SEDIMENTARY FACIES OF OLIGOCENE ROCK UNITS IN ASHDAGH MOUNTAIN-SANGAW DISTRICT- KURDISTAN REGION-NE Iraq.

A Thesis

Submitted to the Council of College of Science, University of Sulaimani, in partial fulfillment of the requirements for the Degree of Master in

Geology

By

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بسم الله الرحمن الرحيم

﴿وَإِنَّ مِنَ الْحِجَارَةِ لَمَا يَتَفَجَّرُ مِنْه
الأَنْهَارُ وَإِنَّ مِنْهَا لَمَا يَشَّقَّقُ فَيَخْرُجُ مِنْهُ
الْمَاء وَإِنَّ مِنْهَا لَمَا يَهْبِطُ مِنْ خَشْيَةِ اللّهِ
وَمَا اللّهُ بِغَافِلٍ عَمَّا تَعْمَلُونَ﴾

البَقَرَة {٧٤}

Supervisor's Certification

I certify that this thesis is prepared under my supervision at Department of Geology, College of Science-University of Sulaimani as a partial fulfillment of the requirements for the Degree of Master of Science in Geology.

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Date: /11/2008

We, the examining committee, here by certify that we have read this thesis and examined the student in it is contents and whatever relevant to it and, in our opinion; it is adequate with "**Very Good**" for the Degree of master of **Science** in **Geology/ Sedimentary Petrology**.

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I hereby certify that this thesis has been read and checked and after indicating all the grammatical and spelling mistakes; the thesis was given again to the candidate to make the adequate corrections. After the second reading, I found that the candidate corrected the indicated mistakes. Therefore, I certify that this thesis is free from mistakes.

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Dedication

I dedicate this study to:

My father's soul, my mother, sisters, brothers, uncles, aunts and all my relatives.

All my professors in Department of Geology, my colleagues and friends.

Those who like Geology.

Acknowledgments

I express my thanks to my supervisor Dr. Amanj for the approving my project selection and his supports, to Professor Dr. Basim Al-Qayim for his consultation and help during a field trip, Dr. Qahtan Ahmad for his consultation, Dr. Dler Baban and Dr. Hawre Mansurbag for their providing some important references and maps.

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Abstract

The possibility of the Oligocene strata in Ashdagh Mountain being certained based on the detailed field observation, study of stratigraphic succession, thin section analysis and fossil contents. The rock strata of the Oligocene detected from Ashdagh Mountain are classified as:

Sheikh Alas and Shurau Formations of the Lower Oligocene age, Baba, Bajawan and Possible Tarjil Formations of the Middle Oligocene age, and Anah Formation of the Late Oligocene age. From field trips, stratigraphic position of these Formations was detected and their contacts with overlying and underlying strata were determined. Physical properties of these rock units have been compared to the Oligocene rock units of the other locations and have shown correlation between them.

Detecting and identifying the index fossils within each Formation proved and showed the presence and development of the Oligocene rock units in the studied area, the index fossils demonstrated during thin section study, from studied sections, it confirmed the presence of the following Formations:

A. *Nummulites intermedius*, *Nummulites vascus*, and *Nummulites fichteli* (Sheikh Alas Formation).

B. *Archaias operculiniformis*, *Austrotrillina paucialveolata*, and *Subterranophyllum thomasi* (Shurau Formation).

C. *Lepidocyclina (Eulepidina) dilatata Lepidocyclina (Nephrolepidina)*

marginatus and Lepidocyclina (Eulepidina) ephippioides (Baba Formation).

D. *Praerhapydionina delicata, Archaias kirkukensis, Austrotrillina asmariansis* and *Austrotrillina howchini* (Bajawan and Anah Formations).

These mentioned Formations are considered to be a part of Kirkuk group Formations but not the whole group, because Palani, Ibrahim and Azkand Formations did not crop out throughout the stratigraphic succession of Ashdagh Mountain.

The Oligocene sediments may have been deposited in a shallow marine environment on a Ramp basin; a restricted reef environment developed within that platform, this is confirmed based on the Microfacies study and field observation for the studied area.

The principles of sequence stratigraphy are compared to the reef system which comprises system tracts and sequence boundaries, and the Microfacies and fossils (Micro and Macro fossils) studied from Ashdagh Mountain are compatible with those of Mid-Inner Ramp.

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Introduction

1.1 Preface:

The occurrence of Oligocene rock strata is argued whether they appeared in Kurdistan or not; this study emphasized the occurrence of Oligocene Formations with their Upper and Lower contacts because Oligocene rock units are the extremely prominent and prolific hydrocarbon reservoirs in Iraq and they are regarded as the most important global economic point of view and of Iraq, that is why this project has been selected and studied.

As the word Oligocene age of Tertiary period is heard in Iraq and Kurdistan, the story of Kirkuk group formations will come to existence. Oligocene formations comprise nine formations, most of them are reefal facies (Sheikh Alas, Baba and Azkand Formations are reef- fore reef facies but Shurau, Bajawan and Anah Formations are reef- back reef facies while Palani, Tarjil and Ibrahim formations are basinal or offshore facies) (Bellen et al, 1959). These nine formations are belonging to Early, Middle and Late Oligocene respectively (table 1.1).

Table (1.1): Stratigraphy of the Oligocene rock units and their depositional environments (after Bellen et al, 1959).

Environment / **Oligocene rock units**	**Back reef**	**Fore reef**	**Open sea**
Upper	Anah fn.	Azkand fn.	Ibrahim fn.
Middle	Bajawan fn.	Baba fn.	Tarjil fn.
Lower	Shurau fn.	Sheikh Alas fn.	Palani fn.

The Oligocene formations were first studied by Bellen, 1956(except Ibrahim Formation in 1957) in Bellen et al (1959). Some of them were studied from drilled wells while others from outcrops. Different oil companies and researchers studied these rock units from different locations such as Qara Chuqh structure, Euphrates valley near Anah village Mughr Al Dhib Northwest of Ga'ara depression near Iraq-Syria border, Sheikh Ibrahim structure, Baba Gur Gur dome, and Nahrawan subsurface structure (South East of Baghdad), Sinjar Mountain, Shiranish village. Ashdagh Mountain, Baski Zanwr Mountain (North West of Ashdagh Mountain) and Darband-i-Sagrma are also reported while Bamo, Sharwal Dra and Bznyan Mountains near Iraq-Iran border are also figured out and outlined from Northeastern of Kurdistan.

These rock units are deposited within Oligocene basin, they are underlined by Eocene rock units (Dammam, Ratga, Jaddalah, Avanh and Pila Spi Formations are recorded) all of them are older in age than this group, while it is overlain by Miocene rock units (Ghar, Euphrates, Jeribi, Serikagni and Fatha Formations).Upper and lower contacts of this group were bounded by unconformities (Jassim and Goff, 2006).

At the Chamchamal town which is located near to the studied area, the Oligocene rock units are reported to be missed (drilled well Chamchamal No.1 and 2 have showed this gap, and the lithological column of both wells were described by Global Petroleum Company in 2003 without mentioning the Oligocene rocks).

Oligocene strata have extensions toward neighboring countries (equivalents) as Syria (Chilou Formation) from West and North West, Iran from East and North East, according to Isopach map of Ditmar, (1971), regional sedimentation basin of the Oligocene was limited from North and Northeast by a zone of reefal carbonate running Northeast-Southeast which is entering Iran; Northeast of Chia Surkh and marking shoreline of positive land towards the North (Youkhanna and Hradecky, 1977).

The equivalent of Oligocene Formations of Iraq to Asmari and Khamir Formations in Iran is correlated to Early-Middle Oligocene Formations of

Iraq (Buday, 1980); Asmari Formation is part of the Tertiary deposits (Oligo–Miocene) of southwest Iran. The sea regressed at the end of Eocene, and a widespread unconformity occurred, causing the absence of Oligocene deposits over most of Kuwait(Mukhopadhyay et al, 1996).

Lithologically, Asmari Formation at the type section consists of 314m of mainly limestone, dolomitic limestones, and argillaceous limestones (Motiei, 1993). In Turkey, Oligocene strata are represented by red Mudstone and Claystone with nodular and massive gypsum known as Selimiye Formation (Tekin, 2001), but in SE. Turkey, Oligocene has not been identified (Egeran, 2007), and in Saudi Arabia it is totally missed (Jones and Rocy, 1994 in Boukhary et al, 2005).

Ditmar and the Soviet team (1971) modified the Bellen's divisions and they recognized only two sequences rather than three based on lithological and well logging correlation. They arranged the formations into two cycles: a lower cycle comprising the Palani, Sheikh Alas, Shurau and Tarjil Formations and an upper cycle comprising the Anah, Azkand, Baba and Bajawan Formations (fig 1.1), However Brun, (1971) divided Oligocene rock units of Iraq into Lower, Middle and Upper Kirkuk Formations based on a Microfossils and Microfacies study of Tertiary from Iraq.

Tectonically and Based on Numman (1997), the Oligocene basin of Iraq is located within the quasi platform and its sediments deposited inside suspended basins, foothill zone of Quasi platform foreland and sagged basins of the Mesopotamia zone of the quasi platform foreland and near Highly Folded Zone of the foreland basin in a smaller portion.

Generally, Oligocene is less widespread or has limited occupying basin.

In Iraq, Oligocene is less represented than the Eocene; it occupied limited area, and it is located mainly within the Mesopotamian basin and low folded zone of unstable shelf (Al-Hashimi and Amer 1985).

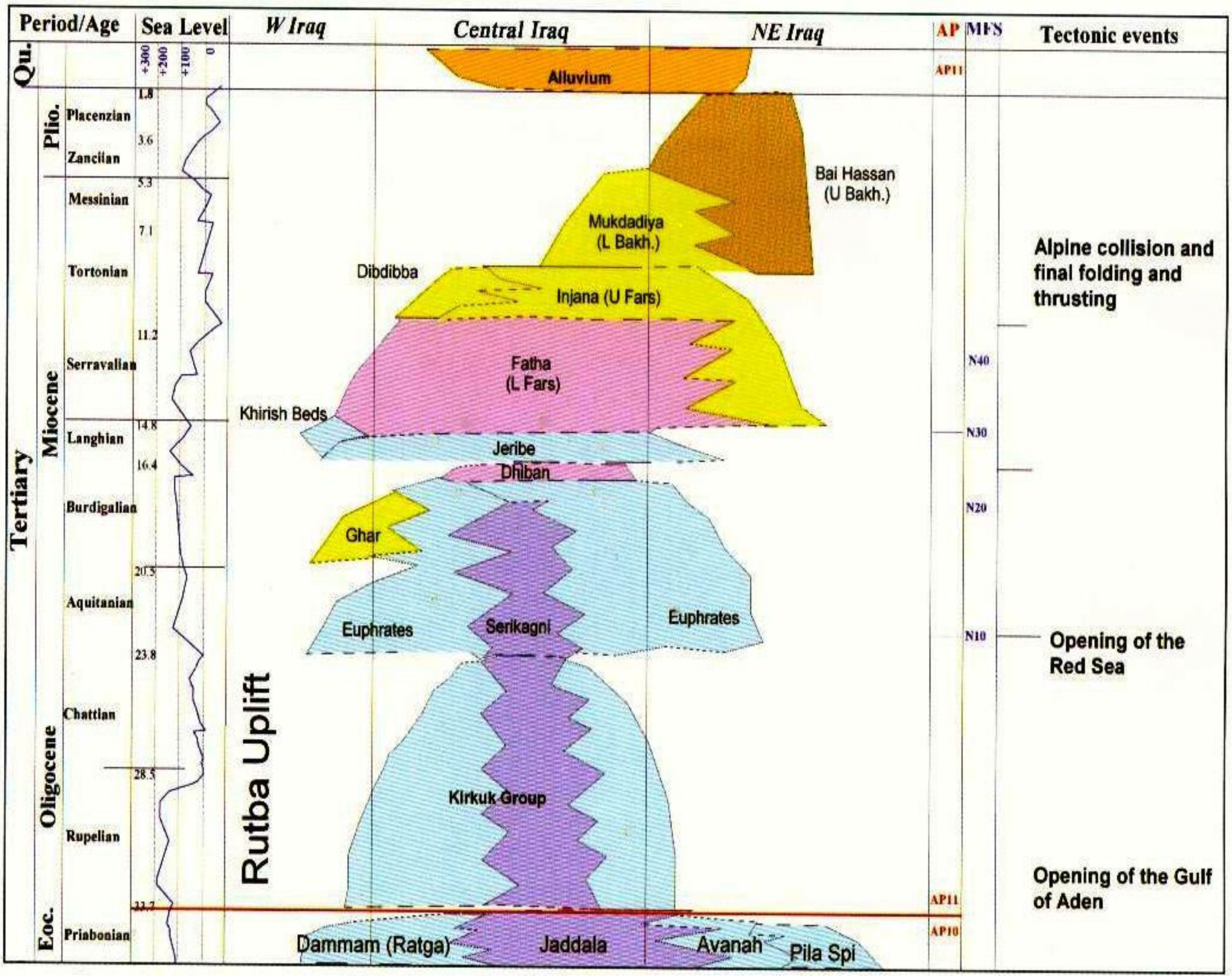


Fig (1.1): Stratigraphic correlation of formations of Mega sequence Ap 11 (Excluding the Qurternary) (after Jassim and Goff 2006).

1.2 Studied area:

Since Oligocene rock units didn’t develop throughout the entire Kurdistan region, so it is necessary to make detailed field trips and investigations for determining and defining the exposed out crops of these rock units.

Several well exposed outcrops of the Oligocene rock units are observed and determined at Garmyan district after detailed field trips.

More than six well exposed outcrops were chosen from the nose and both limbs (NE and SW limbs) of the Ashdagh Mountain, which are located at the nose and both limbs of Ashdagh Mountain (NE and SW limbs). Geographically, Ashdagh Mountain is located at South of Sangaw district as shown in (fig 1.1); Eastern side of Ashdagh Mountain is bounded by Sagrma Mountain series but its western side by Qara Wais Mountain. The following sections are chosen from both limbs of Ashdagh Mountain for sampling:

1. **NE Limb:**

a. Darzila Section: it is located at Northeast of Darzila village about (150) meters from the valley which is known as Sarchawai Awa Spi.
b. Shalaii Section: it lies directly inside Shalaii village (previously called Tawilga village; a destroyed village).
c. Hazar Kani Section: it is (3) Kilometers far from west of Hazar Kani village.
d. Timar-Zinana Section: rock samples have been taken from the Mountain located at the western part of Zinana village toward Timar village.

2. **SW Limb:**

e. Darzila-Jam Res and west abutment of Awa Spi valley: it is found at the eastern part of Jam Res village. It is also called Tirshawaka village.
f. Miraly section: rock strata appear at the Eastern side of Miraly village between both anticlines of Ashdagh structure. Southeastern limb of the anticline is faulted and scarped.
g. Sai Waii section: it appeared at the Southern side of the village.

The location of these sections is shown in both Topographic map Fig (1.2) and Satellite map Fig (1.3).

Table (1.2): illustration of the section names and coordination of the sections:

Limbs	**Section No.**	**Section Name**	**Latitude(N) (Degree)**	**Longitude(E) (Degree)**	**Elevation (Meter)**
NE Limb	a.	Darzila	$35^{o}\ 08^{-}\ 37^{=}$	$45^{o}.17^{-}.24^{=}$	842
	b.	Shalaii	$35^{o}\ 08^{-}\ 41^{=}$	$45^{o}\ 18^{-}\ 22^{=}$	784
	c.	Hazar Kani	$35^{o}\ 09^{-}\ 58^{=}$	$45^{o}\ 17^{-}\ 59^{=}$	779
	d.	Timar-Zinana	$35^{o}\ 12^{-}\ 04^{=}$	$45^{o}\ 17^{-}\ 30^{=}$	869
SW Limb	e.	Darzila-Jam Res	$35^{o}\ 08^{-}\ 43^{=}$	$45^{o}\ 17^{-}\ 22^{=}$	842
	f.	Miraly	$35^{o}\ 15^{-}\ 44^{=}$	$45^{o}\ 10^{-}\ 09^{=}$	1048
	g.	Sai Waii	$35^{o}\ 14^{-}\ 30^{=}$	$45^{o}\ 07^{-}\ 48^{=}$	756

Darzila section has been taken twice, one toward east part of Sarchawai Awa Spi and the second one toward its west part, the reason is because this valley was impressive to attention for the researcher due to cropping out of the lithology of Oligocene rock units (more than 65m), and conspicuous appearance of contacts, while in others are not so clear and so thick.

From structure point of view, Ashdagh Mountain is an anticline structure (assymetrical anticline), the North eastern limb is gentle; its dip angle is about 20-25 degrees and the Southwestern limb is steeper and its dip angle is almost 40-45 degrees, the Southwestern limb is faulted and dragged.

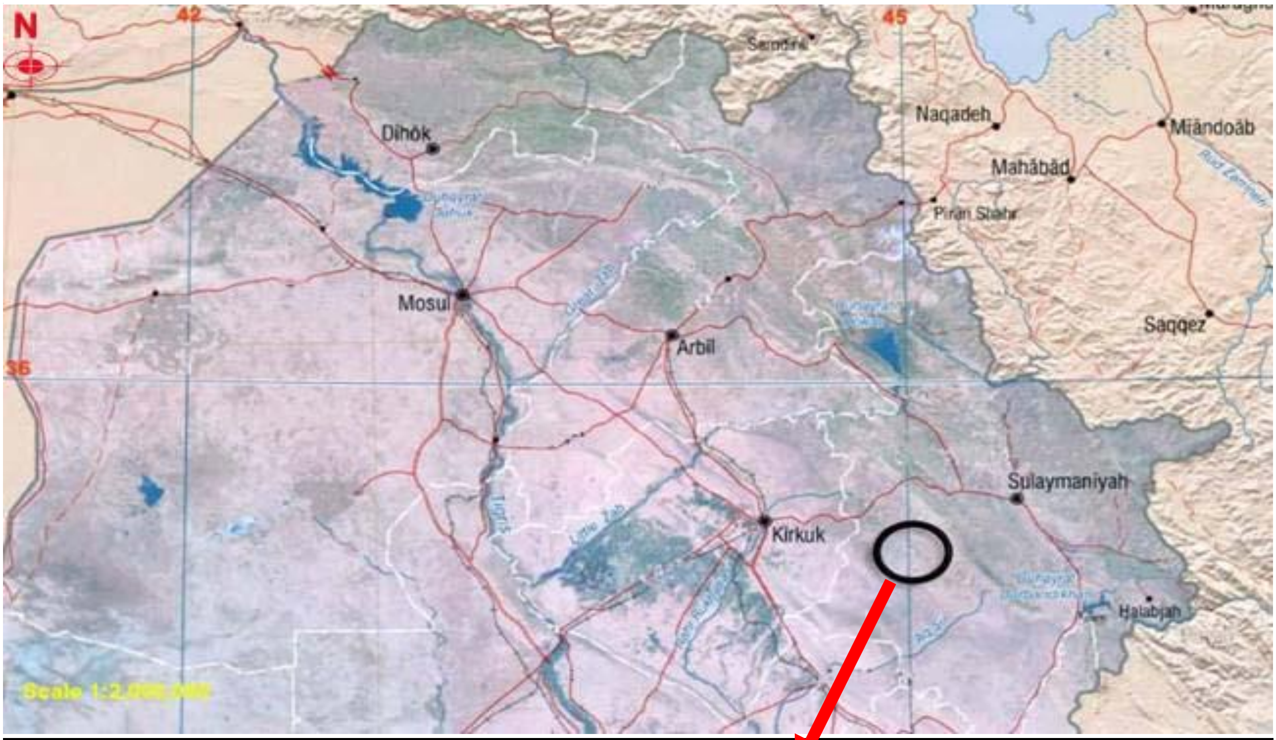


Fig (1.2): Location map for the studied area after central intelligence agency, 2003.

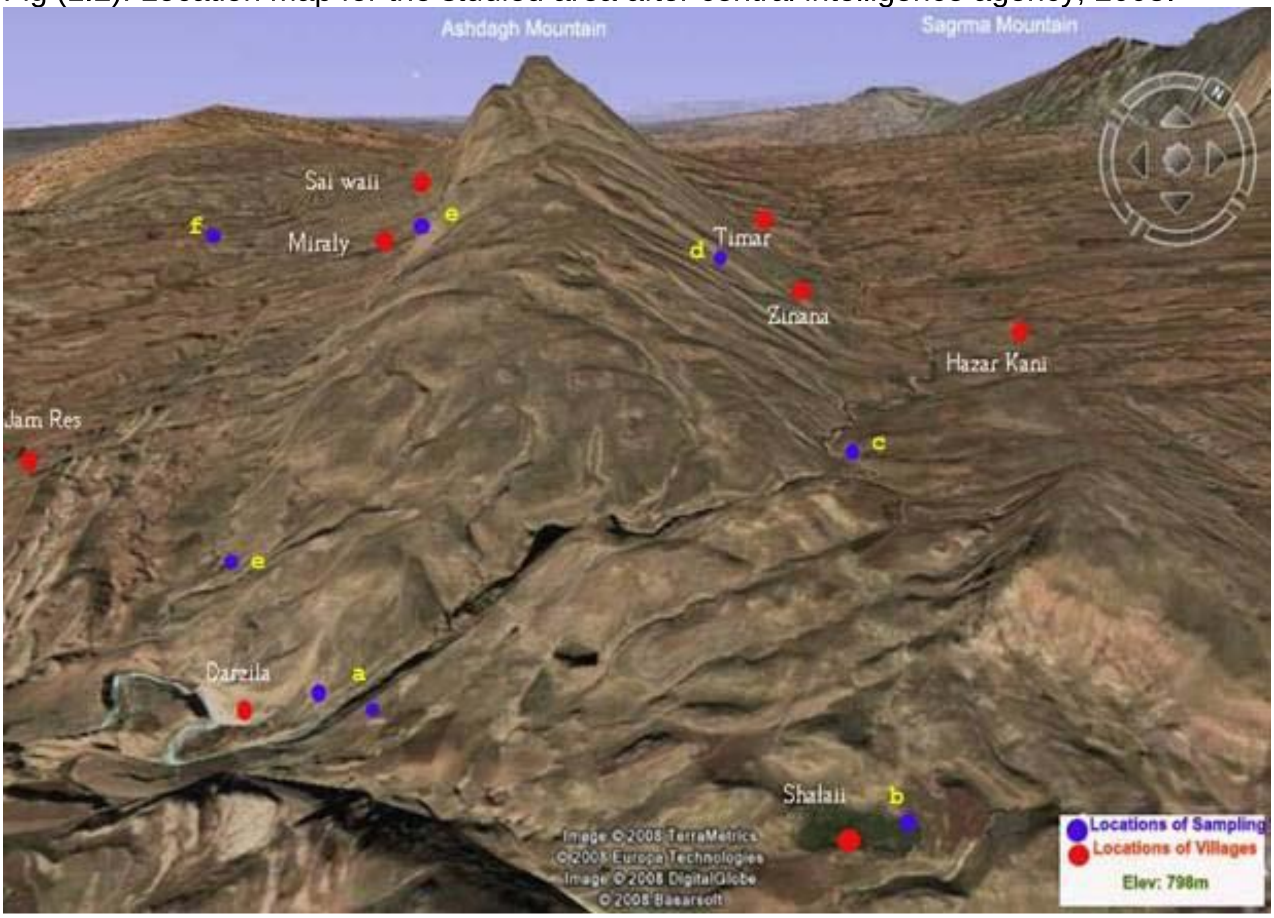


Fig (1.3): Exaggeration of the studied locations (tilted imagery) for the studied area by satellite map from Google Earth.

1.3 Methodology and Sampling:

1. First step of the current study is including the field works and laboratory analysis. More than twenty reconnaissance and detailed surveys (field trips) were done at Garmyan district searching and looking for the exposed and well developed Oligocene outcrops around the area.

2. Measuring and describing lithology, thickness, vertical and lateral facies change other physical properties and recording nature and information about the surface boundary between the rock units.

3. Attempts were done to construct a geological map and geological cross section for the studied area.

4. More than two hundred rock samples had been collected from the seven mentioned stations. Sample collection depended on the vertically lithologic variation; that means the rock samples had been taken according to the lithology characteristics and change in the stratigraphic column of the area. Generally, the samples have taken one meter by one meter but at Darzila section (west part of the valley) the samples were taken half meter by half meter, so as to distinguish the different rock units and their contacts between these Formations, because this place is for the first time studied in detail and it is the merely place in which Oligocene rock units cropped out with such a thickness.

5. Laboratory work included the preparation of two hundred and thirty thin sections (slides) which have been made and prepared for petrography and microfacies study, and fossils identification under Polarizer and Binocular microscope in addition to alizarin red solution; it has been used to differentiate between Calcite and Dolomite minerals.

1.4 Previous studies:

By reading the previous studies about Oligocene and Kirkuk group Formations, it appears that the principal Bibliography and story of Oligocene rock units return to Bellen et.al (1959) who studied stratigraphic column of Oligocene and Al-Naqib (1960) also defined it in Bai Hassan structure Al- Kharsan (1970) studied Lower Oligocene and Lower Miocene Stratigraphy of the Eastern area of Khanaqin Qadha, Iraq.

Ditmar et al (Soviet Team), 1971 (in Jassim and Goff 2006) studied Oligocene rock strata of different positions in Iraq.

Al-Qayim (1975) studied environment of the Oligocene reefal cycle in Kirkuk oil fields. Asafili (1976) studied Geochemistry and Lithostratigraphy of Limestone of Kirkuk group Formations from Kirkuk and Bai Hassan oil fields. Youkhanna and Hradecky (1977) recorded the existence of some Oligocene Formations (Shurau, Baba, Bajawan, Azkand and Anah Formations) around Bamo anticline near Darbandi Khan district.

Al-Sammarai and Al-Mubarak (1978) (in Abid 1983) studied Anah Formation from Qara Chuqh structure, Al-Biaty (1978) (in Abid 1983) from Makhmur area and Behnam (1979) claimed Oligocene formations from Khanaqin). Ditmar et al (1979) (in Jassim and Goff, 2003) studied Oligocene cycles while Assafli (1979) studied the geochemistry of Kirkuk group Formations. Buday (1980) studied and confirmed the reef, back reef and open sea of Oligocene basin. Al-Qayim and Khaiwaka (1980) studied the depositional environment and diagenesis of the Oligocene reef cycles from Kirkuk oil fields. Abid (1983) studied micro facies of Anah Limestone and Muhammad (1983) studied Biostratigraphy of Kirkuk group Formations in Kirkuk and Bai Hassan areas. Al-Hashimi and Amer (1985) studied Tertiary Microfacies of Iraq which also included the Oligocene Microfacies too. Tatar (1988) (in Abid 1983) has done the subsurface study for Oligocene from the Western desert of Iraq, and Bakkal (1988) studied the Eocene-Oligocene boundary, biostratigraphy and sedimentological appraisal from Balad and Tikrit areas. Berbaksh (1990) studied microfacies of Azkand, Anah and Euphrates Formations in Khabaz oil field. Zaki (1992) studied subsurface sedimentology of Oligocene successions- Maisan, Southern Iraq. Al-Banna (1997) studied sedimentology and stratigraphy of Upper Oligocene and Middle Miocene Formations, Western Mosul.

Al-Twaijri (2000) studied the sequence stratigraphy of the Oligocene in Western Iraq Baba Sheikh, (2000) recorded the presence of the Oligocene Limestone in the studied area and he distinguished two types of conglomerate in the Upper part of Pila Spi Formation. Karim et al (in Stankovic and Markovic 2003) recorded the Late Oligocene horizon from a geological cross section of Qaradagh-Kalar basin. Ghafor (2004) studied biometric analysis from Oligocene in the Kirkuk area. Western Zagros Oil Company (2007) distinguished the Oligocene- Miocene reef and Oligocene Fairway between Kalar and Bawanoor without mentioning the name of the location.

1.5 Aims of the study:

The issue about the availability of Oligocene Formations in Kurdistan and its stratigraphic succession is still debated. From all collected data and benefit from previous information, it is attempted to:

1. Define lithologies and their characteristics top and bottom (contacts of the formations), lateral and vertical extensions and their boundaries with their thickness and to make a stratigraphic column for the studied area.
2. Prove that Oligocene rock units (Early, Middle and Late Oligocene) are exist in the studied area especially early Oligocene Formations (Shurau and Sheikh Alas Formations) both of which have neither been studied nor proposed before. So this study gives a new and advanced idea of the geologic study of Garmyan territories, particularly in Economic Commodity (Petroleum) of the area and Kurdistan. Though it is obvious that Oligocene reservoirs rocks are enriched in Hydrocarbon (oil and gas) but Garmyan need more studies.
3. Study fossil contents because it is necessary to diagnose the rock properties, index fossils and for age determination of the rock strata.
4. Relate this study with comprehensions and principles of sequence stratigraphy which is considered a new window of study in Geology to define system tracts with sequence boundaries types. microfacies and sequence stratigraphy studies combined to study the theory of system tracts and sequence boundaries.

5. Correlate the rock units of the studied area with its surrounding areas and drilled wells (oil or gas) to predict petroleum system and reservoir extension of Garmyan territories.

Chapter two: Lithostratigtaphy:

2.1 preface:

Though there are different works which have been done on the Oligocene rock units to study and make separation between the formations, but sometimes complications and difficulty occurred in separating them. Bellen et al (1959), studied the Oligocene Formations, they described these rock units based on their relative stratigraphic positions rather than diagnostic fossils.

Ditmar et al, 1971 modified Bellen's division by recognizing only two sequences based on lithological and well logging correlation as it is illustrated in (fig 1.1).

In this study, it is endeavored to make balance between both of the methods, first by describing lithologies, later by an attempt to segregate their diagnose index fossils to identify and recognize the formal rock units of Oligocene age.

From field trips and thin section studies of the selected stations, it was clarified that the Oligocene rock units that appeared in the studied area are Sheikh Alas, Shurau, Baba, Bajawan, Anah and Possibly Tarjil Formations. Thus according to Bellen et al, 1959 the entire Kirkuk group Formations is not intact here. That is the whole nine Formations are not cropped out together (Palani and Ibrahim Formations), but with the comprehension of Ditmar et al., (1971) it is considered to be intact group because both upper and lower sequences of the Oligocene sequences are revealed.

From the studied area, the formations detected and identified from older to younger are:

1. Lower cycle, which includes Sheikh Alas and Shurau Formations.

Upper cycle: it involves Bajawan, Baba, Tarjil and Anah Formations.

2.2 Lower cycle:

2.2.1 <u>Sheikh Alas Formation</u>: it was described firstly by Bellen, 1956 (in Bellen et al, 1959) from Qara Chuqh dome near Sheikh Alas village. In the type area the formation is composed of dolomitic and recrystallized limestone, generally porous, and occasionally rubbley.

From the studied area , the two places from which this formation are cropping out are Miraly section and Sarchawai Awa Spi valley near Darzila village (the place in which a milky color, sulfurous, nasty odor, bitter and acid taste water are springing); fig (2.1).

This section is considered to be an ideal section from studied area and the whole surrounding territories because most of the mentioned formations and their contacts were clearly exposed and observed. Rock strata in this station consist of thick beds of white-milky color, porous to highly cavernous, recrystallized-Nummulitic bearing limestone layered (Plates 1A and 1B) partially dolomitized, with organic rich in Nummulitic limestone beds (30 cm thick) as illustrated in fig (2.3).

Sometimes, discontinues ribbon and patches of iron oxide are observed at the Lower part of Sheikh Alas Formation. The thickness of the formation is variable due to the dissimilarity nature of the limbs of the Ashdagh Mountain but generally it ranges from 14-18m because of plunging of the limb (or due to pinching).

