Iraqi Bulletin of Geology and Mining *Vol. 2, No. 2, 2006* *pp 39-55*

MICROFACIES AND ENVIRONMENTAL ANALYSIS OF HARUR FORMATION EARLY CARBONIFEROUS (TOURNAISIAN) NORTHERN IRAQI KURDISTAN REGION

Govand H. Sherwani [*], **Srood F. Naqishbandi** [*] and **Sardar M. Balaky** [*]

ABSTRACT

A surface section of Harur Formation of Early Carboniferous (Tournaisian) in Nazdur area, northeast of Zakho town, Northern Iraqi Kurdistan, was selected for this study. Lithologically, Harur Formation consists of thin to medium bedded, black organic limestone, dolomitic limestone, with black micaceous shale mainly in lower and upper parts. The petrographic study has shown that these limestones consist of micrite and sparite groundmass. The skeletal grains included shallow water brachiopods, bryozoans, corals, and echinoderms, in addition to ostracods, while non-skeletal grains included peloids only.

Four different microfacies were distinguished; Boundstone, Grainstone, Lime Packstone, and Lime Wackestone. Each of these had been further subdivided. Using lithologic and paleontologic criteria, the depositional environment of Harur Formation is concluded to be shallow marine environment, mostly reef and reef flanks.

التحليل السحني والبيئي لتكوين هارور الكربوني المبكر (التورنازي)، شمال أقليم كوردستان العراق

كوفند حسين شيرواني و سرود فاروق نقشبندي و سردار محي الدين بالكي

المستخلص

تمت دراسة تكوين هارور، الكربونى المبكر(التورنازي) في مقطع سطحي مختار قرب قرية نازدور الواقعة شمال شرق مدينة زاخو في اقصى شمال أقليم كوردستان العراق . تتألف صخارية تكوين هارور من طبقات رقيقة الى متوسطة السمك من الحجر الجيري العضوي الاسود والحجر الجيري المدلمت المتداخل مع طبقات قليلة السمك من السجيل الاسود الحاوي على المايكا فى الاجزاء العليا والسفلى من التكوين.

أظهرت الدراسة البتروغرافية ان أرضية الحجر الجيري تتكون بشكل اساسي من الوحل الجيري و قليل من الكالسايت السباري . أشتملت الحبيبات الهيكلية في الحجر الجيري على الاحياء التابعة للمياه الضحلة مثل البراكيوبودا ، البرايوزوا ، المرجان ، وشوكية الجلد ، اضافة الى الاوستراكودا، أما الحبيبات غير الهيكلية فقد أقتصرت على الدمالق. كما تم تشخيص اربع سحنات مجهرية فى الحجر الجيري اشتملت على الحجر الحبيبي، الحجر المترابط ، الحجر المرصوص ، الحجر الواكي ، مع تقسيمات ثانوية لكل منها. وبأعتماد الدلائل الباليونتولوجية والصخارية ، أستنتج ان بيئة الترسيب لتكوين هارور كانت بيئة بحرية ضحلة وعلى الارجح بيئة الحيد و جناحي الحيد.

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INTRODUCTION

The Paleozoic section of Iraq, if compared with Mesozoic and Cenozoic sections, was targeted by only few studies. Accordingly, the geologic scope of stratigraphy, facies distribution, and evolution of depositional basins, are all still incomplete and possess many mysterious aspects. This shortage in geologic information is due to limited exposures of Paleozoic rocks and exploration wells that penetrated them.

Paleozoic exposures (outcrops) are restricted in some patches in Northern Iraq and Western Desert in addition to their presence in the subsurface through (Khleisia well No.1) of Northwestern Iraq. Harur Formation was first recognized and described from the Ora fold, Amadia district of Northern Thrust Zone of Iraq by Wetzel and Morton (1952) in Bellen et al. (1959). The total thickness of Harur Formation in its type section is about (62) meters (Bellen et al., 1959), while in the studied section is about (49.5) meters. Based on the evidence of fossils, the age of Harur Formation has been determined as Early Carboniferous (Tournaisian). Lithologically, Harur Formation consists of bedded, black, organic limestone, dolomitic limestone with intercalations of black micaceous shale mainly in lower and upper parts.

The objective of this paper is to manifest microfacies, and to define the depositional environment and history of the Harur Formation.

LOCATION AND METHODS

The Nazdur locality, which is chosen for the present study, is situated in far north of Iraqi territory, about 60 km to northeast of Zakho town, Duhok governorate (Fig. 1). The studied section lies approximately on Lat. 37^{o} 18' 45" N and Long.43^{o} 15' 46" E, nearly 1 km to northeast of Nazdur village, and located on the main road to the village. Extensive fieldwork was carried out in order to study the general geology of the area and structural relations of the Paleozoic formations in the surroundings of the studied section, and to choose an appropriate locality for the present study. The sum of 35 thin sections, prepared from the same number of limestone samples, were studied petrographically.

These thin sections were later stained with Alizarin Red S (ARS) following the procedure of Dickson (1966) for detecting the calcite and dolomite. Detailed petrographic description, along with microfacies analysis, was performed. The petrographic description and microphotography of thin sections were performed by microscopes made available by Geology Department of College of Science, Salahaddin University, Erbil.

