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Neogene stratigraphy and regional correlation of the Çeşme Peninsula, Western Anatolia, Turkey

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Research Article

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ABSTRACT

This study aims to investigate the stratigraphy and regional correlation of terrestrial Neogene sediments and volcanics in the Çeşme Peninsula. Neogene deposition is represented by two main sedimentary successions separated from each other by an angular unconformity. The lacustrine dominated Çeşme group characterized the Lower-Middle Miocene deposition is formed by Şifne, Ovacık and Çiftlik formations. The felsic pyroclastics (Alaçatı pyroclastics), which are the early products of the Armağandağı volcanism, laterally associated with the Çeşme group deposition, deposited on the Şifne formation and interrupted the lacustrine sedimentation. The lacustrine sedimentation continued uninterruptedly with Ovacık and Çiftlik formations after the deposition of pyroclastics, which terminated the sedimentation of the Şifne formation. The calc-alkaline Armağandağı volcanism is composed of felsic pyroclastics, andesitic volcaniclastics (Reisdere volcaniclastics) and lavas (Zeytineli lava) respectively from bottom to top. The Late Miocene-Early (?) Pliocene Kaştepe group, which covers all these units with angular unconformity, is represented by a succession, which grades from alluvial fan (Karagöz formation) up to lacustrine deposits (İnlice formation).

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1. Introduction

This study, which was performed in order to map the region on a 1/25000 scale by defining the terrestrial Neogene deposits and volcanics in the Çeşme Peninsula, is the summary of the geological investigation widely reported in Göktaş (2010) (Figure 1). The Neogene geology of the eastern part of the peninsula was presented by Göktaş (2016*b*). To reveal the stratigraphic succession of rock units in the Çeşme Peninsula, which was subject of local studies in previous investigations, and to investigate the possibilities of regional correlation are the main purpose of the study.

The main geological surveys starting with Kalafatçıoğlu (1961) in the Karaburun Peninsula are mainly related to pre-Neogene rock units (Çakmakoğlu and Bilgin, 2006). Few studies on Neogene carried out in the Çeşme Peninsula include magmatism (Innocenti and Mazzuoli, 1972; Borsi et al., 1972; Türkecan et al., 1998; Kaçmaz and Köktürk, 2004; Helvacı et al., 2009), hydrogeology-geothermal energy (Koçak, 1974; Yılmazer and Yakabağı, 1995; Gemici and Filiz, 2001) and Neogene geology (Besenecker, 1973; Göktaş, 2010, 2016*b*). Innocenti and Mazzuoli (1972) put forward that the “Alaçatı massif” (Armağandağı volcanics in this study) is represented by the calc-alkaline character of latite-andesitic volcanics in their pioneering studies in which they examined petrochemical properties of the Neogene volcanics in the Karaburun Peninsula. Borsi et al. (1972), obtained 18.2 Ma age from the andesite outcrop to the southeast

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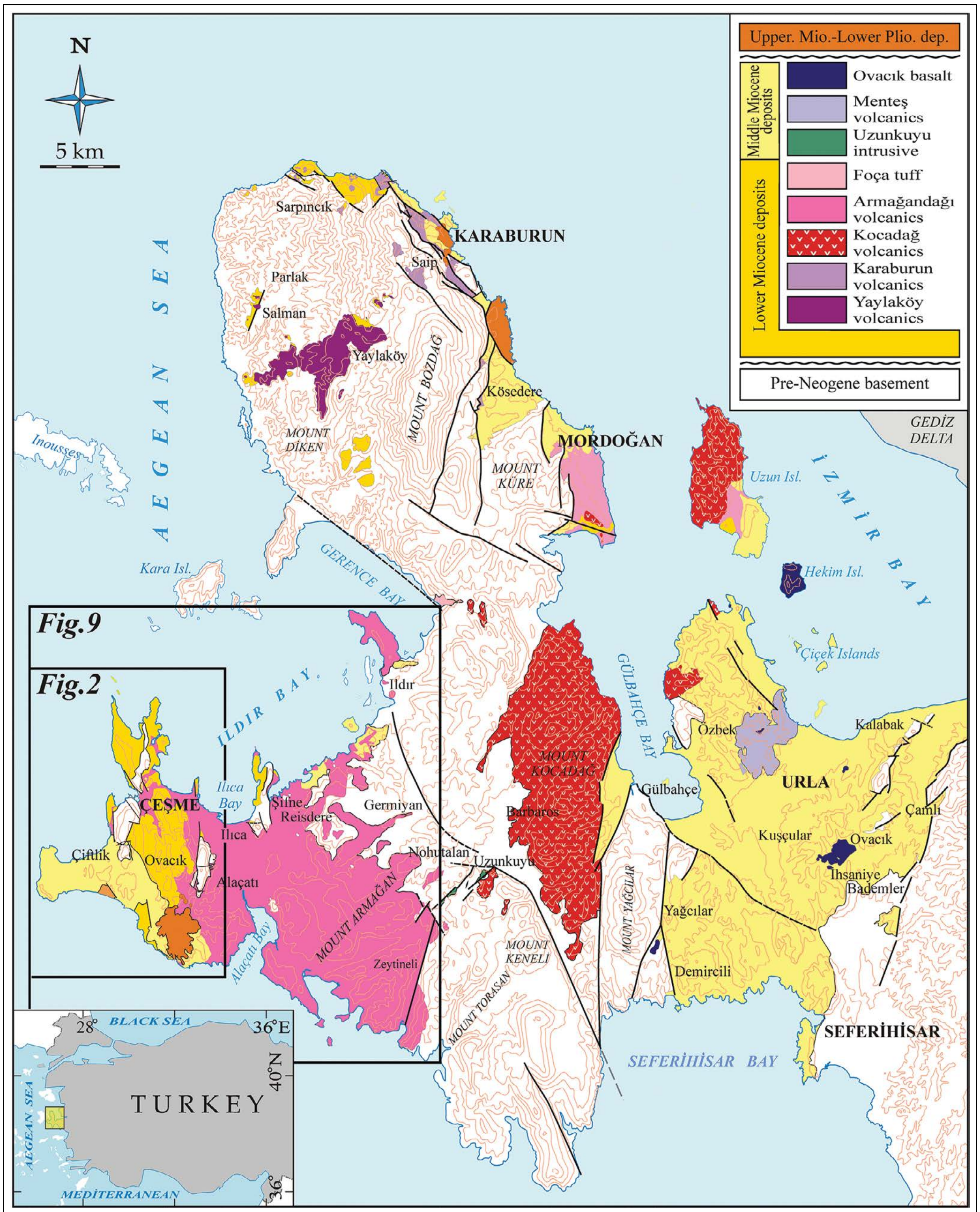

Figure 1- Location of the study area in the Karaburun Peninsula.

of Alaçatı and 17.0 Ma age from dacite cropped out near the Ildır Village by K/Ar method. Besenecker (1973) showed that there were correlating equivalents of Neogene deposits of Chios Island in the Çeşme Peninsula by means of lithostratigraphic correlations and large mammal fossils. Kaçmaz and Köktürk (2004) examined the geochemical and mineralogical properties of "silicic vitric tuffs" (Alaçatı pyroclastics) near Alaçatı and stated that authigenic zeolitizations (mordenite, clinoptilotite-heulandite) developed in the parts subjected to partial alteration. The stratigraphies proposed for Neogene rock units in the Karaburun Peninsula by Türkecan et al. (1998) and Helvacı et al. (2009) were constructed based on the radiometric ages and it was accepted that the Neogene sedimentation and volcanism had developed in a laterally relationship from bottom to top. Göktaş (2010) mapped the region on a 1: 25000 scale revealing the stratigraphy of the Neogene deposits and volcanics on the Çeşme Peninsula the first time. Additionally, Göktaş (2016*b*) examined the Neogene stratigraphy of the region in southern part of the Gulf of Ildır and correlated it with the western part of the peninsula. The latest study on the general geology of the peninsula was performed by Göktaş and Çakmakoğlu (2018).

2. General Geology

The basement under the Neogene rock units are composed of carbonate rocks of the Late Triassic Güvercinlik formation (Erdoğan et al., 1990), which forms N-S extending structural highlands in the Early Miocene basin in the study area. The lacustrine deposits of the Early-Middle Miocene Çeşme group overlap on these structural uplifts with time-lapse transgressive contacts represented by basal conglomerate levels. The basement rocks cropped out in the eastern part of the peninsula (between Ildır, Ilıca and Germiyan districts) are represented by marine sediments deposited from Silurian to Jurassic. Silurian-Carboniferous turbiditic Dikendağı formation (Çakmakoğlu and Bilgin, 2006) and Bashkirian-Viseen Alandere formation (Erdoğan et al., 1990) consisting of clastic and carbonate rocks represent the Paleozoic marine deposition. The Gerence formation (Erdoğan et al., 1990) at the bottom of the Mesozoic sequence, which overlies the Paleozoic basement with an angular unconformity, begins with the Scythian transgressive deposits in its lower part and continues with the carbonate rock-dominated deep sea sediments during the Anisian. The Camiboğazı formation (Brinkmann et al., 1972), which reflects the neritic carbonate deposition of the Ladinian period, transitionally overlies the Gerence formation. The Mesozoic deposition continued with shallow marine carbonate rocks (Güvercinlik formation) in the Upper Triassic (Carnian-Rhaethian), and neritic carbonates of the Nohutalan formation was deposited in the Jurassic (Brinkmann et al., 1972) (Çakmakoğlu and Bilgin, 2006).

Terresterial Neogene rock units, which have exposures in NW part of the Karaburun Peninsula and partly correlated with the Çeşme Peninsula, are represented by the Early Miocene alluvial fan/delta and lacustrine deposits and overlying calc-alkaline Yaylaköy volcanics in two phases (Innocenti and Mazzuoli, 1972; Borsi et al., 1972; Türkecan et al., 1998; Aras et al., 1999; Helvacı et al., 2009; Çakmakoğlu et al., 2013). The lacustrine-dominant Lower-Middle Miocene deposits are exposed along the northern shores of the peninsula whereas the Middle-Upper Miocene deposits on the northeast part. The calc-alkaline "Karaburun volcanics" exposed in N-NE coastal parts of the peninsula intruded in three phases into the lacustrine dominant succession of the Early-Middle Miocene "Karaburun group" (Göktaş, 2014*a, b*). "Kocadağ" and "Armağan Mount" volcanic complexes consisting of calc-alkaline volcanis in rhyolite, dacite and andesite compositions are located in the southern part of the Karaburun uplift seperating from the Urla depression by Gülbahçe fault (Emre et al., 2005; Innocenti and Mazzuoli, 1972; Borsi et al., 1972; Türkecan et al., 1998; Helvacı et al., 2009; Göktaş, 2010).

3. Neogene Sedimentation

The Neogene rock units exposed in the Çeşme Peninsula consist of terrestrial deposits and calc-alkaline volcanics. The oldest deposits in the study area are represented by lacustrine dominant Çeşme group. Armağandağı volcanics have lateral interfingering contact relationship with the section of the Çeşme group over the Şifne formation [Ovacık formation, Çiftlik formation and Ildır formation (Göktaş, 2016*b*)], which is the equivalent the last unit]**.** The Kaştepe group, which overlies all these units with an angular unconformity, has deposits grades from alluvial fan to lacustrine types (Figure 2).

3.1. Çeşme Group

In the study area, the Çeşme group (Göktaş, 2010), which includes of Şifne formation, Ovacık formation, Alaçatı pyroclastics and Çiftlik formation from bottom to top, is represented by a terrestrial deposit succession of approximate 600 meters thick (Figure 3).

