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

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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* Perch-Nielsen, *Watznaueria barnesea* Black, *Ellipsagelosphaera foscincta* 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.

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

1. Introduction

1.1. The Aim of the Study

The study area is located at surrounding of Sarıçakaya 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; Altnlı, 1973a, 1974, 1975; Saner, 1977, 1980; Demirkol, 1973, 1977; Ayaroğlu, 1978, 1979; Şentürk and Karaköse, 1981, 1982; Alkaya, 1981, 1982; Kibici, 1982; Cope, 1991; Altuner et al., 1991; Altuner 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 calcereous 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, Altnlı (1973a) 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 Göktken, 1994; Soussi et al., 1998, 1999) These red colored, carbonated and shaley layers with abundant ammonites also mentioned by...
Altunlı (1973a) 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; Pompecki, 1897; Bremer, 1965; Varol and Gökten, 1994; Alkaya and Meister, 1995; Kuznetsova et al., 2001; Koçyiğit and Altıner, 2002; Okan and Hosgör, 2007). The “Calcare Ammonitico Rosso” facies rocks crop out in “Bayırköy Formation”, in the Central Sakarya Region which also falls in Pontide area (Altunlı, 1973a). The formation was dated as late Sinemurian – Pliensbachian mainly as it contains ammonite fossil in this facies (Abdüüsselamoğlu, 1956; Granit and Tintant, 1960; Altunlı, 1973a; Alkaya, 1981, 1982; Cope, 1991). The presence of some benthic foraminifers (Altunlı et al., 1991; Altunlı and Koçyiğit, 1992; Koçyiğit et al., 1991; Gönçüoğlu et al., 1996; Gedik and Aksay, 2002) and nannoplanktons (Aras et al., 1991) also confirm the Liassic age. Altuner et al. (1991) obtained index fossils indicating Hettangian – early Sinemurian age from the layers underlying ammonitic levels of Bayırköy formation different than Altunlı (1973a), 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. Altuner et al (1991) made a correction for the age of Bayırköy Formation as Hettangian – 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. Altunlı (1973a), 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). Altunlı (1973a) in his study carried out around Sarıçakaya 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 Altunlı (1973a) are not adopted likely in latter studies carried out. After Altunlı (1973a), 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; Gönçüoğlu 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 Kuphal (1954) and Ürgün (1956), as transitional by Abdüsselamoglu (1956), as conformable contact by Saner (1977) and Aras et al. (1991), as an angular unconformity by Altunlı (1973a) 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 (Altunlı, 1973a; 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 (Altunlı, 1973a), 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 Gölçazari – Söğüt line suggested by Altunlı (1973a) 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, Sarıçakaya granitoid, Kapıkaya formation and Bilecik / Soğukçam formation have been thrust 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 Metamorphites” which crop out mainly in western parts of the area known as the “Central Sakarya Region”, the north of Eskişehir. The exposures of Söğüt metamorphites are present at north of Sarıçakaya, 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 metamorphites 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 metamorphites. The petrographical studies of the samples taken from Söğüt metamorphites in the Kayadibi Yayla section (Figure 2, A-B section) located at 5 km north of Sarıçakaya 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 Sarıçakaya 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-Campanian time based on its stratigraphical position as it is overlain by the clastics of the Kapıkaya formation with an initial relationships.

2.2. Sarıçakaya Granitoid

Granite – granodiorite complex is exposed at north of Sarıçakaya county and cut Söğüt metamorphites was investigated under the name of Sarıçakaya granitoid by Göncüoğlu et al. (1996). The unit has outcrops around Kapıkaya Yayla, Beyyayla, Örencik Yayla at north of Sarıçakaya county (Figure 2). Sarıçakaya 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). Sarıçakaya granitoid was locally arenitized and cut by aplite and pegmatitic veins and is observed in complex relationships with schists and amphibolites (Şentürk and Karaköse, 1979, 1981).

Sarıçakaya granitoid cuts Söğüt metamorphics and is overlain by the Kapıkaya formation with an initial contact relationship. Due to this relationship, the age of the Sarıçakaya granitoid should belong to a time earlier than Campanian based on its stratigraphical position, like the age of Söğüt metamorphics. The age of the Sarıçakaya 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).
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 (1973a).

The Liassic deposits in the Central Sakarya Region were first named as “Bayırköy sandstone” by Granit and Tintant (1960), but, Altınlı (1973a) named the same rocks as “Bayırköy formation” since the presence of other lithologies rather than sandstone. Altınlı (1973a) 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–
Söğüt and the Kapıkaya nomenclature were not interested much after Altınlı (1973a). 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 (1973a). 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 (1973a) 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 Sarıçakaya county, around the intrusion of the Sarıçakaya granitoid, Kayadibi Yayla, Kapıkaya Yayla, around Beyyayla – Söğükçam and between Nebiölgülü and Kapıkaya villages (Figure 2). The exposures of the Kapıkaya formation are not continuous as it is in Bilecik and/or Söğükçam formations. It is also noticed in other previous studies that the limestones of Bilecik / Söğükçam formation directly overlie the metamorphic – granitic basement in many places, as also seen in the geological map of the study area (Figure 2) (Altınlı, 1973a, Saner, 1977).

