Biozonation (benthic foraminifera) of Mishrif Formation at Majnoon and Zubair oil fields, southern Iraq

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Abstract: The Mishrif Formation represents a carbonate succession that deposited in major parts of the Arabian Plate during the Cenomanian stage. The formation is rich in fossils including foraminifera, rudists, and algae. This study includes determination of the biozones and biostratigraphic limits of three boreholes sections of Mishrif Formation (Cenomanian) from Majnoon and Zubair oil fields in southern Iraq within the Mesopotamian Basin. A new biostratigraphic scheme is introduced based on the study of benthic foraminifera that occur in the complete succession of Mishrif Formation. Depending on the vertical distribution of benthic foraminifera, four biozones in the studied sections have been established, they include: 1 - Miliolids Abundance Biozone that is characterized by the first appearance of miliolids to first appearance of Nezzazata conica, and include rudist, gastropoda, pelecypoda and algae, 2 - Nezzazata simplex – Nezzazata conica Concurrent Biozone (Middle Cenomanian) is distinguished by the first appearance of Nezzazata simplex, Nezzazata conica, Praealveolina cretacea, and Pseudorhapydionia laurinensis. Other associated benthic foraminifera include Nezzazata concave, Praealveolina tenuis, Chrysalidina sp., Cuneolina pavonia, Multispirina iranica, Biconcava bentori, Qataria dukhani, Dicyclina schlumbergari, Tabrina beingstani, Cisalveolina sp., and Carinocous iraqiensis. 3 - Pseudorhapydionia laurinensis – Praealveolina cretacea Concurrent Biozone (Early Late Cenomanian) is identified by the last occurrence of Nezzazata simplex with the first occurrence of Pseudorhapydionia laurinensis, and Praealveolina cretacea, and the last occurrence of both taxa. This biozone also shows the occurrence of Cisalveolina fallax, Tabarian bingstani, Carinocous iraqiensis, Spiroloculina sp., Chrysalidina gradata, Biconcava bentori, Qataria dukhani, Pseudotextularella sp., and Dicyclina schlumbergari. 4 - Pseuodotulinella reicheli-Chrysalidina gradata Concurrent Biozone (Latest Cenomanian) is marked by the first and last occurrence of Pseuodotulinella reicheli and Chrysalidina gradate. Other diagnosed foraminifera include: Spiroloculina sp., Rotalia sp., Pseudorhapydionia sp., Quinqueloculina sp., Nummulicina heimi, and Discorbis sp. Based on the stratigraphic ranges of the available fossils of the studied sections, the age of Mishrif Formation is estimated to be of Middle-latest Cenomanian.

Keywords: Iraq, Mishrif Formation, Cenomanian, foraminifera

INTRODUCTION

The Cenomanian-Early Turonian Mishrif Formation is one of the most significant carbonate reservoirs in Iraq and the Middle East (Al-Sharhan, 1995; Aqrawi et al., 2010; Mahdi & Aqrawi, 2014).


Based on the distribution of benthonic and planktonic foraminifera, Brun et al. (1975) established a biostratigraphic zonation scheme in Buzurgan, Faqa, and Abu Ghurab oilfields, which are located in the north of Majnoon oil field.

The biostratigraphic scheme includes three major zones as follow (from bottom to top):

1 - Hedbergella gr. washtensis zone: The upper limit of this zone represents the last appearance of Hedbergella gr. washtensis. The zone occupies the bottom of Mishrif Formation. Therefore, the lower limit of this zone extends towards Rumaila Formation. Other associated fauna include Oligostenigna, Hedbergella sp. and Asterohedbergella asterospinosa. According to Brun et al. (1975), a Middle Cenomanian age is assigned to this zone.

2 - Praealveolina gr. cretacea zone: This zone represents a large and important biostratigraphic unit in the Mishrif Formation. The lower limit falls within the first occurrence of Praealveolina gr. cretacea. It coincides with the lower boundary of the Mishrif Formation where the Hedbergella gr. washtensis is absent in some wells. This large zone is divided into two subzones. The lower one is characterized by the occurrence of Ovalveolina sp. and Neoiraqia convexa. The upper subzone is mainly...
made up of the following assemblages: *Praealveolina gr. cretacea*, *Pseudotextulariella* IRK sp2, *Cyclodemia iranica*, *Pseudocyclammina rugosa*, *Discorbis* IRK sp2. Brun et al. (1975) assigned a Middle-Late Cenomanian age to this zone.

