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

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

ABSTRACT

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

1. Introduction

1.1. The Aim of the Study

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

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

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

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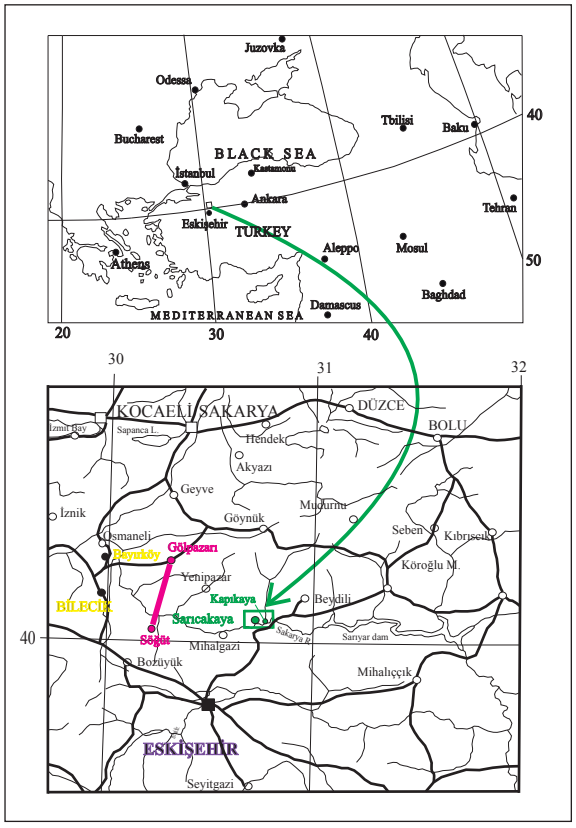


Figure 1- Location map of the study area

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

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

As seen that, there are contradicting data about the age, stratigraphic location, its contact relations with the overlying Upper Jurassic – Lower Cretaceous

sediments of the Kapıkaya formation (Altınlı, 1973*a*), according to previous studies. The studies investigating this contradicting data will make significant contributions to the interpretation of the regional geology. In this context, the meaning of a probable Gölpazarı – Söğüt line suggested by Altınlı (1973*a*) also the place and significance of such a boundary in the manner of regional geology will be investigated.

2. Stratigraphy

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

2.1. Söğüt Metamorphites

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

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

2.2. Sarıcakaya Granitoid

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

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

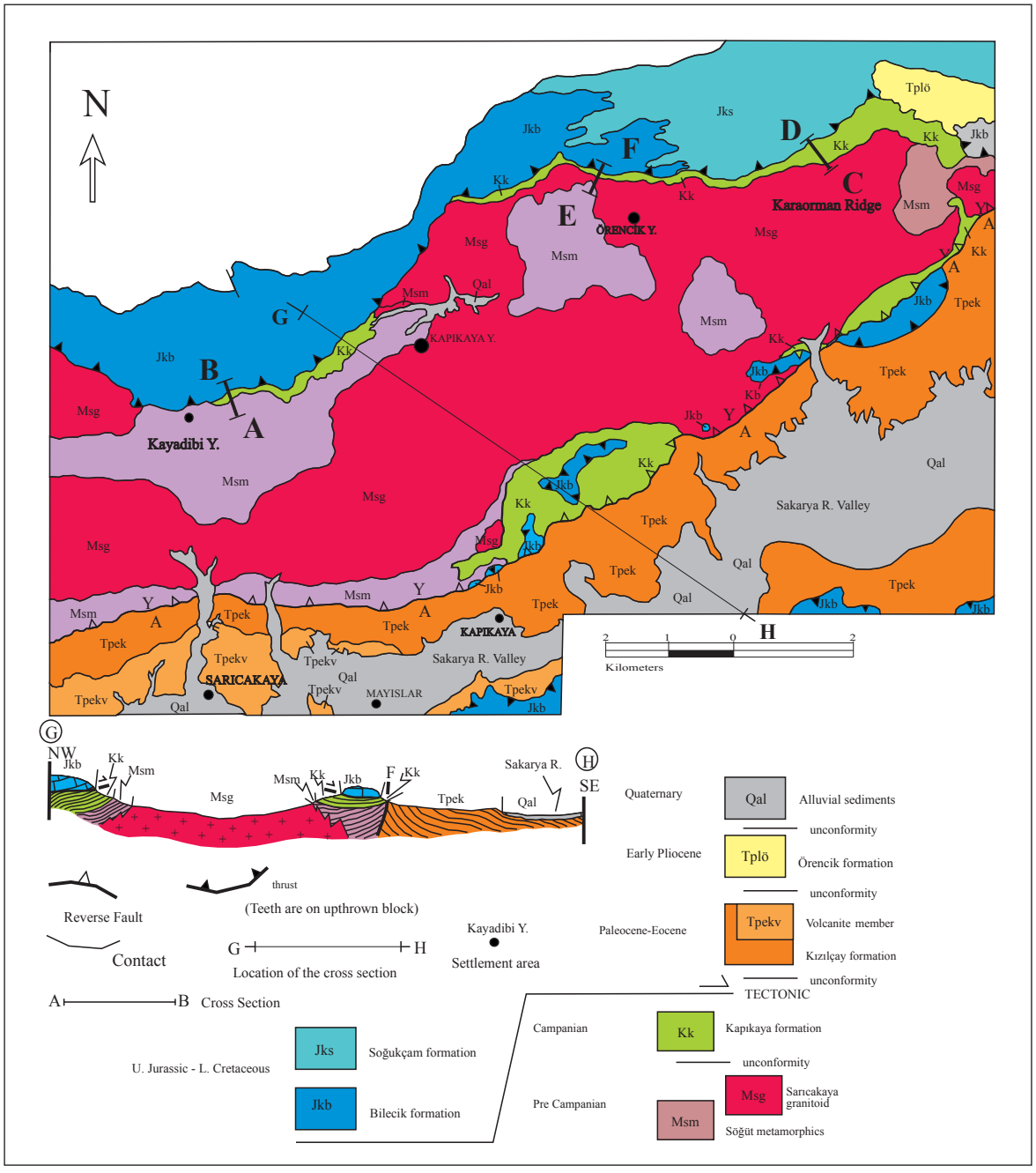


Figure 2- Geological map of the study area and geological cross section (from Göncüoğlu et al., 1996; Gedik and Aksay, 2002)

