Biostatigraphy of Yamama Formation in Faihaa Oil Field, Southern Iraq

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Abstract

The Yamama Formation was studied in three wells (Fh-1, Fh-2, and Fh-3) within Faihaa oil field, south Iraq. Thin sections were studied by using the polarizing microscope examination in order to determine microfossils and biozone. Thirty-five species of benthic foraminifera were recognized, including four index species. In addition, twelve species of calcareous green algae were recognized, including two index species. Other fossils that were recognized in Yamama Formation include Gastropoda, Bryozoa, Coral, Rudist, and Pelecypoda.

Six biozones were observed, which are Charentia cuvillieri sp. (Range Zone of Berriasian age), Psudochnilamina littus sp. (Range Zone of Valanginian age), Nezzazata Perforate sp. and Choffatella sp. (Assemblage Zone of Berriasian-Valanginian age), Desycladales Green Algae-Salpingoporella cf. circassa sp. (Range Zone of Valanginian age). According to these biozones, the age of Yamama Formation was distinguished to be the Berriasian-Valanginian.

Keywords: Yamama Formation, Biostratigraphy, Foraminifera, Calcareous green algae, Faihaa oil field.

Introduction

Yamama Formation is one of the most important oil production reservoirs in the southern Mesopotamian Zone, which belongs to the Early Cretaceous (Berriasian-Valanginian) sequence. The Early Cretaceous succession (late Berriasian- Aptian) extends, from the shore to deep basin, by the Zubair, Ratawi, Yamama, Shuiaba, and Sulaiy formations. It includes important carbonate reservoirs in southern Iraq, namely in the West Qurna, North Rumaila, and Majnoon fields [1]. The lower and upper contacts of Yamama Formation are conformable with Sulaiy and Ratawi formations,

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respectively. The formation is a subsurface unit, which consists of different limestone units, such as fossiliferous limestone, vuggy limestone, chalky limestone, and argillaceous limestone [2]. The present study includes biostratigraphic investigation of Yamama Formation in the wells of Faihaa-1 (Fh-1), Faihaa-2 (Fh-2), and Faihaa (Fh-3) (Table 1), at Faihaa oil field (Figure.1).

The previous studies of Yamama Formation subdivided the formation into different units based on lithological variations and cyclicity. An earlier study [3] divided the Yamama Formation into six units and combined Yamama/Sulaiy Formation as a peloidal limestone overlain by the Ratawi Formation. Another work [4] divided the Yamama Formation into six depositional cycles representing a general regressive sequence. In the southern part of Iraq, Yamama Formation was subdivided into two upper and lower members or reservoir units separated by barriers [5]. Biostratigraphy and microfacies of Yamama Formation in the selected wells, southern Iraq, were also investigated [6]. The biostratigraphic studies of Yamama Formation were mainly based on benthic foraminifera fossils. The current study used both benthic foraminifera and green calcareous algae in the biostratigraphic zonation and age determination.

**Location of the study area**

The Faihaa oil field is located in Basrah Governorate, 20km south-east Basrah city, and extends across the border with Iran (Figure-1). The distance between wells Fh-1 and Fh-2 is 6.606 Km, while that between wells Fh-1- and Fh-3 is 6.075km (Figure.2).

**Table 1**-Geographic coordinates of Faihaa wells (UTM system WGS84) and thickness of Yamama Formation.

| Well No. | Geographic coordinate of well | Thickness of Yamama Formation (m) |
|----------|-----------------------------|----------------------------------|
| Fh-1     | 215343 3426021              | 324m                             |
| Fh-2     | 215502 3432609              | 297.9m                           |
| Fh-3     | 215503 3419884              | 126m                             |
Stratigraphy and Geological Setting
Faihaa oilfield is located in the east of the Mesopotamian Basin in the Zubair subzone that is characterized by a subsurface geologic structure covered by sediments from the Quaternary. This zone is bounded by two faults, the first belongs to Al-Batin fault zone, whereas the second belongs to the Najd fault system between Ramadi-Musaiyib fault zone in the SW and Tikrit-Amara fault zone in the NE [7]. The collision of the Arabian-Iranian plates generated regional compression effect that produced NW-SE trending fold structures. The effect of folding extends along the NW-SE regional trend of the Zagros fold-Thrust Belt. The structure of Faihaa oil field belongs to this trend, which represents an approximately N-S anticline with three structural closures (Figure.2).

