# FACIES ANALYSIS OF THE OLIGOCENE SUCCESSION IN SHARWALDIR ANTICLINE, NE OF KALAR TOWN, NE IRAQ

**Kamal H. Karim[1], Polla A. Khanqa[2], Khalid M. Ismail[3] and Varoujan K. Sissakian[4]**

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## ABSTRACT

Sixty meters thick Oligocene carbonate succession crops out in the area southeast of Derbandi Khan town and northeast of Kalar town. The carbonate succession is exposed in the core of the NW – SE trending Sharwaldir anticline, which extends across the border into Iran. The recorded facies have stratigraphical and paleogeographical importance for understanding of the palaeogeography of NE Iraq; the facies are: Foraminiferal wackestone – Packstone, Bufflestone, Algal – Coral bindstone, Bioclast wackestone – Packstone and Grainstone microfacies. These facies indicated that the lower, middle and upper parts of the section are deposited in fore-reef, reef-crest and reef-back reef environment, respectively. They belong to Baba and Anah formations (lower and upper parts of the section, respectively) while the middle part is a transitional zone between the two formations. The chemistry of the carbonates showed them to be of good quality for Portland and white cement production.

# التحليل السحني لتتابع الأوليغوسين في طية شروالدار، شمال شرق مدينة كلار، شمال شرق العراق

**كمال حاجي كريم، پولا آزاد خانقاه، خالد محمود إسماعيل و فاروجان خاجيك سيساكيان**

**المستخلص**

إن سمك تكشفات تتابع الأوليغوسين الكلسية تصل إلى ٦٠ متر في طية شروالدر التي تقع إلى الجنوب الغربي من مدينة دربنديخان (شمال شرق مدينة كلار). لم يدرس هذا التتابع الكلسي (سابقاً) سحنياً ولا رسوبياً. تمتد هذه الطية عبر الحدود الدولية بين إيران والعراق باتجاه شمال غرب – جنوب شرق، كطية قبابية الشكل. في هذه الدراسة، تم تسجيل عدة سحنات رسوبية وهياكل للمتحجرات ذات الأهمية البيئية والطباقية والجغرافية القديمة، التي لها أهمية كبيرة في فهم جيولوجية شمال شرق العراق. أهم السحنات المسجلة هي Foraminiferal Wackestone – Packstone، Coral bufflestone، Algal – Coral bindstone، Bioclast Wackestone – Packstone وGrainstone microfacies، حيث ترسب الجزء السفلي والوسطي والعلوي في بيئة لاغون مفتوحة وخلف حاجز ولب الحاجز، بالتوالي. استنتجت في هذه الدراسة إن الجزء السفلي والعلوي يعودان إلى تكويني بابا وعنه، على التوالي، بينما يعود الجزء الوسطي إلى نطاق انتقالي بين التكوينين. أظهرت التحاليل الكيميائية للصخور الكاربوناتية أنها صخور ملائمة لصناعة السمنت البورتلاندي والأبيض.

[1] Professor, Department of Geology, School of Science, University of Sulaimani, Iraq
[2] Professor, Kurdistan Institution for Strategic Studies and Scientific Researches, K.R.G., Sulaimaniyah
[3] Assistant Professor, Department of Geology, School of Science, University of Sulaimani, Iraq
[4] Expert, Iraq Geological Survey, P.O. Box 986, Baghdad, Iraq

## INTRODUCTION

The Oligocene strata (Kirkuk Group) are important oil reservoir in Iraq, especially in the Low Folded Zone around Kirkuk (Jassim and Al-Gailani: in Jassim and Goff, 2006). The Oligocene succession consists of reef, back reef and fore reef carbonates or marls, which are subdivided into nine formations (Anah, Azkand, Ibrahim, Bajawan, Baba, Tarjil, Shurau, Sheikh Alas, and Palani formations; Bellen *et al*., 1959; Buday, 1980, and Jassim and Buday, in Jassim and Goff, 2006).

Youkhanna and Hradecky (1978) conducted regional geological survey for the area of north Khanaqeen in which the study area is located; including Sharwaldir anticline, they mapped different Oligocene formations in the area. Moreover, they reported about the paleontology and petrography of the exposed rocks. Recently, Baba Shekh (2006) mentioned two conglomerate beds and fossiliferous limestone beds in the Sangaw area (40 Km from present study area), which he thought to be of Oligocene age. Ameen (2009) referred to the presence of Oligocene rocks in the same area, and in different parts of Kurdistan, northeast Iraq, but not in the High Folded Zone areas. Later, Kharajiany (2009) studied those fossiliferous limestones and recognized Baba, Sheikh Alas, Bajwan, Shurau and Anah formations along both limbs of Aj Dagh anticline; southeast of Sangaw town. Khanaqa *et al*. (2009) proved for the first time the occurrence of Oligocene rocks inside the High Folded Zone of NE Iraq. Ghafor (2004) studied biometric analysis of Oligocene in Kirkuk area.

This study aims to study the facies of the Oligocene succession of the Sharwaldir anticline and its suitability for cement industry.

- **Location and Geological Setting**

The studied area is located about 35 Km to the northeast of Kalar town, about 30 Km to the southeast of Darbandi Khan town (Fig.1); inside the Low Folded Zone. The main structure in the area is Sharwaldir; 10 Km long, double plunging anticline in which the Oligocene rocks are exposed. The relief is about 850 m high (above sea level). The southeastern plunge splits into two small anticlines, which bend toward south southeast (Fig.1). Both plunge areas are disturbed by normal faults. The studied section is located inside a small valley called Manga Bakal and the samples were taken across the right side of the valley; directly to the south of large and famous cave bearing the same name of the valley (Fig.2). The GPS reading of latitude and longitude of the base of the section is 34° 49' 19.36" and 45° 41' 8.82", respectively and located 5 Km to the northeast of Hajilar village.

In addition to sporadic and thick accumulation of recent alluvium sediments, numerous Paleogene and Neogene formations are exposed in the studied area, but the main formations are of Oligocene age. These formations consist mainly of milky (grey when weathered), hard and flinty limestone, which show slight fossil content and bioclasts; in hand specimens. The lower boundary of the Oligocene succession is not exposed, while the upper boundary is with the Middle Miocene Fatha Formation, which comprises of poorly exposed 50 m of alternation of green marl, detrital limestone, and few beds of sandstone. A 100 m thick boulder conglomerate (ex-Bamo Conglomerate) of Pleistocene age (Youkhanna and Hradecky, 1978) unconformably overlies the Fatha Formation (Fig.3).

The study comprised field work to choose the best exposed section, collecting and field description (with 10 X hand lens) of 64 samples, which were thin-sectioned and studied under binocular microscope for facies and age evaluation. The percentage of constituents was estimated using charts given by Folk *et al*. (1970) and Tucker (1991).

▪ **Method of Work**

To achieve the aims of this works, the following procedure was conducted:

- Field study for finding the best section in the studied area.
- Collecting 64 samples form a selected section and describing them in the field by aid of 10 X hand lens. The description of the samples and the thickness of the beds (nearly equal to elevation above stream bed) are included in Table (1).
- Thin sections are prepared for 64 collected samples, from the studied section.
- The thin sections are studied under binocular and polarized microscopes for differentiation of rock constituents, and paleontological identification of the fossils.
- The percentage of the petrographic constituents is estimated by using the charts prepared by Folk *et al*. (1970) and Tucker (1991).
- Three samples are chemically analyzed to evaluate the percentage of oxides for estimation of the suitability of the limestones for Portland and white cement.