3.1.1. Şifne Formation

The type locality of the Şifne formation (Göktaş, 2010), which forms the first succession of the Neogene sedimentation and grades from conglomerate-sandstone assemblage to algal limestones from bottom to top is the Şifne District nearly 5 km west of the Germiyan Village in L16-b3 sheet (Figure 1).

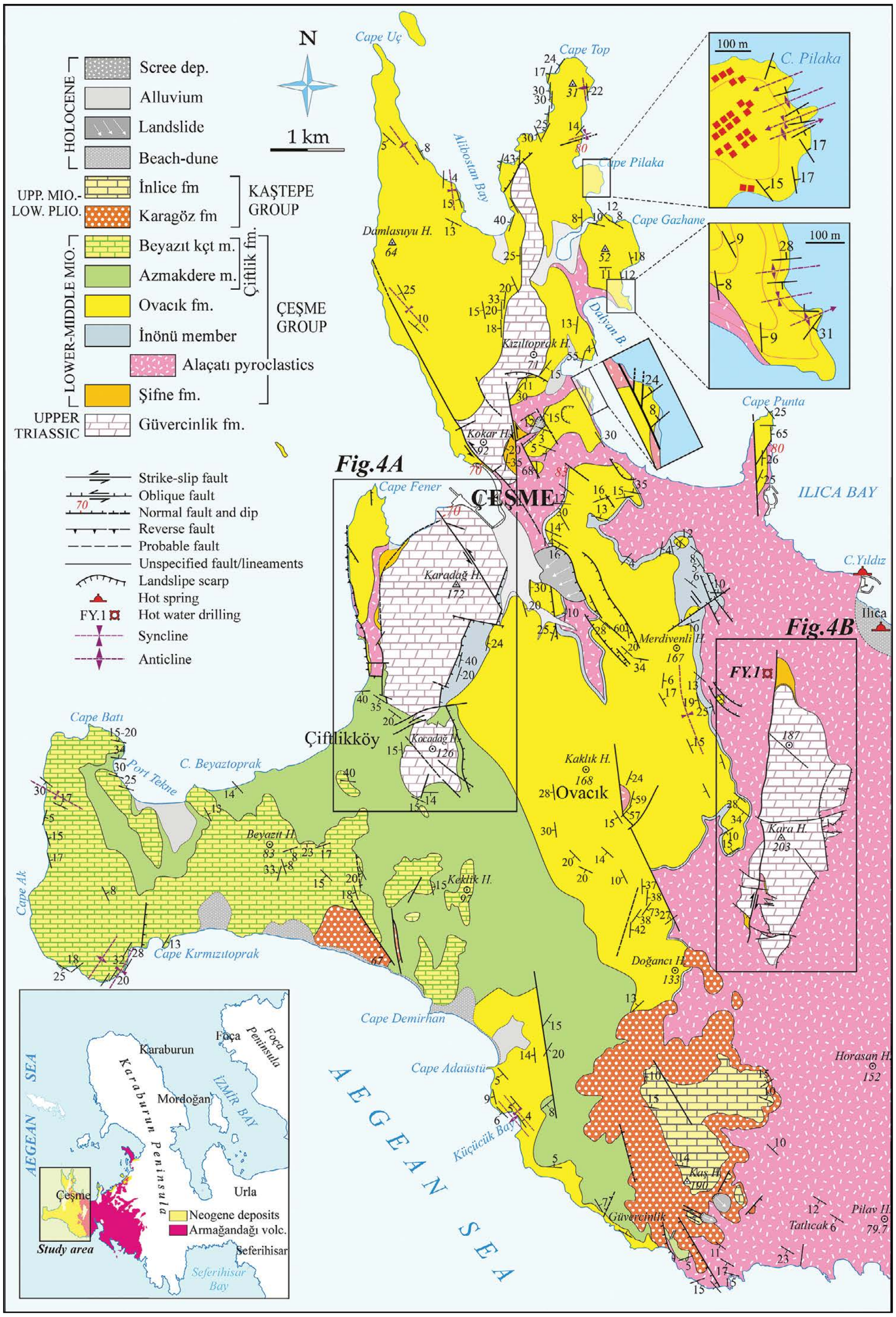

Figure 2- Geological map of the study area (modified after Göktaş, 2010; Göktaş and Çakmakoğlu, 2018).

The Şifne formation, which has few outcrops in the Çeşme Peninsula due to the cover of younger Neogene deposits and Armağandağı volcanics (Türkecan et al., 1998), is represented by limestone. As stated in Göktaş (2016*b*), the main outcrops of the succession, which can be observed at the highest part of 40 meters on the west coast of Şifne Bay, i.e. its type locality, are located in Çeşme district center, on western slopes of the Karadağ Hill and around Kara Hill highs (Figures 2 and 4). The total thickness of the Şifne formation cut from bottom to top in the geothermal drill "FY-1" performed by General Directorate of Mineral Research and Exploration (MTA) is 215 meters (Yılmazer and Yakabağı, 1995) (Figure 3).

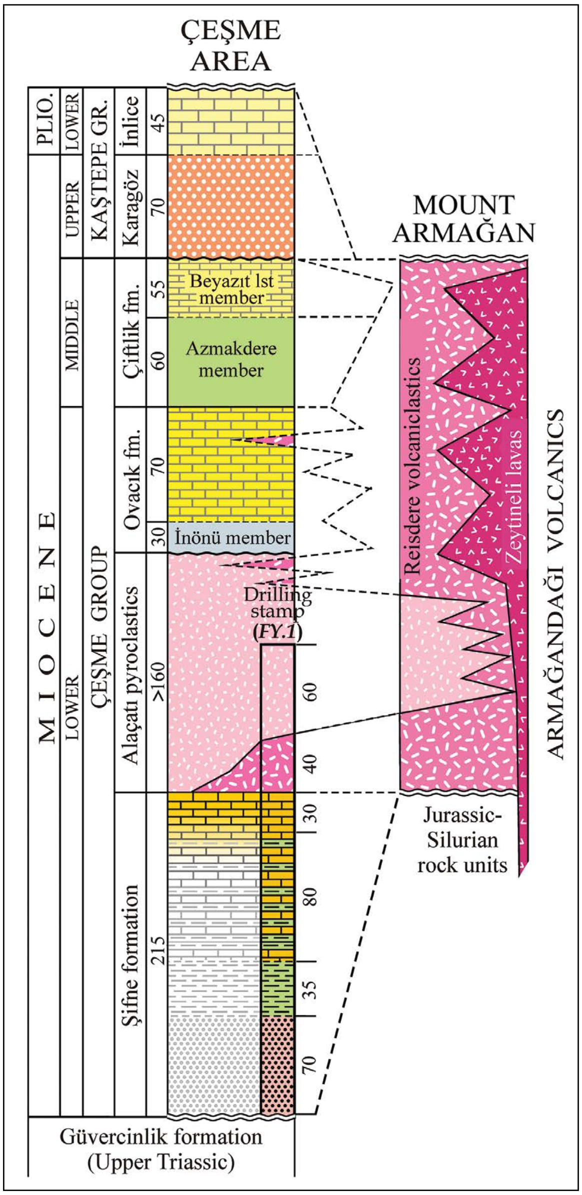

Figure 3- Detailed stratigraphical synthesis of Neogene rock units in the study area.

According to the drilling section data presented by Yılmazer and Yakabağı (1995), the 70 m thick lower part of the sedimentary succession consists of “gray and brown pebbly mudstone, pebbly sandstone and pebblestone, which is interpreted as the alluvial fan/delta deposits. The overlying 145 m thick lacustrine succession starts with gray and green claystones (35 m) containing few marl, clayey limestone and coal-seams and continues with limestone-clayey limestone-marl-claystone alternation (80 m) and then finishes with cream colored algal limestones (30 m) (Figure 3).

The parts of the unit exposed in the study area are lacustrine. In general, it is represented by fresh water algal limestone and thin to medium-bedded clayey limestone in few amounts. The algal limestone at the uppermost part of the succession and underlying sequence of algal limestone, clayey limestone, marl and claystone alternation are exposed on the northern coastline of the Gulf of Şifne to the east of the study area (Göktaş, 2016*b*). Algal limestone is less clear, thick to very thick-bedded and generally has microcrystalline texture. Freshwater algal content is represented by undulating/planar parallel laminated stromatolites. Fenestraes spaces developed parallel to the algal laminae are common. The branched algae in small amounts has been reworked and broken, and formed biosparitic accumulation levels in decimetric thickness within limestone layers. The limestone layers just below the overlying Alaçatı pyroclastics are partly/fully silicified and contain black/brown discoidal chert nodules (Göktaş, 2016*b*).

As mentioned above, biggest part of the Şifne sedimentary succession does not expose in the Çeşme Peninsula and only its uppermost 40 m thick part can be observed. Detritious limestones and carbonated mudstones, which overlap over the basement rocks with time-lapse transgressive contacts, filled karstic cavities and fractures on the unconformity surface along the western slopes of the Karadağ Hill in the SW of Çeşme district center, on the eastern slope of Kokar Hill and in the north of Kızılkaya uplift at the NW of Alaçatı. The Alaçatı pyroclastics were syn-sedimentary deposited on the Şifne formation. According to the well section of Yılmazer and Yakabağı (1995), there is a nearly 40 m thick and possibly laterally discontinuous andesitic agglomerate level between the Alaçatı pyroclastics and Şifne formation which is interpreted as the primary product of the Armağandağı volcanism (Figure 3).

There is not any biochronological data to date the Şifne formation, which constitutes the first sedimentary sequence of the terrestrial Neogene sedimentation in the Çeşme Peninsula. It is known that 18.2 ± 3.5 Ma K/Ar (Borsi et al., 1972) and 17.3 ± 0.1 Ma $^{40}Ar/^{39}Ar$ (Helvacı et al., 2009) ages were taken from Zeytineli lavas within the Armağandağı volcanics which overlie the Şifne formation after the settlement of Alaçatı pyroclastics. Based on these indirect data, it can be proposed that the unit was deposited in Early Miocene sensu lato.

