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Facies, Depositional Environment and Cyclicity of the Fatha Formation in East Baghdad Oil Field, Iraq.

Mazin Y. Tamar-Agha*, Osama J. Mohammad Al-Aslami
Department of Geology, College of Science, University of Baghdad, Baghdad, Iraq

Abstract

This study deals with establishing the depositional environment of the Fatha Formation through facies analysis. It also deals with dividing the formation into units based on the rhythmic nature. Data from selected shallow wells near Hit area and deep wells at East Baghdad Oil field are used. Five major lithofacies are recognized in this study, namely, greenish grey marl, limestone, gypsum (and/or anhydrite), halite and reddish brown mudstone (with occasional sandstone).The limestone lithofacies is divided into three microfacies: Gastropods bioclastic wackestone microfacies, Gastropods peloidal bioclastic packstone, and Foraminiferal packstone microfacies.The lithofacies of the Fatha are nested in a rhythmic pattern or what is known as shallowing-upwards cycle. Each rhythm begins with shallow marine subtidal environment followed by hypersaline lagoonal environment then supersaline lakes and Salinas, and may finally terminate with continental deposits. Each regressive rhythm is followed by a transgressive phase. According the repitions of the lithofacies, the Fatha Formation can be divided stratigraphically into three units namely Unit 1, Unit 2 and Unit 3 (in ascending order). Different kinds of nesting of lithofacies are recognized in each unit. Only Unit 2 shows complete rhythms.

Keywords: facies, cyclicity, Fatha Formation, rhythms and units, evaporite.

السحنات والبيئات الترسيبية والدورات الرسوبية لتكوين الفتحة في حقل شرق بغداد ، العراق.

مازن يوسف تمراغا*، اسامة جاسم محمدالاسلمي
قسم علوم الارض، كلية العلوم، جامعة بغداد، بغداد، العراق

الخلاصة

تم دراسة التحليل السحني لتكوين الفتحة باستخدام توزيع السحنات الرأسي والأفقي وبيئتها الترسيبية. وقد تم استخدام البيانات من الآبار العميقة كونها تمثل الدورات الترسيبة الكاملة للتكوين . ولقد تم تحديد خمس سحنات صخرية رئيسة في هذه الدراسة وهي المارل الأخضر الرمادي، والحجر الجيري، الجبس والانهايدرايت اوكلاهما. الهاليت والحجر الطيني الاحمر. اما سحنة الحجر الجيري فتنقسم إلى ثلاثة سحنات دقيقة. وتتداخل هذه السحنات الصخرية من تكوين الفتحة في نمط ايقاعي أو ما هو معروف باسم دورة التراجع البحري التصاعدي. كل من هذه الإيقاعات تبدأ البيئة البحرية الضحلة تحت المدية تليها البيئة المالحة اللاغون ثم البحيرات فوق المالحة والمالحة، وقد ينتهي أخيرا بالرواسب القارية. ويعقب كل تراجع بحري دورة تقدم وطغيان بحري انتقالي. كما يمكن تقسيم تكوين الفتحة طباقياً إلى ثلاث وحدات وهي من الاسفل الى الاعلى : الوحدة الاولى و الوحدة الثانية والوحدة الثالثة وتم تحديد عدة انواع من التعاقب الترسيبي في كل وحدة ماعدا الوحدة الثانيه التي تظهر تعاقب ترسيبي كامل (دورة كاملة).

*Email: mtamaragha@yahoo.com

Introduction

The Fatha Formation is characterized by rhythmic nature [1-4]. Each rhythm comprises two to five lithologies were namely, greenish grey marl, limestone, gypsum (and/or anhydrite), halite and reddish brown mudstone (with occasional sandstone). Each lithology represents a lithofacies. This study aims at establishing the facies, their vertical and lateral distribution, and establishing the depositional environment. It also deals with the analysis of nesting of the rhthyms and dividing the formation stratigraphically into units.

Many previous divisions of the formation into lesser order stratigraphic units have been attempted. The oldest is that proposed by the oil geologists in Kirkuk Oil Field [1]. The Fatha Formation (known then as Lower Fars Formation) is divided into four units referred to as Beds. These Beds are:

Upper Red Beds (Top)
Seepage Beds
Saliferous Beds
Transition Beds (Bottom)

Later the Geological Survey of Iraq proposed another scheme as they divided the Fatha Formation into six units; each is assigned an alphabetical letter (from A to F) [5]. Some studied the cyclicity of the Fatha Formation thoroughly and accordingly divided it into two members namely, Lower and Upper Members [2]. The Upper Member starts with the first appearance of the reddish brown mudstone. Many authors proposed other scheme whereby they selected five laterally persistent limestone marker beds which can serve for mapping purposes [2, 4, 6]. These marker beds are assigned as M1, M2 etc. M1 and M2 represent the Lower Member and the rest represent the Upper Member [2].

Methodology

The study area focuses on three wells (EB-81, EB-82 and EB-92) from East Baghdad Oil Field. The data available are mostly final well reports, two well logs (Gamma-ray and sonic) and cuttings. These data are acquired from the Iraqi Central Oil Company. In order to get further details of the lithologies, few outcrop sections from the nearest exposures of the Fatha Formation belonging to the same sub-basin are described and sampled. The sections are taken from the Euphrates valley extending in Al-Anbar Governorate from Al-Mohammedy passing through Hit town and ending at the east of Al-Dulab village near Al-Baghdady city Table-1 and Figure-1.

The succession in each borehole is divided into lithofacies according to the logs. The lithofacies in the boreholes are correlated with three outcrops from Hit area which is Dulab, Hit, and Abo-Tiban. The correlation between the surface and subsurface sections is attempted in order to elucidate the nature of the strata because the subsurface sections are represented basically by logs. The established lithofacies are analyzed in their nesting order to establish the cyclicity. According to the cyclic nature, the Fatha Formation is divided into units. Petrographic studies were also carried out on 45 thin section from borehole EB-91 and outcrops samples. The aim of the petrographic studies is to establish the microfacies.

