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MICROFACIES ANALYSIS OF LOWER AND MIDDLE EOCENE CARBONATE ROCKS IN THE EAST OF LAKE VAN (TURKEY)

VAN GÖLÜ (TÜRKİYE) DOĞUSUNDAKİ ALT VE ORTA EOSEN YAŞLI KARBONATLI KAYAÇLARIN MİKROFASİYES ANALİZİ

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ABSTRACT

A detailed study on the microfacies and depositional environments of Lower and Middle Eocene sedimentary rocks outcrop in Van Province (Turkey) were conducted. The investigation was based on sixty five samples collected from three stratigraphic sections and included Toprakkale and Yücelendere formations. These rock units are composed of carbonate rocks. The petrographic study of thin sections have been carried out to investigate their microfacies and depositional environments. The rocks are generally biomicrite. According to the characteristics of carbonate rock samples five microfacies were determined. These are; 1) Wackestone with *Globigerina* and *Acarinina* microfacies, 2) Wackestone-Packstone with *Globigerina* and *Acarinina* microfacies, 3) Packstone-Grainstone with *Globigerina* and *Acarinina* microfacies. 4) Grainstone with *Milioliidae* and Red Algae microfacies. 5) Packstone with *Nummulites* and Red Algae microfacies. These microfacies indicate that Lower-Middle Eocene rocks were formed in depositional environments ranging from shelf lagoon to deep marine. These differences in depositional environments have been interpreted as the result of changes in water level in relation to transgression and regression events.

Keywords: Carbonate Rocks, Eocene, Microfacies, Turkey, Van.

ÖZ

Van İli'nde (Türkiye) yüzeyleyen Alt ve Orta Eosen yaşlı sedimanter kayaçların mikrofasiyesleri ve çökelme ortamları hakkında ayrıntılı bir çalışma yapılmıştır. Çalışma, Toprakkale ve Yücelendere formasyonlarında ölçülen üç stratigrafi kesiti boyunca toplanan altmış beş örnek üzerinde gerçekleştirilmiştir. Bu kaya birimleri karbonatlı kayaçlardan oluşmaktadır. Bunların mikrofasiyeslerini ve çökelme ortamlarını belirlemek amacıyla ince kesitler üzerinde petrografi çalışması yapılmıştır. Kayaçlar çoğunlukla biyomikrittir. Karbonatlı kayaç örneklerinin özelliklerine göre beş mikrofasiyes belirlenmiştir. Bunlar; 1) Globigerina ve Acarinina'lı vaketaşı mikrofasiyesi, 2) Globigerina ve Acarinina'lı vaketaşı-istiftaşı mikrofasiyesi, 3) Globigerina ve Acarinina'lı istiftaşı-tanetaşı mikrofasiyesi, 4) Milioliidae ve Kırmızı Algli tanetaşı mikrofasiyesi, 5) Nummulites ve Kırmızı Algli istiftaşı mikrofasiyesidir. Bu mikrofasiyesler, Alt-Orta Eosen yaşlı karbonatlı kayaçların şelf lagününden derin denize kadar değişen ortamlarda oluştuklarını göstermektedir. Çökelme ortamlarındaki bu farklılıkların transgresyon ve regresyon olaylarıyla ilişkili olarak su seviyesindeki değişimlerin sonucu olduğu yorumu yapılmıştır.

Anahtar Kelimeler: Eosen, Karbonatlı kayaçlar, Mikrofasiyes, Türkiye, Van.

1. INTRODUCTION

Carbonate sedimentary rocks make up nearly 25 percent of all sedimentary rocks in the geologic record. They are present in many Precambrian assemblages and in all geologic systems from the Cambrian to the Quaternary. Precambrian and Paleozoic carbonate successions include abundant dolomite, whereas Mesozoic and Cenozoic carbonates are mainly limestone. Limestones contain richly varied textures, structures, and fossils that yield important information about ancient marine environments, paleoecological conditions, and the evolution of life forms, particularly marine organisms, through time. Carbonate sedimentary rocks are also an economically important group of rocks because limestones and dolomites are useful for agricultural and industrial purposes, they make good building stones, and, most important, they act as reservoir rocks for more than one-third of the world's petroleum reserves. Because of their environmental and economic significance, they have been extensively studied and their mineralogy, chemistry, and textural characteristics are described in hundreds of research papers (Boggs, 2006).

First definitions of "microfacies" were originally coined by Brown (1943) and again independently by Cuvillier (1952) shortly as "petrographic and paleontological criteria analyzed in thin-sections". Today, microfacies is regarded as the total of all sedimentological and paleontological data which can be described and classified from thin sections, peels, polished slabs or rock samples (Flügel, 2004; After Sarıaslan, 2017).

The study area is in the near eastern onshore section of Lake Van included in the East Anatolian Plateau (Fig.1). The East Anatolian Plateau is a portion of the Arabia-Eurasia collision zone where the mean elevation is about 2 km (Zor et al., 2003). The modern Anatolian–African plate boundary is represented by a north-dipping subduction zone that has been part of a broad domain of regional convergence between Eurasia and Afro–Arabia since the latest Mesozoic. A series of collisions between Gondwana-derived ribbon continents and trench-roll-back systems in the Tethyan realm produced nearly East–West trending, subparallel mountain belts with high elevation and thick orogenic crust in this region (Dilek & Sandvol, 2009). The collision between Anatolian and Arabian plates led to severe tectonism starting from Miocene. Hence, allochthon rock units having tectonic contacts and in different ages and sizes, which they lose their primary stratigraphical positions because of tectonic movements during before and after Miocene, are exposed around Van (Sümengen, 2008).

In this study, two lithostratigraphic units which were aged as Lower-Middle Eocene in previous studies (Acarlar et al., 1991; Baykal, 2003; Sümengen, 2008) were studied. These are Toprakkale Formation and Yücelendere Formation.

Toprakkale Formation is named by Acarlar et al. (1991). The unit corresponds to Seske formation defined by Balkaş et al. (1980). Toprakkale formation is composed of limestones which cream, sometimes gray in color, massive or thick-bedded, brecciated in some places. The unit is rich in fossils and contains dolomitic limestones. The lower and upper relations are tectonic and the thickness of the unit is 1500 m (Acarlar et al. 1991). The age of formation was accepted as Late Paleocene - Early Eocene according to *Miscellanea cf, miscella d Archiac - Haume, Anatoliella özalpiensis Sirel, Dictyokathnia vanica Sirel, Miscellanea* sp., *Dictyokathina* sp., *Eponides* sp., *Discocyclina* sp., *Alveolina* sp. fossils (Acarlar et al., 1991). Baykal (2003) also determined benthic foraminifera (*Coskinolina (Coskinon) rajkae* Hottinger and Drobne, *Fallotella (Fallotella) kochanskae persica* Hottinger and Drobne, *Karsella hottingeri* Sirel, *Idalina sinjarica* Grimsdale, *Glomalveolina primaeva* Reichel, *Glomalveolina pilula* Hottinger and Drobne, *Hottingerina anatolica* Sirel, *Missisippina binkhorsti* Reuss, *Pseudocuvillierina sireli* İnan, *Kathina selveri* Smout, *Sakesaria dukhani* Smout, *Smoutina subsphaerica* Sirel, *Soriella bitlisica* Sirel, *Assilina aff. Yuvettae* Schaub, *Ranikothalia cf. Sindensis* Davies, *Textularia* sp., *Valvulina* sp., *Glomalveolina* sp., *Spirolina* sp., *Valvulina* sp., *Eponides* sp., *Laffitteina* sp., *Rotalia* sp., *Smoutina* sp., *Miscellanea* sp., *Assilina* sp.,

Operculina sp., *Ranikothalia* sp., *Discocyclina* sp., *Anomalina* sp.) and algae species (*Ethelia alba* Pfender , *Distichoplax biserialis* Dietrich) which give Tanetian (Late Paleocene) age.

