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Biostratigraphy of the Hartha Formation from Selected Oil Wells, Central Part of Iraq

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Abstract

The current study addressed the Hartha Formation, which is considered one of the most important formations that was deposited during the Upper Cretaceous in Iraq. The Hartha Formation mainly consists of limestone. The study was conducted in three wells (X, Y, and Z) selected from the central part of Iraq. More than 750 thin sections were studied under a polarized microscope for the purpose of determining the age of the Hartha Formation, depending on the Biozones of benthic foraminifera. Twenty-three genera and species of benthic foraminifera were distinguished through petrographic examination. Other fossils, such as Algae, Rudist, corals, Ostracoda, Inoceramus bivalve, Brayozoa, and Echinoderms, were also recognized. Based on benthonic foraminifera, one biozone was identified in the Hartha Formation: Orbitoides tissoti-Orbitoides medius-Orbitoides apiculata Assemblage Zone (Late Campanian-Early Maastrichtian). The age of the Hartha Formation was determined as Late Campanian-Early Maastrichtian, depending on the biozone of benthic foraminifera.

Keywords: Hartha; Biostratigraphy; Orbitoides; Campanian; Maastrichtian

1. Introduction

The Hartha Formation, which was deposited during the Upper Cretaceous (Late Campanian–Maastrichtian), is regarded as one of the most significant carbonate formations in Iraq due to its reservoir characteristics and ability to produce oil in many regions of central and southern Iraq (Aqrawi et al., 2010). The Hartha Formation was first identified in the Zubair Oil Field from a well (Zubair-3) by Rabanit (1952) (in Bellen et al., 1959). The Hartha Formation, with little change in facies, extends to Kuwait (Owen and Nasr, 1958 in Jassim and Goff, 2006). Due to the complexity of the sedimentary basin and the movements that affected it, this formation exhibits the most significant variation from place to place (Al-Zaidy et al., 2013).

The formation is mainly composed of glauconitic limestone, organic detrital materials, and strata of green and gray shale. Locally, the limestone is strongly dolomitized (Jassim and Goff,2006). The Hartha Formation was primarily deposited in a ramp carbonate platform environment during the Santonian Event, a Late Campanian tectonic event.

The Late Campanian-Maastrichtian cycle began with a significant transgression that affected nearly the entire country and was recognized as a notable cycle (Buday, 1980). It led to the deposition of the Hartha Formation's neritic limestone sediments. This cycle ends with uplift and regression caused by the Laramide Orogeny near the Cretaceous-Tertiary boundary (Buday,1980). The Late Campanian and Maastrichtian represent the peak of the obduction and closing of the Southern Neo-Tethys. This led to

major transgression that affected the whole of Iraq (Jassim and Goff, 2006). The formation's thickness varies due to its vertical and lateral transitions into the marly limestone of the Shiranish Formation. Furthermore, the Hartha Formation is intertonguing with the Shiranish Formation or making separate tongues within it (Bellen et al., 1959).

In the southern part of Iraq, the Hartha Formation has a thickness of around 200–250 m, and in the northern part of Iraq, it reaches a thickness of up to 350 m (Buday, 1980). The equivalents of the Hartha Formation are extensively distributed in Kuwait, Syria, Saudi Arabia, and Turkey based on the facies and age (Sharland et al., 2001). In Iraq, the Hartha Formation is equivalent to the Tanjero, Shiranish, Digma, and Aqra-Bekhme formations (Fig. 1). In Saudi Arabia, the Hartha Formation is partially correlated with the Aruma Formation (Jassim and Goff, 2006). In some areas of the eastern part of Syria, the Hartha Formation and Soukhne Formation are correlated (Jassim and Goff, 2006). The Karabogas Limestone Formation in the southeast of Turkey has very similar facies to the Hartha Formation (Buday, 1980). In Kuwaiti, in the northwest, the Hartha Formation is recognized. The Hartha Formation is most probably correlated with the Bahrah Formation towards the southeast (Owen and Nasr, 1958). The Hartha Formation has different boundaries. The upper boundary is conformable with the Shiranish Formation, and the lower boundary with the Sadi Formation is unconformable and is often marked by conglomeritic basal beds (Buday, 1980; Jassim and Goff, 2006).