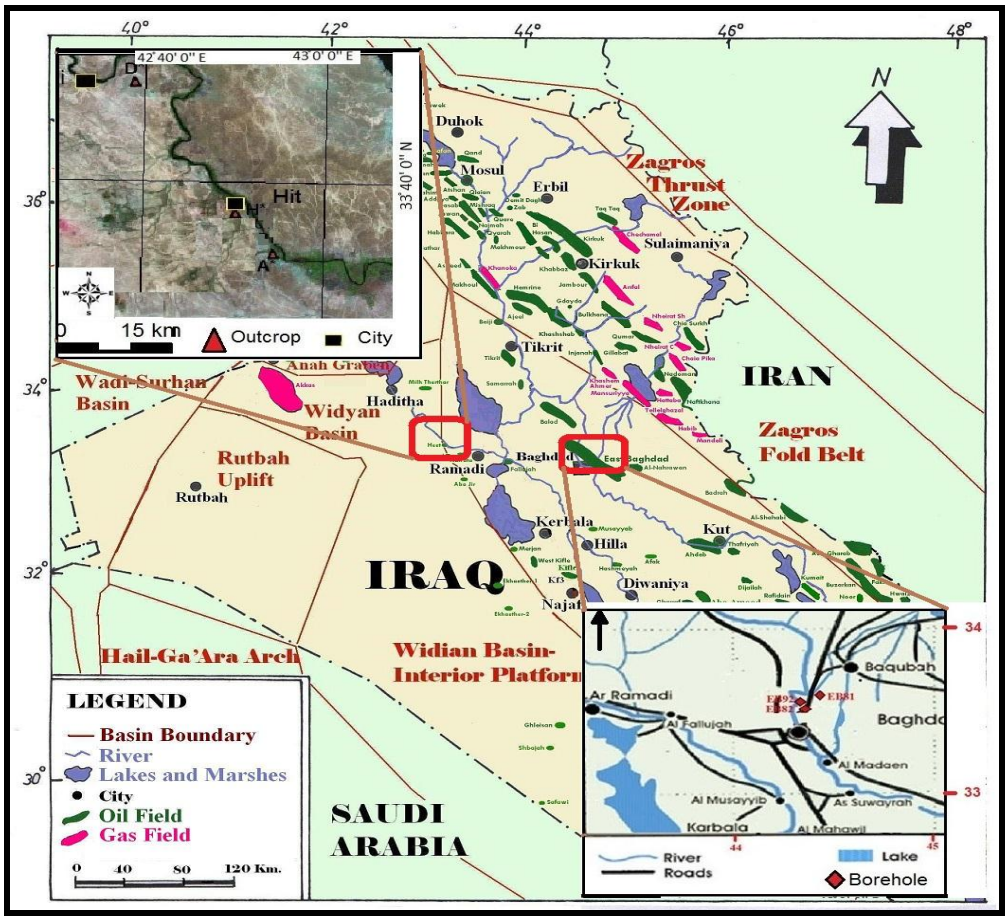

Figure 1-Main Oil and Gas Fields in Iraq and the location map in East Baghdad oil field and Hit area [7].

Table 1- Coordinates, names and thickness of the studies sections.

Section	Type	Location		Thickness of Fatha Fn. (m)
		Latitude	Longitude	
EB-81	Subsurface	43□ 73' 00"	37□ 15' 12"	380.3
EB-82	Subsurface	43□ 74' 20"	37□ 20' 10"	379.0
EB-92	Subsurface	43□ 76' 18"	37□ 05' 06"	376.5
Hit (H*)	outcrop	42□ 49' 06"	33□ 37' 19"	8.5
Dulab (D*)	outcrop	42□ 38' 30"	33□ 50' 00"	3
Abu-Tiban (A*)	outcrop	42□ 53' 35"	33□ 32' 00"	11.3

Geology of the study area:

The studied area is located in the Mesopotamian Zone and Salman Zone of the Stable Shelf of the Mesopotamian Fore deep of the Arabian outer platform, according to the tectonic classification of Iraq. The Salman Zone is a monocline dipping towards the Euphrates River [8]. The Fatha Formation is diachronous and falls into several sub-basins. The most easterly basin falls in west Iran and extends to the Iraqi-Iranian borders and it is of lower Miocene age. The Kirkuk and the Fatha sub-basin are located in central Iraq. They are of middle Miocene age. Finally, the Sinjar basin which extends into Syria is middle-upper Miocene age. The studied area is representing the extension of the central to peripheral part of Kirkuk sub-basin [2, 9]. The middle Miocene sequence is deposited in a broad basin following a marine transgression during a phase of strong subsidence that overlapped the margins of the former Oligocene-early Miocene basin, especially in NE Iraq. The lower contact with Euphrates Formation is conformable. Within the intra-shelf area the sequence comprises a shallow water carbonate (Jeribe Formation) overlain by thick evaporites, carbonate and marls of the Fatha Formation. Important contemporaneous travertine and bitumen lenses, interbedded with basal green marls of the Fatha Formation occur near Hit town. An isolated hill on the left bank of the Euphrates River, 30 km north of Hit is very spectacular. It towers above the surrounding Mesa of the Fatha Formation. [9].

Results and Discussions:

Facies analysis

Five major lithofacies are recognized in this study, from well log and field observation of outcrops, namely, greenish grey marl, carbonate, gypsum (and/or anhydrite), halite and reddish brown mudstone Figure-3, -4 and -5. The carbonate lithofacies only, is divided into three microfacies (using polarizing microscope). The rest rely on field description or from well reports. The following is a description of the facies and their interpretation.

A. Greenish grey marl lithofacies:

It is greenish grey (less frequently yellowish grey), generally massive with conchoidal fractures, occasionally thickly laminated marl or silty marl. The fossils are rare represented by gastropods and oysters. Thickness of marl lithofacies ranges from 65m in well EB-81 to 75 m in well EB-82 with a thickness of 70 m in well EB-92. It is usually found at the base of the rhythm although it is missing on occasions. It has sharp contact with the underlying lithofacies, which can be red mudstone or gypsum and gradual upper contact, commonly to marly limestone and limestone or less frequently with gypsum.

Interpretation – The greenish grey marl is believed to represent different environment by different authors. Some believed that it represents normal marine conditions [2]. Others believe that the presence of oysters indicates brackish-water lagoon [10] and even others to represent subtidal deposits in restricted to open-marine environments [4].