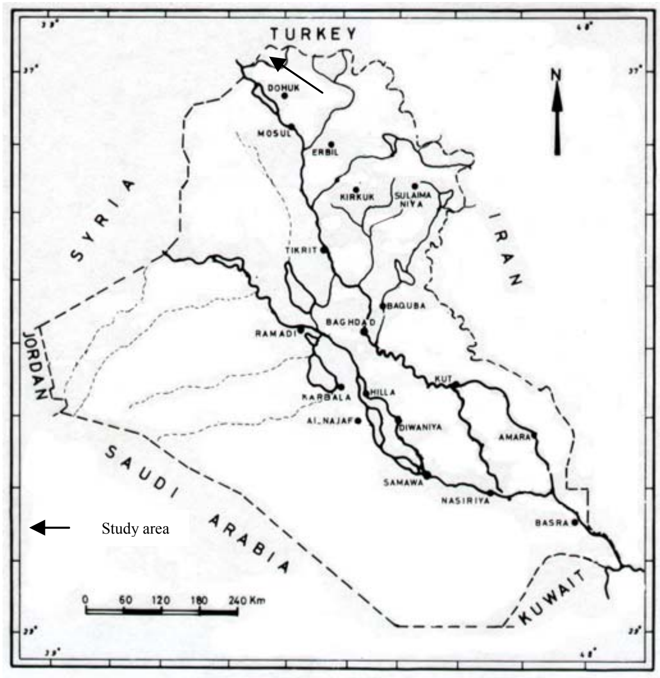


Fig. (1): Location map of study area

GEOLOGIC SETTING AND STRATIGRAPHY

Paleozoic rocks are commonly exposed as isolated patches in some eroded cores and limbs of anticlines in the Thrust Zone of Northern Iraq. Nazdur locality, which is chosen for this study, is located within the Zone of Imbrication of the foreland basin, (according to Numan, 2000) (Fig. 2). Buday et al. (1973) were the first who named Northern Thrust Zone in Iraq. During fieldwork, several E – W trending thrusts were observed. These thrusts (Fig. 3) had given rise to repetition or interruption of strata in the exposed succession. The area is also characterized by presence of several normal and reverse faults and secondary folds. All these structural features led to distortion and complication in the stratigraphic succession of the area. The general trend of structural features is E – W.

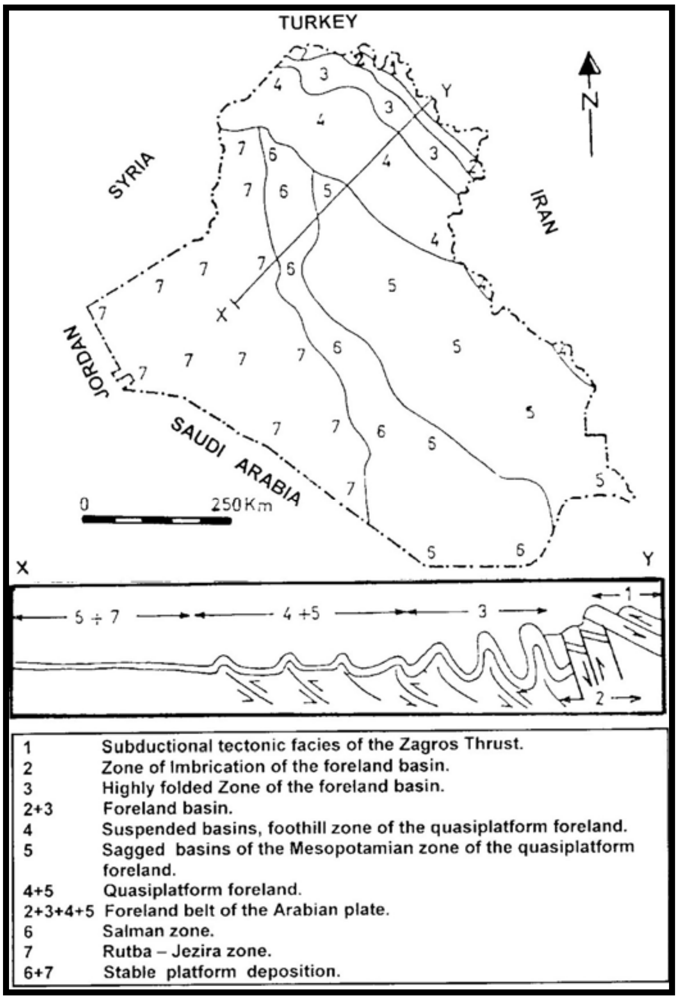


Fig. (2): Major tectonic division in Iraq (after Numan, 2000)

In respect to topography, the Nazdur area lies in a rugged terrain, extending along narrow, steep–sided, long valley of consequent type. The mainstream course in the area is Khabour river, which has tributaries or (drainage lines) of dendritic pattern. In respect to stratigraphy, the section includes a stratigraphic succession, starting with the oldest rock unit of Iraq. The exposed rock units, from oldest to youngest in this section, include Khabour Formation (Ordovician), which underlies Pirispiki Formation (Ordovician). The latter is, in turn, overlain by the younger Kaista Formation (Late Devonian), with Ora Formation (Early Carboniferous) topping them. Followed by Harur Formation (Early Carboniferous), which covers Ora Formation. The section terminates by younger Chia Zairi Formation (Late Permian) (Fig. 3).

