Mineral Res. Expl. Bull., 120, 97-118, 1998

FEATURES OF THE TERTIARY VOLCANISM AROUND SEA OF MARMARA

Tuncay ERCAN*; Ahmet TÜRKECAN*; Herve GUILLOU"; Muharrem SATIR*"; Dilek SEVİN*** and Fuat SAROĞLU*****

ABSTRACT.- In the region around the sea of Marmara, limited by the boundaries of the 1:500 000 scale Istanbul Quadrangle, the volcanism starting in Upper Cretaceous and intermittently continuing through the end of Upper Miocene has been differentiated into five different stages, namely Upper Cretaceous, Eocene, Oligocene, Lower-Middle Miocene and Upper Miocene, and the volcanic outcrops situated in the region have been dated. Together with the detailed petrographic studies, nine samples from different areas and stages have been dated by K/Ar method, resulting in that the oldest and the youngest lava is of 74.3 ± 1.0 million years old (Upper Cretaceous) and 8.9±0.2 years old (Upper Miocene), respectively. Of these, belonging to the first four stages are mostly calcalkaline (some of the Eocene aged samples are tholeiitic) and are of basalt, basaltic andesite, trachyandesite, andesite, dacite, rhyolite type, whereas that of belonging to the fifth stage are alkaline and of basanite, basalt and trachybasalt types. The pyroclastics of various size and the tuffs of the first four volcanism stages crop out in a wide area. The Upper Cretaceous volcanics have completely formed beneath the sea. On the other hand, some of Eocene volcanics have formed beneath the sea which are seen intercalated with sediments while the others have formed on land. The lavas of Oligocene, Lower-Middle Miocene and Upper Miocene age have formed on land and are observed to be intercalated with lacustrine sediments, in places. Of the lavas stranded along the Black sea coast, the Upper Cretaceous aged ones have formed in a group of island arc volcanics and have been produced in a subduction zone and the Eocene, Oligocene and Lower-Middle Miocene aged ones have formed in an environment of compression during and after the collision and have been produced from a material of crust and mantle mixture. It is proposed that the Upper Miocene aged alcaline basaltic volcanics have formed in an environment of extension by the uplift of mantle after the change of tectonic regime in Middle Miocene.

INTRODUCTION

In the area around sea of (Marmara region, an intense volcanism has been effective starting from. Upper Cretaceous to the beginning of Pliocene displaying various stages and forming widespread lavas and pyroclastics having different petrographic and geochemical features. Although there have been many geological studies in the region, there are no special and sufficient studies to reveal the Tertiary volcanism, the regional extension of the volcanic rocks, their ages, stages, petrochemical features and genetic explanations. This study intends to shed light on these questions together with their relations with the adjacent sedimentary rocks and their datings. For this reason, samples from the Upper Cretaceous, Eocene, Oligocene, Lower-Middle Miocene and Upper Miocene were taken and dated by K/Ar method.

THE FEATURES OF THE TERTIARY VOLCANISM

The Tertiary volcanics around the sea of Marmara, limited by the boundaries of the 1:500000 scale Istanbul Quadrangle, and the Upper Cretaceous volcanics cropping out along the Black sea coast have all together been studied and differentiated into five different groups:

Upper Cretaceous volcanics

Upper Cretaceous volcanics in the study area are situated in the north, along the Black sea coast in vicinity of Istanbul and in Igneada, close to Bulgarian-Turkish State Boundary (Fig. 1). They generally are observed to intercalate with the sedimentary rocks of the same age. Upper Cretaceous aged sedimentary and volcanic rocks are widespread in the east of Istanbul, aro-

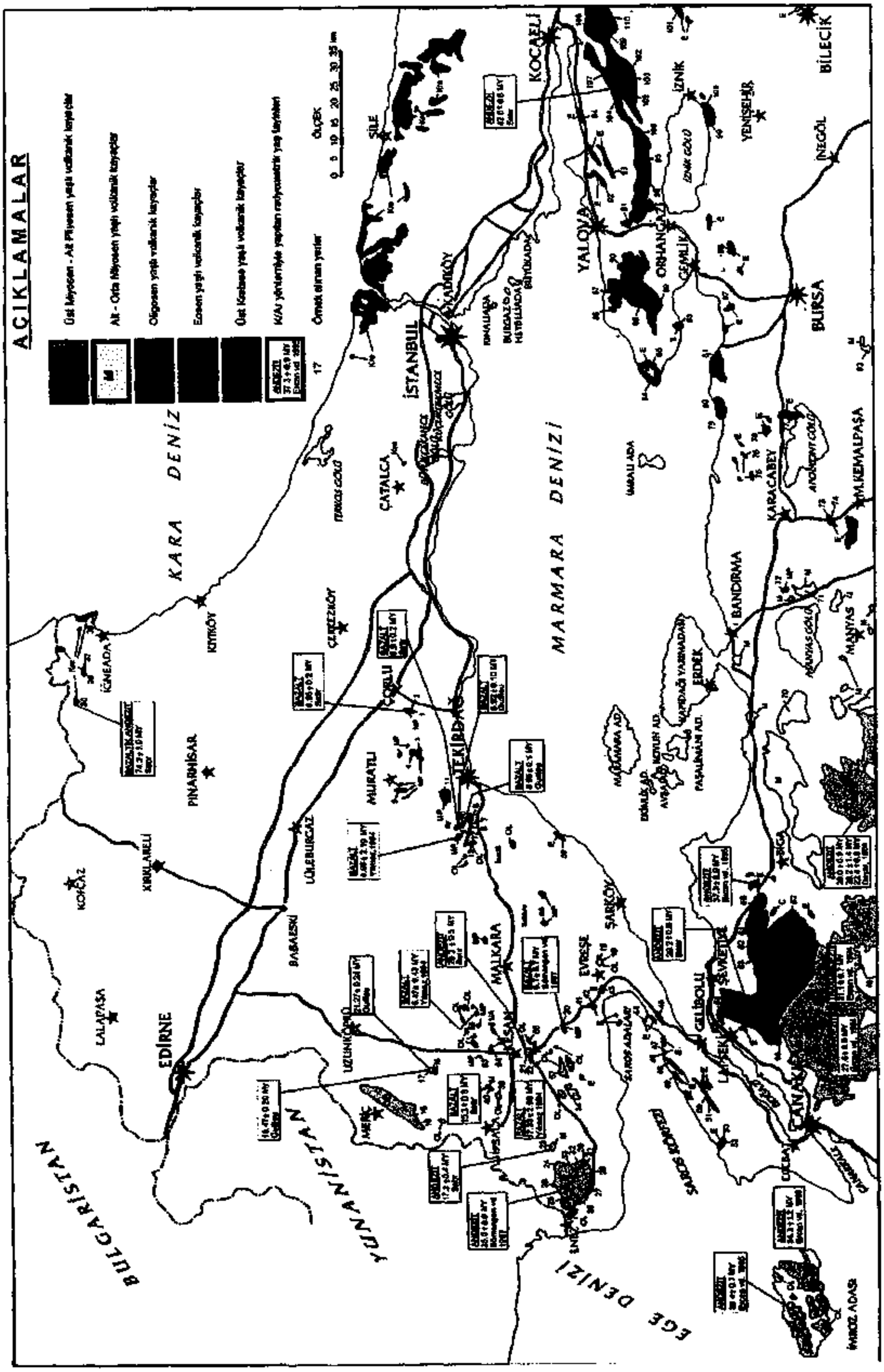

Fig. 1- The distribution of Upper Cretaceous and Tertiary volcanics around sea of Marmara.

und Şile. Flysch type sediments, comprising an alternation of conglomerate, sandstone, siltstone, marl, claystone and limestone, bear various kinds of pyroclastics and lava flows in rather lesser amounts. These are spilitic basalts, basalts, andesites, basaltic andesites, trachyandesites, dacites rhyolitic lavas, agglomerates and tuffs, displaying typical submarine volcanism. The most widespread of these is highly altered andesitic lava which contains plagioclase, rather less hornblende, biotite, augite and opaque minerals. The argillization observed in these rocks is of large scale and significant in industrial point of view. Besides, sericitization, chloritization, carbonatization and zeolitization are observed. Andesitic lavas are of porphyritic, hyaloporphyritic, partly pylotaxitic texture. Plagioclase phenocrysts are hypidiomorph in places and its types such as albite showing polysynthetic twinning and zonal structure, andesine, oligoclase and labrador were determined (Yeniyol and Ercan, 1989/1990). Augites are partly idiomorphic and have uralitized and epidotized in places. Generally biotites have undergone magmatic corrosion. In dacites and rare rhyolites, additional to the minerals listed above quartz crystals in various amounts can be seen. In trachyandesitic lavas sanidine crystals are clearly visible. Spilitic lavas are in lesser amounts than intermediate lavas. Spilites comprise albite, augite and opaque minerals. Serpentinization, chloritization and carbonatization are seen in places. Basaltic lavas display porphyritic, pylotaxitic, hyaloporphyritic and vitrophyric textures. They comprise mainly of plagioclase and augite microliths together with plagioclase, augite, opaque mineral and olivine phenocrystals in a matrix of volcanic glass. Plagioclases display polysynthetic twinning and zonal structure and are of andesine and labradorite type. Augites are observed to be partly twinned and altered. Basaltic lavas also show chloritization, zeolitization, carbonatization and argillization. Upper Cretaceous volcanism, in vicinity of Istanbul, around Anadolukavağı and Rumelikavağı at the northern end of the Bosphorus and Şile, is represented by agglomerates, sinerite, tuffs and lavas. Baykal (1943 and 1971) Baykal and Kaya (1966), Baykal and Önalan (1979), Okay (1948), Akartuna (1953) and Yeniyol and Ercan (1989/1990) who studied fossiliferous sedimentary rocks intercalated with the volcanic rocks representing the submarine volcanisift have concluded that both volcanic and sedimentary. rocks have completely formed during Upper Cretaceous (Santonian - Campanian - Maastrichtian).