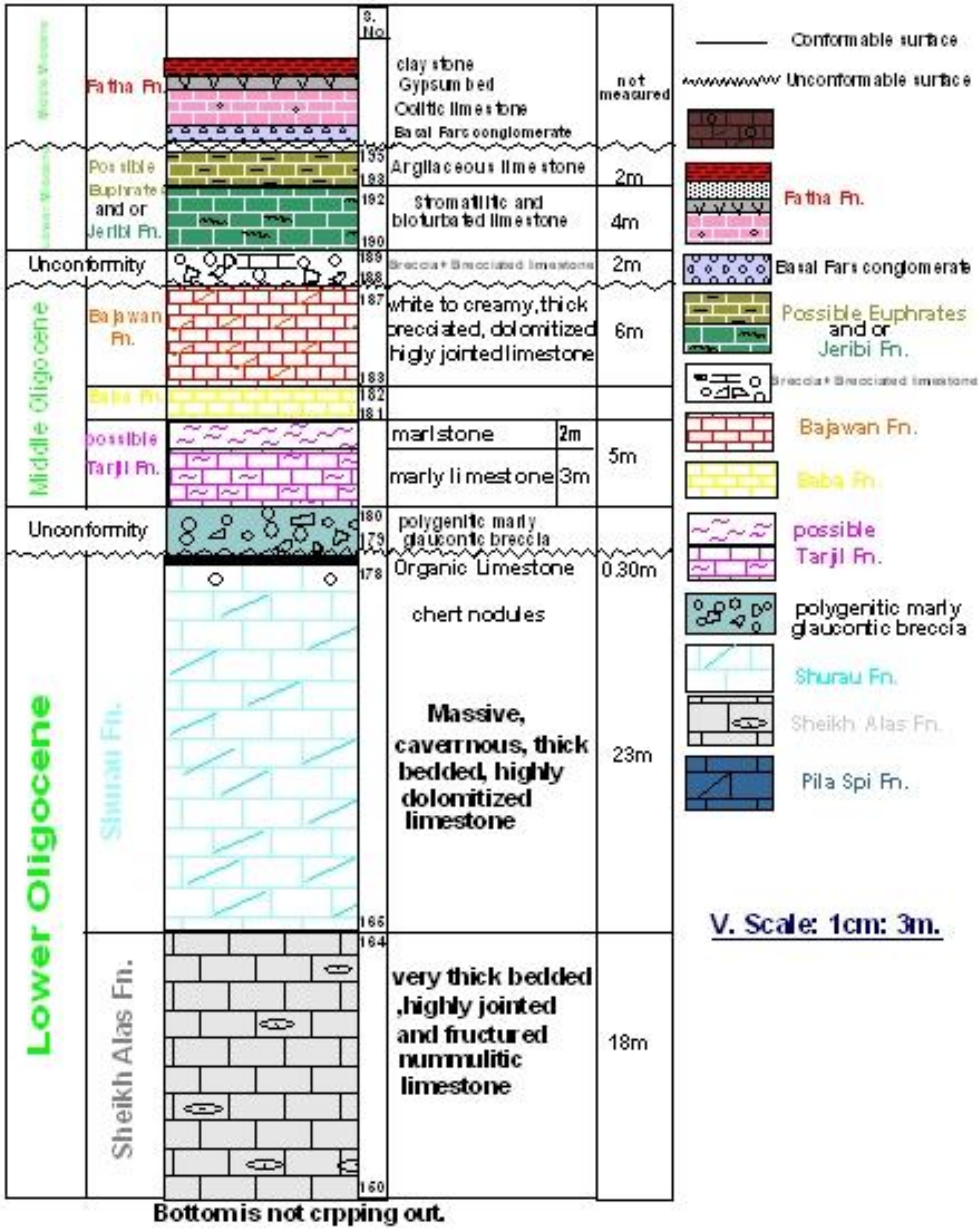
The lower contact of Sheikh Alas Formation is unconformable with Pila Spi Formation but it is conformably overlain by Shurau formation. Al-Hashimi (1980) differentiated Shurau from Sheikh Alas Formation by predominance of Nummulites over Miliolids with benthic foraminiferas in Sheikh Alas Formation.

In the studied area, the difference between these two Formations is made on the base of different fauna contents, but also from field observation, it is noted that the thickness of the beds of Sheikh Alas Formation is thicker than that of Shurau Formation.

Fig (2.1): illustrates the sheikh Alas, Shurau, Bajwan and Baba Formations, Darzila section, Ashdagh Mountain, Sangaw district, (A-a representing direction of sampling from bottom to top).

Fig (2.2): Shurau-Bajwan Formation, near Darzila village, Ashdagh Mountain.

Fig (2.3): Organic rich Nummulitic-Limestone, within Sheikh Alas Fn. near Darzila village, Ashdagh Mountain.


S. No
Fatha Fn.
clay stone
Gypsum bed
Oolitic limestone
Basal Fars conglomerate
not measured
Possible Euphrates and or Jeribi Fn.
Argillaceous limestone
2m
Stromatilitic and bioturbated limestone
4m
Unconformity
Breccia+ Brecciated limestone
2m
Middle Oligocene
Bajawan Fn.
white to creamy, thick brecciated, dolomitized higly jointed limestone
6m
Baba Fn.
possible Tarjil Fn.
marlstone 2m
marly limestone 3m
5m
Unconformity
polygenitic marly glauconitic breccia
Lower Oligocene
Shurau Fn.
Organic Limestone
0.30m
chert nodules
Massive, cavernous, thick bedded, highly dolomitized limestone
23m
Sheikh Alas Fn.
very thick bedded ,highly jointed and fructured nummulitic limestone
18m
Conformable surface
Unconformable surface
Fatha Fn.
Basal Fars conglomerate
Possible Euphrates and or Jeribi Fn.
Breccia+ Brecciated limestone
Bajawan Fn.
Baba Fn.
possible Tarjil Fn.
polygenitic marly glaucontic breccia
Shurau Fn.
Sheikh Alas Fn.
Pila Spi Fn.
V. Scale: 1cm: 3m.
Bottom is not cropping out.

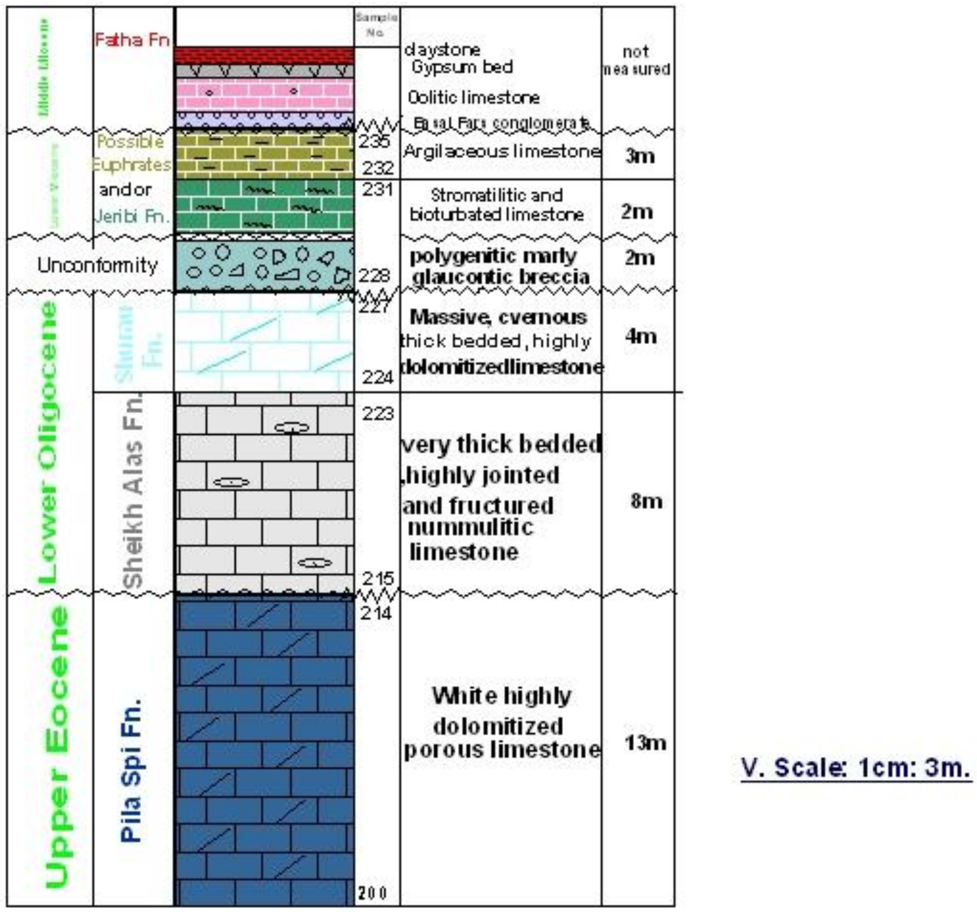


Fig (2.5): stratigraphic column of Oligocene rock units, Miraly- Sai Waii section, Ashdagh Mountain.

2.2.2. <u>Shurau Formation</u>: Bellen (1956) was first who described this Formation in Kirkuk well (K 109) from Kirkuk structure, it described as grey, dense limestone in its upper part and porous coralline limestone in its lower part. From Darzila section, it consists of porous vugy, thick bedded of white-grey fossiliferous limestone beds with extremely large cavernous and jointed rocks. Near the lower contact, the formation contains large solitary and colony of corals (plates 1C and 1D).

The thickness of Shurau Formation laterally decreases and it contains massive limestone –bearing iron oxide patches, in which sometimes these patches form a swarm shape and discontinuous bed in some manner. Nearly one meter of organic rich in limestone bearing Nummulites bed appears at the upper part.

The thickness changes as same as Sheikh Alas Formation due to plunging situation but this thickness reaches 23m and decreases toward the minimum even thin bedded limestone. Shurau Formation is underlined by Sheikh Alas Formation conformably while it is covered by a thick horizon (3m) of polygenetic glauconitic breccia (fig 2.1), in addition to a thin bed of glauconitic beds in which appears near the most upper part of this formation. It means that the upper part of this Formation is unconformable with the Middle Oligocene strata. This is the case in the type area and apparently, in Awasil area too (Buday, 1980). The upper contact according to Bellen et al (1959) is unconformable.

Shurau Formation is overlain by light green marly limestone with intercalation of green color marlstone beds. Totally these beds are 5m thick, and it is possible that they are belonging to Tarjil Formation. These beds (possible Tarjil Formation) occurred and are observed at Darzila section, without distinguishing at other studied sections because they are not clearly appeared. The unconformity is proved according to Buday (1980), by facies and faunal changes.

The same situation is proved in this study during the observation of the out crops, but during a slide study, it appears that there is faunal mixing between Early and Middle Oligocene rock strata then becoming unconformable.

Shurau Formation conformably overlies Sheikh Alas Formation and comprises (30m) of thick bedded, white and dense limestone (Jassim et al, 1984 in Jassim and Goff 2006) from NW of Ga'ara depression near Iraqi-Syria border.

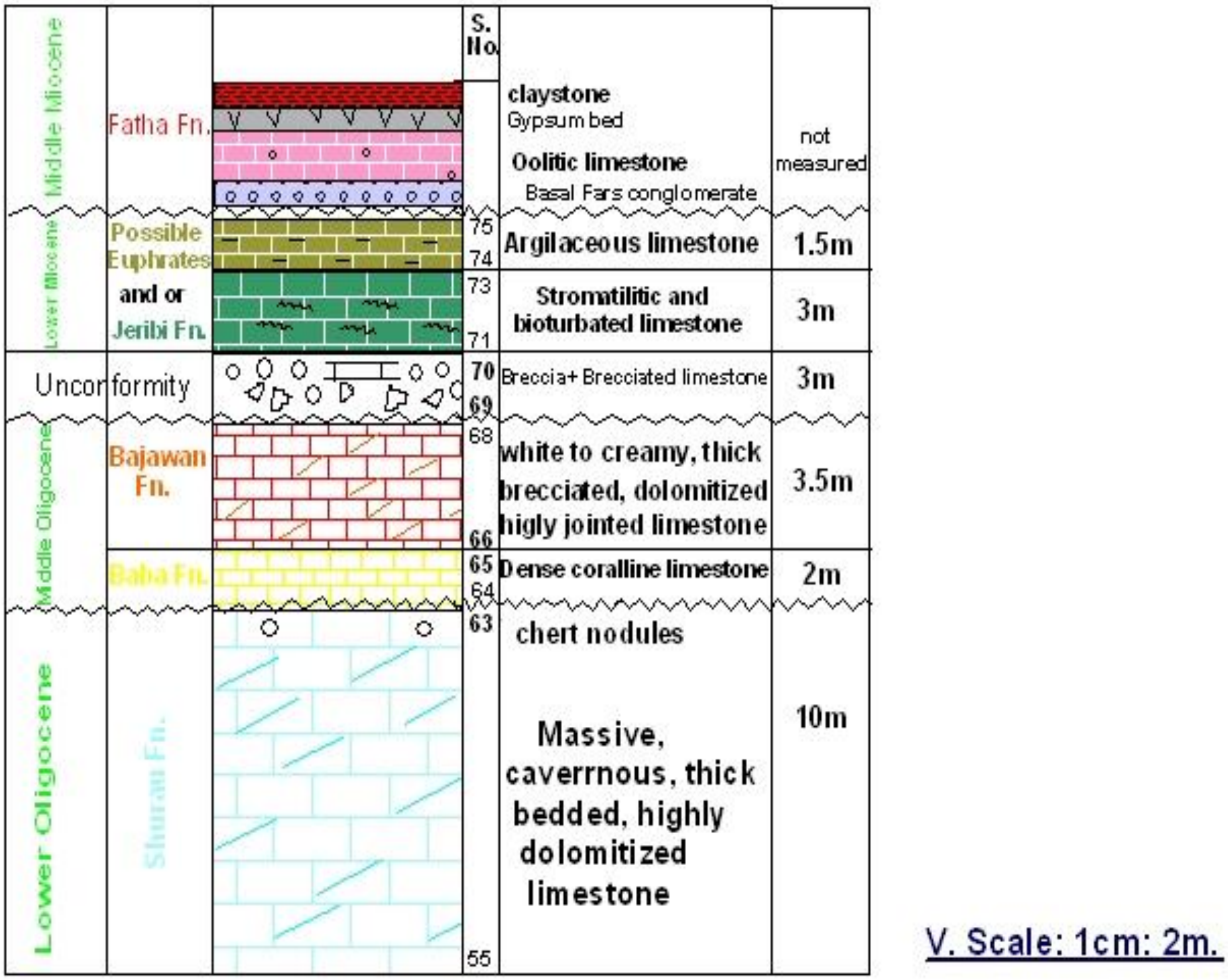


Fig (2.6): stratigraphic column of Oligocene rock units, Timar-Zinana section, Ashdagh Mountain.

At Sharwal Dra Mountain; SE of Maidan town, the underlying formation of Shurau Formation is not observed (covered), and the overlying Formation is Bajawan or Anah Formations but it is not exposed in Bamo anticline (Behnam, 1979).

2.3 Upper cycle:

2.3.1. <u>Baba Formation</u>: it is returning back to the second cycle of Oligocene rock units and Kirkuk group Formations in Iraq and Kurdistan. It was first studied by Bellen (1956) in Kirkuk well (K 109) from Baba

GurGur village (Baba GurGur structure) from which the name of the formation is derived; lithologically the formation consists of porous, dolomitized limestone.

In Darzila and Timar-Zinana sections, it is comprised of 2m of white, massive, highly jointed, fractured, porous partially dolomitized and fossiliferous Limestone bed of chalky appearance and groovy surface; it contains fossils of *Echinoderms, Nummulites and Lepidocyclina spp*. This formation appears from the Eastern side of Darzila valley (Fig 2.7) and Timar-Zinana villages.

The Lower part is defined by 5m of Marly Limestone and Marlstone then a 3m of glauconitic breccia bed. In Darzila section, the lower boundary of Baba Formation is conformable with the Middle Oligocene (Possible Tarjil Formation), but in Timar-Zinana section, the marly limestone and marlstone did not clearly appear.

Sometimes Baba Formation appears as a tongue within Sheikh Alas Formation. The Upper boundary is conformable and interfingered with Bajwan Formation, at Shalaii section, near the most upper part, large foraminiferas such as Echinoderms are present (Plates 1F and 1G).

Al-Naqib (1960) claimed that Baba Formation unconformabely covered Shurau Formation and it is conformably overlain Bajawan Formation some where else. The Lower part of Baba Formation in Baba Gur Gur anticline consists of 24m of porous, dolomitized limestone beds, interbedded with soft marly Limestone. Behnam (1979) claimed that in Sharwal Dra anticline, the Lower part of Baba Formation consists of 7m of marly, soft, fossiliferous Limestone, but in Baba Gur Gur anticline is Tarjil Formation which is gradational. In Sharwal Dra anticline, it is not exposed. He also claimed that the overlying formation in Baba Gur Gur is Bajwan and in Sharwal Dra is Azkand Formation, the contact is un conformable. In Kirkuk well K.14, the Upper contact of Baba Formation is

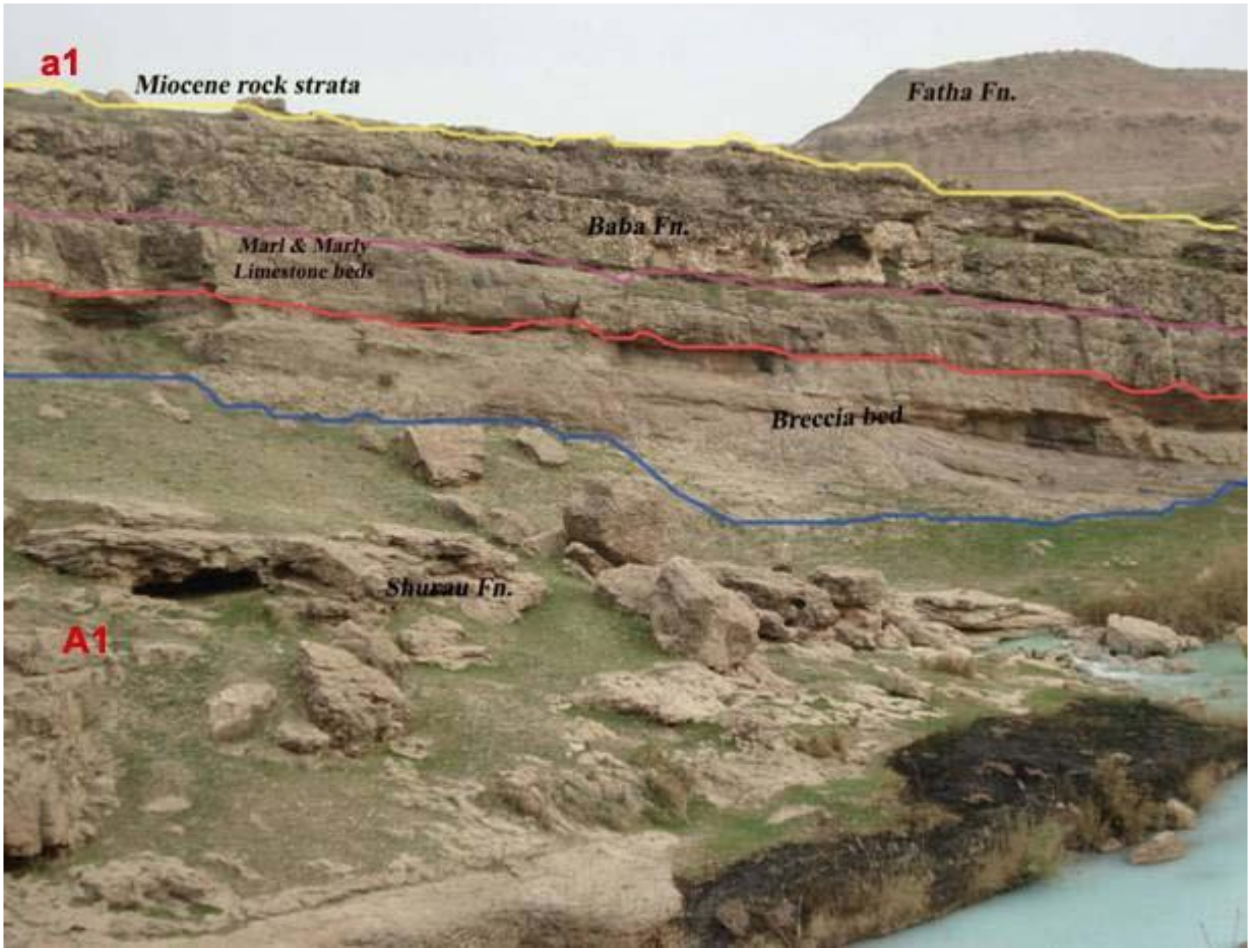


Fig (2.7): Shurau-Baba Formation, Darzila village, Sarchawai Awa Spi section, Ashdagh Mountain, (A1-a1 representing direction of sampling from bottom to top).

2.3.2. <u>Bajawan Formation</u>: This rock unit was described first in Kirkuk well (k 109) by Bellen, 1956 from which it composed of tight, back-reef miliolid limestone, alternating with more porous, partly dolomitized rotalid-algal limestone with fairly abundant coral fragments. From the studied area, Bajawan Formation is cropping out at Shalaii, Darzila- Jam Res and Hazar Kani sections; this formation visually appears as a conspicuous ridge of dolomitic limestone beds, in the lower part, the formation is composed of white-milky color, highly jointed and cavernous, fossiliferous limestone, but the middle part is characterized by highly porous (Tuffeceous or sieve structure formed as a result of dissolution process); this texture looks like tuff of volcanic igneous rock, while near the upper part of the formation, there is interbedidng of thin marl beds. The same properties were mentioned by Buday, (1980); " the formation consists there of tight, back reef, milliolidal Limestone alternating with more porous, partly dolomitized, rotalid –algal reef Limestone, with fairly abundant coral fragments sometimes thin marly interbeds occur too".

Within the studied area, the thickness of Bajawan Formation recorded from Shalaii village (East of Ashdagh Mountain) is 16m (Fig 2.8), so this formation is clearly cropped out; it also appeared from Darzila, Hazar Kani and Timar-Zinana sections but with variable thickness.

The lower contact of the Formation is conformable with Baba Formation, but the upper contact is unconformable with Early Miocene rock strata (possibly Euphrates and or Jeribi Formation) as shown in fig 2.5. It also appears in Bamo anticline which consists of purple-red brecciaed limestone and grey thick bedded limestone.

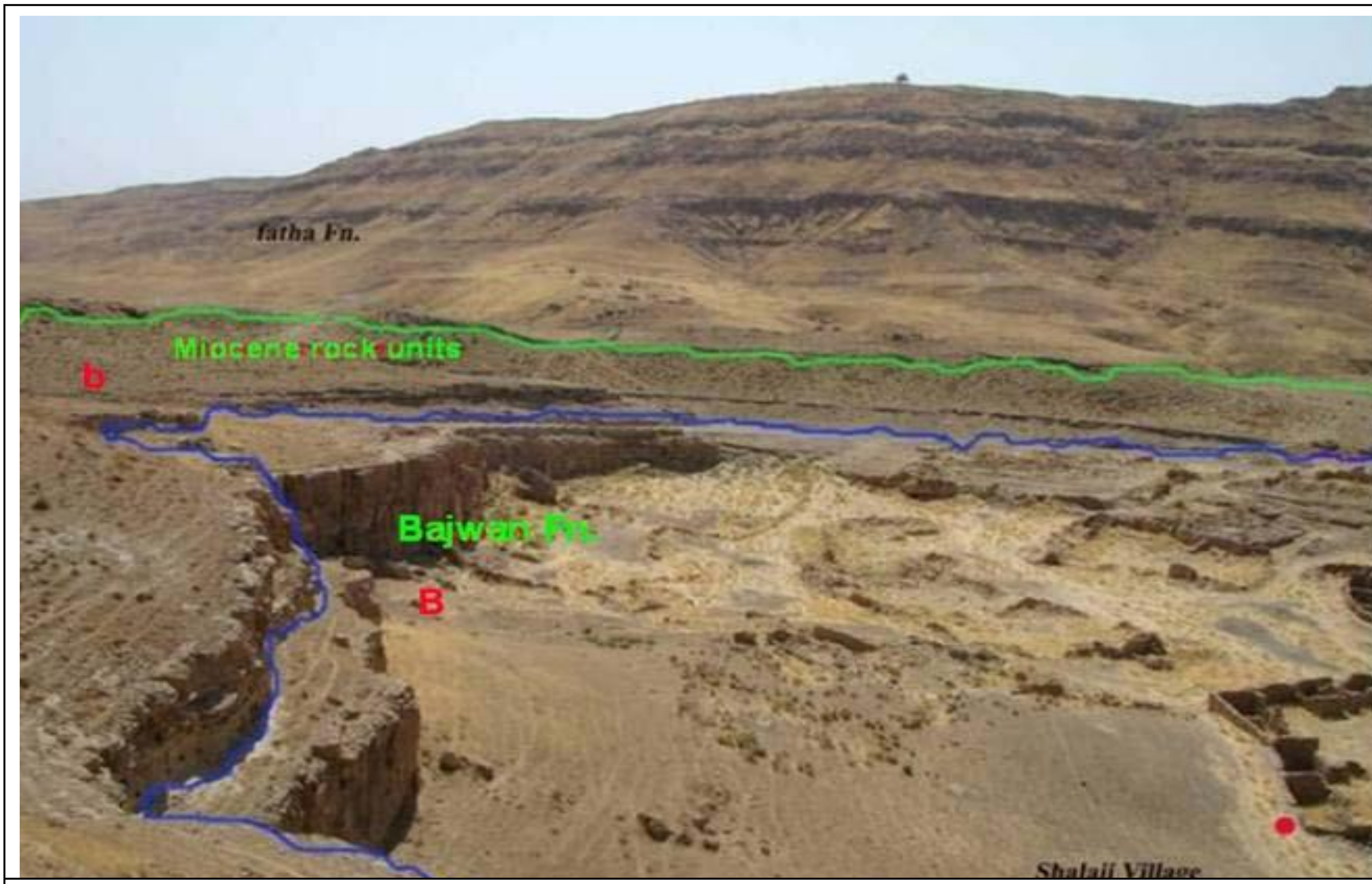


Fig (2.8): Bajawan Formation, Shalaii section, South of Darzila village-Ashdagh Mountain.

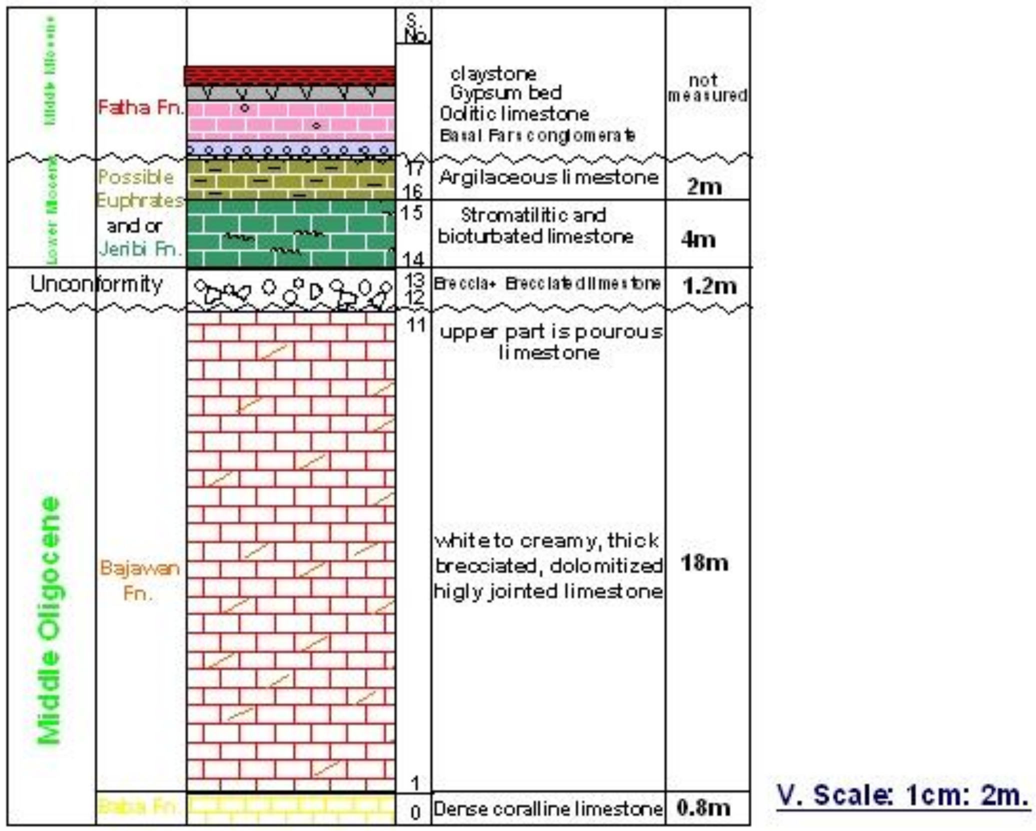


Fig (2.9): stratigraphic column of Oligocene rock units, Shalaii section, Ashdagh Mountain. , (B-b) is representing direction of sampling from bottom to top).

2.3.3. <u>Anah Formation</u>: for the first time it was defined by Bellen, 1956 (in Bellen, 1959) from Euphrates valley; west of Al-Nahiyah village close to Anah. A supplementary type section was also studied in Qara Chuqh anticline. In the type section, it is composed of grey, brecciated, recrystallized, detrital and coralline limestone beds, but in the supplementary type section it consists of grey, dolomitized and recrystallized limestone beds; massive in the lower part and becoming thinner bedded upwards (Jassim and Goff, 2006).

In Hazar Kani section, it includes 2-5m of white- creamy and grey dolomitized, and recrystallized- brecciated limestone bed; it accentuated a build up ridge. The bottom counterpart of the formation is distinguished by a brecciated, recrystallized, detrital, highly jointed and coralline limestone (fig 2.10), but at the upper part, the beds become more brecciated and contain large solitary coral (Pl. 16E). The Upper part included 3m of rubbly, conglomeratic limestone and a conglomerate bed. Near the most upper part and its contact is characterized by stromatilitic, bioturbated limestone beds which is most probable returning to Early Miocene age; that is possible Euphrates and or Jeribi Formations (fig 2.10).

In the studied area, the thickness of Anah Formations is nearly 5m.

The contact of Anah Formation does not clearly appear and it is sometimes debated, while Anah Formation appears in Sharwal Dra and Bamo anticlines. In Sharwal Dra anticline, it consists of 45-55m of white, thick bedded, splentery, detrital and coralline limestone, the underlying formation is Azkand Formation and the contact is conformable, but in Bamo anticline, it consists of 60m of purple and grey thick bedded limestone and it is overlying Bajawan Formation, the contact is not easily determined on that outcrop (Behnam, 1979); The lower part of Anah Formation is Always conformable with Azkand Formation except in case of the Eocene Formations presence (Avanh Formation- Alan Section No.2) from which the contact is unconformable (Abid, 1997).

In the studied sections, the contact does not separately appear because as mentioned above, the lower part is brecciated (fig 2.10), this brecciated part differs from the underlying Bajawan Formation and it may act as an unconformable surface; Anah Formation is available in both northern and southern limbs of Qara Chuqh structure, from Southern limb the thickness of Anah Formation is nearly 32m which conformably overlies Azkand Formation, but in the Northern limb, it unconformabely overlies Bajawan Formation and the unconformity surface is characterized by 1-2m a of breccia bed (Al Sammarai and Al- Mubarak, 1978 in Abid, 1997).

In the studied section, the upper part of this Formation is unconformable with possible Early Miocene rock beds (probably the Euphrates Formation) and the contact between them is a bed of rubbly conglomeratic limestone. This conglomerate is not widespread (Prazak, 1978 in Abid, 1997). In all subsurface sections, this conglomerate bed is not distinguished between Euphrates and Anah Formations.