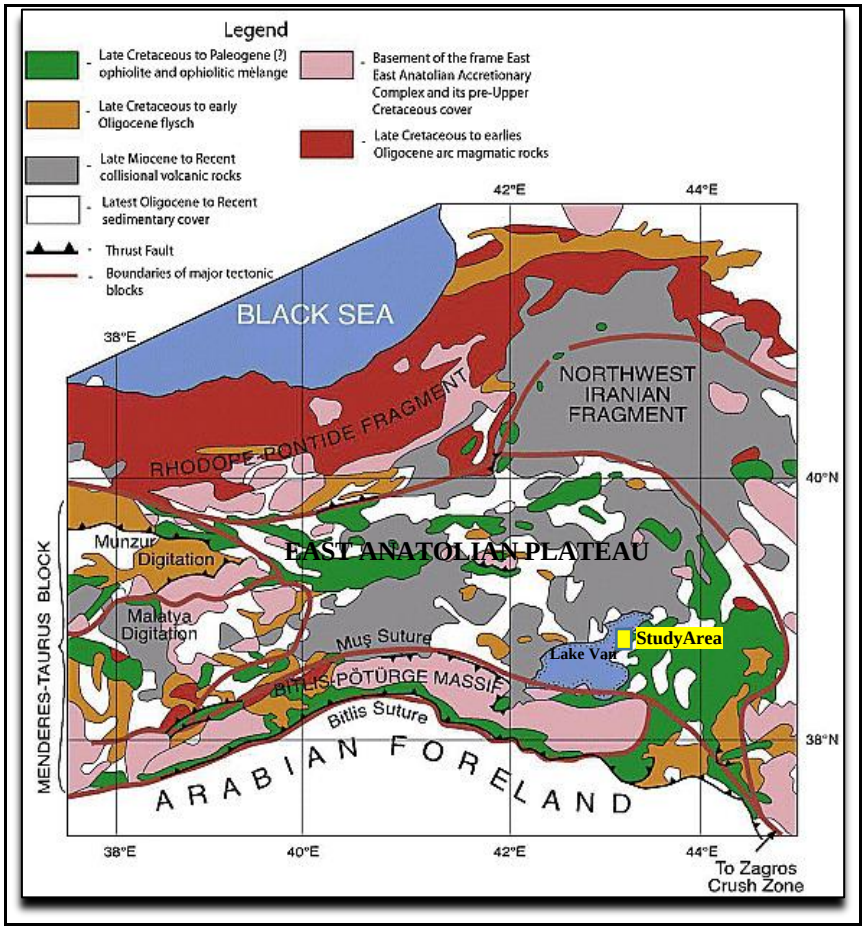

Figure 1. The geology of East Anatolian Plateau (Modified from Şengör et al., 2003.) and location of study area.

Toprakkale Formation outcrops in Şahbağ Hill, near Kalecik Village and east of Alabayır Village in the study area.

Yücelendere Formation, which is composed of clastic and carbonate rocks, is named by Şenel et al. (1984) in east of Özalp (Van). This formation corresponds, in part, to Tekmal formation which is defined by Acarlar et al. (1991). The formation generally consists of reddish, yellowish colored pelagic/semi-pelagic limestone, fine-bedded and fine-grained turbiditic sandstone, mudstone and marl alternation. In addition, poorly sorted conglomerate and cherty limestone levels are observed in the unit. The formation tectonically overlies the Oligo-Miocene Van formation around Alabayır and Tekmal. Çobanoğlu formation is transitional above the formation. Şenel et al. (1984) give Lutetian (Middle Eocene) age to Yücelendere Formation. According to the fossil content (*Globorotalia* sp., *Globigerina* sp., *Discocyclina* sp., *Anomalina* sp., *Globigerinidae*, *Rotalidae*, *Textularidae*), Tekmal Formation was aged as Early - Middle Eocene (Acarlar et al., 1991). Baykal (2003) determined planktonic foraminifera of Early–Middle Eocene (*Planoratalites Pseudomenardii* Bolli , *Turborotalia cerroozolensis cerroazolensis* Cole, *Acarinina bulbrooki* Bolli, *Morozovella angulate* White, *Morozovella* gr. *velascoensis* Cushman, *Morozovella gracilis* Bolli, *Morozovella aragonensis* Nuttall, *Morozovella conicotruncata* Subbotina, *Morozovella uncinate* Bolli (1957), *Subbotina pseudobulloides* Plummer, *Acarinina* sp., *Morozovella* sp., *Catapsydrax* sp., *Globigerina* sp., *Globigerinatheka* sp.). The unit was accepted as Early - Middle Eocene age in this study.

Yücelendere Formation outcrops in Çingene Hill, in Kırmızıtaş Hill and near of Alabayır Village in the study area.

By means of microfacies analysis to determine the depositional environments of Lower-Middle Eocene carbonate rocks of Toprakkale and Yücelendere Formations is the aim of present study.

2.MATERIAL AND METHODS

Field works were achieved in an area which covers about 80 km^2. During these studies, by using geological maps made by the geologists of General Directorate of Mineral Research and Exploration (Turkey), three stratigraphic sections were measured in the locations where the Lower-Middle Eocene rocks were best observed (Fig. 2), observable sedimentological properties were recorded and totally sixty five rock samples were taken. Twelve of these samples belong to Toprakkale Formation and fifty three are from Yücelendere Formation.

In the course of the laboratory work, sixty five thin sections were prepared and examined on a polarizing microscope. The components of the studied rock samples were determined and the carbonate rocks were classified using Folk (1962) (Fig. 3) and Wright (1992) (Fig. 4) classifications. Idealized sequence of standart facies belts of carbonates (Wilson, 1975) (Fig. 5) was used to determine the depositional systems of carbonate rocks.

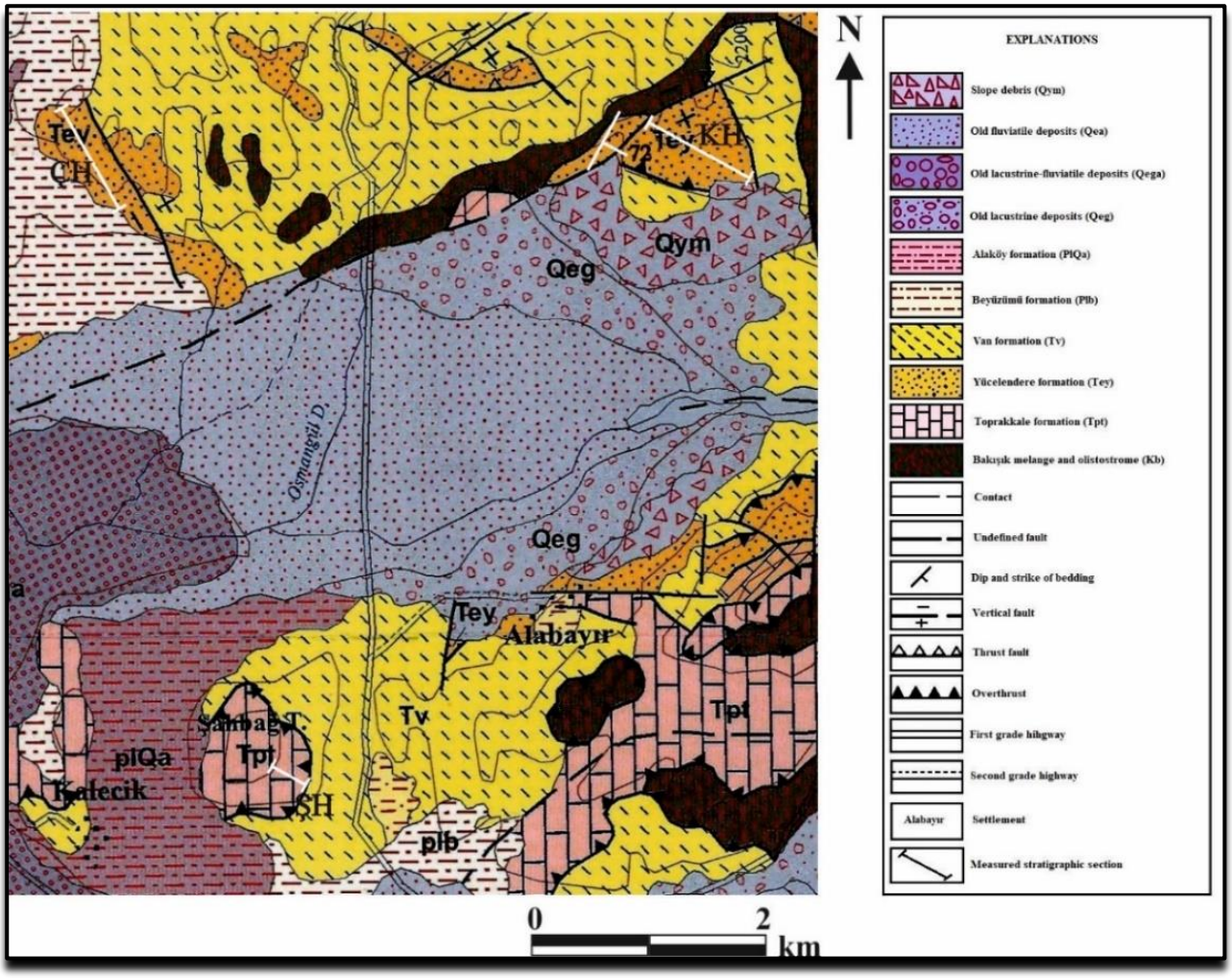

Figure 2. Geological map of the study area (Modified from Sümengen, 2008.) and locations of measured stratigraphic sections (ÇH: Çingene hill, KH: Kırmızıtaş hill, ŞH: Şahbağ hill).

