DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

STRATIGRAPHY, FACIES CHARACTERISTICS AND ECONOMICAL POTENTIAL OF THE PALEOZOIC-MESOZOIC LIMESTONES OF THE BARTIN AREA (WESTERN PONTIDES)

by
Tezcan ÇOBANOĞLU

March, 2009
İZMİR

STRATIGRAPHY, FACIES CHARACTERISTICS AND ECONOMICAL POTENTIAL OF THE PALEOZOIC-MESOZOIC LIMESTONES OF THE BARTIN AREA (WESTERN PONTIDES)

A Thesis Submitted to the
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Geological Engineering, Applied Geology Program

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M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **“STRATIGRAPHY, FACIES CHARACTERISTICS AND ECONOMICAL POTENTIAL OF THE PALEOZOIC-MESOZOIC LIMESTONES OF THE BARTIN AREA (WESTERN PONTIDES)”** completed by **TEZCAN ÇOBANOĞLU** 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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STRATIGRAPHY, FACIES CHARACTERISTICS AND ECONOMICAL POTENTIAL OF THE PALEOZOIC-MESOZOIC LIMESTONES OF THE BARTIN AREA (WESTERNPONTIDES)

ABSTRACT

Under the investigation of economical potential of the Paleozoic-Mesozoic limestones at the Bartın area, Göktepe, Yılanlı, Alacaağzı, Arıtdere formations of Paleozoic and Ulus, Dallıca, Kapanboğazı and Yemişliçay formations of Mesozoic are determined. All of the formation names, except Dallıca Formation, are given from the studies of Tokay et al., (1952), Tüysüz et al., (1999) and Sener et al., (1980).

Dallıca Formation is first determined in this study and its equivalent to the Turonian conglomerate of Tokay. Field works of Tokay around Süzek River, it was not identified by the latter who probably limited his field work along the road where indeed the Lower Visean is cropping out.

Coal, is the main economic potential on the region, other potential deposits, like clay, marl, dolomite and limestone, are existing for lime, cement and brick industries.

In all three industries, cement lime and aggregate producers are using limestone or dolomite deposits. The key sustainable development issue is the access to high quality limestone and dolomite deposits to secure geological reserves for a 30-60 years operation.

Selective mining is the most important mile stone for economical production. Industry always needs constant quality for efficient production and customer satisfaction.

Mining operation needs restricted areas that are well protected for safety and to prevent any environmental inconvenience.

The resource carbonate potential of the limestones and dolomites at the region is approximately 2.5 and 1 billion tonnes. However potential mineable site is not more than one-tenth. After creating quality maps and getting permissions for mining, each quarry works with a potential of 10 million to 100 million tonnes of reserves estimation in their licensed areas.

Keywords: Bartın, Dallıca, Coal, Limestone, Dolomite, Yılanlı, Carboniferous, Selective Mining, Resource estimation.

BARTIN BÖLGESİ (BATI-PONTİDLER) PALEOZOYİK-MESOZOYİK KİREÇTAŞLARININ, STRATİGRAFİSİ, FASİYES KAREKTERİSTİKLERİ VE EKONOMİK POTANSİYELİ

ÖZ

Bartın bölgesi Paleozoyik-Mesozoyik kireçtaşlarının ekonomik potansiyelinin araştırılması adı altında, Paleozoyik yaşlı Göktepe, Yılanlı, Alacaağzı, Arıtdere formasyonları ve Mesozoyik yaşlı Ulus, Dallıca, Kapanboğazı ve Yemişliçay formasyonları belirlenmiştir. Dallıca Formasyonu haricindeki tüm formasyon isimleri Tokay, (1952), Tüysüz ve diğer., (1999) ve Sener ve diğer., (1980)'a ait eski çalışmalardan alınmıştır.

Dallıca Formasyonu ilk kez bu çalışmada belirlenmiştir ve Tokay'ın Turonian yaşlı konglomeraları ile eş yaşlıdır. Tokay'ın Süzek Deresi civarındaki arazi çalışmalarını, Vizeyen yaşlı kireçtaşlarının yüzlek verdiği dere boyunca sınırlandırması nedeniyle, geçmişte belirlenememiştir.

Kömür bölgedeki ana ekonomik potansiyeldir. Diğer ekonomik potansiyeller, kil, marn, dolomit ve kireçtaşlarıdır. Bunlar kireç, çimento ve tuğla sanayi tarafından kullanılmaktadır.

Çimento, kireç ve agrega üreticileri, kireç ve dolomit hammaddelerini kullanmaktadırlar. Sürdürülebilir gelişmenin anahtarı, 30-60 yıllık operasyonları garantileyen yüksek kaliteli dolomit ve kireçtaşı jeolojik rezervleridir.

Selektif madencilik, ekonomik üretimin en önemli kilometre taşıdır. Endüstri, verimli üretim ve müşteri memnuniyeti için eş kalitede girdiye ihtiyaç duyar.

Madencilik operasyonu, herhangi bir çevresel soruna ya da güvenlik sorununa neden olmamak için korunaklı alanlara ihtiyaç duyar.

Bölgedeki kireçtaşı ve dolomit kaynak potansiyeli sırasıyla 2,5 ve 1 milyar tondur. Fakat üretilebilir potansiyel bu miktarın onda birinden fazla değildir. İzin alımları ve kalite haritalarının çıkarılmasının ardından bölgedeki ocaklar ruhsatlı alanlarında ortalama 10 ile 100 milyon ton arasında değişen rezervler ile çalışmaktadırlar.

Anahtar kelimeler: Bartın, Dallıca, kömür, kireçtaşı, dolomit, Yılanlı, karbonifer, selektif madencilik, tahmini kaynak rezerv hesaplama.

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CHAPTER ONE
INTRODUCTION

1.1 Location of the Study Area

Study area is located between Bartın city center and Amasra city at western part of Black Sea, about 80 km east of Zonguldak and it is situated in 1/25.000 scale Zonguldak E28 C1 map (Fig 1.1)

Investigation area comprises coordinates between; UTM Euro 1950 36T, 435000 E - 4615000 N, 438000 E - 4609000 N, 462000 E - 4639000 N, 473000 E - 4614000 N.

Study area is characterizing by sharp topographic relief and Gurgenpınarı, Muhacırlar and Esenpınarı are well known peaks of the area. Most of the area is covered with forests.

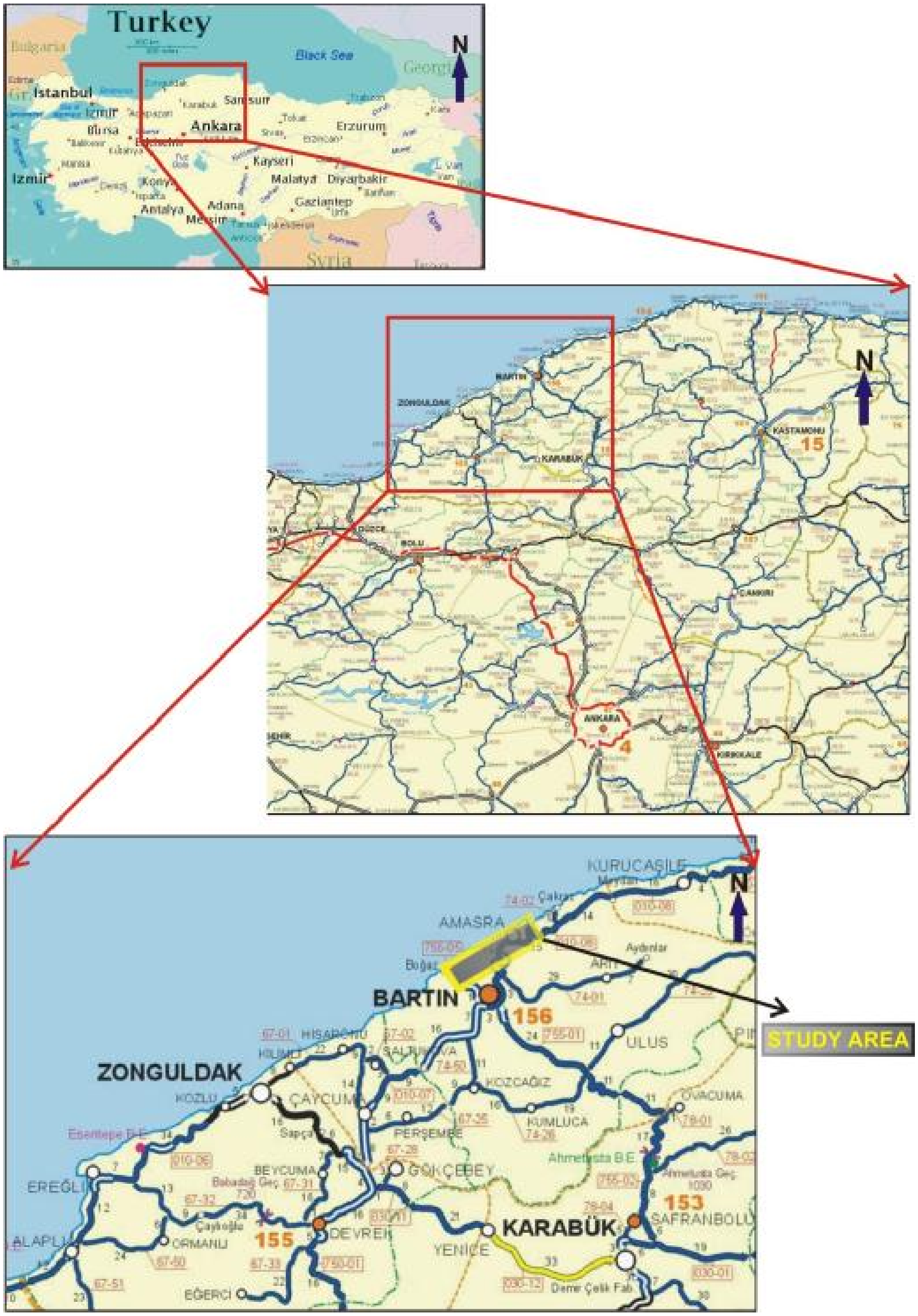

Figure 1.1 Location map of investigation area

1.2 Purpose and Methods

Purpose of this study is to determine the stratigraphy and to evaluate the economic potential of Bartın area.

Methodology is based on sampling of field work, chemical and petrographical analyzing the samples, mapping and the application of the previous studies.

25 thin sections prepared for petrographical analyzes, 20 of them are pictured and 60 samples for chemically analyze are (were) collected.

Carbonate samples were determined and classified (according to) using Dunham (1962), Embry and Klovan (1971), James (1984) and Kendal (2005) (after Folk, 1959) classifications (Fig. 1.2 and Fig. 1.3). Dunham (1962) was classified the carbonate rocks based on primary components and improved by Kendal (2005) (Fig. 1.5). Embry and Klovan (1971) and James (1984) were taken this classification based on allochthonous and autochthonous organisms (Fig. 1.4).

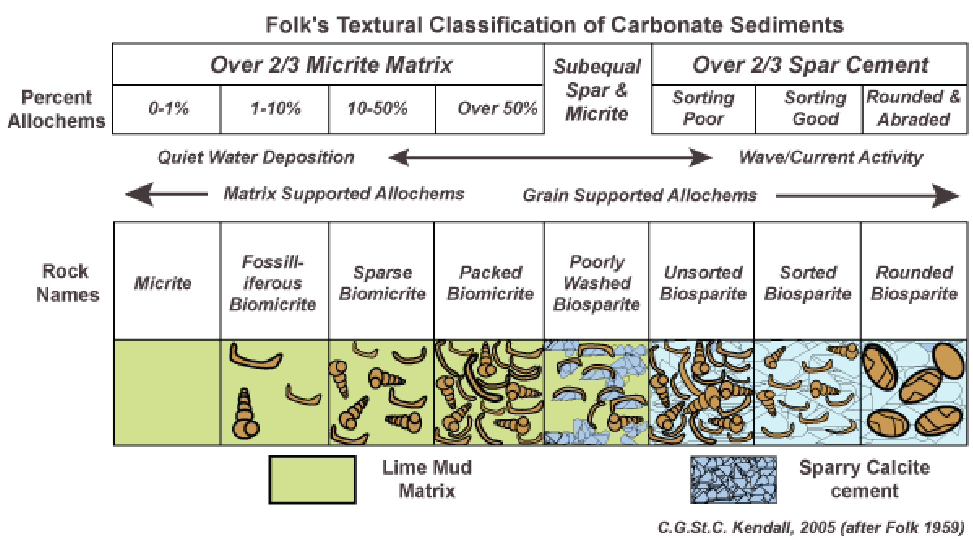

Figure 1.2 Folk’s textural classification of carbonate sediments improved by Kendall, 2005 (after Folk, 1959).

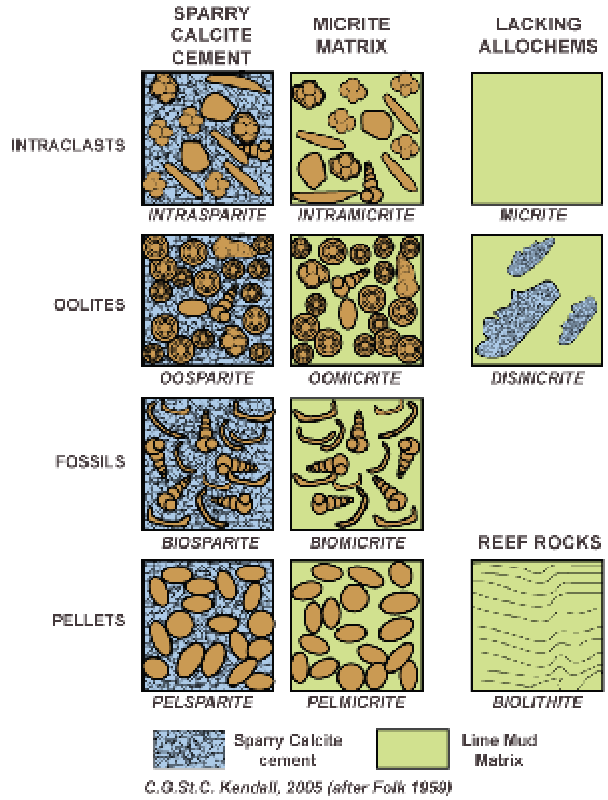

Figure 1.3 Classification of carbonate rocks based on crystal texture (Kendall, 2005 after Folk, 1959).

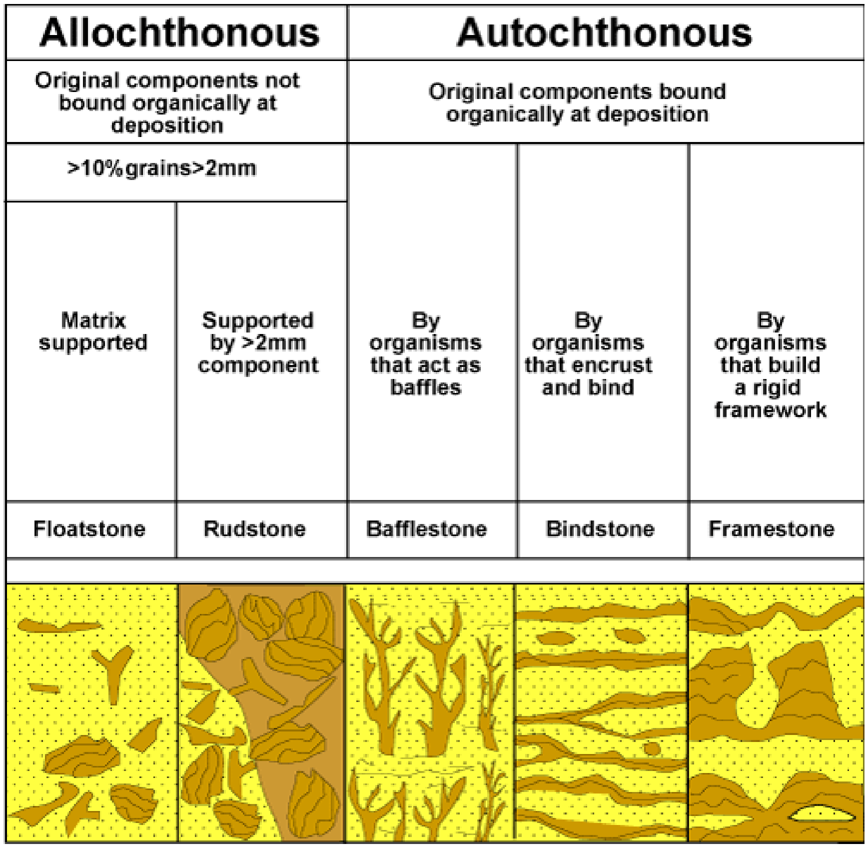

Figure 1.4 Classification of carbonate rocs based on vicinity of organisms Embry & Klovan (1971) and James (1984)

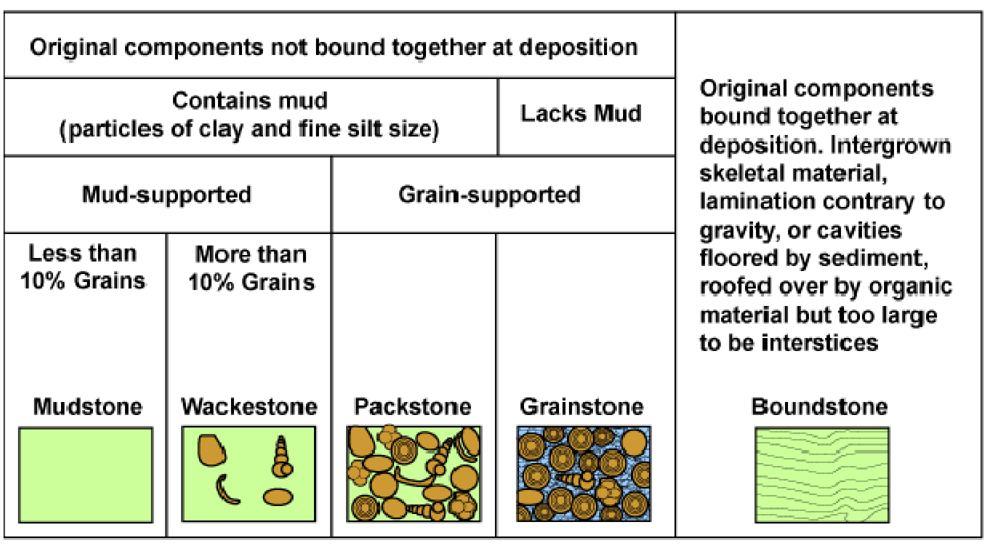

Figure 1.5 Classification of carbonate rocks based on primary components Kendall, 2005 (after Dunham, 1962)

1.3 Scope

The goals of this study are as follows:

To identify the Paleozoic and Mesozoic stratigraphy of the Bartın region based on petrology, sedimentary structures and facies.