This study was carried out in exposures mapped as the Kapıkaya formation by Altınlı (1973a) (Figure 3).
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 fulfilled 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 locally 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
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 pitches out laterally before it reaches the Karaorman Ridge (Figure 12).
### Lithological Explanations

<table>
<thead>
<tr>
<th>Era/Thm</th>
<th>System</th>
<th>Series</th>
<th>Stage</th>
<th>Formation</th>
<th>Thickness (m)</th>
<th>Lithology</th>
<th>Lithological Explanations</th>
<th>Fossils</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mesozoic</strong></td>
<td><strong>Jurassic</strong></td>
<td>Upper</td>
<td>Upper</td>
<td>Soğukçam</td>
<td>Callovian</td>
<td>01 FU-12</td>
<td>TECTONIC</td>
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<td>Globaligerina cf. Oxfordiana (Grgelis), Conuspira sp., Palaomiliolina strumosum (Günbel), Lagunidae, Echinidea, lamellibranch shell sections (Callovian-Oxfordian)</td>
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<td><strong>Kimmeridgian</strong></td>
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<td><strong>Upper Cretaceous</strong></td>
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<td><strong>Kimmeridgian-Callovian</strong></td>
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<td><strong>Oxfordian</strong></td>
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<td><strong>Oxfordian</strong></td>
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**Figure 6-** The columnar section of the Karaorman Ridge (CD).
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
<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>SERIES</th>
<th>STAGE</th>
<th>FORMATION</th>
<th>THICKNESS (m)</th>
<th>LITHOLOGY</th>
<th>LITHOLOGICAL EXPLANATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERATHEM</td>
<td>[ MESOZOIC ]</td>
<td>JURASSIC</td>
<td>KIMMERIDGIAN</td>
<td>BILECIK</td>
<td>[ TECTONIC ]</td>
<td>Greenish gray to gray colored, thin, thin to medium bedded siltstone, claystone and less sandstone alternation</td>
</tr>
</tbody>
</table>

| | | | | | | Nodular, clayey limestone blocks with ammonite in red colored, pebbly, abraded fossiliferous mudstone |
| | | | | | | Beige colored, thick to very thick bedded, massive, arkosic sandstone |
| | | | | | | Red colored, medium to thick bedded, clayey sandstone |
| | | | | | | Greenish gray to gray colored, thin to thin-medium bedded siltstone and less sandstone alternation |
| | | | | | | TECTONIC |
| | | | | | | Granitoid |
| | | | | | | Gneiss, schist, amphibolite |

Figure 8- The columnar section of the Örencik Yayla (EF).
Figure 9 - The generalized stratigraphical section of the study area

<table>
<thead>
<tr>
<th>Lithostratigraphic Unit</th>
<th>Lithological Explanations</th>
</tr>
</thead>
<tbody>
<tr>
<td>01 FU-11</td>
<td>Medium, medium to thin, well bedded micritic limestone with nodular chert</td>
</tr>
<tr>
<td>01 FU-12</td>
<td>Nodular, clays, limestone blocks with ammonites in red, black colored, much fragmented ammonites, and bryozoans, partially cemented peloidal limestones, intraclasts (debris-flow deposits)</td>
</tr>
<tr>
<td>01 FU-07</td>
<td>Muddy limestones of Liasian age, it is underlies liassic limestone considered by (Warner, 1978; Abdülminenoglu, 1959).</td>
</tr>
<tr>
<td>01 FU-24</td>
<td>White - cream-colored, thick bedded, massive, with convoluted structure subarkose - artitic sandstone</td>
</tr>
<tr>
<td>01 FU-21</td>
<td>Beige colored, thick bedded limestone block</td>
</tr>
<tr>
<td>07 FU-264</td>
<td>Greenish gray colored, thin to medium bedded sandstone, siltstone, claystone</td>
</tr>
<tr>
<td>07 FU-269</td>
<td>Metamorphic rock block</td>
</tr>
<tr>
<td>01 FU-03</td>
<td>Pale gray, beige colored, medium bedded sandy limestone</td>
</tr>
<tr>
<td>01 FU-04</td>
<td>Thin bedded claystone</td>
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<td>01 FU-05</td>
<td>Pale gray, beige colored, medium bedded sandstone</td>
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<td>01 FU-06</td>
<td>Beige colored, medium bedded sandstone</td>
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<tr>
<td>01 FU-17</td>
<td>Beige colored, thick bedded sandstone</td>
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<tr>
<td>01 FU-18</td>
<td>Lenticular limestone which Altınlı (1973 a) and Alkaya (1980) according to ammonite fossils.</td>
</tr>
<tr>
<td>01 FU-22</td>
<td>Dirty yellow to beige colored, thick bedded limestone blocks</td>
</tr>
<tr>
<td>01 FU-23</td>
<td>Dirty yellow, medium bedded sandy limestone</td>
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<tr>
<td>01 FU-24</td>
<td>Dirty yellow, medium bedded sandy limestone</td>
</tr>
</tbody>
</table>

97 FU-264: Quadrum sissinghii Perch-Nielsen, Watznaueria barnesae Black, Ellipsagelosphaera fossicincta (late Campanian).
01 FU-11: Protopencopites striatus Weysenchenk, Pseudozymula sp., Labyrinthina Mirabilis Weysenchenk, Sigmoilina sp., Caynaxia sp., Echinidea, Lagenidae, Opalthamium sp., bryoza, alg, lamellibranch shell sections (Kimmeridgian).
01 FU-12: Globalinera cf. Oxfordiana (Ergelis), Conaxipora sp., Palaeomiliolina straunum (Gümbel), Lagenidae, Echinidea and lamellibranch mold sections (Callovian-Oxfordian).
01 FU-21: Involucinatia liassica (JONES), Lingulina sp., Ageria martana (FARINACC), Trocholina turris Frentzen, Trocholina umbo (JONES), Trocholina Involutina liassica Lingulina Agerina martana.
97 FU-264: Quadrum sissinghii Perch-Nielsen, Watznaueria barnesae Black, Ellipsagelosphaera fossicincta (late Campanian).
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 continuously repeated towards the upper layers of arkosic sandstone layer without facing c, d, e levels.
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
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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.
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cover begins with Kimmeridgian in Kayadibi Yayla and Oxfordian in the Karaorman Ridge and becomes younger even up to Early Cretaceous in upper levels (Altunlı, 1973b; Saner 1977, 1980; Görceoğlu et al., 1996; Şentürk and Karakoş, 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 Sarıçakaya county and Kapıkaya village are dated as early Pliensbachian by Altunlı, (1973a) and as Late Hettangian – 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, Watznaueria 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 barnesae Black, Ellipsagelosphaera fossicincta 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). Altunlı (1973a) 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; Ellipsagelosphaera 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
(Figures 6 and 7; sample 01 FU-05) molds of Cenonian (Campanian – 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 (Hettangian – 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

(Figures 6 and 7; sample 01 FU-05) molds of Cenonian (Campanian – 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).

