



Facies analysis and depositional environment of Gir Bir Formation, Northwestern Iraq

Mohammed A. Al-Hajj¹, Ali I. Al-Juboury¹ & Aboosh H. Al-Hadidy²

¹Geology Department, Mosul University, Iraq

²North Oil Company, Kirkuk, Iraq

E-mail: malhaj2006@yahoo.com

Article info

Abstract

Original: 06.10.2015
Accepted: 19.05.2016
Published online:
15.06.2016

Key Words:

Gir Bir Formation,
Facies, rudist
buildups, rimmed
platform

Upper Cretaceous successions of the Gir Bir Formation (Cenomanian-Early Turonian) were studied in 15 wells from northwestern Iraq. The formation is composed of recrystallized, partly dolomitized limestone with local silicification. Benthonic foraminifera (Miliolids, Alveolina, and Orbitolina), rudist and peloids are the main constituents. The studied succession has been affected by several diagenetic events such as; dolomitization, recrystallization, micritization, dissolution, compaction and silicification. Facies analysis revealed that seven microfacies subdivided into eleven submicrofacies could be distinguished, reflecting sedimentary environments including; deep shelf margin, slope/shoal, rudist buildups, back reef/shoal, and protected lagoon in a regressive shallowing-upward sequence. Lateral facies variation showed that reefal facies were commonly located in northwestern parts of the study area, whereas lagoonal facies existed in eastern and southeastern parts. Rimmed carbonate platform is the acceptable model for the Gir Bir Formation.

Introduction

The Mesozoic carbonate platform systems of the Arabian Plate are one of richest hydrocarbon provinces of the world. This is mostly due to combination of their large dimensions and the presence of source and seal rocks within the same depositional system [1].

Iraq's largest hydrocarbon reserves are hosted in Cretaceous sediments, particularly in the Mesopotamian Basin [2]. The Cretaceous succession in Iraq is up to 3000 m thick [3]

and represents part of the megasequences AP8 and AP9 of the Arabian plate sequence stratigraphy [4]. The Cretaceous succession has been extensively studied because it contains abundant reservoir intervals. It is the most productive interval in Iraq and contains about 80% of the country's proven oil reserves [2].

The present work focuses on the upper Cretaceous (Cenomanian-early Turonian) Gir Bir succession in selected wells from north-western Iraq (Figure: 1). Carbonate rocks of the Gir Bir Formation are represented by limestones (mostly recrystallized), marly limestones and fractured dolomites. The aim of the study is to describe facies analysis and reconstruct the depositional environment of the Gir Bir Formation at several wells from northwestern Iraq.

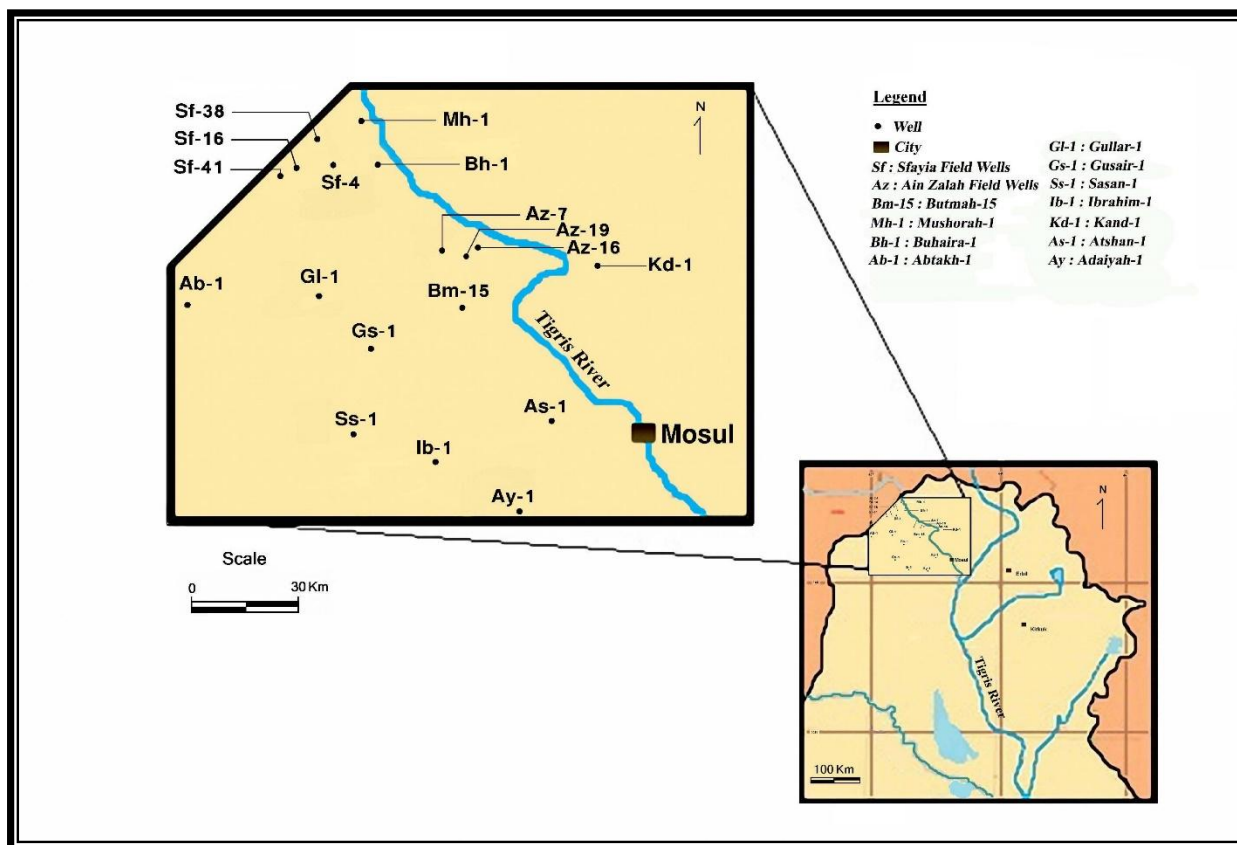


Figure-1: Location of the studied wells from northwestern Iraq

Geological setting

The paleolatitudinal location of the Arabian Plate influenced Cretaceous sedimentary environment in Iraq. Progressive northward drift placed the Arabian plate in equatorial tropical latitudes [5]. Carbonates rocks form the main lithology in the Cretaceous successions of Iraq and most of the Middle East region due to prevalence of warm equatorial climates [6].

The upper Cretaceous successions in north-western part of Iraq have been eroded due to effect of several phases of tectonic movements [7], therefore, they are not completely documented from this part of the country. The study area was a part of the shelf during Cenomanian- early Turonian and was separated from paleoneotethys main basin [8] by the Mosul and Khleisia uplifts [9]. Prevailing of warm conditions on the equatorial Arabian Plate [10] promotes the deposition of reefal and lagoonal facies of the Gir Bir Formation in the area of study. According to Sharland et al. (2001) [4], the studied formations are present in two of the Arabian Plate Megasequences. The Gir Bir Formation is of Cenomanian-early Turonian age and represents the upper part of the late Tithonian-early Turonian AP8 megasequence. Tectonically the area of study lies in the Chamchamal-Butmah subzone of the Foot Hill zone of Iraq [11].

Gir Bir Formation was firstly recognized by Dunnington, 1956 in [12] in the subsurface type section at Mushorah-1 well as recrystallized limestone partly dolomitised. In Sfayia-4 well in northwestern part of the study area where the deeper parts of the basin exists, the formation reaches 231 m thick. Dunnington (1953) in [12] has mentioned that Gir Bir Formation is composed of neritic limestones that were deposited during Cenomanian-early Turonian.

The stratigraphic correlation of the Cretaceous formations including the studied Gir Bir Formation in Iraq and neighboring countries is illustrated in Figure (2). The formation unconformably underlies by the dolomitic rocks of the Albian Qamchuqa Formation. The contact surface is characterized by presence of erosional conglomerate in the upper part of the Qamchuqa Formation in addition to indications of dissolution, moldic porosity and dedolomitization in this part of the underlying formation. The upper contact

Microfacies Analysis

The petrographic investigation on the Gir Bir Formation revealed the presence of several microfacies represented by lime mudstone, pelletal lime mudstone, miliolid wackestone, bioclast wackestone, orbitolina wackestone, planktonic foraminifera-bioclast wackestone, alveolina and miliolid packstone, pelletal packstone, peloid grainstone, echinoderm grainstone, lime floatstone, lime rudstone and lime bafflestone.