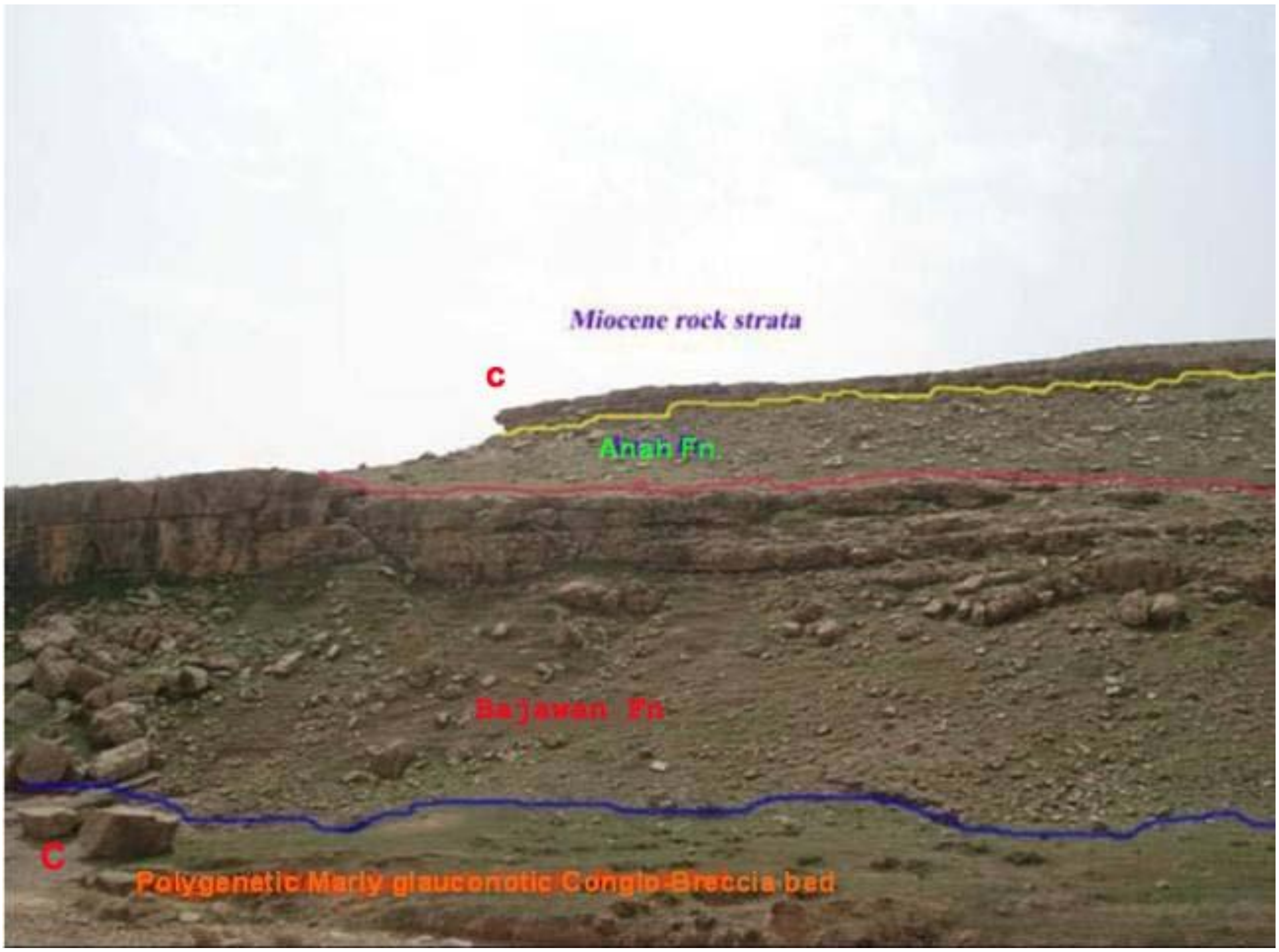


Fig (2.10): Bajawan-Anah Formations, West of Hazar Kani Village, SE-limb of Ashdagh Mountain (C-c) is representing direction of sampling from bottom to top).

The equivalent fore reef Formation of Anah Formation is Azkand Formation; this Formation with Anah Formation represent the upper Oligocene age. It was first described by Bellen (1956 in Bellen, 1959) in the Azkand Cirque of Qara Chuqh structure. In the studied area, it is not clearly cropped out; it may exist in the subsurface of the studied area or might not be deposited.

Behnam (1979) studied Azkand Formation from Sharwal Dra anticline; it is composed of 27m of generally white, massive hard, splentery, dolomitized, Microcrystalline, highly porous limestone and dolostone. This formation conformably overlies Anah Formation.

From the studied sections especially from Darzila, Shalaii and Hazar Kani sections, from which the succession clearly appear, and the total thickness of the Oligocene rock units measured from them nearly 77m

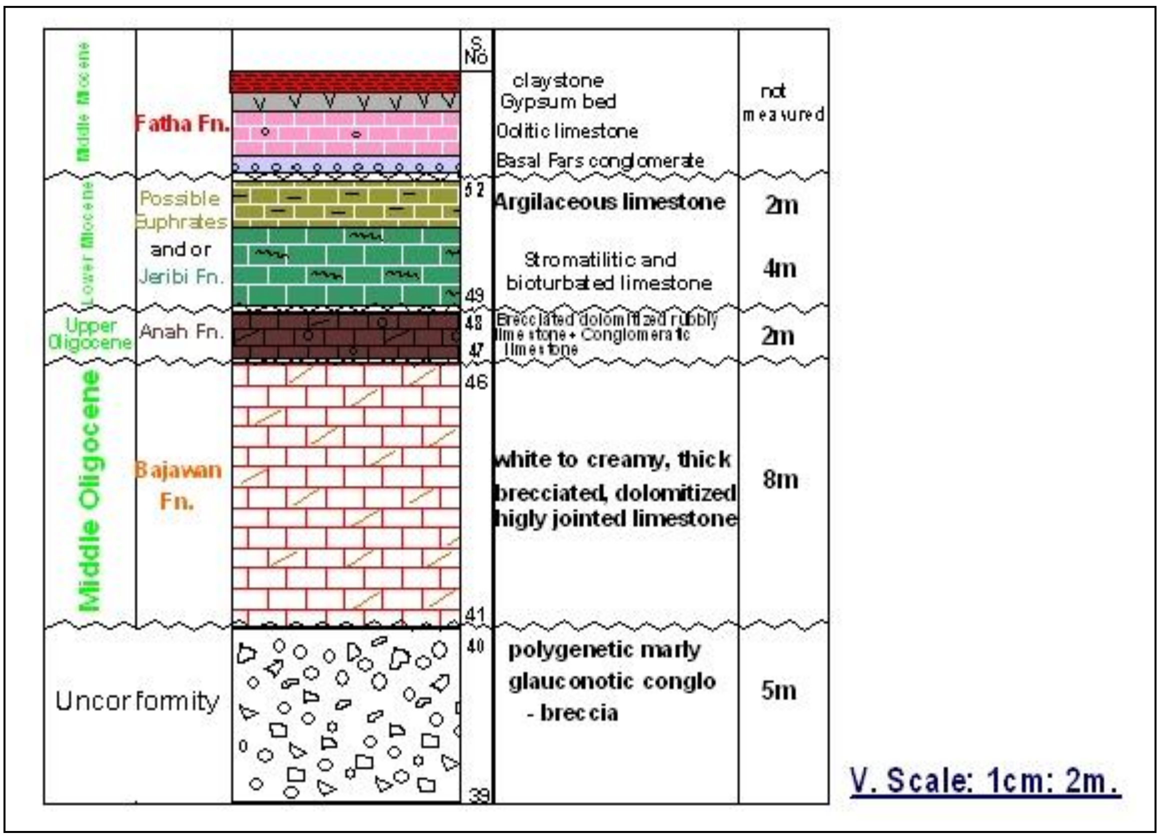


Fig (2.11): stratigraphic column of Oligocene rock units, Hazar Kani section, Ashdagh Mountain.

From field observation, it is obvious that most of rock strata from all sections are fractured, highly jointed, porous and cavernous; these properties gave the Oligocene rock units very good even extraordinary reservoir characteristic and made the oil fields be a giant oil field. Gaddo (1970) made a reservoir zonation for Kirkuk group formations, he suggested that in the most of the reservoir zones of Kirkuk group fracturing occurs to various degrees of importance conferring up on the main limestone of Kirkuk excellent permeabilities and making it a reservoir of such worldwide fame. Exposed carbonate banks, high- energy shoals, of Asmari Formation (Oligocene/Miocene) are important reservoirs in Iran and Iraq; porous, coralline, reefal limestones of Kirkuk group (Oligocene) are also important reservoirs. Clastic reservoirs such as those in the Lower Fars Formation (Miocene) are subordinate (Ahlbrandt, 2000).

2.4 Geological map and cross section of Ashdagh Mountain:

Prepared geological map of Ashdagh Mountain is modified from Stevanovic and Markovic (FAO, 2003) (fig 2.12) and Geological cross sections of the studied area were taken from Darzila section to Timar- Zinana section through Shalaii and Hazar Kani sections (fig 2.13).

2.5 Lithostratigraphic distribution of Ashdagh Mountain:

Based on the field and thin section study, the following map is concluded which shows the stratigraphic distribution of Ashdagh Mountain. The red line represents the boundary between Oligocene and Miocene rock units and the yellow line represents the boundary between Eocene and Oligocene rock units) (fig 2.13).

2.6 Correlation of the studied area with the surrounding areas:

For correlation of Ashdagh Mountain, Qara Chuqh structure and Bamo-Sharwal Dra structure have been chosen (fig 2.15).

Fig (2.12a): contour map of Ashdagh Mountain, Google Earth, 2008.

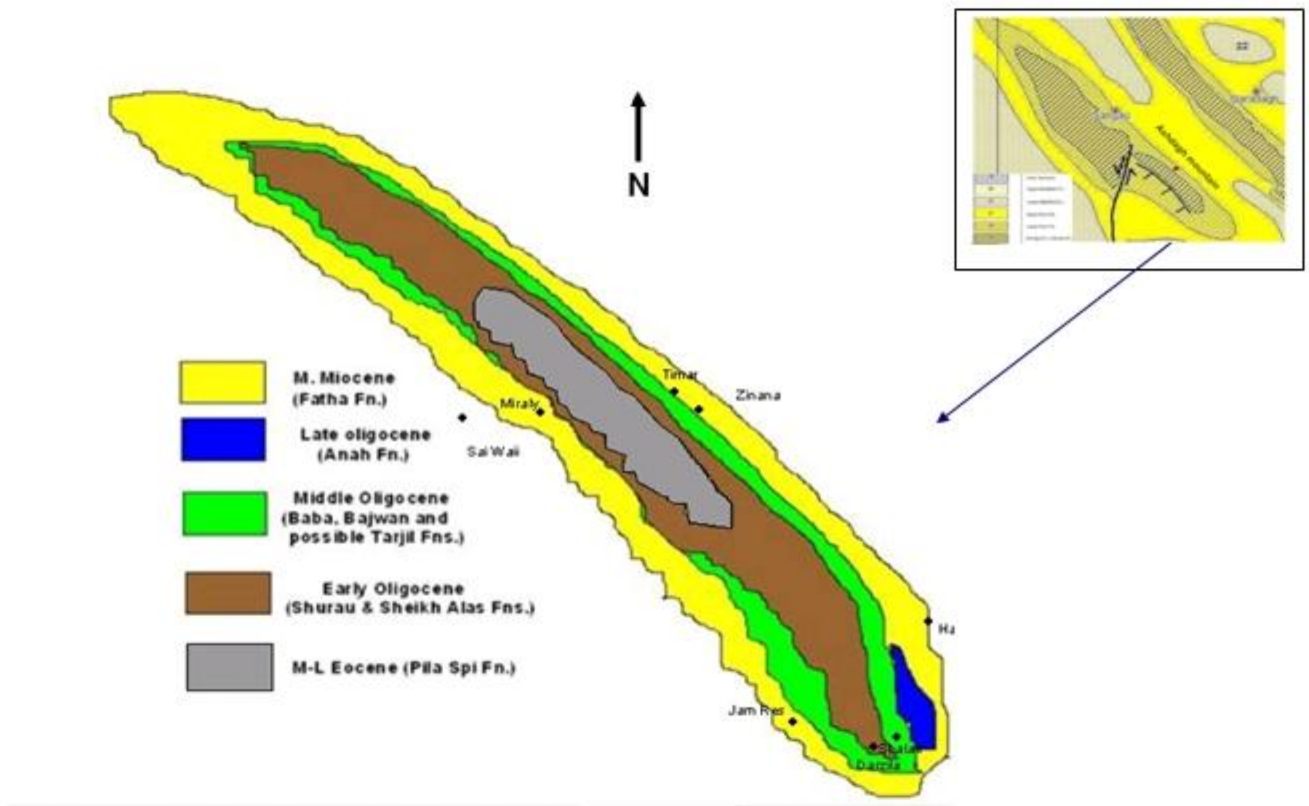


Fig (2.12b): Geological map of Ashdagh Mountain (modified from Stevanovic and Markovic FAO, 2003).

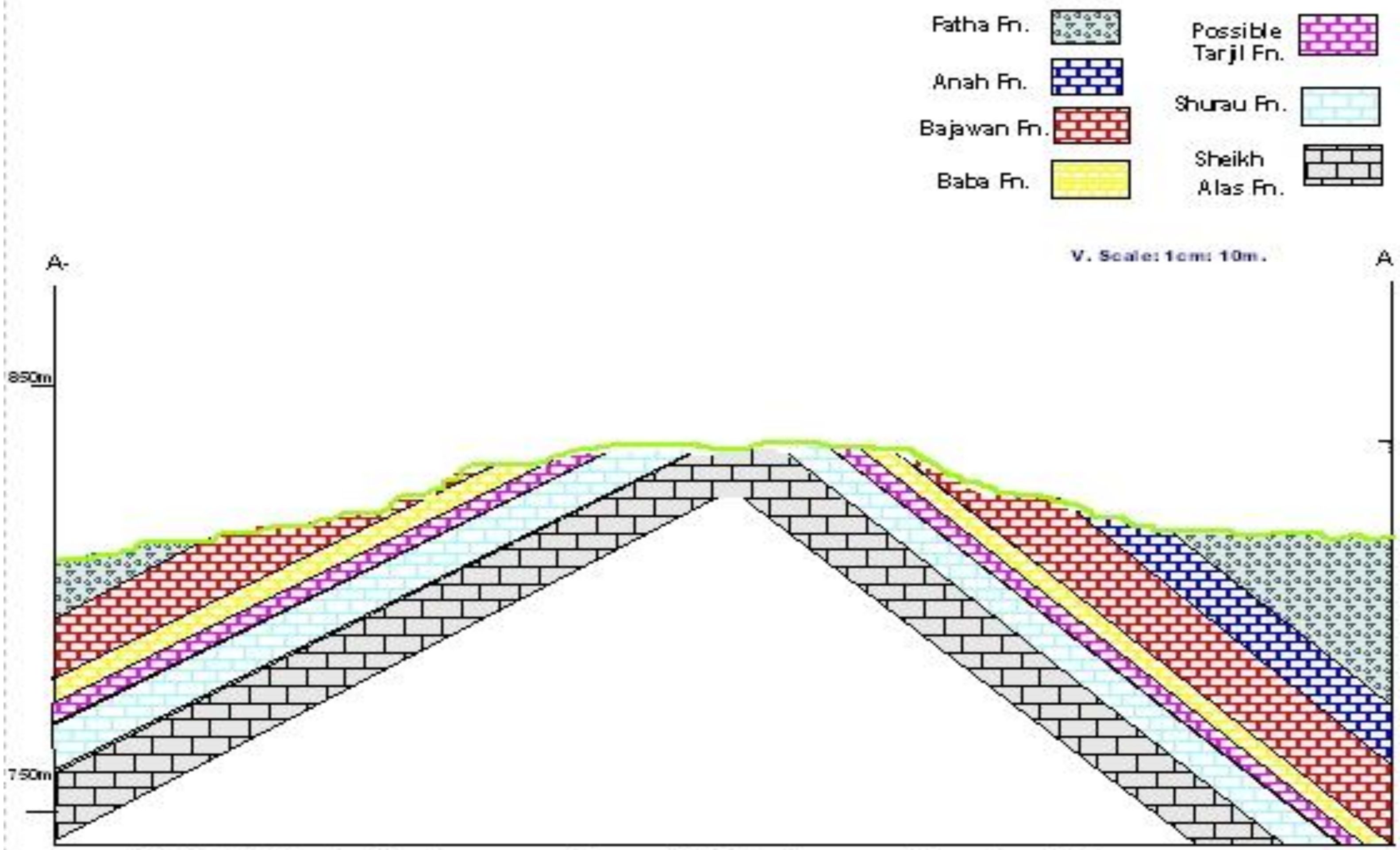


Fig (2.13): Geological cross section of Ashdagh mountain along AA-

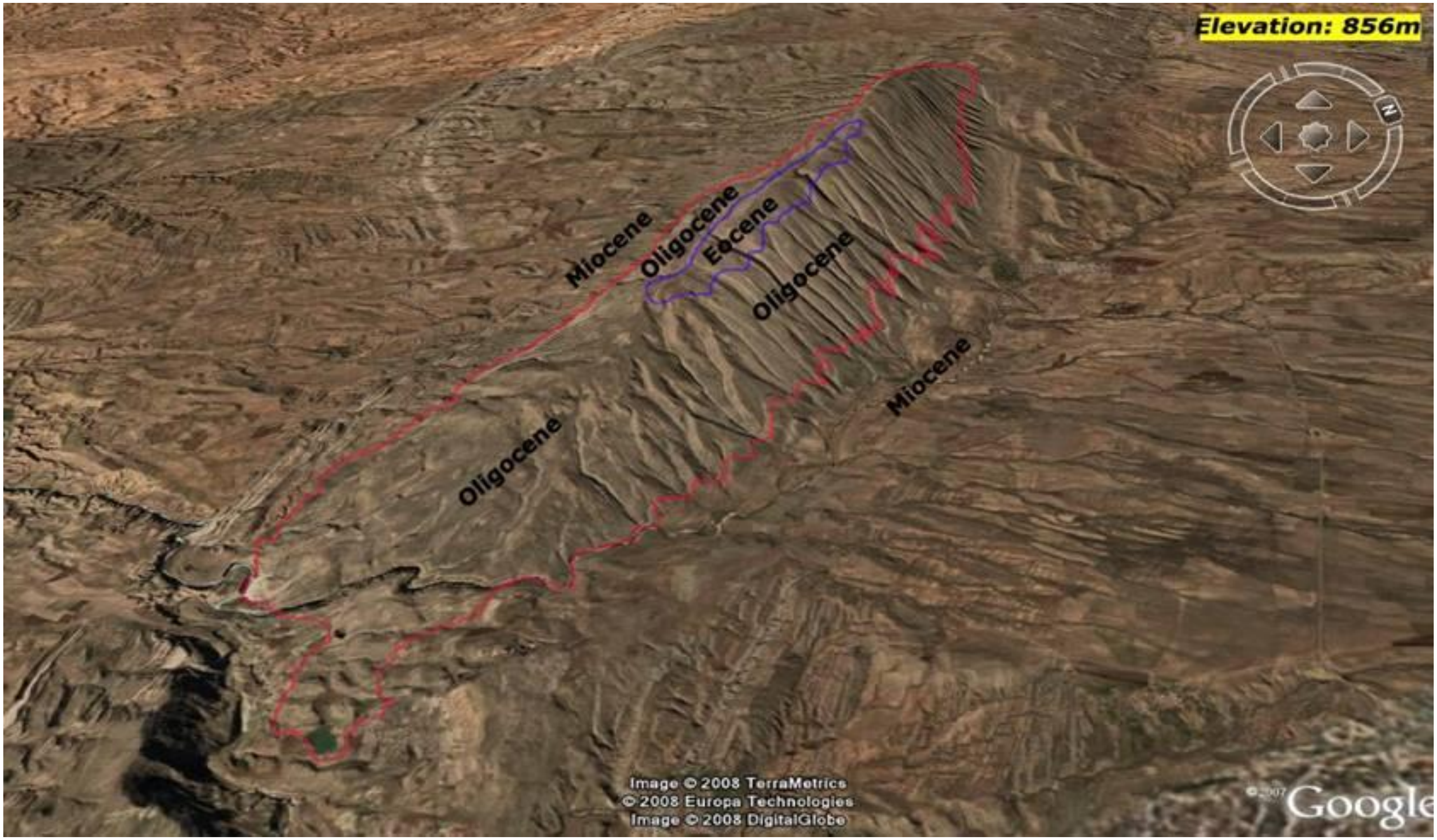
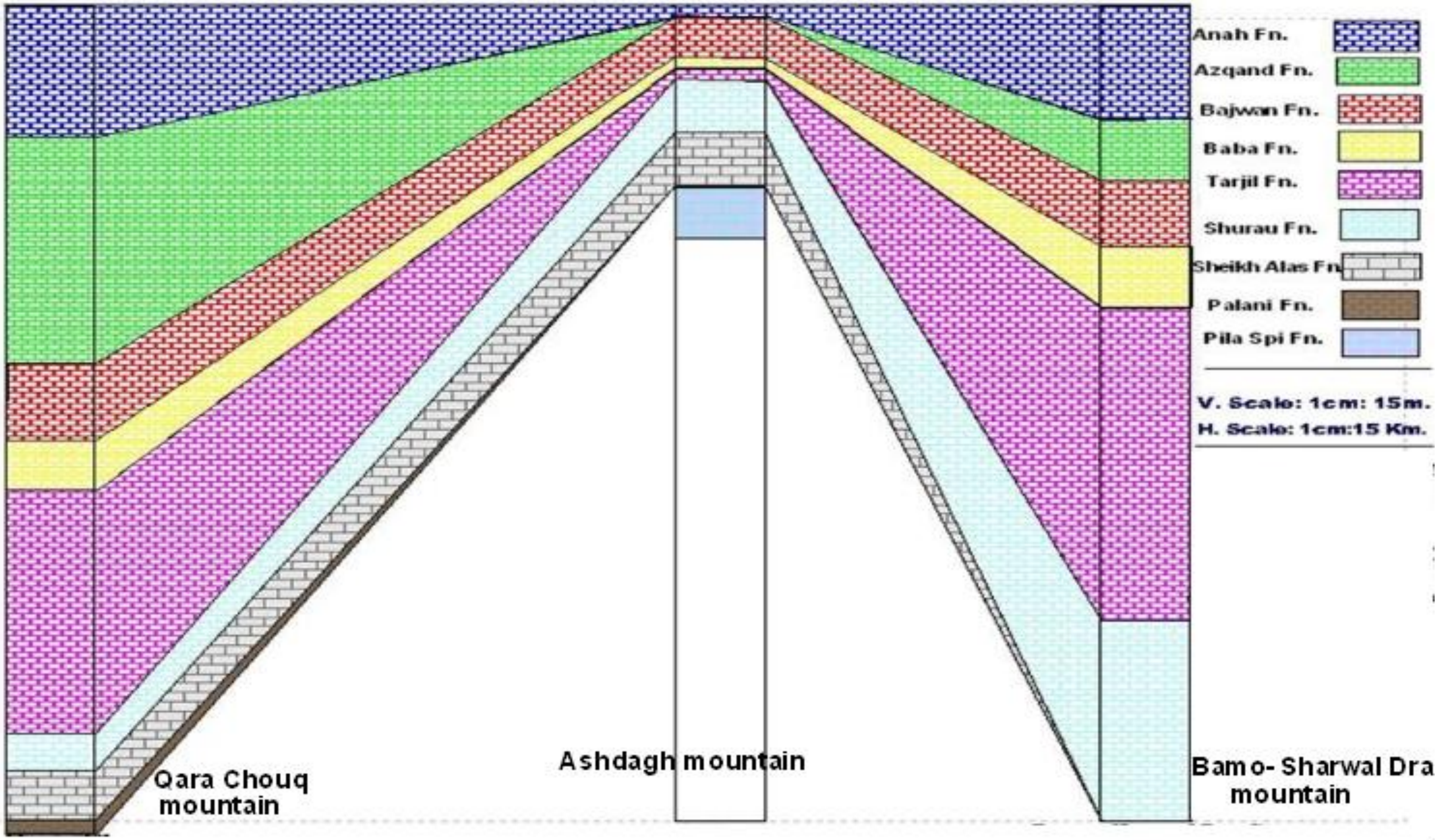


Fig (2.14): Lithostratigraphic distribution of Ashdagh Mountain from satellite (tilted imagery), Google Earth, 2008.



Fig(2.15): Corellation of Oligocene rock units between Ashdagh mountain (current study), Qara Chouq structure (Bellen et al, 1959) and Bamo- Sharwal Dra structure (Behnam, 1979)

Chapter three
Biostratigraphy

3.1 preface:

Rock strata of the studied area are characterized by mostly fossiliferous even cochinous (fossil contents more than 85%). These rock strata are characterized by the presence of microorganism (Benthic Foraminifera) and macroorganisms like Pelecepod, Gastropod and Brayozoa in addition to coral and algae. Some index fossils of benthonic foraminifera are generally used for age determination because of short age, wide geographic distribution, abundancy in the rocks, small size and most of genera and species are well known.

During thin section study of the rock samples of the studied area, some conspicuous index fossils were determined which correlate with Oligocene age (Early, Middle and Late). Based on biostratigraphic zonation of benthic foraminifera of Bellen (1956) for Kirkuk group Formations, he specified different faunal zones (table 3.1).

Some fossil contents are well preserved while others have not clear appearance (Ghosts of fossils) throughout the rock units of the studied area due to dolomitization and recrystallization, while some of the fauna contents are destructed due to mechanical pressure, and some others were deformed because of dissolution process on the rock beds and no longer recognizable as fossils.

Table (3.1): Microfacies, faunal zone and age determination of the Oligocene rock strata (after Bellen et al, 1959):

Facies / Age		Back reef	Faunal Zone	Fore reef	Faunal Zone
Oligocene	Upper	Anah Formation	Miogypsinoid	Azkand Formation	1.Miogypsinoides 2.Miogypsinoides / Lepidocyclina
	Middle	Bajawan Formation	1.Kirkukensis 2. Delicata	Baba Formation	1.Lepidocyclin 2.Lepidocyclina/ Nummulites
	Lower	Shurau Formation	1.Dendrophylum 2.Paucialveolata	Sheikh Alas Formation	Nummulites

During Tertiary periods, there were global events that have effected on the appearance and disappearance of organisms as shown in table (3.2).

The Oligocene and Miocene represent, for the Cenozoic, a period of extensive reef development and are characterized by a number of important changes influencing carbonate-producing biota and the architecture of reefs and carbonate platforms (Bosellini, 2006).

Bellen et al (1959) studied microfossils and microfacies of Oligocene age, Brun (1971) and later Al-Hashmi and Amer (1985).

Table (3.2): Micropaleontological bioevents of Tertiary (Sartorio and Venturini, 1988):

Early Eocene: Maximum spreading of Alveolina facies, significant development of Ornamented Planktonic Foraminiferas (Morzovella subbdinae, Morzovella Formosa, etc…
Middle Eocene: Maximum spreading of Nummulites facies, occurrence of Hantkenina, Globigerinatheka and Turborotallia gr. Ceroazulensis.
Middle-Late Eocene: disappearance of Alveolina facies, extinction of ornamented Planktonic Forams.
Late Eocene: Spiroclypeus/ Pellatispira facies
Eocene-Oligocene Boundary: disappearance of Discocylina, extinction of Turborotallia gr. Ceroazulensis, Hantkenina.
Early Oligocene: last significant of Nummulites facies.
Middle Oligocene: occurrence of Lepidocyclina, significant spreading of Meandropsina, Archais and Austrotrillinia facies.
Latest Oligocene: occurrence of Miogypsinodes.
Early Miocene: occurrence of Miogypsina, spreading of Globigerinoides and Globoquadrina.
Early- Middle Miocene: extinction of Lepidocyclinidae.
Middle-Latest Miocene: Borelis facies, Orbulina facies.

Al-Hashmi and Amer (1985 op. cit,) determined the following fossils in the Oligocene rock units of Iraq:

3.2 Sheikh Alas Formation:

From studied area, the following fossils were recorded within Sheikh Alas Formation:

Nummulites vascus (Pl. 2A and 2B), *Nummulites intermedius*, (Pl. 2B, 2C, 2D,2E, 2G, 1H, and 2A), *Heterostegina assilinoides* (Pl. 2B,3B 4Aand 4C and 4D), *Nummulites fichteli*, (Pl. 2F,2G, 3C,6H and 7D), *Operculina complanata* (Pl. 3A,3H and 4E), *Rotalia viennoti* (pl. 3A, 3E, 3F and 4E), *Ditrupa* (Pl. 3G) and *Dentalium cycloclpeus* or *Operculina alpina*(Pl. 4A).

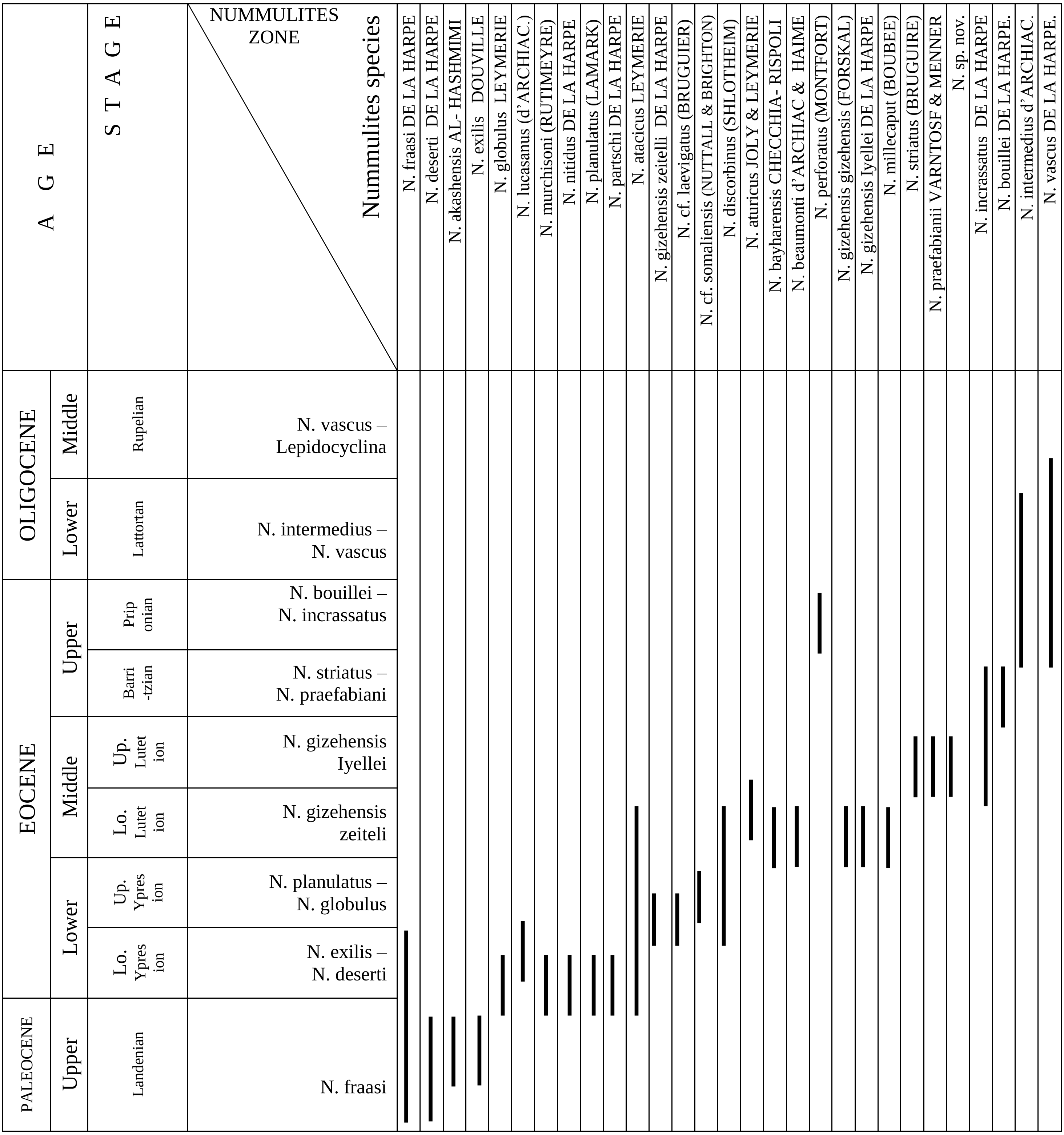
The Oligocene represents a time of transition between the typically Paleogene faunas of the Paleocene/Eocene and the typically Neogene-modern faunas which began to emerge in the Early Miocene (Berrgren, 1984).

Based on Al-Hashimi and Amer (1985) the abundant and index fossils mentioned in Sheikh Alas Formation are:

Nummulites intermedius D'ARCHIAC, *Nummulites vascus* JOLY and LEYMERI, Heterostegina assilinoides BLANKENHORN, *Opreculina complanata* SCHULUMBERGER, *Rotalia viennoti* GRIEG, *Borelis pygmea* HANZAWA, corals, Brayozoa, algae and Mollusk. Beside the mentioned fossils, Muhammad (1983), described these fauna contents in wells (K.175 and K.181): *Nummulites fichteli* MICHELOTTI, *Nummulites incrassatus* DELA HARPE, Nummulites bouilli DELA HARPE, *subterraniphyllum thomasi* ELLIOTT, *Eorupertia sp*, *Lithophyllum sp, Mesophyllum sp, Charophites sp, Tubucellaria sp, Distichopax sp, Nubucularia sp,* and *Miniacina sp.*

Chronostratigtaphically and based on the fauna contents (especially index fossils); Sheikh Alas Formation is described as follow:

This formation represents the oldest reef and fore reef facies of Oligocene (Jassim and Goff, 2006). The age of Sheikh Alas Formation is correlated with Lower-early Middle Oligocene age (Lattorfian-Middle Rupelian) (Al Hashimi and Amer 1985). Based on the index fossils contents and zonation, which are illustrated in fig (3.1), this Formation is located within Nummulites zone.