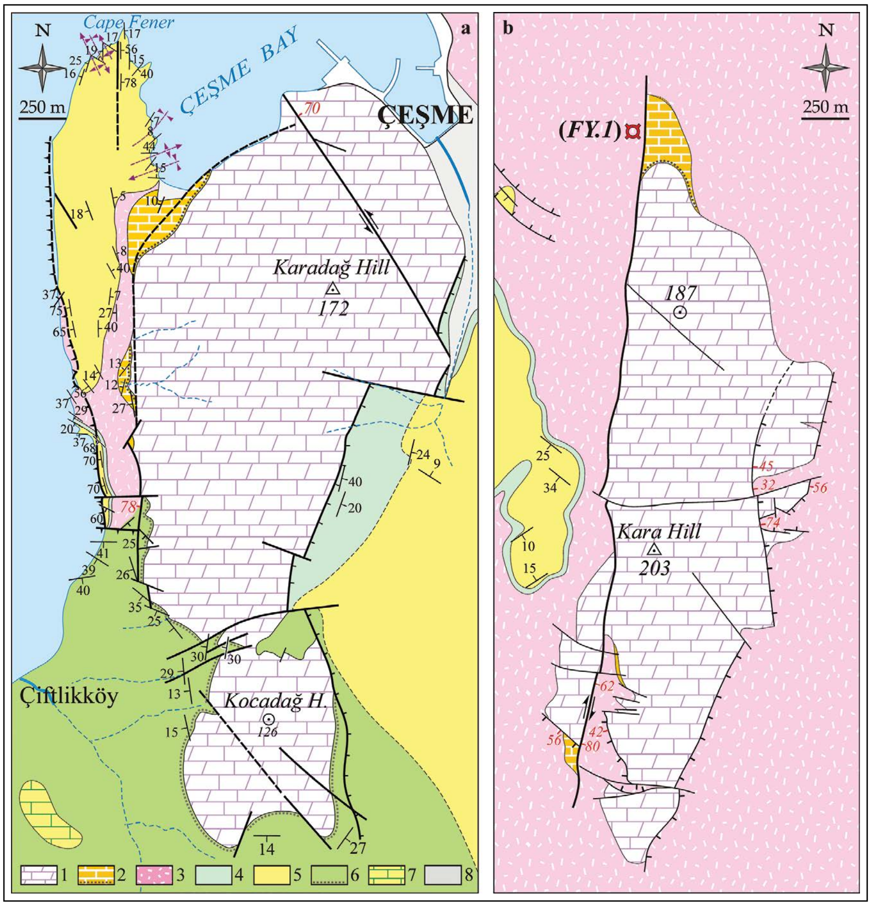

Figure 4- a) Detailed geological map of Karadağ Hill-Kocadağ Hill uplift and its vicinity, 1) Güvercinlik formation, 2) Şifne formation, 3) Alaçatı pyroclastics, 4) İnönü member, 5) Ovacık formation, 6) Azmakdere member, 7) Beyazıt limestone member, 8) alluvium and b) detailed geological map of Kara Hill and its surroundings.

3.1.2. Ovacık Formation

The Ovacık formation consists of a planar, thin-bedded limestone dominant succession. İnönü member signifies the reworked felsic tuff level at the bottom of the sedimentary succession (Göktaş, 2010).

The thickness of the Ovacık formation, which is located between the Alaçatı pyroclastics (Göktaş, 2010) and Çiftlik formation (Göktaş, 2010) in the middle of the Çeşme Peninsula, has an approximate thickness of 100 meters together with the İnönü member (Figure 3).

The succession, which is represented by planar parallel, thin-bedded, laminated limestones, contains claystone and rarely volcanic sandstone interlayers of different thicknesses from bottom to top. The general alteration color of the sequence is whitish/yellowish light gray (Figure 5). The sedimentary succession was broken by NW-SE and N-S trending (reverse, strike-slip and oblique-normal) post-depositional faults and folded in NW-SE, N-S, NE-SW axial directions. The most of these folds, which their axes usually dip to both directions, have several hundreds of meters of axial extension (Figures 2 and 4). The limestone, which is the dominant lithofacies of the sequence, is mostly micritic in texture. Chert bands located in partly or totally silicified limestone layers in cm size and discoidal chert nodules aligned parallel to the bedding are more common in the upper parts of the succession (Figure 5c). Locally, black chert or entirely silicified limestone layers varying in between 40-60 cm in thickness are observed. Brecciated limestone intercalations due to slumping are common (Figure 5c). Limestone layers mostly formed by planar to parallel laminated stromatolites are frequently

Figure 5- a) Angular coarse clasts derived from the Güvercinlik formation observed in carbonaceous mudstones in the transgressive lowermost part of the Ovacık formation, (L16-b4; eastern slopes of the Kızıltoprak Hill), b) yellowish, sandy limestone filled the karstic cavities in the carbonates of Güvercinlik formation in time-lapse transgressive contacts (L16, b4; eastern slopes of the Kızıltoprak Hill), c) chert nodules and brecciated limestone intercalations (black arrow) in distinct thin-bedded limestones of the Ovacık formation, d) parallel, thin-bedded, laminated levels characterizing the lower-middle parts of the Ovacık succession (L16-b1; south of Top Cape), e) claystone interlayers observed within Ovacık succession (L16-b1; south of Top Cape) and f) silicified limestone layers composed of undulating-planar parallel laminated stromatolites in the upper parts of the Ovacık limestone deposit (L16-c1; north of Küçücük Bay).

encountered in the succession. Entirely silicified, thick limestone layers with laminated stromatolites, increase in the upper parts of the succession (approaching the contact with Alaçatı pyroclastics) (Figure 5f). Some of these limestone layers are high-bioturbated. They have low gastropod contents. Claystone in the form of green, yellow, bluish gray colored and massive levels is intercalated as intercalations in limestone dominant parts or alternate with limestones. There are abundant gastropod shell fragments in the levels of blackish-brown claystone, where organic materials are concentrated. The claystone dominant levels, which have 12 meters of thickness, include siltstone, sandstone or limestone intercalations in decimetric thicknesses. Volcanic sandstone interlayers are bluish dark gray colored, massive and have thicknesses varying between 1-3 meters. The volcanic clasts in reworked coarse tuff matrix consist of pumice and andesite fragments in the form of laterally discontinuous lenses and alignments. Andesite fragments are maximum 3 cm in size and angular. The pumices are up to 15 cm in size and subrounded. The clayey diatomite interlayers rarely found in the sequence are whitish light gray, planar parallel thin-bedded/thick laminated in thicknesses ranging from 5-40 cm.

The succession of the Ovacık formation, conformably overlain by the Azmakdere member (Göktaş, 2010) of the Çiftlik formation at WSW of the Kaş Hill (L16-c1), ends with some sedimentary beds which reflect the drying of the lake. Dark beige colored, 60 cm thick limestone layer, which has desiccation cracs, root marks and iron nodules at its surface, is overlain by 10 cm thick, laterally discontinuous claystone with thin lignite seams. Overlying 80 cm thick, light gray clayey diatomite level is parallel laminated and weakly cemented, and consists of discoidal iron concretions, fresh water algae and coalified flora remnants in cm size.

Thin to medium, distinct bedded and pale yellow colored transgressive limestones observed on the E and W slopes of Kızıltoprak Hill, the north of Çeşme district center laterally overlapped the Alaçatı pyroclastics and rested on the dolomitic limestones of the Güvercinlik formation. In the lowermost part, the massive limestone (Figure 5a) containing angular components derived from the in situ weathering of the Güvercinlik formation carbonates filled the karstic cavities and fractures on the unconformity surface of the Upper Triassic carbonates (Figure 5b).

There is no direct fossil data showing the age of Ovacık formation deposited in the lacustrine environment. It is regarded that the Ovacık lacustrine deposition occurred in the late Early Miocene based on: i) MN4 small mammal fauna (17.2-16.4 Ma, Hilgen et al., 2012) contained by the “Aktepe member” (Göktaş, 2014*b*), the equivalent of the unit in the north of the Karaburun Peninsula, ii) the age of 14,6 Ma (Göktaş, 2016*b*) of the lava flow syn-sedimentary emplaced within the Ildır Formation, the lateral equivalent of the unit in south of Ildır Bay and iii) the stratigraphical relationship with the Çiftlik formation, which conformably overlies the unit and consists of big mammal fossils of the MN5 biozone (16.4-14.2 Ma; Hilgen et al., 2012).

İnönü Member: İnönü member (Göktaş, 2010) defines the reworked felsic tuff level, which forms a lateral continuous reference level at the lowermost part of the Ovacık formation that transgressively overlaps the Alaçatı pyroclastics. The type locality of the subunit is Çeşme İnönü District and it has an average thickness of 30 meters.

The main components of the volcanic sandstone lithofacies, which represent the İnönü member, are derived from the underlying Alaçatı pyroclastics. Coarse-grained transgressive sandstone level at the bottom of the sequence is massive and carbonate-cemented in varying proportions in lateral and vertical directions in decimetric or metric thicknesses (Figure 6a, b, c). Specifically, it includes transported accretionary lapillies. Accretionary lapillies, which form lateral discontinuous deposits, is generally poorly sorted. In addition to the accretionary lapilli levels showing individual and irregular distribution grain-supported, packed lenticular deposits are also observed (Figure 6d). The succession, which was deposited by following the transgressive sandstone level and characterize the İnönü member, is represented by bluish dark gray, specifically planar, parallel and thin to medium-bedded, grain supported and well-sorted volcaniclastic sandstone. It is well stratified and has laterally equal layer thicknesses (Figure 6a).

İnönü member, which reflects the initial phase of Ovacık lacustrine sedimentation, unconformably overlies the Alaçatı pyroclastics. It transitionally underlies the limestone-dominant succession in a narrow range. Levels in the transitional zon are represented by carbonate cemented volcaniclastic sandstone and tuffaceous limestone lithofacies.

3.1.3. Çiftlik Formation

Çiftlik formation (Göktaş, 2010) represents the last sedimentary succession of Early-Middle Miocene lacustrine deposition within Çeşme group. The succession, which conformably overlies the

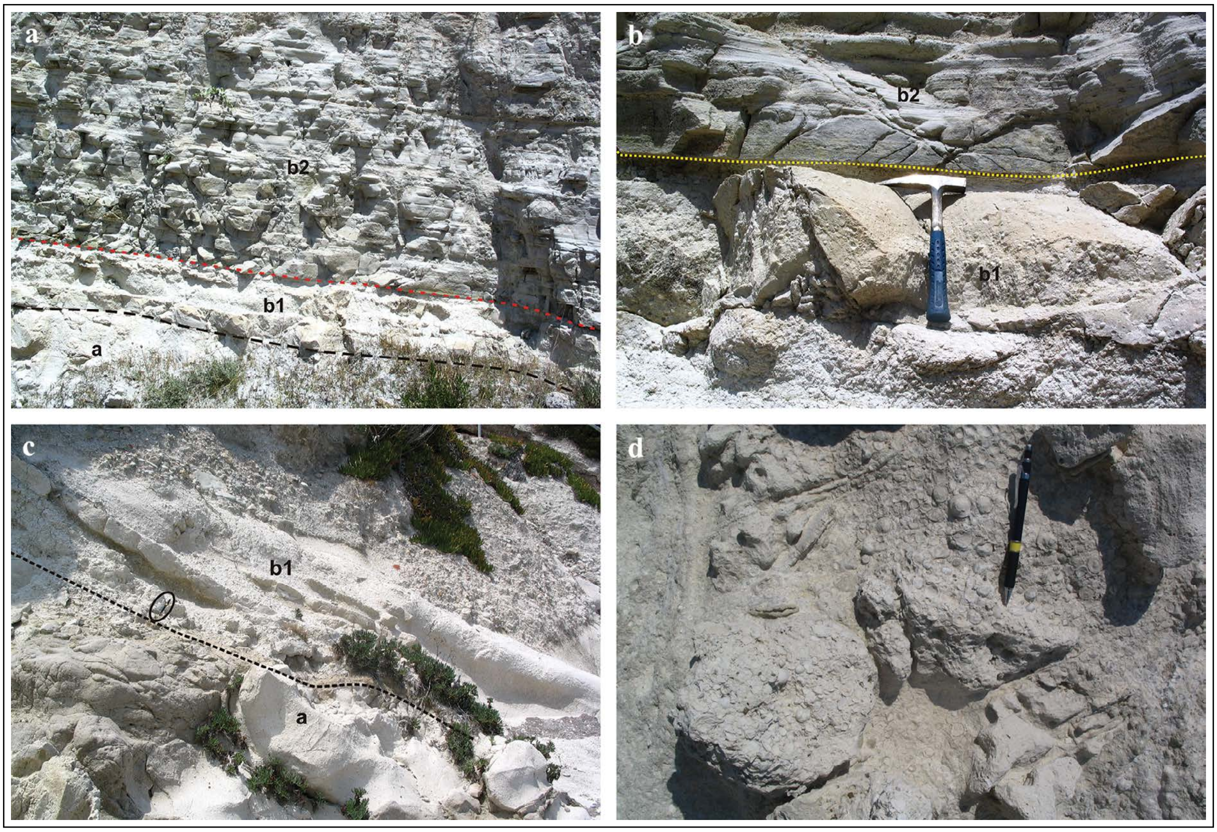

Figure 6- a) A view from the lower section of the sequence (L16-b4; around Kalkandere Hills, north of Çeşme district center). a: Alaçatı pyroclastics, b1: transgressive sandstone level at the bottom of the sequence, b2: planar, parallel thin-bedded volcanic sandstone deposit, characterizing the İnönü member, b) Close-up view of the lowermost part of the sequence, c) Transgressive sandstone level comprises carbonates in varying ratios and includes tuffaceous limestone intercalations (L16-b4; the coastline in east of Kalkandere hills), d) Close-up view of accretionary lapillies.

