DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

STRATIGRAPHY AND FACIES CHARACTERISTICS OF UPPER CRETACEOUS SEQUENCES AROUND İĞNEADA KIRKLARELİ

by

İlhan ARCA

January, 2012

İZMİR

STRATIGRAPHY AND FACIES CHARACTERISTICS OF UPPER CRETACEOUS SEQUENCES AROUND İĞNEADA KIRKLARELİ

A Thesis Submitted to the
Graduate School of Natural and Applied Sciences of Dokuz Eylül University
In Partial Fulfillment of the Requirements for the Degree of Master of Science
In Geological Engineering, Applied Geology Program

by

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January, 2012

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M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"STRATIGRAPHY AND FACIES CHARACTERISTICS OF UPPER CRETACEOUS SEQUENCES AROUND İĞNEADA KIRKLARELİ"** completed by **İLHAN ARCA** under supervision of **PROF.DR. SACİT ÖZER** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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ACKNOWLEDGEMENTS

This Master of Science thesis is produced from Dokuz Eylül University, The Graduate School of Natural and Applied Sciences. Also this study has supported by Tubitak Project no: 109Y121.

I am deeply indepted to my supervisor Prof.Dr. Sacit ÖZER for his supervision, guidance, patience and encouragement throught this study. Moreover, i am also grateful to him for supporting and guidance in field studies and identification of the rudists which made valuable contributions to establish stratigraphic framework.

Special thanks must go to Dr. Bilal SARI for his valuable suggestions on the microfacies studies.

I would like to thank Prof.Dr. İzver ÖZKAR ÖNGEN (İU) for identification of benthic and planktonic foraminifera. and also Prof.Dr. Jean-Pierre Masse (Université de Provence-Marseill) for some suggestions about the determinations of *Orbitolina*s.

Taner KORKMAZ (MU) also deserves a special thanks for his meaningful suggestion to translate some part of manuscript.

Finally, my faithful parents deserve the utmost thanks for their encouragement, continuous support during this study

İlhan ARCA

STRATIGRAPHY AND FACIES CHARACTERISTICS OF UPPER CRETACEOUS SEQUENCES AROUND İĞNEADA KIRKLARELİ

ABSTRACT

This study mainly deals with stratigraphic features and facies characteristics of volcano-sedimetary sequence of İğneada region (Kırklareli). In order to achieve this goals 1050 meter thick three stratigraphic sections were measured in the İğneada Formation showing well-exposed outcrops in the Limanköy, Sislioba and Avcılar areas.

İğneada Formation unconformably overlies the Mahya Formation. consisting of Jurassic micaschissts and marble lenses and it is approximately 600 m thick.

İğneada Formation consists of 15-20 cm thick conglomerates at the bottom levels and it grades to rudist-bearing 10 m thick neritic limestones in the Limanköy area. Rudist fauna consists mainly of radiolitids suggesting an Albian age (probably middle), some benthic foraminifers and algae are also determined. 15-20 m thick, yellow colored sandstones rich-in *Orbitolina* conformably overlie the neritic limestones and consist of *Orbitolina* species indicating an Albian age. *Orbitolina*-bearing sandstones pass upward to 40-50 m thick, yellowish-grey sandstones with thin-shelled bivalvia, planktonic foraminifera are also observed. Upper part of the formation consists alternation of 70-80 m thick, grey pelagic mudstones and 400-420 m thick, volcanic rocks such as andesitic tuffs, basalts, agglomerates and spilitic volcanics and pelagic mudstones. Planktonic foraminifers suggest a Cenomanina-Turonian and probably Coniacian age for the pelagic levels of the formation.

The base of İğneada Formation is represented dominantly by clastics around Avcılar and Sislioba areas when compared with that of Limanköy area. 10-15 m thick conglomerates and sandstones gradually pass upward to *Orbitolina*-bearing sandstones and pelagic mudstone and sandstone alternation and at uppermost part of formation the volcanic rocks are observed.

According to field observations and thin section analysis, seven microfacies have been distinguished. These are: conglomerate-litharenite, rudist fragments-bearing packstone-wackestone, *Orbitolina*-bearing litharenite, carbonate cemented litharenite with thin shell fragments, pelagic mudstone–lithic wackestone, planktonic foraminifera and calcisphere-bearing wackestone and volcanic intarcalated alternation of mudstone and wackestone.

The lithologic and sedimentologic features show that the volcano-sedimentary sequence of the Strandja Zone started to develope on the low relief of the carbonate ramp characterizing by the alluvial, fluvial and sea-shore clastics grading to shallow marine limestones and low energy basinal mudstones supported by volcanic rocks

Keywords: Strandja Zone , Cretaceous, volcano-sedimentary sequence, rudists, benthonic and planktonic foraminifers, stratigraphy, facies, depositional model, carbonate ramp.

İĞNEADA (KIRKLARELİ) DOLAYLARI ÜST KRETASE İSTİFİNİN STRATİGRAFİSİ VE FASİYES ÖZELLİKLERİ

ÖZ

Bu çalışma İğneada (Kırklareli) dolaylarında çökelmiş olan volkano-sedimanter istifinin stratigrafisini ve fasiyes özelliklerini ortaya koymayı amaçlar. Bu amaca yönelik, formasyonun en iyi yüzlek verdiği Limanköy, Sislioba ve Avcılar alanlarında, toplamda 1050 metre uzunluğunda üç adet ölçülü stratigrafik kesit ölçülmüştür

İğneada Formasyonu, Jurasik yaşlı mikaşist ve mermer merceklerinden oluşan Mahya Formasyonu'nu açısal uyumsuzlukla üzerler ve yaklaşık 600 metre kalınlığındadır. Neojen yaşlı Çakıltaşları, İğneada formasyonu uyumsuz olarak örtmektedir.

Limanköy alanında İğneada Formasyonu 15-20 cm kalındığında çakıltaşları ile başlar ardından 15-20 metre kalınlık sunan rudistli neritik kireçtaşlarına geçer. Rudist faunası esas olarak Albiyen (muhtemelen orta) yaşını veren radiolitidlerden oluşur, ayrıca bazı bentonik foraminifer ve alglerde aynı düzeylerde saptanmıştır. Rudistli neritik kireçtalarını uyumlu olarak 10-15 metre kalınlığa sahip *Orbitolina* bakımından zengin sarı renkli kumtaşları üzerler. *Orbitolina* türleri Albiyen yaşını işaret eder. *Orbitolina*'lı kumtaşları, üste doğru 15-20 metre kalınlığa sahip, sarımsı gri renkli ince kavkı parçalı, kumtaşlarına geçer. Bu seviyelerde planktonik foraminiferlerde gözlenmiştir. İstifin en üst kısmı; 70-80 metre kalınlığında, gri renkli pelajik çamurtaşları ve 400-420 metre kalınlığında, andezitik tüf, bazalt, aglomera ve spilitik volkanikler ile çamurtaşı ardalanmasından oluşur. İstifin pelajik düzeylerinden elde edilen planktonik foraminiferler, Senomaniyen-Turoniyen ve olasılıkla Koniasiyen yaşını öngörür.

Avcılar ve Sislioba alanlarında İğneada Formasyonu'nun tabanı, Limanköy alanındaki ile karşılaştırıldığında, baskın olarak kırıntılılarla temsil edildiği gözlenir. 10-15 metre kalınlığındaki çakıltaşları ve kumtaşları, üste doğru dereceli olarak

Orbitolina'lı kumtaşlarına, pelajik çamurtaşı-kumtaşı ardalanmasına geçer. Formasyonun en üst düzeylerinde volkanik kayalar gözlenir.

Arazi gözlemleri ve ince kesit çalışmalarına göre, yedi mikrofasiyes ayırtlanmıştır. Bunlar; çakıltaşı-literanit, rudistli biyoklastik istiftaşı-vaketaşı, *Orbitolina*'lı literanit, karbonat çimentolu ince kavkı parçalı literanit, pelajik çamurtaşı-litik vaketaşı, planktonik foraminifer ve kalsisiferli vaketaşı ve volkanik katkılı çamurtaşı-vaketaşı ardalanmasıdır.

Litolojik ve sedimentolojik özellikler, Istranca Zonu'na ait volkano-sedimanter istifin düşük eğimli bir karbonat yokuşu üzerinde çökeldiğini gösterir. Bu platform, alüviyal, akarsu ve kıyı kırıntılılarının sığ denizel kireçtaşlarına ve volkanik kayalarca destekli düşük enerjili havza koşullarını yansıtan çamurtaşlarına geçişleriyle simgelenir.

Anahtar sözcükler: Istranca Zonu, Kretase, volkano-sedimanter istif, rudistler, bentonik ve planktonik foraminiferler, stratigrafi, fasiyes, çökelim modeli, karbonat yokuşu.

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CHAPTER ONE

INTRODUCTION

1.1 Location of the study area

The study area is located around the İğneada district of Kırklareli where is situated in the northwestern part of Turkey (fig. 1). It approximately covers an area of 115 kilometer square between Limanköy, Avcılar and Sislioba where two 1/100.000-scale sheets are intersected; E19, E20.

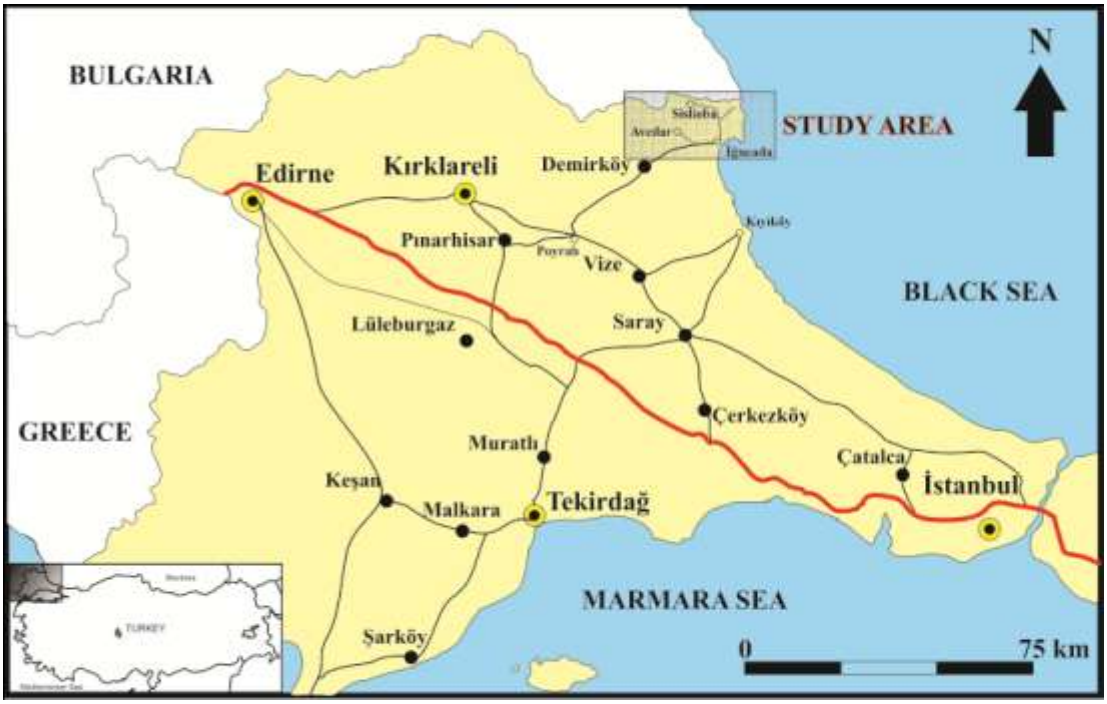

Figure 1. Location map of the study area.

The study area can be reached from by Tekirdağ-Hayrabolu-Vize-Demirköy-İğneada road and from east Istanbul-Vize-İğneada road and from easternsouth Istanbul-Çerkezköy-Vize-İğneada road. Either road reaches to the center of the district. This study was carried out at the Limanköy around the İğneada harbour, İğneade beach, Sislioba and Avcılar villages where the outcrops and contact relationships of the lithologies are well observed. Best outcrops and continuously sequence can be observed in the Limanköy area because of the excavation for the harbour construction.

1.2 Purpose and scope

The scope of this study is the volcano-sedimentary sequence around the İğneada. The main subject of this study is to determine stratigraphic and facies analysis of this sequence.

There are many studies about this region (Alaybeyoğlu, 1988; Çağlayan & Yurtsever, 1998; Okay, 2001), but none of them have proved a detalied stratigraphic, paleontologic and facies features of the volcano-sedimentary sequence. Although, the presence of the rudists have been mentioned in some studies (Pamir & Baykal, 1947; Alaybeyoğlu, 1988; Çağlayan & Yurtsever, 1998), which are located at the bottom of the sequence, have never been identified yet. On the other hand, there is some limited data about the pelagic fossils and the stratigraphic features of the sequence. The facies characteristics and type of the platform of the sequence have not been determined. So, this study is focused to collect detailed paleontologic data supported by the stratigraphy and facies analysis, which is determined after careful field observation and sampling from the measured-stratigraphic section.

1.3 Methods

This study is based on the measured-stratigraphic sections. Three section lines were determined in study area representing the best features of the sequence. 1050 meter stratigraphic section were measured, 67 samples to prepare thin section sample and 8 for washing samples, totally 73 samples were collected from the field. On the other hand, point samples were collected from the outcrops of İğneada Formation in the study area.

The geological map of Alaybeyoğlu (1988) and Çağlayan &Yurtsever (1988) was used in this study.

The rudists have been determined by Prof.Dr. Sacit ÖZER, planktonic foraminefera by Prof.Dr. İzver ÖZKAR ÖNGEN (İstanbul University) and

*Orbitolina*s by Prof.Dr. İzver ÖZKAR ÖNGEN and Prof.Dr. Jean-Pierre MASSE (Université de Provence, Marseille, France).

Microfacies analysis have been determined by the investigation of the thin section samples from the measured stratigraphic sections and have been considered with the combination of the field observations.

Universal transverse mercator (UTM) and european datum 1950 were used as for the geographical information system.

1.4 Previous studies

There are two main geological provences in the study area. These are Strandja Massif and Thrace Basin. Both of them have been studied by many scientists for 60 years.

