CARBONATE MICROFACIES OF SINJAR FORMATION AT SOUTH - WEST OF SULAIMANI CITY, KURDISTAN REGION, IRAQ

A THESIS

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Dedicated to……….

► My Parents

► My Siblings

► My Wife who supported me during my study

► My beloved kids

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Abstract

The research concerned with the study of the microfacies and microfossils of Sinjar Formation from Baranan Mountain. The topic of the research represents a first approach of identification of carbonate microfacies and microfossils. Thus, our study is applied to an area extremely rich in Paleocene-Eocene paleoflora and paleofauna represented by red and green algae, corals and especially large benthic foraminifera (rotallids, discocyclinids, soritids). Furthermore, two profiles were measured in the field (Hazarmerd Section 135m thick and Qazan Section 75 thick) and a number of 368 samples were collected to which additional results of the microscopic investigation on thin sections were added. The microscopy provided information on the microfacies and microfossils that was eventually used for the age determination and reconstruction of the paleoenvironment in the studied area. A complex case study of facies analysis and environmental reconstruction may help a better understanding the area.

Content

1. 1. **Preface**

Baranan mountain is one outcrop of Sinjar Formation in south west of Sulaimani City, northeastern of Iraq, besides of other appearances of it, northwestern of Iraq, due to intense weathering and tectonic motions. Historically, this formation comes to (Paleocen-Eocen). It have extentions or equivalents in neighboring contries (Syria and Iran). The microfacies and microfossils studies of carbonate rocks have significant importance due to the more informations or results which derived from this type of study, about all subjects which concerned with the carbonate rocks, as chemical and biological components, structures,

age, nature and types of sedimentation conditions, depositional basin and other features, guidance which interpret the type of environments and depositional factors.

Microfacies interpretation of carbonate rocks not rely solely on the investigation of sedimentological and paleontological thin-section data , but must also consider geological paleontological criteria, the presence of fosissils in sedimentary rocks provide a record of past life on earth and provide a method for determining the age of these rocks, the final results of any facies study must refers to several prerequisite stages of scientific research to approaching the actual interpretation or reconstruct the paleoenvironments

I. 2. **Geological setting**

Baranan Mountain is one of the cliff, more appearance mountains within the series of rock units, which constituently (lithologically and palaeontologically) represents the Sinjar Formation which located in the south-west of Sulaimani City , northeastern of

Iraq, and it is present in the Foot Hill Zone of High Folded Zone, within the unstable shelf area.

The present deposits in area represented by several depositional cycle, some of them deep water cycle and others shallow (shoal) water cycle. The Sinjar Formation was deposited predominantly in shallow water reef, fore-reef and lagoonal environments through cycle (upper Pleocene-Lowe Eocene), bordered from upper by Gercus Formation (Eocene) and from lower by clastic Kolosh Formation (Al-Surdashy, 1988). Depositional environment of the formation is shallow marine (Reefal) environment (Buday,1980).

1. 3. **Previous studies**

Both Sinjar and Kolosh Formations are present in the Foot Hill Zone and on the south-west margin of the High Folded zone. According to Buday (1980) and Buday and Jassim (1987) the south-west limit of the formation lies along a line crossing the Foot Hill Zone from the south limit of the Sinjar Trough to the Alan structure and passing through Demir Dagh, the north-west end of Kirkuk and the south-west margin of the High Folded Zone around Bawanur in the type area of the Kolosh Formation (Ditmar,1971; Bellen et al.,1959).

There are no enough studies, especially on Baranan Mountain to explain the environmental situation, constituents, structures and other unclear subjects which are related to the studied area, but many studies were done on Sinjar Formation and Baranan Mountain is considered to be part of it.

The Sinjar Formation was first described from the Jabal Sinjar area (near Mannista Village) by Keller (1941, in Buday, 1980). Bellen et al. (1959) regarded that the Sinjar Formation comprises 176 m in the type area of limestone of algal reef, lagoonal miliolid (back reef) and nummulitic shoal (fore-reef) nummulitic shoal facies. Ditmar (1971) studied this formation and recorded that the formation interfingers with the Kolosh Formation in Well Taq Taq-1, and in the type area of the Kolosh Formation (Bellen et al.,1959). In Derbandekhan area of N-E of Iraq, the formation is 120m. thick and in the Foot Hill Zone of N. of Iraq the thickness of formation is 213m. In the well Alan-1, 541m. in Mashorat-1 and 126m. in Demir Dagah (Jassim and Goff, 2006). A descriptive study was done by Dunnington (1958) on the real limestone rocks in jabal Sinjar and extended area between Koisinjaq to Iranian border south of Halabja. The formation is overlaine by Gercus Formation (Bellen et al., 1959). Grimsdale, (1952) determined numerates of microfossils which granted to different types of foraminifera within this formation in the Jabal Sinjar and Darbandi Bazian location. Elliot, (1956) described some groups of algae which were present in this formation. Johnson (1964) submitted detail studies of red algae types which were present in (Early Paleocene-Eocene) period from the north of Iraq which is belong to the Sinjar Formation too.

Al-Saddiki, (1968) limited presence of microfacies in this formation within stratigraphic studies on the petroleum wells and one section located in Jabal Sinjar. He added that the typical section in Sinjar Formation is the single section which contains three different facies that indicate the reefal algae facies, miliolid (back-reef) and neritic nummulites, Discosyclina reef (fore-reef). Al-Sayyab and Al-Saddiki (1970) described twenty four microfossils from algae and foraminifera order in Sinjar Formation (Jabal Sinjar area). Jassim et al. (1975) studied this formation in north-est side of Zimnako fold like toungh in Kolosh Formation.

Al-Kufaishi (1977) studied the sub-surface section from Sinjar Formation at Kirkuk field(K116) and analyzed the trace elements, but did not fined any relationship between non-dissolved element and above mentioned elements distribution. The study of formation was executed by Ebrahim and Nadir (1981) to limit the uses of limestone for cement and sugar industry in Tasluja position. Further studies of this formation refer to the detailed report about all which mentioned above within study of this formation at wells position in Wolublak (Al-Etaby and Muhamad, 1979). Jabr and Al-Ubadi (1973) studied rock lithology of formation in Kani janna area near Sulaimani City and its available range for sugar industrial use. Shathaya (1980) introduced detailed study of microfossils, biostratigraphy and paleoenvironment, depending on biogroups and produced that the typical section in Sinjar reflects typical environment for this formation which has age (Paleocen-Early Eocene) ,whereas other sections give point (evidence) to local environmental conditions.

Al-Khafaji (1980) studied formation in north of Iraq from petrographic, geochemical and supplemented modification factors. Mallick and Al-Qayim (1985) studied formation in Kani Janna area in Sulaimani City, they pointed to presence of a few quantities of phosphorate in this formation. Al-Qayim et al. (1988) in their study of limestone layers overlying Kolosh Formation in Haibat Sultan Mountain explained that these layers do not belong to Sinjar Formation as former researcher thought previously, elsewhere makes no series here to Khormala Formation due to the clear similarity of rock formation. Al-Fadhli and Mallick (1980) studied formation in Sulaimani area and detected two zone of phosphorate. Surdashy (1988) studied Sinjar limestone Formation in Sulaimani area in several sections about lithologic, facies and environment.

1. 4. **The aim of the research**

- The study of Sinjar Formation from Baranan Mountain south west of Sulaimani City, with a special emphasising on their microfacies and microfossils
- Identification of carbonate microfacies
- Identification of microfossils
- Determination of age's Formation
- Determination of depositional environments

1. 5. **Microfacies**

The term Microfacies was suggested by Brown J. S (1943) and refers to the criteria appearing in thin sections under the microscope. Cuvillier. J.(1952, 1958, 1961) re-introduced the name microfacies to characterize paleontological and petrographic criteria in thin sections. According to Flügel E. (1982, 2004) the microsfacies is the total of all the paleontological and sedimentological criteria (qualitative and quantitative) which can be classified in thin sections, peels, and polished samples at magnifications of up to approximately x 200

1. 6. **Methods of Microfacies analysis**

1. 6. 1. **Fieldwork**

Prerequisites for microfacies analysis are geological field studies and profiles with special consideration of facies criteria: Lithology, rock colors, bedding and lamination, sedimentary structures and textures, fossil content, stratigraphic relationships and geometric shapes of rocks Flügel (1982, 2004). For description of carbonate rocks in hand specimens and outcrops the following check list can be used

- Mineralogical composition (calcite, dolomite)
- Matrix (grain size and color: homogeneous or non-homogeneous)
- Cement (sparite)
- Type of particles (peloids, oncoids, terigenous minerals, lithoclasts, ooids, aggregate grains, etc.)
- Particle's size and shape
- Particle frequency
- Particle orientation
- Pores and open-space structures
- Bedding types (horizontal bedding, cross-bedding, lenticular bedding or deformation bedding)
- Features of the surface bedding (ripple-marks, shrinkage cracks, even, uneven)
- Features of the underside (even, uneven, current marks, traces)
- Features within the bedding (lamination, bioturbation, trace fossils)
- Bed thickness
- Dolomitization
- Silicification
- Fossil content (abundance, types)

1. 6. 2. **Sampling**

The number and kinds of samples depend on the geological settings (outcrop conditions, sampling units indicated by types and thickness of bedding)

a. Selection and number of samples:

- Samples for lithological study (texture, structure and fossils on a hand specimen scale)
- Samples for laboratory analysis
- Samples for paleontological study (from shale, marl and non-cohesive strata)
- Reef limestones require large and very large samples because of the high compositional variations within centimeter ranges

b. Size and orientation of samples:

The large-sized samples are recommended. The size 5x4 cm, 5x5 cm and larger up to 20x15 cm have proved useful as formats for thin sections used in microfacies analysis. The oriented samples marked in the field showing the position of the samples in spaces for determining top and bottom of strata.

1. 6. 3. **Laboratory work**

Thin section: the investigation of the composition and fabric of surface and subsurface samples requires standard thin sections with a thickness of approximately 30 micron. These thin sections are usually cut perpendicular to the bedding (Flügel, 2004). Microfacies thin sections are generally larger than regular petrographic slides and large thin sections are necessary for studying reef limestones, coarse-grained detrital limestones and carbonate deposited during events (turbidites, tempestites). A thin section comprising a vertical interval of 5 cm records a set of microsequences corresponding to time intervals within a scale of hundreds, thousands or more years.

Peels: the imprint of etched surfaces on transparent plastic films is the rapid and simplest method for studying samples. The procedure of preparing peels includes:

- Cutting and polishing the sample
- Drying the cut surface
- Flooding the surface with a solvent (acetate)
- Pressing the film onto the surface, the film will settle down into irregularities in the etched surface and produce the replica. After pulling, the peel should be mounted between glasses and studied under the binocular microscope

Polished: cutting and polishing the samples

Our project consists of achieving several prerequisite stages of scientific research. The first stage is in fieldwork in each of the studied successions. Direct observation on the successions and sampling of each individual layer was performed. The preparation in the laboratory include of obtaining one or more thin sections of each sample, as a second stage. The third stage is the microscopic study on thin sections, in the view of identification and description of carbonate microfacies and microfossils. The physical successions drawn in the field were subsequently modified according to the microscopic information, thus the final, “real” successions have been obtained. The qualitative microfacies analysis was based on the methodology elaborated by Dunham (1962) and modified by Embry and Klovan (1971).The final stage is microfacies' results correlation with the corresponding information on the microfossils, which allowed us to reconstruct the depositional environments and project elaboration.

1. 6. 4. **Practical usage of the microfacies studies**

- The microfacies analysis provides valuable tools for understanding the depositional environments of rock's formation and the control factors during the genesis of the carbonate rock
- The results of the microfacies studies present a practical significance due to the information provided in relationship with the hydrocarbon reservoir rocks and the evaluation of the carbonate rocks, in general
- The carbonate rocks represent the most important reservoir rocks for hydrocarbons
- The carbonate rocks may also host metallic ore deposits, with specific facies features. At the same time, the carbonate rocks represent important resources of building materials and chemical industry
- The microfacies study provides data on the porosity and variation of permeability in the bulk rock
- The knowledge on the present-day carbonate deposits plays an important role in the understanding of the formation condition of their fossil equivalents, in the continental, as well as in the marine environments, under various climates.

1. 7. **Location of the studied successions**

Our study in the Palaeocene-Eocene limestones from Baranan Mountain focused on microfacies and microfossils in the Sinjar Formation. Two successions have been selected from Baranan Mountain chain, south-west of Sulaimani City (Fig. 1. 1, 1. 2).

1. 7. 1. **Hazar Merd Succession**

This succession is located at the south of Hazar Merd village and 1-1.5 km south of Hazar Merd Cave. Generally, these limestones occur as banks (Fig . 1. 3, 1. 4), between 10 cm-1 m thick, light grey and grey in color. The total thickness of the succession is about 135 m. The samples were collected from each individualized bank, at intervals selected to reflect all the lithological changes in the succession. A total of 217 samples were collected along the whole succession

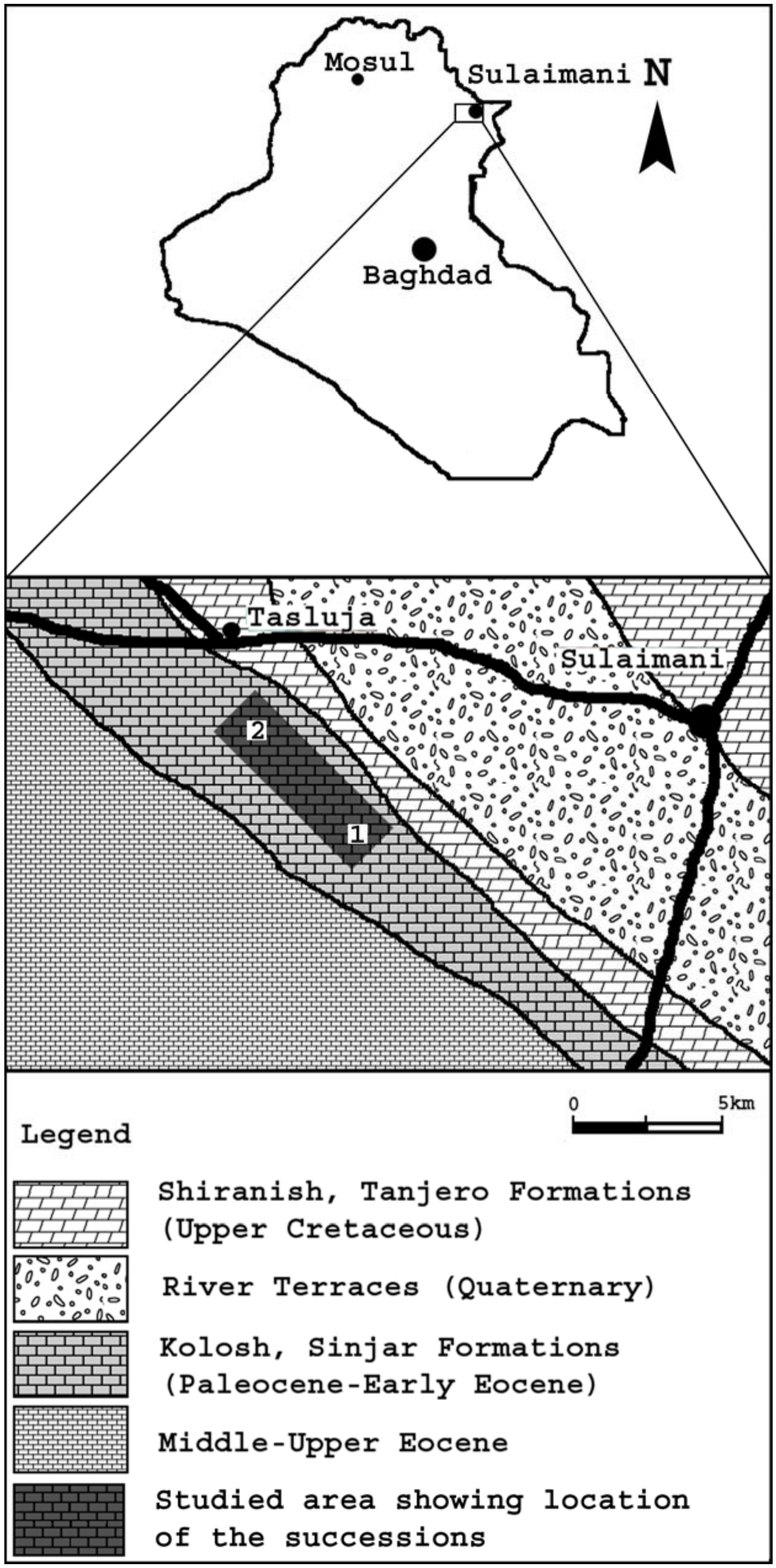


Fig. 1. 1. Location of the studied area

Fig. 1. 2. The location of studied successions on the Google Earth

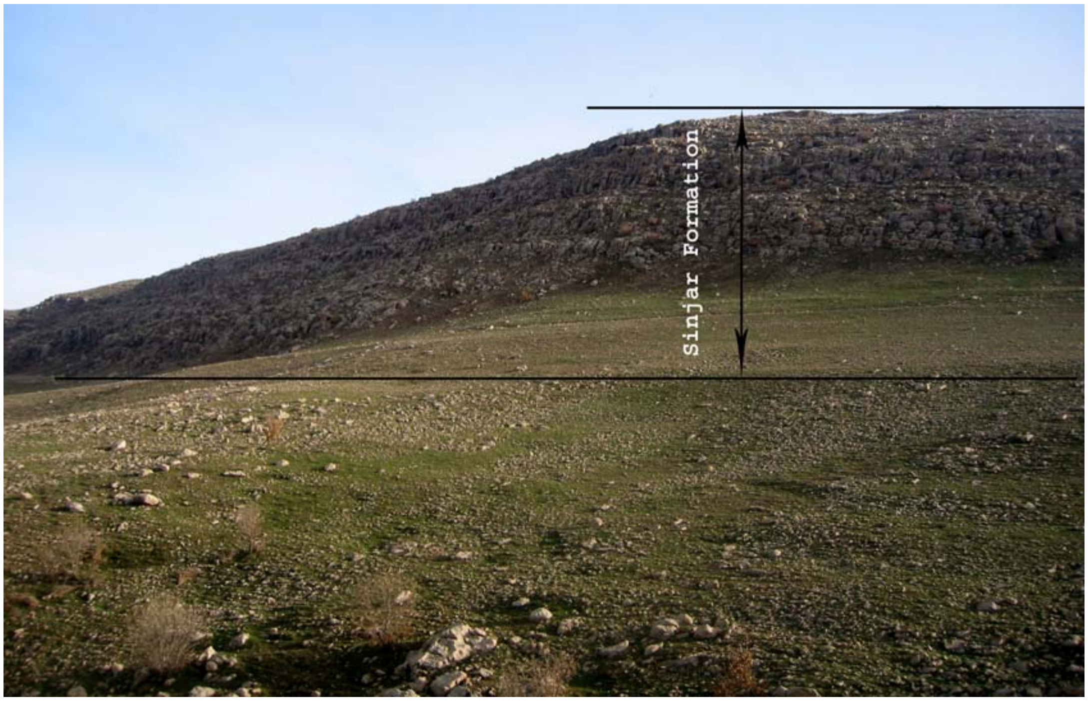


Fig. 1. 3. Hazar Merd Succession.