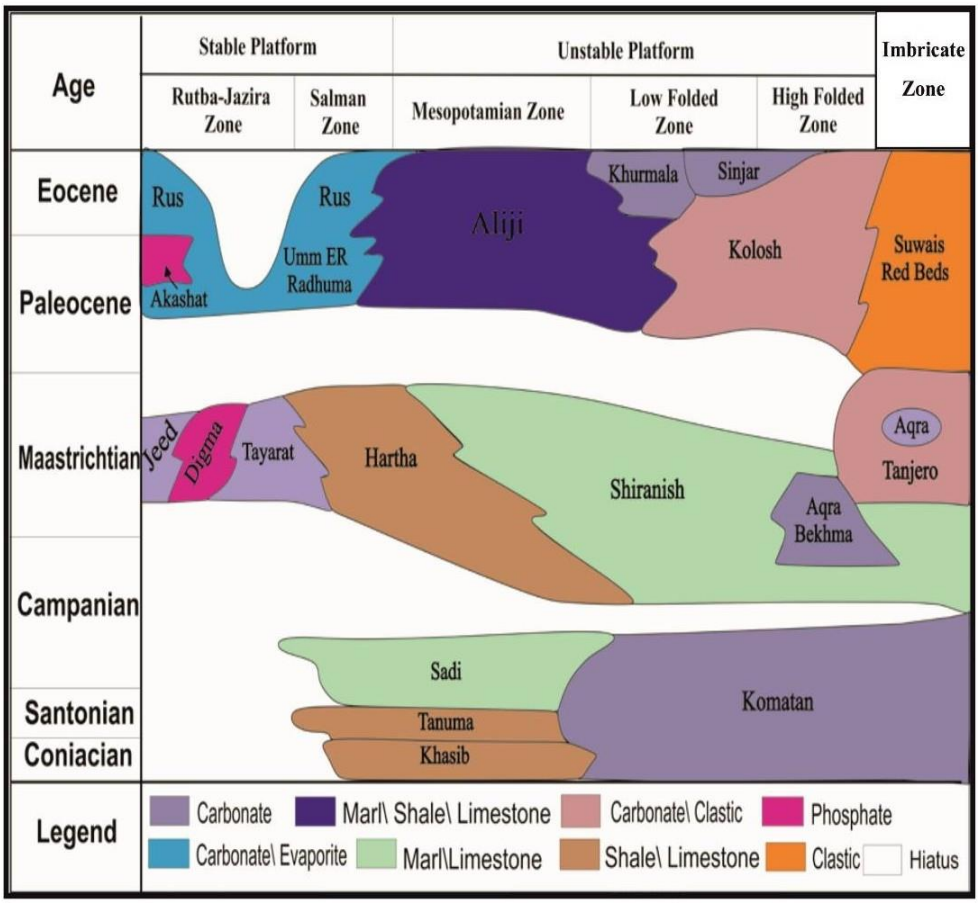


Fig. 1. Lithostratigraphic correlation of the Upper Cretaceous succession in Iraq (after Bellen et al., 1959; Jassim and Goff, 2006)

Homadi and Al-Zaidy (2020) studied Microfacies of the Hartha Formation and showed that the Hartha Formation includes six major sedimentary microfacies. Ismail et al. (2022) studied the depositional environment of the Hartha Formation and recognized three major Sedimentary

paleoenvironments. The diagenesis processes of the Hartha Formation was studied and showed that the formation is affected by several diagenetic processes.

Al-Mutwali (1992) studied foraminifera, stratigraphy, and sedimentology of the Upper Cretaceous-Lower Tertiary succession and showed that the Hartha Formation is deposited at Late Campanian-Early Maestrichtian. Al-Temimi (2010) and Mousa and Shakir (2023) studied the biostratigraphy of the Hartha Formation and determined the age of the formation as Late Campanian-Early Maastrichtian, depending on the documented biozones.

The present study aims to determine the biozones, depending on benthic foraminifera, and to determine the age of the Hartha Formation.

2. Materials and Methods

In the present study, three subsurface sections were chosen from the wells (X, Y, and Z) of an oil field in the central part of Iraq (Fig. 2). The thickness of the Hartha Formation within the study area varies across the three studied oil wells: 460 m at well X, 443 m at well Y, and 429 m at well Z. A total of more than 750 thin sections derived from both core and cutting samples were meticulously examined under a polarized light microscope to assess microfacies characteristics and diagenetic features. The thin sections were prepared by the laboratories of the Oil Exploration Company. Sampling intervals ranged approximately between 0.5 to 2 m, depending on lithological variation and core recovery. Each thin section was examined under a polarized light microscope to identify fossil content, which served as the basis for biostratigraphic analysis and age estimation of the Hartha Formation.