Strandja Zone was generelly studied for understanding it's constitution and evolution. In the middle of 20th century, T.P.A.O had discovered the hidrocarbon potantial of Thrace basin. By the oil and gas investigation companies increase, drillings in the basin reach thousands. As a result, the stratigraphic and depositional settings are well known for the area.

In the Strandja massif; the study by the Çağlayan and Yurtsever (1998), displays that the Massif basically consists of late Variscan gneisses and metagranites. Okay et al. (2001), according to data on the evaporation of zirkon in the metagranites, they gained the massif's age is 271 millions of year (Early Permian). Sunal et al. (2006), indicated that the gneisses intrusion age is Carboniferous. The mainly accepted concept is that the Mesozoic metasediments which are transgressive, unconformably overlie the cristalin basement rocks (Pamir and Baykal, 1947; Aydın, 1982; Çağlayan et al.,1988; Çağlayan and Yurtsever, 1998; Okay et al., 1994, 2001, 2006). However, Hagdorn and Güncüoğlu (2007) specify that the contact between the cristallin basement and the metasediments is unconformable because of geological faulting. Transgressive sequence consists of, from bottom to top, fluvial metaconglomerates, metasandstones, metasiltstones, phyllites and thick platform-type limestones. The only identified fossil index in massif which is located within the Turkish-Bulgarian boundary are Crinoides that are sighted in the metasediments and the recrystalized sandy limestones. According to this data, the Early-Middle Triassic age was obtained and it has been emphasized that it shows the Triassic German type facies characteristics (Hagdorn & Göncüoğlu, 2007).

In the Bulgarian side of the Strandja Massif, Chatalov (1985,1991) determined conodonts, bivalvias, gastropods, ammonites and foraminifers. These fossils belong to the Early Triassic. However, no fossils have been observed yet in the recrystalized marbles which have constituted the upper parts of the massif. Strandja Massif's metamorphic rocks are overlied by the Late Cretaceous sedimentary and volcanic rocks along the Black Sea coast arc(Okay et al., 2001). According to Pamir and Baykal (1947), this sequence consists of bold greyish black colored conglomerates, bold greyish blue colored sandstones that included Cenomanian age *Orbitolina*-bearing limestone lenses and rudist-bearing limestones. The contact between the metamorphic rocks of the Strandja Massif and the Upper Cretaceous sequence is controversial such as geological faulting (Pamir and Baykal, 1947) or unconformablity (Alaybeyoğlu, 1988; Çağlayan and Yurtsever, 1998; Okay et al. (2001). This sequence pass upward to hemi-pelagic siltstones-marns, andesitic tuffs and agglomerates (Pamir & Baykal, 1947; Alaybeyoğlu, 1988; Çağlayan and Yurtsever 1998; Okay et al., 2001). On the other hand, Okay et al. (2001) suggests that the presence of the shallow marine limestones in the uppermost part of the volcano-sedimentary package.

1.5 Regional geological settings

The Strandja is one of the zone (or terranes) of the Pontide orogenic belt showing the Laurussian affinities and located north of the northern branch of the Neo-Tethys. This zone is bounded in the south by a Tertiary Thrace Basin and in the east West Black Sea Basin and comparable to the tectonic units in the Balkans (fig. 2). The Black Sea formed as an oceanic back-arc basin during the Cretaceous in the north of the Pontide magmatic arc because of the subduction of the northern Neo-Tethyan ocean (Chatolov, 1988; Okay&Tüysüz, 1999; Okay et al., 2001; Özer, 2010).

The Strandja Massif show a prolongation towards to Bulgaria and it consists of, in Turkey, a late Variscan-crystalline basement unconformably overlain by a Triassic-Jurassic metasedimentary continental to shallow marine carbonates sequences (Pamir & Baykal, 1947; Okay et al. 2001; Hagdorn & Göncüoğlu, 2007). The metamorphic rocks of the Strandja Massif are unconformably overlain by Upper Cretaceous neritic and pelagic sedimentary rocks, volcaniclastics and volcanic rocks, which exposed around İğneada (Black Sea coast) and north of the Strandja Zone, very close to the Turkish-Bulgarian border. The base of the Upper Cretaceous sequence consists of reddish-brown alluvial conglomerates and sandstones passing upward dark grey, greyish-blue, shallow-marine rudist-bearing limestones and *Orbitolina*-bearing sandstones and greyish, pelagic mudstones interclated with andesitic tuffs, agglomerates and basalts (Pamir & Baykal, 1947; Alaybeyoğlu, 1988; Çağlayan & Yurtsever, 1998; Okay, 2001; Özer, 2010) (fig. 3).

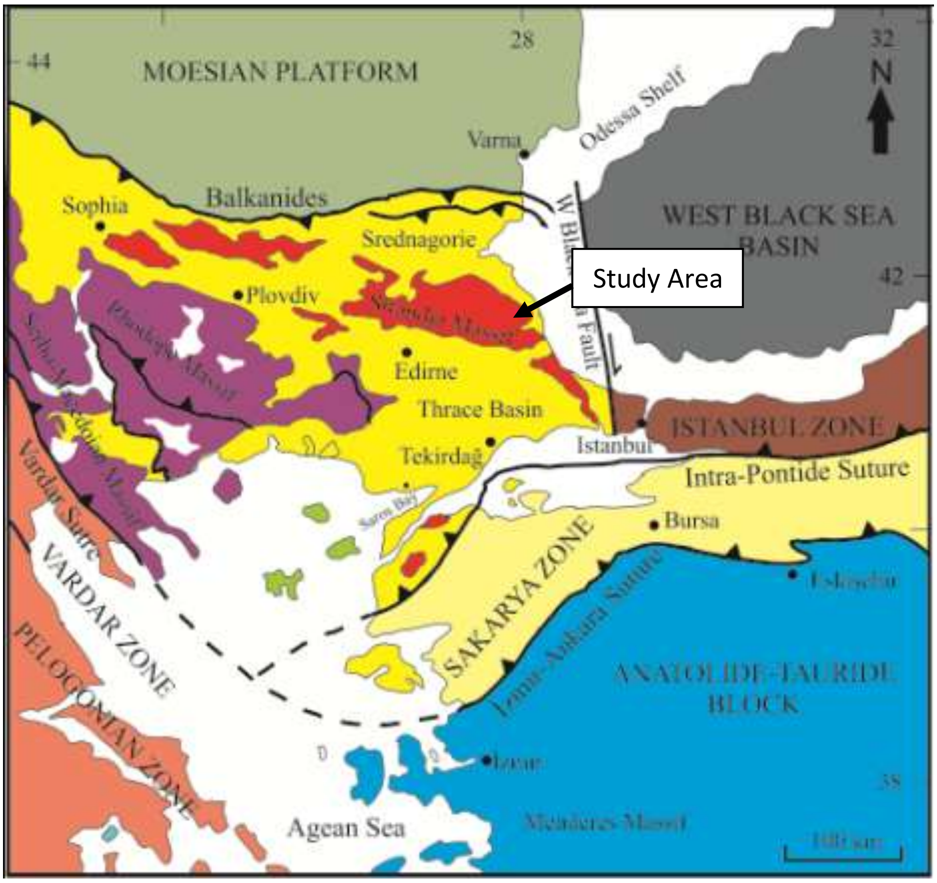

Figure 2. Map showing the main tectonic belts of the nortwestern Turkey (Simplified from Okay et al., 2001).

Akyol (1979), Taner (1981), Aydın (1982) and Okay et al. (2001) signify that Cretaceous Demirköy granodiorite displays widespread dispersal and also microdiorites have been determined in Dereköy.

In the south of the massif, Eocene-Oligocene units which consist of shallow marine limestones and clastic sedimentary rocks (more than 9 km) overlie the metamorphic units by an unconformity (fig. 3) (Turgut et al. 1991; Görür & Okay, 1996).

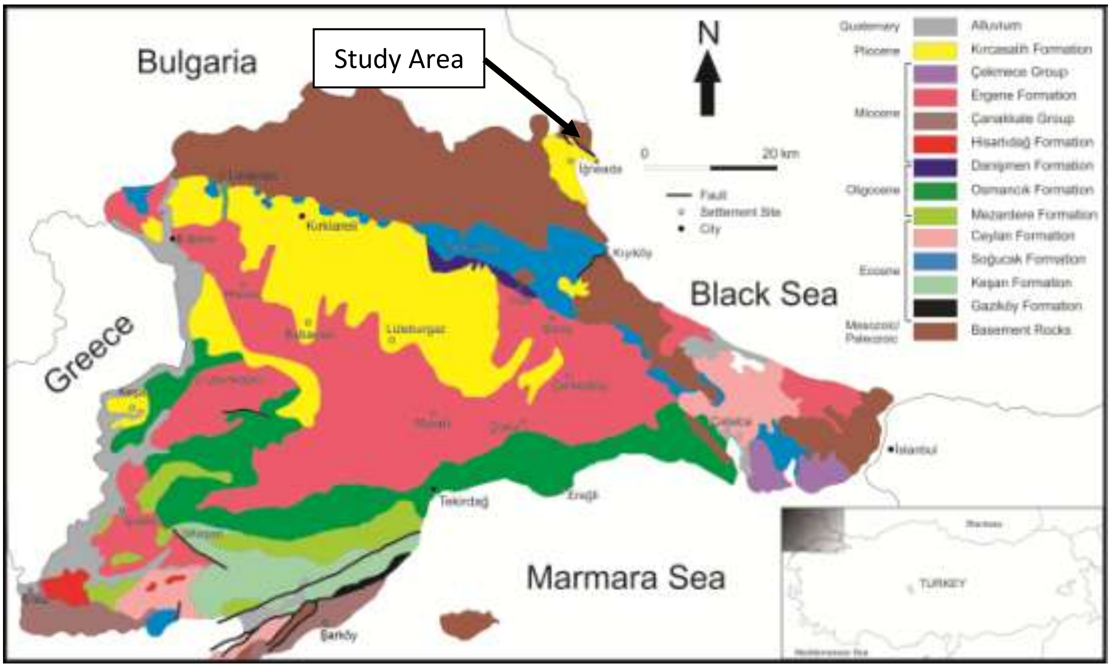

Figure 3. Geological map of the Thrace (simplified from Kasar et al., 1983; Türkecan and Yurtsever, 2002).

CHAPTER TWO

STRATIGRAPHY

2.1. Introduction

The previous studies suggest different names for the formations of volcano-sedimentary sequence (fig 4). Several members are also distinguished in these formations (Pamir&Baykal, 1947; Alaybeyoğlu, 1988; Çağlayan&Yurtsever, 1998; Okay et al., 2001). In this study, the name of İğneada Formation is used according to Alaybeyoğlu (1988) and it does not need to seperate the members in the formation as previous studies because of the stratigraphic and sedimantologic features of the volcano-sedimentary sequence.

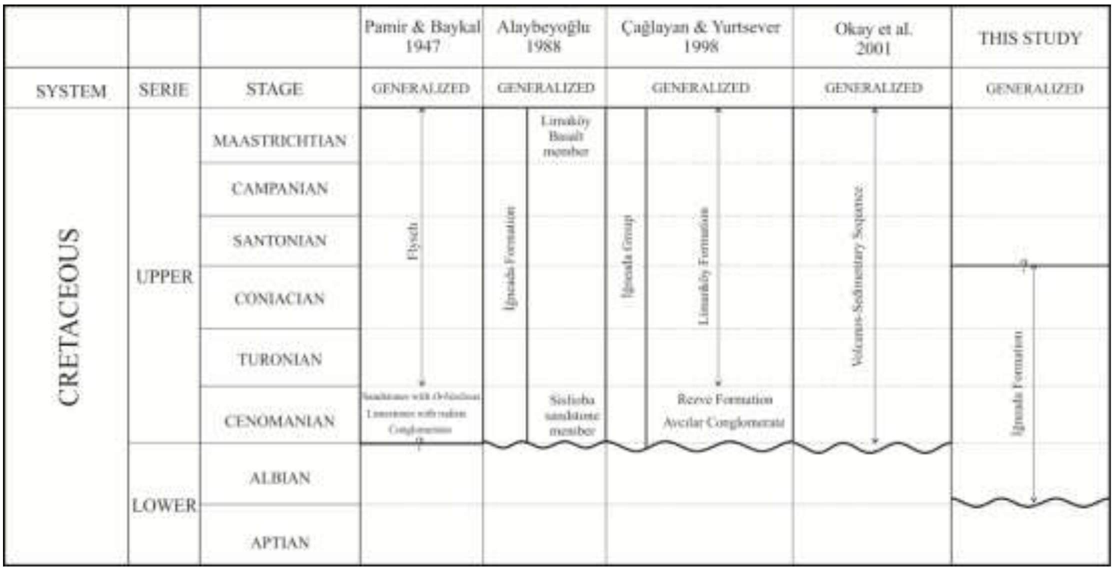

Figure 4. Chart showing the previously suggested sequences of some researchers studied in the İğneada location and comparison of them with the present study.