Ovacık formation, is made up of the Azmakdere member composed of the green claystone-sandstone association, and the Beyazıt limestone member at the top. The type locality of the unit is the Çiftlik District, which is approximately 4 km SW of Çeşme district center. It has a maximum thickness of 115 meters.

Large mammal fossils characterizing the MN5 biozone in the Azmakdere member at the lower part of the sedimentary succession and in the Keramaria unit (Besenecker, 1973), which is the equivalent of the member in Chios Island, indicate the early Middle Miocene (Besenecker, 1973; Bonis et al., 1998). In this study, it is assumed that the Çiftlik formation was deposited in the Middle Miocene sensu lato.

Azmakdere Member: It is located in the lower part of the Çiftlik formation and composed of claystone at the lower part and sandstone-dominant sequences at the upper part. The type locality the subunit shown by Göktaş (2010) is the Azmak stream flowing in N-S direction in southern part of L16-b4 sheet.

The main outcrops of the succession are located in the SW part of the Çeşme Peninsula. Its average thickness is 60 meters.

The sedimentary deposit is generally dark green, partly yellowish or bluish gray colored. Sediments deposited from suspended load are mainly represented by dark green claystone-siltstone assemblage and dominant in the lower part of the sedimentary succession. Rare sandstone and clayey diatomite intercalations are located in the lowermost parts of the massive claystone-siltstone succession. These medium to coarse-grained sandstones are grain supported, generally well sorted, massive or very low-angle climbing rippled. Clayey diatomite consists of laterally continuous intercalations, which their thicknesses vary between 5 and 15 cm and do not show thickness changes in laterally. Claystone layers consisting of high organic matter are blackish, dark green colored. The sand size extraclast content and the average grain size increase towards the middle and upper parts of the succession, and the sandstone deposition developed over the wave base dominates in the shoreface deposit. Storm sand layers represented by coarse sandstone reach thicknesses in decimeters in the same direction. Some levels in which Fe pigment concentration increases are light/dark yellowish brown and well cemented. Claystone-siltstone intercalations are common. It is rarely observed that 10-15 cm thick wave rippled sandstone layers. Grain supported and well sorted coarse sandstone lithofacies in decimetric thickness are generally planar parallel laminated, locally planar (large scale low-angle) cross laminated. Climbing and sinusoidal rippled levels in similar textural properties have decimetric thickness and are rarely found.

At Batı Cape, the levels close to the overlying Beyazıt limestone member are represented by the claystone-dominant succession containing sandstone intercalations (Figure 7a). Green claystone is generally high-bioturbated, massive and rarely planar parallel laminated. It includes white to beige carbonate nodules and rarely laterally discontinuous, clayey limestone intercalations in thicknesses ranging from 20-40 cm. Sandstones, which have more or less laterally continuous interlayers in thicknesses ranging from 10-300 cm, are yellowish or green, massive or cross-bedded (Figure 7b). These sandstone levels include intraclasts derived from claystones and large mammal remains described by Besenecker (1973).

It has conformable stratigraphic relationship with the underlying lacustrine Ovacık formation. The green claystone-dominant succession of the Azmakdere member was deposited by following the sedimentary levels indicating the almost dry up of the Ovacık Lake. This relationship tells us that the sedimentation conditions changed due to the sudden deepening of the basin or the rise of the water level. The transgressive parts of the Azmakdere member rest unconformably

Figure 7- a) A view of the Azmakdere member in the lower part and the Beyazıt limestone member at the top (L16-a3; Batı Cape), b) the sandstone intercalation in the Azmakdere member (L16-a3; Batı Cape), c) transgressive pebbles along the time-lapse unconformable contacts between the carbonates of the Güvercinlik formation and the Azmakdere member deposits (L16-b4; west of Kocadağ Hill) and d) The Azmakdere member deposits rested on the western slopes of the Kocadağ Hill was hydrothermally altered.

on the Karadağ-Kocadağ uplift, which consists of the carbonates of the Güvercinlik formation. At the lowermost parts of these sections, there are basement derived, monolithic, coarse components (Figure 7c). Particularly, on the western slopes of the Kocadağ Hill, the basement carbonate rocks and parts of the formation close to the tectonic contact were affected by effective hydrothermal alteration (Figure 7d). The Azmakdere member is transitionally overlain by the Beyazıt limestone member in general. However, it is unconformably overlain by the alluvial fan deposits of the Karagöz formation in the south of the study area.

The fossil remains of large mammals found by Besenecker (1973) (*Sanitherium leobense, Gomphotherium* sp., *Diplocynodon* sp., *Ruminantia sp.* indet.) in the uppermost part of the Azmakdere deposit outcropping on the Batı Cape on the Çeşme Peninsula is included in MN5 biozone according to Kaya et al. (2003). The "Thymiana mammal fauna" described in the Keramaria unit (Besenecker, 1973), the equivalent of Azmakdere member in Chios, also belongs to MN5 biozone (Bonis et al., 1998) and it is dated approximately as 15.5 Ma according to magnetostratigraphic data of Koufos (2006). MN5 mammalian biozone confined to 14.2-16.4 Ma biochronologically indicates the early Middle Miocene (Hilgen et al., 2012).

This sedimentary succession reflects the lacustrine shoreface deposition. The fine grained clastics which form the lower part of the succession are generally deposited from the suspended material under normal wave base. The upper part of the sequence is dominated by the sandstone deposition developed on the normal wave base.

Azmakdere member is the chrono- and litho-stratigraphic equivalent of the "Karabağları member" defined by Göktaş (2014*b*) in north of the Karaburun Peninsula and also the "Keramaria unit" in Chios (Besenecker, 1973).

*Beyazıt Limestone Member***:** The type locality of the Beyazıt limestone member (Göktaş, 2010), which forms the upper part of the Çiftlik formation, is the Beyazıt Hill in the SW of the Çiftlik District. The apparent thickness of the succession, which its main outcrops are exposed in the south of Çiftlik District, is maximum 55 meters.

The member, which is generally composed of medium to thick-bedded clayey limestone, has rarely distinct thin-bedded and very thick-bedded levels. General alteration color of the unit is whitish light gray. Green claystone, yellowish pale brown and massive mudstone interlayers are common. The limestone is locally dolomitic. Levels bearing algae are common; however gastropod and bivalvia contents are scarce. Beds with polygonal desiccation cracks and levels subjected to synsedimentary deformation are uncommon (Figure 8).

The sub-unit, which transitionally overlies the Azmakdere deposit in a narrow range, is unconformably covered by alluvial fan deposits of the Karagöz formation. The upper boundaries of the

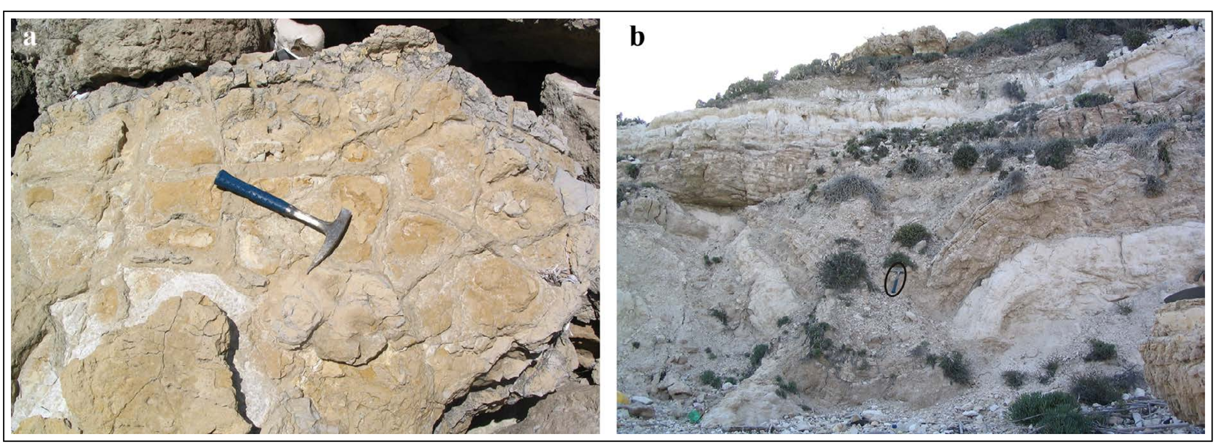

Figure 8- a) Desiccation cracks and b) syn-sedimentary deformations at some levels of the Beyazıt limestone succession exposed on the coast to the SW of Kırmızıtoprak Cape (L16-a3) (Hammer length is 33 cm).

sub-unit are generally determined by the Quaternary erosional surfaces.

3.2. Kaştepe Group

The Kaştepe group (Göktaş, 2010), the last sedimentary sequence of terrestrial Neogene sedimentation in the Çeşme Peninsula (Göktaş, 2010), is bounded by unconformities both at the bottom and the top. The Kaştepe group is constituted by the Karagöz formation in the lower part, which reflects the sedimentation in the alluvial fan environment, and transitionally overlapping lacustrine İnlice formation (Göktaş, 2010). Because of the continuing erosion until today, the apparent thickness of the Kaştepe group is over 100 meters (Figure 3).

There is no age data indicating the depositional period of the sedimentary sequence in the Miocene, which is bounded by the Quaternary erosion surfaces at the top. Kaştepe group, which unconformably overlies the Çiftlik formation, is relatively younger than Middle Miocene. It was proposed that the sedimentation occurred during the Late Miocene-Early Pliocene based on the stratigraphic correlation with the equivalent deposits on the Karaburun Peninsula ("Eşendere group": Göktaş, 2014*a, b*). The Late Miocene-Pliocene "Mytilini" and "Kokkarion" formations (Meissner, 1976; Weidmann et al., 1984) defined on Samos Island can be correlated with the rock units of the Kaştepe group.

3.2.1. Karagöz Formation

Karagöz formation (Göktaş, 2010), which forms the lower part of the Kaştepe sedimentary sequence, is represented by conglomerate, sandstone and mudstone assemblage. The type locality of the unit is the Karagöz Hill in the southern part of the L16-b4 sheet. Most of its outcrops are located in the southern part of the Çeşme Peninsula and the thickness of the succession is 70 meters.

The facies of conglomerate is dominantly channel-fill and associated with pebbly sandstone. Gravels were derived from the pre-Neogene basement rocks and Armağandağı volcanics. The size of gravels shows variation between pebble and cobble and their roundness is generally high. The mudstone consists of pinkish light brown colored, massive and very thick levels and dominates the upper parts of the alluvial deposit. It is poorly sorted and commonly includes sand and granule size clasts with rare pebbles. Due to its carbonate content, it is moderately medium to well cemented and rarely contains caliche nodules. Claystone levels are red colored, massive and moderately consolidated, and accompanies with mudstone.