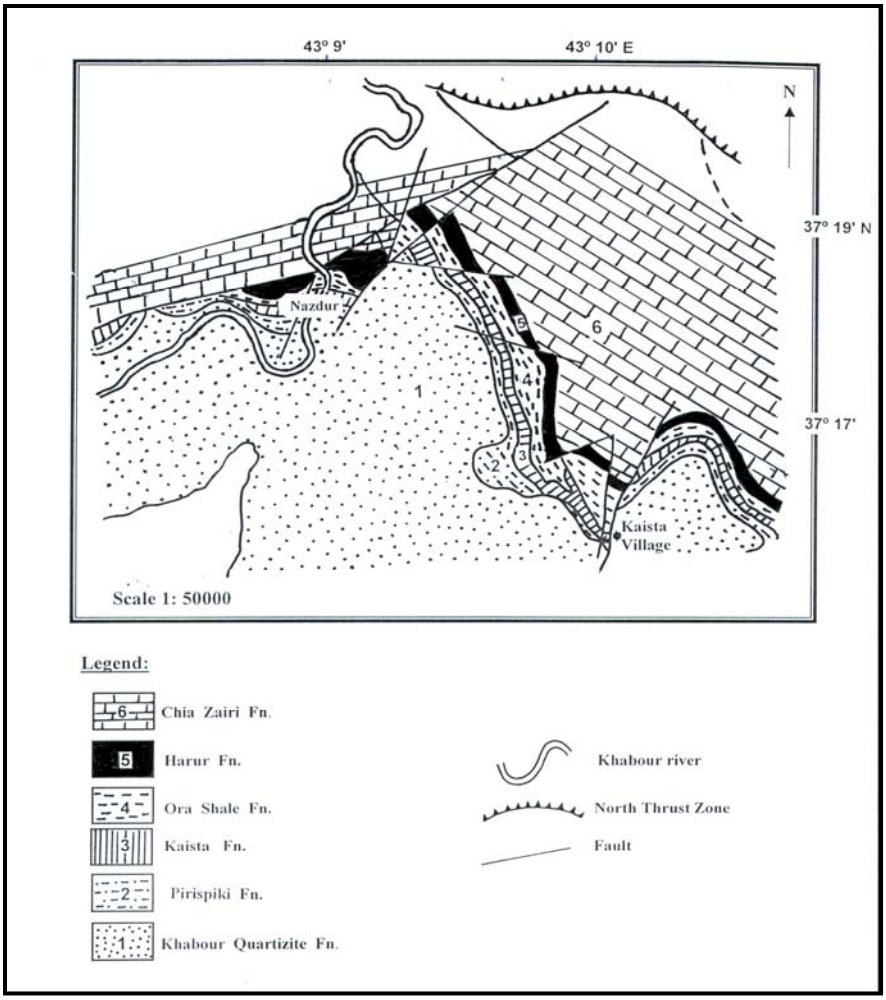


Fig. (3): Geological map of the Northern Thrust Zone of Iraq (after Pesl and Isaac, 1976)

The nature of boundaries is not uniform; the lower boundary is conformable and gradational with underlying Ora Formation, while the upper boundary is unconformable with overlying Chia Zairi Formation (Bellen et al., 1959).

PETROGRAPHY

The lithologic composition of the Harur Formation in Northern Thrust Zone, consists of thin to medium bedded, black, organic limestone, dolomitic limestone, intercalated with black micaceous shale mainly in lower and upper parts (Fig. 4). Thirty five thin sections of limestone samples were examined to demonstrate the petrographic constituents. The followings are the main petrographic constituents of Harur Formation.