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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
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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 underly 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 (1973a) 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 (1973a) 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 tectonic 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 flyschoiadal 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 Sarıçakaya 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 Sarıçakaya 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, *Bolvinopsis* 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 (1973b) dated the unit as Late Jurassic – Barremian (Altınlı, 1974), Late Jurassic – Early Cretaceous (Saner, 1980), Portlandian – Berriasian (Göncüoğlu et al., 1996). Altınler 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 Sarıçakaya 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 “Göçekkaya 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 thrust 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 (1973a) 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 eastern and western 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 (1973a) 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 (1973a) has suggested, this importance becomes apparent when transitioned into a different unit in the eastern 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 (1973a) 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 (1973a). 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 (1973a) into the Bayırköy formation (Saner, 1977, 1978; Şentürk and Karaköse, 1981, 1982; Göncüoğlu et al., 1996; Gedik and Aksay, 2002). Altınlı (1973a) 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;
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.

Altını (1973a) 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 overthrust 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.

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References


Deli, A., Orhan, H. 2007. Geological importance of paleokarsts and neptunian dykes in the Lower Jurassic rocks at the Beytepe village- Çayyolu area (South west Ankara, Turkey), 17. Annual...


Kaya, O. 1991. Stratigraphy of the Pre-Jurassic sedimentary rocks of the western parts of Turkey; type area study and tectonic considerations. *Newslette for Stratigraphy* 23, 123-140.

Kaya, O., Wiedmann, J., Kozur, H. 1986. Preliminary report on the stratigraphy, age and structure of the so-called Late Paleozoic and/or Triassic “melange or “suture zone complex” of Northwestern and western Turkey. *Yerbilimleri* 13, 1-16.


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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.**

**ABSTRACT**

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*, and *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 taxa have previously been reported from the various localities of Turkey (Figure 1) by Sirel (1981, 1988, 1992, 1994, 1996a, c, d, 1997a, b, 1998a,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) rafkae* 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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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 Darmoian (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) is 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)


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

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

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


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 elements 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 bidistica* Sirel, *Dictyoconus baskilensis* Sirel, *Sistaniites* 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).

*Bolkarina*idae n.fam.

Superfamily: Orbitoidacea Schwager, 1876

Family: Bolkarinae 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 characteristically 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.

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 superfamilly Orbitoidacea 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 stoloniferous 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.
Bolkarina aksarayensis Sirel, 1981

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


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


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 Kocaagildere, approximately 2 km SW of Karandere village, NW of Akaray, 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 Kirikkale, 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 Yarışı area, NW of Burdur, Southern Turkey (Figure 1), with G. sphaeroidea, Sistanites iranica Rahaghi, I. sinjarica, A. primitiva, undetermined micellaniid genus and Miliolidae.

It occurs in the light brown-coloured Selandian limestone of Strakayalar gediği, approximately 25 km N of Bolkar mountains (Sirel, 1998b, 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,1998b, 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 Harabekeyiş section, W Elazığ (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 (1998b, 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. 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.

*Cibloflarina* 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 alveolos 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 (1998b), Fleury (1982) and Rahaghi (1983).
**Globoflarina sphaeroidea** (Fleury, 1982)

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


1983 *Globoflarina sphaeroidea* (Fleury), Rahaghi, page 43, plate 15, figures 1-8, plate 16, figures 1-12, plate 17, figures 1-11.

1998b *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 Yarıslı 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**

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 Drohne, 1980

Ataxophragmiidae : Ehrenberg, 1839

Family: Coskinolinidae Moullade, 1965

Genus: *Coskinon* Hottinger and Drohne, 1980

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

Redescription: It is largely based on Hottinger and Drohne (1980) and partly here described species in (Plate V, figures 1-5). Two generations have large and high conical test with kerothecal wall. The subspheric proloculus is followed by more than five rows of biserial (like-textularine) early chambers, later adult chambers become uniserial (Hottinger and Drohne, 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 Drohne (1980, plate 12, figures 1, 18-21). The basal foramina are scattered in central part of the cone (Hottinger and Drohne, 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) (Hottinger 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 Harabekayiş 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* Caudrill, 1944  
Type species: *Ranikothalia nuttalli* Davies, 1927

*Ranikothalia polatlensis* n.sp.

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

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

Derivation of name: Polatl 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 Polatl, 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 abundantly in the sandy limestone without foraminiferal species, so that its age could not be safely fixed. However the sandy limestone with new species comformably overlies 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)


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 macroospheric 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, porcellaneous 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)


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 foraminifer 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 Bolkariniidae (type genus *Bolkarina*) within the superfamilly Orbitoidaceae Schwager by the presence of the chamberlets with annular and radial stolons and lateral chambers. Furthermore, subfamily Globofarinae Sirel 1998b was re-described by the new generic features. Known four Paleocene genera, namely, *Bolkarina* Sirel (type species *B. aksarayensis*), *Globofarina* (type species C.? *sphaeroidea*), *Coskinon* Hottinger and Drobn (type species C. (Coskinon) *rajcae*), and *Nurdanella* Özgen (type species *N. boluensis*) which have previously been described inadequately by the foregoing authors, so that they are here re-described by the new generic data. Furthermore, previously determined three foraminifer species of Paleocene in Sirel (1998b) which were renamed as follows: the nummulitid 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 foraminifer species and other Paleocene species have previously been given in (Sirel, 2012, Figures 11,12) respectively.