3 - *Dicyclina schlumbergeri-Cisalveolina* spp. zone: It is characterized by the association of *Dicyclina schlumbergeri* and *Cisalveolina* spp. A Late Cenomanian-Early Turonian age is considered for this zone by Brun et al. (1975).

The lithology of Mishrif Formation at the studied sections is characterized by gray-brown limestone with pelecypod and gastropod shells, with high occurrence of foraminiferal limestone and rudist debris. The formation is variably dolomitized.

The contacts of the formation are conformable both with the underlying Rumaila Formation and overlying Khasib Formation.

The formation is equivalent to the upper part of the Magwa Formation (the Mishrif Fm.) in Kuwait, to the Sarvak Formation in the Zagros Iran, to the lower part of Judea Formation in the central and northeast Syria, and to Mardin Formation in southeast Turkey (Jassim & Goff, 2006).

**STUDY AREA**

The study area is located in the south of Iraq, and it includes two oil fields, Majnoon and Zubair (Figure 1), the Majnoon oil field is located about 60 km northwest of Basra city and the Zubair oil field is located about 20 km south of Basra city.

**METHODS AND MATERIALS**

In order to determine the biostratigraphy of Cenomanian-Turonian strata in southern Iraq, three borehole sections of Mishrif Formation were selected, which are named: Majnoon-2 (MJ-2), Zubair-43 (ZB-43) and 47 (ZB-47) (Figure 1).

Different cores were sampled for micropaleontology and petrographic study. A total of 90 samples were collected from the three sections and 150 thin sections were prepared from the core samples in the laboratory. Microscopic study was provided in Baghdad University, College of Science, Department of Geology. The biozones of Mishrif Formation is determined according to the vertical distribution of benthic foraminifera.

Ultimately, the biozones distribution was compared to previous works and other biostratigraphic studies of Tethyan realm (e.g., Al-Khersan, 1975; Bernaus & Masse, 2006; Al-Dulaimy & Al-Sheikhly, 2013).

**GEOLOGICAL SETTING**

Majnoon and Zubair oilfields are located in the southern Mesopotamian Basin, where more than 3000 m of Cretaceous sediments were deposited under the influence of tectonic, eustatic and climatic controls (Sadooni & Aqrawi, 2000). The Mesopotamian basin is subdivided into tectonic subzones, which are characterized by structural highs and lows with different trends. The structures are formed by the deformation of the northeastern Tethyan margin of the Arabian Plate during Cenomanian–Early Turonian (Jassim & Goff, 2006).

During the Cretaceous, the basin was part of a widespread carbonate platform located on the NE passive margin of the Arabian Plate (Murris, 1980). This margin was characterized by shallow, warm waters of Neo-Tethys (Sharland et al., 2001). During the Middle Cenomanian-Turonian period sea-level changes together with regional tectonic deformation of the Arabian Platform controlled the availability of accommodation space and therefore the depositional profile during development of Late Cretaceous sequence. These factors planned the maximum flooding surfaces and sequence boundaries which have been identified (Sharland et al., 2001; Farzadi, 2006).

The sediments were deposited on platforms within an inner shelf basin on the passive margin of the Arabian Plate (Ziegler, 2001). High organic accumulations with rich carbonate deposits controlling the growth and development of many positive elements and structures such as Mishrif, Ahmadi, and Rumaila formations were built-up as result of these changes (Van Buchem et al., 2002).

The shallow depositional conditions are dominant in Majnoon oil field, where thick lagoonal successions were deposited indicating higher accommodation space in the eastern part of the Mesopotamian Basin. At Zubair oil field, the deposition of Mishrif Formation was affected by tectonic activity as demonstrated by growth of rudist biostromes and shoal facies along crestal parts of Zubair structure, in addition to the presence of forced regressive succession at the uppermost part of Mishrif Formation (Mahdi et al., 2013; Mahdi & Aqrawi, 2014).