In the study area, the Upper Cretaceous volcanism having small outcrops towards west (Akartuna 1953; Erentöz,1953) is observed again in vicinity of Iğneada. These are basalts, basaltic andesites, spilitic basalts, andesites, rhyodacites and rhyolitic lavas, tuffs and andesites and are intercalated with Upper Cretaceous marine sediments. Pillow lavas are locally observed. They are mostly andesites and basaltic andesites. Andesites are called "pyroxene andesites" since the samples displaying porphyritic texture includes plagioclase and pyroxene crystals. The plagioclases (andesine and oligoclase), crystallized as macro and microphenocrystals in hypidiomorph form, are generally sericitized, chloritized and epidotized. Some display glomeroporphyritic texture. Pyroxenes (clinopyroxene-augite) form assemblages of glomeroporphyritic texture as in xenomorph crystals. Some change into chlorite pseudomorphs including carbonates and carbonatization. The matrix has intersertal texture and is formed by the interfingering plagioclase microliths and the altered pyroxene granules, chlorite and intercitial silica filling the space between. In the matrix, locally, concentric carbonatization, silicification and epidotization is observed. The andesitic lavas which are close to basalts in texture, have been called as pyroxene andesite or basaltic andesite in andesite-basalt transition. Tuffs are in many places have the appearance of lavas and are called as lapilli tuff and crystal tuff. Lapilli tuffs have a silicified, epidotized and prehritized matrix including volcanic rock fragments of andesitic nature and pyroxene andesite fragments, feldspat, amphibole (green hornblende) and pyroxene fragments. The fragments forming the samples are of angular, between 0.36 mm (coarse grained tuff) to 5.5 mm (lapilli) in length. Crystal tuffs include fragments of plagioclase, quartz, amphibole (green hornblende), devitrified glass and chloritized volcanic rocks, and epidotized, carbonatized and argillized fragments, sericite flakes and organic fragments. All these compounds mostly have been bound with material changed into chlorite and/or clay minerals (most probably volcanic glass ashes and dusts). Crystal tuffs generally are composed of fine grained materials of 0.01 mm grain size.

In order to clarify the age problem of the Upper Cretaceous volcanics around the sea of Marmara a sample was taken from a basaltic andesite lava in vicinity of iğneada which yielded 74.3 ± 3.1 million years (Campanian-Upper Cretaceous) by K/Ar method.

Eocene volcanics

In the region around sea of Marmara Eocene volcanism has widespread outcrops in three different areas:

a) Eocene volcanics in Biga peninsula : Between Lapseki and Biga, to the north of Biga peninsula, mostly andesitic and locally dacitic lavas and tuffs which are the first products of Eocene volcanism are observed. They are underlain by the "Soğucak limestone" determined to be of Middle Eocene age by Siyako et al., (1989). Lavas and tuffs are observed to be intercalated with conglomerates having thin coal seams, sandstones and shales, called "Fıçıtepe formation", which is defined to be delta plain -fluvial sediments (Siyako et al., 1989). These volcanics are supposed to be of Lower-Middle Eocene age. On the other hand, there are some opinions about the volcanism to start in Paleocene (Siyako et al., 1989; Ertürk et al., 1990). There is a significant transgression in Middle Eocene resulting in the deposition of shallow marine "Soğucak limestone" in the region while the Eocene volcanism was still effective, forming lavas and tuffs of 1000 m in thickness. Later on, the southern shelf of the basin has gradually deepened and Ceylan formation (Ünal,1967; Siyako et al.,1989) comprising mainly of turbidites was deposited. Two dacitic tuff levels (10-30 m thick), blue and green in color, which forms a marker bed in Ceylan formation (500 m thick) comprising turbiditic sandstone, shale and marls in Biga peninsula, proves that the Eocene volcanism was continuing in Upper Eocene. Together with the lavas and tuffs of andesitic and dacitic nature, there are ignimbritic tuffs that formed close to the land. Despite the presence of all these data, it is very difficult to differentiate and to map the members of the Eocene volcanism. Ercan et al., (1995) have named all the Eocene volcanics in the Biga peninsula as "Balıklıçeşme volcanics" and dated the unit as 37.3 ± 0.9 million years (Uppermost Eocene) based on the K/Ar dating of the sample of andesitic lava with biotite taken from the Balıklıçeşme village. The petrographic studies on the Eocene volcanics situated in Biga peninsula result in that the andesitic lavas contain chloritized and argillized plagioclase microliths with porphyritic texture, plagioclase phenocrystals in a matrix containing pyroxene and opaque minerals and also diopsitic augite crystals whereas the dacitic lavas locally include quartz phenocrystals. Tuffs generally are of vitric and lithic but sometimes appear as ignimbritic in the field. They are composed of, generally, sericitized, argillized plagioclase fragments, quartz fragments and volcanic rock fragments (andesite and dacite) and devitrified glass fragments. These are bound with a matrix composed of sericitized volcanic glass, ash and dust. Grain sizes are varying between 3.2 mm (lapilli) and 0.02 mm (fine grained tuff).

b) Eocene volcanics in Gelibolu peninsula and southern thrace : Eocene volcanism in Gelibolu peninsula and in southern Thrace has outcrops same as that seen in Biga peninsula. For example, in vicinity of Gelibolu town, mostly green and wine colored andesitic and dacitic tuffs are observed as alternating with Middle-Upper Eocene sediments and lavas are seen as small sills in places. Kopp (1964) has differentiated the Gelibolu volcanics as "Kömürtepe Andesite and tuffs", "Kavaklı Andesite", "Uçaktepe tuffite" and "Kocakuş tuffite". Onal and Yılmaz (1983) stating that the volcanics are of Upper Eocene, "Karaağaç member" of flysch type "Burgaz formation" includes tuff levels alternating with the other sedimentary units. Önal (1986) indicates that the Upper Eocene volcanic rocks, "Gelibolu volcanics" in his terminology, are andesites and dacites. Sumengen et al., (1987) have observed tuff levels of Middle Eocene age in "Burgaz formation" which is a 600 m thick flysch unit. The same researchers have indicated the presence of tuff levels in the "Gaziköy formation" which is of shale-sandstone unit situated in the upper levels. These thin bedded, light green colored silicified tuffs are determined to be of Middle-Upper Eocene age. Ceylan formation, observed in Gelibolu peninsula, is a turbiditic sequence reaching up to 500 m in thickness and is an alternation of sandstone, conglomerate and limestone displaying Bouma sequences also includes tuff levels (Siyako et al., 1989) It is of Upper Eocene age (Toker and Erkan, 1985). This formation can be seen in the inner sections of the Thrace basin with increasing acidic tuff levels reaching up to 500 m. The tuffs, observed as silicified locally, are quite widespread and can be correlated in well logs (Siyako et al.,1989). Burkan (1995) studied the distribution of these tuffs in Thrace basin making use of 11 different tuff levels observed in 52 well logs and concluded that especially along the Çorlu-Edirne line there lies a tuff layer of 450 m in thickness. They are of rhyolite, rhyodacite and dacite types and locally zeolitized (Özkanlı and Sonel.1995).

In Gelibolu peninsula, at the thalweg of the dam near Tayfurköy, the green ignimbritic tuffs placed on the Eocene sandstones and the tuffs in vicinity of the Bakla burun to the west of Bolayır are typical outcrops. To the north, on the Keşan-Gelibolu roadcut near Evreşe, Eocene sandstones include volcanic materials and are cut by andesitic lavas. The small islands in gulf of Saros were formed by Eocene lavas (Ercan and Günay, 1984). In vicinity of U9makdere village, to the south of Tekirdağ, the siliceous tuffs of Eocene age are observed together with the flysch of the same age. These tuffs, called "vitric tuffs", include devitrified glass fragments, lesser plagioclase, biotite, sanidine, quartz in very few amount and volcanic rock fragments. They have undergone intense chloritization and the traces of glass chips are visible in them. Grain sizes are between rarely 4 mm (lapilli) and 0.08 mm (coarse grained tuff) but the average grain size can be said to be 0.3 mm (coarse grained tuff). Ertürk and Uygur (1994) studying on the tuffs have differentiated products of. two different lithofacies formed in the marine environment. These are well bedded, laminated green tuffs and locally carbonatized, siliceous white tuffs. They also state that the tuffs are mostly vitric and crystalline in places. Lavas, on the other hand, are of andesitic type with porphyritic texture and include plagioclase and amphibole phenocrystals, Plagioclases range from macrophenocrystals to fine grained and microphenocrystals in size and were crystallized in zonal structure as hypidiomorph. Some of them display antiperthite formation. They have changed into chlorite and/or clay minerals due to alteration. Amphiboles (green hornblende) were crystallized as idiomorphs in forms of medium to thin in size microphenocrystals. Some of them form assemblages in glomeroporphyritic texture while some others display carbonatization. Together with hornblende, sphene is also seen as secondary mineral. The matrix is probably formed by devitrification of volcanic glass and is of cryptocrystalline-felsitic texture. Along the fractures carbonate fillings are seen.

c) The Eocene volcanics in Armutlu peninsula and around the the lake Apolyont : In Armutlu peninsula mostly andesitic lavas, tuffs and agglomerates of Middle-Upper Eocene age spread over wide areas and are in primary relation with the sedimentary rocks of the same age. Akartuna (1968) who studied in the region in detail for the first time, states that the volcanism starts on the flysch with tuffs which is overlain by lava tuffs and agglomerates of Paleocene-Eocene age which are later on called as "Sarısu volcanics" by Erendil et al., (1991). They stated that this formation, comprising pyroclastic and epiclastic rocks of 1000 m. thick, overlies the sedimentary units made up of conglomerate, sandstone, mudstone and limestone of 5-10 m situated over the basement, metamorphic rocks. Pyroclastics levels comprise fine or coarse grained tuffs displaying normal, reverse or symmetrical grading and andesitic tuffs and lava fragments of various size in lapilli. Pyroclastic flow deposits are alternated with lahar deposits of generally symmetric graded and ill sorted. At some levels epiclastic deposits comprising large andesite blocks and pebbles, most probably of shore conglomerate type are situated. In this sequence, lava flows at the upper levels, as 5 m thick layers, are alternated with pyroclastic rocks. Lava flows are andesitic volcanics with plagioclase, pyroxene (augite) and hornblende phenocrysts. Tuffs include plagioclase, glass and volcanic rock fragments having fluidal texture in a glassy matrix. All of this sequence, especially in the upper levels is cut by basaltic dykes. Basalts, with compounds such as olivine, augite and plagioclase, are more fresh than andesites. In the limestones and sandstones situated at the lowest levels of the volcanic sequence fossils of. Lutetian age were found (Erendil et al., 1991) and it was concluded that the sequence started since then. The andesitic lava flow sample taken from the north of İznik, between the villages Osmaniye-Sarısu yields 42.0±0.8 million years (Lutetian-Bartonian) by K/Ar method and therefore the whole volcanism can be said to be of Middle-Upper Eocene age.