To determine the economical potential of limestone’s in Bartın region.

Figure 1.6 Tarlaağzı Visean limestones reaching along the sea, near the small harbour.

CHAPTER TWO
STRATIGRAPHY

2.1 Introduction

The southern passive margin of the oceanic Western Black Sea Basin consists of two tectonic units; The Istanbul Zone and The Sakarya Zone. Both of them called Western Pontides (Okay, A. I. and Tüysüz, O. 1999. Tethyan sutures of northern Turkey) (Fig. 2.1).

This tectonic mosaic formed as a result of progressive welding of continental and oceanic fragments during Paleozoic and Mesozoic.

Istanbul Zone is covered by a sedimentary succession deposited in a southern deepening continental margin basin. This basin was bisected lengthwise during the Maastrichtian forming The Zonguldak Basin in the northwest and the Ulus Basin in the southwest. Both of these basins were formed in the early Cenozoic (Okay, A. I. and Tüysüz, O., 1999). After the juxtaposition of the Central Pontides and the Istanbul Zone, an E-W trending extensional magmatic arc was established on these sedimentary basins in response to northward subducting Neotethys to the south. This magmatic arc which began during the Turonian, gave rise to the Western Black Sea oceanic arc basin (Tüysüz, O., 1999).

The western and the Eastern Black Sea basins also show contrasting geological evolution. The Western Black Sea Basins believed to have opened during the Early Cretaceous as a back-arc basin above the northward subducting Tethys Ocean (Görür 1988, 1991, 1997). Görür et al., (1993) proposed that the break out of the continental crust and the start of the spreading in the Western Black Sea Basin occurred during Cenomanian-Campanian.

Study area is situated in the İstanbul Zone with starting a succession from Devonian to Cretaceous.

In this study, the stratigraphy is based on Tokay et al., (1952).

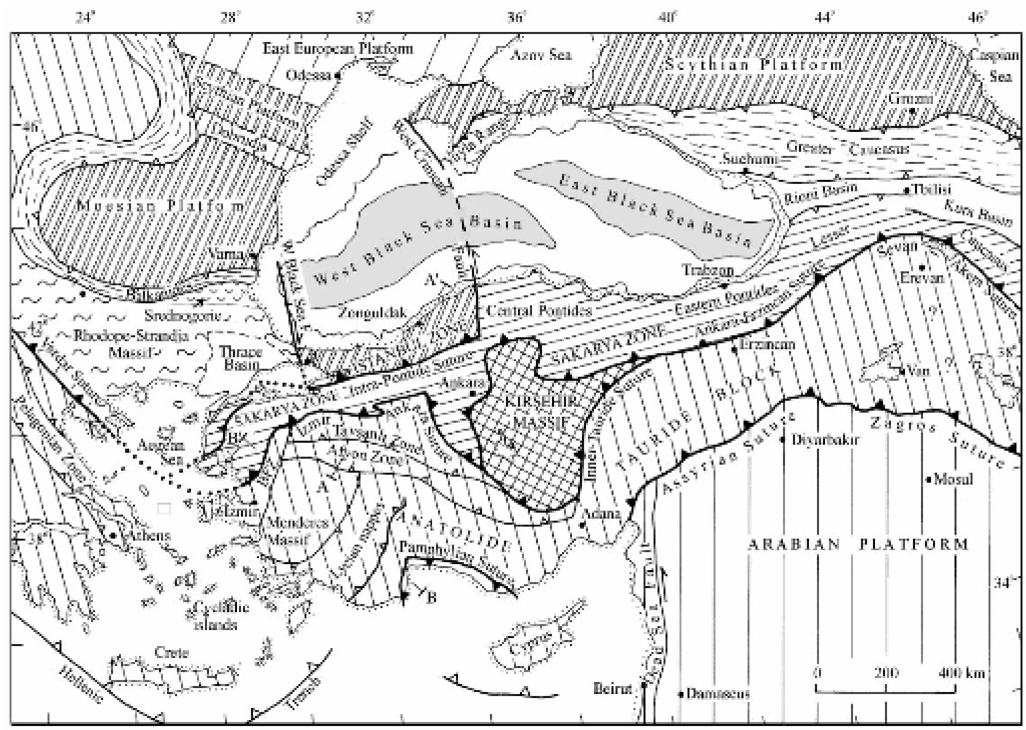

Figure 2.1 Tectonic map of the Aegean and Black Sea region (after Okay & Tüysüz, 1999).

2.2 Stratigraphy

Göktepe,Yılanlı, Alacaağzı, Arıtdere formations of Paleozoic and Ulus, Dallıca, Kapanboğazı and Yemişliçay formations of Mesozoic are determined (Geological Map Figure 2.3 and General Sratigraphic Columnar Section Figure 2.2). All of the formation names, except Dallıca Formation, are given from the studies of Tokay et al., (1952), Tüysüz et al., (1999) and Sener et al., (1980).

2.2.1 Göktepe Formation

2.2.1.1. Description

Göktepe Formation is observed around İnkumu Bay and it is characterized by dolomitic cherty limestones.

2.2.1.2. Lithology

In the centre of the İnkumu anticline, a section is visible on the beach of İnkumu to the west mouth of the Bartin River with almost 200 m thickness (Tokay et al., 1952). This is the section dividing Göktepe Formation. (Fig. 2.4)

Formations stratigraphically higher up include more silicified intercalations. These are followed by micro-conglomeratic or cherty quartzites of light violet, gray, brown and gray, fine to medium grained, even brecciaed limestone. These levels contain *Sprifer crassifulcitus* indicating Early Devonian age according to the Tokay et al., (1952).

Middle Devonian consists of light or dark colored crystalline, cherty and dolomitic limestones. The thickness of the Göktepe Formation can be changing from 300 m up to 1200 m at the north-west part of the study area.

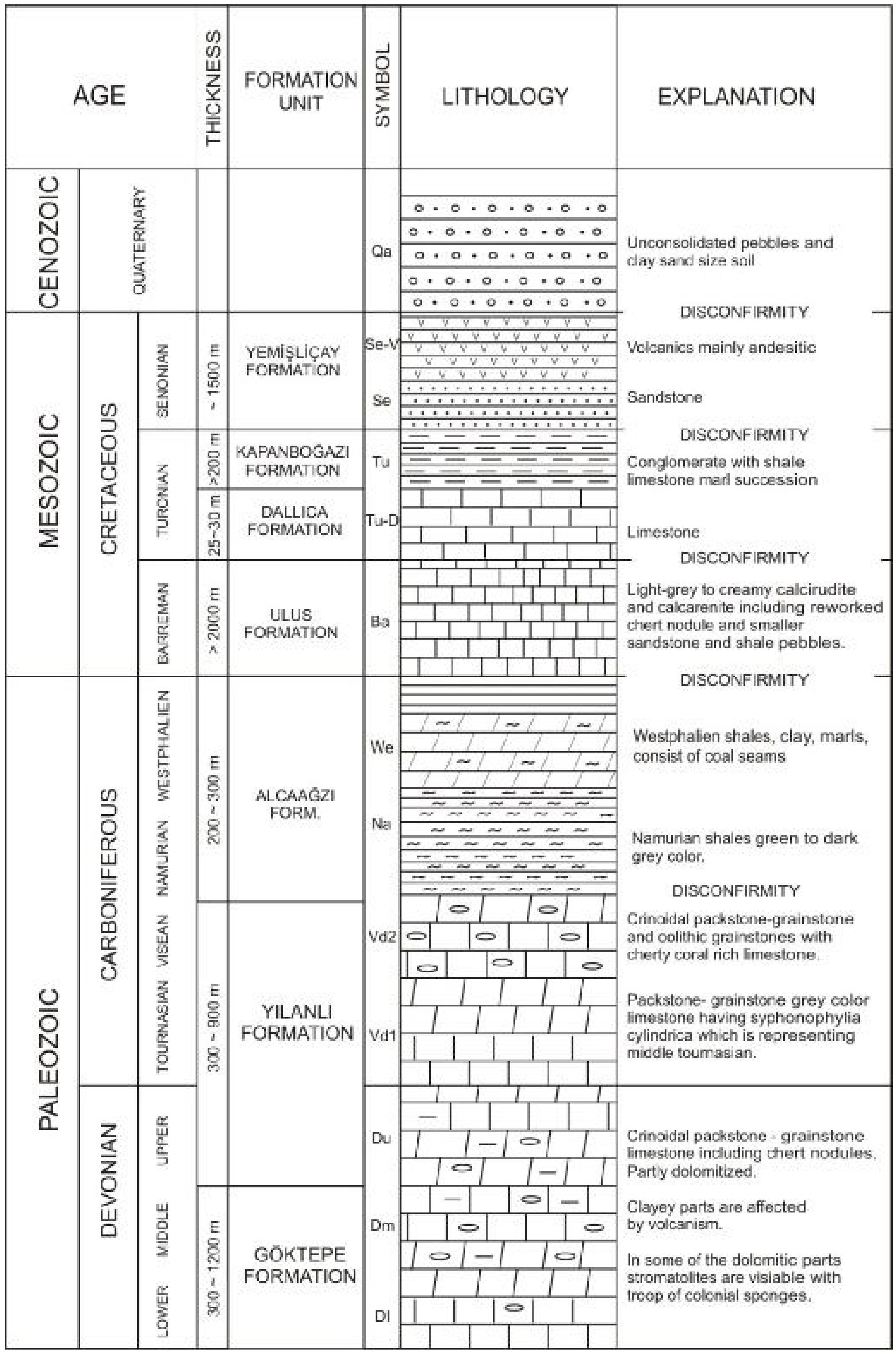

Figure 2.2 Generalized stratigraphic columnar section of the study area.

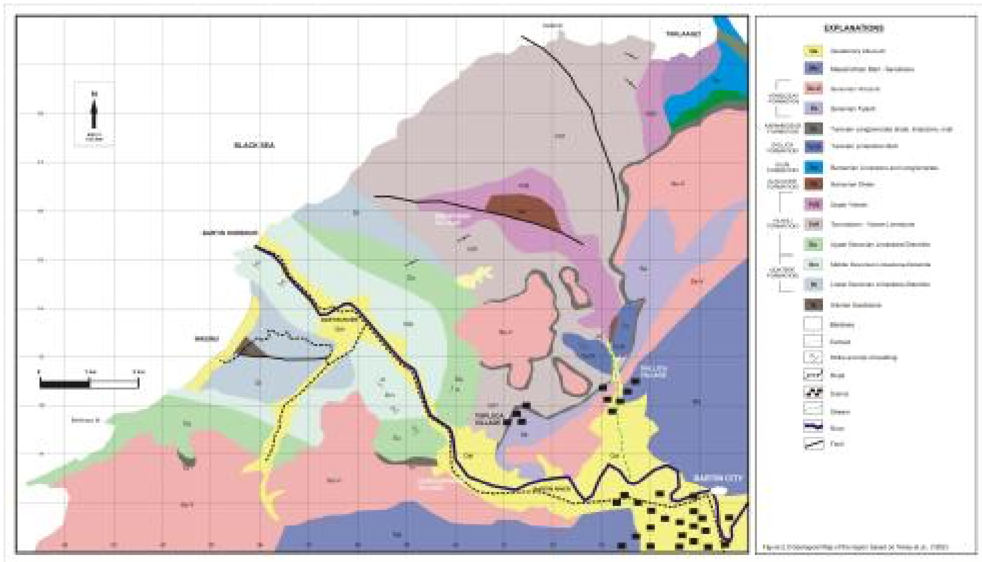

Figure 2.3 Geological Map of the region based on Tokay et. al., (1952)

Figure 2.4 North of İnkumu locality showing the transition (red line) from Lower Devonian up to Middle Devonian of the Göktepe Formation.

Figure 2.5 Middle Devonian dolomitic limestone of the Göktepe Formation, south of Bartın River. Coordinate: 438500 E, 4612350 N.

Figure 2.6 Middle Devonian dolomitic limestone of Göktepe Formation with colonial sponges and stromatolites. South part of Bartin River. Coordinate: 438550 E, 4612635 N.

Figure 2.7 Middle Devonian dolomitic limestones of Göktepe Formation showing the crinkly alteration North part of Bartın River, Coordinate: 438350 E, 4613185 N

2.2.2 Yılanlı Formation

2.2.2.1 Description

The name of the Yılanlı formation is given by Sener et al., (1980), starting from Upper Devonian to Carboniferous. Formation is characterized by cherty limestone including corals. Formation is a potential resource for Lime and Cement industry.

2.2.2.2 Lithology

Formation consists of limestone and dolomitic limestones having a thickness between 350 m to 900 m. Limestones include big chert nodules (Fig. 2.8) and contain *Sprifer verneuili* Murchison, *Productella subacuelata* Murchison, *Arteria corotis communis* Goss indicating Late Devonian age (Tokay et al., 1952).

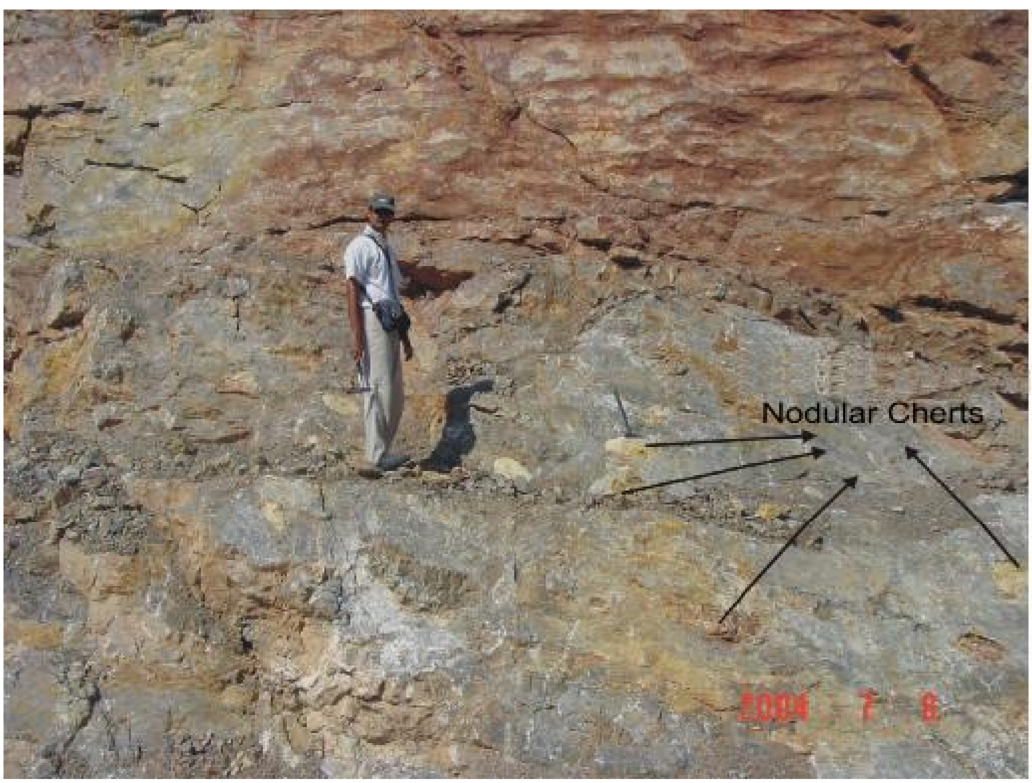

Figure 2.8 Chert nodules (arroes) on the quarry wall of Bartın Lime Industry, Upper Devonian limestones.

Foraminifers are particularly useful for biostratigraphy in the Upper Devonian and the Lower Carboniferous. We collected 30 samples from which thin sections were carried out. For the Carboniferous, we follow the new zonation of Devuyst & Hance (in Poty et al., 2006). Nineteen zones subdivide the Upper Devonian and the Mississippian succession.

Upper Devonian is passing to Tournaisian, consists dominantly of well bedded dark grey mudstones to wackestones with less frequent packstones. Macrofauna seems to be rare but silicified shells were found.