(Fig 3.1): Vertical Range of Nummulites and the established Biozones in Iraq (after Al-Hashimi and Amer, 1985).

This zone is divided into two Assemblages zones (Muhammad, 1983) and they are: a. Nummulites fichteli- Nummulites vascus Assemblage Zone. This zone comprises *Nummulites intermedius* (D'ARCHIAC), *Nummulites fichteli* (MICHELOTTI), *Nummulites vascus* (JOLY and LEYMERI, *Opreculina* *complanata defrance* SCHULUMBERGER, *Heterostegina assilinoides* BLANKENHORN.

b. Nummulites bouillei- Nummulites incrassatus Assemblage Zone. This zone includes both *Nummulites bouillei* DE LA HARPE, *Nummulites incrassatus* DE LA HARPE. Both Nummulites are described from Upper Eocene of Syria {(Cizan, 1935) and (Daci, 1951) in Muhammad, 1983} from Turkey. The first appearance of *Nummulites intermedius* (D'ARCHIAC), Nummulites vascus JOLY and LEYMERI marked the beginning of Oligocene. Other most interesting assemblages, which made their first appearance in the Oligocene, are Borelies, Austrotrillina and Archais (Al-Hashimi and Amer 1985).

Rahaghi, (1984) studied rock strata of Shiraz area, Iran. He proposed that *Nummulites fabiani fabiani, Nummulites fabiani retiatus, Nummulites garnieri* and *Nummulites incrassatus, associated with Silvestrella tetraedra* are the marker fossils of upper Eocene. He also claimed that *Nummulites intermedius* is diagnostic fossil for Lower-Middle Oligocene sediments.

Nummulites fichteli is one of the typical Oligocene Nummulites, in which, according to Grimsdale (1952 in Van Der Vlerk, 1955), "the septa in medium section tend to be approximately radial for the inner one half to two-third of their length, being sharply reflexes in the outer portion". In the Eocene Forams, on the other hand "the septa are inclined and gently curved throughout their length; he also mentioned that the Lower Oligocene is characterized by the occurrence of Nummulites fichteli- intermedius without Eulepidina or Lepidocyclina.

Nummulites intermedius are also recorded from Lower Oligocene of tang-e-Khoshk, Zagros, Iran.

Based on these studies, the age of Sheikh Alas Formation may extend to Late Eocene (Priabonian) if *Nummulites bouillei* DE LA HARPE, *Nummulites incrassatus* (DE LA HARPE) can be seen while there is no evidence proving that it extended to Middle Eocene; (Biozonation of Turkey determined the index fossil *Archias dyarbakrensis* of Middle Eocene, but this index fossil is never mentioned before in such a reef, moreover Nummulites of Middle Eocene are never seen in this study.

The Eocene part of the Kutch- India sequence; they are represented by the genera *Nummulites, Discocylina, Alveolina* and *Asterocyclina,* in order of abundance. Nummulites continues up to the Early Oligocene; giving way to *Archaias, Heterostigina, Lepidocyclina, Miogypsina, Operculina, Planolinderina, Sorites* and *Spiroclypeus* in the younger horizons (Kumar and Saraswati, 1997).

3.3 Shurau Formation: From the studied thin sections of Shurau Formation, these fossils were recorded:

Archaias operculiniformis (Pl. 4G, 5F, 5G and 6D), *Archaias sp* (Pl. 5E, 6A, 6C, 6E and 6F), Nummulites intermedius (Pl. 13D), *Lithophyllum sp* (Pl.4F, 5A, 5H and 13E), *Subterraniphyllum thomasi* (Pl. 5C), *Heterostegina assilinoides*, (Pl. 5D), *Opreculina complanata*(Pl. 5D), Pyrgo(Pl. 5F), Praerhapydionina delicata(Pl. 6A), *Meandropsina iranica*(Pl. 6A*), Ditrupa sp*(Pl. 6F), *Dictoplax* (Pl. 6B), (Pl. 14A*), Coral sp* (Pl. 6G 1C and 1D), Milliolides (Pl. 4H, 5A, 6B, 6D, 6F and 14A) and Echinoid spine(Pl. 4H and 5B).

Al-Hashimi and Amer (1985) described the following fossil groups:

Archaias operculiniformis HENSON, *Peneroplis evolutus* (HENSON), *Peneroplis thomasi* HENSON, *Praerhepydionina delicate* HENSON, *Austrotrillina paucialveolata* GRIMSDALE, *Austrotrillinia globulina* AL.HASHIMI and AMER, *Rotalia viennoti* GREIG, Milliolides and Algae however *Peneroplis planatus var laevigatus* KARR, *spirolina sp*, *Borelis pygmea* HANZAWA, with the other above mentioned fossils rare *Nummulites fichteli* MICHELOTTI. In addition to these, other fossils sensed such as algae, corals, Brayozoa, Pelecepods and Gastropods are recorded by Al- Hashimi, 1974 (in Jassim et al 1984).

With the mentioned fossils assemblages above, Muhammad (1983) recorded:

Subterraniphyllum thomasi ELLIOTT, *Spiroloculina* spp, *Quinqueloculina sp*, Coral *Actinocsis sp, Heterostegina cf assilinoides* BLANKENHORN, *Heterillina hensoni* GRIMSDALE, *Corallaria cf biolithic, Planorbulina sp, Pyrgo sp, Lithophyllum sp, Lithoporella sp, Miniacina sp, Archaeolithothamnium, Microcodium, Peyssinellus sp* and echinoid spines in Kirkuk and Bai-Hassan areas.

Bellen (1956) determined two biozones based on the specified fossils which are Foraminifera zone (Archais) and Algae zone (Dendrophylum).

a. Archais zone: the most important species is *Archaias operculiniformis* (HENSON). This fossil was first described by Henson (1950a) from Lower and Middle Oligocene strata of Kirkuk area and Thomas (1950) from Khmir Formation of South Iran. Smout and Eames (1958) claimed that *Archaias operculiniformis* is present in Kirkuk Well 14, Iraq, Shurau Limestone (Oligocene) and Kuh-i- Khamir, Iran, Lower part of Khamir Limestone (Oligocene).

Austrotrillina paucialveolata GRIMSDALE is considered to be one of the index fossils of Shurau Formation, but it is not available in Sheikh Alas Formation. It was first described by Silvestri (1937) from lower Oligocene rocks of North Iraq later by Grimsdale (1952). Bellen et al (1952) described this fossil from Shurau Formation. *Austrotrillina paucialveolata*, as observed from Southern Spain, dated back to Lower Oligocene.

Al- Hashimi (1974) in (Jassim and Goff, 2006) described it from western desert (Hauran valley) and Behnam (1979) from Oligocene of Khanaqin, NE- Iraq. b. Dendrophylum zone: the most important common algae species is *Dendrophylum gurgurensis* THOMAS but it is not more widespread; the name is changed to *Subterraniphyllum thomasi*.

Based on these index fossils, Shurau Formation returns back to lower Oligocene.

The range of *Praerhapydionina delicata* HENSON, of spiroline habit but with a single, stellar aperture, is given as Lower Oligocene. To date, no *Praerhapydionina* have been discovered in the Eocene of the Mediterranean realm (Hottinger, 2007).

Sartorio and Venturini, (1988) claimed that *Praerhapydionina sp* is common from the Late Eocene to the Early Miocene. They also recorded Archais, *Peneroplidae, Dendritina, Austrotrillina* and *Milliolidae* from Lower Oligocene of Tang-e- Salehat, Zagros, Iran. *Subterraniphyllum thomasi* ELLIOTT is recorded from Oligocene of Iran.

3.4 Baba Formation: From the studied area, these fossils were recorded in Baba Formation:

Nummulites fichteli (Pl. 7A and 7D), *Nummulites vascus* (Pl.8B), *Lepidocyclina (Nephrolepidina) sp*, (Pl. 3D, 3E,3F 8C and 8D), *Lepidocyclina (Nephrolepidina) morgani* (pl.7C), *Lepidocyclina sp* (pl.7C and 7E), *Lepidocyclina (Eulepidina) dilatata* (Pl. 3F, 7F, 7G, 8A, 8B and 8G), *Lepidocyclina (Nephrolepidina) sp*, (Pl. 7C and7D), *Lepidocyclina (Eulepidina) ephippioides* (Pl.7H and 8H), *Lepidocyclina (Eulepidina) marginatus*(Pl. 7B), *Asterigerina rotula* (Pl. 8E and 8F), *Amphestigina sp* (Pl. 8E and 8F), *Heterostegina assilinoides* (Pl. 8E and 8F), and *Heterostegina precursor* (Pl. 8E and 8F), *Spiroclypeus marginatus* (Pl. 6H), *Heterostegina Sp* (Pl. 8A) and Echinoderm (Pl. 1F and 1G).

Al-Hashimi and Amer (1985) mentioned the following fossil assemblage contents:

Lepidocyclina (Eulepidina) elephantina LEMOINE and DOUVILLE, *Lepidocyclina (Eulepidina) dilatata* MICHELOTTI, *Nummulites intermedius* (D'ARCHIAC) *Nummulites vascus* JOLY and LEYMERI*, Heterostegina involuta* SILVESTRI, *Heterostegina cf assilinoides* (BLANKENHORN), *Rotalia viennoti* GREIG, Milliolides, Brayozoa and corals.

In addition to those fossils, these fossils, Bellen et al (1959) and Ctyrocky and Karim (1971a in Jassim and Goff 2006) studied the outcrops of Anah area of W Iraq and identified the following faunas:

Lepidocyclina morgani, Archaias sp, Triloculina sp, Quinqueloculina sp, Robulus sp, Peneroplis spp, Praerhepydionina sp (?), Spiroclypeus marginatus, Ostracoda sp, Gastropod juv, indet Spirobis sp (?), Chalantys sp (?), Corals and Fish teeth.

Based on specific fossil contents, the rock beds of this formation correlated to Middle Oligocene, they extend to Early Late Oligocene. The most individual fossils of this Formation are:

a. *Lepidocyclina (Nephrolepidina) morgani* LEMONIE and DOUVILLE.

Ctyrocky and Karim (1971a in Jassim and Goff 2006) studied this individual fossil from Euphrates valley- Western Desert, and they were corresponded it to Early Late Oligocene.

b. *Lepidocyclina (Eulepidina) dilatata* MICHELOTTI; Ctyrocky and Karim (1971) studied it and they thought that it returns back to Middle Oligocene.

c. *Lepidocyclina (Eulepidina) elephantina* LEMONIE and DOUVILLE.

Generally, Lower part of Baba Formation is dated to Middle Oligocene but its upper part to Early Late Oligocene, while Al-Hashimi and Amer (1985) synchronized this formation to Middle Oligocene.

Butterln, (1984) remarked the appearance of Lepidocyclina from the Oligocene age of France, Matsumaru, (1984) described Oligocene-Miocene Limestone based on *Heterostegina bornneansis, Lepidocyclina (Eulepidina) farosa, Opreculina complanata, Austrotrillina howchini* and *Borelis melo* association.

Rahaghi, (1984) studied strata in the Shiraz area, Iran, and he concluded that *Lepidocyclina (Eulepidina) dilatata, Lepidocyclina formosa* and *Lepidocyclina cancellei* are important fossils of Oligocene age. Chatterji, (1961) recorded Lepidocyclina bearing sequences in India; from the lower Nari beds (Lower Oligocene), from which *Lepidocyclina (Eulepidina) dilatata* MICHELOTTI has been reported.

Nutall (1926) recognized Lepidocyclina horizon in the Oligocene beds of Muta Pass, Sind, Baluchistan border, India from which he described *(Eulepidina) dilatata* MICHELOTTI.

Bosellini et al (1987) studied the Middle Chattian rock of Somalia, and they determined that it consists of strongly bioturbated sandy calcarenites which alternate with cross-bedded quartzarenites, and contains *Nummulites gr. vascus* and *Lepidocyclina (Eulepidina) gr. dilatata.*

Grimsdale, (1952) studied Cretaceous and Tertiary Foraminifera from the Middle East. He recorded *Lepidocyclina (Eulepidina) ephippioides* (James and Chapman) from Kirkuk, Iraq: Oligocene, however Sartorio and Venturini (1988) claimed both *Lepidocyclina (Eulepidina& Nephrolepidina), Heterostegina* and *Amphistestigina* from Upper Oligocene of Monte S. Giovanni, Latium- Italy.

Saraswati (1995) studied Lepidocyclina in the Early Oligocene sequence of Kutch, India. He thought that it is represented by its two subgenera, *Eulepidina and Nephrolepidina.*

The stratigraphic distribution of larger foraminiferids from the Oligocene to Middle Miocene suggests that the three genera *Cycloclypeus, Lepidocyclina* and *Miogypsina* invaded the Australian--New Guinea area during the Middle and Late Oligocene (Chaproniere, 1980).

3.5 <u>Bajawan Formation</u>: From the studied area, these fossils were figured out:

Austrotrillina howchini (Pl. 9A, 9B, 9C, 12H, and 16B), *Austrotrillina paucialveolata* (Pl. 11D and 13A), *Praerhapydionina delicata*(Pl. 16A*),* *Archaias kirkukensis* (Pl. 9F*), Archaias hensoni* (Pl. 10G, and 16B), *Archaias asmaricus* (Pl. 11C), *Peneroplis thomasi* (Pl.

10F, 12B and 15F*), Lithophyllum*(Pl. 10E), *Peneroplis evolutus* (Pl. 11D), *Peneroplis planatus* (Pl. 11G), *Peneroplis evolutus* (Pl. 12C and 15D and 15E and 15H), *Peneroplis proteus*(Pl. 15E), *Archaias sp* (Pl. 10G), *Meandropsina anahensis*(Pl. 9E, 10B, 12D, and 15A, 15B, 15C), *Bigenerina sp* (Pl. 16H), Valvulina sp(Pl. 10C),, *Heterillina hensoni*(Pl. 11H*), Quinqueloculina*(Pl. 9A, 12B, 16B and 16C), *Peneroplis farsensis (Pl. 11A), Spirolina austrica*(Pl. 9G, 10D, 16B and 12A), *Spirolina clyindracea*(Pl. 10D), *Sorites sp* (Pl. 12G), *Rotalia viennoti* (Pl.12E, 12F, 13A, 15A, 15B and 15C), *Coral sp*,(Pl. 9D, 10H, 11A, 11B and 15G), *Lithothamnium sp*,(Pl. 9H), *Ophthalmidium(*Pl. 14B), *Articulina*(Pl. 14D), *Textularia* (Pl. 14E), *Mesophyllum* (Pl. 14F), *Dendritina rangi* (Pl. 14G), *Ophthalmidium* (Pl. 14G), Pelecepod (Pl. 12D and 13C) and Gastropods (Pl. 12D).

Al-Hashimi and Amer (1985) determined the following fauna assemblages:

Praerhapydionina delicata HENSON, Spirolina clyindracea LAMARCK, Peneroplis evolutus HENSON, Peneroplis thomasi HENSON, Archais kirkukensis (HENSON), Archaias hensoni SMOUT and EAMES, Austrotrillina howchini (SCHLUMBERGER), Austrotrillina paucialveolata (GRIMSDALE), Meandropsina anahensis HENSON, Miogypsinoides spp, Lithophyllum sp. Also Archaias asmaricus SMOUT and Eames, Austrotrillina asmariensis ADAMS, Peneroplis planatus (FICHTELI and MOLL), Peneroplis proteus D'ORBIGENY, Peneroplis cf lavigatus D'ORBIGENY, Dendritina rangi d'ORBIGENY, Spirolina austrica d'ORBIGENY, Borelis pygmea HANZAWA, Rotalia viennoti GREIG, Heterillina hensoni GRIMSDALE, Spiroloculina spp, Valvulina sp, Articulina sp, Pyrgo sp, Tubucellaria sp, Corallaria cf biolithic, Illianella sp, *Charophytes, Lepidocyclina (Nephrolepidina) sp, Mesophyllum sp, Planorbulina sp, Lithoporella sp, Lithothamnium sp, Bigenerina sp, Amphiora sp, Textularia sp,* Pelecepods, Gastropods, Bryozoans and echinoid spine are recorded by Muhammad (1983) with the above mentioned faunas.

Archais kirkukensis HENSON: Bellen (1956 in Bellen 1959) described it from upper part of Middle Oligocene of Iraq and he thought that is an index fossil of Middle Oligocene, Behnam (1979) studied *Archais kirkukensis* from Middle and Upper Oligocene.

In Bajawan Limestone of Kirkuk Well 21, *Archais kirkukensis* occurs in abundance and *Archais asmaricus* alone occurs at slightly near level (c. 20 ft). In the same formation, distinction between Anah and Bajawan Formations given here is not always based on conclusive evidence (Smout& Eames 1958); *Archais kirkukensis* recorded from Kirkuk Well 17 and 22 and *Archais asmaricus* from Kirkuk Well 21, Bajwan Formation. Other fossils are:

Archais hensoni SMOUT and EAMES*, Penroplis thomasi* HENSON. *Dendritina rangi* d'ORBIGENY, *Rotalia viennoti* GREIG, *Meandropsina anahensis* HENSON, *Penroplis evolutus* HENSON, and *Borelis pygmae* HANZAWA.

Praerhapydionina delicata HENSON is another prominent index fossil of this formation. *Austrotrillina spp* are considered as conspicuous index fossils of the back reef-lagoon formation of the Oligocene. For example: *Austrotrillina howchini, Austrotrillina striata, Austrotrillina paucialveolata* and *Austrotrillina asmariensis*.

Adams (1968) made distinction between these four suspicious based on the wall structure; in striata type wall with coarse alveoli, in asmariensis type wall with fine, closely spaced alveoli, howchini wall type with bifurcating alveoli and in paucialveolata is irregular.

Based on the above fossils contents Bajawan Formation is dated to Middle- Early upper Oligocene, Sartorio and Venturini (1988) claimed that *Praerhepydionina spp* are common from the Late Eocene to the Early Miocene; They found that P*eneroplidae* and *Milliolidae plus Austrotrillina sp* and *Dendritina sp* are present in the Middle Oligocene of Tang-e- Kiskiasun, Zagros, Iran.

Rasser and Nebelsick (2003) *recorded Lithoporella, Lithothamnion sp.* and *Mesophyllum* from the Oligocene shallow-water carbonates of the Lower Inn Valley (Tyrol, Northern Calcareous Alps).

3.6 Anah Formation: From the studied area, these fossils were figured out:

Austrotrillina howchini (Pl. 16B), *Austrotrillina asmariensis* (Pl. 16F), *Praerhapydionina delicata* (Pl. 16A, 16E and 16G), *Archaias operculiniformis* (Pl. 16B and 16C), *Archaias spp* (Pl. 16A), *Ophthalmidium* (Pl. 14G, 16B and 16C), *Spiroloculina* (Pl. 16C), *Dendritina rangi* (Pl. 16D), *Peneroplis evolutus* (Pl. 16D), *Lithothamnium sp* (Pl. 16D), *Sphaerogypsina* (Pl. 16E), *Spirolina sp* (Pl. 16F*) and solitary coral* (Pl. 1E).

Al-Hashimi and Amer (1985) recorded these fossils:

Corals (Heliastrea defransi) (EDWARD and HAIME), *Archaias asmaricus* SMOUT and Eames, *Archais hensoni* SMOUT and Eames, *Meandropsina anahensis* HENSON, *Peneroplis evolutus* (HENSON), *Peneroplis thomasi* HENSON, *Austrotrillina howchini* SCHLUMBERGER, *Austrotrillina paucialveolata* GRIMSDALE, *Rotalia viennoti* GREIG, Dendritina sp, *Borelis pygmae, Charophytes*, algae and Milliolides.

In addition to the above mentioned fossils, Muhammad, (1983) has recorded:

Archaias kirkukensis HENSON, Austrotrillina asmariensis ADAMS, Miogypsinoides complanata (SCHULUMBERGER), Heterillina hensoni GRIMSDALE, Spiroclypeus blankenhorni HENSON, Peneroplis farsensis HENSON, Peneroplis planatus FICHTELI and MOLL, Peneroplis proteus, d'ORBIGENY, Spirolina austrica d'ORBIGENY, Lepidocyclina (Nephrolepidina) sp, Sorites sp, Spiroloculina spp, Quinqueloculina sp, Valvulina sp, Articulina sp, Corallaria cf biolithic, Actinocsis sp, Subterraniphyllum thomasi ELLIOTT, Lithophyllum, Lithothamnium and Ostracods.

Karim and Ctyrocky (1971a in Jassim and Goff, 2006) studied out crops from the Euphrates valley, and they reported:

Subterraniphyllum thomasi ELLIOTT, Archaias kirkukensis HENSON Austrotrillina howchini (SCHLUMBERGER), Rotalia viennoti GREIG, Milliolides, Robulus sp, Bolivina sp,Textularia sp, Triloculina cf gibba, Quinqueloculina sp, Peneroplis evolutus, Peneroplis thomasi, Miogypsinoides complanata, Hydrobia sp, indet, cons sp juv, Scaphander sp, Acteonia sp, Nassa sp, Natica sp, Mitra sp, Cerithium sp, Pyramidella sp. juv, tympanotommus margaritaceous, Oliva sp, Chlamys sp, Euchilus sp juv, Brayozoa remains, indet., Heliastrea defrance and Fish bones.

However Ditmar et al (1971) recommended that Oligocene rock units are divided into two sequences, Upper and Lower sequences (Upper sequence includes Anah, Azkand, Baba and Bajawan Formations), they considered that there is no difference between these formations in one hand, on the other hand, there is a somehow similarity between fossils of the Anah and Azkand Formations, beside this similarity, there is distinction between them based on fossil contents. The most important distinct fossil is *Miogypsinoides complanatus* (SCHLUMBERGER), described by Hanzawa (1940) from Oligocene age of Iraq.

*Archais asmaricus (*SMOUT and Eames), *Archaias kirkukensis* HENSON *Archaias hensoni* SMOUT and EAMES are mentioned by Bellen et al (1959); *Archais kirkukensis* is recorded from Bai Hassan Well 5, *Archais asmaricus* from Bai Hassan Well 4, Anah Limestone and *Archais hensoni* from Anah, West Iraq, Anah Limestone.

Abid (1983) recorded *Austrotrillina howchini* (SCHLUMBERGER) from Anah Limestone Formation (Western Iraq), he dated it back to Oligocene-Miocene age.

Paul (1961) determined *Rotaliidae, Discorbiidae, Milliolidae, Elphipiidae,* and other groups of foraminifera predominantly restricted to shallow water from Upper Oligocene and Miocene mudstone facies of Peninsula, New Zealand.

Huang, (1984) studied Late Oligocene benthic foraminiferal Assemblages (included Ammonia beccarii).

Hayward, (1984), studied early Miocene strata of Northern New Zealand. He returned *Amphestigina* and *Quinqueloculina* assemblages to inner shelf. Sartorio and Venturini (1988) recorded *Peneroplidae, Spirolina spp Austrotrillina spp and Milliolidae* from the Upper Oligocene of Salento, Apulia, Italy. *Elphidium sp* was recorded from Middle Miocene of Monte Della Grotta, Abruzzo, Italy.

Plate (1)

A. Large *Nummulites sp* well developed within the contact rock units of Sheikh Alas-Shurau Formations, Darzila section, Ashdagh Mountain.

B. Large *Nummulites sp* well developed within the contact rock units of Sheikh Alas-Shurau Formations, Darzila section, Ashdagh Mountain.

C. Colony of *Hexa Corals*, near the contact between Sheikh Alas-Shurau Formations, Darzila section, Ashdagh Mountain.

D. Colony of *Hexa Corals*, near the contact between Sheikh Alas-Shurau Formations, Darzila section, Ashdagh Mountain.

E. Very large Solitary *Coral* within Anah Fn., Hazar Kani section, Ashdagh Mountain.

F. Echinoderm fragment, near the boundary surface of Baba-Bajawan Fns., Shalaii section, Ashdagh Mountain.

G. Echinoderm sp, near the boundary surface of Baba-Bajawan Fns., Shalaii section, Ashdagh Mountain.

H. Pelecepod sp, near the boundary surface of Baba-Bajawan Fns., Shalaii section, Ashdagh Mountain.

Plate(1)

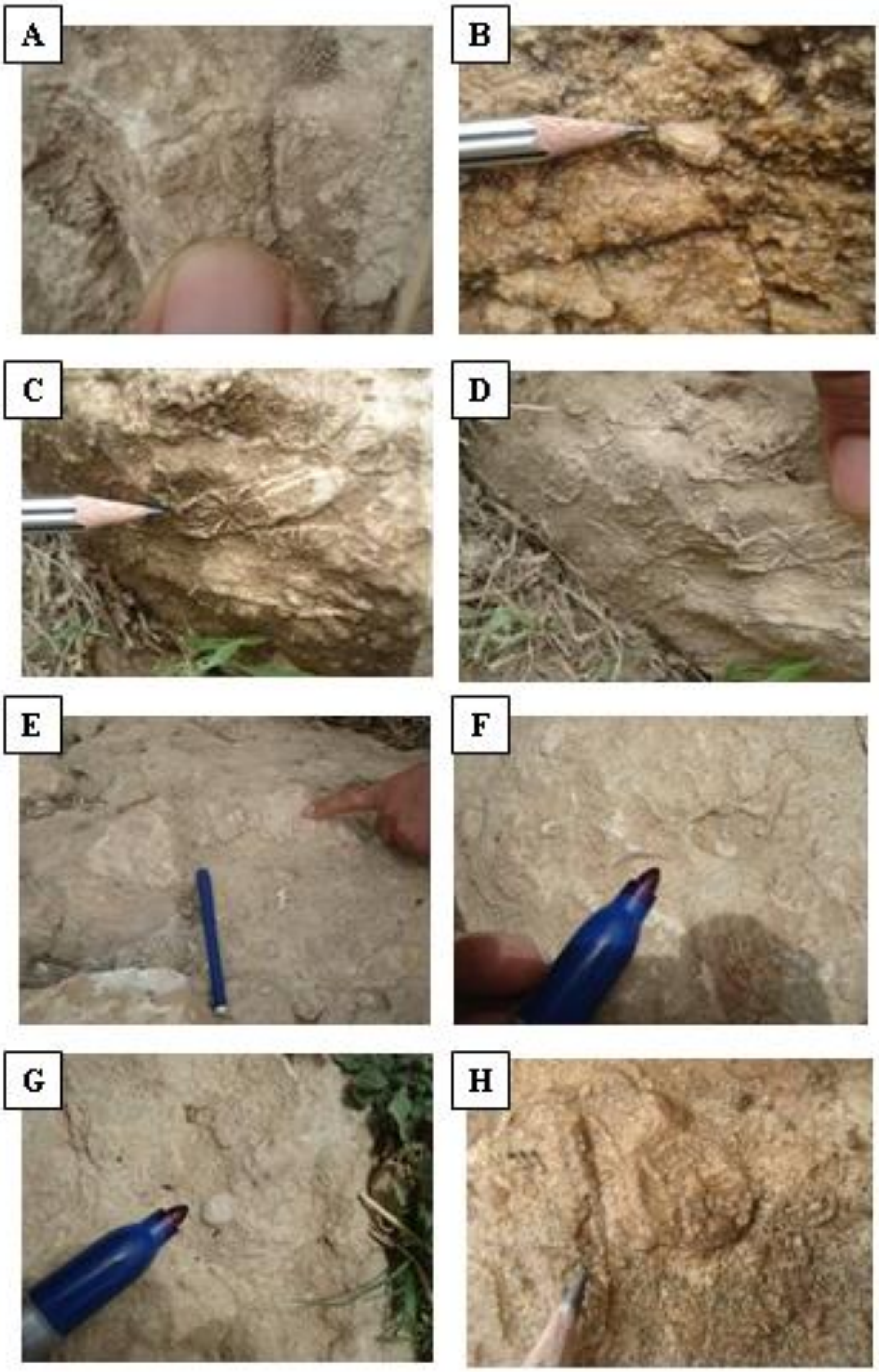


Plate (2)

A. Nummulitic Packstone Microfacies bearing *Nummulites vascus*, Sheikh Alas Fn., Darzila section, 20X slide No.150.

B. Nummulitic Packstone Microfacies bearing *Nummulites intermedius*, Heterostegina *assilinoides* and *Nummulites vascus*, Darzila section Sheikh Alas Fn., 20X, slide No.150.

C. Nummulitic Packstone Microfacies bearing *Nummulites intermedius,* Darzila section, Sheikh Alas Fn., 20X, slide No.179.

D. *Nummulites intermedius* in organic rich Limestone, Sheikh Alas Fn., 20X, Darzila section, slide No.180.

E. Nummulitic Wackestone-Packstone Microfacies bearing *Nummulites intermedius*, equatorial and lateral view, Sheikh Alas Fn., Darzila section, 20X, slide No.151.

F and G: Nummulitic Wackestone.

F. *Nummulites fichteli*, Sheikh Alas Fn., Darzila section, 20X slide No.1.53

G. *Nummulites fichteli*, Sheikh Alas Fn., Miraly section, 20X, slide No.214.

H. Nummulitic Packstone Microfacies bearing *Nummulites intermedius*, Darzila section, Sheikh Alas Fn., 20X, slide No.179.

Plate(2)

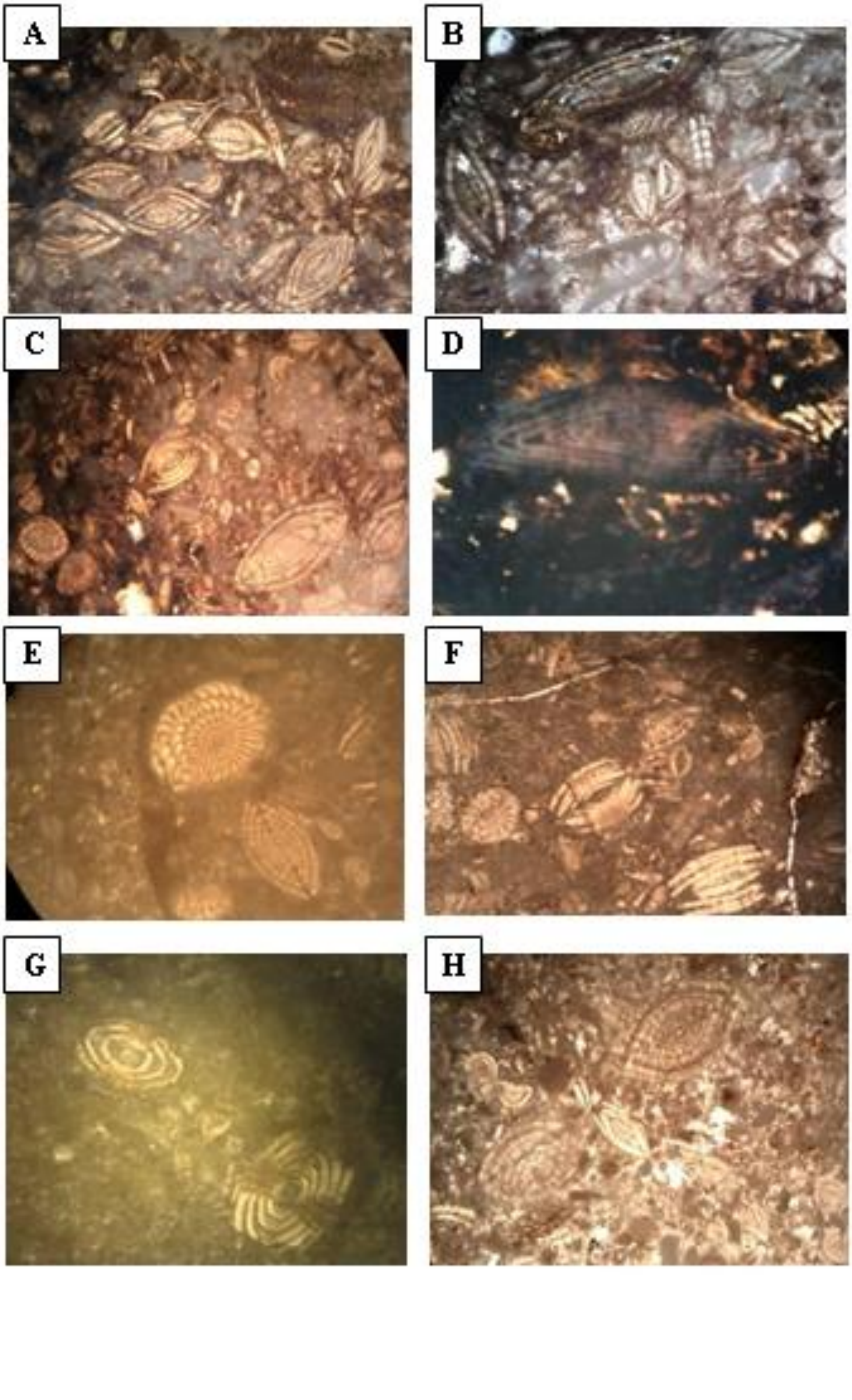


Plate (3)

A. Wackestone- Packstone Microfacies bearing *Operculina complanata* and *Rotalia viennoti,* Sheikh Alas Fn., Darzila section, 20X, slide No.153.