Bargu and Sakınç (1987; 1989/1990) called the lavas "Kızderbent andesite" and differentiated the pyroclastics as "Taşlıtepe formation" and "Geyikdere tuff member", "Tavşanlı tuff member" and "Handere tuff member". They proposed that the depositional environment is a gradually deepening shallow marine environment and the region emerged in Oligocene.

The pyroclastic rocks which locally gets thicker of this volcano- sedimentary sequence defined in Armutlu peninsula have in some places undergone intense alteration. As a result of the diagenetic alteration of these andesitic, dacitic and rhyodacitic tuffs, hauylandite-clinoptilolite group minerals from zeolites, mica, clay mixed layered minerals (seladonite, glokonite), opal-CT from silica group and calcite from carbonates have authigenically formed (Uz et al., 1992; 1995). The tuffs which are seen in white, dirty white, yellow-green in color in the field display crystalline-glassy and lithic transitions. Dusty tuff transitions as bands with binding material which is in ash size can also be seen. The phenocrystals are quartz, plagioclase (albite-orthoclase), sanidine and biotite in the acidic tuffs in which the alteration is higher. Intermediate (andesitic) tuffs include hornblende crystals. Lavas are mostly of andesitic, and in places are of basaltic which cuts the andesitic lavas. Flow breccia structure and concentric alterations in agglomerates are seen in places. Agglomerates are observed from large block (a few meters) to lapilli size. All these coarse clastic volcanic materials are bound loosely with fine grained clay and tuff of volcanic origin.

The Eocene volcanics cropping out in Armutlu peninsula, continue to appear southwestward, in the north of lake Apolyont, along the ranges parallel to the sjiore and in vicinity of Kemalpaşa displaying the same features. Lavas are hard, green in color, mostly andesitic and basic and pillowed. Pyroxene andesitic lavas are of porphyritic and comprise plagioclase, pyroxene, less hornblende and quartz as trace minerals. Plagioclases are of various type and are crystallized as hypidiomorph showing zonal structure. Pyroxenes (clinopyroxene-pidgeonite, augite and orthopyroxene-hypersthenej are generally as hypidiomorph crystals. Matrix is intergranular in places and pylotaxitic and includes primary silica. Carbonatization and chloritization can be seen locally. Brown and green hornblende crystals are idiomorph with their surroundings opacitized. Basaltic andesite lavas contain idiomorph olivine crystals which are chloritized due to alteration. Basaltic lavas are called "olivine basalt", they are porphyritic and comprise plagioclase, olivine arid pyroxene phenocrysts. They are generally hypidiomorph. They are as macro and microphenocrystals, some of them show zonal structure. Mostly they form glomeroporphyritic assemblages. Some of them are poikilitic and have pyroxene inclusions. Olivines are chloritized, carbonatized due to alteration and their fractures are filled with iron oxide. Pyroxenes (clinopyroxene-augite) are hypidiomorph and are in forms of macro and microphenocrystals. The matrix is intergranular and rather coarse grained and they are formed by the plagioclase microliths and microcrystals and by the granulated opaque minerals and chloritized and carbonatized mafic mineral traces in between them. They have amygdaloidal structure in places, filled by chlorite (at the sides) and calcite (in the center).

Oligocene volcanics

The Oligocene volcanics situated around the sea of Marmara crop out at three different areas:

a) Oligocene volcanics in Biga peninsula : Biga peninsula, starting from Lower Oligocene uplifted and emerged (Ercan et al., 1995) and first of all, the area between Çan and Çanakkale and the region around

Manyas were effected from a volcanic stage expressed by widespread lavas and tuffs of andesite, dacite, rhyodacite type. Many of them have been altered and silicified. These are observed in white, yellow, red, brown, green and blue colors and in different situations. Silicified tuffs are hard and conchoidal. Unaltered lavas, which are quite rare, are mostly dark colored and include brown plagioclase crystals, gray-black biotite and dark gray pyroxene phenocrystals. Andesitic lavas are porphyritic and include plagioclase, amphibole and pyroxene phenocrystals. Plagioclases (oligoclase-andesine-labrador) are hypidiomorph and display zonal structure. Sometimes they show antiperthite formation and have poecilitic texture. They have changed into clay minerals in places due to alteration.

Amphiboles (oxytiornblende) are as hypidiomorph macro and microphenocrystals. Some of them are opacitized. Pyroxenes (clinopyroxene-augite) are as hypidiomorph thin microphenocrystals. Dacitic lavas have the same features. The quartz minerals they include are as subautomorph crystals. The components of the tuffs are sericitized, argillitized plagioclase fragments, quartz fragments, volcanic, rock fragments (andesite, quartz andesite and dacite) and devitrified glass fragments. These are bound with a matrix of volcanic glass, ash and dust. Grain size is varying between 3.2 mm (lapilli) and 0.04 mm (fine grained tuff) but generally considered as 0.30 mm (coarse tuff). Ignimbrites are observed with tuffs in places. Great part of the lavas are silisified, argillitized and pyritized locally. There are some hydrotermal quartz veins.in tuffs. In general, all of the mineral deposits in the region have formed in relation with the Oligocene volcanism. The alteration of tuffs have resulted in formation of rich kaoline deposits.

The Oligocene volcanics are called "Can volcanics" by Ercan et al., (1995) during their study in which they showed the distribution of the volcanics. An andesite sample taken from, Lapseki-Umurbey village yielded 29.2±0.6 million years (between Chattian-Rupelian) based on K/Ar dating method. Dayal (1984) reached almost the same result during his study in the area* with the samples taken from the east of Çan: 28.2±2, 28.0±0.9 and 22.4±0.8 million years. The first stages of Oligocene volcanism in Biga peninsula which is known as "Çan volcanics" is very important in NW Anatolia from the rich metallic mining point of view. Hydrothermal alteration is very intense, in such areas, in silicified zones Au, Ag, Pb, Cu, As, Fe, Mo, Zn and Hg deposition are seen which have been exploited since thousands of years.

In the last stages of the Oligocene volcanism producing outcrops of andesitic and locally dacitic lavas, tuffs and agglomerates the nature of the volcanism was changed and instead the above listed generally black dykes and black, small outcrops of trachyandesitic and basaltic lava flows were produced. These which are called "Kirazlı volcanics" by Ercan et al., (1995) have yielded 27.6±0.6 and 31.1 ±0.7 million years by K/Ar dating method. The texture of these trachyandesitic lavas are microlitic porphyritic and hyalomicrolitic porphyritic and they bear plagioclase (labrador and andesine), augite and lesser biotite and hornblende crystals in a glassy microcrystalline matrix. Plagioclases which appear as phenocrystals and microliths have been altered in places and have turned into minerals like sericite and zeolite. Basaltic lavas have intergranular and microlitic porphyritic texture and bear plagioclase (labrador and andesine), augite and olivine minerals in matrix of plagioclases and microliths of mafic minerals.

b) Oligocene volcanism in Gökçeada (Imroz) island : Gökçeada island is entirely made up of Tertiary rocks. At the basement there are two flysch deposits of Eocene and Oligocene age (Akartuna, 1950; Okut, 1975). Lavas, tuffs and agglomerates of andesitic and dacitic nature cut and overlie these rocks. Ercan et al., (1995) obtained 30.4±0.7 and 34.3±1.2 million years of age from the K/Ar dating of two different samples.

c) Oligocene volcanism in Thrace : The Oligocene volcanism in Biga peninsula and in Gökçeada island spreads in Thrace and westward, in Greece and Bulgaria. Ternek (1949) and Kopp et al., (1969) have stated that the volcanism was effective during the whole Oligocene. They also stated that andesitic and dacitic lavas during both two volcanic stages and in Lower Oligocene and towards Upper Oligocene intense andesitic and dacitic and in places trachytic lavas were produced. An andesitic sample collected near a quarry around Keşan yielded 26.2±0.5 million years (Upper Oligocene-Chattian) by K/Ar dating method. The phenocrystals of the dated sample are mainly plagioclase and lesser amphibole (hornblende) and pyroxene. Opaque minerals and apatite are secondary minerals. Plagioclases have turned into sericite and/or clay minerals and they appear as hypidomorph crystals in zonal structure. Some of them form glomeroporhyritic assemblages. Amphiboles (green hornblende) mostly observed as idiomorph crystals. Pyroxenes (augite) are seen in lesser amounts as microphenocrystals. The matrix, having cryptocrystalline felsitic texture, is made up of crystalites.

Oligocene volcanism in Hisarlıdağ, in vicinity of Enez, is being represented by lavas, tuffs and agglomerates of mostly andesitic and dacitic nature. They, which are called "Hisarlıdağ volcanics" by Saner (1985) reach up to a thickness of 800 m. The same name was used for the volcanics in the region by Sümengen et al., (1987). A sample from this region yielded 35.0±0.9 million years (Lower Oligocene) by K/Ar dating method. There are ignimbrites and tuffs in different colors with large fiammes in Hisarlıdağ which formed at different stages, agglomerate levels and andesitic lavas in places. The summit was formed by black and pink colored ignimbrites. The components of the ignimbrites are plagioclase, biotite, devitrified glass fragments and volcanic rock fragments. They are stained by ironoxide hydroxides and volcanic glass flakes are lined up in flow structures. Andesitic lavas include plagioclase, pyroxene and biotite phenocrystals. Plagioclases (andesine) are hypidiomorph in zonal structure. They range in a series from macrocrystals to microliths. Generally they are crystallized in zonal structures as hypidiomorphs. Biotites are observed as hypidiomorph and xenomorph crystals whereas pyroxenes (clinopyroxene-augite) are crystallized as hypidiomorphs. They are stained by the ironoxide hydroxides and due to intense corrosion around they are rounded. The matrix is of cryptocrystalline felsitic texture and margarite and globulite structures due to devitrication of volcanic glass can be observed. In Hisarlıdağ volcanic rocks start with, at the bottom, rhyodacitic tuffs, andesite, altered andesitic tuffs and reddish green tuffs formed by the lahar flow. In the upper levels white rhyolitic tuffs, rhyodacites, andesites, agglomerates and ignimbrites are seen. Between Ipsala and Meriç andesitic and dacitic rocks of Oligocene age crops out. Tuffs generally form thin layers between synsedimentary deposits. Especially around Büyükaltıağaç village ignimbritic tuffs with small obsidian fragments are observed. Altered small dacitic lava outcrops in places can also be seen. .