Syphonophylia cylindrica is a key fossil for Middle Tournaisian found nearby Esenpınar Village. Also in the same region S*yringopora* sp. is determined (Fig. 2.9).

Figure 2.9 S*yphonophylia cylindrical* in Middle Tournaisian, Coordinate: 440400 E, 4615230 N

Tournaisian is supposed to be shown in the Vd1 zone of Tokay’s geological map (Fig. 2.3).

This unit is most likely falling in the Upper Devonian – Tournaisian of Tokay, even if it is included in the Visean on his map.

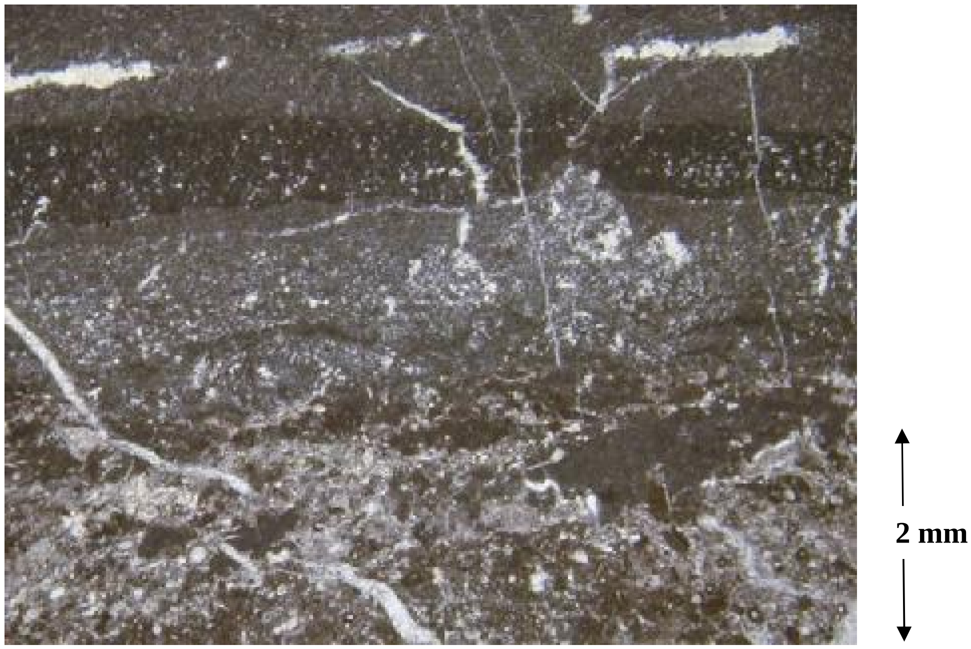

Figure 2.10 Microfacies of sample BA20 lamination

Microfacies of sample BA20 is bioturbated packstone with calcispheres laminated, overlain by mudstone, having the biofacies of Moravamminids and ostracods. Intrpretation is peritidal environment.

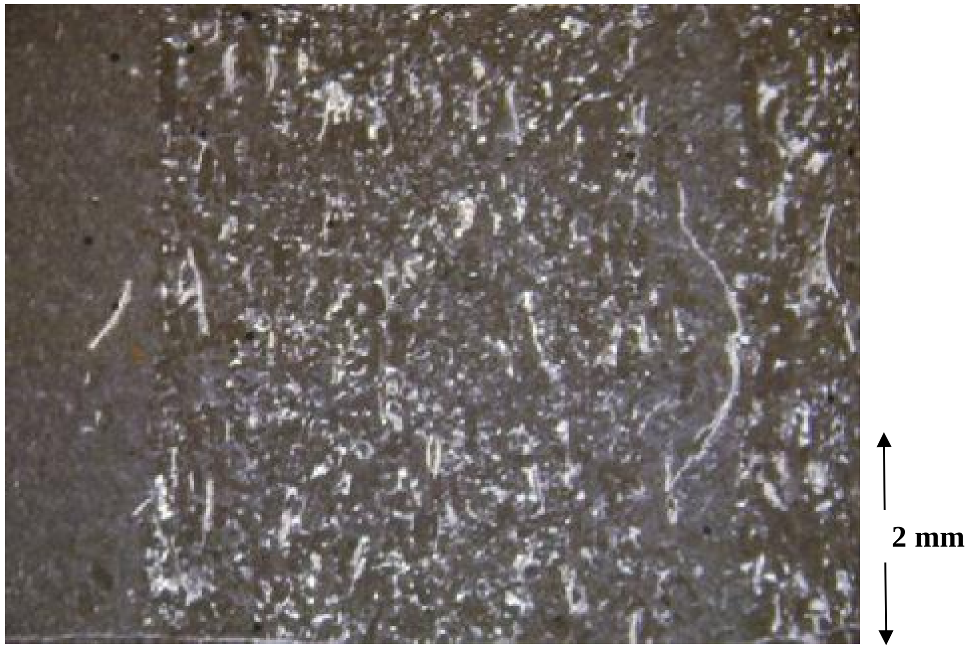

Figure 2.11 Microfacies of sample BA21 lamination

Microfacies of sample BA21 is laminated peloidal packstone to grainstone. Micritic stromatolithic film fixing the peloids is, having the biofacies of Ostracods, rare forams, faecal pellets. Interpretation is peritidal environment.

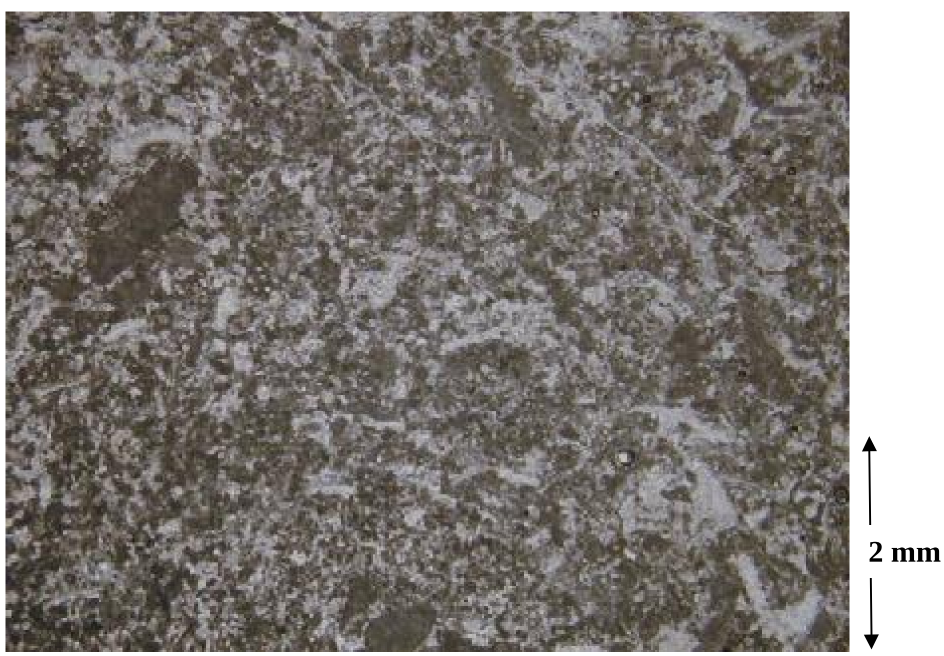

Figure 2.12 Microfacies of sample BA22: Bioclastic packstone.

Microfacies of sample BA22 is bioclastic packstone. Intraclasts are peloids and bioclasts and also having the biofacies of brachiopods, foraminifers, moravamminids Interpretation is a deeper facies, below fair wave base.

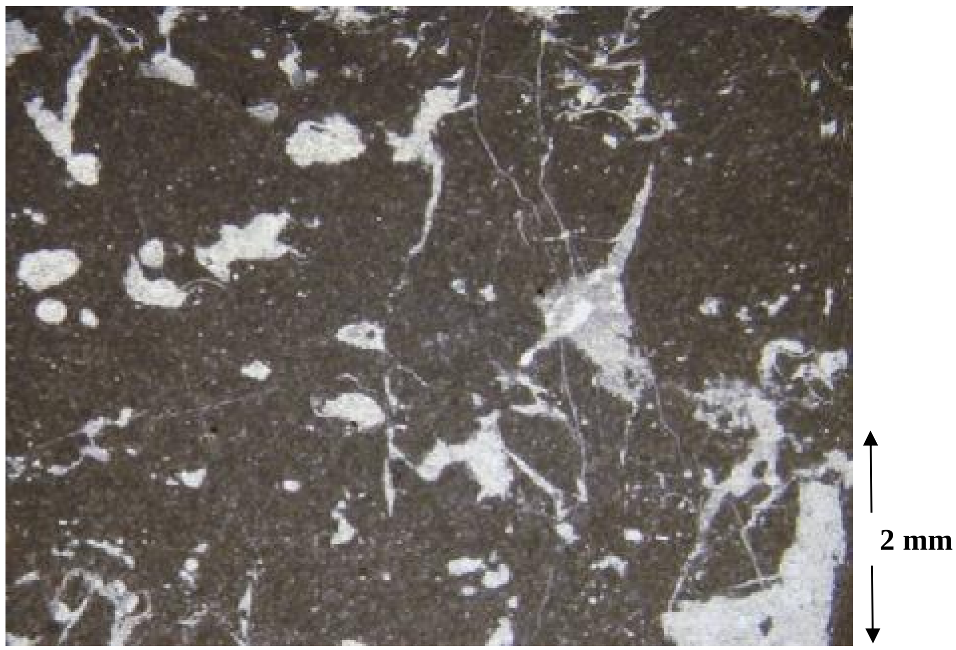

Figure 2.13 Microfacies of sample BA23: Fenestral mudstone

Microfacies of sample BA23 is fenestral mudstone with having the biofacies of gastropods. Interpretation is peritidal environment.

In the lower part, near the andesitic body (North of Akgöz Village) samples BA21 – BA22 contain Middle Tournaisian microfauna typical for Zones MFZ4-5: *Palaeospiroplectammina tchernyshinensis*, *Tuberendothyra* sp., *Granulifferella* sp. (Zonation table of Devuyst & Hance, in Poty et al., 2006).

The lower formations of Visean is consisting of cherty, dolomitized marine limestone (approximately 1250 m thick), contain the D1 zone of *Dibunophyllum* sp. The upper formations, which are argillaceous shale of Culm facies with marine limestone intercalations (180-300m thick), contain the D2 zone of *Dibunophyllum* (Tokay et al., 1952).

Visean limestone is covering Tournaisian and cropping out at short distance from the Visean shales. Dark blue, dark grey colour, coral rich, cherty limestone is having a texture of mainly packstone to grainstone and medium bedded. Thickness of the limestone is measured 100 m.

The interpretation of the limestone is the bioclastic grainstones with a diverse fauna indicating the deposition above fair wave base in an open marine setting. The bioclastic packstone is a deeper facies, below fair wave base.

Figure 2.14 Bioclastic packstone of Visean limestone with rugose corals, along the Süzek River.

This unit straddle the Tournaisian-Visean boundary. Associations representatives of Zones MFZ8 (uppermost Tournaisian) and MFZ9 (lowermost Visean) have been found. The microfauna are abundant and diversified. *Eoparastaffella simplex*, the guide for the base of the Visean is present.

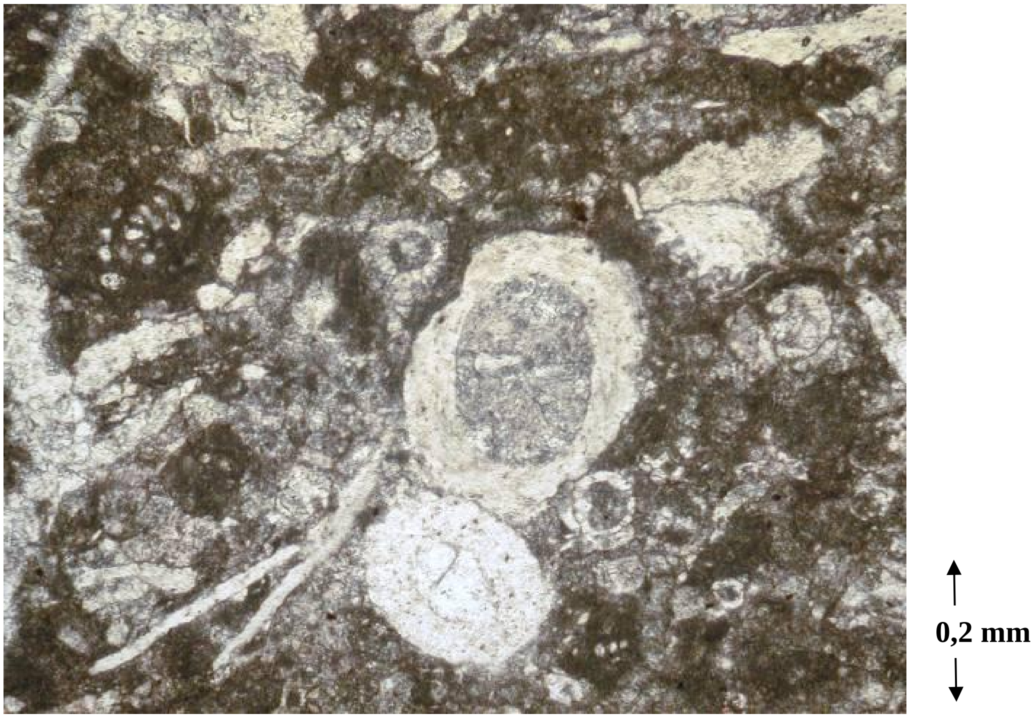

Figure 2.15 Sample BA4; bioclastic pacstone microfacies is having a biofacies of abundant brachiopods, crinoids, moracamminids, less frequent foraminifers.

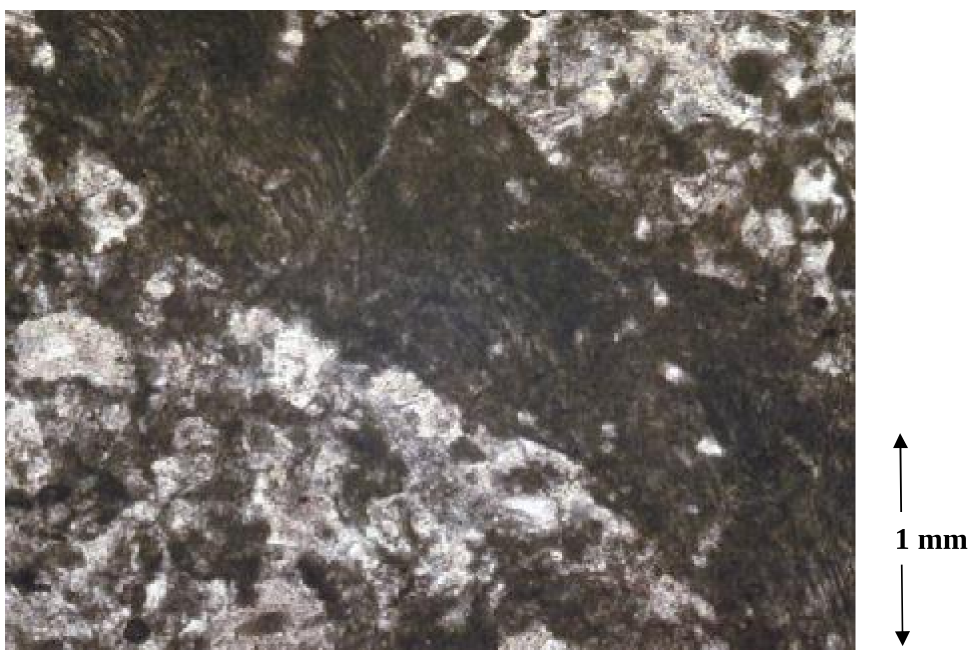

Figure 2.16 Sample BA5; Bioclastic peloidal packstone-grainstone microfacies is having a biofacies of abundant micritized foraminifers, calcispheres, brachiopods, crinoids, gastropods, rugose corals.