Lime mudstone (Gm)

micritic groundmass forms about 90% of this microfacies while skeletal grains (miliolids and bioclasts of gastropods, echinoderms and ostracods) form the rest of the components (Figure 3A). This microfacies has been partially affected by dolomitization, the common dolomite textures recognized are the floating and contact rhomb textures. While severe dolomitization is observed in the Gir Bir Formation some wells (such as Ib-1 and Bm-15) forming the sutured mosaic texture. This microfacies is also affected by cementation, recrystallization and stylolite formation (Figure: 3A). The facies existed in the lower and upper parts of the formation in the wells of (Sf-1, Mh-1, Ib-1 and Bh-1)) while it exists only in the upper part of the formation in the wells of (Gs-1, Bm-15 and Az-19).

Interpretation: The lime-mudstone was deposited in calm water due to the absence of variable amount of skeletal particles. Most of lime mud may be derived from the abrasion and micritization of the skeletal particle especially in the

restricted areas. This facies could be compared with standard microfacies SMF-19 that was deposited in facies zone FZ-8 according to Wilson (1975) [17] and Flügel (1982 and 2004) [18] and [19] which represents semi-restricted lagoonal environment.

Pelletal lime mudstone (Gm2)

Faecal pellets form more than 90% of the constituents that distributed in micritic groundmass with few bioclast of benthonic foraminifera (Figure: 3B). Recrystallization, floating dolomite rhomb texture and some dedolomitization are the main diagenetic processes affecting on these rocks.

Interpretation: Semi restricted coastal lakes of restricted circulation is the probable depositional environment for this microfacies. The predominance of micrite in between particles reflects quiet water condition.

Miliolid wackestone (Gw1)

Miliolids of *Quinquiloculina*, *Pyrgo* and *Triloculia* form about 60% of the constituents in addition to other types of benthic foraminifera like *Alveolina*, *Rotalia*, *Taxtularia*, *Peneroplis*, *Nezzazata*, and *Dicyclina* and few of ostracods, green algae and bioclasts (Figure: 3C). The main diagenetic processes affecting of this microfacies include; recrystallization, granular and drusy cements, stylolite formation and partial dolomitization effect. This microfacies alternate in different part of the studied formation. It exists in the hard thick limestone and dolomitic limestone beds and in marly and shaley limestone in the middle parts of the formation in the wells Sf, 4 and 38, Mh-1 and Bh-1.

Interpretation: This facies could be compared with standard microfacies SMF-18 that was deposited in facies zone FZ-8 according to according to Wilson (1975) [17] and Flügel (1982 and 2004) [18] and [19] which represents semi-restricted coastal lakes of restricted circulation.

Bioclast wackestone (Gw2)

This submicrofacies contains about 70% of bioclast which is represented by rudist, gastropods and echinoderm clasts in addition to few of benthic forams like miliolids and *Alveolina*, and ostracods (Figure: 3D). The micritic groundmass is sometimes affected by severe dolomitization resulting in sutured dolomite texture specially in wells (Bm-15, Ib-1 and Ss-1). Other diagenetic processes affecting on this facies are inversion, recrystallization and selective silicification in addition to dissolution that lead to form moldic porosity. This microfacies exists in the upper parts of the Gir Bir Formation in the wells of Sfiya and Ain

Zala and Bh-1 well while it is found in different parts of the formation in wells (Bm-15, Gs-1, Gl-1, Ib-1 and Ss-1).

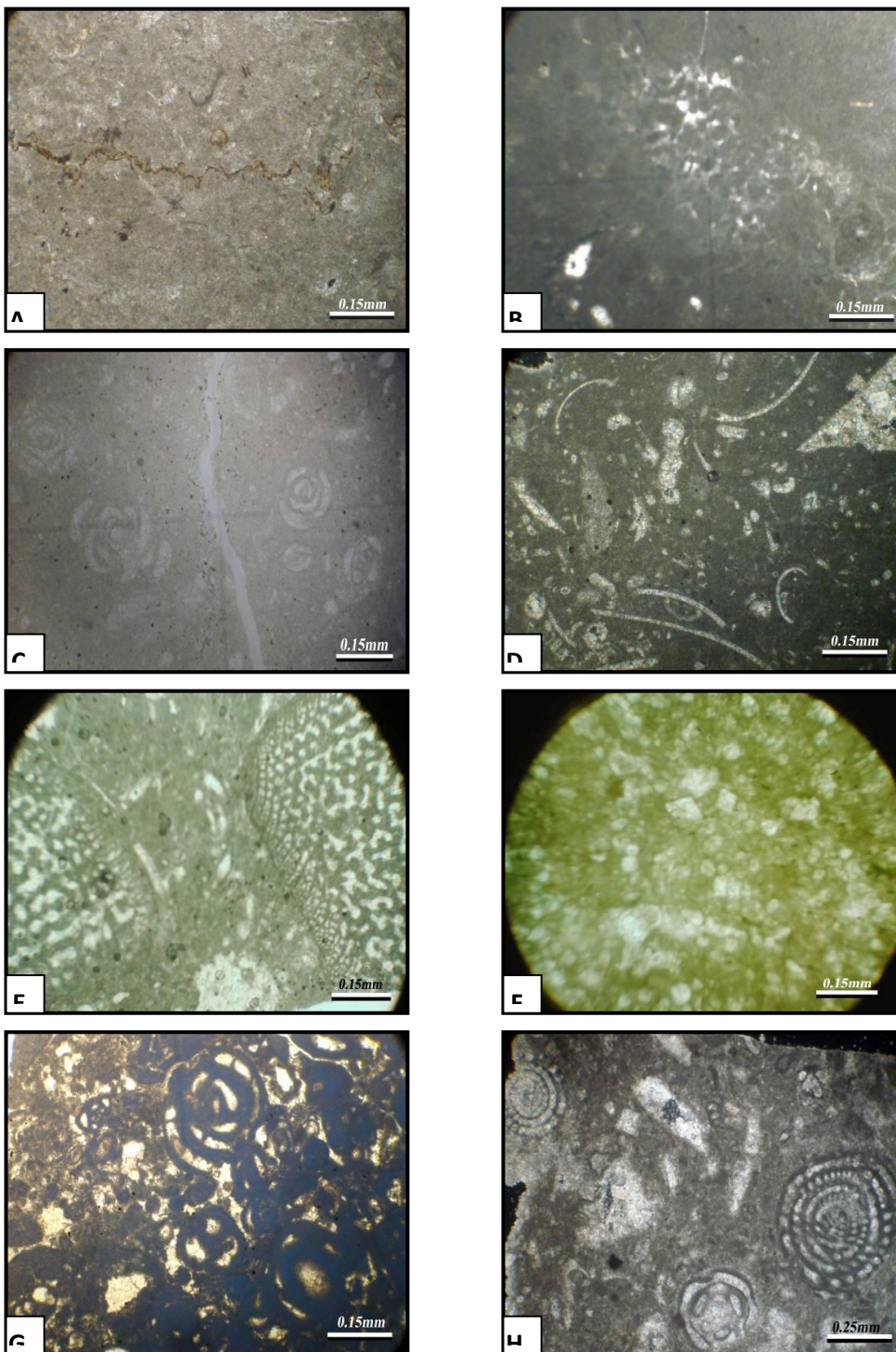


Figure -3: A- lime mudstone (Gm1) with stylolite in the Gir Bir Formation, Mh-1 well, B- pelletal mudstone (Gm2) in the Gir Bir Formation, Bh-1 well, C- miliolid wackestone (Gw1) in the Gir Bir Formation, Sf-4 well, D- bioclast wackestone (Gw2) in the Gir Bir Formation, Mh-1 well, E- orbitolina wackestone (Gw3) in the Gir Bir Formation, Bh-1 well, F- planktonic foraminifera -bioclast wackestone (Gw4) in the Gir Bir Formation, Sf-38 well, G- miliolid packstone (Gp1) in the Gir Bir Formation, Bh-1 well, H- Alveolinia and miliolid packstone (Gp2) in the Gir Bir Formation, Mh-1 well.

