. KV1 lavas separating Yeniliman limestone and Aktepe member is considered to be a reference level. KV2 products are placed on to the top of the Aktepe successions. In the Karaburun Peninsula that during the sedimentation of the Salman member and Yeniliman limestones and it’s equivalents, Neogene volcanisms had not yet started. Although related geochronological (Borsi et al., 1972; Helvacı et al., 2009; Göktaş 2014) and biochronological (Saraç, 2003) data strongly indicates late Early Miocene, but it has been accepted that in a general sense sedimentation of the Haseki Formation developed in Early Miocene (Figure 4).

Salman member: Salman member is the base of the terrestrial Neogene sedimentations, representing Early Miocene basin margin sedimentations. In the study area overlying Yeniliman limestone from bottom to the top has laterally interfingering of red-claret coloured alluvial fan depositions. It is reported that it was marked as fan delta sedimentation around Salman village (Çakmakoğlu et al., 2013). The succession sedimented on to the basement rocks with an angular unconformity and consists mainly of gravelstone, sandstone and with limited amounts of mudstone. Around Bozköy in the main part most of the proximal sediments have been eroded. So in the study area the unit is mainly represented with braided stream deposits, characterizing medial parts of the alluvial fans (Figure 5).

Yeniliman Limestone: Yeniliman limestone consists of algal-biostromal limestones deposited nearshore the Early Miocene lake. Biogenic limestones shaped by locally growing stratiform stromatolites and generally have 100-30 cm thick beddings, locally 30-

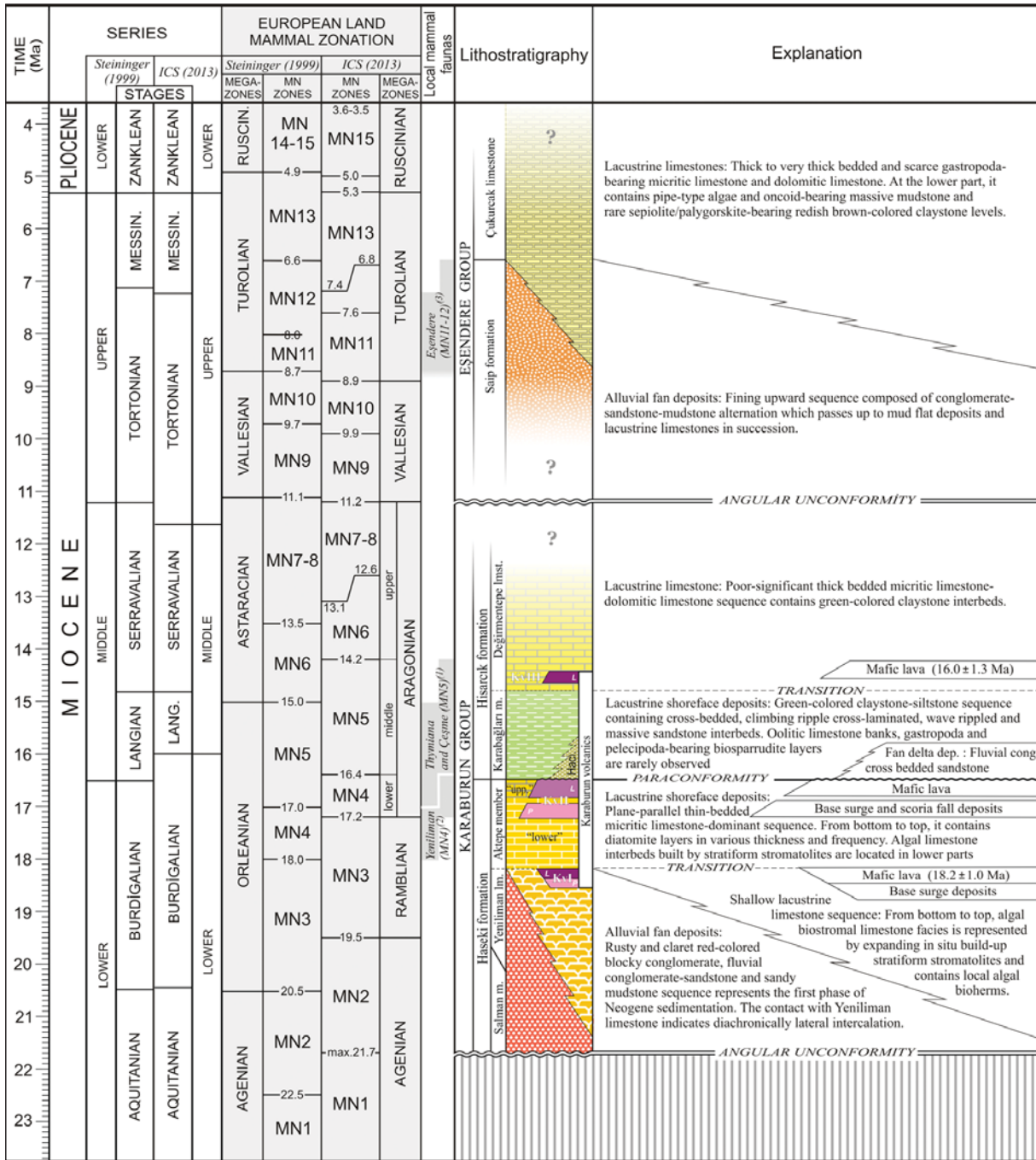


Figure 4- Generalized stratigraphic section of the study area. ⁽¹⁾Besenecker (1973), ⁽²⁾Saraç (2003), ⁽³⁾Kaya et al. (2005). Kv: Karaburun volcanics. L: Lava, P: Pyroclastic.

10 cm or very thick (>100 cm) algal laminated and plane-parallel beddings. Outcrops are mainly in the northern part of Bozköy (Figure 5). The subunit could be correlated with the Şifne formation, defined by Göktaş (2010) in the Çeşme Peninsula.

Aktepe Member: Aktepe member reflects continuation of lacustrine sedimentation outside the

KV1 products spread area. It has been marked by micritic limestones with parallel thin-medium thick beddings. Main outcrops are near the NE of Bozköy. With the emplacement of the KV1 products, the basin gradually became deeper and Aktepe succession with diatomite interbeds has been deposited (Göktaş 2014). KV2 and Aktepe sedimentations are coeval and KV2 products relatively divide the Aktepe

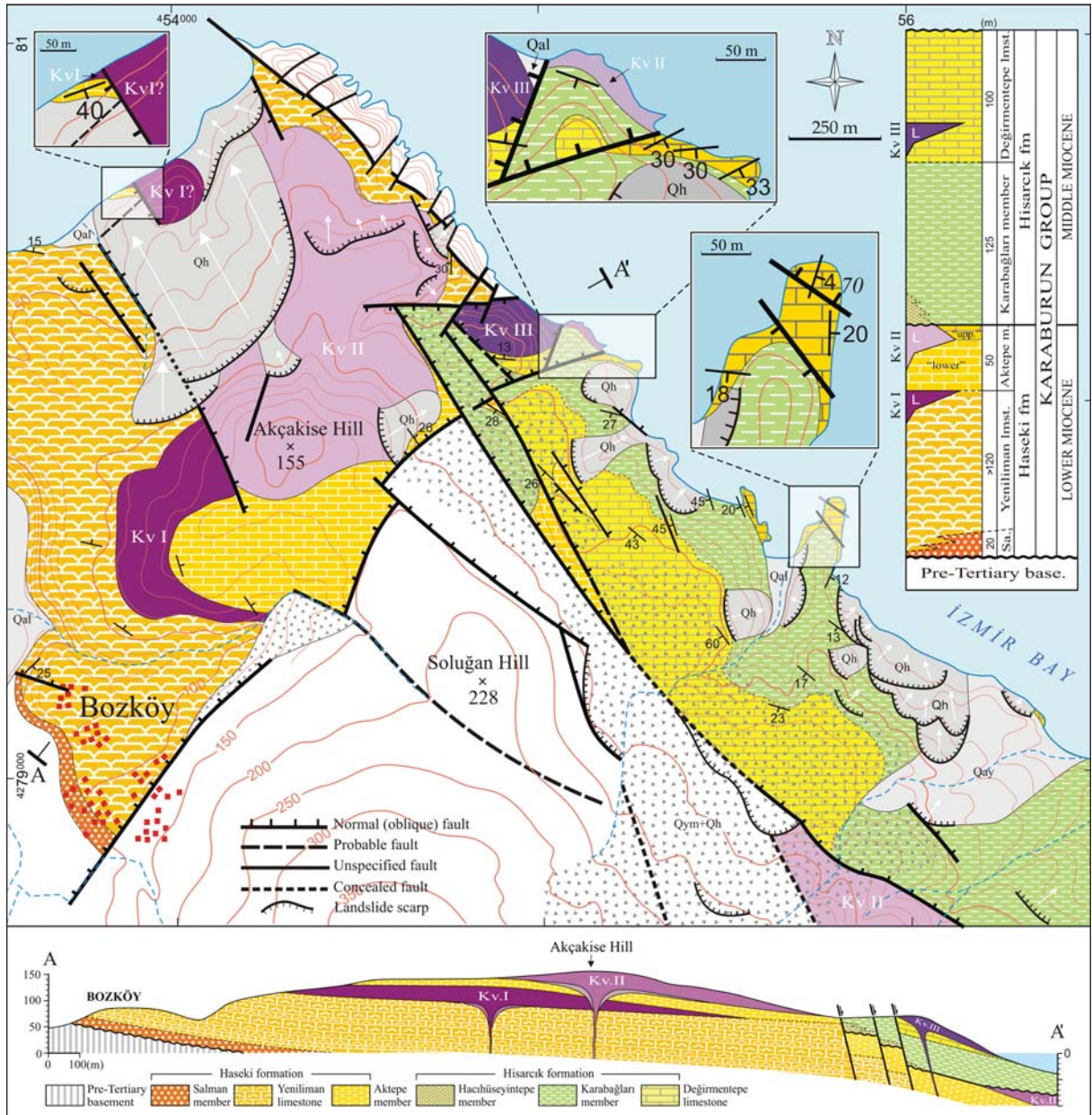


Figure 5- Geological map of Bozköy area. Qal: Alluvium, Qay: Alluvial fan deposits, Qh: Landslide debris, Qym: Scree deposits, Ky: Karaburun volcanics, L: Lava.

succession into ‘lower’ and ‘upper’ parts (Figure 4). The subunit, lithostratigraphically equivalent of the Ovacık formation (Göktaş, 2010) defined in the Çeşme Peninsula. Saraç (2003) defined some small mammal fossils belong to the MN4 biozone in the fine grained parts in the unit cropping out in the north of Tepeboz village (Göktaş, 2014). According to ICS 2013, MN4 biozone corresponding Aragonian is limited by 16.4 Ma-17.2 Ma (Figure 4).