The İğneada Formation is observed following three geographical areas as they show different sequence characteristics related to possible different evolutionary history (Fig. 5):

- Limanköy area
- Sislioba area

- Avcılar area

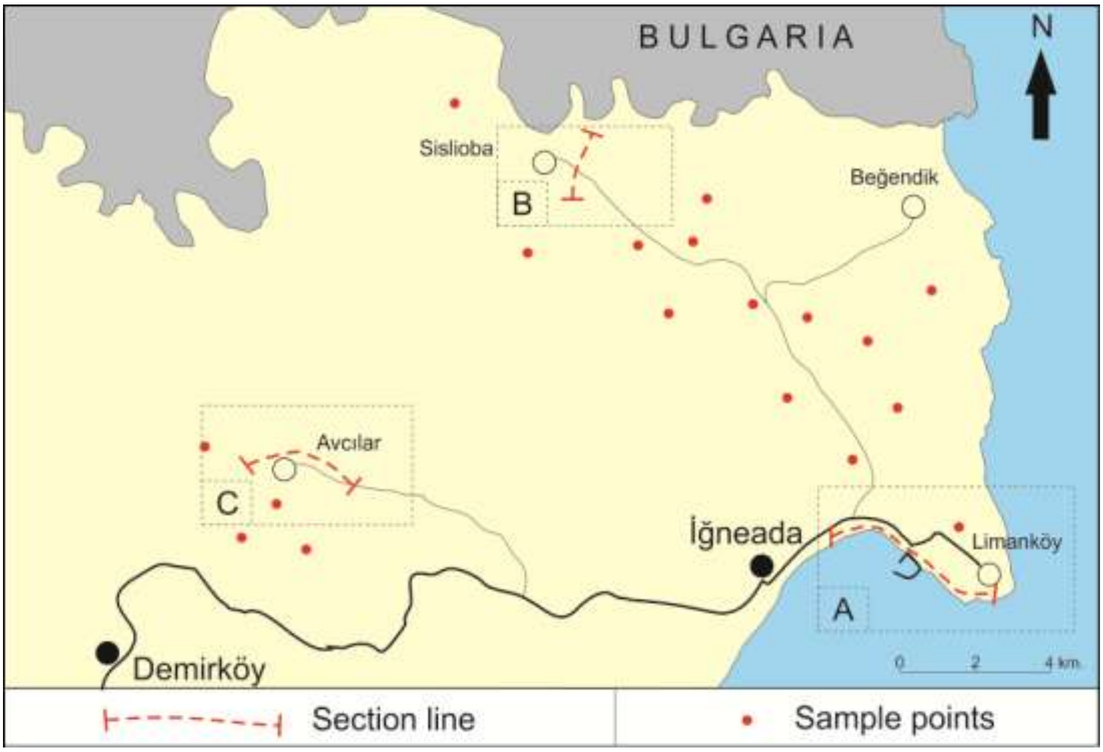

Figure 5. Location map showing the main studied three areas (A, B,C), measured-startigraphic sections.

Generalized stratigraphic sections of the İğneada region is given in the figure 6. Detailed explanations of the columnar stratigraphic section is represented in the following litostratigraphy chapter.

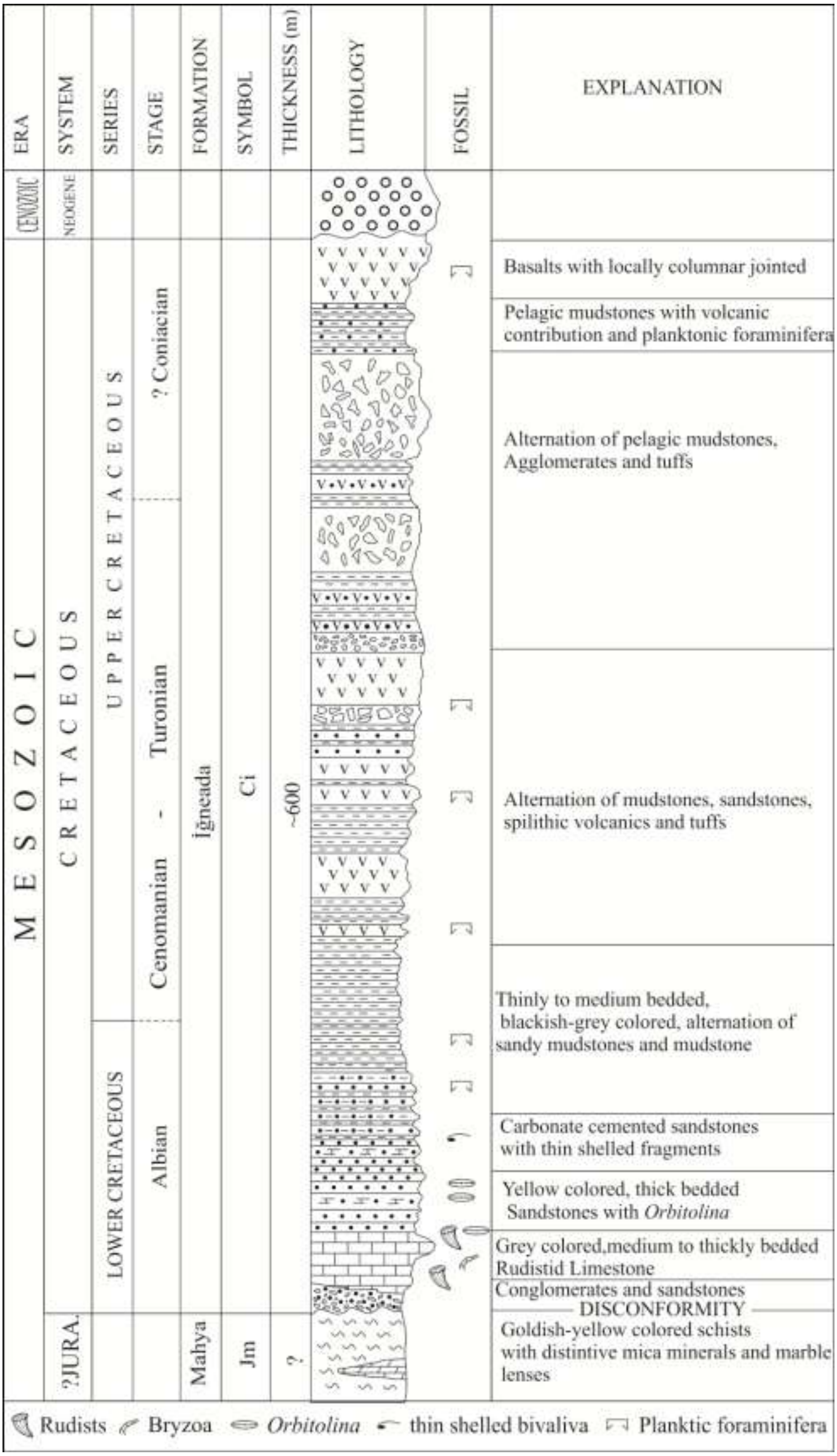

Figure 6. Generalized columnar section of the study area.

2.2 Lithostratigraphy

2.2.1. Limanköy area:

The most pronounced and continuous section of the Early Cretaceous volcano-sedimentary sequence in the Strandja Massif can be observed around İğneada-Limanköy (Fig. 7, 8, 9). Detailed sampling through the measured-stratigraphic section from İğneada harbour to Limanköy beach, the palaeontologic data belonging to rudists, benthonic and planktonic foraminifers were firstly determined. The distributions of these important palaeontologic data are presented in the figures 7 and 8.

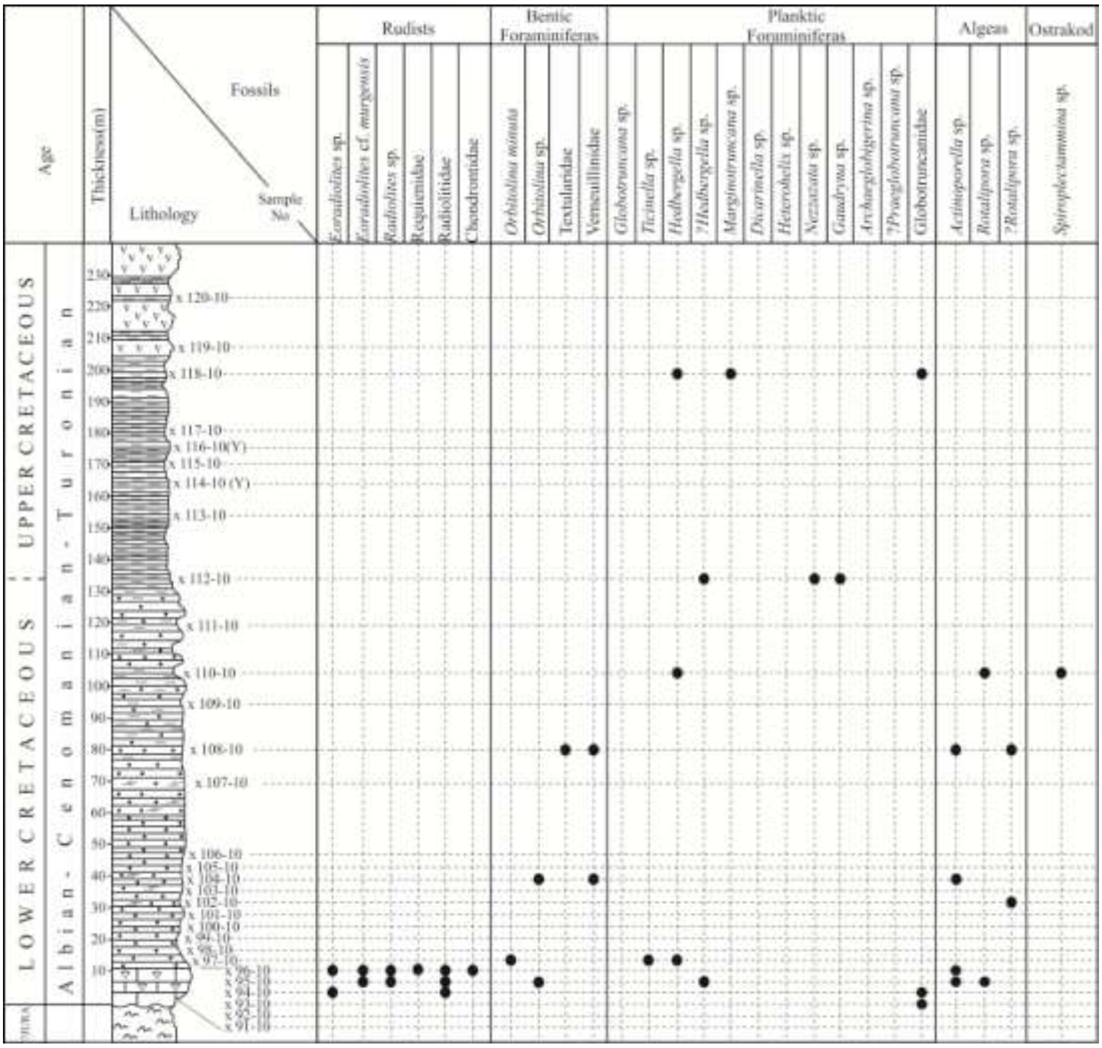

Figure 7. İğneada-Limanköy measured-stratigraphic section showing the distributions of the fossils (Starting point: Zone 35, 585003-4638371; Finishing point: Zone 35, 585735-4637870)

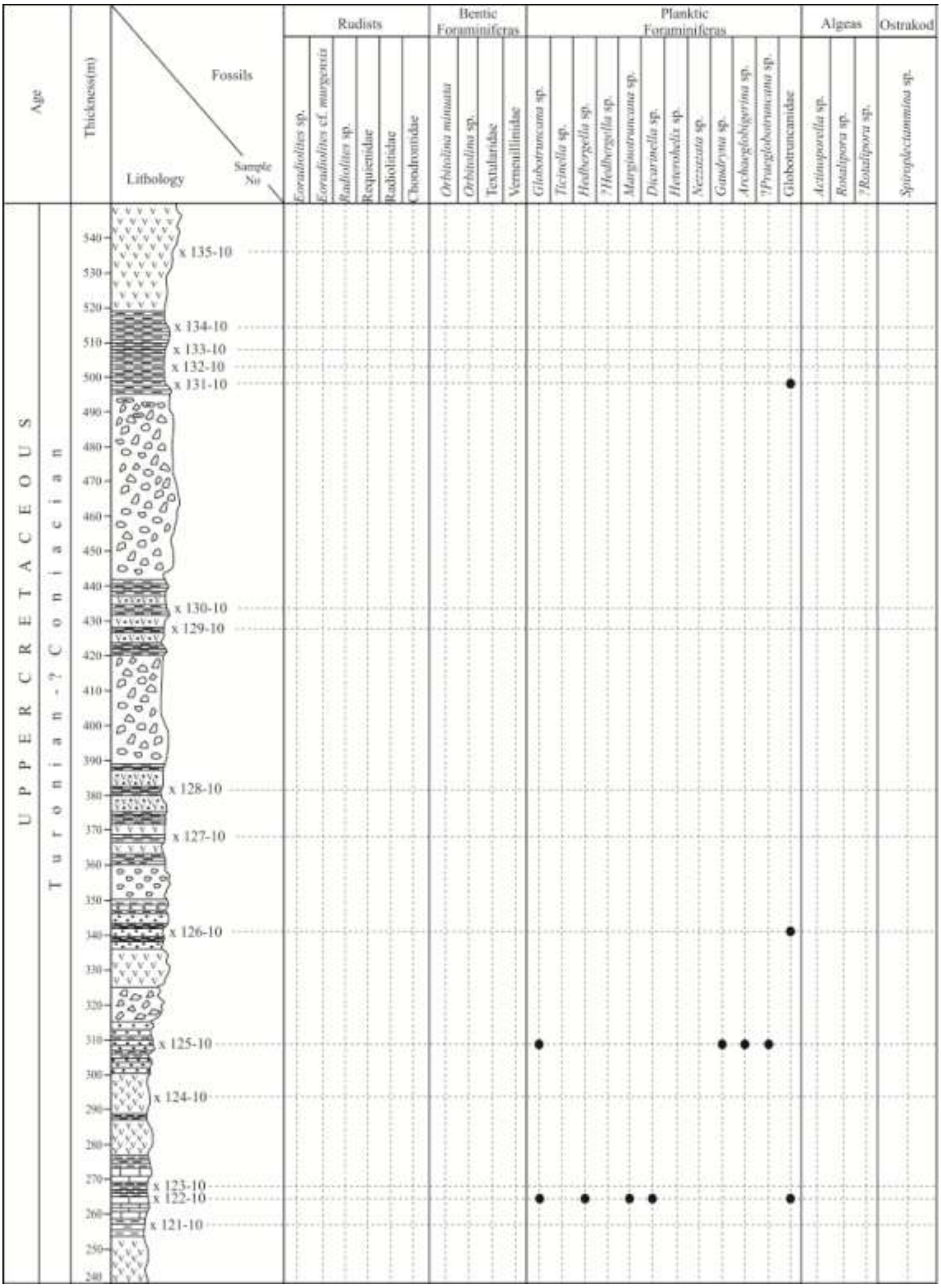

Figure 8. Continuation of İğneada-Limanköy measured-stratigraphic section

Figure 9. Panaromic view of İğneada-Limanköy measured-stratigraphic section showing bottom levels of the sequence (Jm: schists of Mahya Formation, Ci: İğneada Formation). (Coordinate: Zone 35, 585013/4638314).