Interpretation: The characteristics feature of this microfacies is similar to SMF-8 that is deposited in facies zone FZ-7 according to according to Wilson (1975) [17] and Flügel (1982 and 2004) [18] and [19] that represents the open circulation, low energy coastal lakes.

Orbitolina wackestone (Gw3)

Orbitolina forms more than 70% of the skeletal grains of the facies accompanied with some benthic forms like *Taxularia* and *Alveolina* and some planktonic forams. Echinoderm bioclats also existed (*Figure: 3E*). This submicrofacies is affected by many diagenetic processes such as recrystallization that affects on both the micritic groundmass and the skeletal grains. Severe dolomitization was observed also leading to form the floating rhomb and sieve mosaic fabrics (Randazzo and Zchoa, 1984). Compaction is also observed in the form of stylolites. This facies present in the lower and middle parts of the formation in wells of Sfiya and Ain Zala oilfields and in Bh-1 and Mh-1 wells as well.

Interpretation: The richness in orbitolina may indicate deposition of the facies in areas far from the coast and in front of the reef [20].

Planktonic foraminifera-bioclast wackestone (Gw4)

Principally, this microfacies is composed of planktonic foraminifera and bioclats which is represented by small clasts of rudist and echinoderms in addition to presence of calcispheres and some benthic forams such as *Taxularia* and *Rotalia* (*Figure: 3F*). The micritic groundmass contains floating dolomite rhombs due to dolomitization, while cementation in the form of granular cement in chambers of planktonic forams and calcispheres and syntaxial cement around echinoderm clasts are common. This facies exists in the middle part of the formation in wells of Sf-4 and 38, Mh-1 and Bh-1.

Interpretation: This facies could be compared with standard microfacies SMF-3 deposited in the facies zone FZ-3 according to according to Wilson (1975) [17] and Flügel (1982 and 2004) [18] and [19] which represents the basin margin or deep shelf margin.

Miliolid packstone (Gp1)

This microfacies is composed mainly of various types of miliolids; such as *Quinquiloculina*, *Pyrgo*, *Triloculina* That form more than 70% of the total skeletal components. Other types of benthic forams and green algae in addition to pellets are also existed (*Figure: 3G*). Micritization on the outlines of the skeletal grains is the main diagenetic process in addition to recrystallization and compaction that lead to fitted fabric texture between grains. Drusy mosaic texture as a result of severe dolomitization is also observed. This facies existed in the lower and middle parts of the Gir Bir Formation in wells Sf-16, Bh-1, Mh-1, Gl-1, Gs-1 and Bm-15. *Interpretation:* This submicrofacies correlates the standard microfacies SMF-18 that deposited in facies zone FZ-8 according to models of according to Wilson (1975) [17] and Flügel (1982 and 2004) [18] and [19] which represents the restricted coastal lakes. Predominance of more restricted miliolids indicating brackish water environment [21].

Alveolinia and miliolid packstone (Gp2)

This facies is composed of 60-70% of benthic foraminifera, *Alveolina* and large miliolid are the dominant types in addition to *Taxularia* and *Nezzazata* and bioclats (*Figure: 3H*). Recrystallization and cementation are the main diagenetic processes affecting on this submicrofacies while dolomitization is partially affects on some parts of the facies forming drusy mosaic and sieve textures. This facies exists in the middle and upper parts of the formation.

Interpretation: This microfacies represents deposition in shallow open circulated coastal lakes as compared with the SMF-18 that is deposited in FZ-7 according to models Wilson (1975) [17] and Flügel (1982 and 2004) [18] and [19].

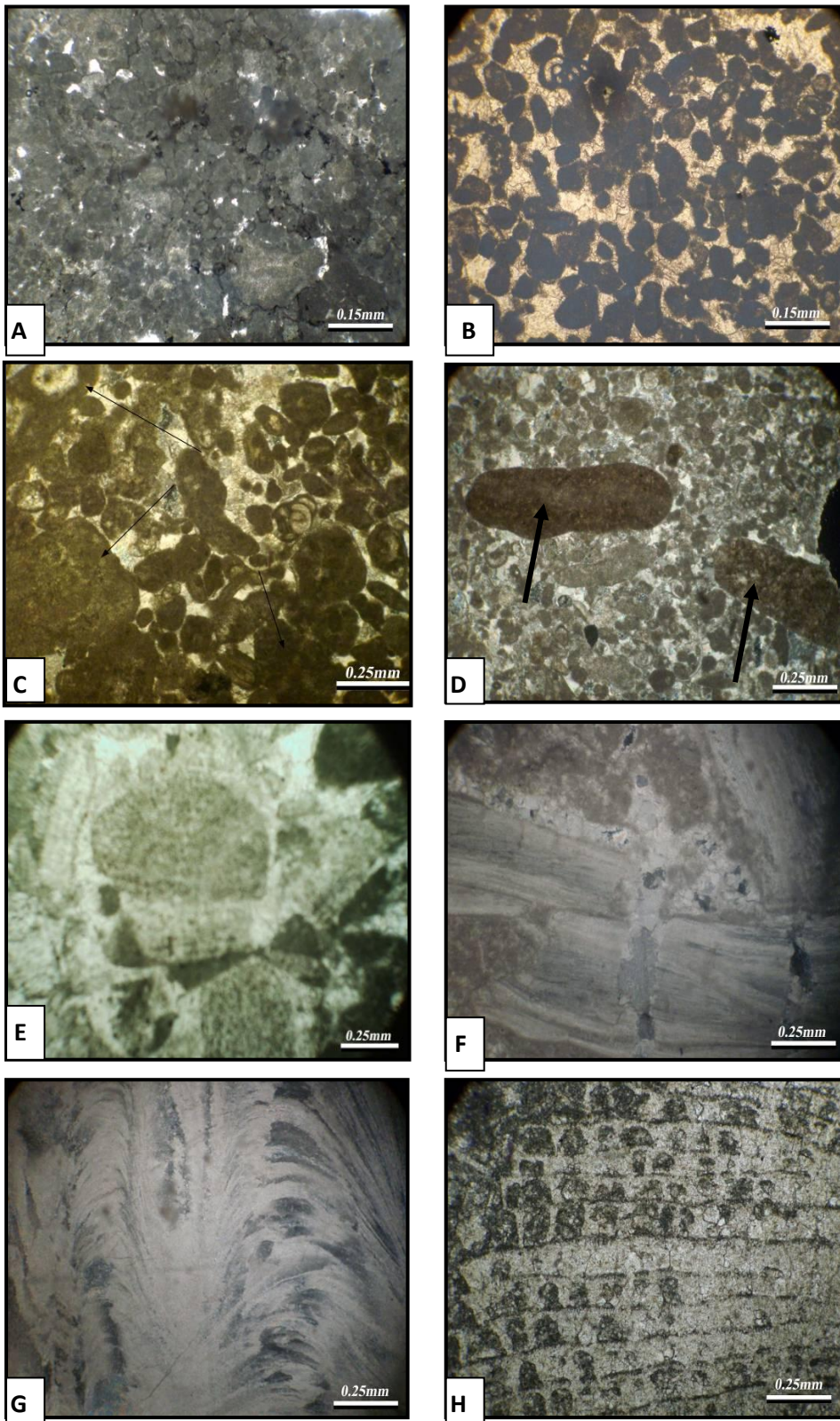


Figure-4: A- pelletal packstone (Gp3) in the Gir Bir Formation, Bh-1 well, B- peloid grainstone (Gg1) in the Gir Bir Formation, Bh-1 well, C- extraclasts (arrows) in peloid grainstone of the Gir Bir Formation, Sf-16 well and D- aggregated grains (lumps, arrows) in peloid grainstone of the Gir Bir Formation, Bh-1 well, E- Echinoderm grainstone (Gg2), Sf-38well, F- lime floatstone microfacies (Gf) in the Gir Bir Formation, Sf-4 well, G- lime rudstone microfacies (Gr), in the Gir Bir Formation, Sf-4 well, H- lime bafflestone microfacies (Gb) including rudist of family Radiolitai in the Gir Bir Formation, Sf-4 well.