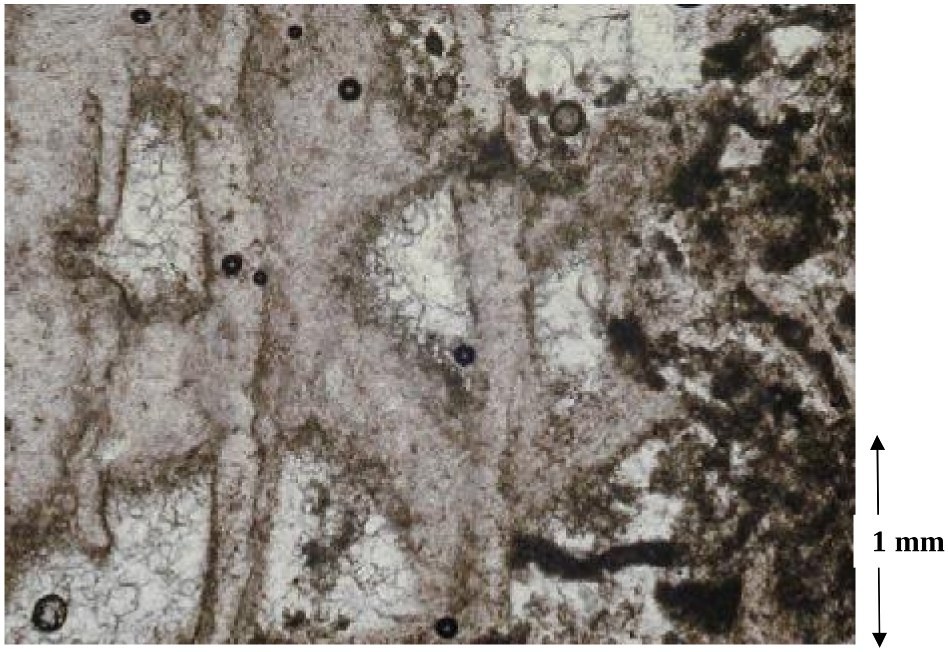

Figure 2.17 Sample BA5 is a detail picture of coral

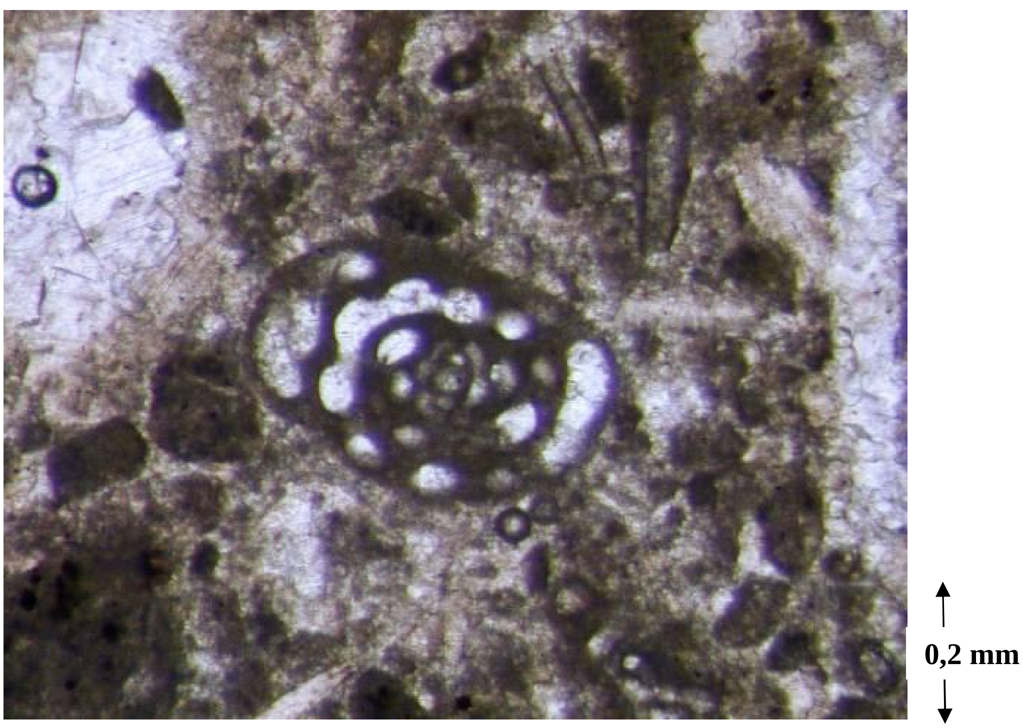

Figure 2.18 Sample BA6 is a bioclastic peloidal packstone microfacies and having a biofacies of abundant micritized foraminifers, calcispheres, brachiopods, crinoids, gastropods, rugose corals

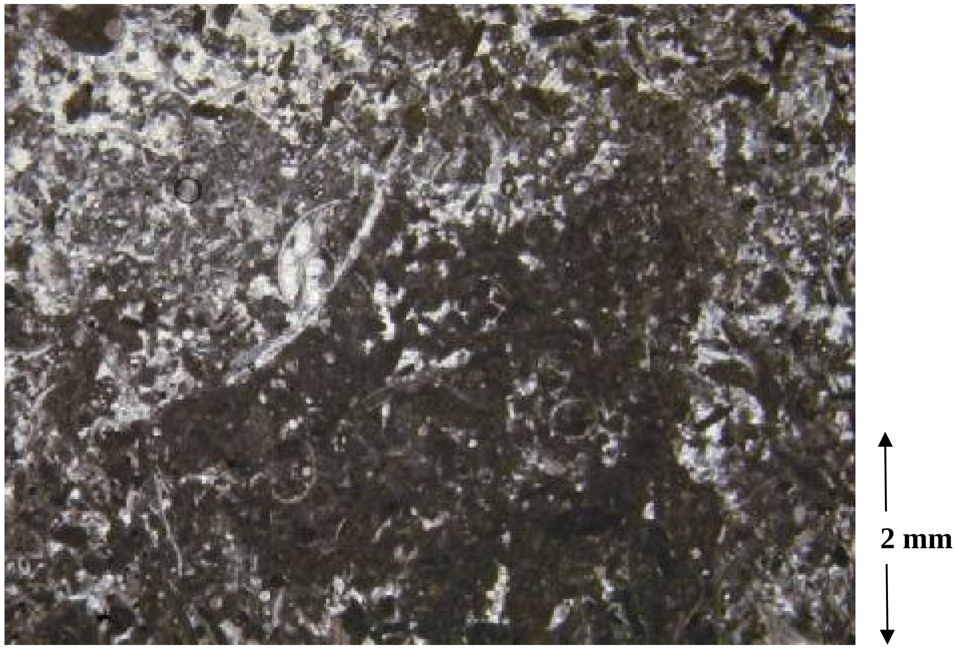

Figure 2.19 Sample BA24; Intraclastic packstone-grainstone and inhomogeneous bioturbation microfacies is having a biofacies of abundant foraminifers, ostracods, moravamminids and calcispheres.

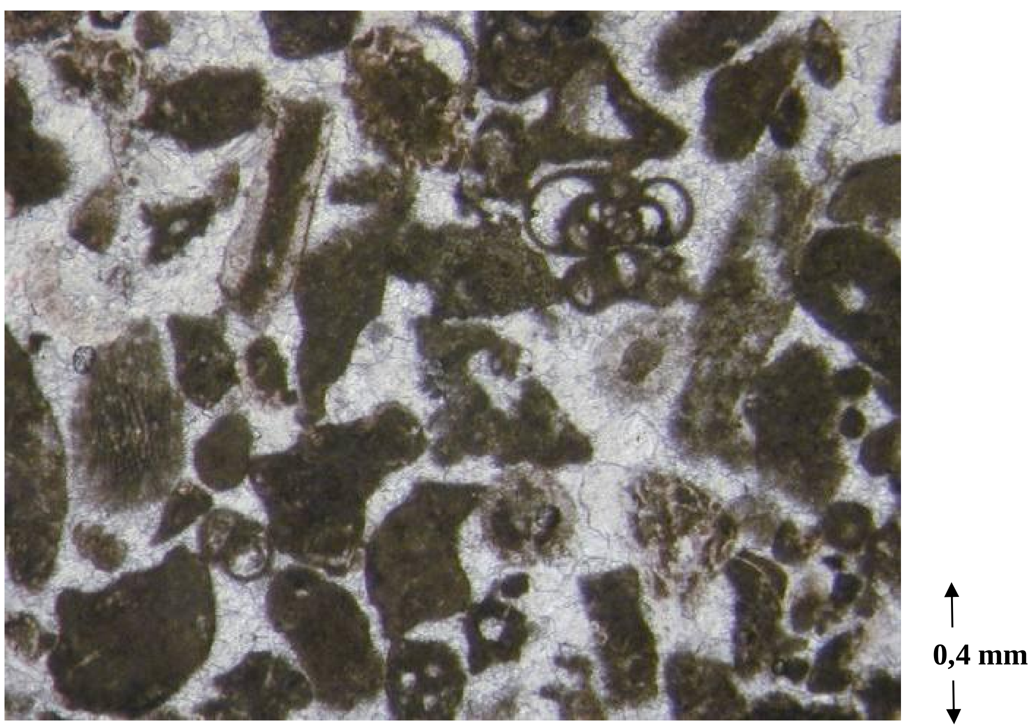

Figure 2.20 Sample BA25 is an intraclastic grainstone in contact with a bioturbated wackestone.and having a biofacies of abundant foraminifers, ostracods, moravamminids and calcispheres.

2.2.3 Alacaağzı Formation

2.2.3.1 Description

Alacaağzı Formation has been seen around Tarlaağzı open-cast, along Suzek River and Esenpınarı Village.

Formation is having the age of Namurian, consists of sandstone and shales containing thin coal seams and overlies the Upper Visean shales and in some places, Devonian is covered with Westphalien Kozlu and Karadon stages of Carboniferous which is economically very important for coal mining (Tokay et al., 1952).

2.2.3.2 Lithology

Alacaağzı Formation consists of Namurian shales, sandstones and Westphalien Kozlu and Karadon stages. Lithology is having a thickness between 200 to 300 m.

The most important fossils are given by Tokay et al., (1952);

Cardiopteridium ivaldenburgense Zimm.
Diplotmena bermudensiforme Schloth.
Pecopteris aspera Bgt.
Mesocalamites
Amongst the characteristic megaspores, there are:
Lagenicula crassiaculeata (Zerndt) Pot. & Kr.
Lagenicula subpilosa (İbrahim) Pot. & Kr.
Rotatisporiies rotatus (Bartlett) Pot. & Kr.
Zonalesporites brasserli (Stach & Z rndt) Pot. & Kr. forma *minor* Dijkstra
Setosisporites praetextus (Zerndt) Pot. & Kr. forma *minor* Dijkstra

This fossil content indicates a Namurian age.

Dating of the lower boundary underwent important shifts, from 333 Main Harland et al., (1982 = GTS 82), whereas the upper boundary has remained stable but not well constrained at 314-315 Ma (Dusar et al., 2006).

The Namurian overlaps with the Mississippian Subsystem (359.2 – 318.1 Ma) and the Pennsylvanian Subsystem (318.1 – 299 Ma) of the Carboniferous Period (ICS - International Commission on Stratigraphy (Dusar et al., 2006).

2.2.4 Arıtdere and Ulus Formations

Permian appears to be conformable over the underlying Carboniferous formations. On the other hand, it has been unconformable overlain by the Lower Cretaceous limestone. Especially in the west it appears to be discontinued. Thin bedded layers at the West increase to the East and South-eastwards, reaching a maximum of 110 meters. The lower beds contain conglomerates including rounded pebbles of chert, green quartz, olive-green sandstone, etc. These supposedly Permian beds are known as the Arıtdere formation in the eastern coalfield (Tokay et al., 1952).

The lowest member of the Cretaceous, which transgresses over the coal bearing Carboniferous and older Palaeozoic formations, is a 0-100-meter thick (400 meters in the east) Barrernian of Urgonian (reef) facies. The overlapping Albian and Cenomanian present a facies consisting of blue marls with thin limestone and sandstone intercalations, and a variable thickness which can reach up to 700 meters, where basins have developed (Tüysuz et al., 1997; Masse et al., 1999, 2002).

These Early Cretaceous carbonates around Amasra are members of Ulus formation. If we look in detail to the Ulus Formation;

The NE-SW trending Ulus Basin, the largest sedimentary basin in the Western Pontides, is called mainly by Cretaceous sediments, which are grouped under the name of the Ulus Formation. Although the Ulus and Zonguldak basins are now separated by the Devrek Basin (Fig. 2.21), they were most probably once continuous under this Tertiary basin. Latest Cretaceous - Eocene all of the Devrek Basin sits conformably on the Zonguldak Basin, while it is generally unconformable in the Ulus Basin. The Ulus Basin can be divided into two parts (Fig. 2.21). The western part, west of the Arıt - Cide line, sits on magmatic and metamorphic rocks of the Sunince Massif in the southwest and on the Upper Jurassic platform carbonates and underlying sediments in the Cide Uplift in the north. The western part of the Ulus Basin is thrust over the Tertiary sediments of the Safranbolu Basin in the southeast (Fig. 2.21). The eastern part of the Ulus Basin is located to the east of the Arıt - Cide line. In the northeast, sediments of the eastern Ulus Basin rest unconformably on Upper Jurassic platform carbonates but show tectonic contacts with the other units. In contrast to the western Ulus Basin, the eastern Ulus Basin has a very complex structure due to syn and post-depositional deformation (Tüysuz et al., 1997).

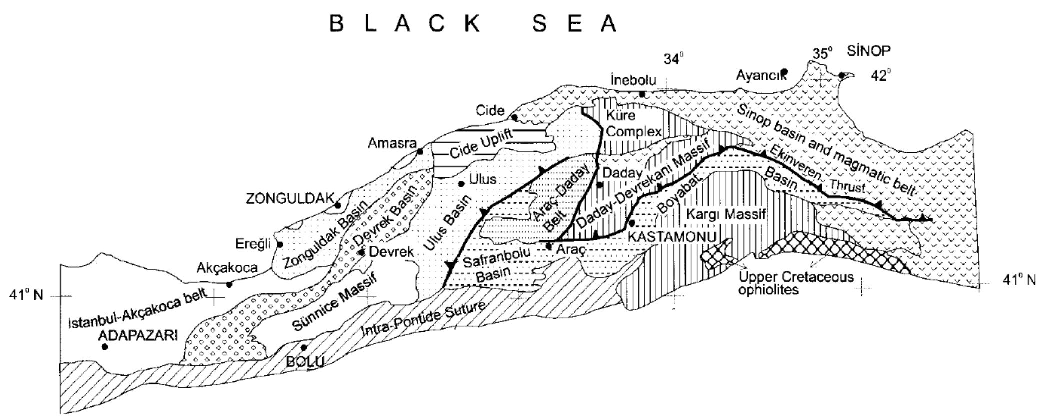

Figure 2.21 The Zonguldak and Ulus basins were called by Lower and Upper Cretaceous sediments. The Devrek Basin, which is called by the uppermost Cretaceous-Eocene clastics, separates these two basins. The Cide Uplift consists of similar rocks to the Zonguldak and Ulus basins. The İstanbul Zone is delimited by the Intra-Pontide Suture to the south and by the Arıt - Daday Belt to the east. The basement of the Central Pontides is present in the Küre area, Daday-Devrekanı and Kargı massifs (Tüysüz et al., 1997).

2.2.5 Dallıca Formation

2.2.5.1 Description

According to Tokay's geological map (Fig. 2.3), the area consists of Visean limestones at the south-western flank of an overturned syncline. Upper Visean and Namurian culm facies occupy the central part of the fold. An unconformity separates the Visean limestone from the Turonian conglomerate and Upper Cretaceous flysch which are gently dipping southwards. On Tokay's map, these Mesozoic units are outcropping only out of the area we investigated.

Dallıca Formation is equivalent to the Turonian conglomerate of Tokay. It was not identified by the latter who probably limited his field work along the road where indeed the Lower Visean is cropping out.

2.2.5.2 Lithology

Light-grey to creamy limy calcirudite (microconglomerate) and calcarenite, including locally cm large reworked chert nodule and smaller sandstone, quartz and shale pebbles. It is organized into m-thick parasequences with coarser-grained calcirudite passing to finer-grained calcarenite in the upper part. Macrofauna is limited to rare large gastropods (up to 15 cm). More coarser-grained conglomerate can be observed locally (Fig. 2.35).

Structure and distribution of the formation is subhorizontal to locally dipping 20° to the south. It extends largely over the investigated area, between Dallica and Gökünceşmesi and it is also present on Karaagaclik hill on the other bank of the N-S valley. The unit is locally deeply affected by karstic dissolution.

The average thickness is 0-20 m, highly variable. Dominant microfacies are calcarenites to calcirudites.

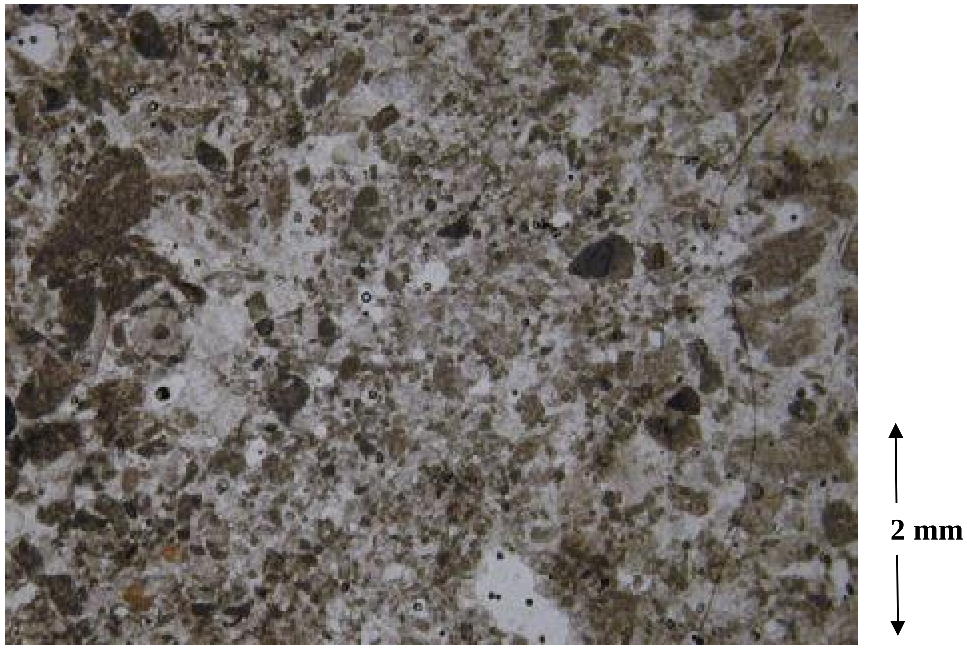

Figure 2.22 Sample BA7 is a Calcarenite: subrounded limestone clasts, many subangular intraclasts, some quartz grains, laminated. Crinoids' biofacies. BA8 is Intraclastic grainstone: angular intraclasts, many angular bioclasts, some angular quartz grains, laminated structure and having a biofacies of crinoids, brachiopods, bryozoans, biserial foraminifers.

