Bull. Min. Res. Exp. (2015) 150: 1-18

Bulletin of the
Mineral Research and Exploration

http://bulletin.mta.gov.tr

The GEOLOGY of GÖKÇEADA (ÇANAKKALE)

Ramazan SARI[a,*], Ahmet TÜRKECAN[b], Mustafa DÖNMEZ[b], Şahset KÜÇÜKEFE[a], Ümit AYDIN[c] and Öner ÖZMEN

[a] *Maden Tetkik ve Arama Genel Müdürlüğü Balıkesir Bölge Müdürlüğü*
[b] *Maden Tetkik ve Arama Genel Müdürlüğü Jeoloji Etütleri Dairesi Başkanlığı*
[c] *Maden Tetkik ve Arama Genel Müdürlüğü Maden Etüt ve Arama Dairesi Başkanlığı*

Keywords:
Gökçeada, Geology, Volcanism, Magmatism

ABSTRACT

The geology and especially the magmatic rocks of Gökçeada, which is the biggest island of Turkey and located at 20 km's west of Biga Peninsula, constitute the subject of this study. Late Ediacaran/Early Paleozoic aged Çamlıca metamorphics which crop out with a tectonic uplift in a narrow area in northwest of Gökçeada are the oldest rocks of the island. Early Eocene aged Karaağaç Formation which is formed by submarine fan deposits unconformably overlies Çamlıca metamorphics. As for the Dağiçitepe volcanic member which is formed by rhyolitic lavas, tuff and tuffites emplaced into Karaağaç Formation cutting Çamlıca metamorphics is the oldest volcanic unit of the study area. On Karaağaç Formation, Koyunbaba Formation has unconformably been deposited which consists of Middle Eocene shallow marine sediments. Then it has conformably been overlain by Soğucak Formation which consists of SE-NW extending reefal limestone. Middle-Upper Eocene aged Ceylan Formation which conformably overlies the Soğucak Formation and the early Oligocene aged Mezardere Formation which conformably overlies Ceylan Formation have been deposited due to turbiditic currents in deep marine environment. Late Eocene(?) – Oligocene aged subvolcanics which cut Mesozoic and Eocene units and emplaced into Eocene aged sedimentary units in the form of crypto dome and dome form the recent rigid topography of the study area and are the second magmatic phase called the "Gökçeada Domes". Diorite-monzonites porphyry which crystallized in lower zones of subvolcanics on the other hand constitutes Mutludere intrusion. In eastern and southern parts of Gökçeada, Late Oligocene Gökçeada ignimbrites are located which are observed in the form of pumice flows on Mezardere Formation. These ignimbrites are then overlain by Early Miocene aged Kesmekaya volcanics which are formed by blocky ash flows. Middle Miocene aged Eşelek volcanics consisting of lava and pyroclastics with composition basaltic andesite and andesite are observed on a large area in east of Gökçeada. Upper Miocene aged Çanakkale Formation which is generally formed by the intercalation of poor consolidated conglomerate, sandstone, siltstone and marl crops out in narrow regions at east, southeast and south of Gökçeada. Quaternary alluvial deposits and debris composed of loose, unconsolidated sand, silt and other sediments unconformably overlie all previous units and complete the succession. Main tectonic structures of Gökçeada are formed by right lateral oblique faults which developed in Neo-tectonic period.

1. Introduction

Gökçeada is located at north of Aegean depression at southwest of Thrace and is approximately 20 km's away from Biga Peninsula (Figure 1). It belongs to Çanakkale Province, and is the biggest island of Turkey with an area of 289 km^2 and a coastal length of 92 km.

This study was made in order to prepare 1/25 000 scaled geological maps which will form a basis to polymetal researches in Gökçeada within scope of "Çanakkale-Balıkesir Ruhsat Etütleri" (Çanakkale-Balıkesir License Researches) subproject carried out between years 2008-2011 of the "Batı-Orta Anadolu Polimetal Maden Aramaları Projesi"

*Corresponding author: Ramazan Sarı, rsarimta@hotmail.com

(Project of West-Central Anatolian Polymetal Mineral Researches) of the General Directorate of Mineral Research and Exploration (MTA). Within this framework, geological maps previously prepared in Gökçeada were assessed, and the revision and/or detailed geological investigations at necessary areas were made. Paleontological, petrographical and mineralogical descriptions of samples were collected on field and their chemical analyses were performed in MTA labs. However, the geochronological dating were made in ActLab (Canada).

First significant geological investigations in Gökçeada have been realized by Akartuna (1950), Okut (1975), Akartuna and Atan (1978). However, especially the studies of Akartuna and Atan (1978) have been used during the preparation of geological maps. Later on; Ercan et al. (1995) have investigated the characteristics of Tertiary volcanism, and Kesgin and Varol (2003), Varol and Baykal (2008) have carried out studies related to the stratigraphy of sedimentary rocks. Ilgar et al. (2008), on the other hand have published 1/100.000 scaled geological map of the island. However, this island can merely be called as the “Land of Domes” because of their excessive domal structures forming the actual morphology. But, the magmatic rocks of Gökçeada have not been mentioned in any of these studies. However, an important magmatic activity in the island is in question. Therefore; the purpose of this investigation is to prepare geological maps in which magmatic rocks widely observed on the island were distinguished in detail, and contribute to researches related to reveal the geological evolution and mineral potential of the region.

2. Stratigraphy

In Gökçeada, metamorphic, magmatic and sedimentary rocks crop out ranging from Mesozoic to Quaternary. The formation names suggested in the book “Thrace Lithostratigraphical Units” (MTA, 2006) of the Stratigraphy Committee were used for the nomenclature of formations in which rocks have formed. The geological map of the island and generalized stratigraphical section of rocks were given in figures 1 and 2, respectively.

2.1. Çamlıca Metamorphics (Pєça)

This unit is composed of sericitic schist, chloritic schist, slate and marble layers. It was defined as “Çamlıca metamorphics” in Biga Peninsula by Okay et al. (1990) and in this study the same name was given to this unit. It crops out on Dağiçi Hill and in the stream located at west of Dağiçi Hill, in a very small area at northwest of Gökçeada (Figure 1).

More than 80% of Çamlıca metamorphics which form in sericitic and chloritic schists, slate and marble types are constituted by gray, dirty brown, greenish colored, well foliated, much micaeous, quartz-mica schists with carbonates in occasion. Petrographically; garnet-mica-quartz schist, and mica-quartz schist were detected in the unit. In addition to quartz and white mica minerals, calcite, biotite, albite, chlorite and garnet minerals are also widely present in these rocks.

The bottom of Çamlıca metamorphics does not appear in Gökçeada. These metamorphics have cropped out by faulting in the stream at west of Dağiçi Hill (Figure 3). The unit is while overlain by an angular discordance by Kuvizian-early Lutetian aged sediments (Figure 4), it is also crosscut by Eocene aged rhyolites and Oligocene aged subvolcanics.

The unit which was aged as Paleozoic by Akartuna and Atan (1978), though there was not found any fossils, is cut by Eocene and Oligo-Miocene granitoids in west of Karabiga town in Biga Peninsula (Ilgar et al., 2008). The age of metamorphism of the unit, using fengites in quartz-mica schists in Biga Peninsula, was determined as 65-69 My using Rb/Sr method (Okay and Satır, 2000). Recent studies carried out show that the primary depositional age of Çamlıca metamorphics is Late Ediacaran and/or Early Paleozoic (Tunç et al., 2012).

When the similarity of lithological and metamorphic characteristics of rocks in close vicinity is taken into consideration, it is thought that Çamlıca metamorphics resemble to Upper tectonical unit which is formed by quartz-mica schist and gneisses consisting of calc schist, marble and amphibolite interlayers in Rhodopian massive between Greece and Bulgaria (Papanikolau and Panagopulos, 1981; Barr et al., 1999; Okay and Satır, 2000; Duru et al., 2008).

2.2. Karaağaç Formation (Tek)

In west-northwest of Gökçeada, conglomerate, sandstone, claystone, marl intercalation and volcanic rocks in rhyolitic composition crop out between Gizli Harbor and Mutlu Stream. This unit was first introduced by Sfondrini (1961) in Thrace as “Karaağaç unit” and was named as Karaağaç Formation in Gökçeada within scope of this study.