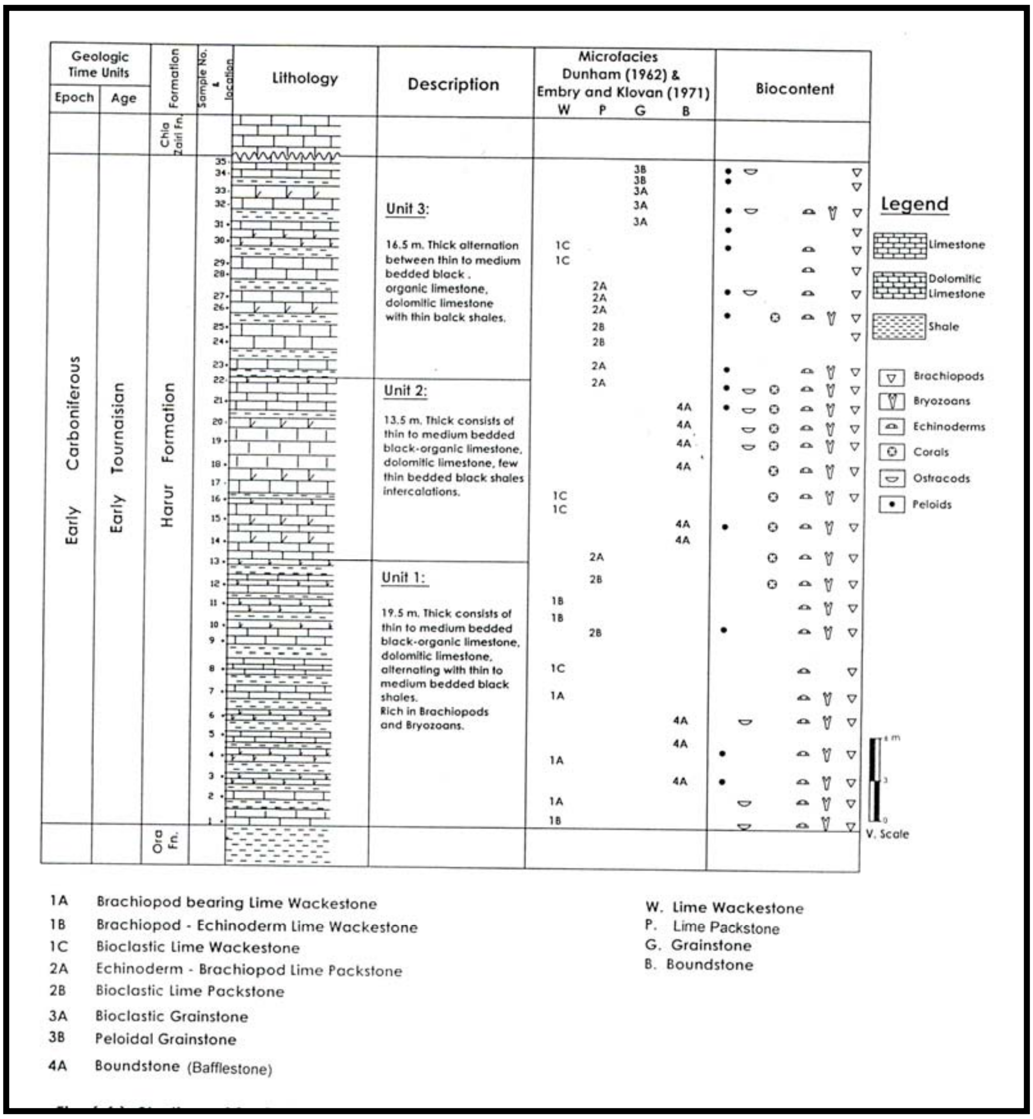


Fig. (4): Stratigraphical Column of Harur Formation, Nazdur area – Northern Iraq

1- Skeletal Grains

Fossils

Fossils are the main skeletal grains in Harur Formation. The present study shows that Harur limestones are characterized by rich fossil content that include:

a- Brachiopods

Brachiopods consist of two unequal valves or curved plates, which are usually hinged along one margin (Horowitz and Potter, 1971). In thin sections, brachiopods possess both articulated tybe (Figs. 5.1 and 5.3), and inarticulated (single valves) type (Figs.5.2, 5.6, 6.3, 6.4 and 6.8), in addition to spines (Figs. 5.2 and 6.8), which exhibit a hollow circular features. Inarticulated brachiopods are more common. Brachiopods represents high ratio of the bulk skeletal grain, and it has dominated all the succession of Harur Formation (Fig. 4).

b- Bryozoans

Bryozoans are colonial animals whose calcareous skeletons exhibit a wide range of shapes. The most common shapes are encrusting, branching, and fenestrate (Horowitz and Potter, 1971). The investigated section shows abundance of bryozoans particularly in lower and middle parts (Figs. 5.3, 5.4 and 6.1).

c- Echinoderms

Echinoderm skeletons are composed of calcareous plates, which are in hundreds or thousands in number (Horowitz and Potter, 1971). Each individual plate of the echinoderm skeleton acts optically as a single crystal of calcite. Consequently, each plate will extinct optically at a single position under crossed nicols in a polarizing microscope (Flugel, 1982). Rocks of Harur Formation obtain high fraction of echinoderm plates (Figs. 5.5, 5.7, 6.4 and 6.7) and their spines (Fig. 5.6), particularly in the middle part of the formation.