In Central Thrace, on the other hand, tuff horizons that have formed in a couple of stages having various thicknesses in between Oligo- Miocene deposits can be seen spread in wide areas. These are the products of Oligocene volcanism (Lebküchner, 1974). These are generally weathered and kaolinitized andesitic and dacitic glassy tuffs and are difficult to differentiate from the sedimentary units (Ercan,1979). Some of them are reworked and some are air-fallen during the formation of deposits. For example, the Oligocene aged tuffs in vicinity of the Seğmenli and Selçuk villages to the west of Tekirdağ are observed have formed in lacustrine environment and are intercalated with the siltstone-claystone units. There are very thin coal seams in between. The tuffs have come from a volcanic center in the vicinity, Kale tepe, and fallen into a lacustrine environment to form layers. Gök (1990) named the tuffs as the "Ferhadanlı tuff member" of the "Danişmen formation" of Middle Oligocene age. They are white, dirty white, light gray in color and bear agglomerate levels with a thickness of maximum 25-30 m. They are processed and used as trass in cement factories. They include abundant quartz, biotite, amphibole (green hornblende), plagioclase and volcanic rock fragments. Cement is made up of volcanic glass, dust, ash, carbonate and clay. The lava samples taken from the Kale tepe are silicified, carbonatized dacitic lavas and have amygdaloids and totally chloritized mafic minerals, quartz and plagioclases turned into clay minerals.

The Oligo-Miocene aged deposits spreading over wide areas in Thrace overlies, in places, volcanic rocks of Oligocene age. Ercan and Gedik (1986) studied the core samples of Maltepe-1 well opened by Deilmann-

Shell Oil Company in the north of Keşan (41 ° 01' 17" latitude and 26° 42' 3" longitude) and found out dacitic and rhyodacitic lavas of Oligocene age at 1850-1860 m depth. The same researchers also studied the core samples taken from inecik-1 well opened by Gulf Oil Company in the east of Malkara (40° 55' 44" latitude and 27° 17' 16" longitude) and observed the existence of dacitic lavas of Oligocene age at 1488-1492 m depth.

The Oligocene volcanism in Thrace is observed in wide areas both in Greece and Bulgaria.

Lower-Middle Miocene volcanics

Lower-Middle Miocene volcanics around the sea of Marmara takes place mainly in two places:

a) Lower-Middle Miocene volcanics in Biga peninsula and in Manyas : During Lower-Middle Miocene an intense volcanism took place in Biga peninsula in different stages and produced andesitic, dacitic, rhyodacitic, trachyandesitic and basaltic lavas, tuffs, agglomerates and ignimbrites. These rocks are well known and well studied with detailed investigations and the datings have yielded 21.5-16.8 million years (Ercan et al.,1990; 1995). The volcanic rocks of Lower-Middle Miocene age in Biga peninsula and around Manyas have formed at the same time with deposits of Neogene age in a terrestrial environment. In places volcanic products have formed and sometimes in depositional environments volcanic rocks and sedimentary rocks have mixed and formed volcano-sedimentary units. Lavas are mainly of andesitic and in places of dacitic and rarely rhyodacitic, trachyandesitic and basaltic. Andesitic lavas are generally pink, purple, dark gray or beige in color, with irregular and angular breaks and rarely show flow structure. They mostly have hyalocrystalline porphyric texture and include plagioclase, biotite, amphibole (hornblende) and pyroxene (augite) phenocrystals. Plagioclases are andesine and oligoclase and crystallized as hypidiomorph in forms macro and microphenocrystals and display zonal structure. Amphiboles (brown hornblende) are generally hyptdiomorph and opacitized mostly. Biotites are as large, medium to small sized phenocrystals as hypidiomorphs and their outer boundaries are opaticized. Pyroxenes (clinopyroxenes-augite) are as hypidiomorph and idiomorph microphenocrystals and their outer boundaries are stained with ironoxide hydroxides. They are observed either as single crystals or as glomeroporphyritic textured assemblages. The matrix is pylotaxitic and in places in cryptocrystalline felsitic texture and made up of plagioclase microliths and cryst lites and cryoptcrystalline mezostas in between them. Dacitic lavas, pinkish white, dirty white in color, includes quartz and coarse plagioclase (andesine-oligoclase), biotite and hornblende phenocrystals. The matrix is in spheroidal texture. This matrix, generally seen in acidic rocks has obtained this feature by the recrystallization of the glass already present. Rhyodacitic lavas have more quartz phenocrystals than dacitic lavas and these phenocrystals are embedded in the matrix. As another difference from dacites, sanidine in less amount is also observed. Tuffs are generally interfingered with andesitic lavas and agglomerates and include epidotized, chloritized and partly carbonatized mostly hornblende (idiomorph), biotite (hypidiomorph), epidot group minerals (pistasite), chlorite fragments, and argillized-sasuritized feldspat fragments. The matrix is generally made up of biotite as microliths, less hornblende, plagioclase microliths (albite), pyroxene and quartz in lesser amounts.

b) Lower-Middle Miocene volcanism in Thrace : Although there are widespread outcrops of Lower-Middle Miocene volcanism in Biga peninsula, in Thrace, the outcrops of this volcanism is observed in five small locations:

/- Koyuntepe, to the east of Hisarlıdağ.- Lavas of pyroxene andesite type are very hard, black in color and have the appearance of basalt. Koyuntepe mountain is made up of these lavas. They have plagioclase and pyroxene phenocrystals and amphibole (brown hornblende) in lesser amounts. Plagioclases (andesine) display zonal structure and are generally hypidiomorph. They include glassy matrix as inclusions and are in various sizes as macro and microphenocrystals. Pyroxenes (clinopyroxene-augite and orthopyroxene-

hyphersthene) have crystallized as hypidiomorph. Clinopyroxenes are much more in amount whereas there are very few amphiboles (brown hornblende), they are opacitized in their surroundings. The matrix is in pylotaxitic texture, the space between the crystals are filled with volcanic glass. The samples yielded 17.3±0.4 million years (Burdigalian-Lower Miocene) by K/Ar method.

//- Asar tepe, in the north of Korucuköy.- Asar tepe is composed of basaltic lavas. The lavas are in porphyritic texture and include abundant olivine and pyroxene and less plagioclase. Olivines are the most abundant phenocrystals. and generally crystallized in hypidiomorph form as macro and microphenocrystals. Some of them form assemblages in glomeroporphyritic texture. Pyroxenes (basaltic augite) display zonal structure and are observed as xenomorph crystals, as thin phenocrystals forming assemblages in glomeroporphyritic texture and microphenocrystals seen as hypidiomorph-single crystals. In these basaltic lavas having coarse grains, the matrix is intergranular in places (the space between plagioclase-labrador microliths filled with pyroxenes and opaque minerals) and intersertal in some places (chloritized mezostaz fill the space between plagioclase microliths). The lavas building Asar tepe are similar with the Upper Miocene basaltic lavas. The samples taken yielded 15.0±0.3 million years by K/Ar method (Lower-Middle Miocene, Burdigalian-Langhian). These are the first products of the alkali basaltic volcanism in Thrace.

Ill-Kale tepe and Kartal tepe near Harala village.- The volcanics forming the Kale tepe and Kartal tepe near Harala (Altınyazı) village are similar with the other Lower-Middle Miocene aged basalts in their appearance. On the other hand, the detailed petrographic and geochemical studies have shown that these are subvolcanic rocks crystallized in depth rather than the basaltic lavas crystallized at the surface. The samples generally have poikilitic texture. They are composed of mainly pyroxene (clinopyroxene-augite) and plagioclase (oligoclase-andesine) in decreasing amount, biotite, olivine, opaque minerals and apatite as secondary mineral and all of them are in alkali feldspaths (orthoclase and sanidine) displaying perthitic structure. Augites are generally hypidiomorph and in glomeroporphyritic texture. Plagioclases are seen as thin spikes and microliths. They change into chlorite and/or clay minerals in places. Biotites are crystallized as hypidiomorphs and opacitized. The trace minerals that changed into chlorite + carbonate + opaque minerals are most probably olivines. The samples, according to Streckeisen 1976 classification, may be micromonzonites in syenite-monzonite transition. The two samples collected in the area have yielded 21.27 + -0.24 and 18.47 + -0.20 million years (Lower Miocene) by K/Ar method. Thus, by this work subvolcanic rocks of Miocene age in Thrace was found for the first time.

IV- Karakaya tepe near Yenimuhacir village northeast of Keşan.- At the basement marl of Oligocene age, sandstone, coal seams and tuffs are situated and the magmatic rocks cutting these are similar to those subvolcanic hypabyssal rocks seen both in Kale tepe and Kartal tepe. They are of porphyritic texture, generally. The main minerals are alkali feldspat, analcime, pyroxene, biotite and olivine. Alkali feldspaths (orthoclase and less sanidine) are observed to include biotite and pyroxene minerals as xenomorph crystals both in intercitial and in poikilitic texture. Change into analcime and clay minerals, in places, are seen. Analcimes are mostly idiomorph and intercitial as xenomorphs and in places found together with zeolite minerals. Pyroxenes (clinopyroxene-diopside) are crystallized as idiomorph and hypidiomorph. Some of them are surrounded with a slight dark mantle (possibly a transition to aegirin augite). They are observed as medium and thin microphenocrystals. Biotites are generally crystallized as hypidiomorph and are in reddish brown color (probably Ti biotite). They are observed as coarse phenocrystals. As secondary minerals apatite and opaque minerals are seen. The samples are named "analcime syenite porphyr", a vein rock, as attached to fold syenides according to Streckeisen I.U.G.S.-1979 classification.

V-Karamaden tepe, in the north of Keşan.- This is a small andesitic dyke. The phenocrystals of the samples are plagioclase, amphibole and pyroxene. The texture of the samples are porphyritic. Plagioclases (oligoclase-andesine) have undergone magmatic corrosion, they are seen as hypidiomorph crystals with zonal structures. Some of them are changed into chlorite and/or clay minerals. Amphiboles (green hornblende) are mostly hypidiomorph as macro and microphenocrystals. Some of them are in glomeroporphyritic texture. Pyroxenes (augite) are crystallized as hypidiomorph. They are seen as macro and microphenocrystals and are lesser than amphiboles. The primary texture of the matrix is hyalopilitic and as a result of alteration chloritization and the formation of secondary silica can be seen.