![Figure 2: Structural contour map at the top of Yamama Formation in Faihaa oil field with the locations of the selected wells [8].](image)

**Figure 2** Structural contour map at the top of Yamama Formation in Faihaa oil field with the locations of the selected wells [8].

**Figure 3** Stratigraphic succession of Yamama Formation in well Fh-1.

| Age | Formation | Depth (m) | Lithologic Succession | Lithologic Description |
|-----|-----------|-----------|-----------------------|------------------------|
| Ratawi | | 4030 | Limestone with benthic foraminifera, Echinoids, Algae, sponge spicules, pellet, Byrozoans | Alteration of shale, Argillaceous limestone |
|       |           | 4050 | Limestone, vuggy, pores, interparticle porosity, algae, stylolite | |
|       |           | 4070 | Dolomitic Limestone | |
|       |           | 4090 | Limestone | |
| Early Cretaceous (Berriasian-Valangian) | | 4110 | Limestone, Benthic foraminifera, channel porosity | |
|       |           | 4130 | Limestone, bioclast, Gastropoda, Green Algae | |
|       |           | 4150 | Limestone | |
|       |           | 4170 | Limestone | |
|       |           | 4190 | Limestone with stylolitic | |
|       |           | 4210 | Limestone with bioclastic and Benthic Foram | |
|       |           | 4230 | Limestone | |
|       |           | 4250 | Limestone | |
|       |           | 4270 | Limestone | |
|       |           | 4290 | Limestone | |
|       |           | 4310 | Limestone with styloite | |
|       |           | 4330 | Limestone with bioclastic and Benthic Foram | |
|       |           | 4350 | Limestone | |
|       |           | 4370 | Argillaceous Limestone | |
The Yamama Formation was deposited during the Lower Cretaceous period within the main retrogressive depositional cycle [1]. The shallow water carbonates of Yamama Formation covered large areas in the eastern shelf platform of the Arabian plate, and their depositions were affected by a moderately high, but falling, eustatic sea level [9]. The formation is assigned to the Berriasian-Valanginian age [3]. The Thickness of the Formation is up to 400m [2], while its maximum thickness in the study area reaches 324m at well Fh-1 (Figure.3).

**Biostratigraphy of Yamama Formation at Well Fh-1**

The following microfossils are identified in the core samples of Yamama Formation at Fh-1 (Figure.4): benthic foraminifera species: Choffatella sp. (d'orbigeny, 1904), Pl.A (Fig.1), Nezzazeta perforate sp. (Omara, 1956), Pl.A (Fig.2), PL, Charentia cuvillieri sp. (d'orbigny, 1904), PL.A (Fig.3), Pseudocyclaminna lituus sp. (Yokoyama, 1890), PL.A (Fig.4), Suborder Miliolina: Spirologulina sp. Pl.A (Fig.5), and Quinquelocline sp. Pl.A (Fig.6). Also, the identified calcareous green algae include Salpingoporella sp. (Deecke), Pl.A (Fig.7) along with the associated fossils of Gastropoda Pl.A (Fig.8).

**Biostratigraphy of Yamama Formation at Well Fh-2**

The following microfossils are identified in the core samples of Yamama Formation at Fh-1 (Figure. 5): Benthic foraminifera species include Korkyrella texana sp. PLB (Fig.1), Nezzazeta simplex sp. PLB (Fig.2), Textulirina sp. PLB (Fig.3), and Praechrysalidina infracretacea sp. (Luperto sinni, 1979), Pl.B (Fig.4). Calcareous green Algae include Clyndroporella sp. (Elliot, 1957), Pl.B (Fig.5) and Bakalovaella Bakalova sp. (Elliot, 1957), Pl.B (Fig.6), whereas the associated fossils are Pelecypoda Pl.B (Fig.7) and Coral Pl.B (Fig.8).