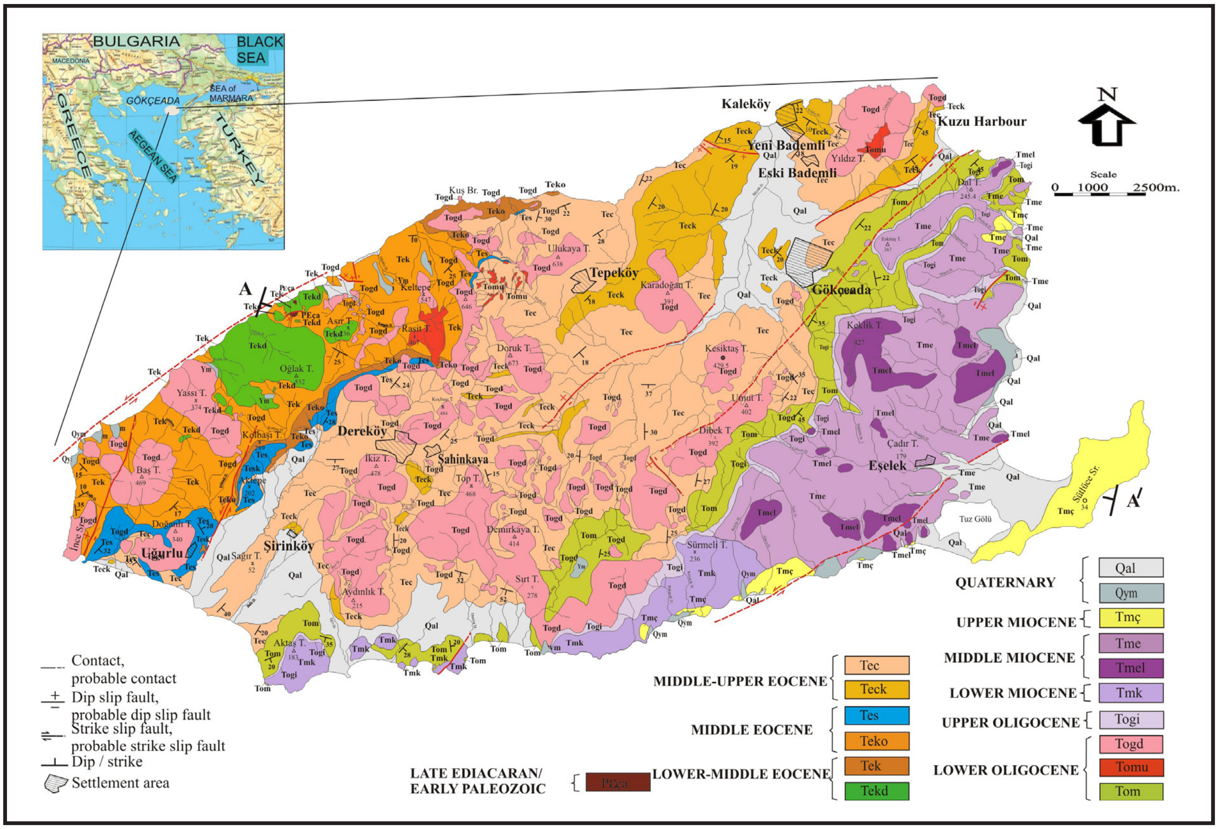

Figure 1- Geological map of Gökçeada (modified from Akartuna and Atan (1978)). Qal- Alluvial; Qym- debris; Tmç- Çanakkale Formation: sandstone, claystone, siltstone etc.; Tme- Eşelek volcanics: Basaltic andesite, andesitic pyroclastics; Tmel- Lava member: Gray-dark gray colored pyroxene andesitic lava; Tmk- Kesmekaya volcanics: Ash-block flow, lahar type pyroclastic flows; Togi- Gökçeada ignimbrite: Dark white colored pumice and pumice flow; Togd- Gökçeada domes: Porphyritic andesite; Tomu- Mutludere intrusion: Quartz monzonite, diorite-diorite porphyry; Tom- Mezardere Formation: Conglomerate, sandstone, siltstone, marl, etc.; Tec- Ceylan Formation: Claystone, sandstone, siltstone, shale, marl, etc.; Teck- sandstone member: Medium-thick bedded sandstone, siltstone; Tes- Soğucak Formation: Reefal limestones: Teko- Koyunbaba Formation: Conglomerate, sandstone, siltstone; Tek- Karaağaç Formation: sandstone, claystone, limestones, marl, conglomerate, etc.; Tekd- Dağiçitepe volcanic: Rhyolitic lava, tuff and tuffite; P€ça- Çamlıca metamorphics: Mica schist, sericitic schist, chloritic schists etc.

Karaağaç Formation begins with conglomerate at the bottom and consists of coarse and thick sandstone layers, rhyolitic tuffs and channel fill sediments towards upper parts. Thin bedded limestone layers take place at lower parts of the formation and consists of much nummulitic fossils. Lensoidal channel fill sediments form the uppermost layer of the succession and channel bottoms have abrasive surface. Within channels, mudstone pieces and mollusks of marine fossils are observed.

The lower contact of the unit unconformably overlies Çamlıca metamorphics in stream at west-northwest of Dağiçi Hill and is then overlain by Koyunbaba Formation.

Karaağaç Formation which has 900 m thickness in Aktaş locality (Kesgin and Varol, 2003) were interpreted as submarine fan deposits which become shallow in upper parts then grades into deltaic deposits (Ilgar et al., 2008).

In samples collected from lowermost parts of the formation which unconformably overlie Çamlıca Formation;

Assilina suteri SCHAUB, 1981,

Assilina tenuimarginata HEIM, 1908,

Assilina cuvillieri SCHAUB, 1981,

Assilina maior HEIM, 1908,

Nummulites praediscorbinus SCHAUB, 1981,

Nummulites cf *lehneri* SCHAUB, 1962,

Nummulites boussaci ROZLOZSNIK, 1924,

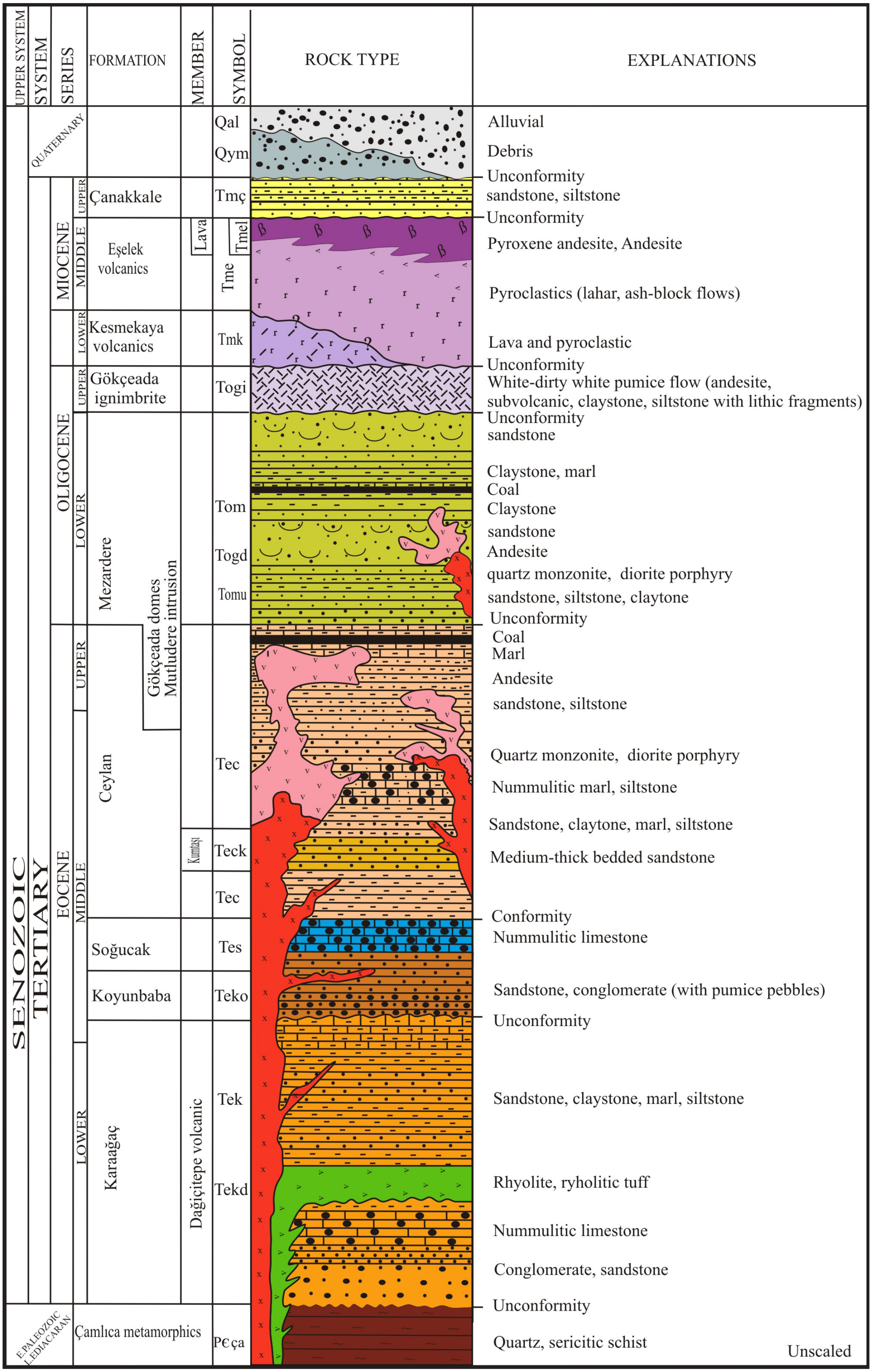

Figure 2- Generalized columnar section of Gökçeada.