Pelletal packstone (Gp3)

Faecal pellets form about 80% of this facies in addition to few of bioclast, miliolid and ostarcode (Figure: 4A). Compaction effect is indicated from bedded stylolites and sutured texture. It exists in the lower and middle parts of the formation in wells of Sf-4, Mh-1, Bh-1, Gs-1 and Ab-1).

Interpretation: This microfacies coincides with the SMF-16 that was deposited in FZ-8 according to models of Wilson (1975) [17] and Flügel (1982 and 2004) [18] and [19] which represents the restricted lagoon with moderate water circulation.

Peloid grainstone (Gg1)

It is composed of pellets that form about 70% of the main components. Most of them are resulted from micritization of skeletal grains in addition to few benthic forams (Figure: 4B), extraclasts and aggregated grains (lump), (Figure: 4C, D). This facies is affected by recrystallization and dissolution forming interparticle porosity. Severe dolomitization in parts of the facies led to formation of drusy texture. It exists in various parts of the formation but concentrated in lower and middle parts in wells Sf-4, Bh-1, Mh-1 while it exists only in the lower parts of the formation in wells Gs-1 and Gl-1.

Interpretation: It is similar in characteristics with SMF-18 that was deposited in FZ-7 according to models of Wilson (1975) [17] and Flügel (1982 and 2004) [18] and [19] which represents the shallow environment in open lagoon.

Echinoderm grainstone (Gg2o)

More than 70% of the skeletal components are composed of echinoderms in addition to few of rudist, ostracods, bioclast and pieces of micrite (Figure: 4E).

Several diagenetic processes are dissolution that make moldic and interparticle porosity and syntaxial cement around echinoderms. It exists in the middle and upper parts of the formation in Sf-38 well.

Interpretation: This submicrofacies has great importance in environmental identification. It may indicate the setting where high energy marine currents exist which lead to washing of micrite [17]. This facies could be correlated with SMF-12 that deposited in FZ-5 according to Wilson (1975) [17] and Flügel (1982 and 2004) [18] and [19].

Lime floatstone (Gf)

The skeletal grains are composed of large rudist clasts with more than 2 mm size which belongs to the family Radiolitiidae and reach up to 30% of the whole facies components accompanied with few of benthic forams and bioclasts and generally are mud-supported (Figure: 4F). The micritic groundmass is generally affected by recrystallization, partial silicification on rudist clasts and cementation. This facies is distributed in the middle and upper parts of the formation in wells Mh-1, Bh-1, Sf 4 and 38, Glr-1, Gs-1, Ab -1 and in Zalah-19. the presence of large rudist may refer to fall from reefal buildups [22].

Interpretation: This microfacies correlates with the standard microfacies SMF-5 that is deposited in facies zones FZ 4 and 7 according to models Flügel (2004) [19] which represents the open shallow lagoon and those settings far from the reef slopes.

Lime rudstone (Gr)

This is a grain-supported microfacies with skeletal grains reach more than 70% of the whole components which are composed mainly of rudist breakage and few of echinoderms and benthic and planktonic forams (Figure: 4G). It affects mostly by recrystallization, compaction and dolomitization in some parts of the microfacies resulting in drusy texture. The microfacies exists in the middle part of the Gir Bir Formation in wells Sf 4 and 38, Mh-1 and Bh-1.

Interpretation: According to Flügel (2004) [19] this microfacies results from fall of large bioclats from reef slopes. It could be correlates with SMF-6 of FZ-4 according to model of Flügel (2004) [19] which represents the reef slope environment.

Lime bafflestone (Gb)

This microfacies is autchthonous source and is composed mainly of 80-90% of rudist in addition to other skeletal grains such as foraminifera, ostracods and bioclats (*Figure: 4 H*). Dissolution in the form of small pores with rudist, selective silicification and recrystallization are the main diagenetic processes affecting on this microfacies. It sometimes exists in about 20m thick in the middle part of the formation in wells Sf-4 and 38, Mh-1 and Bh-1 and in lesser thickness in other parts of the formation.

Interpretation: According to James (1979) [22], rudist build bioherms at margin of platform. The presence of this microfacies in less thickness in the upper part of the formation may refer to patch reef in lagoonal environment. This microfacies correlates with SMF-7 that deposited in FZ-5 according to Flügel (2004) [19] models which represents the organic buildup environment.

Discussion and conclusions

A- Sedimentary environment

The present work shows that the succession of the formation was deposited in a wide spectrum of shallow marine environments; from the deep shelf margin to shallower intertidal and restricted lagoons. This variation in environment is deduced from the presence of different microfacies with varying skeletal, non-skeletal and textural components. Therefore several lateral and vertical facies variations appeared. Based on that, the Gir Bir successions are divided in sub-environments in order to get a clear identification of the sedimentary environments responsible for the deposition of the formation. These sub-environments are as follow:

1- Deep shelf margin sub-environment,

it represents the deeper margin of the shelf which exists commonly in 100-200 of water depth. It is found in the middle part of the Gir Bir Formation in the wells of Sf-4 and 38, Bh-1 and Mh-1. The main facies in this environment are represented by planktonic foraminifera and bioclast lime wackestone submicrofacies and lime floatstone microfacies. Generally the rocks of this environment are fine grained and are composed of organic rich marly limestones and shale.

It includes high amounts of planktonic forminifera, calcispheres, fine grained bioclats (rudist and gastropods clasts). High planktonic forminifera in comparison to other skeletal components refers to deep marine conditions it the outer shelf setting [23]. Presence of rudist, gastropods and echinoderm bioclats in different sizes may refer that they were transported from shallow parts and deposited in the deeper parts of the outer shelf under effect of waves and marine currents [24]. Fine clay and shale refer to a relatively deep sedimentary environment [25] while the richness in calcispheres and planktonic foraminifera indicate deposition in water with depth of 100-200 meter during transgression [26].

2- Slope/shoal sub-environment

This environment covers the area between the main reef body and the open shelf where gentle slope rudist buildups formed. The main facies are lime rudstone microfacies, lime floatstone microfacies and Orbitolina lime wackestone submicrofacies. The coarse-grained rudstone at the top of the platform grades into finer muddy groundmass wackestone-packstone facies towards sea in this environment [27]. The rudstone and floatstone microfacies are distributed in the middle parts of the formation in wells SF-4 and 38, Bh-1 and Mh-1 where rudstone facies form the main facies in the rudist buildups that is composed mostly of coarse-grained rudist clasts eroded from the reef framework and is deposited in a groundmass of micrite in shallow fore-reef settings [28]. Some of angular coarse-grained, badly-sorted rudist clasts also present which may indicate physical and biological erosion due to the effect of sea currents and deposit in high-energy environments with low distance of transportation [29].

The presence of Orbitolina lime wackestone submicrofacies in large thicknesses in the lower parts of the formation in the above mentioned wells and their presence in lesser thicknesses in the middle parts of the formation refer to a fore-reef environment where orbitolina is common in these settings [20]. The presence of bioclasts and pieces of echinoderms with orbitolina indicate the outer shelf shallow environment too [30].

3- Reef/Rudist buildups

The successions in this sub-environment is composed of reef- building organisms that is represented by rudist of Radiolitidae family and is considered as the main reef forming organisms in the Cretaceous [31] that is accompanied with other organisms such as echinoderms, benthic foraminifera, algae and coral [32]. Rudist buildups are different than others formed by coral and algae where it is build by baffling, therefore, it contains on good amount of sediments in between their columns. Most of previous studies classify it as rudstone microfacies formed in shoals, while [33] classify the reef and specially the rudist buildups as close cluster/frame reef in which the rudist columns are close to each other with spaces in between them filled by sediments. This environment exists in the middle parts of the formation in the wells Sf-4 and 38, Bh-1 and Mh-1 with increasing thicknesses in the wells locating to the west of Sfiya field (well Sf-38) where it ranges 10-20 meter while thickness reduced in the well east to the field and also in Bh-1 and Mh-1 wells.