3.1.2. Hisarcık Formation

In a general sense the succession reflects Middle Miocene lacustrine sedimentations and starts with basin margin type pebblestone-sandstone assemblage of the Hacıhüseyintepe member. With lateral-vertical transitions on the top it has lacustrine shoreface succession mainly consisting of green claystone-siltstone assemblage with sandstone interbeds which have been defined as the Karabağları member. The

sedimentary succession ends with the Değirmen-tepe limestone reflecting the final stage of lacustrine deposition. The Hisarcık formation name was first used by Göktaş (2014). Hisarcık is a quarter about 2 km NW of the Karaburun town centre (Figure 6). The sediments crop out in the area between Eşendere and to the NE of Bozköy (Figures 5, 6).

Lacustrine sediments of the Hisarcık formation are the equivalent of the Çiftlik formation in the Çeşme Peninsula (Göktaş 2010). The lower part of the Çiftlik formation has fine grained shoreface sediments of the Azmakdere member. In the Chios Island the equivalent of the Azmakdere member is the 'Keramaria unit' defined by Besenecker (1973). In the Keramaria unit defined 'Thymiana mammal fauna' have been indicating MN5 biozone. According to Bonis et al. (1998) and Koufos (2006) it gives 15.5 Ma age for the Thymiana fauna (Figure 4). From the points of stratigraphic position and lithological similarity the Karabağları member is considered to be the equivalent of the Keramaria and Azmakdere successions which have Early Middle Miocene mammal fossils. There has not been any data available indicating upper time limit of the sedimentation in the Middle Miocene.

Haseki formation and KV2 in the Karaburun Peninsula, Foça tuffs in Foça Peninsula and in Uzun Island, Kocadağ volcanics, Güvercinlik formation and İzmir flysch in the Urla depression, overlaid by Hisarcık formation and the equivalents (present the Middle Miocene sedimentation around FD) with unconformity (Göktaş, 2010, 2011, 2014 and the references therein). The contact with the overlying Eşendere sediments is marked with the Late Miocene angular unconformity.

In the Foça Peninsula the 'Aliğa limestone' (Kaya, 1979, 1981; Dönmez et al., 1998) and it's equivalent 'the Çamdağ limestone' (Eşder et al 1991) may be correlated with the lacustrine deposits of the Hisarcık formation. 'Çamlı conglomerate + Karaburun unit + Urla limestone' (Kaya, 1979, 1981), 'Çamlı formation + Bozavlu formation + Urla limestone' (Sümer 2007) which described in the Urla depression are total equivalents of the Hisarcık Formation.

Hacıhüseyintepe Member: The subunit consists of basin margin gravelstone-sandstones assemblage. The name has being used first time in this study. Hacıhüseyintepe is a hill to the NW part of the Karaburun town centre (Figure 6).

Mapable outcrops are in the western part of the town centre. Visible thickness is about 75 m.

The faults have limited the spread of the Hisarcık formation and have caused post-sedimentary vertical displacements so proximal sediments on the footwall blocks have been totally eroded and sediments on the hangingwall blocks have been covered by younger sediments. Thereof, in the study area subunits have limited outcrops. The outcrops of the member in the west of Hacıhüseyin Hill have laterally limited spread on the hangingwall block of the N10°W trending reactivated(?) boundary fault zone. Around the NE of the Hisarcık quarter the alluvial fan and possible beach sediments cropping out under the scree debris have not been mapped.

At the type locality they have assemblage of fluvial pebblestone-pebbly sandstones consist of well rounded pebbles and coarse sands. They display cross bedded or massive channel fills have greenish gray colours and are weakly compacted. The coarse grained sandstones are cropping out in the NE of the Hisarcık quarter are light gray coloured, grain supported, well sorted and weakly compacted. The sandstones have very low-angle large-scale cross beds also consist of granule series which are suitable for cross-bedding.

Alluvial deposits in front of the boundary faults are overlying KV2 with unconformity. The observed structural contact between the KV2 which is on the footwall block and the rock units of the Hisarcık formation are on the hangingwall block of the fault which is considered to be primarily limiting the basin which has developed as a result of vertical displacements following Middle Miocene deposition (Figure 5, 6). The relationship with the overlying Karabağları member is laterally interfingering and has vertical transitions.

In the generalized stratigraphy fluvial succession at the base of the Hisarcık formation makes one think of alluvial fan/delta(?) deposition at the basin margin limited by the boundary fault. Overlying shoreface succession (Karabağları member) has lateral interfingerings with the medial fan fluvial sediments, with their colours indicating paleoreduction conditions may support underwater deposition. Cross beddings with very low-angles and with advanced textural maturity may indicate beach depositions.

The Karabağları member along the northern shore of the Karaburun Peninsula described by Göktaş

Neogene Stratigraphy of Karaburun

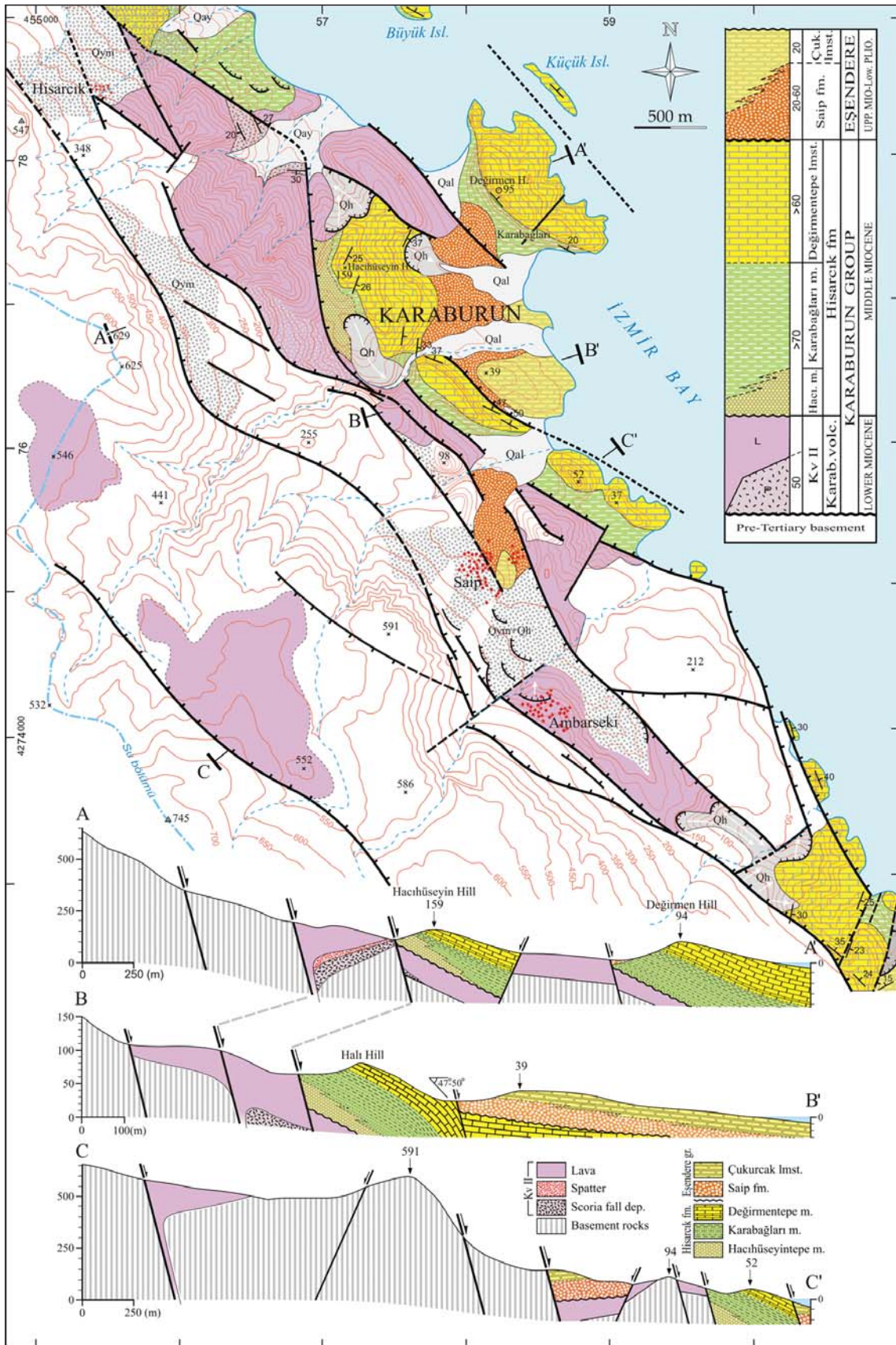


Figure 6- Geological map of the area between Hisarcık village and Eşendere.

(2014) contain of fan delta deposits may be correlated with the Hacıhüseyintepe member. The equivalent of subunit in the Urla depression may be the 'Çamlı conglomerate' (Kaya, 1979; 1981) and 'Çamlı formation' (Sümer, 2007; Göktaş, 2011) reflecting alluvial fan depositions. Equivalent sediments have not been reported in the Foça peninsula (Kaya, 1978, 1979, 1981; Eşder et al., 1991; Dönmez et al., 1998; Genç and Yılmaz, 2000; Altunkaynak and Yılmaz, 2000).

Karabağları Member: The subunit mainly with green coloured succession with plane-parallel claystone-siltstone beds described as the 'Karaburun formation' for the first time by Kaya (1979). In Göktaş (2014) and in this study as the Karaburun name has been used as at the group level so the subunit needed to be renamed. The new member name 'Karabağları' is a location about 1 km to the NE of Karaburun town centre and was first used by Göktaş (2014).