**Biostratigraphy of Yamama Formation at Well Fh-3**

The following microfossils are identified in the core samples of Yamama Formation at Fh-1 (Figure.6): Benthic foraminifera species include Trocholina Sagittaria sp. Pl.C (Fig.1), Nummofallotia apula sp. (Steinmann, 1881), PL.C (Fig.2), and Nautilusulina sp. PL.C (Fig.3). Calcareous green Algae include Arabicodium sp. (Elliot, 1957), PL.C (Fig.4), Salpingoporella cf. circassa sp. PL.C (Fig.5), Terguemella sp. PL.C (Fig.6), and Noemeris sp. (d'archiac), PL.C (Fig.7). Associated fossils include Rudist Pl.C (Fig.8).

**Biozones of Yamama Formation at Well Fh-1**

The Biostratigraphy zones of the current study depend on benthic foraminifera and calcareous green algae. The definitions of these biozones were achieved based on the stratigraphic distribution of these many types of fauna (Figs. 4, 5, and 6), with the following six biozones being distinguished.

1. **Charentia cuvillieri sp. Range Zone**

This biozone was identified depending on the range of extension of the species. The zone was determined based on the first and last occurrence of the species Charentia Cuvillieri in well Fh-1. This species is found in Yamama Formation (Figure. 4) and the thickness of this Biozone is 72m at Fh-1.

**Age of Charentia cuvillieri sp. Range zone**

The age of this biozone is the Early Cretaceous (Berriasian) ([10, 11, 12, 13], as can be shown in table-2 below.

**Table 2**-The age of the index fossil specie (Charentia Cuvillieri ) as indicated by studies in other countries.

| Researcher         | Country | Index fossil | Geological Time |
|--------------------|---------|--------------|----------------|
| Neumann, 1965      | Spain   |              | Late Jurassic   |
|                    |         |              | Tithonian Be.   |
| Tappan,1966        | Syria   |              | Early Cretaceous|
| Gorbachik, 1968    | France  |              |                 |
| Daria & Iranova, 2010| Europe | Charentia cuvillieri sp. |                 |

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2. *Psudochryalidina infracretacea* sp. Range Zone

This biozone was identified depending on the range of extension of the species. The zone was determined based on the first and last occurrence of the species *Psudochryalidina infracretacea* in well Fh-2. This species is found in Yamama Formation (Figure.5), with the thickness of this Biozone being 197.2m at Fh-2.

- **Age of Psudochryalidina infracretacea** sp. Range zone

The age of this biozone is the Early Cretaceous (Berriasian) [12, 13, 14, 15], as shown in table-3 below.

**Table 3**-The age of the index fossil species (*Psudochryalidina infracretacea* sp.), as indicated by studies in other countries.

| Researcher                  | Country   | Index fossil | Geological Time |
|-----------------------------|-----------|--------------|-----------------|
| Luperto, 1979               | Spain     | *Psudochryalidina infracretacea* | Late Jurassic, Early Cretaceous, Tithonian |
| Michal & Barbara, 2005      | France    | *Psudochryalidina infracretacea* | Late Jurassic, Early Cretaceous, Tithonian |
| Seyed & Conrad, 2008        | Iran      | *Psudochryalidina infracretacea* | Late Jurassic, Early Cretaceous, Tithonian |
| Ivovelic & Branko, 2009     | USA       | *Psudochryalidina infracretacea* | Late Jurassic, Early Cretaceous, Tithonian |
| Maryam & Mohammad, 2011     | Iran      | *Psudochryalidina infracretacea* | Late Jurassic, Early Cretaceous, Tithonian |
| Leila & Ahmad, 2018         | Iran      | *Psudochryalidina infracretacea* | Late Jurassic, Early Cretaceous, Tithonian |
| Present study, 2019         | Iraq      | *Psudochryalidina infracretacea* | Late Jurassic, Early Cretaceous, Tithonian |

3. *Pseudocyclammina Lituus* sp. Range Zone

This zone was determined based on the first and last occurrence of the species *Pseudocyclammina Lituus* in wells Fh-1 and 2. The distinguished species are shown in Figures 4 and 5, while the thickness of this Biozone is 72m at well Fh-1.