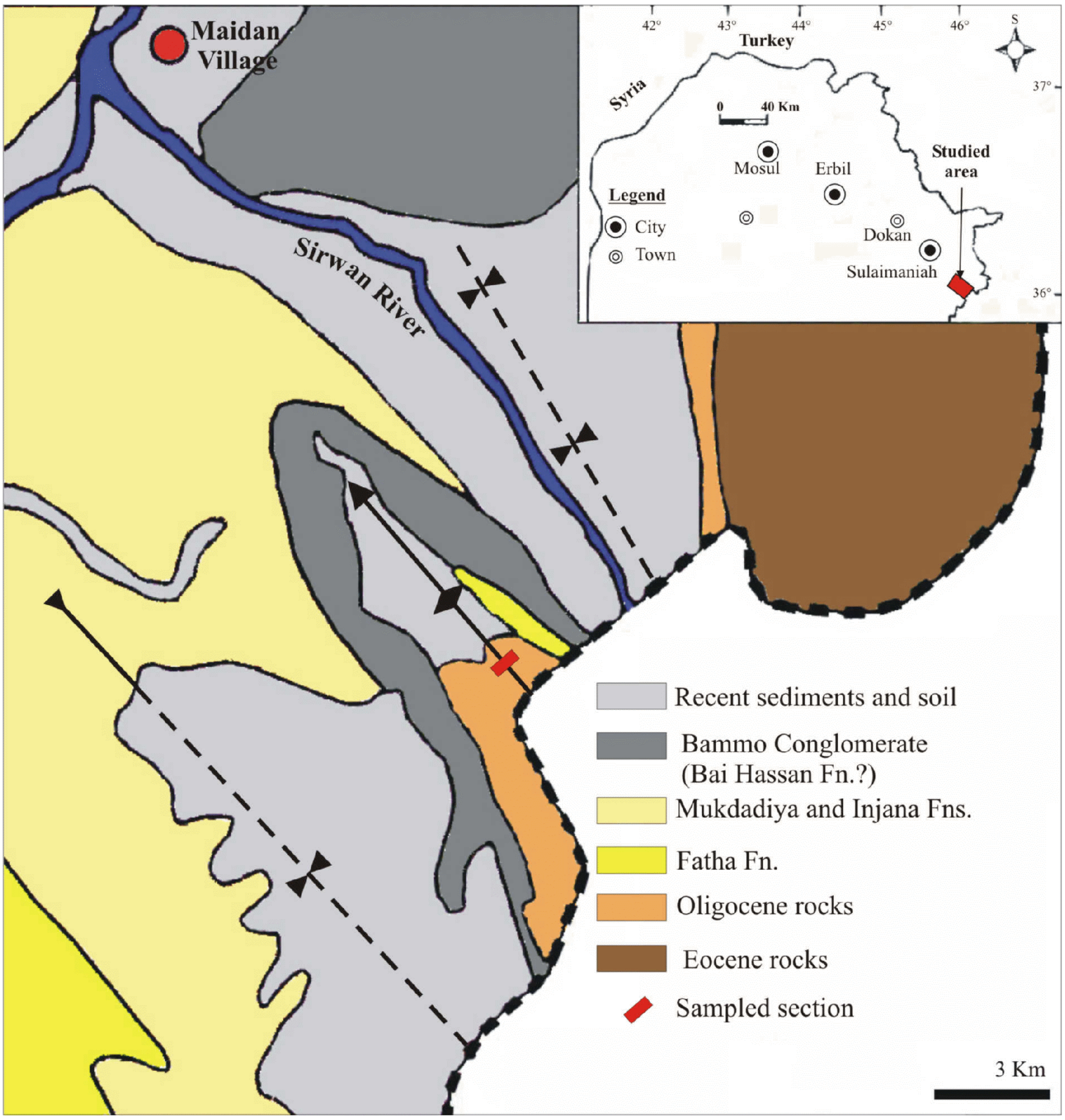



Fig.1: Simplified geological map of the studied area
(Modified from Barwary and Slaiwa, 1993)

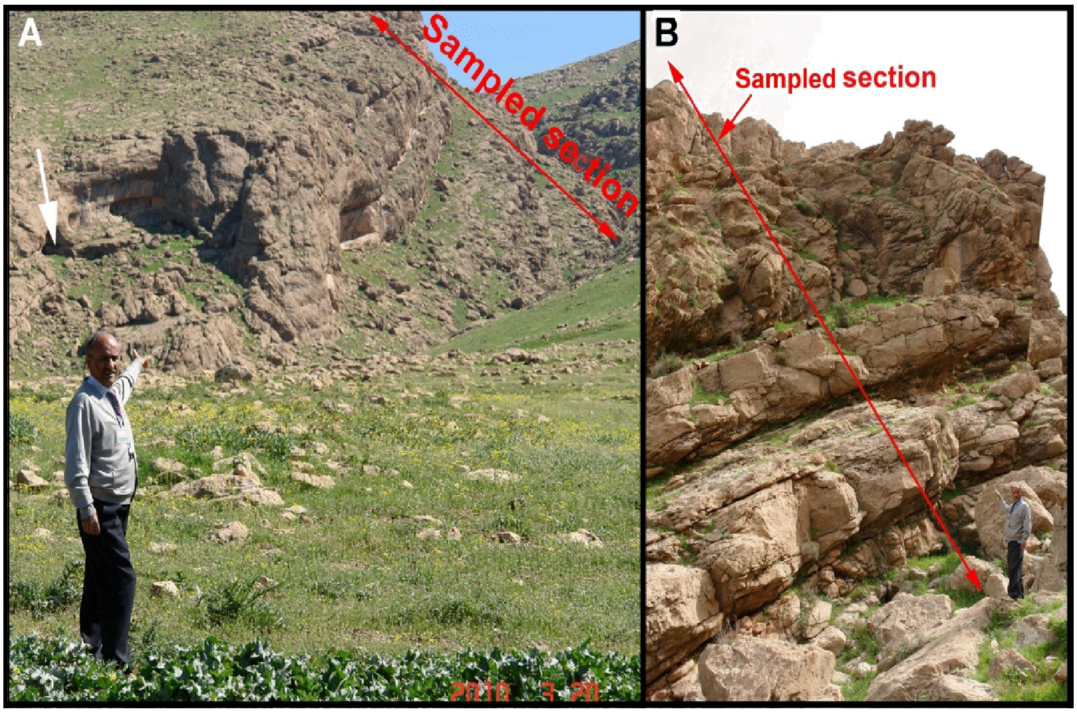



Fig.2: **A)** Manga Bakal valley with location of the sampled section. The white arrow points to a 70 m deep and 30 m wide cave in Oligocene limestone of Fig. (3), **B)** Details of the studied section

**MICROFACIES ANALYSIS**

The facies analysis (lithofacies and microfacies) of the Oligocene succession in the Sharwaldir anticline is based on the classification of Dunham (1962) and its modification by Embry and Klovan (1971). The facies and most of their allochems can be identified visually in hand specimen (by eyes or hand lens), however, all the samples were additionally investigated using both binocular and polarizing microscopes.

The studied section shows relatively diversity of fossils. Most of the facies contain more than three types of fossil skeleton allochemes and rare lithoclasts without any extra-clasts. The main skeletal allochemes are red algae, corals, echinoderms, pelecypods and forams). Amongst the fossils, red algae, which seem to occur in most samples except those that are comprised by coral skeletal grains (Fig.4), required detailed discussion since they seem to influence the rock character greatly including such features as toughness, flinty nature, sharpness of edges, white or milky color and apparent fineness of the grains.

According to Flugel (2004), Tertiary limestone, composed predominantly of red algae, are important hydrocarbon reservoir in Libya and Indonesia. He stressed that to study red algae in thin sections needs high magnification; otherwise algal fragments appear non-structured and may be confused with micrite clasts. Such features were observed too in the sampled section as, in some cases; the thalli have structureless parts similar to micrite (Fig.4).

Another evidence for the inherited properties is that mentioned by Halfar and Mutti (2005) that the facies had rapidly grown during early Late Oligocene and reached maximum abundance during end of Oligocene and Early Miocene (Fig.5). They added that during these ages' red algae were commonly replaced coral-reef environments, accompanied by a decline in other carbonate-producing photographs.

Table 1: Field description of the sampled section (from bottom to top)

| Sample No. | Th. (m) | Field description by hand lens (10 X) |
|---|---|---|
| Zero | 0 | Hard compact gray limestone with lepidocyclina forams (appear glassy) with sporadic white grain may be bioclasts (wackestone) |
| 1 | 2 | Same as previous sample |
| 2 and 3 | 3 | Same as previous sample with less lepidocyclina content (wackestone) |
| 4 | 3.5 | Hard compact gray limestone with lepidocyclina (appear glassy) with sporadic white grain (may be bio or litho-clasts) with very faint minute net structure (packstone) |
| 5 | 4 | Same as sample zero |
| 6 | 5 | Hard and gray to milky limestone with lepidocyclina forams (packstone) |
| 7 | 7 | Hard and gray to milky limestone with rare lepidocyclina forams and with bioclasts and white spots (wackestone) |
| 8 | 8 | Hard and milky limestone. The massiveness of the sample section starts from this sample (wackestone) |
| 9 | 9 | Same as previous sample with circular and lensoidal forams |
| 10 | 9.5 | Same as previous sample with many detrital grains, and intraclastic wackestone |
| 11 | 10 | Milky hard limestone with lenticular forams (foraminiferal packstone-wackestone) |
| 12 | 11 | Intraclastic (detrital) limestone with small lenticular forams packstone |
| 13 | 12 | Foraminiferal lepidocyclina wackestone |
| 14 | 13 | Milky, hard and flintary limestone with algae or coral (possibly framestone or boundstone) |
| 15 | 14 | Milky, hard and partially recrystallized intraclastic or detrital limestone with irregular grains |
| 16 | 15 | Limestone contain uncertain foram may be peneroplis or lithoclasts |
| 17 | 16 | Detrital limestone with rare nummulite and miliolid forams |
| 18a | 17 | Partially recrystallized and slightly chalky limestone (mudstone) |
| 18b | 17 | Recrystallized limestone (mudstone) Some uncertain white spot |
| 19 | 18 | Partially recrystallized limestone and with ghost of uncertain forams. The sample consist of tow parts: one part is algal or coral limestone other part is mudstone |
| 20 | 19 | Same as previous |
| 20 | 19 | Same as previous |
| 21 | 20 | Clear algal or coral limestone (boundstone)with detrital grains |
| 22 | 21 | Massive hard milky limestone no certain structure or texture except few minute holes, but may contain few spots of coral or algae |
| 23 | 22 | Same as previous |
| 24 | 23 | Milky, chalky hard and partially recrystallized intraclastic or detrital limestone. Contain irregular grains and few unknown forams (Intraclastic wackestone) |
| 25 | 24 | Limestone with clear coral or algae colony, appear as network (bindstone) |
| 26 | 25 | Possibly same as previous with broken coral or algal fragments (bindstone) |
| 27 | 26 | Hard milky and massive limestone with clear coral cross section appear as circular spot while longitudinal section is finger like |
| 28 | 30 | Milky, hard very massive, with clear coral or algae and fine broken coral fragments (boundstone) or bafflestone |