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**References**


Sirel, E. 1981. *Bolkarina*, new foraminifer genus (Foraminiferida) and some associated species from the Thanetian limestone (central Turkey). *Eclogae geologicae Helvetiae*, 74, 1, 75-95.

New Benthic Foraminifers in Turkey Paleocene


Sirel, E. 1998a. Revision of the species of Pseudolacazina Caus 1979 (Foraminiferida) from the different localities of Turkey. Bulletin of the Mineral Research and Exploration, 120, 63-68.


Sirel, E. 1999. Four new genera (Haymanella, Kayseriella, Elazigella and Orduella) and one new species of Hottingerina from the Paleocene of Turkey. Micropaleontology, 45 (2), 113-137.


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 88-174).

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 – 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 chambers, 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 - 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.
New Benthic Foraminifera in Turkey Paleocene

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 – V

*Coskinon rajkae* HOTTINGER and DROBNE

(Early Thanetian, all figures from the Harabekayiş section (Sirel, 2009, Figure 10) Elazığ area, Eastern Turkey, 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 - VI**

*Ranikothalia polatiensis* n.sp.

(Late Thanetian?-early Ierbian, all figures from the Kuşçu village, S of Polatlî, 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 – 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)
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THE OSTRACOD FAUNA AND ENVIRONMENTAL CHARACTERISTICS OF THE VOLCANO SEDIMENTARY YOL ÜSTÜ FORMATION IN THE HİNİS REGION, ERZURUM (EASTERN ANATOLIA), TURKEY

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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 ostracod such as; Leptocythere (Amnicythere) cf. littiva Livental, Tyrrhenocythere bailovi (Suzin), Loxoconcha granulata Sars, L. cf. diligera Kulieva, L. agilis Ruggieri, Candona (Caspiocypris) araxica Freels, Candona (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), Candona (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 environments; 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.

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

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), Grevrek 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
stratigraphical and sedimentological 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 Yilmaz (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 crossed cut 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 Yoluestos Village located in the Hınıs Basin.

Type Section: The section 2 which was taken in the Yoluestos 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 Yoluestos 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 1/25000 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, Yoluestos 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 Yoluestos 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 a result 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 assemblage of ostracod fauna with calcified micro molluscs were determined from the washed samples collected from the plant fragments bearing hard travertine limestones and soft clayey limestone layers of 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 (Erdogan, 1966; Yılmaz et al., 1986), Pliocene Bulanık formation (Soytürk, 1973), Pliocene İskınlar 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, Z: 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 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 limestone at 15.6 m; sample 4 from travertine 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 (Casiocypris) 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. itiva 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 scale J47 sheet.
<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>SERIES</th>
<th>FORMATION</th>
<th>MEMBER</th>
<th>THICKNESS (m)</th>
<th>SAMPLE NO</th>
<th>LITHOLOGY</th>
<th>OSTRACODS/GASTROPODS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tertiary</td>
<td>Pliocene</td>
<td>Yolüstü</td>
<td>90</td>
<td></td>
<td></td>
<td>Tuffaceous clayey limestone</td>
<td>+ + +</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Harami</td>
<td>10</td>
<td></td>
<td></td>
<td>Mudstone</td>
<td>Lepidocythere (Amniclythere) cf. liventa</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>9</td>
<td></td>
<td></td>
<td>Sandstone</td>
<td>Loxoconcha agilis Ruggeri</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8</td>
<td></td>
<td></td>
<td>Agglomerate</td>
<td>Loxoconcha granulata Sars</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>7</td>
<td></td>
<td></td>
<td>Tuffaceous marl</td>
<td>Canadona (Caspioecypsis) erinasornis Frecks</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td></td>
<td></td>
<td>Silicified tuff</td>
<td>Canadona (Canadona) arctica Frecks</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td></td>
<td></td>
<td>Marl</td>
<td>Canadona (Phyllocycris) umbiliconica Frecks</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td></td>
<td></td>
<td>Travertine limestone</td>
<td>Canadona (Canadona) paralela pannonica (Zalayi)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td>Limestone with plants</td>
<td>Wiriparch sp.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td>Coal</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td>Marl</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sandstone</td>
<td></td>
</tr>
</tbody>
</table>

Figure 3- Ostracode and gastropode distribution in Hınıs 1 measured section
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 ostracod 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 33rd 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 (Caspioocypris) erzurumensis Freels, C. (Caspioocypris) araxica Freels, C. (Typhlocypris) amblygonica Freels in sample 2; Loxoconcha granulata Sars, L. cf. diligena Kulieva, Candona (Caspioocypris) erzurumensis Freels, C. (Caspioocypris) 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 (Caspioocypris) araxica Freels, C (Typhlocypris) amblygonica Freels, C. (Caspioocypris) 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.

<table>
<thead>
<tr>
<th>OSTRACODE GENERA</th>
<th>SALINITY*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FRESH WATER % 0,3-3</td>
</tr>
<tr>
<td>Leptocythere</td>
<td></td>
</tr>
<tr>
<td>Tyrrhenocythere</td>
<td></td>
</tr>
<tr>
<td>Loxoconcha</td>
<td></td>
</tr>
<tr>
<td>Candona (Typhlocypris)</td>
<td></td>
</tr>
<tr>
<td>Candona(Caspiocypris)</td>
<td></td>
</tr>
<tr>
<td>Candona(Candona)</td>
<td></td>
</tr>
</tbody>
</table>

*Remane standards given in Gökçen (1979) were used for the salinity.
and the accompanying mollusc genera identified in the study.

The genera and subgenera of the ostracoda, such as, *Candona (Casiocypris), 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 subgenera of *Candona (Casiocypris)*, 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.
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: Cythera 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.


