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BULLETIN OF THE MINERAL RESEARCH AND EXPLORATION

CONTENTS

A NEW AGE FINDING IN THE CENTRAL SAKARYA REGION (NW TURKEY)

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Key Words:
Central Sakarya Region,
Kapıkaya Formation,
A New Age Data,
Campanian,
Tectonics.

ABSTRACT

The existence of a metamorphic basement cut by granitoids is known in the Central Sakarya region of northwest Turkey according to the previous studies. Over this metamorphic basement, there is a Liassic unit which contains ammonite, brachiopod and some benthic foraminifers and has a sequence starting with fluvial deposits at the base and grading into coastal, subtidal and shallow marine sediment character towards the top in the vicinity of Sarıcakaya district, Eskişehir City. At different levels of this unit which is called as the "Kapıkaya Formation", the Campanian age fossils such as; *Ceratolithoides aculeus* (Stradner), *Pervilithus varius* Crux, *Watznaueria barnesae* (Black), *Tortolithus* sp., *Biscutum* sp. *Quadrum sissinghi*i Perch-Nielsen, *Watznaueria barnesea Black, Ellipsagelosphaera fosscincta* were identified in this study. These fossil findings clearly reveal the presence of a Campanian aged unit in the region. This unit is composed of flyschoidal facies deposits and includes exotic limestone blocks of Liassic age and is overlain by Malm – Early Cretaceous limestones at the same time. The overlying of Malm – Early Cretaceous rocks to Campanian deposits is closely related to the tectonics that has been effective in the region during or post Campanian.

1. Introduction

1.1. The Aim of the Study

The study area is located at surrounding of Sarıcakaya district and Kapıkaya village to the north of Eskişehir in the region known as the "Central Sakarya" (Figure 1). The non-metamorphic sediments considered to be Liassic in age exist on metamorphic basement which are cut by granites in surrounding of Bilecik and Eskişehir province including also study area (Stchepinsky, 1940; Kupfahl, 1954; Ürgün, 1956; Abdüsselamoğlu, 1956, 1959; Granit and Tintant, 1960; Eroskay, 1965; Altınlı, 1973*a*, 1974, 1975; Saner, 1977, 1980; Demirkol, 1973, 1977; Ayaroğlu, 1978, 1979; Şentürk and Karaköse, 1981, 1982; Alkaya, 1981, 1982; Kibici, 1982; Cope, 1991, Altıner et al., 1991; Altıner and Koçyiğit, 1992; Koçyiğit et al., 1991; Aras et al., 1991; Göncüoğlu et al., 1996; Gedik and Aksay, 2002).

Kupfahl (1954) and Ürgün (1956) claimed that the Liassic sediments transgressively overlie an old and crystalline basement in the region. Abdüsselamoğlu (1956) identified some ammonitic species representing the upper layers of Liassic in the eastern continuity of red, clayey calcerous rocks (marl) within these sediments.

The Liassic layers mentioned by Kupfahl (1954), Ürgün (1956) and Abdüsselamoğlu (1956) were named as the "Bayırköy sandstone" by Granit and Titant (1960). However, Altınlı (1973 *a*) suggested that it would be more suitable to name these sediments as "Bayırköy formation" since it contains many lithologies rather than sandstone in many places. Saner (1980) considered with abundant ammonites, red colored, carbonate intercalation deposited within lithologies other than sandstone in the Bayırköy formation as correlative to "Calcare Ammonitico Rosso Facies" rocks (Hallam, 1969; Galacz, 1984; Varol and Gökten, 1994; Soussi et al., 1998, 1999) These red colored, carbonated and shaley layers with abundant ammonites also mentioned by

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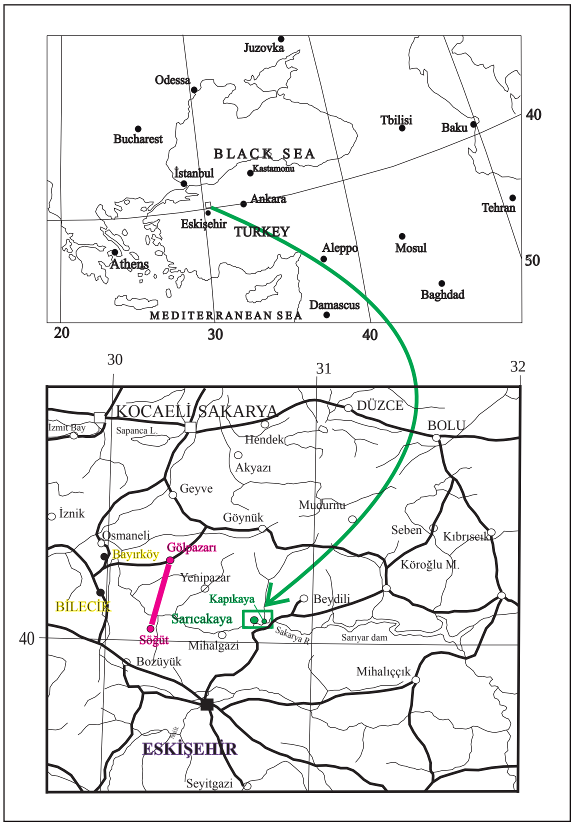


Figure 1- Location map of the study area

Altınlı (1973*a*) are known as "red marl and nodular limestone" in literature (Hallam, 1969; Galacz, 1984; Varol and Gökten, 1994; Soussi et al., 1998, 1999). The "Calcare Ammonitico Rosso" facies rocks (Meister, 2010) that are widely observed in Alpine regions and in Jurassic outcrops of some Mediterranean countries have also many and large exposures in the Pontide Belt along the North of Anatolia named by (Arni, 1939; Ketin, 1966; Gugenberger, 1929; Alkaya, 1981, 1982, 1983, 1991; Görür et al., 1983; Altıner et al., 1991; Koçyiğit et al., 1991; Nicosia et al., 1991; Pompeckj, 1897; Bremer, 1965; Varol and Gökten, 1994; Alkaya and Meister, 1995; Kuznetsova et al., 2001; Koçyiğit and Altıner, 2002; Okan and Hoşgör, 2007). The "Calcare Ammonitico Rosso" facies rocks crop out in "Bayırköy Formation", in the Central Sakarya Region which also falls in Pontide area (Altınlı, 1973*a*). The formation was dated as late Sinemurian – Pleinsbachian mainly as it contains ammonite fossil in this facies (Abdüsselamoğlu, 1956; Granit and Tintant, 1960; Altınlı, 1973*a*; Alkaya, 1981, 1982; Cope, 1991). The presence of some benthic foraminifers (Altıner et al., 1991; Altıner and Koçyiğit, 1992; Koçyiğit et al., 1991; Göncüoğlu et al., 1996; Gedik and Aksay, 2002) and nannoplanktons (Aras et al., 1991) also confirm the Liassic age. Altıner et al. (1991) obtained index fossils indicating Hettangian – early Sinemurian age from the layers underlying ammonitic levels of Bayırköy formation different than Altınlı (1973*a*), Alkaya (1981, 1982), Cope (1991) and many other investigators. Kuru and Aras (1994) gained the Rhaetian (Late Triassic) age from the clastics that form the lower layers of the unit overlying the basement. Altıner et al (1991) made a correction for the age of Bayırköy Formation as Hettangdian – Pliensbachian which previously known as late Sinemurian – Pliensbachian. However, the Rhaetian age data of Kuru and Aras (1994) although seems to be not considered later, have revealed a suspect in the age of the unit lowered to Triassic which previously accepted as Liassic. Altınlı (1973*a*), after Granit and Tintant (1960) redefined the unit in detail under the name of Bayırköy formation, and pointed out that the formation had turned into a more complicated succession eastward with a variable lithology from the line that connecting Söğüt district to Gölpazarı (Figure 1). Altınlı (1973*a*) in his study carried out around Sarıcakaya district (Eskişehir) for this different part of the unit lying in the east of Gölpazarı – Söğüt line used the name "Kapıkaya Formation". The discrimination of Liassic sediments as Bayırköy formation around Bilecik and as Kapıkaya formation around Eskişehir by Altınlı (1973*a*) are not adopted likely in latter studies carried out. After Altınlı (1973*a*), many investigators used the name Bayırköy in their studies comprising the eastern side of Gölpazarı – Söğüt line (Saner, 1977, 1980; Alkaya, 1982; Şentürk and Karaköse, 1981, 1982; Göncüoğlu et al., 1996, Gedik and Aksay, 2002).

According to previous studies, the boundary relationship of Bayırköy and/or Kapıkaya formation with Upper Jurassic – Lower Cretaceous rocks (Bilecik and/or Soğukçam formation) is also underdebate. This contact relationship is considered as unconformity by Kupfhal (1954) and Ürgün (1956), as transitional by Abdüsselamoğlu (1956), as conformable contact by Saner (1977) and Aras et al. (1991), as an angular unconformity by Altınlı (1973*a*) and as parallel disconformity by Şentürk and Karaköse (1981, 1982). Bilecik and/or Soğukçam formation directly overlies the crystalline basement in many of its outcrops (Altınlı, 1973*a*; Saner, 1980). There is also another problem about the ideas which supporting that the Bayırköy / Kapıkaya and Bilecik / Soğukçam formations are transitional in such areas.

As seen that, there are contradicting data about the age, stratigraphic location, its contact relations with the overlying Upper Jurassic – Lower Cretaceous sediments of the Kapıkaya formation (Altınlı, 1973*a*), according to previous studies. The studies investigating this contradicting data will make significant contributions to the interpretation of the regional geology. In this context, the meaning of a probable Gölpazarı – Söğüt line suggested by Altınlı (1973*a*) also the place and significance of such a boundary in the manner of regional geology will be investigated.

2. Stratigraphy

Kapıkaya formation as the main aspect of this study overlies the metamorphic basement consisting of gneiss, schist and amphibolites cut by granites (Figure 2). The granitoids cross-cutting these basement rocks, also known as the "Söğüt Metamorphites", (Yılmaz, 1977) were studied under the name of "Sarıcakaya granitoid" (Göncüoğlu et al. 1996). The Campanian aged Kapıkaya formation is tectonically overlain by Malm – Lower Cretaceous Bilecik and/or Soğukçam formation. The assemblage of rock units formed by Söğüt metamorphites, Sarıcakaya granitoid, Kapıkaya formation and Bilecik / Soğukçam formation have been thrusted over Paleocene Kızılçay formation with a high angular thrust fault trending in WSW - ENE, east-northeast directions along the northern slope of the Sakarya Yayla (Figure 2).

2.1. Söğüt Metamorphites

Yılmaz (1977, 1979) named high-grade metamorphic rocks and their cross-cutting granitoids as "Söğüt metamorphics" which crop out mainly in western parts of the area known as the "Central Sakarya Region", the north of Eskişehir. The exposures of Söğüt metamorphics are present at north of Sarıcakaya, around Kayadibi Yayla, near south of Beyyayla and to the south of Soğukçam village (Figure 2). Yılmaz (1979) claimed that, the metamorphic rocks in Söğüt / Bilecik region were affected by three different metamorphism developed in different conditions. Göncüoğlu et al. (1996) pointed out that the anatexites, which is a data of partial melting especially in muscovite gneiss parts of the Söğüt metamorphics had been observed and mentioned three phase of metamorphism effective in the region. The dominant rock type is formed by gneiss and amphibolite in these metamorphics. The petrographical studies of the samples taken from Söğüt metamorphics in the Kayadibi Yayla section (Figure 2, A-B section) located at 5 km north of Sarıcakaya district are defined as; muscovite-biotite-feldspar-quartz schist (01 FU-13), garnet-albite-quartz-biotite-muscovite schist (01 FU-14), biotite-quartz-sericite schist (01 FU-16) (Figures 3 and 4). The banded structure and foliation in hand specimen and in thin section the banded structures formed by quartz and sericite with variable thickness are observed.

Ustaömer et al. (2011) have dated 89 detrital zircon minerals separated from sillimanite – garnet – mica schist sample at the Central Sakarya metamorphic basement and they have obtained ages ranging from 551 Ma (Ediacaran) to 2738 Ma (Neo-Archean) by U-Pb ion-prob dating method. The Söğüt metamorphics are cut by Sarıcakaya granitoids and is overlain by Kapıkaya formation with initial boundary relationship. Fossils are not preserved due to the metamorphism, and the age of deposition and metamorphism of the unit belongs to Pre-Campainan time based on its stratigraphical position as it is overlain by the clastics of the Kapıkaya formation with an initial relationships.

2.2. Sarıcakaya Granitoid

Granite – granodiorite complex is exposed at north of Sarıcakaya county and cut Söğüt metamorphics was investigated under the name of Sarıcakaya granitoid by Göncüoğlu et al. (1996). The unit has outcrops around Kapıkaya Yayla, Beyyayla, Örencik Yayla at north of Sarıcakaya county (Figure 2). Sarıcakaya granitoid is composed of granite and granodiorites. In the region granodiorites are dominant, whereas migmatites and diorites are also encountered in fewer amounts (Demirkol, 1977; Göncüoğlu et al., 1996). Granodiorites are in red, pink and green colors and composed of plagioclase, quartz, orthoclase and hornblende minerals. Granites consist of alkali feldspar, quartz, plagioclase, hornblende, biotite and muscovite. The migmatitic granites were formed by the partial melting of biotitic gneisses (Göncüoğlu et al., 1996). Sarıcakaya granitoid was locally arenitized and cut by aplitic and pegmatitic veins and is observed in complex relationships with schists and amphibolites (Şentürk and Karaköse, 1979, 1981).

Sarıcakaya granitoid cuts Söğüt metamorphics and is overlain by the Kapıkaya formation with an initial contact relationship. Due to this relationship, the age of the Sarıcakaya granitoid should belong to a time earlier than Campanian based on its stratigraphical position, like the age of Söğüt metamorphics. The age of the Sarıcakaya metamorphics in previous studies was been assigned as 272 Ma (Çoğulu and Krummenacher, 1967), as 290 Ma (Okay et al., 2002) and as 319,5-327,2 Ma (Ustaömer et al., 2011) (latest Carboniferous – Lower Permian).

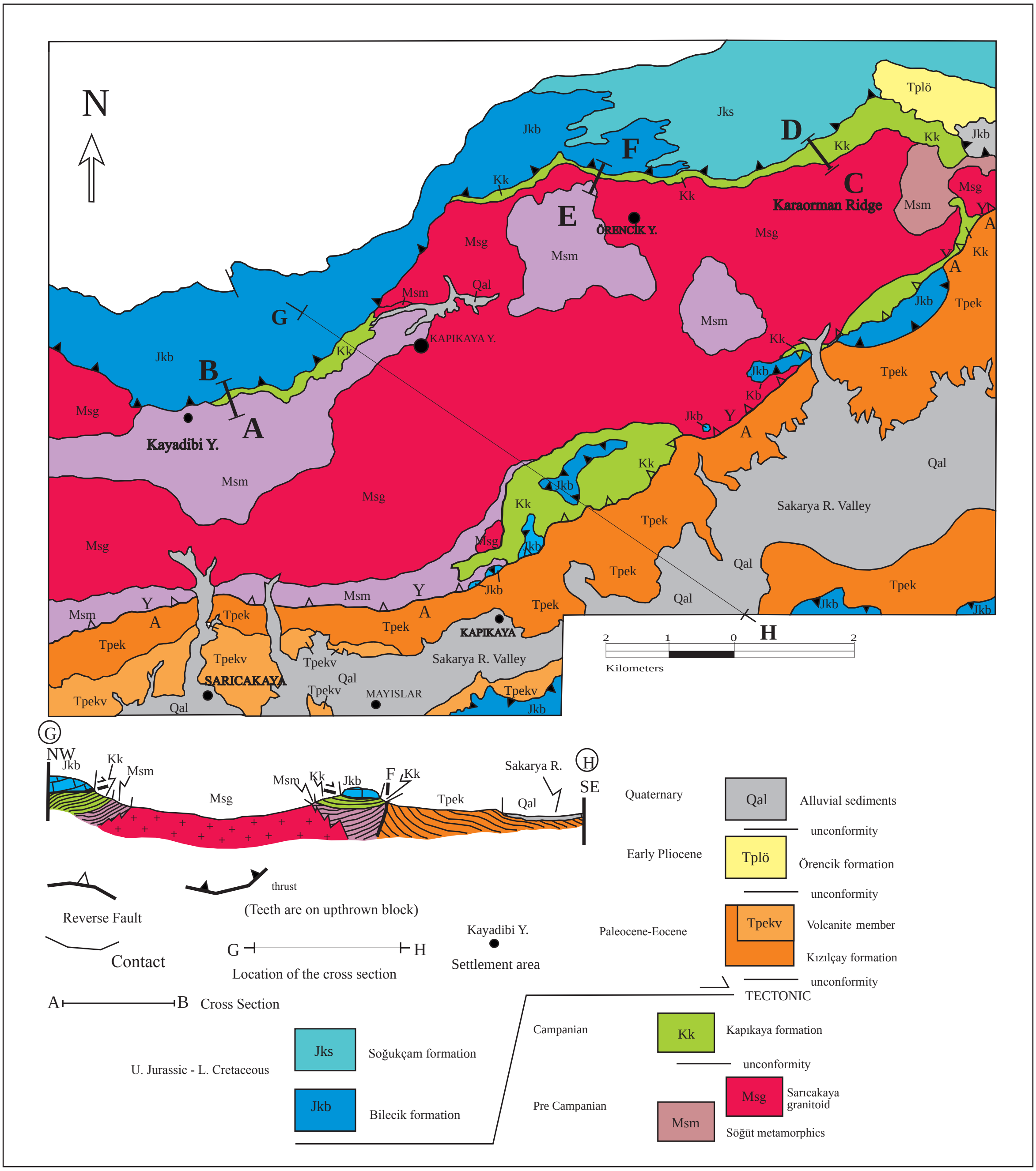


Figure 2- Geological map of the study area and geological cross section (from Göncüoğlu et al., 1996; Gedik and Aksay, 2002)

2.3. Kapıkaya Formation

Kapıkaya formation in Eskişehir city (Figure 1) composed of the alternation of sandstone and shale has its type locality in the vicinity of Kapıkaya village, and was named by Altınlı (1973 *a*).

The Liassic deposits in the Central Sakarya Region were first named as "Bayırköy sandstone" by Granit and Tintant (1960), but, Altınlı (1973*a*) named the same rocks as "Bayırköy formation" since the presence of other lithologies rather than sandstone. Altınlı (1973*a*) also proposed that Bayırköy formation is laterally transitional to "Kapıkaya formation" eastwards and this transition is along the line connecting Gölpazarı to Söğüt county (Figure 1). The line of Gölpazarı–

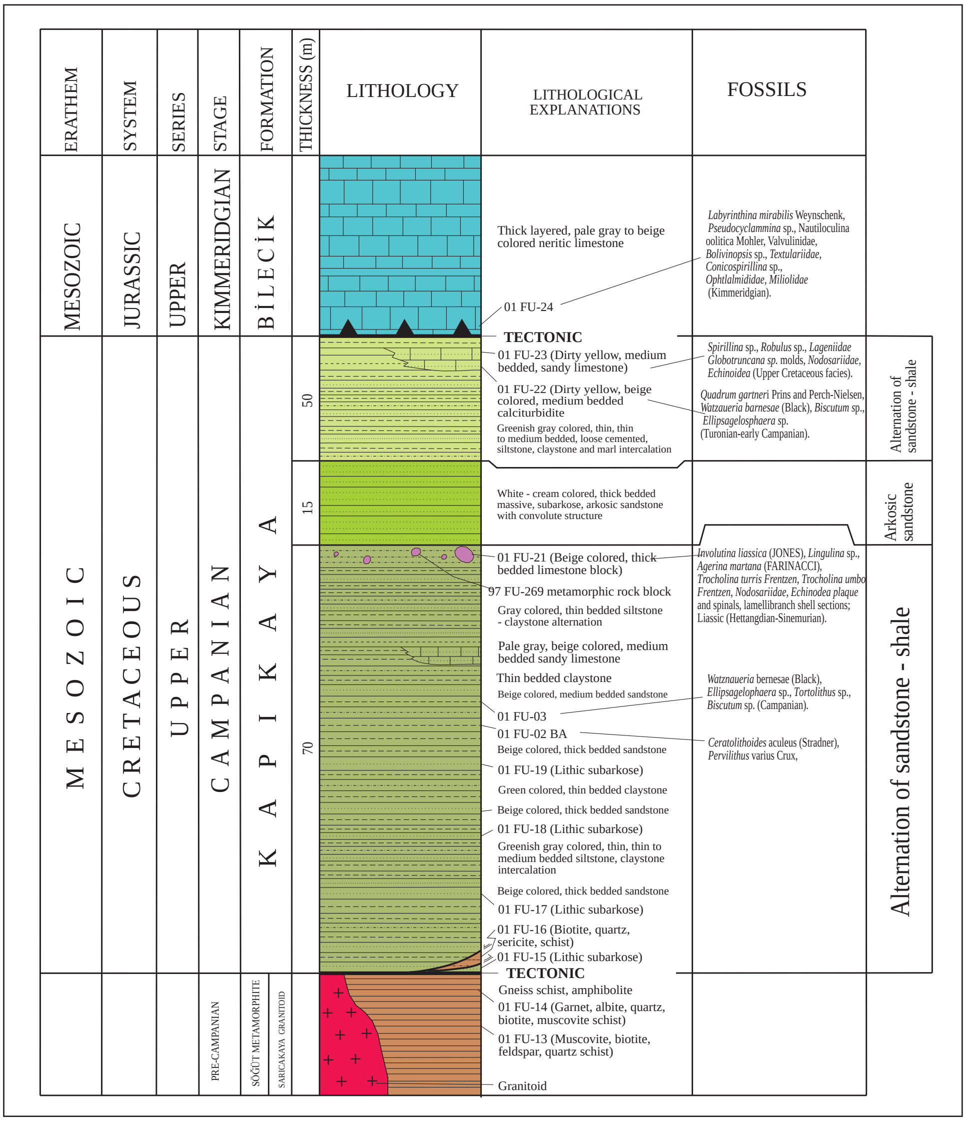
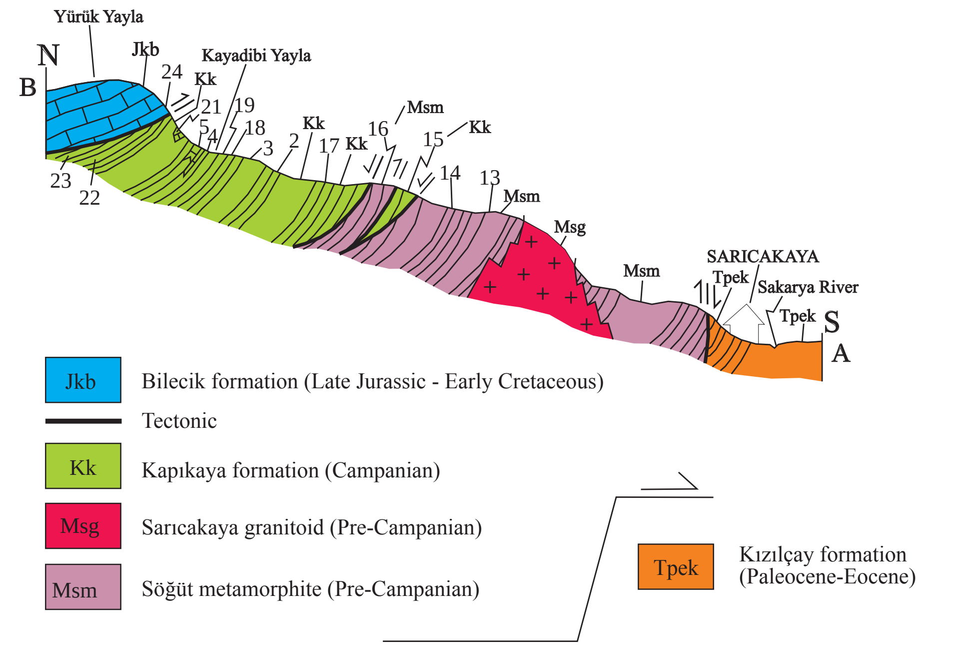


Figure 3- The columnar section of the Kayadibi Yayla (AB).

Söğüt and the Kapıkaya nomenclature were not interested much after Altınlı (1973*a*). Although, Alkaya (1981) mentioned the name "Kapıkaya", but he used the name "Bayırköy" for the interested area in his next study (Alkaya, 1982). Many investigators such as; Şentürk and Karaköse (1979, 1981), Saner (1977), Göncüoğlu et al. (1996) and Gedik and Aksay (2002) used the name "Bayırköy" in their studies in the region for the deposits mapped as "Kapıkaya" by Altınlı (1973*a*). Throughout this study, the Campanian finding obtained from the Kapıkaya formation increased the importance of Gölpazarı – Söğüt line and also the probability of existence of a different unit which was proposed by this investigator to the east of this line. Therefore, the name "Kapıkaya" used by Altınlı (1973*a*) for this unit has been adapted with the Campanian age and a different environmental interpretation in this study.

The Kapıkaya formation has outcrops in the vicinity of Sarıcakaya county, around the intrusion of the Sarıcakaya granitoid, Kayadibi Yayla, Kapıkaya Yayla, around Beyyayla – Soğukçam and between Nebioğlu and Kapıkaya villages (Figure 2). The exposures of the Kapıkaya formation are not continuous as it is in Bilecik and/or Soğukçam formations. It is also noticed in other previous studies that the limestones of Bilecik / Soğukçam formation directly overlie the metamorphic – granitic basement in many places, as also seen in the geological map of the study area (Figure 2) (Altınlı, 1973*a*, Saner, 1977).

This study was carried out in exposures mapped as the Kapıkaya formation by Altınlı (1973a) (Figure



13) *Muscovite-biotite-feldspar-quartz schist*
14) *Garnet-albite-quartz-biotite-muscovite schist*
15) *Lithic subarkose:* Very fine sand, coarse silt and less medium to fine silt size grains cemented with carbonates. Grains consist of quartz, feldspar, mica, and less amount of opaque mineral grains.
16) *Biotite-quartz-sericite schist: It* displays banded structure and foliation in handspecimen, but in thin section banded structure made up of variable quartz and sericitic orientation is observed.
17)*Lithic subarkose (very* similar to sample 15)
18)*Lithic subarkose (very* similar to samples 15 and 17). However, quartz and plagioclase grains in medium sand size and an increase in the percentage of cement were observed)
19) *Lithic subarkose: Grains vary*ing from very fine to very coarse sand are angular and badly sorted. Cementation is carbonate. Grains consist of quartz, argillized feldspar, biotite, muscovite and opaque minerals.

Figure 4- Schematic cross section of the Kayadibi Yayla (cross section AB)

5). Two cross sections were taken across the Kapıkaya formation from south to north direction (Figures 3, 4, 6 and 7), one of them passes through Kayadibi Yayla located nearly 6 km north of the Sarıcakaya county (Figures 2, 5; cross section A-B), whereas the other section pass through Karaorman Ridge from near east of Örencik Yayla located at 14 km northeast of Sarıcakaya county (Figures 2, 5; cross section C-D). The field observations fullfilled around Örencik Yayla (Figures 2, 5; cross section E-F) were added to the study as a complementary section (Figure 8). Although the columnar sections are not the same as the measured stratigraphic section, they have been prepared by carrying out very random and systematical sampling. A generalized stratigraphical section of the Kapıkaya formation is given in figure 9.

The Kapıkaya formation is generally made up of the alternation of sandstone and shale (Figures 9 and 10). The shales are greenish gray colored, thin platy bedded, well-graded and lacally parallel to cross (convolute) laminated.; The sandstone layers generally overlying the shale layers with a sharp bottom contact relationship has sometimes well developed load casts. Beige colored thin to medium- and planar-bedded, poorly-sorted sandstones are laminated at topmost bed and upward transitional to thin siltstone and claystone layers.

In mid-levels of the Kapıkaya formation, there exists white, medium to thick and very thick bedded, coarse grained, poorly sorted to ungraded arkosic sandstone bed consisting of poorly-developed basal structures (Figure 11). The arkosic sandstone beds are parallel to cross laminated and convolute in upper layers (Figure 11). These arkosic sandstone beds can be accepted as a key bed (Figure 12) which they are approximately 20 meters thick having a

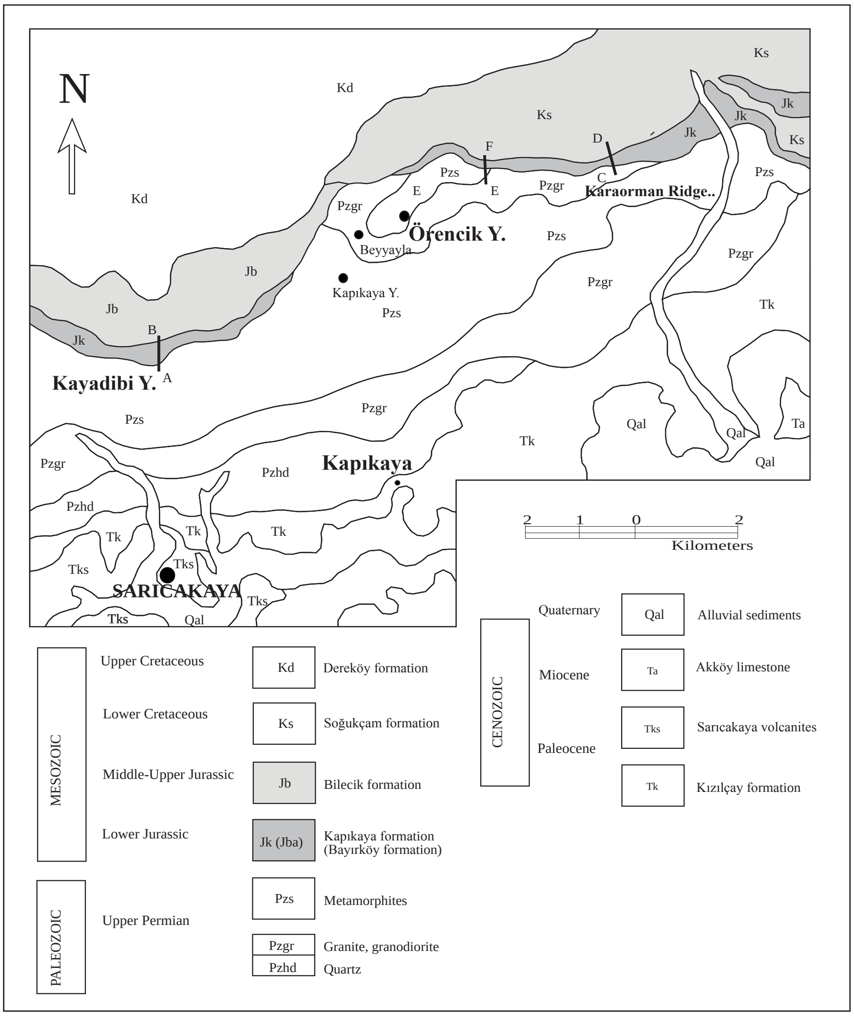


Figure 5- Geological map of the study area (Altınlı, 1973).

lateral continuity extending along far distances, and could be traced in each of three sections (Figure 2; A-B, C-D, E-F cross sections). The white colored, thick-bedded sandy limestone lenses exist in parts underlying arkosic sandstone level within the sandstone – shale alternation of the Kayadibi Yayla section (Figure 3). The macro fossil shell fragments, benthic foraminifers and some pelagic forms were observed within shaley layers and in samples taken from sandy limestone lenses overlying with scoured-base (Figure 3, 9; samples 01 FU-05 and 01 FU-22). The lenses of sandy limestone are also encountered in upper layers of the Kayadibi Yayla section. Kapıkaya formation also consists of sandstone beds which have sharp boundaries with well-developed basal structures overlying loose cemented clayey beds (Figure 13). These sandstone layers which have lateral continuities over long distances are well sorted and upward transitional to the fine grained and laminated beds. Coarse-grained limestone and metamorphic rock fragments and blocks were observed just below the arkosic sandstone level in the Kayadibi Yayla (Figure 13 and 14). A Part of these blocks was formed by Liassic limestones and transported to the depositional environment. The other blocks formed by gneiss – schist and amphibolites are derived from the metamorphic basement and mixed with sediments of Kapıkaya formation. The depositional environment of the Kapıkaya formation and the source areas of derived blocks for this environment were given as a sketch drawing in figure 15; the cross section of the Kayadibi Yayla was also presented in figure 4.

The part of the sandstone – shale alternation below the arkosic sandstone bed is rather thick in the Kayadibi Yayla (Figures 3 and 12), but this level becomes more thinner towards Örencik Yayla, and piches out laterally before it reaches the Karaorman Ridge (Figure 12).

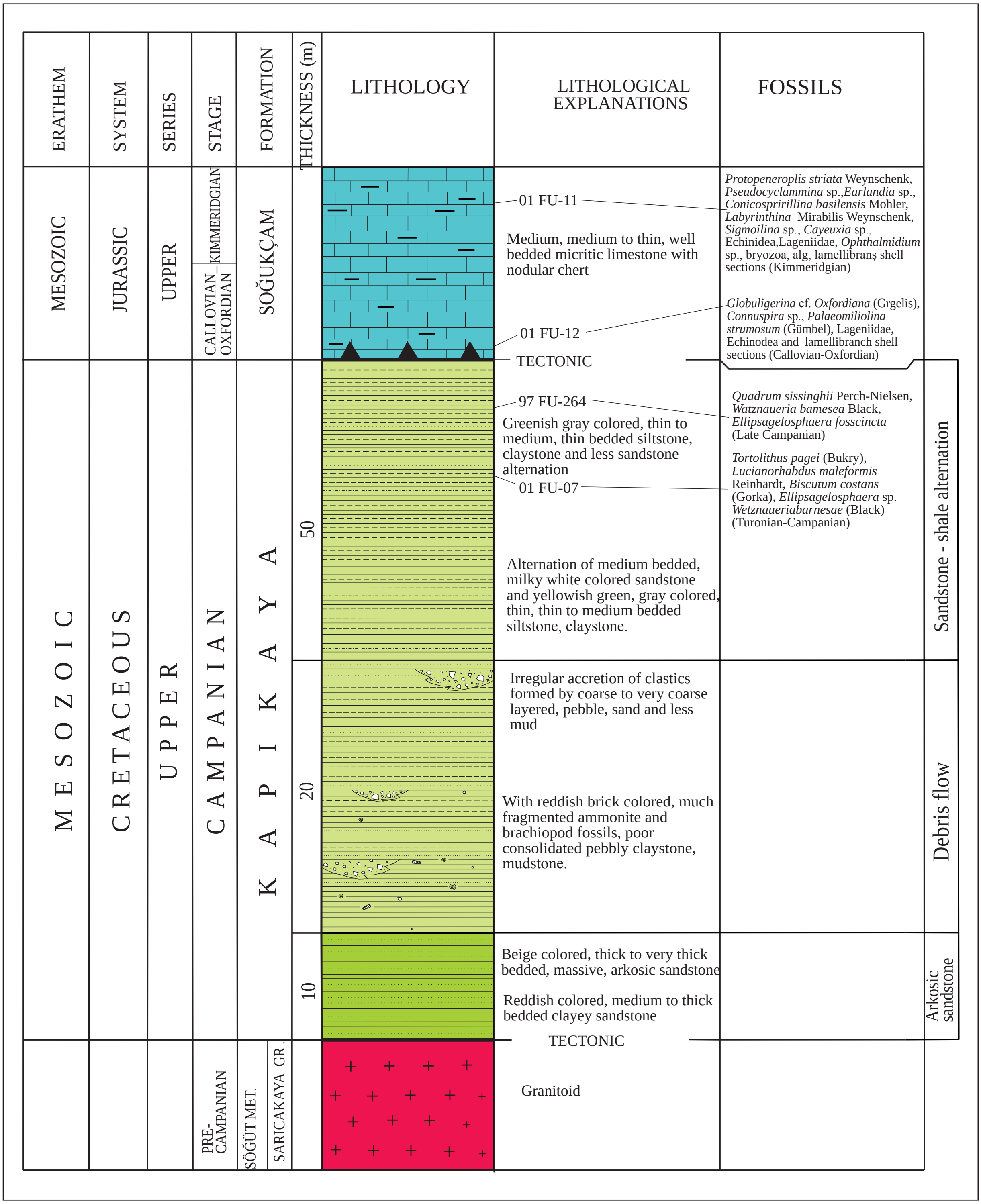


Figure 6- The columnar section of the Karaorman Ridge (CD).

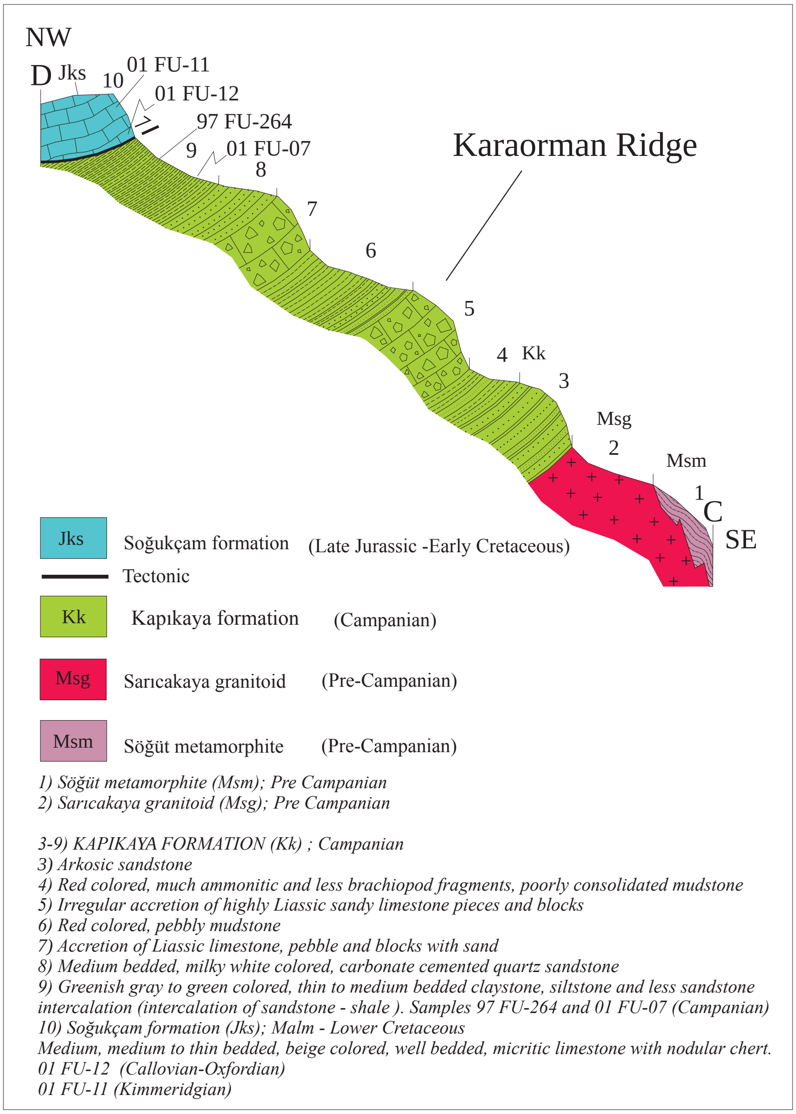


Figure 7- Karaorman Ridge (C-D) Schematic Cross section

A thick mudstone level overlies the arkosic sandstone beds on Karaorman Ridge (Figure 6). This level consists of ammonite, brachiopod, orthoceras and belemnite fossils and is red colored, and massive bedded, with limestone pebbles. Toward upper parts it consists of lenticular fills of sand, pebble and block-sized materials (Figure 16). These lenticular limestone infillings (Figure 17) indicating no bedding, sorting or grading in its main body are transitional to medium to thin-bedded sandstone, siltstone and claystones in the topmost part. The general view and schematic cross-section of the Karaorman Ridge are given in figure 18 and 7. The same mudstone level consists of red colored, much and well preserved ammonite, brachiopod, belemnite, orthoceras bearing clayey, marly, and nodular limestone masses (Figure 8). These masses are conformable with the bedding of Kapıkaya formation and sometimes in the form of overturned blocks towards the Örencik Yayla (Figure 19). The unit has widespread facies changes laterally, which also the mudstone level pinches out in western part of the Örencik Yayla due to the lateral and vertical interfingering with thin bedded sandstone and shale alternation (Figure 12).

The thickness of Kapıkaya formation is 135 m in Kayadibi and 80 m in Karaorman Ridge. The columnar sections of Kayadibi Yayla, Karaorman Ridge and Örencik Yayla are given in figures 3, 6 and 8, respectively and all of them were then correlated in the schematic section given in figure 12. The arkosic sandstone bed is observed in each of three observation

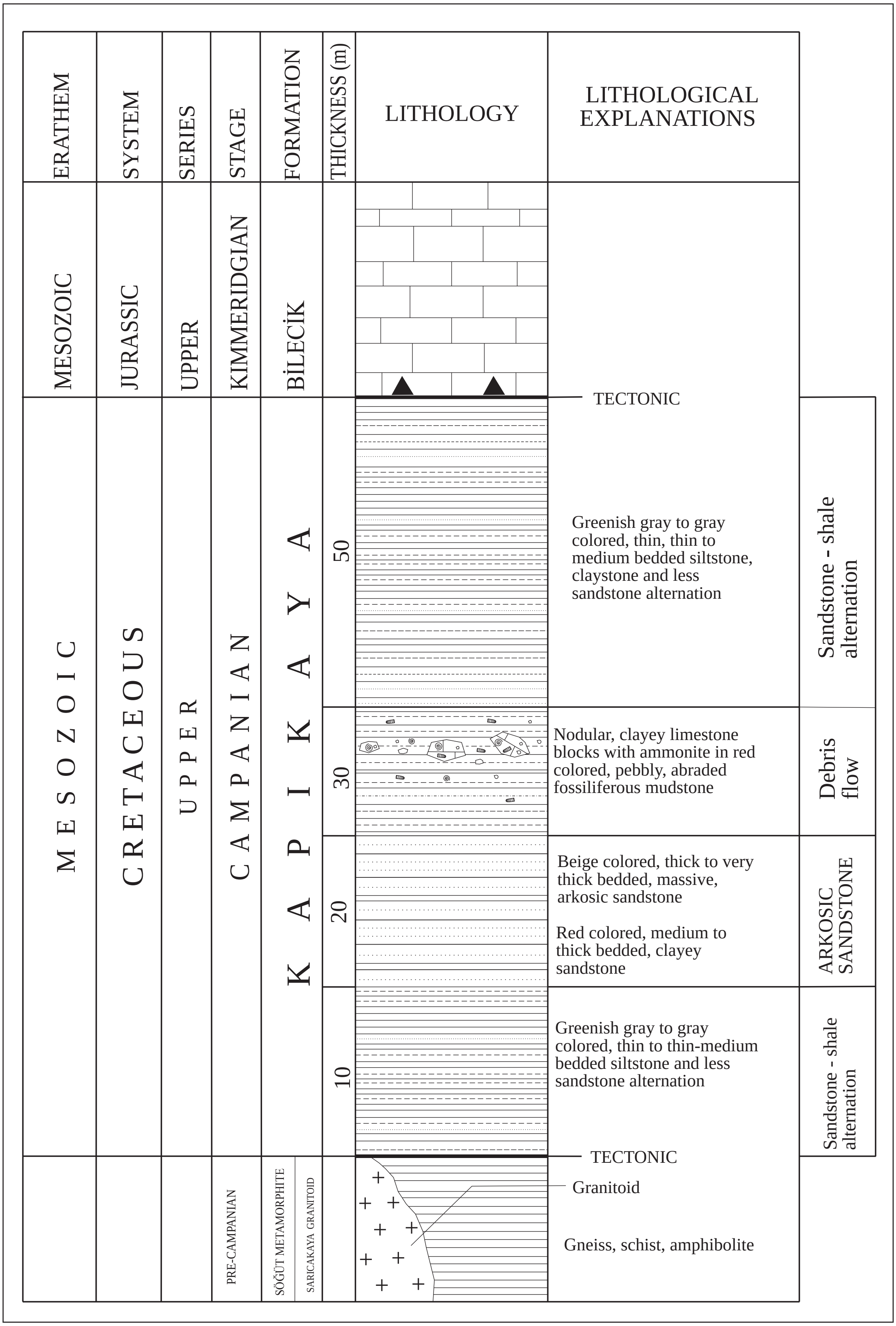
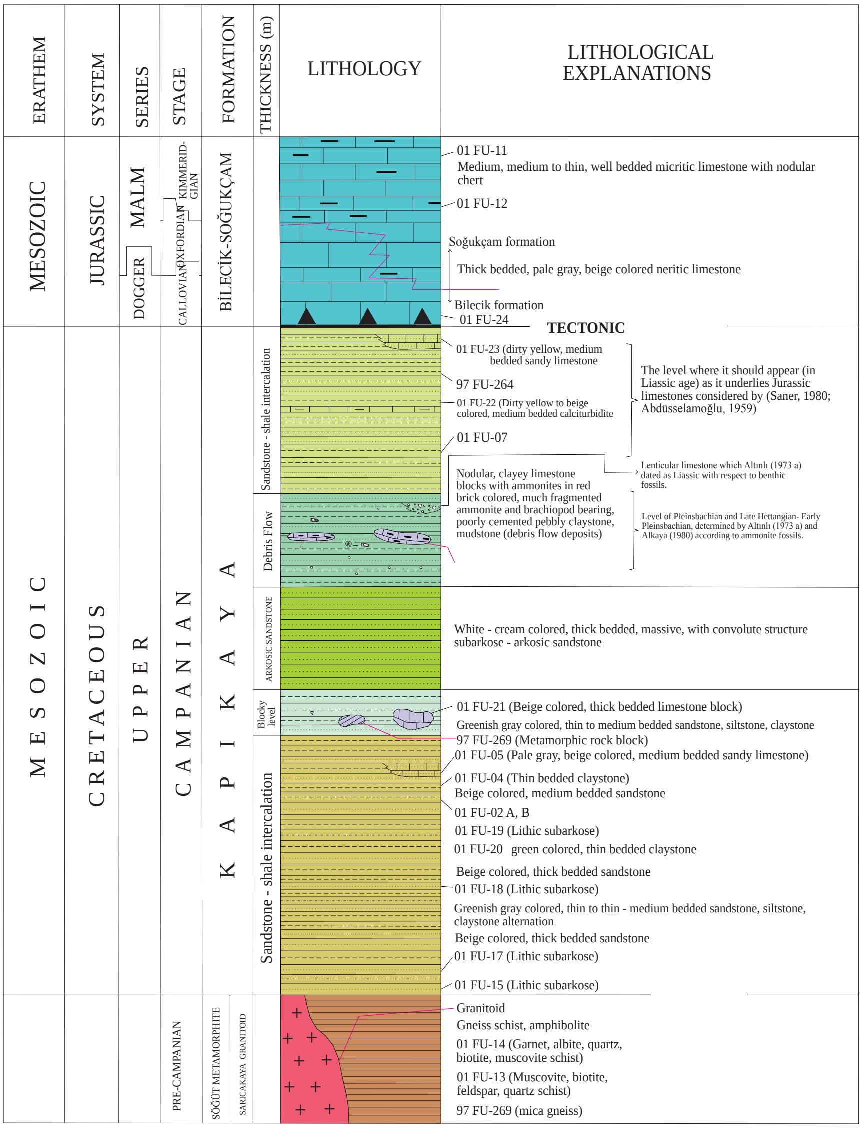


Figure 8- The columnar section of the Örencik Yayla (EF).



97 FU-264: Quadrum sissinghii Perch-Nielsen,Watznaueria bamesea Black, Ellipsagelosphaera fosscincta (late Campanian);
01 FU-11: *Protopeneroplis striata* Weynschenk, *Pseudocyclammina* sp.,*Earlandia* sp., *Conicospririllina basilensis* Mohler, *Labyrinthina* Mirabilis Weynschenk, *Sigmoilina* sp., *Cayeuxia* sp., Echinidea, Lageniidae, *Ophthalmidium* sp., bryozoa, alg, lamellibranch shell sections (Kimmeridgian)
01 FU-12: *Globuligerina* cf. *Oxfordiana* (Grgelis), *Connuspira* sp., *Palaeomiliolina strumosum* (Gümbel), Lageniidae, Echinodea and lamellibranch mold sections (Callovian-Oxfordian)
01 FU-21: *Involutina liassica* (JONES), *Lingulina* sp., *Agerina martana* (FARINACCI),*Trocholina turris* Frentzen, *Trocholina umbo* Frentzen, Nodosariidae, Echinodea plaque and spinals, lamellibranch mold sections; Liassic (Hettangian-Sinemurian).
97 FU-269: Mica gneiss; Major minerals are; quartz, mica (biotite, sericite, muscovite), plagioclase, alkali feldspar (micro perthite), sillimanite, chlorite and accessory minerals; opaque minerals, aptite,banded structure and fiber-lepidogranoblastic texture.
01 FU-22: *Quadrum gartneri* Prins and Perch-Nielsen, *Watzaueria barnesae* (Black), *Biscutum* sp., *Ellipsagelosphaera* sp. (Turonian - early Campanian).
01 FU-23: *Spirillina* sp., *Robulus* sp., Lageniidae *Globotruncana* sp. molds,, Nodosariidae, Echinoidea (Upper Cretaceous facies).
01 FU-24: *Labyrinthina mirabilis* Weynschenk, *Pseudocyclammina* sp., *Nautiloculina oolitica* Mohler, Valvulinidae, *Bolivinopsis* sp., Textulariidae, *Conicospirillina* sp., Ophtlalmididae, Miliolidae (Kimmeridgian)
01 FU-02 A, B: *Ceratolithoides* aculeus (Stradner), *Pervilithus* varius Crux,.
01 FU-04: *Watznaueria bernesae* (Black), *Ellipsagelophaera* sp., *Tortolithus* sp., *Biscutum* sp. (Campanian).
01 FU-05: Rotaliidae, *Globotruncana* sp. molds, Textulariidae, Radiolaritidae, with hyaline wall and pentagonal spinal Nodosariidae, echinoid, lamellibranch shell sections
01 FU-07: *Tortolithus pagei* (Bukry), *Lucianorhabdus maleformis* Reinhardt, *Biscutum costans* (Gorka), *Ellipsagelosphaera* sp.*Wetznaueriabarnesae* (Black) (Turonian-Campanian)

Figure 9- The generalized stratigraphical section of the study area

Figure 10- A view from sandstone - shale alternation in the Kapıkaya formation. Locality: Kayadibi Yayla, lower layers of the Kapıkaya formation. The contact of sandstone layers is sharp and clayey layers are fossiliferous. (Sample 01 FU-04).