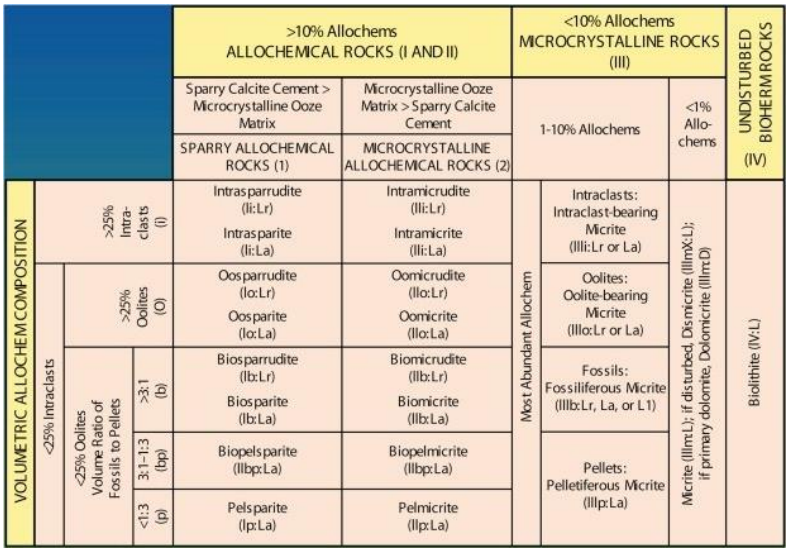

Figure 3. Folk (1962) classification

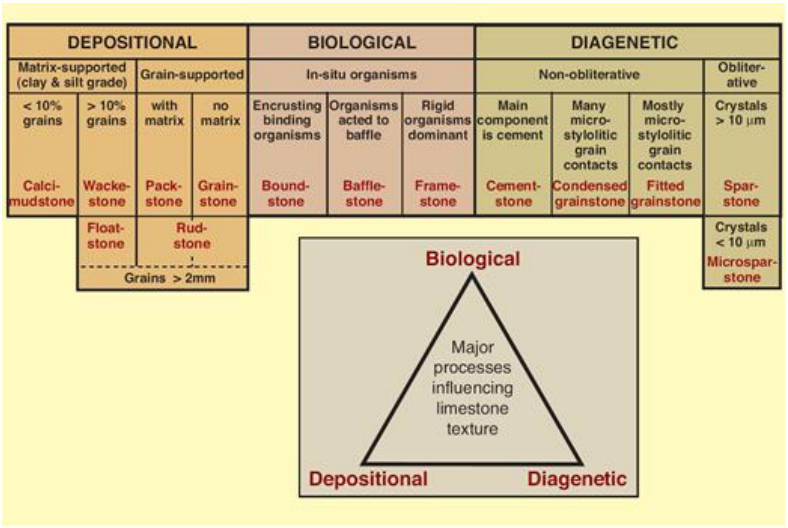

Figure 4. Wright (1992) classification.

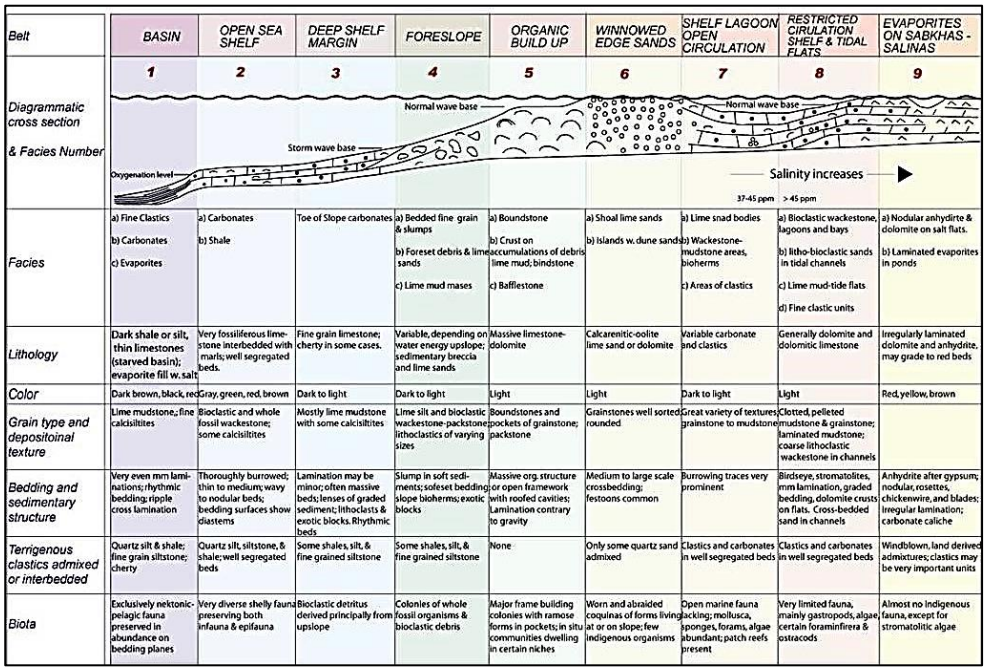

Figure 5. Idealized sequence of standart facies belts of carbonates (Wilson, 1975).

3.RESULTS AND DISCUSSIONS

Measured Stratigraphic Sections

In this study, two formations formed in the Paleocene-Eocene time interval were studied. These formations are Paleocene-Early Eocene aged Toprakkale formation and Lower-Middle Eocene aged Yücelendere formation. Three stratigraphic sections were measured where the lithological characteristics of these formations observe best (Figure 6, 7 and 8). The lines on which the sections were measured were shown in figure 2.