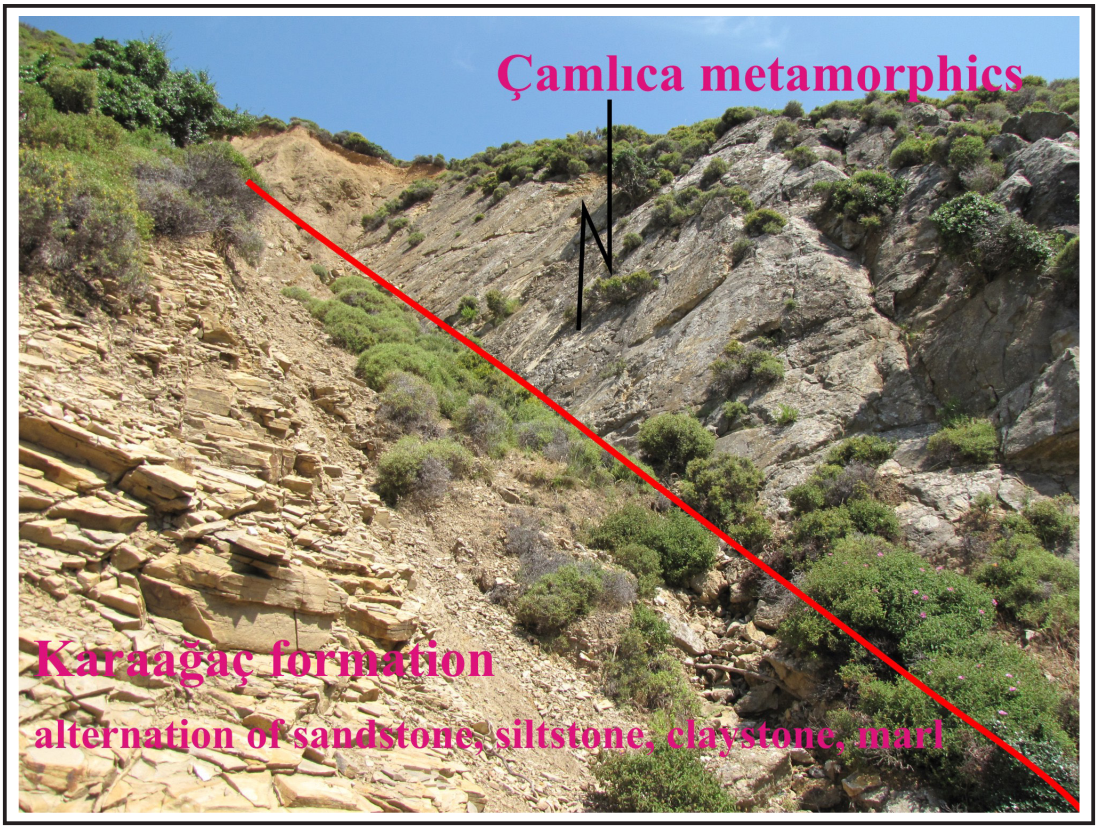

Figure 3- Tectonical contact between Çamlıca metamorphics and Karaağaç Formation (Dağiçi Hill)

Figure 4- Discordant contact between Çamlıca metamorphics and Karaağaç Formation (in the stream at west of Dağiçi Hill).

Assilina sp., *Nummulites* spp., *Discocylina* spp., Linderina? sp. fossils were found and described by Dr. Şükrü Acar. According to this fossil content, the depositional age of the unit should be latest Kuvizian-earliest Lutetian.

2.2.1. Dağiçitepe Volcanic Member (Tekd)

Much altered rhyolitic volcanics which crop out at coast and places close to coasts, northwest of Gökçeada, were first introduced within scope of this study and named as Dağiçitepe Volcanic Member. Unit crops out in Asar Hill, Taşlı Stream, Günbatan Hill, Oğlak Hill, Oğlak stream, Dağiçi Hill and Çatal Hill, and its type locality is Dağiçi Hill (Figure 1).

The unit is composed of lava and tuffs in rhyolitic composition. Lava outcrops are in the form of domes, much jointed and fractured. Especially, well developed columnar structures are observed on the coast. Lavas are white to gray colored and porhyritic in texture. Macroscopically; much quartz, biotite and hornblende phenocryts, and intense epidotization in feldspars are observed.

Lavas of Dağiçitepe volcanics cut Çamlıca metamorphics and are emplaced within Karaağaç Formation. The tuffites which are distinctive with their white color are observed as conformable in deposits. In the first phase of the volcanic activity first tuffs then lavas have erupted and emplaced in the environment, and were occasionally cut by Oligocene aged sub volcanic rocks (Figure 5).

Figure 5- Contact of Karaağaç Formation and Dağiçitepe volcanic (northwestern slope of the hill, elevation: 355 m).

It is considered that volcanic activities in question were effective between ranges of Kuvizian-Lutetian as tuffs intercalate with Karaağaç Formation and domes cut those deposits.

Similar type, whitish tuffs related to volcanics show 1 to 6 meters thickness as intercalated with Lower-Middle Eocene deposits in Limnos Island as well (Innocenti et al., 1994).

2.3. Koyunbaba Formation (Teko)

It crops out as clastics in red-brown, gray and greenish colors in Saklı Harbor at west-northwest of Gökçeada, northeast of Aktepe, south of Raşit Hill, northwest of Dereköy, north of Soğucak Hill, and on Kolbaşı Hill and around Kuş Foreland at north of the island. These clastics extend in SW-NE directions and were named as Koyunbaba Formation. The unit was first named by geologists of Esso Standard (1960) as the Koyunbaba member of Yeniköy Formation, then were upgraded into Formation level by Keskin /1974) and Kasar et al. (1983).

It begins with pebbles at the bottom and grades into conglomerate-sandstone-siltstone-marl intercalation in upper layers. Pebbles, thin to medium bedded formation, are mostly in the form of channel fill. The unit consists of schist, quartzite, limestone pebbles, and rhyolitic pebbles and pumice pieces which is considered as Early Eocene volcanism (Figure 6). Pebbles are well rounded and medium to well sorted. Dark brown, black colored nodules which formed with pyrite condensations are also observed in sandstones.

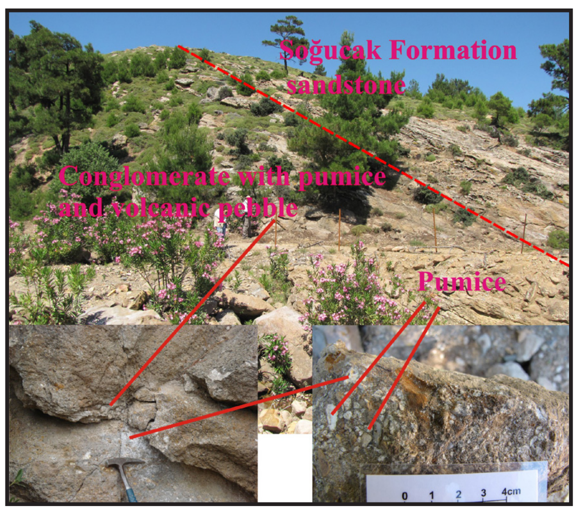

Figure 6- Koyunbaba Formation; volcanic conglomerate, sandstone with pumice (west – southwest of Yumurta Hill).

Koyunbaba Formation unconformably overlies Karaağaç Formation, however conformably underlies limestones of Soğucak Formation. Although there was not detected any fossil at outcrops of the formation in Gökçeada, the age of it should be Middle Eocene according to regional correlation.

The unit was previously described as Fıçıtepe Formation by some investigators (Temel and Çiftçi, 2002; Ilgar et al., 2008; Varol and Baykal, 2008), but in the book of "Thrace Region Lithostratigraphical Units" (2006) of the Stratigraphy Committee it says that;

For Koyunbaba Formation: "Koyunbaba Formation is mainly formed by conglomerate and sandstones and sporadically consists of marl, clay, limestone and huge blocks of the basement. These lithologies represent bottom clastics which are the primary products of Middle-Late Eocene aged marine transgression. Koyunbaba Formation unconformably overlies older units and gradually transits into Soğucak Formation above".

For the Fıçıtepe Formation: "Fıçıtepe Formation is lithologically composed of conglomerate, sandstone and mudstone. It is gradually transitional with Karaburun member of the Karaağaç Formation below, however; there is angular unconformity with Middle Eocene Koyunbaba and Soğucak Formations above."

Considering stratigraphical and lithological characteristics of the unit mapped in Gökçeada, it was named as Koyunbaba Formation in this study.