- **Age of Pseudocyclammina Lituus** sp. Range zone

The age of this biozone is the Early Cretaceous (Valanginian) [10, 12, 15, 16], as shown in table-4 below.
Table 4 - The age of the index fossil species (Pseudocyclammina Lituus), as indicated by studies in other countries.

| Researcher                     | Country   | Index fossil | Geological Time |
|--------------------------------|-----------|--------------|-----------------|
| Yokoyama, 1890.                | Japan     |              |                 |
| Hart, 1962.                    | Iraq      |              |                 |
| Fourcadann & Neumann, 1966.    | Croatia   |              |                 |
| Hottinger, 1967.               | Morocco   |              |                 |
| Fourcade, 1971.                | Spain     |              |                 |
| Sartorio & Venturini, 1988     | Italy     |              |                 |
| Ornelas & Alzaga, 1994.        | Mexico    |              |                 |
| Krajewski & Olszewska, 2007    | Crimea    |              |                 |
| Iranova, 2008.                 | Bulgaria  |              |                 |
| Ceila & Morteza, 2018.         | Iran      |              |                 |
| Pre-Present Study, 2019        | Iraq      |              |                 |

4. Nezzazata Perforate sp.-Choffatella sp. Assemblage Zone
This biozone is defined by three or more different taxa, which may, or may not, be related to each other. The boundaries of the assemblage zone were defined by the occurrence of the typical specified fossil assemblage. This can include the appearance, but also the disappearance, of certain taxa [16]. The occurrence of Nezzazata perforate sp. and Choffatella sp. was recorded. The assemblage zone have the same trend of appearing and disappearing taxa in almost the same depth in well Fh-1 (Figure 4).

- Age of Nezzazata Perforate sp. and Choffatella sp. Assemblage Zone
The age of this biozone is the Cretaceous (Berriasian-Valanginian) [10, 12, 13, 18], as shown in Table 5 below.

Table 5 - The age of fossils (Nezzazata Perforate sp.-Choffatella sp.), as indicated by studies in other countries.

| Researcher          | Country | fossils                        | Geological Time |
|---------------------|---------|--------------------------------|-----------------|
| Ivo Velic, 1983     | Yugoslavia | Nezzazata Perforate sp. | Tithonian  Be.    | N.P. |
| Neumann, 1965       | Spain   | Nezzazata Perforate sp.       | Ch.              |
| Barbara O., 2005    | France  | Choffatella sp.               | Ch.              |
5. Desycladales Green Algae- *Cylindroporella* sp. Range Zone

This biozone was identified depending on the range of extension of the species. The zone was determined based on the first and last occurrence of the species *Cylindroporella* in well Fh-2 (Figure 5). The thickness of this Biozone is 121.8m at well Fh-1.

**- Age of Cylindroporella sp. Range Zone**

The age of this biozone is the Early Cretaceous (Berriasian) [14, 15, 20, 21], as shown in table-6 below.

**Table 6-The age of the index fossil (*Cylindroporella* sp.), as indicated by studies in other countries.**

| Researcher          | Country     | Index fossil       | Geological Time |
|---------------------|-------------|--------------------|-----------------|
| Elliot,1968         | Peninsula   |                    |                 |
| Granier,1990        | Portugal    |                    |                 |
| Mahuel &Elene,1993  | Cuban       |                    |                 |
| Masse & Dalmasso, 1999 | France     |                    |                 |
| Granier,2000        | Abu Dhabi   |                    |                 |
| Seyed&Marc,2008     | Iran        |                    |                 |
| Ahtun &Branko, 2009 | Croatia     |                    |                 |
| Bruno&Alexandre, 2017 | Oman       |                    |                 |
| Leila, Ali &Ahmad, 2018 | Persian Gulf |                  |                 |
| Present study,2019  | Iraq        |                    |                 |

6. Desycladales Green Algae- *Salpingoporella cf. circassa* sp. Range Zone

This zone was determined based on the first and last occurrence of the species *Salpingoporella cf. circassa* in well Fh-3. This species was found in Yamama Formation (Figure. 6), while the thickness of this Biozone is 123m at Fh-3.