Fig. 1. 4. The top of the Hazar Merd succession overlain in south by Gercus Formation

1. 7. 2. **Qazan Succession**

The succession is located at about 1.5-2 km south of Qazan village, (Fig. 1. 5). The succession is 75 m thick. It includes grey and light grey fine grain limestone, with stratification ranging from tens of centimetres to meters of massive limestone. They contain corals and algae which form boundstone microfacies. A total number of 151 samples were collected, illustrating all the lithological changes along the succession in the succession.

Fig. 1. 5. Qazan Succession

2. 1. **Carbonate rocks**

Carbonate rocks are a class of sedimentary rocks composed primarily of carbonate minerals. The two major types are limestone and dolomite, composed of calcite $CaCO_3$ and the mineral dolomite $CaMg(CO_3)_2$ respectively (Pellant, 1990). Chalk and tufa are also minor sedimentary carbonates. Carbonates are formed by precipitation from water; either directly from the water, or induced by organisms, to make their shells or skeletons, and they are formed in special environments. Climate is very important to carbonate rocks. Most modern and ancient carbonates are primarily shallow water platform deposits because photosynthesis is enhanced at shallow depths. The depositional environments range from near-shore lagoons, platform organic buildups, and shelf margin shoals to slope and basinal settings (Carozzi, 1989). Carbonates typically are found in warm, shallow, clear marine water in low latitudes **(**James, N.P., 1984)**.** They are essentially autochthonous, as they are formed very close to the final depositional sites. Their texture is more dependent on the nature of the skeletal grains than on external influences. Reefs, bioherms and biostromes are examples of in-place local deposition where organisms have built wave-resistant structures above the level of adjacent time-equivalent sediments. Many reefal deposits are commonly composed of fragmented, locally-transported skeletal debris and a minor volume of in situ framework organisms. Basin configuration and water energy are the dominant controls on carbonate deposition.

There are three main minerals that form carbonates:

- Calcite ($CaCO_3$), which comes in high magnesium and low magnesium forms.

- Aragonite ($CaCO_3$), which has a different structure to calcite.
- Dolomite ($CaMg(CO_3)_2$), a magnesium rich carbonate produced by diagenesis.

The low magnesium calcite is stable at surface pressure and temperatures. It is therefore the most common mineral in ancient carbonates. However, most modern carbonates are composed of aragonite which is a mineral created by most biological organisms to make their shells or skeletons. Examples of organisms that produce aragonite shells are bivalves, gastropods and Halimeda. Organisms that produce a calcite shell include brachiopods and ostracods (Flügel, 2004).

2. 2. **Classification of carbonate rocks**

Rocks are classified in order to communicate information about them. All classifications of limestones are arbitrary and they frequently overlap or do not fit one's particular needs. Binocular microscopes or hand lenses are the tools commonly available to classify the carbonate rocks. When these instruments are used, it is usually possible to identify the individual grains forming the rock. Thus most classifications require description of the most significant sedimentary particle in the rock. For instance, if a rock is composed of ooids, it is termed an oolitic limestone. If the limestone also contains a minor element such as skeletal fragments, then it is called a skeletal-oolitic limestone. Two of the most widely used classifications are those of Folk (1959,1962) and Dunham (1962). Both classifications subdivide limestones primarily on the basis of matrix content.

Folk (1959) classified limestone by the three components that make up carbonate rocks, which are allochems, micrite, and spar. These amounts are best ascertained with the petrographic microscope and generally with the application of modal analysis, but with some skill and practice satisfactory results can be obtained with good quality hand samples. Allochems are sepatated into four types: intraclasts, ooids, pellets, and bioclasts.

The ***intraclasts*** as being “intra-formational rock fragments” can be of any size but generally its diameter ranging from 2 mm to less than a few centimeters. Compositionally they usually consist of microcrystalline to cryptocrystalline calcite, but they can also contain within them other allochems such as small bioclasts like ostracods. Their shape is variable and will frequently be rounded.

The ***Ooids*** are carbonate grains which are usually small, less than1mm in diameter and they are spherical grains which posses a series of concentric laminations when view in cross section. One must recognize the concentric laminations in order to apply the ooid name. Those ooids, which have diameters greater than two millimeters, are called pisolites.

The ***Pellets*** are microcrystalline to cryptocrystalline calcite or aragonite grains that are probably of fecal origins. They are in most cases less than 2 mm in maximum diameter and elongate or roller in external shape.

The ***Bioclasts*** are the calcite or aragonite tests of organisms that lived contemporaneously with the depositional processes which formed the sediment. There are various types of bioclasts; each with its own unique texture and shape. Any fossils that are not carbonate in nature, teeth, bones, and conodonts will be excluded from bioclasts.

Folk' scheme consists of five classes of carbonate rocks which are designated in geologic shorthand by the Roman numerals I, II, III, IV, V. (Fig. 2. 1, 2. 2). Class I rocks have mesocrystaline (easy to see individual crystals) calcite know as ***spar*** between the allochems. The Class II rocks have ***micrite*** (microcrystalline to crypocrystalline calcite) filling the space between the allochems. Class III rocks have less than 10% by volume carbonate allochems. Class IV rocks are all "undisturbed bioherm rocks" which are almost synonymous with Dunham's boundstones. The 'bafflestone' of Embry and Klovan's (1971) modified that Dunham's classification does not fit well in this class. Class V rocks consist entirely of replacement dolomite.

Class I and II rocks are further subdivided by the relative percentage of the four different types of allochems and the size range of the allochems. Regarding the size of the allochem .If the population of allochems is generally greater than 2 mm in diameter then the root name follows term rudite, but if it is less than 2 mm in diameter the root name follows the term arenite. Class I rocks have spar between the allochems and hence are named the **spar**ites and **spar**rudite. Class II rocks have micrite between the allochems and are thus named the **mic**rites and **mic**rudites.

Each of these four terms must have a prefix that denotes the actual allochem content of the rock. If more than 25% by volume of the allochems are intraclasts then the prefix '**intra**' is applied as in **intra**sparite, **intra**sparrudite, **intra**micrite, and **intra**micrudite. If the rock has 25% or less intraclasts but more than 25% by volume ooids the prefix '**oo**' is applied as in **oo**sparite, **oo**sparrudite, **oo**micrite, **oo**micrudite. If the rock has 25% or less intraclasts, 25% or less ooids, and 67% or greater bioclasts, the prefix '**bio**'will be applied as in **bio**sparite, **bio**sparrudite, **bio**micrite biomicrudite. If the rock has 25% or less intraclasts, 25% or less ooids, and 67% or more pellets (pelloids), the prefix '**pel**' is applied as in **pel**sparite,

pelsparrudite, **pel**micrite, and **pel**micrudite. If the rock has 25% or less intraclasts, 25% or less ooids, and has pellets and bioclasts in roughly the same amounts (33% to 67%), the prefix '**biopel**' is applied as in **biopel**sparite, **biopel**sparrudite, **biopel**micrite, and **biopel**micrudite. The 'bio' always proceeds the 'pel' regardless of their abundance.

The class III rocks contain no more than 10% by volume allochems and the remainder of their volume being mostly micrite (microcrystalline to cryptocrystalline calcite), hence these are the **micrites**. If their allochems and the dominant allochems are intraclasts, the rock is called an **intraclast-bearing micrite**. If the dominant allochems are ooids, it is an **oolite-bearing micrite**. If bioclasts are the dominant allochem then the rock is a **fossiliferous micrite**. If pellets (pelloids) dominate then the rock is a **pelletiferous micrite**. If there is less than 1% allochems in the rock, it is simply a **micrite**. Some micrite will have patchy areas of calcite spar and the micrites are called **dismicrite**. If the rock is composed of microcrystalline to cryptocrystaline dolomite, the rock is **dolomicrite**.

The class IV rocks are the **biolithites** and they lack further subdivision though would be useful.

The class V rocks are the “replacement dolomites” and the rock is called dolomite or dolostone by more recent workers. If the rock contains what are called 'allochem ghosts', then an additional adjective is applied depending upon the dominant allochem ghosts present; intraclastic, oolitic, biogenic, or pellet. These ghosts are the images of the original allochems that have now been replaced by the secondary mineral dolomite. If the rock of any class is observed to have 10% or more quartz sand, silt or clay as terrugenous detritus grains, then the adjectives areanaceous, silty, or argillaceous are applied respectively.

In contrast, Dunham's classification (Fig. 2. 3, 2. 4) and its modification by Embry and Klovan (1971) deal with depositional texture. For this reason, his scheme may be better suited for rock descriptions that employ a hand lens or binocular microscope. For example, if the grains of a limestone are touching one another and the sediment contains no mud, then the sediment is called a grainstone. If the carbonate is grain supported and it contains mud, then it is known as a packstone. If the sediment is mud supported but contains more than 10 percent grains, then it is known as a wackestone, and if it contains less than 10 percent grains and is mud supported, it is known as a mudstone.

If the two classifications are compared, a rock rich in carbonate mud is termed a micrite by Folk and a mudstone or wackestone by Dunham. Moreover, a rock containing little matrix is termed a sparite by Folk and a grainstone or packstone by Dunham. Embry and Klovan (1971) have modified Dunham's classification to include coarse grained carbonates (Fig. 2. 3). In their revised scheme, a wackestone in which the grains are greater than 2mm in size is termed a floatstone and a coarse grainstone is called a rudstone. They also modified the boundstone to introduce the terms bafflestone, bindstone, and framestone. These terms are useful in concept but are extremely difficult to apply to ancient limestones where diagenesis and sample size limit the ability to assess an organisms function.

Volumetric Allochem Composition		Limestones, Partly Dolomitized Limestones, and Primary Dolomites					Replacement Dolomites (V)	
		> 10% Allochems Allochemical Rocks (I and II)		< 10% Allochems Microcrystalline Rocks (III)				
		Sparry Calcite Cement > Microcrystalline Ooze Matrix	Microcrystalline Ooze Matrix > Sparry Calcite Cement	1–10% Allochems	< 1% Allochems	Undisturbed Bioherm Rocks (IV)	Allochem Ghosts	No Allochem Ghosts
		Sparry Allochemical Rocks (I)	Microcrystalline Allochemical Rocks (II)					
				Most Abundant Allochems are:			Evident Allochem	
> 25% Intraclasts		Intrasparrudite Intrasparite	Intramicrudite Intramicrite	Intraclasts: Intraclast-bearing Micrite	Micrite; if disturbed, Dismicrite; if primary dolomite, Dolomicrite	Biolithite	Finely Crystalline Intraclastic Dolomite	Medium Crystalline Dolomite
< 25% Intraclasts: > 25% Oolites		Oosparrudite Oosparite	Oomicrudite Oomicrite	Oolites: Oolite-bearing Micrite			Coarsely Crystalline Oolitic Dolomite	Finely Crystalline Dolomite
< 25% Intraclasts: < 25% Oolites: Volume Ratio of Fossils to Pellets	> 3 : 1	Biosparrudite Biosparite	Biomicrudite Biomicrite	Fossils: Fossiliferous Micrite			Aphanocrystalline Biogenic Dolomite	
	3 : 1–1 : 3	Biopelsparite	Biopelmicrite	Pellets: Pelletiferous Micrite			Very Finely Crystalline Pellet Dolomite	etc.
	< 1 : 3	Pelsparite	Pelmicrite					
< 25% Intraclasts: < 25% Oolites: Volume Ratio of Fossils to Oncoids	1 : 2	Oncosparite Oncosparrudite	Oncomicrite Oncomicrudite	Oncoids: Oncoid-bearing Micrite				

Fig. 2. 1. Classification of carbonate rocks according to Folk (1959, 1962).

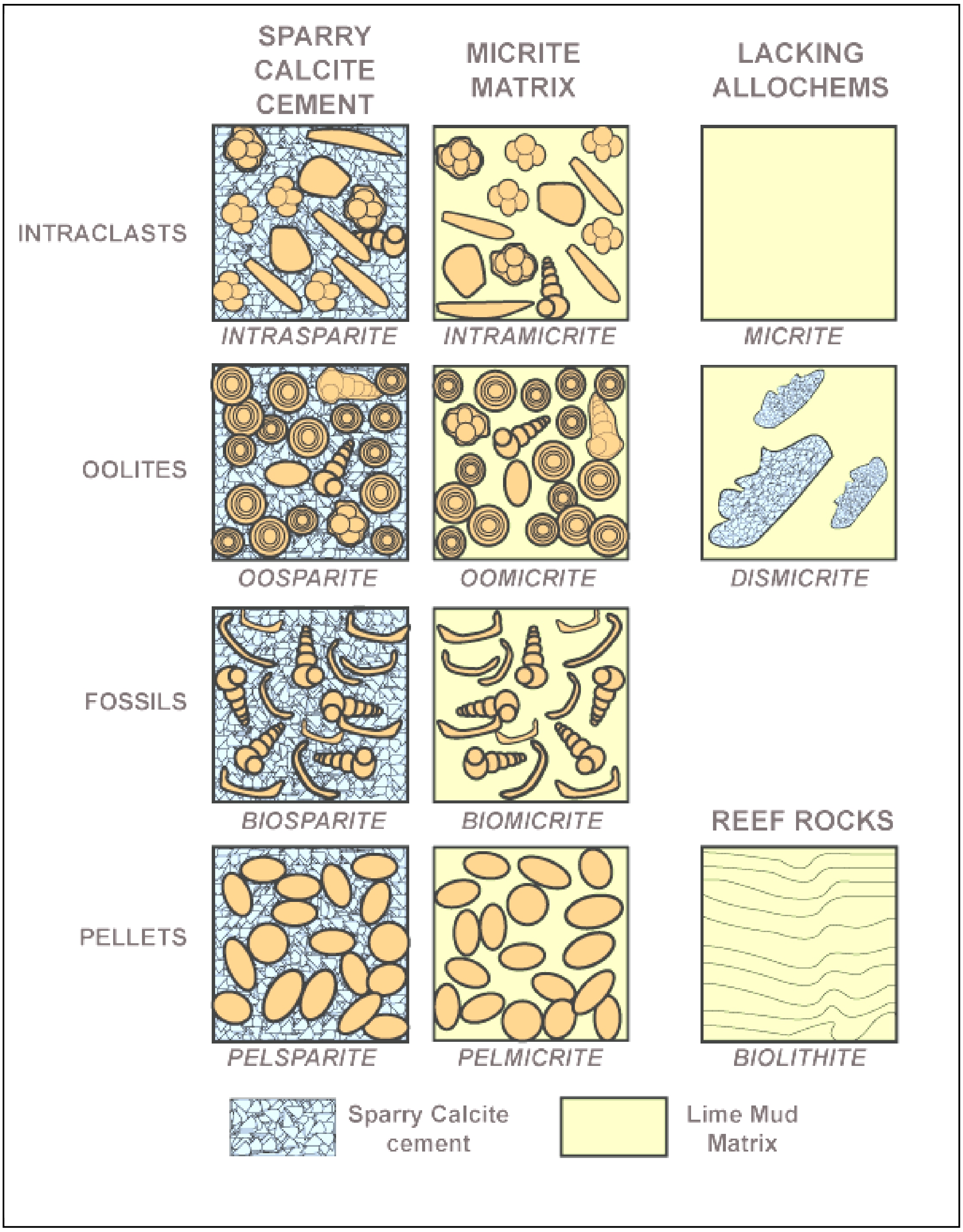


Fig. 2. 2. Classification of carbonate rocks after Folk (1959)