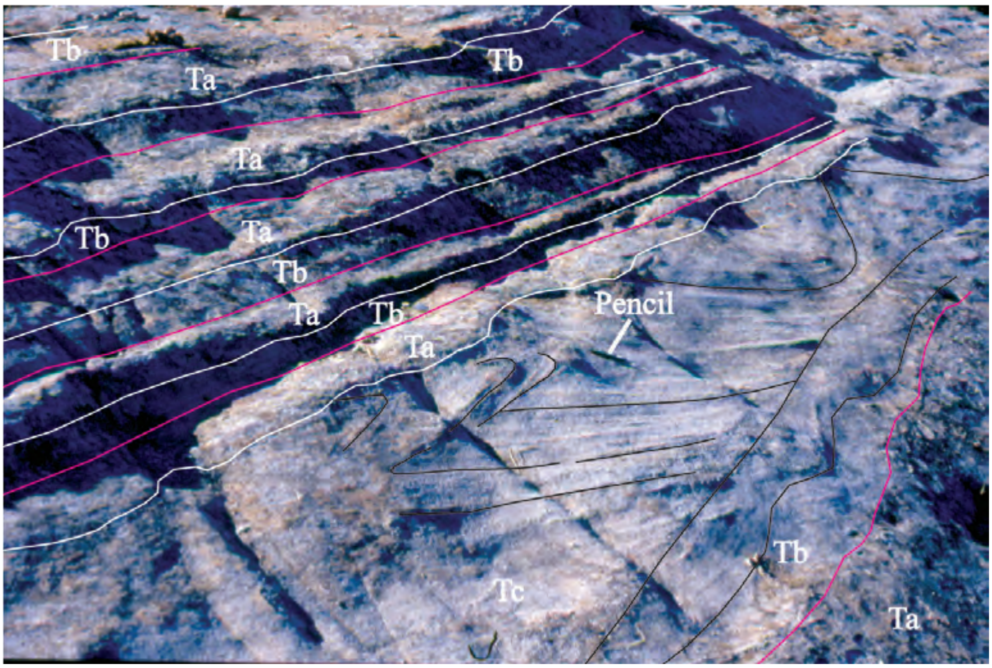


Figure 11- Levels a and b of the Bouma (1962) sequence in arkosic sandstone level; A well developed convolute lamination is observed after a thin and badly preserved b level located at the lower layer in frontal side of the photo. Ta level is pebbly and badly sorted. Planar lamination in Tb level has not been well preserved. Convolute bedding (folded convolutions) in Tc level is well developed. Ta and Tb levels in upper layers are well developed, but there is no Tc level. There is a transition from rapid flow regime to a quite flow regime (from Ta to Tc) Transitions from rapid to quite flow is continously repeated towards the upper layers of arkosic sandstone layer without facing c, d, e levels.

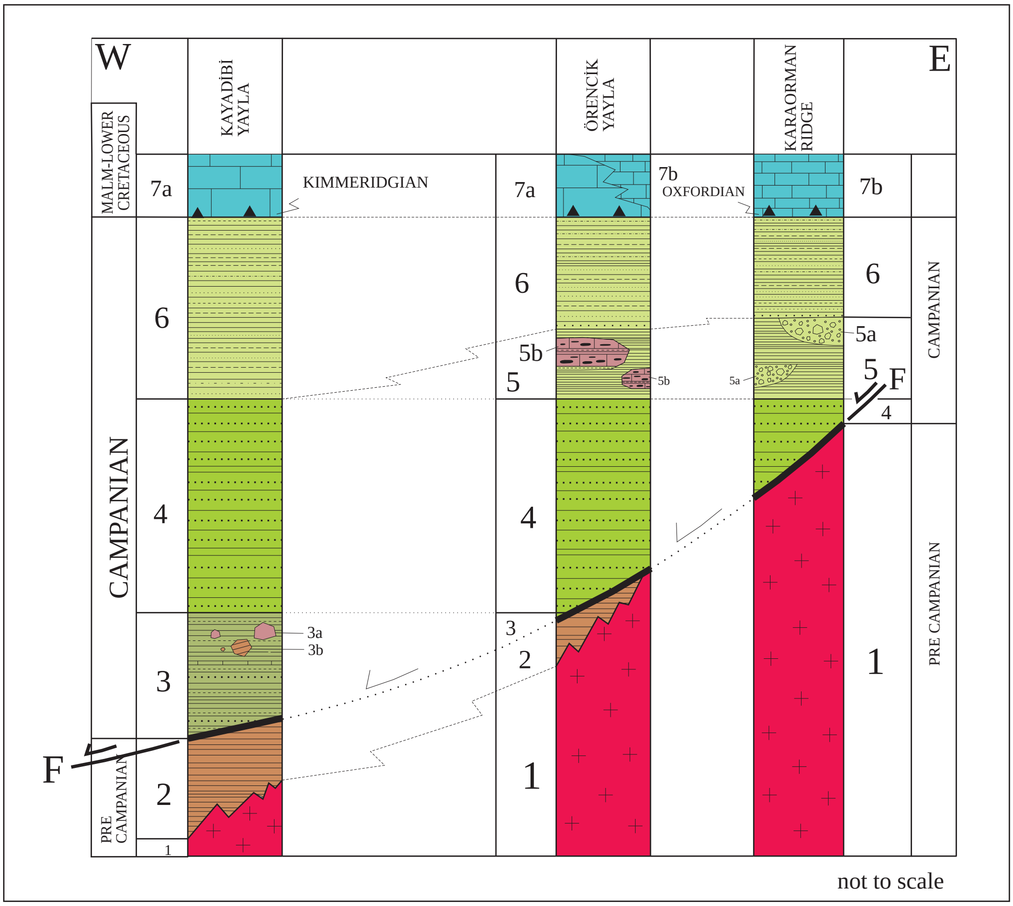


Figure 12- The correlation table of Kayadibi Yayla, Örencik Yayla and Karaorman Ridge columnar sections.

localities (Figure 2; cross sections of A-B, C-D, E-F). The underlying sandstone – shale alternation (Figure 9) thins out from west to east and pinches out between Örencik Yayla and Karaorman Ridge. The mud flow and debris flow deposits including Ammonite-bearing limestone blocks around Örencik Yayla and overlying the arkosic sandstone bed also pinches out laterally from east to west (Figure 12).

The generalized stratigraphic columnar section of the Kapıkaya formation is given in figure 9. The bottom contact of the unit in the study area is not clearly observed. The part of the sandstone and shale alternation underlying the arkosic sandstone bed is rather thick in Kayadibi Yayla (Figure 3). As it is also seen in figure 12, this lower sandstone and shale alternation becomes thinner towards Örencik Yayla, and pinches out before it reaches the Karaorman Ridge. Therefore the arkosic sandstone level is observed as the lowermost layer of the deposit in the Karaorman Ridge (Figure 6). The arkosic sandstone bed is thinner with respect to other two sections in the Karaorman Ridge and consists of brownish clayey mylonitic zone at the bottom. Furthermore some of the layers abuts against the granitic basement (Figure 20). A schist layer belonging to the Söğüt metamorphics in the Kayadibi Yayla is observed again just after the lowermost sandstone level of the unit due to a faulting (Figures 3 and 4). These data indicate the base of Kapıkaya formation may be faulted in the study area. The blocks of the metamorphic basement are observed in the lowermost levels of the unit in Kayadibi Yayla (Figure 3) and these blocks show that Kapıkaya formation took materials derived from the metamorphic basement. Related to the lower contact relationship of the Kapıkaya formation in the study area, it could be said that the unit was deposited initially on a granitic – metamorphic basement, but this contact relationship could not be clearly observed due to tectonism.

The Kapıkaya formation in all its outcrops in the study area is covered by the limestones of Bilecik and/or Soğukçam formations with horizontal to sub horizontal angle. It is regardless to mention about the existence of an overturning since the age of the

Figure 13- A sharp bottom contact relationship in a sandstone bed overlying the clayey layer within the sandstone - shale alternation and well developed primary structures. Underlying clayey layer consists of much nannoplankton.

Figure 14- Within sandstone - shale alternation of the Kayadibi Yayla it is observed; (above photo) Liassic neritic limestone block, (below photo) metamorphic rock block in front, on the right side and Liassic limestone block at back, sandstone - shale alternation on the upper left corner (at distant) and the overlying limestones of Bilecik formation.

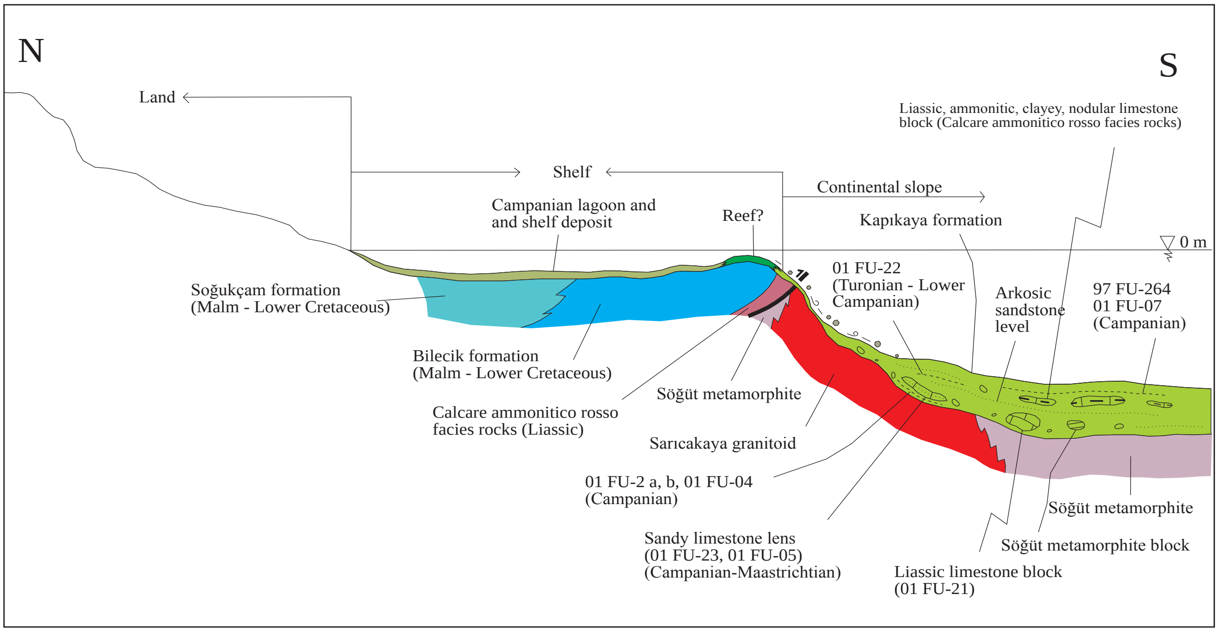


Figure 15- Schematic section showing the depositional environment in Campanian.

Figure 16- Clastic limestone lenses deposited within red - brick colored mudstones on the arkosic sandstone layer in Karaorman Ridge.

Figure 17- Close up view of a clastic limestone lens above the arkosic sandstone level in Karaorman Ridge. Lenticular infilling which it was formed by block - sand size carbonate material. This carbonated material has been accumulated by debris flow within pebbly mudstone which was formed by red mudstone. Two large limestone blocks can easily be noticed within sand, pebbly matrix. Bad sorting and very coarse bedding is observed.

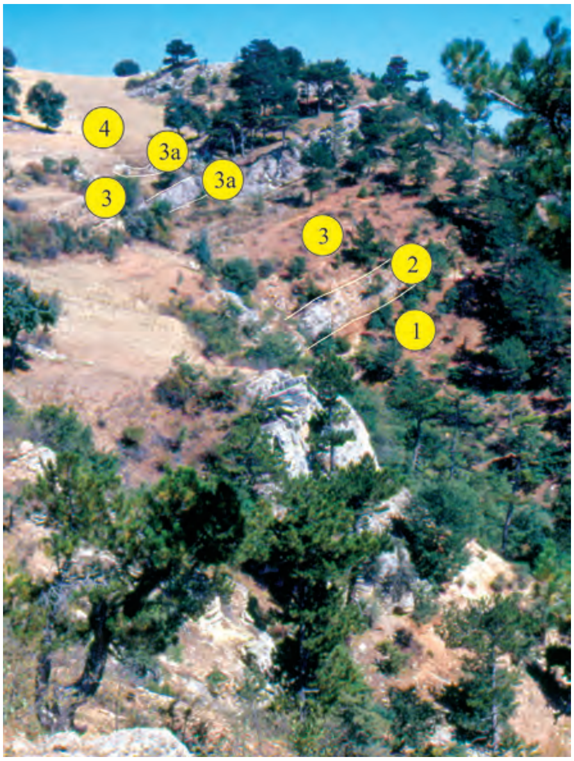


Figure 18- Karaorman Ridge (looking from west); 1- granite, 2- arkosic sandstone, 3- red colored pebbly mudstone with abraded ammonite and brachiopod, 3a- lenticular limestone infillings within mudstone layer, 4- sandstone - shale alternation.

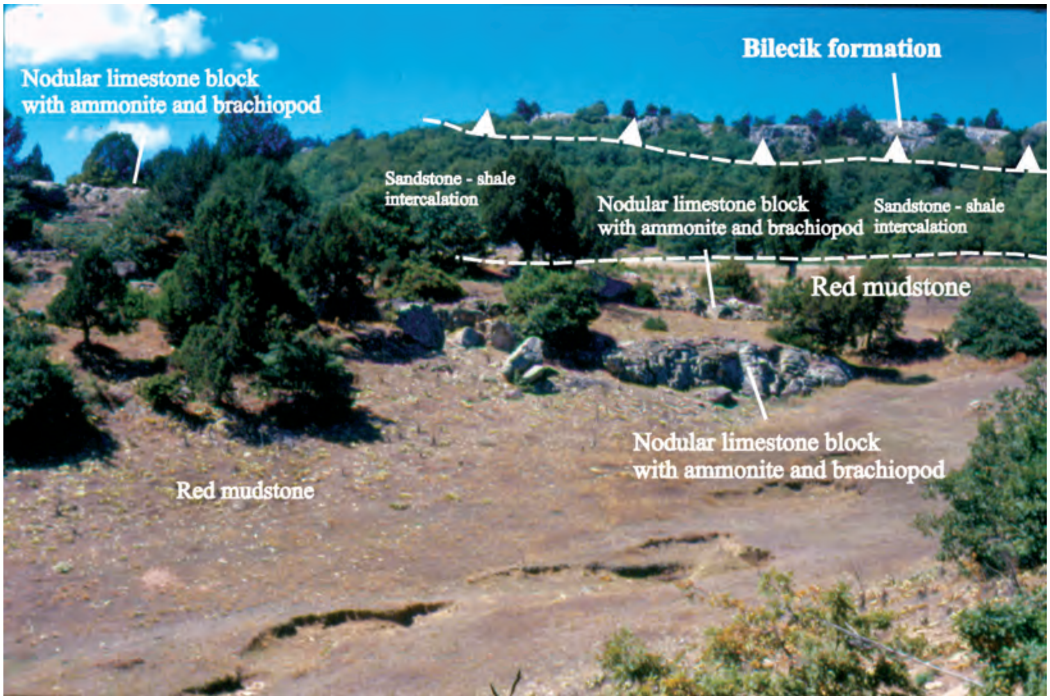


Figure 19- Nodular limestone blocks with ammonite and brachiopod fossils within red mudstone layers around Örencik Yayla. Nodular limestones are in different block sizes that have no lateral continuity.

cover begins with Kimmeridgian in Kayadibi Yayla and Oxfordian in the Karaorman Ridge and becomes younger even up to Early Cretaceous in upper levels (Altınlı, 1973*b*; Saner 1977, 1980; Göncüoğlu et al., 1996; Şentürk and Karaköse, 1981, 1982; Gedik and Aksay, 2002). Therefore it should be clarified that the Kapıkaya formation was tectonically overlain by Bilecik and/or Soğukçam formations. The thrusting of Bilecik / Soğukçam formation onto the Kapıkaya formations is given in figure 21.

The exposures of Kapıkaya formation around Sarıcakaya county and Kapıkaya village are dated as early Pliensbachian by Altınlı, (1973*a*) and as Late Hettandgian – Early Pliensbachian by Alkaya, (1981) (Figure 9). Saner (1980) stated that the age of sandstone, siltstone and claystone alternation (level 9 in Figure 7) should be Liassic which is located in upper layers of the unit at the Karaorman Ridge exposure as it underlies the Bilecik formation (Figure 9). The age of carbonate intercalations within these fine clastics are as well accepted as Liassic due to the same reason by Abdüsselamoğlu (1959) (Figure 9) at south of Soğukçam village,

Turonian – Campanian fossils like; Tortolithus pagei (Bukry), *Lucianorhabdus maleformis* Reinhardt, *Wetznaueria barnesae* (Black), *Biscutum costans* (Gorka), *Ellipsagelosphaera* sp. (sample 01 FU-07, level 9, figure 7) and late Campanian fossils like; *Quadrum sissinghii* Perch-Nielsen, *Watznaueria barnesea* Black, *Ellipsagelosphaera fosscincta* were obtained (Figure 7, level 9, sample 97 FU-264) from the ammonitic and nodular limestone blocks which overlie arkosic sandstone layers in the Karaorman Ridge and Örencik Yayla, and from the clayey beds of clastics which is accepted as Liassic by Saner (1980) that overlie the fragmented Ammonite-fossil bearing, red pebbly mudstone layer (levels 4 and 6 in figure 7). Altınlı (1973*a*) and Alkaya (1981) took the ages of Hettangian and Early Pliensbachian from red colored, ammonitic mudstone layer deposited above the arkosic sandstone beds (levels 4 and 6 in figure 7; level 5b in figure 12) (Figure 9).

Campanian aged nannoplanktons like; *Ceratolithoides aculeus* (Stradner), Pervilithus varius Crux, *Watznaueria barnesae* (Black), *Tortolithus* sp., *Biscutum* sp and Cretaceous fossils like; *Ellipsagelophaera* sp. *Watznaueria barnesae* (Black), *Biscutum* sp. were taken from the clayey layers of clastics below the arkosic sandstone level in the Kayadibi Yayla outcrop of Kapıkaya formation (samples 01 FU-02 A, B; 01 FU-04; figures 3, 4 and 9). In the next sample which was taken from a sandy limestone bed above the previous sample

Figure 20- The contact between arkosic sandstone and granite on Karaorman Ridge. Brownish red colored mylonitic evolution at the bottom of arkosic sandstone. The underlying sandstone layers ends at the contact with granite.

(Figures 6 and 7; sample 01 FU-05) molds of Cenonian (Campaninan – Maastrichtian) Rotaliidae, *Globotruncana* sp. and Textulariidae, radiolaritidae, Nodosariidae and echinoid with hyaline wall and pentagonal spinals, lamellibranch shell sections were observed. Turonian – Early Campanian aged nannoplanktons like; *Quadrum gartneri* Prins and Perch-Nielsen, *Watznaueria barnesae* (Black), *Biscutum* sp., *Ellipsagelosphaera* sp. were obtained in one of the samples (01 FU-22) taken from the fine clastic levels which are deposited above arkosic sandstones and below Bilecik limestones in the Kayadibi Yayla columnar section (Figures 3 and 4).

The limestone blocks within clastics underlying the arkosic sandstone beds consist of Liassic (Hettandgian – Sinemurian) fossils like; *Involutina liassica* (JONES), Agerina martana (FARINACCI), *Trocholina turris* Frentzen, *Trocholina umbo* Frentzen, *Lingulina* sp., *Ophthalmidium* sp., Nodosariidae (sample 01 FU-21) in the columnar section of the Kayadibi Yayla (Figure 2, cross section AB)

The unit which has less fossil content consists of much nannoplankton fossils in clayey and shaley layers despite the less transported benthic foraminifers.

Campanian age was obtained from many of the samples taken at different levels of Kayadibi Yayla and

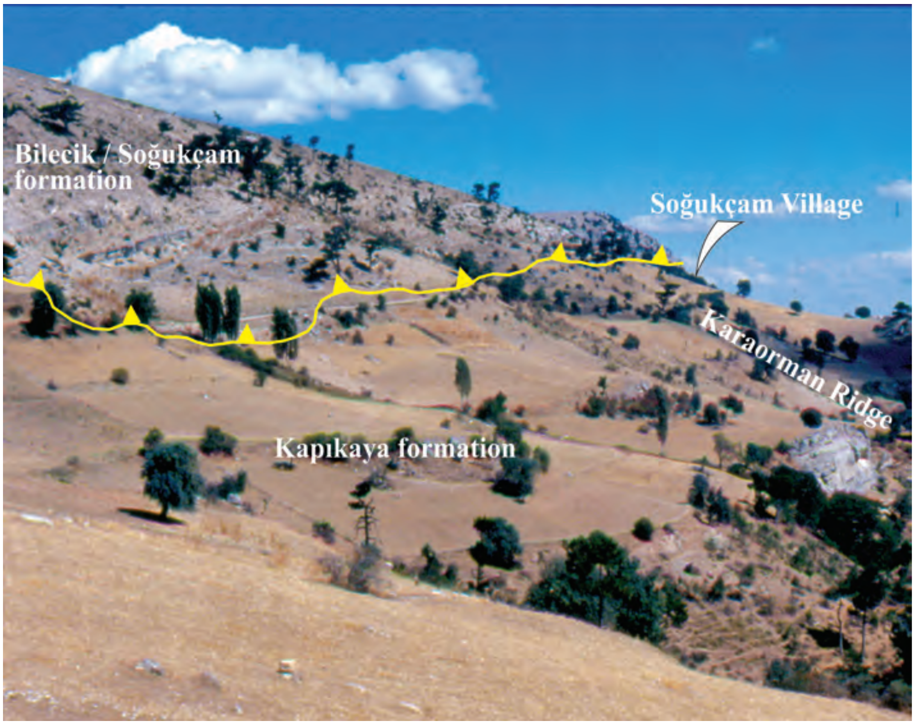


Figure 21- The overthrust between Bilecik/Soğukçam formation and Kapıkaya formation around Karaorman Ridge - Soğukçam village.

Karaorman Ridge columnar sections (Figures 3 and 6). Although the paleontological results of some samples are assigned as Turonian – Campanian or Campanian – Maastrichtian ages; the Turonian and Maastrichtian ages are not used, because the Campanian age has been obtained both from the underlying layer in which the sample of Turonian – Campanian age had been taken and from the overlying layer in which the sample of Campanian – Maastrichtian ages had been taken.

The Campanian age is obtained from the sandstone and shale alternation including Liassic blocks and underlying the Malm- early Cretaceous limestones. Thus, the age of this sandstone and shale alternation of the Kapıkaya formation forming the main body together with arkosic sandstones is Campanian. The Liassic limestones exist in the form of exotic blocks within this main body. For the existence of such exotic blocks, there should be Liassic rocks around the basin margins during Campanian time to give material into the depositional environment. A schematic depositional model related to Campanian time is given in figure 15. The material transportation from basin margin depocenter should have been made by turbiditic processes. The depositional character rock types and the fossil content of the unit also confirm features supporting these turbiditic processes.

Altınlı (1973*a*) have interpreted the lenticular structures infilled by carbonate clastics (Figure 16) and mudstones as “mixed clastics and carbonate coast line”. He also pointed out that, the unit was started to deposition by a marine transgression and later continued as coast-line depositional setting based on its depositional features and fossil content. Altınlı (1973*a*) also determined laminations, convolute, load cast, bench mark, animal nest, downslope failure, trace fossil, small scale cut and fill structures indicating turbiditic processes in Kapıkaya formation. The investigator interpreted the depositional environment as shore and near shore, as he preferred to use the term “flysch like”, “flysch like cycling” instead of using the “flysch” term.

The characteristic properties such as; the graded bedding, convolute and parallel lamination, sharp bottom contact relationship of sandstone beds, lateral continuity of sand beds and levels, the abundance of structures in intrabed and at bottom contact, the minority of reworked benthic fossils, the content of much pelagic fauna and lateral and vertical facies changes observed all in the sandstone and shale intercalation indicate that the unit is a turbiditic type deposit. In the sandstone and shale alternation, the beds thought to be in the Bouma (1962) sequence were encountered. As it is in arkosic sandstone and isolated thick sandstone beds, the levels of a and b in coarse grained levels (Figure 11); and the levels of c, d and e have developed in thin bedded, fine grained and high shaley layers. The fossil content of the unit indicates that the deposition was occurred in marine environment.

According to previous studies Bilecik and/or Soğukçam formation tectonically overlies the Kapıkaya formation and indicates a sedimentary contact relationship with the Bayırköy formation in regional stratigraphy. Due to this sedimentary contact relationship, the Bayırköy formation also overlies the Kapıkaya formation together with Bilecik formation.

The Kapıkaya formation including the Liassic age blocks of the Bayırköy formation indicates that the tectonism providing this contact relationship was effective during Campanian time as well (Figure 15). This shows the presence of tectonical characteristic for the deposits of Kapıkaya formation.

The sedimentary, tectonic and biological properties of the Kapıkaya formation are in line with the definition of flysch of Seilacher (1959). Seilacher (1959) and Kuenen (1959) defined the flysch as the deposits of turbiditic series. According to data of this study, the Kapıkaya formation is formed by the flyschoidal sediments deposited by grain flow, mud flow, debris flow, block falls and slides during turbiditic processes on continental slopes. Liassic aged, much ammonitic, nodular and marly limestone masses, and Liassic aged, neritic limestone blocks are transported materials displaced by turbiditic flows from basin margin to the depositional environment of the Kapıkaya formation (Figure 15).

2.4. Bilecik Formation

This formation consisting mainly of neritic limestones was named by Granit and Tintant (1960) and its exposures are observed in the north of Sarıcakaya county, in vicinities of Kayadibi Yayla, Kapıkaya Yayla, Beyyayla, Örencik Yayla and to the north of Kapıkaya (Figure 2). Granit and Tintant (1960) were not given any type locality for this unit. Altınlı (1973 *a*) has a measured stratigraphical section in Halkapınar which is located at 2 km northwest of Beyyayla in the Sarıcakaya county. Altınlı (1973 *a*) determined Karasu stream outcrop as a type locality for this unit which is at the southwest of Vezirhan town, Bilecik province.

Bilecik formation is formed by medium to thick bedded, gray to white colored, limestones with shells of algea, coral and pelecypods. Much ammonites were encountered in outcrops of the unit at north of Beyyayla – Örencik Yayla (Figure 2). Granit and Tintant (1960) detected 70 index ammonite types from these levels of the unit indicating the Callovian age. The fossils like, *Labyrinthina mirabilis* Weynschenk, *Pseudocyclammina* sp., *Nautiloculina oolitica* Mohler, Valvulinidae, *Bolivinopsis* sp., *Conicospirillina* sp., Textulariidae, Ophthalmididae and Miliolidae which give Kimmeridgian age were obtained from the sample (Figure 4, sample 01 FU-24) taken in first levels overlying the Kapıkaya formation in the Kayadibi Yayla (Figure 3). The thickness of the unit is about 100 meters.

This unit tectonically overlying the Kapıkaya formation is both vertically and horizontally transitional with the micritic limestones of the Soğukçam formation at top in the study area. This transitional relationship with Soğukçam formation can be observed at north of Örencik Yayla (Figure 2). The Kimmeridgian age was obtained from the lowermost levels of Kapıkaya formation in the section of the Kayadibi Yayla (Figure 2, cross section AB).

Göncüoğlu (1996) and Altınlı (1973*b*) dated the unit as Late Jurassic – Early Cretaceous and Callovian – Early Portlandian. Altıner et al. (1991), subdivided the unit into two formations (Taşçıbayır formation and Günören Limestone), stated that the unit which they had studied as Bilecik group was Callovian – Hauterivian in age.

Bilecik formation can be correlated with Alancık formation in Biga peninsula (Bingöl et al., 1973), Mollaresul limestones around Ankara and Ferhatkaya formation in Amasya region (Özcan et al., 1980). Parts of the unit in the study area including algae, coral and pelecypod shells reflect the characteristics of the shelf environment.

2.5. Soğukçam Formation

Altınlı (1974) stated that the unit which he previously defined as thin bedded, clayey white limestones was investigated under the name of “Soğukçam limestone” by Tuna (1974). Except the exposure extending from north of Örencik Yayla to Soğukçam village, the unit has many outcrops partly between Soğukçam – Kapıkaya villages (Figure 2). As it is observed at the north of Örencik Yayla, the Soğukçam formation transitionally overlies Bilecik formation and is composed of gray, white, creamy colored, thin to medium bedded, ammonite bearing, thin claystone intercalations with cherty, micritic and porcelanecous limestones.

At the northeast of Örencik Yayla the samples taken from the levels overlying the Kapıkaya formation on Karaorman Ridge (Figure 2, cross section C-D), (Figure 6, sample 01 FU-12) yielding Callovian – Oxfordian fossils like; *Globuligerina* gr. *oxfordiana* (Grigelis), *Connuspira* sp., *Palaeomiliolina strumosum* (Gümbel), Lageniidae and assigning Kimmeridgian fossils like; *Protopeneroplis striata* Weynschenk, *Pseudocyclammina* sp., *Conicospirillina basiliensis* Mohler, *Earlandia* sp., Labyrinthina mirabilis Weynschenk, *Sigmoilina* sp., *Cayeuxia* sp., *Ophthalmidium* sp., Lageniidae are obtained.

The Soğukçam formation was differently dated by various investigators as; Hauterivian – Barremian (Altınlı, 1974), Late Jurassic – Early Cretaceous (Saner, 1980), Portlandian – Berriasian (Göncüoğlu et al., 1996). Altıner et al., (1991) who had considered the Soğukçam formation as a member within the upper levels of Günören formation of the Bilecik Group dated the unit as Valanginian – Aptian. Due to its thin to medium bedded, cherty and micritic characteristics and fossil content, the unit should have been deposited in an open shelf to slope area. The unit can be correlated with Akbayır formation in Ankara area (Akyürek et al., 1982) and Carcurum formation around Amasya (Özcan et al., 1980).

2.6. Kızılçay Formation

The name of the formation was made by Eroskay (1965). The unit is mainly composed of the alternations of red claystone, mudstone, sandstone and conglomerate. It has an outcrop extending along Sakarya Vadi, around Sarıcakaya county in the study area (Figure 2). According to Altınlı (1974), who suggested the age of the unit as Ladinian, the Kızılçay formation overlies Cretaceous “Gölpazarı group” with an angular unconformity. Gedik and Aksay (2002) have placed the Kızılçay formation onto the unit which is called “Gökçekaya metamorphites” unconformably around Mayıslar town in Sakarya Vadi (Figure 1).

Kızılçay formation is mainly composed of the alternation of mudstone, claystone, siltstone, sandstone and conglomerate. The red mudstones are the dominant rock type giving their color to the unit. The alternation of gray to dark gray conglomerate, pebbly sandstone, sandstone and siltstone is observed as channel fills within the red mudstones. The conglomerate, pebbly sandstone and siltstone lithofacies are well rounded, medium graded, medium sorted with local cross-bedding in these clastic layers. Tiny carbonate lenses are also encountered within mudstone levels alternating with clastics and the trace fossils are frequently observed in sandy and silty levels. It is observed that, pebbly and sandy levels developed generally on a scoured base in the form of fills in red mudstones. Red mudstones and alternating conglomerate and sandstone fillings were assessed as debris flow, flood plain deposits, alluvial plain deposits, and carbonates were interpreted as lacustrine deposits. The formation can be correlated with Kartal formation exposed around Ankara (Rigo de Righi and Cortesini, 1960).

The metamorphic basement cut by the granitoids and the overlying rock assemblages formed by Kapıkaya and Soğukçam formations have been thrusted over Kızılçay formation with a high angle thrust fault. This fault extends in west-southwest, east-northeast directions along the northern slope of Sakarya Vadi.

3. Discussions and Conclusions

Altınlı (1973*a*) investigated the Bilecik Jurassic by subdividing into two formations as, Bayırköy and Kapıkaya. The reason for this distinction is as the Liassic deposition runs differently in east and west sides of the Gölpazarı-Söğüt line (Figure 1). According to this investigator, the sequence which is merely in western side (Bilecik direction) becomes more complex and variable in eastern side (Eskişehir direction). The main factor of this complex and variable structure is the flysch like sediments around Eskişehir. Altınlı (1973*a*) observed the Liassic fossil bearing lenticular red levels within flysch like deposits which he described earlier (Figures 9, 19).

According to the results of the study, the Campanian age of the Kapıkaya formation, the location and the characteristics of Gölpazarı – Söğüt line gains importance. As Altınlı (1973*a*) has suggested, this importance becomes apparent when transitioned into a different unit in the easteran side of Gölpazarı – Söğüt line. In this case, the existence of a new unit, which is Campanian in age and different than Bayırköy formation, should be mentioned at east, Sarıcakaya vicinity (Eskişehir). The age of the unit which Altınlı (1973*a*) has previously studied as Kapıkaya formation is not Liassic as it was also been known earlier, but is Campanian in age based on the paleontological data. The first and the most important result of the study is that the age of Kapıkaya formation according to the paleontological data is Campanian. Accordingly; there should be a terrestrial environment in the region just before the deposition of Kapıkaya formation. During this period, all Jurassic and early Cretaceous deposits (Bayırköy and Bilecik / Soğukçam formation) overlying the crystalline basement should have been eroded and later on the Kapıkaya formation should have transgressively been deposited over this basement.

According to the results of the study, it is also important that there is not any transition into a different unit in the eastern side of Gölpazarı – Söğüt line to the contrary what Altınlı had suggested (1973*a*). In other words; Bayırköy and Kapıkaya formations which were separately described by the investigator is actually the same and only one unit. Nevertheless; many investigators studied in the region considered the areas as Kapıkaya formation by Altınlı (1973*a*) into the Bayırköy formation (Saner, 1977, 1980; Şentürk and Karaköse, 1981, 1982; Göncüoğlu et al., 1996; Gedik and Aksay, 2002). Altınlı (1973*a*) considered the flysch like deposits as the major factor of depositional differentiation and pointed out that they are frequently encountered in western parts of Gölpazarı – Söğüt line as well. That is, the probability of Bayırköy and Kapıkaya formations to be the same and only one unit should not be neglected. Therefore; Campanian finding obtained in the vicinity of Sarıcakaya district and Kapıkaya village in this study should also be investigated and checked in all the areas which were mapped as Bayırköy formation. This investigation is very significant for the regional geology as Bayırköy formation is Liassic in age. For example; it is an important and widely accepted argument in the Geology of Turkey that the Bayırköy formation is folded and discordantly overlies Karakaya deposits (Yılmaz, 1981) and therefore; the Karakaya basin had been closed before the beginning of Liassic time which is known as the age of Bayırköy formation (Şengör and Yılmaz, 1983). It is a similar idea that Karakaya complex has formed the basement of Sakarya zone (Okay, 1984) or the association of Sakarya composite (Göncüoğlu et al., 1997). Bayırköy formation is important in the sense of its Liassic age because the deposits of Karakaya basin has discordantly been overlain by Bayırköy formation as it has been mentioned in many investigations (Bingöl et al., 1973; Akyürek and Soysal, 1983; Akyürek et al., 1984; Kaya et al., 1986; Kaya 1991;

Genç et al., 1986; Koçyiğit, 1987*a, b*; Okay et al, 1990, 1991; Göncüoğlu et al., 2000; Seymen, 1993, 1997; Yılmaz et al., 1997; Akyazı et al., 2001). The age of the Bayırköy formation is closely related with the geological evolution of the region when the Karakaya problem and Sakarya continent are regionally considered. Since the first studies carried out in the region, except for Altınlı (1973*a*), Liassic sediments have not been investigated as dividing into two different units but accepted as the same and one unit under the name of "Bayırköy formation". It is therefore important to investigate the Campanian age finding related with Kapıkaya formation in all areas known as Bayırköy formation. Similar results with that of the Sarıcakaya surround (the Campanian age) do not support the suggestion that the Karakaya basin has been closed before Liassic age (Şengör and Yılmaz, 1983) and this situation makes the closure age of the Karakaya basin and the existence of Sakarya continent more controversial.

The coexistence of Liassic ammonitico rosso facies rocks and Campanian fossils within the Kapıkaya formation may remind that, there is a similarity with Neptunian dykes considered to occur in Liassic deposits around Alacaatlı – Beytepe, Ankara (Deli and Orhan, 2007). The Campanian aged samples in the study area are taken from clayey levels with lateral continuity alternated with sandstone – siltstone beds and from sandy lenticular limestones. Karstic or joint fillings within Liassic deposits mentioned for Ankara surround were not observed in the study area (Deli and Orhan, 2007). As also mentioned in the article that, much ammonitic, Liassic, nodular, clayey limestone are in the form of blocks and filling within debris flow deposits that have both lateral and vertical transitions with sandstone – shale alternation. This alternation forms the main body of the Kapıkaya formation and do not have any lateral continuity either. For these reasons; the presence of the Neptunian dyke development within deposits of the study area is regardless.

Altınlı (1973*a*) and Saner (1980) proposed that the Kapıkaya formation filled out irregular reliefs of an older mountain range which had been worn out and become an Appalachian relief with a transgressive bottom relationship. Liassic aged, much ammonitic, nodular, marly limestone masses; red colored, fragmented, abraded ammonitic mudstone forms and Liassic, Neritic limestone pieces and blocks have been transported by turbiditic processes from marginal to the depositional basin.

Upper Jurassic – Lower Cretaceous Bilecik and/or Soğukçam formations horizontally cover the Kapıkaya formation in the study area (Figure 21). The age of this horizontal cover ranges from the Callovian – Oxfordian age in the lowermost level to Early Cretaceous towards upper layers. There is not observed any overturning on this horizontal cover, therefore the bottom contact relationship with the underlying Campanian aged Kapıkaya formation should be tectonical. In other words; there should be mentioned about the presence of a tectonism which resulted with horizontal movements in post Campanian. Bilecik and/or Soğukçam formations overthrusted on Kapıkaya formation by horizontal movements which became extinct in post-Campanian. The bottom contact relationship of Bilecik and/or Soğukçam formation is tectonical in the study area. Bayırköy formation should also be considered within this tectonical relationship as it has a sedimentary relationship with Bilecik formation. Kapıkaya formation consists of Liassic exotic blocks due to such tectonical relationship. These blocks have been transported into the basin by being detached from the rocks which has sedimentary relation with Bilecik formation (Figures 9, 15). Late Cretaceous tectonism which is closely related with Bilecik and/or Soğukçam formations is quite new and significant for the region.

With this study; the age, depositional environment, facies characteristics and the name of formation for the Kapıkaya formation have been evaluated in detail. Also, the probable relationships of this formation with Bayırköy formation and its effects on the regional geology have been discussed.

Acknowledgment

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DESCRIPTIONS OF TWO NEW FAMILIES, THREE NEW SPECIES AND RE-DESCRIPTION OF FOUR KNOWN GENERA AND ONE SUBFAMILY FROM THE LARGER BENTHIC FORAMINIFERA OF PALEOCENE IN TURKEY

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Key words :
Foraminifera,
taxonomy,
Paleocene,
Turkey.

ABSRACT

Two new foraminiferal families are introduced as follows: the Anatoliellidae (type genus *Anatoliella* Sirel) in the superfamily Ataxophragmiacea Schwager and the family Bolkarinidae (type genus *Bolkarina* Sirel) in the superfamily Orbitoidacea Schwager. Three new species of Paleocene are described and figured as follows: *Ranikothalia polatliensis, Nurdanella paleocenica, Periloculina yilmazi.* In addition, four known Paleocene genera such as *Bolkarina* Sirel, *Globoflarina* Rahaghi, *Nurdanella* Özgen and *Coskinon* Hottinger and Drobne and subfamily Globoflarininae are redescribed.

1. Introduction

1.1. The Aim of the Study

The description of Paleocene and partly early Eocene shallowest-shallow- water foraminiferal taxons have previously been reported from the various localities of Turkey (Figure 1) by Sirel (1981, 1988, 1992, 1994, 1996*a, c, d,* 1997*a, b,* 1998*a ,b* and 1999). The aim of this study is to review the foregoing studies by the generic new data. On this occasion, two new benthic foraminiferal families were established as follows: the ataxophragmid genera such as Thanetian genus *Anatoliella* Sirel (1988) were transferred to the new families Anatoliellidae (type genus *Anatoliella*) by the differentiated structural elements of the endoskeleton and exoskeleton. On the other hand, Daniyen-early Thanetian so-called miscellanid genus *Bolkarina* 1981 has been placed in the new family Bolkarinidae by the numerous small chamberlets with annular and radial stolons and lateral chambers. Four known Paleocene foraminiferal genera, viz the Daniyen-early Thanetian genus Bolkarina (type species *B. aksarayensis* Sirel, 1981), Thanetian, Lutetian genus *Nurdanella* Özgen (type species *Nurdanella boluensis* Özgen, 2000) and early Thanetian genus Coskinon Hottinger and Drobne (type species *Coskinolina (Coskinon) rajkae* Hottinger and Drobne, 1980) late Danian-early Selandian alveolinid genus *Globoflarina* Rahaghi, 1983 (type species *Cyclorbiculina ? sphaeroidea* Fleury, 1982) and subfamily *Globoflarininae* Sirel, 1998 are redescribed by the new generic features. In addition, three new foraminiferal species are described and figured as follows: *Ranikothalia polatliensis* n.sp. from the late Thanetian-early Ilerdian of the Polatlı area, Central Turkey and *Nurdanella paleocenica* n.sp.,*Periloculina yilmazi* n.sp. from the Thanetian of the Van region, Eastern Turkey (Figure 1).

All the random, oriented thin sections and free specimens of the foraminiferal species described and figured in this paper are deposited in the collection of General Directorate of Mineral Research and Exploration (MTA), Ankara, Turkey and Muséum d'Histoire Naturelle de Genève, under the numbers shown in Plates I-VII figure 1.

2. Systematic Paleontology

Two new families, Anatoliellidae and Bolkarinidae are introduced as follows:

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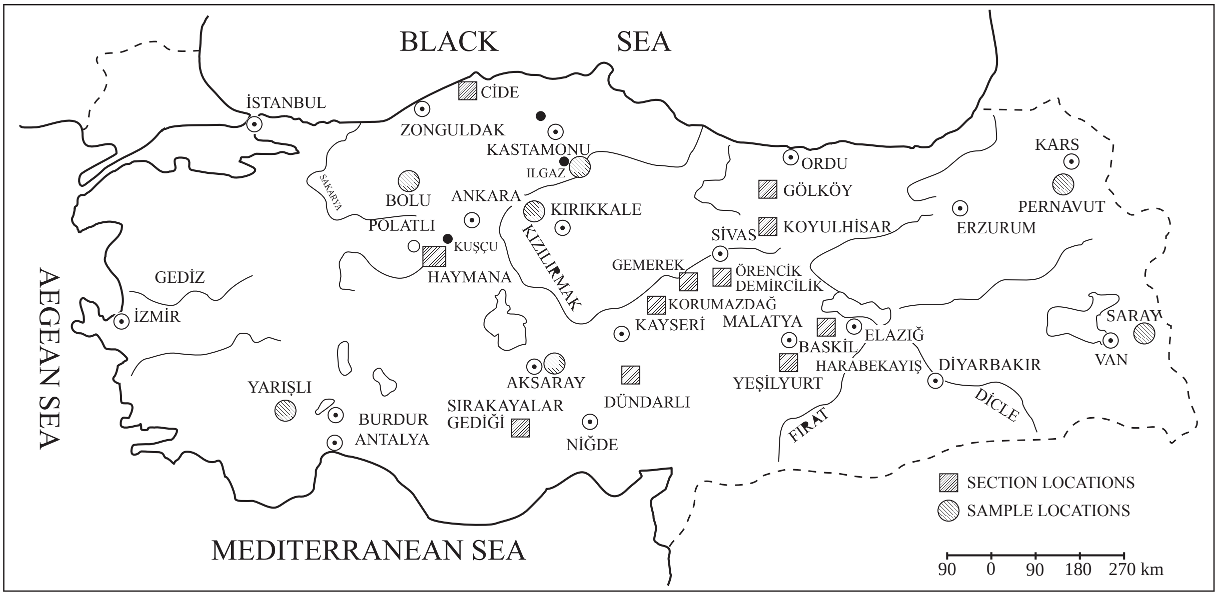

Figure 1- Location map, showing the localities of the measured sections and spot samples in Turkey.

Anatoliellidae n.fam.

Superfamily : Ataxophragmiacea Schwager, 1877

Family : Anatoliellidae n.fam.

Type genus : *Anatoliella* Sirel, 1988

Type species : *Anatoliella ozalpiensis* Sirel, 1988

Description : The description of the new family is based on Schroeder and Darmoıan (1977) and Sirel (1988). The genera of the new family have a conical test with agglutinated wall. The large subspherical-spherical protoconch is followed by a second chamber and few arcuate undivided chambers, arranged in a trochospiral pattern during the early ontogeny, but the divided inflated dome-like adult chambers are arranged in triserial-trochospiral mode in the late ontogeny The marginal zone (exoskeleton) are divided by several generations of the vertical (beam) and horizontal rafters) partitions and they form numerous irregular alveolar compartments in each chamber. The intricated central part of the test (endoskeleton) has few thick irregular pillars recognized at the well oriented vertical sections, on the contrary, numerous basal foramina are recognized in the horizontal section The dimorphism is distinct.

Age : Maastrichtian, Thanetian.

Remark.-The Maastrichtian genus Gyroconulina and the Thanetian genus Anatoliella have previously been placed in the family Ataxophragmiidae Schwager by Schroeder and Darmoian (1977) and Sirel (1988) respectively, although *Gyroconulina* and *Anatoliella* have a high conical, test with agglutinated wall, complex exoskeletal zone with three orders of vertical and horizontal partitions or both, resulting in a subepidermal alveolar compartments, On the other hand, in the latest foraminiferal classification of Loeblich and Tappan (1987, p. 153) the numerous genera together with *Gyroconulina* have been placed in the family Pfenderinidae Smout and Sugden, in spite of the fact that they have not dome-like triserial adult chambers with foregoing endoskeletal and exoskeletal structural elements, except *Gyroconulina*. So that, Gyroconulina and Anatoliella were transferred to the new family *Anatoliellidae.*

Anatoliella ozalpiensis Sirel, 1988

(Plate I, figures 1-12, Figure 2)

1988 *Anatoliella ozalpiensis* Sirel, page 478, plate I, figures 1-9, plate II, figures 1-11.

1990 *Anatoliella ozalpiensis* Sirel, Radoicic, page 92, plate 5, figure 5.

1991 *Anatoliella ozalpiensis* Sirel, Radoicic, page 58, plate 6, figure 1.

1995 *Anatoliella ozalpiensis* Sirel, İnan, page 109-118, plate II, figures 9,10.

1998*b* *Anatoliella ozalpiensis* Sirel, Sirel, page 46, plate 7, figures 6-11, plate 8, figures 9,10.

2008 *Anatoliella ozalpiensis* Sirel, Boudagher-Fadel, page 304, plate 6.2, figure 4.

Description : The type species of the Anatoliellidae n. fam. illustrated in Plate I, figures 1-12 have a high conical tests with complex endoskeletal and exoskeletal partitions in the both generations (Figure 2). The maximum cone height and horizontal diameter are 3.56 mm and 2 mm in the microspheric forms and 1 mm, 1.06 mm in the megalospheric forms respectively The megalospheric embryo consists of a large, subspheric protoconch (0.200-0.300 mm in diameter) with a semilunar second chamber followed by few, low trochospiral undivided early chambers (Plate I, figures 5,9, Figure 2 C). More inflated (dome-like) adult chambers of the late ontogeny are arranged in the triserial mode (Figures 2 D,E). All the endoskeletal and exoskeletal structural elemennts of the dome-like adult chambers are given in Figure 2.

Stratigraphic and geographic distribution : This conical, triserial foraminiferal species with complex structure has been found together with *Pseudodictyokathina vanica* (Sirel), *Karsella hottingeri* Sirel, *Miscellanea juliettae* Leppig, *Soriella bitlisica* Sirel, *Dictyoconus baskilensis* Sirel, *Sistanites* sp. and Miliolidae in the Thanetian limestone blocks within the ophiolitic melange near the village of Saray, NE of Van, Eastern Turkey, (type locality, Figure 1). It occurs in the Paleocene algal limestone of Iraq and Bosnia, where it is associated with algal species described by Radoicic (1990, p. 92 and 1991, p. 58) respectively. It is associated in the Thanetian limestone of Koyulhisar area, N of Sivas, Eastern part of the Central Turkey, with *B. aksarayensis* and algae (İnan, 1995).

Bolkarinidae n.fam.