The carbonate production in the Mesopotamian basin resulted in thick succession of pelagic basinal facies to reefal
and foraminiferal-rich shelf facies. The Mishrif Formation (Middle Cenomanian-Early Turonian) has carbonate sequence sediments rich in rudists, algal, coral reef, and benthonic foraminifera formed above structure within the Mesopotamian basin (Ziegler, 2001). The type section of Mishrif Formation occurs in well Zubair-3 (at Zubair oil field), which was selected by Rabanit (1952). In this well, the Mishrif Formation was subdivided into the following lithologic units (from bottom to top):

1. **Unit G**: Algal (Permocalculus) limestone with miliolids, *Begia* sp., *Cisalveolina* sp. foraminifera.
2. **Unit F**: Limestone, porous, oil stained, leached out fossils, contain calcite veins, miliolids, *Begia* sp., *Cisalveolina* sp., *Dicyclina* sp., *Taberina* sp., *Praealveolina* sp.
3. **Unit E**: Marl, locally chalky.
4. **Unit D** (lower): Limestone, porous, partly very shelly and foraminiferal, contains bands of rudists; foraminifera include *Cisalveolina* sp., *Begia* sp., *Dicyclina* sp., *Dictyoconus* sp., and miliolids.
5. **Unit D** (upper): Limestone, dense, detrital, with gastropods, rotalids, sponge spicules, partly pseudo-oolitic, rare chalky streaks and green shale interbeds.
6. **Unit C**: Marl, algal (Permocalculus), with green-black shale.
7. **Unit B**: Limestone, fine grained, fractured or stylolized, marly, partly pseudo-oolitic, microbrecciated with streaks of marl at base.
8. **Uppermost unit**: Limestone, fine grained, limonitic, freshwater with charophytes, marl; interbedded with black shale.

The depositional environments for the Mishrif have wide range starting with fresh water in the upper Mishrif to the deep marine environment at the lower Mishrif (Aqrawi et al., 2010). The carbonate facies of the formation reflect various depositional environments including deep marine, shallow open marine, rudist biostrome, shoal, back-shoal, lagoon, and tidal flat (Mahdi et al., 2013; Mahdi & Aqrawi, 2014).

The benthic foraminifera in lagoonal facies are diverse, including miliolids, alveolinids, textularids, and Nezzazata. The abundance of these fauna and their association with mud-supported facies indicate low-energy conditions below wave base in the subtidal zone (Mahdi et al., 2013).

The rudist facies passes into deeper water open-marine facies, near Luhaïs, Ratawi and Afaq (Al-Khersan, 1975) and also from Majnoon and Buzurgan fields. Similar facies are present all around the northern end of the Gulf (Ziegler, 2001). The beginning of sea withdrawal is represented by an extensive evaporate pan, Kifl Formation, in response to the epirogenic movements which acted through the Cenomanian-Turonian period leading to a subaerial unconformity (Melhi & Diaih, 1984). This lead to decreasing the rate of subsidence and developed the maximum sea level fall.

During the deposition of Mishrif Formation, the palaeogeography of the Mesopotamian Basin was characterized by two high energy margins, where rudist biostromes were developed (Aqrawi et al., 2010). These margins rimmed an intrashelf basin, which was dominated by mud-rich facies, and has been referred to as the Najaf Basin (Aqrawi et al., 2010).

**BIOSTRATIGRAPHY**

The vertical distribution of identified benthonic foraminifera of the stratigraphic study of the Mishrif Formation supports four biozones for the studied sections. Detailed biostratigraphical study of these biozones is shown as follow:

**Biozone no. 1 (miliolids abundance biozone)**

This biozone is investigated from the base of the Mishrif Formation which ranged 5-11 meters in thickness (Figures 2, 3 and 4). It is characterized by high occurrence of miliolids wackestone-packestone with fragments of rudist, gastropoda, pelecypoda and algal remains. Miliolids biozone is marked by the first appearance of miliolids to first appearance of *Nezzazata conica*, *N. concava* (Plate 3, A) and other benthic foraminifera.