B. Wackestone- Packstone rich with Nummulitic Fragments and some *Heterostegina assilinoides*, Sheikh Alas Fn., Darzila section, 20X, slide No.150.

C. Bioclastic Packstone. *Nummulites fichteli*, Sheikh Alas Fn., Darzila section, 20X, slide No.154.

D. Packstone. *Lepidocyclina (Nephrolepidina) sp*, Baba Fn. tongue within, Darzila section, 20X, slide No.153b.

E. Packstone. *Lepidocyclina (Nephrolepidina) sp* and *Rotalia vienoti,* Baba Fn. tongue within Sheikh Alas, Darzila section, 20X, slide No.153b.

F. Packstone. *Lepidocyclina (Eulepidina) dilatata* and *Rotalia viennoti,* Baba Fn. tongue within Sheikh Alas, section, 20X, slide No.153b.

G. Wackestone- Packstone. *Ditrupa sp*, Sheikh Alas Fn., Darzila section, 20X, slide No.154.

H. Packstone Bearing *Operculina complanata*, Sheikh Alas Fn., Darzila section, 20X, slide No.150.

Plate(3)

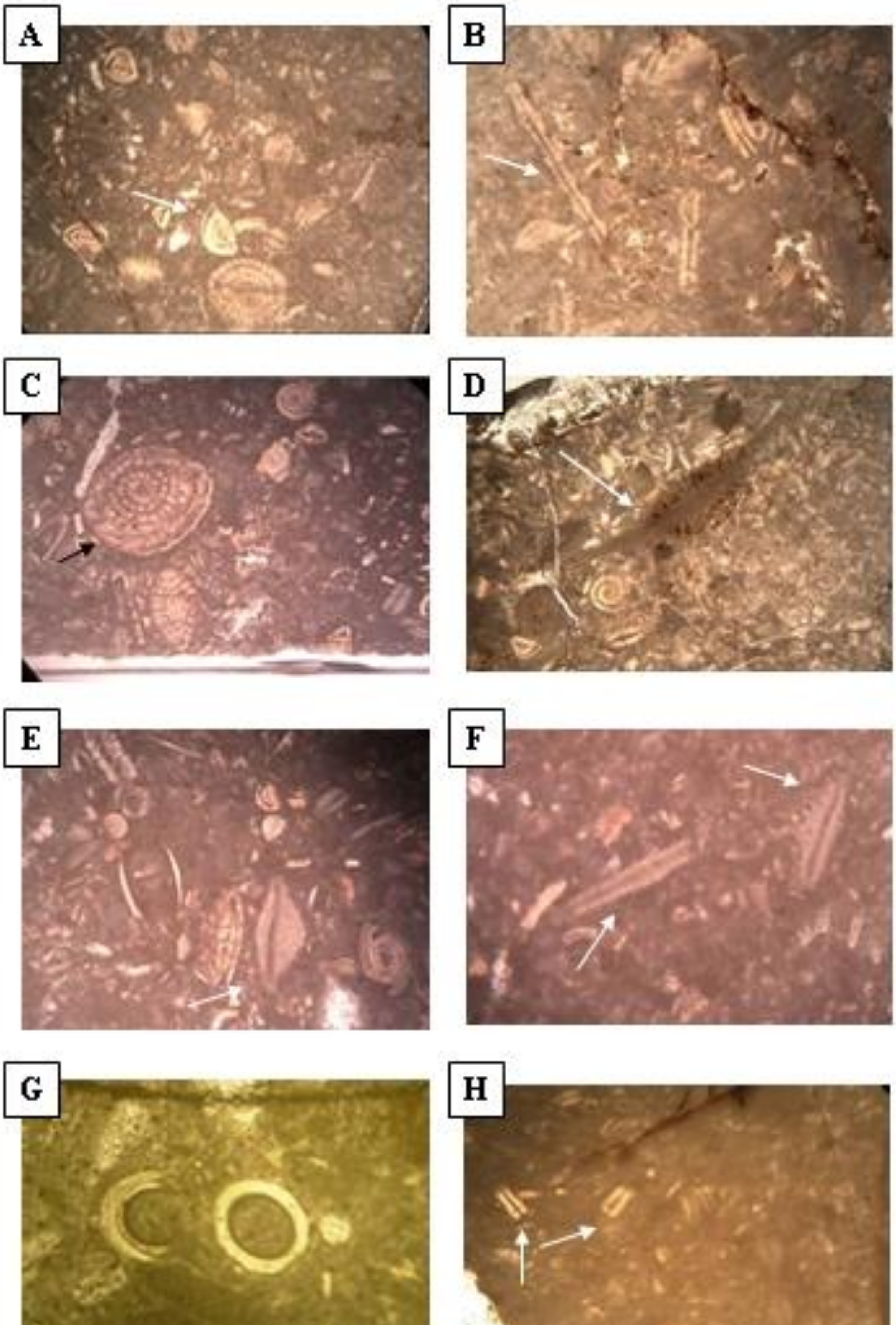


Plate (4)

A. Packstone. (a) *Nummulites intermedius*, (b)Heterostegina *assilinoides* and *(c)Dentalium cycloclpeus or Operculina alpina,* Sheikh Alas Fn. Darzila section, 20X, slide No.153.

B. Packstone. (a) *Lepidocyclina ((Nephrolepidina) marginatus*, (b) *Lepidocyclina (Eulepidina) marginata* and (c) *Heterostegina involuta*, Sheikh Alas Fn., Darzila section, 20X, slide No.153b.

C & D. Wackestone. *Heterostegina assilinoides*, Sheikh Alas Fn., Darzila section, 20X, slide No.155.

E. Wackestone. *Opreculina complanata* and *Rotalia viennoti*, Sheikh Alas Fn., Darzila section, 20X, slide No.154.

F. Pelloidal Packstone bearing *Lithophyllum sp* with *Milliolides*, Shurau Fn., Darzila section, 20X, slide no 163.

G. Pelloidal Packstone bearing *Archaias operculiniformis*, Shurau Fn., Darzila section, 20X, slide no 163.

H. Pelloidal Packstone. Echinoid spine and *Milliolides*, Shurau Fn., Darzila section, 20X, slide no 163.

Plate(4)

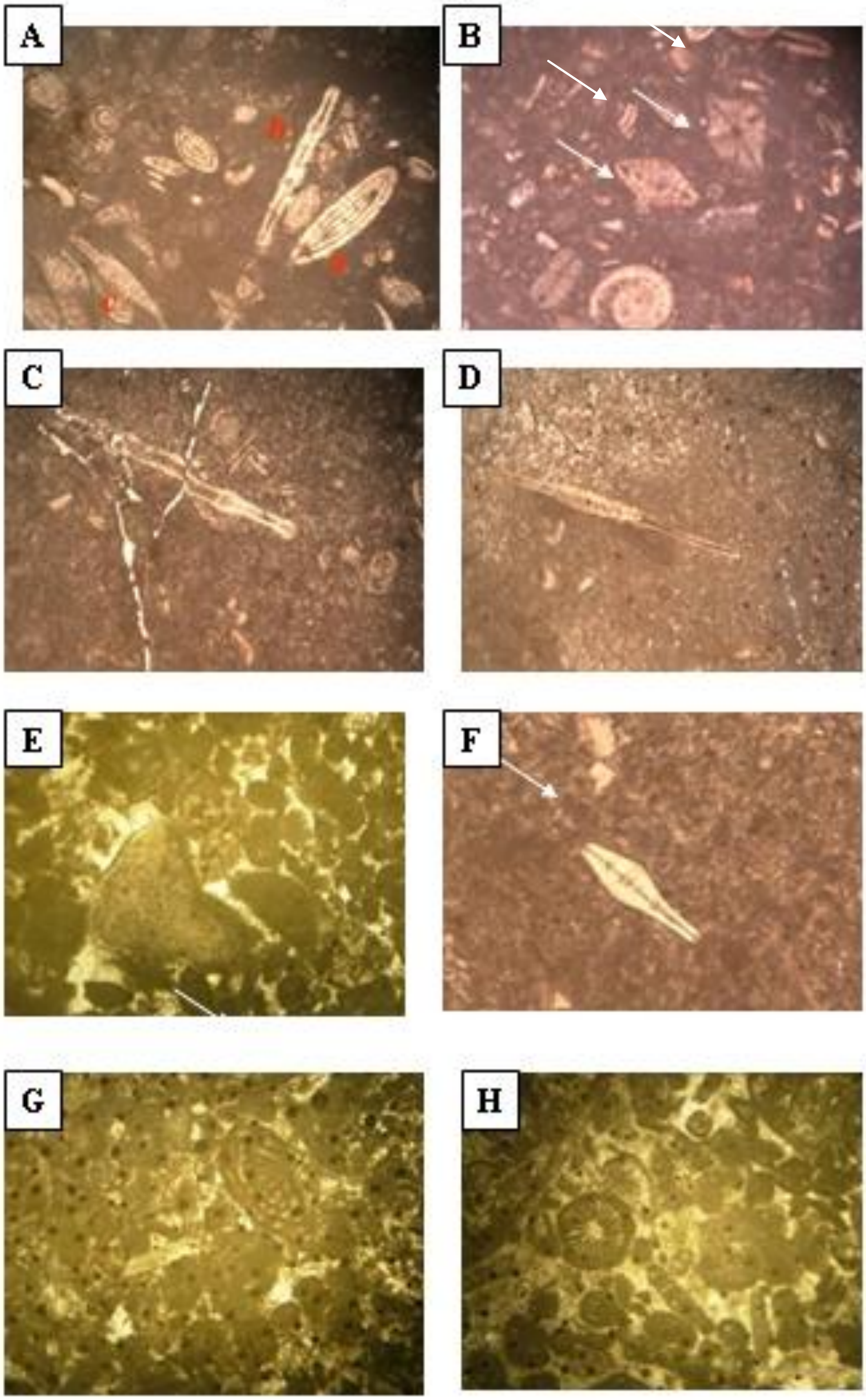


Plate (5)

A.Pellitoidal Packstone-Grainstone. *Lithophyllum sp* and *Milliolides*, Shurau Fn., Darzila section, 20X, slide No.163.

B. Packstone. Echinoid spine. Shurau Fn., Darzila section, 20X, slide No.160.

C. Wackstone-Packstone bearing Fragments of *Nummulites spp* and *Cycloclpeus* with *Subterraniphyllum thomasi,* Shurau Fn., Darzila section, 20X, slide No. 158.

D. Wackstone-Packstone. *Heterostegina assilinoides* and *Opreculina complanata*, Shurau Fn., Darzila section, 20X, slide No. 158.

E. Pellitoidal Packstone-Grainstone. *Archaias sp*, Shurau Fn., Darzila section, 20X, slide No.169.

F. Pellitoidal Packstone-Grainstone. *Peneroplis sp* and *Pyrgo sp*, Shurau Fn., Darzila section, 20X, slide No.169.

G. Pellitoidal Packstone-Grainstone. *Archaias operculiniformis*, Shurau Fn., Darzila section, 20X, slide No.171.

H. Pellitoidal Packstone-Grainstone. *Lithophyllum sp*, Shurau Fn., Darzila section, 20X, slide No.171.

Plate(5)

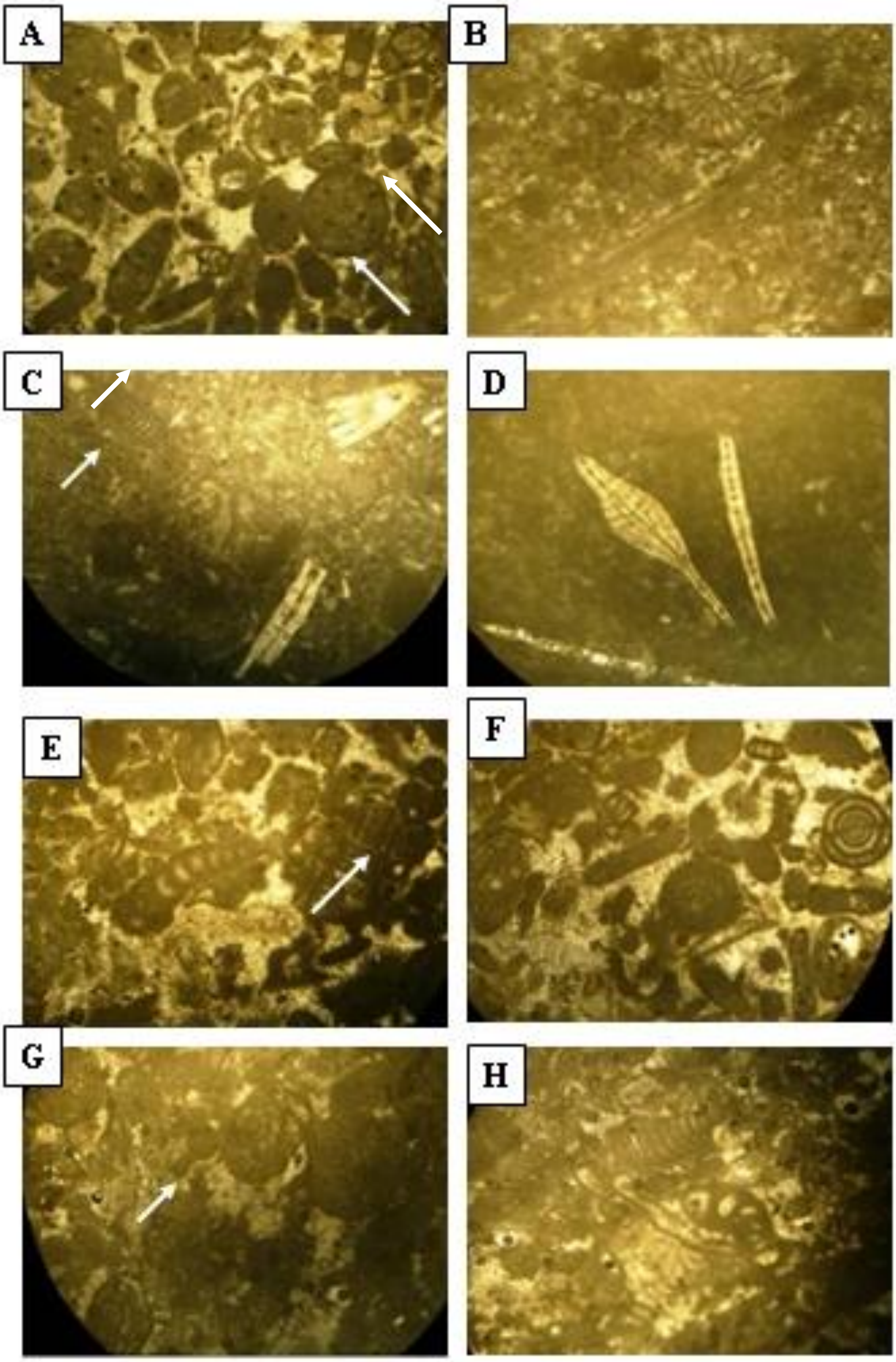


Plate (6)

A. Pellitoidal Packstone-Grainstone bearing *Praerhapydionina delicata, Archias spp, Meandropsina iranica* and *Milliolides*, Shurau Fn., Timar-Zinana section, 20X, slide No.64.

B. Pellitoidal Packstone-Grainstone bearing *Dictoplax* and *Milliolides*, Shurau Fn., Timar-Zinana section, 20X, slide No.64.

C. Pellitoidal Packstone -Grainstone bearing *Archaias sp* and *Milliolides,* Shurau Fn., Timar-Zinana section, 20X, slide No.64.

D. Pellitoidal-Packstone -Grainstone bearing *Archaias operculiniformis* and *Milliolides,* Shurau Fn., Timar-Zinana section, 20X, slide No. 064.

E. Pellitoidal Packstone-Grainstone bearing *Archaias sp* and *Milliolides,* Shurau Fn., Timar-Zinana section, 20X, slide No.064.

F. Pellitoidal Packstone-Grainstone bearing *Ditrupa sp*, *Archaias sp* and *Milliolides*, Shurau Fn., Darzila section, 20X, slide No. 165b.

G. Coral Boundstone. *Coral sp*, Shurau Fn., Darzila section, 20X, slide No.177.

H. Packstone*. Nummulites fichteli*, Baba Fn., Darzila section, 20X, slide No. 178.

Plate(6)

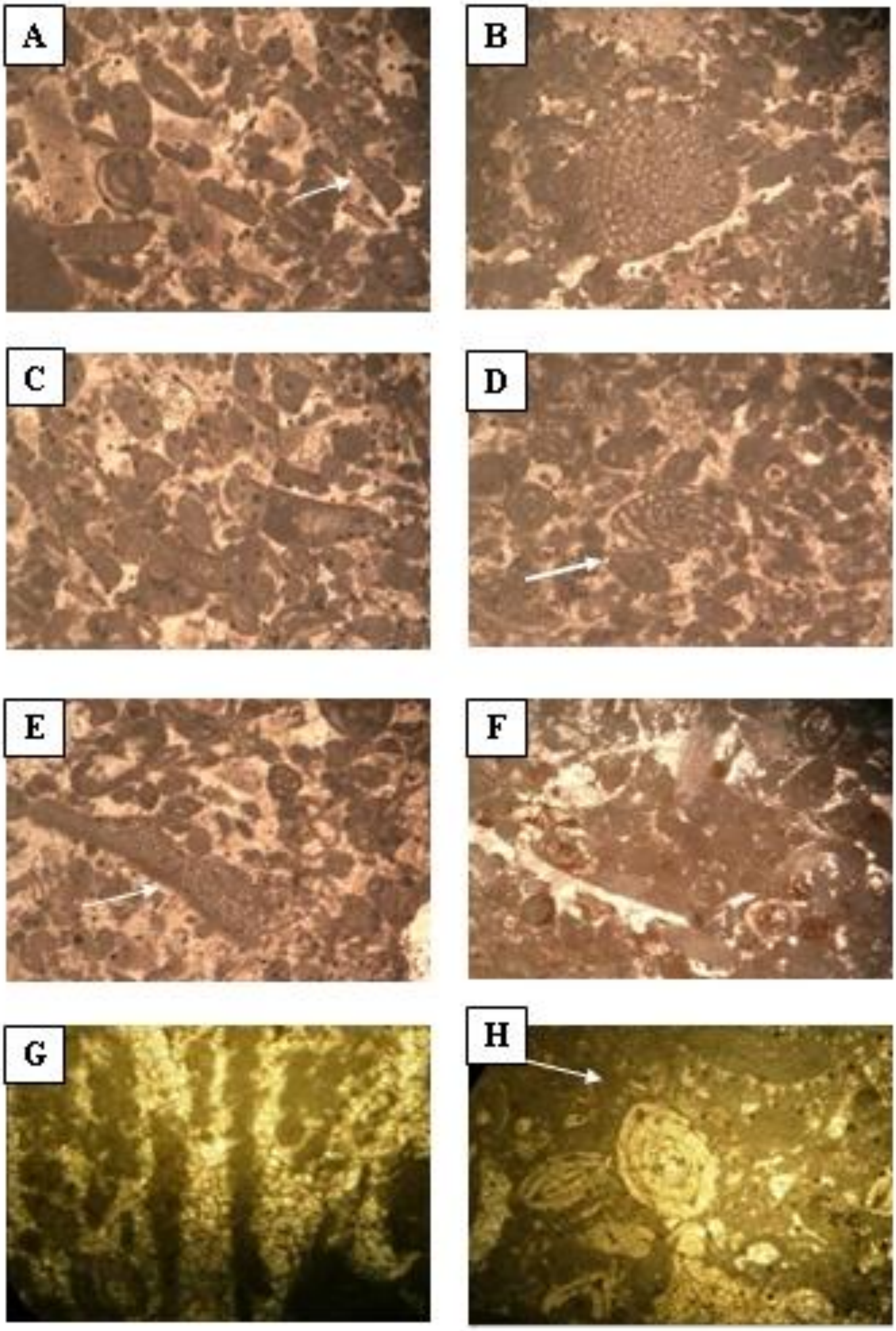


Plate (7)

A. Foraminiferal Packstone bearing *Lepidocyclina (Eulepidina) dilatata* and *Nummulites fichteli*, Baba Fn., Darzila section, 20X, slide No.154.

B. Foraminiferal Packstone bearing *Lepidocyclina (Eulephidina) dilatata, Lepidocyclina (Eulephidina) marginatus* and *Rotalia viennoti*, Baba Fn., Darzila section, 20X, slide No.181.

C. Lepidocylinic Wackestone. *Lepidocyclina sp*, Baba Fn., Darzila section, 20X, slide No.155.

D. Nummulitic Wackestone- Packstone bearing *Nummulites fichteli, Nummulites Fichteli* and *Lepidocyclina sp*, Baba Fn., Darzila section, 20X, slide No.152.

E. Packstone *Lepidocyclina sp*, Baba Fn., Darzila section, 20X, slide No.156.

F. Pelloidal Packstone bearing *Lepidocyclina (Eulepidina) dilatata*, Shurau Fn., Timar-Zinana section, 20X, slide No.062b.

G. Packstone. *Lepidocyclina sp*, Baba Fn., Darzila section, 20X, slide No.156.

H. Packstone. *Lepidocyclina (Eulephidina) ephippioides*, Baba Fn., Darzila section, 20X, slide No.154.

Plate(7)

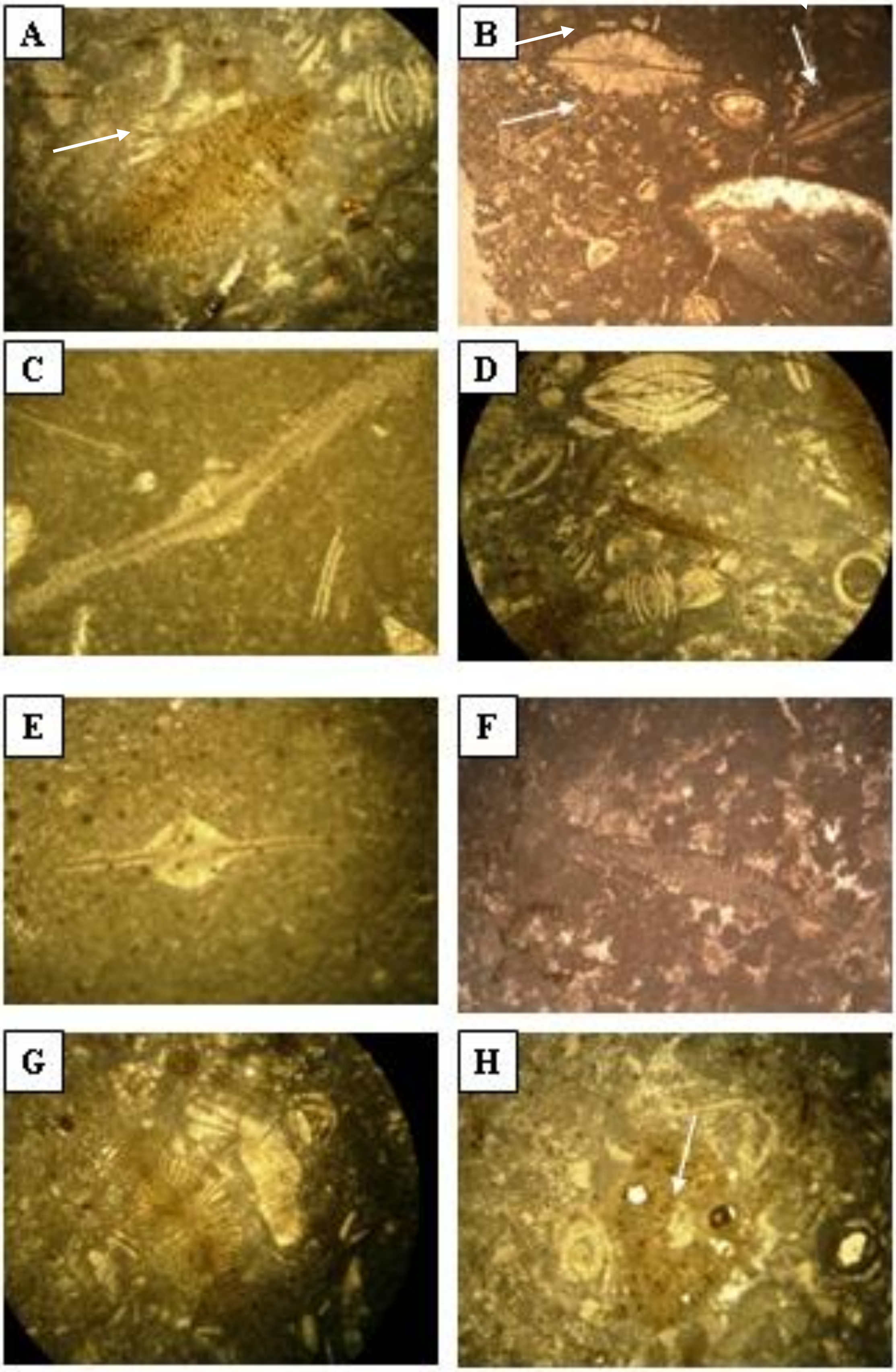


Plate (8)

A. Packstone bearing *Lepidocyclina (Eulephidina) dilatata* and *Heterostegina Sp*, Baba Fn., Darzila section, 20X, slide No.181.

B. Packstone. Lepidocyclina (*Eulephidina) dilatata* and *Nummulites vascus*, Baba Fn., Darzila section, 20X, slide No.181.

C. Packstone. *Lepidocyclina (Nephrolepidina) sp*, Baba Fn., Darzila section, 20X, slide No.181.

D. Packstone. *Lepidocyclina (Nephrolepidina) sp*, Baba Fn., Darzila section, 20X, slide No.181.

E & F. Packstone. *Asterigerina rotula (Kaufman), Amphistigina sp, Heterostigina assilinoides* and *Heterostigina precursor (Tan)*, Baba Fn., Darzila section, 20X, slide No.181.

G. *Lepidocyclina (Eulephidina) dilatata*, Baba Fn., Timar-Zinana section, 20X, slide No.55.

H. Packstone bearing *Lepidocyclina (Eulephidina) ephippioides*, Baba Fn, Darzila section, 20X, slide No.153.

Plate(8)

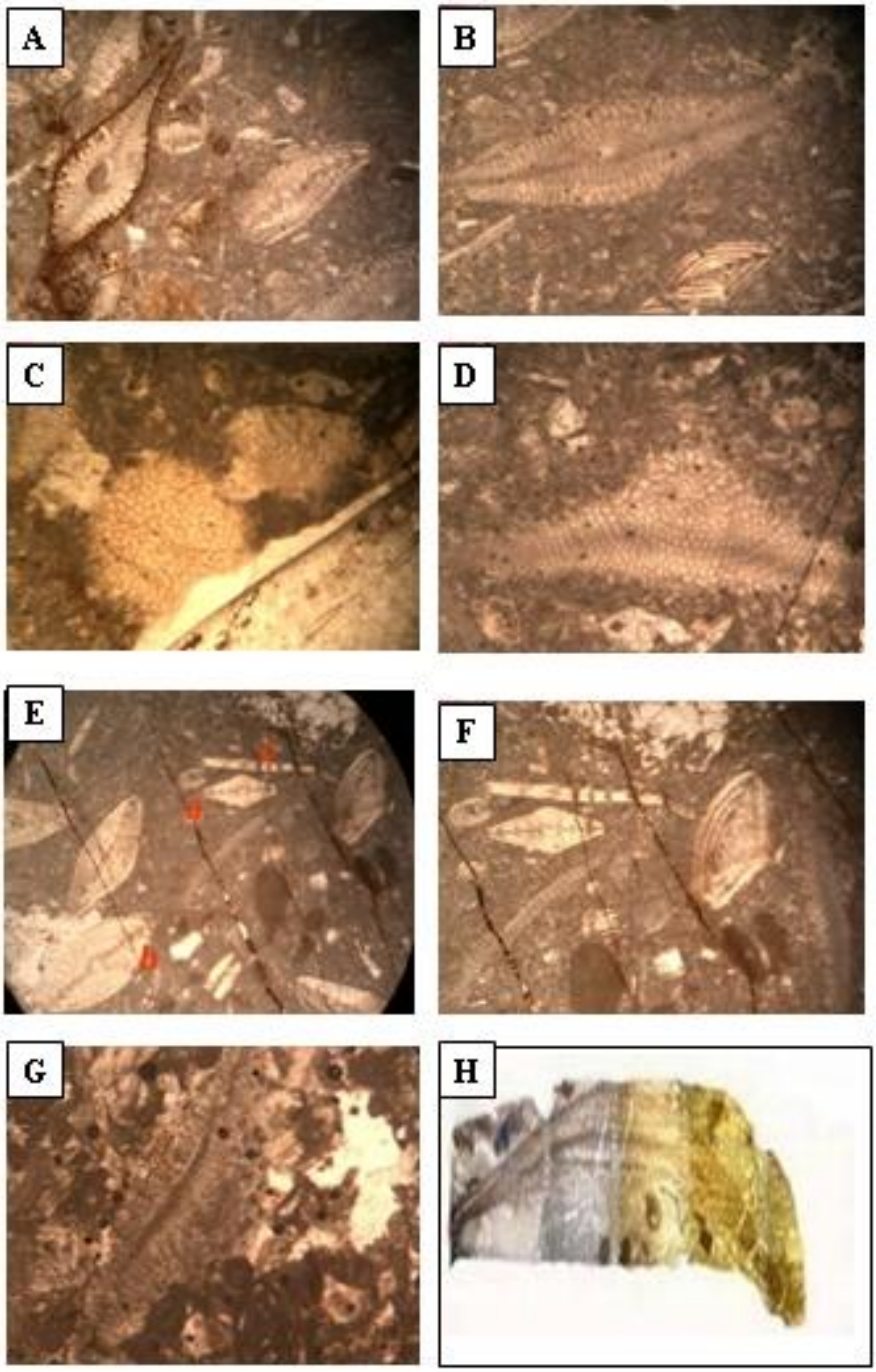


Plate (9)

A. Dolomitized Milliolidal Packstone. *Austrotrillina howchini* and*,* *Quinqueloculina sp*, Bajawan Fn., Darzila section, 20X, slide No.183.