Type locality of the Karabağları member is in the NE of Bozköy along the shore cliff. Visible thickness of the succession varies from 80 m to 175 m.

The succession of the Karabağları member consist of carbonaceous claystone, siltstone and sandstone lithofacieses. Claystone-siltstone assemblages are the main rock type present. They are green coloured with thin-medium thick plane-parallel beddings. Thickness and the amounts of the sandstone interbeds show an increase at the lower levels of the succession. Sandstones are some decimetres thick, mostly coarse grained, grain supported, well sorted and in general well compacted. It is observed disorganized sandstone with some level of climbing ripple cross laminated (Figure 7A) and upper flow regime lineaments bearing sandstone beds. Rarely observed sandstones with hummocky and swaley cross beddings reflecting storm sedimentation conditions (Figures 7B,C). Wave ripple cross laminated sandstone interbeds are quite common (Figure 7D). Wave ripples have caused laterally connected lenticular beddings or isolated wave ripples of 1.5-3.0 cm ripple heights (Figures 7E, F). Within the green coloured massive claystones in some places there are euhedral compositite nodules like calcified colemanite(?) pseudomorphs, possible borate concentration (Figures 7G, H). Within the same zones there are some networks of calcified voids representing the remains of the dissolved-removed evaporates.

Within the two different levels of the succession there are some oolitic limestone beds made of

autochthonous ooids (Flügel 2010). At the lower oosparit bed is 40 cm thick. Its beige coloured, rather strong, generally grain supported with spar calcite cement and according to the compositional definition of carbonate rocks of Folk (1962) represents 'well sorted oosparit' microfacies. Ooids in generally ovoidal with 0.10-0.20 mm size, are single laminated belong to 'superficial ooid' class (Flügel 2010). Same size uncoated grains and 0.30-0.80 mm size subangular extraclasts with cryptalgal micrite coatings can rarely be found. Laminas coatings the nucleus, tangential-concentric microfabrics represent more agitated hydrodynamic conditions (Flügel, 2010). Ooid nucleuses are made of quartz, plagioclase, mica, epidote, chert and calcite extraclasts (Figure 8A). About 80 cm thick oolitic limestone bed (oolitic grainstone) located at the upper part of the succession has been consist of spherical and multi laminated 'normal ooids' (Flügel 2010). Normal graded thickly coated ooids with 0.1 mm-2.5 mm dimensions have been divided into several decimetre thick zones with mm size undulated stromatolitic crusts (Figure 8 B). Ooids are grain supported and have been cemented by spar calcite and the primary pores have been in most cases kept open (Figure 8 C). Extraclasts seen in the spar calcite cement are mostly quartz, feldspat, biotite, muscovite, epidote, chert and calcite fragments. Among the primary voids in the medium-well sized ooids, extra clast fragments of carbonates from the basement units can be seen as rare disseminations. Their angular-subangular shapes and centimetric sizes reflect textural reversing (Figure 8B). Some of the extraclasts have been coated in thin stromatolitic crusts. In places bioclasts have been represented by ostracode piles (Figure 8D). At the bottom of the oolitic limestone there is a 20 cm thick bed with densely bioturbation features. Below this, there is a 120 cm thick clayey limestone bed. It has medium-thick layers with plant icnofossils which are marked by empty plant tubes.

KV2 lavas have been transgressively overlain by the succession. At the bottom of this succession there is a 1 m thick calcsirudite layer. According to textural classifications of Dunham (1962); gray or faded pink coloured limestone is 'rudestone', according to Folk (1962) classification it belongs to 'gastropod-bivalve bearing biosparite' facieses (Figure 8E). Texture wise, it is grain supported and has spar calcite cement. Allochems larger than 2 mm include gastropods, bivalvias and bioclasts. Coarse-very coarse (between 1-2 mm) sand sizes extraclasts and intraclasts are not widespread. Dominant macro fossil

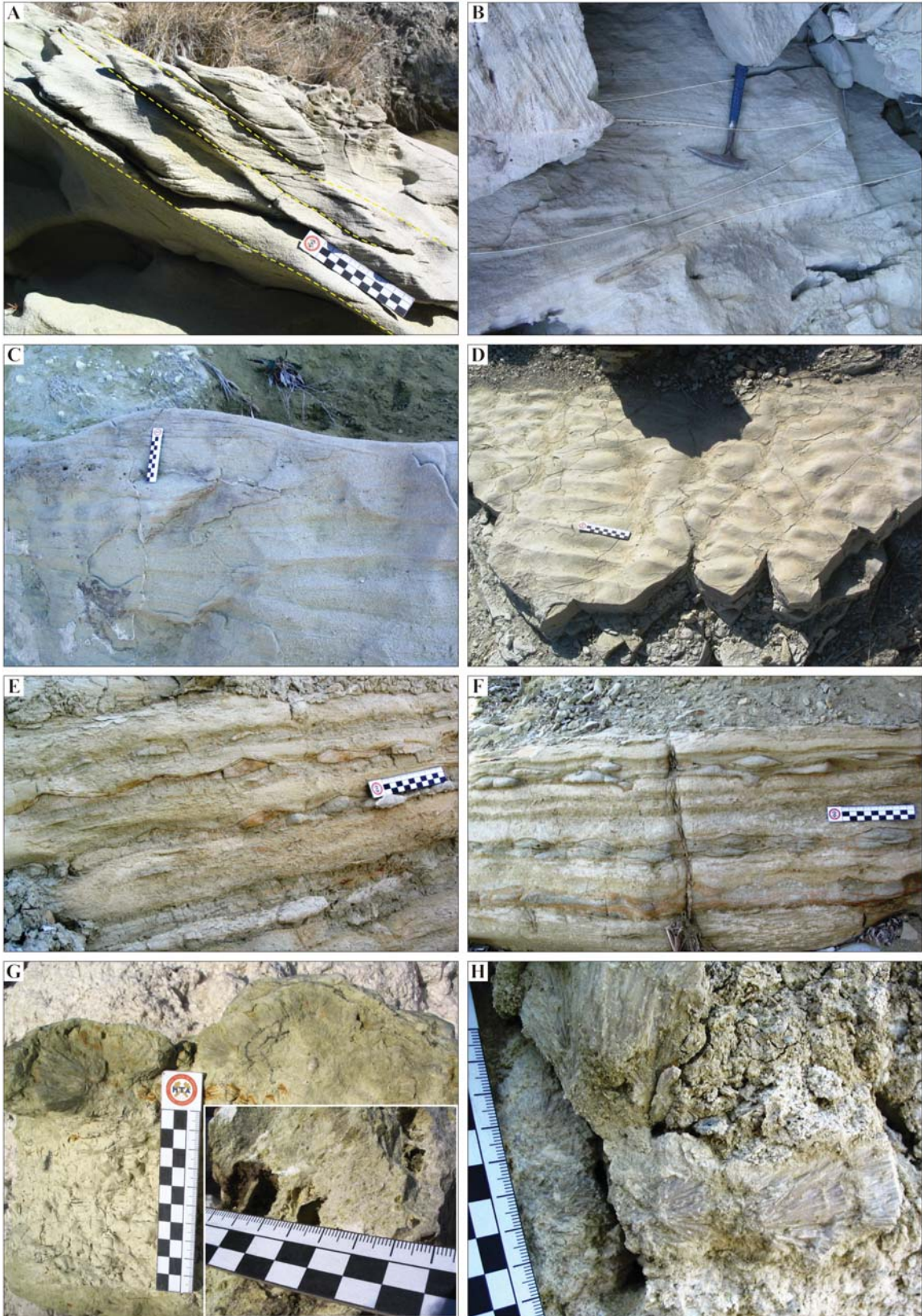


Figure 7- Specific sedimentary structures observed in the Karabağları sedimentary sequence. A) Climbing-rippled sandstone, B,C) Sandstone with HCS and SCS(?), D) Wave rippled sandstone, E,F) Lenticular-bedded wave-rippled sandstone, G,H) Probably boron salt (collemanite?) pseudomorphs.