2.3. Kapıkaya Formation

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

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

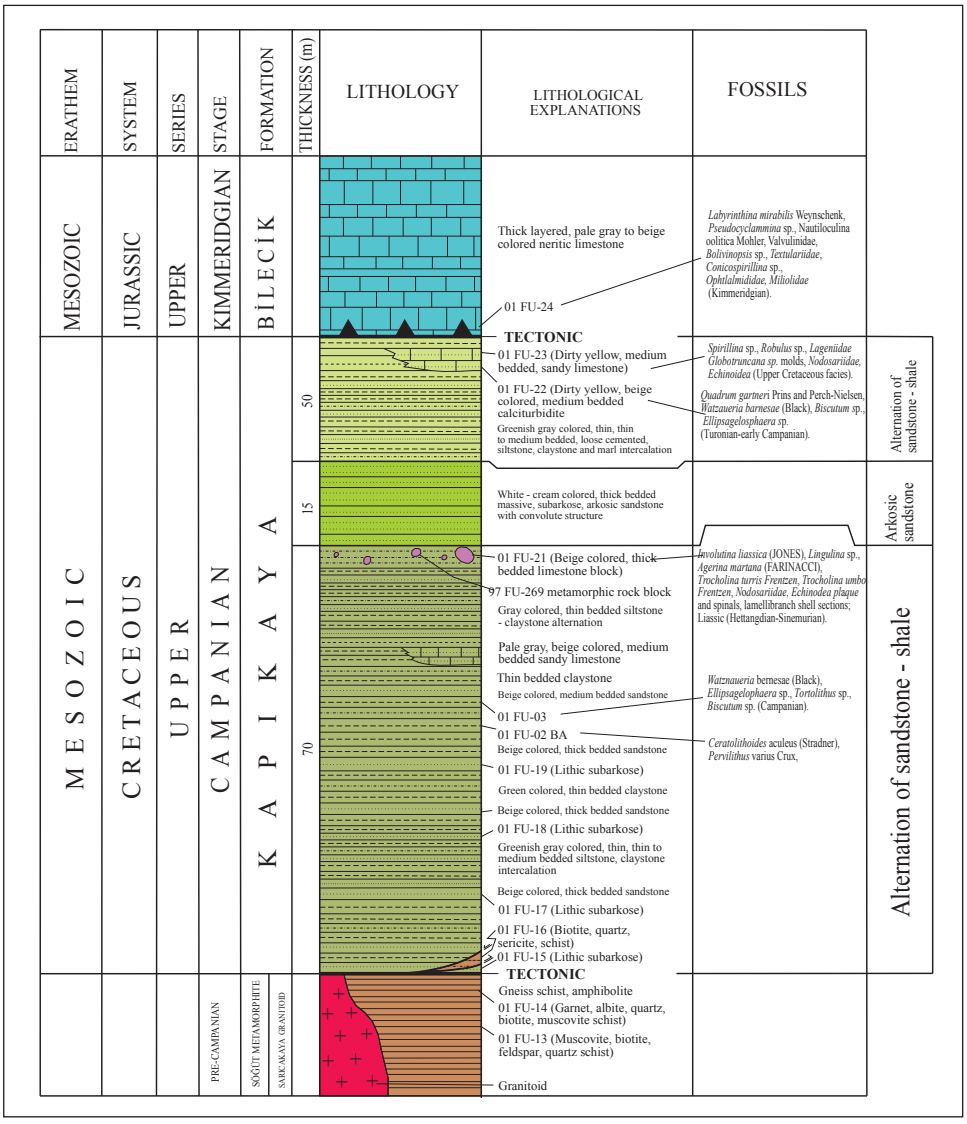
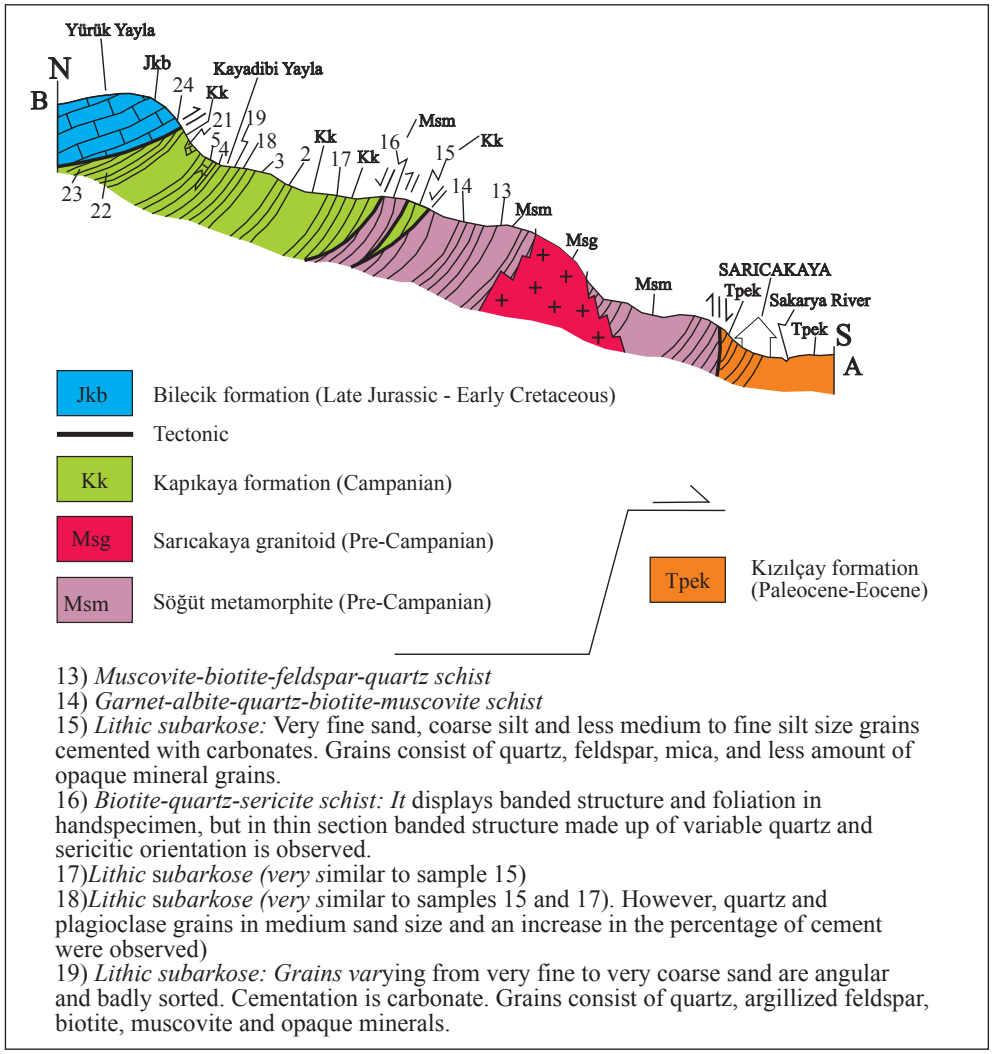