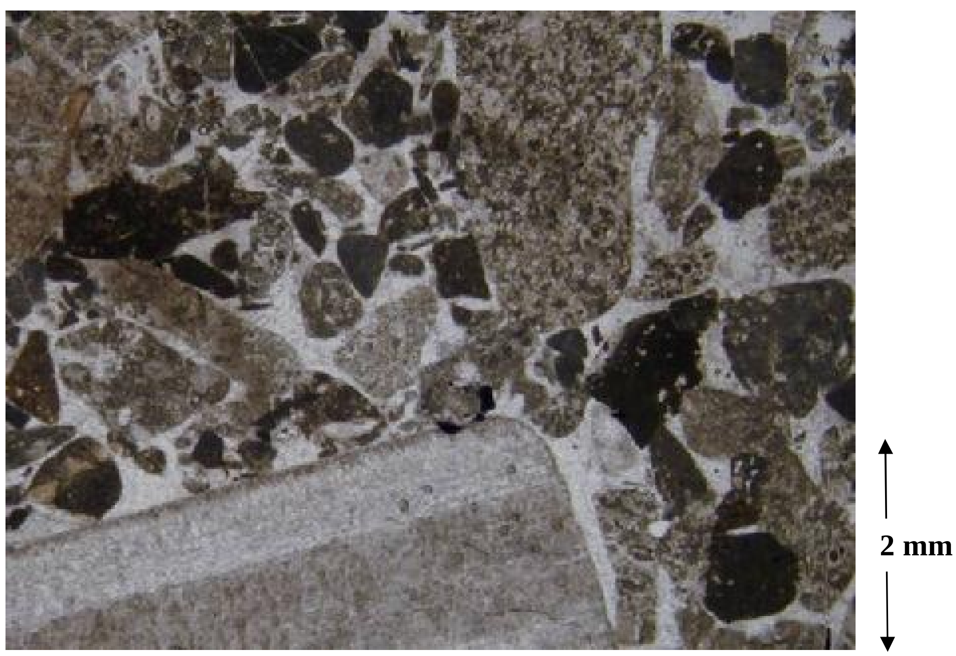

Figure 2.23 Sample BA9 Calcirudite with subrounded clasts and reworked bioclasts.

BA9 is Calcirudite: diverse subrounded lithoclasts, including Upper Devonian limestones with foraminifers and bryozoans, sandstone, quartzite, also angular intraclasts. Is having biofacies of Crinoids, brachiopods, bryozoans, biserial foraminifers.

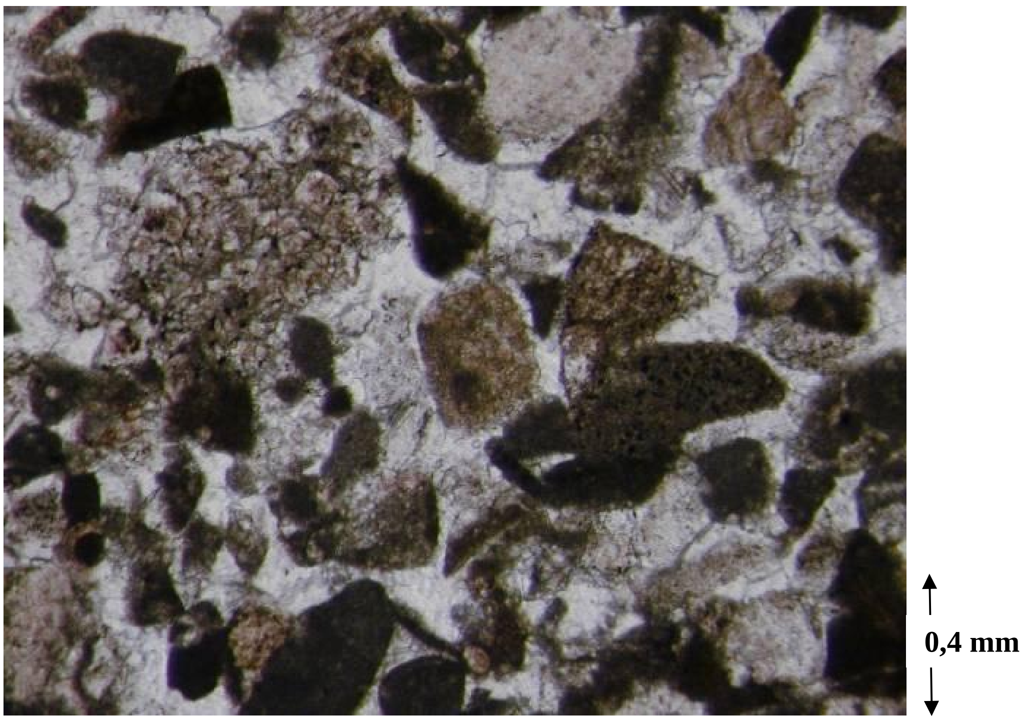

Figure 2.24 Sample BA10 Calcarenite, detail with dolostone clast, angular intraclasts and subrounded extraclasts.

BA10 is Calcarenite: subangular to subrounded mudstone-wackestone clasts, quartz and dolostone, is having a biofacies of rounded echinoid plates.

BA11 is Intraclastic grainstone: Intraclasts are subangular to subrounded mudstone-packestone, some bioclasts and having a biofacies of rare ostracods and crinoids. Some clasts contain foraminifers.

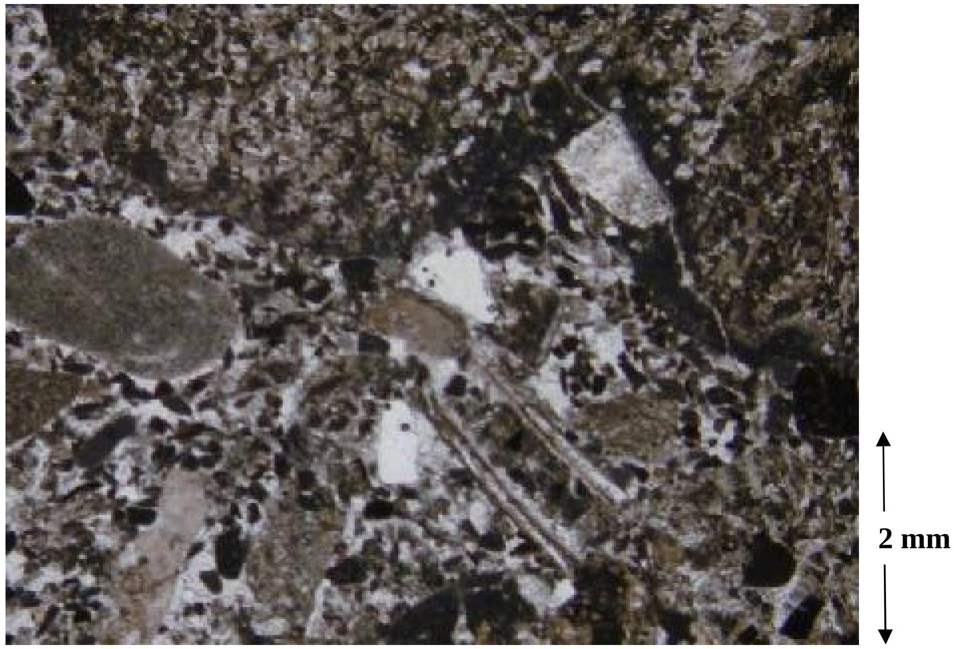

Figure 2.25 Sample BA12 Calcarenite, detail with dolostone clast, angular intraclasts and subrounded extraclasts.

BA12 is Calcirudite: diverse large limestone lithoclasts, subrounded, some small angular intraclasts and quartz grains, is having a biofacies of Rare brachiopod spines and echinoid plates.

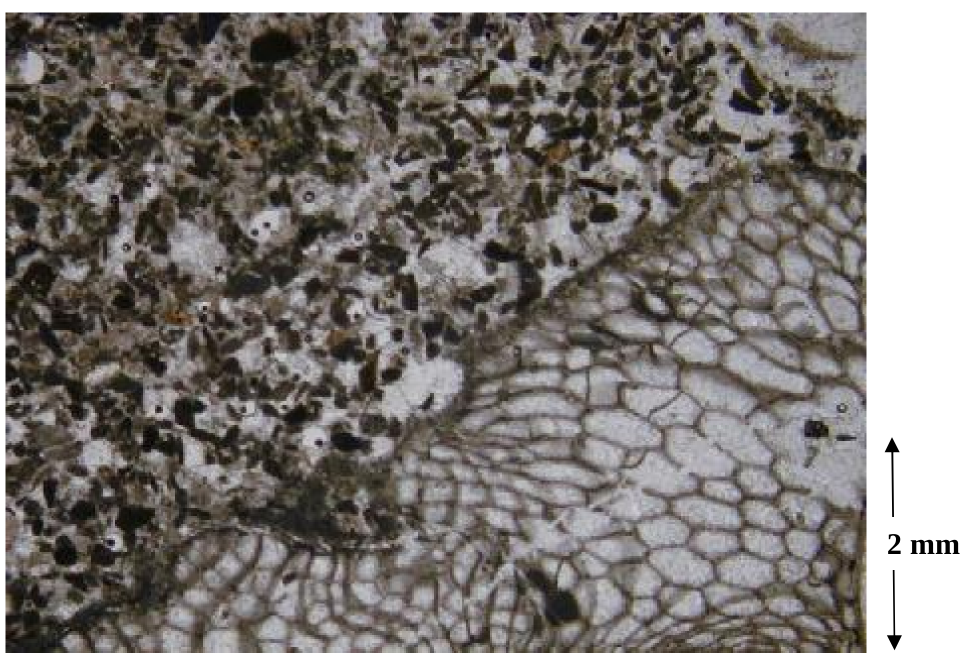

Figure 2.26 Sample BA13 boundstone, here a large encrusting bryozoans.

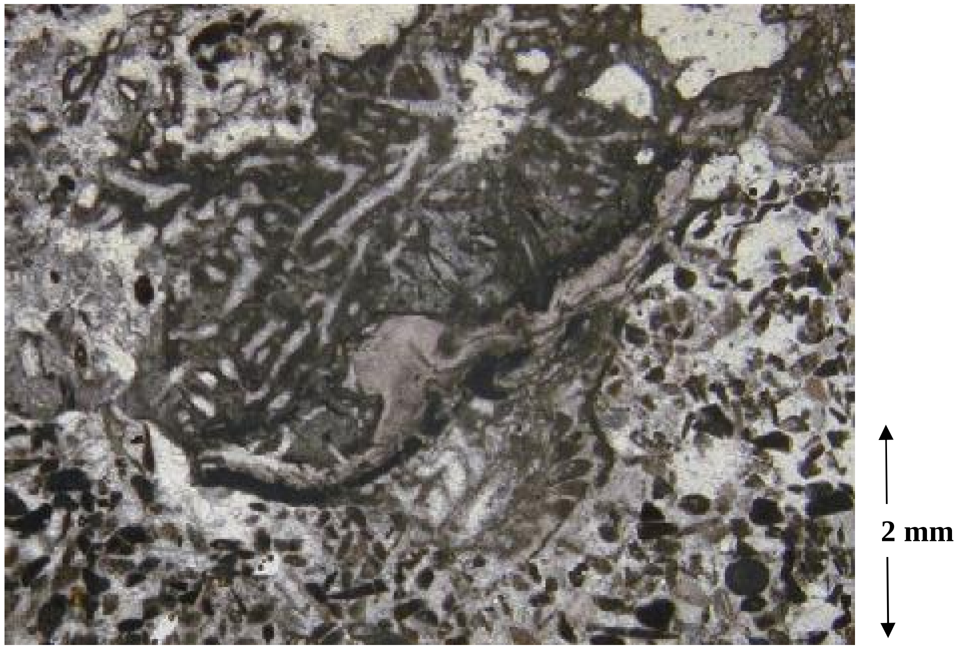

Figure 2.27 Sample BA13 boundstone with tubular algae and branched bryozoans.

BA13 is Boundstone: large algae and briozoans in a matrix of small subangular mudstone-wackestone intraclasts, few small quartz grains, are having a biofacies of Tubular algae and branched bryozoans.

BA14 is Intraclstic grainstone: with subangular mudstone-wackestone clasts, some cherts and quartz grains and many bioclasts and having a biofacies of Echinoid plates and spines.

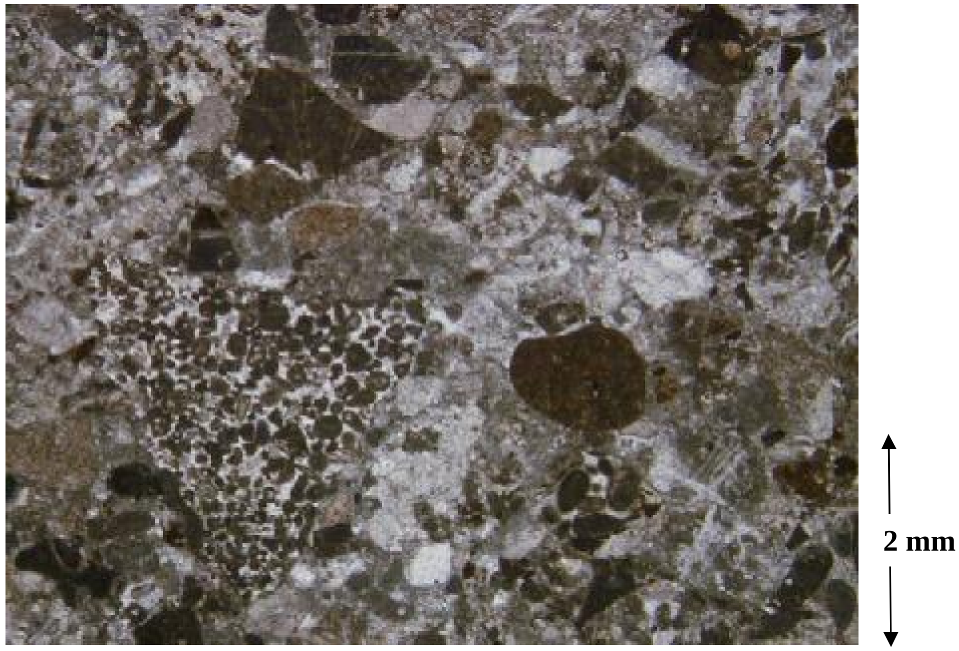

Figure 2.28 Sample BA15 Calcirudite with diverse limestone clasts.

BA15 is Calcirudite: diverse subrounded to subangular clasts of limestone (mudstone, grainestone), dolostone, chert and sandstone, is having biofacies of with algae and bryozoans.

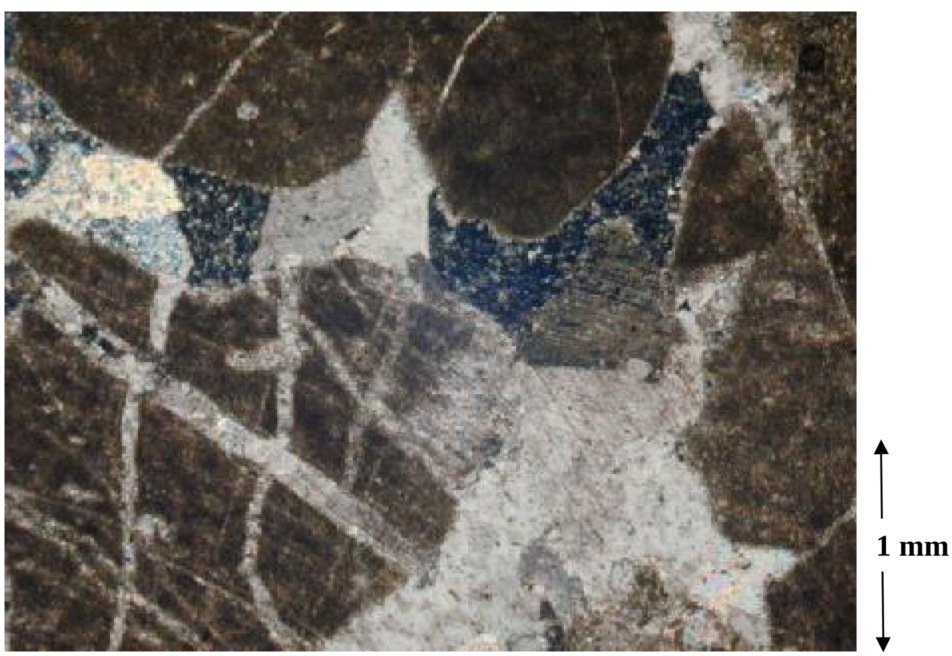

Figure 2.29 Sample BA16 calcirudite, detail on vein pattern of mudstone clasts.

BA16 is Calcirudite: diverse subrounded to subangular clasts of limestone (grainstone, mudstone with complex calcite vein pattern), chert and quartz and having a biofacies of with algae and bryozoans.