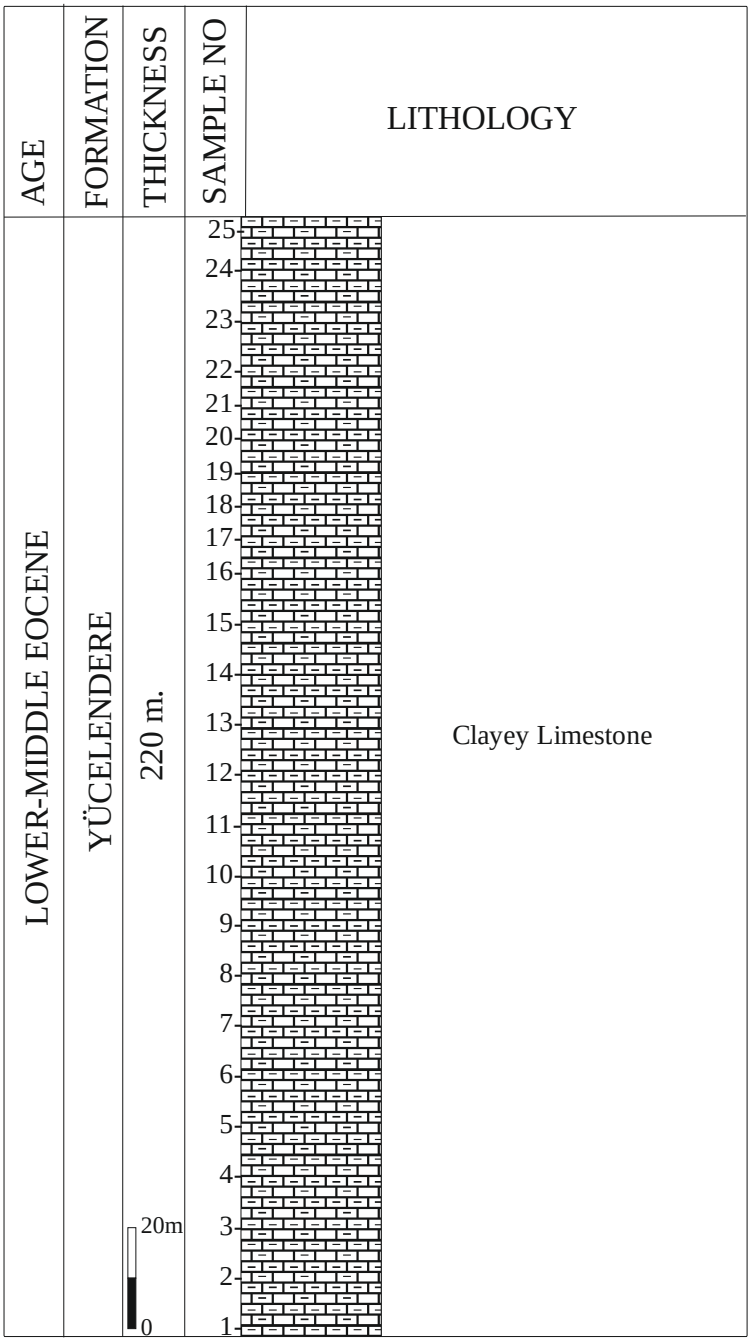

Figure 6. Çingene hill measured stratigraphic section.

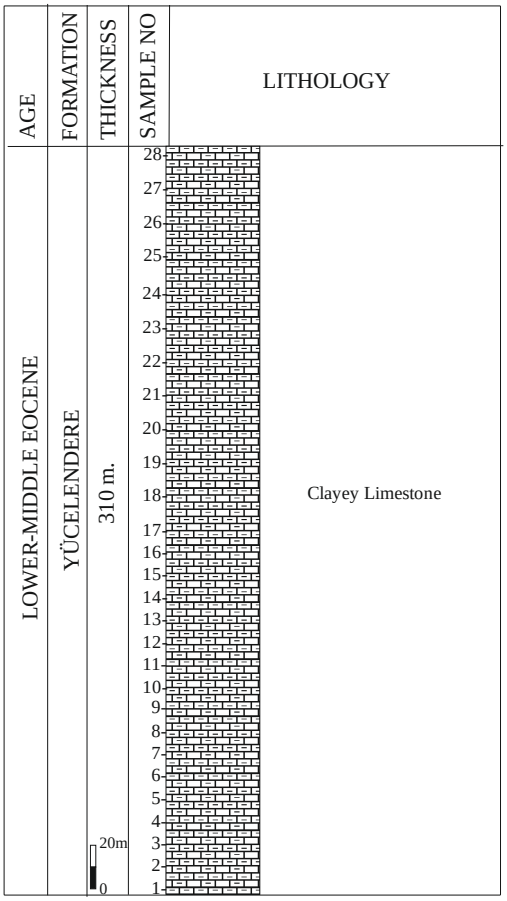

Figure 7. Kırmızıtaş hill measured stratigraphic section.

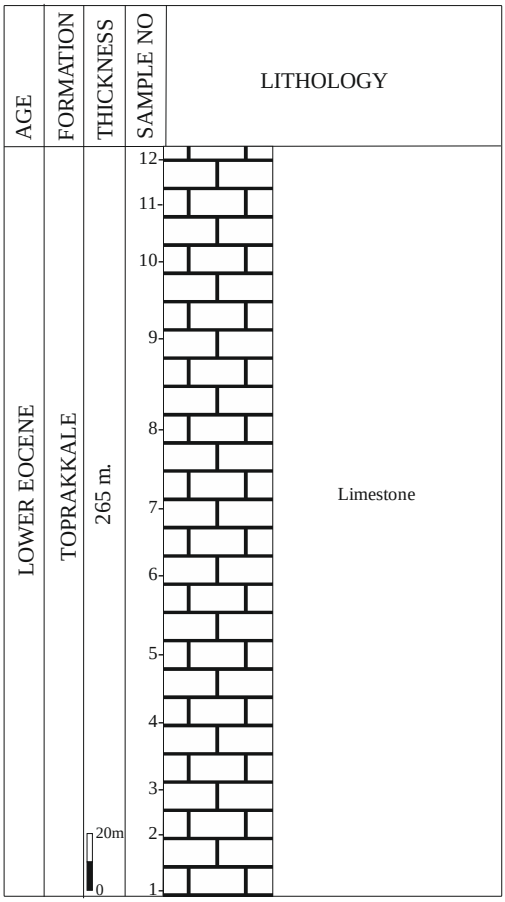

Figure 8. Şahbağ hill measured stratigraphic section.

Petrography

65 thin sections of sedimentary rock samples were prepared and examined on a polarizing microscope. The components of the studied rock samples were determined and the carbonate rocks were classified using Folk (1962) and Wright (1992) classifications (Table 1, 2 and 3).

Table 1. Classification of carbonate rock samples taken from near Çingene hill.

Sample No	Folk (1962)	Wright (1992)
1-25	Sparse Biomicrite	Wackestone

Table 2. Classification of carbonate rock samples taken from near Kırmızıtaş hill

Sample No	Folk (1962)	Wright (1992)
1	Sparse Biomicrite	Wackestone
2	Packed Biomicrite	Packstone
3	Sorted Biosparite	Grainstone
4	Packed Biomicrite	Packstone
5	Sparse Biomicrite	Wackestone
6	Packed Biomicrite	Packstone
7	SparseBiomicrite	Wackestone
8	SparseBiomicrite	Wackestone
9	Packed Biomicrite	Packstone
10	Packed Biomicrite	Packstone
11	Sorted Biosparite	Grainstone
12	Packed Biomicrite	Packstone
13	Packed Biomicrite	Packstone
14	Sorted Biosparite	Grainstone
15	Packed Biomicrite	Packstone
16	SparseBiomicrite	Wackestone
17	SparseBiomicrite	Wackestone
18	SparseBiomicrite	Wackestone
19	Unsorted Intrasparite	Grainstone
20	Sparse Biomicrite	Wackestone
21	Sparse Biomicrite	Wackestone
22	Sparse Biomicrite	Wackestone
23	Sparse Biomicrite	Wackestone
24	Sparse Biomicrite	Wackestone
25	Sparse Biomicrite	Wackestone
26	Sparse Biomicrite	Wackestone
27	Sparse Biomicrite	Wackestone
28	Sparse Biomicrite	Wackestone

Table 3. Classification of carbonate rock samples taken from Şahbağ hill.

Sample No	Folk (1962)	Wright (1992)
1	Packed Biomicrite	Packstone
2	Packed Biomicrite	Packstone
3	Packed Biomicrite	Packstone
4	Sorted Biosparite	Grainstone
5	Sorted Biosparite	Grainstone
6	Packed Biomicrite	Packstone
7	Sorted Biosparite	Grainstone
8	Packed Biomicrite	Packstone
9	Packed Biomicrite	Packstone
10	Packed Biomicrite	Packstone
11	Packed Biomicrite	Packstone
12	Packed Biomicrite	Packstone

Carbonate microfacies

In this study, the samples have been examined in terms of their sedimentological and paleontological content and according to the characteristics of carbonate rock samples five microfacies were determined. These are:

1. Wackestone with *Globigerina* and *Acarinina* microfacies.
2. Wackestone-Packstone with *Globigerina* and *Acarinina* microfacies.
3. Packstone-Grainstone with *Globigerina* and *Acarinina* microfacies.
4. Grainstone with *Milioliidae* and Red Algae microfacies.
5. Packstone with *Nummulites* and Red Algae microfacies.

Wackestone with *globigerina* and *acarinina* microfacies

This microfacies is composed of thin bedded, grey-light brown colored, fossiliferous, micritic limestones. All fossils are planktonic foraminiferas. *Globigerina* (Fig. 9) and *Acarinina* (Fig. 10) are the most common fossils in this microfacies. *Morozovella*, *Morozovella* sp., *Bulbrooki*, *Globigerina* sp., *Globigeriniidae*, *Acarinina* sp. are also determined in thin sections. According to these characteristics the microfacies corresponds to standart microfacies (SMF) - 1 (Wilson 1975). It means that the lithologies of this facies formed in deep marine environment (basin). Wackestone with *globigerina* and *acarinina* microfacies is typically observed in Çingene hill and Kırmızıtaş hill measured stratigraphic sections.