d- Corals

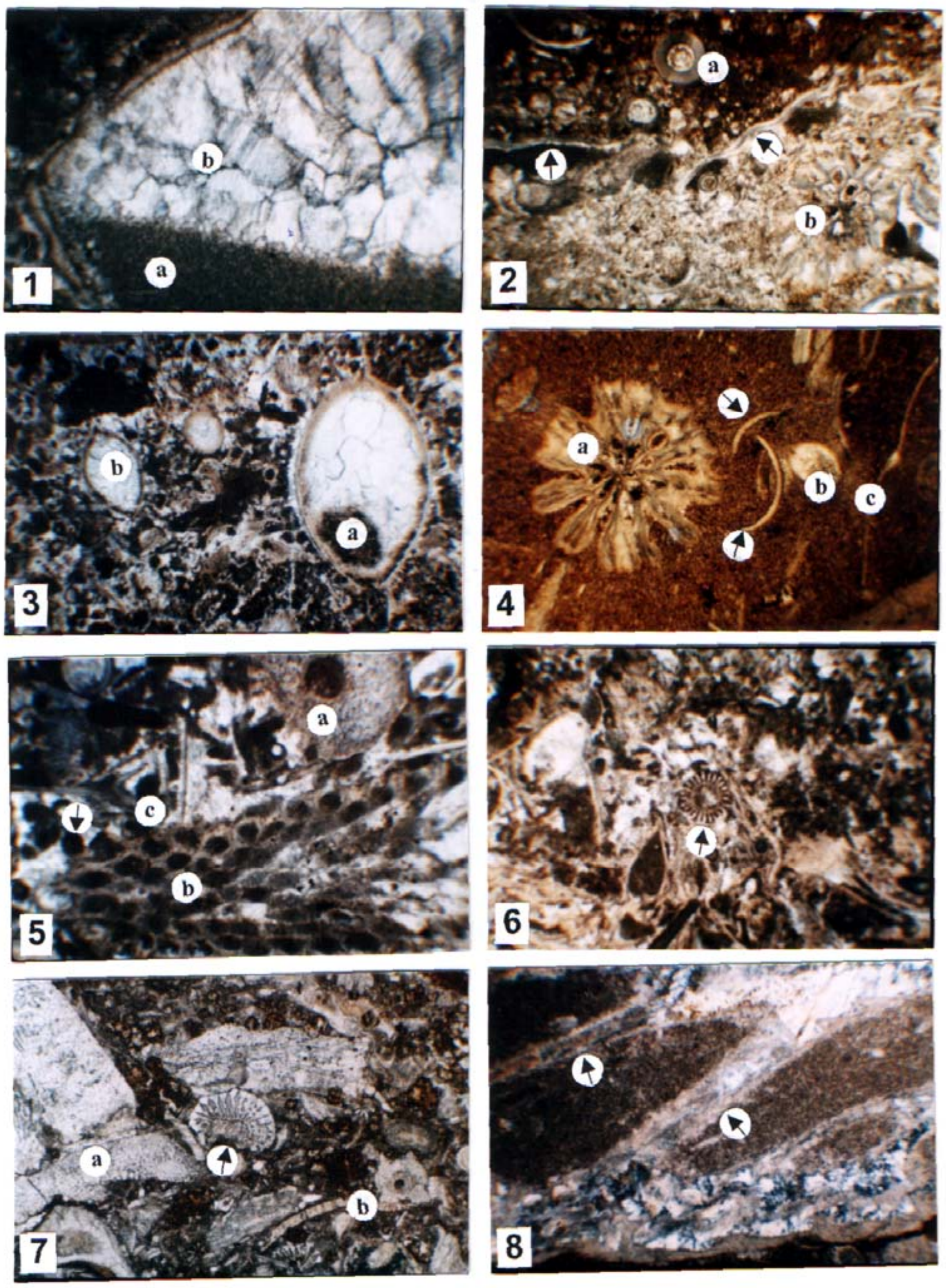
The major fossil group of corals has produced similar types of solitary or colonial skeletons. The present study shows that there is a considerable amount of corals seen within the middle part of Harur Formation (Figs. 5.7 and 5.8).

e- Ostracods

Ostracods consist of two thin valves with inwardly recurved shell margins (duplicature) at one end. Ostracods are presented in a studied section of Harur Formation, in form of articulated valves (Figs. 5.2, 5.7 and 6.7), and single valves (Fig. 5.3), along with other biotypes such as brachiopods, echinoderms, and bryozoans.

f- Bioclasts

Bioclasts of rocks of Harur Formation are reworked skeletons of brachiopods echinoderms, bryozoans (Figs. 5.2, 5.7, 6.3, 6.5 and 6.8), and some unidentifiable mollusks. They give clue to water energy, as round bioclasts refer to high energy level while flattened ones indicate low energy.



Figs. 5.1 – 5.8

Fig. 5.1 –5.8

5.1 Articulated brachiopods, filled with micrite (a) and sparite (b) - drusy cement . This fabric is called Geopetal fabric. H. 4, P.P., 32X.

5.2 Inarticulated (single valve) brachiopods (arrows), with brachiopod spines (a), bryozoans (b), in a micritic matrix. H. 5, P.P., 32X.

5.3 Articulated brachiopods (a), and ostracods (b), surrounded by numerous peloids (fecal pellets). Note uniformity in size. H. 30, P.P., 32X.

5.4 Bryozoans (a), with articulated ostracods (b) and single valves of brachiopods (c) and ostracods (arrows), in a micritic matrix rich in organic materials. H. 2, P.P., 32X.

5.5 Echinoderm plate (a), along other biotopes such as bryozoans (b), and brachiopod valves (c). Note peloids (arrow). H. 26, P.P., 32X.