İğneada Formation rests unconformably over the metamorphic rocks of Mahya Formation which mainly made of gray micaschists and some minor marble lenses. Okay et al. (2001) suggest a Jurassic age for the Mahya Formation (fig. 10).

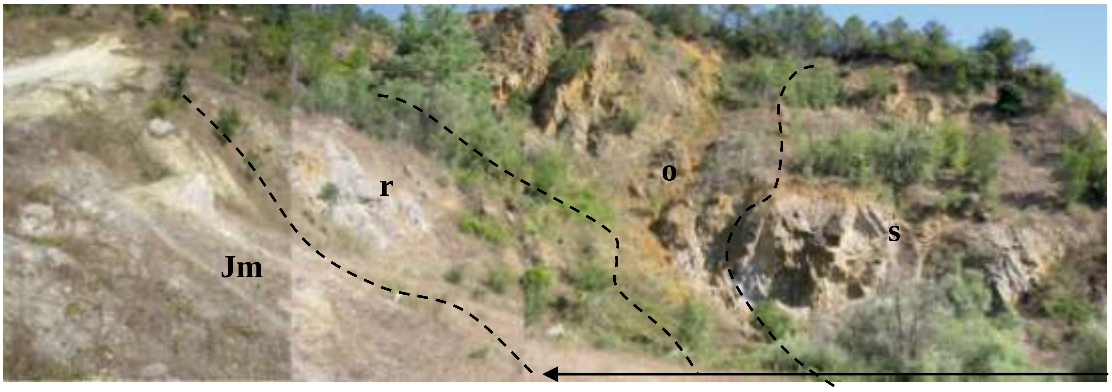

Figure 10. Field view of the contact relationships between Mahya Formation (Jm) and İğneada Formation (Ci). (r:Rudist-bearing limestones, o: *Orbitolina*-bearing sandstones, s: sandstones with thin-shelled bivalvia). (Coordinate: Zone 35, 585024/4638383).

The İğneada Formation shows approximately 600 m thickness (Fig. 9). The bottom of the formation consists of very limited approximately 0.20 m thick conglomerates-sandstones and 10 m thick, medium to thick-bedded, grey colored rudist-bearing crystallized limestones (fig. 11).

Figure 11. Field view of the rudist-Bearing limestones which observed at the bottom level of the İğneada Formation (see Fig. 10). (Coordinate: Zone 35, 585003/4638371).

The 4 m thick lower levels of the limestones are mainly characterized by the calcite veins and also the rudist fragments, but rare pelagic fragments and bryozoa sections are also observed. Two rudist levels can be diffferentiated through the upper levels of the limestones showing the 0.5-1.5 m thickness variation. The first rudist level consists of radiolitid sections and fragments belonging to genus of *Eoradiolites.* The species of this genus can not identified because of the badly preservation of shelled layers. The second one generally contains the sections of *Eoradiolites* and Chondrontidae. The following rudist fauna have been identified (fig 12):

Eoradilites cf. *murgensis* Torre, 1965

Eoradilites sp.

Radiolites sp.

Radiolitidae

Requienidae

The foraminifers and algae have been also identified in rudist-bearing limestones as follow (Fig. 14: A, B, G):

Orbitolina sp.

?*Hedbergella* sp

Actinoporella sp.

Rotalipora sp.

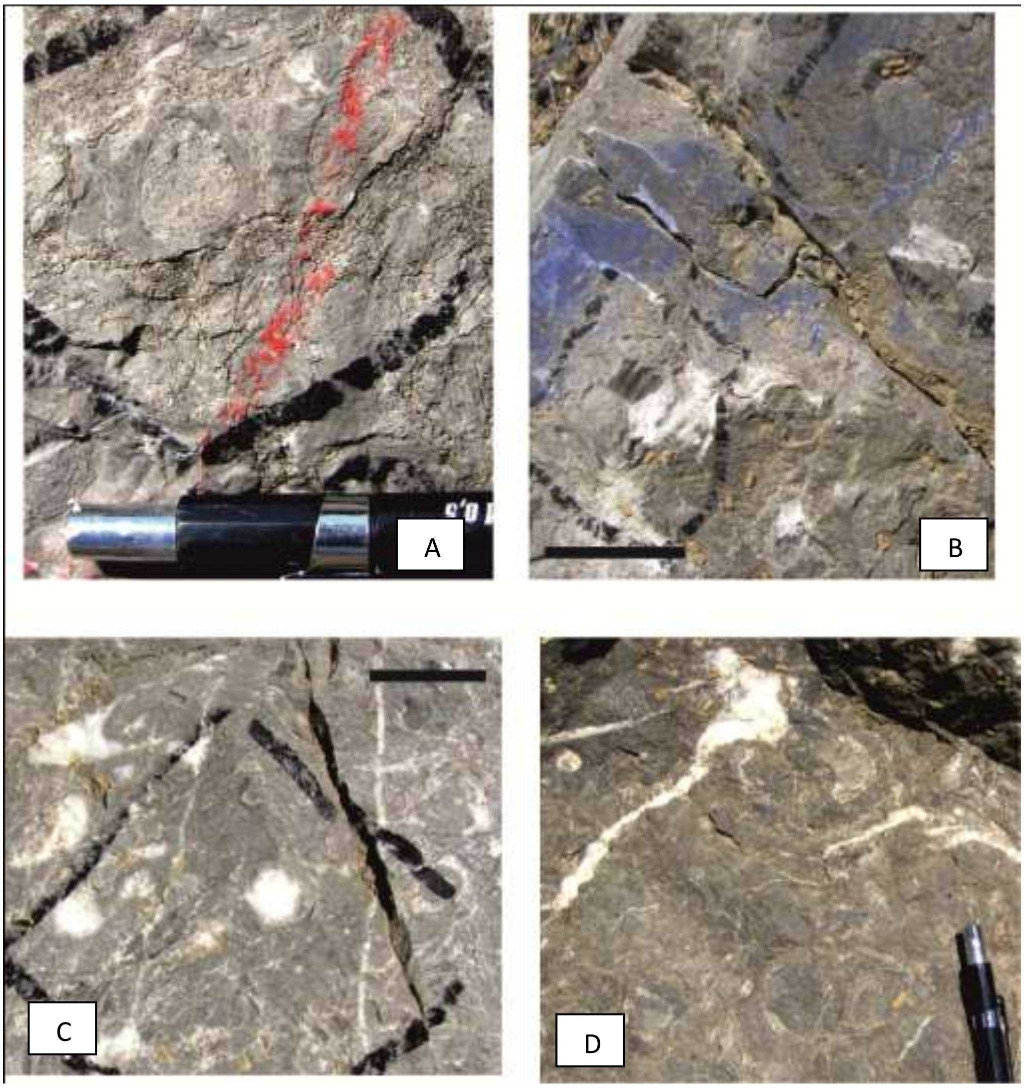

Figure 12. The field view of the rudists, İğneada formation: A) *Eoradilites* cf. *murgensis*, B) *Radiolites* sp., C) *Radiolites* sp. and *Eoradilites* sp., D) *Eoradilites* sp. and Chondrontidae, Scale Bar Is 10 mm (Coordinate: Zone 35, 585003/4638371).

The rudist-bearing limestones pass upward to 20 m thick, medium to thick-bedded, yellowish-grey carbonated sandstones (fig. 13). These levels are characterized by the presence of the abundant *Orbitolina*s. Only one species of the *Orbitolina* such as *Orbitolina minuta* (Douglass, 1960) can be determined. This indicates a monospesific fauna for the *Orbitolina*s. Some planktic foraminifers such as ?*Ticinella* sp. and *Hedbergella* sp. are also present in the sandstones with *Orbitolina*s (Fig. 14).

Figure 13. Photo shows the contact realtionships between rudistid limestones (r), *Orbitolina*-bearing sandstones (o) and thin shelled sandstones (s) (Coordinate: Zone 35, 585078/4638380).

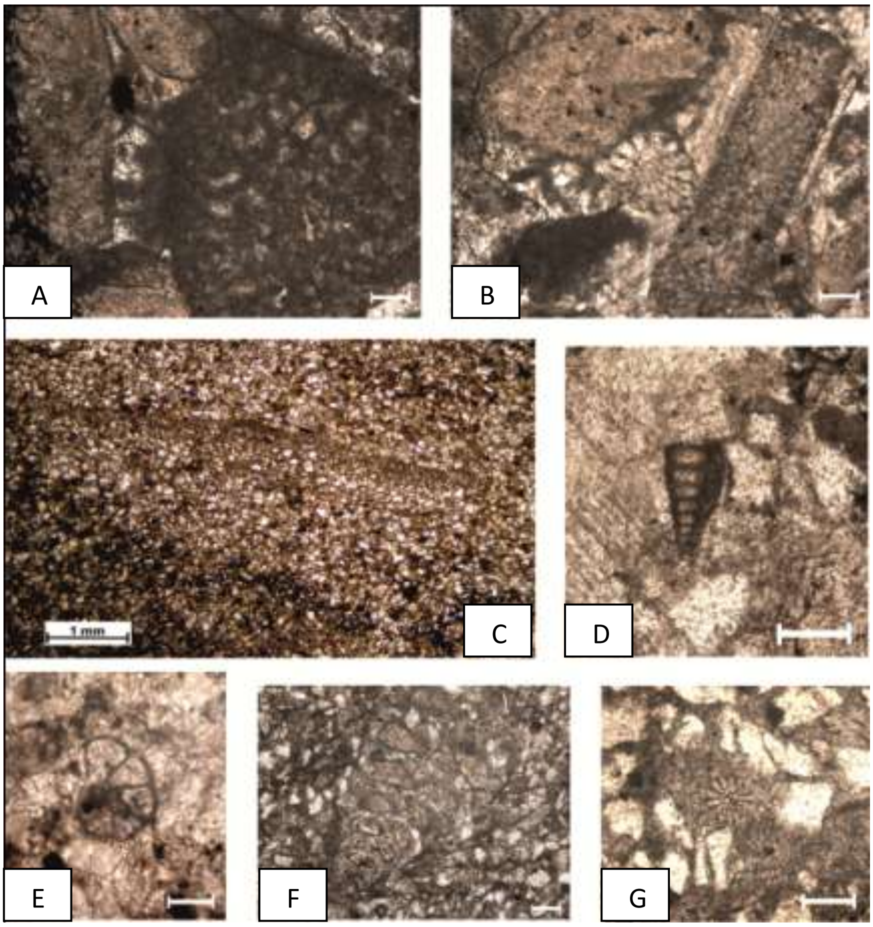

Figure 14. Microphotographs of the bentic foraminifera and algea from the İğneada-Limanköy Measured- Stratigraphic Section: A) *Orbitolina* sp., No.95-10, B) *Actinoporella* sp., No.95-10, C) *Orbitolina minuta*,No.97-10, D) Verneuillinidae, No.104-10, E) *Nezzazata* sp., No.112-10, F) *Gaudryna* sp., No.112-10. G) *Actinoporella* sp., No. 108-10, Scale Bar Is 100µm.

Sandstones with *Orbitolina*s pass upward conformably to thick-bedded, dark yellow colored, approximately of 50 m thick carbonated sandstones with thin-shelled bivalvia (fig. 13).

Some foraminifers and algea accompany the thin-shelled bivalvia (fig 14 D). Following species have been determined:

Orbitolina sp.

Actinoporella sp.

Verneuillinidae

Textulariidae

?*Rotalipora* sp.

planktic foraminifer fragments.

Sequence passes upward to approximately of 110 m thick, pelagic mudstones and alternation of sandy mudstones and sandstones (fig. 15, 16).

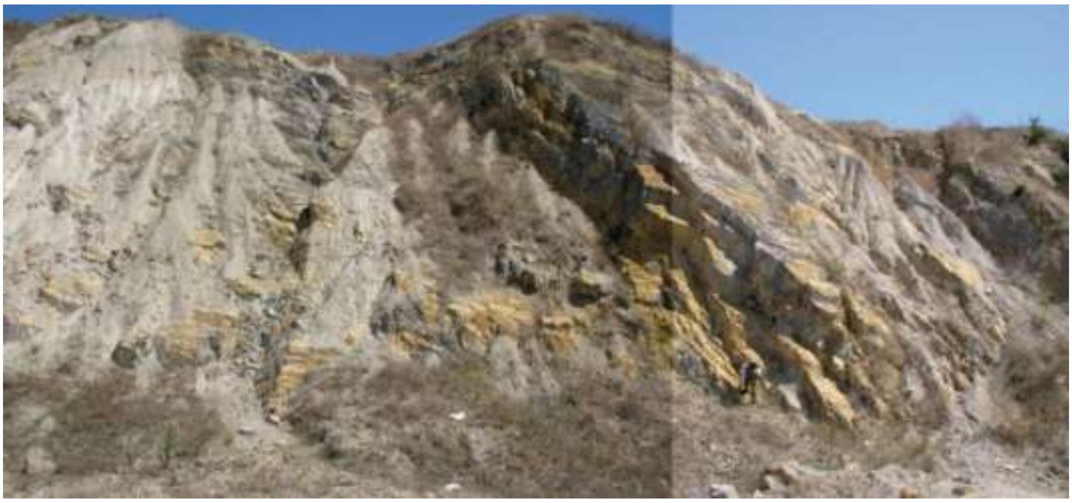

Figure 15. Field view of the pelagic mudstones (Coordinate: Zone 35, 585154/4638396).

Figure 16. Photo shows the alternation of the pelagic mudstones (m) and tuffs (t) (Coordinate: Zone 35, 585383/4638253).

The lower layers are generally blackish-grey colored, medium bedded, but the upper layers are bold greenish-grey and thinly to medium-bedded. Calcispheres are abundantly observed in this levels and also following planktic foraminifers have been determined:

Hedbergella sp.

Spiroplectammina sp.

Gaudryna sp.

?*Nezzazzata* sp.

?*Rotalipora* sp.

The uppermost levels of the sequence presents volcanoclastic character and consists of volcanic rocks (spilitic volcanics, agglomerates, basalts, tuffs) with the alternation of mudstones and wackestones (fig. 17, 18, 19, 20, 21, 22).