Original components not bound together during deposition				Original components not bound together during deposition		Original components were bound together during deposition		
Generally *smaller* grains (arenite and silt size)				More than 10 percent *larger* grains >2mm (rudite size)				
Contains mud (micrite matrix)			Lacks mud (sparite matrix)	Contains mud (micrite matrix)	Lacks mud (sparite matrix)	Organisms act as sediment bafflers (e.g., dendroid corals)	Organisms act as sediment binders (e.g., algal mats)	Organisms act as frame-builders (e.g., intergrown reef corals)
Less than 10 percent grains	More than 10 percent grains							
Mud-supported		Grain-supported		Matrix-supported	Grain-supported	Boundstone		
Mudstone	Wackestone	Packstone	Grainstone	Floatstone	Rudstone	Bafflestone	Bindstone	Framestone

Fig. 2. 3. Classification of carbonate rocks according to Dunham (1962), modified by Embry and Klovan (1971)

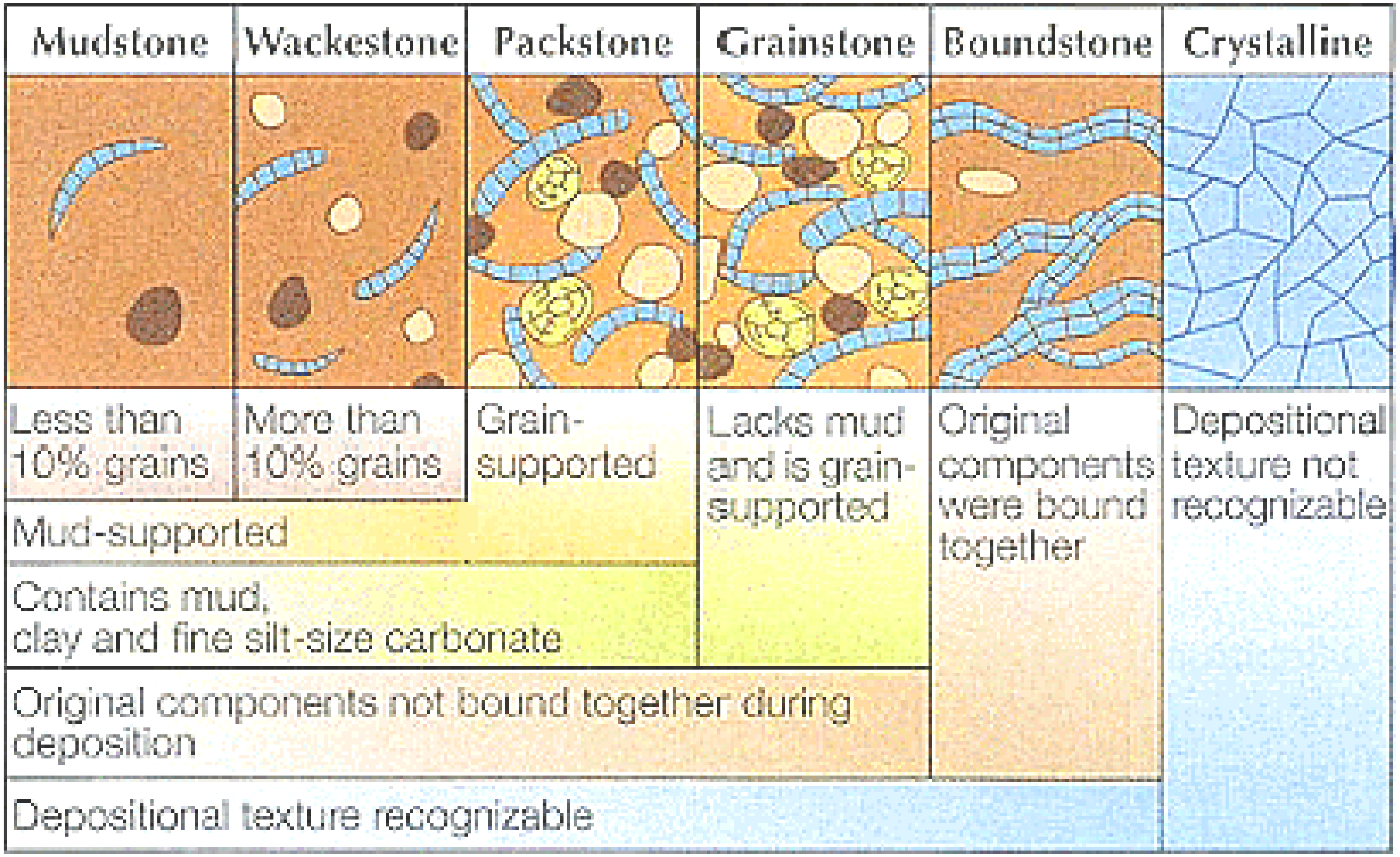


Fig. 2. 4. Classification of carbonate rocks after Dunham (1962)

3. 1. **Description of thin sections**

The laboratory investigation consists of the study about 370 thin sections of carbonate deposits from two successions: Hazar Merd (Fig. 3. 1) and Qazan (Fig. 3. 2) which were used for micropaleontological and microfacies analysis with depending on Dunham classification

3. 1. 1. **Hazar Merd Section**

3. 1. 1. 1. **Microfacies**

➔ **Bioclastic Packston** S. No. (201-212; 246; 249-252; 264-268; 276-288; 2293-306) consists of corals and red algae fragments, echinoid plates and spines, fragments of ostracods, some rotalids (Rotalia), miliolids(*Quinquiloculina*) and rare gastropods are also present(PL.1, 3), miliolid and gastropods (PL.2, 7) in some samples *Discocyclina varians* appears indicating the Paleocene age and formed discocyclinids packstone (PL.2, 8;PL.3, 1) and some of them cotains bryozoans fragments, miliolids, and other forams with *miscellanea sp* indicate Upper Paleocene (PL. 6, 9) and some of them partially dolomitized. In several part of this facies the geopetal structures are also present. Some facies is interlayered with coralligenous boundstone or red algae bindstone (PL. 1, 1, 6)

➔ **Boundstone** S. No. (213-222; 247-248; 253-263; 290-292) contains corals and red algae, sometimes the bioclasts are bound by microbial micrite forming some levels of bindstone, fragments of ostracods, echinoids, and some soritids are also present (PL.1, 7; PL. 2, 1).

➔ **Foraminiferous Packstone** S.No.(223-224; 227-229) this facies contains foraminifera and fragments of red algae, echinoids and corals (PL. 1, 2) with two levels of coralligenous boundstone (PL. 2, 3) and one level of boundstone-packstone with bryozoans (PL. 2, 4, 5, 6). This facies consists of foraminifera (rotaliids, Soritids), fragments of bryozoans, red algae, echinoid plates, some small gastropods.

➔ **Coralligenous boundstone** S. No.(225-226; 269-275) consists of corals and red algae, with some forams and echinoid plates (PL. 1, 8)

➔ **Boundstone** S. No. (240-243) **with corals and red algae (***polystrata alba*), fragments of bryozoans, echinoderm plates and spines, some foraminifera are also present.

➔ **Discocyclinids Packstone**, S. No. (244) this facies contains *Discocyclina varians* (Pleocene) and microbial peloids of algal origin (PL .2, 2).

➔ **Wackstone** S.No. (245; 383) contains some gastropods, fragments of bryozoans and echinoid plates or consist only of some rotaliids and soritids

➔ **Peloidal and foraminiferous grainstone** S.No. (307-309**) contains** peloids of algal origin, soritids, miliolids (PL. 3, 3, 4) red algae (*Amphiroa iraquensis*), and echinoid plates. The later level is mostly formed by soritids *(orbitolites)*

➔ **Soritids rudstone** S. No. (310) consists of larger forams (soritids, discocyclinids, nummulites) (PL. 3, 2) .

➔ **Foraminiferous grainstone** S. No. (312-316; 318-323) contains *soritids, miliolids*, red algae fragments and solitary corals, sometimes the micrite covered the small forams and red algae fragments (PL. 3, 6). This facies passes in upper part into grainstone-boundstone and coralligenous boundstone or the most constituents are forams (soritids, miliolids, discocyclinids). In upper part of this bank it passes into rotaliid grainstone (PL. 3, 7).

➔ **Soritids rudstone** S. No. (317) consists mostly of orbitolites but the discocyclinids *and* miliolids are also present.

➔ **Rotaliids floatstone** S.No.(324) contains mostly rotaliids.The soritids and red algae fragments are present (PL. 3, 5).

➔ **Rotaliids rudstone** S. No. (325). with some soritids and miliolids.

➔ **Rotaliids packstone** S. No.(326-357; 368-382), (PL. 3, 10, 11) with some levels of soritids floatstone (PL. 6, 1, 2). The dolomitization process appears in some levels (PL. 3. 9). In upper part of bank rock this facies passes into boundstone-packstone (PL. 6, 3, 4, 5), consisting of corals, red algae together with above mentioned fossils, or mostly consists of rotaliids, sometimes reaches 60-70%. Other (foram) are represented by *soritids,* nummulites and miliolids. Besides, fragments of echinoids, ostracods, some gastropods and green algae.

➔ **Soritids and rotaliids floatstone** S. No.(358-367). The most components are soritids and rotaliids with discocyclinids and nummulites (PL.4, 6) Besides, fragments of bryozoans, gastropods, echinoid plates and spines are present. Some fossils were identified here: *Archaias kirkukensis, Saudia labyrinthica, Discocyclina, pseudohatigerina, Nummulites, Opertorbitolites transitorius, Textularia, Triloculina, Alveolina, Idalina sinjarica.* This facies is illustrated in fossils' part**.**

➔ **Rotaliid grainstone** S. No.(384-385) contains rotaliids*, soritids, miliolids* and green algae. The geopetal structures are present (PL .4, 7)

➔ **Rotaliids wackstone** S.No.(386-389) this facies is affected by dolomitization processes (PL. 4, 8)

➔ **Rotaliid and miliolids packstone** S. No.(390-394) contains rotaliids and miliolids with other fossils and bioclasts represented by green algae, red algae, echinoid plates and some solitary corals (PL. 5, 1).

➔ **Miliolids grainstone** S. No. (395; 398-401; 405-417) mainly contains the miliolids but the dasycladales are also present (PL. 5, 2) or mainly contains miliolids *(Idalina sinjarica, Biloculina, Quinquiloculina*), other fossils and bioclasts are represented by green algae, red algae fragments and gastropods (PL. 5, 4) or facies appears such as in uppermost part of succession, mainly consisting of miliolids together with green algae, algal peloids which forming two levels of peloidal grainstone (PL. 5, 5, 6), bryozoan fragments , little gastropods, rotaliids, red algae, alveolinids*, (Alveolina primaeva, glomalveolina, Alveolina globosa*).

➔ **Rotaliid packstone** S. No. (396) with *Cibicides nammalensis*;

➔ **Peloidal grainstone** S. No.(397) The peloids are represented by red algae fragments (PL. 5, 3).

➔ **Packstone** S. No. (402-404) consists of red algae fragments, green algae (*dasycladales*), forams, gastropods. The gastropod's shell is filled by green algae, red algae fragments and some forams.

peloidal grainstone (PL. 5, 5, 6), bryozoan fragments , little gastropods, rotaliids, red algae, alveolinids*, (Alveolina primaeva, glomalveolina, Alveolina globosa*).

Finally, the facies associations identified in the Hazarmerd section consist of two main types of microfacies: **Bioconstructed** and **Bioaccumulated**. Each of the facies types presents several subtypes and we can summarise them as follows:

I. **Bioconstructed Microfacies**, reaches 17.75% by volume and comprises four subtypes mostly identified in lower part of succession:

a- Coralligenous boundstone

b- Boundstone-packstone

c- Bryozoans boundstone

d- Boundstone-grainstone

II. **Bioaccumulated Microfacies** comprises five main Microfacies, each of them includes several subtypes of microfacies:

1. Wackstone comprises only three levels in lower and middle part successively:

a- Bioclastic wackestone

c- Soritids and rotaliids wackestone

c- Rotaliids wackestone

2. Packstone Microfacies represents 48.4% of Hazarmerd profile and it is widespread in the lower and medium parts of Hazarmerd section beds, wheras, it decreases in the upper part and it is lacking in the top of profile . This microfacies includes:

a- Bioclastic packstone in lower and middle part

b- Foraminiferous packstone in lower part

c- Rotaliids packstone in middle and towards the upper part

d- Soritids and rotaliids packstone towards the upper part

e- Discocyclinids packstone in lower part of succession.

f- Discocyclinids and miliolids packstone towards the upper part of succession.

3. Grainstone microfacies reaches about 20% by volume and comprises three subtypes in three different levels :

a- Foraminiferous grainstone in middle part

b- Rotaliids grainstone towards the upper part

c- Miliolids grainstone in upper part

4. Floatstone Microfacies reaches 7% by volume and includes:

a- Soritids floatstone

b- Soritids and rotaliids floatstone, both Microfacies are identified in middle part towards the upper part of succession.

5. Rudstone microfacies, mostly consists of soritids and appears only in two levels in middle part .

Finally, the facies associations identified in the Hazar Merd section consist of two main types of microfacies: **Bioconstructed** and **Bioaccumulated**. Each of the facies types presents several subtypes and we can summarise them as follows:

I. **Bioconstructed Microfacies**, reaches 17.75% by volume and comprises four subtypes mostly identified in lower part of succession:

a- Coralligenous boundstone

b- Boundstone-packstone

c- Bryozoans boundstone

d- Boundstone-grainstone

II. **Bioaccumulated Microfacies** comprises five main Microfacies, each of them includes several subtypes of microfacies:

1. Wackstone comprises only three levels in lower and middle part successively:

a- Bioclastic wackestone

c- Soritids and rotaliids wackestone

c- Rotaliids wackestone

2. Packstone Microfacies represents 48.4% of Hazar Merd succession and it is widespread in the lower and medium parts of Hazar Merd section beds, wheras, it decreases in the upper part and it is lacking in the top of succession . This microfacies includes:

a- Bioclastic packstone in lower and middle part

b- Foraminiferous packstone in lower part

c- Rotaliids packstone in middle and towards the upper part

d- Soritids and rotaliids packstone towards the upper part

e- Discocyclinids packstone in lower part of succession.

f- Discocyclinids and miliolids packstone towards the upper part of succession.

3. Grainstone microfacies reaches about 20% by volume and comprises three subtypes in three different levels :

a- Foraminiferous grainstone in middle part

b- Rotaliids grainstone towards the upper part

c- Miliolids grainstone in upper part

4. Floatstone Microfacies reaches 7% by volume and includes:

a- Soritids floatstone

b- Soritids and rotaliids floatstone, both Microfacies are identified in middle part towards the upper part of succession.

5. Rudstone microfacies, mostly consists of soritids and appears only in two levels in middle part .

3. 1. 1. 2. **Micrfossils**

The micropaleontological association identified in the Hazar Merd section cosists of the following algae and foraminifers;

Amphiroa iroquensis, JOHNSON *Sporolithon sp*., *Operculina salsa*, *Discocyclina varians KAUFMANN, Titanoderma*, *Misccellanea sp., Orbitolites complanatus*, LAMARCK, Discocyclina *sp., Quinquiloculina, Saudia labyrinthica* GRIMSDALE*, Archaias kirkukensis,* HENSON*, Idalina sinjarica* GRIMSDALE*, Peneroplis sp., pseudohatigerina sp., Textularia sp., Kathina subspherica* SIREL*, Nummulite sp., Triloculina, Alveolina sp., Assilina sp., Cibicides nammalensis, Biloculina, Miliola, Triloculina, Cymopolia ellongata*, DEFRANCE, *Cymopolia sp., Alveolina globosa* LEYMERIE, *Alveolina primaeva* REICHEL, *Glomalveolina sp*.

The presence of *Discocyclina varians* indicates the Paleocene and *Alveolina primaeva, Saudia labyrinthica* and *miscellanea sp*. appear to be restricted to the late Paleocene*. Idalina sinjarica, Operculina salsa* indicate the late Paleocene-Early Eocene. Besides, *Assilina* and *Miliola* indicate the Early-Middle Eocene. Cymopolia has the most numerous species particularly during Paleocene and Middle Eocene(Genot, 1991).

Hazar Merd Section

Plate 1

1- Coralligenous boundstone (Sample 204)

2- Foraminiferous packstone (Sample 206)

3- Bioclastic packstone (Sample 208)

4- Red algae bindstone(Sample 213)

5- Red algae bindstone (Sample 213)

6- Red algae bindstone (Sample 209)

7-Coralligenous boundstone (Sample 219)

8- Coralligenous boundstone (Sample 225)

Note:- The bar scale is 1mm.