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 conditions with 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 Measured 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, page 102, plate 65, figures 9-14.
1985 Loxoconcha agilis Ruggieri, Stambolidis, page 218, plate 6, figures 3-5.
2002 Loxoconcha agilis Ruggieri, Tunoğlu, page 40, plate 1, figures 6-7.

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.
Stratigraphical and Geographical Distribution:
Azerbaijan – 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
1999 Loxoconcha granulata, Şafak, page 162, plate VI, figure 1.
2004 Loxoconcha granulata, Opreanu, pages 9-10.
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,
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. 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., Sariz (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.

Candona (Caspiocypris) aff. alta (Zalanyi),

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

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


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.


1997b 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, Kubaç 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, Şafak et al., pages 262-266.

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

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

1999 Candona (Candona) parallela pannonica Zalanyi, Şafak et al., page 184, plate IV, figure 7.
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 143, plate 3, figures 1-5.

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., page 4, figure 4.

2010  
**Candona (Candona) parallela pannonica**

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

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

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Stratigraphical and geographical distribution:
Pannoninan Basin, Hungary, Late Pannonian (Zalanyi, 1959); Trebon basin, Czechoslovakia, Tortonian (Kheil, 1963); Denizi – Muğla / Turkey, Pontian (Gökçen, 1979); Uluksla, 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 Hisari / İstanbul - Holocene (Nazi and Taner, 1999); Akyatan Lagoon / SE Adana Turkey - Holocene (Nazi et al., 1999); Black Sea Region / Turkey, Pontian (Tunoğlu, 2001); Gelibolu Pinnsula / NW Turkey, Mid – Late Pannonian - Pontian (Tunoğlu and Ünal, 2001); Eceabat / Canakkale (NW Turkey), Pannonian (Atay and Tunoğlu, 2002); Kilitbahir / Canakkale – Upper Miocene (Atay and Tunoğlu, 2004); Argüvan / Malatya (Eastern Anatolia), Upper Miocene (Nazik et al., 2008); Adıyaman / Southeastern Anatolia, Messinian (Şafak et al., 2009); Iznik and Sapanca lakes / Turkey, Quaternary (Nazik et al., 2010); Denizli / SW Anatolia – Late Miocene (Şafak, 2010).

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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).

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

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**Candona (Candona) candida Müller, 1776**

(Plate II, Figure 9)

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1776  
*Candona candida* Müller

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

1973  
*Candona (Candona) 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. candida* Müller,
Tunoğlu, pages 118-119, plate 9, figures 1-3.


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, Atay and Tunoğlu, page 143, 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.


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

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

Stratigraphical and geographical distribution: Liri Valley / Italy, Pleistocene (Devoto, 1965); Jugoslavia, Pontian (Sokac, 1978); Aydn / 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 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 identified 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. alata (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, 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. alata (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. 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. alata (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. alata (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 (Casiocypris) erzurumensis Freels, C. (Casiocypris) 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 (Nazi et al., 1992; Şafak et al., 1999; Tunoğlu et al., 1995; Ünal, 1996; Şafak and Meriç, 1997; Şafak, 1997; Şafak and Taner, 1998; Kubaç et al., 1999; Nazi et al., 1999a; Nazi et al., 1999b; Tunoğlu, 2001; Tunoğlu and Ünal, 2001; Atay and Tunoğlu, 2002; Atay and Tunoğlu, 2004; Nazi et al., 2008; Şafak et al, 2009; Nazi et al., 2010; Şafak, 2010).

L. agilis Ruggieri species was defined in the numerous 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; Kubaç, 1995; Tunoğlu, 2002; Şafak, 2008). Furthermore, the mollusc fauna defined within this unit were considered 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 (Gökcibaşa – Bozcaada – Çanakkale, Black Sea Coast, and in the Gulf of Mersin) and the NW Black Sea of Romania (Mandestam, 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 a 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 (Casiocypris) araxica Freels, C. (Casiocypris) erzurumensis Freels, C. (Casiocypris) 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, 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 Shornikov (2011) but its occurrence 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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fauna from the continental shelf of the black sea in the Crimea and Sinop Areas, Geo-Ecwo-Marina, 9-10, Romania.


Rathur, A.Q. 1965. Pasinler-Horasan (Erzurum) sahasına ait genel jeolojik raport (H47c1-C2; H48-c4,d3,d4; I47-b1, d2, b3, b4; 148-a1, a2, b1) Maden Tektik ve Arama Genel Müdürlüğü Rapor No. 4168, Ankara (unpublished).


Şafak, Ü. 1997b. Bakırköy Havzası (İstanbul) Tersiyer Çökmelerinin Ostrakod Faunası ve Ortamsal Yorumu, Yerbilimleri, Sayı 30, s. 255-285, Adana.


Şafak, Ü. 2008. Recent Ostracoda Fauna of the Mersin Gulf; Southern Turkey, and their Correlation with Other Gulf and Shelf Environments in the mediterranean and Aegean Regions, Yerbilimleri (Geosound), sayı 52, 1-21.

Şafak, Ü. 2010. Güney-Buldan-Yenicekent-Babadağ-Kale (Denizli, GB Anadolu) Çevresi Tersiyer


Ostracoda Faunas in Hınıs Yolüstü Formation

PLATES
PLATE I

Figure 1- *Leptocythere (Amnicythere) cf. littica* 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
Ostracoda Faunas in Hınıs Yolüşü Formation

PLATE II

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

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

1. Right valve, external view
2. Left valve, external view

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

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

3. Right valve, external view

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

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

6. Right valve, external view

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

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

7. Left valve, external view

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

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

9. Right valve, external view

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

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

10. Right valve, external view
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ABSTRACT

The Early Miocene Oyaca, Kedikayasi and Boyalik 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 SiO2 (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.