A


B

Figure 17. Field views of volcanic intercalated mudstone-wackestone alternation zone. A: Spilitic volcanics, B: Tuffs, C: Agglomerates, D: Alternation of Mudstones (m), Agglomerates (a) And Tuffs (t) (Coordinate: Zone 35, 585542/4638066).

Calcispheres are rare in these levels. Transported rudist shell fragments and benthonic foraminifers are also observed. Following planktic foraminifers have been determined in these levels (fig. 18, 19):

Globotruncana sp.

Hedbergella sp.

Marginotruncana sp.

Dicarinella sp.

Heterohelix sp.

Archaeoglobigerina sp.

?*Praeglobotruncana* sp.

Gaudryna sp.

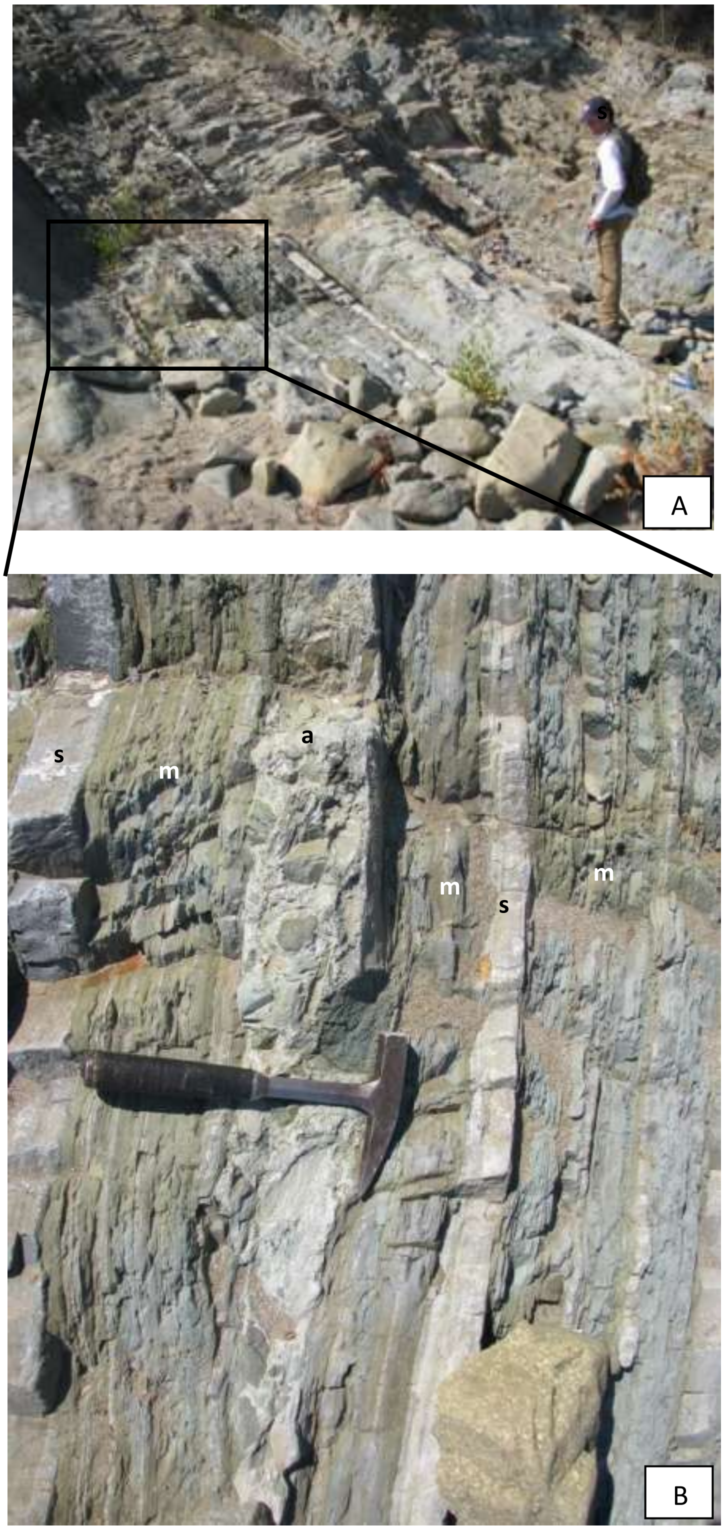

Figure 18. A: Field view of the alternation of sandstones, mudstones and agglomerates. B: Enlarge view the alternation of sandstone (s), mudstone (m) and agglomerate (a) (Coordinate: Zone 35, 585663/4637962).

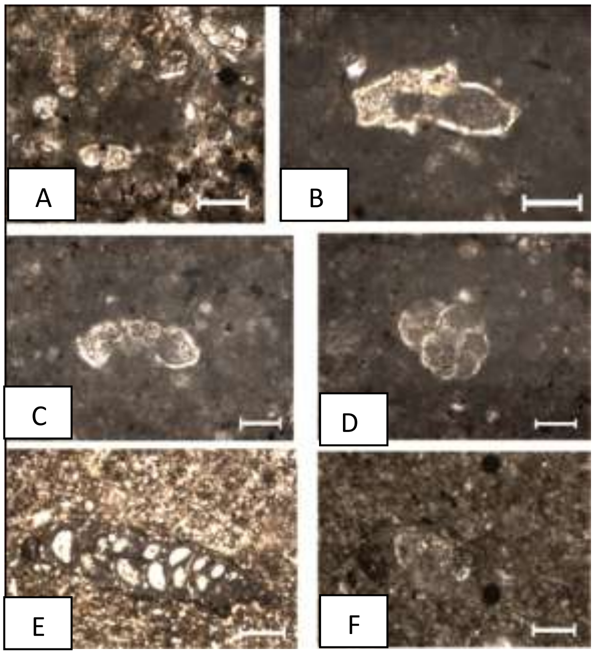

Figure 19. Microphotographs of the planktic foraminifers from the İğneada-Limanköy measured-stratigraphic section: A) Globotruncanidae, No. 118-10, B and C) *Dicerinella* sp.., No. 122-10, D) *Globotruncana* sp., No.122-10, E) *Gaudryna* sp., No. 125-10, F) *Globotruncana* sp., No. 125-10, Scale Bar Is 100µm

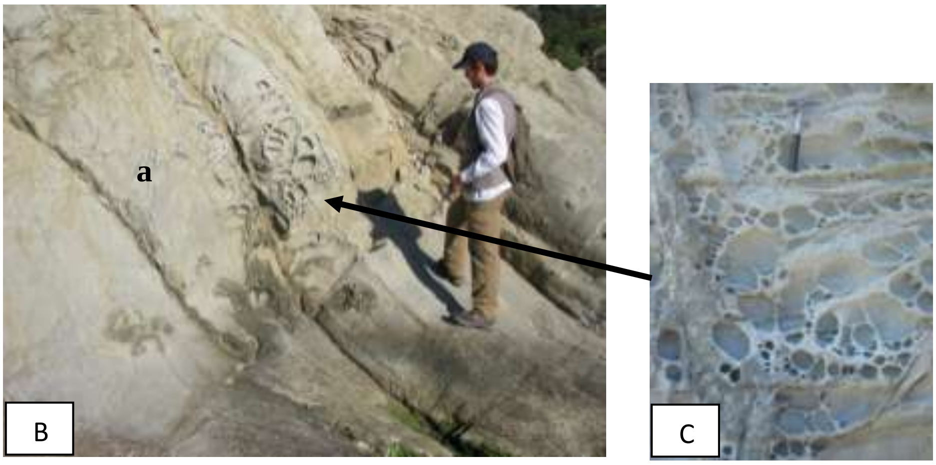

Figure 20. A: The alternation of mudstones (m), Tuffs (t) and agglomerates (a), B: Massive bedded agglomerates presenting solution surfaces (arrow) C: Enlarged view of the previous figure showing the subaqueous gas escape structures (Coordinate: Zone 35, 585663/4637962).

Figure 21. The uppermost levels of İğneada formation that consists of agglomerates (a), mudstones (m) and basalts (b) (Coordinate: Zone 35, 585729/4637868).

Figure 22. Field view of the columnar jointed of basalts (b) (Coordinate: Zone 35, 585735/4637870).

2.2.2. Sislioba area:

This area is located in the north of the İğneada, where *Orbitolina*-bearing sandstones rest by an unconformity over the metamorphic rocks. The sequence made up mainly of 60-70 m thick, well-bedded, reddish-pink sandstones, but conglomerates and pebbly sandstones are rarely observed (Fig. 23, 24).

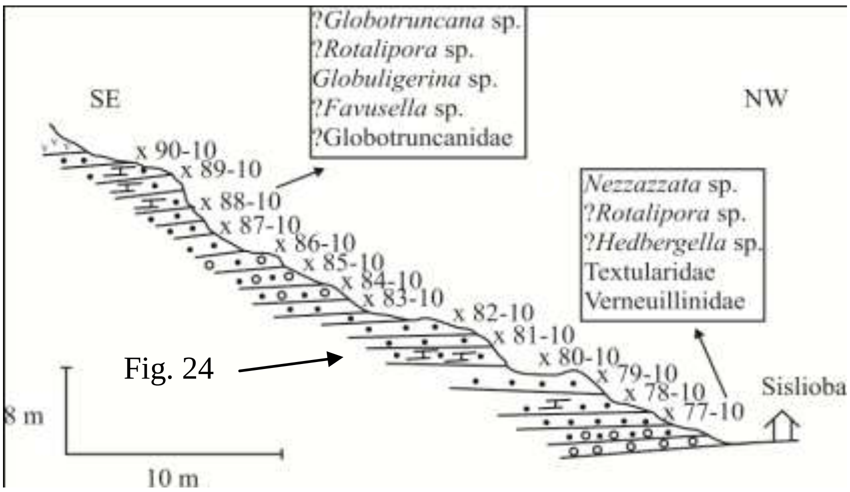

Figure 23. Sislioba measured-stratigraphic showing the distribution of foraminifera (starting point: Zone 35, 576049-4646855;finishing point: 576037-4646914).

Figure 24. Photo showing the medium bedded sandstones

of Sislioba Area (Coordinate: Zone 35, 576041- 4646878)

Although, the sandstones are poor about foraminifer content, following some benthonic and planktonic foraminifers can be determined in the lower levels of the section (fig. 25A):

Orbitolina sp.

Nezzazzata sp.

Textularidae

Verneuillinidae

?*Rotalipora* sp. or ?*Hedbergella* sp.

Planktonic foraminifers have been found in the uppermost levels of the sequence (fig. 25 B, C):

Globotruncanidae

?*Globotruncana* sp.

?*Rotalipora* sp.

Globuligerina sp.

?*Favusella* sp.

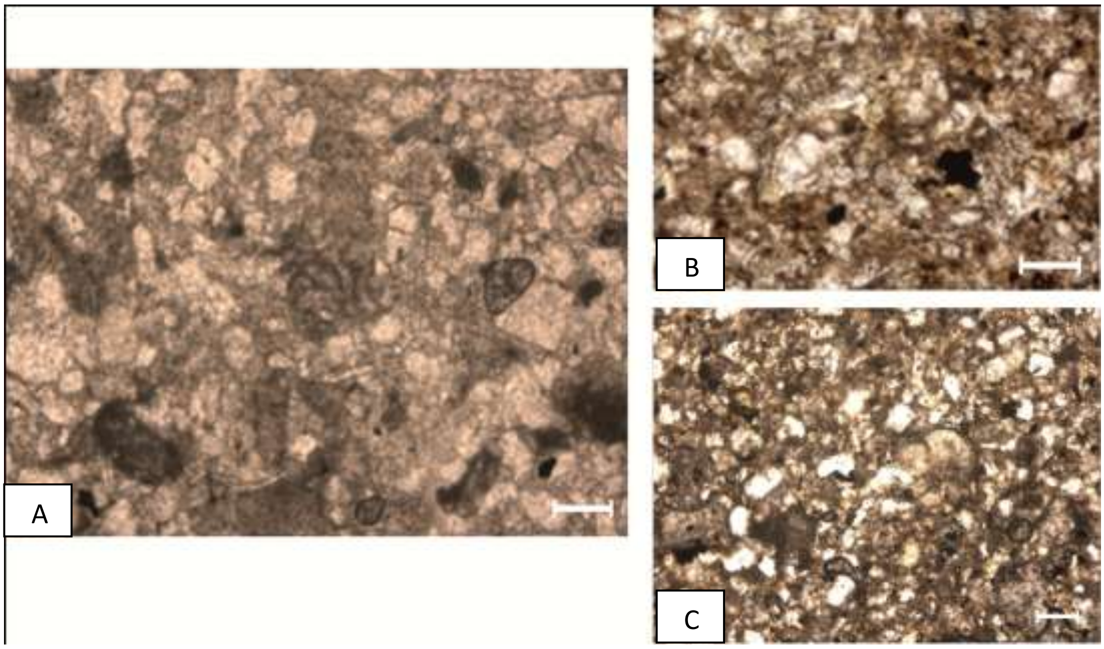

Figure 25. Benthonic and planktonic foraminifers from the Sislioba measured-stratigraphic section:

A) Textularidae, No.77-10, B)? *Rotalipora* sp., No. 88-10, C) ?*Favusella* sp., No. 88-10, scale bar is 100 µm.

2.2.3. Avcılar area:

The stratigraphic relation between Mahya and İğneada Formation is well-observed around Avcılar. İğneada Formation rests unconformably over the metamorphic schists (fig. 26, 27).

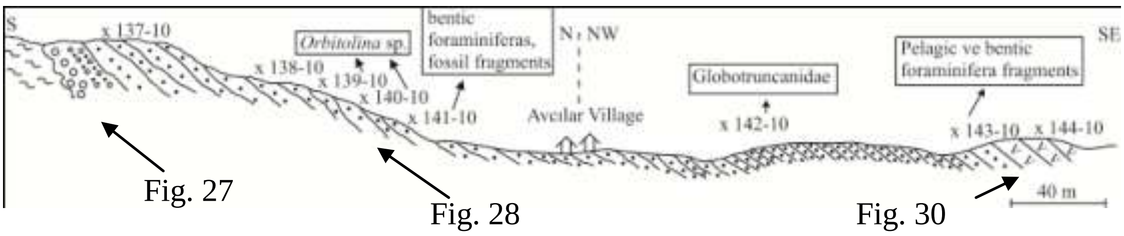

Figure 26. Avcılar measured-stratigraphic section showing the clear stratigraphic relation between the Mahya and İğneada Formation. Also the distributions of the fossil contents (Starting point: schist-conglomerate contact: Zone 35, 570013-4639242; finishing point: volcanic rocks: 571329-4638973).