Plate 1

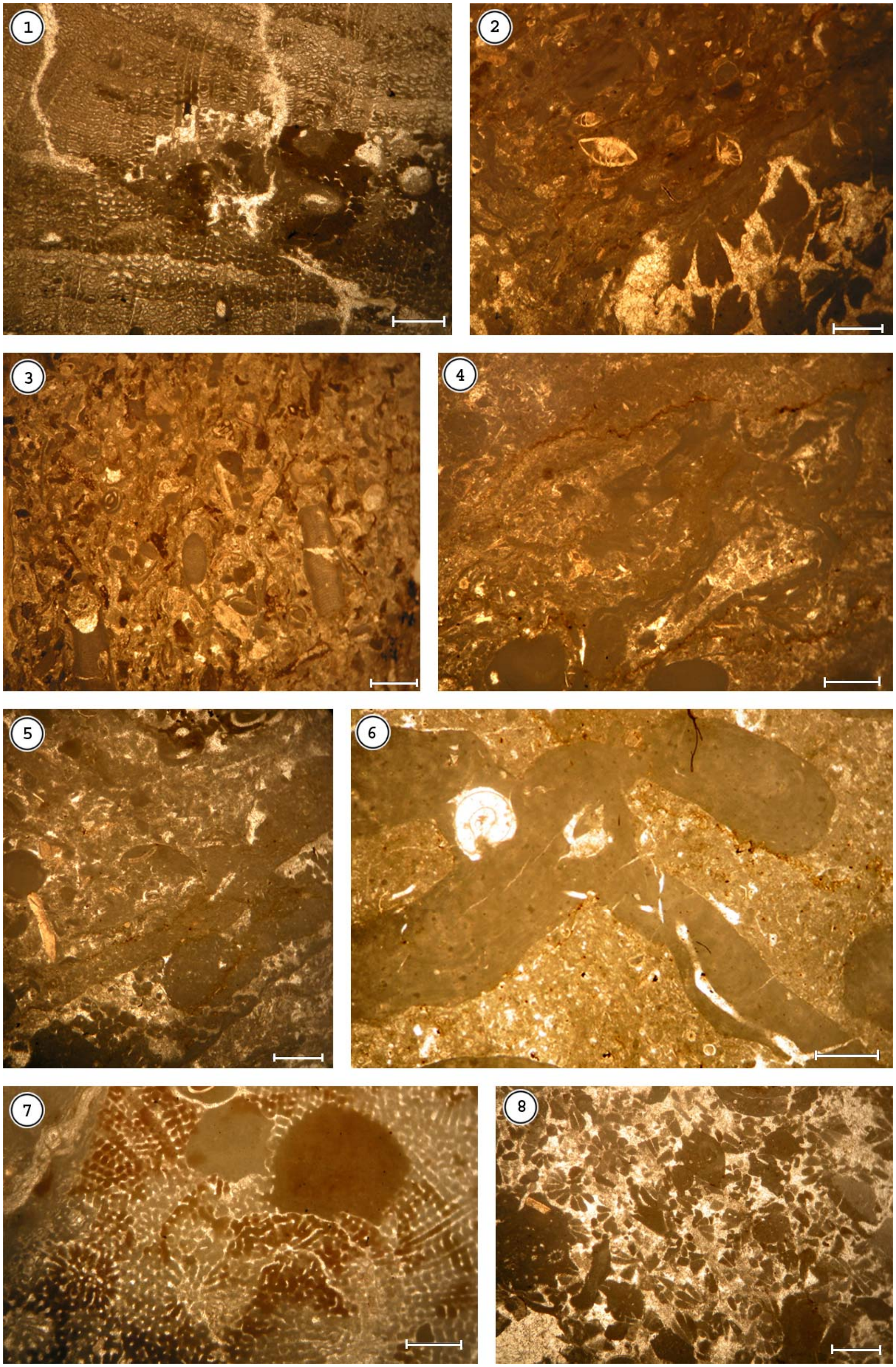


Plate 2

1- Coralligenous boundstone (Sample 219)

2- Discocyclinids packstone (Sample 244)

3- Boundstone –packstone (Sample 230)

4, 5, 6- Bryozoans in boundstone-packstone microfacies (Sample 238)

7- Bioclastic packstone (Sample 264)

8- Discocyclinids packstone (Sample 265)

Note:- The bar scale is 1mm.

Plate 2

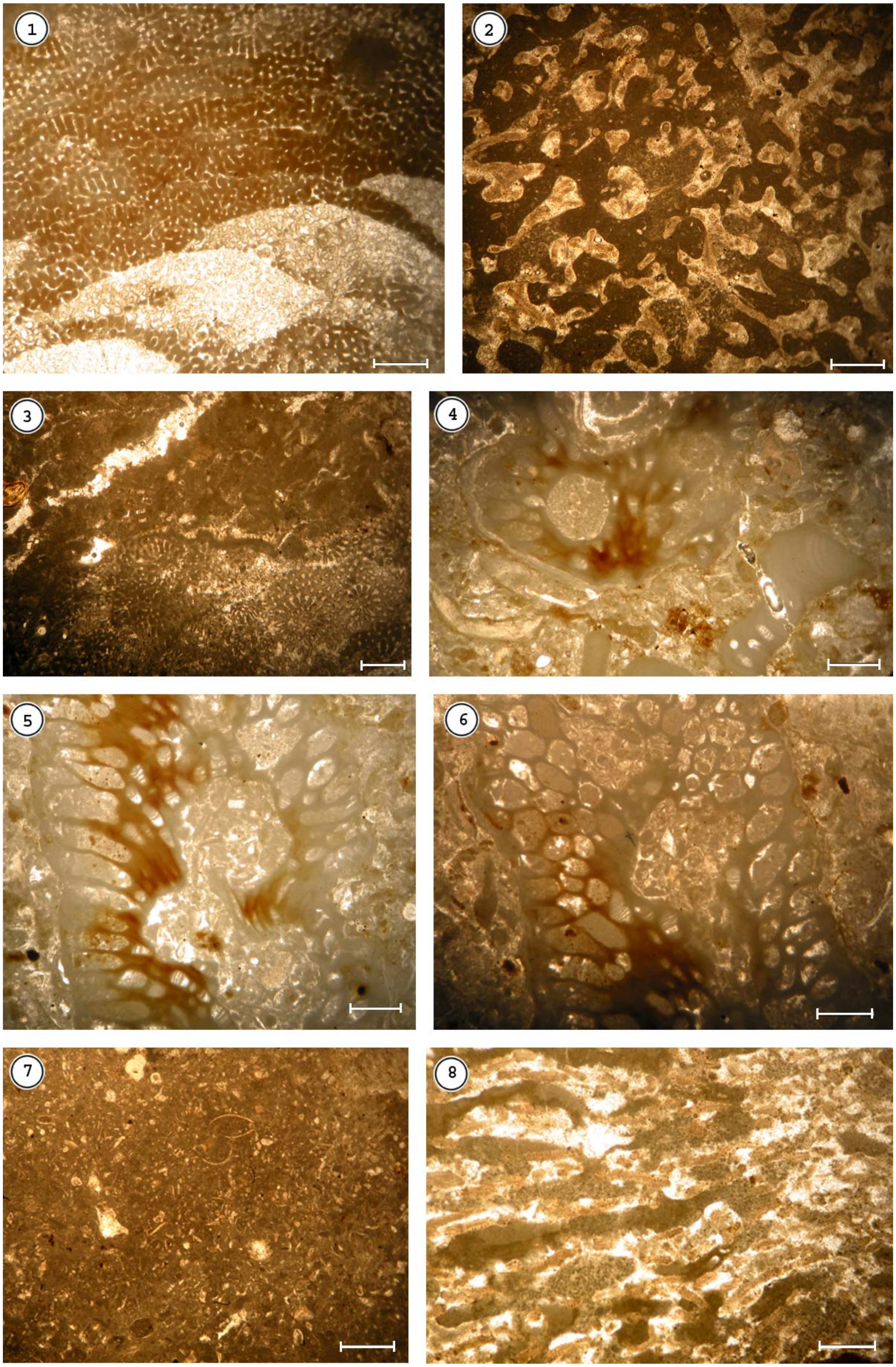


Plate 3

1- Discocyclinids packstone (Sample 265)

2- Soritida rudstone (Sample 310)

3- Peloidal grainstone (Sample 307)

4- Foraminiferous grainstone (Sample 308)

5- Rotaliids floatstone. Also it contains discocyclinids (Sample 324)

6- Soritids and miliolids grainstone (Sample 312)

7- Rotaliids grainstone (Sample 321)

8- Rotaliids rudstone with some Discocyclinids and Soritids (Sample 325)

9- Dolomitized packstone (Sample 331)

10- Rotaliids packstone (Sample 326)

11- Rotaliids packstone (Sample 332)

Note:- The bar scale is 1mm.

Plate 3

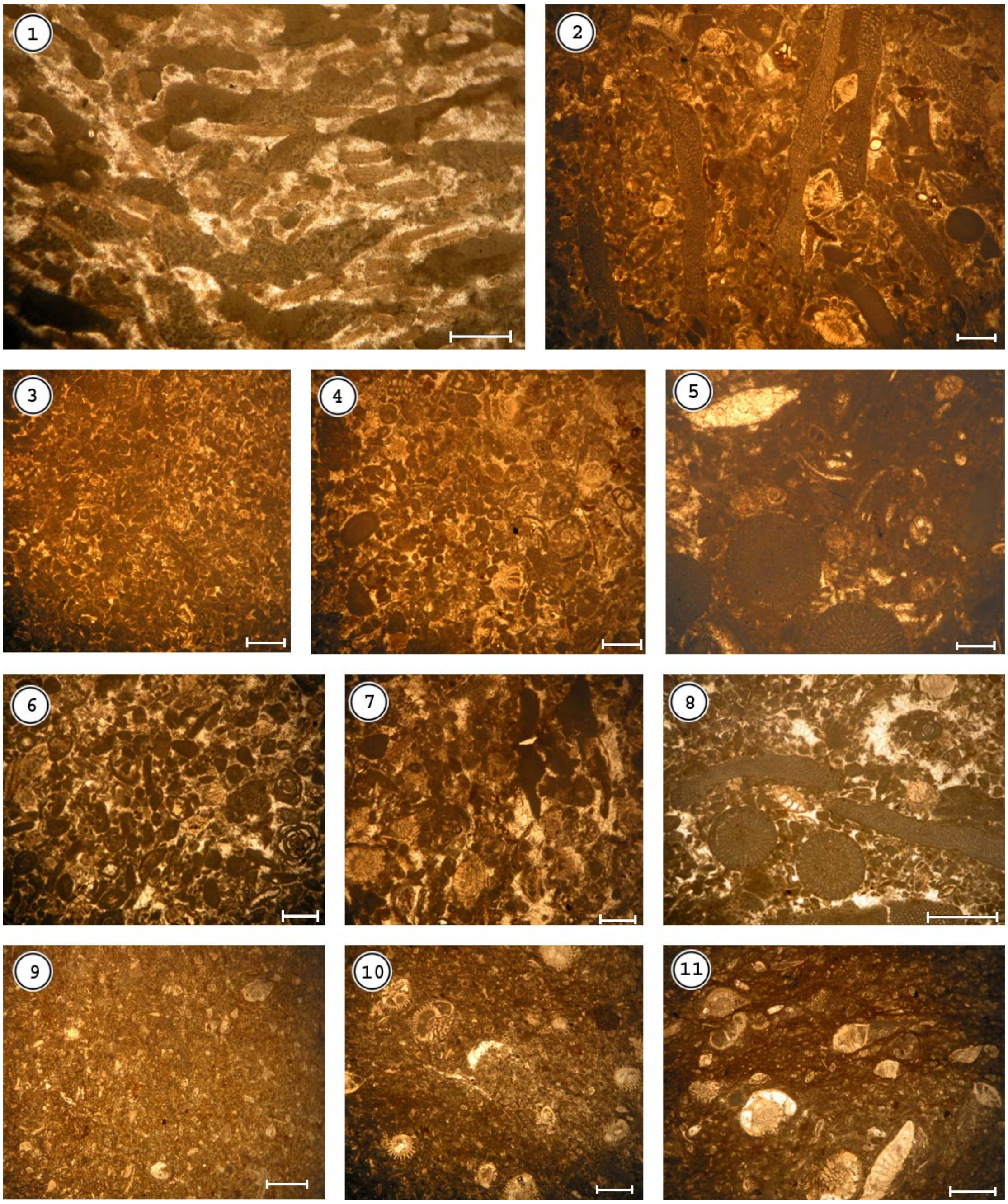


Plate 4

1, 2- Soritids floatstone (Samples 337, 347)

3- Coralligenous boundstone (Sample 348)

4, 5- Coralligenous boundstone –Packstone (Sample 352)

6- Soritids and rotaliids floatstone with Orbitolites (Sample 358)

7- Rotaliids grainstone (Sample 385)

8- Rotaliids wackestone (Sample 386)

Note:- The bar scale is 1mm.

Plate 4

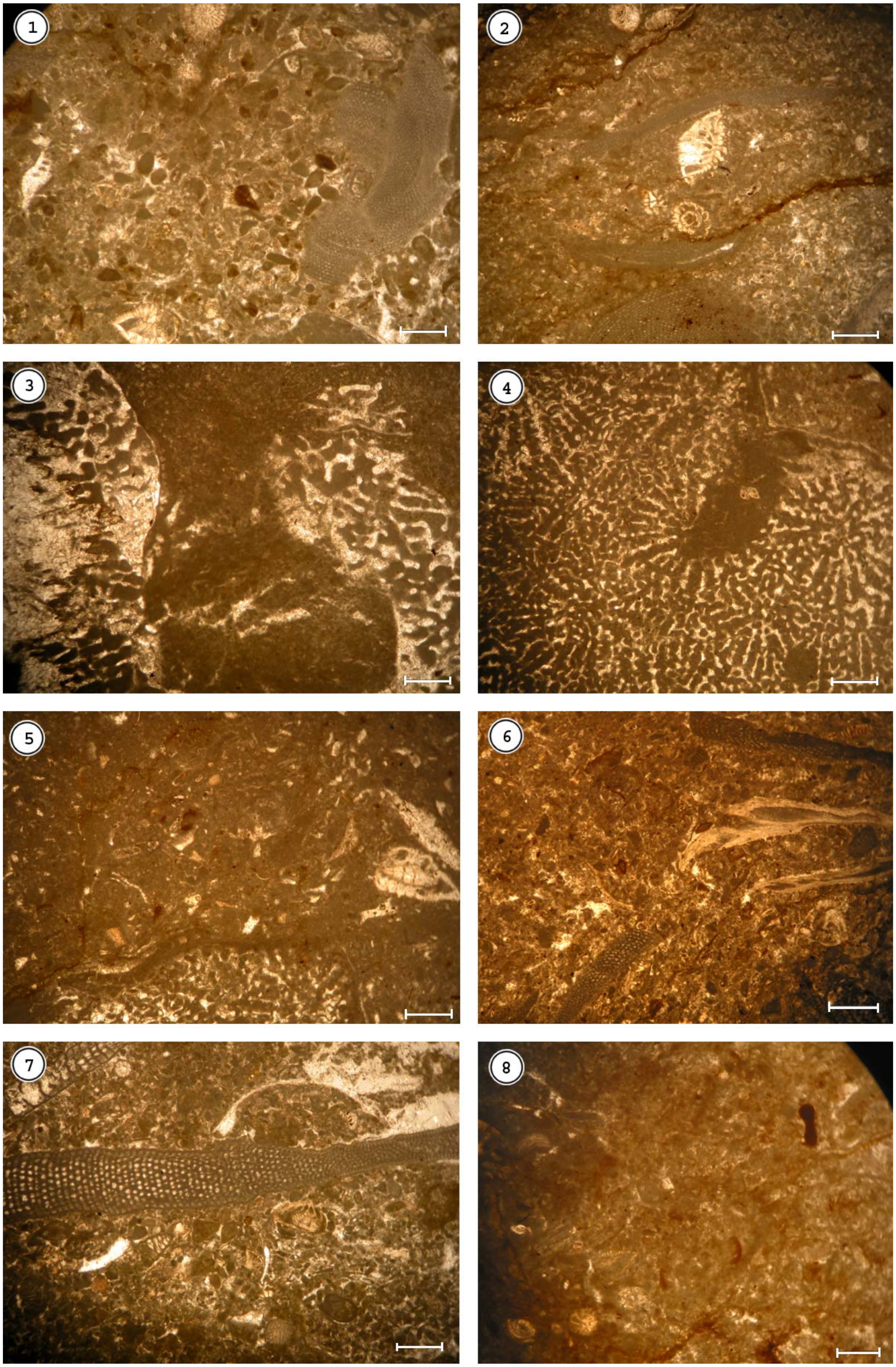


Plate 5

1- Rotaliids and miliolids packstone with *Dasycladals*, *Archaias kirkukensis*. The micrite is transformed into microsparite (Sample 394)

2- *Miliolids* grainstone (Sample 395)

3- Peloidal grainstone (Sample 397)

4- *Miliolids* grainstone (Sample 398)

5- Peloidal grainstone (Sample 412)

6- Peloidal grainstone (Sample 417)

Note:- The bar scale is 1mm.

