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Biostratigraphy of Hartha Formation from Selected Wells in Nasiriyah Oil Field, Southern Iraq

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Abstract

The Hartha Formation has been investigated from a biostratigraphic view in three subsurface sections in the Nasiriyah Oil field, wells Ns1, Ns3, and Ns4, South of Iraq. Hartha Formation is composed of limestone and has various areas of intense dolomitization alternating with marly limestone. The formation ranges in thickness from 126 to 182 meters. Thirteen large and small benthic foraminifer species and genera are identified from Hartha Formation. Based on the large benthic foraminifer's assemblage, one distinct biozone was recognized after an examination of the paleontological datum in the investigated area showed that the studied wells contained a diversity of foraminiferal species, the larger foraminifers biozone was proposed: *Orbitoides medius- Orbitoides tissoti - Orbitoides gensacicus -Orbitoides apiculatus - Omphalocyclus macroporus* assemblage zone (Late Campanian- Early Maastrichtian), this biozone divided in two range subzone: *Orbitoides medius* Partial Range Zone (Late Campanian) and *Omphalocyclus macroporus* Range Zone (Early Maastrichtian). This biozone indicated that the Hartha Formation deposited through (Late Campanian- Early Maastrichtian).

Keywords: Hartha Formation, *Orbitoides medius*, *Omphalocyclus macroporus*, biozone, Campanian, Maastrichtian.

الطباقية الحياتية لتكوين الهارثة من ابار مختارة في حقل الناصرية النفطي, جنوب العراق

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الخلاصة :

تم دراسة الطباقية الحياتية لتكوين الهارثة في ثلاث مقاطع تحت سطحية ناصرية1 وناصرية 2 وناصرية 3 في حقل الناصرية النفطي جنوب العراق, تكوين الهارثة يتكون من الصخور الجيرية و الصخور الجيرية المتدلمته و صخور الطفل الجيري الذي يتناوب مع الصخور الجيرية ,سمك التكوين يتراوح من 126–182 متر. تم تميز ثلاثه عشر جنسا و نوعا من الفورامنيفرا القاعية الصغيرة و الكبيرة. تم تمييز نطاق تجمعي واحد من خلال فحص المتحجرات في منطقة الدراسة, النطاق التجمعي هو

Orbitoides medius– Orbitoides tissoti – Orbitoides gensacicus –Orbitoides apiculatus – Omphalocyclus macroporus.

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هذا النطاق قسم الى نطاقيين هما : نطاق المدى ل *Orbitoides medius* الذي يدل على عمر الكامباني المتأخر و نطاق المدى *Omphalocyclus macroporus* و الذي يدل على الماسترختي المبكر .هذه الانطقة الحياتية تدل على ان تكوين الهارثة ترسب في عمر الكامباني المتأخر – الماسترختي المبكر.

1. Introduction

Hartha Formation is a significant Upper Cretaceous formation in Iraq, because of its reservoir characteristics, which make it a good reservoir in the country's center and southern areas[1]. The Hartha Formation in Zubair-3 was initially described by Rabanit in [1]. The Formation is named after Hartha city which lies on the west bank of Shatt Al – Arab, north of Basrah [1]. According to this study, the formation is made up of organic, detrital glauconitic limestone; the limestones have several areas of intense dolomitization, interbedded marl, and green shale with a thickness of 423 feet. The neritic, primarily shoal-type detrital limestones that make up the Hartha Formation, according to [2] and [3], were deposited on the platform's slopes. The Hartha Formation, according to [4], is composed of glauconitic, algal limestone that is interbedded with shale. *Globotruncana cf. stuarti*, *Cosinella* sp., *Valvulammina* sp., *Ammobaculites* sp., *Monolepidorbis* sp., and *Pseudedomia complanata* are among the fossils of the Hartha Formation that [1] documented.