Superfamily : Orbitoidacea Schwager, 1876

Family : Bolkarinidae n. fam.

Type genus : *Bolkarina* Sirel, 1981

Type species : *Bolkarina aksarayi* Sirel, 1981

Description : The microspheric and megalospheric generations of the type genus *Bolkarina* have a large, thin and undulating lenticular test. The spheric microsphere and megalosphere are followed by numerous small arcuate chambers arranged in a planispiral-involute pattern. The thin septa have characteritically bifurcate intraseptal canals. later adult chambers with subrectangular-poligonal chamberlets are arranged in an annular mode; the connections of between adjacent chamberlets are provided by annular and radial stolons. The broad lateral chambers appear at the both sides of the test of the two generations. Also, the pillars and radial canals (funnels) are developed at the both sides of early stage of two generations. Selandian-early Thanetian.

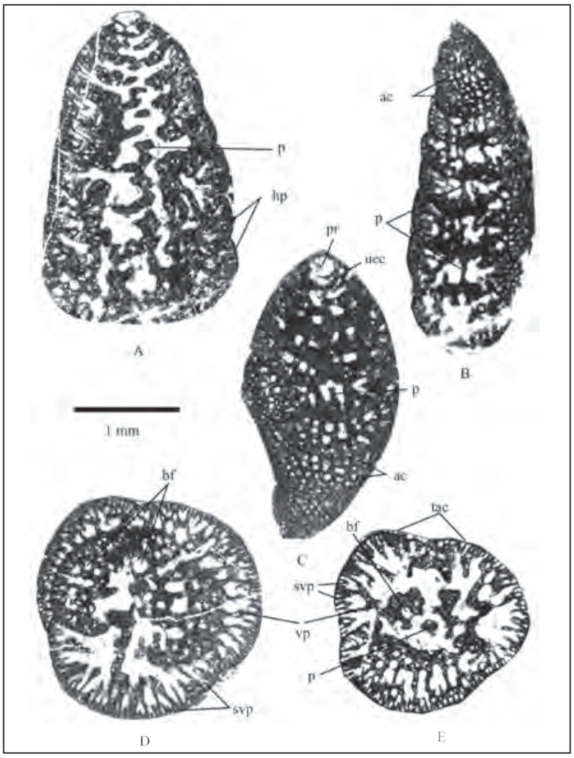

Figure 2- Structural elements of *Anatoliella* Sirel (type genus of Anatoliellidae n.fam.), all figures from Sirel (1988), scale bar 1 mm. A: Vertical section, B form, B: Oblique vertical section, B form C: Centered, oblique vertical section A form, , D: Slightly oblique horizontal section, B form, E: Horizontal section, B form, pr: protoconch. uec: undivided early chambers. p: pillars. hp: horizontal partitions (rafters). vp: vertical partitions (beams). svp: shorter vertical partitions. tac: triserial adult chambers. bf: basal foramina.

Remark : In the original description, the type genus *Bolkarina* has been placed in the family Miscellaneidae Sigal in its planispiral-involute early chambers with pillars by Sirel (1981). In late classification of the foraminiferal genera, the family Miscellaneidae has been suppressed by Loeblich and Tappan (1987, p. 681) and the genera *Miscellanea* and *Bolkarina* have been placed in Pellatispiridae Hanzawa. Last of all, *B. aksarayensis* has been shown in the new family Miscellanitinae within the family Miscellaneidae by Hottinger (2009, p. 2,7). According current knowledge of us, Bolkarina (type species *B. aksarayensis*) shows close similarities with the known taxons of Orbitoidacea Schwager by the lateral chambers on the both sides and annular chambers with subrectangular-hexagonal chamberlets with annular and radial passages (stolons). Besides, the genera of Miscellaneidae and Pellatispiridae definitelly differ from Bolkarina in having the canal system (marginal sutural and spiral canals), septal and umbilical flaps. Otherwise, the genera of the foregoing two families are devoid of the annular chambers, subrectangular-hexagonal chamberlets with radial and annular stolons and lateral chambers of Bolkarina. Therefore, the genus *Bolkarina* was transferred to the new family Bolkarinidae within the superfamily Orbitoiddacea Schwager.

2.1 Redescription of Four Foraminiferal Genera and One Subfamily

In this chapter, the known four Paleocene genera such as *Bolkarina* Sirel, *Nurdanella* Özgen, *Coskinon* Hottinger and Drobne, *Globoflarina* Rahaghi and its subfamily Globoflarininae were re-described in the light of the current generic knowledge.

Bolkarina Sirel, 1981

Redescription : The redescription of the type genus *Bolkarina* is entirely based on the Selandian specimens which are collected from the various locality of Turkey, figure 3 (see the chapter of the stratigraphic and geographic distribution of *B. aksarayensis*). All the previously known and new diagnostic structural elements of *Bolkarina* are given in the chapter of Bolkarinidae n. fam.

Remark : The dimorphic *B. aksarayensis* has characteristically planispiral arcuate early chambers with bifurcate itraseptal canal, the annular adult chambers with stolonuferous subrectangular-polygonal chamberlets and lateral chambers. It occurs abundantly in the Selandian algal limestones of the various localities of Turkey (Figure 1). Also it occurs rarely in the algal limestones of the lowermost Thanetian. On the other hand, the apperance of *Bolkarina* in Danian was reported by Drobne et al. (1988), that is an important phylogenetic data for the evolution between late Cretaceous and Thanetian benthic foraminifera with stolon systems and lateral chambers. According to the current knowledge, all the representatives of foraminiferal Orbitoididae Schwager and Lepidorbitoididae Vaughan disappeared at the end of Cretaceous or at the beginning of Tertiary by the C/T crisis (mass extinction). On the contrary, the orthophragminid genera appear in Thanetian. Because of the existence of the foregoing diagnostic structural elements of Bolkarina (particularly stolon system and lateral chambers), the Danian-early Thanetian genus *Bolkarina* has been considered as a transition form between the late Cretaceos orbitoidids, lepidorbitoidids and Thanetian orthophragminids with stolons and lateral chambers.

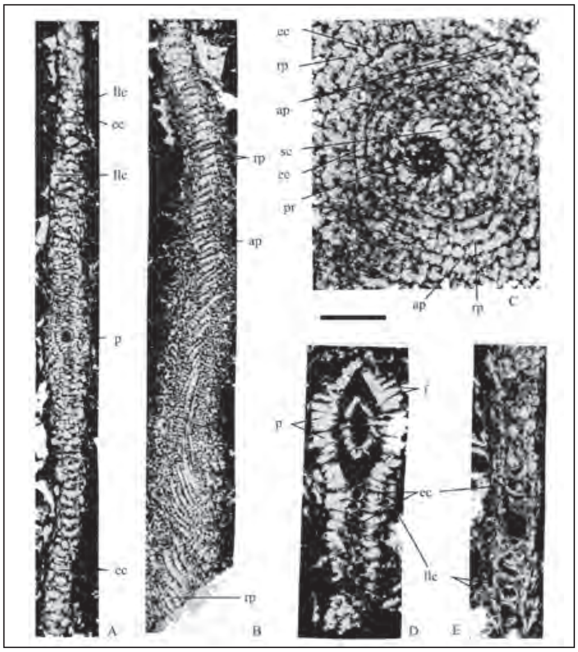

Figure 3- Structural elements of *Bolkarina* Sirel (type genus of Bolkarinidae n.fam.); all figures from Sirel (1981), scale bar in Figure. A: Axial section of B form, scale bar= 1.26 mm, B: Tangential section of B form, scale bar= 1.54 mm, C: Central portion of equatorial section, enlarged from Plate II, figure 1, B form, scale bar= 0.35 mm; D: Incomplete subaxial section of A form, scale bar= 0.4 mm, E: Incomplete subaxial section of B form, scale bar= 0.83 mm. pr: proloculus, sc: spiral chamber, ec: annular equatorial chamberlets, llc: lengthened lateral chambers, ap: annular passages (stolons), rp: radial passages (stolons), p: pillars, f: funnels.

Bolkarina aksarayensis Sirel, 1981

(Plate. II, figures 1-7, Figures 3 A-E),

1981 *Bolkarina aksarayi* Sirel, page 79-82, plate 1, figures 1-3, plate 2, figures 1-4, plate 3, figures 1-6.

1987 *Bolkarina aksarayi* Sirel, Loeblich and Tappan, page 681, plate 801, figures 1-5.

1998*b* *Bolkarina aksarayensis* Sirel, Sirel, page 92-93, plate 53, figures 1-4.

2004 *Bolkarina aksarayensis* Sirel, Sirel, page 53-57, plate 49, figures 1-3, plate 50, figures 1-4, plate 51, figures 1-6.

2009 *Bolkarina aksarayensis* Sirel, Hottinger, page 10-12, Figure 3, plate 21, figures 1-6, plate 22, figures 1-9, plate 23, figures 1-5, plate 24, figures. 1-9, plate 25, figures 1-5.

Description : The description of the megalospheric form is based on the incomplete centered subequatorial section (Plate II, figure 2). According to this specimen, its radius reaches 1.62 mm and the external surface of it is covered by granules. The small spheric megalosphere (0.80 mm in diameter) is followed by 22 arcuate early chambers arranged in planispiral-involute two whorls, measured from the incomplete specimens (Plate II, figure 2). The later stage consists of annular chambers with numerous chamberlets as in the microspheric generation.

The microspheric form has a large, undulating thin discoidal test with an equatorial diameter up to 21 mm and thickness of 1 mm. The microsphere is relatively small, subspherical and its diameter is 0.65 mm. It is followed by arcuate spiral chambers of the early stage, arranged in planispiral-involute 3-3.5 whorls (Plate II, figures 3,6). The adult stage has 64 annular chambers including numerous subrectangular-polygonal chamberlets with radial and annular stolons.

Stratigraphic and geographic distribution : *B.aksarayensis* occurs abundantly in the following localities:

It abounds in the hard, brown-coloured Selandian algal limestone of the type locality, Tilkitepe and Kocaağıldere, approximately 2 km SW of Karandere village, NW of Aksaray, Central Turkey (Figure 1), It is associated there with *Pseudolacazina oeztemueri* (Sirel), *Pseudolacazina donatae* (Drobne), *Akbarina primitiva* (Rahaghi) , *Idalina sinjarica* Grimsdale, *Hottingerina* sp. and Miliolidae.

It occurs in brown-coloured Selandian algal limestone of Mahmutlar village, NW of Kırıkkale, Central Turkey (Figure 1), with *P. oeztemueri*, *P. donatae, A. primitiva,* Peneroplidae and Miliolidae.

It is found in the white-coloured Selandian algal limestone of the Yarışlı area, NW of Burdur, Southern Turkey (Figure 1), with G. sphaeroidea, Sistanites iranica Rahaghi, I. sinjarica, A. primitiva, undetermined micellanid genus and Miliolidae.

It occurs in the light brown-coloured Selandian limestone of Sırakayalar gediği, approximately 25 km N of Bolkar mountains (Sirel, 1998*b*, Figure 16), with *P. oeztemueri, P. donatae, I. sinjarica, A. primitiva* and Miliolidae.

It was observed in the Selandian algal limestones, of the Örencik and Demircilik villages, W of Gürlevik mountains, S of Sivas, Central Turkey (Sirel, 1998b, Figure. 18), with *P. oeztemueri, P. donatae,* undetermined keramospherid genus and Miliolidae.

This species abounds in the Selandian limestones of the Çaldağ, (Sirel, 2009, Figure 2) and Babayakup sections, W of Ankara (Sirel,1998*b*, Figure 11) with numerous foraminiferal species.

It occurs in the Selandian-lowermost early Thanetian limestones of the Bahçecik section with numerous species, S Ankara (Sirel, 2009, Figure 5).

B. aksarayensis occurs rarely in the early Thanetian limestone of the Harabekayış section, W Elazıg (Sirel, 2009, Figure 10) associated with *M. juliettae, Lockhartia diversa* Smout, *Elazigina harabekayisensis* Sirel, *Planorbulina cretae* (Marsson), *Kathina? selveri* Smout and Miliolidae.

Globoflarininae Sirel, 1998

Superfamily : Alveolinacea Schwager, 1876

Family : Alveolinidae Ehrenberg, 1839

Subfamily : Globoflarininae Sirel, 1998

Genus : *Globoflarina Rahaghi*, 1983

Type species :*Cyclorbiculina ? sphaeroidea* Fleury 1982

Redescription : The subfamily Globoflarininae was first described by Sirel (1998*b*, p. 68). It was reorganized by the following new additional generic structural elements of the type genus Globoflarina Rahaghi (Figure 4). Test free, nautiloid to subspheric, the arrangement of the early chambers are triloculine in megalospheric and quinqueloculine in microspheric generations, later planispiral chambers subdivided by aligned septula into numerous chamberlets. One row of alveols are connected with the preseptal passage of preceeding chamber by intercalar (secondary) apertures (as keyhold-shaped), main apertures (intercameral foramen) located just above the septum.

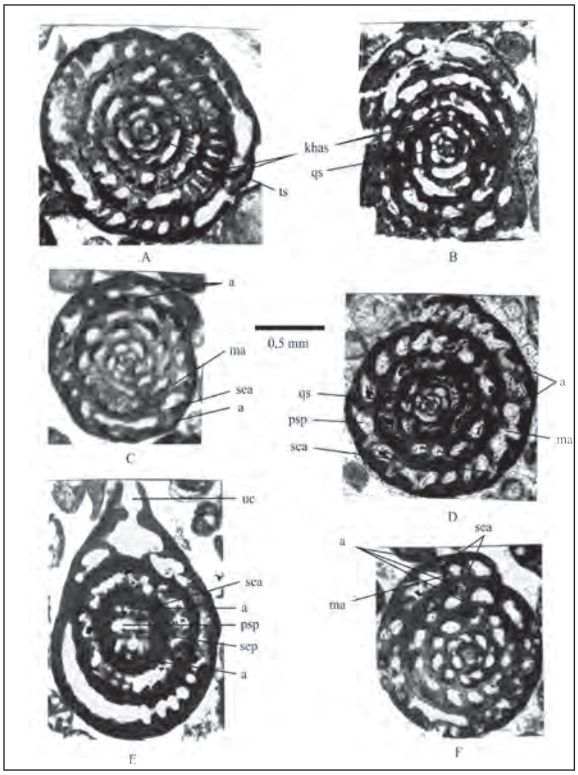

Figure 4- Structural elements of *Globoflarina* Rahaghi (type genus of Globoflarininae Sirel), all figures from Sirel (1998*b*, plate 32,33,34). Scale bar in figure. A: Slightly oblique equatorial section of A form, B: Slightly oblique axial section of B form, C: Equatorial section, probably young B form, D: Equatorial section of B form, scale bar= 0.4 mm,E: Tangential section; F: Non centered equatorial section; ts: triloculine stage, qs: quinqueloculine stage, ma: main aperture, sea: secondary aperture, a: alveols, khas: key-holes apertural system (alveols and secondary apertures together), sep: septula, psp: preseptal passage, uc: uncoiled chambers.

The gerontic uncoiled chambers have incomplete subepidermal partitions and multiple apertural openings (cribrate).

Remark : The type genus of the new subfamily differs from the known genera of Alveolinidae in having uncoiled chambers with subepidermal partitions and cribrate aperture.

Globoflarina Rahaghi, 1983

New description : The redescription of *Globoflarina* Rahaghi (1983) is based on the Anatolian specimens illustrated in (Plate III, figures 1-10, Plate IV, figures 1-6 and Figures 4 A-F). The dimorphic, alveolinid genus has large, nautiloid to subspheric test with imporforate, percellaneous calcareous wall. The spheric, large megalosphere and the small microsphere are followed by one cycles of triloculine chambers in the megalospheric and two cycles of quinqueloculine undivided early chambers in the microspheric forms. The following planispiral adult chambers are subdivided by aligned septula into numerous small chamberlets. The planispiral whorls increase rapidly in height as added, so that the adult test uncoil and become flabelliform in the microspheric generation. The chambers in the flabelliform stage are subdivided by numerous incomplete subepidermal partitions. The main aperture (intercameral foramina) located at the middle part of the septa recognized best in the equatorial sections. The planispiral chambers has one row of alveols which are connected with preseptal passage of preceding chamber by intercalar foramina (as keyholes-shaped) in the septum. The connection between the flabelliform adult chambers provide by the numerous openings (cribrate). Occasionally, the uncoiled chambers develope at the both sides of the test

Remark : The globular specimens was first described and figured as *Cyclorbiculina ? sphaeroidea* from the Paleocene of Greece by Fleury (1982), despite the fact that it has typical alveolinid characters: namely, milioline juvenile chambers, planispiral adult chambers with chamberlets preseptal passage, main and secondary aperture. Later on, the same foraminiferal taxon was introduced as a new genus *Globoflarina* from the upper Paleocene of Iran by Rahaghi (1983). But, the diagnosis of the genus was devoid of the adequately generic features in Rahaghi (1983), therefore, *Globoflarina* was here redescribed by the materials of Sirel (1998*b*), Fleury (1982) and Rahaghi (1983).

Globoflarina sphaeroidea (Fleury, 1982)

(Plate III, figures 1-10, Plate IV, figures 1-6; Figures 4 A-F)

1982 *Cyclorbiculina* ? *sphaeroidea* Fleury, page 160, plate 1, figures 1-9, plate 2, figures 1-11.

1983 *Globoflarina sphaeroidea* (Fleury), Rahaghi, page 43, plate 15, figures 1-8, plate 16, figures 1-12, plate 17, figures 1-12.

1998*b* *Globoflarina sphaeroidea* (Fleury), Sirel, page 68-71, plate 32, figures 1-8, plate 33, figures 1-9, plate 34, figures 1-11.

2009 *Globoflarina sphaeroidea* (Fleury), Sirel, plate IV, figures 1-4.

Description : The test is large, nautiloid to subspheric, slightly depressed at the direction of the coiling axis (Plate III, figures 3,4, Plate IV, figures 2,3,6). The index of elongation reaches 1.75 in the microspheric form, at least 1.5 in the megalospheric specimens. The equatorial diameter ranges from 1,6 mm to 1.75 mm and from 1.3 mm to 1.6 mm in the microspheric and megalospheric generations respectively. The largest length of the uncoiled stage reach 6.5 mm. The spherical megalosphere (0.150-0.160 mm in diameter) is followed by one cycles of undivided triloculine chambers reaching 0.370 mm diameter. Later planispiral whorls are divided by thick septa into numerous chambers with chamberlets in both generations. The microspheric test is composed of two rows of quinqueloculine early, planispiral adult and uncoiled senile chambers.

Stratigraphic and geographic distribution : It occurs in the Selandian limestones of the Yarışlı area, W of Burdur, Southern Turkey (Figure 1). It is associated there with *B. aksarayensis, Laffitteina erki* (Sirel), *A. primitiva*, undetermined miscellanid genus, *I. sinjarica* and *Miliolidae*.

It is found in the late Danian-early Selandian limestones of Bolu area, Western Turkey (Figure 1), with Laffitteina mengaudi (Astre), minimiscellanid type and abundant Miliolidae.

Nurdanella Özgen, 2000

Superfamily : Miliolacea Ehrenberg, 1839

Family : Hauerinidae Schwager, 1876

Genus : *Nurdanella* Özgen, 2000

Type species : *Nurdanella boluensis* Özgen, 2000

Redescription : The redescription of the genus is based on Özgen (2000) and here described *Nurdanella paleocenica* n. sp. (Plate IV, figures 7-12). Two generations have subspheric to ovoid test with imperforate, porcellaneous calcareous wall (Özgen, 2000, plate I, figure 4) and (Plate IV, figure 7). Very small microsphere is followed by two rows of quinqueloculine chambers (Özgen, 2000, plate I, figures 3,7,12,14) and (Plate IV, figure 13). Later undivided adult chambers are arranged in a planispiral pattern (Özgen, 2000, plate I, figure 1, Figure A) and (Plate IV, figures 9,11). The connection of the long and low planispiral chambers provide by the crenated/notched aperture (Özgen, 2000, plate I, figure 4) and (Plate IV, figure 7).

The megalospheric form has a small, subspheric test with imperforate porcellaneous calcareous wall (Özgen, 2000, plate I, figures 10,11). Almost spheric and large megalosphere is followed by 1-1.5 rows of triloculine early chambers (Özgen, 2000, plate I figures 10, 11). Later undivided adult chambers are coiled in a planispiral mode (Plate IV, figure 13). Dimorphism distinct, Thanetian, Lutetian.

Coskinon Hottinger and Drobne, 1980

Ataxophragmiidae : Ehrenberg, 1839

Family : Coskinolinidae Moullade, 1965

Genus : *Coskinon* Hottinger and Drobne, 1980

Type species : *Coskinolina (Coskinon) rajkae* Hottinger and Drobne, 1980

Redescription : It is largely based on Hottinger and Drobne (1980) and partly here described species in (Plate V, figures 1-5). Two generations have large and high conical test with keriothecal wall. The subspheric proloculus is followed by more than five rows of biserial (like-textularine) early chambers, later adult chambers bocome uniserial (Hottinger and Drobne, 1980, plate 2, figures 2,4, plate 12, figures 18, 19, 22, 23). The marginal zone (exoskeleton) is devoid of the vertical and horizontal partitions. The weakly developed endoskeletal pillars appear as from the last biserial textularine chambers Hottinger and Drobne (1980, plate 12, figures 1, 18-21). The basal foramina are scattered in central part of the cone (Hottinger and Drobne, 1980, plate 12, figures 9,16).

Remark : The Ataxophragmid genus was first described and figured as a subgenus of *Coskinolina* Stache (type species *Coskinolina (Coskinon) rajkae* Hottinger and Drobne) from the early Thanetian of Yugoslavia by (Hottinger and Drobne, 1980, page 231). Later on, this benthic subgenus was introduced as the new genus *Coskinon* (type species *Coskinolina (Coskinon) rajkae* Hottinger and Drobne) by Loeblich and Tappan (1987, page 155). Unfortunately, the generic features of *Coskinon*, particularly in the early chambers have not been adequately described by the foregoing authors. Whereas, the vertical sections of Hottinger and Drobne clearly show that the early chamber arrangement is biserial (textularine) (Hottiger and Drobne, 1980, plate 12, figures 18,19, 21-23); and endoskeletal pillars begin as from the last biserial chambers (Hottinger and Drobne, 1980, plate 2, figure 4, plate 12, figures 18,19,21). The genus *Coskinon* differs from *Coskinolina* Stache in possessing five rows of the biserial textularine chambers in the early ontogeny, whereas the early chambers of *Coskinolina* are arranged in trochospiral pattern in Hottinger and Drobne (1980).

Coskinon rajkae Hottinger and Drobne, 1980

(Plate V, figures 1-5)

1980 *Coskinolina (Coskinon) rajkae* Hottinger and Drobne, page 231, plate 2, figures 2,3,4, plate 12, figures 1-28, Figure 2.

1987 *Coskinon rajkae* Hottinger and Drobne, Loeblich and Tappan, page 155, plate 166, figures 2-6.

1998b *Coskinolina (Coskinon) rajkae* Hottinger and Drobne, Sirel, page 47, plate 9, figures 6-10.

Description : Only megalospheric form has been observed in the early Thanetian limestone of the Harabekayış section (Sirel, 1998*b*, plate 9, figures 6-10 and 2009, Figure 10). The test has medium sized, high conical with convex base. The maximum cone height and basal cone diameter are 1.76 mm and 1.75 mm respectively. The ratio basal cone diameter to vertical cone height is 0.67-1.17. The megalosphere (0.100-0.140 mm in diameter) is followed by few biserial textularine early chambers (Plate V, figures 1,2). The exoskeletal elements (vertical and the horizontal partitions) are absent in the marginal zone.

Stratigraphic and geographic distribution : This species occurs in the early Thanetian limestones of the Harabekayış section (Sirel 2009, Figure 10), S of Baskil town, W of Elazığ, Eastern Turkey. It is associated there with *Glomalveolina primaeva* (Reichel), *Vania anatolica* Sirel and Gündüz, *Hottingerina anatolica* Sirel, *Haymanella paleocenica* Sirel, *I. sinjarica, Pseudobroeckinella flabelliformis* Sirel, *Kathina* sp. and Miliolidae.

2.2 Description of Three Species

In this chapter, the description of three new foraminiferal species are introduced as follows:

Superfamily : Nummulitacea De Blainville, 1827

Family : Nummulitidae De Blainville, 1827

Genus : *Ranikothalia* CaudriI, 1944

Type species : *Ranikothalia nuttalli* Davies, 1927

Ranikothalia polatliensis n.sp.

(Plate V, figures 6-9, Plate VI, figures 1-13)

1998*b* *Ranikothalia sindensis* (Davies), Sirel, page 105, plate 64, figures 1-13, plate 65, figures 1-7.

Derivation of name : Polatlı is a town in the Ankara region, Central Turkey.

Holotype : Subaxial section, illustrated in Plate VI, figure 1.

Type locality : In the Kuşcu village, 15 km SE of Polatlı, SW of Ankara, Central Turkey (Figure 1).

Type level : Late Thanetian?-early Ilerdian.

Diagnosis : The microspheric generations have a flattened and large lenticular test with rounded periphery (Plate V, figures 7,9, Plate VI, figure 13), on the contrary, the test becomes inflated lenticular in the megalospheric form (Plate VI, figures 3, 9-11). The diameter of the microspheric test ranges from 3.7 mm to 6.5 mm and the thickness from 0.7 mm to 1.1 mm. The large, subrectangular chambers are arranged in a planispiral-involute whorls and the interval of the spirals increases suddenly toward the last whorl (Plate VI, figure 1). The marginal cord is strongly thickened and developed, in which numerous marginal sutural canals form thick layer of network (Plate V, figures 6,9, Plate VI, figures 7,13).

The inflated lenticular megalospheric test with rounded periphery is middle size. The diameter of the test ranges from 2 mm to 3.1 mm and the thickness from 1 mm to 1,2 mm. The ovoid megalosphere (0.350 X 0,450 mm in diameter) is followed by semilunar second chamber (Plate VI, figures 6,8) and subrectangular numerous chambers. The interval of the whorls increases gradually from the first to the last whorl. The bifurcate intraseptal canals are probably connected with the marginal canals (Plate VI, figure 8) There are 26 chambers in the last whorl measuring 2.9 mm in diameter (Plate VI, figure 8).

Remark : The microspheric form of *R. polatliensis* differs from *R. sindensis* in its loosely coiled whorls with large chambers and rather thickened marginal cord with developed marginal sutural canals (Plate V, figures 6,9, Plate VI. figures 7,8,13). It is distinguished from the type species *Ranikothalia nuttalli* (Davies) in possessing smaller test, thickened marginal cord with developed marginal sutural canals.

Stratigraphic and geographic distribution : All the material concerning this study are collected from the Kuşçu village, SE of Polatlı, SW of Ankara (Figure 1). It occurs aboundingly in the sandy limestone without foraminiferal species, so that its age could not be safely fixed. However the sandy limestone with new species comformably ovelies the sediments of the Paleocene Kartal formation in the type locality. Considering the stratigraphic position of the sandy limestone with *R. polatliensis,* the age of the new species has been thought as early Ilerdian than late Thanetian.

Nurdanella paleocenica n.sp.

(Plate IV, figures 7-13)

1998*b* Unidentified miliolid genus, Sirel, page 51-51, plate 19, figures 1-3, 5,6.

Derivation of name : It occurs in Paleocene.

Holotype : Axial section, figured in Plate IV, figure 7.

Type locality : Exotic limestone block within the ophiolitic melange, near the Saray village, northeast of Van, Eastern Turkey (Figure 1).

Type level : Thanetian (SBZ 3-4).

Diagnosis : The generic characters of the genus are given in the chapter of the re-description of *Nurdanella* Özgen. The microspheric form of the dimorphic miliolid with notched /crenated aperture has a ovoid test with imperforate porcellaneous calcareous test. The largest axial and equatorial diameters reach 1.87 mm and 1,62 mm respectively. The early chambers are arranged in a quinqueloculine pattern (Plate IV, figure. 13). Later adult chambers are coiled in a planispiral mode (Plate IV, figures 9-11). There are 5-6 long and low planispiral chambers in an equatorial sections (Plate IV, figures 8,9).

The specific features of the macrospheric generation are based on only one almost centered equatorial section (Plate IV, figure 11), its diameter is 0.82 mm. The megalosphere (about 0.100 mm in diameter) is followed by probably triloculine early chambers. Later adult chambers are arranged in a planispiral pattern. There are three long and low planispiral chambers in the last whorl of the equatorial section.

Remark : The new species *N. paleocenica* differs from the type species *Nurdanella boluensis* Özgen in its smaller test with low chambers; in addition, the new species has 5-6 chambers in the last whorl of microspheric form (Plate IV, figure 9), whereas There are two chambers in the last whorl of the holotype of *N. boluensis* Özgen (2000, plate 1, figure 1).

Stratigraphic and geographic distribution.- The new species is found in the Thanetian exotic limestone blocks within the ophiolitic melange, located near the Saray village, NE of Van (Figure 1), with abundant foraminiferal species, such as *P. vanica, D. baskilensis, P. flabelliformis, A. ozalpiensis, I. sinjarica* and Miliolidae.

Periloculina Munier-Chalmas and Schlumberger, 1885

Description : The diagnostic characters of *Periloculina* is based on here described *Periloculina yilmazi* n.sp., Drobne (1974 and 1984), Loeblich and Tappan (1987) and Hottinger et al. (1989).

The dimorphic fabularid genus has a ovoid test with central annular trematophore. The trematophoric system is located alternatively crowning the upper or lower, flattened surface of the test with numerous openings supported by pillars (Plate VII, figures 1,11,13); the wall is imperforate, porsellaneous calcareous. Microspheric ovoid test has two cycles of undivided pleuroloculine (probably quinqueloculine) chambers of the juvenile stage (Plate VII, figures 2,4), (Drobne, 1974, plate 11, figures 2,3,6; 1984, plate 2, figure d, plate 5, figures 1,5,7). Later few cycles of divided chambers become biloculine and finally 4-7 cycles of monoloculine (Plates VII, figures 1,4,11,12). The biloculine and monoloculine chambers of the adult stage are subdivided by continuous, longitudinal septula or ribs into numerous chamberlets (Plate VII, figures 3,4,12), (Drobne, 1984, plate 5, figures 5-7) and (Hottinger et al.,1989, plate 23, figure 9) .

Megalospheric generation has a slightly elongated ovoid to subspheric test. The large megalosphere with bottle-neck (Plate VII, figure 9), (Drobne, 1984, plate 4, figures 13,15) is followed by one and half cycles of the undivided triloculine chambers (Plate VII, figures 5,8,10), (Drobne, 1984, plate 2, Figures h-k), later biloculine chambers (Plate VII, figures 7,9), (Drobne, 984, plate 2, figures h-k) are subdivided by septula into numerous chamberlets. The trematophoric aperture supported by pillars, recognized in the well oriented equatorial sections (Plate VIII, figures 9,13) and (Drobne, 1984, plate 4, figure 2).

Periloculina yilmazi n.sp.

(Plate VII, figures 1-13)

1988 *Periloculina slovenica* Drobne, Sirel, page 482, plate VI, figures 1-13.

Derivation of name : This species is dedicated to Yücel Yılmaz who has done a lot of contributions on the geology of Turkey.

Holotype :Axial section of the microspheric form, illustrated in Plate VII, figure 4.

Type locality: Exotic limestone blocks within the ophiolitic melange, near the Saray village, northeast of Van, Eastern Turkey (Figure 1).

Type level : Thanetian (SBZ 3,4).

Diagnosis : The megalospheric generations have a elongated ovoid test with small size. The axial diameter ranges from 1.2 mm to 1.9 mm and equatorial diameter from 2.3 mm to 2.5 mm. The subspheric deformed megalosphere (0.150-0.350 mm in diameter) with bottle-neck is followed by the pleuroloculine early chambers, probably “triloculine” (Plate VII, figures 6, 8,10), later divided chambers arranged in a biloculine mode (Plate VII, figures 7,9,13). The trematophoric aperture is developed at the pole of the ovoid test, supported by thick pillars (Plate VII, figures 9,13).

The microspheric test is large, ovoid and elongated in the direction of the apertural axis (Plate VII, figures 1,2,11). The axial diameter ranges from 4 mm to 4.5 mm and the equatorial diameter from 2.75 mm to 3.25 mm. The early stage composed of three cycles of undivided pleuroloculine chambers. The adult stage comprises 3-4 cycles of biloculine and finally 7-8 cycles of the monoloculine chambers. The tightly coiled biloculine and monoloculine chambers are divided by continuous septula into numerous chamberlets (Plate VII, figures 3,4).

Remark : The fabularid genus *Periloculina* (type species *P. zitteli*) was first described and figured from the Senonian of France by Munier – Chalmas and Schlumberger (1885). Later on, the Senonian species *P. zitteli* was described detailed from the late Coniacian and Santonian of southern France and Spain by Hottinger et al. (1989). The generic characters of the the Thanetian new species *P. yilmazi* apparently similar to that of *P. zitteli* of Loeblich and Tappan (1987, p. 357) and Hottinger et al. (1989). But, the new species differs from *P. zitteli* in its smaller test of the both generations and tightly coiled adult biloculine and monoloculine chambers. It differs from the contemporaneous species *Periloculina slovenica* Drobne (1974 and 1984) in having larger test and tightly coiled adult chambers.

Stratigraphic and geographic distribution : Numerous exotic limestone blocks of Thanetian age were observed within the ophiolitic melange near the village of Saray (Figure 1), yielded abundant foraminiferal species such as *K. hottingeri, D. baskilensis, I. sinjarica, S. bitlisica, M. juliettae* and Miliolidae.

3. Conclusions

The known Maastrichtian genus *Gyroconulina* Schroeder and Darmoian and the Thanetian genus *Anatoliella* Sirel were placed in the new foraminiferal family Anatoliellidae (type genus *Anatoliella* Sirel) within the superfamily Ataxophragmicea Schwager by the complex structure of the endoskeletal and exoskeletal elements (Figures 2 A-E)). The Danian-early Thanetian genus *Bolkarina* Sirel was placed in the new family Bolkarinidae (type genus *Bolkarina*) within the superfamily Orbitoidacea Schwager by the presence of the chamberlets with annular and radial stolons and lateral chambers. Furthermore, subfamily Globoflarininae Sirel 1998b was redescribed by the new generic features. Known four Paleocene genera, namely, *Bolkarina* Sirel (type species *B. aksarayensis*), *Globoflarina* (type species C.? *sphaeroidea*), *Coskinon* Hottinger and Drobne (type species *C.(Coskinon) rajkae*), and *Nurdanella* Özgen (type species *N. boluensis*) which have previously been described inadequately by the foregoing authors, so that they are here redescribed by the new generic data. Furthermore, previously determined three foraminiferal species of Paleocene in Sirel (1998*b*) which were renamed as follows: the nummulitinid species *R. sindensis* as *Ranikothalia polatliensis* n.sp., the unidentified miliolid new genus 6 redescribed as *Nurdanella paleocenica* n.sp., the fabularid species *P. slovenica* as *Periloculina yilmazi* n.sp. The stratigraphic and environmental distributions of here described Paleocene foraminiferal species and other Paleocene species have previously been given in (Sirel, 2012, Figures 11,12) respectively.

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PLATES

PLATE- I

Anatoliella ozalpiensis SİREL

(Thanetian, all figures from the Saray village, NE of Van, eastern Turkey, Figure 1, figures 1-6, 10-12 microspheric forms, figures 7-9 megalospheric forms, scale bar in Plate)

Figure 1- Vertical section, holotype in (Sirel, 1988, plate I, figure 2), showing structural elements of endoskeletal and exoskeletal, (MHNG, GEPI, no 88-170).

Figure 2- Almost vertical section, parallel to the coiling axis, (MHNG, GEPI, no 88-174).

Figure 3- Oblique vertical section, (MHNG, GEPI, no 88-187).

Figure 4- Tangential section, showing several orders of beams and rafters and numerous alveolar compartments (top), (MNGH, GEPI, no 88-171).

Figure 5- Centered oblique section, showing large megalosphere with second chamber and trochospiral early chambers at the apex of the cone and alveolar compartments at the bottom. (MHNG, GEPI, no 88-169).

Figure 6- Horizontal section, indicating triserial arrangement of the inflated adult chambers and showing several order of the exoskeletal vertical partitions, basal foramina and pillars in the central area, (MHNG, GEPI, no 88-179).

Figure 7- Centered vertical section of the young A form, (MHNG, GEPI, no 175).

Figure 8- Centered vertical section of the young A form, (MHNG, GEPI, no 88- 175).

Figure 9- Vertical section of the A form, (MHNG, GEPI, no 88-171).

Figure 10- Slightly oblique horizontal section, (MHNG, GEPI, no 88- 176).

Figure 11- Slightly oblique horizontal section, (MHNG, GEPI, no 88-175).

Figure 12- Slightly oblique horizontal section, (MHNG, GEPI, no 88-181).

All samples are deposited in the collection of Muséum d'Histoire Naturelle de Genève, under the numbers shown in PLATE I.

PLATE I

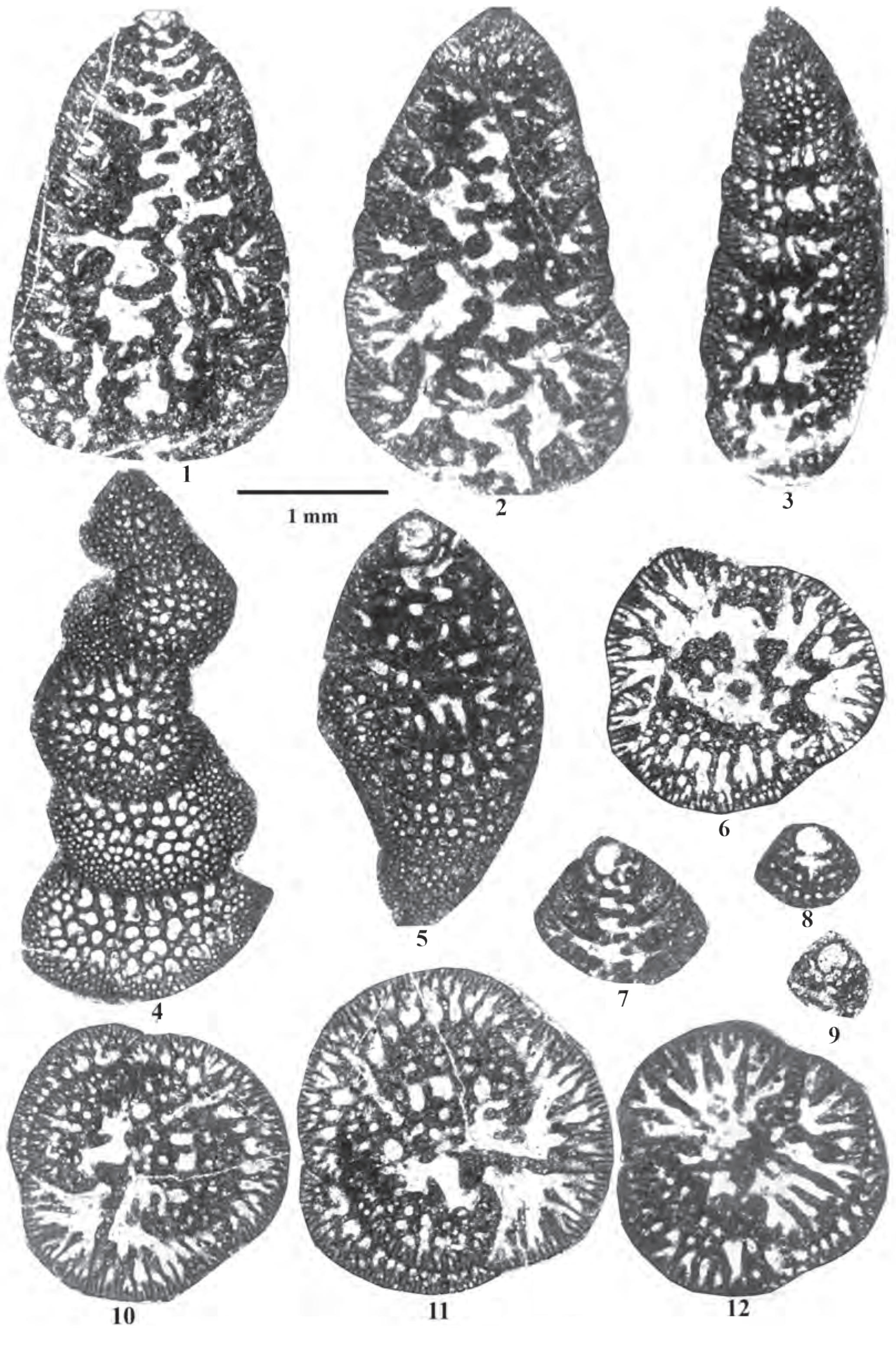


PLATE – II

Bolkarina aksarayensis Sirel

(Selandian-early Thanetian figures 1,3,4,5,6,7 from the Karandere, NW of Aksaray; from the Mahmutlar village, NW of Kırıkkale, Central Turkey; figure 2 from the Bolkar area, Southern Turkey, Figure 1, all figures from Sirel, 1981, scale bar top left of figure 1),

Figure 1- Incomplete equatorial section, B form, holotype, Sirel (1981, plate I, figure1), (Ak-1), scale bar= 2 mm.

Figure 2- Oblique equatorial section, A form, (Bol. 1), scale bar= 0.75 mm.

Figure 3- Incomplete equatorial section of B form, (Ak-20), scale bar=0.75 mm.

Figure 4- Equatorial section of the early spiral shambers, B form, (Ak-2), scale bar= 0.6 mm.

Figure 5- Subaxial section, (Kır. 1), scale bar= 1.8 mm.

Figure 6- Axial section, showing spiral chambers of the early stage, (Ak-6), scale bar= 1.75 mm.

Figure 7- Subaxial section of A form, showing lateral chambers (bottom), (Ak-40), scale bar= 0.57 mm.

PLATE II

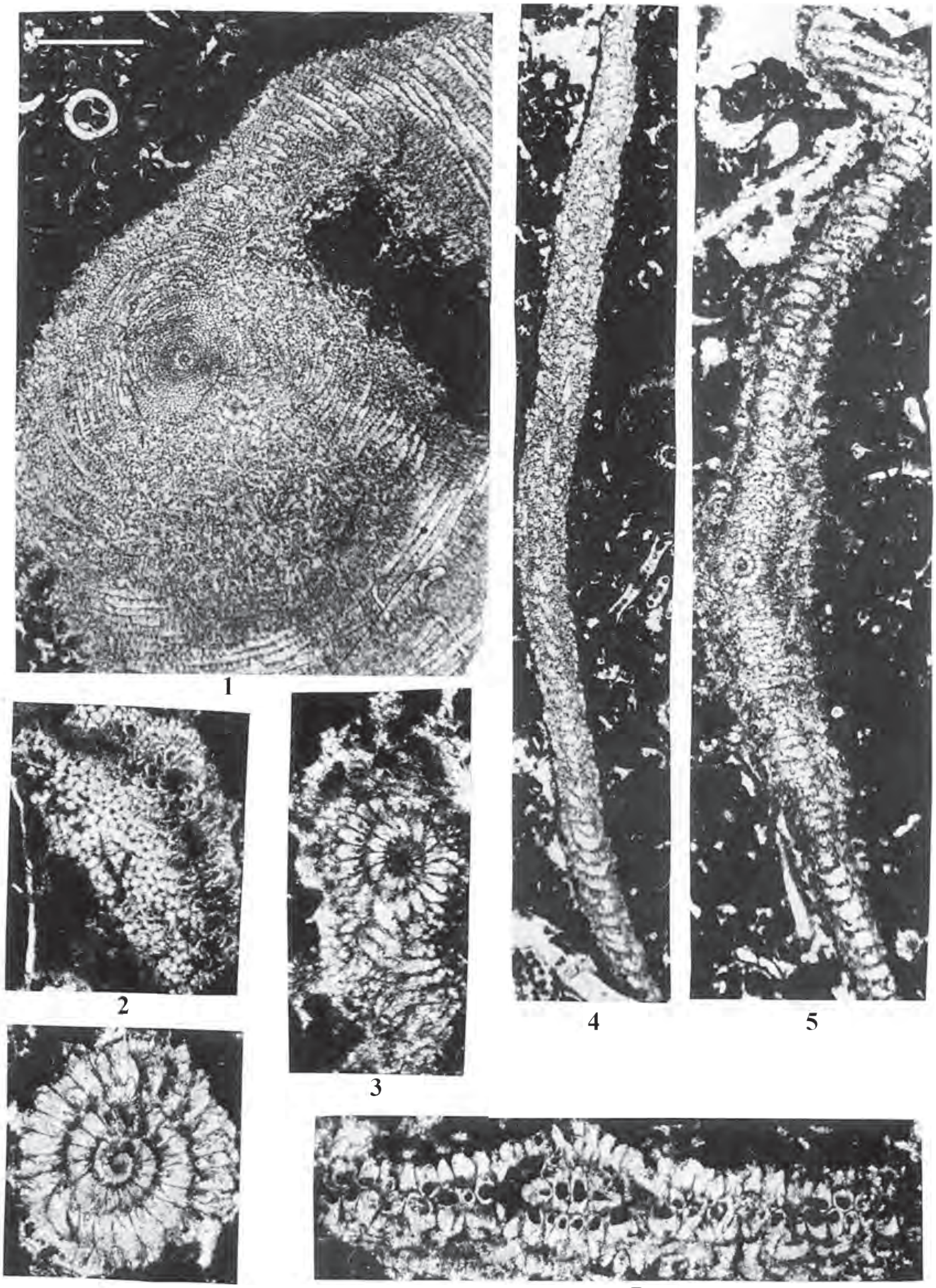


PLATE - III

Globoflarina sphaeroidea (FLEURY)

(Late Danian-early Selandian, all figures from Bolu area, western Turkey, Figure 1, scale bar= 0.45 mm for figures 1,5,10 and scale bar top left of figure 3)

Figure 1- Oblique section, showing two kind of aperture in the upper penultimate whorl (top), (211/4/2), scale bar= 0.45 mm.

Figure 2- Subaxial section with uncoiled stage, (211/18/1), scale bar 1 mm.

Figure 3- Oblique section, inclined to the axial plane, tending uncoil, (211/18/1), scale bar = 1 mm.

Figure 4- Almost axial section (211/20/1), scale bar= 1 mm.

Figure 5- Tangential section, intersecting last two whorls, showing two kind of aperture in the ultimate whorl (at top), (211/15/4), scale bar= 0.45 mm.

Figure 6- Tangential section, showing aligned septula (mid) and secondary aperture with keyhole-shape (mid-top), (211/35/1), scale bar= 1 mm.

Figure 7- Axial section of the megalospheric form, (211/1), scale bar= 1 mm.

Figure 8- Tangential section with uncoiled stage at the both sides, (211/1/1), scale bar= 1 mm.

Figure 9- Subaxial section, (211/5/3), scale bar= 1 mm.

Figure 10-Equatorial section, (211/4/5)., scale bar= 0.45 mm.

PLATE III

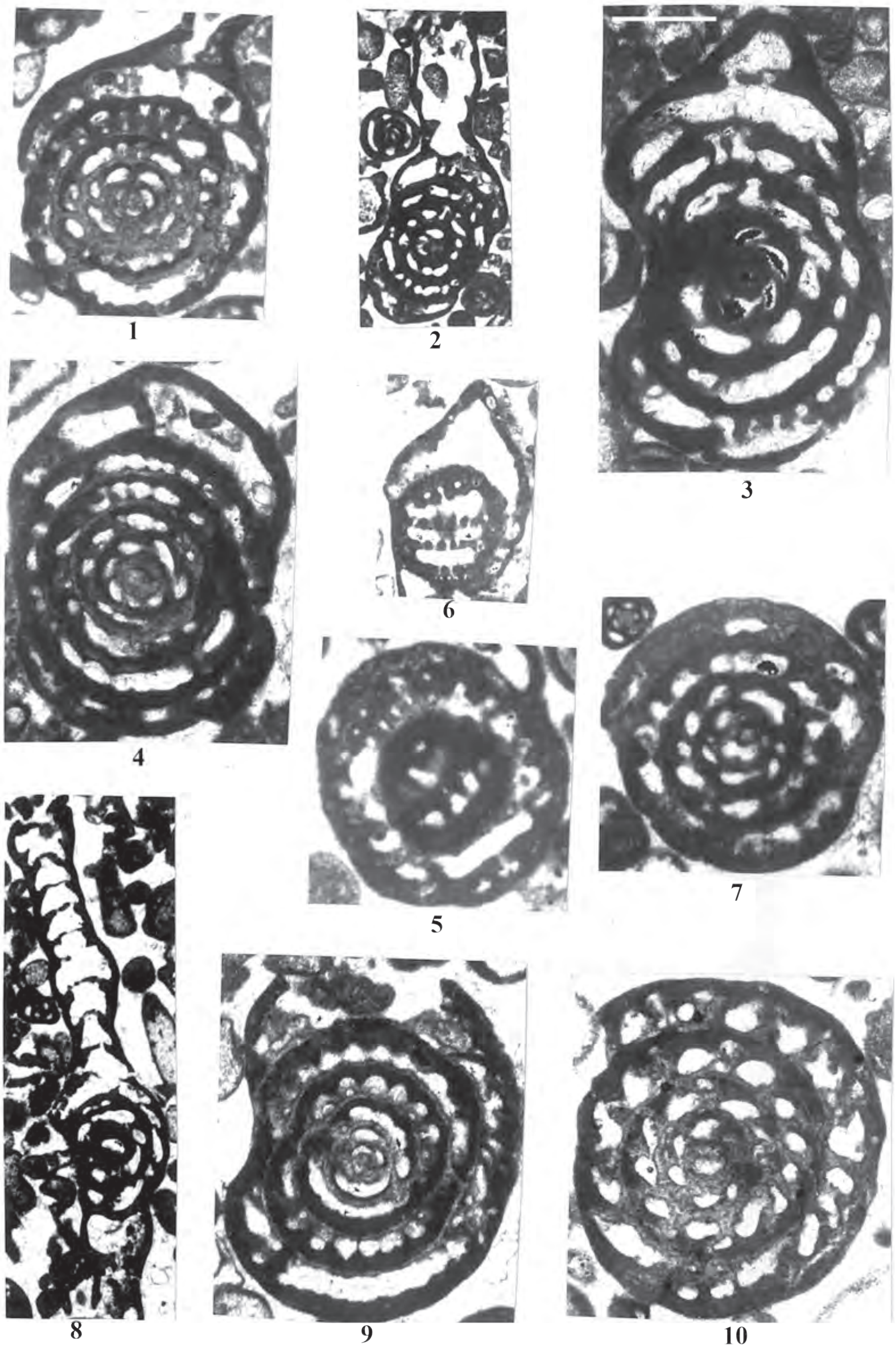


PLATE - IV

Globoflarina sphaeroidea (FLEURY)

(Late Danian-early Selandian, all figures from the Bolu area, western Turkey, Figure 1, figures 5,7 megalospheric form, the others microspheric form, scale bar top right of figure 1)

Figure 1- Non centered axial section, tending uncoil, (211/1), scale bar= 0.45 mm.