The presence of marine gastropods and microfossils indicate marine conditions and the presence of the clays (marl contains 35-65% clay) indicate turbid water. Turbidity is not convenient conditions for survive fauna to and thus hampers the carbonate factory and limestone deposition [3, 11, 12]. It is accordingly believed that the deposition of the greenish grey marl occurred in subtidal area, reflecting restricted to open-marine environments.

B. Carbonate lithofacies:

It is creamy, greyish white, brownish grey and yellowish grey, thin to thick-bedded and well-bedded limestone with subordinate dolomitic limestone. At the base the carbonate is organodetrital whereas at upper part it is almost devoid of fossils. Instead at the upper it may become gypsiferous where the gypsum nodules become frequent. The fossils are mostly gastropods, bivalves and microfossils. Thickness of the carbonate lithofacies ranges from 33 m in well EB-92, 40 m in well EB-81 and 34 m in well EB-82 with an average thickness of 36m. Occasionally, the carbonate lithofacies is observed at the base the formation or also missing in others. It has gradual contact with the underlying and overlying lithofacies. The contact with the underlying marl starts with marly limestone and with the overlying gypsum (and/or anhydrite) the carbonate changes to gypsiferous limestone then gypsum. This lithofacies can be divided into three microfacies. These microfacies are:

B1- Gastropods bioclastic wackestone microfacies: This microfacies is the most dominant in the Fatha Formation. It occurs at different intervals. It is characterized by the presence of about 10-50% of skeletal fragments. The skeletal fragments are mostly represented by complete shells or fragmented gastropods and echinoderm fragments. The matrix is mostly microspar being mostly recrystallized from lime micrite mud. In general dolomite is infrequent (Plt.1. B).

B2- Gastropods peloidal bioclastic packstone -: This microfacies is common and recognized in many intervals (Plt.1.A). It is characterized by large bioclasts and echinoderm fragments.

B3- Foraminiferal packstone microfacies: This microfacies is common and characterizes most parts of the Fatha Formation (Plt.1.C and D). It is characterized by small bioclasts and echinoderm fragments. Benthonic foraminifera and bioclasts are common in this microfacies.

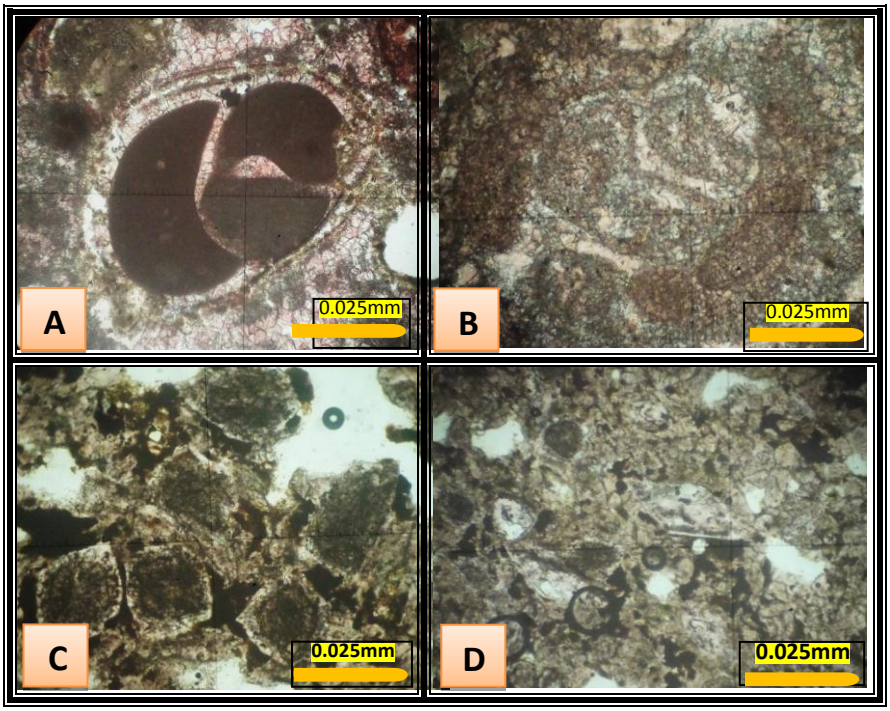

Plate 1- Skeletal grains in the carbonates of the studied sections of Fatha Formation**,** (A) *Gastropod* in packstone, (B) *Gastropod* in wackestone (C) Foraminiferal bioclastic packstone, (D) Foraminiferal bioclastic packstone.

Interpretation – The carbonate lithofacies is believed to represent different environment by different authors. Some authors suggest that the limestone is an intermediate phase between normal marine and supersaline conditions [2]. Others suggests that the carbonates were deposited in a barred hypersaline lagoonal environment with evaporative dolomitization occurred in a tidal-flat setting, where microbial mats were common [4].

In the present study, the transition of the greenish grey marl to carbonate and the carbonate to gypsiferous carbonate supports the views [2]. It is believed that deposition took place first in subtidal normal marine conditions of epeiric sea as indicated by the abundance and diversification of marine fauna. The salinity gradually changes to hpersaline in a lagoonal environment as desiccation continued. The Fatha carbonate in the studied area is almost devoid of microbial mats (stromatolites) unlike the sequence studied by some which reduces the chances of extensive coastal sabkha deposition [4].

C. Gypsum and/or anhydrite lithofacies:

This lithofacies is the most conspicuous and characteristic of the Fatha Formation. It is white to shades of grey laminated to thick bedded. Field observations, from the studied outcrops at Hit area, show that nodules and nodular structures are the most dominant features. Even the laminated gypsum is formed of coalescing nodules Figure-2. The nodules are sub-spherical irregular or even cylindrical (elongated) in shape. In general the nodules show chicken-wire texture, whereas the cylindrical nodules are commonly arranged perpendicular to the bedding plane. The gypsum nodules are mostly surrounded by carbonate film showing mosaic form or without prominent boundary revealing a structureless type.

Figure 2- Nodular gypsum (partially weathered) from Dulab outcrop, west of Iraq.

This lithofacies comprises about half of the Fatha Formation. The total thickness of the gypsum lithofacies ranges from 72 m in well EB-92, 80 m in well EB-81 m and 76 m in well EB-82. It is usually found in the middle of the rhythm and characterize each rhythm. It has gradational lower contact with the underlying lithofacies and sharp contact with the overlying lithofacies.