B. Milliolidal Packstone. *Austrotrillina howchini*, Bajawan Fn., Shalaii section, 20X, slide No.2a.

C. Dolomitized Milliolidal Packstone. *Austrotrillina howchini* Bajawan Fn., Darzila section, 20X, slide No.183.

D. Wackestone .*Coral sp*, Shurau Fn., Darzila section, 20X, slide No.180.

E. Wackestone. *Meandropsina anahensis*, Bajawan Fn., Darzila section, 20X, slide No. 184.

F. Dolomitized Packstone. *Archaias kirkukensis*, Bajawan Fn., Shalaii section, 20X, slide No.1.

G. Packstone. *Dendritina rangi*, equatorial section, Bajawan Fn., Darzila section, 20X, slide No.183.

H. Packstone *Lithothamnium sp*, Bajawan Fn., Darzila section, 20X, slide No.32b.

Plate(9)

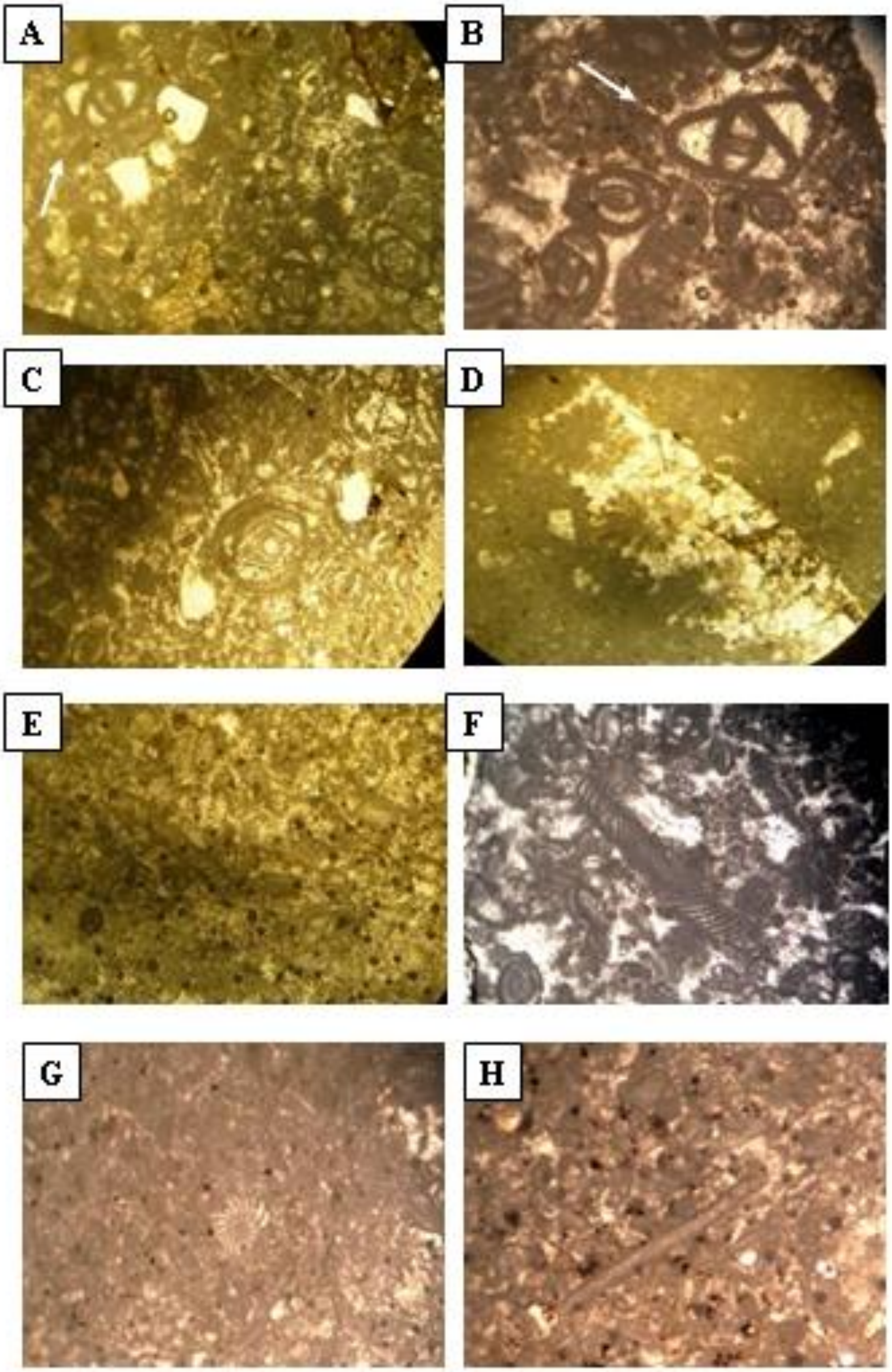


Plate (10)

A. Packstone. *Peneroplis thomasi* and *Archias sp*, Bajawan Fn., Shalaii section, 20X, slide No.2a.

B. Packstone. *Meandropsina anahensis* and *Austrotrillina sp*, Bajawan Fn., Shalaii section, 020X, slide No.2a.

C. Dolomitized Packstone. *Valvulina sp*, Bajawan Fn., Shalaii section, 20X, slide No.1.

D. Dolomitized Packstone. *Spirolina austrica, Spirolina clyindracea* and *Milliolides*, Bajawan Fn., Shalaii section, 20X, slide No.1.

E. Packstone-Wackstone. *Lithophyllum sp*, Bajawan Fn., Shalaii section, 20X, slide No.2b.

F. Packstone. *Peneroplis thomasi*, Bajawan Fn., Shalaii section, 20X, slide No.2b.

G. Packstone. *Archaias hensoni* and *Archaias sp*, Bajawan Fn., Shalaii section, 20X, slide No.2a.

H. Packstone. *Peneroplis sp* trapped within *Coral sp*, Bajawan Fn., Shalaii Section, 20X, slide No.3.

Plate(10)

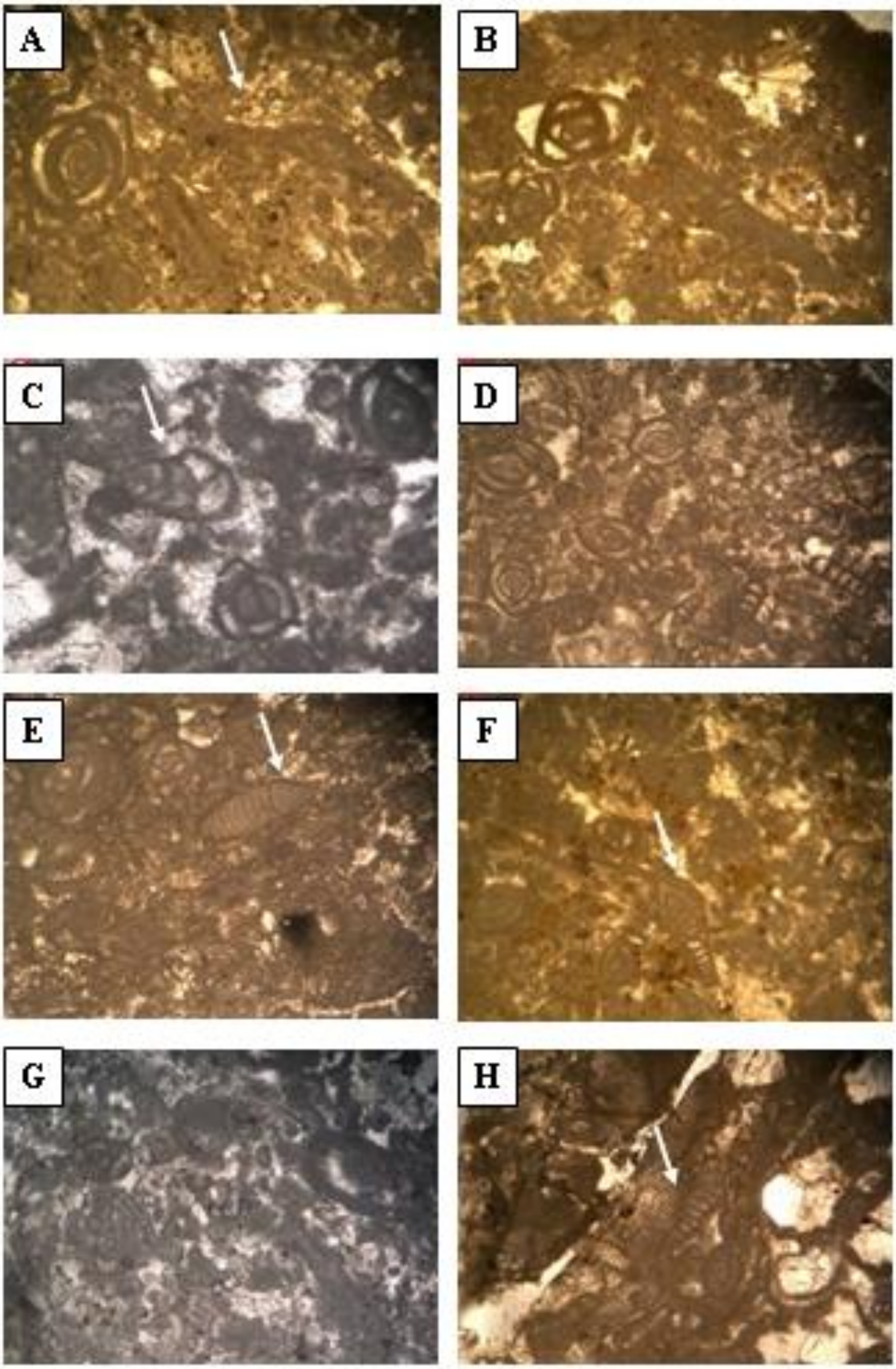


Plate (11)

A. Packstone. *Peneroplis farsensis and* Coral *sp*, Bajwan Fn., Shalaii section, 20X, slide No.003.

B. Boundstone. *Coral sp*, Bajawan Fn., Shalaii section, 20X, slide No.003.

C. Packstone, *Archaias asmaricus*, Bajawan Fn., Shalaii section, 20X, slide No.005a.

D. Milliolidae Wackestone-Packstone*, Austrotrillina asmariensis and Peneroplis evolutus*, Bajawan Fn., Shalaii section, 20X, slide No.005a.

E. Milliolidae Wackstone-Packstone, *Austrotrillina paucialveolata*, Bajawan Fn., Shalaii section, 20X, slide No.005a.

F. Milliolidae Wackstone-Packstone, *Meandropsina anahensis*, Bajawan Fn., Shalaii section, 20X, slide No.005b.

G. Milliolidae Wackstone-Packstone, *Dendritina rangi*, Bajawan Fn., Shalaii section, 20X, slide No.005b.

H. Milliolidae Packstone. *Heterillina hensoni*, Bajawan Fn., Shalaii section, 20X, slide No.006b.

Plate(11)

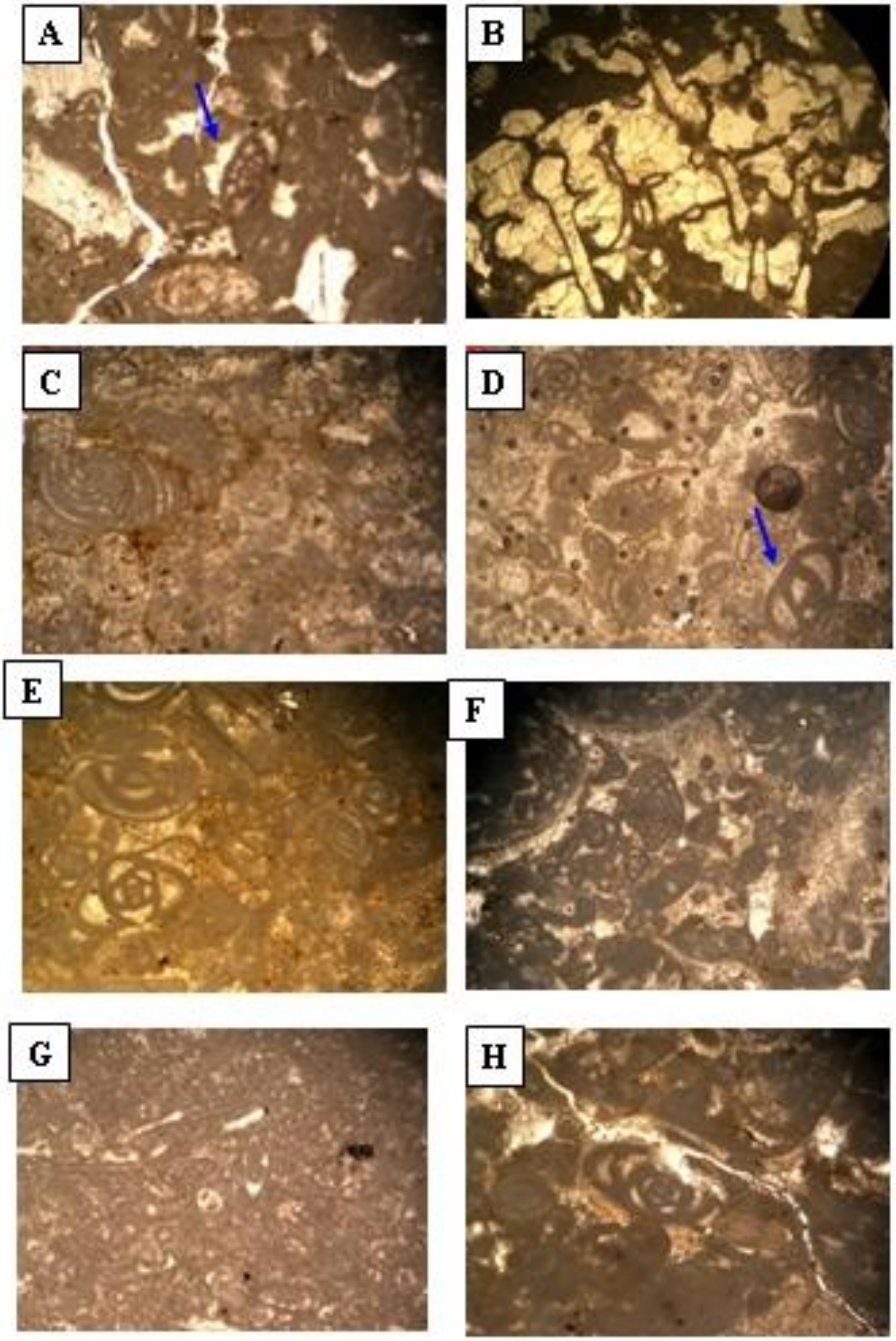


Plate (12)

A. Milliolidae Wackestone-Packstone, *Austrotrillina sp* and *Spirolina austrica*, Bajawan Fn, Shalaii section, 20X, slide No.5a.

B. Milliolidae Wackestone-Packstone, *Peneroplis thomasi* and *Quinqueloculina sp* , Bajawan Fn, Shalaii section, 20X, slide No.5b.

C. Packstone. *Austrotrillina sp, Peneroplis thomasi* and *Peneroplis evolutus*, Bajawan Fn., Shalaii section, 20X, slide No.7.

D. Pelecepod and Gastropods within the Bioclastic Wackstone rich with organic matter, Bajawan Fn., Timar-Zinana section, 20X, slide No.55.

E. Pelloidal Packstone. *Meandropsina anahensis and Rotalia viennoti*, Bajawan Fn., Timar-Zinana section, 20X, slide No.55.

F. Pellitoidal Packstone. *Rotalia vienoti*, Bajawan Fn., Timar-Zinana section, 20X, slide No.55.

G. Pellitoidal Packstone. *Sorites sp*, Bajawan Fn., Timar-Zinana section, 20X, slide No.55.

H. Pellitoidal Packstone. *Austrotrillina howchini*, Bajawan Fn., Timar-Zinana section, 20X, slide No.55.

Plate(12)

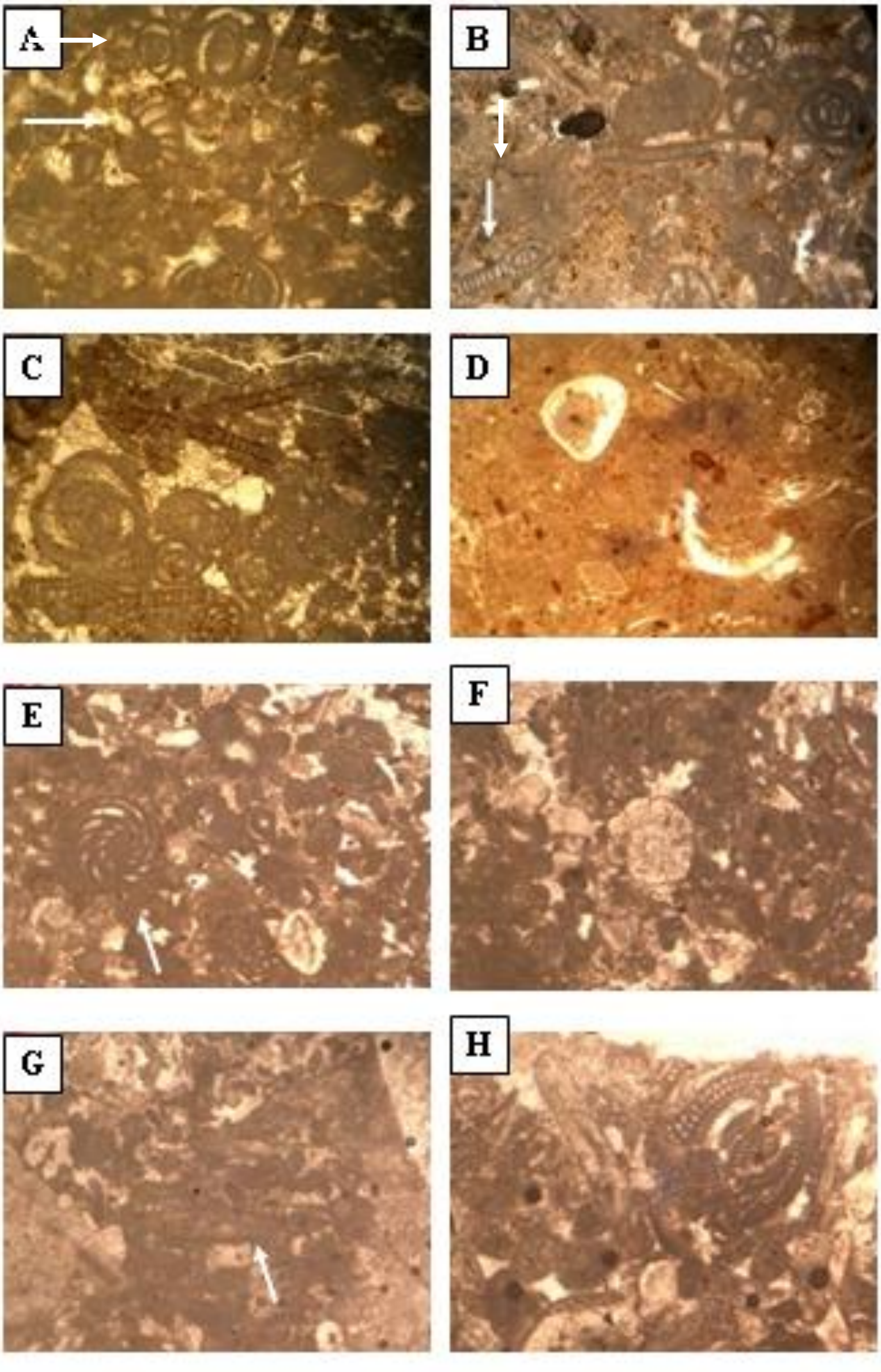


Plate (13)

A. Pellitoidal Packstone. *Austrotrillina paucialveolata and Rotalia viennoti,* Bajawan Fn., Timar-Zinana Fn., 20X, slide No.055.

B. Pelecepod fragments and Milliolides within the Pellitoidal Packstone., Bajawan Fn., Timar-Zinana section, 20X, slide No.058.

C. Pellitoidal Packstone. Pelecepod shell fragments, Bajawan Fn., Timar-Zinana section, 20X, slide No.059.

D. Pellitoidal Wackestone. Broken *Nummulites intermedius* as a result of dissolution, Shurau Fn., Timar-Zinana section, 20X, slide No.62b.

E. Pellitoidal Packstone. *Lithophyllum*, Shurau Fn., Timar-Zinana section, 20X, slide No.62b.

F. Wackestone- Packstone. *Praerhapydionina delicata*, Anah Fn., Hazar Kani section, 20X, slide No.083a.

G. Wackestone- Packstone. Pelecepod shell, Anah Fn., Hazar Kani section, 20X, slide No.084.

H. Packstone. *Lithothamnium sp*, Anah Fn., Hazar Kani section, 20X, slide No.051.

Plate(13)

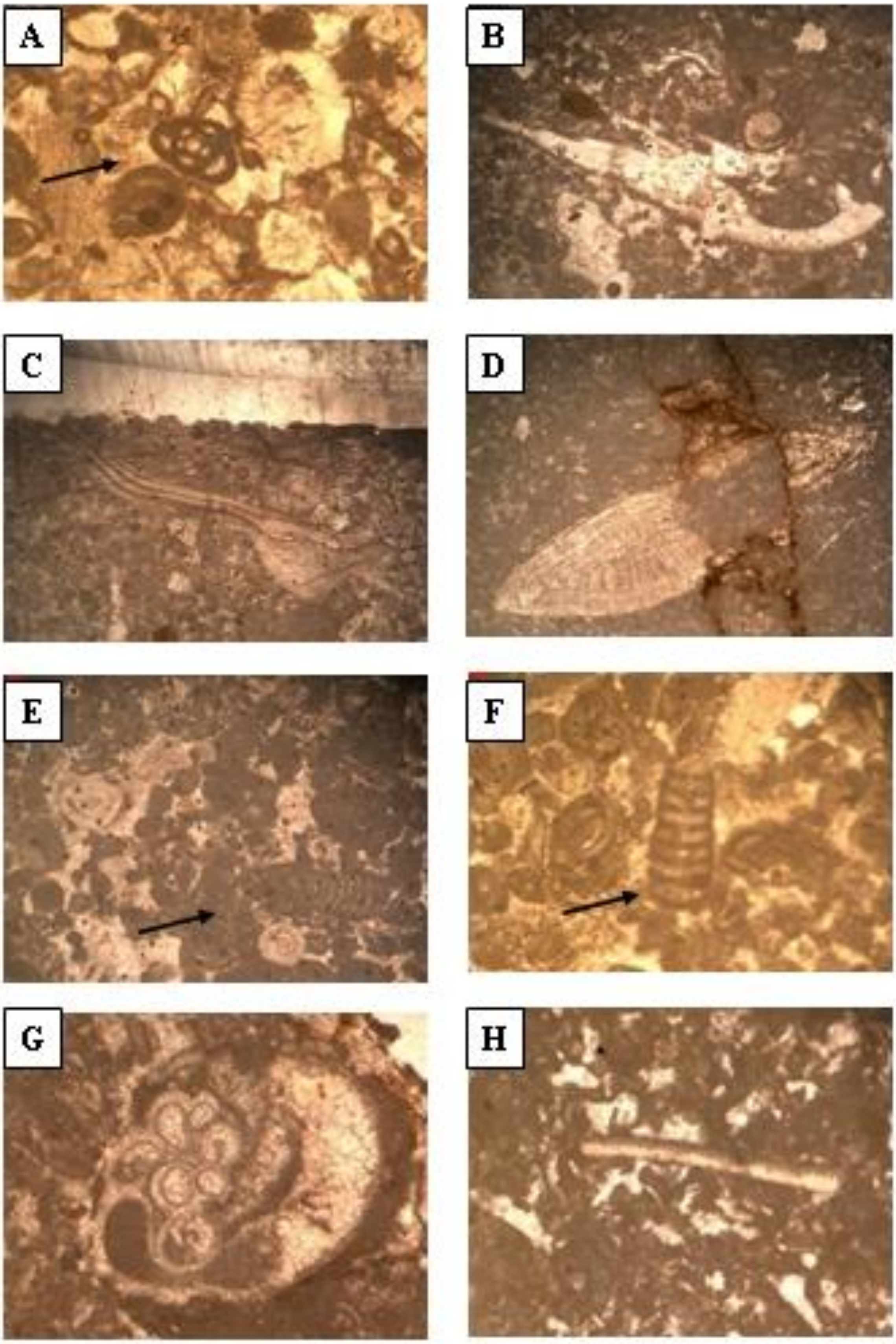


Plate (14)

A. Pellitoidal Wackestone-Packstone bearing *Borelis melo curdica and Milliolides*, possible Jeribi Fn., Timar-Zinana section, 20X, slide No.064.

B. Milliolidal Wackstone. *Ophthalmidium*, Bajawan Fn., Timar-Zinana section, 20X, slide No.065.

C. Milliolide Wackestone*. Unknown sp*, Bajawan Fn., Timar-Zinana section, 20X, slide No.065.

D. Pellitoidal Wackestone. *Articulina*, Bajawan Fn., Timar-Zinana section, 20X, slide No.65.

E. Pellitoidal Wackestone. *Textularia*, Bajawan Fn., Timar-Zinana section, 20X, slide No.65.

F. Milliolide Wackestone. *Mesophyllum*, Bajawan Fn., Timar-Zinana section, 20X, slide No.65.

G. Wackestone- Packstone. *Dendritina rangi and Ophthalmidium*, Bajawan- Anah Formations., Hazar Kani section, 20X, slide No.49.

H. (Intraclast) aggregate of redeposited grains composed of different skeletal and non skeletal grains, Anah Fn., Hazar Kani section, 20X, slide No.46.

Plate(14)

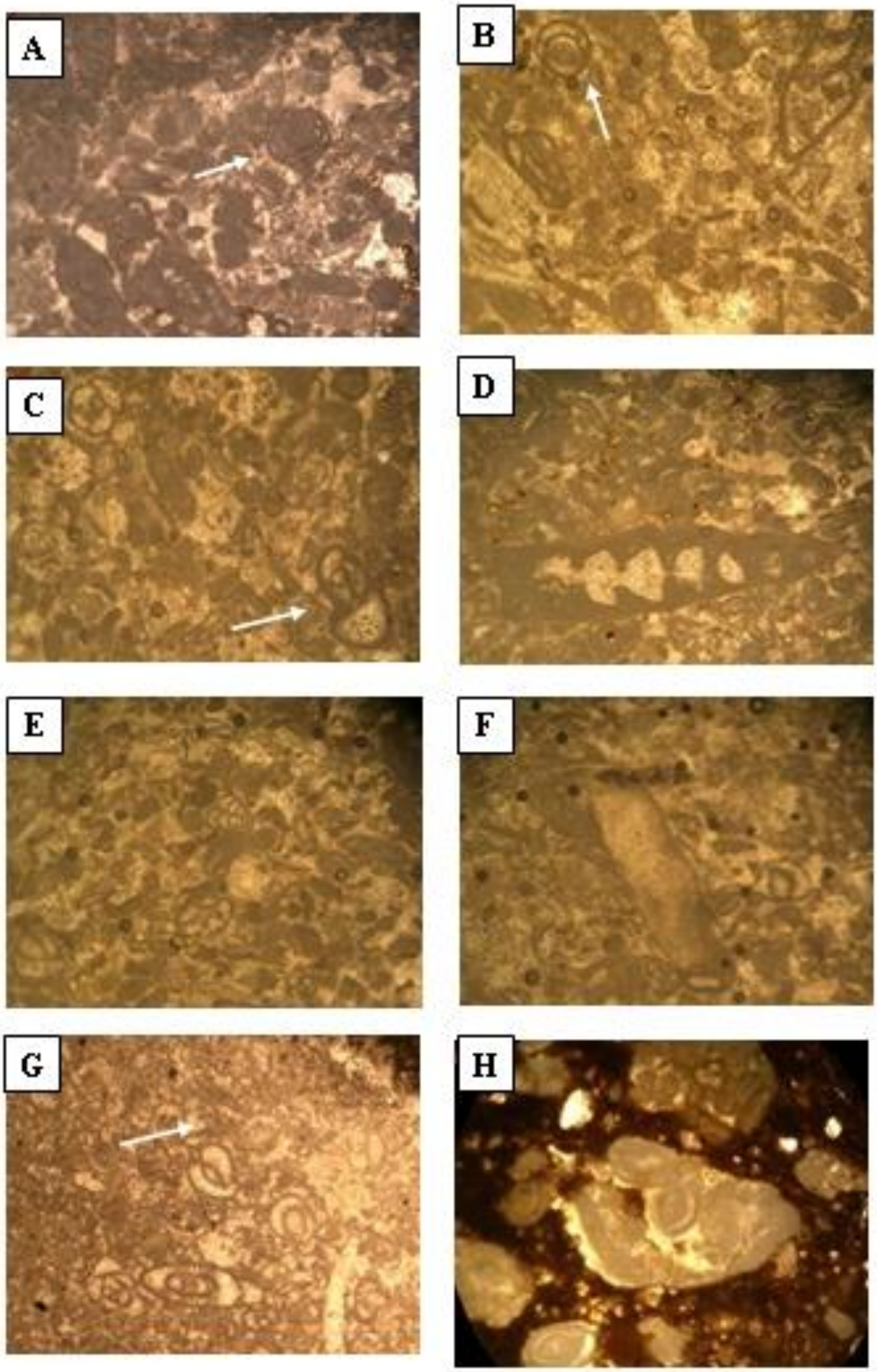


Plate (15)

A. Wackestone- Packstone. *Meandropsina anahensis*, Anah Fn., Hazar Kani section, 20X, slide No.084b.

B. Wackestone- Packstone. *Meandropsina anahensis and Peneroplis evolutus*, Anah Fn., Hazar Kani section, 20X, slide No.084a.

C. Packstone. *Austrotrillina sp, Meandropsina and anahensis*, Anah Fn., Hazar Kani section, 20X, slide No.084a.

D. Wackestone-Packstone. *Peneroplis evolutus*, Bajawan Fn., Hazar Kani section, 20X, slide No.42.

E. Wackestone-Packstone. *Peneroplis proteus, Peneroplis evolutus and Austrotrillina sp*, Anah or Bajawan Fn., Hazar Kani section, 20X, slide No. 45.

F. Wackestone- Packstone. *Peneroplis evolutus*, Bajawan Fn., Hazar Kani section, 20X, slide No. 084a.

G. Boundstone. *Coral sp*, Bajawan Fn., Hazar Kani section, 20X, slide No.044.

H. Wackestone with calcite precipitation. *Peneroplis evolutus*, Bajawan Fn., Hazar Kani section, 20X, slide No. 44.

Plate(15)

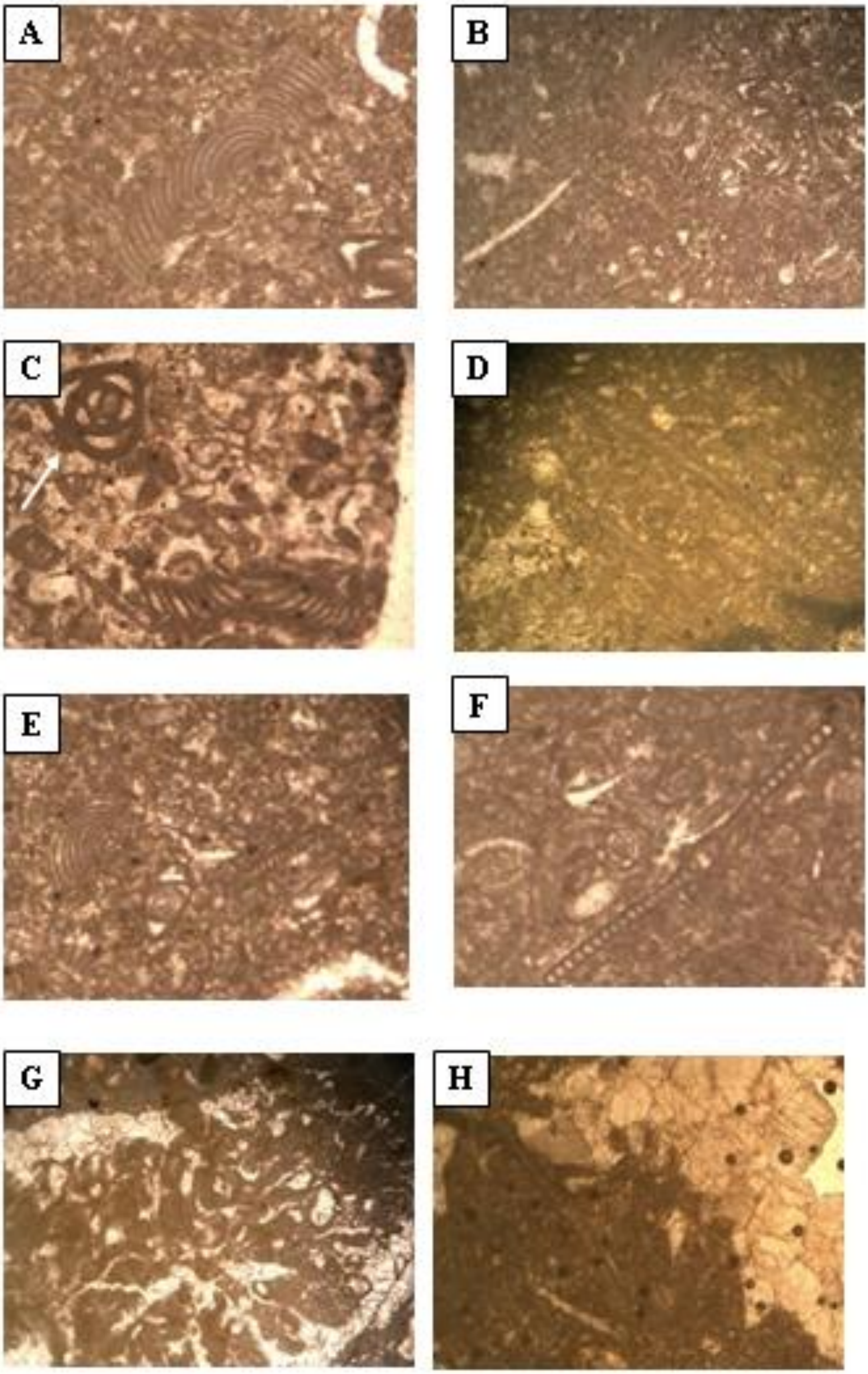


Plate (16)

A. Wackestone- Packstone. *Praerhapydionina delicata, Austrotrillina asmariensis and Archaias spp*. Anah- Bajawan Fn., Hazar Kani section, 20X, slide No.083a.