Figure 2- Non centered axial section, (211/16/2), scale bar= 0.45 mm.

Figure 3- Axial section with uncoiled stage, (211/1/1), scale bar= 1 mm.

Figure 4- Oblique section with uncoiled stage is devoid of the chambers, (211/19/2), scale bar= 1 mm.

Figure 5- Equatorial section, note young gamonts in the last whorl, (211/1), scale bar= 0.45 mm.

Figure 6- Axial section of the young specimen, (211/32/2), scale bar= 0.45 mm.

Nurdanella paleocenica n.sp

(Thanetian, all figures from the Saray village, NE of Van, eastern Turkey, Figure 1, scale bar among figures)

Figure 7- Axial section, probably microspheric form, holotype, showing crenated/ notched aperture in the upper antepenultimate chamber (left) and in the early chamber (right) (112/1),

Figure 8- Subequatorial section, B form, (105/1).

Figure 9- Almost equatorial section, B form, (88/211).

Figure 10- Subequatorial section, (Y.19d/3/3).

Figure 11- Equatorial section, A form, (88/208).

Figure 12- Subequatorial section, probably young A form, (105/1).

Figure 13- Axial section of young B form, showing quinqueloculine early chambers and notched/crenated aperture in the lower ultimate chamber, (105/1).

PLATE IV

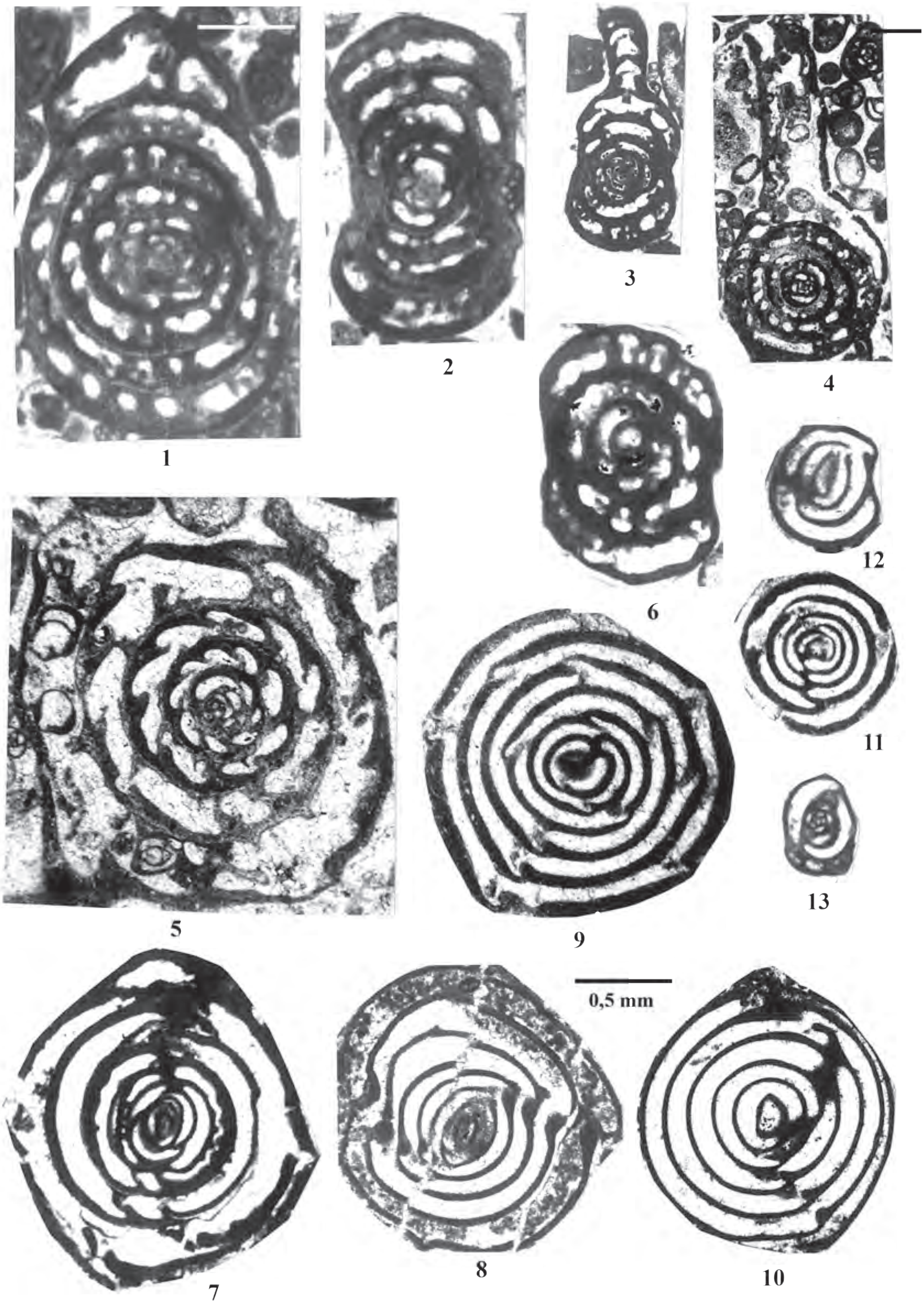


PLATE – V

Coskinon rajkae HOTTINGER and DROBNE

(Early Thanetian, all figures from the Harabekayış section (Sirel, 2009, Figure 10) Elazıg area, EasternTurkey, all figures megalospheric forms, scale bar top right of figure 1)

Figure 1-Vertical section (top), showing biserial early chambers at the apex of the cone and undivided uniserial chambers at the marginal zone, subaxial section of *H. anatolica* (mid) and incomplete axial sections of *G. primaeva* (bottom), (HK. 4/7/3).

Figure 2-Almost vertical section, (HK. 4/2/3).

Figure 3-Almost vertical section, showing biserial early chambers and endoskeletal pillars, (HK. 4/1/3).

Figure 4-Almost vertical section, (HK. 4/12/1).

Figure 5-Almost vertical section, (HK. 4/7/1).

Ranikothalia polatliensis n.sp.

(Late Thanetian?-early Ilerdian, all figures from the Kuşçu village, SE of Polatlı, SW of Ankara, Central Turkey, Figure 1, all figures microspheric form, except figure 8, scale bar on figure 9),

Figure 6- Tangential section of the last two incomplete whorls, showing network of marginal canals, (30/5/5).

Figure 7- Almost axial section, (30/7/2).

Figure 8- Incomplete equatorial section, (30/7/2).

Figure 9- Subaxial section, showing marginal canals at the both pole of the whorls, (30/12/3).

PLATE V

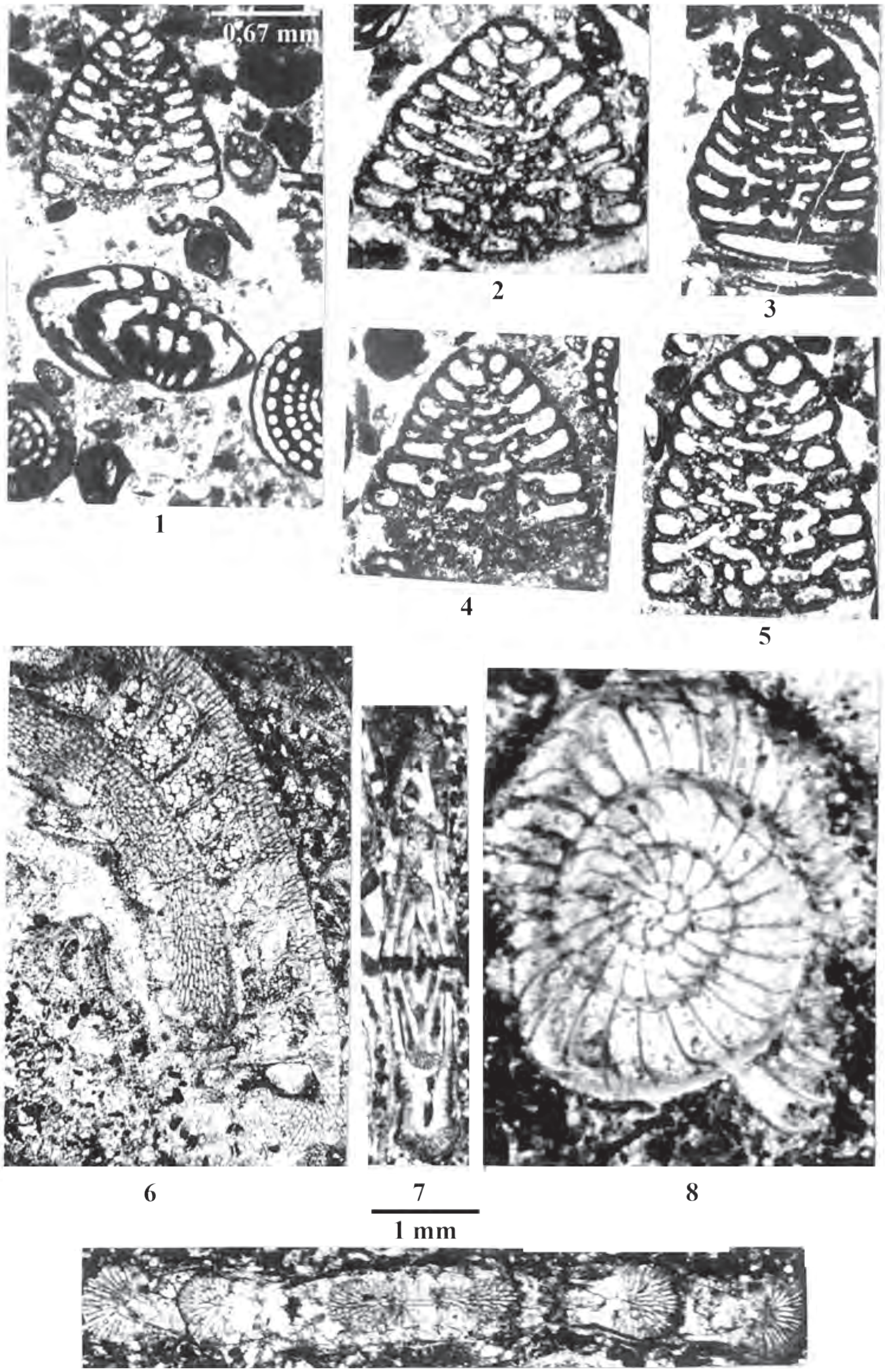


PLATE - VI

Ranikothalia polatliensis n.sp.

(Late Thanetian?-early Ilerdian, all figures from the Kuşçu village, S of Polatlı, SW of Ankara, Central Turkey Figure 1, figures 1,13 microspheric and figures 2-12 megalospheric forms, scale bar in Plate)

Figure 1- Almost equatorial section, holotype, (30/5/1).

Figure 2- Equatorial section, (30/5/2).

Figure 3- Axial section, (30/5/3).

Figure 4- Equatorial section, (30/5/4).

Figure 5- Axial section, (30/5/4).

Figure 6- Equatorial section, (30/5/5).

Figure 7- Tangential section, showing network of marginal canal at the peripheral margin (30/5/7).

Figure 8- Equatorial section, showing marginal cord with marginal stural canals between the ultimate and penultimate whorls, (30/5/8).

Figure 9-Axial section, (30/5/9).

Figure 10-Axial section, (30/5/10).

Figure 11-Axial section, (30/5/11).

Figure 12-Equatorial section, (30/5/12).

Figure 13-Subaxial section, showing marginal canals at the either poles of the whorls, (30/5/13

PLATE VI

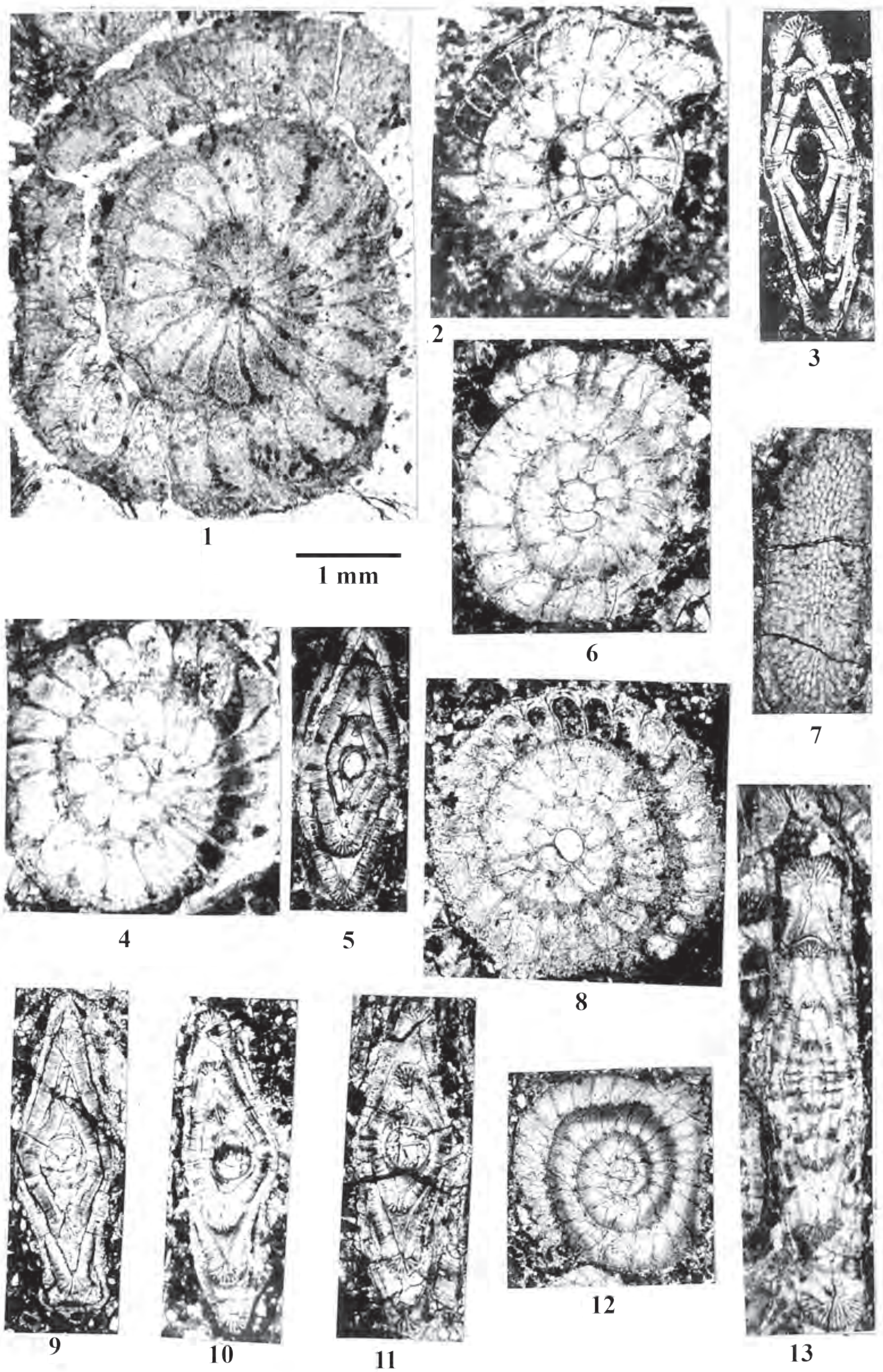


PLATE – VII

Periloculina yilmazi n.sp.

(Thanetian, all figures from the Saray village, NE of Van, Eastern Turkey Figure 1; figures 1- 3,4,11,12 microspheric, figures 5-10, 13 megalospheric forms, scale bar in Plate)

Figure 1-Oblique section, inclined to the axial plane, showing trematophorean pillars at the upper part of the test, (P.1).

Figure 2-Slightly oblique axial section, (P. 2).

Figure 3-Tangential section showing continuous septula, (P. 3).

Figure 4-Centered axial section, perpendicular to the apertural axis, (P.4).

Figure 5-Centered axial section, perpendicular to the apertural axis, (P. 5).

Figure 6-Centered axial section section, showing two cycles of triloculine chambers, (P.6).

Figure 7-Slightly oblique centered axial section, (P. 7).

Figure 8-Centered axial section, (P. 8).

Figure 9-Equatorial section, showing proloculus with bottle-neck and trematophorean pillars at the both poles, (P. 9).

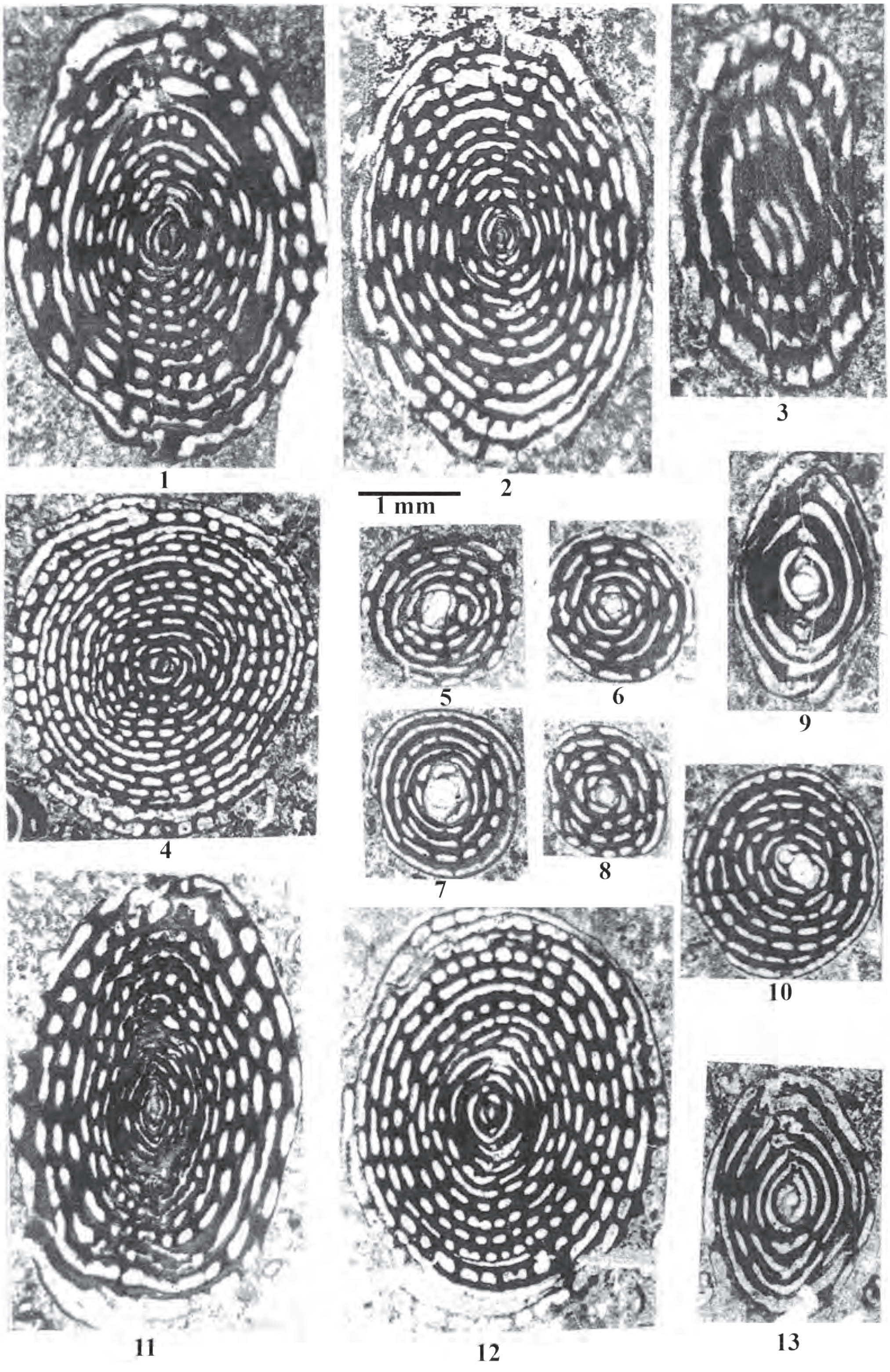
Figure 10-Centered axial section of the adult specimen, (P. 10).

Figure 11-Oblique axial section, (P. 11).

Figure 12-Axial section, perpendicular to apertural axis, (P. 12).

Figure 13-Slightly oblique equatorial section, showing trematophorean pillars at the upper pole, (P. 13)

PLATE VII



BULLETIN OF THE MINERAL RESEARCH AND EXPLORATION

Foreign Edition 2013 146

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From Editor...

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THE OSTRACOD FAUNA AND ENVIRONMENTAL CHARACTERISTICS OF THE VOLCANO SEDIMENTARY YOL ÜSTÜ FORMATION IN THE HINIS REGION, ERZURUM (EASTERN ANATOLIA), TURKEY

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Key words:
Hınıs (Erzurum),
Ostracod,
Freshwater – olihogaline,
Brackish water,
Taxonomy.

ABSTRACT

The volcanosedimentary Yolüstü formation which outcrops in the vicinity of Hınıs Town, the southeast of Erzurum City, consists of conglomerate, marl, agglomerate, claystone, tuffite, fragmented travertine limestone with fragments of sand – pebble - plant, lacustrine limestone and tuffaceous – clayey limestone. In this formation, carefully selected 3 measured stratigraphic sections were taken at levels in which the lithology of hard travertine limestones with plant fragments and soft tuffaceous – clayey limestone are present. Washed samples which had been taken from these sections were studied and assessed, and then ostracods reflecting freshwater and brackish water environments were detected. In the unit, 5 genera and 12 species of ostracod and their taxonomies, which are generally peculiar to Ponto – Caspian basin, were defined. Besides; few micro mollusks, and 2 genera and 1 species of gastropod and 1 species of pelecypod (non well preserved) were found from the recrystallized looking tuffaceous, clayey, consolidated, hard limestone levels. In sequence, genera and species types of osracod such as; *Leptocythere (Amnicythere)* cf. *litiva* Livental, *Tyrrhenocythere bailovi* (Suzin), *Loxoconcha granulata* Sars, *L.* cf. *diligena* Kulieva, *L. agilis* Ruggieri, *Candona (Caspiocypris) araxica* Freels, *C. (Caspiocypris) erzurumensis* Freels, *C. (Caspiocypris)* aff. *alta* (Zalanyi), *C. (Typhlocypris) amblygonica* Freels, *C. (Candona) parallela pannonica* Zalanyi, *C. (Candona) burdurensis* Freels, *C. (Candona) candida* (O.F.Müller), *C. (Candona)* sp. 1 Freels, gastropods like *Valvata piscinalis* (O.F.Müller), *Viviparus* sp. and genus and species types of pelecypod like *Dreissena polymorpha* (Palas) were defined. For the main fossil envrionmtents; *Leptocythere* and *Tyrrhenocythere* indicate the brackish water environment, *Loxoconcha* mesohaline, *Candona (Caspiocypris), C. (Typhlocypris) oligohaline, Candona (Candona), Valvata, Viviparus* and *Dreissena* indicate the freshwater environment.

1. Introduction

1.1. The Aim of the Study

This study has been carried out in Yolüstü formation which is a volcanosedimentary unit in Hınıs Town, Erzurum, Turkey (Figure 1). The formation generally consists of conglomerate, marl, agglomerate, claystone, tuffite, travertine limestone with fragments of sand – pebble – plant, and volcanosedimentary deposits such as; the lacustrine limestone and tuffaceous – clayey limestone (Figure 2).

The purpose of this study is to make an interpretation about the age of ostracod bearing micro fauna which the Yolüstü formation cropping out in the Hınıs Basin (Erzurum) consists of and the environments which the fauna characterizes.

Previous studies about the general geology and volcanism around the study area were carried out by Arni (1939), Pamir and Baykal (1943), Erinç (1953), Tokel (1979), Soytürk (1973), Gedik (1985), Yılmaz et al. (1988), Şengüler and Toprak (1991), Tarhan (1991), Gevrek and Şengüler (1992), Öner et al., (2006). The

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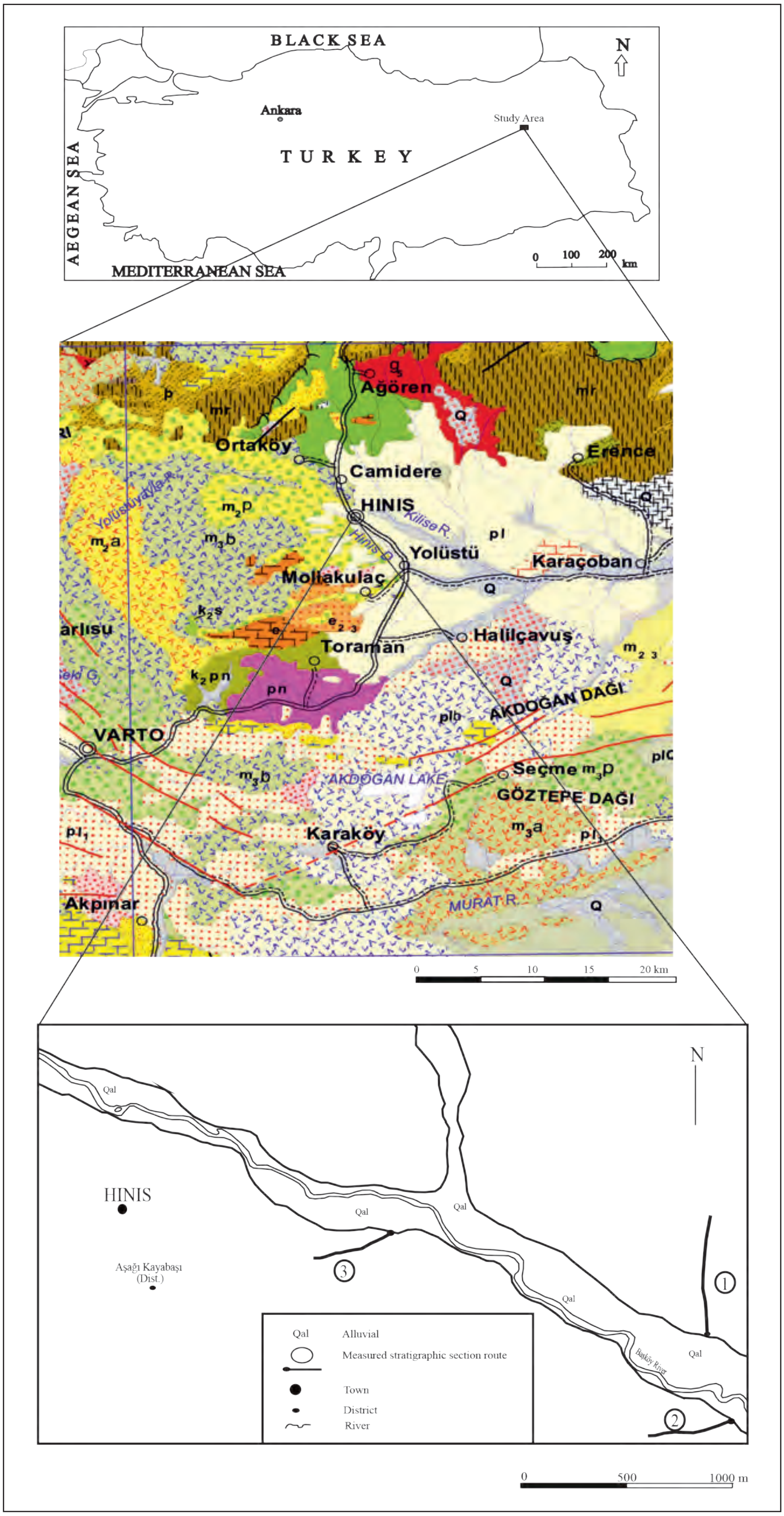

Figure 1- Location map of the study area and routes of measured section

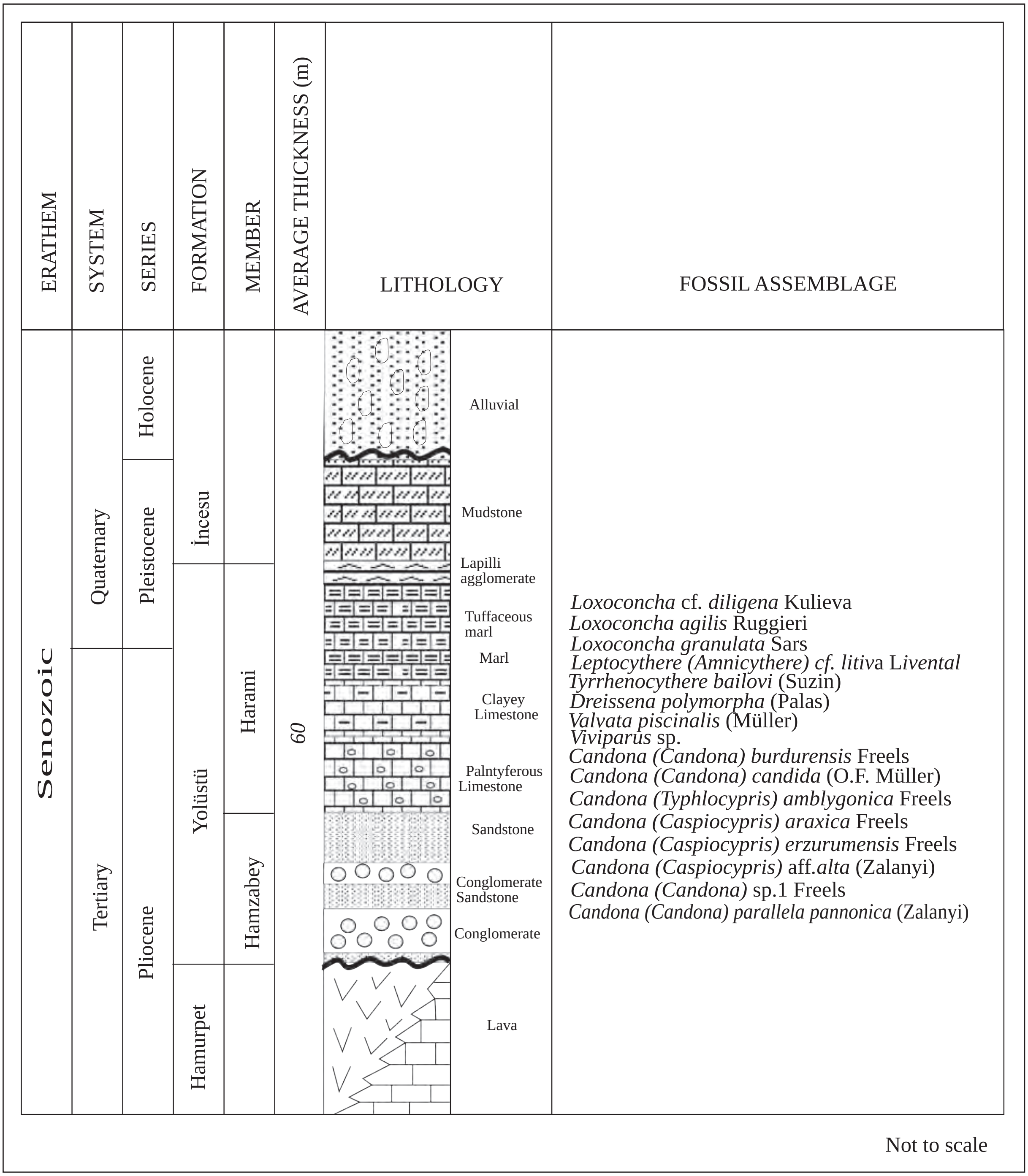

Figure 2- Generalized columnar section of the study area

stratigraphical and sedimantological studies were on the other hand performed by Demirtaşlı et al. (1965), and Gürbüz and Gülbaş (1999). And finally; the investigations about the tectonism and magmatism were carried out by Şengör and Kidd (1979), Şengör (1980), Şaroğlu and Yılmaz (1984), Tokel (1984); Erdoğan (1967) and Özcan (1967).

Total of 3 measured stratigraphical sections have been taken from fragmented and fossiliferous levels of the formation. It has been defined 5 genera and 12 species of ostracod, 2 genera and 1 species of gastropod and 1 species of pelecypod from the washed samples. Plates I and II consist of SEM photos of ostracods which have been defined within this unit.

Some of these genera and species defined are observed in the Central Paratethyan derived basins. The existence of the Central Paratethys in the region can be explained as an effect of closed basin deposit by post Miocene temporal faults of the volcanic sedimentation deposits located at upper levels of depression areas in the transition zone of the Northeast Anatolian – East Anatolian Tertiary basins. This basin then collapsed down at the end of late Miocene (Pontian) by these surrounding faults, and the marshy and shallow deep lagoon was formed by the rivers around it. Looking in regional, disperse and continuous outcrops of this formation in the Hınıs Basin is observed and the volcano sedimentary rocks in this area are horizontally bedded and unfolded. They have preserved their primary structural positions and have been crooscut only by temporal active faults (Tarhan, 1991).

However; the stratigraphy of volcanosedimentary units that had formed during Neogene volcanism around Hınıs (Erzurum – Muş – Bingöl, the eastern Anatolia), the micropaleontological characteristic based on the assemblage of ostracod and their environmental features have been revealed in this study.

2. Stratigraphy

2.1. Yolüstü Formation

The Nomenclature And Description Of The Unit: The formation was first described by Tarhan (1989) and Tarhan (1991) (from Polat, 2011) and took its name from the Yolüstü Village where it was best observed.

Distribution : This formation outcrops in Yeniköy, Karaçoban, Harami, Duman, Halilçavuş, Ovaçevirme, Peyik and Yolüstü villages in the Hınıs Basin. Its type distribution is in Harami – Halife Yards and Yolüstü (Beyazyar, Aros – Peyik ridge and Ziyaret Tepe (hill)). The locations where measured sections were taken in this study are Kayabaşı and Pınarbaşı districts and its surround.

Type Location : The Yolüstü Village located in the Hınıs Basin.

Type Section : The section 2 which was taken in the Yolüstü Formation that unconformably overlies the Hamurpet Lava is in the character of a type section. It was measured within the coordinates of X1: 36775, Y1: 59800, Z1: 1600 m. (start) and as X2: 36800, Y2: 60700, Z2: 1694 m. (end) in 1/25000 scaled in J47 sheet.

Reference Sections : Section numbers 1 and 3 are the reference sections measured within Harami and Hamzabey members of the Yolüstü Formation. These sections were measured at the coordinates of X1: 35125, Y1: 66550, Z1: 1615 m. (start), X2: 34375, Y2: 60320, Z2:1705 m. (end) in 1/25000 scaled J47 sheet, and X1: 35125, Y1: 66550, Z1: 1605 m. (start), X2: 34375, Y2: 60320, Z2: 1702 m. (end) of 1/25 000 scale J47/a3 sheet, respectively.

The horizontally bedding sections were studied in detail and measured from bottom to top as vertically.

Lithological Features : The formation has started its deposition by transgression and ended by regression in the Hınıs Basin. Therefore; the rocks have formed complete series. The unit is generally recognized by the deposits such as; conglomerate, sandstone, siltstone, mudstone, tuffaceous marl, marl, agglomerate, claystone, tuffite, travertine limestone with plant fragments, lacustrine limestone and tuffaceous – clayey limestone, and consists of thin coal seams, sporadically. The dominant lithology of the formation is formed by marl, tuffite, tuffaceous marl and claystones. Sandstone, siltstone and conglomerates are crossbedded. Fine to medium, horizontal beddings are observed in fluvial and in the channel fill deposit unit from place to place.

The Formation has two members distinguished by Tarhan (1991).

The Hamzabey Yard Member : It crops out in Ağması, Yolüstü and in Hamzabey – Zaza yards in map. It takes its name from the Hamzabey yard. It is formed by reddish brown, fine to medium bedded, loose cemented conglomerate and consists of sandstone – mudstone interlayers in places. Conglomerates are well rounded and correlates with the basal conglomerate of the Yolüstü Formation. It vertically and horizontally grades into the units of tuffite, claystone and marl.

The Harami Member : It crops out in Harami, Ovaçevirme, Duman, Halilçavuş villages and in the Halife yard. The travertine limestones with sand – pebble – plant fragments form the bottom of the unit. In upper layers, the agglomerate grades into the dominant lithology of the formation which is; lacustrine limestone, marl, tuffite, tuffaceous marl, sandstone, mudstone, lapilli and agglomerates as a result of the increase in tuff content at inner parts of the basin. It consists of fragments of plant and thin coal interbands. The dominant rock units of the member are travertine limestones (Demirtaşlı et al., 1965; Aziz, 1971; Gedik, 1985 and Tarhan, 1991). Also the washed samples which form the main subject of this study, belong to this unit of the Yolüstü formation and it was revealed that the age of this member ranged from Pliocene to Early Pleistocene.

Contact Relationships : This formation overlies the ophiolite, metamorphous granitic rocks, upper Cretaceous – Lower Miocene deposits, Middle Miocene Bingöl Dağı group, Late Miocene Varto group and Early Pliocene Hamurpet lava cropping out at the bottom and at the circumference of the Hınıs Basin with an angular unconformity. Then, it grades into the conformable and transitional İncesu formation in upper layers (Tarhan, 1991).

Thickness And Distribution : The formation has continuous and widespread exposures in the Hınıs Basin. It is fine to medium layered and horizontally bedded. The average thickness was determined as 700 – 800 m by Tarhan (1991). However, the average thickness of the formation was detected as 60 m from the measurable sections in this study.

The Fossil Content And Age : Pamir and Baykal (1943) stated that the deposits in the Hınıs Basin are post Late Miocene in age.

Nakoman (1968) directed attention to the lacustrine and carbonaceous units in the Karlıova basin and dated carbonaceous units as Middle – Late Pliocene age as aresults of the pollen analysis carried out in coals of the Karlıova Basin.

Tarhan (1991) has obtained Pliocene–Lower Pleistocene ages from the fossil content of this formation, but has assigned the unit as mid Pliocene according to its stratigraphy.

In this study, a rich assemblageof ostracodafauna with calcified micro molluscs were determined from the washed samples collected from the plant fragmentsbearing hard travertine limestonesand soft clayey limestone layersof the measured sections. According to this fauna the age of the formation is Pliocene–Early Pleistocene.

Correlation : The Yolüstü formation shows similarity with the depositional units in the Tekman, Bulanık, Muş, Pasinler and Erzurum basins in terms of lithological, stratigraphical and structural relationships.

Late Pliocene Tuzluca formation (Şenalp, 1969), Pliocene Horasan formation (Rathur, 1965), Late Miocene – Pliocene Hacıömer formation (Erdoğan, 1966; Yılmaz et al., 1986), Pliocene Bulanık formation (Soytürk, 1973), Pliocene Işıklar formation (Demirtaşlı et al., 1965; Aziz, 1971), Pliocene Zırnak formation (Şaroğlu, 1986) and Late Pliocene – Pleistocene Bulanık formation (Şengüler and Toprak, 1991) can be correlated with this formation.

2.2. Measured Stratigraphic Sections

2.2.1. Hınıs 1 Measured Section

Total of 10 washed samples were collected from a 90 m thick section measured between the coordinates which starts at X1: 36775, Y1: 59800, Z1: 1615 m. and ends at X2: 36800, Y2: 60700, Z2: 1705 m. in the 1/25000 scale J47 sheet.

In general, majority of the samples (2 to 10) were collected, in the following order, from the part of the Yolüstü formation where the Harami member is extensively observed and forms a 22 m thick sequence; sample 2 from marl at 12 m; sample 3 from plant detritus bearing limetone at 15.6 m; sample 4 from traverten limestone at 26.4 m; sample 5 from marl at 36.5 m; sample 6 from marl at 42 m; sample 7 from tuffaceous marl at 55 m; sample 8 from mudstone at 70.8 m; sample 9 from limestone at 82.5 and sample 10 from tuffaceous and clayey limestone respectively.

The following species of ostracoda, such as, *Candona (Caspiocypris) erzurumensis* Freels in sample 2 at 12th m; *Candona (Caspiocypris) araxica* Freels, *C. (Typhlocypris) amblygonica* Freels, *C. (Candona) parallela pannonica* Zalanyi in sample 3 at 15.6th m and *(Amnicythere)* cf. litiva Livental, *Loxoconcha agilis* Ruggieri, *L. granulata* Sars in sample 10 at 87.5th m were identified (Figure 3).These ostracod genera indicate transition into freshwater and brackish water environments (Table 1).

2.2.2. Hınıs 2 Measured Section

Total of 8 washed samples were collected from a 94 m thick measured section. The section starts at X1: 35125, Y1: 66550, Z1: 1600 m and ends at X2: 34375, Y2: 60320, Z2: 1694 m in the 1/25.000 scaleJ47 sheet.

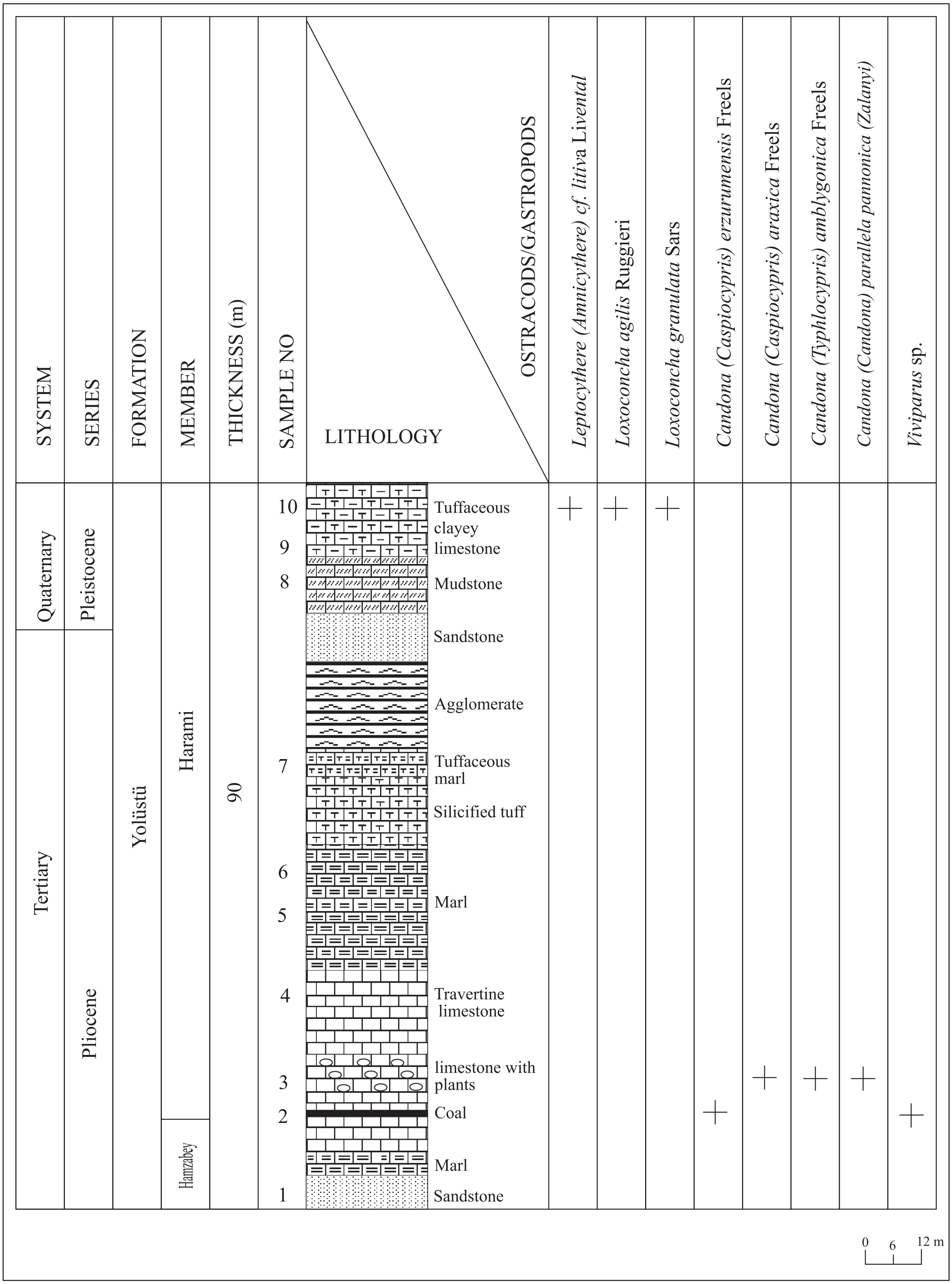

Figure 3- Ostracode and gastropode distribution in Hınıs 1 measured section

Table 1- Environments and salinity degrees in the study area which the Ostracode genera characterize (from Morkhoven,1963 and Krstic,1976)

OSTRACODE GENERA	SALINITY*		
	FRESH WATER % 0,5-3	BRACKISH\SOMATR % 0,3-8(10)	MARINE % 18-45
Leptocythere		——	—
Tyrrhenocythere		——	
Loxoconcha		——	—
Candona (Typhlocypris)	——	–	
Candona(Caspiocypris)	——	–	
Candona(Candona)	——		

*Remane standards given in Gökçen (1979) were used for the salinity.

The sequence in this section is composed of the conglomerate and mudstone of the Hamzabey member and the limestone, marl and tuffaceous marls of the Harami member of the Yolüstü formation, which overlies the Hamurpet lava unconformably.

The eight samples were collected from the following lithologies; sample 1 from the carbonaceous level of the section at 39th m, sample 2 from travertine limestone at 44th m, samples 3 and 4 from marls at 51th m and 57th m, sample 5 from limestone at 65th m, sample 5 from marl at 36.5th m, sample 6 from tuffaceous marl at 69th m, sample 7 from sandstone at 84th m and sample 10 from hard clayey limestone at 94th m.

From the samples collected in this section, the following ostracoda species, such as, *Candona (Candona) parallela pannonica* Zalanyi, *C. (Candona) burdurensis* Freels (sample 1), *Candona (Candona) parallela pannonica* Zalanyi (sample 4 and 5), *Loxoconcha granulata* Sars (sample 8), and *Loxoconcha* cf. *diligena* Kulieva (sample 8), representing changing environments from fresh water through oligohaline to brackish water, were identified.

2.2.3. Hınıs 3 Measured Section

Total of 10 washed samples were taken from the 103 m thick measured section which starts at X1: 35125, Y1: 66550, Z1: 1605 m and ends at X2: 34375, Y2: 60320, Z2: 1702 m in 1/25.000 scale J47-a3 sheet.

The first 20 m of the section belongs to levels of conglomerate - sandstone alternation of the Hamzabey unit in Yolüstü formation. Sample 1 was taken from the 10th m of this unit. There is a 68 m thickness over this sequence and the coal is observed at 10th m of this sequence and sample 2 which was taken at 28.5th m consists of limestone with plant fragments. Sample 3 which was taken at 33th m of the sequence is coal. Samples 4 and 5 were taken from travertine limestones at 36.3th and 42th meters, respectively; and overlie the coal layer from which the sample 3 was taken. Sample 6 was taken from the lacustrine limestone at 46th m and sample 7 was taken from hard clayey limestone at 58th m. Sample 8 was taken from the top of marl at 64th m of the sequence. Sample 9 was taken from tuffaceous marl at 70th m and sample 10 from marl at 83th m.

The sequence which belongs to the Harami unit of the Yolüstü formation conformably grades into the unconsolidated mudstone and sandstones layers of the overlying İncesu formation at 86th m. The thickness of this unit measured in the section is 7 meters.

An alluvial with a thickness of 8 meters takes place at the uppermost level of the section.

Ostracod genera which show the transition from freshwater – oligohaline to brackish water environment such as; *Candona (Caspiocypris) erzurumensis* Freels, *C. (Caspiocypris) araxica* Freels, *C. (Typhlocypris) amblygonica* Freels in sample 2; *Loxoconcha granulata* Sars, *L.* cf. *diligena* Kulieva, *Candona (Caspiocypris) erzurumensis* Freels, *C. (Caspiocypris) araxica* Freels, *C. (Typhlocypris) amblygonica* Freels in sample 4 and 5; *Candona (Candona) candida* (Müller), *C. (Candona) burdurensis* Freels in sample 6; *Leptocythere (Amnicythere)* cf. *litiva* Livental, *Tyrrhenocythere bailovi* (Suzin), *Loxoconcha agilis* Ruggieri, *L. granulata* Sars, *L.* cf. *diligena* Kulieva in sample 7; *Loxoconcha agilis* Ruggieri, *Candona (Caspiocypris) araxica* Freels, *C (Typhlocypris) amblygonica* Freels, *C. (Caspiocypris)* aff. *alta* (Zalanyi) in samples 8 and 9 were described (Figure 5).