The main facies characterizing this environment are bafflestone microfacies intercalated with rudstone and floatstone microfacies in addition to echinoderm lime grainstone submicrofacies. Bafflestone microfacies is the main facies forming the rudist biostorm [22] and [34].

The presence of rudist biostorms as of various sizes clusters may assist in accumulation of part of eroded bioclasts in spaces between them [28] and [35] and this may interpret the association of rudstone and floatstone microfacies in small thickness and in different places within this environment.

Presence of low amounts of orbitolina and alveolina in these microfacies is due to ability of the spaces to host large size skeletal grains like algae, benthic forams and echinoderms [27] and this may interpret the presence of echinoderm lime grainstone submicrofacies in between rudist clusters.

4- Back reef/Shoal

It represents the transitional zone between rudist buildups and the restricted lagoon subenvironments. It is characterized by high energy environment as compared to the restricted lagoon and it could be regarded as back reef shallow shoal setting. It exists in thicknesses range from 40-60 meter in the lower and upper parts of the formation in Bh-1 and Mh-1 wells while thickness reduced in wells of Sfiya oilfields and reaches 30-50 meter. It forms the main succession of the Gir Bir Formation in the wells Ab-1, G1-1, Gsr-1 and Az-7 and thickness reduces too in wells of Az-19, Bm-15, Ss-1 and Ib-1 where it exists only in the lower parts of the formation.

The main facies include; peloid lime grainstone submicrofacies, Alveolinia and miliolid Lime packstone submicrofacies and floatstone and Bafflestone microfacies. Dominance of pellets in lime grainstone facies refers to shallow marine environments (Shoals) mainly [36] and association with large different species of miliolids (*Quinquiloculina* ; *Triloculina*) and other from Rotalids family with pellets indicate that deposition took place in shallow shelf and shallow coastal lakes [37]. Presence of aggregate grains and lithoclasts also indicate such shallow marine environments. Generally the presence of these skeletal grains may refer to warm shallow marine water with depth range between 10-20 meter [38].

Presence of floatstone and bafflestone microfacies in small thickness in different places of this sub-environment and generally in limited (local) distribution refer to patch reefs accumulation in shallow reefal settings where rudist grow in small clusters randomly distributed in back reef shallow settings [39] where water circulation happened with suitable temperature and salinity condition available for their life [40]. The grainstone and rudstone facies near reef grades into packstone and wackestone facies toward lagoons that indicate the reducing in depositional energy [27].

5- Restricted lagoon

This sub-environment is characterized by their fine grained sediments with low diversity in skeletal grains, where one type is concentrated due to high salinity and low water circulation and depth [41]. It exists in the lower and upper parts of the formation in the wells located in the northwestern parts of the study area and in

various thicknesses. The higher thickness recorded is (60) meter in Mh-1 well while thickness decreases towards Sfiya field wells and Bh-1

And that may relates to the erosion processes that remove huge amount of the upper parts of the formation in Bh-1 and Sfiya wells while lagoonal facies dominates in Ib-1 and Ss-1 wells. The main facies in this environment are fossiliferous lime mudstone submicrofacies, pelletal lime mudstone submicrofacies, miliolid lime wackestone submicrofacies, bioclasts lime wackestone submicrofacies and miliolid lime packstone submicrofacies. In addition to back reef microfacies such as pelletal lime grainstone submicrofacies, Alveolinia and miliolid lime packstone submicrofacies and floatstone microfacies. The dominance of muddy-supported microfacies refers to deposition in shallow protected calm marine conditions. High amounts of small-sized miliolids refers to shallow warm water conditions with no more than 40 meter depth with high salinity [42]. While presence of gastropods bioclasts in mudstone microfacies refers to protected marine environments [43], additionally, faecal pellets are the main non-skeletal components in coastal protected lake environments [44]. The shallow back-reef facies in this sub-environment may indicate their presence as tongues in the restricted lagoon [45].

B- Depositional model of Gir Bir Formation

The rimmed carbonate platform is the most acceptable model for the succession of Gir Bir Formation based on the following criteria:

1- Presence of shallowing upward sequence of sedimentary environments in the Gir Bir Formation that is characterized by seaward progradational system. In this system, there is an offlap relation between reef and reef slope facies and those of outer shelf [46].

2- Presence of slope in coarsening upward sequence which may refer to existence of shelf break area that support the rimmed platform model even this slope is a gentle one due to nature of rudist buildups that grow in clusters. Carannante et al. (1999) [29] identified this type of slopes in the Cretaceous successions in Sardinia of Italy.

3- Dominance of back reef and restricted lagoonal facies and patch reefs in the upper parts of the formation promote the presence of marine barrier that allow the dominance of mud-supported facies [46].

4- Existence of rudist buildups in high thicknesses in the Gir Bir Formation of Sfiya oilfield that grade into slope and outer shelf deposits may reveal the rimmed platform. Rudist buildups have progradation system during Cenomanian [47], [48], [49] and [50].

Based on facies analysis and vertical and lateral facies distribution, the depositional model of the Gir Bir Formation is drawn for the study area taking in consideration the paleogeography of the area in the Cenomanian-early Turonian period (*Figure: 5*).

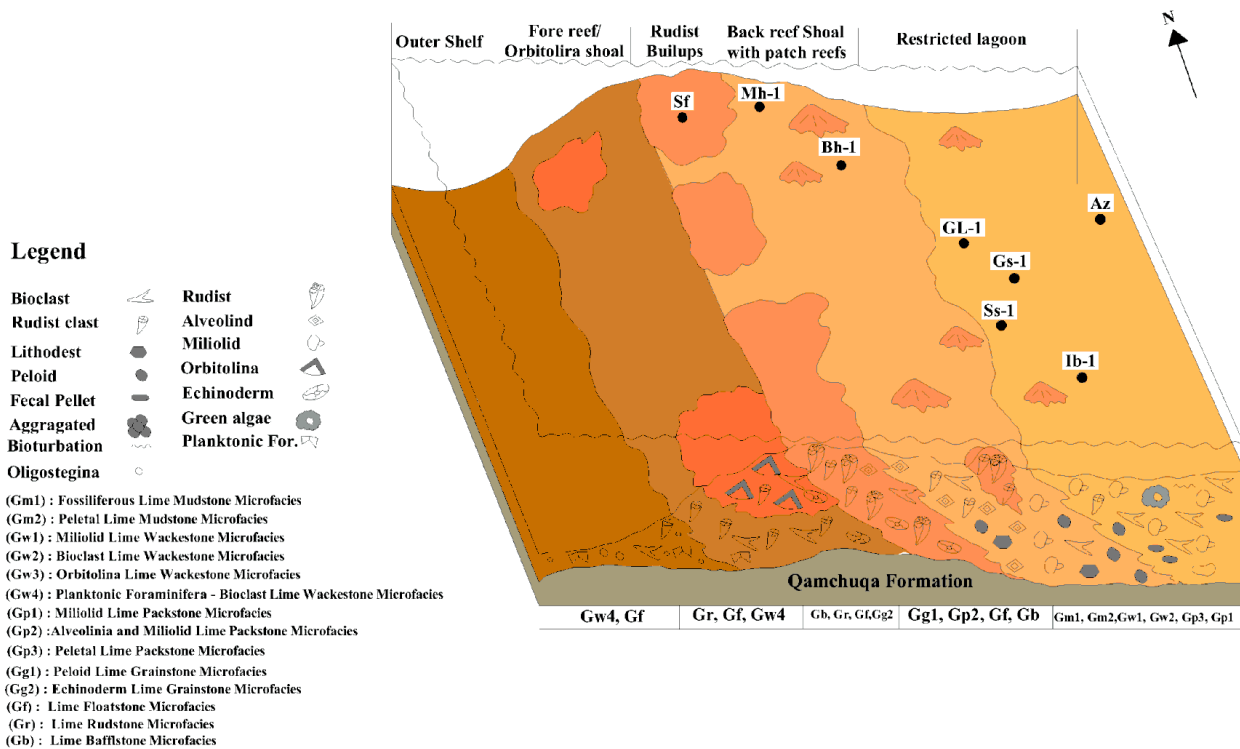


Figure-5: Depositional model of Gir Bir Formation

C- Vertical and lateral distribution of facies.