The formation shows a fining-upward sequence and reflects a braided river dominant alluvial fan deposition. The unit overlies the Alaçatı pyroclastics, Ovacık and Çiftlik formations with an angular unconformity within the territory of Kaş Hill. The İnlice formation, which created the lacustrine part of the Kaştepe group, transitionally overlies the Karagöz formation.

The Saip formation (Göktaş, 2014*b*), defined around the Karaburun district center, is the stratigraphic equivalent of the Karagöz formation. The Karagöz formation can be correlated with the alluvial fan deposits "Mytilini formation" (Meissner, 1976; Weidmann et al., 1984), covering large mammal fossils of Turolian age in Samos Island. In the studies carried out in some Neogene basins such as Urla, Söke-Kuşadası and Aliağa surround, the alluvial fan deposits that could be interpreted as the equivalents of the Karagöz formation were not reported (Kaya, 1979; Eşder et al., 1991; Göktaş, 1998, 2011; Ünay and Göktaş, 1999; Ünay and Göktaş, 1999; Uzelli et al., 2017).

3.2.2. İnlice Formation

İnlice formation (Göktaş, 2010), which constitutes the upper part of the Kaştepe group, is generally characterized by micritic limestones with blue-green algae. The type locality of the unit is İnlice Stream (L16-c1) and its outcrops are mainly located around the Kaş Hill (L16-c1). Here, approximate thickness of the formation is 45 meters.

The deposition, which developed on distal deposits of the Karagöz alluvial succession starts with the lacustrine shore belt deposits composed of massive mudstones and distinct medium-bedded limestone levels. Massive mudstones are dominant in the lower part of the transition horizon. In the upper layers, the mudstone levels of which their frequency and singular thicknesses gradually decrease in succession alternate with limestones. Bluish/greenish, dark gray mudstone levels are generally very thick or massive due to intense bioturbation. The limestone is fine detritious, intense bioturbated and commonly gastropod bearing. The weathering surface is pale yellow or gray. Some limestone layers contain freshwater algae accumulation levels parallel to the bedding planes. The algal grainstone levels, in which branched, tubular and oncoidal algae are packed in the form of grain-supported are located in the lower parts of the succession.

İnlice formation, which is the last Neogene unit on the Çeşme Peninsula reflecting the deposition in the lacustrine environment, transitionally overlies the Karagöz alluvial succession. Its upper boundary was determined by the Late Pliocene (?) - Recent erosion.

The unit is the chrono- and litho-stratigraphic equivalent of the Çukurcak limestone defined by Göktaş (2014*b*) in the NW of Karaburun Peninsula. The İnlice Formation is the equivalent of the "Kokkarion formation" in Samos Island, (Meissner, 1976; Weidmann et al., 1984).

4. Neogene Volcanism

4.1. Armağandağı Volcanics

The Armağandağı volcanics, which start with an acidic volcanism in phreatomagmatic type and continue with predominantly andesitic volcanism, reflect the late Early Miocene-early Middle Miocene calc-alkaline volcanism in the Çeşme Peninsula. Volcanostratigraphically, the underlying felsic pyroclastics were investigated as the Alaçatı pyroclastics, the upper andesitic-dacitic pyroclastics and epiclastic intercalations as the Reisdere volcaniclastics, and the lava assemblages in andesite and less dacite composition as the Zeytineli lavas (Figure 9). Andesitic-dacitic lavas and their cognate volcaniclastics were described by Türkecan et al. (1998) under the name of "Armağandağı volcanics"; and the felsic pyroclastics were considered as the extensions of Foça tuff (Kaya, 1979).

4.1.1. Alaçatı Pyroclastics

According to its volcanostratigraphic level, the Alaçatı pyroclastics, which are regarded to reflect the acidic type early period of Armağandağı volcanism, are made up of rhyolitic-rhyodacitic pyroclastics predominantly represented by superimposed ignimbrite units. No cognate lava extrusions occur throughout the Çeşme Peninsula. Kalafatçıoğlu (1961) first mentioned the existence of these tuffs spreading in the Çeşme Peninsula. The unit was defined as the "silicic vitric tuffs" by Kaçmaz and Köktürk (2004) and named as the "Alaçatı tuff" by Göktaş (2010).

Typical outcrops of the unit, which has an open and covered spread in the majority of the Çeşme Peninsula, are located in the territory of the Alaçatı district. The approximate thickness of the Alaçatı pyroclastics covering the thickest and most widespread products of the Armağandağı volcanism is over 160 meters.

Pyroclastic succession with a whitish light gray weathering surface consists of levels of poorly welded ignimbrite, base surge, fallout and ash fall facies in the order of majority (Figure 10a, b). It was predicted that the phreatomagmatism had developed in shallow lake where the stromatolytic-algal limestones of Şifne formation had been deposited. It can be proposed that the ignimbrite currents in the Çeşme Peninsula, which are mostly oriented towards the west, do not reach the Chios Island, based on the study of Besenecker (1973). 2-4-meter-thick, laterally discontinuous rare volcanic sandstone intercalations in pyroclastic succession, are the products of inactive phases during the volcanism.

The base surge deposits and distal ignimbrites exposed along the coastline to the southwest of the Karadağ Hill (L16-b4) consist extensively of armored or cored accretionary lapillies. The milimetric cores (up to 5 mm) of lapilli diameters (ranging from 2-4 cm) were derived from non-cognate lava fragments or pumices in ignimbrites (Figure 10c). In tafonized pyroclastics along the shoreline between the Tatlıcak and Güvercinlik locations, secondary diagenetic occurrences such as; "liesegang rings" and carbonate(?) concretions cutting the stratigraphication are observed (Figure 10d). Diagenetic concretions with lenticular geometries of which their long axes each metric sizes, form dark gray or dark beige topographic protrusions within generally whitish light gray pyroclastic levels (Figure 10e).

It is the typical feature of ignimbrites that accidental lithic concentration showing irregular grains size distribution from sand fraction to coarse

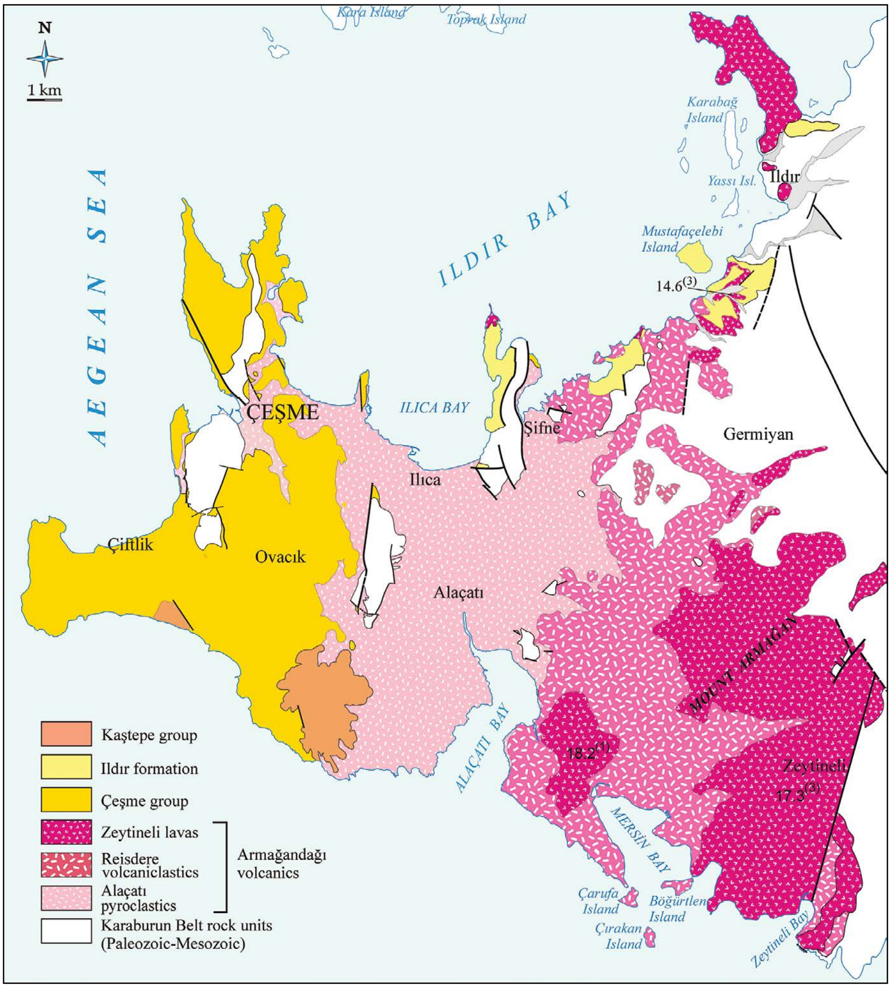

Figure 9- The distribution of the Armağandağı volcanics in the Çeşme Peninsula (Göktaş, 2010).

boulder sizes is high in general. Most of the lithic components are derived from Zeytineli lavas in andesitic and less dacitic composition (Figure 10f). Components carrying from the Reisdere volcaniclastics and the limestones of Şifne formation are more sparse (Figure 10f, g). Lithics transferred from pre-Neogene basement rocks are rare. There was not encountered any cognate lava fragments. The size and concentration of coarse lava fragments mostly in andesitic composition show a significant increasing in the proximal facies of ignimbrite flows. In this facies, decimetric-metric sizes andesitic boulders are encountered. Black andesite boulders over 1 meter size are observed to the east of Alaçatı, (Figure 10h). The concentration of proximal ignimbrites containing coarse andesite fragments in the eastern area of Alaçatı indicates that crater producing the Alaçatı pyroclastics is on the Mount Armağan, and it could not be observed as it covered by the Reisdere volcaniclastics and Zeytineli lavas. Towards the west and especially to the NW of Alaçatı, the transition into distal ignimbrites is observed, the volcanic lithics gradually decrease and the average pumice sizes become smaller as they move away from the probable eruption center.

Black colored, basalt-like andesites with fine crystalline textures are predominant among the lava fragments. The phenocrystalline content of from these lavas, which are defined mostly as pyroxene andesite in porphyritic texture are composed by plagioclase, amphibole and pyroxene. The groundmass is composed of volcanic glass, plagioclase microliths, pyroxene crystallites and opaque minerals. Plagioclase (andesine-labrador) is generally prismatic and polysynthetic twinning. Amphibole (hornblende) is usually subhedral. Orthopyroxene (hyperstene) is in green tones and has abundant cracks. Clinopyroxene (augite) has brown tones, subhedral and zoned. The

Figure 10- a) General view of the Alaçatı pyroclastics (L16-c1; between Tatlıcak and Güvercinlik locations), b) ignimbrite units separated by base turbulence levels (L16-c1; Shoreline between Tatlıcak and Güvercinlik locations), c) close views of ignibrite unit comprising accretionary lapillies in the lower part, and base surge level and cross sections of cored lapillies (L16-b4; shoreline in the sw of Karadağ Hill), d) liesegang rings in the lower part and carbonate(?) concretions (black arrows) and taphonization (L16-c1; Shoreline between Tatlıcak and Güvercinlik locations), e) a lenticular carbonate(?) concretion in massive ignimbrite unit comprising accretionary lapillies (L16-c1; Shoreline between Tatlıcak and Güvercinlik locations), f) some parts of ignimbrites are richer in andesite lava clasts but less in dacite lava fragments. Algal limestone clasts derived from the Şifne formation are rare (black arrows) (L16-b4; east of Alaçatı district, g) a block derived from Reisdere volcaniclastics in ignimbrites (L16-b4; east of Yumru Bay) and h) some of andesitic lava blocks has a size up to 1 meter (L16-b4; east of Alaçatı district).

minor dacite clasts in the volcanic lithic content show red-black color zonation in concordant with the flow structure.