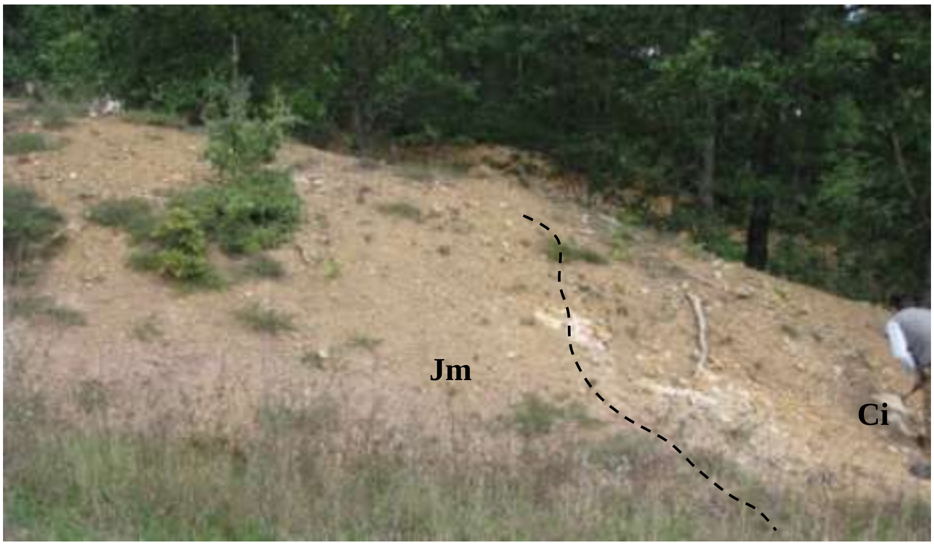

Figure 27. Field view of contact relationships between Mahya (Jm) and İğneada Formations (Ci) in Avcılar area (Coordinate: Zone 35, 570013/4639242).

The 1-2 m thick conglomerates are observed at the base of the formation. These levels pass upward to approximately 250 m thick, well-bedded, yellowish-grey sandstones (fig 28.). The sandstones are poor on fossil contents, however some benthonic foraminifers such as *Orbitolina* sp. and benthonic foraminifer fragments and undertermined foraminifer fragments have been determined towards the upper levels of the sandstones (fig. 29).

Figure 28. Photo shows the medium to thinny bedded sandstones with *Orbitolina*s (Coordinate: Zone 35, 570130/4639273).

The sandstones pass upward to pelagic mudstones within some Globotruncanidae and also pelagic and benthic foraminifer fragments can be observed . The volcanic rocks are observed in the uppermost part of the section (fig. 30).

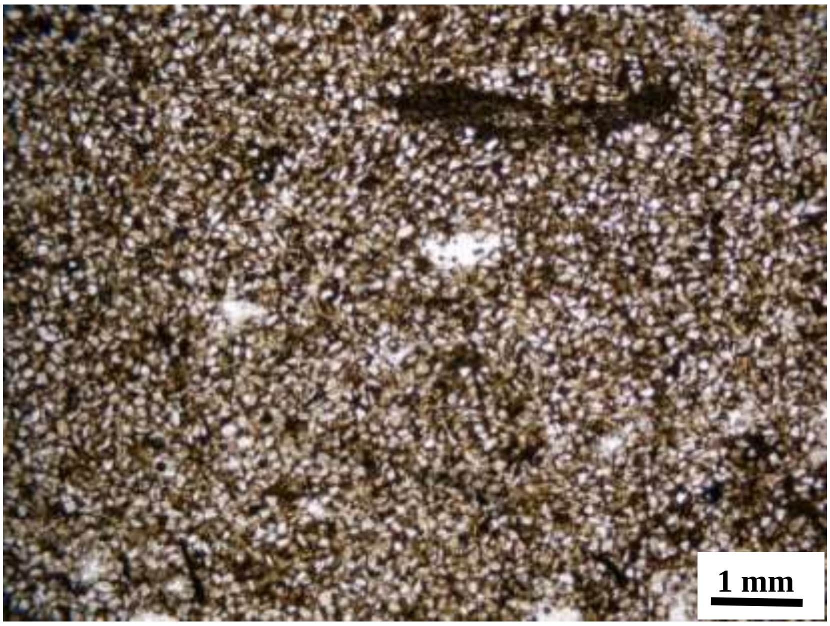

Figure 29. Thin section shows the presence of the *Orbitolina*s In the Avcılar sandstone, sample no.139-10.

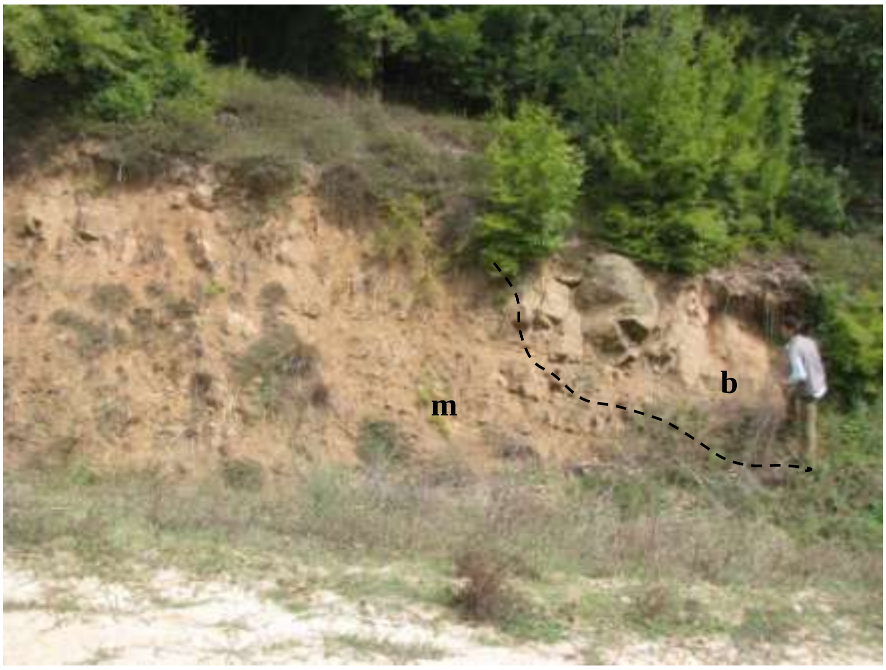

Figure 30. Photo shows the contact relationships between mudstones (m) and basalts (b) (Coordinate: Zone 35, 571329/4638973).

2.3 Age and discussion

Pamir and Baykal (1947) was suggested a Cenomanian age for the Orbitolina-bearing sandstones. The equilevant levels of these sandstones throught the Bulgaria was accepted as the Cenomanian age (Chatalov, 1988). Çağlayan & Yurtsever (1998), Alaybeyoğlu (1988) and Okay et al. (2001) apply also the Cenomanian age for the bottom levels of the İğneada Formation. But, our study reveals that the presence of diagnostic Orbitolina species indicating Albian age.

The rudists have not been determined until today in the İğneada Formation. The rudist determinations give also the Albian (probably middle) age for the rudist-bearing levels, which conformable with that of Orbitolina-bearing sandstones. There is some minor paleontological data until today about the pelagic mudstones interclated with the volcanic rocks of the succession. The Late Cretaceous age was generally accepted in the previous studies for these levels (Pamir & Baykal, 1947; Çağlayan & Yurtsever, 1988; Alaybeyoğlu, 1988; Okay et al., 2001). The presence of the Maastrichtian shallow-marine limestones in the uppermostpart of the sequence was also announced by Okay et al. (2001). However, the planktonic foraminifers, which are firstly determined in this study, suggest a mainly Cenomanian-Turonian and probably Coniacian age. This indicates that the Upper Cretaceous is partly represented in the region in contrary the previous informations.

CHAPTER THREE

FACIES AND DEPOSITIONAL SETTING

3.1 Introdution

Seventy-three thin samples collected from the volcanosedimentary successions of the strandja masif. They have been analysed to reveal the depositional enviroments. The limestones are based in the classification of Dunham (1962) and Embry Klovan (1971). The sandstones are based in the classification of Folk (1954) and Dott (1964).

3.2 Facies

As a conclusion of the field observations and thin sections analysis, seven microfacies types are distinguished as follows:

3.2.1 Microfacies -1. Conglomerate-litharenite

This facies is determined by field observation and thin section analysis. It consists of conglomerates, pebbly sandstones and observe generally in the Avcılar and Sislioba section. The lithology indicates that the high energy is dominated during the sedimentation. The gravels such as schists and marbles derived from the basement rocks are generally observed in this facies (Fig. 31A). The pebbles are medium to well rounded. Sorting is fine and grain supported texture is observed. No fossil content have been spotted. Upper level of this microfacies contains pebbles decrease to sand size and it graduate to uppermost levels to sandstones. Lithic sandstones have been determined because of the more than %50 of clastics are lithic rock fragments (Fig. 31B).

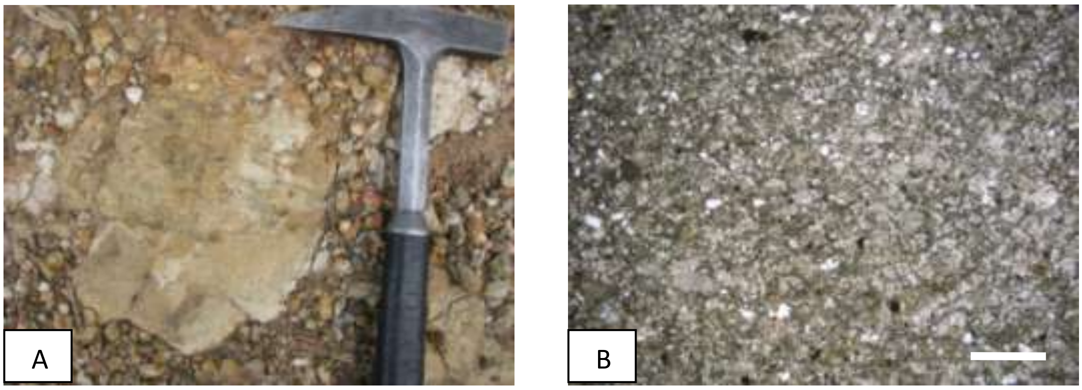

Figure 31. Conglomerate-litarenite microfacies (A: close up field photo of Conglomerates, Avcılar area (Coordinates: Zone 35, 570013-4639242) B: Uppermost levels of the facies that made of litharenite. Sample no:137-10, Scale bar is 1 mm.).

3.2.2 Microfacies type-2. Rudist shell fragments-bearing bioclastic packstone-wackestone

This microfacies is represented with of bioclastic packstone and wackestone. In the lower levels high energy dynamics controls the sedimentation. Grain supported texture and sparry calcite cement are observed in some parts in the thin sections but dominantly contains micrite matrix. (Fig. 32 A, B). Rudist fragments relatively smaller than upper levels. Upper levels of this facies, rudist shell fragments size became bigger straight to upward and micritic cement is exists (Fig. 32 C, D). This incident proves that the energy has been decreased. Benthonic foraminifera fragments, bivaliva fragments, stilolites and micritic envelopes are also observed.

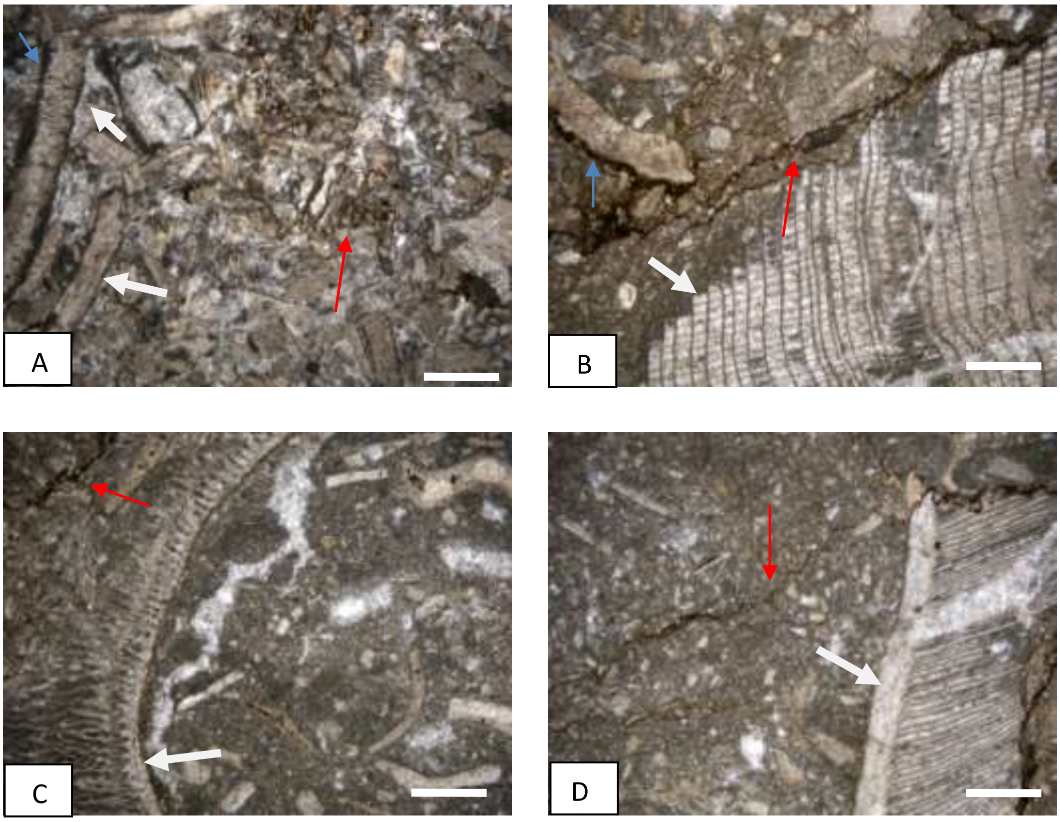

Figure 32. Rudist shell fragments-bearing bioclastic packstone-wackestone microfacies (A: white arrows indicate rudist shell fragments, red arrow stylolite and blue arrows micritic envelopes in all microphotos. Sample no: 95-10. B: typical packstone microfacies can be observed at the left top corner of the microphoto. A large rudist (radiolitid) fragment is observed at the right bottom corner. Sample no: 95-10. C: Bivalvia fragments and a large rudist fragment observed together in micrite matrix. Sample no: 96-10 D: black arrow shows Rudist shell and red arrow indicates stylolite. Sample no: 96-10. Scale bar is 1 mm.).