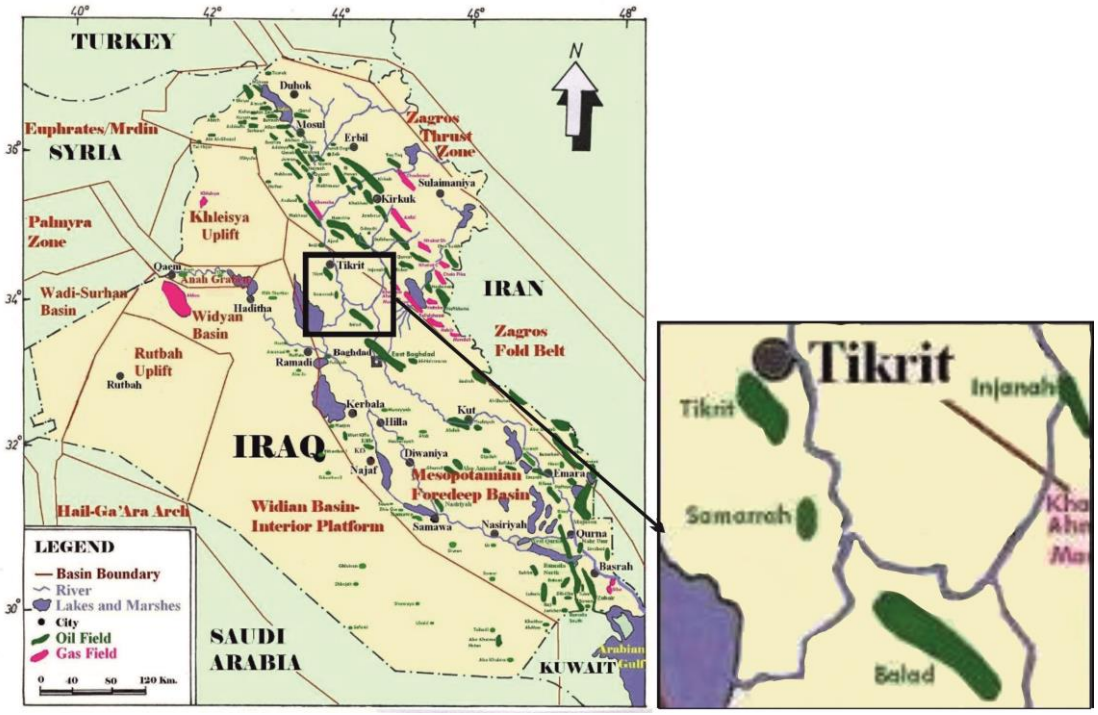


Fig. 2. Location map of the study area (Al-Ameri et al., 2011)

3. Results and Discussion

3.1. Biostratigraphy

Biostratigraphy is the study of the occurrence of fossils within rocks and the classification of rocks into biozones based on the distribution of fossils contained within them (Murphy and Salvador, 1999). Index fossils are the most advantageous for making accurate stratigraphic correlations for age and time,

which are characterized as having (1) wide geographical dispersion, and (2) relatively short geological time (Keller et al., 2007). Consequently, their occurrence within rocks provides an important way to match rocks that have the same age. Consequently, their occurrence within rocks provides an important means to match rocks of the same age. The microfossils that were recognized in the Hartha Formation are shown in Figs. 3, 4 and 5. The identified microfossils are: *Orbitoides* sp. (Fig 6-a), *Orbitoides tissoti* Schlumberger (Fig 6-b), *Orbitoides medius* d'Archiac (Fig 6-c), *Orbitoides apiculata* Schlumberger (Fig 6-d), *Omphalocyclus* sp. (Fig 6-e), *Omphalocyclus macroporus* (Lamarck) (Fig 6-f), *Siderolites calcitrapoides* Lamarck (Fig 6-g), *Pseudosiderolites* Smout (Fig 6-h), *Prasiderolites* Douvillei (Fig 6-i), *Arnaudiella* sp. (Fig 7-a), *Monolepidorbis* sp. (Fig 7-b), *Rotalia skourensis* Pfender (Fig 7-c), *Rotalia trochidiformis* Lamarck (Fig 7-d), *Rotalia* sp. (Fig 7-e), *Nezzazata* sp. (Fig 7-f), *Lenticulina* sp. (Fig 7-g), *Sulcoperculina vermunti* Thiadens (Fig 7-h), *Sulcoperculina globousa* de Cizanacourt (Fig 7-i), *Textularia* sp. (Fig 8-a), *Rotorbinella campaniola* (Fig 8-b), *Pseudomphalocyclus blumenthali* Meric (Fig 8-c), *Pseudolituonella reicheli* (Fig 8-d), *Triloculina* sp. (Fig 8-e), and association with other fossils: Echinoid spine (Fig 8-f), *Dasycladacean* algae (Fig 8-g), Coral (Fig 8-h), Algae (Fig 8-i), Echinoid Plate (Fig 9-a), *Inoceramus* bivalve (Fig 9-b), Bryozoan (Fig 9-c), Rudist (Fig 9-d), Ostracods (Fig 9-e), and Pelecypoda (Fig 9-f).

3.2. Biozone of the Hartha Formation

Based on the occurrence of benthic foraminifera and their stratigraphic distribution (Figs. 3, 4, and 5), one biozone has been identified in this study. The identified biozone is:-

3.2.1. Orbitoides tissoti-Orbitoides medius Orbitoides apiculata-Assemblage zone

The determination of this zone is by the range of extension of three species of *orbitoids*. This zone occurs in all parts of the Hartha Formation, and the thickness of the zone is around 445 m at well X, 431 m at well Y, and 405 m at well Z. The identified benthic foraminifera assemblage and other fossils within the zone are*: Orbitoides* sp., *Omphalocyclus macroporus (*Lamarck), *Omphalocyclus* sp., *Monolepidorbis* sp., *Siderolites calcitrapoides* Lamarck,*Pseudosiderolites* Smout, *Rotalia* sp., *Nezzazata* sp., *Rotalia trochidiformis* Lamarck, *Prasiderolites* Douville, *Pseudolituonella* reicheli, *Arnaudiella* sp., *Triloculina* sp., *Lenticulina* sp., *Textularia* sp., *Sulcoperculina vermunti* Thiadensm, *Rotorbinella campaniola*, *Pseudomphalocyclus blumenthali* Meric,*Rotalia skourensis* Pfender, *Sulcoperculina globousa* de Cizanacourt, *Dasycladacean* algae, algae, echinoid spine, echinoid plates, pelecypoda shell fragments, coral, ostracods, bryozoan, rudist, *inoceramus* bivalve.