In the region, the Alaçatı pyroclastics overlies the laterally discontinuous andesitic volcaniclastics reflecting the beginning of the Armağandağı volcanism and algal-biostromal limestones of the Şifne formation. The contact relationship with Şifne formation is observed in the center of Çeşme district and around the Kara Hill basement uplift to the west of Alaçatı. As seen on the eastern shores of the Gulf of Alaçatı, the density currents formed the Reisdere volcaniclastics overlie the Alaçatı pyroclastics with laterally interfingering. The alluvial fan deposits of the Karagöz formation extensively exposed in the SW of Alaçatı overlie the Alaçatı pyroclastics with an angular unconformity.

4.1.2. Reisdere Volcaniclastics

The Reisdere volcaniclastics are mainly composed of intermediate pyroclastics and lahar levels of the Armağandağı volcanism. These volcaniclastics are widespread in the west of Mount Armağan (Figure 9).

Andesitic pyroclastics are predominantly in the facies of blocky ash flow. The multilayered pyroclastic flow units together with lahar layers are meters in thickness and have no internal structures. The size andesitic lava fragments are centimeters and decimeters, they are angular and sub-angular. The concentration of coarse lava fragments is variable and they show irregular distribution in the coarse ash matrix. The pyroclastic flow units, inwhich coarse lava fragments are reverse graded, are rarely observed.

The epiclastic levels, which were deposited by reworking previous density flow deposits, are in volcanic mud/debris flow facies known as the “lahar”. The andesitic coarse volcaniclastic content is generally high. These mass flow layers, whose matrix is composed of poorly sorted volcanic sandstone, are usually massive and their thickness is generally metric. They form superimposed sedimentation units or alternate with blocky ash flow layers. The stratification, which becomes evident by the vertical change in coarse clast concentration, is mostly less developed (Figure 11).

Based on field data, the Reisdere volcaniclastics widely spreads over the basement rocks of the Karaburun Belt and Alaçatı pyroclastics. According to evaluations on the FY-1 geothermal drilling conducted by MTA, 40 meters thick “andesitic agglomerate” which is considered to reflect the beginning of the Armağandağı volcanism (Yılmazer and Yakabağı, 1995), underlies the Alaçatı pyroclastics and overlies the Şifne formation (Figure 3). Andesitic coarse lava fragments are common in the Alaçatı pyroclastics support the andesitic volcanism that precedes the settlement of felsic ignimbrites. The Reisdere volcaniclastics are accepted as laterally interfingered with the Zeytineli lavas from bottom to top, which constitute the lava assemblage of Armağandağı volcanics (Figure 3). There is no contact relationship between the Reisdere volcaniclastics and the Ovacık

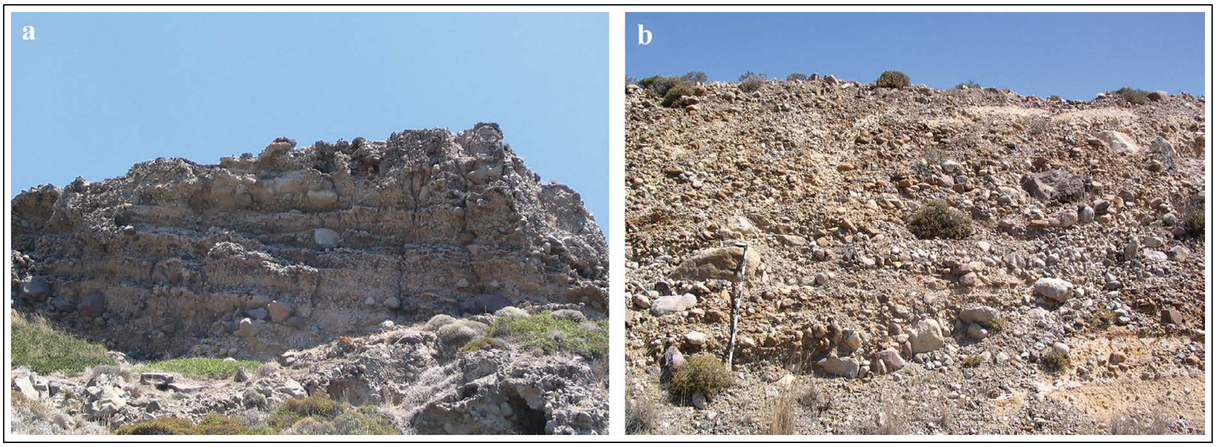

Figure 11- a) General view of the lahar layers and b) a layer having high pebble-block concentration (Jacob’s staff is 150 cm) (L16-b4; NE of the Alaçatı district).

and Çiftlik formations, which are considered to have deposited synchronously. This lateral relationship was proposed based on the indirect data. The volcanic sandstone interlayers with andesitic component in the Ovacık formation and Reisdere volcaniclastics deposited with lateral interfingering into the Ildır formation, which is accepted as the equivalent of the Çiftlik formation as defined in Göktaş (2016*b*), are indirect examples.

4.1.3. Zeytineli Lavas

Zeytineli lavas represent mostly andesitic and less dacitic lava assemblage of Armağandağı calc-alkaline volcanism. The first study related to the petrographic and petrochemical properties of lava belongs to Innocenti and Mazzuoli (1972). Türkecan et al. (1998) examined the petrographical and geochemical properties of the lava assemblage within scope of the "Armağandağı Volcanics".

The lava samples examined in previous studies have been described as quartz-latite andesite (Innocenti and Mazzuoli, 1972), 'andesite' and 'pyroxene andesite' (Türkecan et al., 1998). In this study, the phenocrystals of mostly the hyalomicrolitic-porphyritic samples with few flow textured samples, which are defined as "pyroxene-hornblende andesite", are composed of plagioclase, pyroxene, amphibole and biotite. Plagioclase (andesine-labrador) is mostly subhedral, usually polysynthetic twinned, and locally zoned. Clinopyroxene (augite) is euhedral-subhedral, pale brown colored, rarely twinned and glomeroporphyritic textured. Orthopyroxene (hyperstene) is in green tones and usually fractured. Amphibole (hornblende) is usually subhedral and in brown tones, and it forms glomeroporphyritic texture or is found as opacified relicts. Biotite is in the form of large and small lamellae and it is rarely observed. The groundmass is composed of volcanic glass, plagioclase and biotite microliths, pyroxene crystallites and opaque minerals. Biotite microliths are in elongated prismatic form. Opacification is widespread in amphibole and biotites.

The sample taken from black, fine-crystalline and basalt-like lava level which overlies the Alaçatı pyroclastics near Zeytineli, is defined as the "olivine basalt". Plagioclase and pyroxene form the phenocrystals of hypocrystalline-porphyritic (intersertal) textured rock. Plagioclase (labrador) has generally polysynthetic twinning and prismatic shape. The groundmass of the rock is composed of volcanic glass, oriented plagioclase, olivine and pyroxene microliths and opaque minerals.

The Zeytineli lava assemblage, which is considered as laterally interfingered with the Reisdere volcaniclastics, represented the multi-phased lava eruptions synchronously developed with the deposition of lacustrine units on the Şifne formation of the Çeşme group. The lateral relationship was constructed based on the chronostratigraphic relations and limited lithostratigraphic observations. The first order stratigraphic relationship was observed between the Zeytineli lavas and Ildır formation sediments (Göktaş, 2010; 2016*b*).

4.1.4. Major Element Oxide Geochemistry of the Armağandağı Volcanics

The major element oxide compositions of 12 samples collected from the Alaçatı pyroclastics by Kaçmaz and Köktürk (2004) were evaluated on the TAS diagram of Le Bas et al. (1986) and determined that all the samples plotted in the sub-alkaline zone and accumulated mostly in rhyolitic and few in dacitic areas (Figure 12a). Kaçmaz and Köktürk (2004), showed that the samples, which they had plotted on the Zr/TiO_2-Nb/Y diagram based on the stable elements prepared by Winchester and Floyd (1977), were concentrated in rhyodacite/dacite composition area (Figure 12b). The samples Ç.18 in the andesite composition area and Ç.20 in the dacite composition area represent lava clasts commonly found in felsic ignimbrites. All samples are calc-alkaline in character (Figure 12c) and have high potassium content (Figure 12d).

The main element oxide compositions of the samples taken from the previous studies (Innocenti and Mazzuoli, 1972; Türkecan et al., 1998; Helvacı et al., 2009; Göktaş, 2010), which represent the lava assemblage of the Armağandağı volcanics (Table 1), were plotted on the TAS diagram of Le Bas et al. (1986), and it shown that all samples were located in the subalkaline zone and accumulated mainly in the andesitic and less dacitic composition area (Figure 12A). In the AFM diagram of Irvine and Baragar (1971), the samples in calc-alkaline character are located in "high potassium andesite" area in the K_2O-