2.3. Paleoenvironmental Interpretation

It is suggested that the Yolüstü formation generally deposited in littoral,lagoonal and lacustrine environments.The findings of the previous studies of Morkhoven (1963), Freels (1980), Wenz (1922), Taner (1980), Sayar (1991) were considered in the paleoenvironmental interpretation of the ostracoda

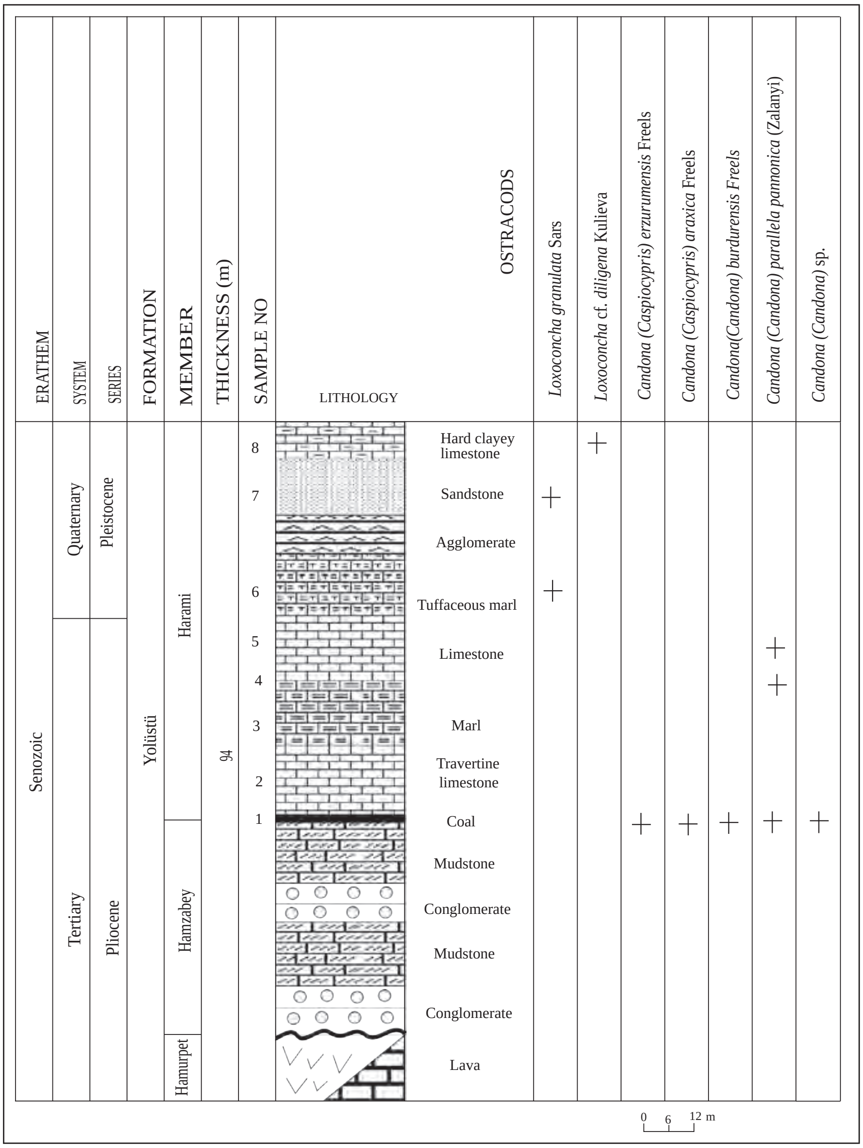

Figure 4- Ostracode distribution in Hınıs 2 measured section

and the accompanying mollusc genera identified in the study.

The genera and subgenera of the ostracoda, such as, *Candona (Caspiocypris), C (Typhlocypris), C (Candona),* which are determined from the sample collected from the plant fragments bearing hard traverten limestone in the lower level of the second member of the Yolüstü formation, characterize a lacustrine environment. The ostracoda genera, such as, *Leptocythere (Amnicythere), Tyrrhenocythere, Loxoconcha,* which are identified from the soft clayey limestone deposits in the upper levels, indicate brackish water, but the accompanying mollusc genera such as, *Valvata, Viviparus, Dreissena* represent fresh water environment.

In considering the vertical distribution of the ostracoda in the sections, it is realised that the environmental conditions in the study area changed from fresh water through oligohaline to brakish water.

3. Taxonomy

In this study, 13 ostracods were defined as follows; 1 species of *Leptocythere*, 1 species of *Tyrrhenocythere*, 3 species of *Loxoconcha;* 3 subgebera of *Candona (Caspiocypris)*, 1 subgenera of *Candona (Typhlocypris)*, 4 subgenera of *Candona (Candona)* and 6 species of *Candona* one of which is at sp. level. SEM microphotographs of the ostracod genera and species determined in this study are presented in Plates I - II.

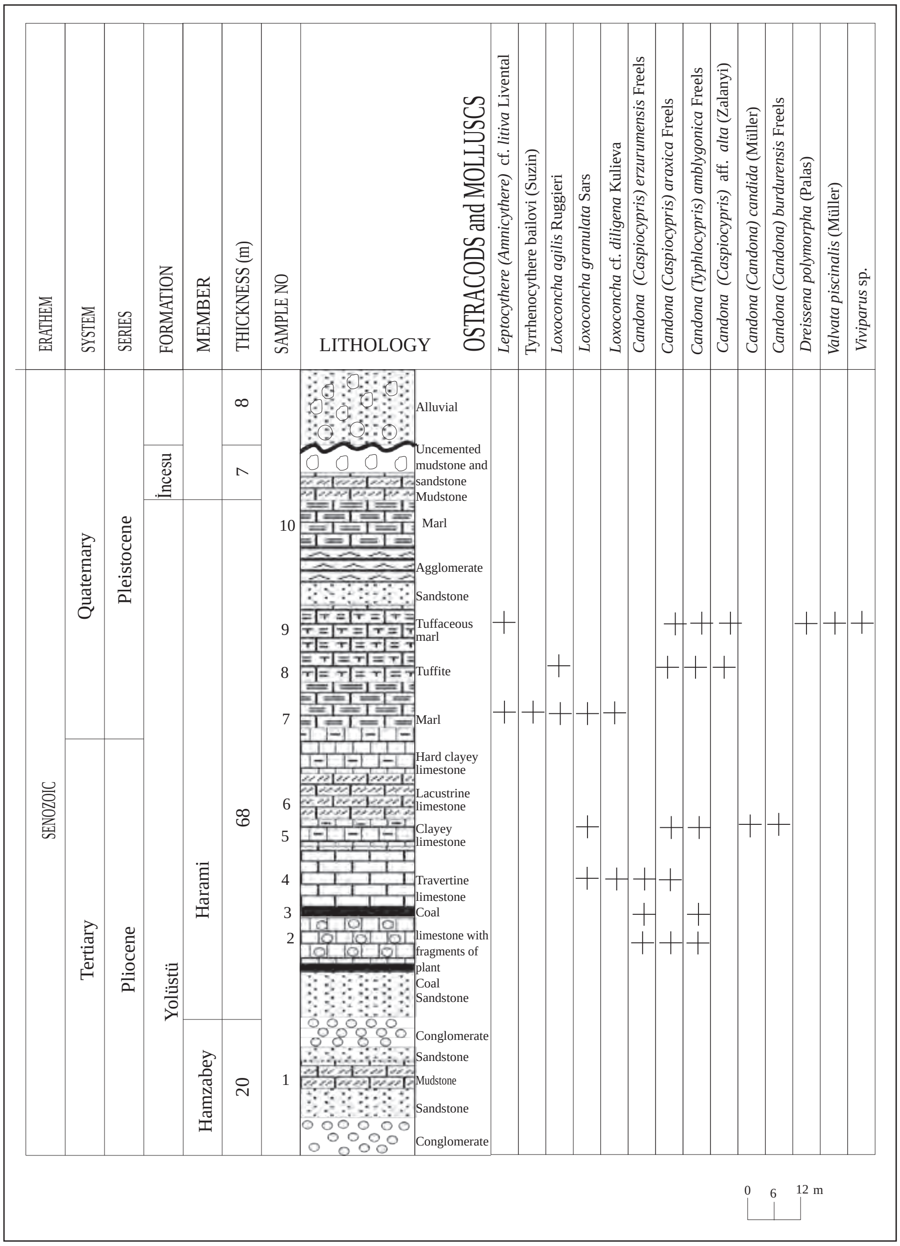

Figure 5- Ostracode distribution in Hınıs 3 measured section

The taxonomy of Hartmann and Puri (1974) was used in the classification and the taxonomy of Moore (1961), Morkhoven (1962) and Freels (1980) were also considered.

Subclass : Ostracoda Latreille, 1806

Order : Podocopda Sars, 1866

Suborder : Cytheraca Baird, 1850

Family : Leptocytheridae Hanai, 1957

Genus : *Leptocythere* Sars, 1928

Subgenus : *Leptocythere* Sars, 1928 and *Amnicythere* Devoto, 1965

Species Type : *Cythere pellucida* Baird, 1850

Stratigraphic Distribution : Oligocene-Recent

Environment : Some species represent brackish water, the others represent shallow marine (littoral) environments (Morkhoven, 1963).

Leptocythere (Amnicythere) cf. *litica* Livental, Agalarova et al., 1961

(Plate I, Figure 1)

Leptocythere (Amnicythere) cf. *litica*, Carbonnel, 1978, plate 2, figure 9

Leptocythere (Amnicythere) cf. *litica* Livental, Agalarova et al., Krstic and Dermitzakis, 1981, plate VI, figures 5-6.

Stratigraphical and geographical distribution : Azerbaijan, Pontic and Caspian Basin, Pontian-Pliocene (Agalarova et al., 1961), Corinth Canal – Greece, Pleistocene (Krstic and Dermitzakis, 1981).

Localities in this study : Hınıs 1 Measured section, sample 10, Early Pleistocene; Hınıs 3 Measured Section, samples 7 and 9, Early Pleistocene.

Family : Hemicytheridae Puri, 1953

Subfamily : Hemicytherinae Puri, 1953

Genus : *Tyrrhenocythere* Ruggieri, 1955

Species-Type : *Tyrrhenocythere pignatti* Ruggieri, 1955

Stratigraphic Distribution : Late Messinian / Pontian – Recent. It forms a starting level especially in Paratethys since Pontian (Krstic, 1976).

Environment : Recent species occur in brackish and freshwater conditionswith up to 9-13% salinity and 30 m depth (Krstic, 1976).

Tyrrhenocythere bailovi (Suzin, 1956)

(Plate I, Figure 2)

Tyrrhenocythere bailovi Suzin = 1956 *Tyrrhenocythere pseudocandona* Livental,1929

Tyrrhenocythere bailovi (Suzin), Krstic and Dermitzakis, 1981, plate III, figures 17-22

Stratigraphic and geographical distribution : Moscow, Tertiary (Suzin, 1956), Corinth Canal – Greece, Pleistocene (Krstic and Dermitzakis, 1981)

Localities in this study : Hınıs 3 Mesaured Section, sample 7, Pliocene – Early Pleistocene.

Family : *Loxoconchidae* Sars, 1925

Genus : *Loxoconcha* Sars, 1866 (= Normania Brady, 1866,= Loxoleberis Sars, 1866)

Species Type : *Cythere rhomboidea* Fischer, 1855

Stratigraphical Distribution : Paleocene – Recent

Environment : Littoral depth, mesohaline salinity (Morkhoven, 1963)

Loxoconcha agilis Ruggieri, 1967

(Plate I, Figure 5)

1964 *Loxoconcha agilis* Ruggieri, Puri, Bonaduce and Malloy.

1975 *Loxoconcha agilis* Ruggieri, Bonaduce, Ciampo and Masoli, page102, plate 65, figures 9-14.

1985 *Loxoconcha agilis* Ruggieri, Stambolidis, page 218, plate 6, figures 3-5.

1995 *Loxoconcha agilis* Ruggieri, Kubanç, page 108, plate 10, figure 3.

2002 *Loxoconcha agilis* Ruggieri, Tunoğlu, page 40, plate 1, figures 6-7.

2008 *Loxoconcha agilis* Ruggieri, Şafak, page 1.

Stratigraphical and geographical distribution : Bay of Naples - Recent (Puri et al., 1964); Adriatic Sea - Recent (Bonaduce et al., 1975); Evros Delta – North Aegean / Greece –Recent (Stambolidis, 1985); Aegean Sea – Recent (Kubanç, 1995); Black Sea, Zonguldak -Coasts of Amasra - Recent (Tunoğlu, 2002); Mersin Gulf - Recent (Şafak, 2008).

Localities in this study : Hınıs 1 Measured Section, sample 10, Pliocene – Early Pleistocene; Hınıs 3 Measured Section, samples 7 and 8, Pliocene – Early Pleistocene.

Loxoconcha cf. *diligena* Kulieva, 1961

(Plate I, Figures 3-4)

1961 *Loxoconcha* cf. *diligena* Kulieva, Agalarova et al., 46 page.

1981 *Loxoconcha* cf. *diligena* Kulieva, Krstic and Dermitzakis, page 488, plate VI, figures 7-8.

Stratigraphical and Geographical Distribution: Azerbajian – Pliocene and Post Pliocene (Kulieva et al., 1961); Corinth Canal, Greece – Pleistocene (Krstic and Dermitzakis, 1981).

Localities in the study: Hınıs 2 Measured Section, sample 8, Early Pleistocene; Hınıs 3 Measured Section, samples 4 and 7, Pliocene.

Loxoconcha granulata Sars, 1866

(Plate I, Figures 6-8)

1865 *Palmoconcha guttata*, Norman

1866 *Loxoconcha granulata*, Sars

1956 *Loxoconcha unodensa*= *Loxoconcha gorschkovi*, Mandelstam,

1962 *Loxoconcha unodensa*= *Loxoconcha gorschkovi*, Mandelstam et al., Turkmenistan

1969 *Loxoconcha granulata*, Shornikov, Izd. Naukova Dumka, II, pages 163-269, Kiev.

1981 *Loxoconcha granulata*, Athersuch and Horne, in Stereo Atlas A.8: 117-124.

1981 *Loxoconcha granulata*, Krstic and Dermitzakis, plate III, figures 17-22.

1985 *Loxoconcha granulata,* Horne, Stereo Atlas 12, 28: 158.

1999 *Loxoconcha granulata,* Şafak, page 162, plate VI, figure 1.

2004 *Loxoconcha granulata,* Opreanu, pages 9-10.

2005 *Loxoconcha granulata,* Opreanu, Tom LI, pages 62-70.

2008 *Loxoconcha granulata,* Şafak, pages 5, 14, table 1

Stratigraphical and geographical distribution: Warsaw – Pleistocene (Mandelstam, 1956), Pliocene and Post Pliocene in Turkmenistan (Mandelstam et al.,1962); Russia - Recent (Shornikov; 1969, 2011); Netherlands – Recent (Athersuch and Horne, 1981); Corinth Canal, Greece - Pleistocene (Krstic and Dermitzakis, 1981); Gökçeada-Bozcaada-Çanakkale - Recent (Şafak, 1999); Black Sea Coast – Recent (Opreanu, 2004), NW Black Sea Romania – Recent (Opreanu, 2005); Mersin Gulf – Recent (Şafak, 2008).

Localities in this study : Hınıs 2 Measured Section, sample 7, Early Pleistocene.

Upper family : Cypridoidea s. str. Baird, 1845

Family : Candonidae Kaufmann, 1900

Subfamily : Candoninae Kaufmann, 1900

Genus : *Candona* Baird, 1845

Subgenus : *Candona (Typhlocypris)* Vejdovsky, 1882

Synonym : *Kochia* Hejjas, 1894

Advenocypris Snejder, 1956

Cavernocandona Hartmann, 1964

Species - Type : *Cypris eremita* Vejdovsky, 1880

Candona (Typhlocypris) amblygonica Freels, 1980

(Plate I, Figure 9)

1980 *Candona (Typhlocypris) amblygonica* Freels, Turkey Taf.9, figures 15-20. 1981

Stratigraphical and geographical distribution: Erzurum – Hınıs / Turkey, Mid-Upper Miocene (Freels, 1980).

Localities in this study : Hınıs 1 Measured Section, sample 3, Pliocene.

Subgenus : *Candona (Caspiocypris)* Mandelstam, 1956

Species- Type : *Bairdia candida* Livental, 1929

Stratigraphical Distribution : Oligocene (Eocene?) - Recent

Environment : Freshwater, seldom brackish (Morkhoven, 1963)

Candona (Caspiocypris) araxica Freels, 1980

(Plate II, Figures 1-2)

1980 *Candona (Caspiocypris) araxica* Freels

2001 *Candona (Caspiocypris) araxica* Freels, Tunoğlu, page 134, table 4, page 138, table 5.

Stratigraphical and Geographical distribution: Erzurum – Pasinler/Turkey, Upper Miocene – Pliocene (Freels, 1980), Black Sea Region/Turkey, Middle – Late Miocene - ? Pliocene (Tunoğlu, 2001).

Localities in this study : Hınıs 1 Measured Section, sample 3, Pliocene; Hınıs 2 Measured Section, sample 1, Pliocene; Hınıs 3 Measured Section, samples 2, 3, 5, 8, 9, Pliocene – Early Pleistocene.

Candona (Caspiocypris) erzurumensis Freels, 1980

(Plate II, Figure 3)

1980 *Candona (Caspiocypris) erzurumensis* Freels

Stratigraphical and geographical distribution : Erzurum - Pasinler/Turkey, Upper Miocene (Freels, 1980).

Localities in the study : Hınıs 1 Measured Section, sample 2, Pliocene; Hınıs 2 Measured Section, sample 1, Pliocene; Hınıs 3 Measured Section, samples 2, 3 and 4, Pliocene.

Candona (Caspiocypris) aff. *alta* (Zalanyi, 1929)

(Plate II, Figures 4-5)

Aff. 1929 Paracypris *alta* n. sp., Zalanyi, Morpho-System, Studien, page 44, figure 14.

Aff. 1971 *Candona (Thaminocypris) alta* (Zalanyi), Krstic, Neogene Ostracod, Serbien, table II, 3-5.

1974 *Candona (Caspiocypris) alta* (Zalanyi,), Hanganu, Danube-Motru, table III: 10-12.

1980 *Candona (Caspiocypris)* aff. *alta* (Zalanyi), Freels, Turkey, Taf. 4, figures 1-8.

1992 *Candona (Caspiocypris) alta* (Zalanyi), Şafak et al., Sarız (Kayseri)/Turkey, plate 4, figure 1.

1992 *Candona (Caspiocypris) alta* (Zalanyi), Nazik et al., Tufanbeyli (Adana)/Turkey, plate II, figure 8.

2005 *Candona (Caspiocypris) alta* (Zalanyi), Vasiliev et al., pages 3-6, table 1.

Stratigraphical and geographical distribution: Caspian Basin (Zalanyi, 1929); Romania-Sarmatian (Hanganu, 1974); Sivas and Şebinkarahisar/Turkey, Upper Miocene (Freels, 1980), Sarız and Tufanbeyli/ Turkey - Pliocene (Şafak et al., 1992; Nazik et al., 1992); Southern Carpathians – Mio-Pliocene (Vasiliev et al., 2005).

Stratigraphical and geographical distribution : Caspian Basin

Localities in this study : Hınıs 3 Measured Section, samples 8 and 9, Pliocene – Early Pleistocene.

Species -Type : *Cypris candida* Müller, 1776

Candona (Candona) parallela pannonica Zalanyi, 1959

(Plate II, Figure 6)

1959 *Candona parallela pannonica* Zalanyi, pages 200-202, plate 3, figure a-c

1963 *Candona pokornyi* Kheil, pages 23-25, plate 2, figures 1-4.

1979 *Candona (Candona) parallela pannonica* Zalanyi, Gökçen, page 119, plate 7, figures 1,2.

1988 *Candona parallela pannonica* Zalanyi, Nazik, page 80, plate 4, figure 8-11, plate 7, figure 11.

1989 *Candona parallela pannonica* Zalanyi, Tanar, pages 143-144, plate 11, figures 1-3.

1997 *Candona (Candona) parallela pannonica* Zalanyi, Şafak and Meriç, page 194, plate V, figures 8-9.

1997*b* *Candona (Candona) parallela pannonica* Zalanyi, Şafak, pages 262-266.

1998 *Candona (Candona) parallela pannonica* Zalanyi, Şafak and Taner, plate 1, figure 9.

1999 *Candona (Candona) parallela pannonica* Zalanyi, Kubanç et al., page 791.

1999 *Candona (Candona) parallela pannonica* Zalanyi, Şafak et al., page 184, plate IV, figure 7.

1999 *Candona (Candona) parallela pannonica*

Zalanyi, Nazik et al., page 117.

1999 *Candona (Candona) parallela pannonica* Zalanyi, Nazik et al., page 144, plate III, figures 6-7.

2001 *Candona (Candona) parallela pannonica* Zalanyi, Tunoğlu, page 131, table 1.

2001 *Candona parallela pannonica* Zalanyi, Tunoğlu and Ünal, page 177, plate 3, figures 2-4.

2002 *Candona (Candona) parallela pannonica* Zalanyi, Atay and Tunoğlu, page 143, plate 3, figures 1-5.

2004 *Candona (Candona) parallela pannonica* Zalanyi, Atay and Tunoğlu, page 13.

2008 *Candona parallela pannonica* Zalanyi, Nazik et al., page 494, plate 1, figure 4.

2009 *Candona parallela pannonica* Zalanyi, Şafak et al., page 206, plate 3, figure 10.

2010 *Candona (Candona) parallela pannonica* Zalanyi, Nazik et al., plate 4, figure 4.

2010 *Candona (Candona) parallela pannonica* Zalanyi, Şafak, page 57, plate 3, figures 1-2.

Stratigraphical and geographical distribution: Pannoninan Basin, Hungary, Late Pannonian (Zalanyi, 1959); Trebon basin, Czechoslovakia, Tortonian (Kheil, 1963); Denizli – Muğla / Turkey, Pontian (Gökçen, 1979); Ulukışla, Adana / Turkey, Pontian (Nazik, 1988); Mut Basin, Turkey, Burdigalian (Tanar, 1989); Kahta / Adıyaman, Messinian (Şafak and Meriç, 1997); Bakırköy Basin - İstanbul / Turkey, Messinian = Pontian (Şafak, 1997); NW Karaman - İçel / Turkey – Quaternary (Şafak and Taner, 1998); İzmit Bay - Pleistocene (Kubanç et al, 1999); western İstanbul - Pliocene (Şafak et al., 1999); Anadolu Hisarı / İstanbul - Holocene (Nazik et al., 1999); Akyatan Lagoon / SE Adana Turkey - Holocene (Nazik et al., 1999); Black Sea Region / Turkey, Pontian (Tunoğlu, 2001); Gelibolu Peinnsula / NW Turkey, Mid – Late Pannonian - Pontian (Tunoğlu and Ünal, 2001); Eceabat / Çanakkale (NW Turkey), Pannonian (Atay and Tunoğlu, 2002); Kilitbahir / Çanakkale – Upper Miocene (Atay and Tunoğlu, 2004); Arguvan / Malatya (Eastern Anatolia), Upper Miocene (Nazik et al., 2008); Adıyaman / Southeastern Anatolia, Messinian (Şafak et al., 2009); İznik and Sapanca lakes / Turkey, Quaternary (Nazik et al., 2010); Denizli / SW Anatolia – Late Miocene (Şafak, 2010).

Localities in this study: Hınıs 1 Measured Section, sample 3, Pliocene, Hınıs 2 Measured Section, samples 1, 3 and 4, Pliocene

Candona (Candona) burdurensis Freels, 1980

(Plate II, Figures 7-8)

1980 *Candona (Candona) burdurensis* Freels, page 101, taf. 17, figures 15-23.

1996 *Candona (Candona) burdurensis* Freels, Tunoğlu and Bayhan, page 101, Taf.17, figures 15-23.

1999 *Candona (Candona) burdurensis* Freels, Kubanç et al., page 791.

2005 *Candona (Candona) burdurensis* Freels, Matzke-Karasz and Witt, page 118, plate 1, figure 2.

Stratigraphical and geographical distribution : Burdur Lake - Burdur / Turkey, Late Pleistocene (Freels, 1980); Burdur Basin / Turkey, Pliocene (Tunoğlu and Bayhan, 1996); İzmit Bay - Pleistocene (Kubanç et al., 1999); Yalova (İzmit vicinity / Turkey) - Meotian (Matzke-Karasz and Witt, 2005).

Locaities in this study : Hınıs 2 Measured Section, sample 1, Pliocene; Hınıs 3 Measured Section, sample 5, Pliocene.

Candona (Candona) candida Müller, 1776

(Plate II, Figure 9)

1776 *Candona candida* Müller

1965 *Candona candida* Müller, Devoto, page 337, figure 36.

1973 *Candona (Candona) candida* pliocenica Müller, Krstic, page 151-173, figures 1,2.

1978 *Candona candida* Müller, Sokac, pages 24-25, plate 9, figures 1-4.

1980 *Candona candida* Müller, Freels, pages 80-82, plate 13, figures 6-8.

1984 *Candona (Candona)* aff. c*andida* Müller, Tunoğlu, pages 118-119, plate 9, figures 1-3.

1991 *Candona candida* Müller, Pietrzenuik, page 106, plate 2, figures 5-7.

1996 *Candona candida* Müller, Ünal, pages 116-117, plate 7, figures 3, 4; plate 13, figure 1.

1997 *Candona (Candona) candida* Müller, Şafak, page 94, plate IV, figure 8.

2001 *Candona candida* Müller, Tunoğlu and Ünal, page 177, plate 3, figure 7.

2002 *Candona (Candona) candida* Müller, Atay and Tunoğlu, page 143, plate 3, figures 6-8.

2003-2004 *Candona candida* Müller, Bossio et al., page 69.

2004 *Candona candida* Müler, Atay and Tunoğlu, page 13.

2008 *Candona candida* Müller, Beker, Tunoğlu and Ertekin, page 14, plate2, figures 2,3.

2010 *Candona candida* Müller, Şafak, page 56, figure 7.

Stratigraphical and geographical distribution : Liri Valley / Italy, Pleistocene (Devoto, 1965); Jugoslavia, Pontian (Krstic, 1973); Pannonian Basin, Pontian (Sokac, 1978); Aydın / Turkey, Late Miocene (Freels, 1980); Sinop Peninsula / Turkey, Pontian (Tunoğlu, 1984); Germany, Miocene (Pietrzenuik, 1991); Gelibolu Peninsula, Early Pannonian – Pontian (Ünal, 1996); Karaman / Turkey, Pliocene (Şafak, 1997); Gelibolu Basin / NW Turkey, Pannonian-Pontian (Tunoğlu and Ünal, 2001); Ecaabat / Çanakkale / NW Turkey, Pannonian (Atay and Tunoğlu, 2002); Toscana, Italy, Neogene (Bossio et al., 2003-2004); Kilitbahir / Çanakkale – Upper Miocene (Atay and Tunoğlu, 2004); Karapınar - Konya / Central Anatolia, Pliocene – Lower Pleistocene (Beker et al., 2008); Denizli / SW Anatolia, Late Miocene (Şafak, 2010).

Localities in this study : Hınıs 3 Measured Section, sample 5, Pliocene.

Candona (Candona) sp.1 Freels, 1980

(Plate II, Figure 10)

1980 *Candona (Candona)* 1Freels, p. 97, Taf. 17, figure 1-3.

Stratigraphical and geographical distribution : Muş Basin / Turkey, Pliocene – Lower Pleistocene (Freels, 1980).

Localities in this study : Hınıs 2 Measured Section, sample 4, Pliocene.

4. Discussion and Results

Rich ostracod assemblages and micro molluscs,which constitutes the subject matter of this study,were identifined from the washed samples collected from the soft clayey limestone and plant fragments bearing travertine limestones in the Yolüstü formation.

Ostracods, such as, *Leptocythere (Amnicythere)* cf. *litiva* Livental, Agal., et al., *Tyrrhenocythere bailovi* (Suzin), *Loxoconcha granulata* Sars, *L.* cf. *diligena* Kulieva, *L. agilis* Ruggieri, *Candona (Caspiocypris) araxica* Freels, *C. (Caspiocypris)erzurumensis* Freels, *C (Caspiocypris)* aff. *alta* (Zalanyi), *C. (Typhlocypris) amblygonica* Freels, *C. (Candona) parallela pannonica* Zalanyi, *C. (Candona) burdurensis* Freels, *C. (Candona) candida* (O.F.Müller), *C (Candona)* Freels, and micro gastropods and pelecypods like *Valvata piscinalis* (O.F.Müller), *Viviparus* sp., *Dreissena polymorpha* (Palas) are the fossils observed in the formation. *Leptocythere (Amnicythere)* cf. *litiva* Livental, *Tyrrhenocythere bailovi* (Suzin), *Loxoconcha granulata* Sars, *L.* cf. *diligena* Kulieva, *L. agilis* Ruggieri, *Candona (Caspiocypris) araxica* Freels, *C. (Caspiocypris) erzurumensis* Freels, *C.(Caspiocypris)* aff. *alta* (Zalanyi), *C. (Typhlocypris) amblygonica* Freels, *C. (Candona) parallela pannonica* Zalanyi, *C. (Candona) burdurensis* Freels, *C. (Candona) candida* (O.F.Müller), *C. (Candona)* sp. 1 Freels gibi ostrakod ve *Valvata piscinalis* (O.F.Müller), *Viviparus* sp., *Dreissena polymorpha* (Palas) are the fossils observed in the formation. Ostracods like, *Candona (Caspiocypris) araxica* Freels, *C. (Caspiocypris) erzurumensis* Freels, *C. (Caspiocypris)* aff. *alta* (Zalanyi), *C. (Typhlocypris) amblygonica* Freels, *C. (Candona) parallela pannonica* Zalanyi, *C. (Candona) burdurensis* Freels, *C. (Candona) candida* (O.F.Müller), *C. (Candona)* sp.1 Freels generally indicate age for the travertine limestone and the ostracods, such as, *Leptocythere (Amnicythere)* cf. *litiva* Livental, *Tyrrhenocythere bailovi* (Suzin), *Loxoconcha granulata* Sars, *L.* cf. *diligena* Kulieva, *L. agilis* Ruggieri together with the micro mollusks such as; *Valvata piscinalis* (O.F.Müller), *Viviparus* sp., *Dreissena polymorpha* (Palas), in general, indicate Early Pleistocene age for the plant fragments bearing hard travertine (Figure 2).

Freels (1980) assigned the following ostracod fauna as Late Miocene; *C (Caspiocypris) erzurumensis* Freels, *C. (Caspiocypris)* aff. *alta* (Zalanyi), *C (Typhlocypris) amblygonica* Freels, *C (Candona) candida* (O.F.Müller), *C. (Candona)* 1 Freels. But he recognized *C. (Candona) burdurensis* Freels genus as Pleistocene. However; Krstic and Dermitzakis (1981) considered the fossil assemblage characterized by *Leptocythere (Amnicythere)* cf. *litiva* Livental, *Loxoconcha granulata* Sars, *L.* cf. *diligena* Kulieva, *Tyrrhenocythere bailovi* (Suzin) occur as Pleistocene.

C. (Candona) parallela pannonica species was defined as Miocene – Quaternary age by many investigators (Nazik et al.,1992; Şafak et al., 1999; Tunoğlu et al., 1995; Ünal, 1996; Şafak and Meriç, 1997; Şafak, 1997; Şafak and Taner, 1998; Kubanç et al., 1999; Nazik et al., 1999*a*; Nazik et al., 1999*b*; Tunoğlu, 2001; Tunoğlu and Ünal, 2001; Atay and Tunoğlu, 2002 ; Atay and Tunoğlu, 2004; Nazik et al., 2008; Şafak et al, 2009; Nazik et al., 2010; Şafak, 2010).

L. agilis Ruggieri species was defined in the numereous studies carried out in the Bay of Naples, Adriatic Sea, Evros Delta, Aegean Sea, Black Sea, along the coasts of Zonguldak–Amasra and in the Gulf of Mersin (Puri et al., 1964; Bonaduce et al., 1975; Stambolidis, 1985; Kubanç, 1995; Tunoğlu, 2002; Şafak, 2008). Furthermore, the mollusc fauna defined within this unit wereconsidered as Pliocene in the Dardanelles by Taner (1997). Loxoconcha cf. diligena Kulieva sp., an ostracod species, was defined in Azerbaijan and Corinth Canal (Greece) as Pliocene - Post Pliocene and Pleistocene (Kulieva et al., 1961; Krstic and Dermitzakis, 1981).

Loxoconcha granulata Sars species was considered as Pleistocene – Recent in age in several studies carried out in Warsaw, Russia, Netherlands, Greece (Corinth Canal), Turkey (Gökçeada – Bozcaada – Çanakkale, Black Sea Coast, and in the Gulf of Mersin) and the NW Black Sea of Romania (Mandelstam, 1956 and 1962; Shornikov, 1969; Athersuch and Horne, 1981; Krstic and Dermitzakis, 1981; Şafak, 1999; Opreanu, 2003- 2004 and 2005; Şafak, 2008).

Previous investigators regarded the İncesu formation as late Pleistocene, since it rests on the lacustrine, tuff and clayey limestone units of the Yolüstü formation with an gradational contact. Therefore the Yolüstü formation is considered to have deposited at the interval of middle Pliocene (Tarhan, 1961). In this study, the fossil assemblage of the ostracoda forms identified in this unit (the Yolüstü formation) indicates an age interval of Pliocene-early Pleistocene.

The following ostracoda fauna,in particular, *Tyrrhenocythere bailovi* (Suzin), *Candona (Caspiocypris) araxica* Freels, *C. (Caspiocypris) erzurumensis* Freels, *C. (Caspiocypris)* aff. *alta* (Zalanyi) are regarded as characteristic forms of Ponto – Caspian and Pannonian Basin (Central Paratethys) in origin, and they indicate transition starting from oligohaline to brackish water environments representing of closed and different basinal characteristics.

As it has already been noted in many ostracoda studies carried out in Hungary, Azerbaijan, Russia and in other places that the following fauna like *Leptocythere (Amnicythere)* cf. *litiva* Livental, Agal., *Loxoconcha granulata* Sars, *L.* cf. *diligena* Kulieva occur in gulf and marine influenced canal, i.e. Corinth canal,environments, and they represent transition into brackish water. *Loxoconcha agilis* Ruggieri sp. has not been referred among the Mediterranean originated Loxoconcha species in the study of Schornikov (2011) but its occurence has been noted in the studies carried out along the coasts of the Black Sea.

Ostracods, such as, *C (Candona) parallela pannonica* Zalanyi, *C. (Candona) burdurensis* Freels, *C (Candona) candida* (O.F.Müller), *C (Candona)* sp. 1 Freels and micro molluscs as *Valvata piscinalis* (O.F.Müller), *Viviparus* sp., *Dreissena polymorpha* (Palas) indicate a freshwater environment. This faunal assemblage indicates a continuous intake of fresh water into the depositional environment of the plant fragment bearing travertine limestone.

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PLATES

PLATE I

Figure 1- *Leptocythere (Amnicythere)* cf. *litica* Livental, in Agalarova et al., 1961

Hınıs 1 Measured Section, Yolüstü formation, Harami member, Sample 10, Early Pleistocene

1.Left valve, external view.

Figure 2- *Tyrrhenocythere bailovi* (Suzin, 1956)

Hınıs 3 Measured Section, Yolüstü formation, Harami member, Sample 7, Early Pleistocene

2. Left valve, external view.

Figures 3-4- *Loxoconcha* cf. *diligena* Kulieva, 1961

Hınıs 2 Measured Section, Yolüstü formation, Harami member, Sample 8, Early Pleistocene

3. Shell, right valve, external view.

4. Shell, left valve, external view.

Figure 5- *Loxoconcha agilis* Ruggieri, 1967

Hınıs 3 Measured Section, Yolüstü formation, Harami member, Sample 7, Pliocene - Early Pleistocene

5. Shell, left valve, external view.

Figure 6-8- *Loxoconcha granulata* Sars, 1866

Hınıs 3 Measured Section, Yolüstü formation, Harami member, Sample 7, Pliocene - Early Pleistocene

6. Shell, left valve, external view

7. Shell, right valve, external view

8. Shell, left valve, external view

Figure 9- *Candona (Typhlocypris) amblygonica* Freels

Hınıs 1 Measured Section, Yolüstü formation, Harami member, Sample 3, Pliocene

9. Left valve, external view

PLATE I

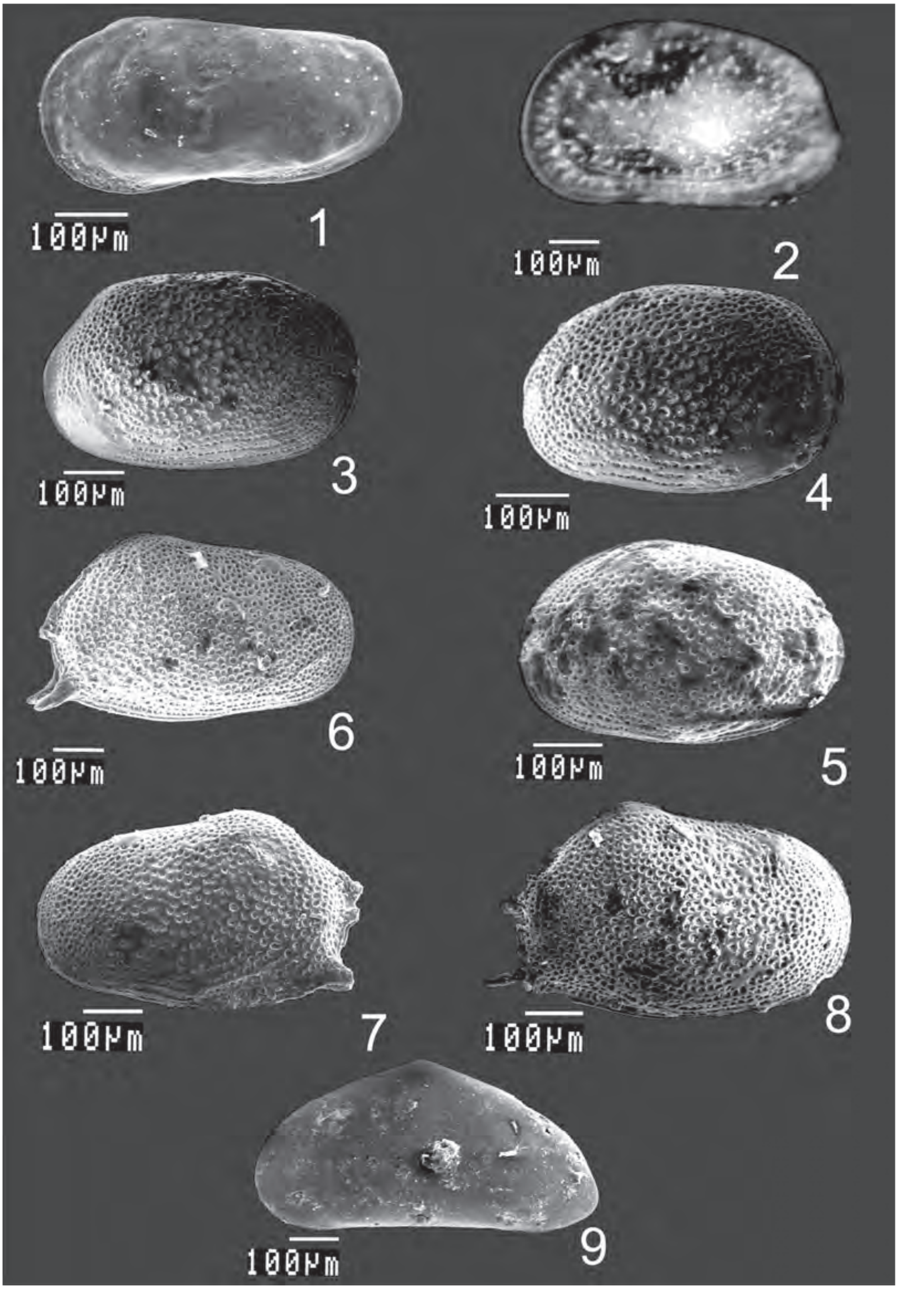
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PLATE II

Figures 1-2- *Candona (Caspiocypris) araxica* Freels, 1980

Hınıs 1 Measured Section, Yolüstü formation, Harami Member, Sample 3, Pliocene

1. Right valve, external view

2. Left valve, external view

Figure 3- *Candona (Caspiocypris) erzurumensis* Freels, 1980

Hınıs 1 Measured Section, Yolüstü formation, Hamzabey Member, Sample 2, Pliocene

3. Right valve, external view

Figure 4-5- *Candona (Caspiocypris)* aff. *alta* (Zalanyi, 1929)

Hınıs 3 Measured Section, Yolüstü formation, Harami Member, Sample 8, Early Pleistocene

4. Right valve, external view

5.Right valve, external view

Figure 6- *Candona (Candona) parallela pannonica* Zalanyi, 1959

Hınıs 2 Measured Section, Yolüstü formation, Harami Member, Sample 1, Pliocene

6. Right valve, external view

Figure 7-8- *Candona (Candona) burdurensis* Freels, 1980

Hınıs 2 Measured Section, Yolüstü formation, Harami Member, Sample 1, Pliocene

7. Left valve, external view

Figure 9- *Candona (Candona) candida* Müller, 1976

Hınıs 3 Measured Section, Yolüstü formation, Harami Member, Sample 5, Pliocene

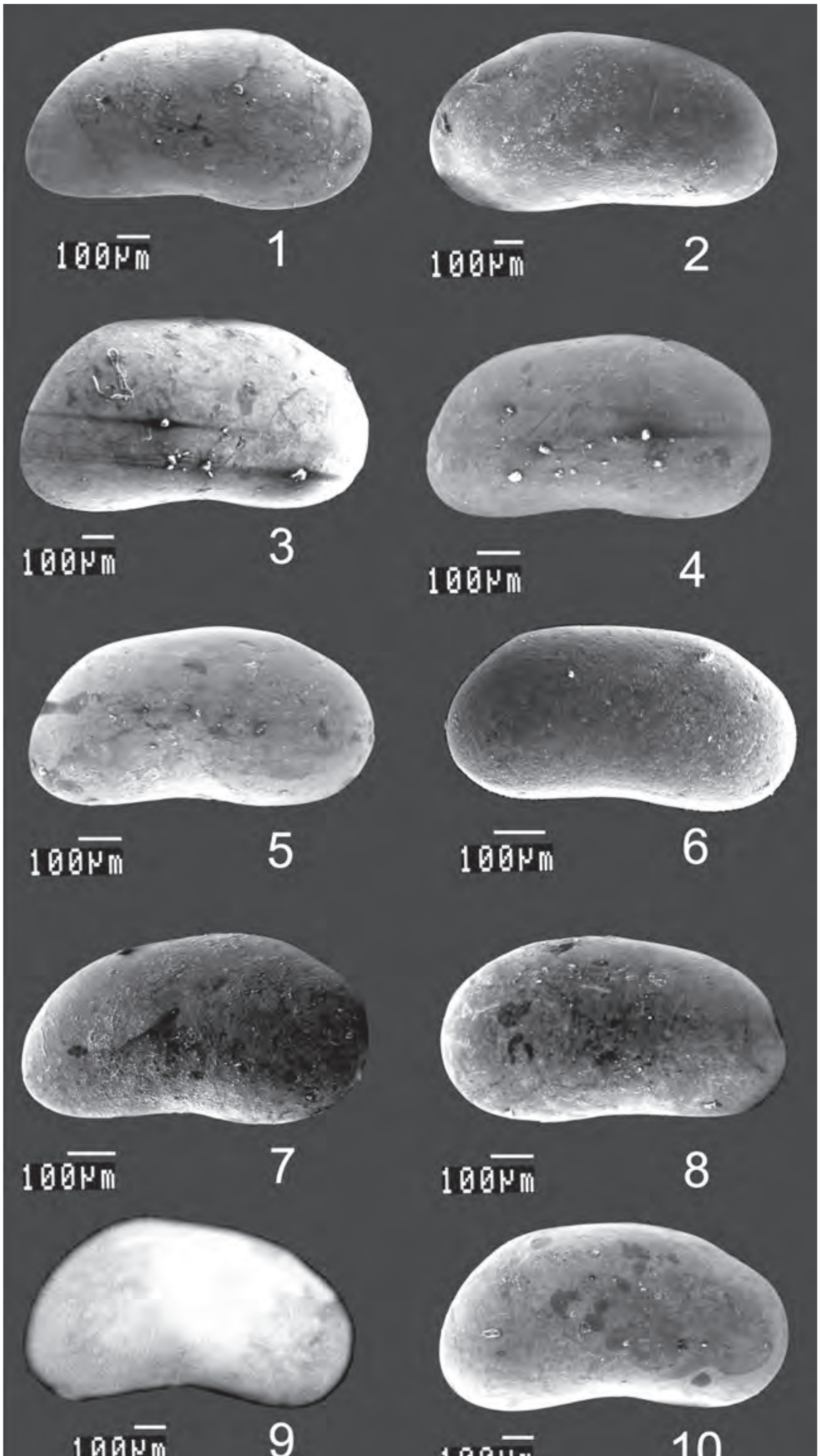
9. Right valve, external view

Figure 10- *Candona (Candona)* sp.1 Freels, 1980

Hınıs 2 Measured Section, Yolüstü formation, Harami Member, Sample 1, Pliocene

10. Right valve, external view

PLATE II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PETROGENETIC CHARACTERISTICS OF OYACA – KEDİKAYASI – BOYALIK ADAKITES IN SW ANKARA (CENTRAL ANATOLIA, TURKEY): EVIDENCE FOR SLAB MELT METASOMATISM

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Adakite,
Ankara,
partial melting,
petrogenetic modeling,
metasomatism

ABSTRACT

The Early Miocene Oyaca, Kedikayası and Boyalık dacites, situated approximately 50-60 km southwest of Ankara have affinities similar to adakitic rocks. They have porphyritic texture with a variable amount of plagioclase feldspar, hornblende and lesser biotite phenocrysts and a groundmass of plagioclase and quartz microcrysts. They have high Sr/Y (55-79 ppm) and (La/Yb)n (21-32 ppm) ratios, and low Y (10-19 ppm) and heavy rare earth element contents. According to their SiO_2 (62.3-69.70 % wt.) and MgO (0.62-2.23 % wt) contents, they are referred to as high silica adakites, indicating the effects of slab-derived melts in their genesis. The adakites in the study area are enriched in Large Ion Lithophile Elements (LILE) (e.g., Ba: 800-1395 ppm, Sr≥720 ppm) relative to High Field Strength Elements (HFSE) (e.g. Nb: 20-10 ppm, Ta: 0.8-1.2 ppm). Low Rb/Sr and high Ba/Sr ratios in these adakites indicate that they are resulted from an amphibole bearing mantle source, as amphiboles have low Rb concentrations. Thus, partial melting of an amphibole bearing mantle source would be responsible for low Rb concentrations). For that reason, non-modal partial melting calculations from a 13 % amphibole bearing garnet peridotite were carried out in order to determine the source features of adakites. The variations between La/Yb vs La and (Tb/Yb)n vs (La/Yb)n in partial melting studies demonstrate that the adakites in the study area were most probably derived from an amphibole bearing garnet peridotite mantle source via 5-10 % degrees of partial melting.

1. Introduction

1.1. The Aim of the Study

Most of the magmas of subduction zone are interpreted to have formed by the partial melting of metasomatised mantle wedge. However, recent studies have shown that these magmas could also be formed by the melting of subducting oceanic crust (Defant and Drummond, 1990; Stern and Kilian, 1996; Martin, 1999; Beate et al., 2001; Bourdon et al., 2002; Defant et al., 2002). Such sodic and felsic slab melts were named as adakite by Defant and Drummond (1990). Despite many investigations have been carried out about the adakite/adakitic magmatism in recent years, their genesis and evolutionary history are still discussed. It has been suggested by studies that adakite/adakitic rocks are the products of high pressure crystal fraction and assimilation of hydrous basaltic magmas (Macpherson et al., 2006) or low pressure crystal fraction and assimilation of basaltic magmas (Castillo et al., 1999; Castillo, 2006); crystal fractionation and/or differentiation of subduction-related magma in the crust-mantle transition zone (Eyuboğlu et al., 2011*a*); partial melts of subducted oceanic crust (Defant and Drummond, 1990; Stern and Kilian, 1996; Martin, 1999; Xu et al., 2000; Beate et al., 2001; Bourdon et al., 2002; Zhu et al., 2009); partial melts of thickened and delaminated mafic lower crust (Xu et al., 2002; Chung et al., 2003;

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Hou et al., 2004; Rollinson and Tarney, 2005; Wang et al., 2005; Wang et al., 2007*a, b;* Liu et al., 2008; Karslı et al., 2010; Eyüboğlu et al., 2012b) and the products generated by a slab window processes in a subduction-related setting (Eyüboğlu et al., 2011*b, c;* Eyüboğlu et al., 2012*a, b*). Extraordinary trace element characteristics as well high Mg, Ni and Cr contents in adakite and adakitic rocks are explained as metasomatism of mantle by slab melts (Sajona et al., 2000).