Plate 5

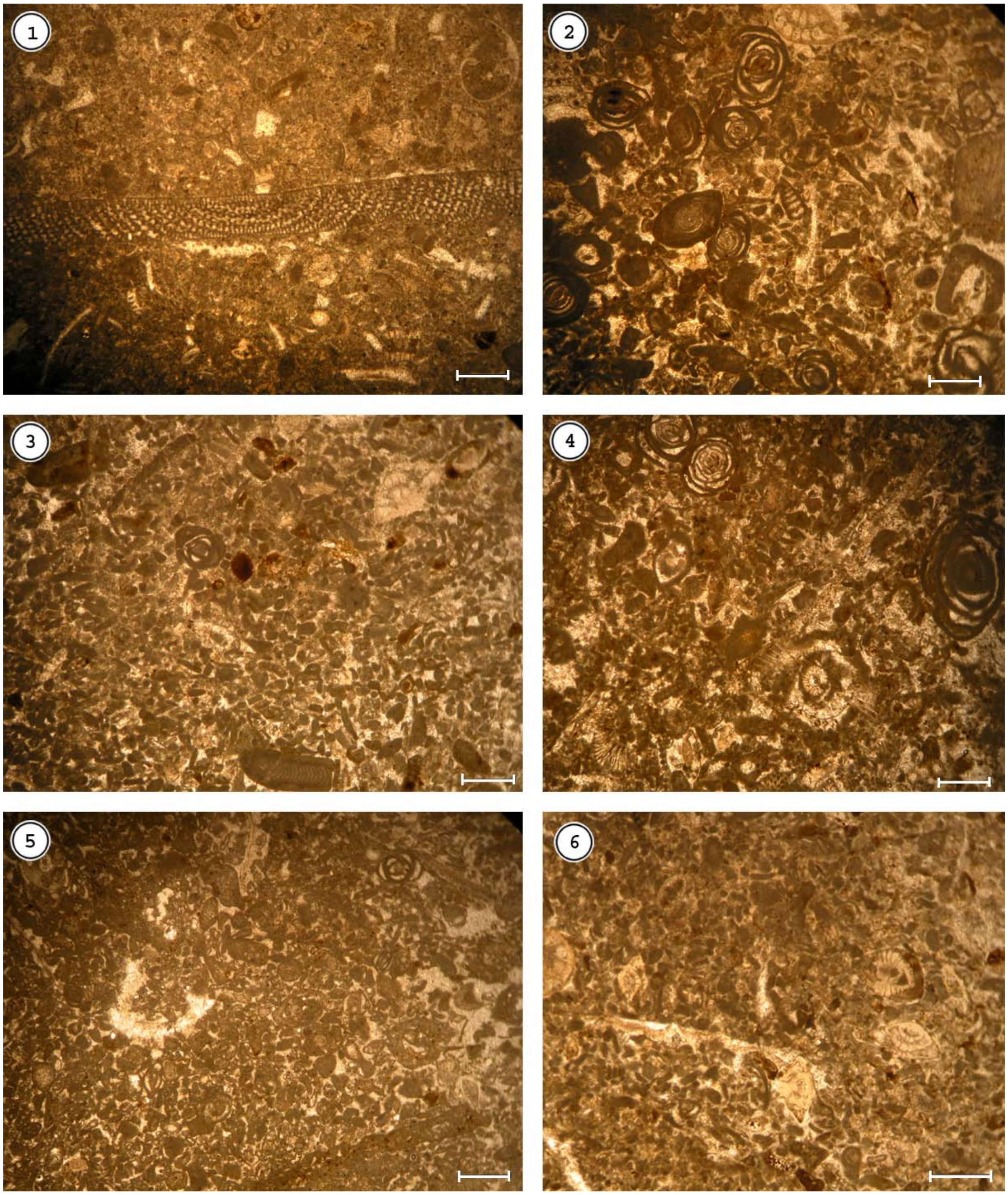


Plate 6

1- *Discocyclina varians* KAUFMAN (arrow), (Sample 366)

2- Nummulite (Sample 367)

3- *Operculina salsa* (arrow), (Sample 382)

4, 7- *Sporolithon* (Samples 350, 222)

5, 8- *Discocyclina varians* KAUFMAN (Sample 265)

6- *Discocyclina* sp. (Sample 307)

9- *Miscellanea sp*. CARTER (Upper Paleocene), (Sample 297)

10- *Idalina snjarica* GRIMSDALE (317)

11- *Peneroplis* sp.,axial section (Sample 319)

12, 14- *Orbitolites* (Sample 326, 337)

13- *Pseudohatigerina sp.* (Sample 320)

Note:- The bar scale is 1mm.

Plate 6

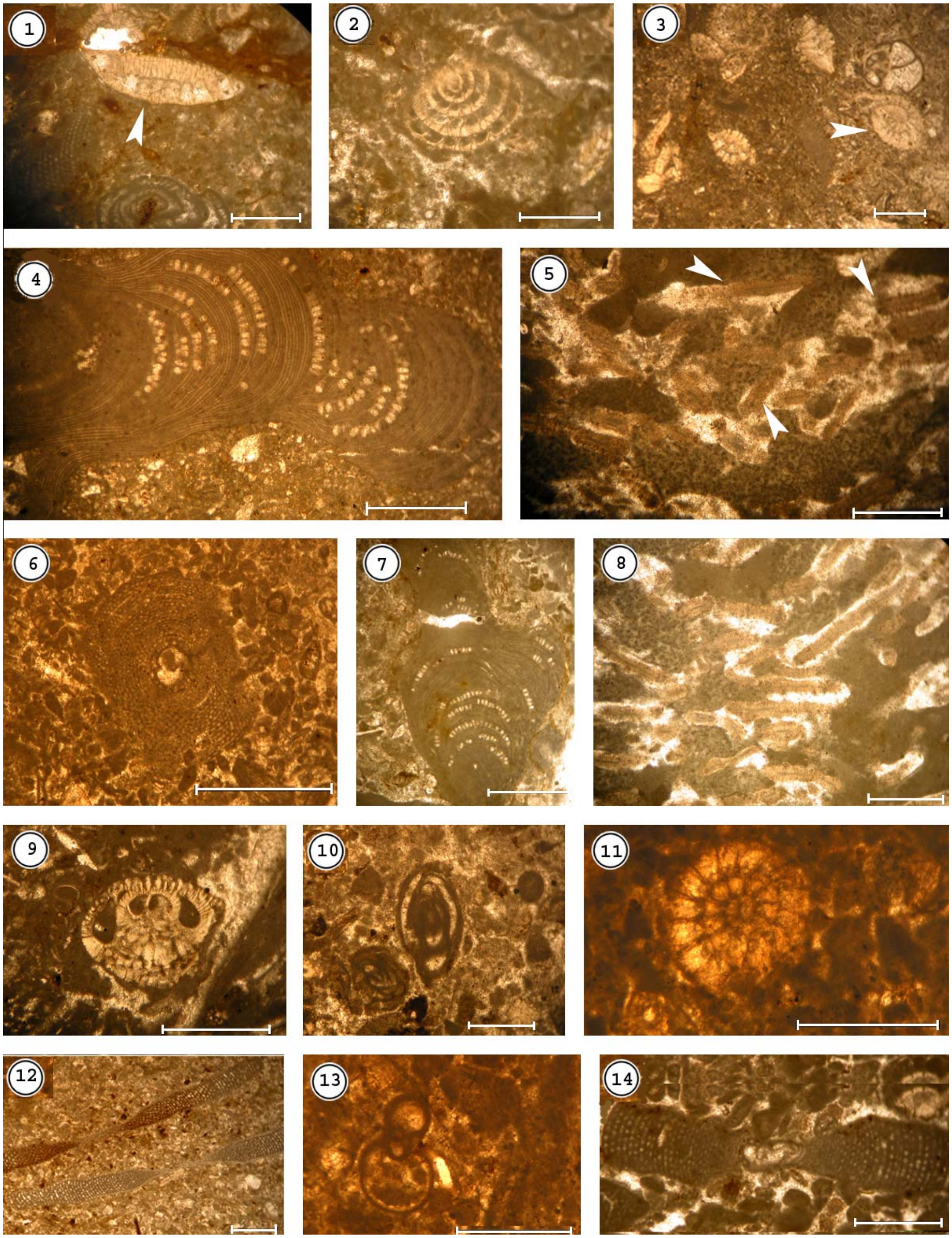


Plate 7

1- *Saudia labyrinthica* GRIMSDALE (Sample 337)
2-*Textularia sp.* (Sample 352)
3-*Kathina subspherica sirel* (arrow), subaxial section (Sample 357)
4- *Orbitolits* (Sample 359)
5- *Saudia labrinthica* GRIMSDALE (arrow), (Sample 358)
6- *Pseudohatigerina sp.* (Sample 360)
7- *Saudia labrinthica* GRIMSDALE (Sample 358)
8- *Triloculina* (Sample 364)
9- *Discocyclina* (Sample 360)
10-*Nummulites* (Sample 365)
11-*Idalina sinjarica* GRIMSDALE (Sample 366)
12- *Pseudohatigerina sp.* (Sample 365)
13- *Assilina* (arrow), (Sample 382)
14- Geopetal structure (Sample 385)
15- *Quinquiloculina* (Sample 385)
16- *Cibicides nammalensis* (Sample 390)
17- *Idalina sinjarica* GRIMSDALE (black arrow) *Cymopolia sp*. (white arrow), (Sample 393)
18- *Biloculina* (Sample 393)
19- *Miliola* (Sample 393)

Note:- The bar scale is 1mm.

Plate 7

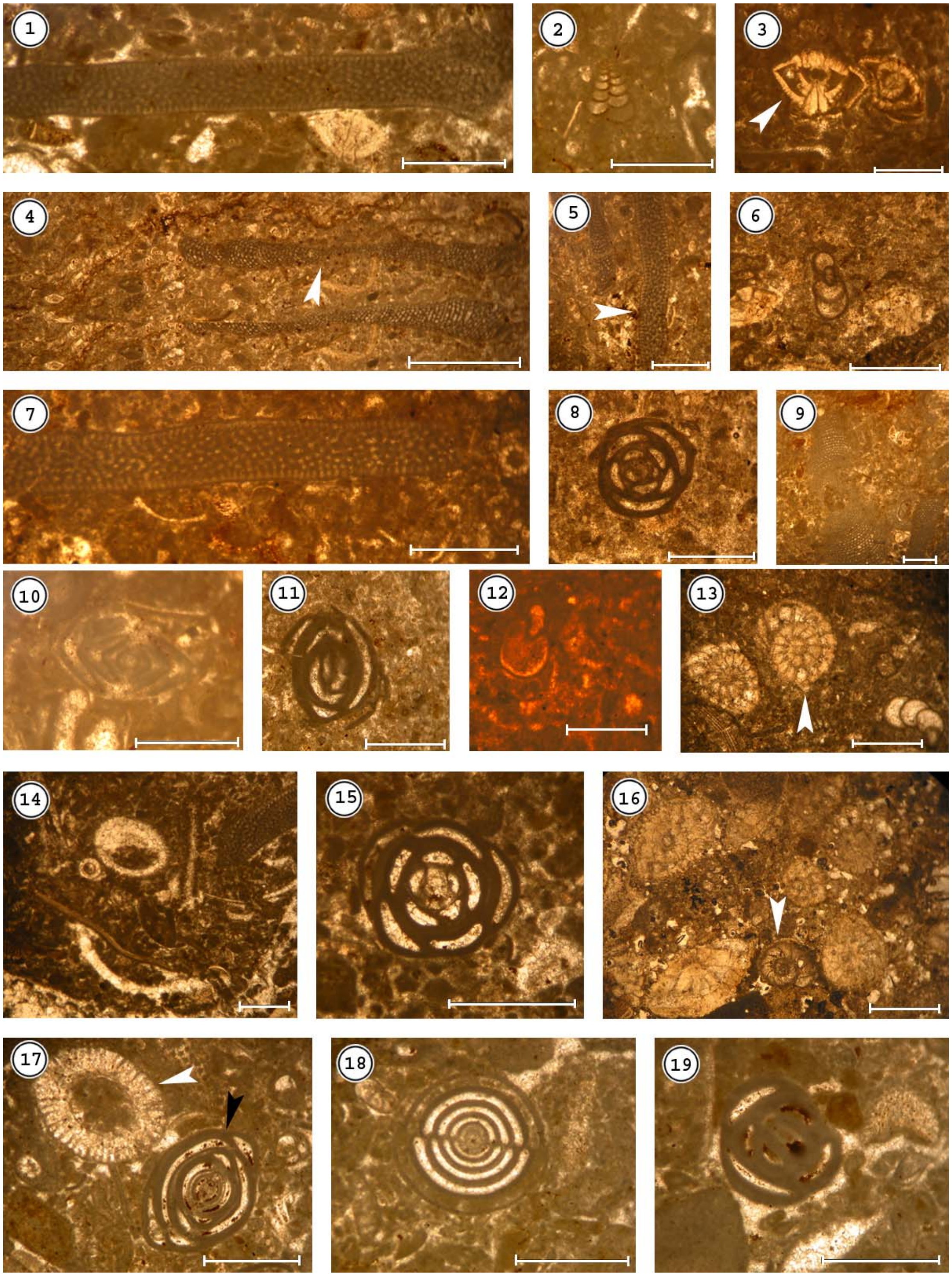


Plate 8

1-*Triloculina* (Sample 393)

2, 3- *Cymopolia ellongata* DEFRANCE, oblique section (Sample 393)

4- *Cymoplia sp.* (white arrow), *Idalina sinjarica* (black arrow), (Sample 393)

5- *Miliolid* (Sample 395)

6- *Idalina sinjarica* (Sample 400)

7- *Archaias kirkukensis* Henson (Sample 394)

8, 10- *Cymoplia sp.* (Sample 393, 394)

9- *Biloculina (Pyrgo),* (Sample 400)

11- *Cibicids nammalensis* (Sample 396)

12- Gastropod (Sample 400)

13-*Dissocladella* inside the shell of Gastropod. Gastropod's shell is filling by green algae, red algae fragments and foram (Sample 404)

14- *Archaias kirkukensis* Henson, equatorial section (Sample 406)

Note:- The bar scale is 1mm.

Plate 8

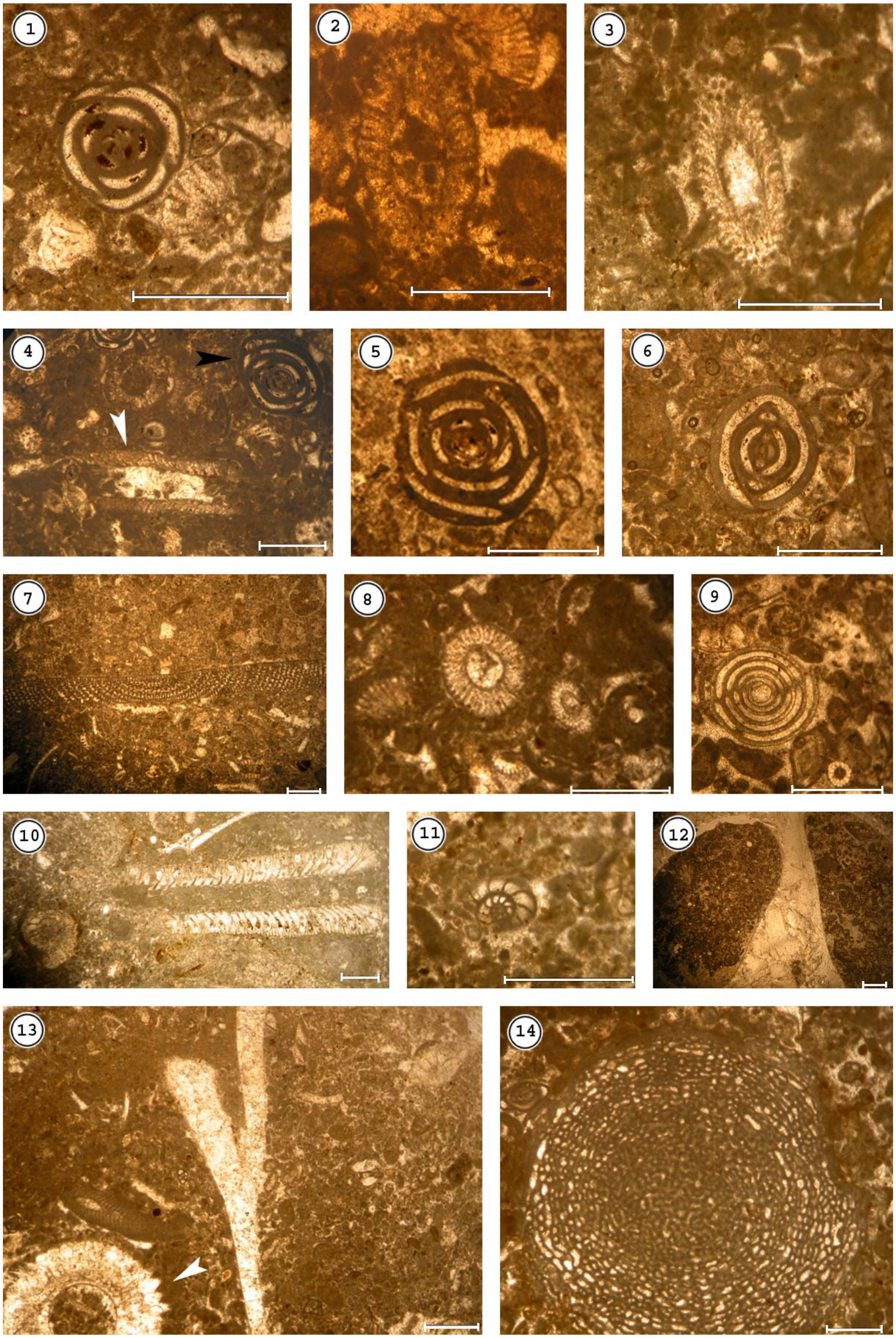


Plate 9

1- *Alveolina globosa* Leymerie (Sample 411)

2- *Alveolina globaso* Leymerie (arrow) with fine foram (Sample 411)

3- *Glomalveolina sp.* Reichal and Renz (Sample 411)

4- *Glomalveolina sp*. Reichal and Renz (white arrow), foraminifer (black arrow) probably *Idalina sinjarica* (Sample 411)

5- *Archaias kirkukensi*s Henson (black arrow), *Parachaetetes* ? (white arrow) (Sample 417)