Upper Miocene volcanics

The Upper Miocene volcanic rocks around the sea of Marmara are seen as cutting the Tertiary sedimentary rocks and forming single volcanic cones. They are seen in Thrace but now here else in the region, except for a small outcrop situated to east of lake Manyas. They are completely of alkali olivine basalt type. They have used the young opening fissures to reach to the surface and have spread around them forming small flow outcrops and volcanic cones. In Thrace, some young basaltic volcanics crop but as scattered in between Çorlu and Tekirdağ (Kara tepe, Çevrimkaya köyü, Balabanlı köyü, Muratlı, Karakaya tepeleri, Osmanlı köyü, Beşik tepe), in vicinity of Malkara (Karademir köyü, south of Ballıköy) and in vicinity of Keşan (Mahmutköy, Kartal tepe, Sivri tepe, Küçükdoğanca köyü, Beğendik köyü). The samples defined as olivine basalt are in porphyritic texture and bear abundant olivine, less plagioclase, and lesser pyroxene as thin phenocrystals. In some samples very few biotite is found. The matrix is of intergranular texture, the space between interfingering plagioclase microliths are filled with granulated pyroxene, less olivine and lesser opaque minerals. In a very small area intersertal texture is seen. Olivines are the most abundant minerals and they are mostly crystallized as idiomorph. Some of them are observed as relicts changed into chlorite and calcite while the others are as less altered. They are surrounded by secondary, granulated opaque minerals (magnetite?). Pyroxenes (clinopyroxene-augite) are seefl in zonal structure as hypidiomorph crystals. The texture is generally glomeroprophyritic. Plagioclases are generally seen in the matrix rather than as phenocrystals.

The age of the young alkali basaltic volcanism in Thrace has been under debate for long years. For example, Umut et al., (1984) and Umut (1988) proposes that they can be divided into two groups of Upper Miocene-Pliocene age and of Pliocene-Quaternary age while Ercan (1992) states that the latest stage of the basalts was effective towards the end of the Pliocene. Tapırdamaz and Yaltırak (1997) proposes that a part of these basalts may be of Pliocene-Quaternary age. Sümengen et al., (1987), depending upon a radiometric dating of a sample taken from Mahmutköy to the south of Keşan, states that the basalts are 6.7±0.7 million years old (Upper Miocene). Besides, there are some other dating results from some outcrops such as 4.88±2.19 million years and 6.47±0.43 million years (Upper Miocene) (Yücel Yılmaz, personal communication). In order to shed light to the problem, during this research, four different sample was dated by K/Ar method. The sample taken from Kara tepe (the basaltic cone appearing the youngest in the region) in vicinity of Çorlu yielded 8.95±0.2 million years (Upper Miocene) and the samples taken from Karakaya tepe in the north of Tekirdağ yielded 8.9±0.2, 8.96±0.1, 8.92±0.1 million years (Upper Miocene). Therefore the age of the youngest volcanism is determined as Upper Miocene. No volcanic rocks of Pliocene and Quaternary were found.

GEOCHEMICAL FEATURES OF THE TERTIARY VOLCANISM AROUND THE SEA OF MARMARA

During this study carried out around the sea of Marmara, other than the petrographic and geochronologic studies on the volcanic rocks differentiated into five groups according to their ages, chemical analyses on the representative samples were done and some geochemical results were also obtained. Four samples from Upper Cretaceous volcanics, 27 samples from Eocene volcanics, 21 samples from Oligocene volcanics, 9 samples from Lower-Middle Miocene volcanics and 13 samples from Upper Miocene volcanics (Fig.1) were collected and the total 74 samples were analized in MTA Chemical Laboratories to determine the major elements (Tables 1-2-3-4-5). Besides, 9 samples used

Table 1- Chemical analyses related with Upper Miocene volcanics.

SAMPLE NO	T-1	T-2	T-3	T-4	T-5	T-9	T-10	T-11	T-14	T-20	T-55	T-58	T-60
SiO_2	47,60	46,93	49,04	50,14	50,67	46,62	47,00	46,49	46,72	47,36	49,37	54,55	45,32
TiO_2	2,61	2,47	2,55	2,53	2,74	2,38	2,32	2,89	2,07	2,33	2,10	1,25	2,14
Al_2O_3	12,53	12,76	13,79	14,18	14,49	12,02	12,13	12,08	11,89	13,99	13,44	13,30	11,71
Fe_2O_3	3,34	2,59	4,62	8,58	6,00	1,73	2,47	5,10	2,52	4,70	3,48	2,54	2,24
FeO	7,52	8,59	6,69	2,58	4,81	9,17	8,69	6,95	8,89	6,83	7,46	4,26	10,08
MnO	0,10	0,21	0,10	0,20	0,10	0,10	0,20	0,11	0,21	0,11	0,11	0,10	0,20
MgO	11,48	12,35	7,15	6,08	5,37	13,47	12,13	11,76	14,47	9,22	9,66	9,56	12,22
CaO	9,60	8,85	10,01	9,52	10,34	9,32	9,10	10,26	8,48	10,81	9,03	6,55	9,57
Na_2O	2,82	2,68	3,68	3,75	2,84	2,38	3,13	2,78	2,58	2,33	2,42	1,56	4,18
K_2O	1,67	1,85	1,74	1,82	1,93	2,07	2,02	0,75	1,55	1,70	2,31	5,51	1,32
P_2O_5	0,73	0,72	0,61	0,61	0,71	0,73	0,81	0,85	0,62	0,64	0,63	0,83	1,02

Table 2- Chemical analyses related with Lower-Middle Miocene volcanics.

SAMPLE NO	T-17	T-23	T-40	T-54	T-68	T-69	T-70	T-71	T-82
SiO_2	53,46	58,23	48,96	62,54	62,03	61,78	67,49	61,25	74,88
TiO_2	1,15	0,62	2,19	0,62	0,61	0,72	0,60	0,70	0,57
Al_2O_3	16,25	16,70	13,13	16,40	16,57	16,48	16,12	17,07	8,51
Fe_2O_3	2,72	3,84	1,19	3,42	3,50	3,57	3,30	3,60	2,21
FeO	5,66	4,43	9,43	3,38	1,42	2,63	1,11	2,81	1,59
MnO	0,21	0,10	0,10	0,10	0,10	0,10	0,10	1,00	0,11
MgO	5,35	4,33	8,96	2,77	2,03	1,96	0,60	2,21	2,27
CaO	7,55	8,45	9,38	6,66	4,58	5,97	3,22	5,52	4,65
Na_2O	2,52	2,47	3,65	2,87	3,66	3,19	3,53	3,41	2,04
K_2O	4,19	0,72	2,40	1,03	5,08	3,30	3,73	2,11	2,95
P_2O_5	0,94	0,10	0,63	0,21	0,41	0,31	0,20	0,30	0,23

Table 3- Chemical analyses related with Oligocene volcanics.

SAMPLE NO	T-8	T-13	T-18	T-19	T-21	T-22	T-24
SiO_2	69,88	72,74	86,33	71,95	58,79	62,91	59,31
TiO_2	0,54	0,31	0,64	0,53	0,58	0,52	0,62
Al_2O_3	14,19	17,38	7,95	16,93	18,67	15,73	16,99
Fe_2O_3	2,76	0,57	3,07	3,55	2,65	3,44	3,41
FeO	0,81	0,52	0,48	0,42	4,67	3,04	4,53
MnO	0,11	0,10	0,11	0,11	0,12	0,31	0,10
MgO	1,72	0,10	0,05	0,74	1,96	2,10	2,99
CaO	5,05	1,47	0,21	0,21	4,38	4,72	7,11
Na_2O	1,94	1,99	0,21	0,26	5,30	4,51	2,78
K_2O	2,80	4,71	0,74	5,08	2,77	2,62	1,96
P_2O_5	0,22	0,10	0,21	0,21	0,12	0,10	0,21

Table 3- (Continued

SAMPLE NO	T-26	T-27	T-28	T-29	T-30	T-31	T-32
SiO_2	61,58	64,01	65,71	62,21	60,81	60,26	67,01
TiO_2	0,72	0,62	0,61	0,82	0,62	0,71	0,51
Al_2O_3	18,47	18,27	17,79	18,36	17,58	17,51	15,96
Fe_2O_3	5,63	1,81	2,45	5,26	4,14	2,74	5,16
FeO	0,10	2,27	0,71	0,41	2,79	5,14	0,51
MnO	0,10	0,10	0,10	0,10	0,10	0,10	0,10
MgO	0,46	1,03	0,40	0,51	1,34	2,34	0,51
CaO	2,05	2,79	1,42	3,47	7,03	6,31	3,07
Na_2O	3,90	3,61	3,44	3,37	3,21	2,75	2,66
K_2O	6,67	5,16	7,08	5,10	2,17	1,93	4,30
P_2O_5	0,31	0,31	0,30	0,41	0,21	0,20	0,20

Table 3- (Continued)

SAMPLE NO	T-33	T-34	T-39	T-56	T-57	T-66
SiO_2	66,64	71,24	57,89	76,70	65,11	66,80
TiO_2	0,50	0,31	1,13	0,32	0,52	0,53
Al_2O_3	16,64	16,69	13,60	16,81	16,36	15,43
Fe_2O_3	4,90	2,00	1,62	1,03	2,02	2,02
FeO	1,00	1,22	4,84	0,21	2,15	2,75
MnO	0,10	0,20	0,10	0,11	0,10	0,11
MgO	0,40	0,31	5,77	0,11	1,78	1,48
CaO	3,11	1,83	5,67	0,21	7,55	2,85
Na_2O	2,61	3,05	2,78	0,63	2,31	3,59
K_2O	3,91	2,95	5,77	3,68	1,99	4,23
P_2O_5	0,20	0,20	0,82	0,21	0,10	0,21

Table 4- Chemical analyses related with Eocene volcanics.