Interpretation – The gypsum and/or anhydrite is believed to represent different environment by different authors. Some believed that representing the supersaline state [2]. While other believed that this lithofacies may represent very shallow, arid, semi-restricted marine environment that underwent reflux and influx processes [4].

In the present study it is believed that this lithofacies represents supersaline state as the progressive desiccation of the lagoon continued. The incoming influx of water was in equilibrium with the evaporated water to form such thick evaporite beds. The gypsum nodules are of replacive and displacive nature, though the former is more common.

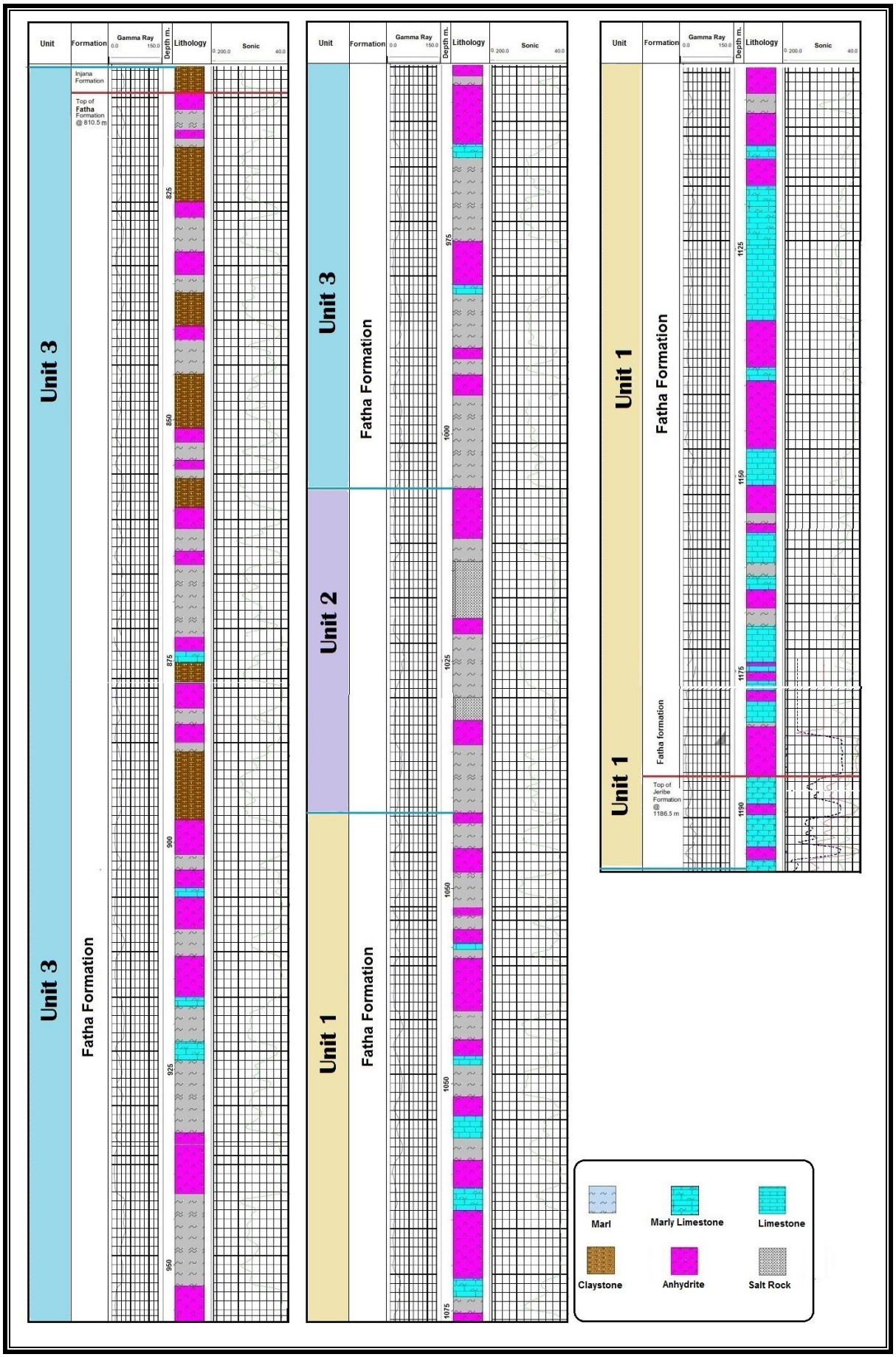

Figure 3- Lithological section of Fatha Formation in well EB-92 (redrawn from the final well report).