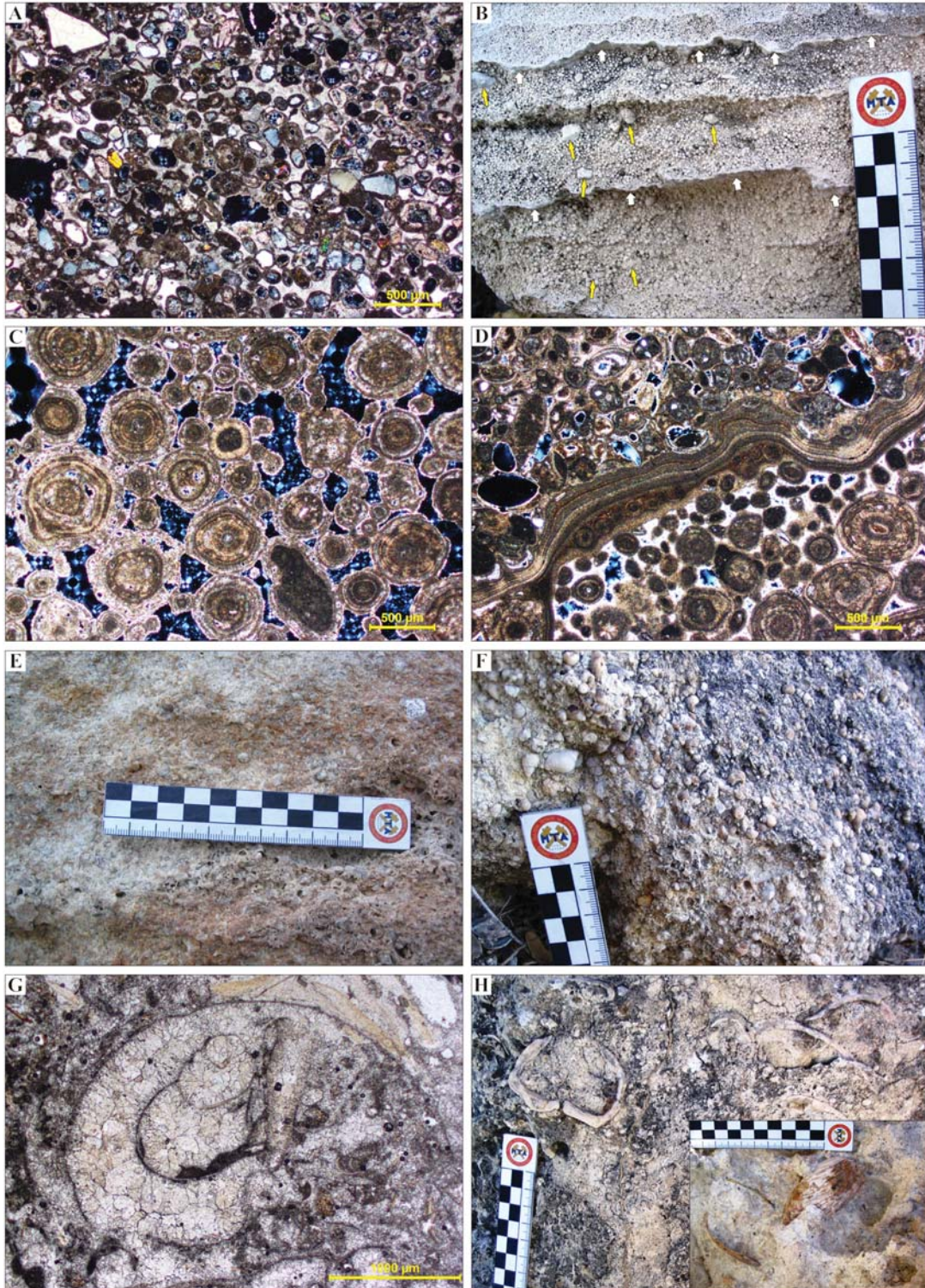


Figure 8- The specific textures of carbonate rocks in the Karabağları sedimentary succession. A) Microphotograph of relatively well-sorted superficial ooids (2,5 x); B) Macroscopic view of a normally graded oolitic limestone level. White arrows show stomatolitic crusts while the yellow ones point the extraclasts belonging to basement rocks; C) Microphotograph of oosparite (ooidal grainstone) facies (2,5x); D) Ooid-ostracoda clustering in the upper part of same facies, separated by a stromatolitic crust; E) Macroscopic view of gastopoda-bivalvia bearing biosparrodite (rudstone) facies; F, G) A macroscopic view and a microphotograph of a part of the same facies with abundant gastropoda (2,5x); H) Another macroscopic view of gastopoda-bivalvia bearing biosparrodite facies.

contents are uniform gastropods (Figure 8F). Gastropods are in mm size and have thin white shells (Figure 8 G). On the other hand bivalvia shells are not as common as gastropods but they have thick shells and have been well preserved. They may be up to 10 cm in size (Figure 8H).

KV2 has been transgressively overlaid by the Karabağları member. Outside the KV2 lavas emplacement areas underlying Aktepe member has sharp concordant contact. This indicates sublacustrine paraconformity, indicating continuity of lacustrine sedimentations. The contact with the overlying Değirmentepe limestone is concordant and in a limited area it is consecutively transitional.

Sedimentary facieses defined in the sedimentary successions indicate lacustrine shoreface sedimentations developed on the storm wave base. At the bottom of the successions there are sandstones with the features indicating sedimentations developed under high energy conditions and in the upper levels the amount of suspension sediments present increases, indicating that from lower levels towards the top sedimentation energy has decreased. Aktepe and Karabağları successions have sedimented at the shoreface of the same basin. But paraconformity between these successions was caused by the basin margin faults. These faults sharply changed the sedimentation conditions, sediments transported from the land areas increased and mainly green coloured detritics with fine grain developed on the carbonate rock dominant Aktepe succession.

The ‘Azmakdere member’ (Göktaş, 2010) in the Çeşme Peninsula, ‘Karaburun shale-litharenite unit’ (Kaya, 1979) and the ‘Bozavulu formation’ (Sümer, 2007) in the Urla depression are the lithostratigraphic equivalents of the Karabağları member. The ‘Yapalak member’ has been described in Aliğa limestone by Kaya (1979) is the possible equivalent of the subunit in the Foça Peninsula.

Değirmentepe Limestone: The subunit is marked with the carbonate rocks present in the upper parts of the Hisarcık formation. The name for the first time is used in this study. Değirmentepe is the name of a hill located about 1.25 km to the NE of the Karaburun town centre (Figure 6).

Type locality is around the Karaburun town centre, thickness of the succession varies from 75-150 m.

The succession is composed of limestone-dolomitic limestone and has centimetric claystone

interbeds in the lower levels. The limestone are thick layered but not well marked, has micritic texture, in places have some gastropods, fresh water algae and have fenestrates. They are concretionary aspect in the NW-SE outcrop area to the NE of the Soluğan Tepe (Figure 5). They have sands and granules derived from the KV2 and from the Pre-Neogene carbonate rocks.

In the generalized stratigraphy they are overlaid with an angular unconformity by Upper Miocene alluvial fan deposits (Saip formation). The fault zone running N45°W direction from the Karaburun town centre towards Bozköy is considered to be primarily bordering the Middle Mioce basin. This reactivated fault separates the KV2 in the footwall block and the limestone which has become tilted towards the fault plane in the hangingwall block (Figure 5). The lavas here are considered to represent 3rd stage of the Karaburun volcanisms and are at the low part of the succession.

‘Beyazıt member’ (Göktaş, 2010) in the Çeşme peninsula, ‘Urla limestone’ (Kaya, 1979; Sümer, 2007; Göktaş, 2011) in the Urla depression and the carbonate rocks of the Aliğa limestone in the upper part are the regional equivalents of the lower unit.

3.1.3. Karaburun Volcanics

Late Early Miocene calc-alkaline mafic volcanics (Mg#=54–72: Helvacı et al., 2009), are located in the NE coastal part of the Karaburun Peninsula. First time Türkecan et al. (1998) named then as ‘Karaburun volcanics’ and considered that they were emplaced at least in three stages. Lava flows and limited pyroclastics emplacement and outcrops are controlled by the oblique fault system extending NW-SE direction (Karaburun Fault Zone: Uzel et al., 2013) (Figure 9).

Karaburun volcanism has lateral connection with the Lower-Middle Miocene lacustrine sedimentation in the study area (Figure 10). Previous to the first two stage eruptions, related pyroclastics of the base surge and scoria air fall deposits were emplaced.

In the previous studies (Türkecan et al., 1998; Helvacı et al., 2009; Göktaş, 2014) and in this study, major element analyses (Table 1) of the samples are shown in the TAS diagram of Le Bas et al. (1986). The majority of the analysed 29 samples indicated andesite (9) and basaltic trachyandesite (10) and less numbers of samples indicate basaltic andesite (6) and

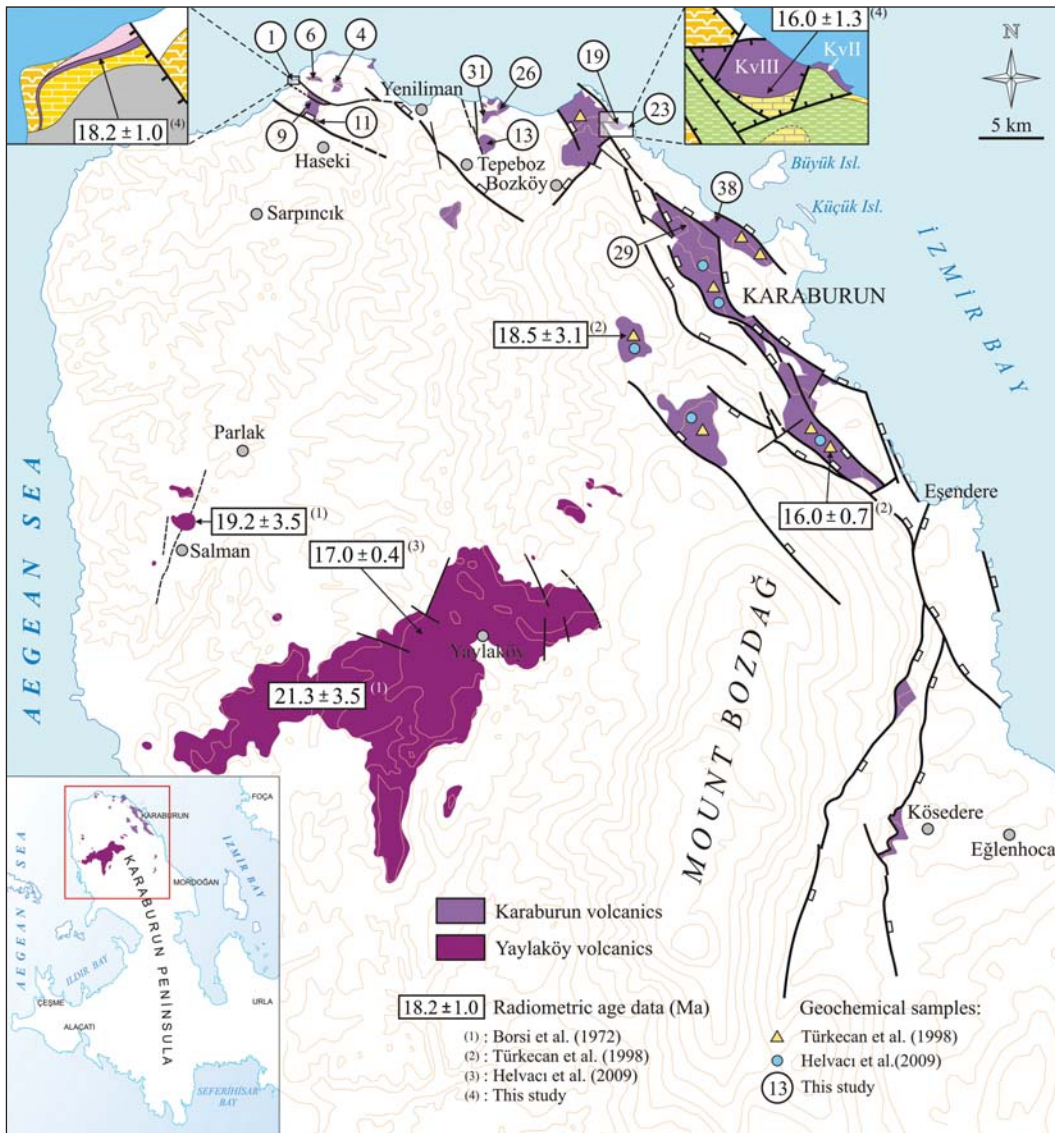


Figure 9- The mafic volcanics from the northern part of Karaburun Peninsula.

trachyandesite (4) compositions (Figure 11A). Göktaş (2014) and in this study 7 out of 12 samples have given andesite and 3 samples indicated basaltic andesite and 2 samples trachyandesite compositions. Analyses of the samples collected by Helvacı et al. (2009) have been concentrated in the basaltic andesite (shoshonite) field in the diagram. All of the analyses of the samples of Le Maitre et al. (2002) SiO₂ vs K₂O in the diagram fall into the high potassium bearing basaltic andesite (Figure 11B). All of the samples are in subalkali and calc-alkaline characters. Within the general extension of the KV all of the samples studied in the northern part in this study show a change in total alkali-silica contents towards the volcanics in the southern part which were the subject of the previous study. In the northern volcanics (in this

study) SiO₂ content shows variation between 53.4-56.9%. In the northern volcanics (Tırkecan et al., 1998; Helvacı et al., 2009) it varies between 46.3-57.8%.