SAMPLE NO	T-43	T-44	T-45	T-46	T-47	T-49	T-50	T-51	T-52	T-53	T-59	T-61	T-62
SiO_2	57,89	70,42	57,33	71,96	73,15	78,95	73,38	73,70	60,78	56,33	70,32	74,54	62,37
TiO_2	0,71	0,22	0,83	0,42	0,41	0,30	0,21	0,31	0,63	0,64	0,41	0,32	0,61
Al_2O_3	18,28	15,95	16,68	14,56	14,63	12,75	14,36	15,05	17,82	19,31	14,48	14,69	17,24
Fe_2O_3	4,38	0,92	5,87	1,39	0,89	0,40	0,39	0,57	2,85	4,23	1,03	1,12	4,06
FeO	3,10	1,16	2,50	1,21	1,24	0,91	1,75	0,87	2,62	2,95	1,86	0,65	1,83
MnO	0,10	0,11	0,10	0,11	0,10	0,10	0,11	0,10	0,10	0,11	0,10	0,11	0,10
MgO	2,44	1,65	3,13	1,37	1,34	0,51	0,55	0,30	2,93	4,83	0,62	1,30	1,52
CaO	5,38	2,97	6,78	1,90	0,72	0,10	0,96	0,51	5,03	5,90	3,10	3,24	3,55
Na_2O	4,06	2,09	3,65	3,80	3,91	2,83	5,00	5,83	4,93	4,83	3,93	0,25	6,09
K_2O	3,25	4,40	2,71	3,17	3,50	3,04	3,19	2,66	2,10	0,64	3,93	3,67	1,72
P_2O_5	0,41	0,11	0,42	0,11	0,10	0,10	0,11	0,10	0,21	0,21	0,21	0,11	0,91

Table 4- (Continued)

SAMPLE NO	T-63	T-64	T-66	T-67	T-73	T-74	T-75	T-76	T-77	T-78	T-79	T-80	T-81
SiO_2	56,97	63,45	66,80	49,60	62,11	61,69	49,71	48,06	58,30	60,39	67,38	56,50	49,99
TiO_2	0,82	0,52	0,53	0,99	0,52	0,61	1,76	1,60	0,83	0,75	0,52	0,82	1,65
Al_2O_3	20,02	17,15	15,43	16,75	18,63	17,19	16,05	17,09	17,70	18,98	17,42	17,98	19,78
Fe_2O_3	5,97	5,40	2,02	8,68	4,75	5,44	4,97	6,50	4,93	5,20	3,05	3,99	5,75
FeO	2,16	0,77	2,75	3,69	1,78	1,02	7,83	4,53	3,25	1,63	1,92	5,10	7,68
MnO	0,10	0,10	0,11	0,22	0,10	0,10	0,21	0,11	0,10	0,11	0,21	0,21	0,11
MgO	1,13	1,55	1,48	4,85	2,28	1,42	7,25	6,84	4,16	1,73	0,49	3,90	3,74
CaO	6,16	5,99	2,85	10,69	5,59	5,66	9,11	13,03	7,81	6,04	4,35	8,22	9,23
Na_2O	3,39	3,00	3,59	3,20	1,76	3,54	1,55	0,96	1,56	3,02	2,38	2,36	1,54
K_2O	2,98	1,86	4,23	1,21	2,28	3,03	1,24	0,85	1,15	1,94	1,97	0,72	0,33
P_2O_5	0,31	0,21	0,21	0,11	0,21	0,30	0,31	0,43	0,21	0,22	0,31	0,21	0,22

Table 4- (Continued)

SAMPLE NO	T-83	T-84	T-85	T-86	T-87	T-88	T-89	T-90	T-91	T-92	T-93	T-94	T-95	T-96
SiO_2	55,72	56,75	52,91	51,06	57,91	58,92	55,70	58,07	58,33	72,94	66,41	69,92	59,14	63,05
TiO_2	0,82	0,62	1,45	8,01	0,68	0,64	1,05	1,10	0,85	0,55	0,51	0,43	0,71	0,72
Al_2O_3	20,75	12,90	14,52	16,02	17,94	19,11	18,92	18,08	17,50	14,96	17,16	15,53	17,84	16,92
Fe_2O_3	2,67	0,89	3,06	2,35	6,16	2,88	3,19	5,00	6,26	2,62	1,94	2,46	6,22	6,12
FeO	4,50	10,90	7,51	2,84	2,43	4,77	6,12	4,17	2,86	0,83	1,10	1,16	1,10	0,58
MnO	0,10	0,21	0,10	0,20	0,11	0,21	0,21	0,11	0,11	0,11	0,10	0,11	0,10	0,10
MgO	2,66	7,84	8,30	2,40	3,63	2,12	4,52	3,72	3,92	1,00	0,51	1,29	1,53	0,82
CaO	9,41	9,29	9,34	14,42	7,72	7,22	4,73	6,57	6,36	4,88	5,41	4,82	6,53	3,79
Na_2O	2,86	0,41	2,49	1,30	1,48	2,55	5,36	1,53	1,70	0,78	5,52	3,11	5,51	7,07
K_2O	0,31	0,10	0,10	1,20	1,70	1,27	0,11	1,42	1,91	1,22	1,23	1,07	1,12	0,62
P_2O_5	0,20	0,10	0,21	0,20	0,23	0,32	0,11	0,22	0,21	0,11	0,10	0,11	0,20	0,21

Table 4- (Continued)

SAMPLE NO	T-97	T-98	T-99	T-100	T-101	T-102	T-103	T-104	T-105	T-106	T-107	T-108	T-109	T-110
SiO_2	51,89	48,98	64,68	55,95	70,29	58,26	60,79	59,21	63,27	64,34	57,77	57,60	57,31	52,23
TiO_2	1,14	1,38	0,63	1,04	0,42	0,95	0,94	0,82	0,74	0,51	1,03	0,82	0,92	1,15
Al_2O_3	18,23	19,38	16,17	19,17	14,16	16,95	16,77	16,96	17,40	17,87	17,02	18,51	17,40	19,85
Fe_2O_3	6,51	7,20	3,65	3,90	3,36	3,24	3,53	3,28	3,05	5,21	4,77	2,22	3,90	5,08
FeO	3,27	3,67	2,25	3,57	0,76	4,71	3,62	4,73	4,09	0,74	3,41	5,32	4,41	4,36
MnO	0,10	0,21	0,10	0,10	0,10	0,11	0,10	0,21	0,11	0,10	0,10	0,10	0,10	0,21
MgO	4,66	2,13	1,46	2,80	0,63	3,71	2,41	3,29	0,27	0,61	2,27	2,57	3,48	4,28
CaO	9,53	11,71	4,69	7,46	4,41	6,36	4,93	6,37	4,43	4,49	7,02	7,10	6,96	6,58
Na_2O	3,52	4,15	4,49	5,49	4,41	3,50	4,51	3,70	4,64	4,29	4,33	4,53	4,09	4,70
K_2O	0,93	0,85	1,67	0,31	1,26	2,01	2,20	1,23	1,69	1,63	1,96	1,03	1,23	1,36
P_2O_5	0,21	0,32	0,21	0,21	0,21	0,21	0,21	0,21	0,32	0,20	0,31	0,21	0,20	0,21

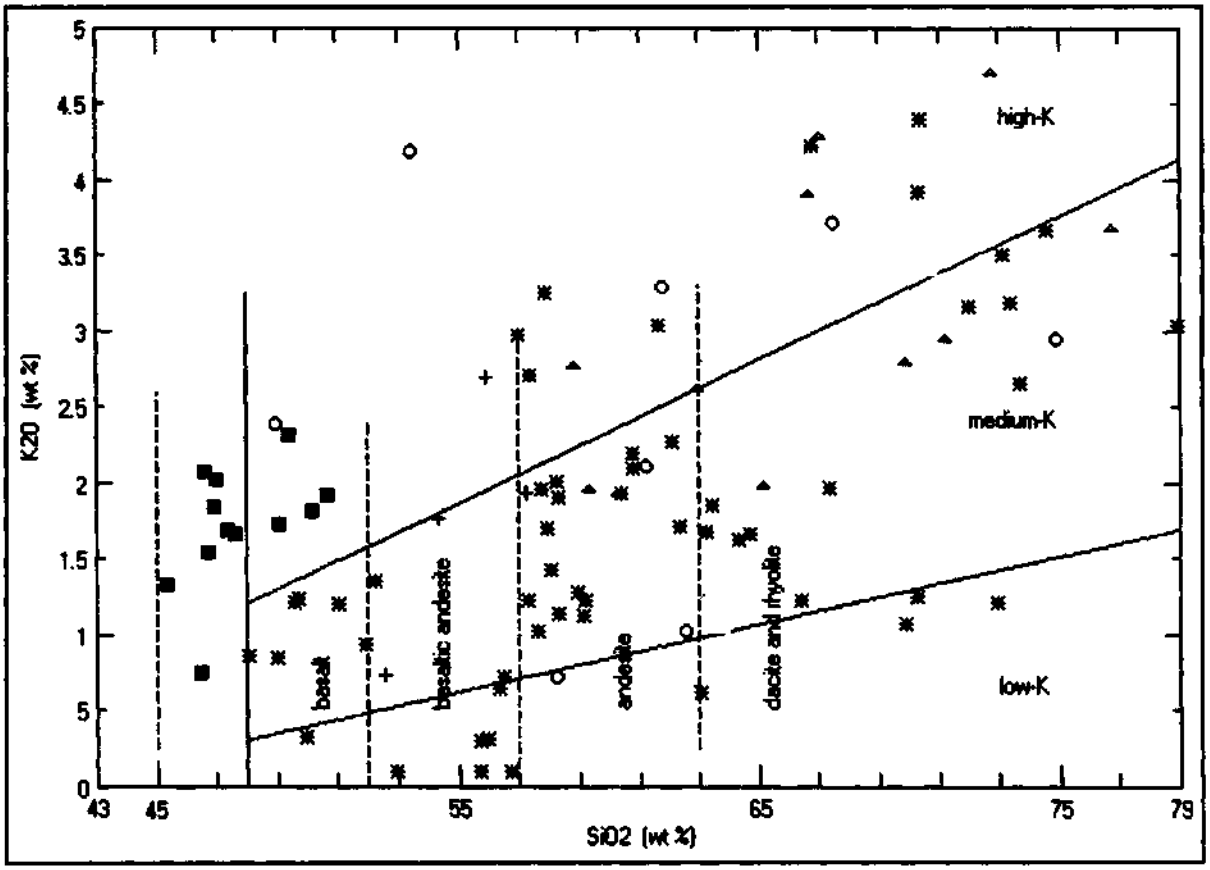

Fig. 3- K_2O-SiO_2 diagram of volcanics (legend same as in Fig. 2).

of calcalkaline and high potassium nature, and Eocene volcanics have tholeiitic character. The same situation was observed on the FeO-(Na_2O+K_2O)-MgO diagram, too (Fig.4).

According to their chemical composition, when the (Na_2O+K_2O) and SiO_2 contents of the samples were plotted on the diagram prepared by Le Maitre et al., (1989), it can be said that the Upper Cretaceous volcanics are basaltic andesite, and trachyandesite, Eocene volcanics are basalt, trachybasalt, trachyandesite, basaltic andesite, andesite, trachyandesite, trachyte, dacite and rhyolite, Lower-Middle Miocene volcanics are trachyandesite, trachybasalt, andesite, dacite and rhyolite, Upper Miocene volcanics are basanite, basalt, tracybasalt and trachyiandesite (Fig. 5). This result is concordant with the petrographic determinations.