The Species *Orbitoides tissoti* indicates a Campanian age (Afghah, 2010) in southwest Iran and in west Iran (Meriç and Çoruh,1991). Van Gorsel (1975); Van Hinte (1976); Nemann (1987); Salaj and Narin (1987) denoted *Orbitoides medius* index fossil of Late Campanian age. In Oman, Kayğılı et al. (2021) recorded *Orbitoides medius* species from the Late Campanian in the Qahlah Formation and from the Maastrichtian and the Simsima Formation. Abdelghany (2006) recorded this species from the Early Maastrichtian in the Qahlah Formation. In the southwest of Iran, Afghah (2010) noted that the species *Orbitoides medius* is present in both Campanian and Maastrichtian ages in the Tarbur Formation. In the eastern part of Greece, Zambetakis-Lekkas and Kemeridou (2004 and 2006) mentioned that *Orbitoides medius* belongs to the Maastrichtian succession.

The *Orbitoides medius* species was reported from the early Late Campanian age (Özcan et al., 2019). In Iraq, Al-Dulaimi (2011) documented that the *Orbitoides medius* specie refer to the Maastrichtian age. Görmüş et al. (2017) recorded the species *Orbitoides medius*, *Omphalocyclus macroporus*, and *Orbitoides apiculatus* from the Maastrichtian age, in the Sulaimaniyah area in the northern part of Iraq. The *Orbitoides apiculatus* was documented to belong to the Maastrichtian age in Iraq (Lawa, 1983; Al-Kubaysi, 2006; and Al-Dulaimi, 2011).

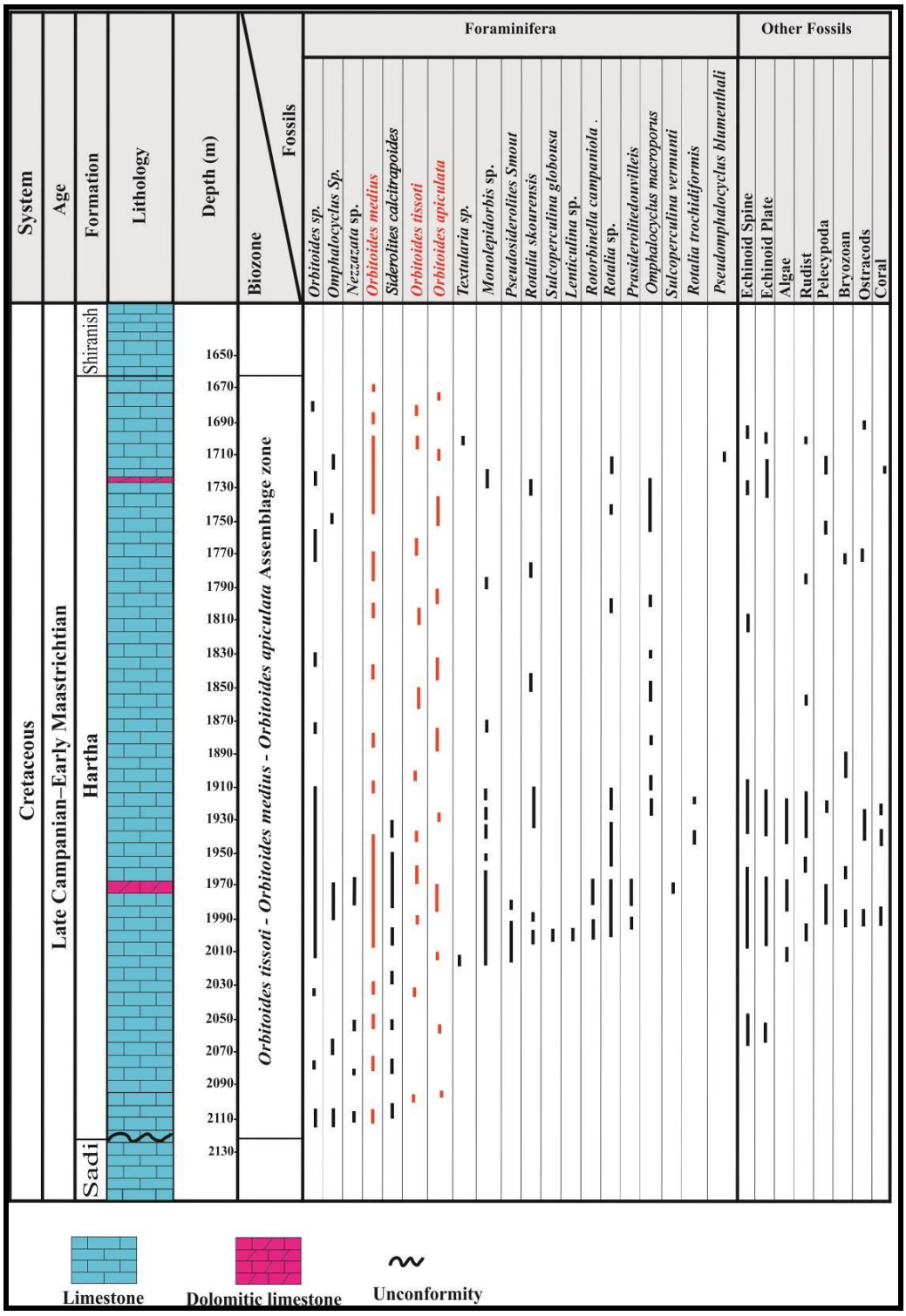


Fig. 3. Biostratigraphic section shows biozones and fossil distribution of the Hartha Formation at oil well X