2.4. Soğucak Formation (Tes)

Much nummulitic limestones and less amount sandy, pebbly limestones crop out in this formation. The unit that have similar characteristics were named as Soğucak Formation in Gökçeada (Sümengen and Terlemez, 1991) and the same name was also used for their outcrops in Gökçeada. It crops out extending in NW-NE directions, in west-northwest of Gökçeada among Saklı Harbor, Ak Hill, Yumurta Hill, Soğucak Hill, north of Soğucak Hill, Delik Hill and Karaçalı Hill, in northeast of Mutlu Hill and northwest of Ulukaya Hill (Figure 1).

The unit is generally composed of limestone and lesser amount of sandstone. Limestones are occasionally horizontally bedded, lensoidal, gray to pale gray, white colored, hard, porous and with dissolution spaces. It grades into clayey limestone in upper layers. Sandstones and thin pebbles are 1 to 2 meters thick at layers closer to bottom. Much gastropoda, coral and nummulite fossils were described in limestones belonging to Soğucak Formation. Varol and Baykal (2008) found Fabiania cassis (Oppenheim), *Spharegypsina* sp., *Alveolina* sp., *Gypsina* sp., *Nummulites* sp., *Discocylina* sp., *Gyroidinella* sp., *Rotalia* sp., *Asterocyclina* sp., *Globigerapsis* sp., *Asterigerina* sp., Rotalidae in the formation that display the characteristics of patch reef and aged the formation as Middle Eocene. Especially in Aktepe, nummulitic fossils with diameters exceeding 5 cm are available (Figure 7).

Figure 7- Soğucak Formation; nummulite fossils in limestones (South of Ak Hill).

While Soğucak Formation is transitional with Koyunbaba Formation in Gökçeada, it is unconformably overlain by Early Eocene aged Karaağaç Formation. This unit is transitional with the overlying Ceylan Formation and cut by Oligocene aged Gökçeada domes.

Soğucak Formation which is composed of sparitic, micritic limestones, pebble and sandy limestones reflect the deposition which occurred in shallow marine environment due to its sedimantological and structural characteristics and fossil assemblage (Ilgar et al., 2008).

Measured thicknesses of the unit are 60 and 120 meters around Ak Hill and Dereköy, respectively (Kesgin and Varol, 2003).

2.5. Ceylan Formation (Tec)

Ceylan Formation is formed by the alternation of claystone-sandstone-shale. The formation was first introduced by Ünal (1967) in Thrace and was first used in Gökçeada by Temel and Çiftçi (2002). The unit crops out in NE-SW directions and is observed in a large area of the island among Şirinköy, Dereköy, Şahinkaya, Tepeköy, Bademli Village, Kuzu Harbor and Gökçeada town center (Figure 1).

Ceylan Formation is formed by the alternation of shale-sandstone. Unit which is deposited in deep sea becomes shallower and grades into Mezardere Formation. Shales are greenish, bluish gray, hard and highly altered in places close to volcanics, metamorphosed in places, with splinted breaks, folded in places and are thin sandstone banded. Sandstones generally consist of quartz, yellowish gray colored, hard, with angular breaks, carbonate cemented, fine to medium grained. Plant residuals are occasionally observed. Sandstones which can be mapped in the study area were mapped as Sandstone Member (Figure 1). Non-economical, lensoidal lignite occurrences reaching up to 40-50 cm thicknesses were also encountered in the unit which graded into Mezardere Formation by getting shallower (Figure 8). Engraved tuff and very fine grained volcanic materials were also encountered within deposits of Ceylan Formation.

Figure 8- Lenses of lignite within upper layers of shallowing Ceylan Formation (eastern and northeastern slopes of Orta Hill).

Ceylan Formation which shows thicknesses of nearly 400–900 meters (Kesgin and Varol, 2003) conformably overlies Soğucak Formation and is conformably overlain by Mezardere Formation. The unit was also cut by Gökçeada domes.

Fossil assemblages which were obtained from Ceylan Formation deposited in turbiditic system, generally in deep sea, indicate that the unit is Middle-Late Eocene (Akartuna and Atan, 1978; Kesgin and Varol, 2003; Ilgar et al., 2008).

2.5.1. Sandstone Member (Teck)

Yellowish, pale brown, medium to thick bedded, well sorted mappable sections of sandstones containing top and bottom structures such as; cut, fill and flute etc. within Ceylan Formation were distinguished as the "Sandstone Member". The unit crops out in SE of Tepeköy, Dereköy, Doruk Hill and in vicinity of Kaleköy and Kuzu Harbor. Archeological excavations carried out in the region indicated that sandstones had been used as building stone since B.C. 3000 (Figure 9) (Hüryılmaz, H., 2011, oral communication).

Figure 9- Ceylan Formation; the use of Sandstone member as building stone in B.C. 3000 (Büyükdere valley, Yenibademli tumulus).

2.6. Mezardere Formation (Tom)

This unit which is formed by early Oligocene aged conglomerate and lesser amount of sandstone, siltstone and marl in Gökçeada was named as Mezardere Formation. The Formation was first introduced and named by Ünal (1967) in Thrace, and it was first used by Temel and Çiftçi (2002) in Gökçeada.

The unit extends as a strip in NE-SW directions between Kuzu Harbor and Aktaş Hill (SW of Gökçeada) in northeast of Gökçeada. Outcrops are observed in north of Dal Hill (NE of Gökçeada) and SE of Gökçeada town center, in east; between Dibek Hill and Gölyeri Hill, in Balıkçı locality, in southwest; north and east of Aktaş Hill (Figure 1).

The unit is generally formed by the alternation of conglomerate and by lesser amount of sandstone, siltstone and marl. Mezardere Formation begins to deposit with yellowish, mustard colored, fine to medium grained, medium to badly sorted, medium to thick bedded sandstones. These sandstones intercalate with blue-gray and white colored marls. Within marl bearing layers, bitumen and coal occurrences are encountered sporadically. In sandstones ripple marks and lamellibranch mollusks are observed in occasion.

The thickness of the unit is approximately 500 meters (Temel and Çiftçi, 2002).

Mezardere Formation conformably overlies Ceylan Formation. The unit is cut by Gökçeada domes, covered by Gökçeada ignimbrites and cut and covered by the products of Eşelek volcanism.

Based on nannofossil samples collected from outcrops of Mezardere Formation in Gökçeada, the age of the unit was determined as Early Oligocene (Ilgar et al., 2008).

The dominant lithology to be conglomerate and the occurrence of biostromal sandstone with lamellibranch and pebblestone layers, bituminuous marl and clayey lignite layers and frequent presence ripple marks from bottom to top show that the formation was deposited in littoral environment and the environment was sometimes subjected to low and high energy zones (Akartuna and Atan, 1978).

These rock assemblages were interpreted as delta front deposits by Sümengen et al. (1987).

2.7. Mutludere Intrusion (Tomu)

This unit was first introduced and mapped in this study and exhibits small outcrops in Kargalı stream, north of Mutlu Stream and Dereköy north (west of Tepeköy), and in Aksu Stream between Yenibademli and Kuzu Harbor on the island (Figure 1). The unit has intruded very close to surface and seated at very shallow depths.

The main body which is present with fewer dikes is in the composition of quartz monzonite and diorite porphyry (Figure 10).

Figure 10- Mutludere intrusion; diorite porphyry (Mutlu Stream).

Intrusion is generally altered-highly altered in places, and silica, silica veins-veinlets, sericite, chlorite, epidote, magnetite veins-veinlets in occasion, hydrothermal biotite veinlets, argillization and carbonation are observed. In rock, coarse plagioclase and lesser amount of orthoclase and hornblende crystals are seen in crystalline groundmass in various sizes ranging from fine to coarse grain. Disseminated and pyrite vein-veinlets, chalcopyrite, magnetite, formations of malachite along fault and joint surfaces are observed in the rock. During microscopic studies, plagioclase, biotite and amphibole were described as diorite porphyry with phenocrysts. Plagioclases have polysynthetic twinning and zoning, with grain sizes ranging between 0.8-2 mm. Sericite, carbonate and clay alteration were detected in plagioclases in few amounts. Biotites have size range between 0.4-0.8 mm and few chloritization, opacification and hydrobiotitization were detected. Biotites are sometimes in the form of clusters, fine grained and widely chloritized. However, amphiboles observed in less amounts show transformation into carbonate, biotite, chlorite and opaque minerals. Groundmass material is silicified and was formed by microcrystalline quartz (secondary?), chloritized biotite, altered feldspar microcrystals and carbonates in trace amounts. Few apatite and zircon were detected as accessory minerals. Besides; anhedral opaque mineral is also observed as dispersed throughout the rock.