Adakite and adakitic rocks can form in different tectonical environments and by different processes. In this study, the Oyaca, Kedikayası and Boyalık dacites which was previously investigated by Bozkurt et al (1999) and Alıcı Şen (2009) are re-assessed geochemically and petrogenetically to determine whether these dacites were the products of adakitic magmatism or not. In doing so; major oxide and trace element data of Oyaca, Kedikayası and Boyalık dacites have been taken from Bozkurt et al. (1999) and Alıcı Şen (2009). With regard to the chemical composition of the dacitic samples, it is concluded that that they have features similar to adakites. During the evaluation studies, petrogenetic modeling studies have been used to address the question of which source is responsible for the genesis of these rocks. The study area is located among İzmir – Ankara – Erzincan Suture Zone (IAESZ), Sakarya Continent and Kırşehir Block (Figure 1). The early tectonic evolution of the Ankara region consists of the collision of Rhodopian – Pontide plates with the Kırşehir Metamorphic Massif to the south (Şengör and Yılmaz, 1981). The IAEZS is one of the main compressional paleotectonic structures in northern Anatolia. The İzmir – Ankara suture zone is the remnant of northern branch of the Neotethys ocean which, around Ankara, was closed in late Eocene (Görür et al., 1984; Koçyiğit, 1991; Koçyiğit et al., 1995; Bozkurt et al., 1999; Kaymakçı, 2000). Extensive Miocene volcanism has developed in Ankara and its surroundings after collision (Wilson et al., 1997; Tankut et al., 1998; Toprak and Türkecan, 1998; Varol et al., 2007; Varol et al., 2008; Koçyiğit et al., 2003; Temel et al., 2010). Geological units are ophiolitic mélange and Eocene flysch consisting the remnants of Neotethyan oceanic lithosphere, volcanic products and accretionary materials derived from the northern branch of Neotethys Ocean (Koçyiğit, 1991, Tüysüz and Yiğitbaş, 1994; Bozkurt et al., 1999). There is an intrusive contact relationship between Miocene volcanic units, and Eocene flysch and the ophiolitic mélange (Ünalan and Yüksel, 1985; Bozkurt et al., 1999; Şahin, 2007). The location of the study area in regional tectonical map and its simplified geological map are given in figure 1. Sedimentary (carbonate and clastics) and volcanic rocks are the most common rock types in the region.

The study area lies within IAESZ, between the Sakarya continent and the Kırşehir block, about 50-60 km SW of Ankara. The area is important to evaluate the volcanic evolutionary history of subduction, collision and the following post collisional processes. Besides; acidic rocks of Miocene Balkuyumcu volcanism located at 20 – 30 km NW of the study area as well show similar features to adakite (Varol et al., 2006; 2007). Therefore; these adakitic volcanisms in SW Ankara are important for the determination of genetic and evolutionary stages.

2. Petrographical and Geochemical Characteristics of the Oyaca – Kedikayası – Boyalık Dacites

Dacites in the study area have hypocrystalline porphyritic texture with variable amount of plagioclase feldspar, hornblende with lesser biotite phenocrysts. Oxides are common accessory minerals. The groundmass of the rock is mainly composed of plagioclase, quartz microlites, hornblende microcrysts and lesser amount of glass. Plagioclase microlites and hornblende microcrysts in the groundmass show preferred orientation and quartz microcrysts have rounded corners. Euhedral to subhedral plagioclase phenocrysts (2 – 4 mm) are the most common mineral, and zoning and twinning are typical. Although plagioclase phenocrysts are generally fresh, some have glass inclusions and argillic alteration through their fractures and rims. Hornblende phenocrysts, displaying significant pleochroism, are present as green elongate euhedral grains. Most of the hornblende phenocrysts are characterized by oxidized rims. Hornblende phenocrysts occasionally form cumulates. Biotite phenocrysts, which exist in minor amounts, generally show brownish pleochroism. Biotite phenocrysts, which display oxide replacement around their rims, have occasionally corroded texture.

Results of major oxide and trace element analyses taken from Bozkurt et al., (1990) and Alıcı Şen (2009) are given in table 1. Rocks with dacitic composition are calc-alkaline in character with high SiO_2 (% 62-70 wt.), Al_2O_3 (>% 15.50 wt.), Na_2O (>% 4.0 wt.), Sr (648-1026 ppm), Ba (648-1810 ppm), low TiO_2 (<% 0.90 wt.), K_20 (% 1.51-2.08 wt.), high field strength element (HFSE) (Nb: 20-10 ppm, Ta: 0.8-1.2 ppm), heavy rare earth element (HREE) [especially Yb (<1.70 ppm)] and Y contents. High Sr, low Y values and high

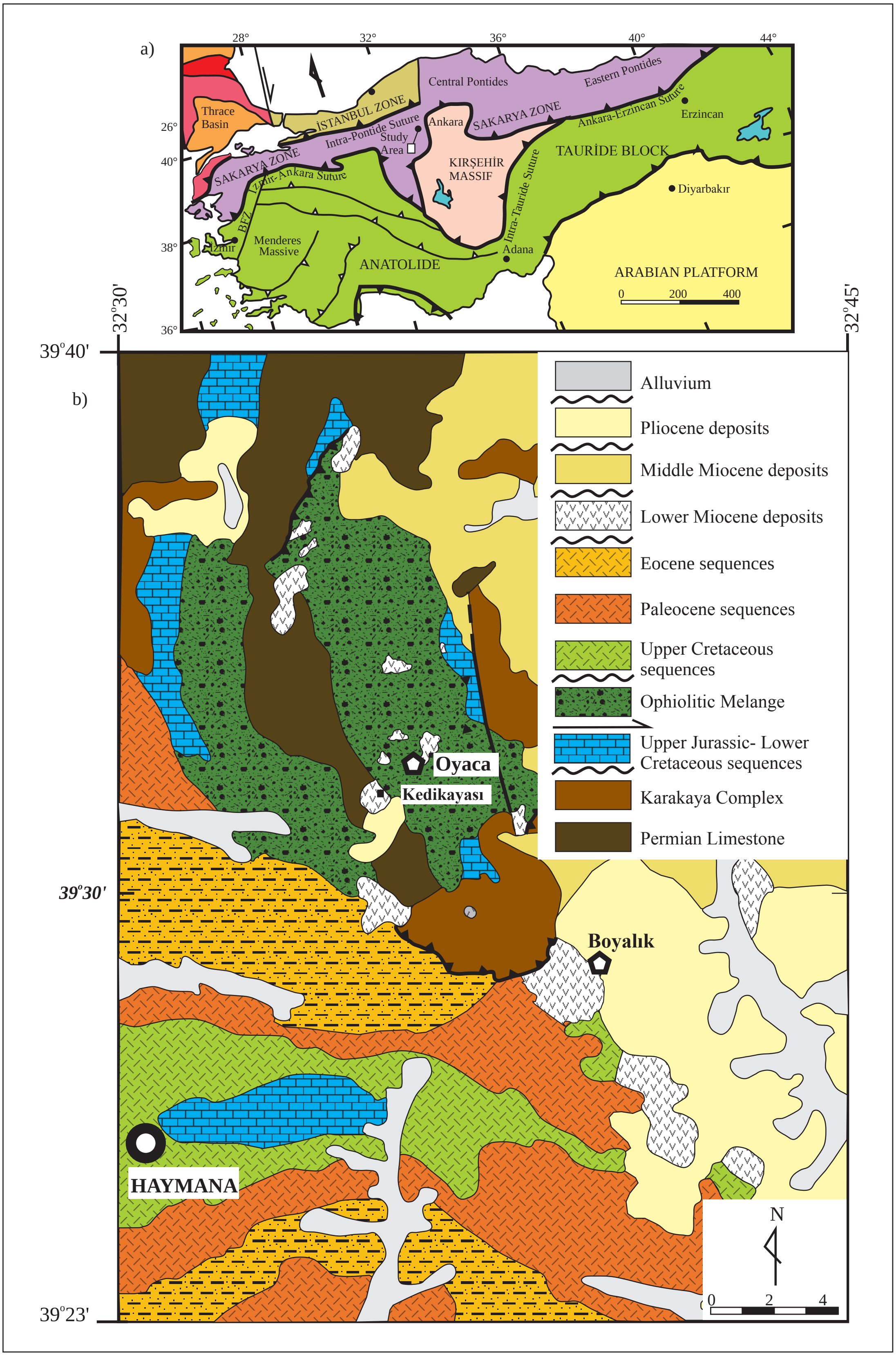


Figure 1-a) Tectonics of Turkey (Okay and Tüysüz, 1999); b) Simplified geological map of studied area and its surroundings (after 1/500.000 scaled map of MTA).

Table 1- Major-oxide, trace and rare earth element data of Oyaca, Kedikayası ve Boyalık adakites (data from Bozkurt et al., 1999 and Alıcı Şen, 2009).

	OYACA				KEDİKAYASI				BOYALIK							
	OY3	OY6	OY7	OY9	OY15	OY17	OY18	OY20	BY-06-1	BY-06-2	BY-06-3	BY-06-4	BY-06-5	BY-06-6	BY-06-13	BY-06-14
SiO_2 (wt. %)	66,12	64,54	62,3	65,43	65,18	63,42	64,46	65,4	64,77	66,51	66,20	66,19	65,50	69,68	63,44	63,03
MgO	1,13	1,85	1,74	1,62	1,78	2,23	1,68	0,68	1,69	1,45	1,77	0,62	1,58	0,50	1,27	0,97
CaO	4,11	5,18	5,73	5,27	4,37	4,84	4,52	4,28	6,52	4,95	4,85	5,27	4,93	3,67	5,08	4,86
MnO	0,06	0,06	0,09	0,06	0,07	0,12	0,07	0,05	0,11	0,07	0,06	0,06	0,04	0,00	0,02	0,02
TiO_2	0,49	0,47	0,59	0,47	0,5	0,54	0,57	0,48	0,59	0,51	0,48	0,54	0,44	0,46	0,83	0,86
FeO	2,55	2,60	3,05	2,42	2,86	3,01	2,79	2,34	2,88	2,74	2,76	2,53	2,17	1,74	2,71	2,63
Fe_2O_3	1,02	1,04	1,22	0,97	1,15	1,20	1,12	0,93	1,15	1,10	1,11	1,01	0,87	0,69	1,08	1,05
Na_2O	4,09	4,37	4,2	4,64	4,8	5,06	4,88	5,12	3,52	4,07	4,29	4,35	4,31	4,27	4,40	4,40
K_2O	1,61	1,51	1,52	1,63	2,08	1,87	1,91	1,99	2,16	1,77	1,62	2,04	1,65	1,74	1,77	1,76
Al_2O_3	16,16	15,67	15,41	16,02	16,14	16,28	16,66	16,88	16,80	16,17	16,42	17,10	16,67	17,10	17,44	17,61
P_2O_5	0,29	0,26	0,36	0,27	0,37	0,44	0,35	0,31	0,30	0,26	0,25	0,27	0,20	0,22	0,52	0,52
Total	97,63	97,55	96,21	98,8	99,3	99,01	99,01	98,46	100,51	99,61	99,81	99,97	98,35	100,08	98,58	97,72
Cr (ppm)	48	28	38	39	22	26	28	24	11,47	10,65	11,67	16,34	34,08	37,04	18,36	18,92
Ni	26	19	24	23	16	25	16	13	20,12	10,29	10,86	11,61	34,77	20,20	24,73	23,23
Zr	110	131	103	118	155	139	142	138	86,26	75,46	63,52	73,50	83,91	107,20	81,19	78,91
Rb	44	45	42	43	54	48	49	52	66,71	41,16	40,42	44,67	37,01	39,22	29,02	19,33
Sr	775	940	831	868	892	946	1007	1026	772,27	720,45	780,85	890,08	647,65	658,41	953,28	975,06
Y	14	15	15	11	17	15	17	13	12,15	11,20	10,48	14,03	10,47	10,64	16,76	18,64
Nb	16	15	17	15	18	19	17	20	10,49	12,83	11,82	12,80	11,05	11,84	17,91	17,78
Ba	938	1210	919	873	1332	1311	1295	1393	1810,82	948,08	951,41	1052,71	650,92	647,67	804,27	806,44
La	63	37	76	35,8	49	46,3	59	51	46,64	38,51	37,46	46,16	28,71	31,57	43,27	43,30
Ce	49	66	48	63,3	97	82	86	86,3	82,05	67,66	66,24	74,55	50,61	53,10	81,59	81,55
Pr		7,13		6,86		9		9,45	8,95	7,40	7,20	9,13	5,54	6,10	9,46	9,46
Nd	27	24,2	32	23,5	37	31,4	26	32,1	29,30	24,14	23,55	30,66	18,31	20,24	32,70	32,96
Sm		3,54		3,47		4,64		4,55	4,46	3,75	3,61	4,97	3,01	3,35	5,47	5,55
Eu		1,05		1,04		1,36		1,35	1,47	1,16	1,11	1,42	0,93	1,00	1,54	1,60
Tb		0,37		0,37		0,47		0,44	0,46	0,41	0,39	0,55	0,36	0,38	0,60	0,63
Gd		2,76		2,7		3,58		3,31	3,23	2,83	2,74	3,77	2,46	2,66	4,23	4,32
Dy		1,9		1,88		2,48		2,27	2,21	2,03	1,97	2,74	1,90	1,98	3,04	3,31
Ho		0,36		0,36		0,47		0,42	0,41	0,37	0,37	0,52	0,36	0,37	0,58	0,64
Er		0,95		0,97		1,24		1,13	1,10	1,01	1,02	1,42	0,99	0,99	1,52	1,78
Yb		0,93		0,94		1,19		1,08	0,98	0,90	0,93	1,33	0,91	0,89	1,41	1,68
Lu		0,15		0,15		0,19		0,16	0,14	0,12	0,15	0,20	0,14	0,14	0,21	0,26
Hf		1,47		1,71		1,42		1,24	0,86	0,84	1,71	1,31	2,21	1,94	2,36	2,33
Ta		0,86		0,85		1,1		1,18	0,72	0,91	0,84	0,89	0,82	0,80	1,11	1,11
Pb	21	31	19	20	36	27	28	32	21,18	21,81	18,04	21,71	23,53	18,82	21,19	22,20
Th	9	10,7	10	10,5	16	13,7	11	15,7	13,51	10,55	10,86	11,31	8,27	8,24	9,39	8,89
U		2,36		2,85		2,81		2,45	3,90	2,30	2,55	2,92	2,20	1,68	1,90	1,54

Sr/Y ratios are the general characteristics of adakitic rocks and reflect the features of high pressure and slab melting (Defant and Drummond, 1990; Martin et al., 2005). According to these criteria; Oyaca, Kedikayası and Boyalık dacites plot in the adakitic area in Sr/Y-Y and (La/Yb)n-(Yb)n diagrams with their high Sr/Y (55-79) and (La/Yb)n (21-32) (Thompson (1982) and low Y (10-19) and (Yb)n (5.2-6.4) contents (Figures 2 and 3). (Hereinafter "adakite" term will be used).

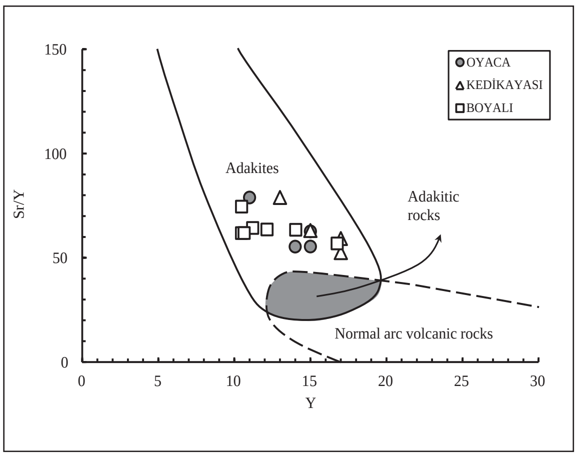


Figure 2- Sr/Y-Y discrimination diagram of studied adakites (Defant and Drummond, 1990).

In the MgO-SiO_2 differentiation diagram (Figure 4) (Martin et al., 2005), all the samples plot in the high SiO2 adakite region, indicating the effects of slab-melting in the genesis of adakites (Martin et al., 2005).

Primitive mantle and Mid Ocean Ridge Basalts (MORB)-normalized spidergrams of the selected samples from Oyaca-Kedikayası-Boyalık adakites are illustrated in figure 5. The common features of

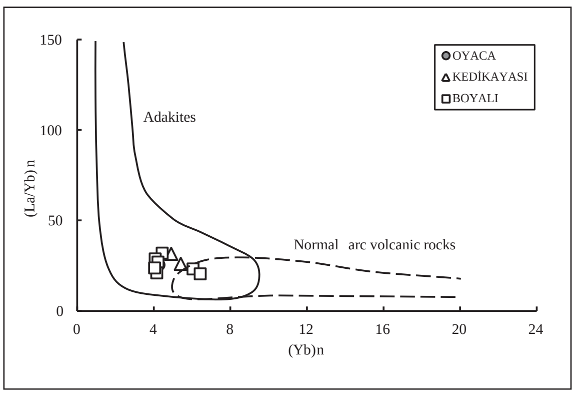


Figure 3- (La/Yb)n- (Yb)n discrimination diagram of studied adakites (Defant and Drummond, 1990). Values normalized to chondrite (Thompson, 1982).

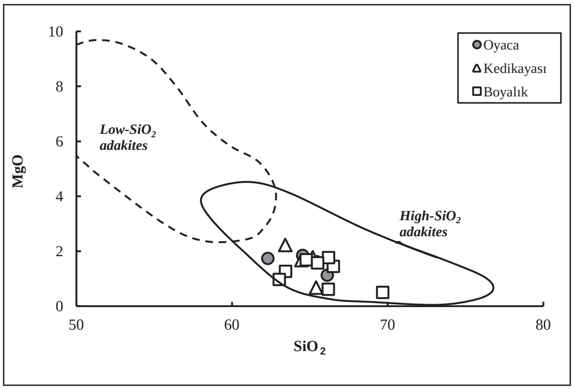
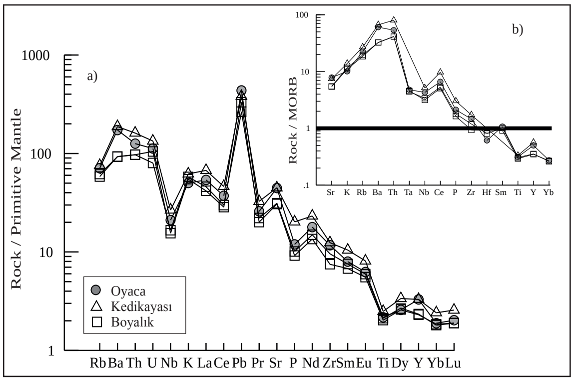


Figure 4- MgO-SiO_2 discrimination diagram of studied adakites.



Figurel 5-a) Primitive mantle (Sun and McDonough, 1989) and b) MORB (Pearce, 1983) normalized spider diagrams of the representative samples from studied adakites.

the samples are negative anomalies in Nb, Ta and Ti and positives anomalies in K, Th, Ba and Pb elements. Moreover, samples are enriched in large ion lithophile elements (LILE) but are depleted in Y and Yb relative to MORB.

Chondrite-normalized rare earth element (REE) spidergram (Nakamura, 1974) (Figure 6) demonstrate that the studied adakites are enriched in light rare earth elements (LREE) relative to heavy rare earth elements (HREE). High [(La/Yb)n: 21-32] ratio also indicates a significant LREE / HREE fractionation.

3. Source Characteristics and Petrogenetic Modelling

Adakites and adakitic rocks are represented by high concentrations of Al_2O_3 (≥%15), Na_2O (3.52-5.12), La/Yb, and low HFS (Nb, Ta) elements, and low Yb contents along with their high SiO_2 content (Richards and Kerrich, 2007; Eyüpoğlu et al., 2011*a, b, c;* Eyüboğlu, 2012*a, b*). High Sr, low Y and Yb

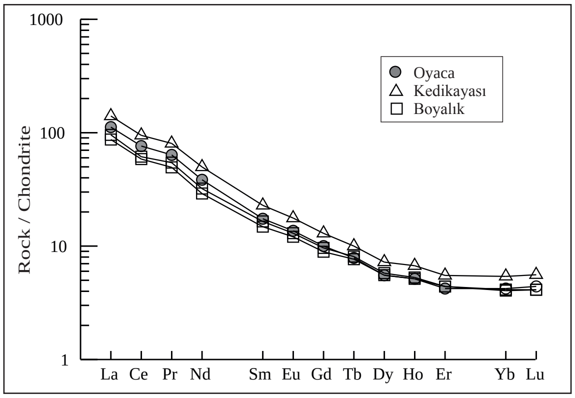


Figure 6- Chondrite-normalized rare earth element (Nakamura, 1974) spider diagrams for the representative samples from studied adakites.

values can be explained by the presence of plagioclase and/or garnet minerals in the source area. The degree of enrichment of Sr and Yb elements in the melt is controlled by the residual plagioclase and garnet phase in the basaltic source. The partition coefficient (Kd) of Sr element in plagioclase for basaltic melts is 1.83; however, Kd value of Y element in garnet is around 11.50 (Rollinson, 1993). Accordingly; in cases when plagioclase and garnet are residual phases, the enrichment level of Sr and Yb, respectively, will be low. The stability of plagioclase depends on the pressure. While the plagioclase mineral loses its stability under high pressure conditions, garnet becomes stable (Moyen, 2009). Therefore; under these conditions, while Sr becomes enriched in liquid phase, Yb becomes enriched in garnet phases. This explains the high Sr/Y ratios in adakites. High Sr and Sr/Y ratios combined with low Y and Yb contents can also be observed in asthenosphere derived magmatic rocks, but these rocks are generally represented by high Nb, Nb/Y (>1.5), Nb/La (>1.0) ratios (Edwards et al., 1991; Pearce, 1983; Jung and Hoernes, 2000). However; adakites are depleted in Nb, Ti and Ta. Thus, when the chondrite-normalized spider diagrams of the Oyaca, Kedikayası and Boyalık adakites are studied, positive anomalies in Ba, K and Th elements and negative anomalies in Nb, Ta and Ti elements are observed together with high Sr and low Y and Yb concentrations (Figure 5). Such geochemical features are characteristic for subduction zone magmatism, because phases such as sphene, rutile and perovskite are stable at 80 – 100 km depths in subduction zones. Elements such as, Nb, Ta and Ti in such conditions are retained in these stable phases, so the magmas becomes depleted in these elements (Saunders et al, 1980; Foley et al, 2000; Ringwood, 1990). Futhermore, high Ba/Nb (45-172) and Nb/La (≤0.41) ratios in Oyaca, Kedikayası and Boyalık adakites indicate that magmatic rocks in the study area were not derived directly from asthenospheric mantle, which suggests the presence of subduction signatures in the genesis of volcanism (Gill, 1981; Fitton et al., 1991; Wang et al., 2004).

In addition; Nb and Ta contents of the slab derived melts and fluids also presents differences among them because slab derived fluids are depleted in Nb and Ta with respect to slab-derived melts (Tatsumi et al., 1986; Tatsumi and Nakamura, 1986; Martin et al., 2005). Defant et al. (1992), Maury et al. (1996), Sajona et al. (1996) and Martin et al. (2005) claim that mantle wedge derived magmas which have been metasomatized by slab melts are high in Nb (7 ppm<Nb<20 ppm). Nb contents in Oyaca, Kedikayası and Boyalık adakites range between 11-20 ppm and relatively high Nb content reveals that adakites in the study area might have been derived from a mantle source which was enriched in slab melts.

Rb/Sr, Ba/Rb and K/Rb ratios are used to determine the presence of phlogopite and amphibole in the source region because while amphibole has high K and very low Rb contents, the phlogopite is enriched in Rb, Ba and K (Ionov and Hofmann, 1995; Martin et al., 2005). Accordingly; the melt of an amphibole bearing source is characterized by low Rb, Rb/Sr and high K/Rb , and the melt of a phlogopite bearing source has low K/Rb and high Rb/Sr ratios (Furman and Graham, 1999). Rogers et al. (1985), Calmus et al. (2003) and Martin et al. (2005) emphasize that the depletion in Rb in adakitic rocks is an indicator for the presence of metasomatic amphibole in peridotitic source. Moreover; the existence of amphibole and/or phlogopite in the source region can be related to metasomatised mantle as both minerals are metasomatic volatile bearing phases (Jiang et al., 2012). Adakites in the study area plot close to the amphibole bearing source in Rb/Sr – Ba/Rb diagram (Figure 7). In addition, the K/Rb ratio in adakites is used to determine the character of the source region. This ratio is approximately 1050 in low silica adakites but is around 350 in high silica adakites (Martin et al., 2005). The K/Rb ratio varies between 270 – 380 in Oyaca, Kedikayası and Boyalık adakites. This variation indicates that adakites in the study area have characteristics similar to high silica adakites that may have been derived from a metasomatic peridotite source, which interacted with slab melts. Therefore; as mentioned above, it is plausible that samples in the investigated area have not been derived from an asthenospheric source, but the source consists of subduction components.

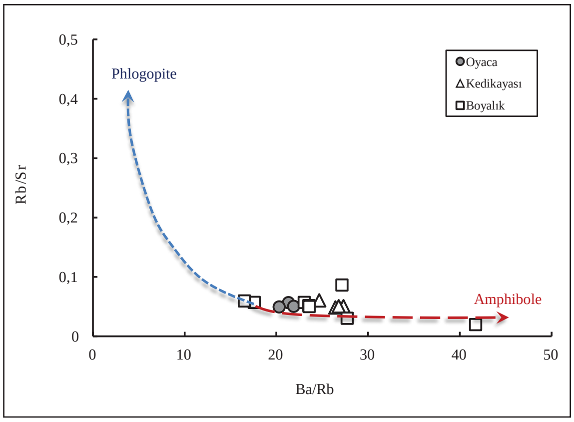


Figure 7- Rb/Sr - Ba/Rb discrimination diagram of studied adakites (Furman and Graham, 1999).

Low Nb/La and high Rb/Ba ratios also support the arguments mentioned above (Figure 8) since the low Nb/La ratio (<1) indicates the presence of subduction components at the magmatism. However, high Ba/Rb ratio occurs as a result of slab-melt or melting of subducting sediment (Wang et al., 2004). According to low Nb/La (≤0.41) and high Rb/Ba ratios in Oyaca, Kedikayası and Boyalık adakites, slab or sediment melting is likely during in their genesis (Figure 8).

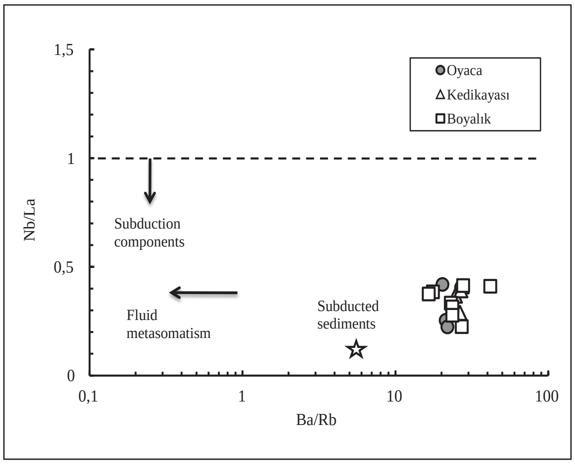


Figure 8- Nb/La - Ba/Rb discrimination diagram of studied adakites (Wang et al., 2004).

Low Rb/Sr (0.02-0.09) ratios and low % K2O (1.5 - 2.2) and high Mg # (31-57) values in Oyaca, Kedikayası and Boyalık adakites also indicate the interaction of slab melt / mantle peridotite, because low Rb/Sr (0.01-0.04) (Hou et al., 2004) and high Mg# values are encountered in the interaction of slab derived melt / mantle peridotite (Rapp et al., 1999; Hou et al., 2004). However, the processes such as lower crustal melting and/or crustal contamination are responsible for low MgO contents, Mg# values and high K_2O contents in adakites.

Consequently; the general opinion obtained from trace element geochemistry shows that adakites in the study area have an amphibole bearing metasomatized mantle source. Therefore; non-modal batch melting model of Shaw's (1970) was applied using rare earth element data. In the modeling, 13% amphibole bearing garnet peridotite [Sample no: MK5C, (Rampone and Morten, 2001)], which is the fragments of metasomatized mantle wedge, were used as initial composition. The melting model was calculated starting from this initial composition. Mineral / melt partition coefficient (Kd) values of rare earth elements are from Rollinson (1993) and Mc Kenzie and O'Nions (1991). La, Ce, Tb and Yb concentrations and modal mineralogy of amphibole – garnet peridotite (Xi), and the melting mode values (Pi) are from Rampone and Morten (2001) and Barry et al. (2003), respectively. Data used in the calculation of modeling are seen in table 2.

Table 2- Values used in non-modal batch melting model calculations.

	Amphibole-garnet peridotite	
	Source Mode (Xi)	Melt Mode (Pi)
Olivine	0,77	0,05
Orthopyroxene	0,05	0,05
Clinopyroxene	0,01	0,30
Amphibole	0,13	0,20
Garnet	0,04	0,40
	Bulk Partition Coefficient (D_0)	Melt Mode (P_0)
La	0,0110	0,0863
Ce	0,0193	0,1377
Tb	0,0973	0,5756
Yb	0,2760	1,1875
	Starting Composition Initial Concentration (C0)	
La	2,800	
Ce	5,250	
Tb	0,056	
Yb	0,230	

Rare earth element values of amphibole garnet-peridotite obtained from non-modal batch melting at different melting degrees (F %) are listed in table 3 and chondrite normalized spider diagram is illustrated in figure 9. According to this diagram, it is considered that Oyaca, Kedikayası and Boyalık adakites have been formed from a source represented by amphibole garnet peridotite via 5 -10 % F partial melting.

Similarly; La/Yb-La and (Tb/Yb)n-(La/Yb)n diagrams are shown in figure 10. La/Yb and Tb/Yb ratios change depending on the presence of garnet mineral. High La/Yb and Tb/Yb ratios indicate a residual garnet phase (Moufti et al., 2012) because, as also mentioned above, Yb element exhibits a compatible behavior with garnet phase and is retained by garnet. It is observed that adakites in the study area plot on the amphibole bearing garnet peridotite melting curve.

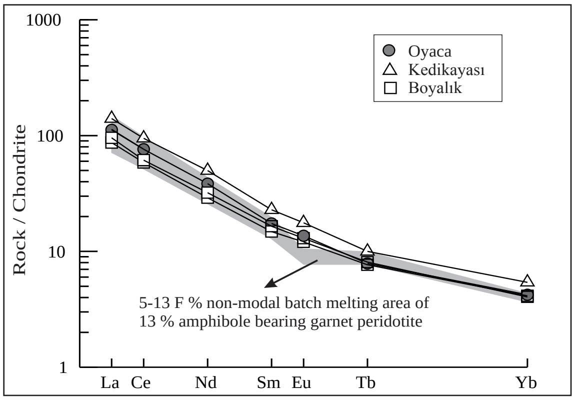


Figure 9- The comparison of Oyaca, Kedikayası and Boyalık adakites with data calculated from non-modal batch melting of 13 % amphibole bearing garnet peridotite at 5 and 13 % melting on a primitive-normalized REE spider diagram. (Chondrite-normalization data are from Nakamura (1974).

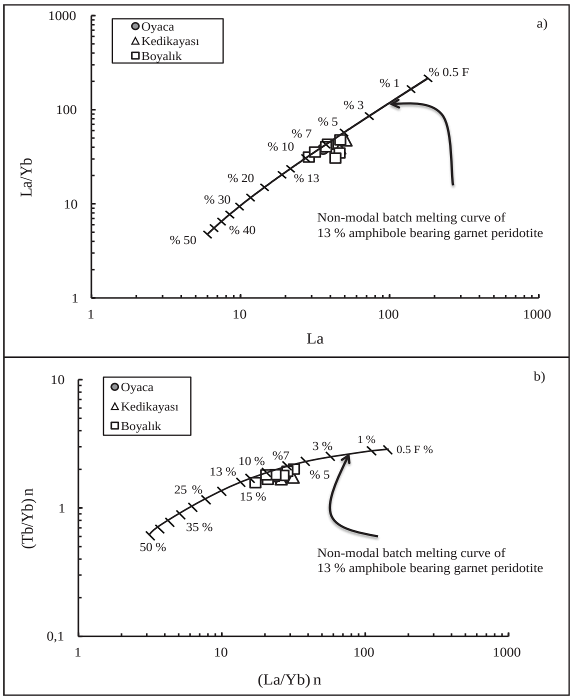


Figure 10- a) La/Yb-La and b) (Tb/Yb)n - (La/Yb)n diagrams for the Oyaca, Kedikayası and Boyalık adakites on non-modal batch melting models of amphibole bearing garnet peridotite. Ticks with a number represent the degree of partial melting. n denotes normalization to Chondrite of Thompson (1982).

Geochemical data and petrogenetic modeling studies show that Oyaca, Kedikayası and Boyalık adakites represent 5 -13 % partial melts from an amphibole bearing mantle source. Besides, the presence of amphibole minerals in samples also indicates that hydrous conditions were effective at the source of volcanism. It is considered that early Miocene Oyaca, Kedikayası and Boyalık adakites located in the post collisional environment were derived from an enriched peridotitic mantle source which was interacted with slab melts during previous subduction process.

4. Conclusions

In this study, it is determined that early Miocene dacitic rocks from the Oyaca, Kedikayası and Boyalık alkaline and calc alkaline magmatic suite are adakite in composition. Geochemical evaluations are consistent with the effects of subduction processes in the genesis of Oyaca, Kedikayası and Boyalık adakites. High silica, MgO and Nb contents indicate that slab derived melts had played an important role in the genesis of these rocks.High Ba / Rb ratio also indicates the presence of amphibole in their origin. Therefore; the studies of petrogenetic modeling were performed starting from an amphibole bearing peridotite source. The result of the modeling suggests that the adakites formed by 5-13 % partial melting of the amphibole bearing peridotite source.

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HYDROGEOCHEMICAL AND ISOTOPIC INVESTIGATION OF NASRETTIN HOCA SPRINGS, ESKİŞEHİR, TURKEY

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Key words:
Nasrettin Hoca springs,
Hydrogeochemistry,
Isotope,
Protection area,
Trace element,
Sivrihisar-Eskişehir,
Turkey

Abstract

The aims of this study are to investigate the water quality, the contamination and water-rock interaction of the Nasrettin Hoca springs, with an ultimate aim of establishing protection measures. Within the scope of this study, the springs in and around the catchment area, Bağbaşı springs, Hatip spring, Ali spring, Saracık Fountain and Babadat spring, were investigated. The springs are of Ca-Mg-HCO_3 type when basic hydrogeochemical features are considered, are under the influence of marble-limestone and metaophiolitic units located in the recharge area and are of shallow circulation. The trace element contents of the springs show the influence of the carbonate rocks comprising the reservoir (Sr) and the basement rocks (Ni, Al). The protection areas of Nasrettin Hoca springs against contamination are determined as three different zones by considering the hydrogeologic and topographical features of the region and the Turkish Standards.

1. Introduction

1.1. The Aim of the Study

The study area is located in Central Anatolia, about 120 km northeast of Ankara which is the capital of Turkey (Figure 1). The hydrogeological investigations, aimed at characterizing the hydrogeological properties of the formations and hydrogeochemistry of the water resources, concentrated on the whole Eskişehir basin rather than focusing on the current study area (Süral and Eser, 1998; Demiroğlu, M., 2008; Çelmen, 2008), therefore this study can be considered as the first detailed one regarding the hydrogeology and water chemistry of Nasrettin Hoca spring area.

The drinking and domestic water supplies in inner Anatolia are mostly in contact with the evaporite rocks during recharge-storage-circulation-discharge stages due to the widespread occurence of these rocks throughout the region. Therefore, the water quality is adversely affected by the geologic units and by the contribution from the geothermal fluids (Çelik, 2002; Çelik and Yıldırım, 2006; Çelik et al., 2008; Çelmen and Çelik, 2009). In Inner Anatolia Region, Nasrettin Hoca springs are one of the most important fresh water resources located very close to the capital city of Turkey, Ankara. The average yearly precipitation recorded between years 1924-2005 in Sivrihisar meteorological station is 393.2 mm; thus, in such a semi-arid region, where fresh water is of vital importance, these resources should be protected against point and/or non-point source contaminations, especially against the anthropogenic ones. Establishment of protection areas against contamination requires the knowledge of the hydrogeologic setting as well as the groundwater quality (Demirel, 1988; Doerfliger et al., 1999; Elhatip and Afsin, 2001). Therefore, this study is carried out to investigate these water springs and to evaluate their potentials.

The aims of this study are to investigate the water quality of seven springs located around Nasrettin Hoca town in Sivrihisar district, to evaluate the recharge and discharge mechanisms of Bağbaşı springs, to compare the chemical properties of the spring waters to the geology of the study area, to determine protection areas against possible contaminants. In order to achieve the objectives, in-situ physicochemical measurements were carried out on a monthly basis for a hydrologic

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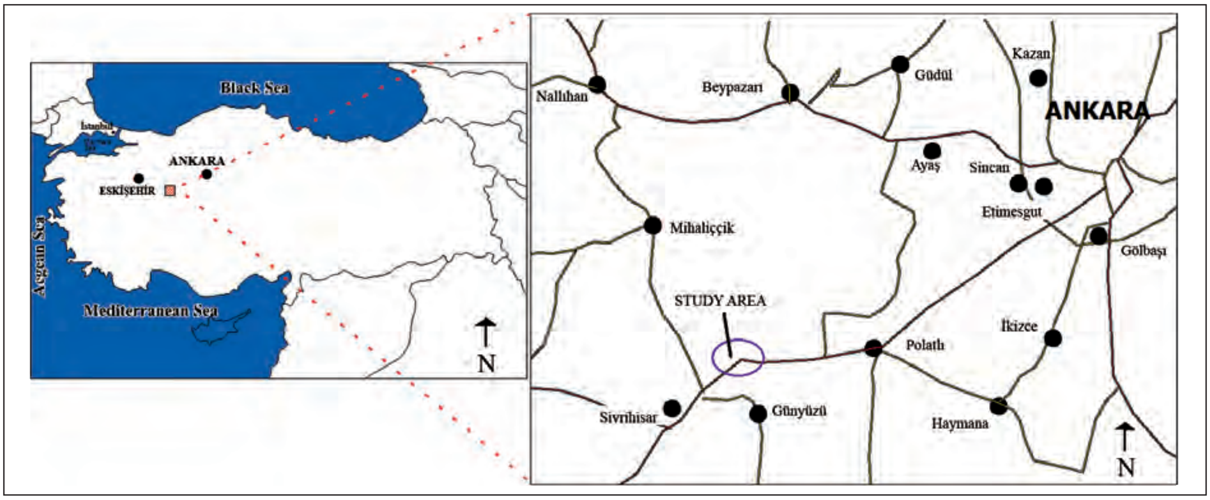

Figure 1- Location map of the study area (not to scale).

year for Bağbaşı spring group (BK-1, BK-2, and BK-3) having an average yield of 157 l/s during the study period. The measurements were carried out four times in a year for the rest of the springs.

2. Geological and Hydrogeological Background

There are four basic rock sequences exposed in the study area which are, from bottom to top, Paleozoic metamorphics, Eocene units, Miocene units and Quaternary deposits. Paleozoic metamorphics, also called Sivrihisar metamorphics, are the basement rocks in the area and made up of Göktepe, Kertek and Eryiğit units (Figure 2). Göktepe unit is made up of serpentinite, metabasite, amphibolite and thin marble bands with chert additions. Above the metaophiolitic basement, thin to medium layered, metachert bearing, dark colored marble and layered metabasites are present (Demiroğlu, 2008). Due to the extensive alteration of these units to clay minerals and also due to the limited and discontinuous presence of the marbles, these units were assumed to be impermeable. Kertek unit marbles, another unit making up the Paleozoic metamorphics, are medium to thick layered and have black-gray chert bands. These bands increase in amount towards Göktepe unit. It is possible to observe thin lamination in micaschists, whereas calc-schists and quartz-schists show moderate lamination. Aplite and quartize veins have been developed in the schists parallel to the folding and lamination (Demiroğlu, 2008). The diabase dykes observed in the western parts of the area cut the whole series. The schists and the aplite and quartzite veins inside Kertek unit are slighlty permeable to impermeable; the marbles lying above are permeable. However, the continuity of the water flow inside the marbles is prevented by the diabase dykes. Marbles are believed to contribute to the recharge of Nasrettin Hoca springs. Besides, one of the springs, namely Babadat spring, is fed by the marbles and is discharged from the alluvium contact. Lastly, Eryiğit unit, the upper sequence of Sivrihisar metamorphics, is comprised of fine grained, quartz bearing feldspathic schists, phyllites and thick layered, fractured marbles having a massive appearance from place to place. Schists and phyllites are impermeable, whereas the marbles are permeable. Eryiğit unit outcrops in a narrow area around southwestern part of the study area and has no importance regarding the water potential of the basin.

The Eocene units, namely Sivrihisar granodiorite, expose around south and west of Koçaş (Figure 2). The granodiorites have low primary porosity but have secondary porosity and permeability developed by weathering and discontinuity planes. Çelmen (2008) stated that Hamamkarahisar thermal springs, located around the area, are recharged through the discontinuity planes inside the granodiorites; however, in general these units can be considered as impermeable in the study area.

The Miocene units consist of Hisar, Çakmak and Mercan formations. Hisar formation contains coarse grained, matrix supported sandstones formed in a lakeshore environment. It is possible to observe decreasing grain size away from the basement rocks so this formation was interpreted as fan deposits. Hisar formation is located in the recharge area of Nasrettin Hoca springs. Although there is no observable spring discharge from these units, it is believed that they play an improtant role in the recharge of the Nasrettin Hoca springs and they are described as permeable.

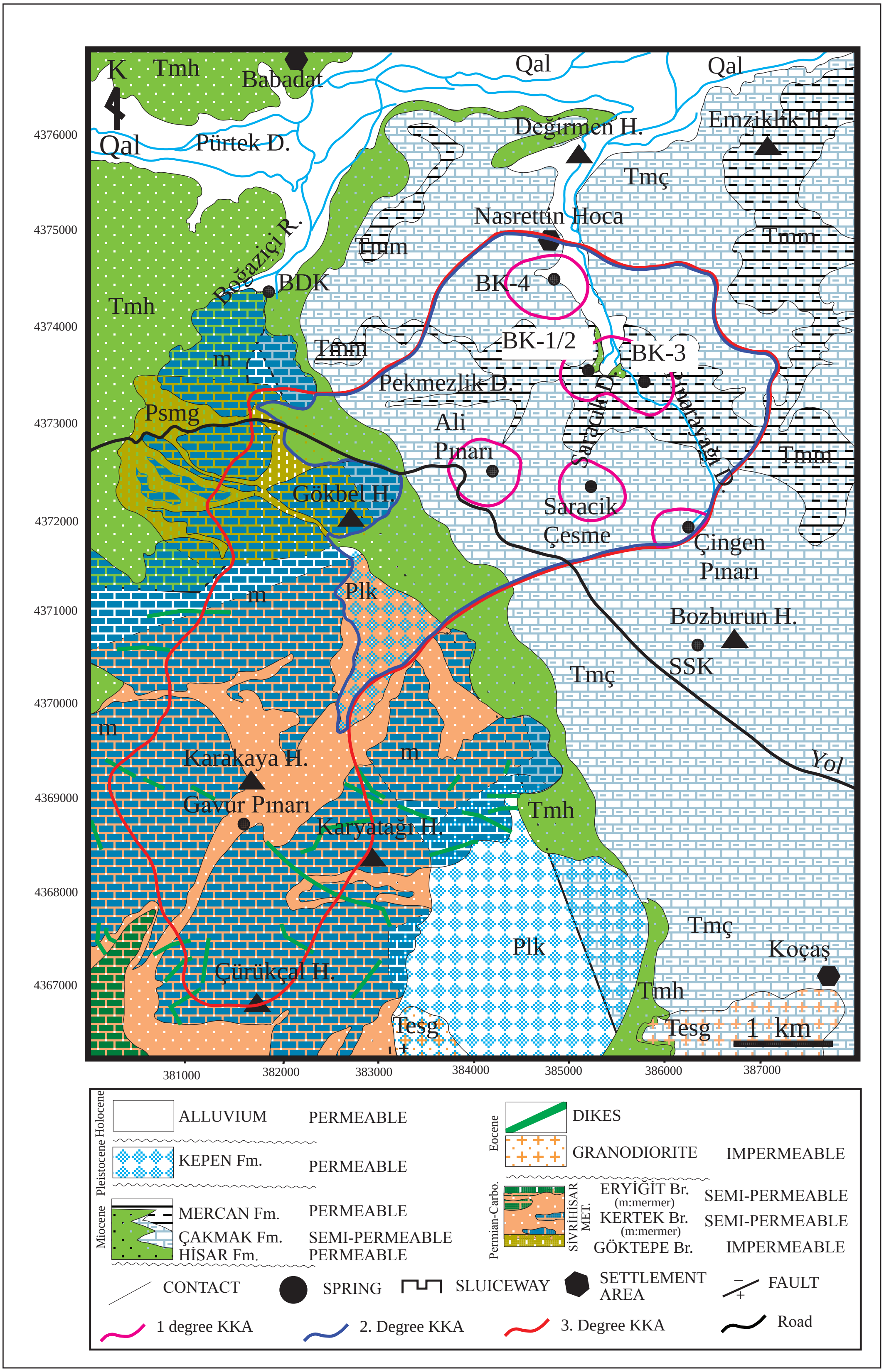

Figure 2- Hydrogeology map of the study area (Modified from Süral and Eser, 1998; Demiroğlu, 2008).

Çakmak formation, conformably lying upon the Hisar formation, can be described as sand, silt and clay alternation, medium-thick bedded limestone and white, green, brown marn, pebblestone with gypsum and peat addition. There are both permeable and impermeable units inside this formation and due to this attribute, some springs springs (Ali spring, Saracik fountain, Cingen and Hatip springs) were developed along the impermeable contacts. The discharges of these springs are less than 1 l/s throughout the year. Clayey and marly levels act as impermeable barriers during the formation of these springs. This formation, having low yield, is defined as semi-permeable. Mercan formation, having lateral and vertical transition with Çakmak formation, can be found above Hisar formation during the shallow lake environment conditions. Mercan formation consists of an alternation of thin-medium-thick bedded limestone, cherty limestone, marn and claystone. Surficial karstification can be observed in a limited area where the limestones are fractured and where clay content decreases. Bagbasi springs recharge from Paleozoic units, where they are also stored and they discharge from Mercan formation along the strata planes (Figure 3). There are some vertical fracture developments in the limestones which play an important role in the spring discharges. Similar spring occurences are described by Springer and Stevens (2009) as hillslope and gushed (Figure 4a and b). Although this formation contains impermeable marns, it also discharges high yield springs therefore it can be described as permeable.

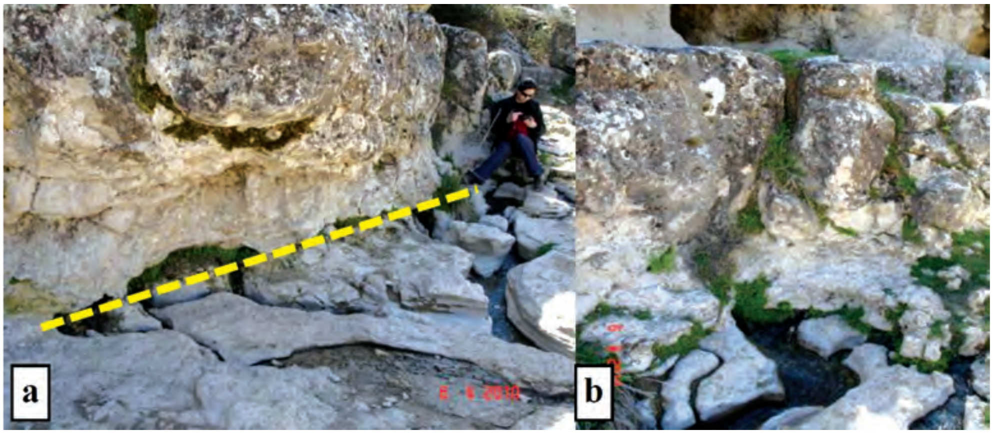

Figure 3- Appearance of the Bagbasi spring (BK-2) a) remote view b) up close view. The discharge of the spring is shown with a yellow line.

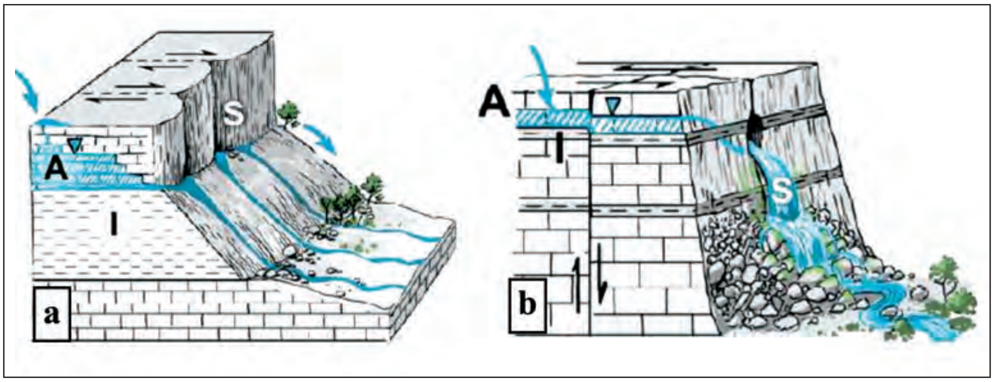

Figure 4- Hillslope (a) and gushed (b) spring occurences (A: Aquifer, I: Impermeable basement, S: Spring) (from Springer and Stevens, 2009)

Pleistocene Kepen formation, located along the hillside of Karyatağı and Karakaya hills, is another unit inside the catchment area of Nasrettin Hoca springs (Figure 2). This formation has a loose texture and it contains angular pebbles. Although it is considered as permeable, no water flow can be observed. It is highly possible that this formation acts as an infiltration zone (i.e. vadose zone) during the recharge of the springs.