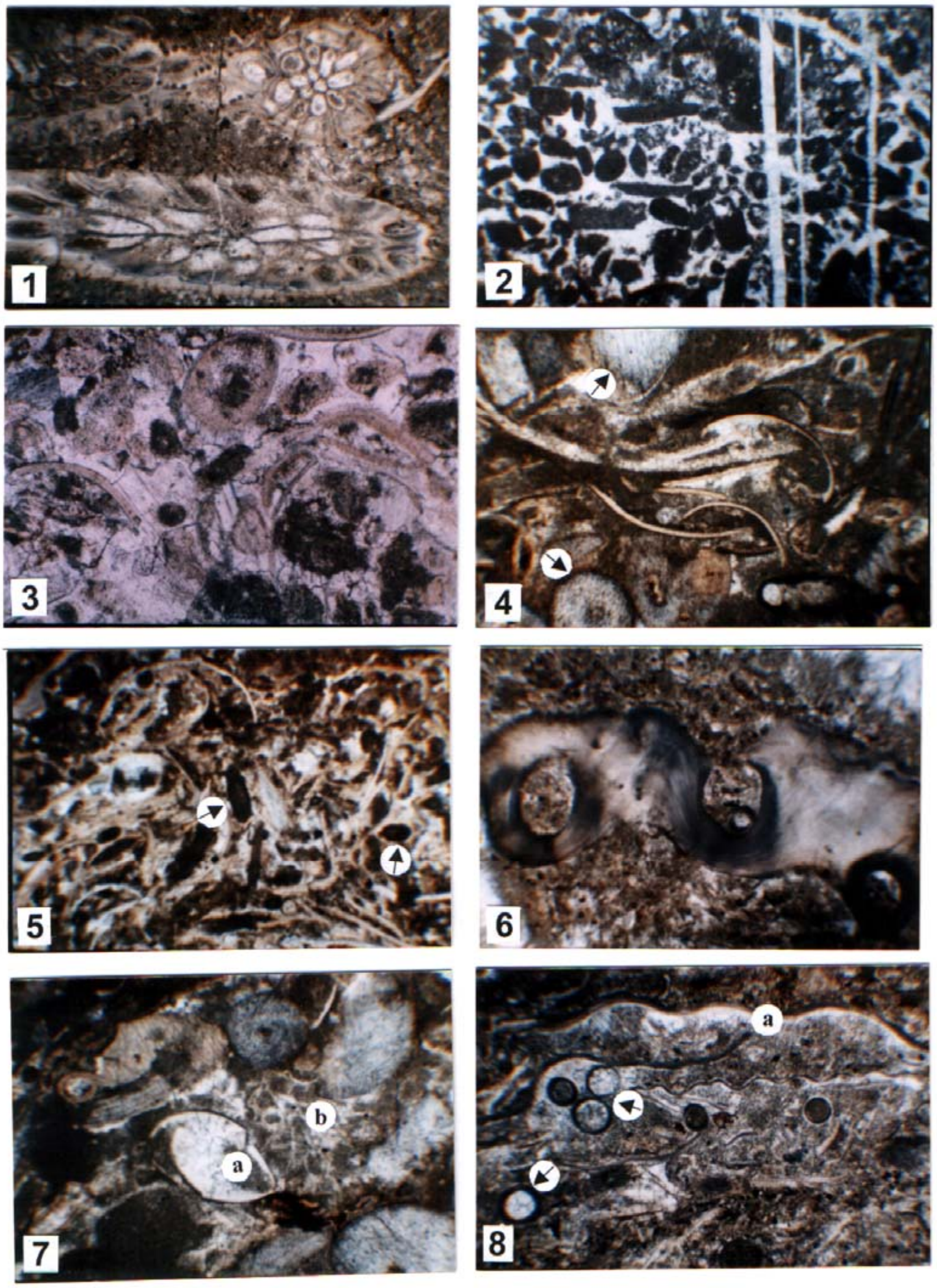
5.6 Echinoderm spine (arrow), surrounded by several brachiopod valves in a micritic matrix. H. 27, P.P., 32X.

5.7 Corals (arrow) with echinoderm plate (a) and brachiopod valve (b) in a micritic matrix. H. 15, P.P., 32X.

5.8 Boundstone (Bafflestone Submicrofacies) Microfacies,. Note, restricting of sediments (micrite) in between the ribs of corals (arrows). H. 21, X.N., 32X.

Key Words

H. Harur Formation
P.P. Plane Polarized
X.N. Crossed Nicols
X. Magnification power



Figs. 6.1 – 6.8

Figs. 6.1 – 6.8

6.1 Boundstone (Bafflestone Submicrofacies) Microfacies. Bryozoan skeletons are the major component of this facies. H. 6, P.P., 32X.

6.2 Peloidal Grainstone Submicrofacies. Note peloids (fecal pellets) in spary calcite groundmass. H. 31, P.P., 32X.

6.3 Bioclastic Grainstone Submicrofacies. The facies consists of brachiopod clasts with some peloids in a spary calcite matrix. H. 32, P.P., 32X.

6.4 Echinoderm – Brachiopod Lime Packstone Submicrofacies. The facies is rich in brachiopod valves, with minor amount of (arrows) micritic matrix. H.22, P.P., 32X.

6.5 Bioclastic Lime Packstone Submicrofacies. Closely packed brachiopod valves has characterized this facies. Peloids (arrows) present. H. 27, P.P., 32X.

6.6 Brachiopod bearing Lime Wackestone Submicrofacies. Note large shells of brachiopods in micritic matrix. H. 4, P.P., 32X.

6.7 Brachiopod – Echinoderm Lime Wackestone Submicrofacies. Echinoderms are the major component of this facies, in addition to that, ostracods (a) and bryozoans (b) are also present. H. 23, P.P., 32X.

6.8 Bioclastic Lime Wackestone Submicrofacies. Brachiopod clasts (a) and brachiopod spines (arrows) which exhibit a hollow circular feature the major component of the facies. H. 3, P.P., 32X.

Key Words

H. Harur Formation
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2- Non Skeletal Grains

The presence of such grains is relatively limited in limestones of Harur Formation. The only available types are peloids (pellets) (Figs. 5.3, 5.5, 6.2 and 6.5). Others such as ooids, oncoids, intraclasts , extraclasts …etc are missing within the rocks of Harur Formation.

3- Groundmass (Matrix)

Matrix is the part that ties all grains, and stands as indicator of intensity of water current and type of depositional environment (Folk, 1962). Groundmass designates the primary matrix broadly defined as (micrite) as well as (sparite) formed by cementation or neomorphic processes (Flugel, 1982). The microscopic studies showed that limestones of Harur Formation are mainly composed of lithified carbonate mud (Figs. 5.4, 5.8, 6.1, 6.4 and 6.6), particularly in the lower and middle parts, with an exception in upper parts where spar is noticed (Figs. 6.2 and 6.3).