Distribution of facies both vertically and horizontally has great importance in recognizing and understanding of sedimentary environments and sea level changes. During regression, facies prograde seaward forming shallow-upward sequences where the supply of sediments exceeds the accommodation space while during transgression these facies retrograde landwards forming fining-upward sequences where supply is low than the accommodation space and it accumulates aggradationally when the supply is equal to accommodation space [46].

In order to show the facies distribution for the Gir Bir Formation in the area under study, two cross sections drawn (Figures: 6 and 7). Figure (6) is parallel to the axis of the Gir Bir basin of deposition starting from Mh-1 and ends with Ay -1 well, while Figure (7) is perpendicular to the axis from Mh-1 well and pass through wells of Sfiya oilfield and ends with Ab-1 well. Therefore, some important notes are excluded. The economic (reservoir) importance for the horizontal and vertical facies distribution in shallow facies (the reefal and its nearby environments) has its important role in revealing the thickness and development of petroleum reservoirs [51].

Concerning vertical facies distribution; In the lower part of the formation, the succession starts with facies of open platform (slope) that are represented by Orbitolina lime wackestone submicrofacies which dominates in most of the wells in the northwestern parts of the study area and they grade upward into shallow lagoonal facies. In the middle parts of the Gir Bir formation, the open shelf deep facies exists with small thickness as compared to the shallower marine facies that range from fore-reef to lagoonal facies that dominate over most succession of the formation in the wells under study. Most facies show retrograde succession starting from outer shelf/fore reef and ends with shallow lagoonal facies in coarsening upward sequence and in progradation system of accumulation.

Reefal facies of rudist buildups appear in two forms; the first if large biostorms where it reaches 20 meter thick in Sfiya oilfield, the other is small-sized patchy reefs in local distribution in the lower and upper parts of the formation in back reef and lagoonal facies in most of the studied wells.

In the lateral facies distribution, the reefal facies concentrate in the northwestern parts of the study area (Sfiya oilfield) and in good thicknesses (Figure: 6), while thickness decreases and form wedge shape towards the eastern part (Ain Zalah oilfield) and in Bm-15 well and also in south and southeastern parts of the study area (wells Ib-1 and Ab-1). The lagoonal shallow facies replaces the reefal facies in the wells of eastern, southern and southeastern parts while the facies of the Gir Bir Formation disappears in wells (kd-1, As-1 and Ay-1) in the eastern parts of the study area.

The sedimentary basin shows some deepening toward the Syrian border in the northwest, where Gir Bir Formation correlates Masif Formation in Swaidiya oilfields of Syria that was deposited in different marine conditions ranging from shallow shelf and reef to deep marine environment (Nikolaevskil, 1972 in [52]). Presence of Gir Bir Formation in low thickness in the eastern parts; Ain Zalah oilfield, But-15, and southeastern parts (wells G1-1, Ss-1, Ib-1) and southern parts (Ab-1 well), (Figure: 8) accompanied with lagoonal facies may indicate that these areas are close to the land where the Gir Bir Formation disappears in Kd-1, Ay-1 and As -1 wells. This facies variation is related to the paleogeography of the area under study.

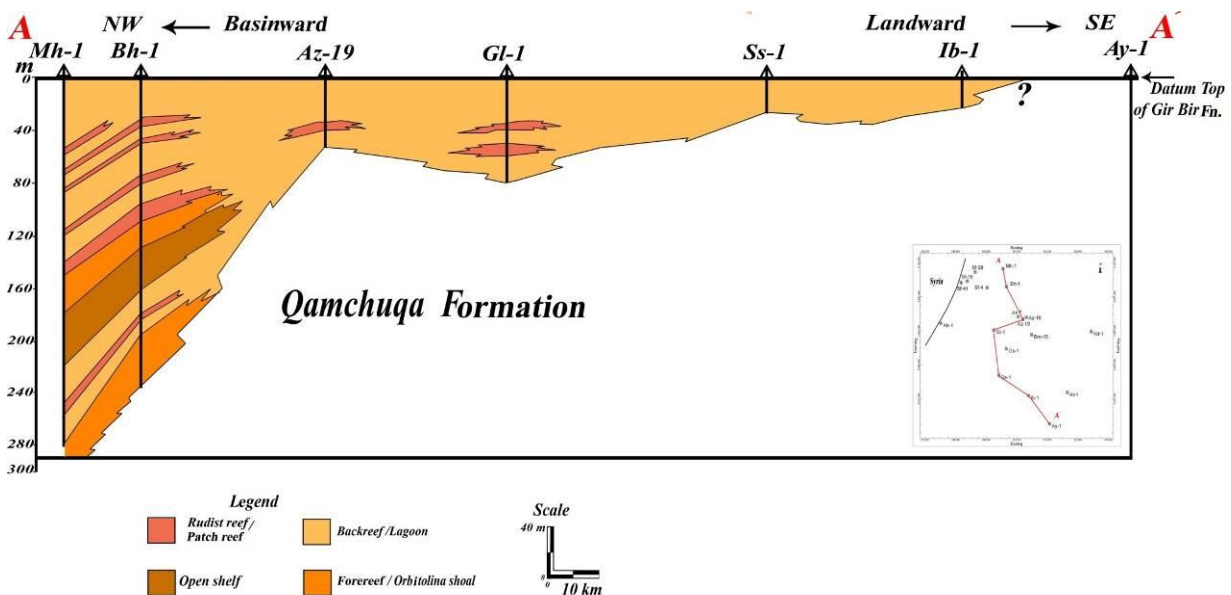


Figure-6: Lateral correlation of Gir Bir succession in the section A-A'' parallel to basin axis

The paleogeography of the region shows that effect of the Hail Arc was active in the Cenomanian-early Turonian period which separates the Mesopotamian basin from east Mediterranean basin [53]. This may indicate that western parts of the arc were the area of the last wells in where the formation disappeared which was existed in a positive area during this period.

The Gir Bir successions range from the shallow coastal areas near the arc (Ss-1, Ib-1 and Ab-1 wells) which are represented by shallow lagoonal facies into deeper area (reefal facies) in the western and northwestern parts (wells of Sfiya oilfield). Dominance of reefal facies in the last area may relate to presence of inherited paleohigh that support suitable conditions for rudist buildups to grow at shelf margin during Cenomanian. Sadooni (2005) [54] refers that most of rudist buildups in many of Cretaceous formations of Iraq (Shuaiba, Maudud and Mishrif) are grown on inherited paleohighs.