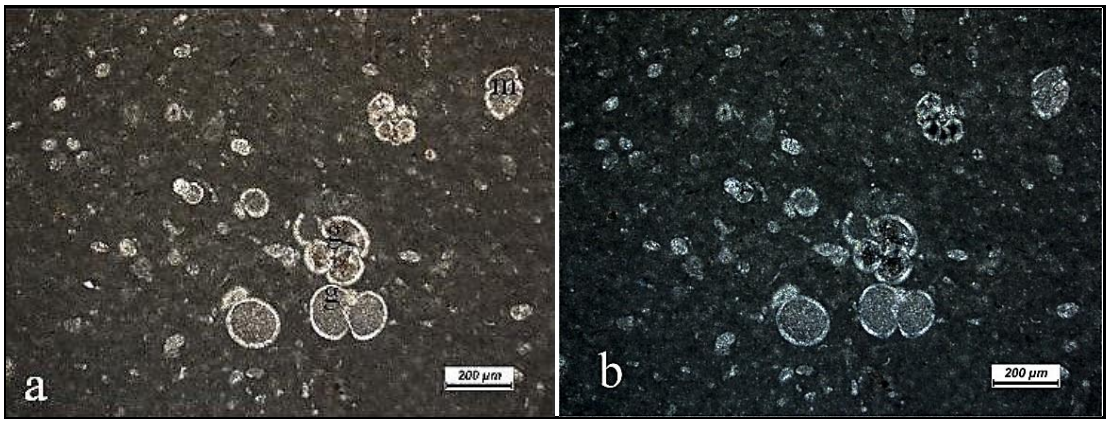

Figure 9. Thin section photographs of Wackestone with *Globigerina* and *Acarinina* microfacies (a:PPL, b:XPL, g:*Globigerina*, m:*Morozovella).*

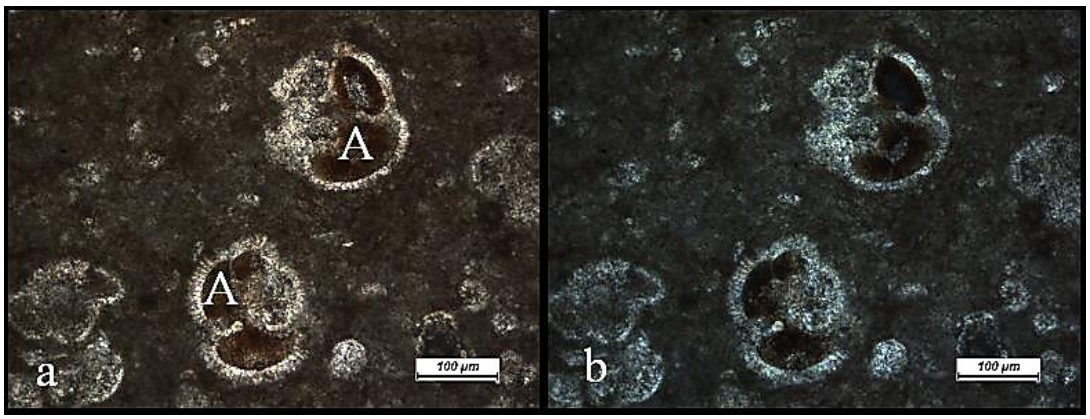

Figure 10. Thin section photographs of Wackestone with *Globigerina* and *Acarinina* microfacies (a:PPL, b:XPL, A: *Acarinina* sp.*).*

Wackestone-packstone with *globigerina* and *acarinina* microfacies

This microfacies consists of thin bedded, gray colored, fossiliferous, micritic limestones. The fossils which were determined are all planktonic foraminiferas. The most abundant fossils in this microfacies are *Globigerina* (Fig. 11) and *Acarinina*. There are *Morozovella*, *Morozovella* sp., *Acarinina* sp.,

Globigerina sp., *Globigerina* spp., *Tintinid*, *Calpionellidae*, *Truncorotoloides*, *Textulariidae*in rock samples too. Micritization and recrystallization are also observed in samples. The microfacies corresponds to standart microfacies (SMF) - 2 (Wilson. 1975). The belt which lithologies of this facies formed is open sea shelf. Wackestone-Packstone with *Globigerina* and *Acarinina* microfacies is typically observed in Çingene hill and Kırmızıtaş hill measured stratigraphic sections.

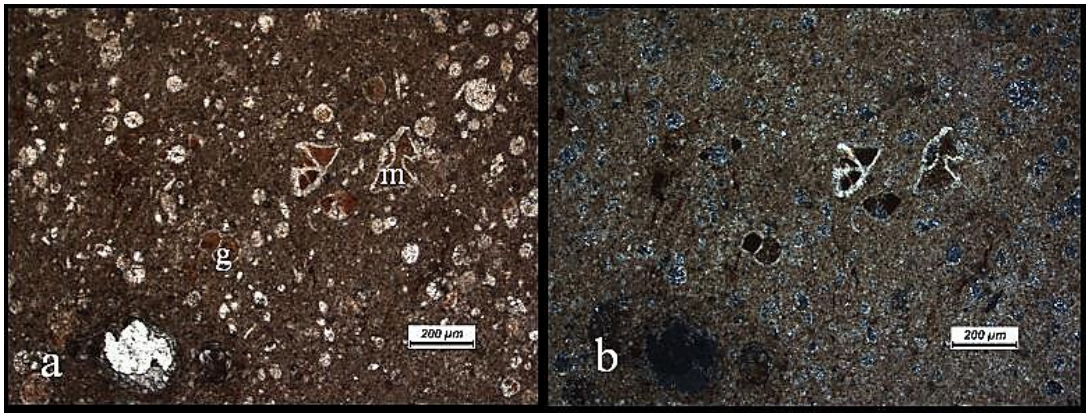

Figure 11. Thin section photographs of wackestone-packstone with *globigerina* and *acarinina* microfacies (a:PPL, b:XPL, g:*Globigerina* sp., m:*Morozovella* sp.*).*

Packstone-grainstone with *globigerina* and *acarinina* microfacies

This microfacies is composed of thin bedded, grey-light brown colored, fossiliferous, micritic and sparitic limestones. All fossils are planktonic foraminiferas (Fig. 12), but some of them are transported. *Globigerina* and *Acarinina* are the most common fossils in this microfacies. *Globigerina* sp.,*Globigerina* spp., *Acarinina* sp., *Acarinina* spp. Are also found. *Rotalidae*, *Textularidae*, *Discocyclina* sp. and *Nummulites* sp.are transported fossils in thin sections. According to these characteristics the microfacies corresponds to standart microfacies (SMF) - 3 (Wilson. 1975). It means that the lithologies of this facies formed in deep shelf margin. Packstone-grainstone with *globigerina* and *acarinina* microfacies is typically observed in Kırmızıtaş hill measured stratigraphic section.

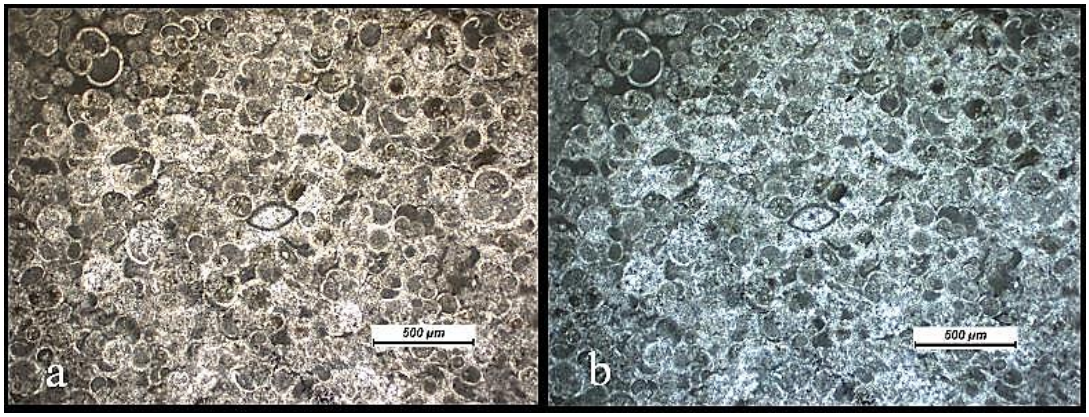

Figure 12. Thin section photographs of packstone-grainstone with *globigerina* and *acarinina* microfacies (a:PPL, b:XPL*).*

Grainstone with *milioliidae* and red algae microfacies

This microfacies is composed of massive, light brown colored, fossiliferous, sparitic limestones. All fossils are bentonic foraminiferas. *Miliolidae* (Fig. 13) and Red Algae are the most common fossils in this microfacies. *Peneropliidae*, *Rotalidae*, *Ostracoda* are also found. Transported macro fossil clasts (Fig. 14) are abundant. According to these characteristics the microfacies corresponds to standart microfacies (SMF) - 4 (Wilson. 1975). It means that the lithologies of this facies formed in a shelf lagoon. Grainstone with *Miliolidae* and Red Algae microfacies is typically observed in Kırmızıtaş hill and Şahbağ hill measured stratigraphic sections.