In the west of Iraq, Al-Mutwali (1992) recorded *Orbitoides medius - Orbitoides apiculate* zone from the Early Maastrichtian age and *Orbitoides tissoti- Orbitoides medius* from the Late Campanian . Al-Temimi (2010) reported *Orbitoides tissoti* rang zone from the Late Campanian age. Mousa and Shakir (2023) defined the *Orbitoides medius, Orbitoides tissoti, Orbitoides gensacicus, Orbitoides apiculatus, Omphalocyclus macroporus* assemblage zone for a Late Campanian-Early Maastrichtian age in the south of Iraq .

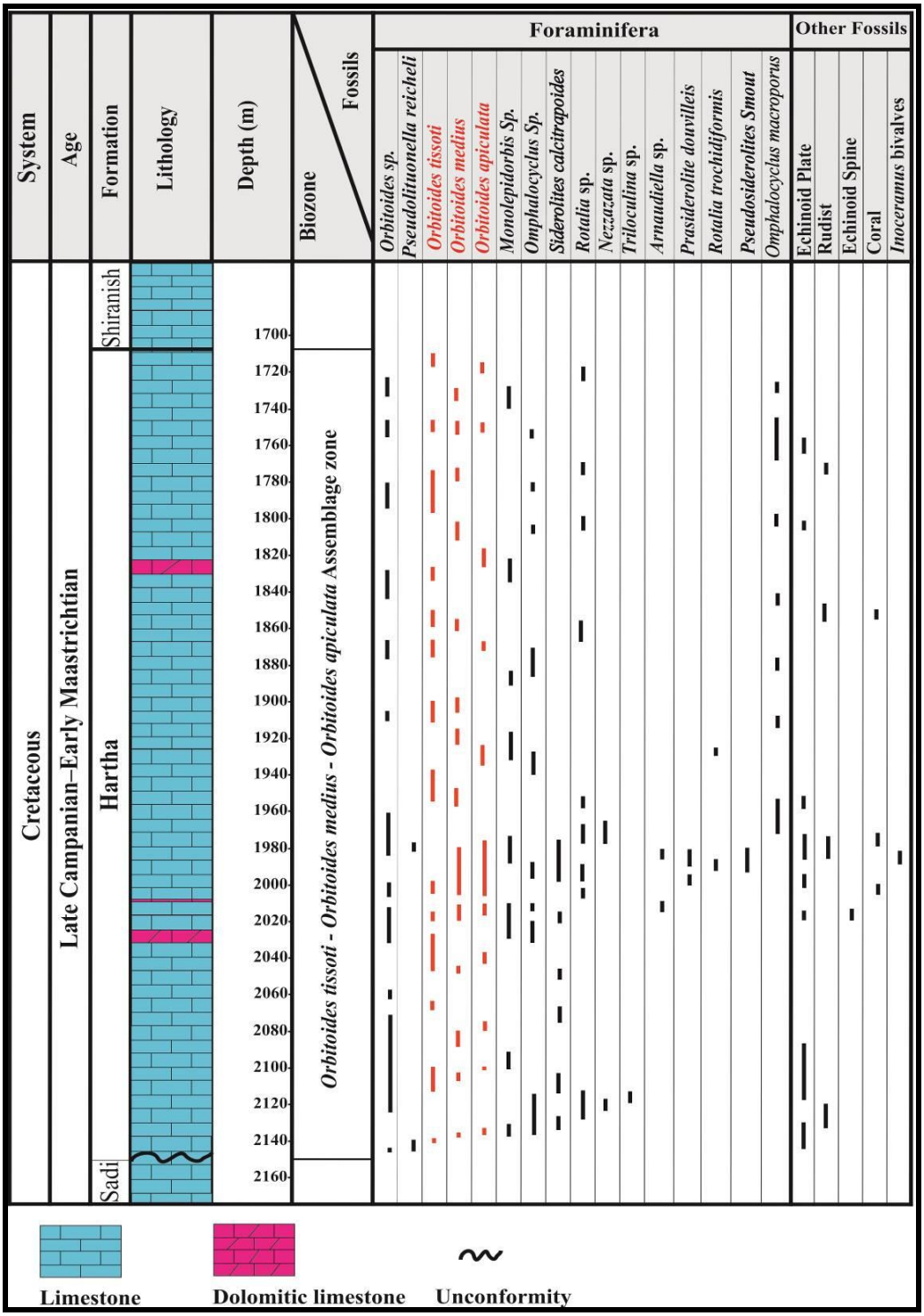


Fig. 4. Biostratigraphic section shows biozones and fossil distribution of the Hartha Formation at oil well Y

According to the stratigraphic position and paleontological data, the age of this range zone is determined as the Late Campanian-Early Maastrichtian**.** This biozone is compared with its similar biozone in other countries (Table 1).