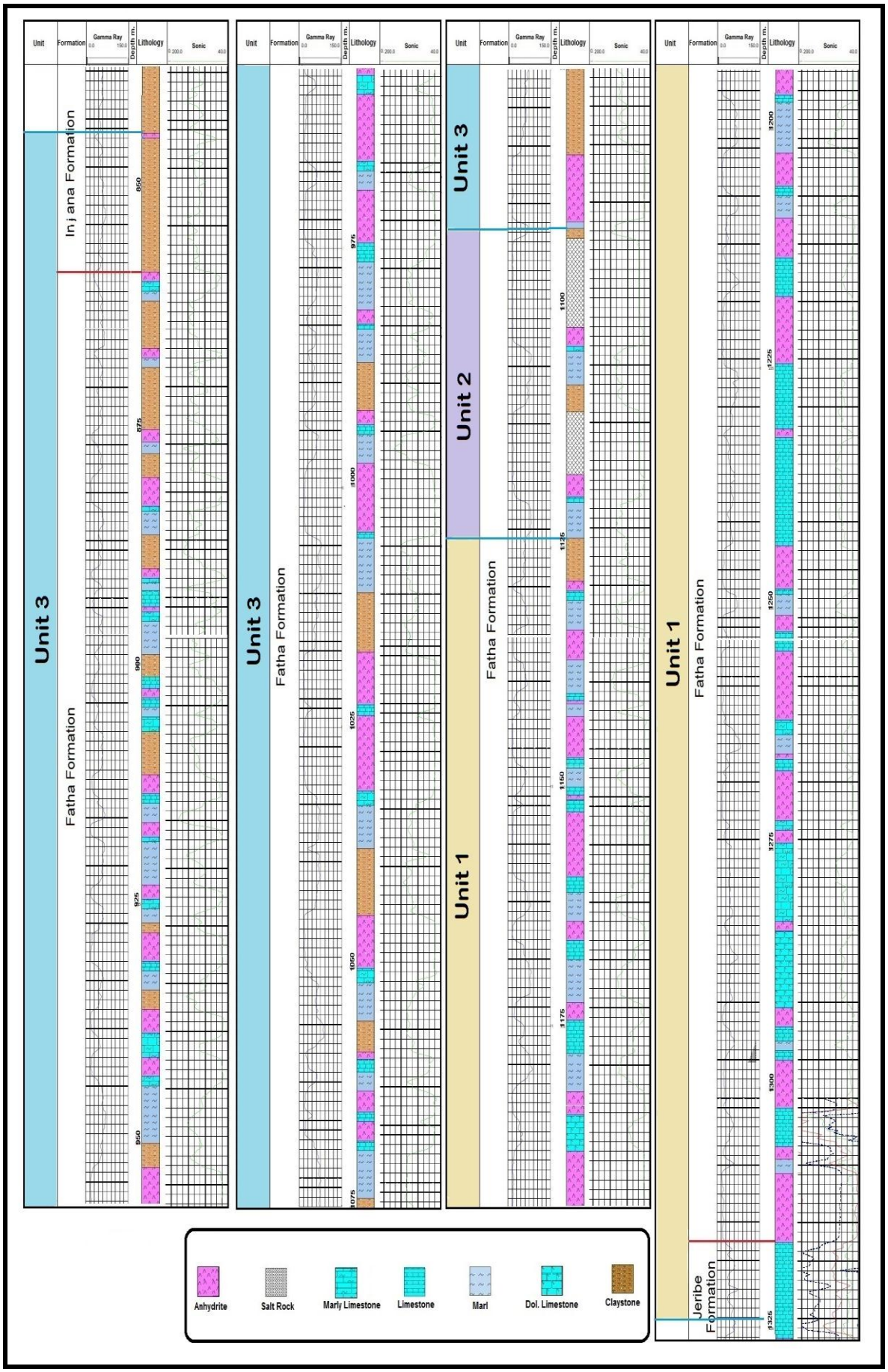

Figure 4- Lithological section of Fatha Formation in well EB-81 (redrawn from the final well report).

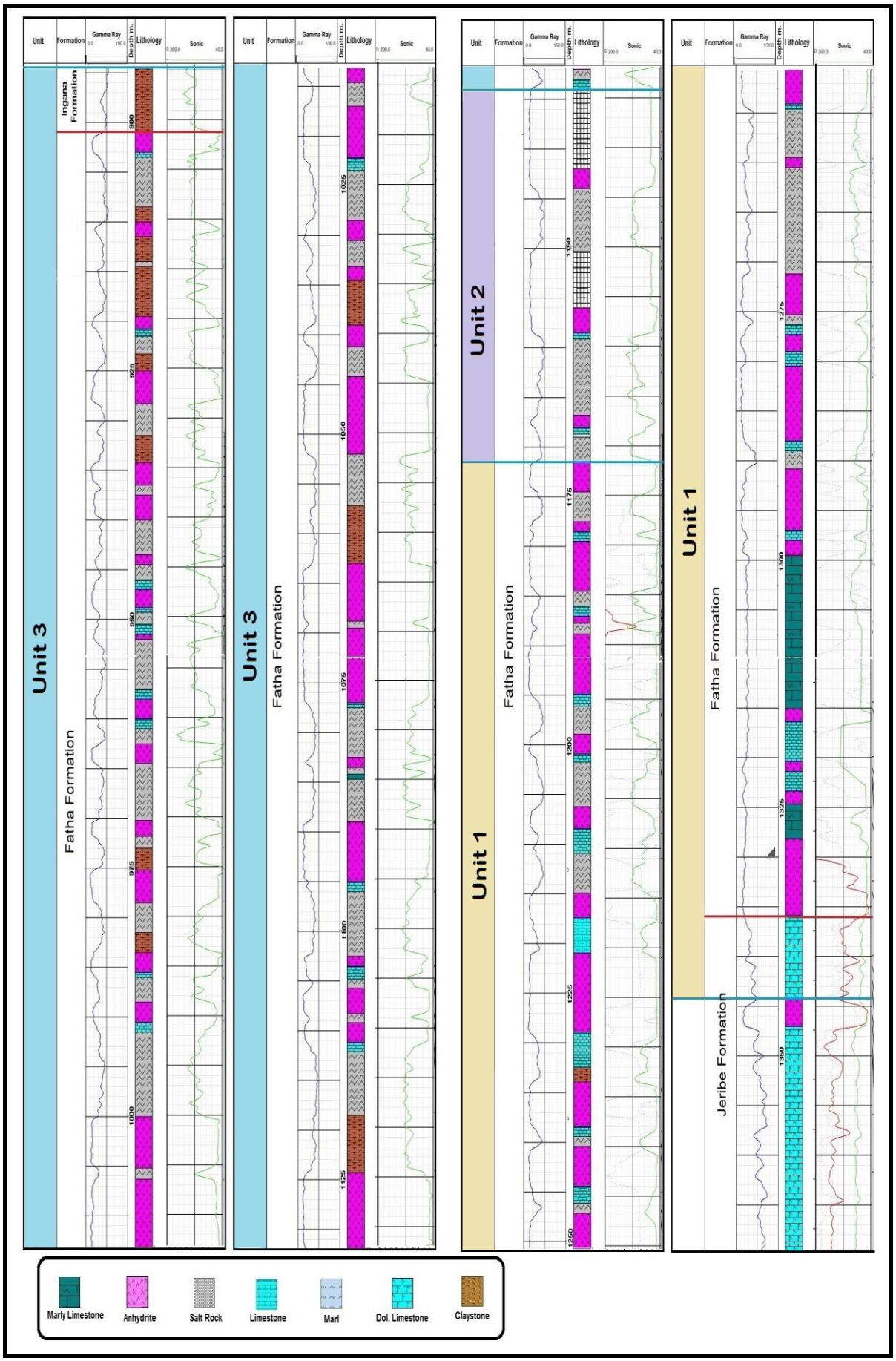

Figure 5- Lithological section of Fatha Formation in well EB-82 (redrawn from the final well report).