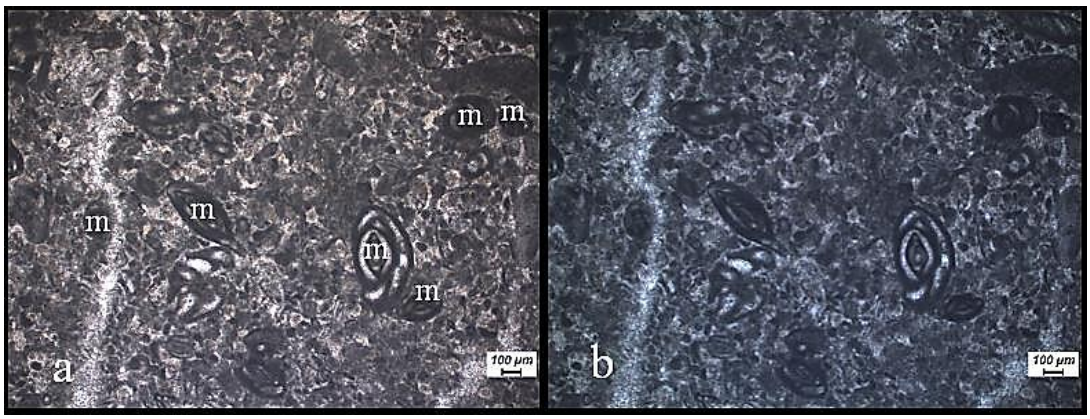

Figure 13. Thin section photographs of grainstone with *miliolidae* and red algae microfacies (a:PPL, b:XPL, m:*Milioliidae).*

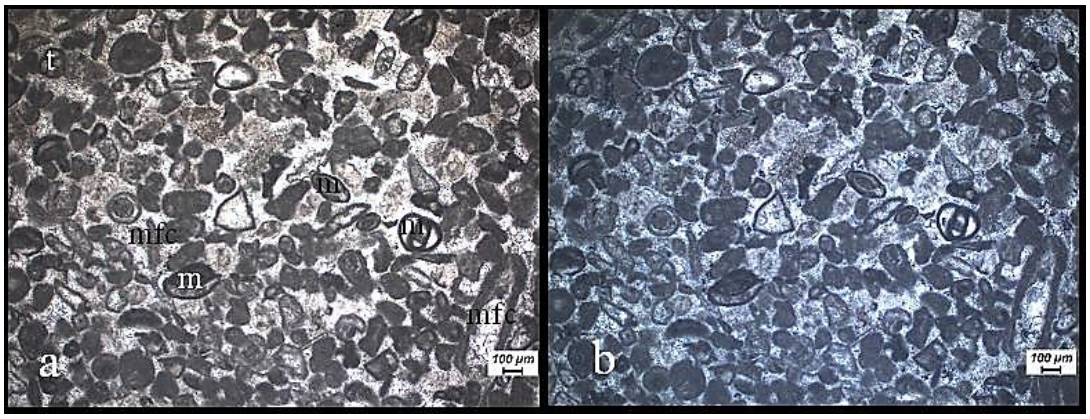

Figure 14. Thin section photographs of grainstone with *miliolidae* and red algae microfacies (a:PPL, b:XPL, m:*Milioliidae*, t:*Textulariidae*, mfc:Macro fossil *clasts).*

Packstone with *nummulites* and red algae microfacies

This microfacies is composed of massive, light brown and gray colored, fossiliferous, micritic limestones. All fossils are bentonic foraminiferas. *Nummulites* sp. (Fig. 15), Red Algae (Fig. 17), are the most common fossils in this microfacies. *Discocyclina* sp.(Fig. 12, Fig. 14), *Alveolina* sp., *Rotaliidae Cibicides* sp., *Sphaerogypsina* sp., *Rotalidae*, *Flosculina* sp. (Fig. 16), *Textularidae*, *Linderiina* sp., *Acervuliniidae, Milioliidae,* Ostracoda, Bryozoa, *Distichoplax* sp., *Asilina* sp., *Rotalia* sp., *Eponides* sp., *Miscellena* sp., *Acervuliniidae* sp., *Operculina* sp., Gastropoda are also present. Pelecypoda and Coral clasts, Echinoid spins are transported macro fossil clasts. According to these characteristics the microfacies corresponds to standart microfacies (SMF) - 5 (Wilson. 1975). Therefore, the lithologies of this facies formed in a shelf environment. Packstone with *Nummulites* and Red Algae microfacies is typically observed in Kırmızıtaş hill and Şahbağ hill measured stratigraphic sections.

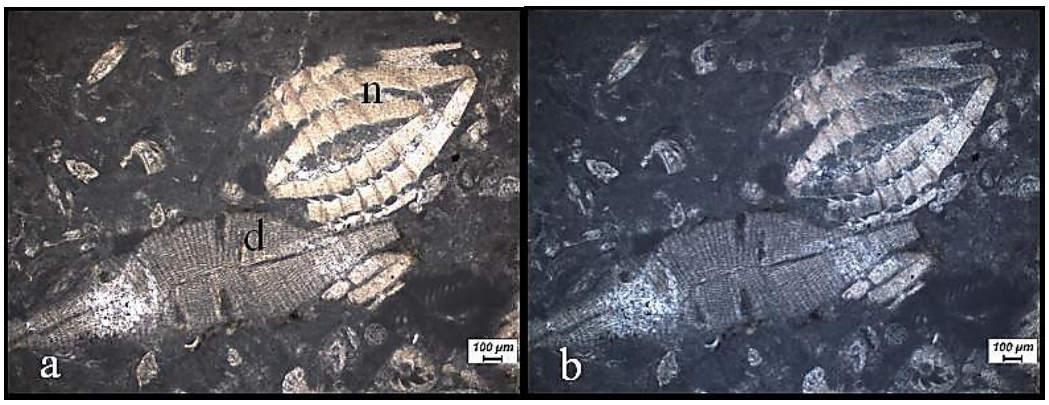

Figure 15. Thin section photographs of packstone with *nummulites* and red algae microfacies (a:PPL, b:XPL, n:*Nummulites* sp., d:*Discocyclina* sp.*).*

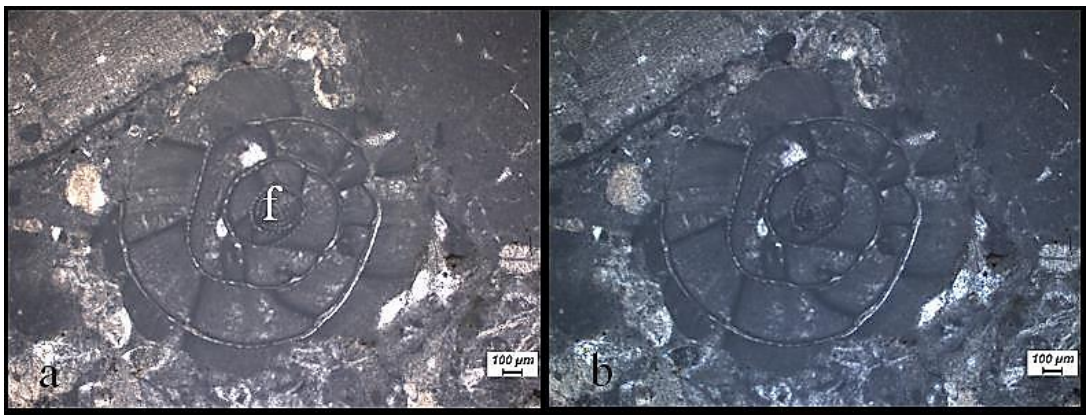

Figure 16. Thin section photographs of packstone with *nummulites* and red algae microfacies (a:PPL, b:XPL, f: *Flosculina* sp.*)*.