Figure 3- The columnar section of the Kayadibi Yayla (AB).

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

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

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



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

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

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

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

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

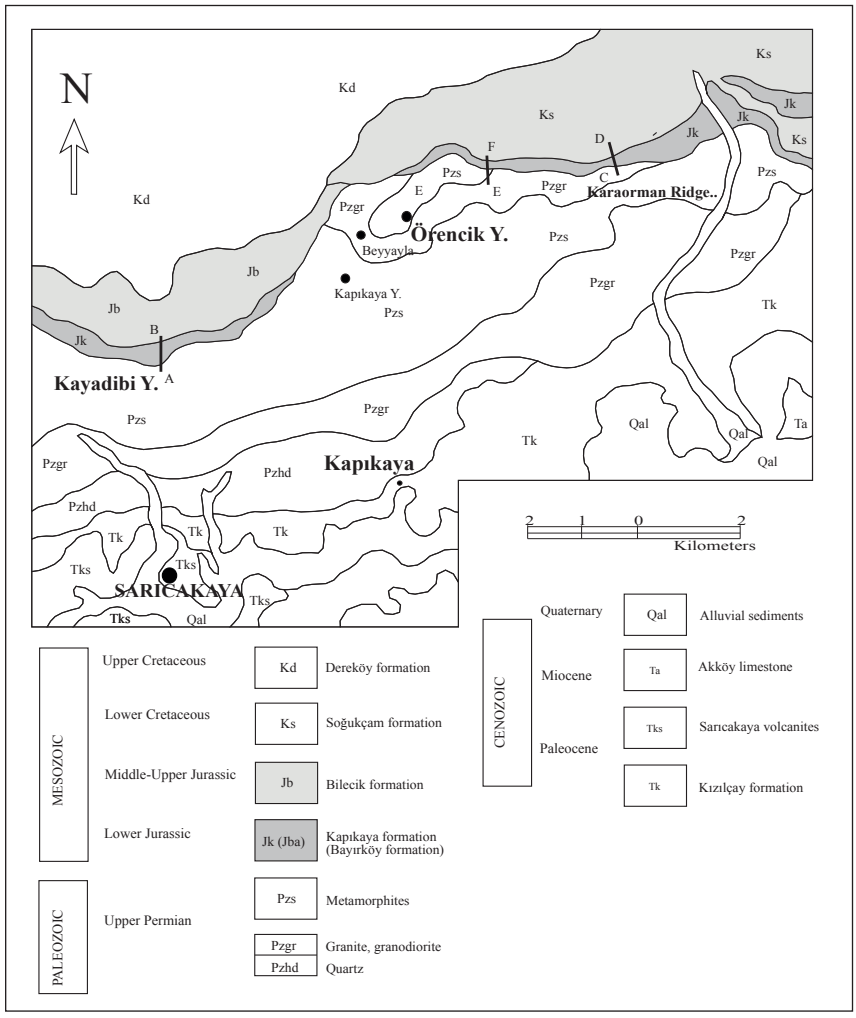


Figure 5- Geological map of the study area (Altınlı, 1973).