Cont. table 1

| Sample No. | Th. (m) | Field description by hand lens (10 X) |
|---|---|---|
| 29 | | Same as previous |
| 30 | 31 | Limestone milky, hard very massive, with clear coral or algae (boundstone or bafflestone) |
| 31 | 32 | Limestone milky, hard very massive, with bioclast and lithoclasts (packstone) |
| 32 | 34 | Milky, hard with forams may be nummulite |
| 33 | 36 | Limestone some parts of the sample contain coral and coral fabrics with unknown white spot and forams |
| 34 | 37 | Detrital limestone contain white spot may be foram or red algae (Intraclastic-bioclastic packstone) |
| 35 | 38 | Light rosy limestone and partially recrystallized with grey spots (mudstone) |
| 36 | 39 | Milky, hard limestone with rare forams (miliolids and rotalids) may contains corals (wackestone) |
| 37 | 40 | Limestone white and slightly chalky, with intraclastic and discoidal forams |
| 38 | 41 | Limestone medium grain intraclastic and bioclastic packstone (detrital limestone) |
| 39 | 42 | Limestone milky hard massive may be finely detrital limestone (no fossil) |
| 40 | 43 | Limestone not clear texture but contain forams (glassy looking), it possibly contain mixture of foram and bioclasts (packstone) |
| 41 | 44 | Limestone clear detrital limestone with miliolid forams |
| 42 | 46 | Limestone partially recrystallized (may be detrital limestone) |
| 43 | 47 | Bioclastic limestone with miliolids and rare nummulites |
| 44 | | Same as previous |
| 45 | 48 | White limestone partially recrystallized no clear texture or fossils |
| 46 | 49 | Limestone coral or algal framestone with bioclasts with few miliolids and nummulites |
| 47 | 50 | Limestone white partially recrystallized no clear texture or fossils with faint white spots |
| 48 | 51 | One coral steam, most of it consists of detrital limestone litho or bioclasts |
| 49 | 52 | Fine grain milky limestone (no signs of fossils and clasts) |
| 50 | 53 | Fine grain milky limestone (no signs of fossils and clasts) |
| 51 | 54 | Limestone may be detrital and contain coral or ooids |
| 52 | 55 | Limestone two parts one contains clear and other one contains clasts with miliolids and nummulites |
| 53 | 56 | Limestone contain clear coral and clasts some of them are broken (bioclasts) |
| 54 | 57 | Limestone contain calcite filled pores may by coral or algae there is some sign of detrital limestone and few nummulite |
| 55 | 58 | Deformed coral (bufflestone) with coral and other bioclasts |
| 56 | 59 | Coral (bufflestone) |
| 57 | 60 | Detrital limestone (bioclastic and lithoclastic packstone or wackestone) |
| 58 | 61 | Coral (bufflestone or framestone) |
| 59 | 71 | Coral or algal skeleton and bioclasts |
| 60 | 62 | Clear sparse branched coral (bufflestone) |
| 61 | 63 | Lithoclastic packstone with possible forams |
| 62 | 64 | Bioclastic and coral bearing limestone with few nummulites |
| 63 | 64.5 | Same as previous |
| 64 | 65 | Fine grain milky flintery limestone with some grains with mesh structures (no fossil and clasts) |

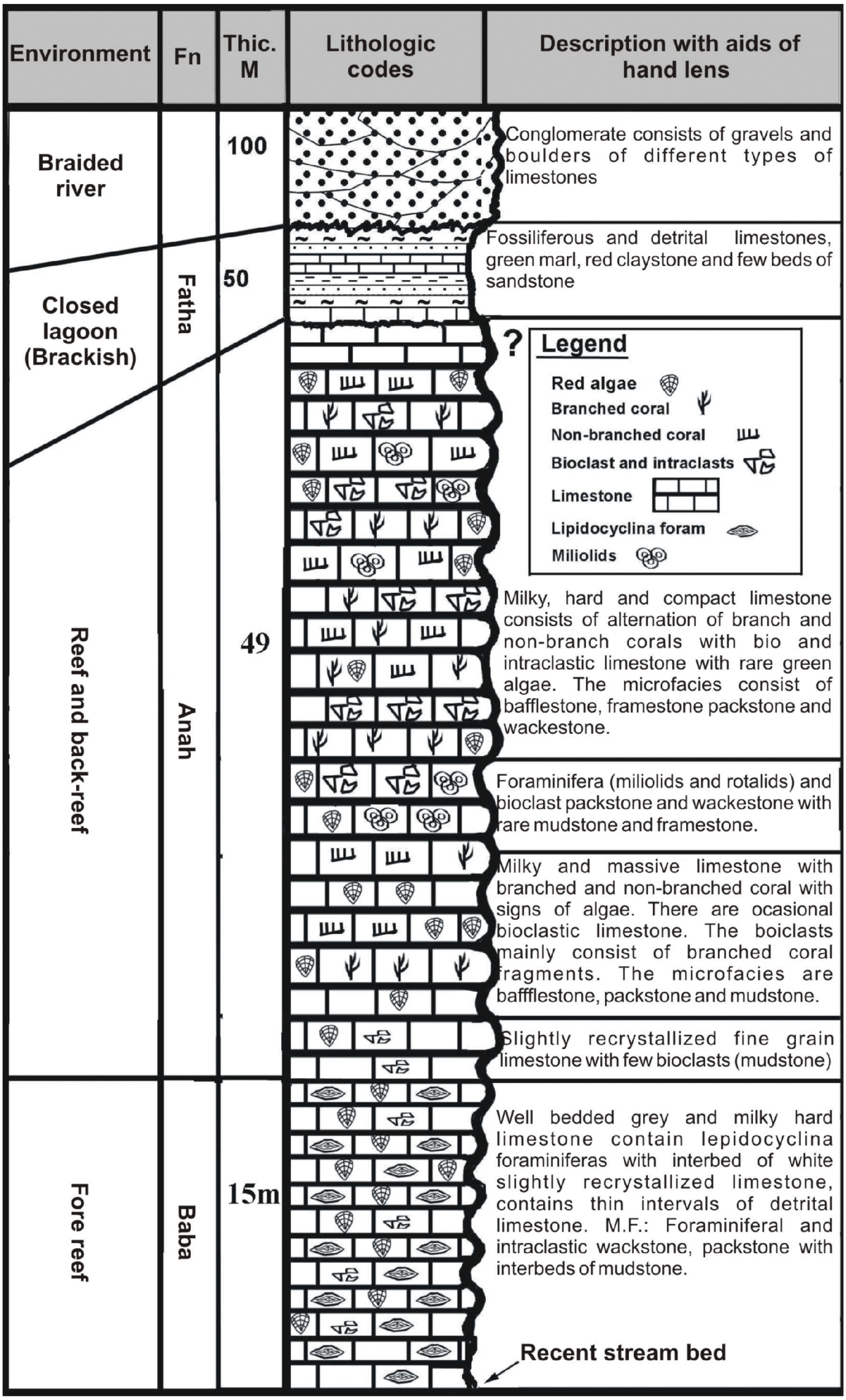



Fig.3: Stratigraphic column of the sampled section
with field description of the samples by 10 X hand lens

Bassi and Nebelsick (2000) mentioned that Calcareous algae are important constituents of Tertiary shallow water carbonates in the Oligocene carbonates in the circum-Alpine region. The content of the red algae, in the aforementioned region, had often resulted in the designation of these limestones as "Lithothamnienkalk". The red algae either exists as encrusting (crustose) or erected forms (thalli), the former occurs as small multilayered body, few millimeters to few centimeters thick. It consists of intergrown skeletal grains, which appears in thin section as laminations and shows sediment-floored cavities that are roofed over by these laminations (Fig.4B). The spaces between crusts are filled with wackestone or mudstone. The latter is erected and non-encrusting form; consists of several joined and segmented thalli (Fig.6). Each segment consists of partitioned filaments (medulla) and peripheral cellular filaments (cortex) (Fig.6). Accordingly, it is assumed that the red algae has important role in the composition and texture and ultimately the physical properties of the Oligocene rocks in Sharwaldir anticline.

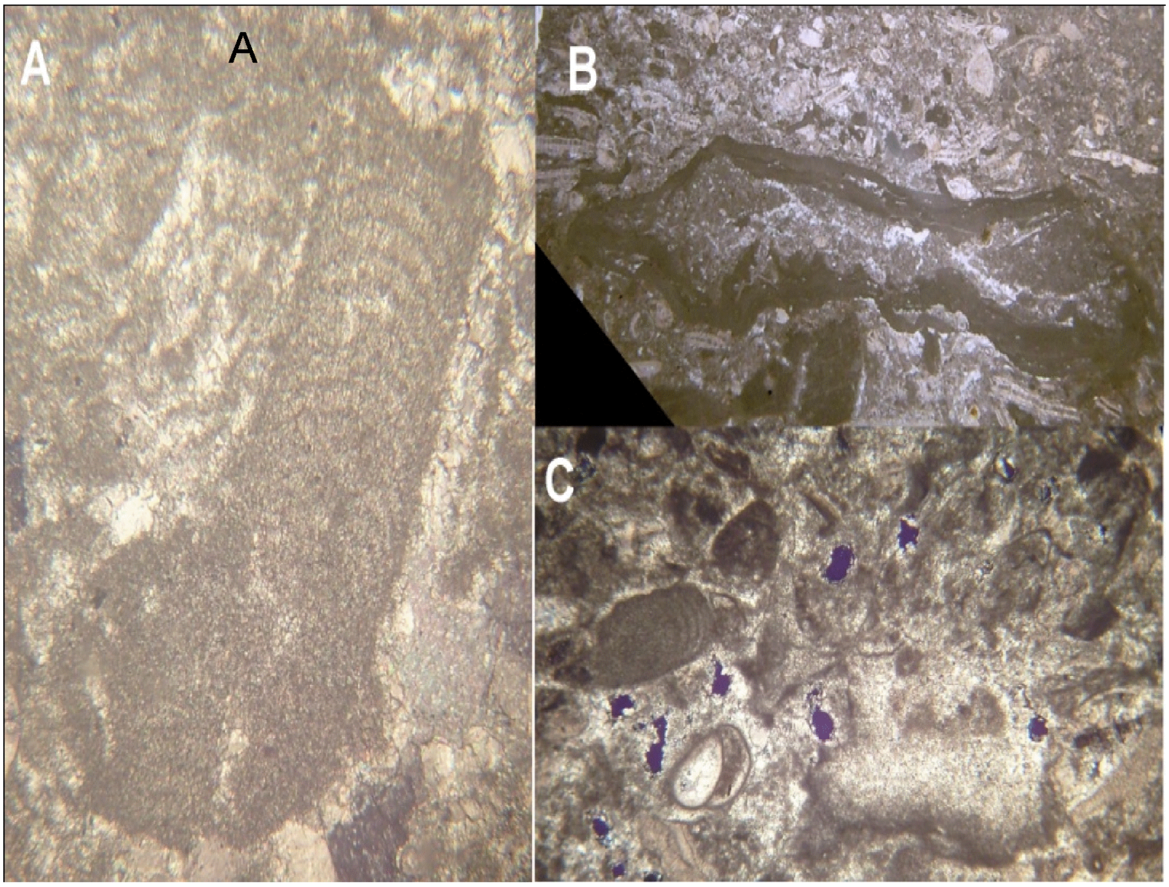



Fig.4: **A)** An erected red algae thalli in which the portioned filaments can be seen in the upper part, whereas in the lower part the texture is not similar to the upper part, and is similar to background (Sample no.20, 12 X)
**B)** Encrusting red algae that have the form of elongated nodule, (Sample no.5, 7 X)
**C)** Crustose (lower middle) and erected (left middle) algae (Sample no.46, 10 X)