Numerous studies of recent sediments have shown that lime mud (micrite) can be originated by variety of processes (Bishop, 1972; Tucker, 1981 and Flugel, 1982). While, it is here believed that most of micrite of Harur Formation is produced by biochemical precipitation, through algal photosynthesis.

MICROFACIES

The present study, as in many other previous investigations, had utilized the easy and practical classification of Dunham (1962) and its modification by Embry and Klovan (1971), for naming facies types of carbonate rocks. Then, these facies were compared with the Standard Microfacies (SMF) and Facies Zones (FZ) of Wilson (1975) and Flugel (1982) to testify the equivalence between both sets.

In this study, four main microfacies types are recognized in limestones of Harur Formation. Each, was latter on subdivided into several subfacies, based on significant fossil type and ratio of fossils to matrix. Below are the main microfacies recognized upon the petrographic study of Harur Formation?

1- Boundstone Microfacies

It is the limestone in which the calcareous material , created by organisms , were combined through the deposition, like reefal deposits (Dunham, 1962). This facies is subdivided depending on organism's activities (Embry and Klovan, 1971) to the following subfacies:

- Bafflestone Submicrofacies (Figs. 5.8 and 6.1)

This facies is formed due to restricting the sediments that are present in between the ribs of the organisms, which form local calm environment. The facies is observed in lower and middle parts of the formation (Fig. 4). The community of this facies is due to trapping deposits among the branches of bryozoans, and /or ribs of corals, during deposition. Whereas the bryozoans form the main component of this facies, and most of them exist in the core of the reef. Other fossils of the facies, such as brachiopods, echinoderms, and ostracods are spread in micritic matrix. This facies is equivalent to SMF (7) within FZ (5).

2- Grainstone Microfacies

This facies is characterized by dominance of grains which are deposited in a spary calcite matrix. The presence of micrite is less than 15% (Dunham, 1962). Grainstone is well observed in the upper part of Harur Formation. Depending on grain type, this facies is subdivided into two submicrofacies, as follows:

a- Bioclastic Grainstone Submicrofacies (Fig. 6.3)

This facies is rarely found within the upper part of Harur Formation (Fig. 4). It is characterized by rich organic clasts. The facies is formed in both back and fore reefs, and composed of reef components (Wilson, 1975). The bioclasts include fragments of brachiopods, echinoderms, corals and bryozoans. While, non-skeletal grains include few peloids. This facies resembles Wilson's SMF (5) of FZ (4).

b- Peloidal Grainstone Submicrofacies (Fig. 6.2)

Peloids are the major components of this facies, although some echinoderm and bryozoan clasts may exist. The matrix of the facies consists of spary calcite and microsparite. The presence of this facies is limited within the upper part of the formation. According to Wilson (1975), this facies can be found in shallow warm water with moderate circulation. The facies corresponds to SMF (16) in FZs (7, 8)

3- Lime Packstone Microfacies

This facies consists of skeletal grains up to 60%, leaving minor micrite inbetween (Dunham, 1962). The detailed description of this microfacies enables classification to smaller subdivisions:

a- Echinoderm – Brachiopod Lime Packstone Submicrofacies (Fig. 6.4)

This subdivision is observed in the middle and upper parts of Harur Formation. It is rich in brachiopods and their spines with minor amount of echinoderms, in addition to bryozoans and ostracods. Non–skeletal grains include peloids. The facies is equivalent to SMF (5) of FZ (4).

b- Bioclastic Lime Packstone Submicrofacies (Fig. 6.5)

This facies is found within the lower and upper parts of Harur Formation (Fig. 4). It consists, mainly, of brachiopod, echinoderm, and bryozoan clasts. The facies corresponds to SMF (4) in FZ (4).

4- Lime Wackestone Microfacies

This one represents the most common facies in Harur Formation. Grains of wackestone usually range between (10 − 50)% in a micritic matrix. Skeletal grains, similarly to most other facies, include; brachiopods, bryozoans, echinoderms, and ostracods. Non−skeletal grains include peloids only. Depending on the ratio of these grains, wackestones of Harur Formation, can be subdivided into the following classes:

a-Brachiopod – bearing Lime Wackestone Submicrofacies (Fig. 6.6)

This stands as a characteristic facies of Harur Formation. It is restricted in the lower part of the formation (Fig.4). The main feature of this facies is brachiopod valves either of articulated or inarticulated types. Some echinoderms, bryozoans, and ostracods are also noticed. Non-skeletal grains include peloids only. The micritic matrix is often rich in organic or clayey materials. This facies is equivalent to SMF (8) within the FZ (7).

b- Brachiopod – Echinoderm Lime Wackestone Submicrofacies (Fig. 6.7)

This facies is dominated by echinoderms (either plates or spines), as the main skeletal grains, and minor amount of brachiopods. Some bryozoan clasts and ostracods are frequently observed. Non−skeletal grains include peloids only. This facies is frequently distributed in lower and middle parts of Harur Formation and corresponds to SMF (8) within the FZ (7).

c- Bioclastic Lime Wackestone Submicrofacies (Fig. 6.8)

This subdivision is found within the middle and upper parts of Harur Formation. It is rich in clasts of brachiopods and echinoderms, in addition to some clasts of bryozoans. The matrix consists of micrite and was reported to be enriched in organic matter. This facies is equivalent to SMF (9) within FZ (7).