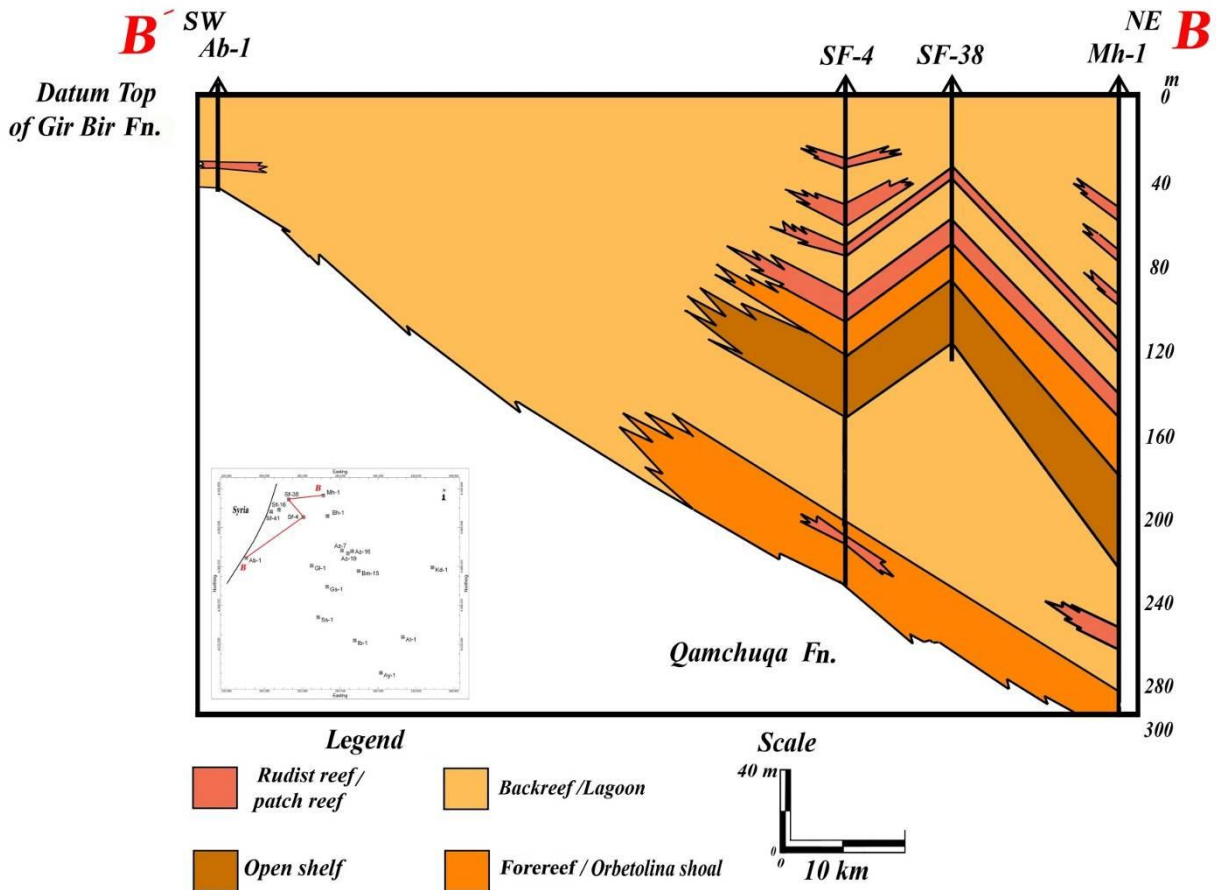


Figure-7: Lateral correlation of Gir Bir succession in the section B-B' perpendicular to basin axis

This scenario indicates the hypothesis of separated basins with the main foreland basin that are formed on the passive margin due to listric faults affected on the basement rocks of the region. Ameen (1992) [55] has mentioned that Mosul and Kirkuk blocks affected by stress during subduction in which inversion in movement led to listric faults that led in turn to the formation of grabens and half-grabens. It is supposed that Gir Bir Formation was deposited in local basin within the main Arabian platform which is represented by the eastern areas of east Mediterranean during Cenomanian to early Turonian.

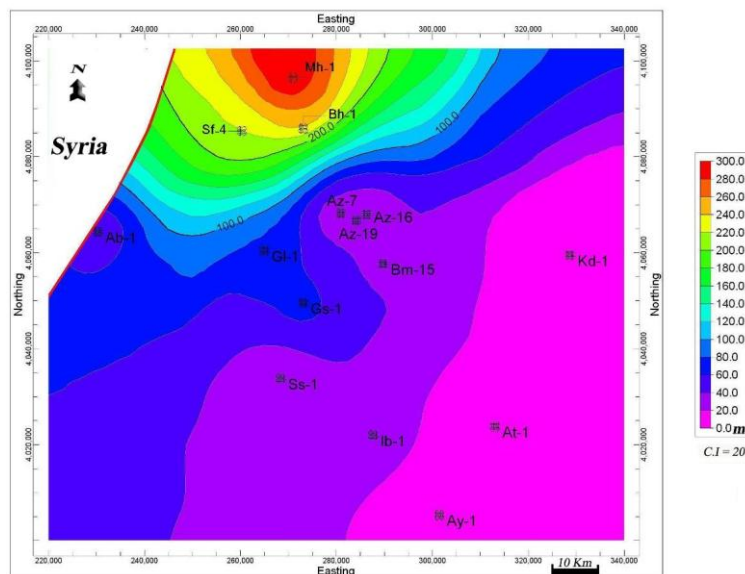


Figure-8: Isopach map of Gir Bir Formation in the study area

References

- [1] Murris, R.J. "Middle East stratigraphic evolution and oil habitat". AAPG Bull., 64, pp.597-618. (1980).
- [2] Al-Sakini, J.A. "Summary of the petroleum geology of Iraq and the Middle East". Northern Oil Company Press (Naft –Al-Shamal co.), Kikuk, Iraq (in Arabic), pp. 179. (1992).
- [3] Saddoni, F.N. & Aqrawi, A.A.M. "Cretaceous sequence stratigraphy and petroleum potential of the Mesopotamian basin, Iraq". In: Alsharahn A. & Scott, B. (Eds.) "Middle East Model of Jurassic-Cretaceous carbonate system", SEPM special publication, 69, pp. 315-334. (2000).
- [4] Sharland, P.R., Archer, R., Casey, D.M., Davies, R.B., Hall, S.H., Heward, A.B., Horbury, A.D., & Simmons, M.D. "Arabian Plate Sequence Stratigraphy", GeoArabia, Special Publication 2, Gulf Petrolink. Manama, Bahrain, pp.371. (2001).
- [5] Aqrawi, A.A.M., Goff, J.C., Horbury, A.D. & Sadooni, F.N. "The Petroleum Geology of Iraq". Scientific Press, pp. 424. (2010).
- [6] Beydoun, Z.R. "Arabian hydrocarbon geology and potential, plate tectonic approach". AAPG studies in Geology, 19-29. (1991).
- [7] Buday, T. "The Regional Geology of Iraq, Stratigraphy and Paleogeography". Dar Al-Kutub publishing house, Mosul University. Mosul, Iraq, pp. 445. (1980).
- [8] Jassim, S.Z. and Goff, J.C. "Geology of Iraq". Dolin, Prague and Moravian Museum, Brno, Czech Republic. Pp.341. (2006).
- [9] Chatton, M. & Hart, E. "Review of the Cenomanian to Maestrichtian stratigraphy in Iraq". Unpublished report, Iraq Petroleum Company, Palaeontological Department, Kirkuk.(1961).
- [10] Schlager, W. & Philip, J. "Cretaceous Carbonate platforms", In: Gisburg, R.N. & Beaud, B. (Eds.) "Cretaceous Resources, Events and Rhythms". NATO ASC series 304, Kluwer Academic Publisher, pp.173-195. (1990).
- [11] Jassim, S.Z. and Buday, T. "Late Tithonian-Early Turonian Megasequence AP8": In Jassim, S.Z. and Goff, J.C. (eds) "Geology of Iraq". Published by Dolin, Prague and Moravian Museum, Brno. pp. 124-154. (2006).
- [12] Bellen, V.R.G., Dunnington, H.V., Wetzel, R. and Morton, D.M. "Lexique Stratigraphic International". V.3, Asie Fascicule loa-Iraq. Paris, pp. 333. (1959).
- [13] Al-Jawari, H.A.KH. "Study of Upper Cretaceous at selected sections of Sfia wells NW Iraq", MSc thesis, Baghdad University, Iraq. (1989).
- [14] Al-Esa, M.E. & Fassola, N.A. "Biostratigraphy of the Upper Cretaceous reservoir at Butmah field". Oil studies and Researches Journal, 2, 152-168. (2011).
- [15] Gradstein, F.M., Ogg, J.G., Smith, A.G., Bleeker, W. & Lourens, L.J."A new geologic time scale 2004". Cambridge University Press, pp.589.(2004).
- [16] Al-Naqib, K.M. "Geology of the Arabian Peninsula, southern west Iraq". United States Geological survey, Professional Paper, No. 560-G, pp. 54. (1967).
- [17] Wilson, J.L. "Carbonate Facies in Geological History". Springer-Verlag New York Heidelberg Berlin, pp. 471. (1975).
- [18] Flügel, E." Microfacies of Limestone", Christenson, K. (Translator), Springer-Verlag, Berlin, pp.633. (1982).
- [19] Flügel E. "Microfacies of Carbonate Rock, Analysis, Interpretation and Application". Springer-Verlag, Berlin, pp. 976. (2004).
- [20] Boudagher, M.K. "Evolution and Geological Significance of Larger Benthic Foraminifera". Developments in Paleontology and Stratigraphy, 21, Elsevier, pp. 540. (2008).
- [21] Mack, G. H., James, W. C. "Cyclic sedimentation in the mixed siliciclastic- carbonate Abo-Hueco transitional zone (Lower Permian), southwestern New Mexico". Journal Sedimentary Petrology 56, pp. 635-647. (1986).