Textures of the lavas are quite similar. Studied samples have hypocristalline porphyritic texture. Olivine is the main phenocryst. In general they have pilotaxitic and less interstitial matrix material, irregular distribution or in parts vague flow structure marked by the orientation of plagioclases, pyroxene, olivine microliths/microcrystals and rare volcanic glass. Quartz xenocrysts by magmatically corroded and encircled pyroxene microliths/microcrystals indicates magma mixing.

Neogene Stratigraphy of Karaburun

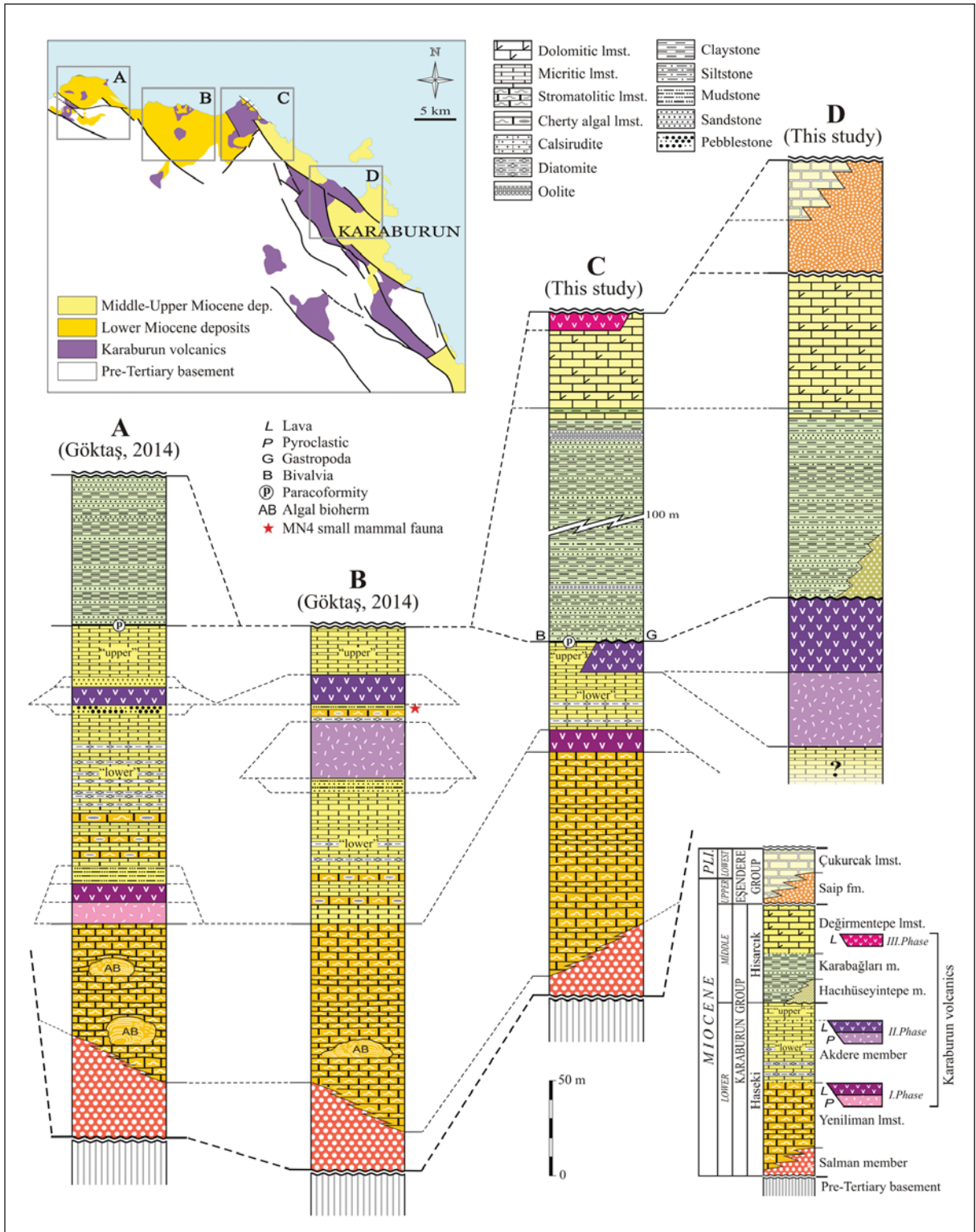


Figure 10- The stratigraphic position and correlation of Karaburun volcanics.

Table 1- Results of major element analyses of samples collected for this study from Karaburun volcanics (gray coloured ones) and samples given in Göktaş (2014).

Sample	UTM 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	LOI
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-4281155N	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
19K	0454935E-4280165N	56.9	16.4	6.9	3.7	6.4	3.7	2.3	0.6	0.3	0.1	0.09	0.11	2.25
23K	0455140E-4280170N	53.8	15.4	7.3	4.4	9.3	3.2	2.3	0.8	<0.1	0.1	0.10	0.10	2.75
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
29K	0456360E-4278135N	54.8	15.5	7.1	3.8	8.0	3.2	2.6	0.7	0.5	0.2	0.10	0.10	3.05
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
38K	0456850E-4278315N	55.3	16.3	7.3	3.3	8.3	3.5	2.6	0.8	0.4	0.2	0.09	0.11	1.60

KV1 and KV2 lavas have been aged by K/Ar method. As a result of the radiometric dating the KV1 located between Yeniliman limestone and Aktepe member gave 18.2±1.0 Ma (Göktaş, 2014) and lava located at the lower level Değirmentepe limestone which is the last member of the Karaburun group gave 16.0±1.3 Ma (Table 2).

First stage volcanics: Göktaş (2014) for the first time reported lithostratigraphic position, petrographical characters and age of these volcanics. These volcanics represent beginning of calc-alkaline mafic volcanisms in the NE of Karaburun Peninsula. KV1 lavas has outcrops in the north of Bozköy and here they separate Yeniliman limestone from the Aktepe member (Figures 5, 10A, C).

Second stage volcanics: They have extensive lava flows and are the most volumetrically important volcanics of the Karaburun volcanics. KV2 volcanism started while Aktepe member was continuing sedimentation, so these volcanics relatively separated the lacustrine succession into 'upper' and 'lower' sections (Figures 10A, B). The lavas at the bottom of the Karabağlar succession have been considered in the framework of KV2 (Figures 5, 6 and 10C, D). Base surge sediments emplaced at the initial stage of the volcanism in the north of Tepeboz (Göktaş, 2014). In the study area pyroclastics are represented with scoria air falls.

There is a NW trending normal fault with oblique displacement extending from the east of Hisarcık quarter towards Eşendere separating Neogene rock units from the basement rocks. KV2 products have

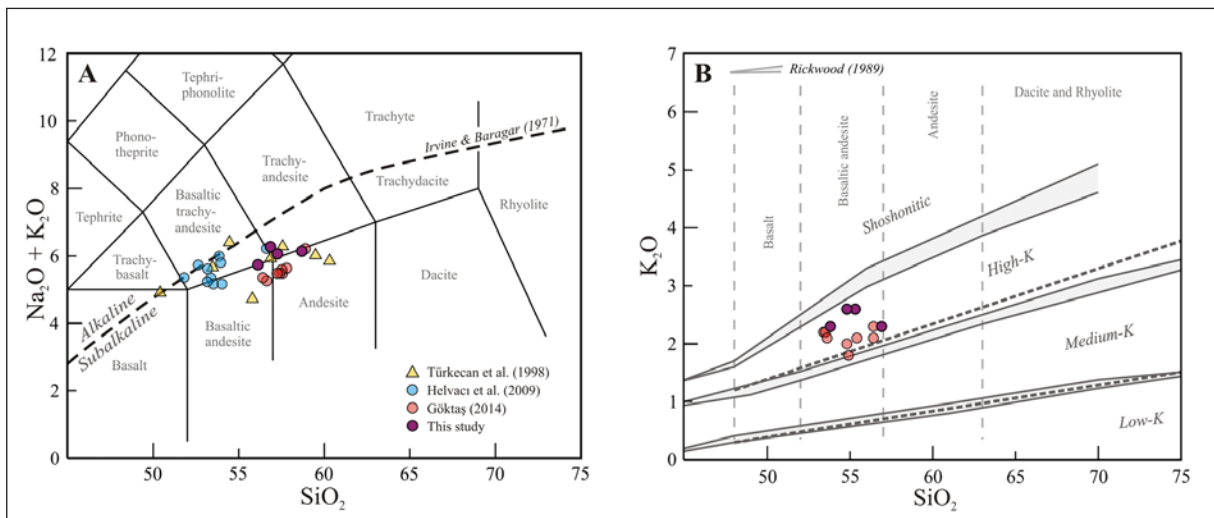


Figure 11- The evaluation of Karaburun volcanics using the diagrams of total alkali-silica(A) of Le Bas et al. (1986) and K₂O vs SiO₂ (B) of Le Maitre et al. (2002).

Table 2- K/Ar ages from the first stage (1K: Göktaş, 2014) and third stage (19K: this study) of Karaburun volcanics.