D. Halite Lithofacies:

Halite is present in subsurface sections only. It is found in the middle of the Fatha succession at the studied oil wells (EB81 and EB82). The halite lithofacies is pale reddish brown and massive. Thickness of the halite horizons ranges from 10 m in well EB-81 to 7 m in well EB-82. It is usually found at the upper part of the rhythm, when it is complete. It has sharp contact with the underlying and overlying lithofacies. It is infrequently followed by red mudstone.

Interpretation – Lithofacies maps constructed by many authors show that halite occupies the center of the basin [2, 4, 13]. Some believes that this lithofacies is a result of further desiccation of the Fatha Formation to near dryness before the next rhythm [2]. In this work it is believed that the halite lithofacies represents the end of the marine facies and the reduction of the water to its minimal. It indicates hot and dry weather. The thick halite beds reflect a balance between the rate of incoming water and the evaporated water.

E. Reddish brown mudstone lithofacies:

Mudstone comprises reddish brown and pale brown, friable to medium tough mudstone (claystone, silty claystone, siltstone and occasional sandstone). It is greasy when clayey and gritty when contains silt. It contains isolated anhydrite nodules in parts. In general, it is massive and calcareous mudrocks and rarely fossiliferous. Some authors mentioned presence of sandstone in the lithofacies [2, 4, 14]. In the present study such lithology is not found. Thickness of mudstone ranges from 40 m in well EB-92, 33 m in well EB-81 and 35 m in well EB-82. Vertically, it is changing sharply into greenish grey marly limestone and limestone.

Interpretation – Reddish brown mudstone is believed to have deposited in different environments by different authors. Some believed that it represents deposition in continental and transitional environment representing desiccation of the basin, i.e. coming to complete dryness [2]. Others accorded with this view [4, 14].

Lithostratigraphic divisions and Rhythms:

In this study the Fatha Formation is divided into three units, according to the nature of rhythmic repetition, namely Unit 1, Unit 2 and Unit 3 (in ascending order). Unit 1 represents the Lower Member and Units 2 and 3 represent his Upper Member. These units are described below:

Unit 1: This unit represents the oldest unit and has a gradational contact with the underlying Jeribe Formation and sharp contact with the overlying Unit 2. It comprises greenish grey, limestone and gypsum (and/or anhydrite lithofacies). The thickness of this units ranges between 197m in well EB-81, 183m in well EB-82 and 156 m in well EB-92. The lithofacies are nested in four types of facies associations Figure-6 as follows:

1. Lithofacies A, B and C.
2. Lithofacies B and C.
3. Lithofacies A and C.
4. Lithofacies B, A, B and C

Unit 2: This unit represents the middle unit of the Fatha Formation and the oldest unit in the Upper Member [2]. It has sharp contact with the overlying and the underlying units. It comprises greenish grey, limestone and gypsum (and/or anhydrite lithofacies), halite and reddish brown mudstone. The thickness of this unit ranges between 58 m in well EB-81, 32 m in well EB-82 and 35 m in well EB-92. The lithofacies are nested in one facies associations Figure-6 representing the complete or ideal cycle, as follows: greenish grey marl (Lithofacies A), carbonates (Lithofacies B), gypsum and/or anhydrite (Lithofacies C), halite (Lithofacies D) and reddish brown mudstone (Lithofacies E).

Unit 3: This unit represents the youngest unit and has a sharp lower contact, with the underlying unit and gradational contact with the overlying Injana Formation. It comprises greenish grey, limestone, gypsum (and/or anhydrite lithofacies) and red mudstone. The thickness of this unit ranges between 346 m in well EB-81, 255 m in well EB-82 and 199 m in well EB-92.

The lithofacies are nested in five types of facies associations Figure-6 as follows:

1. Lithofacies A, B and C.
2. Lithofacies C and E.
3. Lithofacies B and C.
4. Lithofacies B and E.
5. Lithofacies B, A, B, C and E.

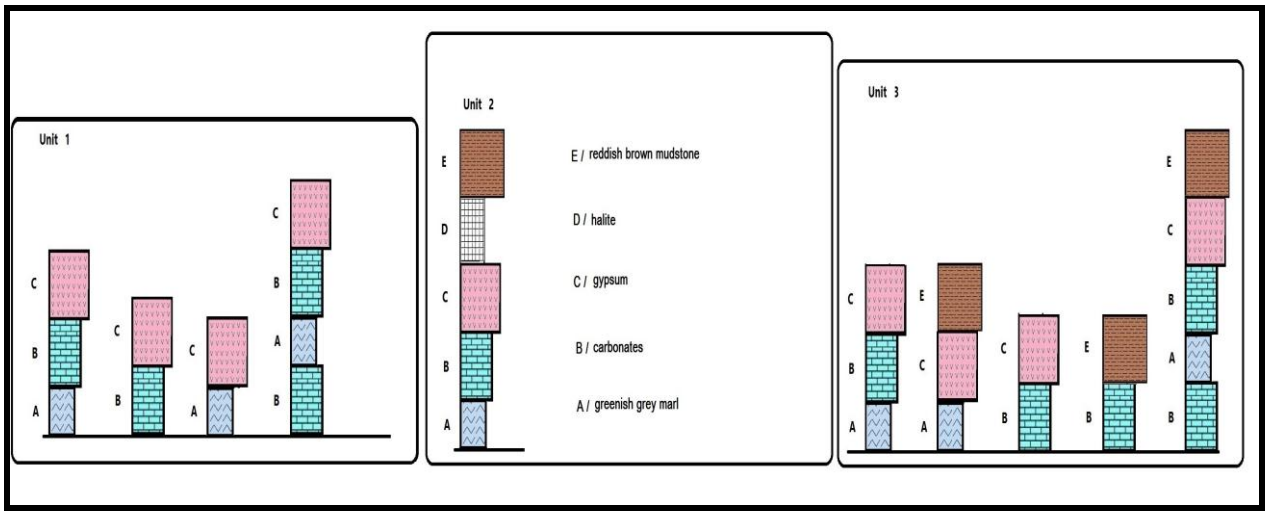

Figure 6- Units and cyclicity of Fatha formation in studied drilled wells.