BA17 is Intraclastic grainstone: Subangular mudstone-wackestone clasts, some quartz grains, bioclasts and having a biofacies of echinoderms.

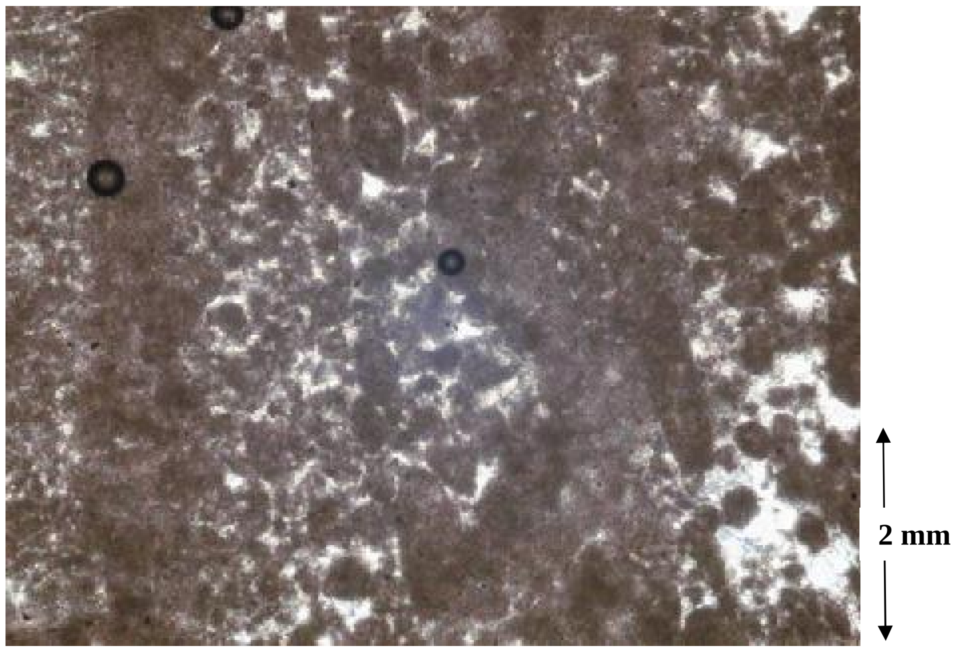

Figure 2.30 Sample BA18 Intraclastic grainstone/packstone as a graded and laminated structure.

BA18 is Intraclastic/peloidal grainstone/packstone: Subangular mudstone-wackestone clasts, peloids, bioclasts, and quartz and chert grains. Laminated, graded and having a biofacies of two foraminifers in matrix.

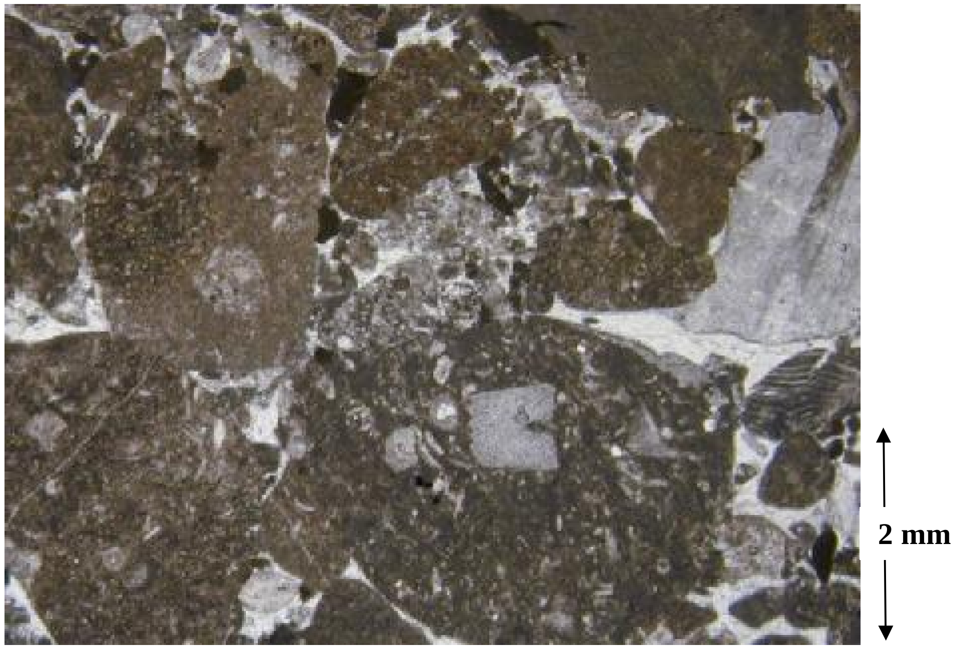

Figure 2.31 Sample BA19 Calcirudite with diverse limestone clasts and reworked bioclasts.

BA19 is Calcirudite: diverse limestone clasts, subrounded, sutural contacts, some reworked bioclasts, intraclasts and quartz grains and having a biofacies of echinoderms.

The poor roundness of the lithoclasts indicates the proximity of the source. The Dallica limestone is probably filling a channel-like structure, cross-cutting the underlying Devono-Carboniferous succession. The sandstone fragments originate probably from the Lower Devonian. Upper Devonian lithoclast are abundant. The small subangular mudstone-wackestone clasts could represent the Middle Tournaisian which is underlying the Dallica limestone in the area we investigated. The source for the better rounded dolostone lithoclast can be the Middle Devonian (Fig. 2.32).


Calcirudite resting on a calcarenite

Coarse grained calcirudite

Contact between Dallica Fm. (above hammer) and Visean limestone.

Figure 2.32 The interpretation of the contact between Carboniferous and Dallıca Formation.

Figure 2.33 Weathered surface of the Dallıca Formation. Old quarry on the east flank of the valley. Picture is taken along the Süzek River.

Figure 2.34 Effect of karstic dissolution in the Dallıca Formation, close to Akgöz Village.

Figure 2.35 Big gastropodas (~15 cm) in Dallıca Formation, 200 m north of Bartın Lime Industry.

The matrix/cement yields very rare biserial foraminifers and a fragment of a large agglutinated one.

The clasts contain a typical uppermost Devonian association (DFZ7 Zone) including the key taxa *Quasiendothyra kobeitusana, Q.* cf. *konensis, Latiendothyra parakosvensis*, cf. one clast with *Chernyshinella* sp. could originate from younger Tournaisian strata.

Table 2.1 Position of the foraminiferal zones recognized at Dallica. Dotted line for reworked material included in Dallica Formation (table from Devuyst et al., in Poty et al., 2006).

Chronostrat.			Foraminiferal zones: This paper	Conil et al. 1991		Mamet 1974	Conodont zones: Conil et al., 1991 and this paper		Coral zones: This paper		3rd order seq. strati.: Hance, P. & D., 2001
MISSISSIPPIAN	S.	Arnsb. / Pend.	MFZ16	Cf7		17-19	boll.	*Adetognathus unicornis* / *Gn. bilineatus bollandensis*	RC9		11
	VISEAN	Warnantian	MFZ15	Cf6	δ	16s	*bilineatus*	*Gnathodus bilineatus bilineatus*	RC8		10
			MFZ14		γ	16i			RC7	β	9
			MFZ13		α–β	15	? *T. transatlanticus*			α	
		Liv.	MFZ12	Cf5		14 / 13			RC6		8 / 7
		Mol. emend.	MFZ11	Cf4	γ–δ	12		*Taphrognathus transatlanticus*	RC5		6
			MFZ10		β	11 / 10		*Gnathodus cracoviensis*	RC4	β2	
			MFZ9		α2		homo.	*Gnathodus homopunctatus*			5
	TOURNAISIAN	Ivorian	MFZ8		α1	9	*S. anchoralis*	*Mestognathus praebeckmanni* ? ?		β1	4
			MFZ7								
			MFZ6	Cf3			*cordiformis*	*Polygnathus bischoffi* / *Doliognathus latus*	RC3	α / γ	
			MFZ5	Cf2		8	*carina*	*Dollymae bouckaerti*		β / α	3
			MFZ4	Cf1	γ			*Gnathodus*	RC2		
		Hastarian	MFZ3		β	7		upper *obsoleta*			2
			MFZ2		α'' / α'	pre-7		lower *obsolete* / upper *cooperi*	RC1	γ	
			MFZ1		α			*duplicata - cooperi*		β / α	1
DEVONIAN	FAMENNIAN	"Strunian"	DFZ8					upper *praesulcata*	RC0	β	
			DFZ7	Df3	ε	6		upper *expansa*			
			DFZ6		δ	5		middle *expansa*		α	
			DFZ5		γ						

2.2.6 Kapanboğazı and Yemişliçay Formations

The Ulus Group is conformably overlain by a red limestone-marl succession, the Kapanboğazı Formation of Cenomanian-Turonian to Early Campanian age (Görür et al., 1993), which is replaced laterally and vertically by a thick volcano-sedimentary sequence, the Yemişliçay Formation of Turonian-Campanian age (Gedik and

Korkmaz 1984; Aydın et al., 1986; Yiğitbaş and Elmas 1997). The volcanic rocks consist essentially of andesitic and subordinate basaltic lavas and the associated pyroclastic rocks. The intercalated sediments are formed from shale, marl and pelagic limestone.

The Kapanboğazı Formation consists dominantly of thinly bedded red pelagic micrites with thin shaly partings and beds. There are also rare grain and debris flows, made up of metamorphic rock fragments.

The Kapanboğazı Formation forms a marker zone throughout the Central and Eastern Pontides (Pelin et al., 1982; Görür et al., 1993) and is interpreted as a postrift sequence deposited following the formation of the first oceanic crust in the Black Sea back arc basin (Görür, 1988; Görür et al., 1993).

The Kapanboğazı Formation passes laterally and upward to a sequence of volcanic agglomerate, tuff, and pelagic limestone 125–250 m in thickness. Pelagic limestones occur both as interbeds and as blocks in the volcanic rocks. Pelagic limestones sampled from the basal and upper parts of the Yemişliçay Formation contain planktonic foraminifers.

The Yemişliçay Formation was formed in a submarine magmatic arc above the northward subducting Neo-Tethyan oceanic lithosphere. The subalkaline geochemistry of the Senonian magmatic rocks from the Eastern Pontides is compatible with a subduction origin (e.g., Manetti et al., 1983; Akıncı, 1984; Çamur et al., 1996; Arslan et al., 1997).

CHAPTER THREE
ECONOMIC POTENTIAL

3.1 Introduction

In agreement with Ereğli Coal Exploitation Enterprise geological investigations have been carried out for several years by Mineral Research and Exploration Institute (M.T.A), in order to access the economic value of the coal seams in Carboniferous formations in Bartın (Tokay et al., 1952).

Beside coal there are more potential deposits at the region like clay, marl, dolomite and limestone.

For several years, STFA Construction Company produced dolomite for steel industry from the west part of Bartın city centre.

Lime, Cement and Brick industries are existing with high production capacities which are using the potential of Bartın region deposits.

There are several quarries in the region operating for aggregate, lime and cement productions. Specifications of the quarries vary depending on the industry of use.

The carbonate potential of the area is supporting the industry of Bartın which is also creating a sphere of business at the region. Figure 3.1 is showing the spread of the industry along the Bartin River.

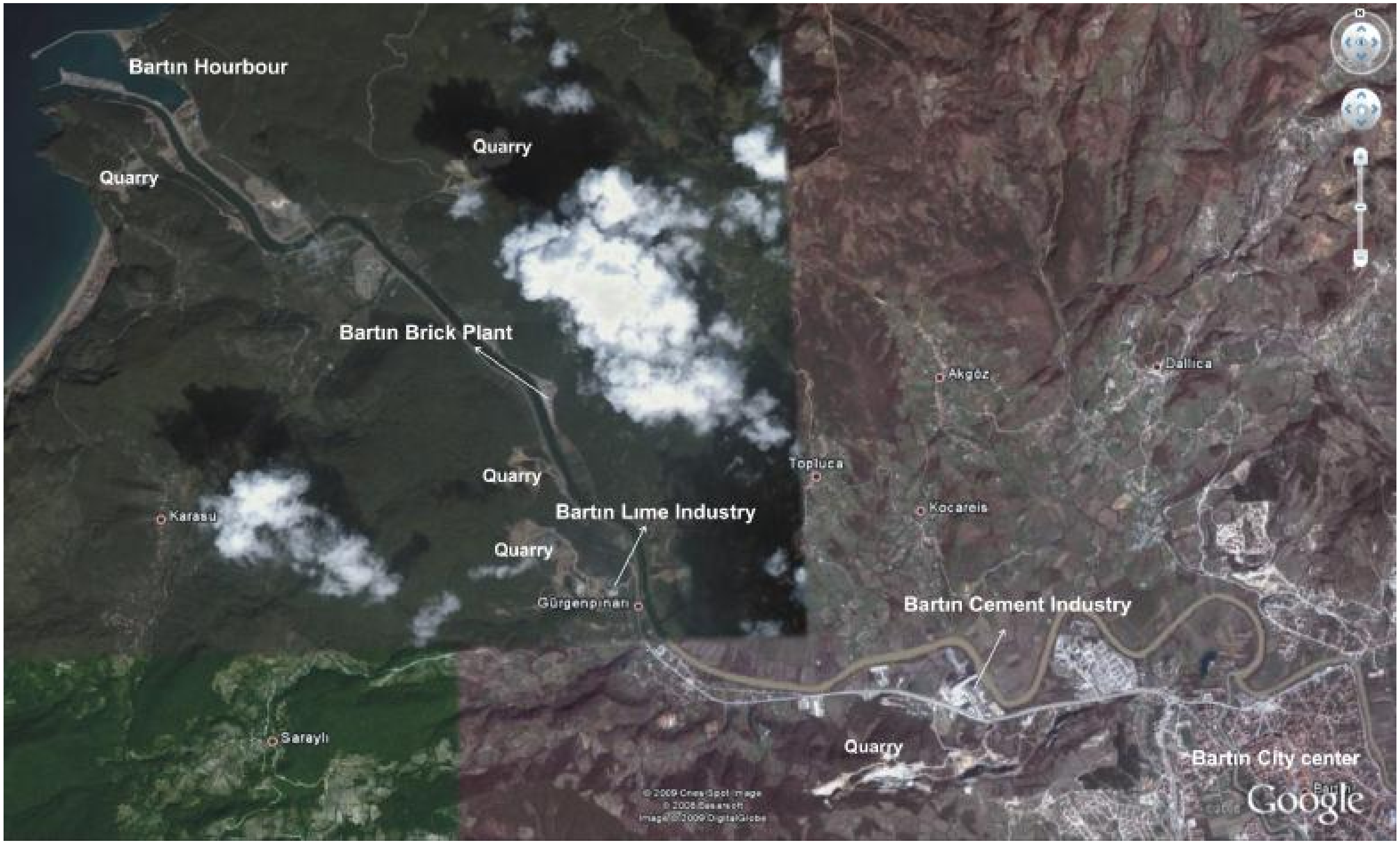

Figure 3.1 Satellite views of Bartın Industrial Zones from Google Earth

3.2 Industry

In all three industries, cement lime and aggregate producers are using limestone or dolomite deposits.

Lime is produced by dissociating the chemical constituents of limestone, which is composed of the mineral calcite ($CaCO_3$), by heating it to temperatures up to 1300° C. This heating process, called calcination, results in the production of lime, or calcium oxide (CaO), and carbon dioxide (CO_2). In the nineteenth and early twentieth century's lime was used mostly in construction for making mortar, plaster, and whitewash, but it also was used for tanning hides, agricultural applications, and sanitation. Today lime is used in steelmaking, flue gas desulfurization (smokestack scrubbing), water treatment, metallurgy, soil stabilization, and many other applications.

Making lime could be as simple as digging a small pit into which fuel (usually wood) and limestone were placed in alternating layers, then allowed to burn for several days. Vertical shaft kilns were built of stone, typically in the side of a hill, wherein alternating layers of limestone and fuel were fed into the top of the kiln, and lime was drawn out of the bottom through a draft or draw tunnel, allowing continuous production. Some kilns were fashioned after beehive coke ovens, where in the limestone was flash burned.

By combining calcium oxide, silica, and alumina in large kilns, portland cement is manufactured from the raw materials limestone, shale, and clay, respectively. Mixed with sand, aggregate, and water, portland cement is used in making concrete and in masonry applications.

Crushed stone mainly provided aggregate in concrete and asphalt highways and other construction and also provided railroad ballast.

Figure: 3.2 Bartın Lime Industries.

In the lime or dolime production processes, the quarried limestone or dolomite is crushed, and sorted by size in screening plants. At this stage:

- Part is sold directly, for example as aggregates for road construction or for concrete
- Part is ground to lime fertiliser or pulverised into limestone powder, used in applications such as flue gas cleaning.

The rest, high quality limestone (Calcium Carbonate content around 95%) with a defined particle size is calcinated in the lime burning plant at a temperature of 900-1200°C, at which temperature it is decarbonated. During that process, calcium carbonate is converted into calcium oxide (CaO – with the resulting by-product of CO_2):

- Known as quicklime, it is used ground or as lumps, in a wide variety of applications, such as the iron and steel industry, or in construction

- Part is "slaked" to calcium hydroxide or hydrated lime ($Ca(OH)_2$) by the addition of water, which is used mainly in the construction industry. The two principal products are quicklime and hydrated lime.