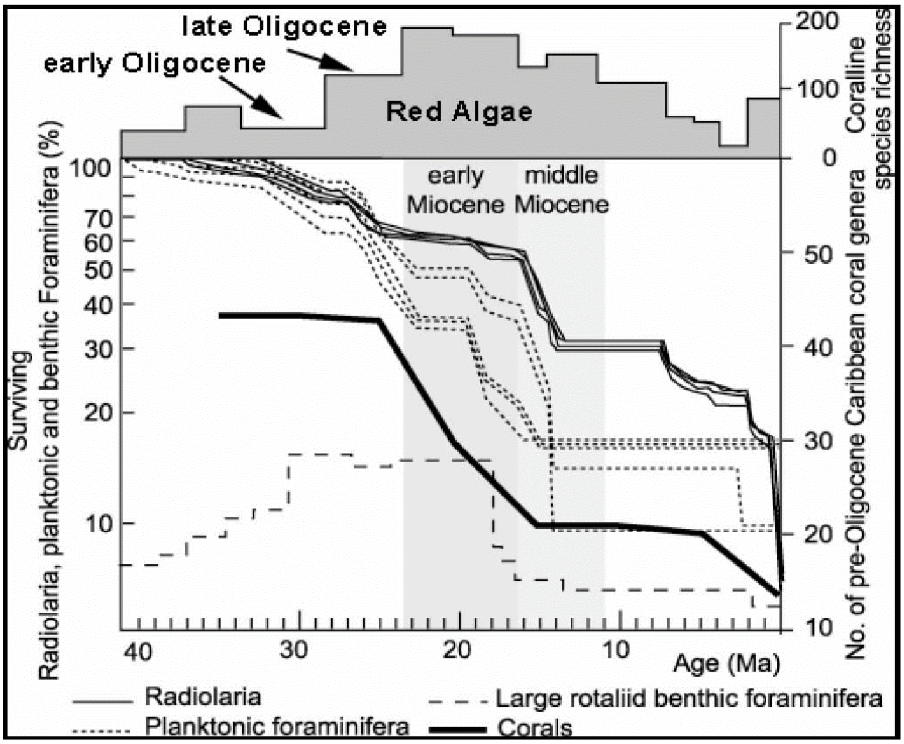



Fig.5: Rapidly increase abundance of red algae facies during early Late Oligocene, its maximum abundance was during Late Oligocene and Early Miocene (Halfar and Mutti, 2005)

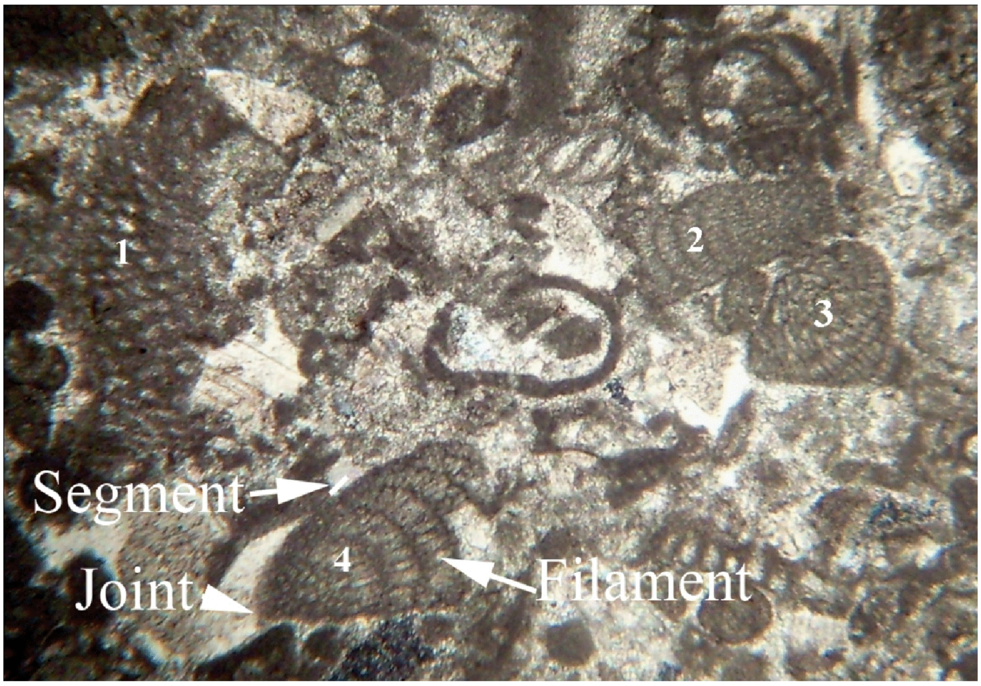



Fig.6: Reworked red algae bioclast showing different orientation and sections, **1)** Cross-section, **2** and **4)** Longitudinal section showing segments and filaments, **3)** Oblique section

- **Foraminiferal Wackestone – Packstone Microfacies**

This facies is common in the lower part and gradually disappear in the middle part and can be recognized either in thin sections or by hand lens. The ratio of the grains is (15 – 70) % and they are mud supported. The allochems of this facies consist mainly of lepidocyclina and red algae (Fig.7g) with accessory nummulites (Fig.7b), echinoderms, pelecypods skeletons and their bioclasts. Toward the middle part, lepidocyclina totally disappears while both miliolids, nummulites and corals appearance, with increase in the ratio of red algae. In rare cases, nummulite packstone can be seen in one sample in the middle part. In many cases, this facies make up the spaces between the bindstone and bufflestone bodies. Along the whole section; in all levels and in the slides, forams can be seen. In two slides both, nummulites and miliolids can be seen together, which is unusual occurrence as they belong to two different environments. But, the dwarfed size of both indicates an environment that was more or less tolerable for both. The bypass mixing by wave and current is not excluded.

- **Bufflestone Microfacies**

This facies consists of stalk-shaped and branching fossils that were trapped sediments during deposition by acting as baffles, slowing down water movement and allowing sediment to settle (Embry and Klovan, 1971). According to Flugel (2004), the feature for identifying the bafflestone is the presence of large number of in situ stalk-shaped fossils. This facies was described by Sadiq (2009) in the Aqra Formation (Maastrichtian) in Chwarta area, which consists of elongated rudist skeletons, each (5 – 10) cm long and (2 – 3) cm, in diameters.

In Sharwaldir section, the Bufflestone Microfacies contains large and small branching rogues coral colonies, which can be seen in outcrops. The length of some branches is more than 20 cm, as they are found in the middle and upper parts of the sampled section (Fig.8). The structure of the corals is mainly destroyed by recrystallization; consequently, the fine texture is replaced by spary calcite. The spaces between the branches are mainly filled by micrite (mudstone or wackestone) with some bioclasts. Walker and James (1992) have put this facies in the colonization stage of the reef structure. The presence of corals indicates normal marine salinity (Riding and Tomas, 2006).

- **Algal – Coral Bindstone**

Bindstone or framestone is defined by Flugel (2004) as "occurrence of sessile benthic fossils that are densely spaced and preserved in life position. The morphology and distribution of the fossils should fit into an imaginary three dimensional organic framework. Organisms contributing to the formation of framestones have changed during Phanerozoic and include corals, coralline sponges, stromatoporoids, rudist bivalves and calcareous red algae".

Original components were bound together during deposition as shown by intergrown skeletal matter, lamination contrary to gravity, or sediment-floored cavities that are roofed over by organic or questionably organic matter and are too large to be interstices (Dunham, 1962). According to Embry and Klovan (1971), the bindstone contains in situ tabular or lamellar fossils, which are encrusted and bound sediment during deposition and the matrix forms the supporting framework of the rock.

In Sharwaldir section, the Bindstone facies consists predominantly of well-preserved or partially recrystallized red algae that are not affected by fragmentation. This facies include massive (non-branching) corals too, which are, in some cases, totally recrystallized (Figs.9 and 10). The matrix consists of wackestone with bioclasts of green algae (dasycladales), gastropods and echinoids plates. The red algae bindstone is usually well preserved while those of corals are mostly recrystallized.