Quaternary alluviums in the study area are made up of pebble, sand, silt and clay sized particules. There is no visible water discharge point in the alluvium units located around Purtek and Dedebağ streams however, Babadat spring (BDK) discharge from the contacts between marbles and the alluvium. The yield of the spring was measured to be 38 l/s in May 2010. It should also be noted that there is usage of groundwater through wells around Purtek stream bed. Alluvium units in the region were interpreted as a high-yield aquifer besides constituting the productive agricultural fields in the study area (Demiroğlu, 2008; Demiroğlu and Örgün, 2010).

3. Sampling and Field Studies

Within the scope of this study, springs around Nasrettin Hoca town, Bağbaşı (BK-1, BK-2, BK-3), Hatip (BK-4), Babadat (BDK), Ali (AP), Gavur springs (GP), Saracık fountain (SCK), and Hamamkarahisar (HK) springs were sampled to trace the hydrochemical behaviour of Bağbaşı spring group during a water year. In situ pH, temperature and electrical conductivity measurements were carried out by using GIS-F460 and WTW-350i Multi-analysers. Samples for major cation and trace element analyses and anion analyses were collected separately in 500 ml HDPE plastic bottles, preserved at 4 °C prior to analyses. The samples to be used for major and trace element analyses were acidified to pH<2 by using ultra pure HNO_3. Concentrations of F-, NO_3^-, PO_4^{-3}, and HCO_3^- were measured by using a PALINTEST 200 spectrophotometer, major cation and trace element contents were determined with an Inductively-Coupled Plasma Optic Emission Spectroscopy (ICP-OES) at the laboratories of Ankara University Department of Geological Engineering.

Samples for stable isotope ($\delta^{18}O$ and δD) and tritium (^3H) analyses were collected in 1000 ml HDPE plastic bottles. Oxygen-18 and deuterium ratios were determined on a Micromass 602C mass spectrometer using standard methods at the laboratories of the Turkish State Hydraulic Works (DSİ). Tritium contents were determined by a liquid scintillation counting system (Packard Tri Carb 2260 XL) after electrolytic enrichment. Analytical uncertainities of the individual measurements are estimated to be within ±0.3 ‰ for $\delta^{18}O$ and ± 1‰ for δD. The analytical precision of the tritium measurements are about ±1 TU.

4. Results and Discussion

4.1. Hydrogeochemical Facies

Groundwater is recharged naturally by rain and snow melt and its chemistry is modified through various chemical reactions from recharge to discharge. For instance, some elements can be transferred between the water and solid mineral phases during dissolution/precipitation of carbonate, silicate, sulphide and/or evaporate minerals along flow paths. The most influential groups of minerals on water chemistry are the most soluble groups, carbonates and evaporates. Silicates, being a member of the most important and common rock-forming mineral group, can be considered as the least soluble mineral group, having little effect on water chemistry. Determination of the major and trace element contents of the water and interpretation of these results help in issues like identifying the water-rock interaction on the surface or under ground and the exact mechanisms of this interaction.

Results of the field chemical data, trace element results for water and rock samples and isotope analyses results of water samples are reported in tables 1, 2, 3 and 4 respectively. According to table 1, pH ranges from 7.30 to 8.34, reported to be lowest in BK-1 and highest in Gavur spring. Electrical Conductivity (EC) values vary between 338.6 µS/cm (BK-3) and 965 µS/cm (BK-4). Time-dependent changes in the spring EC values show a decreasing trend from April to December 2010 without showing excessive fluctuations (Figure 5). The high EC value, pertaining to BK-4, is attributed to the seepage of the sewage through a septic tank located 50-100 m away

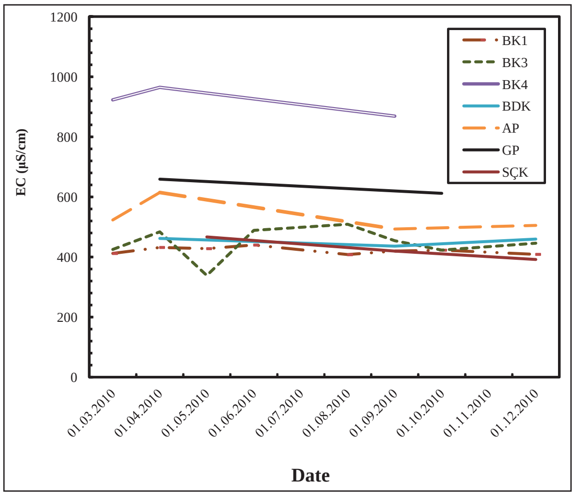

Figure 5- Time-dependent change of the spring EC values

from this spring. This finding is also supported by nitrate and phosphate test results.

The major ion analyses results of the springs were evaluated by using Schoeller and Piper diagrams. According to Schoeller diagram, the chemical characters of all the samples are more or less similar, the dominant ions are Ca-Mg and HCO_3 i.e. the samples are of Ca-Mg-HCO_3 type and the samples are predominantly recharged from carbonate rocks (marble, limestone) (Figure 6). The increase in sulfate ion concentration in sample BK-4 is predicted to be related to antropogenic contamination (Table 1).

When the trace element analyses results of both water and rock samples are evaluated together (Table 2 and table 3), it can be seen that the trace element contents of the water samples are influenced by the aquifer formations, namely marbles and limestones, together with the metamorphic rocks making up the impermeable basement. Strontium (Sr) and nickel (Ni) are the most prominent trace elements present in the water samples (Table 2). Sr is abundant in the carbonate rocks outcropping around Bagbasi spring area. Ni and Aluminum (Al) is observed in the water samples in low concentrations and when their distribution in the rocks is taken into consideration, it can be seen that this element is more abundant in metamorphic rocks instead of carbonates (Table 3). To sum up, the trace element contents of the springs show the influence of the carbonate rocks comprising the reservoir (Sr) and also the rocks comprising the impermeable basement (Ni, Al). It is also noteworthy that the samples with the highest EC values (BK-4 and SCK) are also enriched in trace elements relative to the rest of the samples.

Table 1- Field chemical data and major ion content of the spring samples for April (4), May (5), June (6), August (8), September (9), October (10), December (12). All of the samples were collected in 2010 (N: Not available).

Sample ID	T (°C)	pH	EC (µS/cm)	Na^+	K^+	Ca^{+2}	Mg^{+2}	Cl^-	SO_4^{-2}	HCO_3^-	NO_3^-	CBE (%)
BK-1/4	22.5	7.3	432	8.4	1.6	119.4	22.3	10.4	0.0	158.6	1.28	2,6
BK-3/4	17.3	7.56	484	15.0	2.8	120.3	24.3	6.9	13.8	159.9	0.65	1,0
BK-4/4	14.3	7.49	965	27.6	4.2	186.0	32.6	46.1	29.5	202.0	N	3,1
BK-1/5	23.8	7.61	428	64.2	1.3	91.4	18.6	3.7	0.0	193.3	N	0,9
BK-3/5	17.4	7.63	338.6	14.6	2.6	176.1	23.0	9.2	18.4	213.3	N	4,0
BK-1/6	25.6	8.25	440	6.2	1.1	253.9	15.8	5.1	0.0	241.6	N	8,8
BK-3/6	20.4	7.92	489	11.6	2.3	253.8	19.6	6.6	8.3	241.1	N	4,4
BK-1/8	23.2	7.61	408	6.4	1.2	203.0	16.4	6.5	0.0	195.2	N	7,6
BK-3/8	17.8	7.68	509	14.9	3.4	142.6	24.0	3.6	13.9	187.0	N	3,8
BK-1/9	22.5	7.71	420	5.9	1.1	258.7	16.8	5.3	1.0	246.4	N	3,1
BK-3/9	17.2	7.57	454	12.3	2.2	192.1	19.5	4.6	18.0	195.2	N	8,0
BK-4/9	16.5	7.59	869	23.4	3.8	192.8	33.0	67.0	44.6	170.2	N	1,4
BK-1/10	20.1	7.7	423	7.3	1.4	130.4	19.9	4.5	3.2	168.7	N	2,1
BK-3/10	14.7	7.73	471	13.2	2.4	172.6	21.6	18.7	4.1	211.7	2.96	5,7
BK-1/12	16.9	7.78	409	8.3	1.4	100.4	19.4	0.0	1.2	143.7	3.20	1,2
BK-3/12	16.8	7.55	446	14.7	2.5	122.9	21.3	12.2	1.0	167.9	3.60	3,0
BK-1/3	21	7.81	412	7.7	1.3	143.5	16.9	1.6	0.0	185.4	0.95	1,4
BK-3/3	16.2	8	425	13.3	2.3	122.1	19.2	1.0	11.8	162.6	3.36	5,8
BK-4/3	124	8.92	923	29.5	3.8	133.9	29.7	10.3	14.9	192.9	28.00	0,3
BDK/4	20.9	7.5	462	87.6	1.3	88.8	19.4	6.6	0.0	215.6	N	2,1
BDK/9	22	7.68	436	10.2	1.5	103.2	22.8	5.0	0.0	148.4	0.18	0,3
BDK/12	16	8.18	460	12.9	1.6	119.7	21.4	0.0	3.5	170.1	3.12	2,7
AP/4	13.4	7.78	615	18.0	1.0	125.1	27.4	13.3	0.0	179.3	7.50	2,0
AP/9	20.3	7.54	493	17.6	1.0	131.4	26.7	8.3	2.9	184.5	N	0,7
AP/12	14	7.64	505	17.1	0.9	115.3	22.8	0.0	5.3	168.4	N	2,3
AP/3	11	8.3	523	11.0	1.5	104.1	21.4	3.1	0.0	150.1	6.40	1,7
GP/4	12.5	7.63	659	29.3	2.2	154.3	22.0	7.0	46.7	179.6	0.55	0,5
GP/10	17.4	8.34	612	15.9	1.4	150.5	11.8	10.2	7.4	142.6	N	0,2
SCK/5	14.4	7.51	467	18.9	4.2	112.4	22.5	3.6	0.0	173.9	N	0,4
SCK/9	15.1	7.87	420	16.6	3.6	103.4	20.0	5.5	7.4	144.5	1.32	3,7
SCK/12	13.8	7.8	392	16.4	3.4	97.4	17.2	5.5	3.7	138.9	6.00	4,1

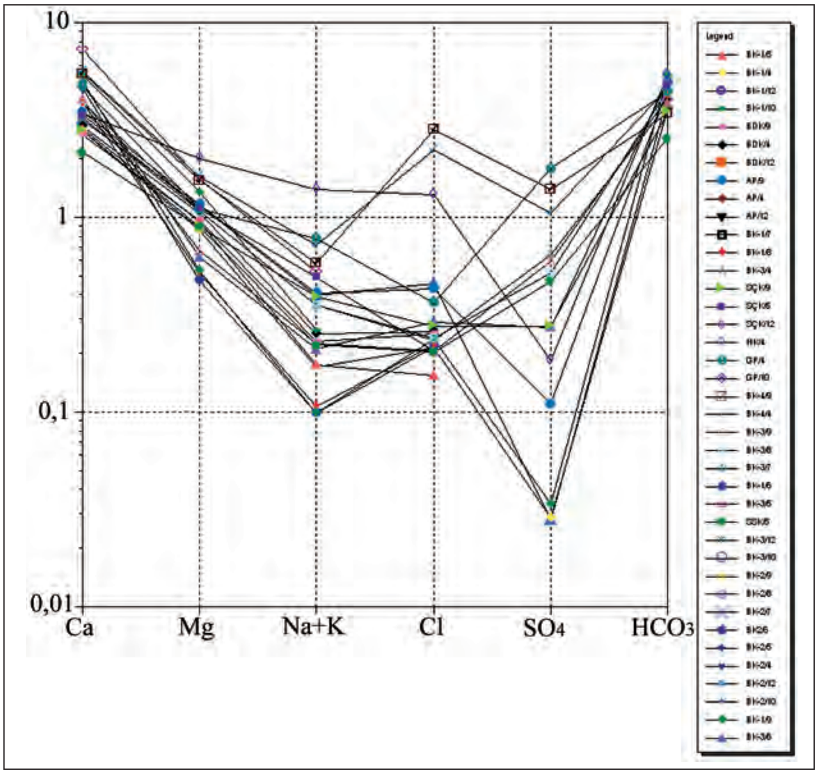

Figure 6- Schloeller diagram of the springs

Table 2- Trace element contents of the springs in ppb. N: Under detection limit. Except for SÇK all the analyses were carried out in samples collected in April. Sample SÇK was collected in May.

Sample ID	Al	Li	Ni	Sr
BK-1	N	N	0.067	0.409
BK-3	0.009	N	0.117	0.578
BK-4	N	0.045	0.13	1.282
BDK	0.005	N	0.083	0.337
AP	N	0.03	0.125	1.027
GP	N	N	0.118	0.489
HK	N	0.04	0.185	0.634
SÇK	0.016	0.028	0.155	0.832

4.2. İsotopic Properties of the Springs

In hydrogeology, isotope data are used to facilitate the analyses of hydrologic and hydrogeologic problems and also to support the conventional methods. Environmental isotopes contribute to the investigations related to the origin, flow and evolution of groundwater, its renewability and the subsurface processes affecting its quality, and to the studies related to groundwater and surface-water interactions (Clark and Fritz, 1997). The isotopes of oxygen and hydrogen are used extensively in hydrogeologic investigations as markers of water source and as ideal tracers since they are present in water in its natural state since their behaviour in the hydrologic system is known thoroughly.

4.2.1. Relationship of Oxygen-18 ($d^{18}O$) and Deuterium (dD)

The δD and $\delta^{18}O$ values in precipitation and fresh waters generally plot close to a straight line that is the Global Meteoric Water Line (GMWL). This line, determined by Craig (1961) and presented in Equation $\delta D = 8\ \delta^{18}O + 10$ (‰ SMOW), defines the relationship between $\delta^{18}O$ and δD in worldwide fresh waters.

Local Meteoric Water Lines (LMWL) may also exist, having slightly different slopes and intercepts than the GMWL, as a result of differences in altitude, local climate and distance from the moisture source (Rozanski et al., 1993). If groundwater $\delta^{18}O$ and δD values plot near the present precipitation water line for the sampling area, the waters are likely meteoric in origin, that is to say, derived from precipitation without subsequent modification. If they do not plot along this line, they have been impacted by some physical or chemical process prior to recharge, or during the groundwater's journey through the aquifer

Table 3- Whole rock analyses results for the rock samples. BK2 and BK4: Mercan formation, GP1, GP2,GP3,GP4, GP5: Sivrihisar metamorphics- Kertek unit, KC1, KC2, KC3, KC5, KC6: Sivrihisar metamorfics- Göktepe unit.

Sample ID	BK2	BK4	GP1	GP2	GP3	GP4	GP5	KC1	KC2	KC3	KC5	KC6
Element												
Na_2O	0.08	0.08	1.66	0.07	0.48	0.07	0.09	0.07	0.24	0.07	0.08	0.16
MgO	0.14	6.93	8.69	3.32	4.53	0.47	4.28	3.94	4.46	4.06	7.25	0.35
Al_2O_3	1.17	3.89	14.27	19.77	17.82	1.05	0.48	12.37	12.81	11.65	1.59	0.75
SiO_2	4.29	18.19	46.09	51.35	51.10	86.80	1.36	44.18	47.82	44.87	8.55	6.97
P_2O_5	0.01	0.08	0.07	0.15	0.12	0.03	0.00	0.08	0.07	0.06	0.04	0.01
SO_3	0.18	0.34	0.09	0.11	0.12	0.13	0.04	0.14	0.56	0.15	0.39	0.69
Cl	0.03	0.02	0.00	0.01	0.00	0.00	0.02	0.02	0.23	0.06	0.03	0.05
K_2O	0.23	0.85	0.16	4.51	4.19	0.64	0.01	2.93	3.03	2.93	0.41	0.02
CaO	54.73	28.97	7.74	0.58	1.48	0.19	53.48	7.58	6.40	6.43	33.83	43.60
TiO_2	0.07	0.18	0.56	0.45	0.28	0.07	0.02	0.66	0.72	0.67	0.10	0.03
V_2O_5	0.00	0.01	0.04	0.03	0.01	0.05	0.00	0.02	0.03	0.03	0.01	0.00
Cr_2O_3	0.01	0.01	0.04	0.05	0.04	0.00	0.00	0.05	0.06	0.04	0.01	0.00
MnO	0.01	0.06	0.15	0.14	0.07	0.00	0.01	0.04	0.03	0.04	0.05	0.00
Fe_2O_3	0.58	1.72	9.00	6.98	4.93	0.82	0.10	6.52	5.66	6.34	1.17	0.02
LOI	38.44	38.90	11.74	12.63	14.97	9.68	39.84	21.86	17.86	22.89	46.97	47.49
Ni	10.70	47.10	107.00	34.60	15.50	7.40	3.40	206.60	175.70	174.70	44.00	1.00
Sr	167.37	400.00	193.10	47.50	154.50	3.60	252.60	147.30	144.60	143.10	429.90	73.00

(Clark and Fritz, 1997). For local investigations, like this study, it is important to compare surface water and groundwater data with local meteoric water line. International Atomic Energy Agency (IAEA) and World Meteorological Organization (WMO) have a station in Ankara where the content of hydrogen and oxygen isotopes in precipitation has been surveyed. Ankara LMWL defined by Equation $\delta D= 8\ \delta^{18}O + 10.63$ (‰ SMOW) was obtained by using the data from the database called Global Network of Isotopes in Precipitation (GNIP) (IAEA/WMO, 2004; Sayin and Özcan Eyüpoğlu, 2005). Since IAEA Ankara station is close to the study area, Ankara LMWL was used in this study.

At a given location, the seasonal variations in $\delta^{18}O$ and $\delta^{2}H$ values of precipitation and the weighted average annual $\delta^{18}O$ and $\delta^{2}H$ values of precipitation remain fairly constant from year to year because the climatic conditions such as temperatures and the vapor source are almost constant (Clark and Fritz, 1997). Generally, rain in the summer is isotopically heavier (more positive values) than rain in the winter due to the seasonal temperature differences. Springs recharged by direct precipitation are expected to reflect these seasonal variations mostly. The isotope analyses results presented in table 4 are evaluated in light of this information. According to table 4, the $\delta^{18}O$ values range between -8.31‰ and -10.87‰ and the δD values range between -63.55‰ and -76.06‰. Tritium (^{3}H) contents of the springs lie between 1.3-4.25 TU, lowest value belonging to AP, whereas the highest ones belonging to GP and BK-4.

Accordingly, if the results taken from the same location in different seasons are considered, it is possible to observe seasonal variations in some of the samples. For instance, when $\delta^{18}O$ results for May 2010 and September 2010 are compared for sample BK-1, it can be seen that there is almost a 1 ‰ enrichment in this isotope. The samples collected in May 2010 and September 2010 can be considered to represent winter ($\delta^{18}O$= -10.66 ‰) and summer precipitations ($\delta^{18}O$ = -9.75 ‰), respectively. Thus, the summer precipitation recharging this spring is isotopically heavier than that of winter precipitation, just like expected. Likewise, a seasonal enrichment in the heavier isotope contents in other samples (enrichments for BK-4 and GP are 0.5 ‰ and 0.4 ‰, respectively) can be observed.

In order to understand the relationship between oxygen-18 (^{18}O) and deuterium (D), the results were plotted and presented in Figure 7 together with GMWL and Ankara LMWL. According to this figure, some of the samples plotted along the GMWL, whereas some of them showed deviation. Generally, it is known that deviations from meteoric water line are caused by different processes like evaporation, condensation, water- rock interactions, mixing of waters having different origins and seasonal effects (Clark and

Table 4- Oxygen-18 ($\delta^{18}O$) and deuterium (δD) signature and Tritium (^3H) content of the spring samples within the study area (Numbers after slash are calendar months. 4: April, 5: May, 6: June, 8: August, 9: September, 10: October). All of the samples were collected in 2010.

Sample ID	$\delta^{18}O$	δD	T(TU)
BK-1/4	-10.4	-73.4	2.85
BK-3/4	-9.85	-71	2.75
BK-4/4	-9.69	-68.6	4.20
BK-1/5	-10.7	-72.4	1.90
BK-3/5	-9.98	-70.5	2.20
BK-1/6	-9.24	-71.5	1.95
BK-3/6	-9.99	-70.9	1.80
BK-1/8	-10.2	-73.3	3.65
BK-3/8	-9.7	-72.2	2.75
BK-1/9	-9.75	-73.1	3.45
BK-3/9	-9.58	-71.3	3,00
BK-4/9	-9.05	-67.7	3.35
AP/4	-9.43	-68.3	1.30
AP/9	-9.29	-68.2	1.45
GP/4	-10.9	-76.1	4.25
GP/10	-10.5	-75.7	2.95
SCK/9	-8.31	-63.6	3.75

Fritz, 1997). The deviations from the GMWL in the samples from the study area are due to the evaporative enrichment of these samples and according to Figure 7, there is an evaporation line formed.

4.2.2. Relationship of Elevation and Oxygen-18 ($\delta^{18}O$)

Oxygen-18 content of precipitation changes with changing altitude, temperature, latitude etc. At higher altitudes where the average temperatures are lower, precipitation will be isotopically depleted. For $\delta^{18}O$, this depletion is about 0.15‰ and 0.5‰ per 100-m rise in altitude. This altitude effect can be used in distinguishing groundwaters recharged from different altitudes (Clark and Fritz, 1997). Normally, springs showing seasonal variations in discharges (i.e. dry in summer and increasing discharges in winter) and having different discharge elevations can be used to reveal out the relationship of $\delta^{18}O$ with altitude. Unfortunately, for the study area, there is no data available regarding precipitation from different altitudes. The relationship of elevation and $\delta^{18}O$ was revealed out in a study carried out in Beypazarı trona area located about 80 km north-east of the Nasrettin Hoca springs (Apaydin, 2004) on the same latitude with the study area. According to Apaydin (2004), the depletion in $\delta^{18}O$ per- 100-m rise in altitude is 0.44‰ and for May 2000, the equation relating altitude to $\delta^{18}O$ is defined as $\delta^{18}O = -0.0044 * (\text{elevation}) - 4.811$. Considering the proximity of Beypazarı trona area to the study area and two sites being under the influence of similar climatic conditions, the Equation given by Apaydin (2004) was adapted to this study and the calculated recharge elevations came out be ranging between 1000 m and 1380 m (Table 5). As suggested by today's topography, the highest topographic elevation is 1690 m and observed around Çürükçal hill (Figure 2). Therefore, all the sampled springs are recharged from an area between Çürükçal and Gökbel hills.

Table 5- The discharge elevations recorded in the field and the recharge elevations calculated by Apaydın 2004.

Sample ID	Discharge Elevation (m)	Recharge Elevation (m)
BK-1	929	1329
BK-2	930	1007
BK-3	936	1175
BK-4	930	1109
BDK	914	1202
AP	987	1202
GP	1180	1377
SCK	986	1202
HK	918	1241

4.3. Evaluation of Tritium Data

The tritium contents of the sampled springs are correlated with Electrical Conductivities (EC) (Figure 8). Accordingly, the springs with high EC values also contain high tritium (GP and BK-4). This finding can be verified by the facts that GP is located upstream of the basin and BK-4 is contaminated by the sewage wastes. Although BK-1, BK-3 and BDK springs have similar characteristics, sample AP has lower tritium content (Figure 8).

4.4. Conceptual Hydrogeological Model of Nasrettin Hoca Springs

Bağbaşı springs, located in the northeastern edge of the 26 km^2 basin area, discharges from Miocene Mercan formation along 10 different points. Gavur Spring is located close to the peak of recharge area,

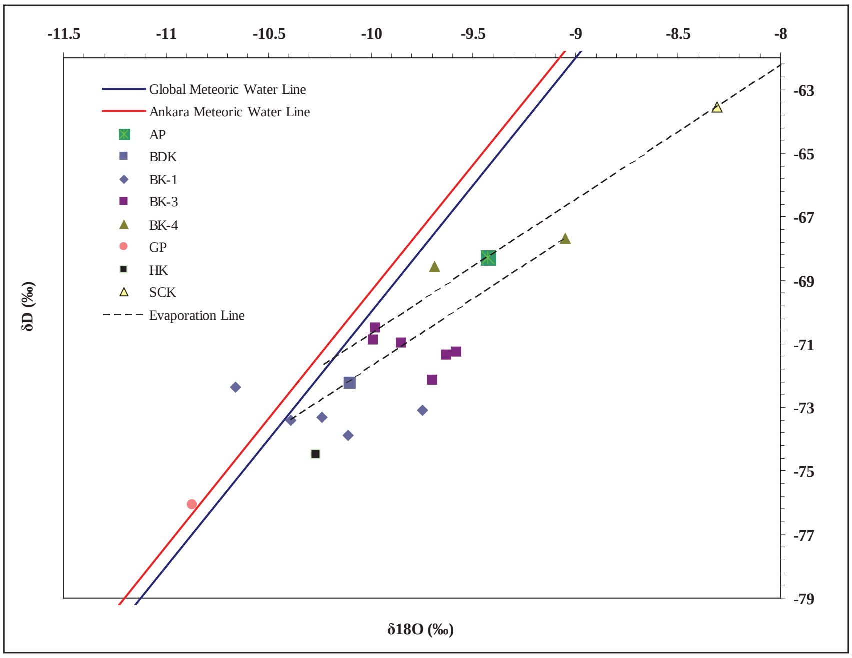

Figure 7- $\delta^{18}O$- $\delta^{2}H$ graph of the springs

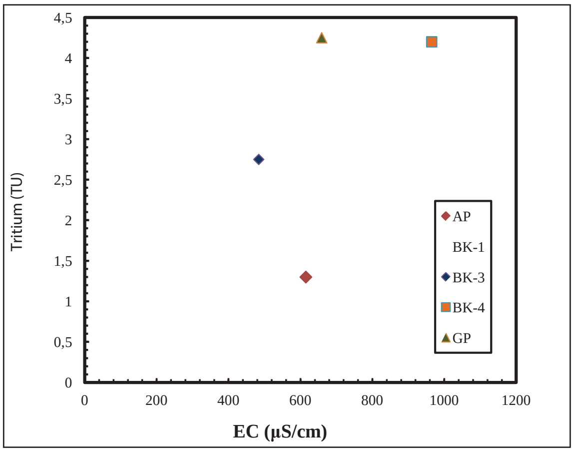

Figure 8- Tritium vs EC graph of the sampling points

whereas Ali-Hatip and Saracık springs are located close to Bağbaşı springs, when both altitude and distance is considered (Figure 2). The average yearly discharge of Bağbaşı springs is 125 l/s, whereas the discharges of other springs located in the basin area are less than 1 l/s.

The basement rocks outcrop in high altitude areas between Çürükçal and Gökbel-Karanlık hills located in southwestern part of the basin. Fractured marbles, lying over Sivrihisar metamorphics, provides the percolation of rain towards the saturated zone thereby providing recharge to the aquifer system. These units are also responsible from the Ca-Mg-HCO^3 character of the waters. Impermeable Göktepe and Kertek units are located beneath the marbles. Diabase dykes slow and partially prevent the water flow in marbles. Miocene units, located in northeastern half of the basin unconformably overlies the basement units and transmit the water from marbles to the springs. The groundwater flow in Miocene units usually reaches to discharge points through pebblestones-sandstones and clayey limestones. These waters gain their hydrochemical identity along the flow paths by dissolving the minerals in permeable and impermeable units during percolation, storage and flow. The isotopic features of the springs show that the springs are recharged along the foots of the Çürükçal and Gökbel hill areas between elevations 1000-1300 m (Figure 2). Miocene siltstone-marl units located nearly horizontal and they won't recharge the springs with their impermeable character. The groundwater flow in saturated zone takes place in a heterogenous environment involving different lithologies, therefore this heterogeneous structure should be taken into consideration when protecting the springs.

4.5. The Protection Areas of Nasrettin Hoca Springs

According to the hydrochemical analyses results gathered during the investigation period, nitrate levels in the springs range between 0.18 mg/l and 28 mg/l and, sample BK-4 can be considered as the most contaminated whereas BDK and GP, are the least contaminated among other samples. The nitrate concentrations in the springs located along the northern part of the study area, except BK-4, are between 0.65 mg/l and 3.6 mg/l. Although these values does not exceed the maximum allowable concentrations set by Turkish Standards (TS-266, 2005) it can still be assumed that agricultural activities have already been affecting these springs. On the other hand, the southern part of the basin is geologically suitable for the construction of stone and sand quarries and these springs can directly be affected by such activities as well.

Three different protection areas were constituted in this study to conserve the water quality of these springs, being prone to contamination (Figure 2). First (Absolute) protection area was established in vicinity of the springs within a circular area having a diameter of 300 m. Second (Short range) protection area was established by considering the lithologies and other factors capable of transporting the contaminants. Third protection area was determined as the basin area (2). When designating the boundaries of these areas, Water Contamination and Control Regulations, Legislation to protect water resources and Basin Protection Regulations were taken into account (TS-266, 2005).

5. Conclusion

In the study, the springs around Nasrettin Hoca town were investigated and it has been found out that the groundwater reservoir units are the marbles, pebblestones-sandstones and clayey limestones; the impermeable basement is made up of schists, metaophiolites, marns and claystones. When the hydrogeochemical features are considered, the sampled springs are of Ca-Mg-HCO^3 type, are under the influence of marble-limestone (i.e. carbonate rocks) and the basement rocks (Göktepe and Kertek units) as suggested by the trace element contents.

The recharge elevations of Nasrettin Hoca springs, according to $\delta^{18}O$ content, came out to be between 1000 m and 1380 m These elevations correspond to the areas located towards the south of the basin, where the marbles and Pliocene-Miocene aged pebbles and sandstones outcrop.

The contaminants in Nasrettin Hoca springs are generally lithology-related. However, there is one particular sample, BK-4, which is contaminated by the fosseptic wastes with regard to nitrate and phosphate and has high EC values. The Protection Areas of the springs are evaluated herein and determined as three different zones by considering the hydrogeology and the topographical features of the study area and Turkish standards.

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NEOGENE STRATIGRAPHY OF THE ESKİŞEHİR GRABEN AND THE INVESTIGATION OF COAL DEPOSITION BY SEISMIC REFLECTION METHOD

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Key words:
Eskişehir,
Stratigraphy,
Coal,
Seismic reflection

Abstract

The study area is located within the Eskişehir Graben, north of Ağapınar village in the Sevinç district and east of Eskişehir City. Miocene deposits unconformably overlie the basement of Paleozoic metamorphites and Mesozoic ophiolites. The m1 series constituted by gravel, sandstone and claystone is observed at the base of Miocene deposits. The overlying m^2 series, from bottom to top, represents a sequence of partly conglomerate, green claystone, coal, gray sandstone, dark gray to green siltstone, bituminous marl, claystone, coal, green claystone, sandstone and fine grained conglomerate. The m^3 series of limestone and conglomerate is patchy and Pliocene deposits consisting of loose gravel, claystone overly them. The stratigraphical succession in the region covered by Neogene deposits has been investigated during surveys and reservoir drilling in licence areas belonging to MTA. High resolution shallow seismic reflection data were collected on two lines crossing each other considering field conditions (vegetated areas, irrigation channels, Porsuk River, railway line, etc.) and locations of boreholes made in the basin. These collected data were assessed in the Data Processing Center of the Seismic Research Division of the Geophysical Research Department (MTA),to produce the final sections of the seismic reflection. The data were then correlated with borehole data on or adjacent to the lines. The surface of reflection (yellow colored level) which could be continuously traced through all sections was deduced as the Paleozoic basement corresponded to ophiolites in borehole data. Reflection surfaces which are observed in areas, where the seismic basement deepened by multi-staged discontinuity surfaces of the seismic basement and rely especially on slopes of seismic basement, were determined as coal-claycontactzone. It was also revealed that, data obtained from drilling works continuing in the region correlate with geophysical interpretations made on seismic profiles.

1. Introduction

1.1. The Aim of the Study

The purpose of this study is to investigate the detectability of suitable sites for coal deposition and coal seams in the basin by geophysical methods before running drilling investigations in Neogene basins in our country. The seismic reflection, one of the geophysical methods, has successfully been applied in environments where there are sufficient acoustic impedance contrasts with respect to upper/lower and surrounding units that form as layers. Seismic reflection method was applied in this study as coal seams displayed significant differences regarding the surrounding units in terms of elasticity.

For the last 20 years, seismic reflection methods in 2D and 3D with high resolution have been used by many investigators in order to specify the structural and stratigraphical characteristics of coal in detail (Henson and Sexton 1991; Gochioco 1991*a, b;* Miller et al., 1992; Pietsch and Slusarczyk 1992; Gang and Goulty 1997; Peters 2005; Hendrick 2006). The low resolution in shallow seismic reflection method with high resolution depends on the frequency spectrum

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of the data recorded and the interval velocity of the layer in interest. Resolvable layer thickness is equal to the one fourth of the dominant wavelength of a seismic wavelet (Widess, 1973). The dominant signal frequency and the interval velocity of coal in this study were estimated as 45 Hz. and 1850 m/sec, respectively. Accordingly; the minimum resolvable layer thickness was approximately determined as 10 meters.

Geological discontinuities available along coal seams can be considered as the most important problem that increase the cost encountered at coal production stage. The seismic reflection method has also another importance in determining such problems that might come out during the production planning stage.

The detection of both the upper and lower boundaries of the coal seam has equal importance in seismic investigations where the coal seams are explored. Therefore; it is preferred to have high accuracy during estimation in such basins.

The study area is located at the north of Sevinç district and Ağapınar village, the eastern part of Eskişehir (Figure 1). In other words; it is situated within the Eskişehir Graben, to the north of the Eskişehir Fault zone (Ocakoğlu, 2007). The basement rocks in the study area consist of Paleozoic metamorphites and tectonically associated Mesozoic ophiolites (Figure 2). Basement rocks are unconformably overlain by Miocene deposits. The m1 series consisting of conglomerate, sandstone and claystone is observed at the bottom of Miocene deposits. The overlying m2 series represents, from bottom to top, an alternating sequence of partly conglomerate, green claystone, coal, gray sandstone, dark gray to green siltstone, bituminous marl, siltstone, coal and green claystone, sandstone and fine grained conglomerate. The m3 series consisting of limestone and partly conglomerate, and Pliocene deposits consisting of loose conglomerate and claystone underlain by m2 series. Quaternary alluvial, recent sediments and alluvial fans cover all older units in the area (Figure 3).

2. Methodology

2.1. Data Collection

Seismic lineswere determined as a result of studies for determining the seismic program design and field parameters and their locations were assured by field observations. With these data, parameters were specified performing check shots on related lines for the selection of data collection and record parameters as a result of QC (Quality Control).These parameters were then assessed.

Lengths of crosscutting NW-SE directing ESV0903 and NE-SW directing ESEV0904 profiles are 15.324 and 7.452 meters, respectively; in the study of seismic reflection performed within the scope of project (Figure 4).

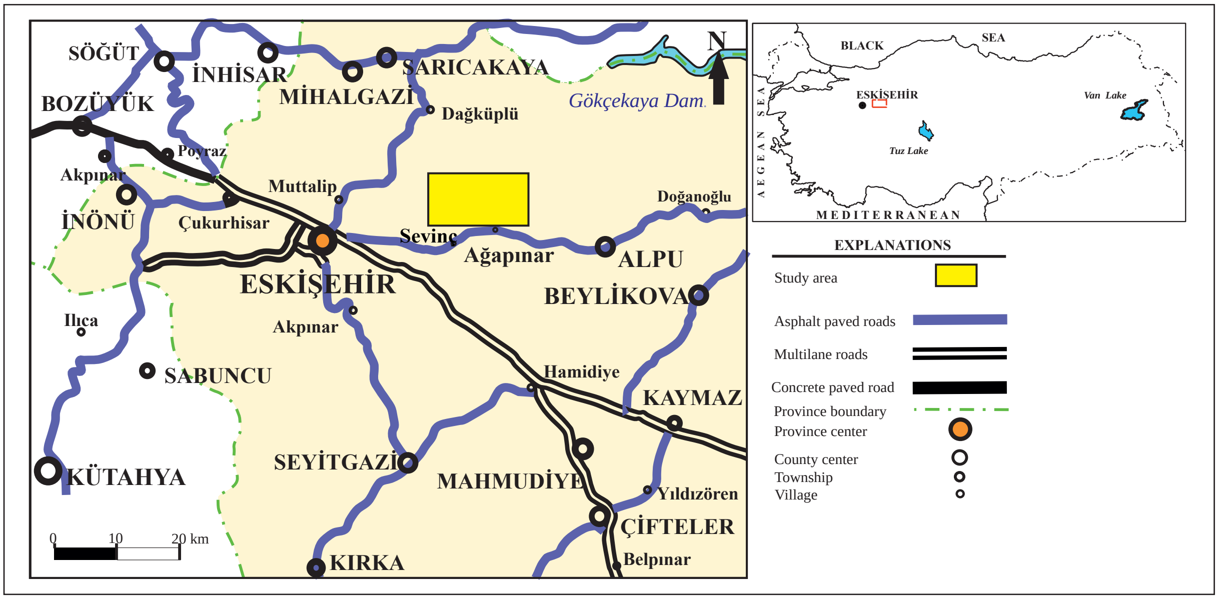

Figure 1- Location map of Sevinç - Ağapınar (Eskişehir) Coal Site.

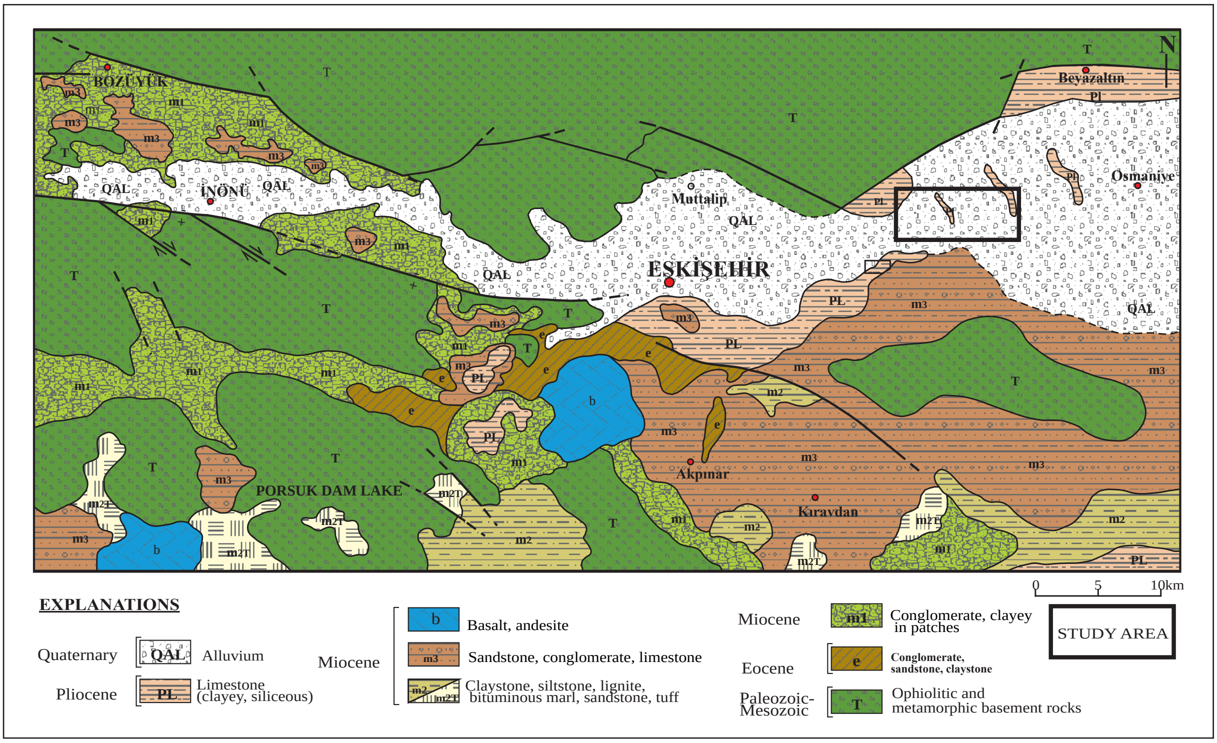

Figure 2 – Generalized geological map of the Eskişehir Basin (Şengüler 2011)

For check shots; 240 channel spread was made and the offset amount was considered to be increased beginning from 30 meters.The optimum distance was determined considering the shallowest level in the study and that the closest traces could get affected from seismic noises originating from shots.

Sercel 428 XL data acquisition equipment was used in the study. The system is composed of both the ground and recording equipment. The seismic energy in the study was formed by using 2 (Mini Vib II) vibro seismic energy sources.

Parameters given below were selected regarding the depth at which the information to be acquired, the purpose of the study, vertical and horizontal separations and to increase the data quality. In doing so; the spread geometry was selected as asymmetric spread (Table 1).

2.2. Seismic Data Processing

The purpose of the seismic data processing is to make data collected more meaningful and interpretable. To do that, first the data collected is refined from noises by means of various data processing techniques related to the purpose and target of the study.

The best seismic profile was obtained by data processing on data conducted within the scope of project and data collected on field. During data processing, total of 1647 (valid shootings) shooting points were madeon ESV0903 and ESV0904 seismic lines as 1127 and 520 points, respectively (Izladı et al., 2010).

Data collected on field were recorded in SEDG format, and then the quality control of each shooting was performed by being investigated in data analysis mode in Disco Focus software. Data processing flow chart which was used as a basis for the data collected on field and built for the use of Seismic Researches Division was given in figure 5.

3. Geology of the Study Area

The study area is located within the Eskişehir Graben at the north of Eskişehir Fault Zone, the eastern part of Eskişehir (Figure 1).

3.1. The Basement Rocks

Paleozoic metamorphites and Mesozoic ophiolites form the basement rocks in the area. Metamorphic rocks are tectonically in contact with ophiolitic rocks at north of the basin (Figure 2) with an imbricated structure directed from north to south (Gözler et al.,

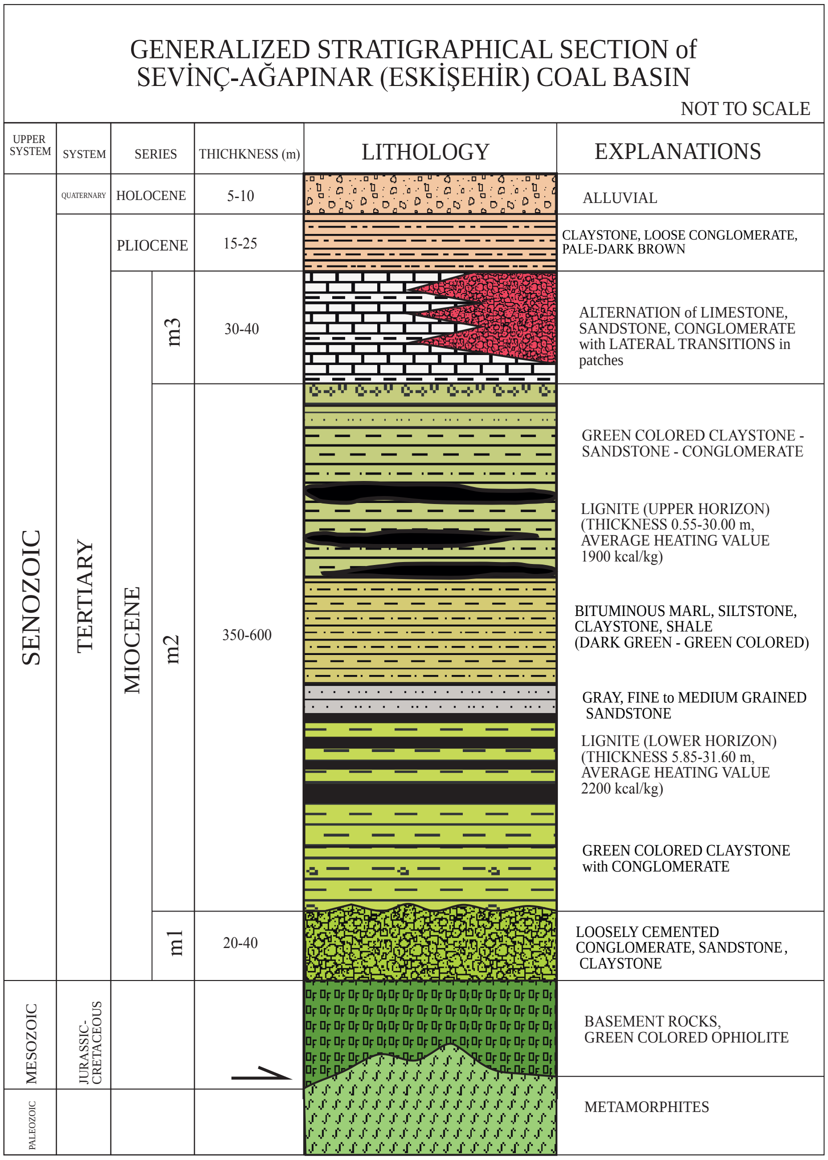

Figure 3 – Generalized stratigraphical section of Sevinç - Ağapınar (Eskişehir) Coal Basin (Şengüler 2010).

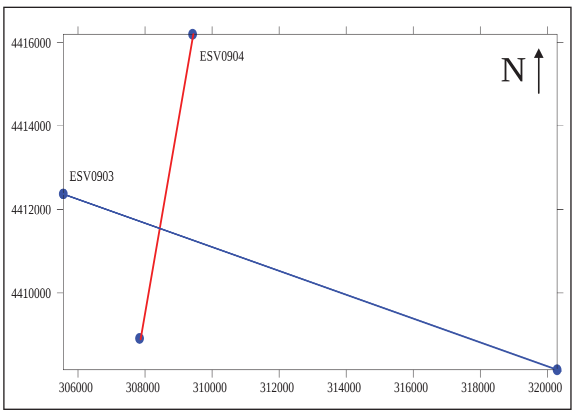

Figure 4 – Plot of ESV0903 and ESV0904 lines.

1996). It is hard to make a guess for the thickness of these rocks which display folded, faulted and fractured structures. However; it was observed that, schists and marbles in the area had thicknesses of 1000 and 200 meters, respectively.

The ophiolitic mélange, which does not have a regular sequence, is represented by; radiolarites, radiolarian limestones, mudstones, serpentinites, diabase, limestone, schist blocks, partly serpentinized peridotite and partly metamorphosed diabase and gabbro. The unit is generally dark green, brown and red colored, and highly folded and fractured structures are observed in radiolarite and mudstones.

Table 1- Shooting geometry applied in Seismic Reflection and recording parameters.

Sweep type	Linear
Sweep frequency rate	20-200 Hz
Sweep amount	8
Sweep time	8 sec
Sweep Taper	300 msec
Recording time	2 sec
Sampling rate	1 msec
Spread type	asymmetric
Shooting distance	12m
Group distance	6 m
Fold	60
Receiver type in-line	50cm (6 pack 2 string)
Offset	48 m

Serpentinization is widely observed in parts where peridotitic nappes are very near the contacts; however, the rate of serpentinization decreases within the massif. Peridotite and gabbro have formed high relief areas at the very north of the study area and at the south of the basin.

Melange, peridotite and gabbroic rocks, and metamorphites and metadetrites are tectonically associated among each other. This relation is determined by rather thick limonitized, carbonated and silicified listwaenite zones which run several kilometers at some places (Gözler et al., 1996).

3.2. Miocene Deposits

Miocene deposits unconformably overly Paleozoic and Mesozoic rocks forming the basement of the basin. At the bottom of Miocene deposits, m1 series takes place consisting of pebble, sandstone and siltstone. These deposits, on the other hand, are overlain by m2 and m3 series (Figure 3).

3.2.1. m1 Series

The m1 series at the base of the Miocene rocks is distinctive with its thick to very thick layer and red, yellowish gray, gray to pale gray and mostly with its red, brown-red colors. This unit starts with conglomerate and gravel ranging from pebble size to block size consisting of schist, marble, radiolarite, chert, gabbro, diabase, serpentinite, granodiorite and limestones from the underlying older units (Siyako et al., 1991). The conglomerates are typically cemented by dolomite in areas close to ultramafic rocks but are cemented by chalcedony and limonite where listwaenitization is dense, however the cement is calcite near metamorphic and carbonate rocks (Gözler et al., 1996).

3.2.2. m2 Series

The m2 series which overlies the m1 series, from bottom to top, represents a deposition formed by a sequence of partly pebbly green claystone, coal, gray sandstone, dark gray to green siltstone, bituminous marl, claystone, coal and green claystone, sandstone and fine grained conglomerate. The deposit is mainly green to yellow in color and partly speckled. The lower levels of claystone and marls which are observed as in very thin layers are red to purplish red in color and pass into green color.

Yellow colored parts of the m2 series take place generally in the upper levels of claystone and marls. There are observed partly sandy limestone bands within marls, and quartzite, marble, ophiolite, radiolarite and granodiorite pebbles in yellow to yellowish gray sandy limestones. Thinlayers of sandstone transitional with conglomerate are observed within layers of marl-claystone. Gray colored, fine to medium grained sandstone layer presenting thicknesses that vary between 2-5 meters which is located over the lower coal seam is distinguishable (Şengüler, 2011). The thickness of m2 series varies between 350-600 meters in deeper parts of the basin, but this thickness is about 400 meters in the study area (Figure 3).