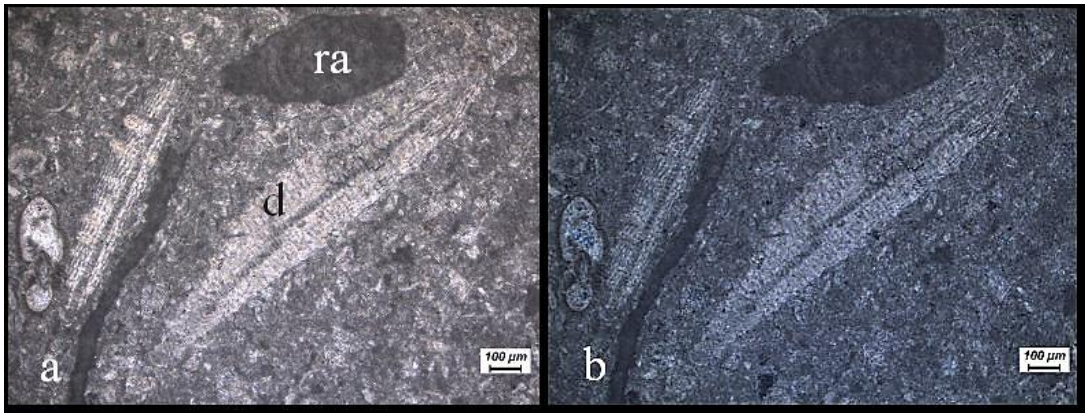

Figure 17. Thin section photographs of packstone with *nummulites* and red algae microfacies (a:PPL, b:XPL, ra:Red Algae, d*:Discocyclina* sp.*)*.

According to Wilson (1975), these microfacies indicate that Lower-Middle Eocene rocks were formed in environments range from shelf lagoon to deep marine (basin) environment (Fig. 18). These differences in depositional environments have been interpreted as the result of changes in water level in relation to transgression and regression events (Fig. 19, 20, 21).

Belt	BASIN	OPEN SEA SHELF	DEEP SHELF MARGIN	FORESLOPE	ORGANIC BUILD UP	WINNOWED EDGE SANDS	SHELF LAGOON OPEN CIRCULATION	RESTRICTED CIRULATION SHELF & TIDAL FLATS	EVAPORITES ON SABKHAS - SALINAS
	1	2	3	4	5	6	7	8	9
Diagrammatic cross section & Facies Number	Normal wave base; Storm wave base; Oxygenation level; Salinity increases; 37-45 ppm; > 45 ppm								
Facies	a) Fine Clastics b) Carbonates c) Evaporites	a) Carbonates b) Shale	Toe of Slope carbonates	a) Bedded fine grain & slumps b) Foreset debris & lime sands c) Lime mud mases	a) Boundstone b) Crust on accumulations of debris lime mud; bindstone c) Bafflestone	a) Shoal lime sands b) Islands w. dune sands	a) Lime snad bodies b) Wackestone-mudstone areas, bioherms c) Areas of clastics	a) Bioclastic wackestone, lagoons and bays b) litho-bioclastic sands in tidal channels c) Lime mud-tide flats d) Fine clastic units	a) Nodular anhydirte & dolomite on salt flats. b) Laminated evaporites in ponds
Lithology	Dark shale or silt, thin limestones (starved basin); evaporite fill w. salt	Very fossiliferous lime-stone interbedded with marls; well segregated beds.	Fine grain limestone; cherty in some cases.	Variable, depending on water energy upslope; sedimentary breccia and lime sands	Massive limestone-dolomite	Calcarenitic-oolite lime sand or dolomite	Variable carbonate and clastics	Generally dolomite and dolomitic limestone	Irregularly laminated dolomite and anhydrite, may grade to red beds
Color	Dark brown, black, red	Gray, green, red, brown	Dark to light	Dark to light	Light	Light	Dark to light	Light	Red, yellow, brown
Grain type and depositoinal texture	Lime mudstone,, fine calcisiltites	Bioclastic and whole fossil wackestone; some calcisiltites	Mostly lime mudstone with some calcisiltites	Lime silt and bioclastic wackestone-packstone; lithoclastics of varying sizes	Boundstones and pockets of grainstone; backstone	Grainstones well sorted; rounded	Great variety of texture; grainstone to mudstone	Clotted, pelleted mudstone & grainstone; laminated mudstone; coarse lithoclastic wackestone in channels	
Bedding and sedimentary structure	Very even mm lami-nations; rhythmic bedding; ripple cross lamination	Thoroughly burrowed; thin to medium; wavy to nodular beds; bedding surfaces show clasterns	Lamination may be minor; often massive beds; lenses of graded sediment; lithoclasts & exotic blocks. Rhythmic beds	Slump in soft sedi-ments; soleset bedding; slope bioherms; exotic blocks	Massive org. structure or open framework with roofed cavities; lamination contrary to gravity	Medium to large scale crossbedding; festoons common	Burrowing traces very prominent	Birdseye, stromatolites, mm lamination, graded bedding, dolomite crusts on flats. Cross-bedded sand in channels	Anhydrite after gypsum; nodular, rosettes, chickenwire, and blades; irregular lamination; carbonate caliche
Terrigenous clastics admixed or interbedded	Quartz silt & shale; fine grain siltstone; cherty	Quartz silt, siltstone, & shale; well segregated beds	Some shales, silt, & fine grained siltstone	Some shales, silt, & fine grained siltstone	None	Only some quartz sand admixed	Clastics and carbonates in well segregated beds	Clastics and carbonates in well segregated beds	Windblown, land derived admixtures; clastics may be very important units
Biota	Exclusively nektonic-pelagic fauna preserved in abundance on bedding planes	Very diverse shelly fauna preserving both infauna & epifauna	Bioclastic detritus derived principally from upslope	Colonies of whole fossil organisms & bioclastic debris	Major frame building colonies with ramose forms in pockets; in situ communities dwelling in certain niches	Worn and abraided coquinas of forms living at or on slope; few indigenous organisms	Open marine fauna lacking; mollusca, sponges, forams, algae abundant; patch reefs present	Very limited fauna, mainly gastropods, algae, certain foraminfrera & ostracods	Almost no indigenous fauna, except for stromatolitic algae

Figure 18. Idealized sequence of standart facies belts of carbonates (Modified from Wilson, 1975). (The locations of microfacies which were determined in study area were shown in blue frames).

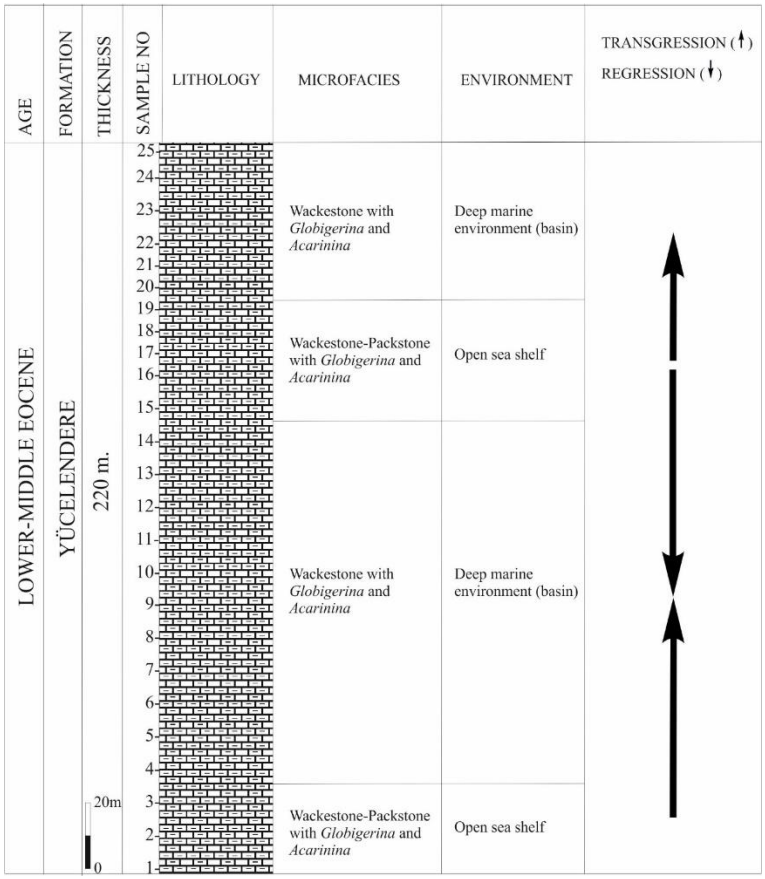

Figure 19. Microfacies and their environments in Çingene hill measured stratigraphic section.