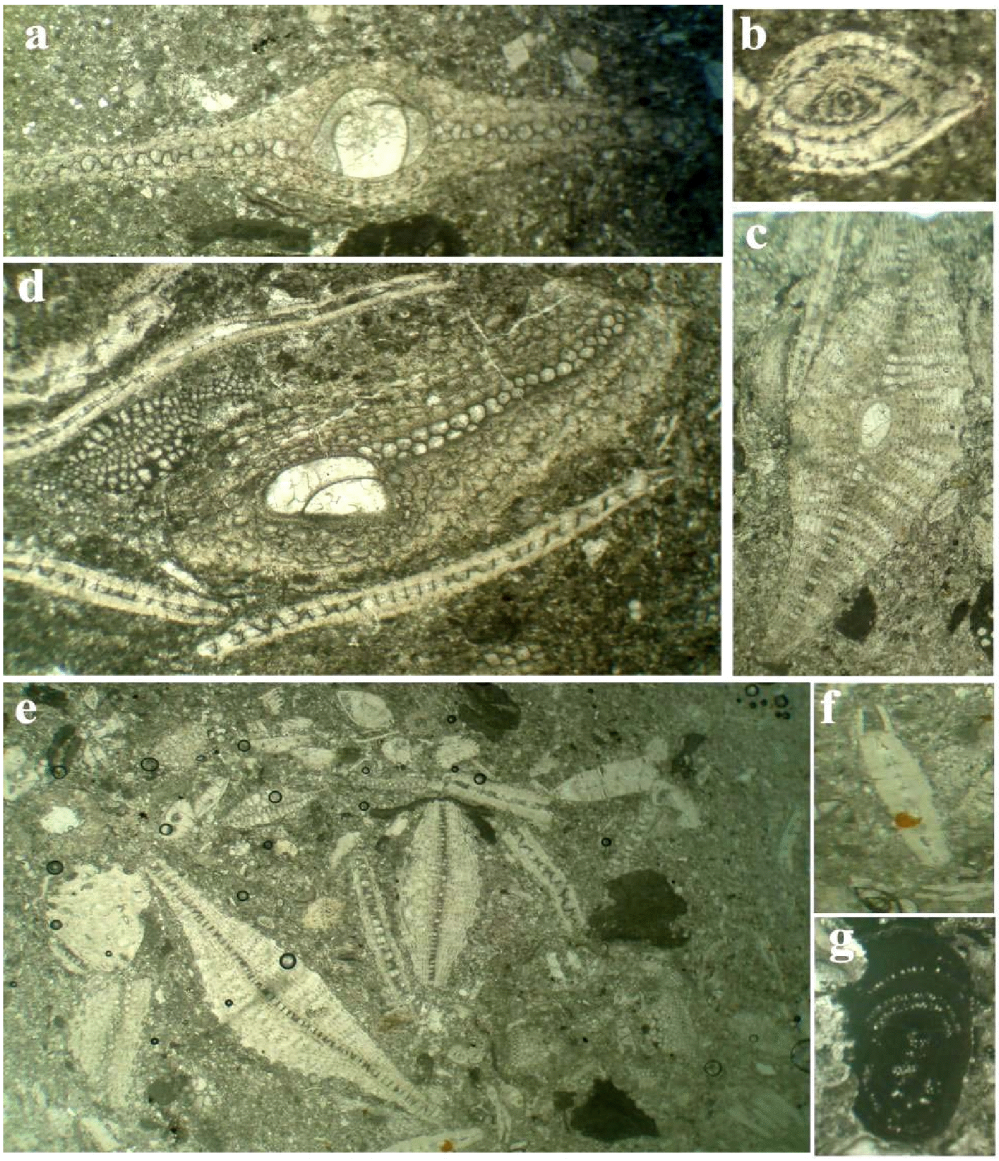



Fig.7: Microfacies of the Baba Formation (Middle Oligocene)

**a)** Lepidocyclina packstone – wackestone, with *Lepidocyclina* (*Eolephidina*) *elephantine* LEMOINE and DOUVILLE (10 X)

**b)** Bioclastic Packstone – wackestone with *Nummulites vascus* JOLY and LEYMERIE (20 X)

**c)** Lepidocyclina packstone – wackestone, with *Lepidocyclina* (*Eolephidina*) *delatata* (10 X) (MICHELOTTI) and *Heterostegina praecursor* TAN (10 X)

**d)** Lepidocyclina packstone – wackestone, with *Lepidocyclina* (*Eolephidina*) *elephantine* LEMOINE and DOUVILLE and *Heterostegina praecursor* TAN (10 X)

**e)** Lepidocyclina packstone – wackestone, with *Lepidocyclina* (*Eolephidina*) *elephantine* LEMOINE and DOUVILLE and *Heterostegina involuta* SILVESTRI, *Heterostegina praecursor* TAN, *Nummulites vascus* JOLY and LEYMERIE (Sample no.3, 10 X)

**f)** Bioclastic Packstone – wackestone with *Heterostegina involuta* SILVESTRI (20 X)

**g)** Bioclastic Packstone – wackestone with *Lithophyllum* sp. (Algae) (50 X)


Fig.8: Coral (Bafflestone) of the upper part of the succession,
**A)** Fresh outcrops section,
**B)** Oblique to longitudinal weathered outcrop sections

- **Grainstone Microfacies**

Grainstones are clast-supported and mud-free carbonate rocks and consist of skeletal and non-skeletal carbonate grains. The absence of mud has various causes such as deposition in high-energy environments (e.g. in intertidal and shallow subtidal environments), rapid accumulation of grains allowing no coeval mud sedimentation. Grainstones are highly variable with regard to grain type, shape, size, and sorting (Flugel, 2004).

Grainstones are common rocks in platform and ramp carbonates. They are usually related to the locus of wave energy absorption such as shorelines, shoals or shelf break where they form thick accumulation at the outer shelf margins or in inner ramp setting. Bank-margin sands occur in tidal bar belts, tidal deltas, and marine sand belts, back-reef areas, on beaches and in subaerial dunes. Accumulation of grainstone can also originate below the wave sweep base owing to current effects (Tucker, 1991).

The grainstones facies distinguished by grain support and spary calcite groundmass with the ratio of micrite being less than 5% (Dunham, 1962). The facies is rare in the sampled section and appears only in the middle part of the section (sample 38, Table 1) in which well-sorted and rounded red algae, peneroplis, and miliolid and mollusk bioclasts are characteristic. In spite of roundness, the grains are more or less elongated in shape due to the nature of the original bioclasts, which all have elongated shape as appear from exited wackestone and packstone in other samples.

- **Bioclast Wackestone – Packstone**

The richness of the studied succession with red algae and other skeletons suggest shallow water level. The differentiation of the in situ red algae from their bioclasts is difficult because the thalli is jointed into many branches and segments, which could have easily separated as in situ and reworked. In slides, the broken or differently arranged segments are indicated as bioclast (Figs.11, 12 and 13). Echinoderm plates and spines are common with red algae in addition to accessory bioclasts of pelecypods and forams. This facies occur at different levels in the middle and upper parts of the section and randomly alternate with bufflestone and/ or boundstone. Yamano *et al.* (2001) described such facies from areas behind the reef usually as unconsolidated bioclasts, such as coral fragments, coralline algae and mollusks.

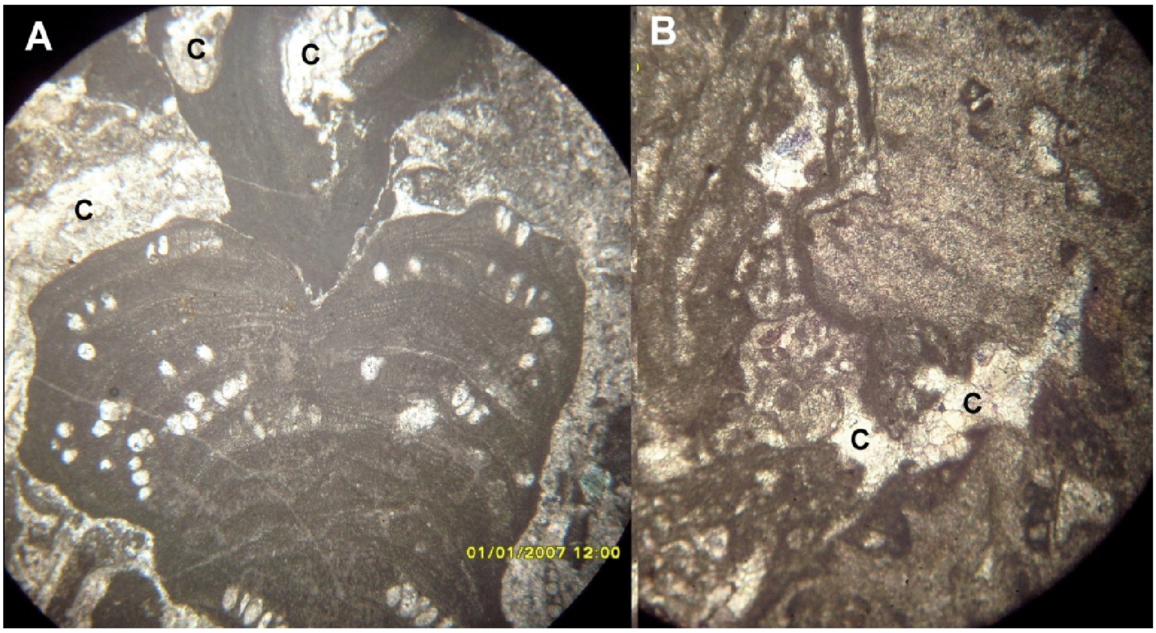



Fig.9: **A)** Two photos of crustose red that enclosed many pockets of sediments (**c**), filled with recrystallized to secondary sparite (Sample no.26, 10 X)
**B)** Same type of algae with same characteristics (Sample no.12, 10 X)