In mineralogical analysis of petrographical samples taken from surface and drill cores intrusion rock was described as diorite porphyry - monzodiorite porphyry. In zones where hydrothermal alteration is condensed the rock has almost lost its primary texture and preserved its minerals in few sections and is porphyritic in texture. As primary mineral, fully argillized and seritisized feldspar in few amounts were determined. In groundmass, argillized feldspars, dispersed silicification, carbonation, chloritization and formation of epidote were also observed.

In macroscopic and microscopic studies, the observation of coarse epidote minerals indicates that hydrothermal fluids that cause alteration are in mesothermal or hypothermal temperatures.

Due to the intrusion, in localities of Kargalı, Mutlu and Akarsu Streams, condensed, highly clayey, sericitic, chloritic, epidotic pyrite alteration with silica vein-veinlets, and hematitic-limonitic altered zones with malachite and azurite and magnetitic vein-veinlets are observed. Disseminated, pyritic vein-veinlets and mineralized zones with chalcopyrite are also observed in altered zones.

The unit has intruded into deposits of Karaağaç Formation and Ceylan Formation. The effects of the intrusion are observed in the vicinity of contact and host rocks have sporadically turned into hornfels as a result of low graded thermal metamorphism (Figure 11).

Figure 11- Fels-hornfels zone which developed at the contact of diorite-monzodiorite porphyry intruding into sedimentary rocks (Mutludere).

It was observed that the intrusion was emplaced cutting Late Eocene deposits, so it was deposited into the environment in post Eocene time. Furthermore; it is known that Fakos intrusion in Limnos Island is Early Miocene (Innocenti et al., 1994; Pe-Piper et al., 2009). The age of contact metamorphism created by the intruding granitoid in Semadirek (Samothrace) Island is 40,9±2,2 My (Seymour et al., 1996). Also, the age of Kestanbol granite emplaced in west Anatolia is 28 My (Fytikas et al., 1984). Gökçeada is the region of domes and several Oligocene aged domes and cryptodomes are observed in this area. When all these data are taken into consideration, it is considered that Mutludere intrusion was emplaced into the region in Oligocene time. However, looking in regional scale, it should not be ignored that these intrusions has begun to emplace into the region starting from Middle Eocene.

2.8. Gökçeada Domes (Togd)

Volcanic rocks cover very large areas in Gökçeada. All volcanics in the Island were collected under the name of "Ayvacık Formation" by Temel and Çiftçi (2002) and were defended that these had formed in early Middle Miocene. Nonetheless; these volcanics in the island show differences in terms of their structural shapes, products, compositions and their ages. Andesite and diorite porphyry type volcanic rocks which emplaced in the form of dome-cryptodome arranging in NE-SW directions were named as Gökçeada domes in this study. Domes have been emplaced into the region in shallow depths due to the intrusion which is considered to have begun in Middle Eocene and formed small lava flows cropping out in places (Figure 1).

Andesite and rocks in diorite porphyry composition are observed in the form of domes which intruded into shallow depths in 3 km diameters in occasion. In addition to lava domes, small lava flows and monogenetic breccias are also encountered with many sills and dikes. In lavas, both magmatic and sedimentary derived enclaves are observed.

Lavas are generally holocrystalline porphyritic in texture in thin section studies. Main mineral constituents are formed by plagioclase and amphibole minerals which are observed in the form of subhedral or euhedral prismatic phenocrysts or microphenocrysts, and clinopyroxene and biotite minerals in trace amounts. Euhedral apatite and opaque minerals are observed as accessory constituent. In some amphibole phenocrysts, inner zoning is available. Plagioclase phenocrysts sometimes gather and form glomerocrystal groups. Magma mixing textures are spread in plagioclase phenocrysts. In all amphibole minerals weak corrosions at circumferences and reaction belts formed by pyroxene+opaque mineral aggregates are observed.

The groundmass is generally microcrystalline in subvolcanic ones, and the degree of crystallinity is a bit higher compared to samples flowing at the surface and is formed by coarser size minerals. The textural feature of the groundmass implies that the cooling conditions could be close to subvolcanic conditions. Mineralogical composition of the groundmass is basically formed by plagioclase minerals, clinopyroxene minerals which are observed as needlelike, opaque minerals and by chlorite minerals which are possibly to be the secondary origin.

Gökçeada domes have been emplaced into Eocene units cutting all those units between Mesozoic-Eocene time intervals and flown as small lava flows in occasion. Domes have baked and deformed deposits in places (Figure 12), and sometimes have formed sudden cooling walls as they contacted with aqueous surface.

Figure 12- Subvolcanics of Gökçeada domes cutting Ceylan Formation (Köklü Hill).

Gökçeada domes were emplaced into the island in Oligocene. According to radiometric dating made within scope of this study in Çal Hill (NW of Uğurlu village) the age was detected as 28,6±0,8 My using K/Ar method. However, Ercan et al. (1995) detected 30,4 My and 34,3 My according to radiometric dating carried out in domes in Ulukaya and Kapıkaya, respectively. All these data indicate that the magmatic activity which forms the domes of Gökçeada occurred in Early Oligocene.

2.9. Gökçeada Ignimbrite (Togi)

It crops out in east and south of Gökçeada, and was first introduced in this study and named as Gökçeada ignimbrite. Outcrops start from east of Gökçeada and extend until Aktaş Hill at southern coast (Figure 1). The center of eruption of the ignimbrite could not be detected and have been emplaced into east and south of the island, most probably generated from a caldera that remained in the sea. Similar ignimbrites are also available in Limnos Island located at south of Gökçeada (Innocenti et al., 1994).

Gökçeada ignimbrite is in white, dirty white and pink colors and observed as pumice flows.

Pumices, which is one of the components forming ignimbrite are generally white, dirty white in color and consist of biotite and amphibole minerals. Lithics are usually formed by andesitic subvolcanic rock fragments. Rock fragments such as claystone and shale were also encountered sometimes. Dense pumice bearing, white colored ignimbrites have occurred due to pumice flows. In general, lithics are denser in lower layers, pumices become denser towards upper layers and their diameters occasionally reach 20-25 cm. Pumices are generally rounded and acquire a view of flame structure in occasion. Taken and detached fragments of claystone and shale were also encountered. Their sizes may range from a few millimeters to few decimeters, and were subjected to changes in color and view by the effect of temperature. Particles of wood residuals are also encountered within the unit (Figure 13). Sizes of pink colored ignimbrite components are smaller (<2 cm) compared to white colored ones and rich in lithic. Pink colored ignimbrites are more coherent compared to white colored ignimbrites and were formed by pumice flows in the first phase of the eruption due to column depression. Pumice back falls are also present on flow occasionally.

Figure 13- Wood residuals within Gökçeada ignimbrite (northern-northeastern slopes of Aktaş Hill).

Gökçeada ignimbrite unconformably overlies Ceylan and Mezardere Formations and is unconformably overlain by Kesmekaya and Eşelek volcanics. Ash-block flow and lahar type forms which are considered to be the products Eşelek volcanics are present on ignimbrite.

As it overlies Mezardere Formation which is stratigraphically known as Early Oligocene and underlies Early-Middle Miocene Eşelek volcanics, it is considered that the volcanic activity that forms Gökçeada ignimbrites have become effective in Late Oligocene.

Ignimbrite formations of Gökçeada are most probably the products belonging to a volcano which remained in sea, the area where Gökçeada-Biga Peninsula and Limnos Island surrounds. Ignimbrites are also present in Biga Peninsula and Limnos Island, and it is highly probable that one part of Gökçeada ignimbrites is the equivalent of some ignimbrites in those areas.

2.10. Kesmekaya Volcanics (Tmk)

Nomenclature for ash-block flows and andesitic lavas located at south of Gökçeada were given as; tuff-agglomerate-andesite (Akartuna and Atan, 1978), Çan volcanics (Ercan et al., 1995), Hisarlıdağ volcanics (Kesgin and Varol, 2003) and Ayvacık formation (Temel and Çiftçi, 2002) in previous studies (names come from outside the island). This unit was first introduced and named as Kesmekaya volcanics in this study. Volcanics crop out between Sürmeli and Aktaş hills in southern coast of Gökçeada (Figure 1).

Kesmekaya volcanics are located on Gökçeada ignimbrites with formations of blocky ash flow, debris flow and lahar type pyroclastic flow which formed due to domal eruptions.

Lavas have been emplaced by flowing over blocky ash flows. They are gray to pink colored, generally andesitic in composition and porphyritic in texture. Flow structures are macroscopically observed and consist of plagioclase, biotite and hornblende as phenocryst.

In microscopic studies, hypocrystalline series is porphyritic in texture and is fine grained. Plagioclase and clinopyroxene minerals which are observed almost in the form of subhedral or euhedral phenocrysts form the main mineral constituents. Apart from these, fully opacified mineral pseudomorphs which are widely observed in sizes of microphenocryst or phenocryst and are highly probably to be the residual of amphibole and/or mica were also encountered.

Textures of magma mix such as; dusty zones, mesh texture, corroded edges etc. are widely observed in plagioclase phenocrysts.