DEPOSITIONAL ENVIRONMENT OF HARUR FORMATION

The microscopic study of thin sections had revealed different facies types of which similarity in litho and biocontent was obvious in the studied section. While concerning to the terminology of Dunham's (1962), it was found that microfacies types of Harur Formation range from Boundstone, Grainstone, Lime Packstone, to Lime Wackestone. All these, except Grainstone, have micrite−dominated matrix.

The dominance of micrite, within these facies, indicates that sea bottom was stagnant and calmenough for lime mud to accumulate (Dunham, 1962).

Some variations in microfacies type take place when the grain /matrix ratio changes due to variation in rate of accumulation of each, in addition to rate of water agitation. The dominance of micrite had reduced cementation, which is a result of missing of strong currents capable of removing (or washing out) micrite and creating space for cementing materials carried by solutions.

When the classified microfacies of Harur Formation are treated following the concepts of SMF and FZ of Wilson (1975) and Flugel (1982), it is found that facies of Harur Formation correspond to SMFs (4,5,7,8,9,16) which belong to FZs (4,5,7,8).

From the environmental point of view, microfacies have been controversially significance. Thus, Boundstone (Bafflestone) microfacies were deposited in shallow warm environment, within FZ (5) in reefal environments, rich in corals, bryozoans, and brachiopods.

While, Grainstone microfacies, which is rich in clasts of brachiopods, echinoderms, lesser amount of bryozoans and corals, was deposited at both flanks of reefal banks. Although, the composition of the above mentioned facies consists of reefal fragments (Wilson, 1975).

The peloidal Grainstone microfacies may deposit at shallow warm waters with moderate circulation (Wilson, 1975). In another hand, Bioclastic Lime Packstone microfacies which is rich in clasts of brachiopods, with some echinoderms, was deposited in fore – reef environments (or fore – reef flank), This facies, which is located within FZ (7) represents, shelf lagoon with open circulation below normal wave base (Wilson,1975).

In this study, much attention was paid for the characteristic fossils such as common bryozoans, corals, brachiopods, and echinoderms. Although, bryozoans are colonial animals whose calcareous skeletons exhibit a broad range of shapes (Horowitz and Potter, 1971). Fragments of bryozoans are most abundant in shelf limestones and coral reefs (Cuffey, 1972). Paleozoic bryozoans are generally associated with brachiopods, echinoderms, and solitary corals (Flugel , 1982). Corals are common and remarkable fauna in limestones of Harur Formation, which indicate clearly shallow carbonate seas, and were major contributors to reefs and banks from the Ordovician to the Recent (Horowitz and Potter, 1971).

Brachiopods are common within wackestone to packstone microfacies. They are distributed world wide from the Cambrian to the Recent, but were most abundant in Paleozoic where they are a significant contributor to skeletal limestones. Brachiopods had probably occupied all marine ecologic niches, but were most abundant in shallow continental seas (Flugel, 1982).

Echinoderms are widely distributed along the studied section of Harur Formation. Fragments of echinoderms are most common in shelf limestones, but may be important microfossils of shallow water and basinal limestones (Flugel, 1982). The shallow water origin of Harur Formation`s echinoderms is more acceptable due to their associations with other shallow water organisms such as bryozoans and corals. In addition to that, the shallow water nature of this environment is supported by missing diagnostic features of deep water indicators such as planktonic forams , radiolarians , ammonoids ,… etc., which are all conspicuously absent from rocks of Harur Formation.

From the sum of all petrographic and facies analysis, it is here concluded that Harur Formation had deposited in shallow marine environment mostly reef and reef flanks.

SUMMARY AND CONCLUSIONS

Microfacies and environmental analysis of the Early Carboniferous (Tournaisian) Harur Formation, in Northern Iraq has been studied. Detailed field observations were carried out in Nazdur section, northeast of Zakho town. Petrographic studies and microfacies analysis have led to the following conclusions:

- The lithologic composition of Harur Formation consists of thin to medium bedded, black, organic limestone, dolomitic limestone, intercalated with black, micaceous shale mainly in lower and upper parts.
- The petrographic constituents of limestones of Harur Formation are represented in the following:
  -Matrix mainly composed of micrite with lesser sparite.
  -Non – skeletal grains include peloids only.
  -Skeletal grains include; bryozoans, brachiopods, corals, echinoderms and ostracods.
- Using Dunham’s (1962) classification, and modification of Embry and Klovan (1971), the microscopic study has shown the following four principal microfacies types and their subdivisions :
  - a- Boundstone (Bafflestone) Microfacies
  - b- Grainstone Microfacies
    - i- Bioclastic–Grainstone Submicrofacies
    - ii- Peloidal–Grainstone Submicrofacies
  - c- Lime Packstone Microfacies
    - i- Echinoderm–Brachiopod Lime Packstone.
    - ii- Bioclastic Lime Packstone.
  - d- Lime Wackestone Microfacies

i- Brachiopod–bearing Lime Wackestone.

ii- Brachiopod–Echinoderm Lime Wackestone.

c- Bioclastic Lime Wackestone.

- Applying lithologic and paleontologic criteria ; traditional and standard microfacies analysis, the depositional environment of Harur Formation is concluded to be shallow marine environment, mostly reef and reef flanks.

ACKNOWLEDGMENTS

The authors would like to express their appreciation to Dr. Ahmed M. Aqrawi, Head of Geology Department, Salahaddin University for supplying available facilities. Mr. Dana N. Radha, Mr. Idris, N. Ahmed, and Mr. Waleed S. Sinjary, are thanked for their help during fieldwork.

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