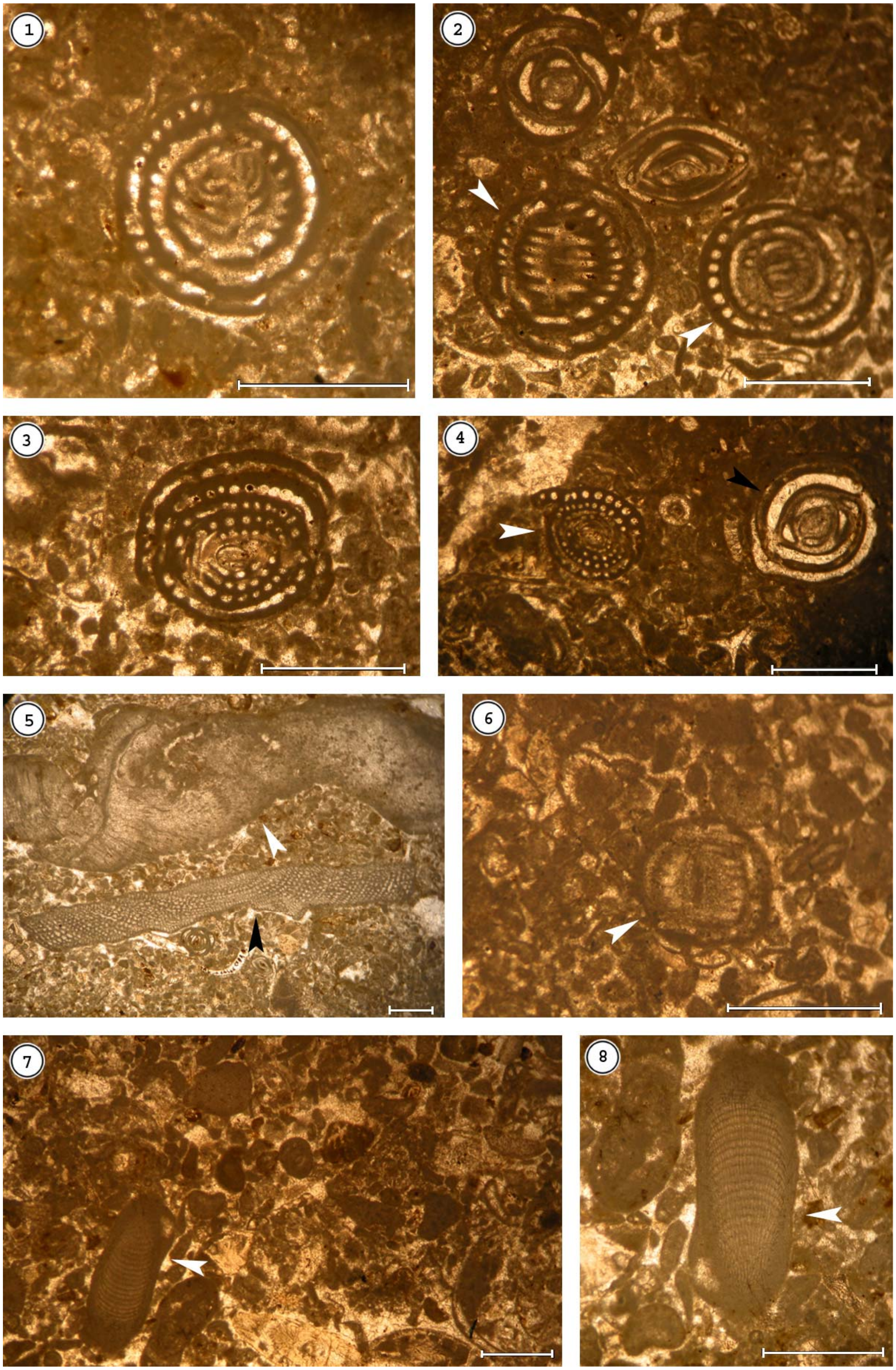
6- *Alveolina primaeva* Reichel (arrow), (Sample 412)

7- *Amphiroa iraquensis* (arrow), (Sample 416)

8- *Amphiroa iraquensis* (Sample 416)

Note:- The bar scale is 1mm.

Plate 9



3. 1. 2. **Qazan section**

3. 1. 2. 1. **Microfacies**

➔ **Rotaliids-miliolids grainstone** S.No.(420) with red algae fragments.

➔ **Bioclastic packstone** S.No. (421-439; 467-471; 488-494; 506-511; 531-534) consists of red algae fragments, echinoid spines, bioclasts, textulariids, coral fragments, gastropods (PL. 10, 3, 6, 7) or with rare foram (PL. 11, 5). This facies is intercalated with some levels of boundstone-grainstone (PL. 10,1, 2) containing forams, red algae and coral fragments. The sample (433) is completely dolomitized (PL. 10, 4, 5), other diagenetic processes represented by dissolution under pressure produced stylolites, or consists of red algae fragments, echinoid plates, ghosts of nummulites due to dolomitization and ostracods fragments (PL. 12, 4, 5)

➔ **Coralligenous boundstone** S.. No. (440-466; 521-530; 535-555) mostly consists of colonial corals and red algae. Sometimes the septa of coral are filled by microbial peloids, probably introduced by red algae. The present stylolitization processes produced some types of stylolites. Within this facies four levels of grainstone are present (PL.11, 3), and (PL. 11, 6) consisting of intraclasts, green algae, red algae and coral fragments (PL. 10, 8; PL. 11, 1, 2, 4) or interlayered with foraminiferous grainstone and bioclastic packstone (PL. 11, 7).

➔ **Boundstone, grainstone and packstone** S. No. (495-505)**.** These facies are interlayered with each other and consist of coral, red algae, echinoid plates and spines, intraclasts and bioclasts.

Some grainstones contain large fragments and form a rudstone microfacies (PL.11, 8)

➔ **Grainstone-boundstone** S. No. (512-516**)** consisting of coral fragments, intraclasts and forams. It is affected by dissolution processes that produced stylolites (PL.12, 2)

➔ **Boudstone with coral and red algae** S. No. (517). The micrite is transformed into sparite and apparition of stylolites due to the dissolution under pressure.

➔ **Rotaliid grainstone** S. No. (518-519) with intraclasts and red algae fragments .

➔ **Rudstone** S. No. (520) with larger rotaliids and red algae fragments

➔ **Foraminiferous grainstone** S. No.(556-557). consists of forams (*miliolids, peneroplids, soritids),* green algae (dasycladales), fragments of corals and intraclasts (PL.12, 6);

➔ **Soritids floatstone** S. No.(558-570). goes upward to the top of the section, the coarse floatstone facies most frequently contains large amount of soritids with red algae, green algae, miliolids, and gastropods. In this part of succession the fossils *Saudia labyrinthica, Orbitolites complanatus, Biloculina, Quinquiloculina, Clypenia meriendae, Morozovella angulata, clypeina, Idalina sinjarica* and *Discocyclina* were identified.

We can summarise the Microfacies identified in Qazan section as follows:

I. Bioconstruted Microfacies

The percentage of boundstone facies in the Qazan section reaches to about 55% of total succession. This facies mainly consists of coral, red algae and sometimes contains forams and echinoid plates. In some levels the skeletons of coral are filled by microbial peloids introduced by red algae. It appears in the first third, in middle part intercalated with grainstone and packstone , and 18 meters thick towards the uppermost part of the succession

II. Bioaccumulated Microfacies comprises three types and several subtypes Microfacies:

1- Grainstone reaches apercentage of 8% by volume and comprises;

a. Rotaliids-miliolids grainstone in the first level of succession.

b- Rotaliids grainstone in middle part with 2 m. thick, and some levels intercalated with boundstone and packstone

c- Foraminiferous grainstone in thin layer towards the upper part

2- Bioclastic Packstone reaches 28.2%by volume and appears in several levels in middle part and goes upward.

3- Soritids floatstone in the uppermost part of the succession.

3. 1. 2. 2. **Microfossils**

The micropaleontological association in the Qazan section consists of the following calcareous algae and foraminifers:

Parachaetetes, *Pseudohatigerina sp., Amphiroa iraquensis, Quinquiloculina, Acicularia, Idalina sinjarica,* GRIMEDALE*, Opertorbitolites transitorius,* HOTTINGER*, Saudia labyrinthica,* GRIMEDALE, *Orbitolites complanatus* LAMARCK, *Biloculina, Clypenia meriendae ,Morozovella angulata , Clypeina, Discocyclina.*

The presence of *Saudia labyrinthica* appears to be restricted to the late Paleocene and *Idalina sinjarica* indicates the late Paleocene-Early Eocene**.**

Qazan Section

Plate 10

1, 2- Red algae boundstone –grainstone (Samples 429, 431)

3- Bioclastic pacstone (Sample 432)

4, 5- Completely dolomitized (Sample 433)

6, 7- Bioclastic packstone (Sample 435, 436)

8- Coralligenous boundstone (Sample 443)

Note:- The bar scale is 1mm.

Plate 10

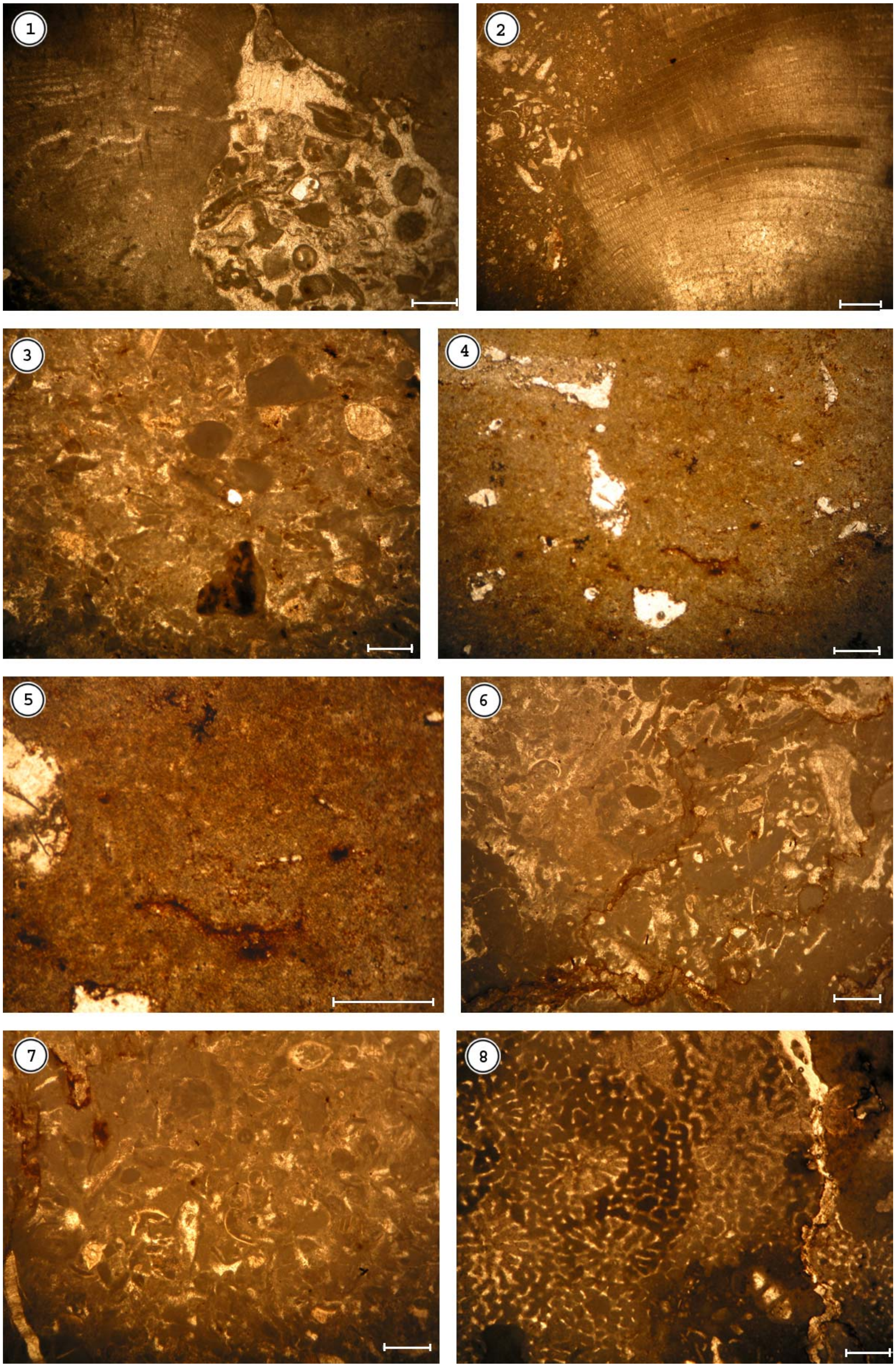


Plate 11

1, 2- Coralligenous boundstone (Sample 443, 449)

3- Grainstone with red algae red algae fragments (Sample 455)

4- Coralligenous boundstone (Sample 465)

5- Bioclastic packstone (Sample 468)

6- Coralligenous boundstone (Sample 473)

7- Foraminiferous granstone (Sample 483)

8- Rudstone with large fragments of red algae (Sample 500

Note:- The bar scale is 1mm.

Plate 11

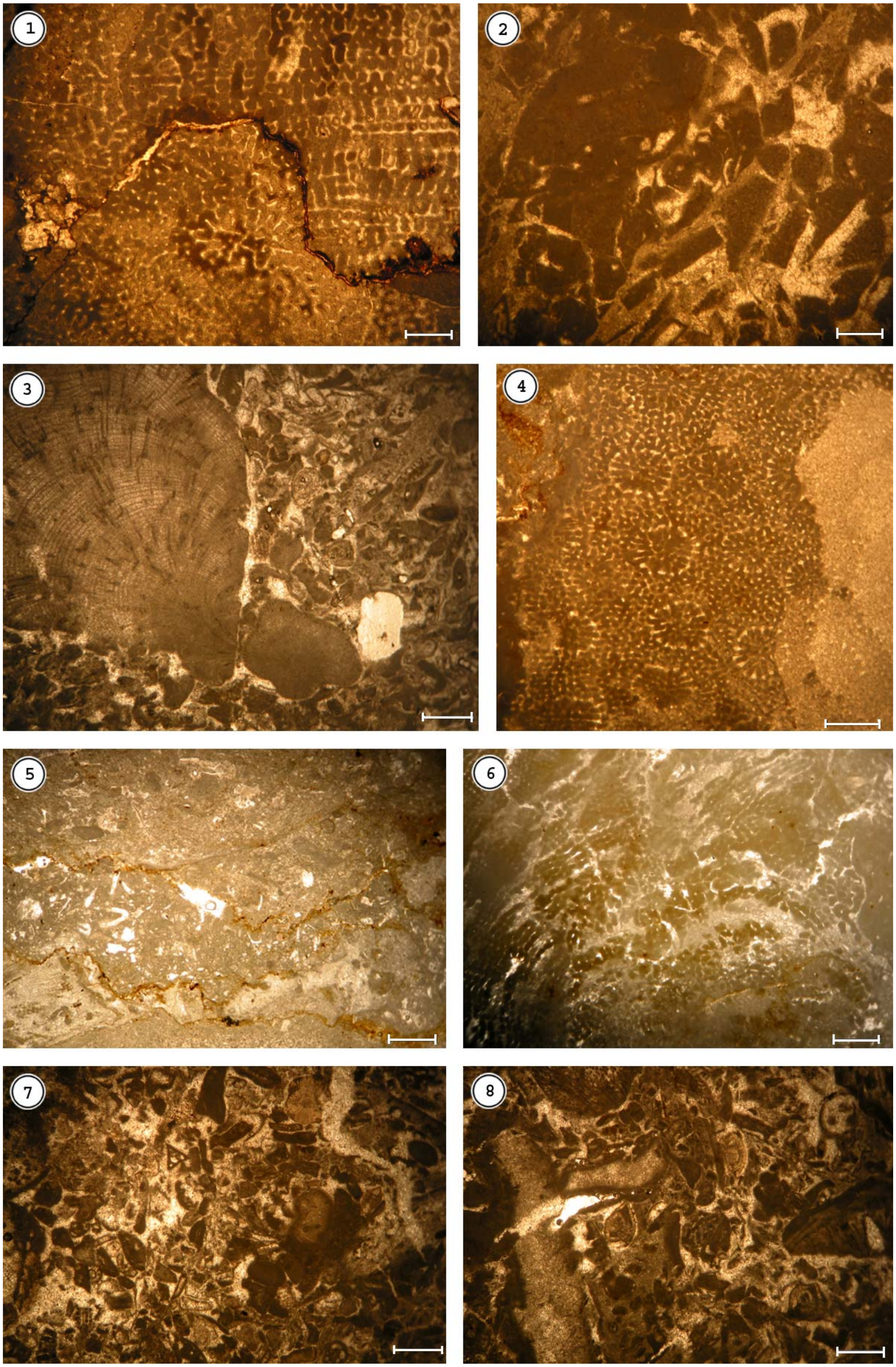


Plate 12

1- Coralligenous boundstone with red algae (Sample 542)

2- Grainstone-boundstone (Sample 515)

3- Coralligenous boundstone (Sample 555)

4, 5- Dolomitization of bioclastic packstone (Sample 532)

6- Foraminiferous grainstone (Sample 557)

7, 8- Soritids floatstone (Sample 558)

9- Soritids floatstone (Sample 559)

10- Foraminiferous grainstone (Sample 564)

11- Soritids floatstone (Sample 566)

Note:- The bar scale is 1mm.