3.2.3 Microfacies type-3. *Orbitolina*-bearing litharenite

This facies is made of lithic rock clastics, quartz, carbonate and *Orbitolina* fragments (fig. 33 A, B). The sandstones are generally fine to coarse grained, moderate rounded and well-sorted. Calcite and iron oxide cements are observed in the fractures**.** *Orbitolina*s were protected in the facies because of relatively lower energy and the grains in the sandstones have similar hardness. Otherwise grains will have rubbed themselves then friction causes that the calcite shelled organism have lost their main structural features.

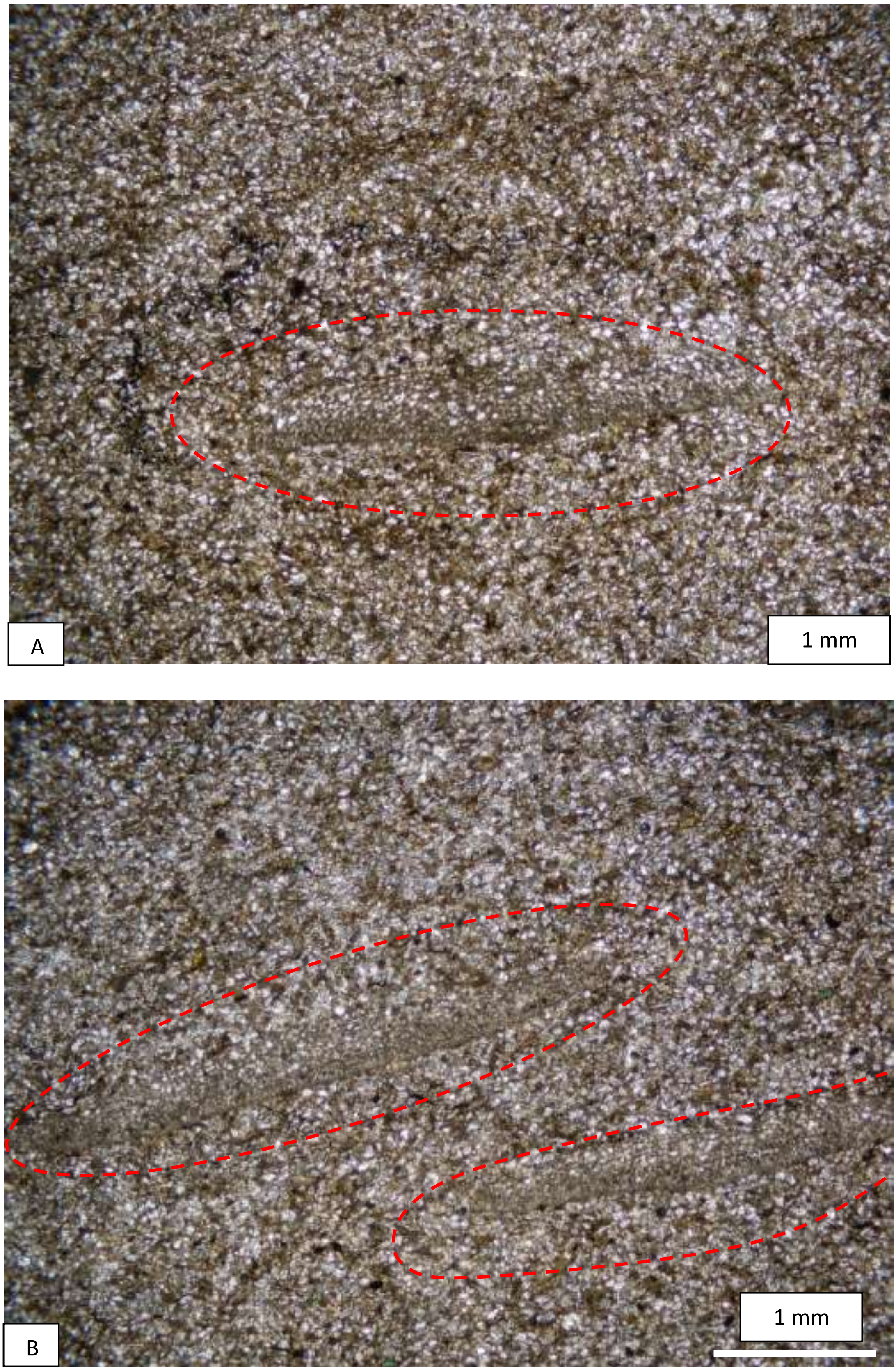

Figure 33. A, B: *Orbitolina*-bearing litharenite microfacies (Red dashed circles indicate the *Orbitolina*s in the litharenite microfacies. A: Sample no: 97-10 and B: Sample no: 99-10)

3.2.4 Microfacies type-4. Carbonate cemented litharenite with thin shell fragments

This facies is mainly distinguished from *Orbitolina*-bearing sandstone microfacies by its rich thin-shelled bivalvia fragments and cement material. According to thin section analysis, carbonate cement and also thin shelled fragments are observed. Clastic inputs consist of quartz and lithic rock fragments. Grain supported texture determined and the grains represent well sorting and medium rounding (fig. 34).

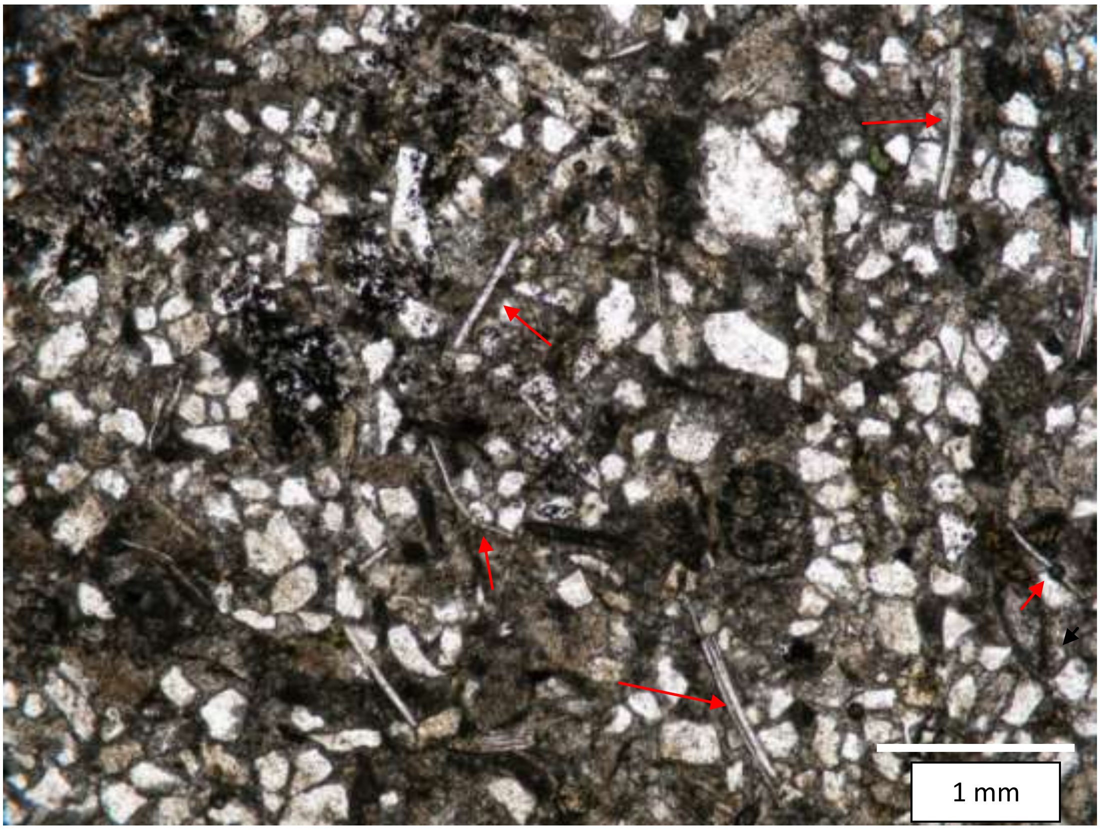

Figure 34. Carbonate cemented litharenite with thin shell fragments microfacies (Thin shell fragments are indicated with red arrows. Sample no: 107-10).

3.2.5 Microfacies type-5. Pelagic mudstone and lithic wackestone

This microfacies consists of alternating pelagic mudstone and muddy sandstone. Fine-grained lithic rock clastics and rare planktonic fossil fragments observed in pelagic mudstone levels and muddy sandstone dominantly composed of fine sorted and well rounded thin sand grains with the contribution of silt and clay sized clastic.

Features of the sequence indicate a transition zone between shallow and deep marine condition. Grains size represent variability due to periodic energy fluctuation (fig. 35).

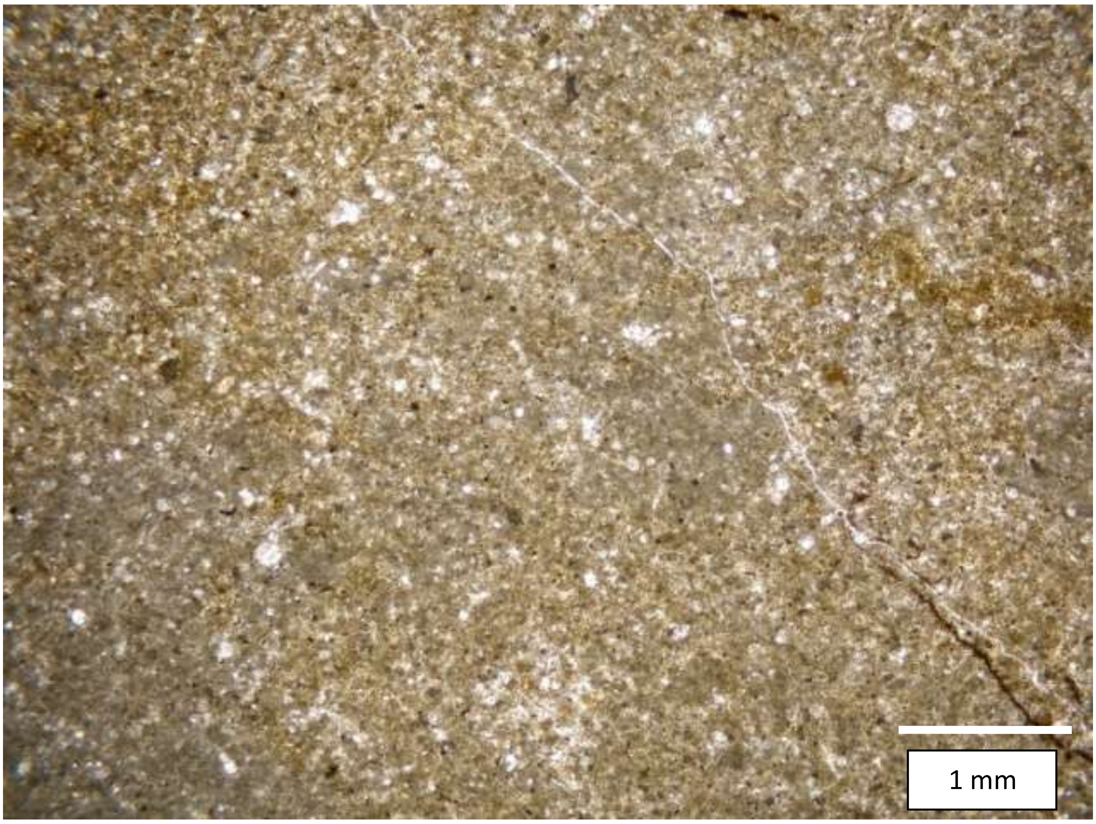

Figure 35. Pelagic mudstone and lithic wackestone microfacies (Mud matrix with micro calcite cement and silt sized materials are main components of this facies. Sample no: 118-10).

3.2.6 Microfacies type-6. Planktonic foraminifera and calcispheres-bearing wackestone

Commonly micro calcite and recognizable pelagic fossils signify this facies. Planktonic foraminifera and calcisphere presence in micrite matrix is an evidence of the pelagic marine conditions. By the decreased of energy, facies enables to develop micritic depositional settings (fig. 36).