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

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

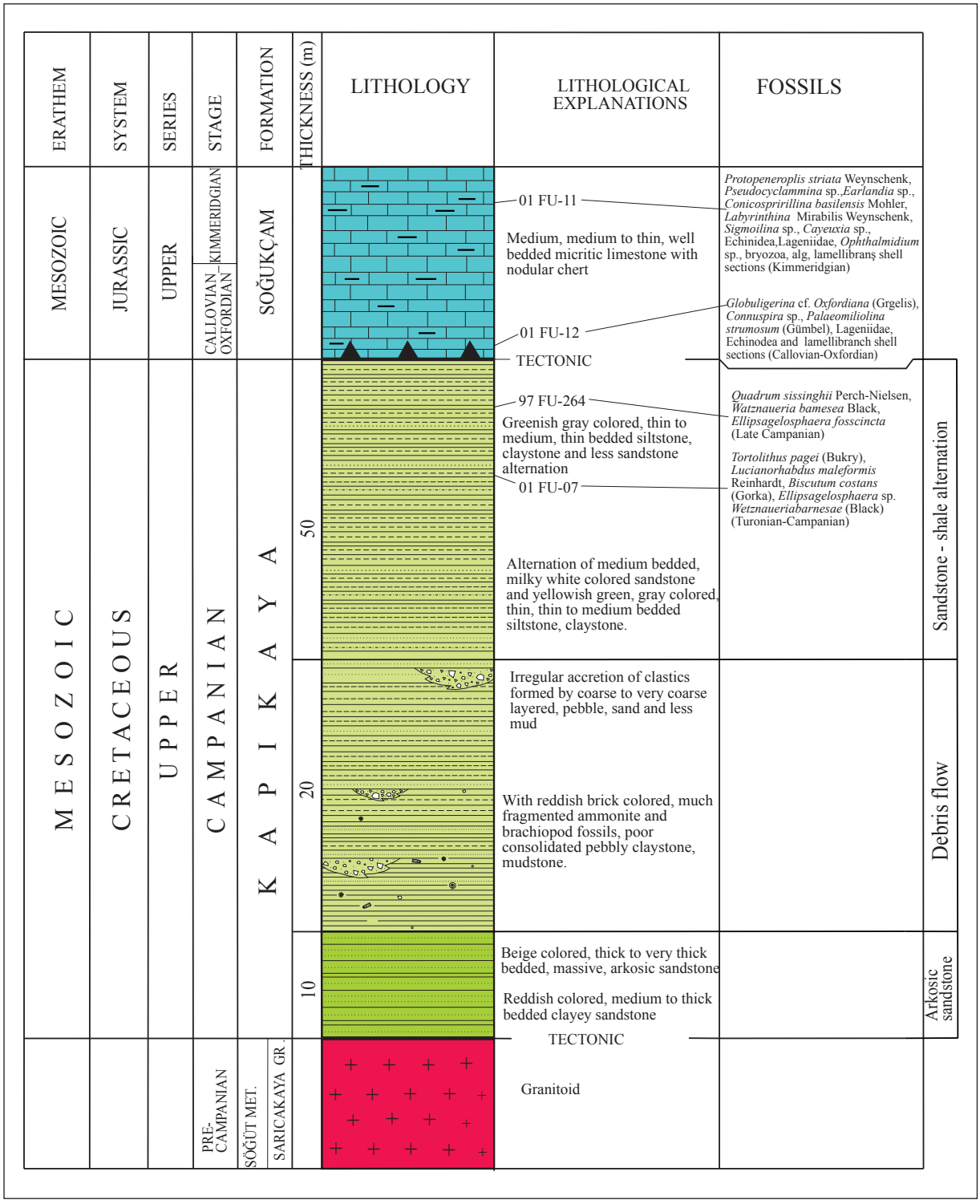


Figure 6- The columnar section of the Karaorman Ridge (CD).