RESULTS

By this research, the post-Upper Cretaceous volcanic rocks around the sea of Marmara were differentiated in five groups and through detailed petrographic and radiometric studies the "age" problem was clarified and some undated volcanics were dated.

Especially in Thrace, some alkali basalts which were claimed to be of Plio-Quaternary age by some previous researchers by field observations were sampled and dated -some of them were dated two times- to be of Upper Miocene age. Besides that, the existence of Miocene aged subvolcanic rocks, which had not been observed before this study, was put forward. This study aims only the dating, distribution and the petrographic features of the volcanic rocks around the sea of Mar-

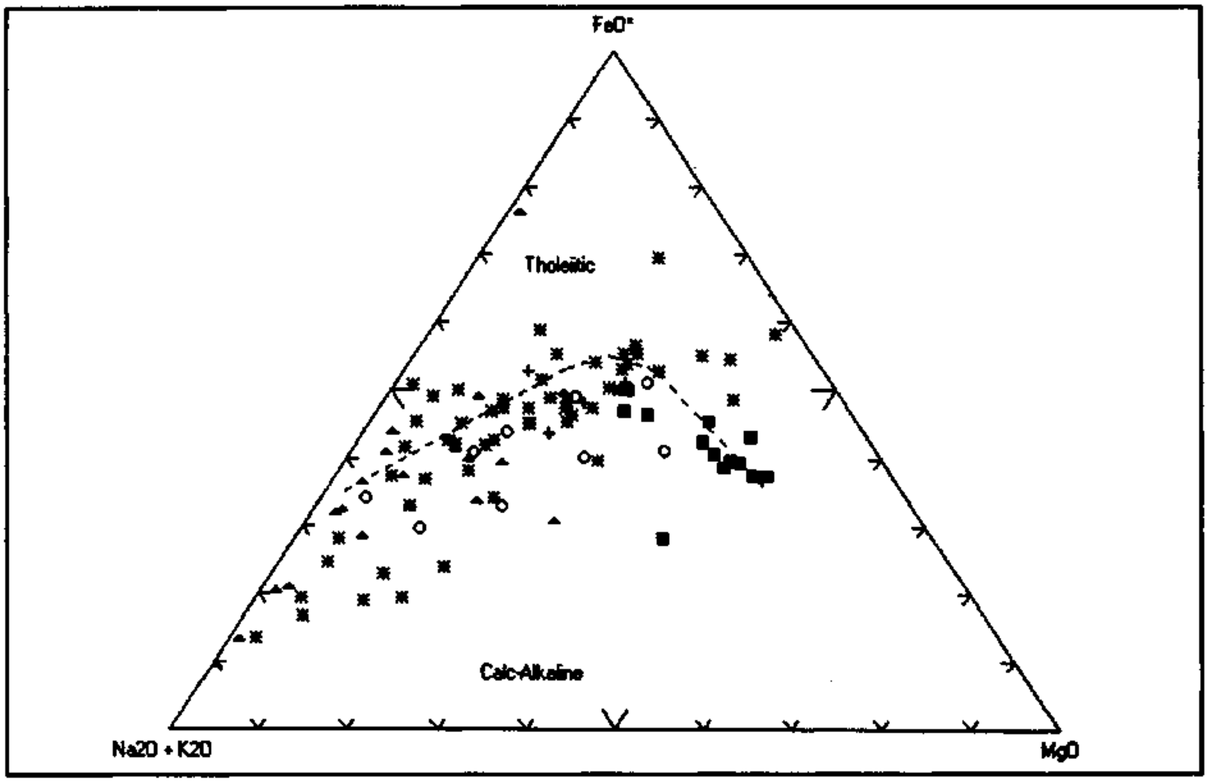

Fig. 4- FAM triangle diagram of volcanics (legend same as in Fig. 2).

mara but not the genesis of them. In fact, there are many research on the volcanic rocks in the region including the major, trace and rare earth elements and the genesis of the volcanic rocks. For example, it was concluded that the Upper Cretaceous volcanic rocks are generally produced from the crust and they belong to a group of island arc volcanics produced from a subduction zone developed in a compressional regime due to the converging plates (Yeniyol and Ercan, 1989/1990).

The major and trace element contents of the granitic rocks situated around İğneada together with the volcanics in Thrace and known to be of Upper Cretaceous age by K/Ar (Moore et al., 1980; Ohta et al., 1988) imply that they were formed in an island arc type subduction zone (Tokel and Akyol, 1987). It is stated that after the subduction of Sakarya continent and Rhodop-Pontide block, the continent to continent collision started in Upper Cretaceous and ended in Lower Tertiary (Şengör and Yılmaz, 1981; Yılmaz, 1995) but after the consumption of the oceanic material the convergence continued in Eocene. This convergence was taken up with the shortening and thickening of the crust and titosphere which possibly continued until Middle Miocene (Yılmaz, 1989). Therefore, post-Upper Cretaceous Eocene, Oligocene, Lower-Middle Miocene volcanics are the last products of the subduction and collision, post-collision type volcanics (Ercan et al., 1995; Ercan,1992). Polat et al., (1997) studying the Thrace volcanics in detail from the point of view of geochemistry proposes that andesitic volcanics of Eocene and Oligocene age are from subcontinental lithospheric mantle whereas alkali basalts of Upper Miocene age from asthenospheric mantle. The alkali basalts of Upper Miocene age must have formed due to the uplift of mantle arising from an extensional system created by a new tectonic regime in the region after Middle Miocene.

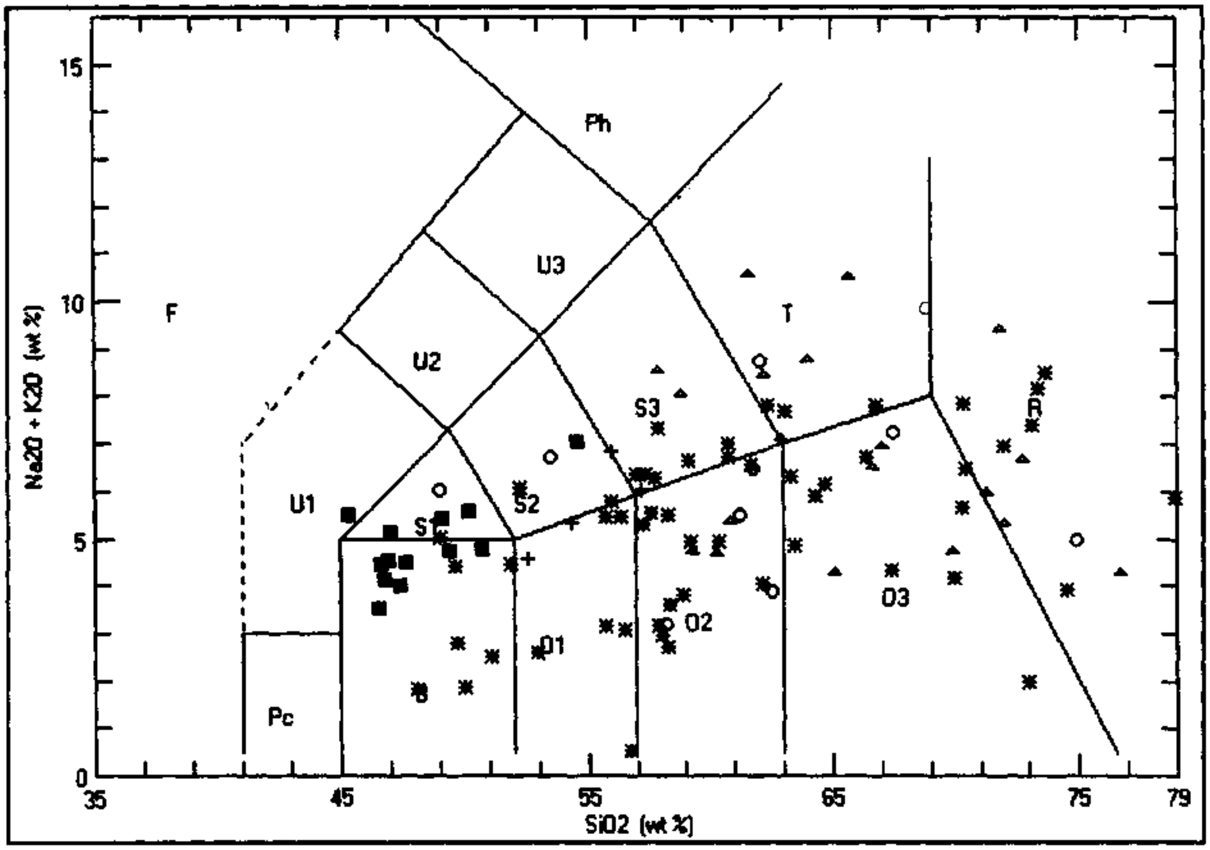

Fig. 5- Naming of the volcanics in the diagram prepared by Le Maitre et al., (1989) (legend same as in Fig. 2).

ACKNOWLEDGEMENTS

The writers would like to thank İrfan Özcan and Kemal Yenigün for their invaluable help during the fieldwork of this study which was realized in context of the project "Map of Tertiary-Quaternary Volcanics of Turkey" of MTA General Directorate Geological Research Department.

Manuscript received July 28, 1997

REFERENCES

Akartuna, M., 1950, İmroz adasında bazı jeolojik müşahadeler: Türkiye Jeol. Kur. Bült., 2/2, 8-17.

———, 1953, Çatalca-Karacaköy bölgesinin jeolojisi: İst. Üniv. Fen. Fak. Monog. 13, 86 s.

Akartuna, M., 1953, Şile Şaryajının İstanbul Boğazı kuzey yakalarında devamı: MTA Derg., 61,14-20.

———, 1968, Armutlu yarımadasının jeolojisi: İst.Üniv. Fen Fak. Monog. 20, 12 s.

Bargu, S. and Sakınç, M., 1987, Armutlu yarımadasında Kretase-Paleosen ilişkisi: Türkiye Jeol. Bült., 30, 41-48.

———and———, 1989/1990, İzmit Körfezi ile İznik Gölü arasında kalan bölgenin jeolojisi ve yapısal özellikleri: İstanbul Üniv. Müh.Fak. Yerbilimleri Derg., 6/1-2,45-76.

Baykal, F., 1943, Şile mıntıkasının jeolojisi: İst.Üniv. Fen.Fak. Mecm., B, VII/3, 166-233.