The lower contact of the Hartha Formation begins with the first appearance of *Orbitoides* index fossil, and the upper contact with the first appearance of Planktonic foraminifera (Fig. 9g), which indicates the Shiranish Formation. The lower and upper contacts of this formation give evidence that the studied formation is the Hartha Formation.

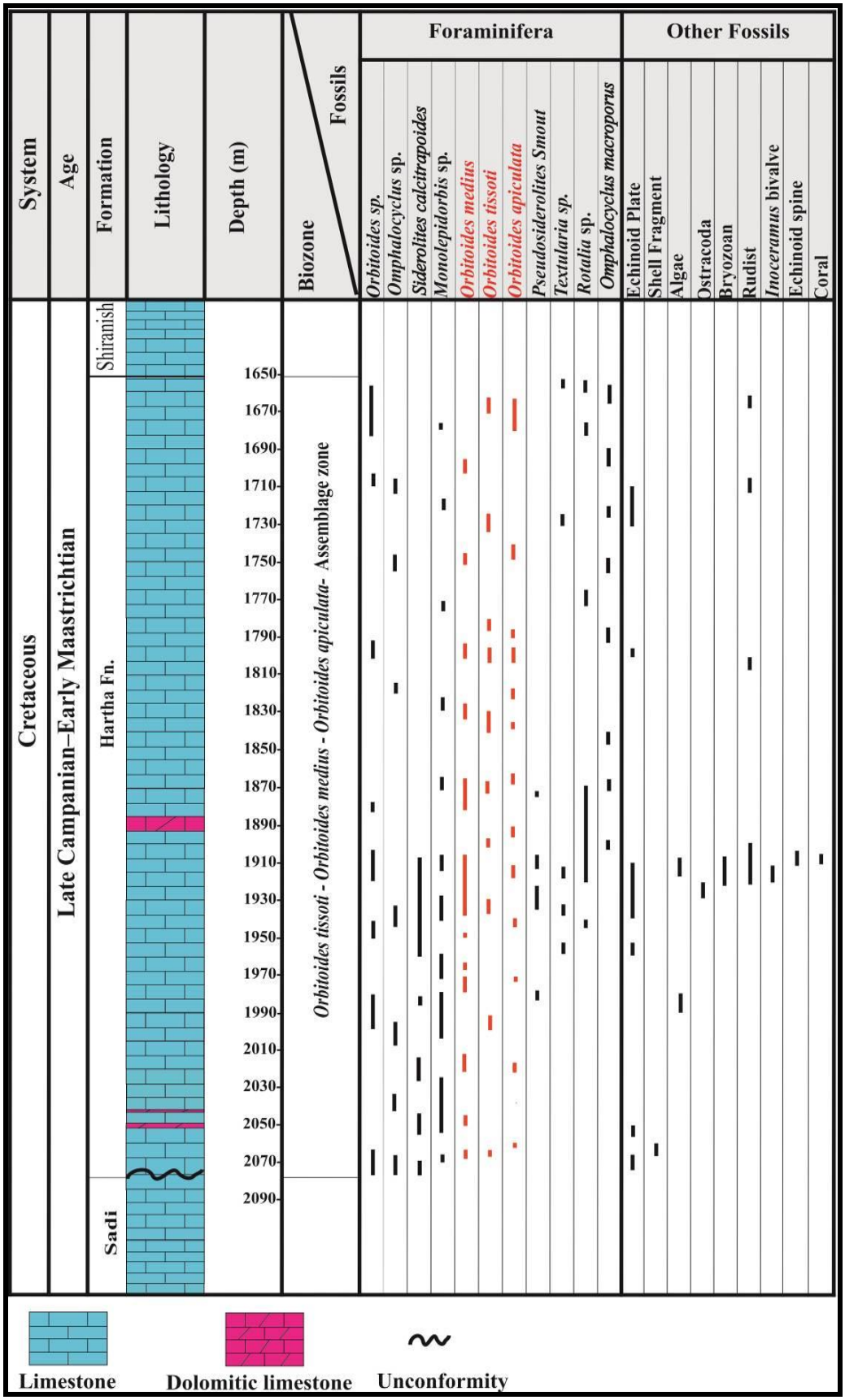


Fig. 5. Biostratigraphic section shows biozones and fossil distribution of the Hartha Formation at oil well Z

Table. 1. A comparison between the biozone, which was recorded in this study, with similar biozones in Iraq and other countries.