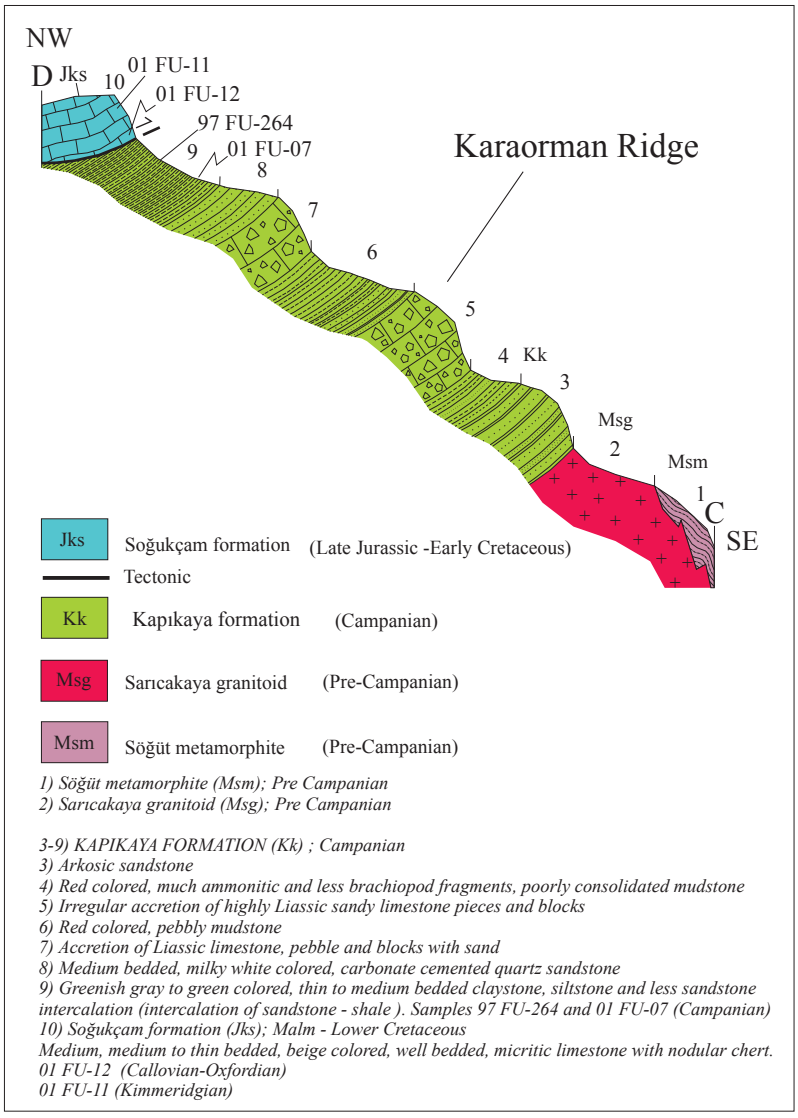


Figure 7- Karaorman Ridge (C-D) Schematic Cross section

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

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

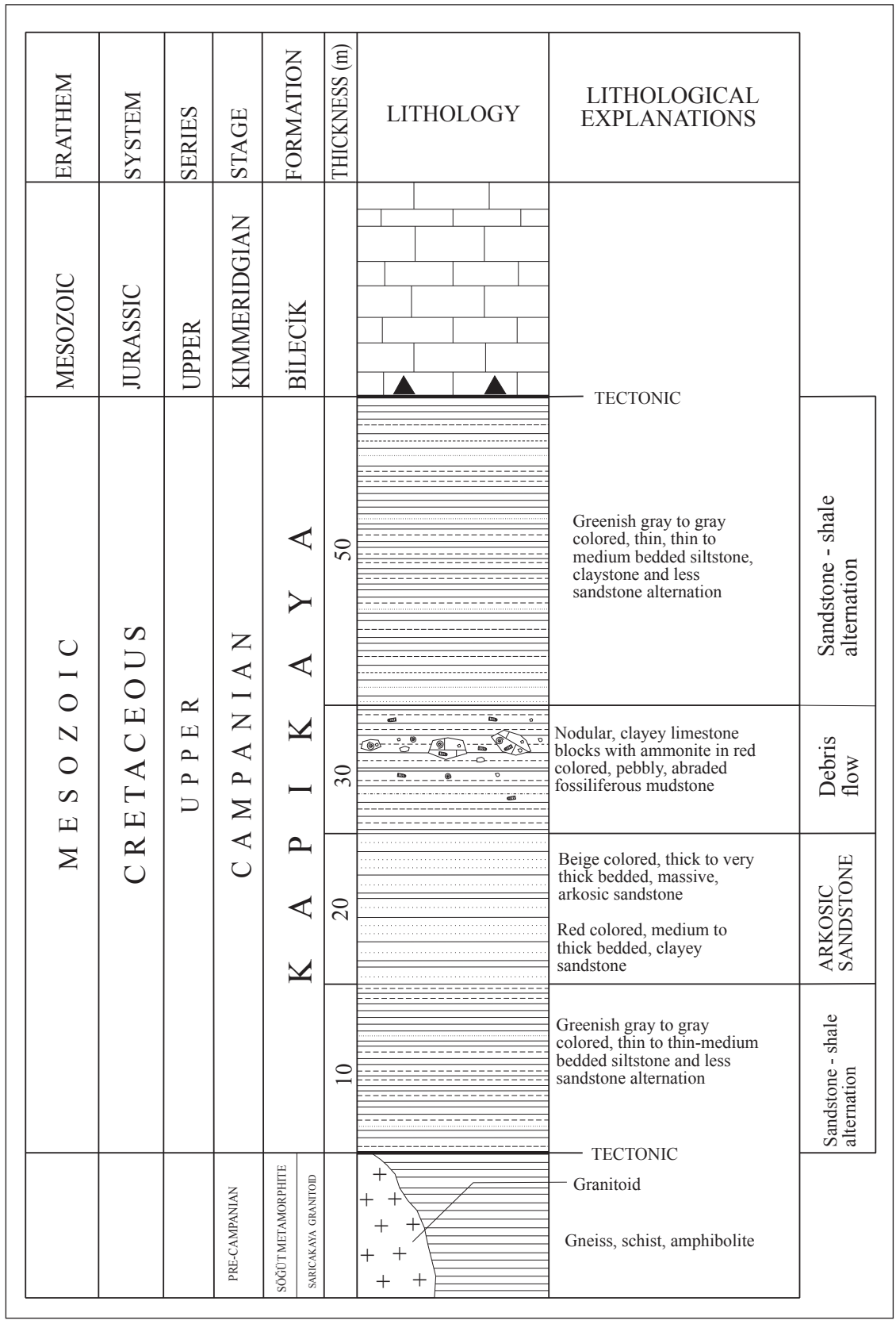
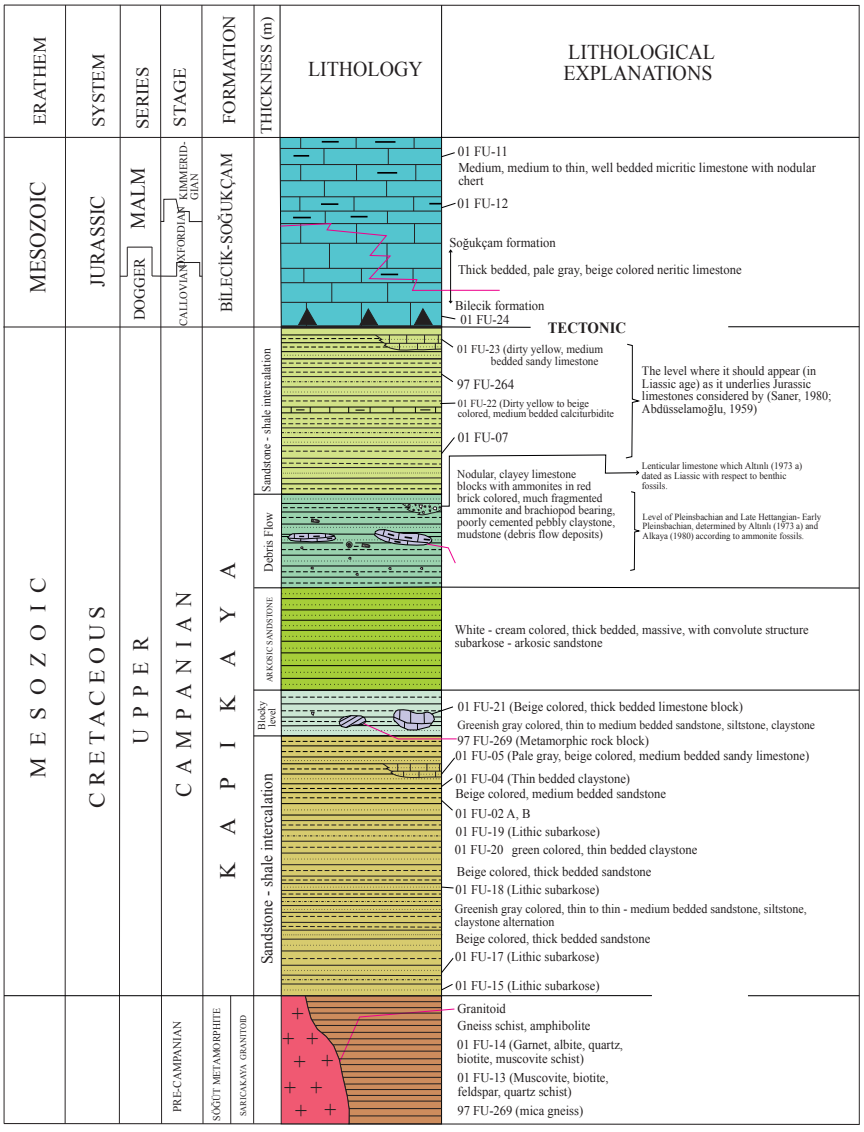


Figure 8- The columnar section of the Örencik Yayla (EF).