———, 1971, Historik jeoloji: KTÜ Yayını No:38, 436 sayfa, Trabzon.

Baykal, F. and Kaya, O., 1966, İstanbul Boğazı kuzey kesiminin jeolojisi: Türkiye Jeol. Kur. Bült., 10, 31-43.

———and Önalan, M., 1979, Şile sedimanter karışığı (Şile Olistostromu): Türkiye Jeol. Kur. Altınlı Semp. Bildiriler Kitabı, 15-26.

Bürkan, K., 1955, Trakya Havzasındaki tüflerin stratigrafik konumu, yayılımı ve hidrokarbon potansiyeli: Trakya havzası Jeolojisi Sempozyumu Bildiri Özleri Kitabı 48.

Dayal, A., 1984, Yenice (Çanakkale) granitinin petrografisi ve buna bağlı cevherleşmeler: Doktora tezi, Dokuz Eylül Üniv. Fen Bilimleri Enst., (unpublished), Izmir.

Ercan, T., 1979, Batı Anadolu, Trakya ve Ege adalarındaki Senozoyik volkanizması: Jeoloji Mühendisliği Derg., 9, 23-46.

———, 1992, Trakya'daki Senozoyik volkanizması ve Bölgesel Yayılımı: Jeoloji Müh. Derg., 41, 37-50.

———and Günay, E., 1984, Kuzeybatı Anadolu, Trakya ve Ege adalarındaki Oligo-Miyosen yaşlı volkanizmanın gözden geçirilişi:Türkiye Jeoloji Kurultayı Bült., 5, 119-139.

———and Gedik, A., 1986, Karadeniz ve Trakya'da yapılan derin sondajlardan alınan karotlardaki volkanik kayaçların petrolojisi ve volkanizmanın bölgesel yayılımı: Jeomorfoloji Derg., 14, 39-48.

———; Ergül, E.; Akçaören, F.; Çetin, A.; Granit, S. and Asutay, J., 1990, Balıkesir-Bandırma arasında jeolojisi, Tersiyer volkanizmasının petrolojisi ve bölgesel yayılımı: MTA Derg., 110, 113-130.

———; Satır, M.; Steinitz, G.; Dora, A.; Sarıfakioğlu, E.; Adis, C.; Walter, H.J. and Yıldırım, T., 1995, Biga Yarımadası ile Gökçeada Bozcaada ve Tavşalı adalarındaki (KB Anadolu) Tersiyer Volkanizmasının özellikleri: MTA Derg., 117, 55-86.

Erendil, M.; Göncüoğlu, M.C.; Tekeli, O.; Aksay, A.; Kuşçu,I.; Ürgün, B.; Tunay, G. and Temren, A., 1991, Armutlu yarımadasının jeolojisi: MTA Rap., 9165, (unpublished), Ankara.

Erentöz, C., 1953, Çatalca bölgesinde Jeoloji tetkikleri: MTA Yayl., B 17,94s.

Ertürk, O.; Dinçöz, E. and Alaygut, D., 1990, Petrology of the Cenozoic Volcanics in the Biga Peninsula, NW Turkey: International Earth Sciences Congress on Aegean Region Proceedings, II, 368-384.

———and Uygur, E., 1994, Petrographical, Sedimentological and diagenetic characteristics of the Ceylan tuffs and their reservoir potential, Thrace basin, Turkey: IAVCEI International Volcanology Congress, Abstracts, Ankara.

Gök, L, 1990, Tekirdağ-Malkara (Tekirdağ ili) Keşan-Ipsala (Edirne ili) arasının jeolojisi: MTA Rap., 9710 (unpublished), Ankara.

Irvine, T.N. and Baragar, W.R.A., 1971, A guide to the chemical classification of the common volcanic rocks: Can. Jour. Earth. Scien., 8, 523-548.

Kopp, K.O., 1964, Geologie Thrakiens it: Die insel und der chersones: N. Jb. Geol. Pae. Abh. 119, 172-214.

———, Pavoni, N. and Schindler, C., 1969, Das Ergene Becken: Beihefte Geol. Jahrbuch., 76, 136 s.

Le Maitre, R.W.; Bateman, P.; Dudek, A.; Keller, J.; Lameyre, J.; Le Bas, M.J.; Sabine, P.A.; Schmid, R.; Serenson, H.; Streckeissen, A.; Wooley, A.R. and Zanettin, B., 1989, A classification of igneous rocks and glossary of terms: Blackwell Scientific Publications, 208 p, Oxford.

Lebkücher, R.F., 1974, Orta Trakya Oligoseninin Jeolojisi hakkında: MTA Derg., 83, 1-29.

Moore, W.J.; McKee, E.H. and Akıncı, Ö., 1980, Chemistry and chronology of plutonic rocks in the Pontide mountains, Northern Turkey: Europen Copper Deposits- Belgrade, 209-216.

Ohta, E.; Doğan, R.; Batık, H. and Abe, M., 1988, Geology and mineralization of Dereköy porphry Copper Deposit, Northern Thrace, Turkey: Bull. Geol. Surv. Japan, 39/2, 115-134.

Okay, A.C., 1948, Şile, Mudarlı, Kartal ve Riva arasındaki bölgenin jeolojik etüdü: İst. Üniv. Fen Fak. Mecm., XIII/4, 311-335.

Okut, M., 1975, Çanakkale ili, Gökçeada ilçesi Hammadde Prospeksiyon Raporu: MTA Kuzeybatı Anadolu Bölge Müdürlüğü Rap., 297 (unpublished).

6nal, M., 1986, Gelibolu yarımadasındaki iki ana kayanın organik jeokimyası ve kil mineralleri ile incelenmesi: Türkiye Jeol. Kur. Bült., 29/1, 97-104.

——— and Yılmaz, H., 1983, Gelibolu yarımadasında iki ana farklı yaşta fliş fasiyesindeki kil mineralleri ve gömülme derinliğine ait bazı ipuçları: Jeoloji Müh. Derg.,18, 23-30.

Özkanlı, M. and Sonel, N., 1995, Trakya Havzası Geç Eosen yaşlı tüf seviyelerinin rezervuar potansiyeli: Trakya Havzası Jeolojisi Sempozyumu Bildiri Özleri Kitabı, 49.

Peccerillo, A. and Taylor, S.R., 1976, Geochemistry of Eocene calcalkaline volkanic rocks from Kastamonu area, Northern Turkey: Contrib, Mineral. Petrol., 58, 63-81 .

Polat, A.; Korrich, R.; Yılmaz, Y.; Yaltırak, C. and Tapirdamaz, C., 1997, Trace element Systematics of Cenozoic Calc-alkaline to Alkaline volcanism in NW Turkey; Implications for Magma sources in a Collisional Tectonic Setting: Tectonophysics (Inpress).

Saner, S., 1985, Saros körfezi dolayının çökelme istifleri ve tektonik yerleşimi, Ege denizi, Turkiye: Turkiye Jeol. Kur. Bült., 28, 1-10.

Siyako, M.; Bürkan, K.A. and Okay, A.I., 1989, Biga ve Gelibolu yarımadalarının Tersiyer Jeolojisi ve hidrokarbon olanakları: TPJD Bült., 1/3, 183-199.

Sümengen, M.; Terlemez, İ.; Şentürk, K. and Karaköse, C., 1987, Gelibolu yarımadası ve güneybatı Trakya Havzasının stratigrafisi, sedimentolojisi ve tektoniği: MTA Rap., 8128 (unpublished), Ankara.

Şengör, A.M.C. and Yılmaz, Y., 1981, Tethyan evolution of Turkey: A plate tectonic approach; Tectonophysics, 75,181-241 .

Tapırdamaz, C. and Yaltırak, C., 1997, Trakya'da Senozoyik Volkaniklerinin Paleomanyetik özellikleri ve Bölgenin tektonik evrimi: MTA Derg., 119, 27-42.

Ternek, Z., 1949, Geological study of the region Keşan-Korudağ: Doktora tezi, İstanbul Üniv. Fen Fak. 78 s., (unpublished), Istanbul.

Tokel, S. and Aykol, A., 1987, Kırklareli-Demirköy granitoidinin jeokimyası: Kuzey Tetis Ada yayı sisteminde Srednogorie-lstranca bölümünün evrimi: Turkiye Jeoloji Kurultayı, 1987 Bildiri Özleri Kitabı, 17-18.

Toker, V. and Erkan, E., 1983, Gelibolu yarımadası Eosen formasyonları nannoplankton biyostratigrafisi: MTA Derg.,-101/102, 72-91 .

Umut, M., 1988, Kırklareli C-4 paftası izahnamesi: MTA Genel Müdürlüğü 1/100.000 ölçekli Açınsama nitelikli Türkiye Jeoloji Haritaları Serisi, Ankara.

———; Imik, M.; Kurt, Z.; Özcan, I.; Ateş, M.; Karabıyıkoğlu, M. and Saraç, G., 1984, Edirne ili-Kırklareli ili-Luleburgaz (Kırklareli ili)-Uzunköprü (Edirne ili) civarının Jeolojisi: MTA Rap., 7604 (unpublished), Ankara.

Uz, B.; Esenli, F.; Manav, H. and Aydos, Z., 1995, Karamursel-Yalova arasındaki (Kuzeybatı Anadolu) piroklastik kayalarda otijen mineral oluşumları: Yerbilimleri (Geosound), 27,135-147.

———;——— and———, 1992, Yalova-Karamürsel arası bölgede Eosen yaşlı tüflerde Zeolitleşmenin etüt ve değerlendirilmesi: A.Ü. Isparta Müh. Haftası-VIII Bildiri Özleri Kitabi, 11.

Ünal, D., 1967, Trakya Jeolojisi ve Petrol imkanları: TPAO Arama Grubu Rap., 391 (unpublished).

Yeniyol, M. and Ercan, T., 1989/1990, Istanbul Kuzeyinin Jeolojisi ve Üst Kretase Volkanizmasının Petrokimyasal özellikleri ve Pontit'lerdeki Bölgesel yayılımı: İst. Üniv. Fak. Yerbilimleri Derg., 7/1-2, 125-147.

Yılmaz, Y., 1989, An approach to the origin of young volcanic rocks of Western Turkey: In: A.M.C. Şengör (ed); Tectonic Evolution of the Tethyan region, Kluwer, The Hague, 159-189.

———, 1995, Ege Bölgesindeki Genç Magmatizmanın oluşumu ile Litosferin Evrimi arasındaki ilişki üzerine düşünceler: Jeofizik, 9, 107-110.