**- Age of Salpingoporella cf. circassa sp. Range BioZone**

The age of this biozone is the Early Cretaceous (Valanginian) [13, 15, 20, 22], as be show in table-7 blew.
### Table 7: The age of the index fossil (Salpingoporella cf. circassia), as indicated by studies in other countries.

| Researcher                     | Countries       | Index fossil          | Geological Time       |
|--------------------------------|-----------------|-----------------------|-----------------------|
| Elliott, 1957                  | Qatar           |                       | Early Cretaceous      |
| Elliott, 1968                  | France          |                       | Tithonian             |
| Mahuel & Elene, 1993           | Cuban           |                       | Be.                   |
| Aziz & El-Sattar, 1997         | Abu Dhabi       |                       | Va.                   |
| Branko, 2004                   | Croatia         |                       | Ha.                   |
| Maryam & Mohammadi, 2011       | Iran            |                       | Ba.                   |
| Cristian & Bruno, 2016         | Romania         |                       |                       |
| Leila & Ahmed, 2018            | Persian Gulf    |                       |                       |
| Present study, 2019            | Iraq            |                       |                       |

![Figure 4](image-url) - The biostratigraphy of Yamama Formation at well Fh-1
**Figure 5**- The biostratigraphy of Yamama Formation at well Fh-2.
| Epoch      | Age         | Formation   | Depth | Benthic Foraminifera | Algae | Pelecypoda | Coral | Turtle | Fish | Fossils |
|------------|-------------|-------------|------|----------------------|-------|------------|-------|--------|------|---------|
| Valanginian|             |             |      |                      |       |            |       |        |      |         |
|            |             |             |      |                      |       |            |       |        |      |         |
| Early Cretaceous |         | Yamama      |      |                      |       |            |       |        |      |         |
| Berriasian |             |             |      |                      |       |            |       |        |      |         |

**Figure 6**-The biostratigraphy of Yamama Formation at well Fh-3.
Plate - A -
Fig.1: Choffatella sp. Foraminifera, Yamama Formation, axial section, Fh-1 at depth (4211.5m). Age: Early Cretaceous to Recent.
Fig.2: Nezzazata perforate sp. Foraminifera, Yamama Formation, subequatoriale section, Fh-1 at depth (4177m). Age: Early Cretaceous.
Fig.3: Charentia cuvillieri sp. Foraminifera, Yamama Formation, axial section, Fh-1 at depth (4027m). Age: Berriasian.
Fig.4: Pseudocyclammina Lituus sp. Foraminifera, Yamama Formation, axial section, Fh-1 at depth (4031.5 m). Age: Valanginian.
Fig.5: Spiroloculina sp. Miliolidae, Yamama Formation, oblique section, Fh-1 at depth (4186m). Age: Jurassic - Early Cretaceous.
Fig.6: Quinguelocina SP. Miliolidae Yamama Formation, oblique section, Fh-1 at depth (4193.5m). Age: Jurassic - Early Cretaceous.
Fig.7: Salpingoporella sp. Algae Dasyclaies, Yamama Formation, transverse section, Fh-1 at depth (4037.5m). Age: Jurassic.
Fig.8: Gastropoda sp. Yamama Formation, oblique section, Fh-1 at depth (4270.5m). Age: Cambrian – Holocene.

Plate - B -
Fig.1: Korkyrella texana sp. Foraminifera, Yamama Formation, axial section, Fh-2 at depth (4062.80m). Age: Early Cretaceous.
Fig.2: Nezzazata simplex sp. Foraminifera (Omara, 1956), Yamama Formation, oblique axial section, Fh-1 at depth (4177m). Age: Early Cretaceous.
Fig.3: Textulirina sp. Foraminifera, Yamama Formation, axial section, Fh-2 at depth (4126.7 m). Age: Early Cretaceous.
Fig.4: Praechrysalidina infracretacea sp. Foraminifera (Luperto Sinni,1979 ), Yamama Formation, transversal section, Fh-2 at depth (4278.3m). Age: Valanginian-Aptian.
Fig.5: Cylindroporella sp. Algae Dasyclaies (Elliott,1957), Yamama Formation, oblique section, Fh-2 at depth (4062.80m). Age: Early Cretaceous (Berriasian).
Fig.6: Bakalovaella sp. Algae Dasyclaies (Elliott,1957 ), Yamama Formation, oblique section, Fh-2 at depth (4101.90m). Age: Early Cretaceous.
Fig.7: Pelecepod, Yamama Formation, axial section, Fh-2 at depth (4098.80m). Age: Paleozoic – Recent.
Fig.8: Coral fragment, Yamama Formation, longitudinal section, Fh-2 at depth (4095.90m). Age: Paleozoic – Recent.