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

Figure 9- The generalized stratigraphical section of the study area

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

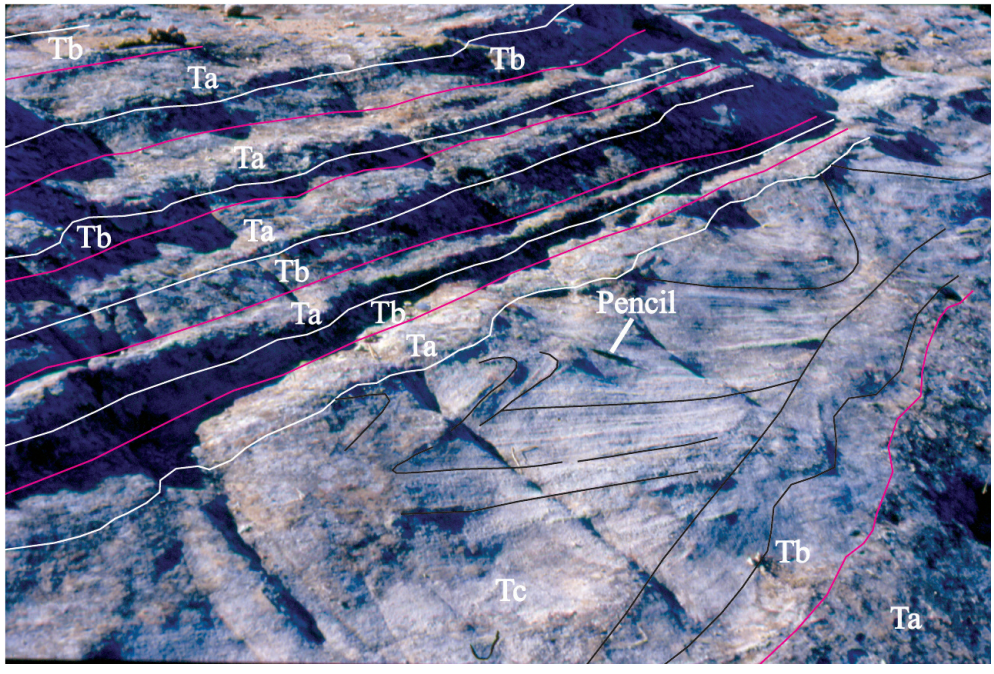


Figure 11- Levels a and b of the Bouma (1962) sequence in arkosic sandstone level; A well developed convolute lamination is observed after a thin and badly preserved b level located at the lower layer in frontal side of the photo. Ta level is pebbly and badly sorted. Planar lamination in Tb level has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

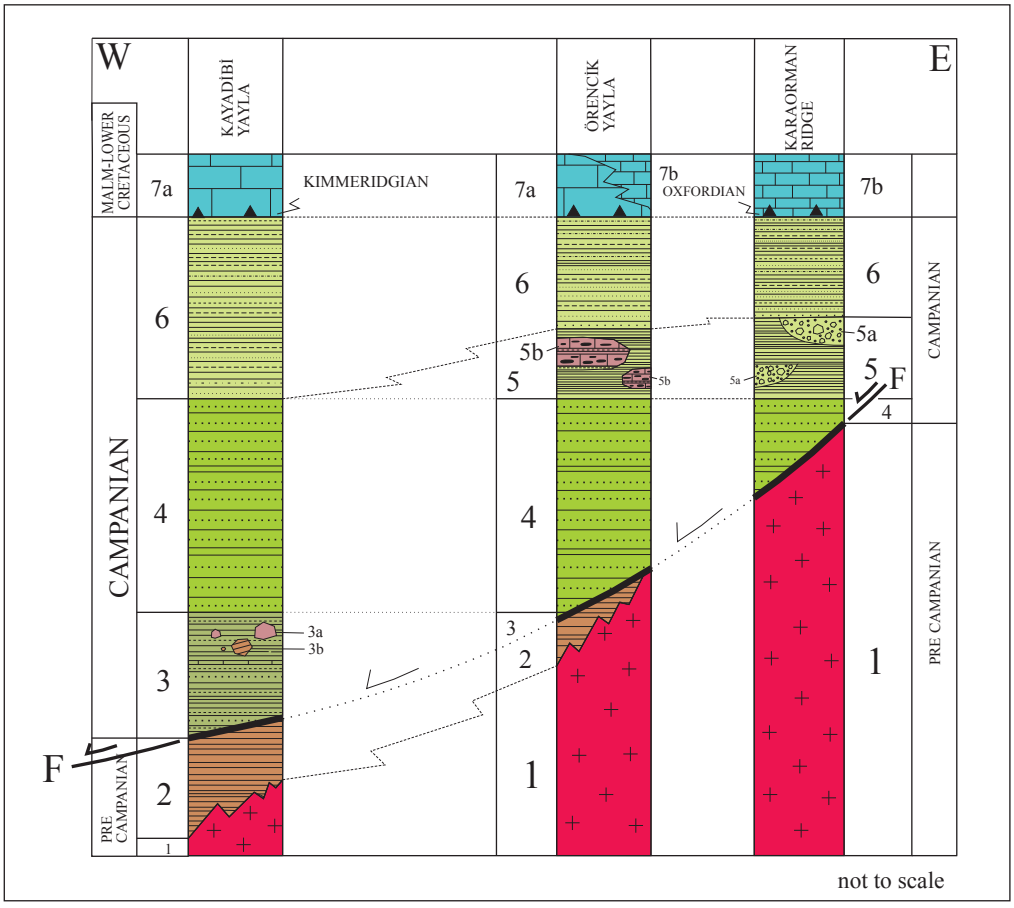


Figure 12- The correlation table of Kayadibi Yayla, Örencik Yayla and Karaorman Ridge columnar sections.