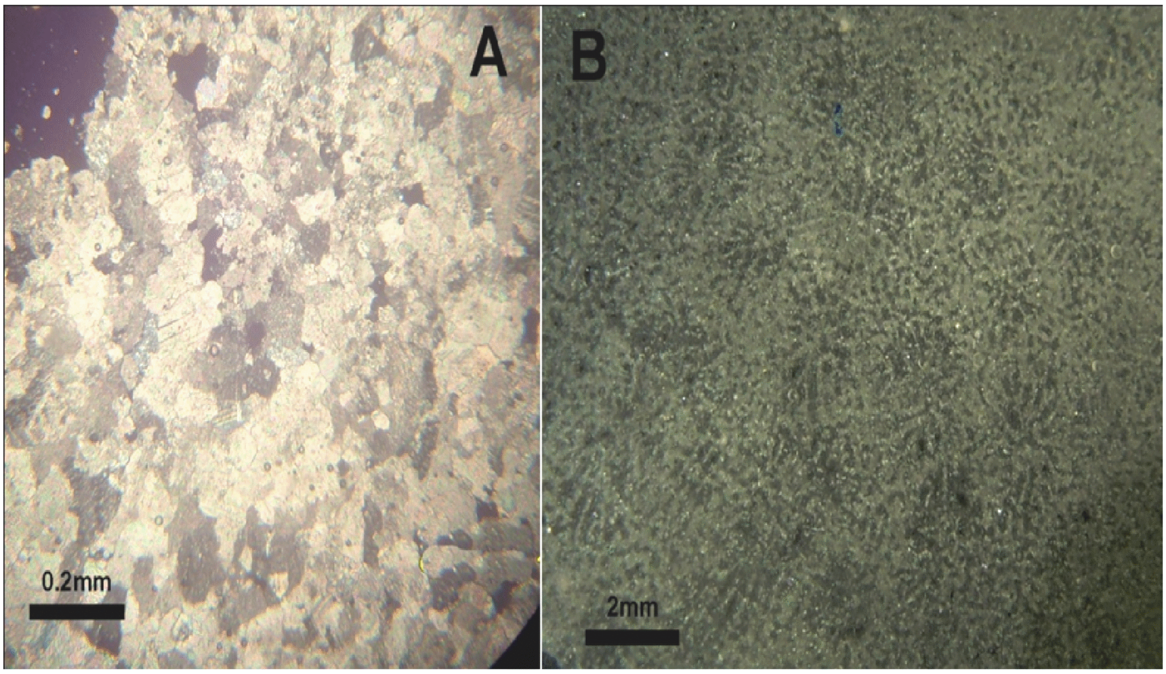



Fig.10: **A)** Recrystallized coral bindstone under XP in which no sign of coral can be seen, (Sample no.60, 15 X)
**B)** The same slide, as can be seen by hand lens 3 X, which shows ghost of coral

**FORMATIONS AND AGE DETERMINATION**

The Oligocene rocks are represented in the studied area by two formal units of neretic facies, Baba and Anah formations. Microfacies orthochemical and allochemical numerical data and neretic foraminiferal assemblages are given in Fig. (14).

Baba Formation is represented by 16 m of the lower part of the section; its base is not exposed. The exposed interval contains index benthonic larger foraminiferal groups of *Lepidocyclina* (*Eulepidina*) *elephantina*, *Lepidocyclina* (*Eulepidina*) *dilatata* (Michelotti), *Nummulites vascus* Joly and Lymerie, and *Heterostegina praecursor* Tan, *Heterostegina involuta* Silvestri. The association of these species with red algae and sparse nummulites characterizes Baba Formation. The environment of this formation is fore-reef to reef of Middle Oligocene age.

Anah Formation is represented by the top 50 m of the section and contains benthonic foraminiferal groups: *Borels pygmae* HANZAWA, *Austrotrilina howchini* (SCLUMBERGER), *Rotalia viennoti* GREIG, *Lithophyllum* sp. (Algae), *Miogypsinoides dehertii* VANDER VLERK, *Peneroplis farsensis* HENSON, *Peneroplis* sp., *Lepidocyclina* (*Nephrolepidona*) sp., Miliolid (*Pyrgo* sp.), *Lithophyllum* sp. (Algae), *Archais asmaricus* SMOUT and EAMES, *Austrotrilina howchini* (SCLUMBERGER) and *Praerhapydionina delicata* HENSON. This association with red algae characterizes Anah Formation. The environment of this formation is back-reef to reef of Late Oligocene age.

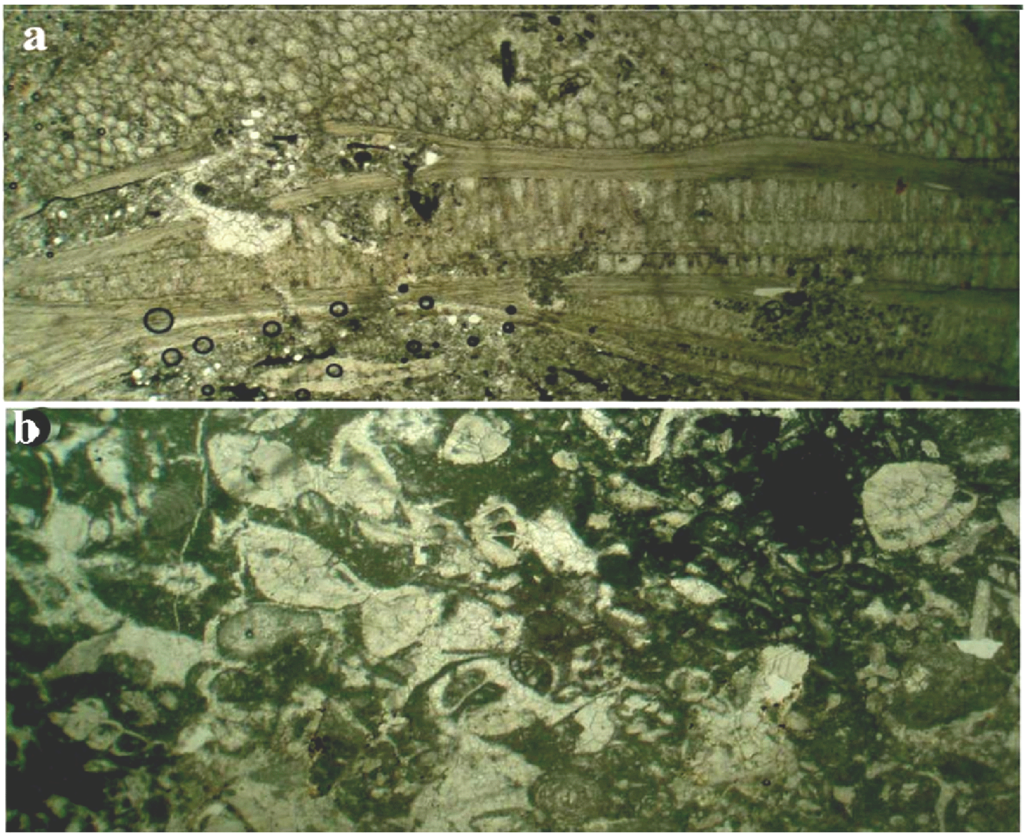



Fig.11: Microfacies of Sharwaldir section,
**a)** Baba Formation, Middle Oligocene
**b)** Foraminiferal Packstone – Wackestone
with *Nummulites vascus* JOLY and LEYMERIE (20 X)