Sample	Material	K (%)	$^{40}\text{Ar}^{\text{rad}}$ (ccSTP/gr)	$^{40}\text{Ar}^{\text{rad}}$ (%)	Age (Ma)
1K	Whole rock	2.234	1.591×10^{-6}	28.9	18.2 ± 1.0
19K	Whole rock	1.354	8.462×10^{-7}	17.3	16.0 ± 1.3

maximum extension on the footwall block of this fault and it underlies of the Hisarcık formation (Figure 6). There are spatter lavas and scoria air falls under the lavas between Hisarcık quarter and Karaburun town centre. Because of thermal oxidation typically red coloured spatter lavas have been weakly agglutinated. General alteration colour of mafic pyroclastics is yellowish gray. Thickness of the plane-parallel scoria fall layers is in the range of decimetres. 60-80 cm thick welded tuff beds consist of coarse ash (1/16-2 mm: Fisher, 1966) containing 2-4 mm size subangular lava clasts are dark gray coloured. Scoria lapilli (2-64 mm: Fisher, 1966) sediments increase upwards in the succession (Figure 12 A). Average grain size of the lava fragments (fine vesiculated or non-vesiculated) is about 10 mm. The framework is clast supported and mainly it does not have any matrix material. Coarse ash tuffs have lapilli size scoria fragments, in some places they may also have armoured/cored lapillies (“core-type lapilli”: Schumacher ve Schmincke, 1991) (Figure 12B). In the upper part of the succession there may be ballistic blocks containing coarse lava fragments with less vesicles. Approaching to the lavas on the top, sizes (maximum 60 cm), numbers and gas vesicles of blocks.

Third stage volcanites: Small volume of lava eruptions on the Değirmentepe limestone defined the

third stage lavas. Their presence has been established from the relative stratigraphy and from the radiometric data. Type locality is 1.25 km to the NE of Bozköy (Figure 5). Türkecan et al. (1998) collected samples from the area between Hisarcık quarter the Eşendere harbour and had them analysed. The samples were weakly alkaline (SiO_2 : 46.3%; $\text{K}_2\text{O}+\text{Na}_2\text{O}$: 4.50%) contemporary lavas (16.0 ± 0.7 Ma) may belong to the third stage (Figure 9).

3.2. Eşendere Group

Late Miocene-early Early Pliocene terrestrial succession has been limited by regional scale angular unconformities both on the top and at the bottom which consists of alluvial fan deposits (Saip formation) at the lower part and lacustrine limestones (Çukurcak limestones) with lateral-vertical transitions on the top. The groups name Eşendere is related to the Eşendere fishing port in the Ambarseki village.

In the near SE part of the study area around Eşendere port, mudstone is the dominant rock type in the succession. ‘Eşendere large mammal fauna’ (Kaya et al., 2005) in the mudstone has been correlated with the MN11+12 biozones indicating Turolian (Figure 4). Biostratigraphic data showed

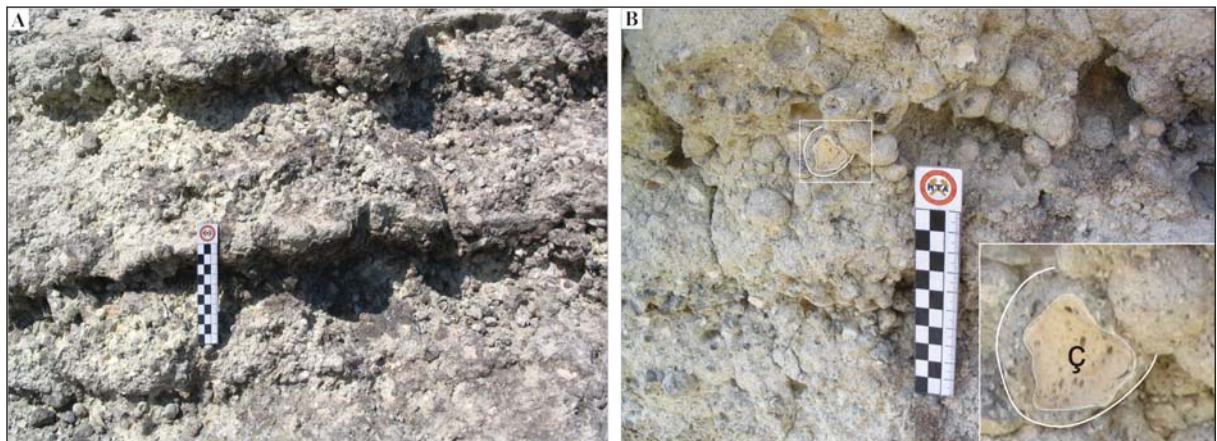


Figure 12- The second stage pyroclastics are exposed at the ~1,5 km southeast of Hisarcık village. A) Scoria fall deposits, B) Armoured/cored lapillies are observed in scoria falls (c: core).

that in the Akhisar depression Late Miocene regional sedimentation continued until the end of early Early Pliocene (~5 my) (Kaya et al 2004). In a general sense this data indicates that Eşendere group sedimentation developed during Late Miocene-early Early Pliocene(?).

Eşendere group is the stratigraphic equivalent of the 'Kaştepe group' described by Göktaş (2010) in the Çeşme Peninsula. The presence of equivalent sediments in the Foça Peninsula and in the Urla depression has not been reported in the previous work.

3.2.1. Saip Formation

The succession consisting of faded reddish brown coloured pebblestones and sandstones has for the first time has been defined under the 'Saip formation' name. Name of the unit comes from the Saip village near by.

The unit with lateral discontinuity has outcrops in the area between Değirmen Hill and Saip village (Figure 6). Thickness of the sedimentary succession is 30-50 m.

The fining-upward succession represents low profiled alluvial fan deposition. Alluvial succession consist of pebblestones-pebbly sandstones, representing braided stream sedimentation. In the upper parts it has sandy mudstone beds. Channel fills consist of rounded-subrounded pebbles.

The unit represents Late Miocene basin margin sedimentation. During late Middle Miocene compression phase (Yılmaz, 2000; Yılmaz et al., 2000) the unit was deformed and covered the Hisarcık formation with angular unconformity. The contacts with the basement rocks and with KV2 have been controlled by the faults either developed during sedimentation or reactivated at a later stage. Çukurcak limestone, with lateral-vertical transitions overlay the unit.

Saip formation could be correlated with the Karagöz formation defined by Göktaş (2010) in the Çeşme Peninsula.

3.2.2. Çukurcak limestone

It is marked with lacustrine carbonate rocks. The unit is the first time defined and named in this study. Çukurcak is the name of the area near SE of the study area where the unit has typical outcrops.

The thickness of the succession around Karaburun town centre is about 25 m.

The lacustrine succession consists of limestones and dolomitic limestones. Altered surfaces of the limestone are whitish light gray coloured, fresh rocks are beige coloured. In general they have micritic texture and are very compact. They have mainly thick-very thick, in places thin-medium layered and in some places rarely with gastropods. Towards the base the unit is light red brown colour, has massive mudstone with fresh water alga's and sepiolite/palygorskite bearing scarlet red brown coloured massive claystone interbeds.

The limestone succession is the last representatives of the Neogene sedimentations in the Karaburun Peninsula. In the generalized stratigraphy it is covered by Holocene alluviums.

The unit is the equivalent of the 'İnlice formation?' defined by Göktaş (2010) in the Çeşme Peninsula.

4. Structural-Stratigraphic and Paleogeographic Evolution

Early Miocene paleogeography of the coastal part of Aegean region has been marked by a big perennial lake with low energy sedimentation conditions. The lacustrine sedimentation in the NE of Karaburun Peninsula started with the stromatolitic-algal limestones and continued with micritic limestones. In a wide neighbourhood in the Foça Peninsula, thinly plane parallel bedded limestones and bituminous shales sedimented (Zeytindağı formation: Kaya, 1979). In the area of Foça Peninsula is, freatomagmatic eruptions produced felsic ignimbrites (Foça tuff: Kaya, 1979) during end of the Early Miocene. Although emplacement of ignimbrites interrupted the sedimentation of the Zeytindağı formation it continued with the Aliğa limestone (Kaya, 1979) all through early Middle Miocene. Within the distribution area in FD, rhyolitic ignimbrites are a reference stratigraphic level separating Early Miocene and Middle Miocene lacustrine sedimentations. Late Middle Miocene (Yılmaz, 1989; 1990, 2000; Yılmaz et al., 2000, 2001) is considered to be magmatically quite period in Western Anatolia but there are no reported sediments in FD. Under the compressions in Foça and Urla areas early Middle Miocene sediments are deformed and became subjected to erosion. Following compressions the area was subjected to extensional forces in Late Miocene (Yılmaz, 2000; Yılmaz et al.,

2000). It is accepted that in the newly developed basins fillings continued until end of early Early Pliocene (Kaya et al., 2004).

In the NE part of the Karaburun Peninsula dominant lacustrine sedimentation is considered to have started in Early Miocene and have continued until the end of early Early Pliocene(?). At the end of Early Miocene and at the beginning of Late Miocene boundaries of the sedimentation basin became narrower and sedimentation continued in this newly shaped basin. At about in the Early-Middle Miocene border defined discordance between Haseki and Hisarcık lacustrine sedimentations indicated the presence of the fault there. The faults shaped the western margin of the FD and vertical movements of the faults changed sedimentation conditions in the basin but did not cause sedimentation discontinuity. In the eastern part of FD, rhyolitic ignimbrites are present between Zeytindağı formation and Aliğa limestone successions. The explosive magmatism producing these rhyolitic ignimbrites became active at about the same time.

Around the Karaburun Peninsula there have not been any reliable data indicating beginning of Neogene sedimentation and so, opening time of the Miocene basin in this part. In the study area the Salman member starting with alluvial fan/delta deposition of Early Miocene lacustrine sedimentation is marked by the Yeniliman limestone and on its continuation the Aktepe member. The KV1 products have been locally emplaced on to the Yeniliman limestone platform, so lake depositions have not been disrupted and micritic limestone of the Aktepe member as the dominant succession transitionally and concordantly overlaid the algal limestone within a rather wide time interval. Chrono-lithostratigraphic equivalence of KV1 in the Çeşme Peninsula could be the latite andesites of 18.2 Ma of age (Borsi et al., 1972). Geochronological and lithostratigraphic data suggest that in different parts of the Karaburun Peninsula (Armağandağı, Kocadağ, Yaylaköy and Karaburun) effective calc-alkaline volcanism started following the initial products of Miocene terrestrial sedimentation (Salman member and Yeniliman limestone and its equivalent the Şifne formation in the Çeşme Peninsula) developed (Figure 13).