- [22] James, N.P. "Reef and mound": In Walker, R.G. and James, N.P.,(eds.) "Facies Models, Response to Sea Level Change". Geo.Text1, Geol. Asso. of Canada, pp.27-47. (1979).
- [23] Gibson, T.G. "Planktonic benthonic foraminiferal ratios: Modern Patterns and Tertiary applicability". Marine Micropalontology, V.15, pp.29-52. (1989).
- [24] Lehrman, D.J., Wei, J. and Enos. P. "Controls on facies architecture of a large Triassic carbonate platform, the great bank of Guizhou, Nanpanjiang basin, south China". Jour. sed. Res., V.68, No.2, pp.311-326.(1998).
- [25] Chillingar, G.V., Bissell, H.J. and Faibridge, R.W."Carbonate Rocks: Origin, Occurrence, Classification". Elsevier Published Company Amserdam, pp.471 (1967).
- [26] Adams, T.D., Khlili, M. and Khorsrovi Said, A. "Stratigraphic significance of some oligosteginid assemblages from Lurestan province northwest Iran". Micropalaeontology , No.13, P.55-67. (1967).
- [27] Pomar, L., Gilil, E., Obrador, A., and Ward, W. "Facies architecture and high-resolution sequence stratigraphy of Upper Cretaceous platform margin succession, southern central Pyrenees. Spain". Sedimentary Geology, V.175, pp.339-365. (2005).
- [28] Laviano, A., Maresca, M. and Tropeano, M. "Stratigraphic organization of rudist biogenic beds in the Upper Cenomanian successions of the Western Murge (Apulia, Southern Italy)".GEOBIOS, V.22, pp.159-168.(1998).
- [29] Carannante, G., Graziano, R., Pappone, G., Ruberti, D., and Simone, L. "Deposition system and response to sea level oscillations of the Sennonia rudist bearing carbonate shelves, Examples from central Mediterranean areas". Facies, V.40, pp.1-124. (1999).
- [30] Simmons, M.D., Whittaker, J.E. and Jones, R.W. "Orbitolinids from Cretaceous sediments of the Middle East-a revision of the F.R.S. Henson. and associates collection": In Hart, M.B., Kaminski, M. and Smart, C.,(Eds). Proceeding of the 5th International workshop on Agglutinating Foraminiferal . Grzybowski Foundation, special publication, 7, pp.411-437. (2000).
- [31] Coogan, A. H. "Early and Middle Cretaceous Hippuritacea (rudist) of the Gulf Coast": In Bebout, D. G., and Loucks, R.G., (eds) "Cretaceous carbonate of Texas and Mexico". Bur. of Econ. Geol., University of Texas, report of investigation No.89, pp.32-70. (1977).
- [32] Wood, R. "The changing biology of reef-building". Palaios, V.10, pp.517-529. (1995).
- [33] Riding, R. "Structure and composition of organic reefs and carbonate mud mounds: Concepts and categories". Earth-Science Reviews, V.58, pp.163-231. (2002).
- [34] James, N.P. "Reef environment": In Scholle, P.A., Bobout, D.G. and Moor, C.H.,(eds.) "Carbonate Depositional Environments". AAPG, Bull., Memoir 33, pp.345-440. (1983).
- [35] Wood, R. "Nutrients, predation and the history of reef building". Palaios, V.8, pp.526-543. (1993).
- [36] Antoshkina, A. "Organic buildups and reefs on the Paleozoic carbonate platform margin", Pechor-Urale, Russia. Sedimentary Geology, V.118, pp..187-211. (1998).
- [37] Forman, M.J. and Schlanger, S.O. "Tertiary reef and associated limestone facies from Louisiana and Guma." Geology. V.65, pp. 611-627. (1957).
- [38] Murray, J.W. "Ecology and Applications of Benthic Foraminifera". Cambridge University Press, Cambridge, pp.426. (2004).
- [39] Platel, J.P. "The Turonian rudist-bearing carbonate platforms of the Charentes et du Périgord areas, Aquitaine basin(France)". Géogios, M.S.,No.22, pp.295-311. (1998).
- [40] Schafer, P. and Senowbari-Daryan, B. "Facies development and palaeoecologic zonation of four Upper Triassic patch-reefs, Northern calcareous Alps near Salzburg, Austria": In Tommey, D.F.(eds.) "European Fossils Reef Models". SEPM, Special Publication, No.30, pp.241-260. (1981).
- [41] Longman, M.W. "A process approach to recognizing facies of reef complexes": In Toomey, D.F.,(eds.) "European Fossils Reef Models". SEPM, special publication, No.30, pp. 9-40. (1981).
- [42] Hedley, R. H. and Adams, G.G. "Foraminifera". Academic press, London, pp.265. (1976).
- [43] Hallock, P. and Clenn, E.C. "Larger foraminifera: A tool for paleoenvironmental analysis of Cenozoic carbonate depositional facies". Palaios, V.1, pp.55-64. (1986).

- [44] Polsak, A. "*Upper Cretaceous biolithitic complexes in a subduction zone: Examples from the Inner Dinarides, Yugoslavia*": In Toomey, D.F., (eds.) "*European Fossil Reef Models*". SEPM., Special Publication, No.30, , pp.447-473.(1981).
- [45] Burchette, T.P. & Britton, S.R. "*Carbonate facies analysis in the exploration for hydrocarbons : a case-study from the Cretaceous of the Middle East*". In: Brenchley, P.J. & Williams, B.P. (Eds), *Sedimentology, Recent Development and Applied Aspect*. Blackwell, 185-199. (1985).
- [46] Read, J.F. "*Carbonate platform facies models*". AAPG. Bull. ,1,P.1-21. (1985).
- [47] Eberli, G.P., Ginsburg, R.N. "*Segmentation and coalescence of Cenozoic carbonate platforms, Northwest Great Bahama Cobequid Bay-Salmon River Estuary (Bay of Fundy)*". *Sedimentology*. V.37, pp.577-612.(1987).
- [48] Philip, J., Borgomano, J. and Al-Makiry, S. "*Cenomanian-Early Turonian carbonate platform of Northern Oman: Stratigraphy and palaeo-environments*". *Palaeogeography, Palaeoclimatology, Palaeoecology*, V. 119, pp.77-92. (1995).
- [49] Steuber, T., and Loser, H. "*Species richness and abundance patterns of Tethyan Cretaceous rudist bivalves (Mollusca: Hippuritacea) in the central-eastern Mediterranean and Middle East, analyzed from a palaeontological database*". *Palaeogeography, Paleoclimatology, Palaeoecology*, V.162, pp.75-104. (2000).
- [50] Ferry, S., Merran, Y., Grosheny, D. and Mrouech, M. "*The Cretaceous of Lebanon in the Middle East (Levant) context*". *Notebooks on Geology*, 2, pp. 38-42.(2007).
- [51] Sherwani, G.H. "*Sequence stratigraphy and sedimentary systems of Cenomanian-Early Turonian in southern Iraq*". Unpublished Ph.D. Thesis, University of Baghdad. Iraq, pp. 147. (1998).
- [52] Metwali, M.H., Philip, G. and Moussly, M.M. "*Petroleum bearing formations in Northeastern Syria and Northern Iraq*". AAPG. Bull.,V.58, No.9, pp.1781-1796. (1974).
- [53] Al-Mashadani, A. "*Geodynamic evolution of Iraqi sedimentary basins: Consequences of the distribution of fluids*." DSc. Thesis, Pau University, France, pp. 320. (1984).
- [54] Sadooni, F.N. "*The nature and origin of Upper Cretaceous basin-margin rudist buildups of the Mesopotamian Basin, southern Iraq, with consideration of possible hydrocarbon stratigraphy entrapment*". *Cretaceous Research*, V. 26, pp.213-224. (2005).
- [55] Ameen, M.S. "*Effect of basement tectonics on hydrocarbon generation, migration and accumulation in Northern Iraq*". AAPG. Bull, V.76, No.3, pp.356-370. (1992).