• 30-40% in the iron and steel industry: steel process innovation, such as electric furnace, iron ore quality, and lime quality improvements for steelmaking technology have reduced the amount of lime to produce one tonne of steel to 30-60 kg, compared to over 90 kg in the 1970s

• 30% in environmental protection, agriculture, and forestry – such as in the desulphurisation of flue gases from waste incineration plants, the treatment of drinking water, organic and inorganic sludge, soil amendments, with new growing markets such as the advanced treatment of sewage sludge and animal by-products and organic wastes

• 15-25% in civil works and clayed soil stabilisation

• 10-15% in a myriad of other sectors, e.g. the chemicals industry, non-ferrous metal refining, PCC for paper, food, feed, and healthcare.

The key sustainable development issue is the access to high quality limestone and dolomite deposits to secure geological reserves for a 30-60 years operation. From the geological perspective, they are available in almost infinite quantities, although their geographic distribution is highly uneven in particular when the minimum calcium carbonate content must be 95% as a basic technical bottom line for lime production. The term limestone also includes dolomite: a rock containing different amounts of a double calcium and magnesium carbonate (pure dolomite being CaCO3.MgCO3.

The main raw materials used in the cement manufacturing process are limestone, sand, shale, clay, and iron ore. The main material, limestone, is usually mined on site while the other minor materials may be mined either on site or in nearby quarries. Another source of raw materials is industrial by-products. The use of by-product materials to replace natural raw materials is a key element in achieving sustainable development.

Mining of limestone requires the use of drilling and blasting techniques. The blasting techniques use the latest technology to insure vibration, dust, and noise emissions are kept at a minimum. Blasting produces materials in a wide range of sizes from approximately 1.5 meters in diameter to small particles less than a few millimetres in diameter.

Material is loaded at the blasting face into trucks for transportation to the crushing plant. Through a series of crushers and screens, the limestone is reduced to a size less than 100 mm and stored until required. Depending on size, the minor materials (sand, shale, clay, and iron ore) may or may not be crushed before being stored in separate areas until required.

In the wet process, each raw material is proportioned to meet a desired chemical composition and fed to a rotating ball mill with water. The raw materials are ground to a size where the majority of the materials are less than 75 microns. Materials exiting the mill are called "slurry" and have flow ability characteristics. This slurry is pumped to blending tanks and homogenized to insure the chemical composition of the slurry is correct. Following the homogenization process, the slurry is stored in tanks until required.

In the dry process, each raw material is proportioned to meet a desired chemical composition and fed to either a rotating ball mill or vertical roller mill. The raw materials are dried with waste process gases and ground to a size where the majority of the materials are less than 75 microns. The dry materials exiting either type of mill are called "kiln feed". The kiln feed is pneumatically blended to insure the chemical composition of the kiln feed is well homogenized and then stored in silos until required.

If we summary the raw material operation;

1. Quarry: Typically limestone, marl and clays as well as other materials containing the required proportions of calcium, silicon, aluminium and iron oxides are extracted using drilling and blasting techniques.

2. Crusher: The quarried material is then reduced in size by compression and/or impact in various mechanical crushers. Crushed rock is reduced in size from 120 cm to between 1.2 and 8 cm. Drying of raw material may also be necessary for efficient crushing and pre-blending.

3. Conveyor: Raw material is then transported from the quarry using conveyors, rail wagons or other suitable logistics solutions specific to the cement plant.

Quarrying is the most important part in production, the value of the raw material is affecting directly the cost of the product.

Figure 3.3 Limestone quarry of Bartın Lime Industry along the Bartın River

Figure 3.4 Limestone quarry of lime industry along Bartın River

3.3 Quarry and Open Pit Mine

The purpose of mine and quarry blasting is to fracture or fragment the rock mass to enable excavation. It is important to understand that not all the energy produced when the explosive is detonated goes into breaking the rock. Some of it is "lost" in the form of heat, sound (causing noise), displacement (when this is excessive it causes fly rock) and ground shaking (causing vibrations). Blasting can therefore be seen to give rise to a number of unwanted and sometimes disturbing effects, but with modern technology and techniques, these impacts can be minimised.

Drilling and blasting for economic evolution of optimum bench height in quarries:

The determination of economical bench height may vary with the types of machinery and equipment being used, topography, environmental conditions, operation plans, etc. Moreover, bench height is closely related to the unit cost of the product. To maintain the cost at an optimum level, determining an economical bench height has to be based on individual economic assessments of quarrying operations followed by the consolidation of individual assessments. Basic quarrying operations consist of blast hole drilling, blasting, loading and transportation. However, other parameters besides bench height, such as rock properties, blast hole diameter, bench geometry, type of explosives being used, size of fragmented rock, loading and transportation equipment, road grades and road stability, etc. directly or indirectly influence the determination of the unit cost of the product.

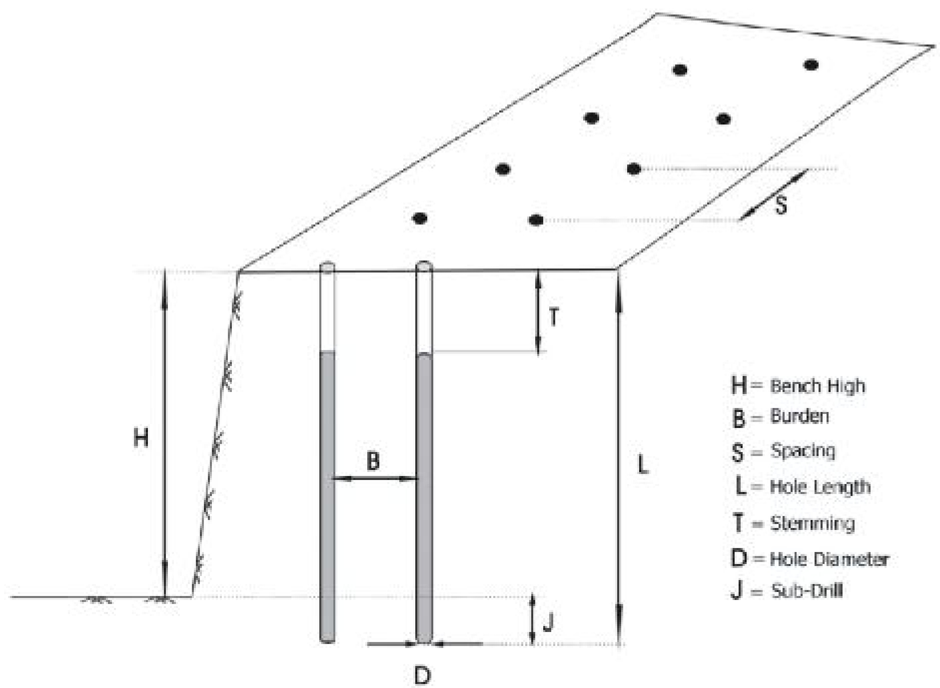

Figure 3.5 Blast hole geometry on a bench (Köse et al., 2005).

Drilling is the first parameter on the quarry design to have an optimum result for blasting economy and safety. In limestone quarries benches are usually having 12 m height depending on the topography and production facilities. Opening between two hole is based on the diameter of drilling. This methodology has counted from the usage of explosives. In figure 3.5, a simple drilling model is shown on a quarry bench. Recently, depending on the new techniques benches are drilling incline and J size deeper from the base level (Köse, et al., 2005).

Holes fill with explosive ANFO (Nitrate Oil), dynamite and detonator.

In general terms, the levels of vibration will get higher as the amount of explosive increases, and will decrease as the distance between the blast and the monitoring location increases. The amount of explosive is taken as the largest amount which is detonated at one particular instant in time .Many blasts are multi-hole blasts and can have delays between each hole being detonated, which is an excellent way of reducing vibrations. However, it should be remembered that the generally accepted "8 millisecond rule" suggests that any holes detonated within 8ms of each other should be considered as going off simultaneously, so to reduce the charges should be detonated at least 8ms apart.

3.4 Chemical Quality of Formations

Selective mining is the most important mile stone for economical production. Industry always needs constant quality for efficient production and customer satisfaction.

When we have a look all the parameters we discussed above for selective mining, we need to have a clear view of geological composition. Quarry production is always controlled by sampling and analyzing methods. All reserves and resources are discovered to clarify the quarry production and plans.

For example in the lime industry, the deposit is a key aspect which will govern the quality of the final products and the life expectancy of the plant. The chemical quality of the inputs should always been controlled.

For selective mining one of the most important things is to determine the constant chemical quality in the quarry operation. Sampling is an important aspect.

3.4.1 Göktepe Formation

Depending on the chemical analyzes of Middle Devonian, the influence of dolomitization creating the high $MgCO_3$ content on the region. Quarries on the region need to have a map of $MgCO_3$ distribution for selective mining.

Table 3.1 Chemical analyzes of dolomite samples from Göktepe Formation in west part of Bartın River.

Sample	C Total	Al2O3 %	Fe2O3 %	MgO %	S %	SiO2 %	Mn3O4 %	CaCO3 %
BS-1	13,037	0,18	0,14	19,1	0,038	0,92	0,021	58,43
BS-2	12,905	0,04	0,05	20,6	0,002	0,56	0,021	55,97
BS-3	12,57	0,26	0,64	17,9	0,01	1,35	0,018	60
BS-4	12,937	0,24	0,23	20,3	0,014	1,08	0,02	55,67
BS-5	13,155	0,15	0,09	20,5	0,002	0,98	0,019	55,61

Many samples are taken to have a chemical idea between formations to see the influence of the quality.

Table 3.2 Chemical quality of Göktepe Formation varies around Topluca Village

SAMPLE	Lo.I.	SiO2	CaO	MgO	R2O3	S
K1	41,51	1,06	53,59	1	0,03	0,052
K2	45,86	0,44	31,99	18,96	0,074	0,1
K3	42,34	0,38	54,16	0,8	0,058	0,071
K4	42,92	0,24	53,59	0,6	0,058	0,087
K5	42,14	1,04	53,59	0,8	0,13	0,075
K6	42,62	0,38	54,44	0,4	0,022	0,05
K7	43,4	0,22	54,45	0,2	0,086	0,028
K8	45,8	1,04	35,2	16,54	0,15	
K9	46,9	0,89	31,2	20,58	0,14	0,03
K10	46,4	0,08	33,4	19,36	0,02	0,021
K11	47,15	1,6	30,8	20,78	0,15	0,047
K12	43,4	0,22	54,25	0,8	0,086	0,028
K13	42,9	1,16	53,62	1	0,014	0,034
K14	46,41	0,78	30,59	20,97	0,27	0,037
K15	41,88	4,61	51,73	0,6	0,064	0,027
K16	43,11	1,76	53,4	0,4	0,036	0,025
K17	43,17	1,66	52,84	0,8	0,13	0,011
K18	45,42	1,06	35,6	16,38	0,069	0,12
K19	47,07	0,19	32,82	18,98	0,054	0,086
K20	44,36	0,58	48,67	4,39	0,054	0,066

3.4.2 Yılanlı Formation

Chemical quality of the limestone varies depending on the chert nodules, volcanic intrusion and dolomitization. The complex geological history is affected the formation can also be seen from analyzes of the stone.

Table 3.3 Chemical analyzes of samples from Yılanlı Formation. Samples BL1 to BL 4 are from Upper Devonian others are from Tournaisian to Visean.

Sample	C Total %	Al2O3 %	Fe2O3 %	MgO %	S %	SiO2 %	Mn3O4 %	CaCO3 %
BL1	12.208	0.280	0.300	3.900	0.018	1.010	0.008	89.91
BL2	12.382	0.080	0.020	0.500	0.040	0.330	0.004	98.12
BL3	12.219	0.070	0.120	0.430	0.027	0.700	0.005	97.84
BL4	12.566	0.150	0.490	12.700	0.018	0.550	0.017	71.91
BL5	12.039	0.070	0.080	0.430	0.031	0.370	0.006	98.20
BL6	11.913	0.240	0.050	0.460	0.048	0.620	0.006	97.71
BL7	12.116	0.130	0.160	0.710	0.017	0.310	0.010	97.57
BL8	11.976	0.180	0.260	0.680	0.105	0.580	0.013	97.00
BL9	12.626	0.290	0.150	4.670	0.030	0.840	0.018	88.58
BL10	11.832	0.820	1.530	15.800	0.055	5.110	0.022	59.06
BL11	12.269	0.110	0.070	0.400	0.026	0.300	0.004	98.32
BL12	13.045	0.070	0.090	20.900	0.017	0.230	0.014	55.57

Tournaisian seems less affected from dolomitazation which is giving higher $CaCO_3$ content.

Table 3.4 Chemical analyzes of Yılanlı Formation, Tournaisian and Lower Visean.

Sample	C Total %	Al2O3 %	Fe2O3 %	MgO %	S %	SiO2 %	Mn3O4	CaCO3 %
BT1	11,963	0,07	0,04	0,28	0,069	0,81	0,004	98,02
BT2	12,208	0,07	0,03	0,82	0,058	0,65	0,006	97,09
BT3	11,881	0,05	0,03	0,29	0,087	0,15	0,004	98,65
BT4	11,87	0,1	0,05	0,47	0,027	0,94	0,006	97,56
BT5	12,054	0,05	0,09	0,18	0,051	0,32	0,004	98,74
BT6	11,84	0,04	0,06	0,71	0,01	0,26	0,005	97,83
BT7	12,056	0,03	0,04	0,28	0,011	0,24	0,005	98,78

Sampling is an important issue for quarry operation to control strictly the extraction. Mining engineers and geologists are making a team work to follow the best quality for production. Source material is directly affecting the process of industry from raw material to fuel inputs.

3.4.3 Dallıca Formation

The chemical quality of the Dallıca Formation is important for industry of use. Impurities like silica or iron content seems to be lower than other formations on the same region. When we compare with the Devonian and Carboniferous this young formation is having different origin and diagenesis which is creating varied chemical behaviour.

Table 3.5 Chemical analyzes of Dallıca Formation

Sample	Al2O3	Fe2O3	MgO	S (%)	SiO2	Na2O	K2O	P2O5	TiO2	Mn3O4	CaCO3
D1	0,16	0,04	2,66	0,049	0,75	0,013	0,025	0,074	0,01	0,018	93,07
D2	0,26	0,07	1	0,023	0,99	0,006	0,044	0,079	0,014	0,016	96,23
D3	0,21	0,03	0,68	0,051	0,52	0,006	0,024	0,008	0,01	0,008	97,39
D4	0,11	0,05	0,6	0,068	0,4	0,004	0,011	0,01	0,006	0,009	97,72
D5	0,26	0,03	0,5	0,024	0,65	0,006	0,027	0,004	0,01	0,007	97,65
D6	0,14	0,06	0,52	0,023	1,31	0,006	0,03	0,013	0,009	0,019	97,05
D7	0,16	0,05	0,36	0,03	1,22	0,006	0,023	0,01	0,008	0,016	97,44
D8	0,1	0,05	0,26	0,011	1,33	0,006	0,02	0,009	0,011	0,018	97,65
D9	0,53	0,13	0,24	0,022	1,01	0,006	0,004	0,01	0,007	0,276	97,47
D10	0,1	0,1	0,26	0,009	0,18	0,006	0,004	0,01	0,004	0,182	98,75
D11	0,19	0,12	0,66	0,072	0,76	0,006	0,035	0,07	0,014	0,063	97,07
D12	1,2	0,47	0,28	0,03	6,62	0,006	0,156	0,057	0,042	0,089	90,75
D13	0,79	0,3	0,31	0,015	5,3	0,006	0,111	0,12	0,029	0,099	92,62
D14	0,13	0,04	0,52	0,039	0,34	0,006	0,026	0,006	0,011	0,004	98,01
D15	0,19	0,05	0,54	0,075	0,49	0,006	0,046	0,006	0,014	0,006	97,65
D16	0,26	0,1	1,49	0,012	1,11	0,006	0,048	0,013	0,013	0,027	95,08

For selective mining; chemical quality maps are also useful for specifying the convenient parts of the quarry (Figure 3.5).

After having more geological information, the chemical quality correlations between units are directly affecting the reserve estimations.

Geologists are drawing quality maps on the main geology to direct the production inside the quarry or mining areas.

With this methodology selective mining is easier to organize, which saves the production cost.