Key words: Adakite, Ankara, partial melting, petrogenetic modeling, metasomatism

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., 2011a); 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;
Hou et al., 2004; Rollinson and Tarney, 2005; Wang et al., 2005; Wang et al., 2007a, b; Liu et al., 2008; Karsli et al., 2010; Eyüboğlu et al., 2012b) and the products generated by a slab window processes in a subduction-related setting (Eyüboğlu et al., 2011b, c; Eyüboğlu et al., 2012a, 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 (Sengör and Yılmaz, 1981). The IAESZ 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 mélangé 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 (Ünalalan and Yiğül, 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 SiO2 (% 62-70 wt.), Al2O3 (>% 15.50 wt.), Na2O (>% 4.0 wt.), Sr (648-1026 ppm), Ba (648-1810 ppm), low TiO2 (>% 0.90 wt.), K2O (% 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).
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).

In the MgO-SiO₂ 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

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**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).

<table>
<thead>
<tr>
<th></th>
<th>OYACA</th>
<th>KEDIKAYASI</th>
<th>BOYALIK</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂ (wt.%)</td>
<td>66.12</td>
<td>64.54</td>
<td>62.34</td>
</tr>
<tr>
<td>MgO</td>
<td>1.13</td>
<td>1.85</td>
<td>1.74</td>
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<tr>
<td>CaO</td>
<td>4.11</td>
<td>5.18</td>
<td>5.73</td>
</tr>
<tr>
<td>MnO</td>
<td>0.06</td>
<td>0.06</td>
<td>0.09</td>
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<tr>
<td>TiO₂</td>
<td>0.49</td>
<td>0.47</td>
<td>0.59</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>4.09</td>
<td>4.37</td>
<td>4.2</td>
</tr>
<tr>
<td>K₂O</td>
<td>1.61</td>
<td>1.51</td>
<td>1.52</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>97.63</td>
<td>96.21</td>
<td>98.8</td>
</tr>
<tr>
<td>Total</td>
<td>97.63</td>
<td>96.21</td>
<td>98.8</td>
</tr>
</tbody>
</table>

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

**Figure 3** - (La/Yb)n-(Yb)n discrimination diagram of studied adakites (Defant and Drummond, 1990). Values normalized to chondrite (Thompson, 1982).
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 Al₂O₃ (≥%15), Na₂O (3.52-5.12), La/Yb, and low HFS (Nb, Ta) elements, and low Yb contents along with their high SiO₂ content (Richards and Kerrich, 2007; Eyüpoğlu et al., 2011a, b, c; Eyüboğlu, 2012a, b). High Sr, low Y and Yb 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 spheine, 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). Furthermore, high Ba/Nb (45-172) and Nb/La (<0.41) ratios in Oyaca, Kedikayası and Boyalık adakites...
Petrogenetic Properties of Ankara (SW) 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, Kedikayasi and Boyalik 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, Ba/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, Kedikayasi and Boyalik 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.

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, Kedikayasi and Boyalik adakites, slab or sediment melting is likely during in their genesis (Figure 8).

Low Rb/Sr (0.02-0.09) ratios and low % K2O (1.5 - 2.2) and high Mg # (31-57) values in Oyaca, Kedikayasi and Boyalik 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$_2$O 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: MKSC, (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.

<table>
<thead>
<tr>
<th>Source Mode (Xi)</th>
<th>Melt Mode (Pi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Olivine</td>
<td>0.77 0.05</td>
</tr>
<tr>
<td>Orthopyroxene</td>
<td>0.05 0.05</td>
</tr>
<tr>
<td>Clinopyroxene</td>
<td>0.01 0.30</td>
</tr>
<tr>
<td>Amphibole</td>
<td>0.13 0.20</td>
</tr>
<tr>
<td>Garnet</td>
<td>0.04 0.40</td>
</tr>
<tr>
<td>Bulk Partition Coefficient (D0)</td>
<td>Melt Mode (P0)</td>
</tr>
<tr>
<td>La</td>
<td>0.0110 0.0863</td>
</tr>
<tr>
<td>Ce</td>
<td>0.0193 0.1377</td>
</tr>
<tr>
<td>Tb</td>
<td>0.0973 0.5756</td>
</tr>
<tr>
<td>Yb</td>
<td>0.2760 1.1875</td>
</tr>
<tr>
<td>Starting Composition</td>
<td>Initial Concentration (C0)</td>
</tr>
<tr>
<td>La</td>
<td>2,800</td>
</tr>
<tr>
<td>Ce</td>
<td>5,250</td>
</tr>
<tr>
<td>Tb</td>
<td>0.056</td>
</tr>
<tr>
<td>Yb</td>
<td>0.230</td>
</tr>
</tbody>
</table>

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, Kedikayasi and Boyalik 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.
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.

Acknowledgments

We would like to thank to Prof. Erdin Bozkurt and Prof. Erkan Aydar for their supports during the reassessment of samples and to Prof. Güner Ünalan and Dr. Bahadır Şahin for their supportive criticisms and contributions. We are greatly indebted to Dr. Yavuz Hakyemez for his helps during the preparation of the geological map.