To the southeast of Rutbah Karim and Ctyroky in [5] found the following fossils in the carbonate units of the Hartha Formation: *Vautrina cf syriaca* Vautrin, *Eoradiolarites* sp., *Tylostoma* sp., *Nerinea cf bronni*, *Hexacorallatrochus* sp., *Radiolarites cf sequanosus Radiolarites cf sequanosus*, *Tylostoma aff syriaca* Conard and *Micraster* spp. Al-Temimi [6] examined the biostratigraphy and paleoecology of the Hartha Formation in Southern Iraq and identified five zones of benthonic foraminifera with ages ranging from Late Campanian to Early Maastrichtian in addition to seven zones of planktonic foraminifera of Late Campanian- Early Maastrichtian age.

The Hartha Formation is a target for hydrocarbon accumulation and the subject of few studies, which was a deciding factor in the selection of this research. This study aims to define the Hartha Formation's biostratigraphy to estimate the formation's age and foraminifer zonation in the studied sections using microfossil assemblages.

2. Stratigraphy and tectonic setting

The Late Campanian-Maastrichtian cycle, which began with a massive transgression that spanned nearly the entire country, was recognized as a significant cycle [2], which caused the neritic limestone sediments of the Hartha Formation to deposit. Another uplift and regression brought on by the Laramide Orogeny around the Cretaceous-Tertiary boundary mark the end of the cycle [2]. According to [7], the southern Neo-Tethys was finally closed during the Late Campanian and Maastrichtian, which resulted in a significant major transgression occurring over the whole country of Iraq.

On the Stable Shelf, the Hartha Formation is widely distributed both above and below the surface, except for the top portion of the Rutbah Uplift, which is exposed to erosion. The Hartha Formation was replaced by the Digma Formation in some areas of the northern Stable Shelf, and it is also intertongued with the Shiranish Formation toward the Unstable Shelf [8].

The thickness of the Cretaceous rocks varies widely not only between different areas of Iraq but also within a single formation. Overall, the thickness gets thinner as you move toward the country's southeast [9]. In the majority of oil fields, especially in central Iraq, the Hartha

Formation was present with thickness varies as a result of the formation's lateral and vertical passage into the marly limestone of the Shiranish Formation. Furthermore, the Shiranish is frequently intertongued with the Hartha Formation, which also frequently makes separate tongues [1]. In southern Iraq, the Hartha Formation is typically 200 to 250 m thick, and in northern Iraq, it can reach 350 meters thick [2]. The Hartha Formation's equivalents can be found in large quantities in Saudi Arabia, Kuwait, Turkey, and Syria [8], depending on the facies and age. According to [1] and [9], the Shiranish, Tanjero, Aqra-Bekhme, and Digma Formations are equivalent to the Hartha Formation in Iraq (Figure 1). The Hartha Formation in southwest Iraq contains Safawi facies, as noted by [8] and [7]. Aruma Formation and Hartha Formation in Saudi Arabia have some correlations [7]. In some places, the Soukhne Formation in Eastern Syria is correlated to the Hartha Formation [7]. The Hartha Formation's facies are comparable to that of the Karabogaz Formation in SE Turkey. According to [10], this formation, with little modification in facies, continues to Kuwait, in Southeast Kuwait has referred to the combined lateral counterparts of the Hartha and overlying Qurna formations as the Bahra Formation, which has never been fully defined in a publication. The marly of the Qurna Formation has moved lateral southward into limestones, making these formations there less distinct than in the Basrah fields or northern Kuwait. The Ruilat Formation is the Hartha Formation's equivalent in Qatar. Hartha Formation is connected to the Qatrane and Ghareb formations in Jordan's northwest [11]. The formation lacks age and facies analogues in Iran's east and southeast [11].