Tuff and tuffite is encountered within m2 series at the southern part of the basin. These units consist of white, speckled, pinkish and brick red colored, fine grained pyroclastic materials. There is observed welded tuff around the basin, and tuffite intercalating with marl and clay within the basin. Marls and clays are generally in green, yellow, gray in color and partly speckled, and are observed at the deepest part of the basin. It is possible to see very thinly banded limestones in patches among marl and clay layers.

Coal formations are observed at places where lower parts of marl and claystones overlie conglomerate and sandstones. The formation of coal and bituminous marl at the north of Sevinç - Ağapınar takes place at depths varying between 250 – 450 meters (Şengüler, 2010). The coalification in the study area is in the form of two horizons. The heating value of coals

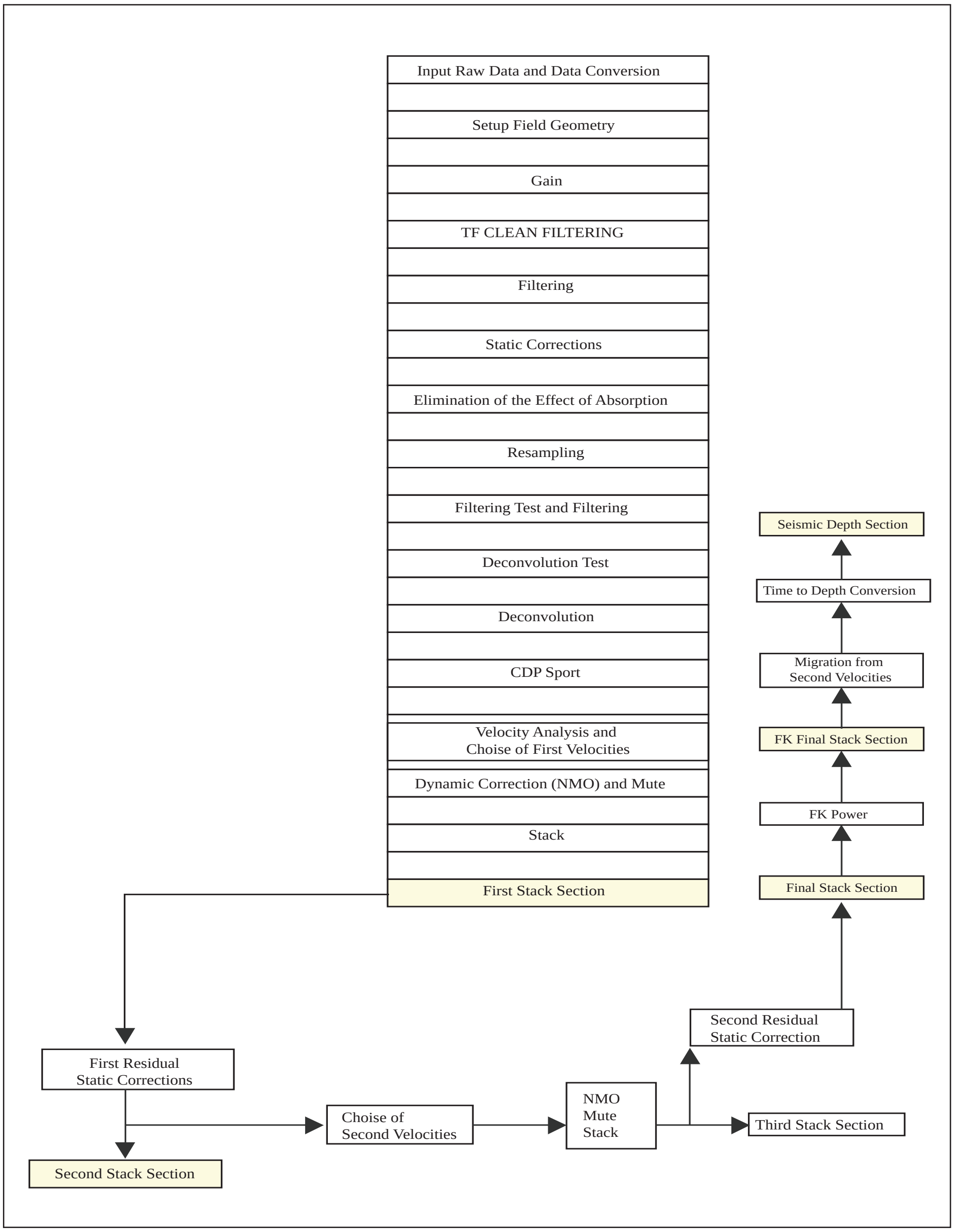

Figure 5 – The generalized flow chart of data processing of MTA Seismic Division.

varies between 1500 -3000 kcal/kg, and the average heat value is 2050 kcal/kg. It was again estimated that, the moisture as 34 %, ash as 32 %, volatile material as 21 %, fixed carbon as 13 % and sulfur as 1.5 %. The average coal thicknesses between the lower and upper coal horizons are different, and the average coal thicknesses for both zones are around 13 -14 meters.

Tuffite and marl intercalations are common at south of the basin. These are both laterally and horizontally transitional with the underlying unit and generally inter tongue with conglomerate and sandstone (1 meter). Places where there is intercalating vertical transition with tuffites above was observed at southern parts of the basin. Limestone intercalations were observed within conglomeratic sandstones and tuffites. Besides; lensodial and wedging tuffite and conglomerates were encountered within limestones as well.

3.2.3. m3 Series

This series consists of partly encountered limestone and pebble in upper layers. The limestone is in creamy white and gray colored and generally is observed as lenses. It is observed in the form of silicified and partly siliceous inter banded limestones at west, and as porous clayey and tuffaceous limestones at east. The sandstone was also encountered as alternating. Limestones and conglomerates display lateral transitions at north of the basin of the study area. Thickness of the unit in the study area is between 30 -40 meters (Figure 3).

3.3. Pliocene Deposits

Pliocene deposits in the study area are represented by creamy to pale brown claystone and by loosely cemented conglomerate. Conglomerate layers underlain by m3 series contain pebbles of all units older than it. Pebble sizes range between 1-10 cm and the thickness of the unit varies between 15 – 25 meters.

3.4. Quaternary Deposits

Quaternary alluvial, recent sediments and alluvial fans unconformably cover all older units (Figure 3).

4. Drilling Investigations

Drilling investigations related to reservoir determination which started in 2002 within the scope of “Project of Eskişehir Basin Coal Explorations” still continue in license areas of MTA. Some of the exploration studies and reservoir drillings conducted within the scope of project (which were assessed in the study) were located on and near the seismic lines and shown as blue points in figure 4.

5. Geological and Geophysical Interpretation of Seismic Reflection Sections

In 2009, a seismic section over two lines were generated during seismic reflection studies conducted on license areas of MTA at north of Sevinç District and Ağapınar Village in Eskişehir. After data processing of these sections were completed in Data Processing Center of the Geophysical Researches Department, the main structural characteristics of the geological environments were studied and interpreted.

The product generated after the process of seismic data is the section of a seismic time in this method. In seismic time section,the horizontal axis indicates the CDP numbers in terms of meter as distance on the seismic line measured on field. However, the vertical axis displays the travel time in terms of seconds.

Average velocities obtained during seismic data processing stage were used in the assessment made by correlating the aforementioned two seismic time sections with borehole lithologies drilled near lines. These velocities do not represent velocities ofthe actual formation layer, but only make an approach. If the vertical seismic profile (VSP), check shots, and/ or geophysical well log (density, sonic) data were not obtained in drilling wells in the study area then the depths estimated using average velocities which had been obtained only from data processing would make a predictive approach to actual depths.

The reflection surface (yellow colored level) which can continuously be traced along all sections was detected as the seismic basement entrancewhen seismic sections were assessed in general. On interpreted sections, the reflection of surfaces observed in areas especially where the seismic basement were deepened by the effect of both sided, cascaded fault lines (green colored levels) were specified as the coal-clay bypass zone.

It is considered that, discontinuities observed on surfaces of reflection that could be traced on interpreted seismic time sections correspondwith fault lines. Most probably, the basin deepens by the effect of fault lines corresponding with the CDP points numbered as 14063 -15280 in ESV0903 line and with CDP points numbered as 22120 – 23640 in ESV0904 line, and displays a multi staged and fractured structure in it. The seismic basement as well shows an elevation in north - south and in east - west directions beginning from these CDP points. Besides; there is observed a multi staged and highly fractured structure cutting through the seismic basement and cover layers as well in the basin.

5.1 ESV0903 Line

The probable deepestplace was determined as 650 meters,considering the average velocity between CDP points of 14560-14600 as 2030 m/sec, as a result of the average velocity obtained by velocity analysis for the level designated as the seismic basement based on interpreted time section.

Wells of ES-JF, ES-44, ES-45 and ES-9 along the line were plotted onto the scaled section at corresponding CDP points (Figure 6). The level determined as coal-clay zone in the study corresponds one to one with the carboniferous level cut in the well. Considering the average velocities at CDP points that correspond to ES-JF well, the coal velocity was

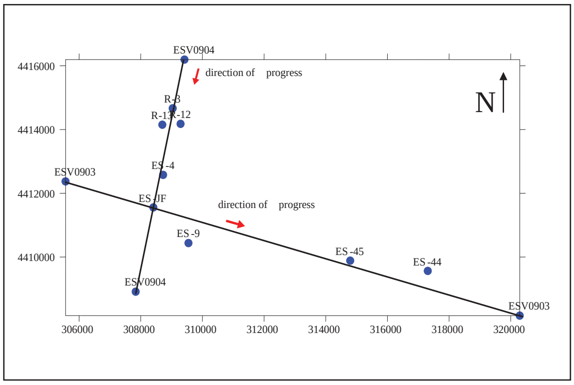

Figure 6 – Location of drillings on and near the lines.

approximatelyestimated as 1871 m/sec. By using this velocity,it was estimated that the probable deposition of the coal begins at a depth of 355 meters. This value almost corresponds approximately with the value of 356.15 meters which was determined in borehole data.

Considering the average velocities on CDP points corresponding to ES-9 well, the coal velocity was approximately estimated as 1867 m/sec. By using this velocity,it was estimated that the probable deposition of the coal begins at a depth of 399 meters. This value almost corresponds approximately with the value of 376.15 meters which was determined in borehole data. No traces of coal were encounteredin wells of ES-44 and ES-45 located near the line.

5.2. ESV0904 Line

The probable deepestplace was determined as 741 meters,considering the average velocity between CDP points of 22840 - 22880 as around 2100 m/sec as a result of the average velocity which was obtained by velocity analysis for the level designated as the seismic basement based on interpreted time section.

Wells of R-3, R-12, R-13, ES-4 and ES-JF along the line were plotted onto the scaled section at corresponding CDP points. The level determined as coal-clay zone in the study shows one to one correspondence with the carboniferous level cut in the well (Figure 7). Taking the average velocities at CDP points corresponding to ES-JF well into consideration, it was determined that the coal velocity detected for coal was estimated as 1810 m/sec approximately. Using this velocity, the coal-clay zone probably begins at a depth of 348 meters. This value almost corresponds approximately with the value of 356.15 meters that was determined in borehole data.

Considering the average velocities at CDP points corresponding to ES-4 well on the line, the coal velocity was determined approximately as 1808 m/sec. By using this velocity,the probable depth ofthe coal-clay zone begins at a depth of 316 meters. This value almost matches with the depth value detected by borehole data obtained which is 316.7 meters.

Considering the average velocities at CDP points corresponding to R-3 well on the line, the coal velocity was determined approximately as 1814 m /sec. By using this velocity,the probable estimated depth for coal-clay zone is 290 meters. This value almost matches with the depth value detected by borehole data obtained which is 304.85 meters.

Considering the average velocities at CDP points corresponding to R-12 well on the line, the coal velocity was determined approximately as 1819 m / sec. By using this velocity,it was estimated that the coal-clay zone probably begins at a depth of 364 meters. This value almost matches with the depth value detected by borehole data obtained which is 358.8 meters.

Considering the average velocities at CDP points corresponding to R-13 well on the line, the coal velocity was determined approximately as 1818 m / sec. By using this velocity,it was estimated that, the depth for coal-clay zone probably begins at a depth of 250 meters. This value almost matches with the depth value detected by borehole data obtained which is 243.3 meters. In order the depth to be relatively seen in the study, all well logs on seismic sections were plotted over lines as scaled.

The borehole data which was opened after the seismic reflection had been completed on the field as well indicate that the seismic reflection method could be used in coal sites. In drilling investigations performed in 2010 on the field, wells corresponding with seismic lines were studied. So, these wells and the compatibility of coalified zone detected on the stack section interpreted in 2009 indicate that, disciplined studies would contribute a lot to the country in terms of both the economy and time.

As a result of the seismic process performed in Data Processing Center, the average velocity for the drill R230 coinciding with ESV0903 Line was used as 1817 m/sec. (Figure 8). In depth conversion made by using this velocity, the depth at which the coalified zone begins at CDP point number 15610 was found as 410 meters. The coal was tested at 399 meters at the

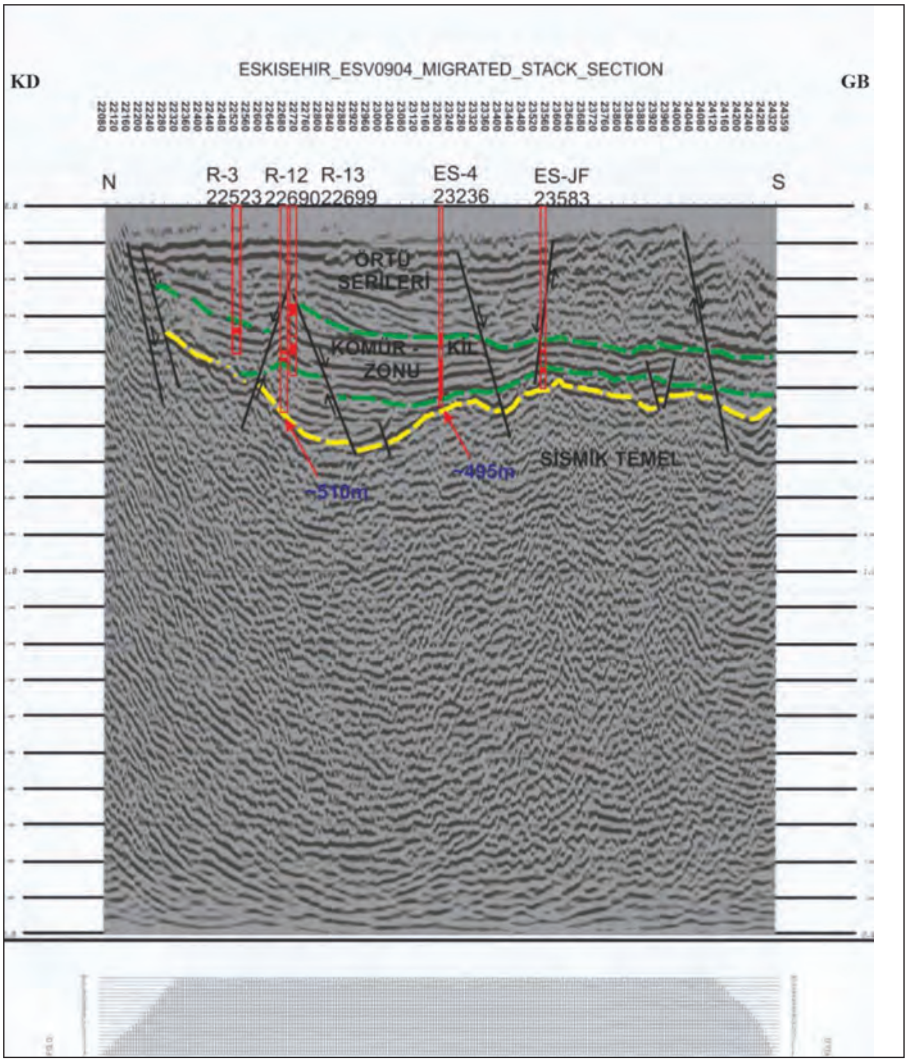

Figure 7 – Interpreted, migrated stack section of ESV0904 line.

drilling run at the same point. The average velocity for the drill R34 coinciding with ESV0904 Line was used as 1810 m/sec. In the depth conversion made by using this velocity, the entry depth into the coalified zone at CDP point number 23909 was found as 348 meters. The coal was tested at 306 meters at the drilling run at the same point. Sections of average velocity anomaly for the lines were given in figures 9 and 10.

6. Results

It can be seen above that, there are small differences between the depths estimated during data processing for the entrance of the coal bearing zone and entrance values of drillings for the coal bearing zone. The reason is that, the estimated and used velocities during data processing are not completely the same with actual velocities of the medium. Since the most ideal velocities representing the medium could be obtained from methods such as; Sonic Log and Check Shot, the depths estimated will make the best approach to actual depths. However; in cases when these methods cannotbe used, then depth conversions can be made by using velocities estimated at data processing stage and an approach to actual depths can be achieved. As a result, all methods make an approach to actual velocity of the medium and differences at depth values given above are within acceptable limits of the depth estimated from velocities selected at data processing stage.

On interpreted ESV0903 and ESV 0904 sections, the reflection of surfaces observed on areas especially where seismic basement were deepened by the effect of both sided, cascaded fault lines (green colored levels) were specified as entrance for coal-clay zone.

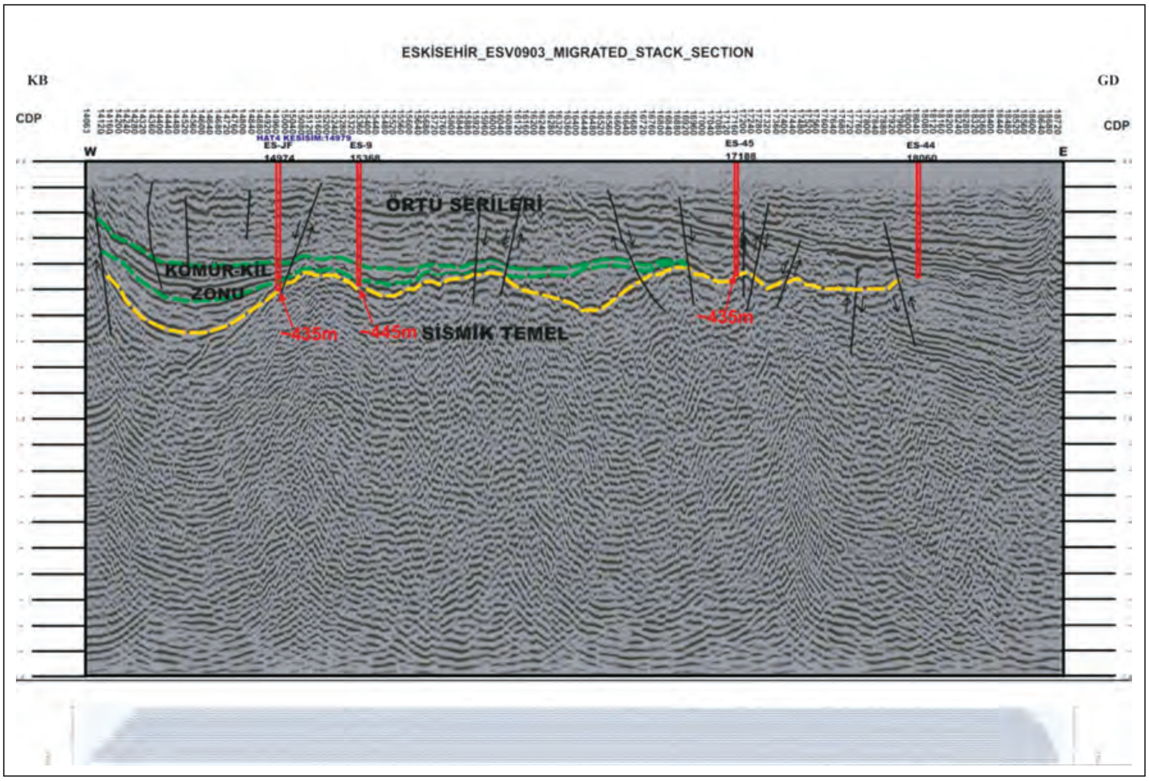

Figure 8 - Interpreted, migrated stack section of ESV0903 line.

It was seen that, these zones were conformable with lithological unit boundaries of these levels determined when compared with borehole data performed on the field.

It was seen that, the seismic basement was deepened especially in the region of ESV0904 section to the west of the study area and the coal thickness became thickened.

It is considered that, discontinuities seen on reflection surfaces that can be observed on interpreted seismic time sections correspond to fracture systems. Most probably; the basin deepens by the effect of mutual fracture systems and displays a multi staged and fractured structure in it. This fact is also compatible with sections obtained by resistivity studies that have been carried out in Eskişehir basin in recent years.

All these studies that have been carried out within scope of project reveal that, geophysical methods supported by geological data could be used for the determination of the basement topography in covered Neogene areas.

Acknowledgment

This study has been made within the framework of “Project of Eskişehir Basin Coal Explorations” conducted by the Department of Energy Raw Material Research of the General Directorate of Mineral and Exploration (MTA).

Korhan Köse and Vasfi Pektaş have made literature surveys forthe positioning of lines by using the seismic program design relevant to the purpose of the study and by aeromagnetic and regional gravity maps studied prior to field investigations.

Data collected in the field have been processed and made ready for the interpretation by Z. Rezzan Özerk and Sinem Aykaç of the Data Processing Center of Seismic Researches Division in Geophysical Researches Department.

During seismic reflection studies, seismic section along two lines have been formed and data processing completed at Seismic Data Processing Center of the Geophysical Researches Department then these data have then been interpreted by A. Tolga Toksoy and Abdullah Gürer.

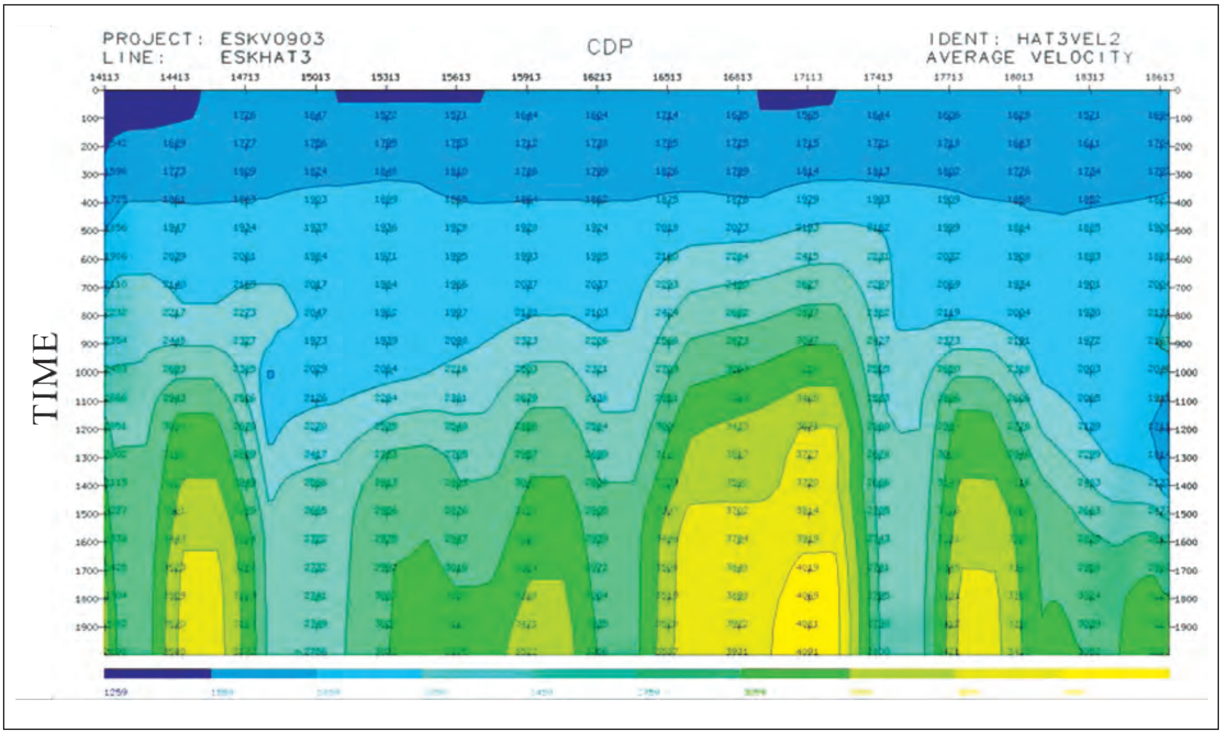

Figure 9 – Average velocity anomaly section of ESV0903 seismic line.

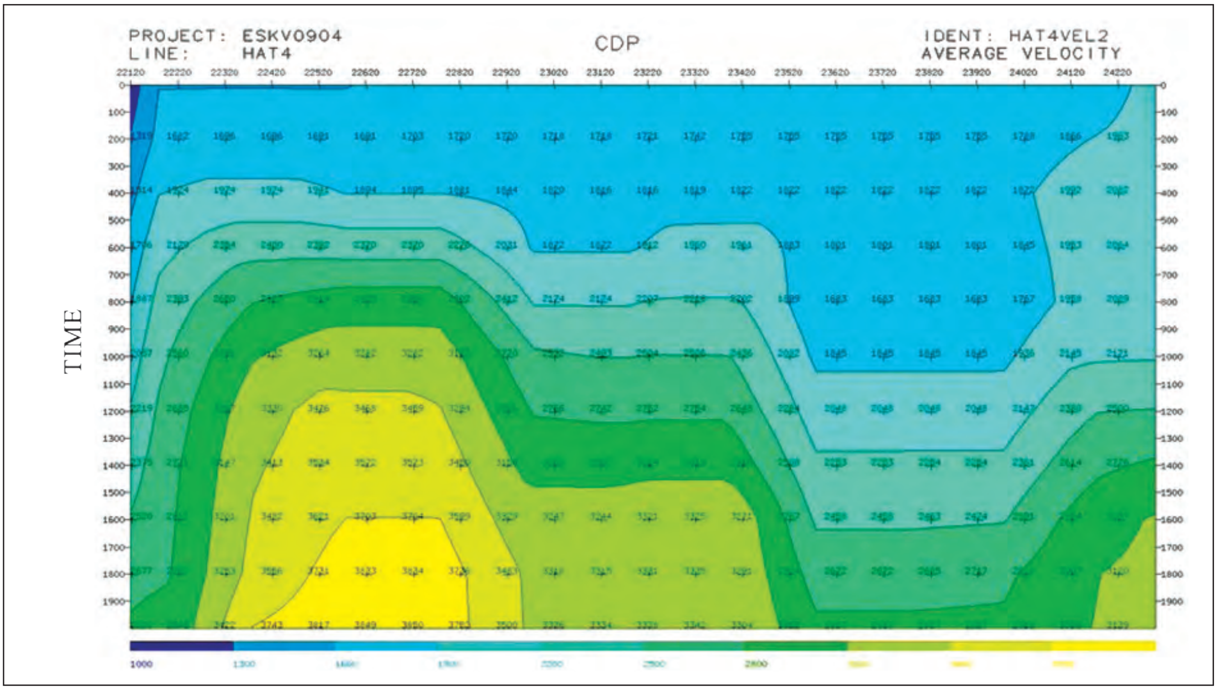

Figure 10 - Average velocity anomaly section of ESV0904 seismic line.

We are thankful to Yılmaz Bulut, Korhan Usta, Mahir Sezgin, Semih Kutlu, İmam Çelik, to all staffs of the Laboratory Division of the Geophysical Researches Department, the Seismic Data Collection Unit and to map technicians who have contributed a lot at different stages of the investigations.

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Foreign Edition 2013 146

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BULLETIN OF THE MINERAL RESEARCH AND EXPLORATION
NOTES TO THE AUTHORS

1.Publication Objectives

• to contribute to the scientific communication on geology in Turkey and the international community

• to announce the geological researches made in Turkey to the foreign countries,

• to announce the scientific researches and practices made by the General Directorate of Mineral Research and Exploration (MTA) on geology to the public,

• to use the journal as an effective media for international publication exchange by keeping the journal in a high level in terms of quality, scope and format,

• to contribute to the efforts of developing Turkish has the science language and eliminating foreign words from Turkish.

2. Scope-Qualification

At least one of the following qualifications is required for publishing the papers in the Bulletin of Mineral Research and Exploration

2.1. Research Articles and Compilations

2.1.1. Original Scientific Researches

• This type of articles covers original scientific research and its results that contribute to the fundamental issues ofgeology, deals with exploration and evaluation of underground resources, and examines environmental issues in term.

2.1.2. Development Researches

The studies using new approaches and methods to solve any problems related to geology and / or the researches using new approaches and methods to solve any problems related to the science of engineering performed in the General Directorate of Mineral Research and Exploration,

2.1.3. Criticizing Compilations

Researches that compile, with the help of a critical approach, previous studies made on Geology and put forth a new vision about it.

2.2. Criticism and Response Articles

• The articles that criticize all or a part of an article published in the latest issue of the journal, when sent within the six months after distribution of the journal, are published in the following first issue.

• Criticizing articles, before publication, are sent to the author/authors of the criticized articles in order to take their response. Criticisms on the articles of multiple authors are sent to the corresponding author.

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• The rules of scientific discussions and ethics must be obeyed while criticizing and replying. Each of the criticizing and replying articles with figures must not exceed four pages. The pages and their use must be appropriate to "Spelling Rules" section.

2.3. Short Notes

• The data obtained from scientific researches and practices made or ongoing in the field of geology, and short, concrete and concise writings that reflect the new findings on the existence of previously unknown related to geosciences in Turkey are included in the "Short Notes" section of the Bulletin of Mineral Research and Exploration.

• The articles that can be published in the "Short Notes" section, in order to ensure promptness of communication, are published without any delay in the first or at the latest second issue shortly after the date of the publication request sent to the Chairman of Redaction Board.

• The articles together with all figures and tables must not exceed four pages to be published in the "Short Notes" section.

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The studies that will be submitted to the journal for publication, being prepared in accordance with the rules of the Bulletin of Mineral Research and Exploration preferably Turkish and/ or English, are sent by electronic application from the internet address www.dergi.mta.gov.tr.

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The files individually named in the form of "Text", "Figures", "Tables" are required to be sent by CD.

- Text must not be previously published partially or completely in elsewhere.

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- The articles which do not comply with the publication rules of the Bulletin of Mienral Research and Exploration in terms of quality and format are given back without being examined of in terms of content.

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- The studies of which correction is deemed necessary are sent back to the author/authors with the demand of correction. The Editorial examines the articles to see whether the suggested corrections are implemented.

- If there are suggestions that are not accepted and corrected by the author in correction suggestions given by the editors and referees, a report with the corrected copies explaining the rationale of rejectionof these proposalsby the author must be sent to Editorial.

- The articles submitted to the bulletin of Mineral Research and Exploration with request of publication together withall theillustrationsmust not exceed 30 pages. For the articles exceeding 30 Pages, Redaction Board decision is taken if deemed appropriate by the referees and editors.

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- The Bulletin of Mineral Research and Exploration is published at least two times per year, each issue one in Turkish and the other in English.

- The spelling rules of Turkish Language Institution are valid for the Turkish issue. However, spelling forms of technical terms are used in accordance with the decision of the Editorial Board for the spelling of the words related to geology (For example, underground, surface, earth's crust, geology, etc.).

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- The articles submitted for the first examination to the Bulletin of Mineral Research and Exploration with request of publicationmust be written in A4 (29.7 x 21 cm) size, word format, 10-point normal Times New Roman and double-spacedlines.

- 2.5 cm space must be left around top, bottom, left and right side of the page. The formulas requiring the use ofspecial charactersand symbols must be submitted on computer.

- Initials of all words must be capital letter in all sub-titles. The first degree titles used in this paper must have number and be left-aligned, 10 point bold Times New Roman must be used. The second degree titles must have number and be left-aligned, they must be written with 10 point normal Times New Roman. The third degree titles must have number and be left-aligned, they must be written with 10 point italic Times New Roman. The fourth degree titles must be left-aligned without giving number; 10 pointitalic Times New Roman must be used, the text must continue placing a colon after the title without paragraph returns (See:Sample article: www.dergi.mta.gov.tr).

- Line spacing must be left after paragraphs within text.

- Paragraphs must begin with 0.5 mm indent

- A text must cover the below sections respectively;

-Title

-Author name and surname, and *sign (address, e-mail address must be writtenat the bottom ofthepage)

-Abstract

-KeyWords

-Introduction

-Body

-Discussion

-Conclusion

-Acknowledgements

-Works cited.

5.1. Title of the Article

- The title must reflect the subject of the article as shortly as possible, clearly and adequately. The subjects which are not handled sufficiently must be kept outsidethe scope of the title. The whole title must be written with capital letters and 10-pointbold Times New Roman. For each articles, a “Short Title” not exceeding 50 characters, separately for the Turkish and English issues, must be given at the end of the text.

5.2. Author’s Name, Address and E-Mail Address

- Author/authors’ name and surname must be written without remarking appellation.Name must be written in minuscule and surname must be capitalized.

- The engagement address which will be located after author/authors’ name andthe surname must include only organization name, the task must not be specified.

- Address details must be located in a lower line and be10 points and italics.

- For the articles having two ormore authors, the number must be placedon authors’ surnames and their address details must be located in a lower line by leavingone line space. Moreover in this section, responsible author for the article must be specified using the asterisk (*) mark and e-mail, telephone and / or fax information belonging responsible author must be given.

- Whilebeing written author’s name and engagement address, abbreviations must be avoided. Addresses must be written in the language of the country they belong without translating the minto another language.

- Referenced author’s name and contact information must be added to the end of the text.

5.3. Abstract

- The abstract must be understood without referencing other parts of the article.

- The abstract must be organized in the form ofa short presentation of the text; it must reflect the aim, the contribution to those known, provided new data and interpretations.

- Short and simple sentences must be used for narration.

- Addressing other sections and illustrations of the text or other writings must be avoided at the abstract section.

- The knowledge must not be included in the abstract section if the knowledge is not defined in body.

- The abstract must not exceed 200 words and must be written as one paragraph.

- The abstract part must be written with 10-point normal Times New Roman and single-spaced lines. • “Abstract” must not be given for the writings that will be located in “Short Notes” section.

- English abstract must be under the title of”Abstract”.

5.4. Key Words

Five keywords indicating the general content of the article must be selected and noted in this section in order to scan easily.

5.5. Introduction

- In this section, there must be such information as the purpose of the study, location, research methods and previous studieson the subject which makes the article ready for reading and facilitate the understanding.

- If there are unusual or unconventional ways in the article for naming, classification and abbreviation, the reason for this must benotedin this section. Each of the subjects that will be located in this section can forma separate paragraph or one sub-title can be used for each of the subjects if necessary (for example, methods, materials,terminologyetc.).

• When needed reminder information for facilitating the understanding of the text, this section can also be used (for example, statistical data, bringing out the formulas, experiment or application methods, and others.).

5.6. Body

• In this chapter, there must be data, findings and opinions that are intended to convey the reader about the subject. The body section forms the main part of the article.

• The data used the other sections such as “Abstract”, “Discussions”, and “Results” is caused by this section.

• While processing subject, care must be taken not to go beyond the objective highlighted in “Introduction” section. The knowledge which do not contribute to the realization of the purpose of the article or are useless for conclusion must not be included.

• All the data used and opinions put forward in this section must prove the findings obtained from the studies or they must be based on a reference by citation.

• Guidance and methods to be followed in processing subjects vary according to the characteristics of the subjects dealt with.Various phased topic titles can be used in this section as many as necessary.

5.7. Discussions

• Objectively transferred data and findings in the body section ofthe article must be discussed in this section by the author. Discussions must be apart section from the results.

5.8. Conclusions

• The new data and findings provided from the examination of the subject forming the article must be stated concisely and concretely in this section.

• The subjects that are not mentioned sufficiently and / or unprocessed in the body section must not be included in this section.

• The conclusions can be given in the form ofsubstances in order to emphasize the results of the research and be understandable expression.

5.9. Acknowledgments

Important contributions to the realization of research forming the subject of the article are stated in this section. While specifying contributions, the attitude diverted the original purpose of this section away is not recommended. Acknowledgments must be made according to the following examples.

• This study wascarried outunder the...................... project.

• I/we would like to thank to ……..........… for contributing the development of this article with his/her critiques.

• Academic and / or authority names are written for the contributions made because of ordinary task requirement.

For example:

“Prof. Dr. İ. Enver Altınlı has led the studies”.

“The opinions and warnings of Dr. Ercüment Sirel are considered in determining the limits of İlerdiyen layer.”

• The contributions made out of ordinary task requirement:

For example:

“I would like to thank to Professor. Dr.MelihTokay who gives the opportunityto benefit from unpublished field notes.”; “I would like to thank to State Hydraulic Work 5. Zone Preliminary-Plan Chief Engineer Ethem Göğer.”Academic and /or task-occupational titles are indicated for this kind of contributions.

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For example:

Such sentencesas “I would like to thank to our General Manager, Head of Department or Mr. /Mrs.President ……………who has providedmethe opportunity toresearch”must be used.

5.10. Works Cited

• The documents cited in the article must be included completely in this section.

• Care must be taken not to make the wrong while providing the information relating to mentioned documents. Publication names must not be abbreviated.

• Works cited must be written in Times New Roman, 9-point type face.

• The works must be listed in order of the alphabet taking into consideration surnames of the authors.

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Pamir, H.N. 1953. Türkiye kurulacak bir hidrojeoloji enstitüsü hakkında rapor. *Türkiye Jeoloji Bülteni* 4, 1, 63-68.4, 1, 63-68.

Barnes, F., Kaya, O. 1963. İstanbul bölgesinde bulunan Karbonifer'in genel stratigrafisi. *Maden Tetkik ve Arama Dergisi* 61,1-9.

Robertson, A.H.F. 2002.Overview of the genesis and emplacement of Mesozoic ophiolites in the Eastern Mediterranean Tethyan region. *Lithos* 65, 1-67.

• If more than one document by the same authors is cited, firstly the ones having single name must be placed in chronological order, then the ones having two names must be listed in accordance with chronological order and second author's surname, finally the ones having multiple names must be listed in accordance with chronological order and third author's surname.

• If the document is abook, these are specified respectively: surnames of the author/authors, initial letters of author's/authors' first names. Year of publication. Name of the book (initial letters arecapital). Name of the organization which has published the book (in italics), name of the publication wherethe document is published, volume and/ or the issue number, total pages of the book.

For example :

Meric, E. 1983. Foraminiferler. *Maden Tetkik ve Arama Genel Müdürlüğü Eğitim Serisi* 23, 280 s.

Einsele, G. 1992. Sedimentary Basins. *Springer-Verlag*, p 628.

• If the document is published in a book containing the writings of various authors, the usual sequence is followed for the documents in a periodic publication. Then the editor's surname andinitial letters of their name /names are written. "Ed." which is an abbreviation of the editor word is written in parentheses. Name of the book containing the document (initial letters arecapital). Name of the organization which has published the book (*in italics*). Place of publication, volume number (issue number, if any) of the publication wherethe document ispublished, , numbers ofthe first and last page of the document.

For example:

Göncüoğlu, M.C., Turhan, N., Şentürk, K., Özcan, A., Uysal, Ş., Yalınız, K. 2000. A geotraverse across northwestern Turkey. Bozkurt, E., Winchester, J.A., Piper, J.D.A. (Ed.). Tectonics and Magmatism in Turkey and the Surrounding Area. *Geological Society of London* Special Publication 173, 139-162.

Anderson, L. 1967. Latest information from seismic observations. Gaskell, T.F. (Ed.). The Earth's Mantle. *Academic Press*. London, 335-420.

• If name of a book where various authors' writings have been collectedis specified, those must be indicated respectively: book'seditor/editors' surname/ surnames, and initial letters of their name/names. "Ed." which is an abbreviation of the editor word must be writtenin parentheses. Year of Publication. Name of the book (initial letters arecapital). Name of the organization which has published the book (*in italics*), total pages ofthe book.

For example:

Gaskel, T.F. (Ed.)1967. The Earth's Mantle. *Academic Press*, 520 p.

• If the document is an "Abstract" "published declaration essence", information about the document must be given in the following order: surnames of the author/authors, initial letters of author's/authors' first names. Year ofpublication. Name of the document. Name (in italics), date and place of the meeting where the declaration is published, numbers ofthe first and last pages of the abstract in the book.

For example:

Yılmaz, Y. 2001. Some striking features of the Anatolian geology. 4. *International Turkish Geology Symposiums*, 24-28 September 2001, London, 13-14.

Öztunalı, Ö. ve Yeniyol, M. 1980. Yunak (Konya) yöresi kayaçlarının petrojenezi. *Türkiye Jeoloji Kurumu 34. Bilim Teknik Kurultayı*, 1980, Ankara, 36

• If the document is unpublished documents as report, lecture notes, and so on., information about the document must be given by writing the word "unpublished" in parentheses to the end of information about the document after it is specifiedin accordance with usual order which is implemented for a document included in a periodic publication.

For example:

Özdemir, C. Biçen, C. 1971. Erzincan ili, İliç ilçesi ve civarı demir etütleri raporu. *Maden Tetkik ve Arama Genel Müdürlüğü* Rapor No: 4461, 21 s. Ankara (unpublished).

Akyol, E. 1978. Palinoloji ders notları. *EÜ Fen Fakültesi Yerbilimleri Bölümü*, 45 s., İzmir (unpublished).

• The followings must be specified for the notes of unpublished courses, seminars, and so on.: name of the document and course organizer. Place of the meeting. Name of the book, corresponding page numbers.

For example:

Walker,G. R.Mutti, E. 1973.Turbidite facies and facies associations. Pacific Section Society for Sedimentary Geology Short Course. Annaheim. Turbitides and Deep Water Sedimantation, 119-157.

• If the document is a thesis, the following are written: surnameof the author, initial letter of the author's first name. Year of Publication. Name of the thesis. Thesis type, the university where it is given, the total number of pages, the city and "unpublished" word in parentheses.

For example:

Seymen, İ. 1982. Kaman dolayında Kırşehir Masifi'nin jeolojisi. Doçentlik Tezi, İTÜ Maden Fakültesi, 145 s. İstanbul (unpublished).

• Anonymous works must be regulated according to publishing organization.

For example:

MTA. 1964. 1/500.000 ölçekli Türkiye Jeoloji Haritası, İstanbul Paftası. Maden Tetkik ve Arama Genel Müdürlüğü, Ankara.

• The date, after the name of the author, is not given for on-printing documents; "in press"and / or "on review" words in parenthesis must be written. The name of the article and the source of publication must be specified, volume and page number must not be given.

For example:

Ishihara, S. The granitoid and mineralization. Economic Geology 75th Anniversary (in press).

• Organization name, web address, date of accesson web address must be indicated for the information downloaded from the Internet. Turkish sources must be given directly inTurkish and they must be written with Turkish characters.

For example:

ERD (Earthquake Research Department ofTurkey). http://www.afad.gov.tr. March 3, 2013.

• While specifying work cited, the original language must be used; translation of the title of the article must not be done.

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• All drawings, photographs, plates and tables used in this paper is called “illustration”.

• Illustrations must be used when using them is unavoidable or they facilitate the understanding of the subject.

• While selecting and arranging the illustrations’ form and dimensions, page sizeand layout ofthe magazine must be taken into consideration, unnecessary loss of space must be prevented as much as possible.

• The pictures must have high quality, high resolution suitable for printing.

• The number of illustrations must be proportional to the size of the text.

• All illustrations must be sent inseparate files independent from the text.

• While describing illustrations in the text, abbreviations must be avoided and descriptions must be numbered in the order they are mentioned in the text.

• Photographs and plates must be given as computerfiles containing EPS, TIFF, or JPEG files in 600dpi and higher resolutions (1200 dpi is preferred) so that all details can be seen in the stage of examination of writing.

6.1. Figures

• Drawings and photos together but not the plate in the text can beevaluated as”Figure” and they must be numbered inthe order they are mentioned in the text.

• The figures published in the Bulletin of Mineral Research and Exploration must be prepared in computing environment considering the dimensions of single-column width 7.4cm or double-column width 15.8cm. Figure area together with the writing at the bottom should not exceed a maximum 15.8x21.

• Figures must not be prepared in unnecessary details or care must be taken not to use a lot of space for information transfer.

• Figures must be arranged to be printed inblack-and-white or colored. The figure explanations being justified in two margins must be as follows:

Figure 1 -Sandıklı Town (Afyon); a) Geological map of thesouth-west, b) general columnar section of the study area(Seymen1981), c) major neotectonic structures in Turkey (Koçyiğit 1994 changed).

• Drawings must be drawn by well-known computer programs painstakingly, neatly and cleanly.

• Using fine lines which can disappear when figures shrinks must be avoided. Symbols or letters used in all drawings must be Times New Roman and not be less than 2 mm in size when shrink.

• All the standardized icons used in the drawings must be explained preferably in the drawing or with figure caption if they are very long.

• Linear scale must be used for all drawings. Author’s name, figure description, figure number must not be included into the drawing.

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6.2. Plates

• Plates mustbe used when needed a combination of more than one photo and the publication on a special quality paper.

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• The original plates must be added to the final copy which will be submitted if the article is accepted.

• Figuresand plates must be independently numbered. Figures must be numbered with Latin numerals and plates with Roman numerals (e.g., Figure1, Plate I).

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- All tables must be prepared preferably in word format in Times NewRoman fonts.

- Tables together with table top writing must not exceed 15x8 cm size.

- The table explanations being justified in two margins must be as follows:

Table 1 - Hydrogeochemical analysis results of geothermal waters in the study area.

7. Nomenclature and Abbreviations

- Unusual nomenclature and unstandardized abbreviations must be avoided in the article. Incases where unusual nomenclatures and unstandardized abbreviations are considered to be compulsory, the followed way and method must be described.

- Full stopmust not be placed between the initials ofwords for standardized abbreviations (MER, SHW, etc.).

- Geographical directions must be abbreviated in Turkish language (N, S, E, W, and NE).

- The first time used abbreviations in the textare presented in parentheses, the parenthesis is not used for subsequent uses.

- Themetric system must be used as units of measure.

- Figure, plate, and table names in the article must not be abbreviated. For example, "as shown in generalized stratigraphiccross-sectionof the region (Figure 1………….."

7.1. Stratigraphic Terminology

Stratigraphic nomenclature must be appropriate with the rules of Stratigraphic Classification and Nomenclature prepared by Turkey Stratigraphy Committee. Care must be taken to use formalized formation names

7.2. Paleontologic Terminology

Fossil names in phrases must be stated according to the following examples:

a. For the use authentic fossil names:

e.g. Calcareous sandstone with *Nummulites*

b. When the authentic fossil name is not used.

e.g. nummulitic Limestone

c. Other examples of use;

e.g. The type and species of Alveolina

Alveolina type and species

Taxonomic ranks must be made according to following examples:

- The names of the fossils should be stated according to the rules mentioned below:

Superfamily : Alveolina Ehrenberg, 1939 Family: Borelidae Schmarda, 1871 Type genus: *Borelis* de Montfort, 1808 Type species: *Borelis melenoides* de Montfort, 1808; *Nautilus melo* Fitchel and Moll, 1789	*Not reference, Not stated in the Reference section.*
Borelis vonderschmitti (Schweighauser, 1951) (Plate, Figure, Figure in Body Text	*Schweighauser, 1951 not reference.*
1951 *Neoalveolina vonderschmitti* Schweighauser, page 468, figure 1-4	*Cited Scweighauser (1951), stated in the Reference section.*
1974 *Borelis vonderschmitti* (Schweighauser), Hottinger, page, 67, plate 98, figure 1.7	*Cited Hottinger (1974), stated in the Reference section.*

a. For the first use of the fossil names, the type, speices and the author names must be fully indicated

Alveolina aragoensis Hottinger
Alveolina cf. *Aragoensis* Hottinger

b. When a species is mentioned for the second time in the text:

A.aragoensis
A.cf.aragoensis
A.aff.aragoensis

c. It is accepted as citiation if stated as Alveolina aragoensis Hottinger (1966)

• The statment of plates and figures (especially for articles of paleontology):

a. for statment of the species mentioned in the body text

Borelis vonderschmitti (Schweighauser, 1951).

(plate, figure, figure in the body text).

b. When citing from other articles

1951 *Neoalveolina vonderschmitti* Schweighauser, page 468, figure 1-4, figure in body text

1974 *Borelis vonderschmitti* (Schweighauser), Hottinger, page 67, plate 98, figure 1-7

For the citiation in the text

(Schweighauser, 1951, page, palte, figure, figure in the body text)

(Hottinger, 1974, page, plate, figure 67, plate 98, figure 1-7, figure in the bodytext.)

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All the citiations in the body text must be indicated by the last name/ last names of the author/authors and by the year of publication.

The citiations in the text must be referred according the following examples.

• For publications written by one author:

-It is known that fold axial plain of Devonian and Carboniferious aged units around Istanbul is NS oriented (Ketin, 1953, 1956; Altınlı, 1999).

-Altınlı (1972, 1976), defined Bilecik sandstone in detail.

• For publications written by two authors:

- The upper parts of the unit contain Ilerdian fossils (Sirel and Gündüz, 1976; Keskin and Turhan, 1987, 1989).

• For publications written by three or more authors:

- According to Caner et al. (1975) Alıcı formation reflects the fluvial conditions.

- The unit disappears wedging out in the East direction (Tokay et al., 1984).

• If reference is not directly obtained but can be found in another reference, cross-reference should be given as follows:

- It is known that Lebling has mentioned the existance of Lias around Çakraz (Lebling, 1932: from Charles, 1933).

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