References


Eyüboğlu, Y., Santosh, M., Chung, S.L. 2011a. Crystal
fractionation of adakitic magmas in the crust-
mantle transition zone: Petrology, geochemistry
and U-Pb zircon chronology of the Seme adakites,
Eastern Pontides, NE Turkey. *Lithos*, 121, 151-166.
Eyüboğlu, Y., Chung, S.L., Santosh, M., Dudas, F.O.,
Akaryalı, E. 2011b. Transition from shoshonitic
to adakitic magmatism in the Eastern Pontides,
NE Turkey: Implications for slab window melting.
*Gondwana Research*, 19, 413-429.
Eyüboğlu, Y., Santosh, M., Chung, S.L. 2011c.
Petrochemistry and U-Pb zircon ages of adakitic
intrusions from the Pulur Massif (Eastern Pontides,
NE Turkey): implications for slab roll-back
and ridge subduction associated with Cenozoic
convergent tectonics in Eastern Mediterranean.
Eyüboğlu, Y., Santosh, M., Yi, K., Bektas, O., Kwon, S.
2012a. The nature of transition from adakitic to non-adakitic
magmatism in a slab-window setting: A synthesis
from the Eastern Pontides, NE Turkey. *Geoscience
Eyüboğlu, Y, Santosh, M., Yi, K., Bektas, O., Kwon, S.
2012b. Discovery of Miocene adakitic dacite from
the Eastern Pontides Belt and revised geodynamic
model for the late Cenozoic Evolution of eastern
associated with Late Cenozoic extension in the
Western United States: compositional variations in
space and time. *Journal of Geophysical Research*,
96, No: B8, 13693-13711.
Foley, S.F., Barth, M.G., Jenner, G.A. 2000. Rutile/melt
partition coefficients for trace elements and an
assessment of the influence of rutile on the
trace element characteristics of subduction zone
magmas. *Geochimica et Cosmochimica Acta* 64,
933–938.
Furman, T., Graham D. 1999. Erosion of lithospheric mantle
beneath the East African Rift system: evidence
*Springer - Verlag*, New York.
Palaetectonic evolution of the Tuzgölü basin
complex, central Turkey: sedimentary record of a
Eastern Mediterranean. *Geological Society
(London)*, Special Publications 17. 467-482.
Origin of adakitic intrusives generated during mid-
Miocene east-west extension in southern Tibet.
amphiboles and micas: implications for subduction-
related metasomatic trace element fractionations.
*Earth and Planetary Science Letter* 131 (3-4), 341-
356.
Jiang, Y.-H., Liu, Z. Jia, R.-Y. Liao, S.-Y. Zhou, Q., Zhao, P.
2012. Miocene potassic granite–syenite association
in western Tibetan Plateau: Implications for
shoshonitic and high Ba–Sr granite genesis. *Lithos*
134-135, 146-162.
and isotope (Sr, Nd, O) geochemistry of Cenozoic
alkaline rift-type volcanic rocks from the Rhôn
area (central Germany): petrology, mantle source
characteristics and implications for asthenosphere-
lithosphere interactions. *Journal of Volcanology
Karsli, O., Dokuz, A., Uysal, I., Aydin, F., Kendemir,
Cenozoic adakitic volcanism by partial melting of
mafic lower crust, Eastern Turkey: Implications
for crustal thickening to delamination. *Lithos* 114,
109-120.
Kaymakçı, N. 2000. Tectonostratigraphical evolution of the
Çankırı Basin (Central Anatolia, Turkey).
*Geological Survey Division, ITC-Enschede*,The
Koçyiğit A. 1991. An example of an accretionary fore-
arc basin from northern central Anatolia and its
implications for the history of subduction
of Neotethys in Turkey. *Geological Society
of America Bulletin* 103, 22-36.
Koçyiğit A., Türkmenoğlu, A., Beyhan, A., Kaymakçı,
N., Akyol, E. 1995. Post collisional tectonics of
Eskişehir-Ankara-Çankırı segments of the İzmir-
Ankara-Erzincan suture zone (IAESZ): Ankara
orogenic phase. *Turkish Association of Petroleum
Geologists Bulletin* 6, 69-86.
Koçyiğit A., Winchester, A.J., Bozkurt, E., Holland, G.
2003. Sar Koçyiğit volcano volcanic suite: implications for the
subductional phase of arc evolution in the Galatean
Arc Complex, Ankara, Turkey. *Geological Journal*
38, 1–14.
Liu, S., Hu, R-Z., Feng, C-X., Zhou, H-B., Li, C., Chi, X-G.,
Peng, J-T., Zhong, H., Qi, L., Qi, Y-Q., Wang, T.
2008. Cenozoic high Sr/Y volcanic rocks in the
Qiangtang terrane, northern Tibet: geochemical
and isotopic evidence for the origin of delaminated
lower continental melts. *Geological Magazine* 145,
463-474.
Macpherson, C.G., Dreher S.T., Thirwall M.F. 2006.
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HYDROGEOCHEMICAL AND ISOTOPIC INVESTIGATION OF NASRETTIN HOCA SPRINGS, ESKİŞEHİR, TURKEY

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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-HCO3 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.

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

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 occurrence 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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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 quartize veins inside Kertek unit are slightly 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 important 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 occurrences 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.

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 particles. 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 HNO3. Concentrations of F-, NO3-, PO43-, and HCO3- 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 (δ18O 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 uncertainties of the individual measurements are estimated to be within ±0.3 ‰ for δ18O 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.
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 HCO₃ i.e. the samples are of Ca-Mg-HCO₃ 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 anthropogenic 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).

<table>
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<tr>
<th>Sample ID</th>
<th>T (°C)</th>
<th>pH</th>
<th>EC (µS/cm)</th>
<th>Na⁺</th>
<th>K⁺</th>
<th>Ca²⁺</th>
<th>Mg²⁺</th>
<th>Cl⁻</th>
<th>SO₄²⁻</th>
<th>HCO₃⁻</th>
<th>NO₃⁻</th>
<th>CBE (%)</th>
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4.2. Isotopic 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 ($\delta^{18}O$) and Deuterium ($dD$)

The $\delta D$ 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 $\delta D = 8 \times \delta^{18}O + 10$ (% SMOW), defines the relationship between $\delta^{18}O$ and $\delta D$ 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 $\delta D$ 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 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.