**Biozone no. 2 (Nezzazata simplex – Nezzazata conica concurrent biozone)**

The lithology aspect of this biozone is comprised of light to dark gray thick to medium-bedded limestone. It
is characterized by rudist bioclast to bioclast packstone-grainstone with algal, Mollusca fragments. The thickness of this biozone is illustrated in Figures 2, 3 and 4, which extended over the miliolids biozone.

The biozone *Nezzazata simplex* – *Nezzazata conica* is recognizable in the middle portion of these sections and is marked by the first appearance of *Nezzazata simplex* (Plate 1, F) and Plate 2, D) and *Nezzazata conica* and the first appearance of *Praevalveolina cretacea* (Plate 2, E&F) and *Pseudorhapydionia laurinensis* (Plate 3, H).

Common foraminifera of this biozone consist of *Nezzazata concave* (Plate 3, A), *Preneroplise* sp., *Praevalveolina tenuis*, *Chrysalidina sp.*, *Cuneolina pavonia*, *Nezzazata* sp. (Plate 1, H), *Nezzazzetinella picardi* (Plate 1,G), *Multispirina iranica* (Plate 1,C), *Biconcava bentori*, *Qataria dukhani* (Plate 1, A), *Dicyclina schlumbergari* (Plate 1, D), *Tabrina beingstani*, *Cisalveolina sp.* (Plate 3, E), and *Cisalveolina fallax* in the three sections including recording of *Carinoconus iraqiensis* from well Zb-47.

*Nezzazata simplex* and *Nezzazata conica* have been recorded before from middle Cenomanian sequence of some parts of middle east (Iran, Turkey, Egypt and Jordan) by many researchers (e.g., Husinec et al., 2000; Schulze et al., 2005; Shahin, 2007; Sari et al., 2009; Filkorn & Scott, 2011; Orabi et al., 2012; Ghanem & Kuss, 2013; Afghah & Fadaei, 2014; Orabi & Hamad, 2018). Velić & Vlahovic (1994) documented the above taxa from Croatia.

Filkorn & Scott, 2011; Orabi et al., 2012; Ghanem & Kuss, 2013; Afghah & Fadaei, 2014 and Orabi & Hamad, 2018 documented the *Nezzazata simplex*, *N. conica*, *Cuneolina Cenomanian sequence*. Husinec (2000) reported *Daxia cermana* and *Nezzazata simplex* from Cenomanian succession of southwestern Sinai (Egypt) (Afghah & Fadaei, 2014), and documented range of these taxa from lower to middle Cenomanian.

Tasli et al. (2005) suggested *Biconcava bentori* and *Pseudorhapydionina dubia* as biozone for Middle and Upper Cenomanian strata of south Turkey. Velić (2007) recorded similar biostratigraphic data from Karst Dinaridos south east Europe. Ghanem & Kuss (2013) have documented *Pseudorhipidionia casertana* from Middle Cenomanian *Chrysalidina gradata* partial range zone of Northwest Syria (Orabi & Hamad, 2018).
Orabi & Hamad (2018) determined several benthic taxa were comparable with Middle Cenomanian Psededomia drorimensis range zone of Ogg (2004), among those, Nezzazatinella picardi, Nezzazata simplex, Praealveolina tenuis and Cuneolina pavonia.

Hamaoui (1965; 1966) illustrated the last occurrence of Thomasinella recorded in Middle Cenomanian age from Israel deposit. Weidich & Al-Harithi (1990) recorded the presence of Thomasinella punica in Jordan sediments indicating Middle Cenomanian (Orabi & Hamad, 2018).

Afghah & Fadaei (2014) determined the Nezzazata conica, Chrysalidina Assemblage zone as Middle Cenomanian age in south west Iran. Afghah & Fadaei (2014) confirmed Nezzazata conica - Nezzazata simplex Assemblage Zone Middle Cenomanian in Zagros area from Iran. Aguilara–Franco (2003) documented Nezzazata conica from Cenomanian sequence of southern México. Sari et al. (2009) recorded the Nezzazata conica as Middle to Upper Cenomanian sequence in the southwestern area of Turkey. Various recording of Nezzazata simplex taxon range zone have been documented in the Middle to Late Cenomanian strata of south west Turkey. Berna & Masse (2006) recorded the new species Carinoconus iraqiensis sp. associated with Praealveolina cretacea as indicator for Middle Cenomanian in southern of Iraq.