Phenocryst components of the rock are located in a microcrystalline groundmass, and it is constituted by rodlike prismatic plagioclase minerals, needlelike mica minerals, rare clinopyroxene minerals and opaque minerals. Volcanic glass material can be distinguished under microscope. Phenocryst/groundmass ratio of the rock is high.

The unit overlies Gökçeada ignimbrite and is overlain by Eşelek volcanics though its contact cannot be clearly detected.

According to K/Ar radiometric dating performed in lavas of Kesmekaya volcanics, 37,2±1 My was detected in Sümeli Hill, but there are still some suspects as the age determination has been carried out in plagioclases. The unit overlies Gökçeada ignimbrite and has similar stratigraphical and lithological characteristics with Early Miocene volcanics in Biga Peninsula in regional correlation (Dönmez et al., 2005, 2008). Therefore; it is considered that the volcanism that forms Kesmekaya volcanics might have occurred in Early Miocene.

2.11. Eşelek Volcanics (Tme)

Volcanic products which are formed by lava and pyroclastics in basaltic andesite and andesitic compositions in east of Gökçeada were first mapped in this study and named as Eşelek volcanics. The unit spreads on a large area including Kocaçavuş and Esencik Hills at southwest of Eşelek starting from Eğrice Hill (north of Kuzu Harbor) and Dal Hill (southeast of Kuzu Harbor).

Eşelek volcanics are composed of lavas and pyroclastics in basaltic andesite and andesitic compositions. Debris flow and pyroclastics in the character of blocky ash flow located below are overlain by lava flows which are not very thick and widespread. Lavas related to the unit were distinguished and mapped as member.

Pyroclastics are formed by blocky ash flow and lahar type forms. Sizes of blocks in ash-block flows are quite variable and can occasionally reach up to 1 meter. Peat formations as in black stains and dark brown colored ironoxide nodules are present in tuffs.

2.11.1. Lava Member (Tmel)

Lavas have generally sheet jointed structure. Lavas that overlie pumice flows most probably have come to aqueous environment and been subjected to quench fragmentation due to sudden cooling. Therefore; there is observed a brecciated structure especially at the bottom. Lavas which are named as pyroxene andesite are gray colored, porphyritic in texture and have thin phenocrysts.

In thin section studies, they have holocrystalline porphyritic texture and are fine to medium grained. Main mineral constituents are plagioclase minerals which are observed as subhedral or euhedral prismatic phenocrysts, and few biotite minerals accompanying those plagioclases. Opague minerals are widely present as an accessory component. Thin opacification belts around amphibole and biotite phenocrysts are abundant. In the body of plagioclase phenocrysts, textural features indicating magma mixture has widely developed. Besides; it was observed that mantling was quite abundant in the outer edges of many plagioclase phenocrysts and of some were surrounded by spheluritic texture K-feldspar mantles. K-feldspar occurrences in spheluritic texture are occasionally observed also in the form of patches in groundmass of rock. The character of groundmass is microcrystalline and is fully crystallized. Groundmass mineralogy is formed by rodlike prismatic plagioclase minerals, needlelike mica minerals and opaque minerals. Groundmass texture has become complicated because of probable metasomatic substitution processes. To describe rodlike prismatic plagioclase minerals is often difficult. Phenocryst/ groundmass ratio of the rock is high. Additionally; magmatic enclaves that are visible by naked eye in hand specimens and which are possibly to have generated from monzodiorite or diorite were also observed. As these are holocrystalline in texture, they can easily be noticed within groundmass of rock. The mineral composition is constituted by plagioclase, clinopyroxene and biotite minerals.

Eşelek volcanics overlie Mezardere Formation and Gökçeada ignimbrite but is unconformably overlain by Çanakkale Formation. Lavas have cut, baked and deformed Gökçeada ignimbrite in their contacts (Figure 14). Besides; lavas have been disintegrated due to sudden cooling when flowing over ignimbrites probably in aqueous environment and caused orientation in pumices as well within ignimbrite.

It is considered that the unit was emplaced into the medium in Early-Middle Miocene period as the unit overlies Kesmekaya volcanics and unconformably underlies Late Miocene Çanakkale Formation.

2.12. Çanakkale Formation (Tmç)

The unit which is composed of conglomerate, sandstone siltstone and marl was named as "Çanakkale Formation" and was first described by Şentürk and Karaköse (1987). It outcrops in narrow areas at east, southeast and south of Gökçeada (Figure 1). The outcrop in east and southeast is present in the peninsula at east–northeast of Tuzgölü (Salt Lake). The outcrops in south on the other hand are observed in small areas along the coast between Tuzgölü and Kapıkaya.

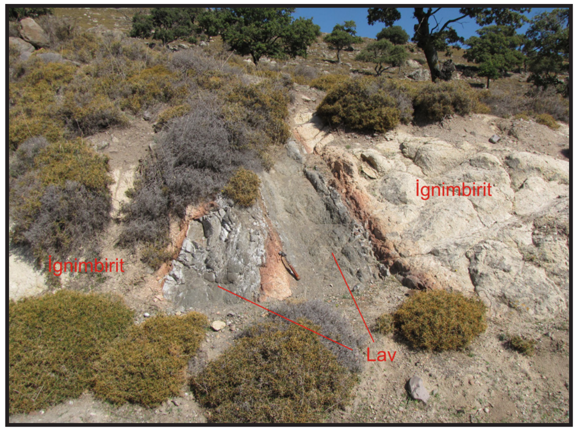

Figure 14- Dikes of Eşelek volcanics cutting Gökçeada ignimbrite (along the road in south-southwest of Kocabaş Hill)

It is generally composed of less consolidated conglomerate, sandstone, siltstone and marl intercalations. The formation is made up of carbonates of laterally and vertically transitional shoreface, beach, tidal flat, falling tide delta and tidal environment (Ilgar et al., 2008). The dominant lithology of the unit is sandstone. Sandstones are pale yellow-yellowish gray, loose cemented, dispersive, fine to medium grained, very well sorted, and cross bedded in occasions. Very fine grained shale, conglomerate, bioclastic conglomerate layers take place between sandstones.

Çanakkale Formation of which its thickness was determined as approximately 15 meters in the island (Temel and Çiftçi, 2002) transgressively overlies Eşelek volcanics. The upper part of the formation is covered by recent beach deposits.

The unit was aged as Pontian by Akartuna and Atan, (1978) in the island. However, it was aged as Late Miocene (Middle-Late Panonian) by Atabey et al. (2004) in Biga Peninsula.

Çanakkale Formation is the only unit representing Late Miocene Sea in the region and reflects rocky shore environment.

2.13. Debris (Qym)

It is observed as in the form of free debris flows on the slopes of exposed domes on the island.

2.14. Alluvials (Qal)

It is composed of Quaternary aged conglomerate, sandstone, siltstone and mudstones which developed in stream beds, on ancient depressions and on shore belt plains. The unit is observed in east-northeast of Uğurlu village, south of Şirinköy, south of Yerkaya Hill and Kapıkaya locality, between the town center of Gökçeada and Kaleköy and along the stream beds and plains around Eşelek village (Figure 1).

3. Tectonics

Gökçeada is the island which has a high risk of earthquake in Aegean seismological region. During archeological excavations carried out on the island, it was revealed that settlements located on the island had been affected from earthquake and remnants of people subjected to natural disaster in Yenibademli, Höyük were detected (Hürıylmaz, 2011).

Gökçeada is generally under the control of northeast–southwest extending fault sequences. The northern part of the island has been uplifted relative to southern part and the inclination of beds varies between 20°-40° towards southeast. Units get younger starting from west to east (Figure 15). The strongest data of tectonical uplift are metamorphic rocks cropping out in a very narrow area at north of the island.

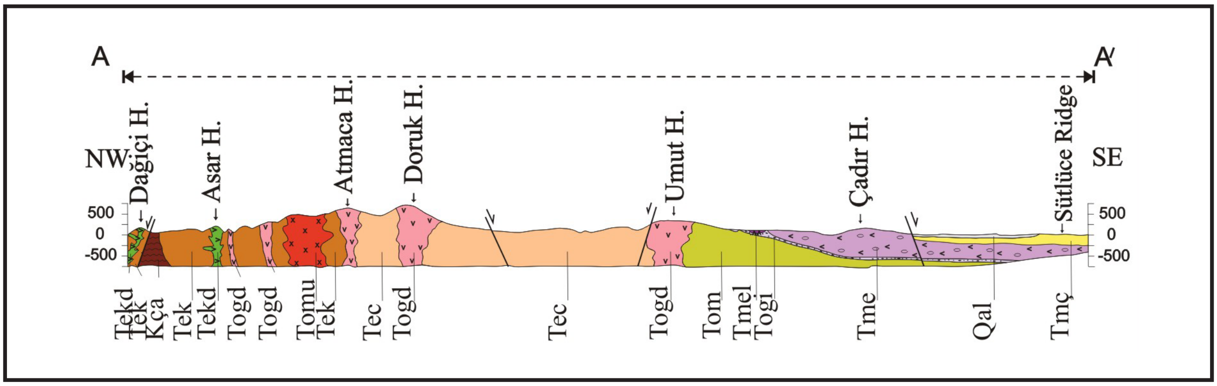

Figure 15- Schematic geological section (unscaled) of Gökçeada in NW-SE direction (Kça; Çamlıca metamorphics, Tek; Karaağaç Formation, Tekd; Dağiçitepe volcanic, Tec; Ceylan Formation, Tom; Mezardere Formation, Tomu; Mutludere intrusion, Togd; Gökçeada domes, Togi; Gökçeada ignimbrite, Tme; Eşelek volcanics, Tmel; Eşelek volcanics lava member, Tmç; Çanakkale Formation, Qal; Alluvial).