B. Wackestone- Packstone. *Peneroplis thomasi, Archaias hensoni, Austrotrillina howchini, Quinqueloculina and Ophtalmidium*. Anah Fn., Hazar Kani section, 20X, slide No.083a.

C. Wackestone- Packstone. *Archaias operculiniformis, Spiroloculina, Quinqueloculina and Ophtalmidium*. Anah Fn., Hazar Kani section, 20X, slide No.083b.

D. Wackestone- Packstone. *Dendritina rangi, Peneroplis evolutus* and *Lithothamnium sp*, Anah Fn., Hazar Kani section, 20X, slide No.050.

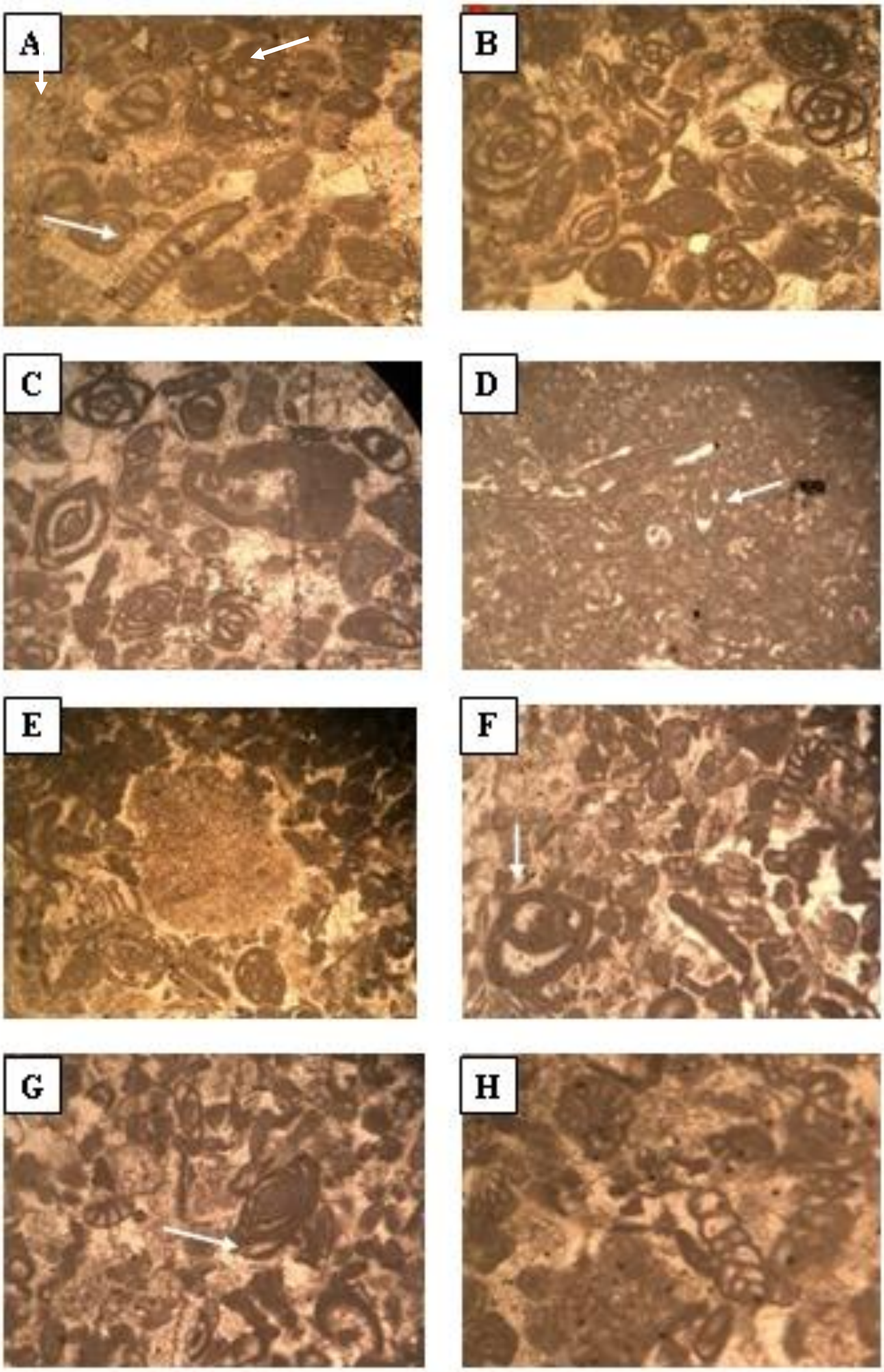
E. Packstone. *Sphaerogypsina and Archaias sp*. Anah Fn., Hazar Kani section, 20X, slide No.083b.

F. Packstone. *Spirolina, Austrotrillina asmariensis and Milliolide* spp. Anah Fn., Hazar Kani section, 20X, slide No. 084a.

G. Packstone. *Archaias sp* Anah Fn., Hazar Kani section, 20X, slide No.84b.

H. Packstone. *Bigenerina sp*. Anah Fn., Hazar Kani section, 20X, slide No.084b.

Plate(16)



Chapter four
Facies analysis and sequence stratigraphy

4.1 preface:

Sequence stratigraphy is defined by Posamentier et al, (1988): Van Wagoner, (1995) as the study of rock relationships within a time-stratigraphic framework of repetitive, genetically related strata bounded by surface of erosion or non deposition, or their correlative conformities. It is also defined by Embery, (2001 in Catuneanu, 2006) as the recognition and correlation of stratigraphic surface which represent changes in depositional trends in sedimentary rocks. Such changes were generated by the interplay of sedimentation, erosion and oscillating base level and are now determined by sedimentological analysis and geometric relationships.

From the above definition, it is shown that there is a relation and interaction between rock and time; that is:

1. Rock as a substance which physically, chemically and /or biologically deposits in a sedimentary basin (accommodation space), whereas its geometry, expansion depth and source of material are related to the type of sediments and sedimentary rocks.

2. Time or Chronostratigraphy: it includes the succession of events that originated during the time of sediment production and their impact on the accommodation space, type of sediments, sediment thickness, parasequence sets and stacking patterns. Those events include climate, eustatic sea level change and subsidence.

a. Temperature or Climate: it comprises raining, glaciations, flooding and temperature; change in the orbital characteristics and its geometry has a role in the variation of earth temperature (dissolution and freezing of ice poles) which in turn, affects on the falling and rising of sea level because such changes are influencing the distribution and amount of solar energy.

b. Tectonic subsidence is controlled and affected by stretching, cooling and loading.

Zachos et al (2001) considered that much of the higher frequency change in climate (10^4 to 10^5 years) is generated by periodic and quasi-periodic oscillation in Earth's orbital parameters of eccentricity, obliquity and precession that affect the distribution and amount of incident solar energy.

c. Eustatic sea level change resulted from variation in the volume of ocean basins or of within those basins. The volume of ocean basin is controlled by the rate of sea floor spreading and sedimentation in the ocean basin, while the volume of sea water is controlled by glaciations and Ocean). Accommodation space and sediment flux are generally regarded as the two major control factors affecting on the development of depositional sequences, their stacking patterns and component stratal units (Schlager, 1993; Leader1994 in Emery and Mayers.1996).

Tectonically driven events triggered a major shift in the dynamics of the global climate system and of course they had a great effect on sequence stratigraphy of the sedimentary basins of the Earth (Zachos et al, 2001).

Within these global changes, if one returns to the Arabian plate and Iraq, the latest Eocene –Recent Megasequence in Iraq was associated with the collision of Neotethys ocean along the North and East sides of the Arabian plate, and the opening of the gulf of

Aden and the Red sea on the South and west sides of the plate (Jassim and Goff, 2006).

The opening of the Red sea and Gulf of Aden was associated with thermal uplift, flood basalt and rifting (Jassim and Goff, 2006). The Gulf of Aden was opened first in Oligocene time followed by the Red sea in the Early Miocene (Markis and Hence, 1992, Hughs and Baydoun, 1992 in Jassim and Goff, 2006).

4.2 Eustacy and stratal units considered by sequence stratigraphy:

Previously, mentioned the factors leading to change in the eustatic sea level (such as variation in the volume of ocean basins, which is controlled by the rate of sea floor spreading and sedimentation in the ocean basins). This variation has an important role in the determination of the thickness of the deposited stratal units, their patterns and their cyclic nature (they are related to tectonism; that is uplift and falling) as illustrated in (table 4.1).

The thickness of these stratal units is classified as:

Table (4.1): Relation between Stratal units and Eustacy (after Vail et al, 1977a).

Stratal units		Thickness (m)	Time span	Order of Cyclicity	Type of curves	Controlled by
1	**Mega sequence**	≥ 1000 m	>50 Ma	First	Smooth long term	Tectono-Eustacy
2	**super sequence**	≥ 400 m	3-50 Ma	Second	Long term	Change in the rate of tectonic subsidence
3	**sequence**	10-400 m	0.5-3 Ma	Third	Smooth short term	Glacio-Eustacy
4	**Para sequence**	10^{th} of meter	0.1-0.5 Ma	Fourth	Short term	Autocyclic process

Based on Ditmar et al (1971), the Oligocene rock units in Iraq are subdivided into two sequences: lower and upper sequences (Sequence can be defined as relatively conformable (that is, containing no major unconformities) genetically related succession of strata (bed or bed set) bounded by unconformities or their correlative conformities. According to the above classification of stratal units, the exposed Oligocene rock units within the studied area can be classified as:

A. Lower sequence: it includes Shurau and Sheikh Alas Formations. More than 50 meters of carbonate sediment deposited in nearly 5.2 million of years (33.7-28.5 Ma).

B. Upper sequence: it includes Baba, Bajawan and Anah Formations, they are located at this cycle of sequence; more than 20m of sediments were deposited which took a span of time 4.8 million of years (28.5-23.7 ma). Both sequences are related to the third order cyclicity and it is controlled by Glacio-Eustacy; “Brun, Chierci et al (1984) studied the fossils of West Africa basins; they reported that Oligocene species are very rare and geographically scattered because of sediment hiatus in these different basins. This hiatus is related to Glacio-eustatic movements which affected the whole West-African continental margin during the Late Eocene and Oligocene".

Jassim and Goff, (2006) thought that the latest Eocene-Recent deposits are considered as Megasequence (AP11). They also subdivided this Megasequence into three sequences:

a. Latest Eocene-Oligocene sequence.
b. Early-Middle Miocene Sequence.
c. Late Miocene-Recent sequence.

The Oligocene basin accentuated in a relatively stable tectonic situation (with consideration of small local tectonism); subsidence rate in Oligocene to Early Miocene time was relatively low, the Mesopotamian basin became narrower and shallower as the western part of Arabia was thermally uplifted (Jassim and Goff, op cit.); The Eocene-Oligocene deformation was weak or absent in the Sinjar trough and the Syrian arc (Kazmin, 2002).

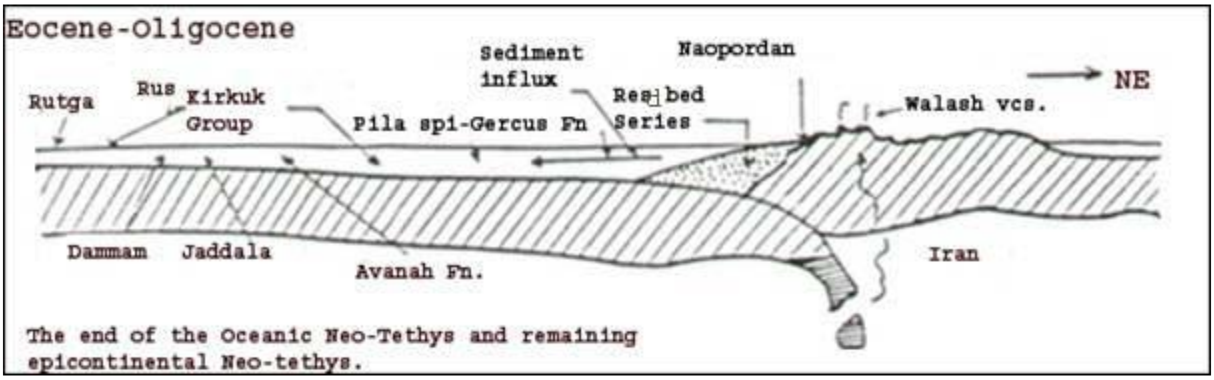


Fig (4.1): The Cenozoic plate tectonic scenario (Eocene-Oligocene) for Iraq; Collisional set-up, platform, marginal basin and molasses basin (after Numan, 1998).

From figure (4.1), it is shown that the Oligocene basin is less affected by tectonism of Zagros tectonic activity. During the Oligocene time, a carbonate reef system was formed and occupied a restricted area and it terminated in the Early Middle Miocene; "In the Late Eocene, shallow-marine carbonates prograded simultaneously from the SE and NW. This bidirectional progradation led to rapid narrowing and final closure of the Mesopotamian basin. Since the Oligocene, the remnant basin was filled with evaporites and siliciclstics derived from the Zagros. Thick siliciclstics with evaporites caps may form stratigraphic traps for oil/gas migrated from the Mesozoic source rocks (Liu and Mitchell, 2006)".

The initial stage of Oligocene reef started after a long period of erosion, subaerial exposure or non deposition of Pila Spi Formation.

Consequently, a first portion of the reef (antecedent surface) generated; sedimentation was initially dominated by reefal carbonates of Kirkuk and Asmari Formations which fringed the rapidly narrowing foredeep basin on both the stable platform (to the southwest) and the emerging Zagros structures (Sharland, 2001).

(Al Qayim 2006) proposed that the lower sequence (Lower Oligocene) developed after a long period of subaerial exposure and erosion accompanied by an unconformable lower contact. He also mentioned that the Early stage of reef nucleation and zonation into the associated facies represent the transgression system tract (TST), This trough (Mesopotamian Basin) broadens in the Upper Cretaceous and narrows again in the Paleogene, becoming the foredeep basin to the Zagros Fold belt in the Miocene (Abreu et al, 2006).

The Oligocene Basin was somehow an isolated platform. Or Sag-interior Oligocene basin (Al Qayim 2006) and its facies represent platform facies (Al Mashhadani 1986).The Oligocene (Rupelian to Chattian); this time period spanned the deposition of the Pabdeh-Chilou (Palani) Formations (Iran, Iraq) and their regional equivalents. A major unconformity and sedimentary hiatus (base of AP11 dated at 34 Ma) affected much of the Arabian Plate (Ziegler, 2001).

Generally the Oligocene basin of Iraq represents an isolated platform inside a carbonate ramp; this basin is a remnant part of Neotethys formed as a result of closing of Neotethys Ocean due to convergining of the Arabian and Iranian plates which formed such a restricted basin. Amirshahkarami et al., (2007) studied the sedimentary facies and sequence stratigraphy of the Asmari Formation (Upper Oligocene-Miocene) at Chaman-Bolbol, Zagros basin, Iran; they reported that Asmari Formation represents sedimentation on a carbonate ramp “the age of Asmari Formation is reassessed to Late Oligocene by Laursen et al (2006)". Platform is defined as an informal term used for all major shallow-water carbonate succession, including ramps, rim and rimmed shelves, and isolated build ups, particularly where these can not immediately be assigned to one or single one of these categories (Burchette and Wright, 1992). They also divided carbonate platform in to 4 parts: inner ramp, mid ramp, outer ramp and Basin (fig 4.2).

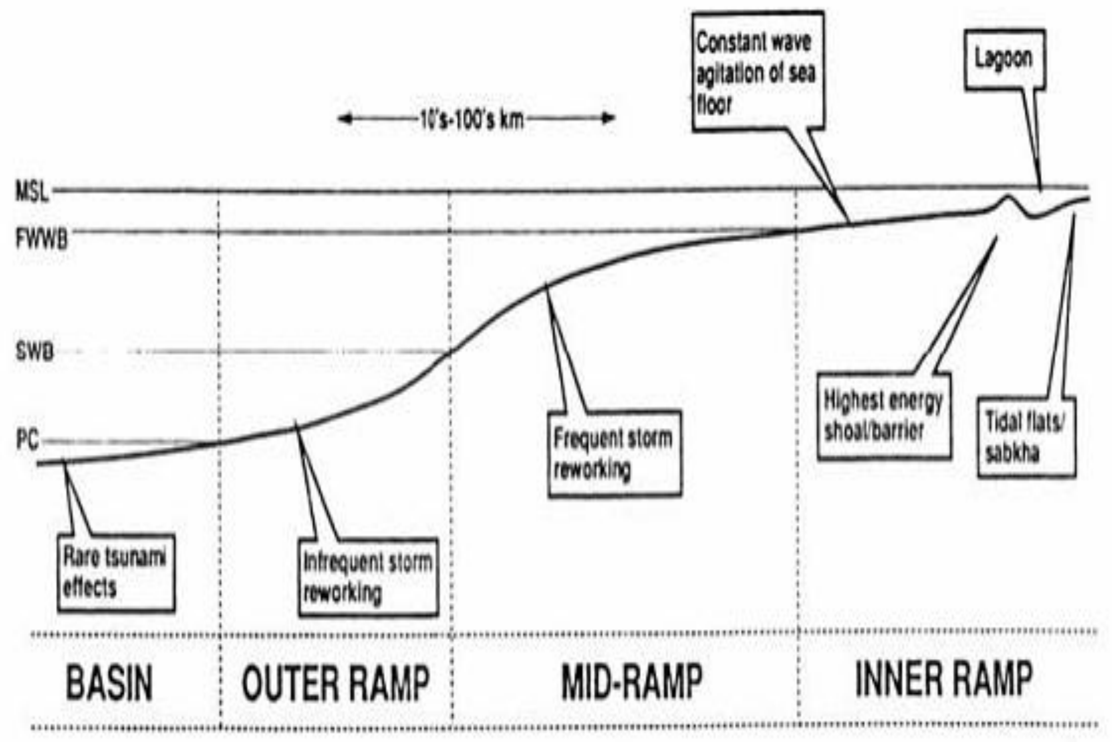


Fig (4.2): The main environmental subdivisions of a "homoclinal" carbonate ramp. *MSL*= mean sea level; *FWWB*= fair-weather wave base; *SWB*; storm wave base; *PC*; pyrocline= (not always identifiable in the rock record). Water depths corresponding to these boundaries are variable (after Burchette and Wright, 1992).

Based on the above classification, the Oligocene basin of the studied area is considered to be inside a platform, this platform included an Inner-Mid ramp in the Foreland basin, and the sediments were deposited in shallow water environment .The inner ramp was a supply source of carbonate sediments production; the inner ramp, sea ward of the beach and barrier facies, is an efficient″ carbonate factory″, providing carbonate for both back-barrier region and the outer, deeper ramp (Einsele, 2000).

4.3 Microfacies

Because Microfacies is complementary with sequence stratigraphy and it is important for determining the stacking patterns, facies change is important for specifying shallowing or deepening of the basin. Based on Emery and Klovan (1971in Brook, 2005), the main Microfacies of the studied area are classified as following:

Table (4.2): the main Microfacies of the studied units:

Age	Formation	Microfacies	Facies	Section
Late Oligocene	Anah Fn.	Rubbly, conglomeratic (reef Patches) and Milliolidae Wackestone.	**Back-reef**	Hazar Kani section
Middle Oligocene	Bajawan Fn. ------------- Baba Fn.	Pellitoidal-Glauconitic Wackestone Milliolidae Wackestone. Mudstone. Pellitoidal dolomitized Mudstone. Coral-Algal Milliolidae Packstone. Wackestone. Dolomitized Packstone. Algal- Milliolidae Packstone. Coral- Boundstone. Milliolidae Packstone. Bioclastic Packstone.	**Back-reef**	Shalaii section
		Nummulitic-Lepidocyclinae Packstone.	**Fore-reef**	Darzila section
Unconformity or Sequence boundary; Chert, Iron Oxide and Glauconite				
Early Oligocene	Shurau Fn. ------------- Sheikh Alas Fn.	Fossiliferous- Algal Packstone. Dolomitized Wackestone-Packstone. Milliolidae- Pellitoidal Wackestone. Mudstone. Milliolidae- Pellitoidal (Bioclastic)Packstone - Grainstone. Nummulitic-Pellitoidal Wackestone.	**Back-reef**	Darzila section
		Nummulitic Wackestone- Packstone. Wackestone. Nummulitic Wackestone. Packstone-Wackestone. Fragmented foraminiferal Packstone.	**Fore-reef**	Darzila section

To compare the Microfacies of the studied area with the ramp microfacies, the following model for Microfacies of ramp is shown which is preferred by Brandely and Krause (1996) in table (4.3):

Table (4.3): General Microfacies of Ramp (after Brandely and Krause, 1996):

Outer Ramp		**Mid Ramp**			**Inner Ramp**	
Slope	Open Marine	Bank and Shoal			Shallow Subtidal	Sabkha
1. Shaly whole fossil Limestone. 2. Cherty lime Wackestone.	1. Dark Argillaceous Bioclastic Limestone. 2. Dark Microbial Limestone.	1. Cross-Bedded Bioclastic Packstone. 2. Lenticular Mudstone to Wackestone.	1.Pelmatozoan Packstone. 2. Lenticular Mudstone to Wackestone	1. Ooid Grainstone	1. Dolo-Mudstone. 2. Ostracod – Calcisphere Limestone. 2. Intraclast-Peloid Limestone.	Dolo-Mudstone with Anhydrite

From tables (4.2) and (4.3), it is obvious that the Microfacies of the studied area is compatible with the general microfacies of ramp system especially Mid-Inner Ramp Microfacies; Detailed Microfacies analysis and Paleoecological study of the Oligocene succession of Western Iraq suggested a ramp like setting inherited from the low gradient Late Eocene basin (Al- Twaijri , 2000).

Werner (1992), claimed that inner-ramp deposits consist mostly of oolitic or bioclastic components. These components build shoals, barriers, and back-barrier sediments and shoreface sediment bodies that migrate or prograde fast. Lagoonal sections, if they exist, may exhibit a variety of mud-, wacke-, or packstone sediments and Mid-ramp deposits form below the fair weather wave base and therefore reflect storm deposition in the sediments. During fair weather, interval sediments are formed by suspension fall-out (terrigenous mud or lime) and become bioturbated.

The study of petrography and field trips showed the absence or lack of siliciclasts in the studied area, distribution of fossils according to their specific environment (tidal flat, lagoon, back reef, reef and forereef), and a microfacies study confirmed that the basin of Oligocene is platform basin. Rasouli et al (2006) studied Asmari Formation of Oligocene- Miocene age in Iran. They considered that detailed field and petrographic investigations of Asmari Formation resulted in the recognition of several facies related to arid tidal-flat, back barrier lagoon, barrier (reef/grainstone), shallow and deep open marine (pelagic and calciturbidite facies) facies belts. The presence of numerous calciturbidite beds that are interbedded with pelagic facies and the absence of siliciclastic components in the Lower and Middle parts of Asmari Formation indicate the existence of an isolated platform, similar to the Bahamian Platform, during their deposition.

To apply the principles of sequence stratigraphy (carbonate sequence stratigraphy), the method of isolated platform has been chosen and thrives were done to coincide with such a method.

4.4 Reef System and System Tracts:

To explain the system tracts and sequence boundaries, there is a schematic model for reef environment which shows system tracts and basin geometry (fig.4.4):

During a transgressive system tract (TST), both stages of start up and catch up occur (fig. 4.4a and b). At the beginning of start up, carbonate build up or barrier will accentuate, at that time nucleation of Shurau and Sheikh Alas Formations started originating (fig 4.3).

Accommodation space shows starvation of sediment and the system tract consists of retrograditional set of parasequences, once the carbonate – producing system has survived the start up phase. It will grow vigorously if environmental conditions remain favorable, keeping pace with rising sea level, which can lead to the development of strangely aggradtional margins (Emery and Myers, 1996), nevertheless it will be destroyed or diminished.

During the catch up stage, the carbonate production followed rising of sea level and builds aggradtional margin. In such a situation, both Sheikh Alas Formation (reef-Fore reef) and Shurau (reef-back reef) Formation were conformably deposited (Fig 4.4b).

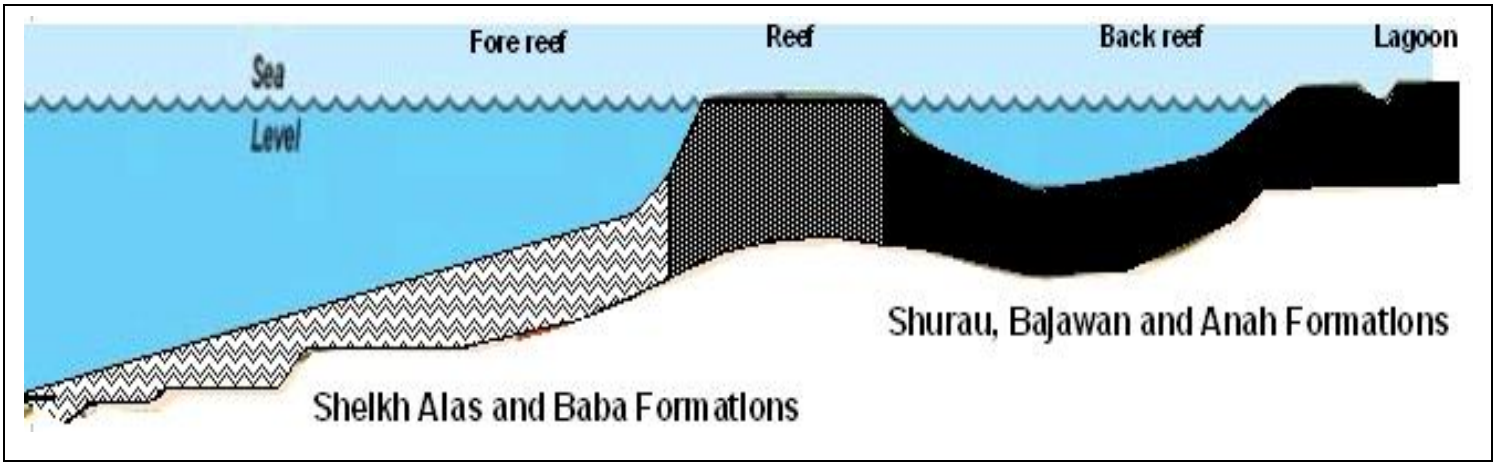


Fig (4.3): Cross section showing the depositional environment of the Oligocene Formations of the studied area.

At the end of the catch up stage and with further production of carbonate sediment, later maximum flooding surface (MFS) occurred which separated high system tract (HST) from transgressive system tract (TST). Though (MFS) is a turning point from retrograditional to progradtional system tract; during retrograditional and progradtional system tracts, a healthy reef originated, it included reef-fore reef Sheikh Alas Formation and reef-back reef Shurau Formation. Progradation of back facies (Shurau Formation) overwhelmed the fore reef facies (Sheikh Alas Formation); hence Pelloidal facies of back reef succeeded or covered packstone facies of the fore reef (table 4.3). The back reef facies shows pellets and intraclasts better than the reef facies (Al-Qayim and Khaiwaka, 1980) (Pl.4E and F).

It means that shifting of back reef facies did not reach the margin of the basin, but more progradation indicated by Benthic Foraminifera (*Lepidocyclina spp*) indicates forward facies shifting toward deeper part of the basin; Bosellini et al (1987), studied the reef "Oligocene-Miocene strata of NE-Somalia", and they reported that the lepidocyclines were thriving in front of the reef.

The Lower Oligocene back reef and fore reef counterpart were succeeded by a transgressive surface of Middle Oligocene back reef and fore reef facies, so that the later reef complex was deposited on the older reef one. The main organisms in the reef and back reef are the larger Foraminifera *Archaias kirkukensis*, and *Praerhapydionina delicata*, with the Milliolides *Austrotrillina howchini* and *Heterotrillina hensoni* together with *Peneroplis* like *Peneroplis evolutus* in the back reef facies; (Edgell, 1997); the fossils of those benthic Foraminiferas are also detected within the studied area.

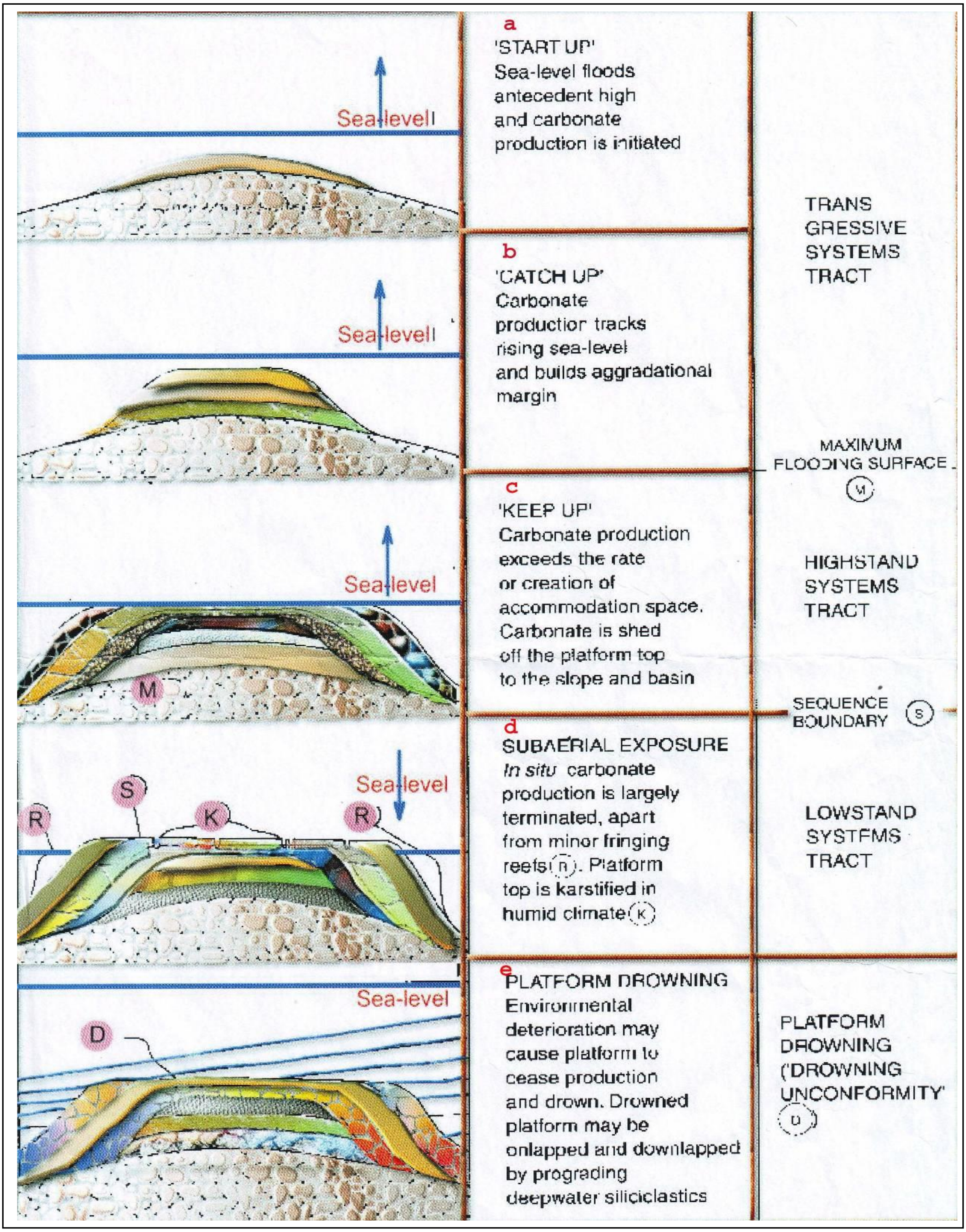


Fig.(4.4): Schematic model for an isolated carbonate platform, showing idealized systems tract geometries and platform drowning (after Emerry and Myers, 1996).

At the keep up stage which followed HST (fig 4.4), the rate of sediment production (carbonate sediment) exceeds the rate of accommodation creation which caused the reef mount structure approach sea level (water surface) (fig. 4.4c); a keep up carbonate system tract displays a relatively rapid rate of accumulation and is able to keep up with relatively sea level rise (Sarg, 1988).