Stage	Late Campanian	Early Maastrichtian	Middle Maastrichtian	Late Masstrichtian
Van Gorsel (1978)	*Orbitoides tissoti*	*Orbitoides medius*		*Orbitoides apiculate*
Al -Mutwali (1992)	*Orbitoides tissoti- Orbitoides medius*	*Orbitoides medius - Orbitoides apiculate* Zone	-----	-----
Zambetaks and Kemeridou (2006)	------	------	*Orbitoides medius*	*Orbitoides apiculate* Zone
Al-Temimi (2010)	*Orbitoides tissoti* Zone		-----	-----
Afghah (2010)	-----	*Orbitoides apiculate* Zone		
Mousa and Shakir (2023)	*Orbitoides medius* Zone	*Orbitoides medius- Orbitoides tissoti - Orbitoides gensacicus -Orbitoides apiculatus - Omphalocyclus macroporus* Zone	-----	-----
The present Study	*Orbitoides tissoti - Orbitoides medius - Orbitoides apiculata* Zone		-----	

In Iraq, Bellen et al. (1959), Al-Temimi (2010), and Mousa and Shakir (2023) recorded the age of the Hartha Formation as the Late Campanian-Early Maastrichtian, depending on the fossil assemblage. The present study determined the age of the Hartha Formation as Late Campanian-Early Maastrichtian based on the biozone that was recorded in this study, according to the presence of index fossils *Orbitoides tissoti*, *Orbitoides medius*, and *Orbitoides apiculata*, which refer to the Late Campanian - Early Maastrichtian age, and also depending on the previous studies, which determined that the Hartha Formation is of Late Campanian-Early Maastrichtian age.

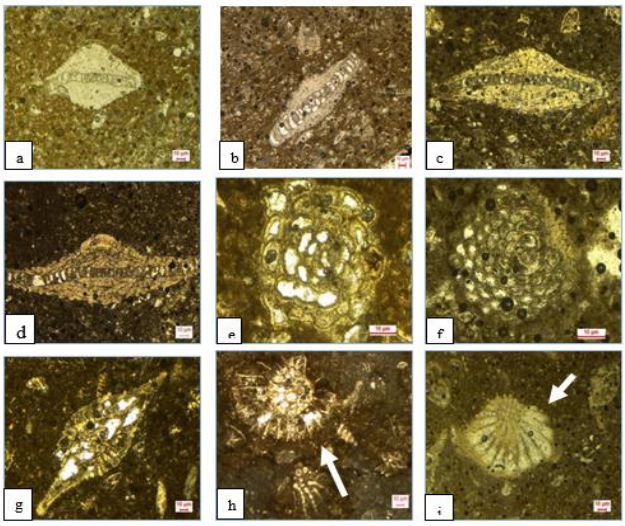


Fig. 6. a) *Orbitoides* sp., well X, at depth 1939.09 m. b) *Orbitoides tissoti* Schlumberger, well X, at depth 1942.47 m, c) *Orbitoides medius* d'Archiac, well X, at depth 1983.79 m., d) *Orbitoides apiculata* Schlumberger, well X, at depth 1972.81m, e) *Omphalocyclus* sp., well Y, at depth 1981.81 m., f) *Omphalocyclus macroporus* (Lamarck), well X, at depth 1925m, g) *Siderolites calcitrapoides* Lamarck, well Y, at depth 1979. 27 m, h) *Pseudosiderolites* Smout, well Z, at depth 1924.5 m, i) *Prasiderolites Douvillei*, well X, at depth 1993. 27m

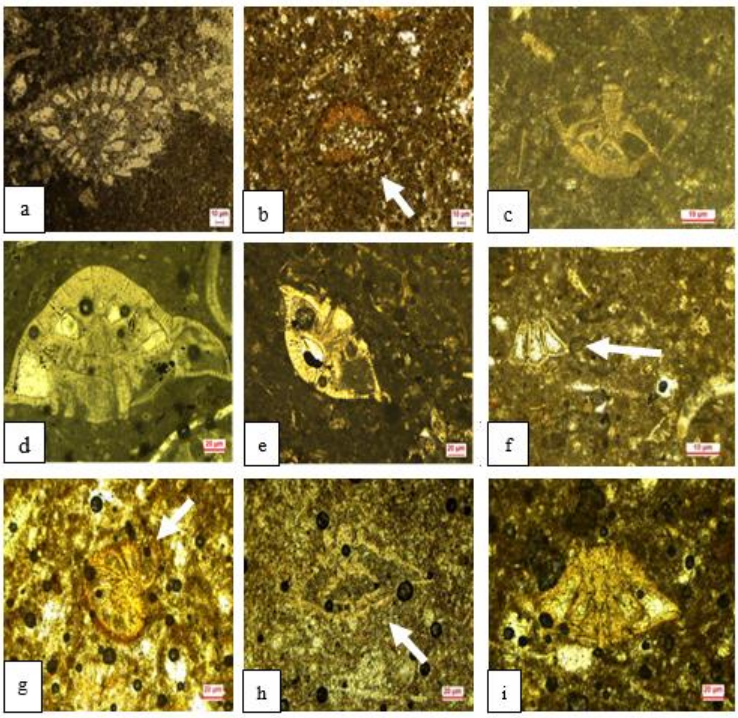


Fig. 7. a) *Arnaudiella* sp., well Y, at depth 1979m, b) *Monolepidorbis* sp., well X, at depth 1992.68 m., c) *Rotalia skourensis* Pfender, well x, at depth 1911 m. d) *Rotalia trochidiformis* Lamarck, well X, at depth 1918.36 m., e) *Rotalia* sp., well X, at depth 1918.36 m., f) *Nezzazata* sp., well Y, at depth 1979 m. g) *Lenticulina* sp., well X, at depth 1999.68 m. h) *Sulcoperculina vermunti* Thiadens, well X, at depth 1974.37 m, i) *Sulcoperculina globousa* de Cizanacourt, well X, at depth 1999.68 m