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

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

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

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

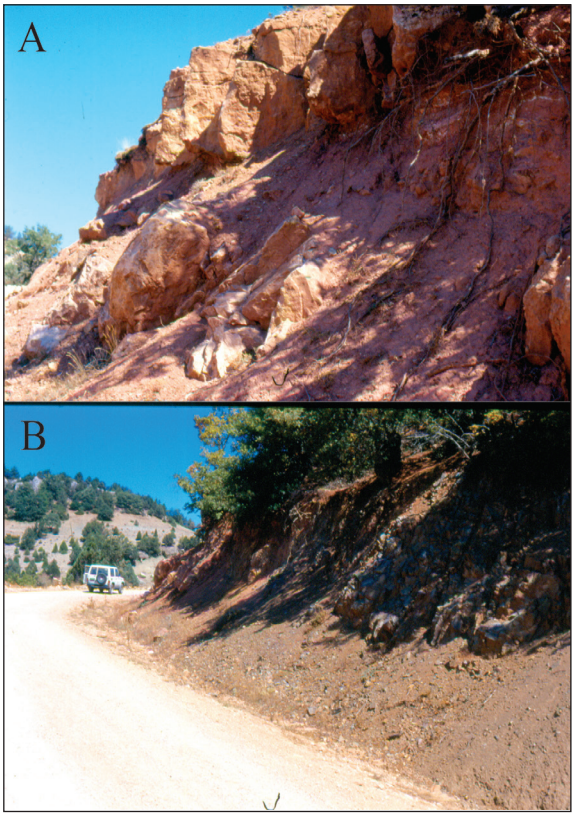


Figure 14- Within sandstone - shale alternation of the Kayadibi Yayla it is observed; (above photo) Liassic neritic limestone block, (below photo) metamorphic rock block in front, on the right side and Liassic limestone block at back, sandstone - shale alternation on the upper left corner (at distant)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

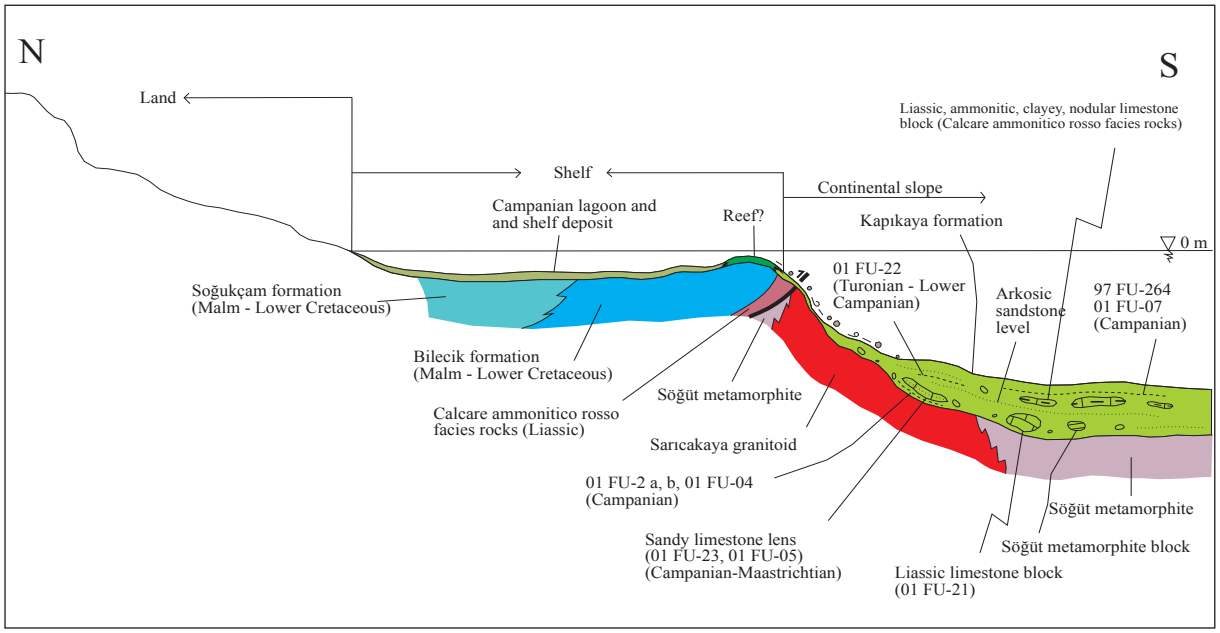


Figure 15- Schematic section showing the depositional environment in Campanian.

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

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

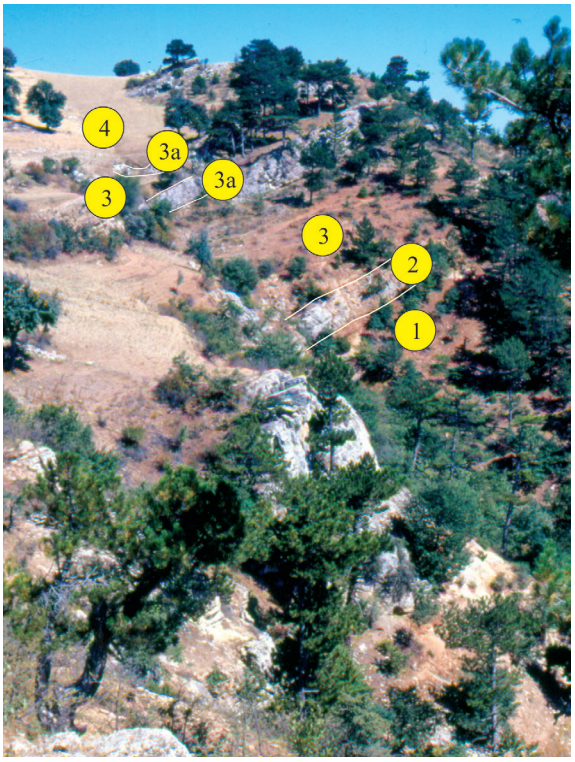


Figure 18- Karaorman Ridge (looking from west); 1- granite, 2- arkosic sandstone, 3- red colored pebbly mudstone with abraded ammonite and brachiopod, 3a- lenticular limestone infillings within mudstone layer, 4- sandstone - shale alternation.