Depositional Environment:

The lithofacies of the Fatha Formation (middle Miocene) are nested in a rhythmic pattern. The complete or ideal rhythm begins with greenish grey marl (Lithofacies A) followed by carbonates (Lithofacies B), gypsum and/or anhydrite (Lithofacies C), halite (Lithofacies D) and finally terminated by reddish brown mudstone (Lithofacies E). The rhythms are commonly incomplete, except in the middle part of the Fatha Formation at the center of the basin. Incomplete rhythms are usually represented by at least two lithofacies; one of them is represented by gypsum and/or anhydrite lithofacies (Lithofacies C). The contacts between the facies are generally gradational.

Facies analysis indicates that the each package of facies represents a regressive rhythm or what is known as shallowing-upwards cycle. Each rhythm begins with shallow marine subtidal environment (Lithofacies A), followed by hypersaline lagoonal environment (Lithofacies B), then supersaline lakes and salinas (Lithofacies C and D), and may finally terminate with continental deposits (Lithofacies E). Each regressive rhythm is followed by transgressive phase and triggers another regressive.

Isopach, isolith maps Figure-7 constructed by other authors [2, 4, 10] and facies analysis carried out in the present study reveals that the regressive-transgressive rhythms are deposited in a broad and shallow foreland basin adjacent to the Zagros and Taurus Mountain ranges. This basin comprises subtidal shelf with lagoons. The majority of the nodular gypsum and/or anhydrite are deposited in the lagoon. Some of these nodules may have also deposited in both coastal sabkhas (Lithofacies C) and inland sabkhas (associated with Lithofacies E). The frequency and thickness of the evaporites indicate hot and arid climate. The concentric arrangement of lithofacies, especially the evaporite deposits indicates a bull-eye fashion of arrangement which indicates close basin or possibly semi-barred basin [13].

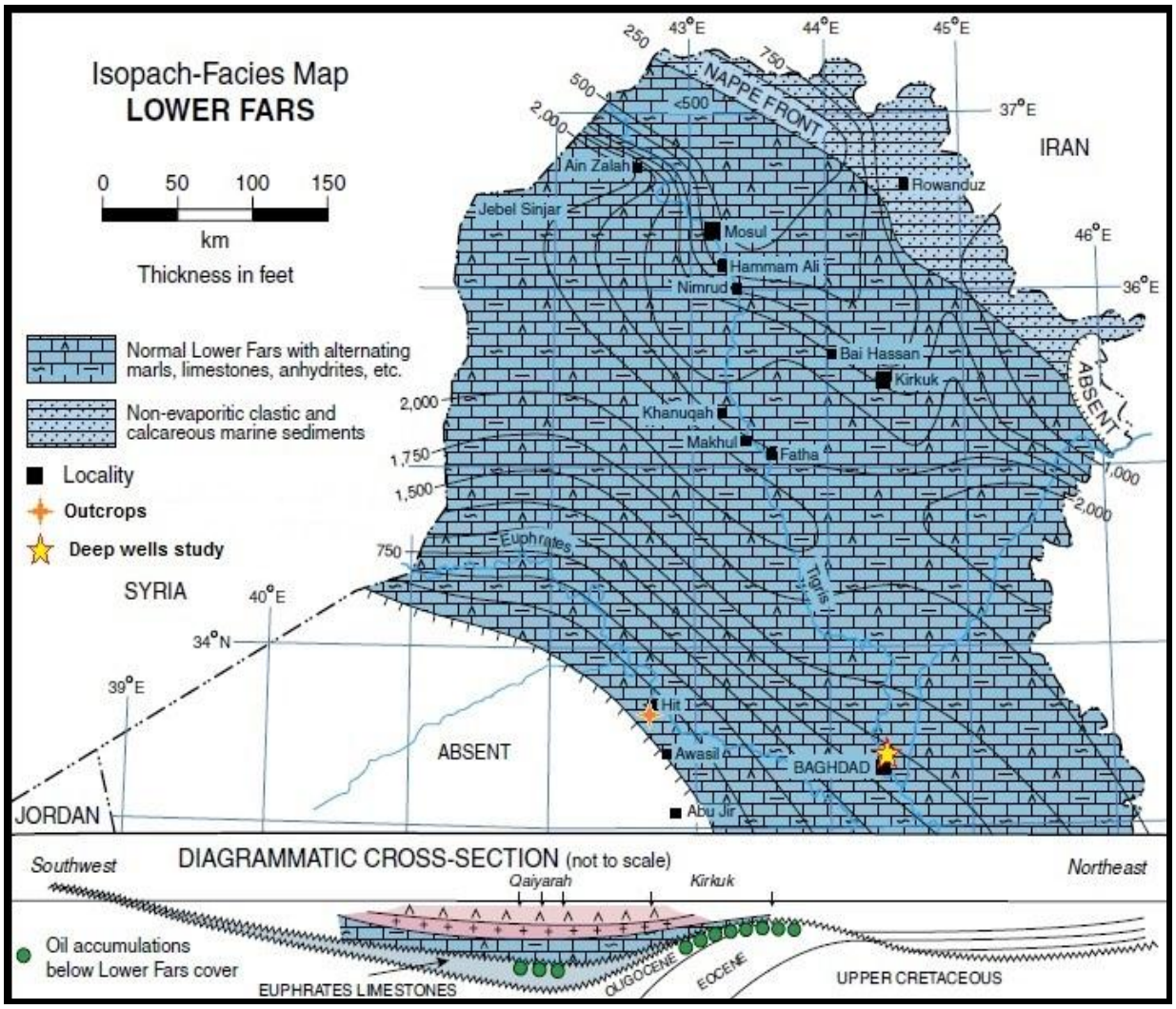

Figure 7- Isopach-facies map of Fatha Formation (Lower Fars) showing the studied wells location [13].

Experimental studies, since the work of Usiglio in 1848, showed that there is a definite order of crystallization of salts from sea water during its evaporation. This order depends on the solubility product of the crystallized salts. Carbonate minerals begin to crystallize at the reduction of the original volume to about its half. Gypsum begins to crystallize when the original volume is reduced to about 20% followed by halite when the water volume reaches approximately 10% of the original volume. Finally, magnesium and potassium salts are deposited when less than about 5 percent of the original volume of water remains. This crystallization order occurs in natural evaporite deposits too, despite some discrepancies between the theoretical sequences (laboratory results) and the observed (rock record) [15].