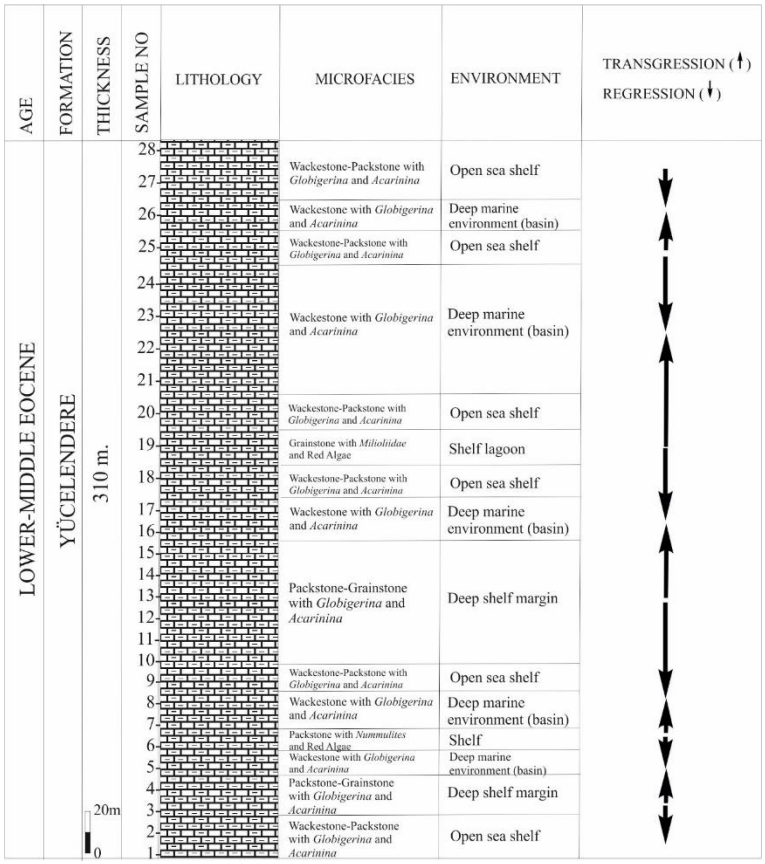

Figure 20. Microfacies and their environments in Kırmızıtaş hill measured stratigraphic section.

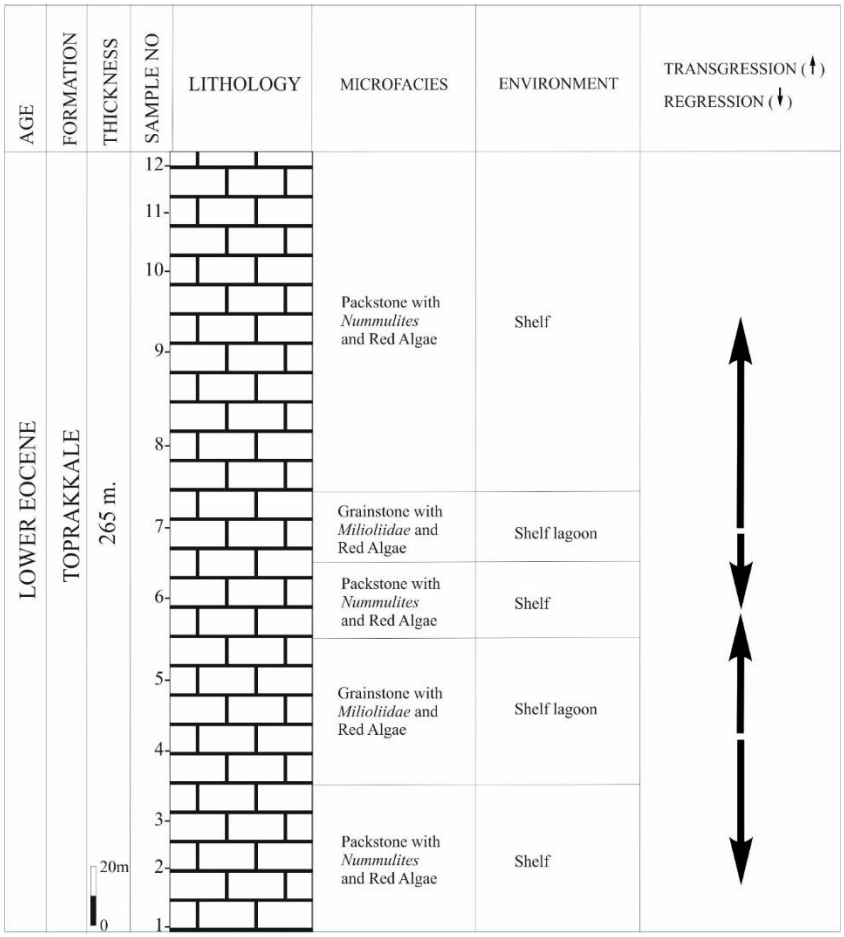

Figure 21. Microfacies and their environments in Şahbağ hill measured stratigraphic section.

4. CONCLUSIONS

A detailed study on the microfacies analysis and depositional environments of Lower and Middle Eocene sedimentary rocks outcrop in Van Province (Turkey) in the East of Lake Van were conducted. The investigation was based on sixty five samples collected from three stratigraphic sections and included Toprakkale and Yücelendere formations. These rock units are composed of carbonate rocks.

The components of the studied rock samples were determined and the carbonate rocks were classified using Folk (1962) and Wright (1992) classifications. According to Folk (1962) classification fifty eight rock samples are biomicrite while six are biosparite and one is intrasparite. By using Wright (1992) classification fourty one samples were named as wackestone, seventeen were pacstone and seven were grainstone.

Discocyclina sp., *Alveolina* sp., *Textularridae*, Red algae, *Rotaliidae*, *Nummulites* sp., *Cibicides* sp., *Pelesipod* Shell parts, *Echinoid* spin, *Sphaerogypsina* sp., coral, *Flosculina* sp., *Linderiina* sp., *Acervuliniidae*, Macrofossil clasts, *Miliolidae*, *Peneropliidae*, *Ostracoda*, Macro Shell parts, Macrofossil clasts, *Bryozoa*, *Distichoplax* sp., *Gastropoda* limit, *Asilina* sp., *Eponides* sp., *Rotozalia* sp., *Miscellena* sp., *Acervuliniidae*, *Operculina* were determined in the rock samples of Toprakkale Formation.

Globigerina, *Globorotalia*, *Morozovella*, *Acarinina* sp., *Bulbrooki*, *Truncorotoloides*, *Globigerina* spp., *Globigerina* sp., *Antaciidae*, *Textulariidae*, *Flosculina* sp., *Nummulites* sp., *Rotaliidae* , *Discocyclina* sp., *Alveolina* sp., *Milioliidae*, Red algae, *Globigeriniidae*, *Acarinina* spp., *Ostracoda*, *Morozovella* sp., *Calsiphere*, Bioclastic, *Tintinid*, *Calpionellidae* were determined in the rock samples of Yücelendere Formation.

According to the characteristics of carbonate rock samples five microfacies were determined. These are; 1) Wackestone with *Globigerina* and *Acarinina* microfacies, 2) Wackestone-Packstone with *Globigerina* and *Acarinina* microfacies 3) Packstone-Grainstone with *Globigerina* and *Acarinina* microfacies 4) Grainstone with *Milioliidae* and Red Algae microfacies, 5) Packstone with *Nummulites* and Red Algae microfacies. According to Wilson (1975), these microfacies indicate that Lower-Middle Eocene rocks were formed in environments range from shelf lagoon to deep marine (basin) environment. The changes in depositional environments have been interpreted as the result of changes in water level in relation to transgression and regression events.

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