Gökçeada was tectonically studied by Koral et al. (2008). According to the authors, the fault system in which it was considered to be in North Anatolian Fault System had a great effect in acquiring the recent morphology of the island. This system extends as linear along the northern coast at westernmost side of the island. Another fault segment however extends along the long axis of the island. The fault called "Kefalos Fault" in southeastern part of the island restricts Tuzla Lake depression. These faults are generally right stepped and almost dip slip oblique faults (Figure 16). The authors detected that these oblique faults had also their northwest directing antithetic and northeast directing synthetic faults.

Lineaments specified as antithetic and synthetic faults by Koral et al. (2008) have definite contact which formed by the intrusion of Gökçeada domes into sedimentary units according to us. During studies performed by us, locations of tectonical zones detected along the long axis of Gökçeada were changed in certain amounts, and additionally; İnceburun, Aktepe, Zeytinli, Kuzu Limanı and Koç Dere Faults were determined (Figure 16).

İnceburun Fault: It is a tectonical zone with a strike of N30W and dip amount of 45SE in Karaağaç Formation that has the alternation of siltstone, sandstone, claystone and marl in stream at southwest of İnceburun location.

Aktepe Fault: It extends along valley at east of Uğurlu village, Aktepe, Kolbaşı Hill and Oğlak Hill and is a right lateral oblique fault with a strike of N60E and dip amount of 50SE.

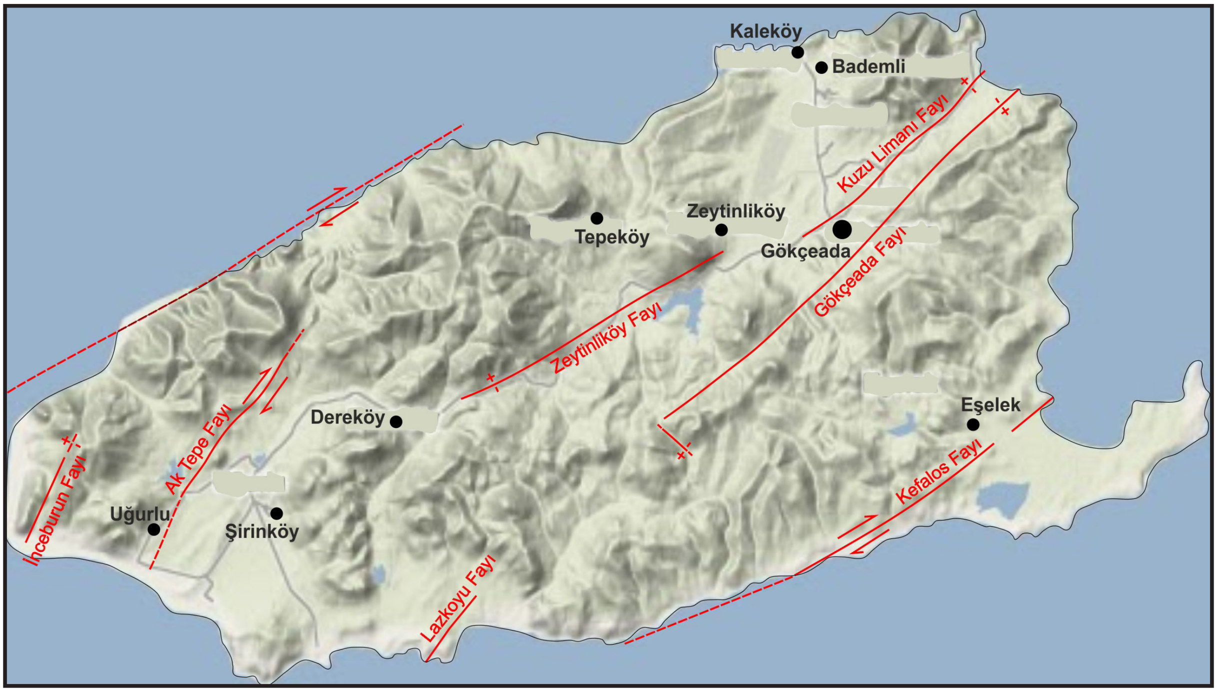

Figure 16- Significant faults of Gökçeada transferred on Googleearth image.

Zeytinliköy Fault: This zone is observed until Zeytinliköy along the Gökçeada-Dereköy auto road in south-southeastern parts of Doruk Hill and has developed within Ceylan Formation.

Kuzu Harbor: This tectonical zone has a strike of N40E and dip amount of 55SE between Kuzu Harbor and Gökçeada and developed within Ceylan formation.

Koç Dere Fault: It is observed as NW-SE directing dip slip normal fault zone at the contact of Middle-Upper Eocene Ceylan Formation and Oligocene aged Gökçeada domes in Koç Stream.

4. Results

In this investigation, 1/25.000 detailed geological and 1/100.000 scaled revision studies were performed throughout the island and significant contributions were made for the geology of the island by new findings obtained. Within this scope;

It was detected that the primary depositional age of Çamlıca metamorphics, which had been dated as Paleozoic by previous investigators (Akartuna and Atan, 1978), was Late Ediacaran and/or Early Paleozoic (Tunç et al., 2002) as a result of studies carried out in their equivalences in Biga Peninsula. So the age of Çamlıca metamorphics in the island was assessed as the Late Ediacaran and/or Early Paleozoic.

The unit which had been defined as the Fıçıtepe Formation in the island by some previous investigators (Temel and Çiftçi, 2002; Ilgar et al., 2008; Varol and Baykal, 2008) was described as Koyunbaba Formation because of contact relationships and lithological characteristics, and it can be correlated with Koyunbaba Formation which was introduced in MTA (2006) and display a spread in Thrace.

In this study, the presence of deep/semi deep seated rocks in Gökçeada were detected and mapped the first time. Due to the intrusion, highly clayey, serisitic pyrite alteration with chlorite and epidote and silica vein-veinlet in occasion; and altered zones with malachite and azurite in occasion with hematite and limonite, and magnetite vein-veinlets are observed. Within altered zones disseminated and pyritic vein-veinlet, and chalcopyritic mineralized zones are also present.

Volcanics have been formerly grouped under Oligocene (Ercan et al., 1995, Kesgin and Varol, 2003) or in one formation at the age of Early-Middle Miocene (Temel and Çiftçi, 2002) in previous studies. However, in this study these volcanics were separated into six different formations according to their stratigraphical and lithological characteristics at different ages. Also, the products of Eocene aged acidic volcanism were first time detected in the island.

While Oligocene volcanics are observed in central and northern parts of the island in the form of domes, the products of Miocene aged volcanism are located in southern and eastern parts of the island in the form of lavas and pyroclastics. Island volcanics which crop out in the island which are called as Çan volcanics (Ercan et al., 1995), Hisarlıdağ volcanics (Kesgin and Varol, 2003) and Ayvacık Formation (Temel and Çiftçi, 2002) in previous studies were defined in detail and named considering their lithological characteristics. Again, the presence of ignimbrites most probably originating from a center which remained in the sea was detected the first time on the island.

Gökçeada was tectonically studied in detail by Koral et al. (2008). As a result of studies carried out by us, the locations of tectonical zones which had been detected along the long axis of Gökçeada were changed in certain amounts, and additionally; İnceburun, Ak Tepe, Zeytinli, Kuzu Harbor and Koçdere Faults were investigated.

Acknowledgement

This study was made within scope of "Batı Anadolu Polimetal Maden Aramaları Projesi" (Project of West Anatolian Polymetal Mineral Explorations) of MTA between the years 2008-2011. We would like to thank to Dr. Evren Yazgan and Dr. Evren Atakay Gündoğdu for petrographical descriptions, to Dr. Şükrü Acar and Ayşegül Aydin for paleontological descriptions, and to Prof. Erdinç Yiğitbaş who revised this article and made invaluable criticisms.

Received: 18.01.2014
Accepted: 12.11.2014
Published: June 2015

References

Akartuna, M. 1950. İmroz Adasında bazı jeolojik müşahadeler. *Türkiye Jeoloji Kurumu Bülteni* 2/2, pp.8-17.