In the northern part of the Karaburun Peninsula the distribution of Lower Miocene alluvial and lacustrine deposits, Bozdağ in present position was a peninsula placed in the widely spread Early Miocene lake. With this position it is considered to be the

ancestor of the Karaburun peninsula. It is known that in the western and eastern part of the ?Bozdağ High? Lower Miocene successions have been represented with different sedimentary facieses, to that Middle Miocene successions are rather simple and uniform (Besenecker, 1973; Kaya, 1979; Göktaş, 2010, 2011, 2014; Çakmakoğlu et al., 2013). In the Foça Peninsula all along Early Miocene volcanites developed along with the lacustrine simple sedimentations and caused frequent interruption of the sedimentation in vertical and lateral directions causing change of order of the sedimentation. From the beginning of Middle Miocene onwards sedimentation developed in a rather monotonous way. The reasons for these may be explained; i) Calc

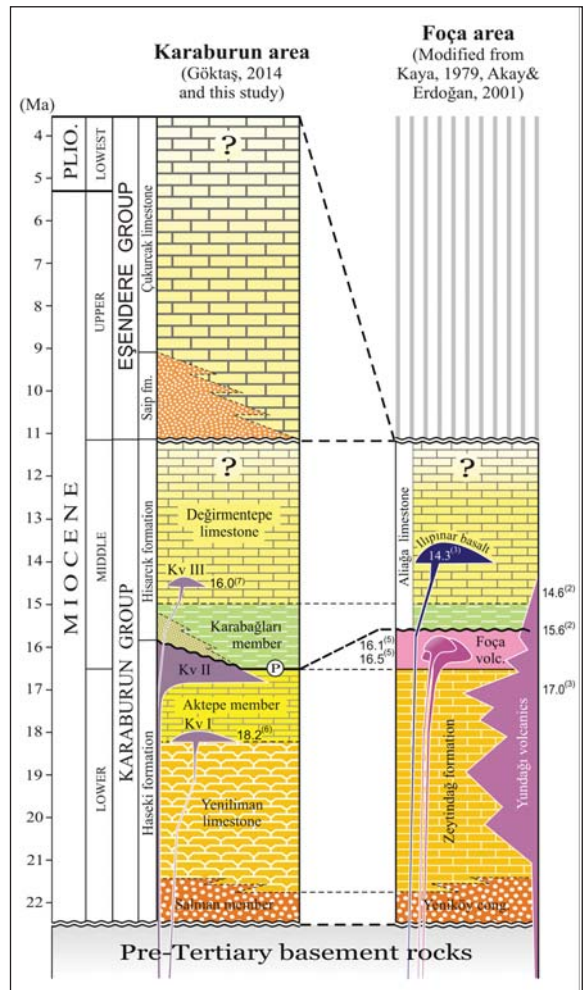


Figure 13- The stratigraphical correlation of volcanism and sedimentation from Karaburun and Foça areas. (1)Borsi et al. (1972), (2)Ejima et al. (1987), (3)Ercan et al. (1996), (4)Helvacı et al. (2009), (5)Altunkaynak et al. (2010), (6)Göktaş (2014), (7)This study. P: Paraconformity, Kv: Karaburun volcanics.

alkali felsic-mafic volcanism which caused local changes in the Early Miocene lacustrine sedimentation became extinct at the beginning of Middle Miocene [According to Altunkaynak et al. (2010) youngest ages are between 16.1-16.6 Ma], ii) ~2 Ma stagnation changing from calc-alkaline to alkaline volcanism (Altunkaynak et al., 2010), iii) Alkaline volcanism mainly became active in early Middle Miocene (between 14.7-14.1 Ma; Altunkaynak et al., 2010) and it was mostly represented with the extrusions in the parts outside sedimentation basins or they were small enough extrusives not to cause any changes in the sedimentation order [14.3 Ma age (Ercan et al., 1997) like Ilıpınar basalt (Kaya, 1979)]. As is the case in the study area lacustrine sedimentations kept their continuity outside the felsic ignimbrite (Foça tuff) extension areas. Haseki and Hisarcık depositions are evidence of this. Ignimbrite flows extend from Uzun Ada to the area around Mordoğan. These areas were subjected to lake transgression and Hisarcık formation and the equivalents at least continued sedimentation all through early Middle Miocene (Figure 13). Altunkaynak et al. (2010) had 16.5-16.1 Ma age by $^{40}\text{Ar}/^{39}\text{Ar}$ method for the underwater rhyolite domes. Lateral connections of ignimbrites with these rhyolite domes have been proven. Akay and Erdoğan (2001) by using age data of Altunkaynak et al. (2010) for the rhyolite domes, conclude that calc-alkaline asidic volcanism in the

Foça Peninsula continued becoming effective during between latest Early Miocene and earliest Middle Miocene.

The NW trending normal fault zone between Karaburun high and the FD became distinct in Middle Miocene. With the emplacement of KV2 products following limited disruption of sedimentation this fault zone controlled the Hisarcık lacustrine deposition (Figure 14). At the basin margin alluvial sediments of Hacıhüseyintepe member overlie KV2 lavas with erosive unconformity. These alluvial sediments in a lateral direction pass into fine grained shoreface sediments which sediments on the Aktepe platform limestones with paraconformity. Deposition of Hisarcık formation transitionally overlies shoreface sediments and ends with the Değirmentepe limestone where it is leaning at the basin's coastal margin.

Late Miocene succession overlies Hisarcık formation with angular unconformity, from base towards the top it consist of alluvium fan deposits grading into lacustrine limestones of the Eşendere group. Angular unconformity at the base of the Late Miocene is related to the compressional deformation in late Middle Miocene. There are no sedimentary deposits in the areas representing internal parts of the Foça depression basin (Urla area, Uzun Island, Hekim Island, Çiçek Islands) on the Aliağa limestone

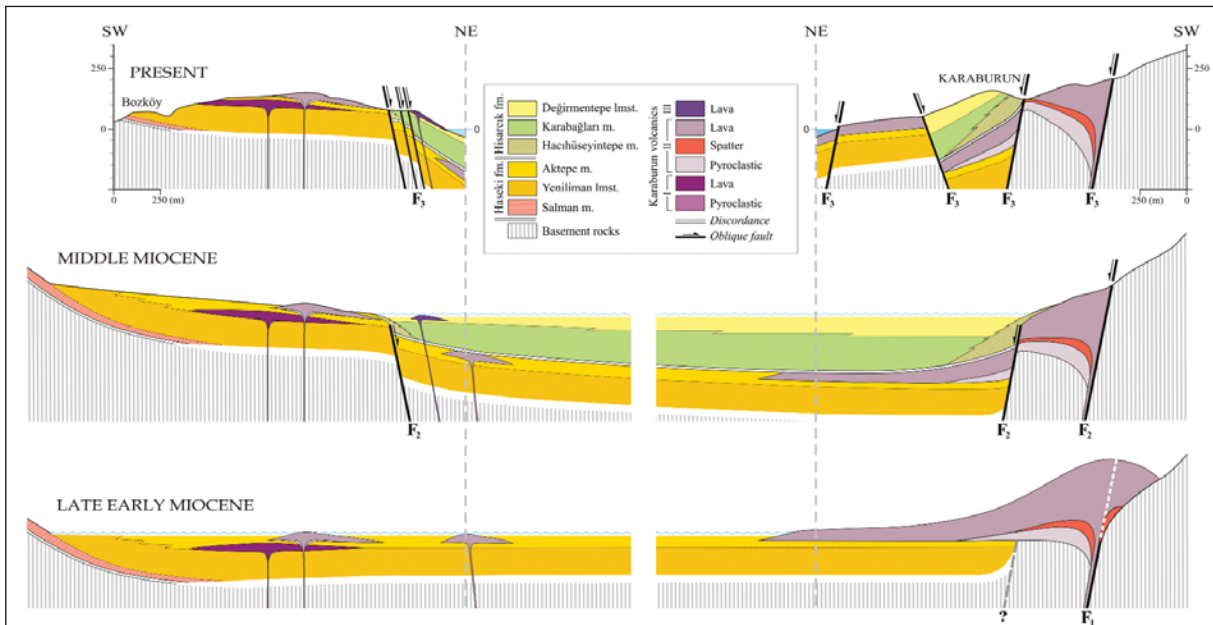


Figure 14- The stratigraphical-structural evolution of early-middle Miocene sedimentation and volcanism of Karaburun group. F₁: late early Miocene fault, F₂: early middle Miocene faults, F₃: Post-middle Miocene to pre-Holocene faulting.

to be correlated with the Eşendere sedimentary succession (Göktaş, 2011). Compressional movements in late Middle Miocene caused westward tilting of the Foça basin and the probability of the sedimentation axis slipping towards Karaburun Peninsula may explain the reason. As mentioned before that lacustrine sediments equivalent to the Çukurcak limestone which developed in the Late Miocene basins beyond FD are known to have continued developing in early Early Pliocene. In Western Anatolia late Early Pliocene compression phase (Koçyiğit et al., 1999; Yılmaz, 2000; Bozkurt, 2000; Bozkurt and Sözbilir, 2004; Kaya et al., 2004) is considered to have separated the consecutive two phase extensional process. It may be suggested that during the Pliocene compression phase Çukurcak limestone rose above the water level and became subjected to erosion.

5. Discussion

In the generalized stratigraphy of Helvacı et al. (2009) terrestrial Neogene sediments altogether were considered to be Lower Miocene age and these Middle and Upper Miocene sedimentary successions explained in this study have been considered non exist. It was also claimed that in the volcanostratigraphy of the Karaburun Peninsula the Karaburun volcanics represent the oldest (18.5 Ma), Yaylaköy volcanics represent the youngest (17.0 Ma) calc-alkaline volcanisms. As it is known Yaylaköy volcanism is two phases (Aras et al., 1999; Çakmakoğlu et al., 2013). Borsi et al. (1972) suggested 19.2-21.3 Ma age for the first phase volcanism. Accuracy of these age interval is questionable but even so, it is obvious that 17.0 Ma of age for the second phase volcanism can not by itself represent Yaylaköy volcanism. In this study it has been suggested that Yaylaköy and Karaburun volcanics are at about in the same lithostratigraphic position and no other volcanism developed before these two (Figure 2).