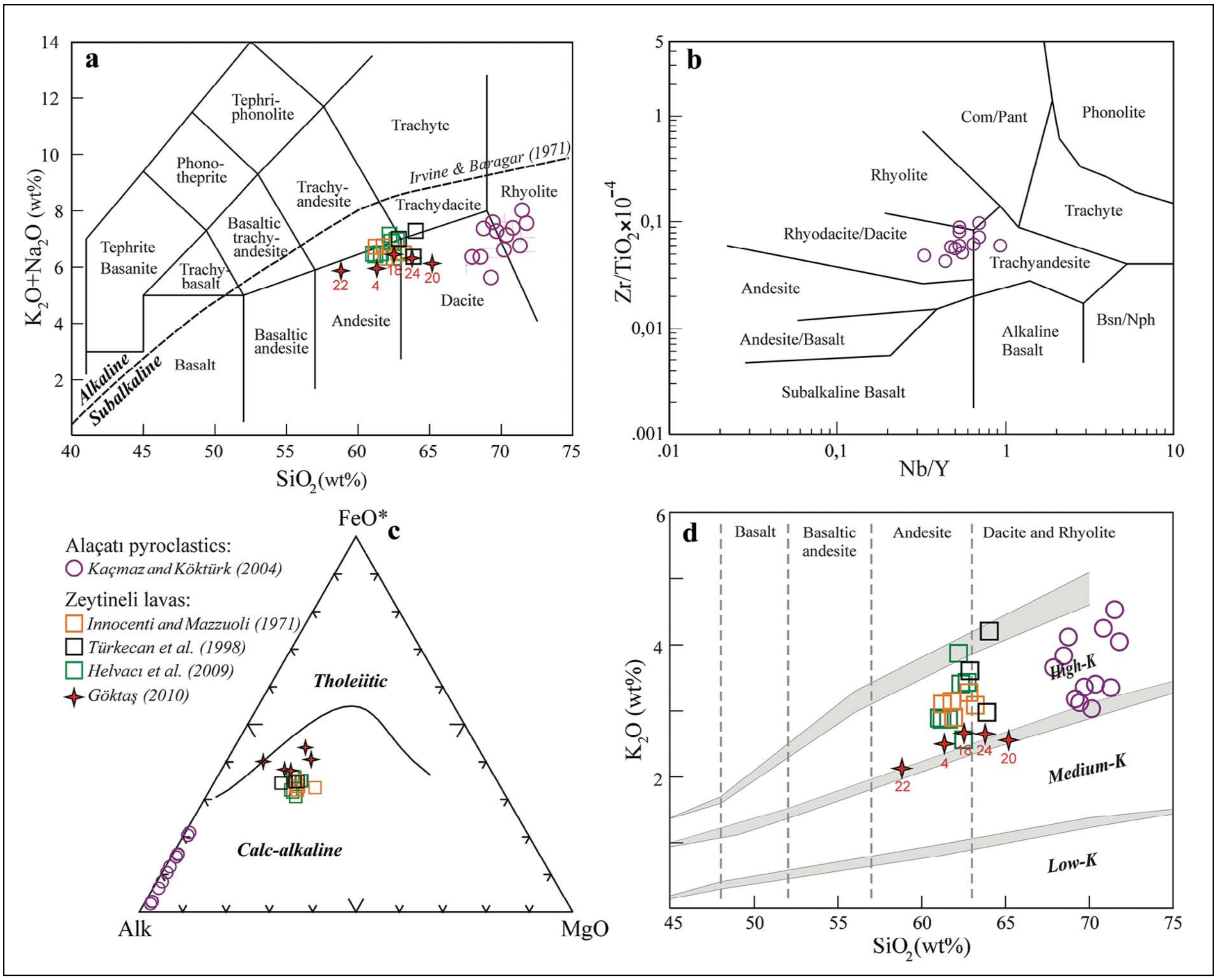

Figure 12-Evaluation of the results of major element analysis of the Armağandağı volcanics taken from previous studies; a) TAS diagram (Le Bas et al., 1986), b) Zr/TiO_2-Nb/Y diagram (Winchester and Floyd, 1977), c) AFM diagram (Irvine and Baragar, 1971) and d) K_2O-SiO_2 diagram (Le Maitre, 1989).

Table 1-Results of the major element oxide analysis of the samples collected by Göktaş (2010) from the Zeytineli lavas.

Sample	*East*	*North*	SiO_2	Al_2O	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	SrO	BaO	LOI
Ç.18	*47.615*	*38.673*	61.10	16.80	5.70	2.20	5.30	3.70	2.60	0.50	0.30	0.10	0.08	0.14	1.35
Ç.20	*47.615*	*38.673*	63.80	16.00	5.20	1.00	5.60	3.50	2.50	0.50	0.20	0.10	0.08	0.14	1.35
Ç.22	*57.140*	*33.585*	58.10	18.20	7.10	2.40	5.70	3.70	2.10	0.80	0.30	0.10	0.08	0.08	0.25
Ç.24	*52.150*	*36.550*	62.60	16.30	5.50	1.90	5.30	3.60	2.60	0.60	0.20	0.10	0.06	0.07	0.20
Ç.4	*53.275*	*45.380*	59.90	16.70	6.30	0.10	5.90	3.40	2.40	0.60	0.20	0.10	0.07	0.09	1.40

SiO_2 diagram of Le Maitre et al. (1989) (Figures 12c and 12d).

4.1.5. Geochronology of the Armağandağı Volcanics

Borsi et al. (1972), took an age of 18.2 ± 3.5 Ma from quartz-latite andesite (biotite) by the K/Ar method. The age obtained from an andesite sample of Helvacı et al. (2009) is 17.3 ± 0.1 Ma by means of the $^{40}Ar/^{39}Ar$ method. These radiometric data are related to the activity of the Armağandağı intermediate volcanism in the late Early Miocene. The age of 14.6 ± 0.6 Ma by K/Ar method taken by Göktaş (2010) from a lava flow, which is considered as an extension of Zeytineli lavas around Ildır, shows that the calc-alkaline andesitic volcanism in the Çeşme Peninsula continued until the early Middle Miocene.

5. Stratigraphical Correlation and Paleogeographic Evolution

Large part of the Early-Middle Miocene basin, which has deposits on the Çeşme Peninsula and along the eastern shores of Chios Island, has been submerged by the collapse of the Aegean land. Early Miocene deposits defined by Besenecker (1973) in Chios Island and the possible chronostratigraphic equivalents in the Çeşme Peninsula are represented by different sedimentary facies. However, Middle Miocene sedimentation can be correlated in terms of depositional environment, rock composition and mammal faunas. The green lacustrine shoreface succession, representing the early Middle Miocene (Langhian) deposition, is the stratigraphic reference level that enables the first-degree correlation between the Early-Middle Miocene successions in the western (Chios Island) and eastern (Çeşme Peninsula) parts of the basin. The Azmakdere member, which forms the lower part of the Çiftlik formation on the Çeşme Peninsula, and Keramaria unit, its equivalent in Chios Island, was firstly correlated by Besenecker (1973) based on the mammalian fossils belonging to the MN5 biozone. The Early Miocene sedimentary deposits under this datum level are dominantly represented by lacustrine limestones (Şifne and Ovacık formations) in the east of the basin, whereas in the Chios Island representing the west of the basin, the fluvial sediments were filled defined by Besenecker (1973) as “Thymiana” and “Zyfia” units (Figure 13).

In this study, the chrono-lithostratigraphic equivalents of the Early-Middle Miocene lacustrine dominant sediments studied within scope of the Çeşme group in the north of Karaburun Peninsula are included in the Karaburun group (Göktaş, 2014*a, b*) (Figure 14). Şifne formation, which corresponds to the beginning of terrestrial Neogene sedimentation in coastal Aegean regions and ends with algal limestones grading from alluvial deposits to lacustrine sediments, can be correlated with Salman+Yeniliman limestone members of the Haseki formation, the same stratigraphic level with the Karaburun group (Göktaş, 2014*a*). Şifne formation, which its important part does not expose in the Çeşme Peninsula, is represented by laminated stromatolithic limestones that increase in the upper part of the succession.

By the syn-sedimentary deposition of the Alaçatı pyroclastics on the Şifne lacustrine carbonate platform, the Early Miocene lacustrine sedimentation was interrupted (restricted with the settlement time and spread areas of pyroclastics). The Alaçatı pyroclastics, which reflect the acidic early period of the Armağandağı volcanism are the products of phreatomagmatism developed in the shallow lacustrine environment where Şifne formation were deposited. The gradual increase of non-cognate (in composition of andesite and less dacite) coarse lava fragments contained by ignimbrites towards the Mount Armağan indicates that the crater which produce the Alaçatı pyroclastics were located around this mountain. The field data indicate that ignimbrite flows are mostly oriented to the west and south. However, it has been evaluated that these ignimbrite flows did not reach Chios Island. In Chios, the rhyolitic ignimbrite level of 15.5 Ma (Bellon et al., 1979) spreading as a reference level at the bottom of the Keramaria succession, is younger than the ignimbrites in the Alaçatı pyroclastics and has no equivalent in the Çeşme Peninsula (Figure 13).

Early Miocene lacustrine sedimentation maintained its continuity in the regions outside the spreading areas of Alaçatı pyroclastics, as it was in the north of the Karaburun Peninsula. The Early Miocene basin suddenly deepened with the settlement of Yaylaköy volcanics on the stromatolitic-algal limestone platform, blue-green algae with limited photosynthetic possibilities gradually decreased and the lacustrine sedimentation characterized by thin-laminated micritic limestone (Aktepe member: Göktaş, 2014*a*) developed in north of the Karaburun Peninsula. In the Çeşme Peninsula, the Ovacık formation was deposited during the lacustrine transgression process following the settlement of Alaçatı pyroclastics in the Early Miocene basin. Ovacık formation, which unconformably overlies the Alaçatı pyroclastics by its İnönü member, reflects the continuation of the Early Miocene lacustrine sedimentation, which was interrupted by the settlement of the Alaçatı pyroclastics. The rock type assemblage and stratigraphic position of the Ovacık formation suggests a first-degree correlation with the Aktepe member (Figure 14).

Early-Middle Miocene lacustrine sedimentation on the Çeşme Peninsula continued with the Çiftlik formation, which was conformably deposited over the Ovacık formation. In contrast to the conformable relationship between the two successions, the

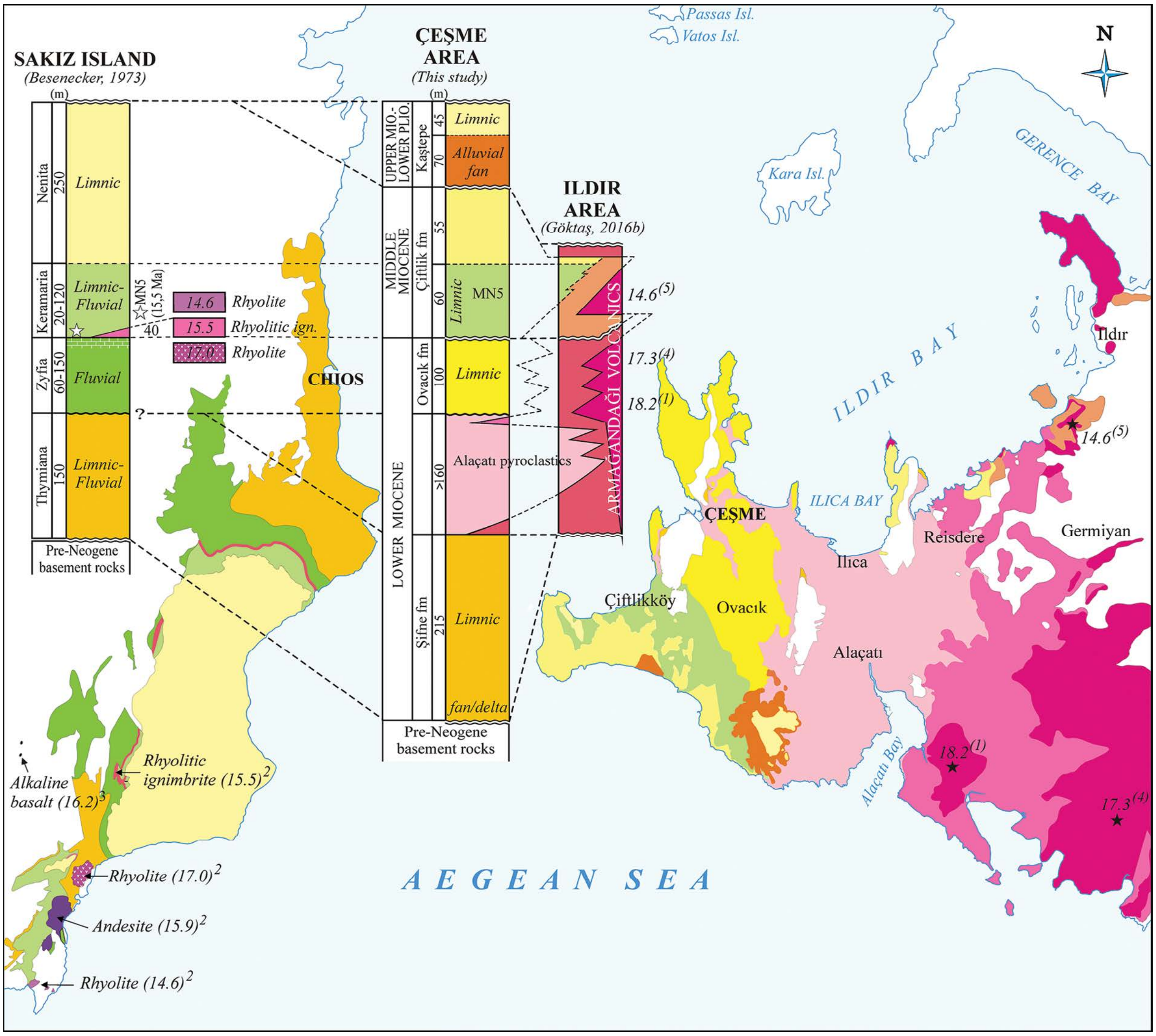

Figure 13-Stratigraphic correlation of Neogene rock units in Chios Island and the Çeşme Peninsula. Radiometric ages: [1]Borsi et al. (1972), [2]Bellon et al. (1979), [3]Pe-Piper et al. (1994), [4]Helvacı et al. (2009), [5]Göktaş (2010).