The studied column showed quite thick evaporite beds, exceeding 10 metres at times. Obviously, some special geological conditions are required to accumulate such thick sequence of evaporites [15]. The basic requirements for deposition of marine evaporites are aridity (rates of evaporation exceed rates of precipitation) and partial isolation from the open sea. Isolation can be accomplished by means of a barrier that restricts free circulation of ocean water into and out of the basin. The role of the barrier is either attributed to tectonic reasons [2] or owing to sea-level changes due to climatic changes attributed to orbital cycles [3]. However to attain thick evaporite sequence as in the studied area, a balance is required to prevail between the incoming and the evaporated water.

A diagram is constructed for well EB 81 of the East Baghdad Oil Field Figure-8 showing the evaporation percentage as reflected from lithologies. The values of the evaporation percentages of the different lithologies are taken from previous studies as mentioned earlier in the text. The diagram shows that evaporation percentage is generally low in the lower part of the Fatha Formation (Unit 1), allowing carbonates and gypsum to be deposited dominantly first, at a considerable thickness. No

desiccation is achieved at this Unit.The evaporation percentage gradually increases upwards and most of the individual rhythms reach complete desiccation as indicated by the presence of reddish-brown mudstone (Unit 2). Halite appears in this unit which infers that the evaporation rate to complete drying is gradual. In the upper part of the formation the halite is missing which means that the drying of the basin was swift and hence bypassing the deposition of the halite. The diagram shows that the rhythms become thinner and more frequent in the upper part of the formation indicating that the influx of water and its evaporation were faster.

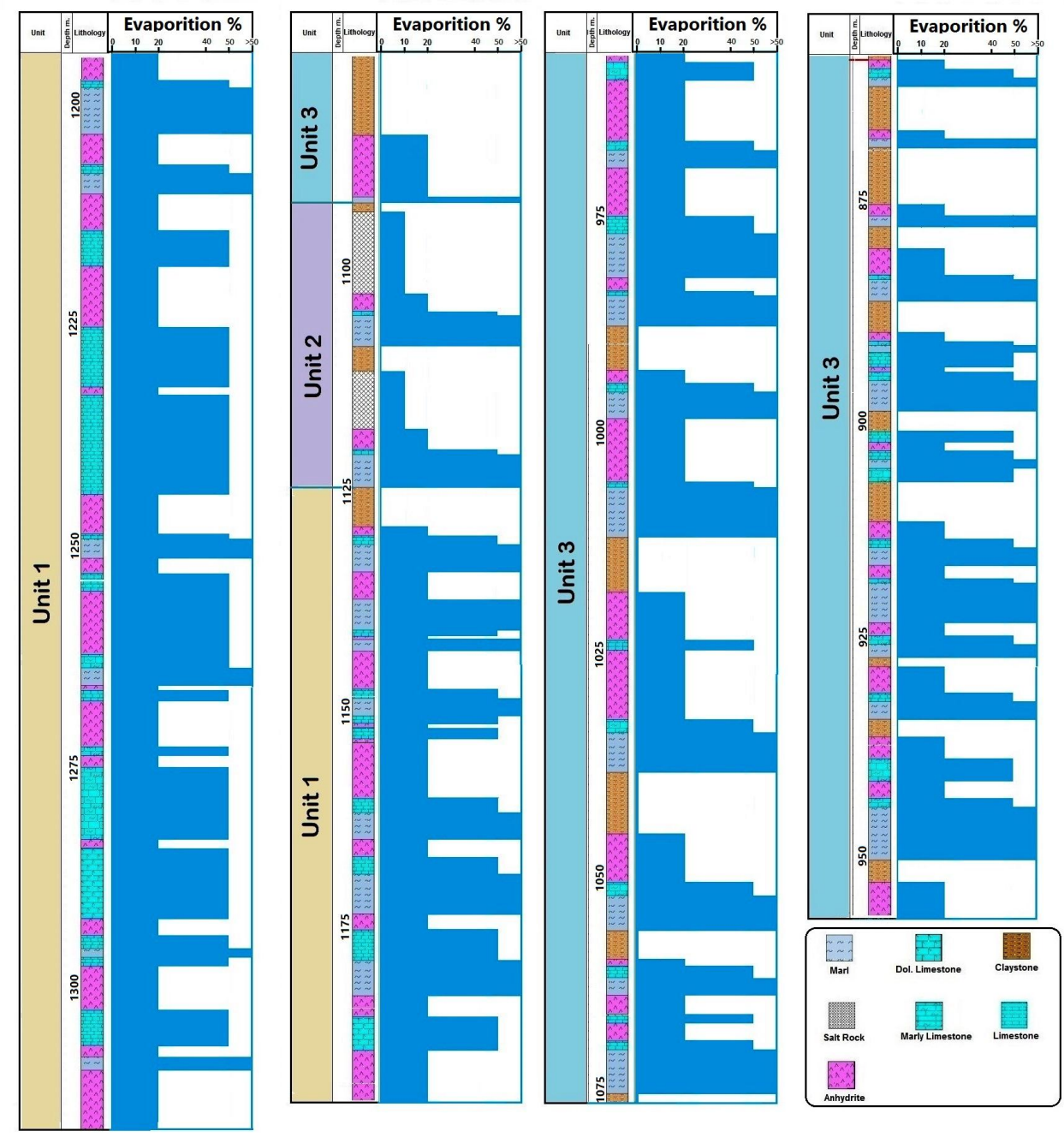

Figure 8- Evaporation percentage of the incoming water as reflected by lithologies in the Fatha Formation at well EB 81 at East Baghdad Oil Field.

Conclusions

Five major lithofacies are recognized in this study namely, greenish grey marl, limestone, gypsum (and/or anhydrite), halite and reddish brown mudstone (with occasional sandstone). The limestone lithofacies, only, is divided into three microfacies namly, Gastropods bioclastic wackestone microfacies, Gastropods peloidal bioclastic packstone microfacies. These lithofacies are arranged

vertically indicating that the Fatha Formation in the study area comprises tens of shallowing-upwards cycle starting with shallow marine deposits and ending with complete drying of basin (desiccation) represented by continental deposition. The depositional basin of Fatha Formation comprises subtidal shelf with lagoons. The nodular gypsum and/or anhydrite are most probably deposited in the lagoon, inland sabkhas, and coastal sabkhas, and indicate hot and arid climate. In this study The Fatha Formation can be divided into three units named Unit 1, Unit 2 and Unit 3 (in ascending order).

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