Uzel et al (2013) presented simple Neogene map of the Karaburun peninsula. According to this map and to the general stratigraphic order, lacustrine sediments of the Haseki and Hisarcık formations explained in this study are considered to be the equivalents of the 'Aliğa limestones' (Akay and Erdoğan, 2001) in the Foça Peninsula and have been considered to be the 'Lower sequence?' (Lower-Middle Miocene) (Figure 2). Proposed succession order for the 'Upper sequence' (Middle-Upper Miocene) makes one think of lithostratigraphic

correlation with Middle Miocene Hisarcık formation. In this study Hisarcık formation is said to lie on the Haseki formation with unconformity, is the equivalent of the Aliğa limestone (Kaya, 1979) in Foça Peninsula and the Urla limestone (Kaya, 1979) in the Urla depression. This conclusion is based on the age of the alkali volcanics with which they have transitional relations with (Figure 2).

Altunkaynak and Yılmaz (2000), Altunkaynak et al. (2006) have divided the Neogene succession in Foça Peninsula mainly into two sediment groups such as 'lower' and 'upper' groups. Calc-alkaline volcanics at 16.1-16.6 Ma age and the alkaline volcanics at 14.1-14.7 Ma age, have lateral connection with the lower group and have been considered to be Lower-Middle Miocene, and the overlying with unconformity the marl-limestone succession to be Upper Miocene-Pliocene. In the referred studies proposed ages for the sedimentary successions have been based on relative chronostratigraphy. There is no primary evidences available proving the presence or age of the upper sedimentary succession. Altunkaynak et al. (2010) mapped the early Middle Miocene volcanics and all of these volcanics have been placed on the calc-alkaline volcanics but their contact relations with the lower group can not be observed (In the Foça Peninsula the only alkaline volcanic rock outcrop which has clear cut contact relations with the sedimentary successions is the Ilıpınar basalts within the Aliğa limestone). In the same map proposed relative Upper Miocene-Pliocene age for the limestone outcrops were described to be the Aliğa limestone (Kaya 1978; Eşder et al., 1991; Dönmez et al., 1998). As chrono stratigraphic position of the Ilıpınar basalts has been proven, Altunkaynak et al (2010) reported that early Middle Miocene alkali volcanism crops out in the form of mafic-felsic doms/dykes which indicates the volcanism is in the same age with deposition of the Aliğa limestones (Figure 2). In this study it was shown that Aliğa limestone represents early Middle Miocene sedimentation and transgressively overlay Foça tuffs and Late Miocene-early Early Pliocene(?) sedimentation did not develop in the Foça Peninsula.

The suggestion of there is no deposition at Upper Miocene-lowest Pliocene period in Miocene successions of Foça Peninsula and Urla depression, based on the lithostratigraphic data in the previous work and are also based on the unpublished field observations of the author. This evaluation is also based on the information that in Western Anatolia in

the Late Miocene basins, sedimentation on unconformity planes starts with alluvial fan sediments, but in the said area these fan sediments are not present. To investigate the reason for this gap in the Neogene stratigraphy is considered to be beyond the scope of this work. But on the other hand presence of these sediments only in the eastern coastal region of Karaburun Peninsula may be explained; i) with the reactivation of the faults determining the eastern border of the Bozdağ High, there is one sided tilting of the FD base westwards and as a result migration of the sedimentation axis to the same direction and ii) rising of the Miocene platform limestones in other parts of the basin (Foça and Urla areas) above lake water and changing into non-depositional areas.

In FD, there has not been any reliable time data indicating upper and lower boundaries of Middle Miocene and Late Miocene-early Early Pliocene(?) sedimentation processes. i) Direct or indirect time data obtained from Hisarcık formation and the regional equivalents all indicate early Middle Miocene sedimentations (Besenecker, 1973; Ercan et al., 1997; Kaya et al., 2003; Koufos, 2006; Altunkaynak et al., 2010; Göktaş, 2011; Karacık et al., 2013). Main radiometric age data indicating late Middle Miocene sedimentation have been obtained from the alkali volcanics which have lateral connections with the Urla limestone, indicating 11.3-11.9 Ma K/Ar age (Borsi et al., 1972). But these referred radiometric ages have quite high error range (± 3.5 Ma), so they are not very reliable. But, still latest studies indicate early Middle Miocene for synsedimentary age (Göktaş, 2011: 14.8, 14.5, 12.5 Ma; Karacık et al., 2013: 13.2 Ma). There is no data available to indicate volcanic activity during late Middle Miocene. This may be related to the compression phase previous to the Late Miocene extension. ii) The only proof of Late Miocene sedimentation in the FD is the large mammal fossil found by Kaya et al. (2005) in the Eşdere group sediments. The MN 11+12 biozones indicated by the fauna suggest early Turolian (Figure 4). iii) In the generalized stratigraphy of FD, lack of sufficient data prevents evaluation of 4 million years of time gap between late Middle Miocene-early Late Miocene. This period is needed to be studied.

6. Results

In this study in the NE coastal region of the Karaburun Peninsula, lateral and vertical distribution of KV with terrestrial Neogene sediments and their stratigraphical relations have been established. In the

generalized stratigraphic order, rock units have been classified and have been mapped at 1:25.000 scale, rock units in the Çeşme and Foça peninsulas and in the Urla depression have been correlated with each other, and suggestions have been made towards structural-stratigraphic and paleogeographic evolutions.

In the generalized stratigraphy, Neogene sequence sedimented on the Upper Cretaceous-Lower Tertiary İzmir flysch with angular unconformity. Within the Neogene sequence on a regional scale mainly two sedimentary successions separated from each other with angular unconformity have been defined in the Karaburun group (Lower-Middle Miocene) and Eşdere group (Upper Miocene-Lowermost Pliocene(?)). Haseki (Lower Miocene) and Hisarcık (Middle Miocene) formations belonging Karaburun group, an unconformity with no sedimentation disruption has been identified between these formations.

Lower Miocene sedimentary successions cropping out in the Karaburun Peninsula have been considerably eroded vertically and laterally since then. Early Miocene basin has been represented by isolated sediment remains. As initial records of the boundaries have been wiped out so explanation details of structural-paleogeographic characters of the period have been insufficient. It has been concluded that the faults observable now separating the Lower Miocene sediments from the basement rocks developed after the sedimentation. NW-SE trending oblique/normal faults controlling Middle Miocene lacustrine sedimentations have developed with an unconformity on the Lower Miocene basin fillings without any time gap. Upper Miocene sediments have been deposited with an angular unconformity on the Middle Miocene rock units which rise above water as a result of regional compression.

Early-Middle Miocene sedimentation of the Karaburun group has been studied by dividing them into two formations. It has been concluded that they were mainly developed in the lacustrine environments. Early Miocene sedimentation of the Haseki formation starts with the alluvial/fan delta sediments of Salman member, continues with lateral intricate time overlapping algal-biostromal Yeniliman limestone and ends with dominantly micritic limestone of the Aktepe member following emplacement of the 1st stage KV. Hisarcık formation lies with unconformity on the Aktepe member and 2nd stage KV. Hisarcık formation from base to the

top has been divided into fan delta sediments of Hacıhüseyintepe member, fine grained shoreface sediments of Karabağlar member and Değirmentepe limestone and studied. Unconformity at the base of Hisarcık formation has been correlated with the vertical movements of the fault which shaped the eastern edge of the Bozdağ rise while FD were developing (Figure 14). It was suggested that boundaries of the structural highs between FD and Karaburun and Yamanlar were shaped at the beginning of Middle Miocene and Hisarcık and equivalents sedimented in the basin which acquired basin character in FD in general. It has been shown that basin margin sediments of the Hacıhüseyintepe member lean at the KV lavas with erosional unconformity, lateral equivalence, the shoreface sediments of the Karabağları member overlay the Aktepe platform carbonate with well defined concordant contact. This contact may reflect paraconformity developed under water. Based on the biochronological and geochronological data obtained from the regional equivalents of the Hisarcık formation it has been accepted that Hisarcık formation developed mainly in early Middle Miocene and sedimentation processes ended with Late Middle Miocene regional compression.

In the generalized stratigraphy the Eşendere group lies on the Hisarcık formation with angular unconformity. Rock units from bottom to the top consisting Upper Miocene-Lowermost Pliocene(?) alluvial fan deposits grading to lacustrine deposits have been defined within the Eşendere group. Presence of Upper Miocene sediments only on the western margin of FD may be explained by possible reactivation of the remains of the Middle Miocene old boundary faults at the beginning of Late Miocene, causing westward tilting of the sedimentation axis and so sedimentation continued in a narrower basin.

Depending on the relative lithostratigraphical relations; calc-alkaline mafic volcanics which have lateral relationship with the Karaburun group lacustrine sediments have been concluded to have developed in three stages; the lava flows of the last stage have been determined by the K/Ar method to be 16.0 ± 1.3 Ma. Pyroclastic facieses emplaced prior to the lava flows have been for the first time identified as a map unit. The data on the lavas have been evaluated together with the previous work data and it has been concluded that they have calc-alkaline-neutral composition; in the study area from north towards south they show compositional change; from andesite (-trachyandesite) field to (basaltic andesite-)

basaltic trachyandesite. In the same direction they display high potassium calc-alkaline series to shoshonite series. The KV sample analyses conducted within the frame of this work and the analyses of the geochemical data of the Yaylaköy volcanics in Helvacı et al. (2009) have been correlated and it has been concluded that both groups have accumulations in the high potassium andesite field. Chrono-lithostratigraphic data of the volcanics in this study and Salman-Yaylaköy area fit well with the previous work data, both volcanic groups mainly have positioned in about the same level. First products of calc-alkaline volcanism in the northern part of Karaburun Peninsula were emplaced following the start of alluvial fan/delta and laterally connected lacustrine deposition in the Early Miocene basin.

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