According to Al-Naqib, 1967; Gaddo, 1971 and Brun et al., 1975 the occurrence of Nezzazata simplex is an indicator for Early Cenomanian – Late Cenomanian deposits at southern Iraq. El-Naggar & Al-Rifaiey (1973) suggested the age of the Mishrif Formation of southern Iraq as Late Cenomanian depending on Praealveolina tenuis and documented the Biconcava bentori as an indicator for Cenomanian – Turonian in southern Iraq. Al-Dulaimy & Al-Sheikhly (2013) determined the age of the Mishrif Formation in southern Iraq as Cenomanian – Early Turonian depending on Nezzazata simplex, Parealveolina tenuis, Biconcava bentori and Cisalveolina fallax.

Likewise, biostratigraphic data on Nezzazata simplex and Nezzazata conica are acceptable proof for the assignment of Middle Cenomanian age of this Zone.

### Biozone no. 3 (Psedorhapydionian laurinsiensis, Praealveolina cretacea concurrent biozone)

This zone is characterized by grey medium bedded of thick bedded rudist limestone with fragments of bivalve, gastropod and ostracod. The thickness of this biozone is illustrated in Figures 2, 3 and 4.

This zone shows the last occurrence of Nezzazata simplex corresponding with first occurrence of Psedorhapydionian.
Plate 1: (A) *Qataria dukhani*, (B) *Pseudotexularella* sp., (C) *Multispirina iranica*, (D) *Dicyclina schlumbergri*, (E) *Nezzazatinella picardi*, (F) *Nezzazata simplex*, (G) *Nezzazatinella picardi*, (H) *Nezzazata* sp.
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localities. From the Late Cenomanian of different localities. From the Late Cenomanian of different Chrysalidina gradata et al., 1990; Velić & Vlahovic, 1994; Husinec 2000; Korbar et al., 2001 and Afghah & Fadaei, 2014 documented the Chrysalidina gradata from the Late Cenomanian of different localities.

Velić (2007) recognized the Chrysalidina gradata from Middle and Upper Cenomanian deposit in Southeastern Europe. In Turkey the Cenomanian – Turonian boundary is recognized by last occurrence of Chrysalidina gradata and Pseudolitouonella recheli (Sari et al., 2004).

Brčić et al. (2017) determined the middle to late Cenomanian age of Milna Formation by the presence of benthic foraminifera that include Broekina (Pastrikella) balcanica Cherchi et al., Chrysalidina gradata D’orbigny, Pseudopydonia dubia, Vitalina radoicicae.

Al-Jumaily (2001) recorded the Chrysalidina gradata and Pseudolitouonella recheli as Upper Cenomanian from southern Iraq. In present study this zone indicates a Late Cenomanian age according to foraminifera constituents.

CONCLUSIONS

Previous studies assigned a Cenomanian-Early Turonian age for Mishrif Formation, while the current study shows that the age of the formation is Middle-late late Cenomanian, which indicates the absence of Turonian succession in the study area as evidenced by the absence of benthic foraminifera and occurrence of planktonic foraminifera in their place that belong to Khasib Formation. This is due to the truncation of Turonian biostratigraphic zones by erosion, and therefore most of Turonian successions are absent in the eastern Arabian Plate region (Harris et al., 1984). During Turonian, the erosion process lasted several million years in the Arabian Plate (Scott, 1990), and it is related to tectonic activity and a global eustatic fall in sea level (Sharland et al., 2001). The effect of these events is recorder in the uppermost part of Mishrif Formation in Majnoon and Zubair oil fields (Mahdi et al., 2013; Mahdi & Aqrawi, 2014).

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AUTHOR CONTRIBUTIONS

SIMA and YKI carried out the identification of foraminifera and biostratigraphic interpretation. Writing original draft, editing, and reviewing were done by FTA.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare that are relevant to the content of this article.

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