lithofacies change reflecting the sudden deepening of the basin is evident. The environmental frame where the Ovacık formation was deposited remained unchanged and lacustrine sedimentation continued under the depositional conditions specific to different depths of the same basin. The thin detritious shoreface sedimentation of the Azmakdere member developed on the limestones of the Ovacık formation, show that the basin was suddenly deepened on a regional scale and the fine clastic sediment transportation increased. The sedimentation energy of the Azmakdere deposit increases from bottom to top. The deposition from suspension under normal wave bottom, represented by the dark green claystone-siltstone assemblage, dominates the lower parts of the succession. Intercalations of climbing rippled storm sand rarely found in the deposit are typical. In upward direction, sand-size sediment transportation increased, and a massive, locally cross-bedded and weakly compacted sandstone dominating succession was deposited. The large mammalian bones found by Besenecker (1973) in the Batı Cape are in this sandstone layers. The overlapping of the Azmakdere deposits outcropping around the Kocadağ Hill onto the carbonates of the Güvercinlik formation with diachronous transgressive contacts shows that this elevation is one of the islands that existed in the Early Miocene basin. The N-S trending fault, which restricts the Kocadağ uplift from the west, reactivated after deposition and altered the Azmakdere member deposits by giving way to high Fe

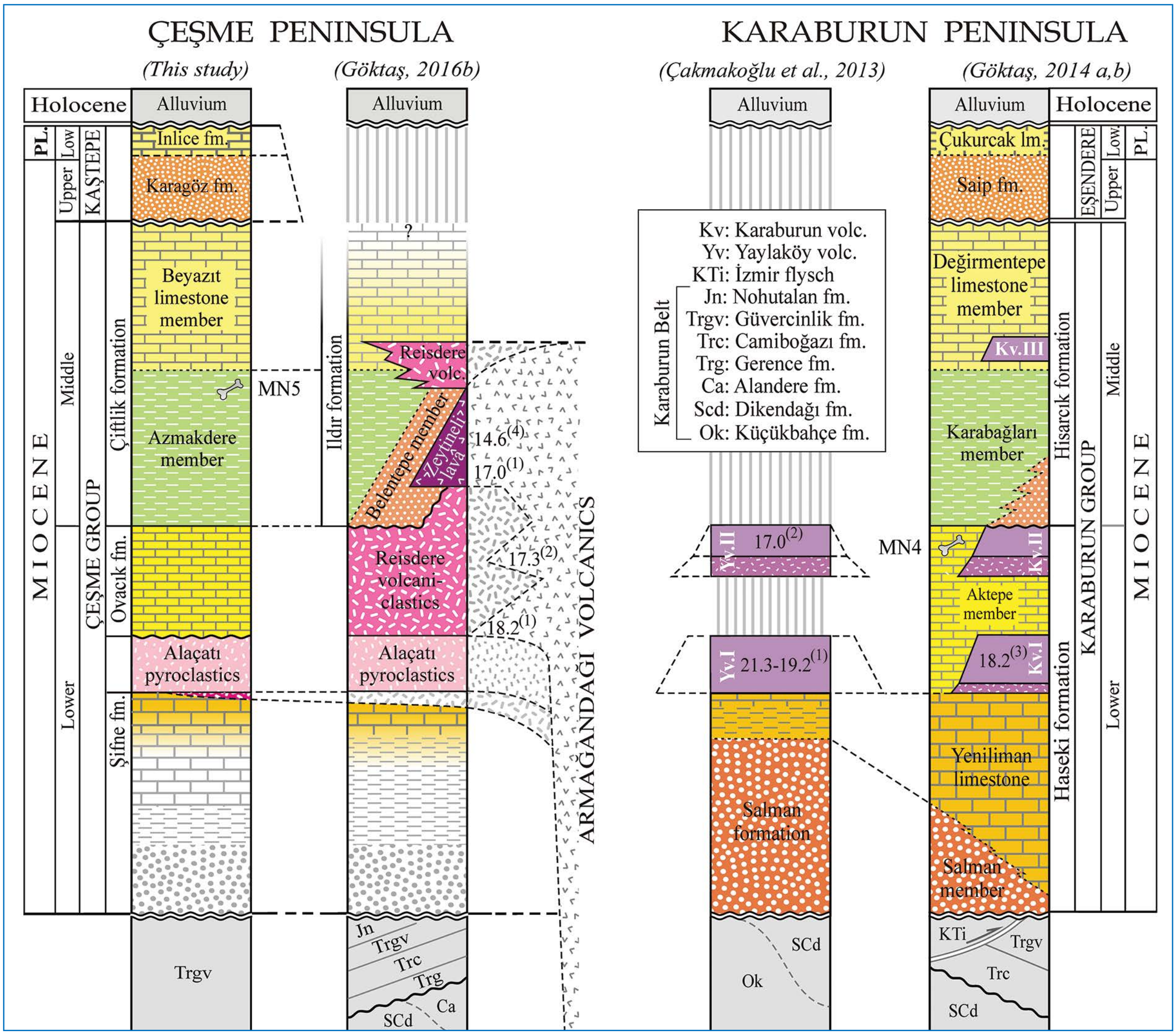

Figure 14- Correlation of Neogene rock units in the Çeşme and Karaburun peninsulas (modified from Göktaş 2016*b*). Radiometric ages: [1]Borsi et al. (1972), [2]Helvacı et al. (2009), [3]Göktaş (2014*a*), [4]Göktaş (2010).

bearing hydrothermal solutions. The Beyazıt limestone member, which forms the upper part of the Çiftlik formation, is the last unit of the Çeşme group. It can be asserted that the Early-Middle Miocene lacustrine sedimentation, which is represented by the Çeşme group, regionally ended with short compressional phase prior to the Late Miocene extension that affects the Western Anatolia (Yılmaz, 2000; Yılmaz et al., 2000). The stratigraphical position, type of deposition and rock type assemblage of the Çiftlik formation suggest the correlation with the Ildır formation defined in south of Ildır Gulf (Göktaş, 2016*b*) and the Hisarcık formation (Göktaş, 2014*b*) in the north of the Karaburun Peninsula (Figure 14). However, the alluvial deposits forming the lower parts of the Ildır and Hisarcık formations (Belentepe member: Göktaş, 2016*b* and Hacıhüseyintepe member: Göktaş, 2014*b*) do not have correspondence in the region where the Çiftlik formation was deposited. According to Göktaş (2016*b*), the Belentepe member was deposited at the margins of the Early Miocene basin around the Ildır Bay, which tectonically deepened early in the Middle Miocene and expanded towards NE of the Çeşme Peninsula. The Azmakdere member, which was deposited synchronously in the west of peninsula, represents the open lake facies. The Azmakdere member can be regarded as the equivalent of the Karabağları member defined by Göktaş (2014*b*) in north of the Karaburun Peninsula. The Beyazıt limestone member is the equivalent of the Değirmentepe limestone member in the same area (Figure 14). The Middle Miocene Urla group (Göktaş, 2011; 2016*a*), defined in the Urla basin and İzmir Bay islands, includes the sedimentary assemblages that can be correlated with the Çiftlik formation.

The fields observations related to the order of succession of the Armağandağı volcanics formed by the products of Early-Middle Miocene calc-alkaline acidic-intermediate volcanism on the Çeşme Peninsula, suggest that the volcanism developed mainly with the settlement of the Alaçatı pyroclastics. However, i) the "andesitic agglomerate" level situated between the Şifne formation and Alaçatı pyroclastics according to drilling data and ii) andesitic lava fragments largely present especially in proximal sections of the felsic ignimbrites presenting the Alaçatı pyroclastics show that the intermediate volcanism started just before the settlement of the Alaçatı pyroclastics (Figure 3). There is not any data related to the volcanic activity during the depositional period of Şifne formation. Andesitic (-dacitic) volcanics observed on the Alaçatı volcanics start with Reisdere volcaniclastics consisting of pyroclastics and epiclastics in lahar facies and continues with laterally interfingered cognate lava extrusions along the whole succession (Zeytineli lava). The youngest known products of the Zeytineli lavas are laterally associated with the sediments of the Ildır formation (Göktaş, 2016*b*). The 14.6 ± 0.6 Ma K/Ar age obtained from the andesite flow in alluvial deposits of the Belentepe member indicates that the Armağandağı intermediate volcanism has continued at least until the early Middle Miocene (Göktaş, 2016*b*). Based on radiometric data, the bimodal alkaline volcanism started in the Urla depression, which continued its activity until the end of the Middle Miocene, while the Armağandağı calc-alkaline volcanism became extinct in the Early Middle Miocene (Göktaş, 2011, 2016*a, b*).

The Kaştepe group, extending in south of the Çeşme Peninsula, starts with the alluvial deposits (Karagöz formation) and ends with the lacustrine deposits (İnlice formation), and it is the last succession of the Neogene sedimentation. The succession, considered to have deposited during the Late Miocene-Early Pliocene, overlies the Alaçatı pyroclastics and the lacustrine sediments of Ovacık and Çiftlik formations with an angular unconformity. The Eşendere group defined by Göktaş (2014*b*) in NE sections of the Karaburun Peninsula, which represents the western edge of the Foça Depression, is considered as the equivalence of the Kaştepe group in terms of regional stratigraphic position, order of succession and similar rock type assemblages. In the studies carried out in other parts of the Foça Depression (Urla section, İzmir Bay islands and Foça section) and in Söke-Kuşadası basin, no succession that can be compared to those of the Kaştepe group were identified (Kaya, 1979; Eşder et al., 1991; Göktaş, 1998, 2011; Ünay and Göktaş, 1999; Uzelli et al., 2017). The Late Miocene-Early Pliocene "Mytilini"+"Kokkarion" formations (Meissner, 1976; Weidmann et al., 1984) identified in Samos Island can be correlated with the Kaştepe group.

The area where the Çeşme Peninsula is located is fragmented by the average N-trending faults in the Early Miocene and mostly by NW trending (strike-slip, reverse, oblique-normal) faults after the Middle Miocene, and folded in NW-SE, N-S, NE-SW axis extensions as commonly observed in the Ovacık formation (Sözbilir et al., 2007). Most of ones having relatively short-axis plunge dipping in two directions (Figure 2). All lacustrine units within the Çeşme group overlap with transgressive conglomerates on the basement rocks, which are represented by the Güvercinlik formation uplifted by the N trending faults. This relationship reflects that these uplifts constitute the basement islands within the Early-Middle Miocene basin. The majority of these faults reactivated after the deposition of the Çeşme group. In the region uplifted during the short compressional phase before the late Miocene extension (Yılmaz, 2000; Yılmaz et al., 2000), the Early-Middle Miocene lacustrine basin deposited by the Çeşme group became terrestrial and the eroded basin fill has become material for the alluvial fans (Karagöz formation) which reflect the beginning of the Late Miocene deposition.

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