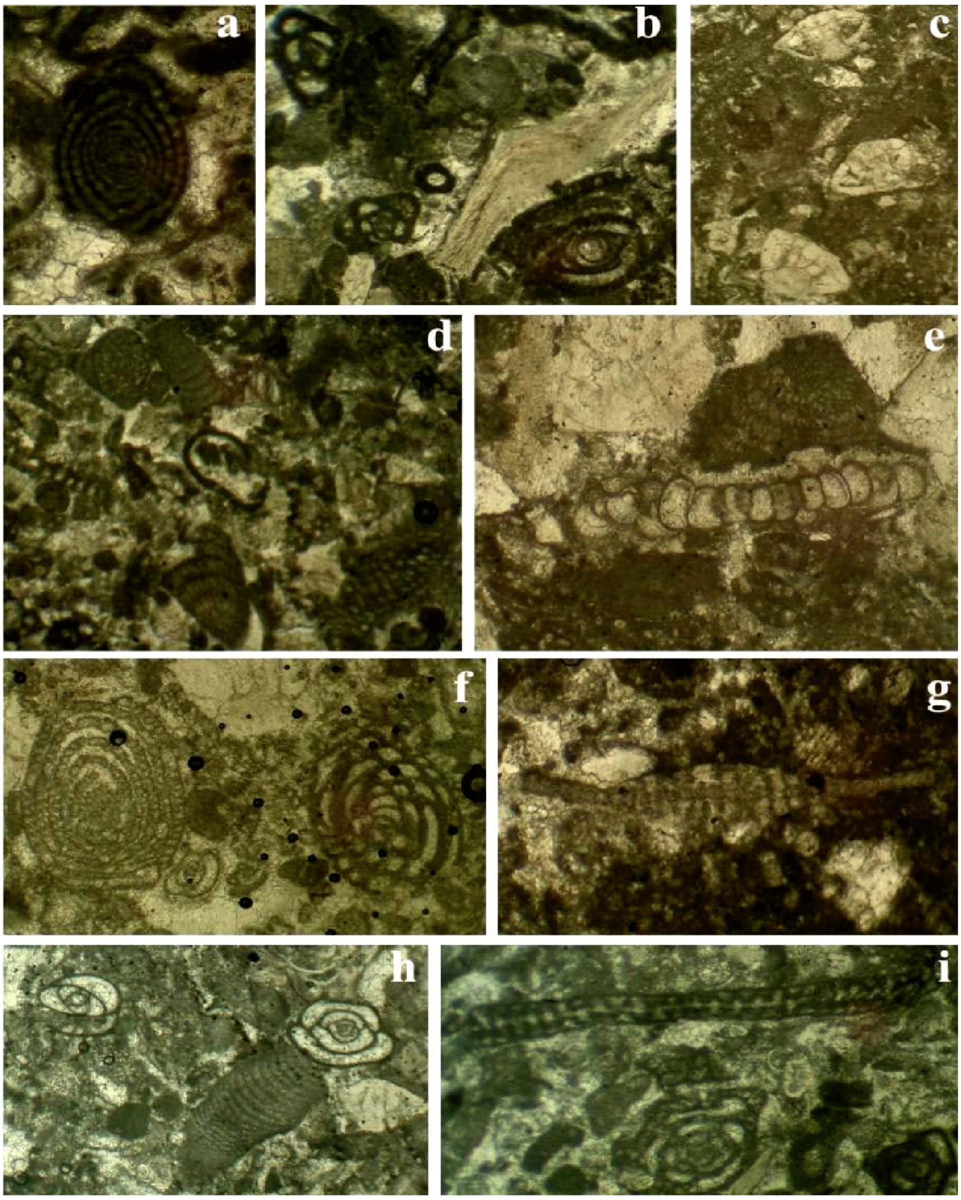



Fig.12: Microfacies from Sharwaldir section, Anah Formation, Late Oligocene

**a)** Miliolids bioclastic packstone – wackestone with *Borels pygmae* HANZAWA (25 X)
**b)** Miliolids bioclastic packstone – wackestone with *Austrotrilina howchini* (SCLUMBERGER) (50 X)
**c)** Bioclastic packstone – wackestone with *Rotalia viennoti* GREIG (50 X)
**d)** Miliolids bioclastic packstone – wackestone with *Miogypsinoides* sp., *Peneroplis* sp. and *Lithophyllum* sp. (Algae) (40 X)
**e)** Miliolids bioclastic packstone – wackestone with *Miogypsinoides dehertii* VANDER VLERK (40 X)
**f)** Miliolids bioclastic packstone – wackestone with *Peneroplis farsensis* HENSON and *Borels* sp. (50 X)
**g)** Bioclastic packstone – wackestone with *Lepidocyclina* (*Nephrolepidona*) sp. (25 X)
**h)** Bioclastic packstone – wackestone with Miliolid (*Pyrgo* sp.) and *Lithophyllum* sp. (Algae) (50 X)
**i)** Bioclastic packstone – wackestone with *Archais asmaricus* SMOUT and EAMES (marginal section) and *Austrotrilina howchini* (SCLUMBERGER) (40 X)

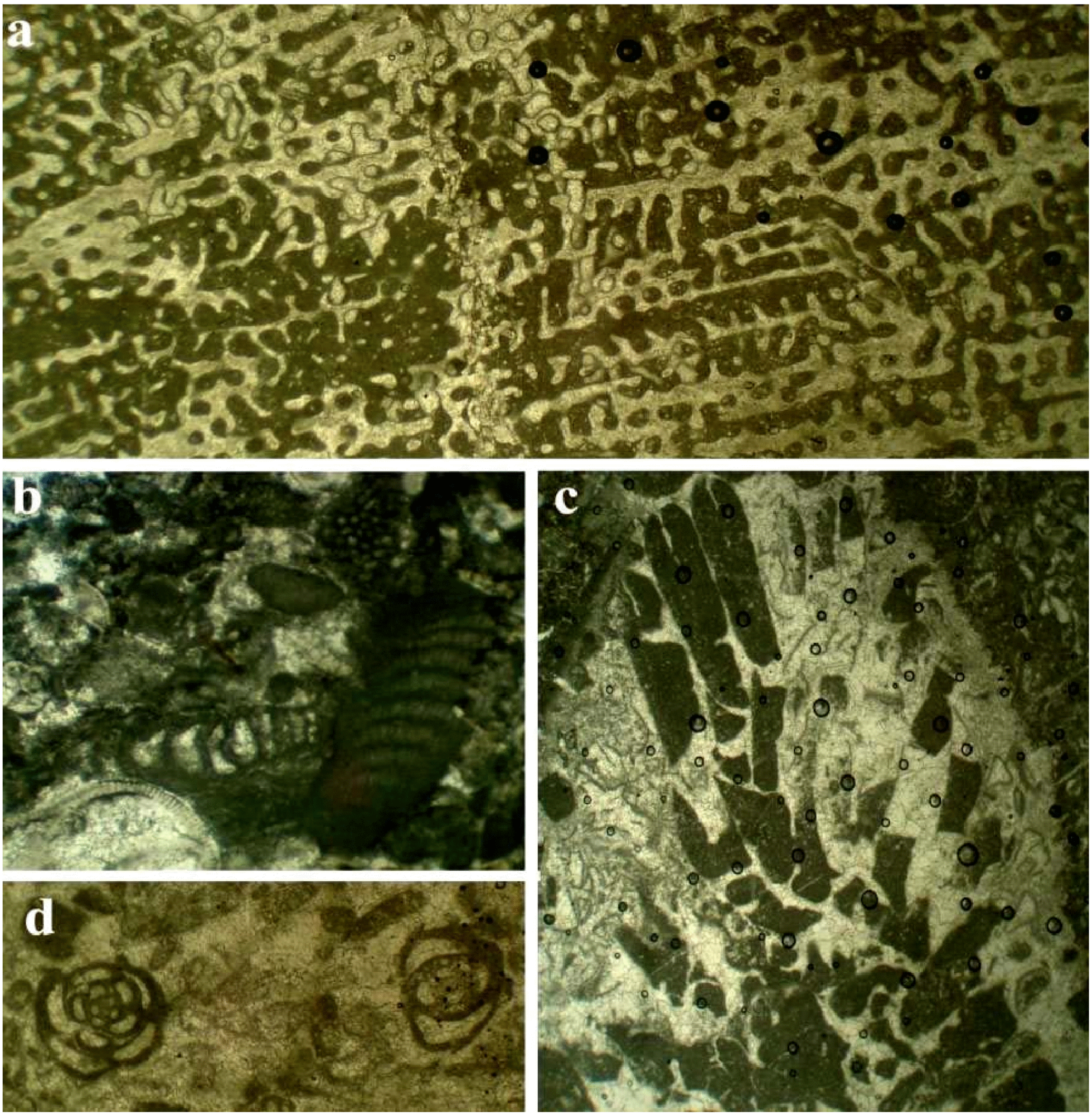
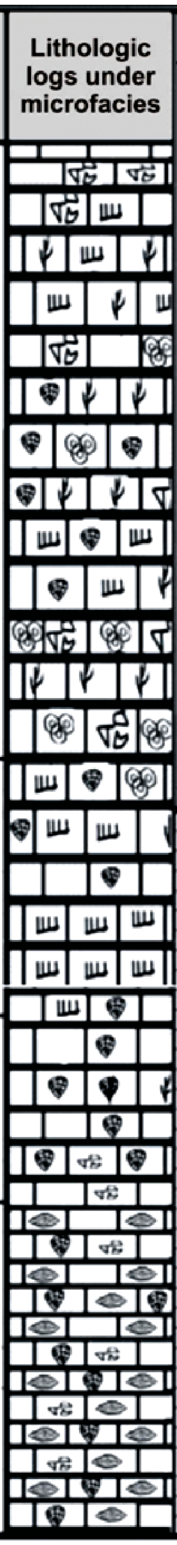



Fig.13: Microfacies from Sharwaldir section, Anah Formation, Late Oligocene

**a)** Boundstone with coral biolithite (sample no.27, 25 X)
**b)** Bioclastic packstone – wackestone with *Praerhapydionina delicata* HENSON,*Miogypsinoides* sp. and *Lithophyllum* sp. (Algae) (50 X)
**c)** Boundstone with coral biolithite consists exclusively of Coral (*Heliastra defrancei*) (10 X)
**d)** Bioclastic packstone – wackestone with *Austrotrilina howchini* (SCHLUMBERGER) (50 X)