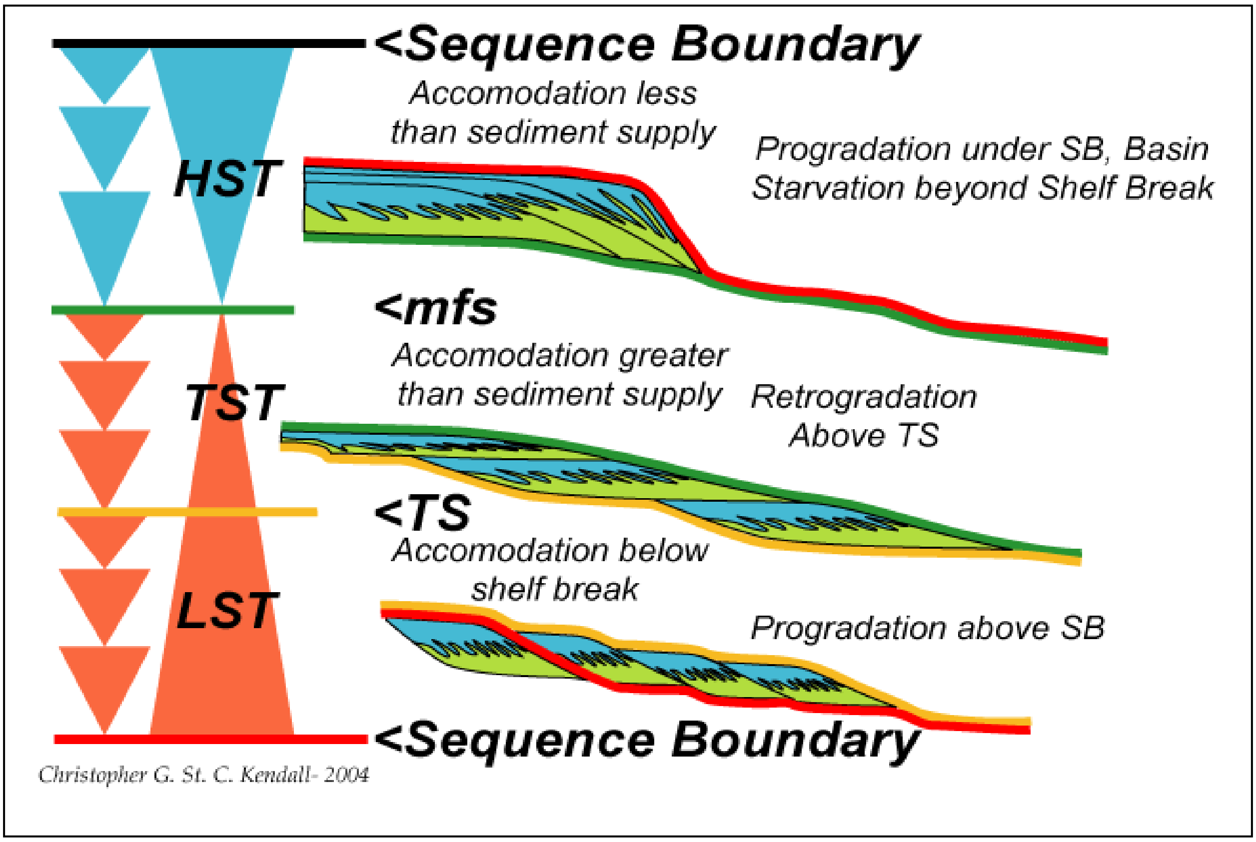


Fig (4.5): relation between accommodation space and sediment supply with system tracts compression (after Christopher and Kendall, 2004).

The mount- like structure grows laterally toward shallow depth (shoal barrier, tidal flat and lagoon) and to slope or deeper basin. It means the reef mount pursuits growing from lateral sides "high stand shedding".

From the stages; start up, catch up and keep up, it is obvious that with passing of time duration, the volume of the previously sedimentary basin becomes small (begins shrinkage) and is reduced (fig. 4.4c).

Gradual increase of the benthic Foraminifera proportions going upwards through the Oligocene interval indicates shallowing of the sedimentary environment (Kucenjak et al, 2006).

So this stage shows (HST) which overlies (MFS) and underlies sequence boundary (fig. 4.4d). In the studied area, this sequence boundary segregated the lower Oligocene sequence from the upper Oligocene sequence; the sequence boundary represents 3-5m of glauconitic-breccia bed (Darzila breccia), it is also represented by iron oxide nodules near the boundary. This breccia occupied an incised valley after shelf breaking.

In the isolated carbonate platform, (especially in reef situation), when environmental situations are unchangeable or tectonically in a steady state, the sequence boundary reflects the final stage of keep up and beginning of subaerial exposure, consequently carbonate production will cease (fig. 4.4d). The originated mound reef structure starts erosion and weathering forming insitu intraclast or reef patches; the fossil contents of the intraclasts as same as of the below rock strata, it enhanced the evidence of intra basinal processes like weathering and fragmentation of the rock strata and the angularity of the grains proved that they were not transported for a long distance. The product (green marly glauconitic-breccia) represents the fourth order cyclicity; it represents a parasequence (2-3m thick), it has been spanned 0.1-0.5 M y, and it is a short term process which represents an autocyclic process, later the sequence boundary had formed (fig. 2.1, 2.2, 4.4c and 4.4d); near the sequence boundary, discretely patches of iron oxide and chert have been seen and they give an indication of the sequence boundary which represent the surface of erosion, while the glauconitic breccia is representing water-sediment contact. Glauconite minerals represent quite sedimentation in shallow water, it is evidence of contact between water and sediment; the genesis of these minerals (Glauconites) is strickely confined to the sediment-sea water interface or its extension in the very early stages of burial diagenesis (Velede,1992), he also clarified that Glauconites tend to be found along calm, shallow shores of oceanic platforms. Glauconitic minerals are not restricted only to marine environment; Parry and Reeves (1984a) have reported the occurrence of glauconitic mica in Pluvial Lake mound, Texas (USA), glauconitic Illite was formerly described in Oligocene Lacustrine sediments of the North Aquitaine basin, France by Jung (1954).

The sequence boundary of Lower Oligocene sequence is denoted by sequence boundary type 2 (SB2); it is characterized by relative fall in sea level but it does not force a shift in the position of the shore line. This process represents either progradational or aggradtional stacking pattern but not retrograditional stacking pattern (fig. 4.5).

Hence carbonate production is no longer pursued and finally ceases, the sequence boundary will occur as indicated by karstification, vug, pores, and chert nodules.

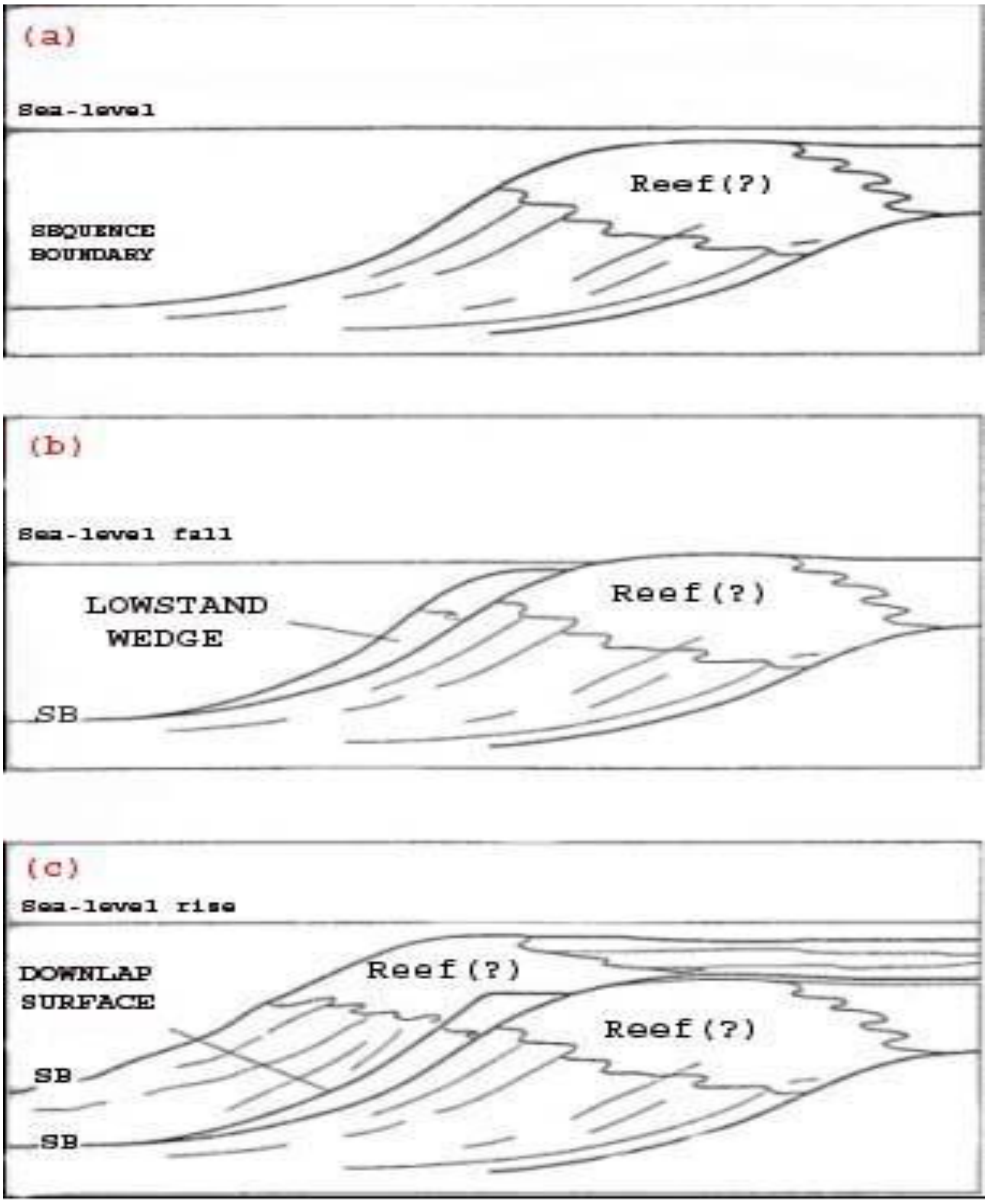


Fig (4.6): cartoon of highstand Progradation composed with volumetrically smaller lowstand wedge, Bahama platform, Tertiary (after Eberli and Cinburg, 1987 in Emery and Myers, 1996).

In the carbonate depositional system, during a low stand system tract (LST), it is likely to be less productive (Emerry and Myers, 1996), it could even stop; in the Oligocene basin, LST is less developed due to short duration (Al Qayim, 2006), and probably Lowstand wedge start generation (fig. 4.4b).

It is obvious that the rejuvenation of reef system had commenced during Middle Oligocene (fig.4.6c), it is represented by new TST; that means new start up and catch up, MFS and HST start.

Supply of sediments and rate of deposition became unusually high. Gradually the volume of the previously basin started decreasing because of production and deposition of carbonate produced materials and shifting laterally toward land and basin.

The consequences of Middle Oligocene seem to be like Early Oligocene; second reef body originated in which reef-fore reef facies (Baba Formation) and reef- back reef and reef-lagoon facies (Bajawan Formation) were deposited (fig 4.5). The second cycle of Middle Oligocene is developed almost similarly with relatively extensive reef association which indicates longer high stand interval as compared to the lower cycle (Al-Qayim, 2006).

During Middle Oligocene period, the created basin is occupied by reef- back reef facies (represented by Bajawan Formation) and reef- forereef facies Baba Formation) (fig: 4.3). Both of them have unconformabely set on the previous Lower Oligocene sequence which included Shurau and Sheikh Alas Formations; A transgressive reef building shoreward over its earlier back reef lagoonal facies is seen in Kirkuk oil field where Middle Oligocene reef and fore reef deposits have built shoreward over the earlier Lower Oligocene reef (Edgell, 1997).

The back reef-reef facies of the Bajwan Formation started prograding over the forereef Baba Formation and overlies it conformably.

Stability of tectonics by this time led to the development of the reef body and progress in deposition of the back reef facies was more than the reef facies during (MFS) and resulted in the back reef-reef facies of Bajwan Formation prograding upon the forereef Baba Formation, it is indicated by one meter of Wackestone of back reef facies which deposited over Nummulitic Packstone of fore reef facies. Finally the reef body has reached water level and appeared to air and catch up stage started, the reef ceased carbonate deposition and erosion initiated; that is subaerial exposure. Sequence boundary originated between Middle Oligocene reef system and the next steep of reef nucleation.

This sequence boundary returns to the base of the third reef body which originated after the termination of the second reef body. Repetition of the reef formation resulted in the formation of third reef body. So the Oligocene reef is considered to be a triple reef, but the cycle reef- back reef and reef-fore reef was denoted by more lagoonal facies than both former reef facies because it occupied narrower sag basin than Early and Middle Oligocene basins. It started from upper Oligocene to Early Miocene. In the studied area, it is represented by Anah Formation (fig 4.5); The Oligocene and Miocene represent, for the Cenozoic, a period of extensive reef development and are characterized by a number of important changes influencing carbonate-producing biota and the architecture of reefs and carbonate platforms (Perrin, 2002).

Finally, local tectonic activity, change in the environmental factors such as input of siliciclastic sediments of Middle Miocene of Fatha Formation, change in the temperature toward cooler which resulted in the dissolution of carbonate sediment and salinity; saline water entered the basin kilt the biota kingdom led to the termination of the triple reef. Thus, during late Eocene-Early Miocene, carbonate sediments dominated Mesopotamian basin but they terminated during Middle Late Miocene. By this time, cup rock for Oligocene reservoir rock units has formed and acted as a seal for trapping produced hydrocarbon which made one of the world wide giant oil fields; repetitive cycles of marine regressions and transgressions were suitable in the Oligocene for the deposition in the remanent foreland basin of the well differentiated carbonate sequence of Kirkuk group which makes the giant Kirkuk oil field (Numan, 1998).

AL- Juboury et al (2006) reported that repeated periods of local tectonic movement, as well as world wide sea level variation in Early Miocene (Langhian) resulted in stratigraphic succession similar to those of Burdigalian. These may have contributed to marine transgression and deeper environments rich in Planktonic Foraminifera in deeper part of the basin that then changed into an open Lagoonal environment rich in Milliolides through out all of Jeribi Formation.

So input of siliciclstics that came from continent during Miocene time resulted in the platform deformation or drowning; environmental deterioration may cause platform to cease carbonate production and drown. Drowned platform may be onlapped and downlapped by prograding deep water siliciclstics as shown in the fig (4.4e).

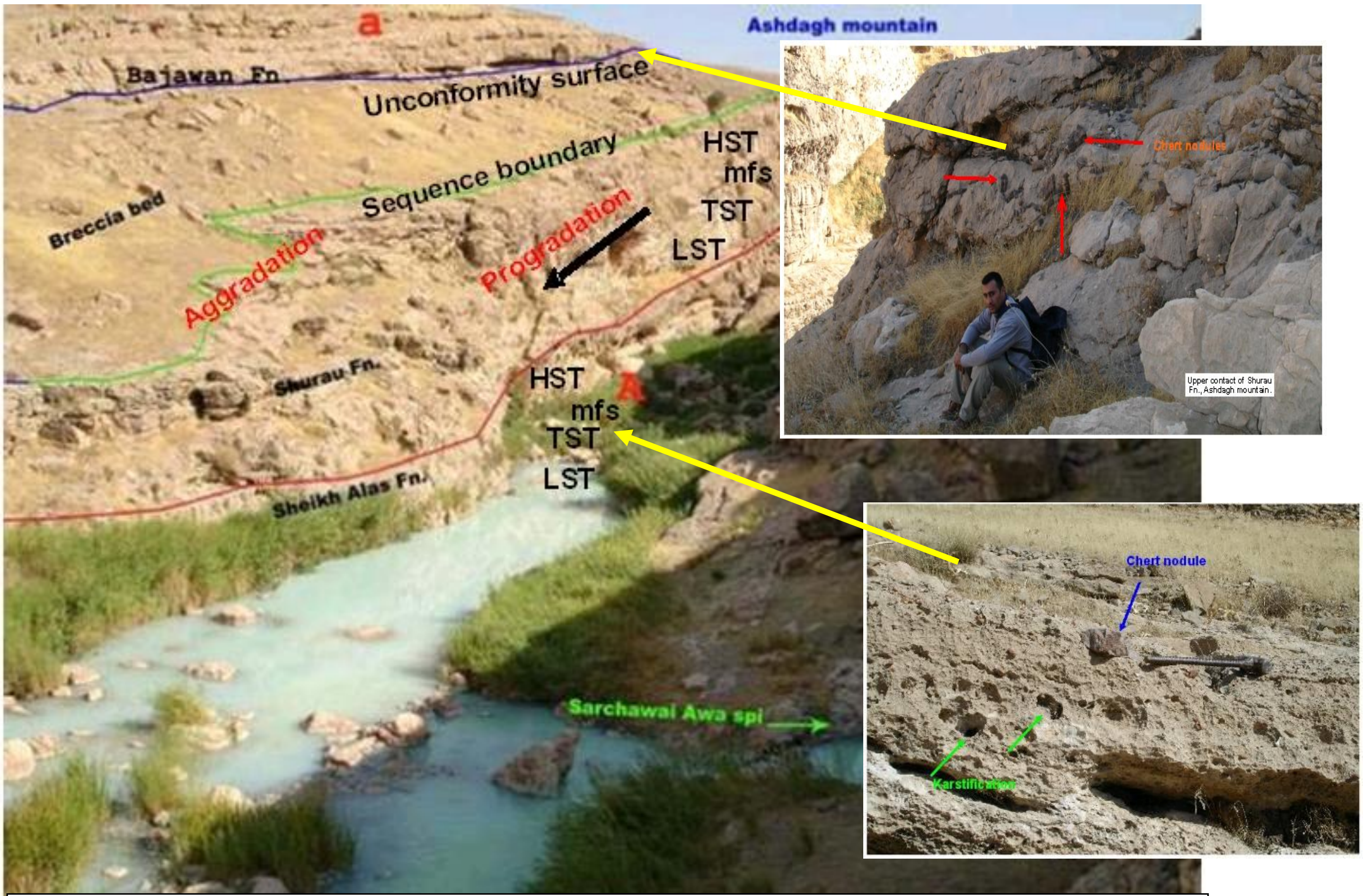


Fig (4.7): showing the principles of sequence stratigraphy (system tracts and Sequence boundary) and applied on Lower Oligocene Epoch of the studied area.

Chapter five
Conclusions, Recommendations and References

5.1 Conclusions:

During the study of possible presence of Oligocene strata in the Ashdagh Mountain by field examination, stratigraphic study, thin section analysis and identification of the index fossil content the following points are concluded:

1. From this research, it is inferred that Oligocene rock units are present and developed by different thickness in the studied area; they are determined based on several field observation.

2. Geographically, the location of the studied area delineated and the boundary of the Oligocene rock units is figured out and separated from Eocene and Miocene rock units which are denoted by Pila Spi and Fatha Formations respectively.

3. Nearly 78m of the Oligocene strata is exposed, specifically from Darzila to Hazar Kani section from which these rock strata have clearly appeared.

4. The detected rock units of Lower, Middle and Upper Oligocene are Sheikh Alas, Shurau, Baba, Bajawan and Anah Formations and are separated. Sheikh Alas and Baba Formations are representing reef-fore reef facies while Shurau, Bajawan and Anah Formations representing reef- back reef- lagoon facies.

5. Ashdagh Mountain is an asymmetry structure (it is an anticline; NE limb is gentle and its dip angle is about 20-25^o, but SW limb is steeper and its dip angle is 40-45^o, the SW limb is faulted. Mostly the structure is composed of Oligocene rock units except some part of the crest from

which Pila Spi Formation appears, while near the toes of the Mountain, Fatha Formation appeared. Formerly, the Mountain was considered as Pila Spi Formation and with the presence of only a little Bajawan Formation without mentioning the other five Oligocene Formations.

6. During the study, it is shown that the Lower and Upper sequences of the Oligocene strata are figured out and both sequences are separated by a thick bed of polygenetic-Glauconitic Breccia which has 3-5m (Darzila Brecciaed; called by researcher).

7. Generally, rock strata of Ashdagh Mountain are fossiliferous. Among them, some of them which are determined are considered as index fossils of Oligocene age, a part of them has general trend in geologic history and is not regarded as index fossils, and some of them are observed but not included in this thesis because they are unidentified and hard to specify their names (they may be regarded as new species or sub species).

The important index fossils of the formations that were determined in this study are:

A. Sheikh Alas Formation: *Nummulites intermedius*, *Nummulites vascus*, and *Nummulites fichteli*.

B. Shurau Formation: *Archais operculiniformis*, *Austrotrillinia paucialveolata*.

C. Baba Formation: *Lepidocyclina (Eulepidina) dilatata*, *Lepidocyclina (Nephropidina) marginatus* and *Lepidocyclina (Eulepidina) ephippioides*.

D. Bajawan and Anah Formations: *Praerhapydionina delicata*, *Archaias kirkukensis*, *Austrotrillinia asmariansis* and *Austrotrillinia howchini*.

8. The Oligocene rock units in the studied area are representing a reef basin inside a platform, it ranges from Inner to Middle ramp, and their facies represent platform facies.

9. Generally Sheikh Alas Formation indicated by Nummulitic wackestone- packstone, Shurau Formation by Milliolide- Pellitoidal

packstone- grainstone, Baba Formation by Nummulitic- Lepidocyclinae packstone, Bajawan Formation by Milliolidae packstone- coral-Algal packstone-wackestone and Formation by rubbly, conglomeratic(Reef patches) and Milliolidae wackestone.

10. From the current study, it can be concluded that a part of Kirkuk group Formations appears at Garmyan district-Northeastern Kurdistan (SW of Sulmaini city and NE of Kirkuk city).

5.2 Recommendations:

1. Because it is the first time that this area is geologically studied or might be studied but secretly by oil companies, and or it is done by researchers but the studies are not declared. So, detailed geological surveys are required to understand the geologic situation of the area, rock strata, their geographical distribution…etc. because a thesis can not cover whole information of a new studied area.
2. There are some bed rocks located between Anah (Late Oligocene-Early Miocene) and Fatha (Middle Miocene) Formations. Probably they return back to Early-Middle Miocene which are not included in this study but they are observed during field trips, they need more studies to define them.
3. Nearly five (5) meters of Globigerinal Marl and Marly Limestone are discovered later which are located between Baba and Bajawan Formations from Darzila section, it is most probable to be Tarjil Formation but it is not included in this study.
4. There are huge numbers of caves, sink holes and collapses observed in the studied area, formed as a result of diagenesis and geomorphologic processes. To acquire interpretation of these processes, it is required to study the geomorphology of the area because these landscape features are very attractive for touring

purpose, also to know the rate of risks of the collapse, because they have formed hazardous features in some places.

5. From the economic point of view, it is very crucial to study petroleum system of the area though generally the Oligocene rock units and especially rock strata of the studied area are characterized by highly porous and permeable which make them a very prolific hydrocarbon reservoir regarding the geographical distribution (expansion) of these strata and existence of Cap Rock (Fatha Formation) plus structure; the fault within the Mountain might form a seal (structural trap). These opportune factors most probable formed an oil field or gas field in the area.
6. Biostratigraphy and zonation of these studied Formations are impressive to determine the accurate age especially its lower part with the Upper Eocene age (its contact with Pila Spi Formation). Fossil studying is also suggested because these strata contain some probable new fossils and undetermined species or previously are not mentioned.
7. Diagenesis is one of the most important processes (particularly porosity and permeability enhanced for reservoir characterization study) which is not included in this study.
8. Sedimentary environment is another problem preferred to be studied in detail.

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ڕووخساره نیشتەنیەکانی چینە بەردەکانی ئۆلیگۆسین لە شاخی ئاشداغ- ناحیەی سەنگاو- هەرێمی کوردستان – باکووری ڕۆژهەڵاتی عێراق

نامەیەکە
پێشکەش کراوە بە کۆلیجی زانست لە زانکۆی سلێمانی وەك بەشێکی تەواوکەر بۆ بەدەست هێنانی پلەی ماستەر لە زانستی جیۆلۆجی دا

لەلایەن
سۆران عوسمان عەبدوڵڵا خەراجیانی
بەکالۆریۆس لە زانستی جیۆلۆجی / ٢٠٠٣

بەسەرپەرشتی
د. ئامانج ئیبراهیم فەتاح
پرۆفیسۆری یاریدەدەر

ڕەزبەری ٢٧٠٨ کوردی   تشرینی یەکەمی٢٠٠٨ زاینی

پوختە

لەم توێژینەوەیەدا ئەگەری هەبوونی چینەبەردەکانی ئۆلیگۆسین لە شاخی ئاشداخ سەلمێنرا بە پشتبەستن بە لێکۆڵینەوەی کێڵگەیی, لێکۆڵینەوەی چینەبەدوایەکداهاتووەکان و ئەو بەبەردبووانەی لەناو بەردەکاندا هەبوون.

ئەو چینەبەردانەی (یان پێکهاتووەکان)ی ئۆلیگۆسین کە لەشاخی ئاشداخدا پشکنران بریتی بوون لە : پێکهاتووەکانی شێخ عەلاس و شۆراو لەماوەی ئۆلیگۆسینی زوو, پێکهاتووەکانی بابا و باجوان و ئەگەری تارجیل لە ماوەی ئۆلیگۆسینی ناوەڕاستدا و پێکهاتووی عانە لەماوەی ئۆلیگۆسینی درەنگ دا.

شوێنی ستراتیگرافی ئەم پێکهاتووانە و سنوورەکانیان دیاری کراوە بەبەراود لەگەڵ چینەکانی سەروو ژێری خۆیاندا. ڕەوشتە فیزیاییەکانی ئەم چینەبەردانە بەراودکراوە لەگەڵ چینەبەردەکانی ئۆلیگۆسینی شوێنەکانی چواردەوری و دەرکەووتووە کە چوونیەکن لەگەڵ یەکتریدا.

پشکنین و ناسینەوەی بەبەردبووە ناسراوەکان لەناو هەریەکە لەو پێکهاتوانەدا ئەوەیان پیشانداوە و سەلماندیان کە چینەبەردەکانی ئۆلیگۆسین لەو ناوچانەی لێکۆڵینەوەیان تێدا ئە نجام دراوە (واتە لە شاخی ئاشداخ) بوونیان هەیە. ئەو بەبەردبووە ناسراوانەی کە دەرکەوتوون لە دیراسەی بڕگەی تەنك (Thin Section) دا جەخت لەسەربوونی ئەو پێکهاتووانە دەکەنەوە کە ئەوانیش:

أ. Nummulites intermedius, Nummulites vascus, and Nummulites fichteli لەناو پێکهاتووی شێخ عە لاس دا.

ب. Archaias operculiniformis, Austrotrillina paucialveolata, and Subterraniphyllum thomasi لە پێکهاتووی شۆراودا.

ج. Lepidocyclina (Eulepidina) dilatata, Lepidocyclina (Nephrolepidina) , marginatus and Lepidocyclina (Eulepidina) ephippioides) لەناو پێکهاتووی بابادا.

د. . Praerhapydionina delicata, Archais kirkukensis, Austrotrillina asmariansis and Austrotrillina howchini for Bajawan and Anah لەناو پێکهاتووەکانی باجوان و عانەدا.

ئەو پێکهاتووانەی کە پێشتر باسکران دادەنرێن بە بەشێك لە پێکهاتووەکانی گروپی کەرکوك, بەڵام هەموو گروپەکە دەرنەکەوتوون چونکە پێکهاتووەکانی پالانی و ئیبراهیم و ئازقەند دەرنەکەوتوون لە چینەبەردەکانی شاخی ئاشداخ دا. نیشتووەکانی ئۆلیگۆسین لەناو ئاوی حەوزێکدا نیشتوون کە قوڵاییەکی کەمی هەبووە و شوێنەکە بریتی بووە لە حەوزێکی تەخت(ڕامپ):وە ژینگەیەکی ڕیفی جیابووەوە لەناو ئەو حەوزە تەختەدا گەشەی کردووە (لەبەشی ناوەو و ناوەڕاستی ئەو حەوزە تەختەدا). ئەمەش جەختی لەسەرکراوەتەوە بە لێکۆڵینەوەی شێوازە ووردەکان و تێبینیيە کێڵگەیيیەکانی ناوچەی ئامازە پێکراودا.

بنەماکانی چینزانی لەدوایيەك لەگەڵ سیستمی ڕیفدا پەیڕەو کراوە کە سیستم تراکت و سکوێنس باوندەری دەگرێتەخۆی (sequence boundary) and (system tracts) , وە لێکۆڵینەوەی شێوازە ووردەکان و بەبەردبووەکان (بەبەردبووی گەورە و بچووك) لە شاخی ئاشداخ هاوشێوەی ئەوانەیە کە لە بەشی ناوەوە و ناوەڕاستی حەوزێکی تەختدا دەنیشن.

السحنات الرسوبية للوحدات الصخرية الأوليكوسين في جبل آشداخ - ناحية سنكاو- اقليم كردستان-شمال شرق العراق

رسالة
مقدمة الى **مجلس كلية العلوم-**
جامعة السليمانية كجزء من المتطلبات
نيل درجة ماجستيرفي علم
الأرض

من قبل

سوران عثمان عبدالله خراجياني
بكالوريوس / ٢٠٠٣

باشراف

د. آمانج ابراهيم فتاح
مساعد بروفيسور

شوال ١٤٢٩هـ **تشرين الأول - ٢٠٠٨ م**

المستخلص

تم التأكد من وجود طبقات الأوليكوسين في جبل اشداخ اعتمادا على المشاهدات الحقلية و الدراسة الطباقية و فحص الشرائح الرقيقة و ما تحتويه من المتحجرات.

التكاوين التي تم التعرف عليها في هذه الدراسة هي:

تكوين شيخ علاس و تكوين شوراو (أوليكوسين الأسفل) و تكوين بابا و باجوان (أوليكوسين الأوسط) و تكوين عانة العائد لفترة الأوليكوسين الأعلى مع احتمالية وجود تكوين تارجيل العائد لفترة الأوليكوسين الأوسط أيضا.

وقد شملت الدراسة تثبيت الموقع الطباقي لهذه التكاوين مع تحديد نوعية تماسها مع الطبقات السفلى والعليا, اضافة الى مقارنة الصفات الفيزيائية الصخرية لها مع وحدات صخرية مناضرة لها في مناطق أخرى مختلفة.

لقد استدلت على التكاوين التي تم ذكرها بالاعتماد على تشخيص عنه أنواع من المتحجرات الدالة داخل كل من هذه التكاوين و تم التدق عليها كما و برهنت على تطور الوحدات الصخرية للأوليكوسين في منطقة المدروسة. والممثلة بما يلي:

أ. *Nummulites intermedius*, *Nummulites vascus*, and *Nummulites fichteli* و الدالة على تكوين شيخ علاس.

ب. *Archais operculiniformis*, *Austrotrillina paucialveolata*, and *Subterraniphyllum thomasi* و الدالة على تكوين شوراو.

ج. *Lepidocyclina (Eulepidina) dilatata, Lepidocyclina (Nephrolepidina) and Lepidocyclina (Eulepidina) ephippioides* و الدالة على تكوين بابا.

د. *Praerhapydionina delicata, Archais kirkukensis, Austrotrillina asmariansis* and *Austrotrillina howchini* for Bajawan and Anah و الدالة على تكويني باجوان و عانة.

ان التكاوين المذكورة تمثل جزءا من تكاوين مجموعة كركوك دون المجموع والتي تشمل ايضا تكاوين بالاني, ابراهيم و آزقند والتي لم يستدل على وجودهم في التتابع الطباقية لجبل آشداخ.

ان المشاهدات الحقلية و دراسة سحنات الدقيقة للنماذج الصخرية المختارة أكدت أن طبقات الأوليكوسين في منطقة الدراسة قد ترسبت في بيئة بحرية ضحلة متمثلة بمنحدربحري: تطور فيه بيئة حيدية معزولة.

ان مبادىء الطباقية التتابعية لنظام الحيد و الممثلة بالمسارات النمطية (system tracts) و والحد التتابعي (sequence boundary) مع دراسات السحنات الدقيقة والمتحجرات الدقيقة و الكبيرة تم تطبيقها على جبل آشداخ وقد أظهرت الدراسة بأن المنطقة تشمل بيئة المنحدر القريب الوسطي(Mid-inner ramp).