Plate - c –
Fig.1: Trocholina Sagittaria sp. Foraminifera, Yamama Formation, axial section, Fh-3 at depth (4139m). Age: Valanginian.
Fig.2: Numnofalollota apula sp. Foraminifera (Luperto sinni, 1968), Yamama Formation, oblique section, Fh-3 at depth (4146.75m). Age: Early Aptian.
Fig.3: Nautiloculina sp. Yamama Formation, axial section, Fh-3 at depth (4040.90m), Age: Valanginian.
Fig.4: Arabicodium sp. Algae Silphonales (Elliott,1957 ), Yamama Formation, axial section, Fh-3 at depth (4063.40m). Age: Early Cretaceous.
Fig.5: Salpingoporella cf. circassa sp. Algae Dasyclaies (Deecke), Yamama Formation, tangential section, Fh-3 at depth (4146.75m). Age: Valanginian.
Fig.6: Terquemella sp. Algae Dasyclaies (D'archiac),Yamama Formation, tangential section, Fh-3 at depth (4068m). Age: Early Cretaceous.
Fig.7: Noemeris sp. Algae Dasyclaies (D'archiac),Yamama Formation, tangential section, Fh-3 at depth (4146.75m). Age: Cretaceous to Recent.
Fig.8: Rudest, Yamama Formation, axial section, Fh-3 at depth (4048.80m), Age: Paleozoic – Recent.
Conclusions
This study involves the biostratigraphy of three wells belonging to Yamama Formation, Faihaa oilfield, Southern Iraq.

Thirty three species of benthic Foraminifera and ten species of calcareous green algae were distinguished, which are:
Charentia cuvillieri sp., Pseudocyclammina Lituus sp., Nezzazata gyra sp., Trocholina Sagittaria sp., Rectocylammina sp., Nautiloculina cf broenimini sp., Trocholina sp., Palorbitolina Lenticularis sp., Maynicina sp., Nezzazata concava sp., Rercorcella halleinensis sp., Nezzazata Conica sp., Nautiloculina sp., Nezzazata simplex sp., Nezzazata perforese sp., Sipiroloquina sp., Quinguelocina sp., Ovalveolina sp., Choffatella sp., Textullirina sp., Pyrgo sp., Alveolinida sp., Cuneolina sp., Praeaveolina sp., Cuneolinapavonia sp., Triluculina sp., Orbitolina sp., Glomospirea sp., Korkyrella texana sp., Tintinnopsis carpathica sp., Praechrysalidina infracretacea sp., Nummofallotia apula sp. and Nummuloculina sp., calcareous green algae: Salpingoporella sp., Biokoviiella robusta sp., Gymnocodiceacean sp., Halimeda sp., Arabicodium sp., Cylindroporella sp., Bakalovaella Bakalova sp., Terquemella sp., Salpingoporella cf. circassa sp., and Noemeris sp., with other fossils like Pelecypods, Gastropods, Rudest, Coral. and Pryzoan.

Six biozones were distinguished in Yamama Formation, depending on the index fossil species These zones are:

1. Charentia cuvillieri sp. Range Zone of Early Cretaceous (Berriasian).
2. Pseudochrysalidina infracretacea sp. Range Zone of Early Cretaceous (Berriasian).
3. Pseudocyclammina Lituus sp. Range Zone of Early Cretaceous (Valanginian).
4. Nezzazata Perforate sp.-Choffatella sp. Assemblage Zone of Early Cretaceous (Berriasian-Valanginian).
5. Desycladales Green Algae-Cylindroporella sp. Range Zone of Early Cretaceous (Berriasian).
6. Desycladales Green Algae-Salpingoporella cf. circassa sp. Range Zone of Early Cretaceous (Valanginian).

The age of the Yamama Formation was determined as the Berriasian- Valanginian, depending on the identified biozones of benthic Foraminifera and calcareous green algae.

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