| Formation | Environment | Microfacies | Sam. No. | Orthochims | | Allochims | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Sparite | Micrite | Lithoclast | Bioclast | Foram. | Algae | Coral | Mollusk | Echinoid | Others |
| Anah Formation | Reef with ocassional change to back – reef | Randomly occurrence of Coral and algal bindtone or bufflestone with nummulite, miliolid and bioclasts wackstone-packstone filling available spaces | 65 | 10 | 15 | 10 | 10 | 15 | 20 | 15 | 10 | 5 | 5 |
| | | | 64 | 12 | 13 | - | 15 | 5 | 15 | 20 | - | 5 | 5 |
| | | | 63 | 15 | 25 | 5 | 20 | 15n | 10 | - | 10 | 5 | 5 |
| | | | 62 | 5 | - | - | - | 2 | 3 | 80 | 5 | 5 | 5 |
| | | | 61 | 5 | - | - | - | 2 | 3 | 80 | 5 | 5 | 5 |
| | | | 60 | 5 | - | - | - | 2 | 3 | 80 | 5 | 5 | 5 |
| | | | 59 | 10 | 20 | 5 | 10 | - | 15 | 20 | 5 | 10 | 5 |
| | | | 58 | 15 | 35 | 5 | 20 | - | 10 | - | - | 5 | 5 |
| | | | 57 | 15 | 35 | 5 | 20 | - | 10 | - | | 5 | 5 |
| | | | 56 | 10 | 35 | 5 | 20 | - | 10 | - | - | 5 | 5 |
| | | | 55 | 8 | 12 | 5 | 12 | 3 | 25 | 15 | 5 | 10 | 5 |
| | | | 54 | 5 | 15 | - | 20 | 10n | 20 | 10 | 5 | 10 | 5 |
| | | | 53 | 13 | 17 | 10 | 20 | 10 | 20 | 5 | 10 | 5 | - |
| | | | 52 | 10 | 15 | - | 20 | 15m | 20 | - | 10 | 5 | 5 |
| | | | 51 | 8 | 12 | 8 | 20 | 10 | 25 | - | 12 | 3 | 2 |
| | | | 50 | 10 | 15 | | 10 | 15 | 27 | 3 | 5 | 10 | 5 |
| | | | 49 | 9 | 11 | - | - | - | - | 80 | - | - | - |
| | | | 48 | 11 | 14 | 5 | 25 | 8 | 17 | 5 | 5 | 10 | - |
| | | | 47 | 3 | 12 | - | 25 | 10 m | 23 | 7 | 5 | 12 | 3 |
| | | | 46 | 9 | 6 | 11 | 24 | 15m | 20 | 5 | 2 | 8 | 5 |
| | | | 45 | 4 | 16 | 5 | 25 | 8 | 30 | 5 | 2 | 5 | - |
| | | | 44 | 5 | 18 | 2 | 5 | 15m | 10 | 40 | - | - | 5 |
| | | | 43 | 8 | 12 | 5 | 15 | 20n | 15 | 10 | 5 | 5 | 5 |
| | | | 42 | 5 | 25 | 5 | 5 | 15 m | 15 | 10 | 5 | 10 | 5 |
| | | | 41 | 5 | 20 | 5 | 5 | 25 m | 15 | 5 | 5 | 10 | 5 |
| | | | 40 | 10 | 15 | 5 | 10 | 20n | 15 | 10 | 5 | 5 | 5 ps |
| | | | 39 | 10 | 15 | 5 | 10 | 20n | 15 | | 5 | 15 | 5 ps |
| | | | 38 | 20 | 5 | 5 | 40 | 10 | - | - | 10 | 5 | 5 |
| Transtiona zone | Possible reef crest | Coral and algal bindstone or bufflestone with nummulite and bioclasts wackstone filling available spaces | 37 | 11 | 14 | 5 | 10 | 15n | 30 | 2 | 3 | 10 | - |
| | | | 36 | 90 | 10 | - | - | - | - | - | - | - | - |
| | | | 35 | 90 | 10 | - | - | - | - | - | - | - | - |
| | | | 34 | 5 | 15 | 3 | 7 | 15m | 40 | - | - | 5 | 10 |
| | | | 33 | 5 | 15 | 5 | 15 | 10n | 30 | 5 | 5 | 8 | 2 |
| | | | 32 | 10 | 15 | 5 | 20 | 10n | 20 | - | 5 | 10 | 5 |
| | | | 31 | 10 | 15 | - | 20 | 10n | 30 | - | 5 | 10 | - |
| | | | 30 | 10 | 15 | - | - | - | - | 75 | - | - | - |
| | | | 29 | 5 | 10 | - | 15 | 5 | 5 | 45 | 3 | 10 | 2 |
| | | | 28 | 5 | 10 | - | 15 | 5 | 5 | 45 | 3 | 10 | 2 |
| | | | 27 | 5 | 15 | - | - | - | - | 80 | - | - | - |
| | | | 26 | 5 | 20 | 5 | 10 | 10 | 35 | - | 5 | 8 | 2 |
| | | | 25 | 10 | 20 | - | - | - | - | 65 | - | - | 5 |
| | | Red algae bindstone with bioclasts wackstone | 24 | 5 | 15 | 10 | 35 | 5 | 5 | 10 | 5 | 10 | - |
| | | | 23 | 10 | 40 | - | 5 | 5 | 20 | - | 5 | - | 5 |
| | | | 22 | 8 | 17 | 5 | 15 | 5 | 30 | - | 5 | 10 | 5 |
| | | | 21 | 10 | 25 | 5 | 5 | 15 | 25 | - | 5 | 5 | 5 |
| | | | 20 | 5 | 20 | - | 5 | - | 35 | 15 | - | 10 | - |
| | | | 19 | 5 | 25 | - | 10 | 20 | 25 | 5 | 5 | - | 5 |
| | | | 18 | 20 | 35 | - | 5 | 10 | 15 | - | 10 | - | 5 |
| | | | 17 | 15 | 30 | - | 10 | 5 | 20 | - | 5 | 10 | 5 |
| | | | 16 | 12 | 20 | 3 | 20 | 20 | 15 | 5 | 5 | - | - |
| | | | 15 | 10 | 25 | - | 20 | 10 | 20 | 5 | 5 | 3 | 2 |
| Baba Formation | Fore – reef platform | Lepidocyclina-red algae-bioclast wackstone-packstone | 14 | 5 | 20 | 5 | 15 | 20 | 15 | 5 | 10 | - | 5 |
| | | | 13 | 11 | 15 | 4 | 15 | 20 | 15 | 5 | 5 | 5 | 5 |
| | | | 12 | 7 | 7 | 6 | 15 | 10 | 25 | 10 | 10 | 3 | 5 |
| | | | 11 | 10 | 15 | 2 | 13 | 25 | 15 | 5 | 5 | 5 | 5 |
| | | | 10 | 6 | 9 | 5 | 10 | 30 | 20 | - | 10 | 5 | 5 |
| | | | 9 | 10 | 14 | 1 | 10 | 30 | 15 | 5 | 5 | 5 | 5 |
| | | | 8 | 12 | 15 | 3 | 5 | 30 | 25 | - | 2 | 3 | 5 |
| | | | 7 | 7 | 5 | 3 | 20 | 30 | 20 | 5 | 5 | 5 | 5 |
| | | | 6 | 5 | 20 | 5 | 20 | 20 | 20 | 5 | - | 5 | 0 |
| | | | 5 | 15 | 20 | - | 5 | 25 | 15 | 10 | 5 | 5 | 0 |
| | | | 4 | 8 | 5 | 5 | 10 | 30 | 20 | 2 | 3 | 2 | 10 |
| | | | 3 | 10 | 14 | 5 | 10 | 35 | 15 | 1 | 2 | 4 | 3 |
| | | | 2 | 5 | 15 | 0 | 20 | 25 | 15 | 5 | 0 | 5 | 5 |
| | | | 1 | 5 | 15 | 5 | 10 | 35 | 10 | 5 | 0 | 5 | 0 |
| | | | B0 | 5 | 15 | 5 | 15 | 30 | 15 | - | 5 | 5 | 5 |
| | | | A0 | 5 | 15 | 5 | 15 | 40 | 15 | 0 | 0 | 5 | 0 |

Fig.14: Microfacies and petrographic section of the studied succession, with petrographic components estimated under polarized microscope, using qualitative and visual evaluation

## ECONOMIC ASPECT

Three samples collected from lower, middle and upper parts of the section were chosen for chemical analysis (Tbale 2). The Oligocene carbonates of Sharwaldir Mountain indicate suitability for Portland and white cement manufacturing. The limestone constituents form more than 90% of the bulk sample. The percentage of the CaO is more than %53 and MgO is less than 2% (Tables 2 and 3). Quarrying conditions are favorable in addition to accessibility through good paved road to the mountain. Large reserve can be estimated through site investigations.

Table 2: Chemical analysis of three sample of Sharwaldir Mountain (suitable for clinker)

| S.No. | AM | SM | LSF | $Na_2O$ | $K_2O$ | $SO_3$ | MgO | CaO | $Fe_2O_3$ | $Al_2O_3$ | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 0.55 | 3.36 | 1697.44 | 0.02 | 0.04 | 0.05 | 1.69 | 53.00 | 0.20 | 0.11 | 1.02 |
| **2** | – 0.15 | 5.52 | 4962.20 | 0.02 | 0.01 | 0.04 | 0.22 | 54.00 | 0.08 | 0.01 | 0.38 |
| **3** | 1.6 | 2.0 | 645.10 | – | 0.04 | < 0.07 | 0.21 | 55.35 | 0.05 | 0.08 | 0.26 |
| **Mean** | 0.66 | 3.63 | 2434.9 | 0.02 | 0.03 | 0.05 | 0.71 | 54.1 | 0.11 | 0.06 | 0.54 |

Table 3: Mean value of chemical analysis of three samples of Sharwaldir Mountain, compared with standard composition of Portland and White cements and limestones from Sarchinar and Tasluja cement factories

| Sharwaldir Lst. | Tasluja Lst. | Sarchinar Lst. | White Cement | Portland Cement | (%) |
|---|---|---|---|---|---|
| 54.1 | 52.15 | 44.5 | > 45 | > 45, (58 – 67) | **CaO** |
| 0.71 | 0.2 | 0.21 | < 2 | < 2, (1 – 5) | **MgO (Max.)** |
| 0.05 | – | – | 0.05 | 0.05, (0 – 1) | **$Na_2O + K_2O$** |
| 0.06 | 1.93 | 3.34 | – | (4 – 8) | **$Al_2O_3$ Max.** |
| 0.54 | 2.57 | 11.78 | – | (16 – 25) | **SiO2 Min.** |
| 0.11 | 0.4 | 0.72 | < 0.1 | (2 – 5) | **$Fe_2O_3$ Max.** |
| – | 1 | 1 | – | – | **I.R. Max.** |
| – | 41.65 | 36.61 | – | (0.5 – 3) | **L.O.I.** |

## CONCLUSIONS

The followings can be concluded from this study.

- The studied exposed formations in Sharwaldir anticline are of Oligocene age and represent Baba (Middle Oligocene) and Anah (Late Oligocene) formations.
- Five microfacies were described from the studied sections in Sharwaldir anticline, these are: Foraminiferal Wackestone – packstone microfacies, Bufflestone microfacies, Algal – coral Bindstone, Grainstone microfacies, and Bioclast Wackestone – Packstone.
- The chemical analyses of three samples of limestone showed good quality of limestone for use in cement industry.

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