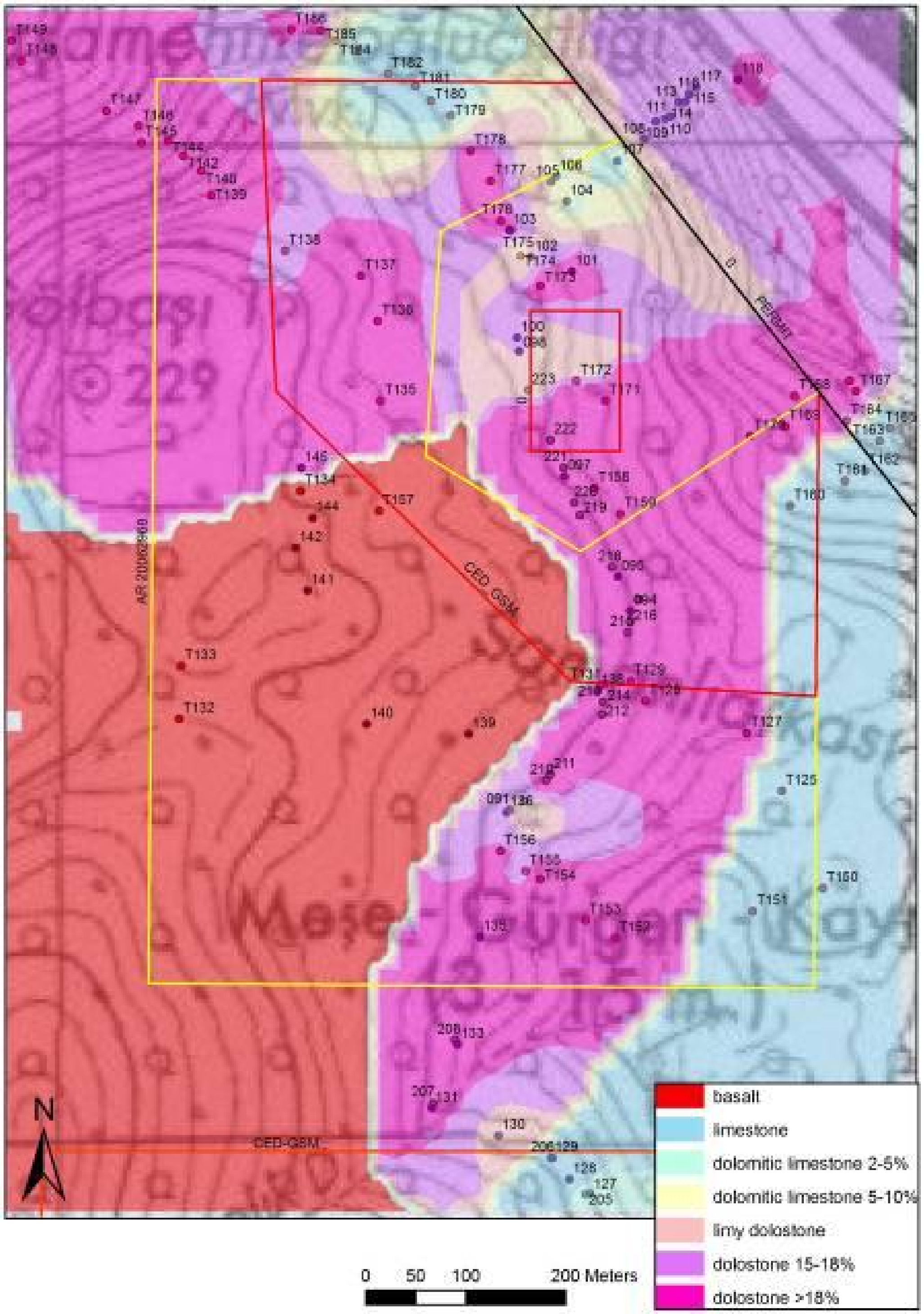

Figure 3.5 MgO Quality Map in Middle Devonian at the west part of Bartın River.

It is likely to create different maps with different colours for specific elements on same region (Figure 3.6).

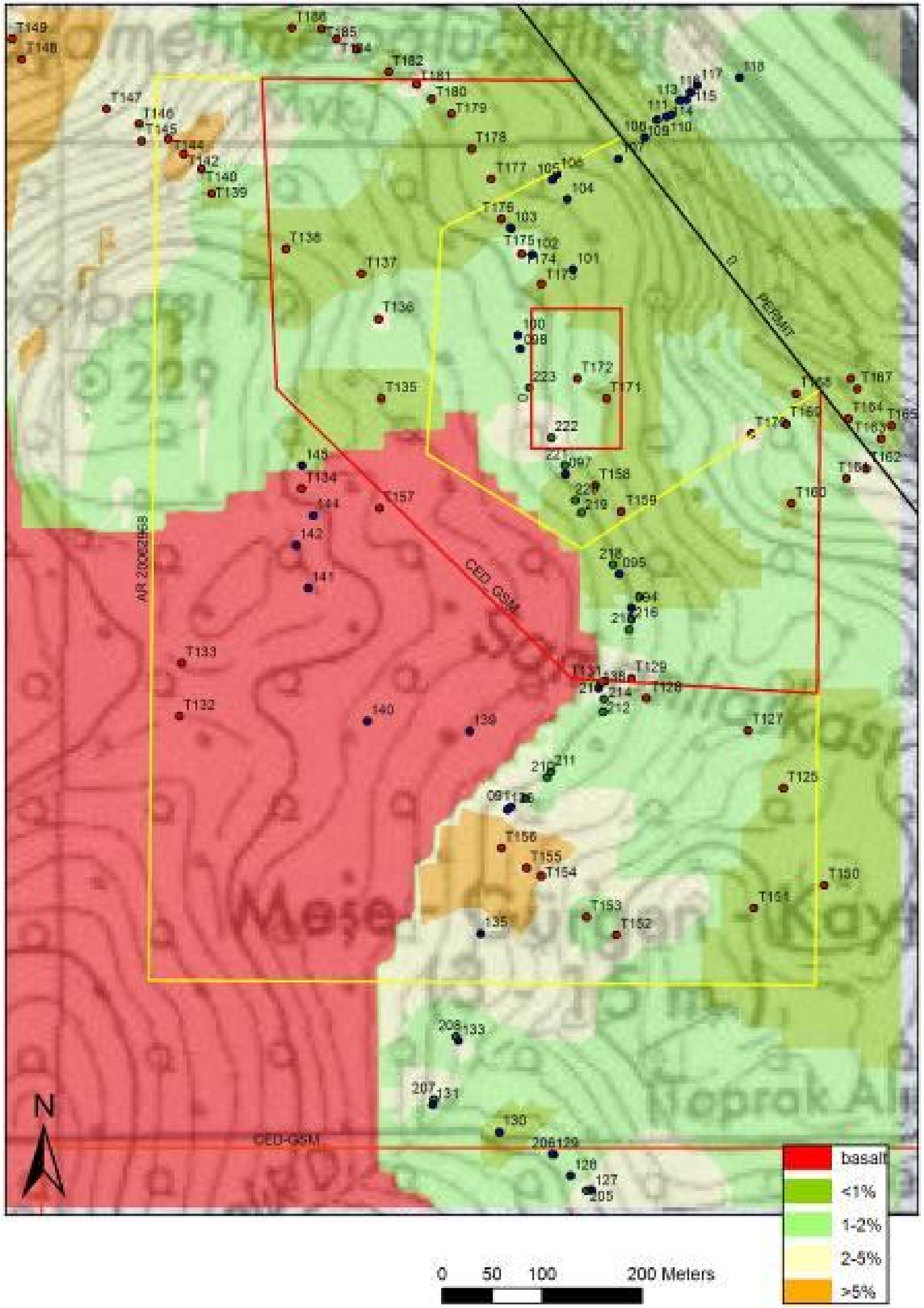

Figure 3.6 Silica distribution map in Middle Devonian at the west part of Bartın River.

3.5 Carbonate Resources

Industries are making the extraction with mining licenses which is given by ministry. Life of the industry is directly related to the resource potential at the region. Depending on the transportation costs quarries are placed in a limited distance around the industry. Industry needs to be proven the reliable amount of the resource to count the life expectancy.

Mining operation needs restricted areas that are well protected for safety and not to cause any environmental inconvenience.

Carbonate resource of limestones and dolomites at the region is approximately 2.5 and 1 billion tonnes. However potential mineable site is not more than one-tenth. After creating quality maps and getting permissions for mining, each quarry works with a potential of 10 million to 100 million tonnes of reserves estimation.

An industry like cement is working with 1Mt/y or lime 0, 5 Mt/y of extraction.

Reliable resource is the main aspect for the new investments and the improvements for the industry.

3.6 Methodology of Mining Reserves

All elements needed for the validation of the reserves must be given: geological, administrative and technical constraints, calculation method (manual approach, software used), accuracy and uncertainties.

Geological constraints include the geological knowledge of the deposit, with the vertical and lateral distribution of the quality. The available data (drillings, geological mapping, cross section) must permit to construct a coherent model, leaving few uncertainties (which are of course always possible but should be minimized). A synthesis of these data must be given. An error coefficient will be estimated. It is obvious that for a horizontal layer with a constant quality this coefficient can be close to 0 %. On the contrary, in a faulted and folded context, with erratic dolomitisation, it will be maximum, even with numerous drillings. It should however not be higher than 20 %, otherwise reserves have to be classified as resources.

Administrative constraints include the licence and property boundaries. Technical constraints are related to the mining plan (position of the installations, access tracks), considering that it is best fitting the geology and that quarrying is economic (impact of the stripping ratio). Some constraints are in many cases imposed by the extraction permit: final slope of the quarry wall, maximum depth, width of the benches, protection buffer zone inside the licence boundary. These constraints have to be clearly explained.

Life expectancy should be based on reserves only, except if the context is favourable for the reclassification of resources under reserves; good geological knowledge, permitting in progress and on the good way.

Calculation of life expectancy will not consider “fatal products” except if these stones are feeding a stone processing plant that has been designed to process those quantities and if the final products are marketable. In that case, a distinction will be made between the life expectancy of the lime plant and that of the aggregate plant.

The yearly extraction rate to take into account should integrate new market perspectives with a “security” coefficient. Another possibility is to consider the maximum capacity of the lime plant and/or stone processing plant.

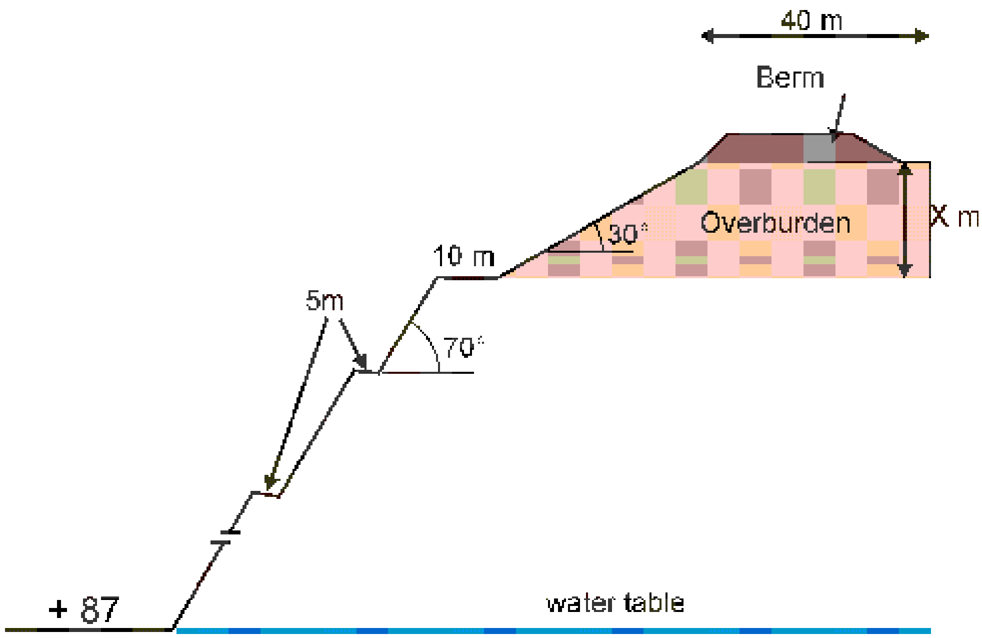

Figure 3.7 3D model of a basic quarry

The reserve estimate is a volume included between two surfaces: the upper surface of the layer (below the overburden, cap rocks or overlying low purity stones) and the quarry layout at the end of the extraction. The calculation can be easy (horizontal layer under a flat surface) to very complex (irregular topography, complex geological model). The use of 3D mining software makes possible to modulate any surface and to calculate complex volumes. It implies of course to have an updated 3D topographic map.

The reserve must be estimated for each economically mineable and marketable layer with a specific composition and use: high purity limestone, high purity dolomite, magnesia, limestone, aggregates, metallurgical stone. All data will be used to get a clear perspective for the life of the industry.

CHAPTER FOUR
CONCLUSIONS

The Upper Devonian and the Lower Carboniferous of Western Pontides present clear Eurasian affinities. Particularly, striking similarities exist with Southern Belgium, still considered as the type area for the Lower Carboniferous.

Several papers are dealing with the Upper Devonian and Lower Carboniferous of the Zonguldak Basin (Dîl, 1975; Dîl, 1976; Dîl et al.,, 1976). The Bartin area is documented by Tokay (1952), but recent papers are lacking and the stratigraphic position of the different units should be reassessed.

- Tokay was not able to recognize the Tournaisian (by the fossil content). According to him, the thickness of the Upper Devonian and Tournaisian ranges between 350 and 900 m. It consists of limestones and dolomitic limestone. Some levels, well-bedded, contain glauconite and are sandy.

- The thickness of the Viséan limestones reaches 1200 m. Dominant lithologies are cherty coral rich limestones. Cherts layers are supposed to be more abundant in the upper 120 m.

- The uppermost Viséan consists of shales and sandstones with marine intercalations.

Upper Devonian is passing to Tournaisian, consists dominantly of well bedded dark grey mudstones to wackestones with less frequent packstones. Macrofauna seems to be rare but silicified shells were found.

Tournasian was able to be named for the first time with fossil content in this study*, Syphonophylia cylindrica is* a key fossil for Middle Tournaisian found nearby Esenpınar Village. Also in the same region S*yringopora* sp. is determined.

Tokay (1952) mentions that; the Upper Cretaceous is uncomfortably resting on the Palaeozoic SW of Amasra. It starts with a 15 m-thick conglomerate indicated on his map as Upper Cretaceous Flysch and extending as a narrow irregular band over 11 km between Gürgenpinar in the SW to Kazpanari in the NE. This conglomerate is fine-grained and consists of Devonian and Lower Carboniferous reworked limestone fragments (dominantly), cemented by calcite. Tokay indicates that this unit can easily be misinterpreted as Palaeozoic, but it contains fragments of Melobesiae, Bryozoans and primitive forms of *Miscellanea*. It always underlies the first andesitic layer.

The area was prospected under the investigation of Bartın region. The exposure there is poor and we did not find complete sections exposing the Devonian-Carboniferous boundary. The Dallıca revealed interesting. New formation, named Dallıca is determined in this study.

According to Tokay’s geological map, the area consists of Visean limestone at the southwestern flank of an overturned syncline. Upper Visean and Namurian culm facies occupy the central part of the fold. An unconformity separates the Visean limestone from the Turonian conglomerate and Upper Cretaceous flysch which are gently dipping southwards. On Tokay’s map, these Mesozoic units are outcropping only out of the area we investigated.

Dallıca Formation unit is equivalent to the Turonian conglomerate of Tokay. It was not identified by the latter who probably limited his field work along the road where indeed the Lower Visean is cropping out along the Suzek River.

Foraminifers are particularly useful for biostratigraphy in the Upper Devonian and the Lower Carboniferous. Specialists identify them in thin sections. We collected 25 samples from which thin-sections were carried out.

The Upper Devonian and Lower Carboniferous of Dallıca can easily be correlated with the classical area of southern Belgium. The foraminifers associations do not display endemism and are very useful for stratigraphy. More work is needed however to correlate our succession with the 3rd order sequences of Belgium (Hance et al.,, 2001). The interval covering the MFZ4-5 to MFZ9 foraminiferal zones corresponds to sequences 3 to 5 in Belgium. At Dallica, we were not able to recognize clearly highstand system tracts (crinoidal packstones-grainstones, oolithic grainstones).

Only Lower Visean elements are present in Yılanlı Formation. If the Visean shales are really Upper Visean in age, this suggests that the contact between the Visean shales and the underlying limestones at Dallica could be a significant stratigraphical gap. The new problem to be solved is to determine the location of 1200 m Visean limestones mentioned by Tokay et al., (1952). A larger surface area is covered by these limestones on the northern flank of the syncline. It would be most interesting to investigate deeper this area.

There are potential deposits at the region like coal, clay, marl, dolomite and limestone.

Coal, natural gas (metan), lime, cement and brick industries are existing with high production capacities which are using the potential of Bartın region deposits.

In all three industries, cement lime and aggregate producers are using limestone or dolomite deposits.

General production parameters are following the process of quarrying, crushing, conveying and calcinations.

Typically limestone, marl and clays as well as other materials containing the required proportions of calcium, silicon, aluminium and iron oxides are extracted using drilling and blasting techniques. The quarried material is then reduced in size by compression and/or impact in various mechanical crushers. Crushed rock is reduced in size from 120 cm to between 1.2 and 8 cm. Drying of raw material may also be necessary for efficient crushing and pre-blending. Raw material is then transported from the quarry using conveyors, rail wagons or other suitable logistics solutions specific to the plant.

The purpose of mine and quarry blasting is to fracture or fragment the rock mass to enable excavation.

Selective mining is the most important mile stone for economical production. Industry always needs constant quality for efficient production and customer satisfaction. Geological composition needs to have clarified. Quarry production is always controlled by sampling and analyzing methods. All reserves and resources are discovered to clarify the quarry production and plans. Chemical quality maps are developed by geologist in use of mining engineers at the quarry.

Reserve estimation is the last step of the mining plan after having all the information to get the operation ready to be started.

Industries are doing the extraction with mining licenses which is given by ministry. Life of the industry is directly related to the resource potential at the region. Depending on the transportation costs quarries are placed in a limited distance around the industry.

Carbonate resource of limestones and dolomites at the region is approximately 2.5 and 1 billion tonnes. However potential mineable site is not more than one-tenth. After creating quality maps and getting permissions for mining, each quarry works with a potential of 10 million to 100 million tonnes of reserves estimation.

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