Akartuna, M. Atan, O.R. 1978. Gökçeada'nın (Çanakkale) jeoloji ve sedimantaloji hakkında ön rapor. *Maden Tetkik ve Arama Genel Müdürlüğü Jeoloji Dairesi Rapor Arşivi Rapor No: 105*. Ankara. (unpublished).

Atabey, E., Ilgar, A., Saltık, A. 2004. Çanakkale havzasının Orta-Üst Miyosen stratigrafisi, Çanakkale, KB Türkiye. *Maden Tetkik ve Arama Dergisi* 128, pp.79-97.

Barr, S.R., Temprley, J., Tarney, J. 1999. Lateral growth of the continental crust through deep level subduction-accretion: Are-evaluation of central Greek Rhodope. *Lithos* 46, pp.69-94.

Dönmez, M., Akçay, A. E., Genç, C.Ş., Acar, Ş. 2005. Biga Yarımadasında Orta-Üst Eosen volkanizması ve denizel ignimbiritler. *Maden Tetkik ve Arama Dergisi* 131, pp.49-61.

Dönmez, M., Akçay, A. E., Duru, M., Ilgar A., Pehlivan, Ş. 2008. 1/100.000 Ölçekli Türkiye Jeoloji Haritaları Çanakkale H17 Paftası. No: 101. *Maden Tetkik ve Arama Genel Müdürlüğü*. Ankara.

Duru, M., Pehlivan, Ş., Ilgar A., Dönmez, M., Akçay, A. E. 2008. 1/100.000 Ölçekli Türkiye Jeoloji Haritaları Ayvalık İ17 Paftası. No: 98. *Maden Tetkik ve Arama Genel Müdürlüğü,* Ankara.

Ercan, T., Satır, M., Dora, A., Sarıkoğlu, E., Yıldırım, T., Adis, C., Walter, H.J., Özbayrak, İ.H. 1995. Biga Yarımadası, Gökçeada, Bozcaada ve Tavşan Adaları'ndaki Tersiyer yaşlı volkanitlerin petrolojisi ve bölgesel yayılımı. *Maden Tetkik ve Arama Dergisi* 117, pp.55-86.

Esso Standard, 1960. I sayılı Marmara petrol bölgesi AR/EST/105, 106, 108 ve 109 hak sıra numaralı sahalara ait terk raporu. *TPAO Arama Grubu Arşivi. Rapor No: 131*. Ankara, (unpublished).

Fytikas, M., Innocenti, F., Manetti, P., Mazzuoli, R., Peccerillo, A., Villari, L. 1984. Tertiary to Ouaternary evolution of volcanism in the Aegean region: The Geological Evolution the Eastern Medditrranean. J. E. Dixon, A. H. F. Robertson (Ed.). *Geological Society of London.* Special Publication. 17, pp.687- 699.

Hüryılmaz, H. 2011. Gökçeada-Yenibademli Höyük 2010 Yılı Kazıları. 33. Kazı sonuçları toplantısı, 23-28 Mayıs *2011. Malatya. Kültür Varlıkları ve Müzeler Genel Müdürlüğü Yayın No: 155-1. pp.1-18.*

Ilgar A., Demirci, E.S., Duru, M., Pehlivan, Ş., Dönmez, M., Akçay, A. E. 2008. 1/100.000 ölçekli Türkiye Jeoloji Haritaları Çanakkale H15 ve H16 Paftaları. No: 100. *Maden Tetkik ve Arama Genel Müdürlüğü,* Ankara.

Innocenti, F., Manetti, P., Mazzuoli, R., Pertusati, P., Fytikas, M., Kolios, N. 1994. The geology and geodynamic significance of the island of Limnos, North Aegean Sea, Greece. Neues jahrbuch für Geologie und Palaontolgie-Monatshefte. H.11,661-691

Kasar, S., Bürkan, K., Siyako, M., Demir, O. 1983. Tekirdağ-Şarköy- Keşan – Enez bölgesinin jeolojisi ve hidrokarbon olanakları. *Türkiye Petrolleri Anonim Ortak*lığı *Arama Grubu Rapor No. 1771*. Ankara, (unpublished).

Keskin, C. 1974. Ergene Havzası ve kuzeyinin stratigrafisi. *Türkiye İkinci Petrol Kongresi Bildiriler Kitabı* 131-163.

Kesgin, Y., Varol, B. 2003. Gökçeada ve Bozcaada'nın Tersiyer jeolojisi (Çanakkale). *Türkiye. Maden Tetkik ve Arama Dergisi*. 126, pp.49-67.

Koral, H., Öztürk, H., Hanilçi, N. 2008. Tectonically induced coastal uplift mechanism of Gökçeada Island, Northern Aegean Sea, Turkey. *Quaternary International* 197 (2009) pp.43–54.

MTA. 2006. Trakya Litostratigrafi Birimleri Kitabı. Stratigrafi Komitesi. *Maden Tetkik ve Arama Genel Müdürlüğü*. Ankara.

Okay, A.İ., Siyako, M., Bürkan K. A. 1990. Biga Yarımadası'nın jeolojisi ve tektonik evrimi. *Türkiye Petrol Jeologları Derneği Bülteni* 2/1, pp.83-121

Okay, A.İ., Satır, M. 2000. Coeval plutonism and metamorrphism in a Latest Oligocene metamorphic core complex in Northwest Turkey. *Geological Magazine* 137/5, pp.495-516.

Okut, M. 1975. Çanakkale ili, Gökçeada ilçesi hammadde prospeksiyon raporu. *Maden Tetkik ve Arama Genel Müdürlüğü Kuzeybatı Anadolu Bölge Müdürlüğü Rapor No: 297.* Balıkesir. (unpublished)

Papanikolaou, D., Panagopoulos, A. 1981. On the structural style of Southern Rhodope, Greece. *Geologica Balcanica* 11, pp.12-22.

Pe-Piper, G., Piper, J. W., Koukouvelas, I., Dolansky, L. M., Kokkalas S. 2009. Postorogenic shoshonitic rocks and their origin by melting underplated basalts. The Miocene of Limnos, Greece. *Geological Society of America Bulletin* 1-2, pp.39-54.

Seymour, K. S., Tsikouras, V., Kotopouli, K., Hatzipanayiotou, K., Pe-Piper, G. 1996. A window to the operation of microplate tectonics in The Tethys Ocean: the geochemistry of the Samothrace granite. Aegean Sea. *Mineralogy and Petrology* 1, pp.251–272.

Sfondrini, G. 1961. Surface geological report on Ar/ TPAO/1/538 and 537. *Türkiye Petrolleri Anonim Ortakl*ığı *Arama Grubu Rapor No: 1429.* Ankara. (unpublished).

Sümengen, M., Terlemez, l.,Şentürk, K., Karaköse, C. 1987. Gelibolu Yarımadası ve güneybatı Trakya havzasının stratigrafisi, sedimentolojisi ve tektoniği. *Maden Tetkik ve Arama Genel Müdürlüğü Rapor No: 8128.* Ankara. (unpublished).

Sümengen, M., Terlemez, İ. 1991. Güneybatı Trakya yöresi Eosen çökellerinin stratigrafisi. *Maden Tetkik ve Arama Dergisi* 113, pp.17-30.

Şentürk, K. Karaköse, C. 1987. Çanakkale Boğazı ve dolayının jeolojisi. *Maden Tetkik ve Arama Genel Müdürlüğü Rapor No: 9333*. Ankara. (unpublished)

Temel, R. Ö., Çiftçi, N. B. 2002. Gelibolu Yarımadası, Gökçeada ve Bozcaada Tersiyer çökellerinin stratigrafisi ve ortamsal özellikleri. *Türkiye Petrol Jeologları Derneği Bülteni* 14, pp.17-40.

Tunç, İ. O., Yiğitbaş, E., Şengün, F., Wazeck, J., Hofmann, M., Linnemann, U. 2002. U-Pb zircon geochronology of northern metamorphic massifs in the Biga Peninsula (NW Anatolia-Turkey): new data and a new approach to understand the tectonostratigraphy of the region. *Geodinamica Acta.* 25, 3-4, Special Issue: Tectonics of the Eastern Mediterranean - Black Sea Region: Part A Dedicated in honor of Aral Okay's 60th birthday. doi:10.1080/09853111.2013.87724

Ünal, O. 1967. Trakya jeolojisi ve petrol imkanları. *Türkiye Petrolleri Anonim Ortakl*ığı *Arama Grubu Rapor No: 391*, 103p. Ankara (unpublished).

Varol, B., Baykal, M. 2008. Trakya Tersiyer karbonatlarının sedimantolojik ve kronostratigrafik özellikleri. *Türkiye Petrolleri Anonim Ortakl*ığı *Araştırma Merkezi.* 104p. Ankara. (unpublished).