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<th>Sr</th>
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<td>N</td>
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<td>0.409</td>
</tr>
<tr>
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</tr>
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Figure 6- Schloeller diagram of the springs
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 $\delta^2H$ values of precipitation and the weighted average annual $\delta^{18}O$ and $\delta^2H$ 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 $\delta^2H$ values range between -63.55‰ and -76.06‰. Tritium (3H) 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 Fritz, 1997).

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<th>GP2</th>
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**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 metamorphics- Göktepe unit.
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 (δ¹⁸O)

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 δ¹⁸O, 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 δ¹⁸O with altitude. Unfortunately, for the study area, there is no data available regarding precipitation from different altitudes. The relationship of elevation and δ¹⁸O 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 δ¹⁸O per 100-m rise in altitude is 0.44‰ and for May 2000, the equation relating altitude to δ¹⁸O is defined as δ¹⁸O = -0.0044*(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.

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 km² basin area, discharges from Miocene Mercan formation along 10 different points. Gavur Spring is located close to the peak of recharge area,
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\textsuperscript{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 heterogeneous 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 do 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-HCO₃ 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 δ¹⁸O 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.

Acknowledgments

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References

Çelmen, O., Çelik M. 2009. Hydrogeochemistry and
environmental isotope study of the geothermal water around Beypazari granitoids, Ankara, Turkey. *Environmental Geology* 58, 8, 1689-1701.


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

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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 m2 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 m3 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.

Key words: Eskişehir, Stratigraphy, Coal, Seismic reflection

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 1991a, 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
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 lines were 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).
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 made on 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.,
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.

---

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<thead>
<tr>
<th>Lithology Explanations</th>
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<tr>
<td>Claystone, loose conglomerate, pale-dark brown</td>
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<tr>
<td>Alternation of limestone, sandstone, conglomerate with lateral transitions in patches</td>
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<tr>
<td>Green colored claystone - sandstone - conglomerate</td>
<td>30-40</td>
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<tr>
<td>Lignite (upper horizon) (thickness 0.55-10.00 m; average heating value 1900 kcal/kg)</td>
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<tr>
<td>Bituminous marl, siltstone, claystone, shale (dark green - green colored)</td>
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</tr>
<tr>
<td>Gray, fine- to medium-grained sandstone</td>
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<td>Loosely cemented conglomerate, sandstone, claystone</td>
<td>20-40</td>
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<tr>
<td>Basement rocks, green colored ophiolite</td>
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<td>Metamorphites</td>
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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. Thin layers 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

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

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<td>Receiver type in-line</td>
<td>50cm (6 pack 2 string)</td>
</tr>
<tr>
<td>Offset</td>
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</tbody>
</table>
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 of the 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 entrance when 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 correspond with 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 deepest place 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...
approximately estimated 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 encountered in wells of ES-44 and ES-45 located near the line.

5.2. ESV0904 Line

The probable deepest place 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 of the 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 304.85 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 358.8 meters.

Considering the average velocities at CDP points corresponding to R-12 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
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
cannot be 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.
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 for the 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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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.

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

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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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  - Conclusion
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• 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 outside the scope of the title. The whole title must be written with capital letters and 10-point bold 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.

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

• The abstract must be organized in the form of a 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.

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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.

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

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- This study was carried out under 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:

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- All illustrations must be sent in separate files independent from the text.

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- Figures must be arranged to be printed in black-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 the south-west, b) general columnar section of the study area (Seymen 1981), 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 shrink 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.

- Photos must have the quality and quantity that will reflect the objectives of the subject.

6.2. Plates

- Plates must be used when needed a combination of more than one photo and the publication on a special quality paper.

- Plate sizes must be equal to the size of available magazine pagespace.

- Figure numbers and linear scale must be written under each of the shapes located on the Plate.

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

- Figures and plates must be independently numbered. Figures must be numbered with Latin numerals and plates with Roman numerals (e.g., Figure 1, Plate I).
• There must be no description text on Figures.

6.3. Tables

• All tables must be prepared preferably in word format in Times New Roman fonts.

• Tables together with table top writing must not exceed 15x8 cm in 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. In cases where unusual nomenclatures and unstandardized abbreviations are considered to be compulsory, the followed way and method must be described.

• Full stop must not be placed between the initials of words 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 text are presented in parentheses, the parenthesis is not used for subsequent uses.

• The metric 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 stratigraphic cross-section of 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:

<table>
<thead>
<tr>
<th>Superfamily : Alveolina Ehrenberg, 1939</th>
</tr>
</thead>
<tbody>
<tr>
<td>Family: Borelidae Schmarda, 1871</td>
</tr>
<tr>
<td>Type genus: <em>Borelis</em> de Montfort, 1808</td>
</tr>
<tr>
<td>Type species: <em>Borelis melenoides</em> de Montfort, 1808; <em>Nautilus melo</em> Fitchel and Moll, 1789</td>
</tr>
<tr>
<td><strong>Borelis vonderschmittii</strong> (Schweighauser, 1951) (Plate, Figure, Figure in Body Text)</td>
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<tr>
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<tr>
<td><strong>1974 Borelis vonderschmittii</strong> (Schweighauser), Hottinger, page, 67, plate 98, figure 1.7</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Not reference, Not stated in the Reference section.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schweighauser, 1951 not reference.</td>
</tr>
<tr>
<td>Cited Schweighauser (1951), stated in the Reference section.</td>
</tr>
</tbody>
</table>
a. For the first use of the fossil names, the type, species 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 citation if stated as Alveolina aragoensis Hottinger (1966)

* • The statement of plates and figures (especially for articles of paleontology):
  a. for statement 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 citation in the text

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

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

8. Citations

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

The citations 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 Carboniferous aged units around Istanbul is NS oriented (Ketin, 1953, 1956; Altinli, 1999).

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

   • For publications written by two authors:


   • For publications written by three or more authors:

   - According to Caner et al. (1975) Ahcî 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 existence of Lias around Çakraz (Lebling, 1932: from Charles, 1933).

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