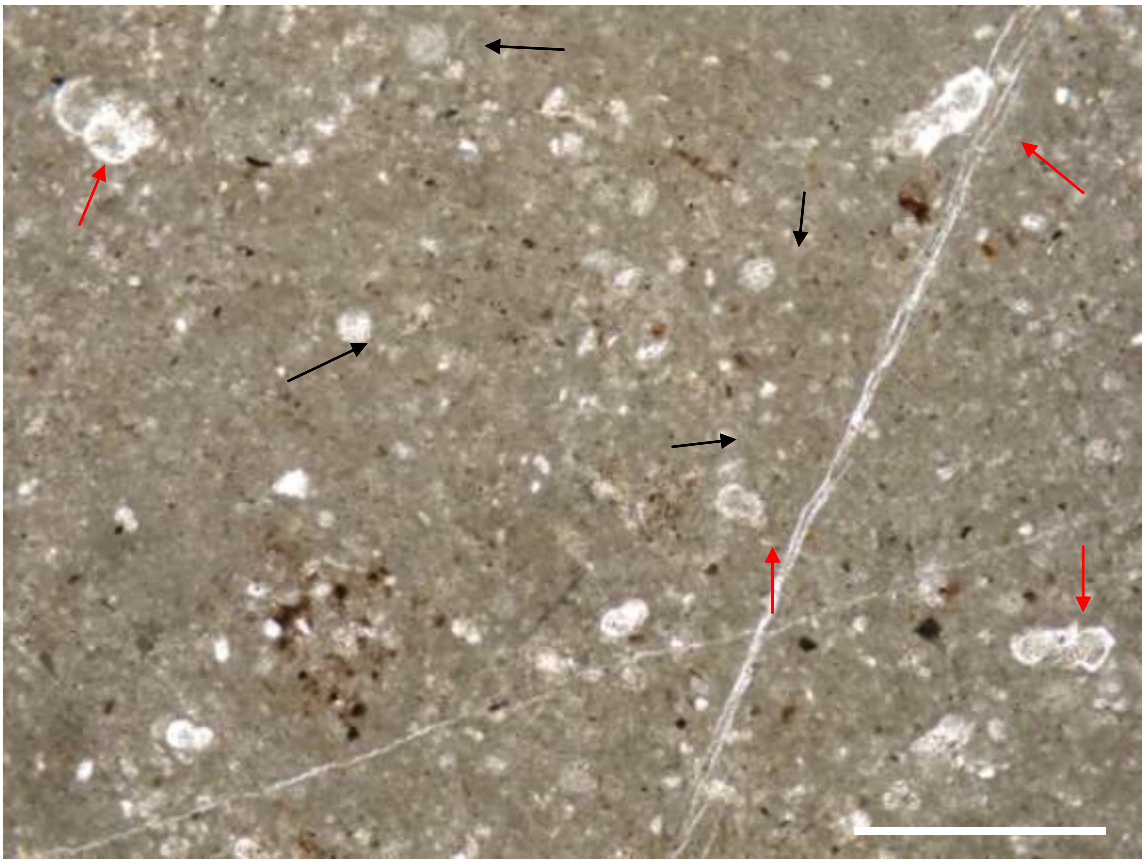

Figure 36. Planktonic foraminifera and calcispheres-bearing wackestone microfacies (Red arrows indicate planktonic foraminifera and black arrows show calcispheres in microphoto. Sample no: 122-10. Scale bar is 1 mm.).

3.2.7 Microfacies type-7. Volcanic intercalated mudstone and wackestone alternation

Alternation of mudstone and wackestone basically make up the frame of this facies. Volcanic intercalations are respective that distinguish it from others. Agglomerates, tuffs, spilitic volcanic and basalts are the main volcanic rocks. By the careful investigations on the field study, thin laminated mudstones which also can be called as shales have been observed. This data reveals the space that inditaces non-volcanic activity period. Also planktonic foraminifera have been determined in the thin section of this levels and it proves the pelagic conditions (fig. 37 A, B, C).

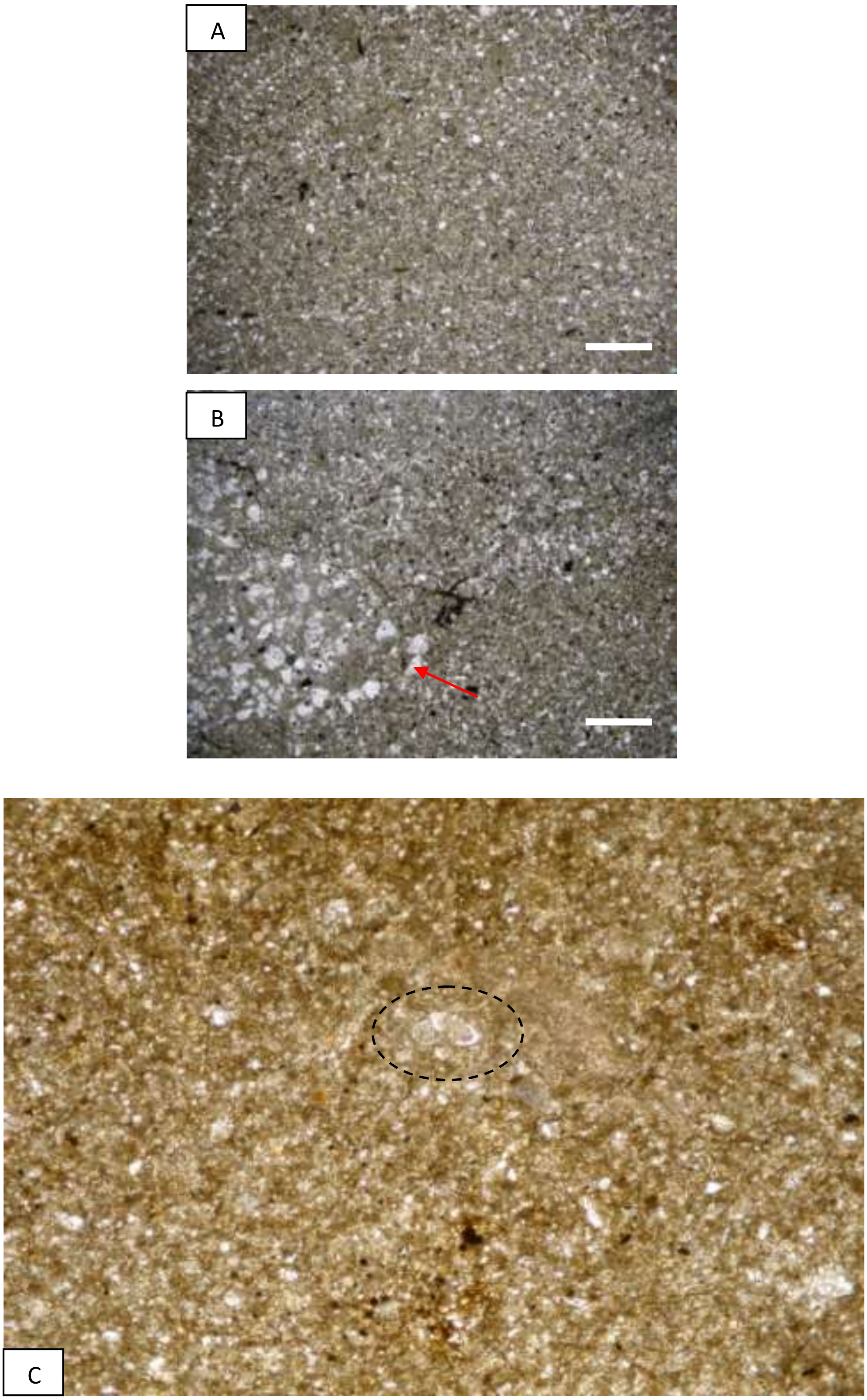

Figure 37. A, B, C: Volcanic intercalated alternation of mudstone and wackestone microfacies (A: Microphoto from wackestone. Sample no: 130-10 ,B: Volcanic material inputs shown by red arrows. Sample no: 130-10 ,C: Black dashed circle indicates the planktonic foraminifers. Sample no: 131-10. Scale bar is 1 mm.).

3.3 Depositional setting

The volcanosedimentary sequence of the Strandja Zone was deposited in an intra-arc basin, together with its western continuation of the Srednogorie Zone, above the northward-subduction Vardar-Intra-Pontide ocean (Chatolov, 1988; Okay et al., 1994, 2001).

The lithologic and sedimentologic features show that the volcano-sedimentary sequence of the Strandja Zone started to develope on the low relief of the carbonate ramp characterizing by the alluvial and sea-shore clastics grading to shallow marine limestones and low energy basinal mudstones supported by volcanic rocks (fig. 38).

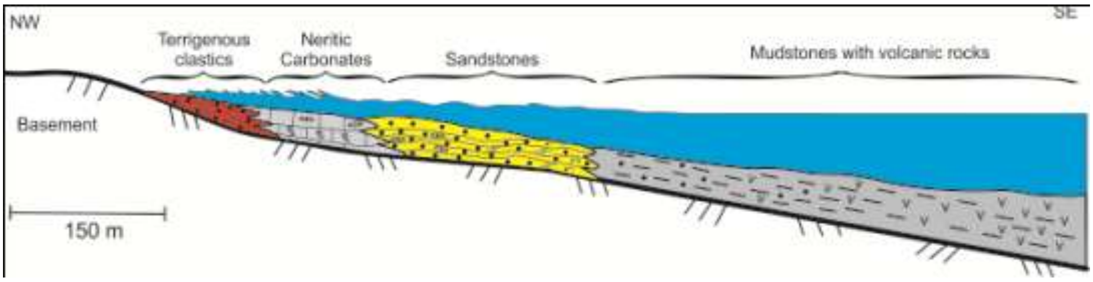

Figure 38. Depositional model of İğneada volcano-sedimentary sequence.

The field observations indicate that the base of the sedimentation show three different types as follows: In Avcılar area; the clastic input from terrestrial zone is extensive (Fig. 31A). The pebbles are well-rounded indicating that the high energy conditions were dominant during the begining of the sedimentation. The microfacies data are also support this interpretation. The similar observations are also observed in the Sislioba area. Only, the size of clastic inputs show difference features when compared with those of Avcılar area. The sand sized clastics are dominant and the pebbles coarser than the pebbles of the Avcılar area (Fig. 31). This texture indicates that the modarate energy conditions were developed in the Sislioba area supporting by the microfacies characters (Fig. 31B). The volcano-sedimentary sequence starts in the Limanköy area with a few centimeters of conglomerates and sandstones, but dominantly the rudist-bearing limestones (Fig. 12), which are not observed in the other two areas as indicated above. The presence of the rudist-bearing neritic limestones indicate the development of the shallow-marine conditions in the carbonate platform. The fragmentation of the rudist shells and diagenetic features (Fig.32) indicate the high to moderate energy conditions. The clastics and neritic limestones pass upward to *Orbitolina*-bearing sandstones marking the persistence of the shallow-marine conditions during the deposition of the Lower Cretaceous sequence in the carbonate ramp platform (Figs. 10, 13, 14, 33). However, the limited development of the neritic limestones shows the continuation of clastic supporting from the source area. The *Orbitolina*-bearing sandstones pass upward the sandstones with thin-shelled bivalvia and pelagic mudstones indicating the development of the low energy conditions in the platform (Figs. 13, 15, 34). The thickening of the pelagic mudstones towards the upperpart of the sequnce show the persistence of the low energy basinal conditions and also deepening and so drowning of the carbonate platform (Figs. 15, 16, 35, 36). Due to the submarine volcanic activity, this basin was filled by the volcanic rocks interclated with the pelagic sediments (Figs. 16, 35).

The carbonate-platform sequences are very limited in the Strandja zone because of the intense volcanic activity and/or rapid subsidence inhibiting the carbonate sedimantation and the steep bathymetric profiles of the basin resulting the little available substrate for shallow-marine carbonate sedimantation (Özer, 2010). The absence of the shallow-marine carbonates in the Srednogorie Zone-Bulgaria (Chatolov, 1988), which is the western continuation of the Strandja Zone, may be support this assumption.

The volcanic activity is well-known through the İstanbul Zone and especially central to eastern Pontides during the Late Cretaceous (Okay & Tüysüz, 1999; Okay et al., 2001; Özer et al., 2010). But, the Lower Cretaceous neritic sediments of the Strandja zone related with the Upper Cretaceous volcanic activity, can not be observed in the İstanbul Zone and Pontides. Although, the carbonate ramp platform modele was suggested by Özer et al. (2010) and Özer (2010) for the İstanbul Zone, where the basement of the sequence start with latest Campanian clastics and rudist-bearing limestones (Özer et al., 1999; Özer, 2010).

CHAPTER FOUR

CONCLUSIONS AND DISCUSSIONS

- The stratigraphy and facies characteristics of the volcano-sedimentary sequence (İğneada Formation) were studied in three areas of the Strandja Zone such as Limanköy, Avcılar and Sisilioba and following results are obtained and discussed:

- The previous studies suggest a Late Cretaceous age for the volcano-sedimentary sequence outcropping in the Strandja Zone. However, the rudist and *Orbitolina* determinations from the base section of the sequence indicate an Albian (Early Cretaceous) age for the İğneada Formation, which was firstly founded in this study.

- Although the previous studies accept a Late Cretaceous age for the volcano-sedimentary sequence according to the limited paleontologic data, our detailed stratigraphic observations and rock samples from the measured-stratigraphic sections reveal that the middle and upper parts of the İğneada Formation consists of planktonic foraminifers indicating a Cenomanian-?Coniacian age.

- The İğneada Formation rests unconformably over the metamorphic rocks of the Mahya Formation and consist of, from bottom to top, conglemarates, sandstones, rudist-bearing limestones, sandstones rich-in *Orbitolina*, sandstones with thin-shelled bivalvia, mudstones with planktonic foraminifera and the alternation of the divers volcanic rocks such as andesitic tuffs, agglomerates, spilitic lavas and basalts with pelagic mudstones.

- Total of 1050 m thick three stratigraphic sections were measured. The field observations show that the thickness of the İğneada Formation is about 600 m. The previous studies suggest 500 meter thickness for this formation

- In the Limanköy area the İğneada Formation starts with very limited thickness of conglemerates but especially with rudist-bearing neritic limestones, however in the Avcılar and Sislioba areas the base of the formation consists of conglomerates and sandstones without neritic limestones.

- According to macro and microfacies studies of the formation, which is firstly described in this study, seven microfacies types were distinguished. These were: Conglomerate-Litharenite, Rudist fragments-bearing packstone-wackestone, Orbitolina-bearing litharenite, Carbonate cemented litharenite with thin shell fragments, Pelagic mudstone – lithic wackestone, Planktonic foraminifera and calcisphere-bearing wackestone, volcanic intarcalated alternation of mudstone and wackestone.

- The field observations and the facies studies allow us to create a depositional model for the volcano-sedimentary sequence in the Strandja Zone. The sequence was started to develope on the low relief of the carbonate ramp characterizing by the alluvial, fluvial and sea-shore high-energy clastics grading to shallow marine limestones and sandstones and upward to low energy basinal mudstones supported by volcanic rocks. The shallow-marine carbonates are very limitly developed on the platform because of the intense clastics supports from the source area, pelagic sedimentation accompaying with submarine volcanic activity and rapide subsidence indicating the presence a carbonate ramp characteristics and finally deepening and so drowning of the carbonate platform.

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