Plate 12

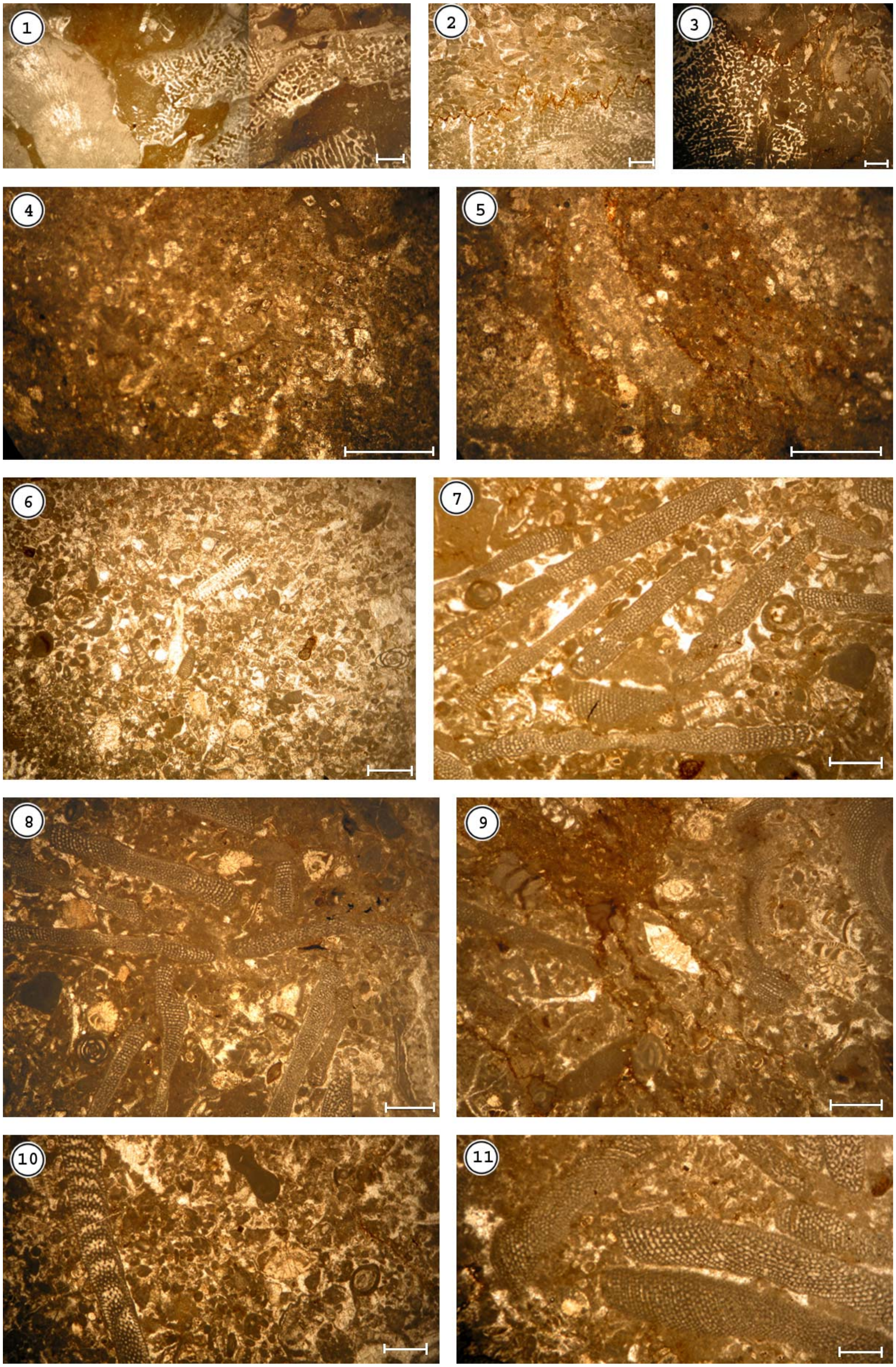


Plate 13

1- *Kathina sp.* (arrow), (Sample 432)

2- *Parachaetetes* (Sample 453)

3- *Pseudohatigerina sp.* (Sample 487)

4- *Amphiroa iraquensis.* (Sample 489)

5- *Polystrata alba* (Sample 542A)

6- *Idalina sinjarica* (Sample 554)

7- *Gastropod* (Sample 517)

8- *Acicularia* (green algae), (Sample 446)

9- *Opertorbitolites transitorius* Hottinger (Sample 557)

10- *Saudia labyrinthica* (arrow), (Sample 558)

11-*Orbitolites complanatus* (Sample 558)

12-*Biboculina* (Sample 558)

13-*Quinquiloculina* (Sample 558)

Note:- The bar scale is 1mm.

Plate 13

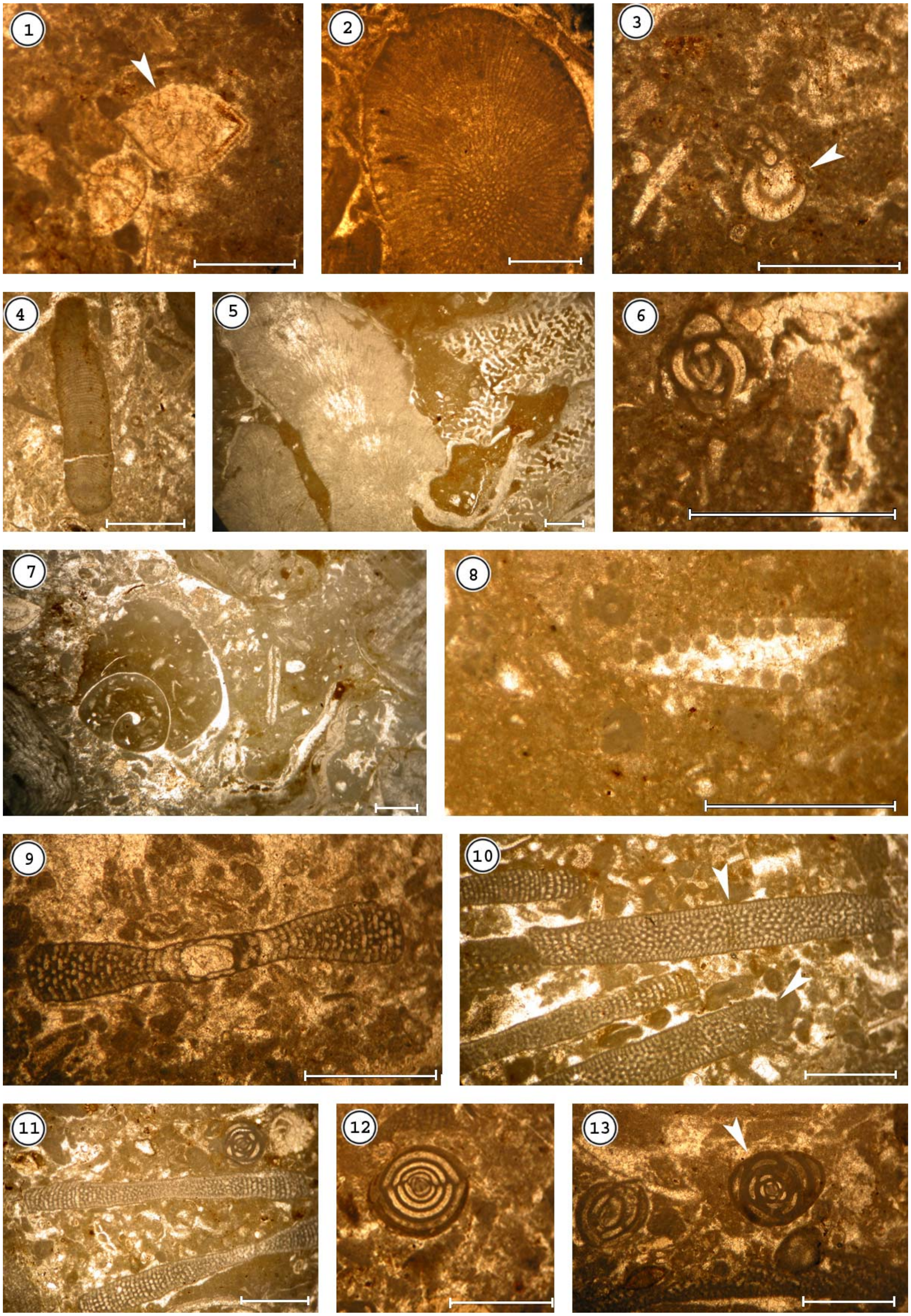


Plate 14

1-*Orbitolites complonatus* (white arrow) and *Saudia labyrinthica* (black arrow), (Sample 559)

2- *Opertorbitolites transitorius* Hottinger (Sample 558)

3- *Saudia labyrinthica*? (white arrow), (Sample 564)

4- *Clypenia meriendae* (Sample 564)

5- *Morozovella angulata (arrow),* (Sample 564)

6- *Idalina sinjarica* (Sample 570)

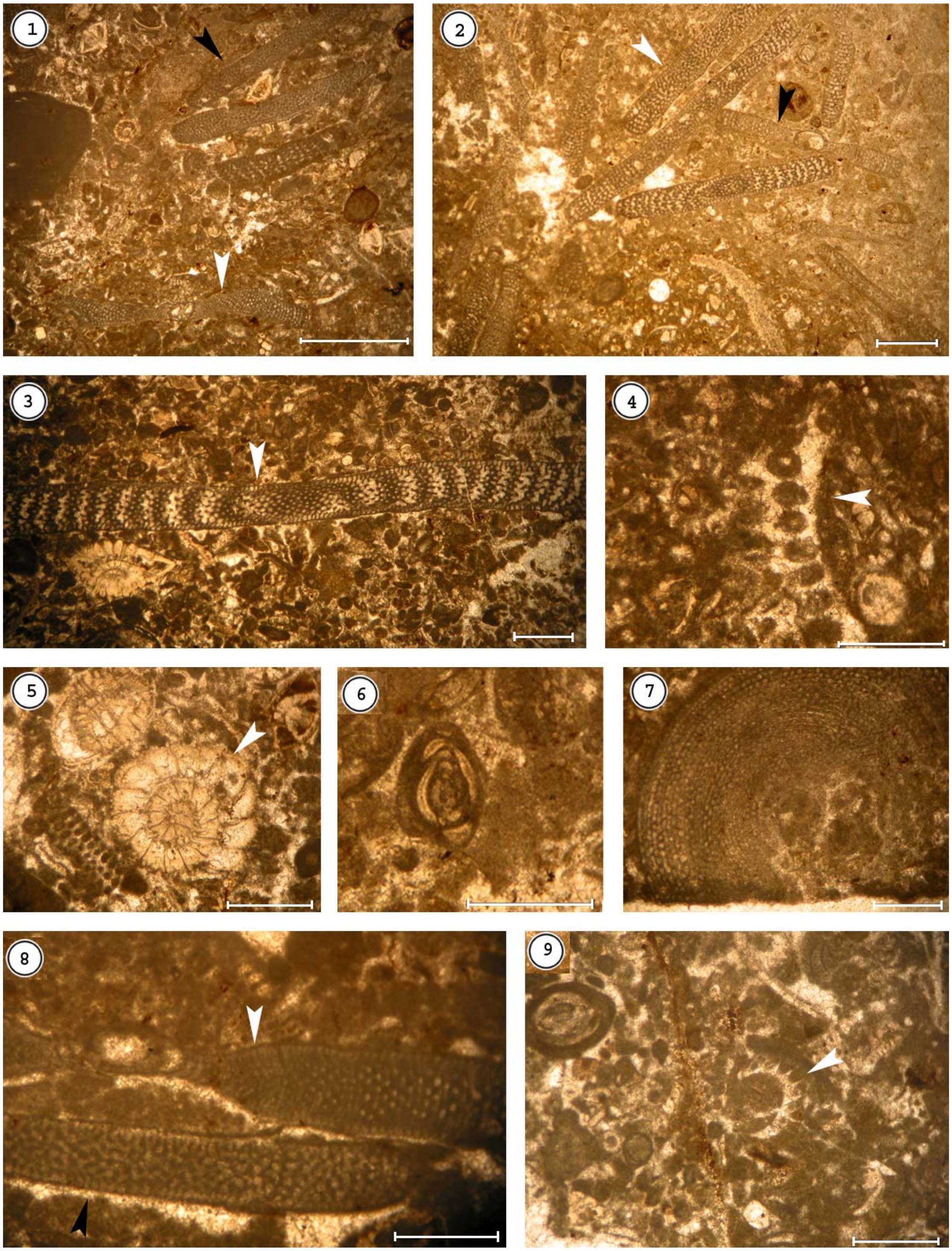
7- *Discocyclina* (Sample 566)

8- *Orbitolites complanatus* (white arrow) and Saudia labyrinthica (black arrow), (Sample 566)

9- *Clypeina* (arrow), (Sample 564)

Note:- The bar scale is 1mm.

Plate 14



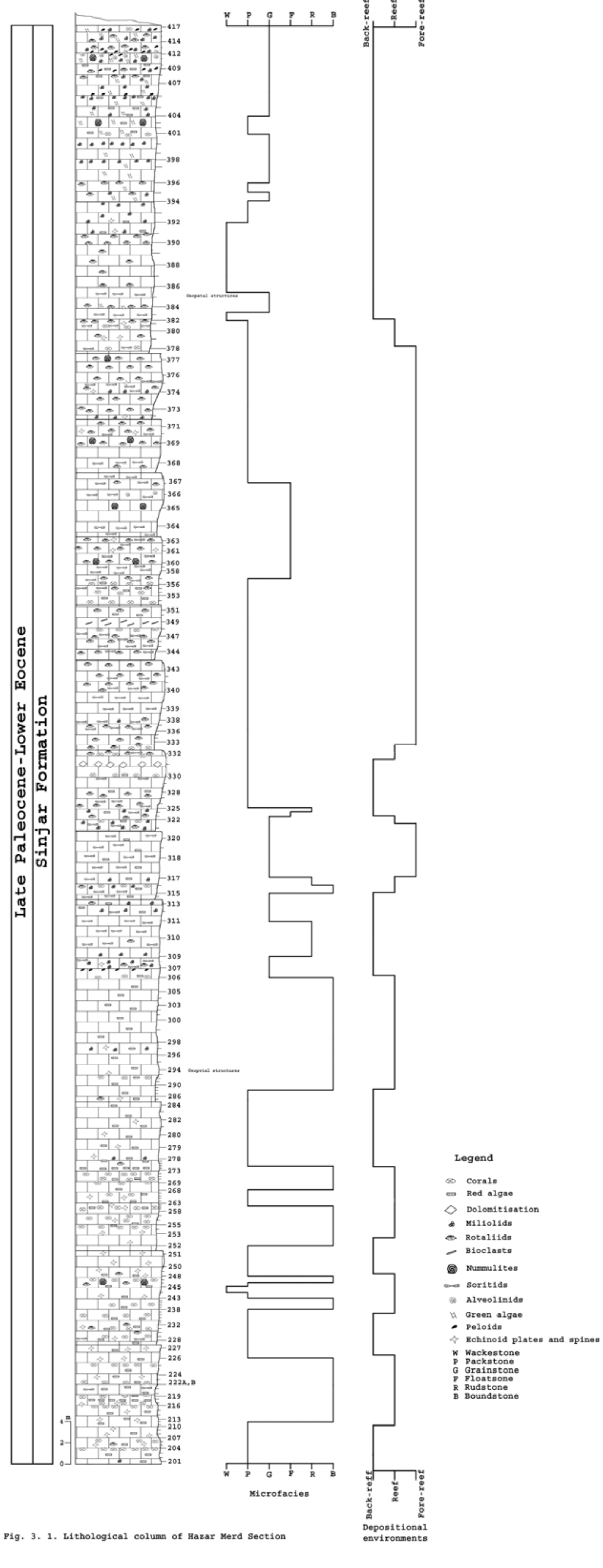


Fig. 3. 1. Lithological column of Hazar Merd Section

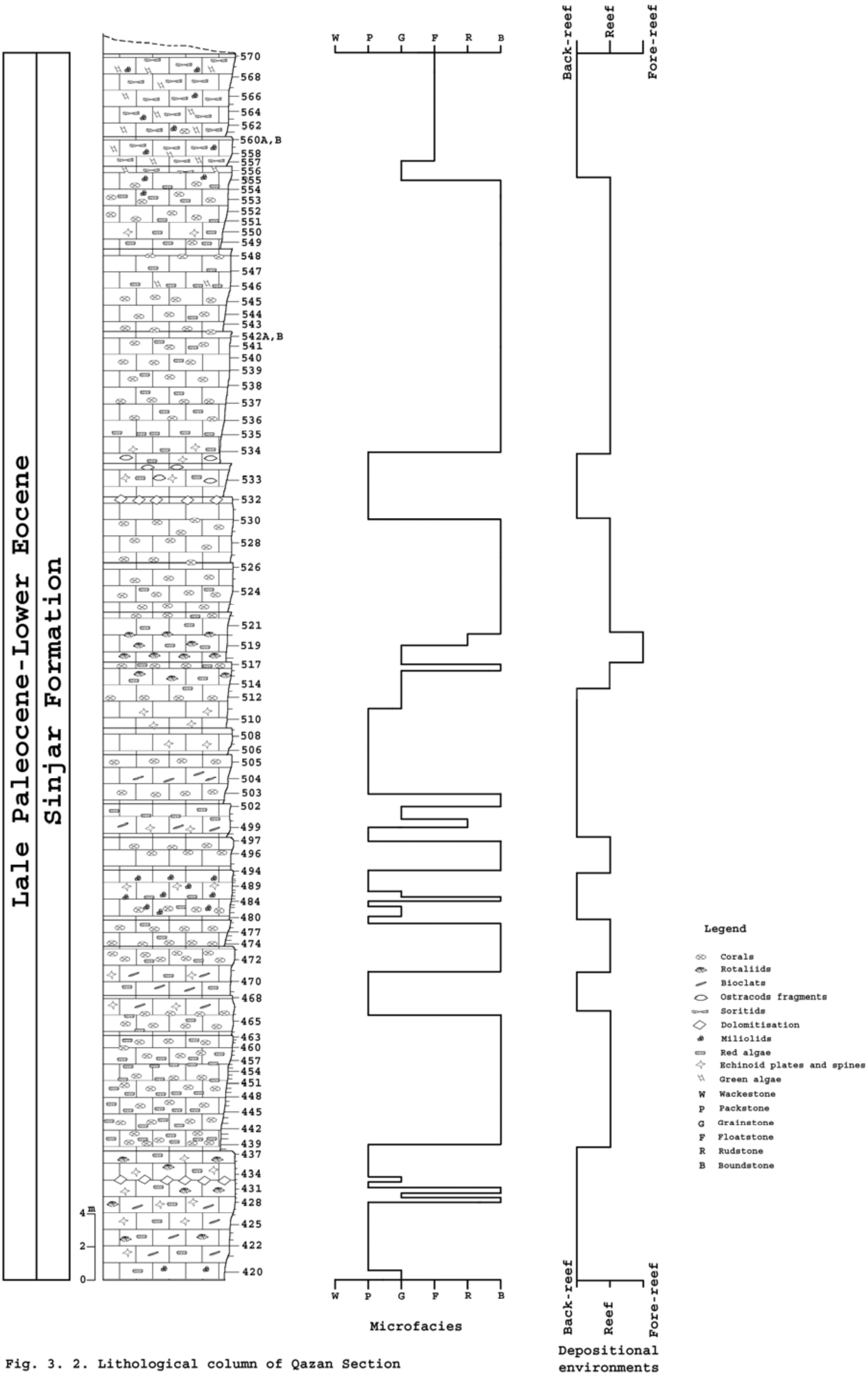


Fig. 3. 2. Lithological column of Qazan Section

4. **Depositional environments**

With reference to the information obtained from studies on Sinjar Formation and variable depositional environment conditions, it appears that the prevailing was the reef and the associated facies. In addition, sometimes back-reef milliolid facies and more often, fore-reef, shoal nummulitic facies occur too. The study, which appeared the rocks of this formation deposited in shoal neritic environment, reef and fore-reef, is mainly based on analysis of samples, some significant field notice, and beneficial guidance. The real paleoenvironment that the sediments were deposited on it can be imagined.