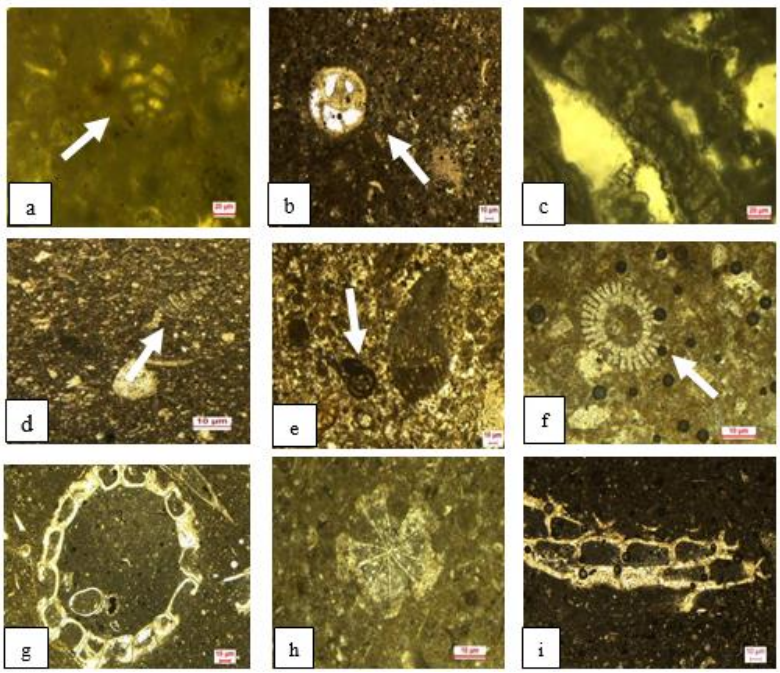


Fig. 8. a) *Textularia* sp., well Z, at depth 1937 m. b) *Rotorbinella campaniola*, well x, at depth 1997.79 m. c) Part of *Pseudomphalocyclus blumenthali* Meric, well x, at depth 1715m.d) *Pseudolituonella reicheli*, well Y, at depth 2143 m. e) *Triloculina* sp., well Y, at depth 2115. f) Echinoid spine, well X, at depth 1967.5 m. g) *Dasycladacean* algae, well Z, at depth 1981.39 m. h) Solitary Coral, well Y, at depth 1975.89m. i) Algae, well X, at depth 1989.80 m

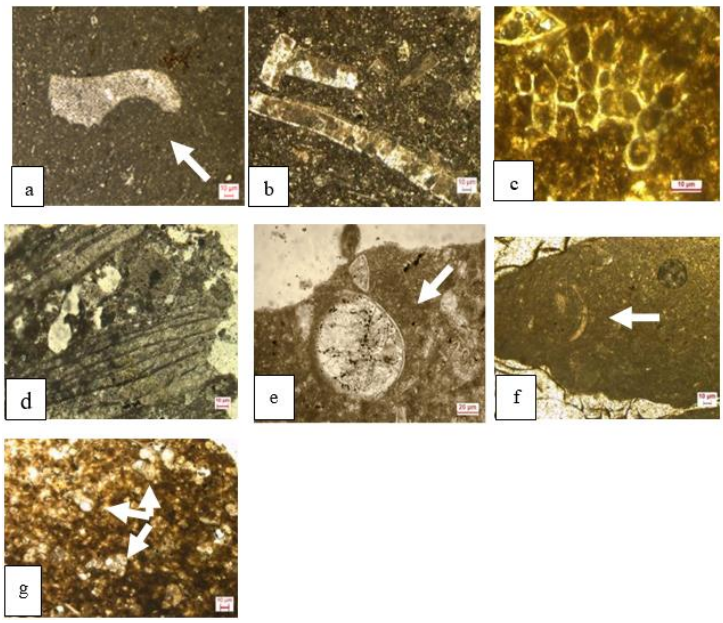


Fig.9. a) Echinoid Plate, Well Y, at depth 1989. 37m. b) *Inoceramus* bivalve, well Z, at depth 1913 m. c) Bryozoan, well Z, at depth 1910.61 m. d) Rudist, well Z, at depth 1659m e) Ostracoda, well X, at depth 1775m. f) Pelecypoda, well Z, at depth 2063 m. Planktonic foraminifera, well X, at depth 1665 m

4. Conclusions

The biostratigraphy of the Hartha Formation in the central part of Iraq is studied in three wells (X, Y, and Z) from an oil field. Twenty-three genera and species of foraminifera and other fossils were recognized. One Biozone was recognized in the Hartha Formation depending on benthonic foraminifera, which is*: Orbitoides tissoti- Orbitoides medius -Orbitoides apiculata* Assemblage Zone. A Late Campanian-Early Maastrichtian age for the Hartha Formation is determined, based on the biozone of benthonic foraminifera.

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