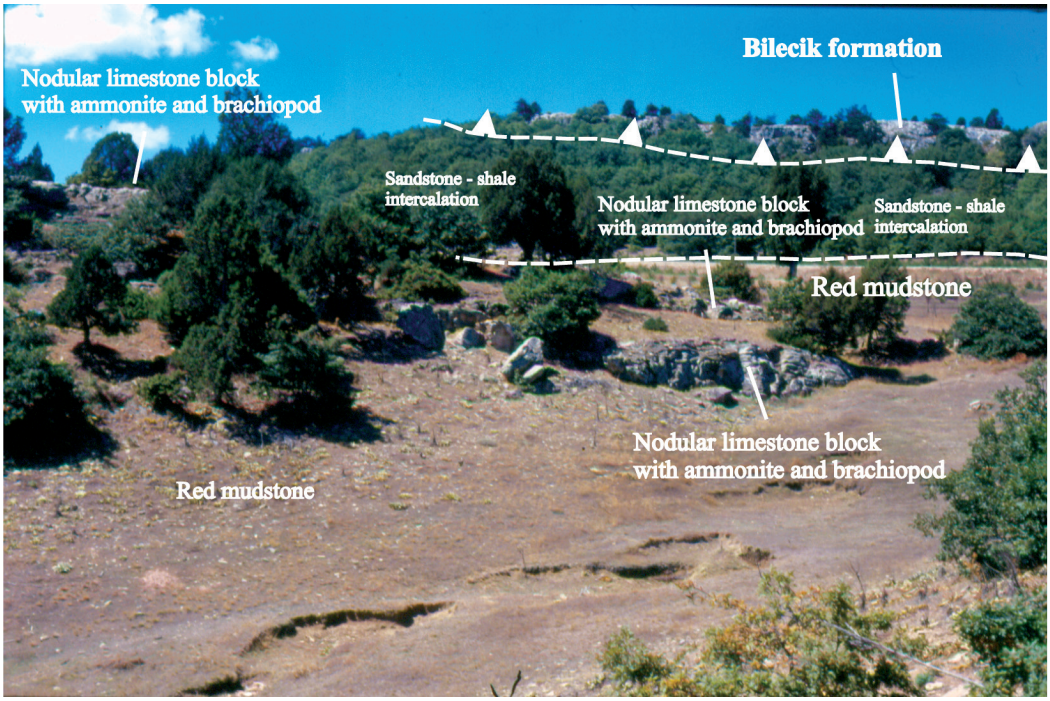


Figure 19- Nodular limestone blocks with ammonite and brachiopod fossils within red mudstone layers around Örencik Yayla. Nodular limestones are in different block sizes that have no lateral continuity.

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

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

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

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

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

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

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

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

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

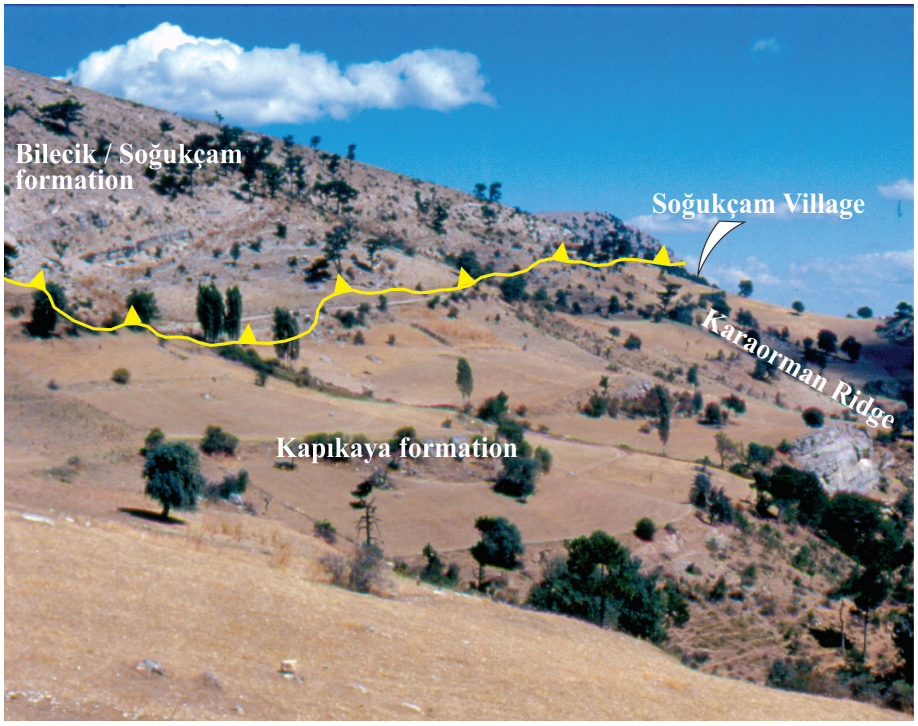


Figure 21- The overthrust between Bilecik/Soğukçam formation and Kapıkaya formation around Karaorman Ridge - Soğukçam village.

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

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

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

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

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

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

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

2.4. Bilecik Formation

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

determined Karasu stream outcrop as a type locality for this unit which is at the southwest of Vezirhan town, Bilecik province.

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

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

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

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

2.5. Soğukçam Formation

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

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

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

2.6. Kızılçay Formation

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

Kızılçay formation is mainly composed of the alternation of mudstone, claystone, siltstone, sandstone and conglomerate. The red mudstones are

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

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

3. Discussions and Conclusions

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

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

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

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

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

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

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

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

Acknowledgment

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