In another aspect, the numerate indications such as the reverse formation of facies, point to unstability of deposit conditions during this period which consolidate the theory of progradition (transgression) and retrogradition (regression) of Sea during deposition of sediments, thus the change of sea level (relatively at small scale) was contemporaneous with both of the two mentioned processes which caused deposition of different recycling facies.

The current study depends on relation between paleoorganisms, environment and life pattern as well as the sedimentary indications and microfacies to interpret or to provide real depositional environment.

Bioconstructed Microfacies comprises four subtypes mostly identified in lower part and consists of coralligenous boundstone, boundstone-packstone, bryozoans boundstone and boundstone-grainstone.

According to Wilson (1975) and Al-Hashimi (1985) all above subtypes of facies deposited in warm water, coral reef environment, rich in red algae, corals, bryozoans, which can be called compound reef too. Thus this depositional zone is equivalent to the Knoll reef or Patch reef according to reef classification system by Einsele (2000) and shelf margin according to reef sub-division modified from Tucker and Wright (1990) who explained that the shelf margin equivalent to reef, lagoon and shore zone complex equivalent to back reef and upper slope, Lowe slope is equivalent to fore reef as illustrated in (Fig. 4. 1).

The other types of Microfacies found in the study are **bioaccumulated microfacies** which comprising several main types, and each of them includes several subtypes of microfacies in both sections such as bioclastic wackestone, soritids and rotaliids wackstone, rotalids wackestone, bioclastic packstone, foraminiferous packstone, rotaliids packstone, soritids and rotalids packstone, discocyclinids packstone, discocyclinids and miliolids packstone, foraminiferous grainstone, rotaliids grainstone, miliolids grainstone, soritids floatstone, soritids and rotaliids floatstone. Rudstone microfacies mostly consist of soritids and appear only in two levels in middle part which considered to be one of the fore-reef characteristics. The Microfacies mentioned above determined or pointed to the environment which deposited in it.

We can summarize that the depositional environments in the rocks in the studied area were deposited as follows:

1. Reef

Reefs consist of colonial organisms and represent the most complex organogeneous depositional structures. They show high mechanical resistance due to the encrusting organisms and relatively high dome-type geometries as compared to the neighbouring sediments. The internal structure of the rocks formed in the reef differs according to the genesis and position within the reef structure. In the central facies, the in-situ deposition is dominating, thus the typical resulting rocks are *bafflestones, bindstones* or *framestones*; in the marginal areas the allochtonous material prevails, and *floatstones* or *rudstones* form (Daoud, 2006).

In both Hazar Merd and Qazan sections reef facies are present in the first half part and goes up to the upper part of Qazan section and represented by boundstone consisting especially of corals, red algae as well as bryozoans, echinoid plates and spine with mollusks and foram (rotaliids, miliolids, soritids) as shown in (fig. 3. 1, 3. 2).

Henson, (1950) pointed to some groups of organism too which listed above. Modern coral reef can have lateral extensions of up to 2000 km. (e. g. Great barrier Reef) one of the patch reefs in the Galala mountains in Egypt has a hight of about 12 m. and width of about 50 m. (Schelbner and Speljer, 2007) , sometime the reef represented by rim or barrier (Einsel, 2000), or shelf margin according to reef sub-division modified from Tucker and Wright (1990). Denizot (1968) found *Polystrata* in reef facies deposits, similarly to the case of the limestones from Baranan Mountain.

This facies almost applies to Qazan section in a discrete manner due to progradition and retogradition patterns, whereas this facies restricted only in the lower part of Hazar Merd section in a discrete manner as described above in Qazan section. Originally this facies represented by marine submerged high land as an inner platform that probably due to tectonic origin, different and gradual deep environment (Al-Rawi, 1979).

2. Fore-reef

The external side (fore-reef) represents the part exposed to open sea and submitted to the winds' and waves' energies. They consist of clastic deposits derived from the central area and show stratification that is distally thinning and curving, will be interlocked with the basinal deposits. In the proximal areas, the sediments are represented by poorly sorted, poorly reworked coarse, ruditic and arenitic (rudstones and floatstones) deposits (Daoud, 2006). The rocks in this facies mainly consist of reefal bioclastic, like fragments of red algae, corals, bryozoans, and are rich in foram (rotaliids, alveolinids, discocyclinids, soritids) with some nummulites, and other fragments which were transported by physical factors as water current, waves, and attractive forces. These side facies appear in most part of Hazar Merd section (Fig. 3. 1), but in a discrete manner due to progradition and retrogradition patterns during sediments deposition, whereas, restricted in Middle part (few meters) of Qazan section (Fig. 3. 2).

3. Back reef facies

These facies are bordered by extended area from coast to reef from back side. They consist of small foram which have thin wall as *Milliola* and *Peneroplids* (Forman, 1950; Henson, 1950), and represented by lagoon and shore –zone complex according to reef sub-division modified from Tucker and Wright (1990). The peloids grainstone of algal origin with dasycladales (green algae) which are growing in warm, shallow water (Valet, 1979, Flügel, 1982), and in lagoonal water behind reefs (Génot, 1987; Dieni et al., 1985) appear in the upper part of Hazar Merd section indicating also to back-reef.

Brasier, (1975) concluded that the high numbers and qualities of milliola indicate to protected environment from back-reef environments and each one at reef flat. Thus, mentioned the wide spread of miliolids never indicate fore-reef, in another aspect, the presence of fine grain dolomites as shown in the lower and middle part of Qazan section and in the middle part of the Hazar Merd section indicate this facies. This facies is widespread in the first half part in both Hazar Merd and Qazan sections interlayered with boundstone. The size of forams in back-reef is different (smaller and with thin walls) from each one in fore-reef (Ager, 1963).

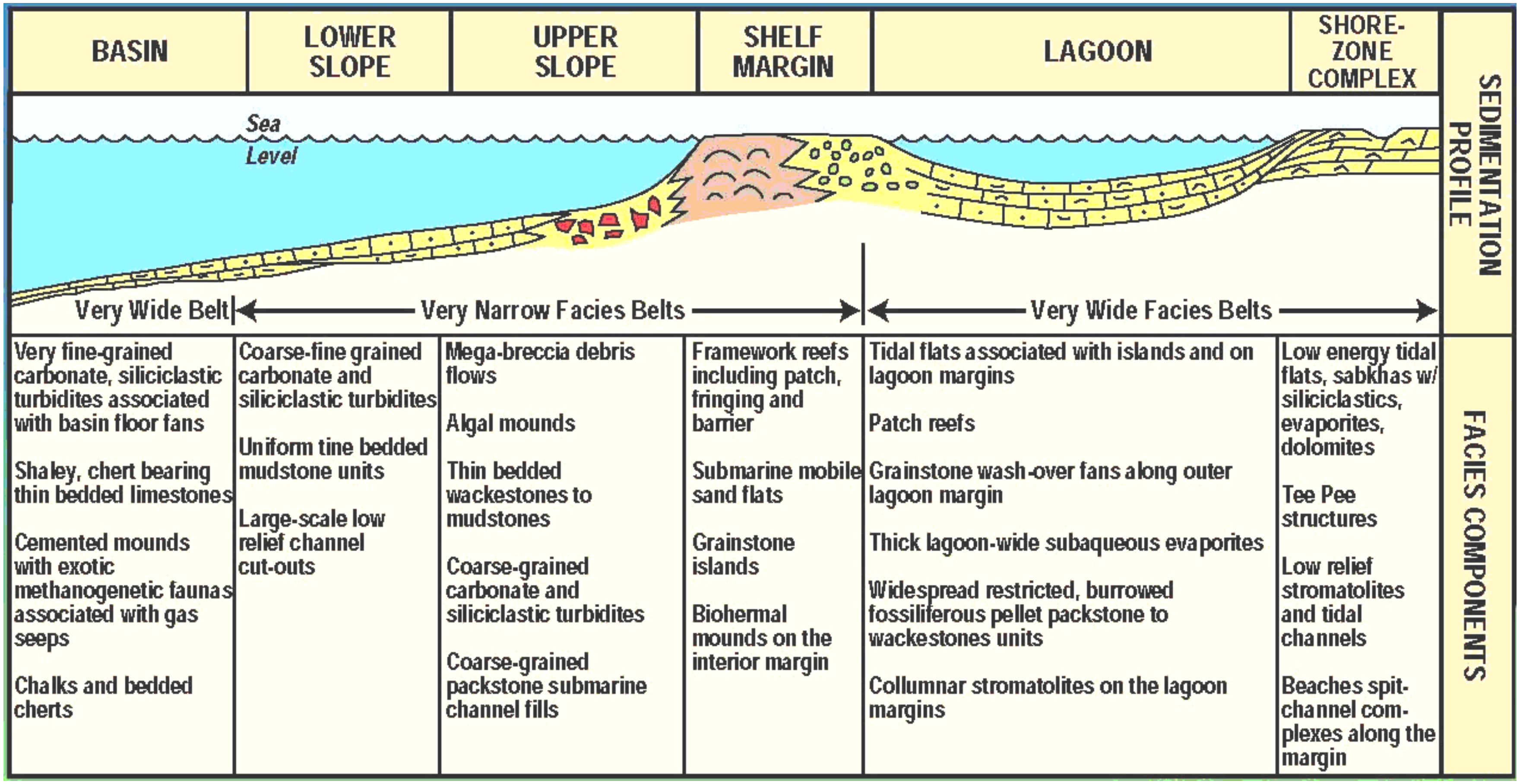


Fig. 12. Facies Belts according to Wilson (1975). Modified by Tucker and Wright (1990).

Conclusions

- Twenty five microfacies were identified from Hazar Merd and Qazan Sections;
- The microfacies allowed us to identify three types of paleoenvironments: Back-reef, reef and fore-Reef;
- Thirty five microfossils consisting of algae and foraminifera were identified In both Hazar Merd and Qazan sections, some of them are good indicators of the age and paleoecology;
- The presence of green algae (dasycladales) and red algae such as *Sporolithon* indicates that the limestones of Sinjar Formation are formed in warm, shallow and illuminated water;
- Based on the microfossil association consisting of *Alveolina primaeva*, *Saudia labyrinthica*, *miscellanea sp*., *Idalina sinjarica*, *Operculina salsa*, *Assilina* and *Miliola* we have assigned a Late Paleocene to Early-Middle Eocene age to the Sinjar limestones Formation from the Baranan Mountain.

Recommendation

Several subjects can be identified for future studies from our works:

1. Diagenesis processes
2. Evaluation of the pre-cementation porosity
3. Chemical analysis

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الخلاصة

يتعلق البحث بدراسةِ السحنات المجهرية و المتحجرات الدقيقة لتكوين السنجارالجيري من سلسلة برانان الجبلية. الهدف من البحثِ هو ايجاد وتشخيص السحنات المجهرية والمتحجرات الدقيقة في منطقة غنية جداً بالمتحجرات النباتية القديمة Paleoflora والمتحجرات الحيوانية القديمة paleofauna والعائدة للباليوسين- الايوسين والمتمثلة بالطحالبِ الحمراءِ والخضراءِ و المجاميع المرجانية وبالاخص المنخربات القاعية الكبيرة مثل rotaliids, discocyclinids , soritids ولهذا الغرض تم اختيار مقطعين في موقع الدرلسة وهما مقطع (هه زار ميرد) بسمك 135م و مقطع (قازان) بسمك 75 م .وتم جمع 368 نمودج من النماذج الصخرية لتحضير الشرائح الرقيقة ودراستها مجهرياً

من خلال دراستنا توصلنا الى معلومات مفيدة عن السحنات والمتحجرات الدقيقة و التي استخدمت فيما بعد لاعادة بناء وتصور البيئة القديمة paleoenvironment في منطقة البحث . إنّ الا حجارَ الجيرية المرجانية الطحلبية coralgal bioconstructed الظاهرة على المكاشف الصخرية في المنطقة المدروسة معروفة لكونها خزانات للنفط في عدة مناطق من العالم . الدراسة التفصيلية والدقيقة لتحليلِ السحنات الرسوبية و إعادةِ البناء للبيئة القديمة سيُساعد في فَهم أفضل للمنطقة .

پوختە

لەم توێژینەوەیەدا گرنگی دراوەبە (ووردەشێوازەکان) وە (بەبەردبووە ووردەکان) لە پێکهاتووی سنجار لە زنجیرە چیای بە رانان .ئامانج لەم توێژینەوەدا دیاریکردن و دەست نیشان کردنی ووردە شێوازە کاربۆناتەکان و بە بە ردبووە کاربۆناتەکانن

carbonate microfacies وە carbonate microfossils لە ناوچەیەکی دە وڵە مە ندو پڕ لە بە بە رد بوی گیانداری و ڕووەکی واتە paleofauna and paleoflora کە ئە گەڕێتەوە بۆ سە ردە میPaleocene-Eocene ئە مانیش بریتین لە قە وزەی سوورو سە وز و کۆمە ڵەی شیلان وبە تایبە تیش (foraminifera) ی گەورەی بنکی large benthicوەك rotaliids, discocyclinids ,soritids بۆئەم مە بە ستەش دوو بڕ گە وە ر گیران کە ئە وانیش بڕگە ی هە زار مێرد بە ئە ستوری 135 م و بڕگەی قازان بە ئە ستوری 75 م لە گە ڵ کۆکردنەوەی 368 نمونە بۆدروست کردنی بڕگەی تەنك (thin section) لێکۆڵینەوەی. لێکۆڵینەوەی ووردبینی زانیاری تەواو ئەبەخشێت دەربارەی ووردە شێوازەکان وبەبەردبووەکان دواتر سوودی لێوەردەگیرێت و بەکار دەهێنرێت بۆ خە ملاندن و دووبارە دروست کردنەوەی ئەوژینگە کۆن و پێشینانەی کە نیشتووەکانیان لێی نیشتوون لە ناوچەی توێژینەوەکەدا. هەروەها ئەو چینە بەردە کلسیانەی کە بە هۆی قەوزەو شیلانەوە دروست بوون coralgal limestone bioconstructed کە دەر کەوتوون لە ناوچە ی توێژینەوەکەدا ناسراون بەوەی کەکۆگای نە وتن لە زۆر شوێنی جیاجیای جیهاندا . لێکۆڵینەوەی ورد و چڕو شیتەڵ کردنی شێوازەکان facies وەبنیات نانەوەی ژینگەی کۆن Environmental reconstruction یارمە تیە کی باشن بۆخوێندنەوەو زیاتر گەیشتن ونزکبونەوە لە ڕاستی ناوچەکە.

ووردە شێوازە کاربۆناتەکانی پێکهاتووی سنجار لە باشوری خۆرئاوای شاری سلێمانی, هەرێمی کوردستان- عیراق

نامەیەکە
پیشکەش کراوە بە کۆلیجی زانست-زانکۆی سلیمانی وەك بەشێکی تەواوکار لە پێویستیەکانی بەدەستهێنانی پلەی دبلۆمی بالاّ لە زانستی زەوی ناسی

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2708 خەرمانان   2008 ی لە دایکبوون

السحنات المجهرية الكاربوناتية لتكوين السنجار في جنوب غرب مدينة السليمانية باقليم كردستان العراق

رسالة
مقدمة الى كلية العلوم بجامعة السليمانية كجزء مكمل من متطلبات
نيل درجةالدبلوم العالي في العلوم
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