Al-Rawi [12] investigated the facies of the Hartha Formation in northern and central Iraq, demonstrating that the formation was made up of a variety of facies that represented a variety of subenvironments. According to [13] who studied the sedimentology of the Hartha Formation in middle and western Iraq, the depositional environment of Hartha Formation in middle and northern Iraq gradually changes from a deep outer shelf to a shallow environment, a shoal to a lagoon, and then to a tidal flat environment [11; 14; 15; 16; 17; 18]. Locally, backreef and lagoonal facies can be found by [7] at the Stable shelf's margins in the region surrounding Khlesia High.

The Hartha Formation has different contacts depending on the region. In southern Iraq, the boundary is conformable and the formation is frequently covered by pelagic sediments of the Shiranish Formation, also known as the Qurna Formation [14]. This formation is dated to the *Gansseri* Zone of the Latest Campanian age Darmoian in [19], and the lower contact is conformable with the Sa'di Formation [2]. Al-Ali [20] researched the Hartha Formation in the Al-Qayara oil field. He identified the lower, nonsequential contact with the Sa'di Formation and the upper contact with the Shiranish Formation as unconformable.

The Hartha Formation is Late Campanian-Early Maastrichtian in age, according to [19; 21; 5; 11;15; 22; 23; 24;17; 6; 25; 26]. Bellen [1] and [18] propose that the Hartha Formation is Late Campanian- Maastrichtian. According to [16], the Hartha Formation is (Late Campanian – Middle Maastrichtian).

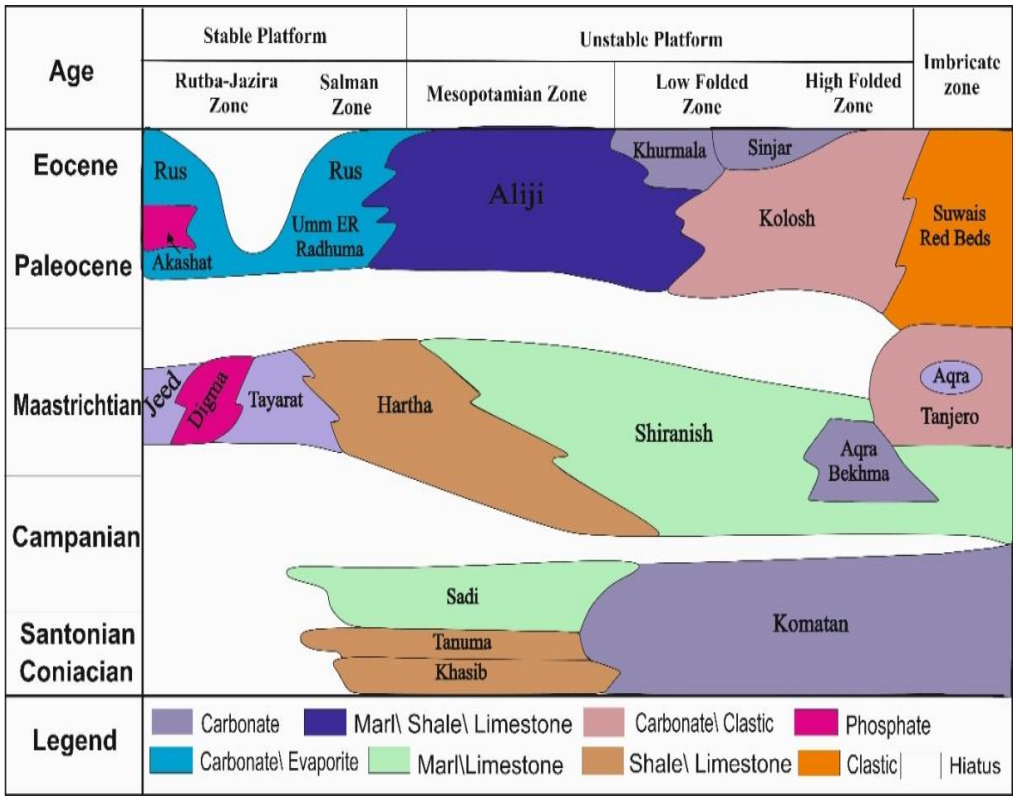

Figure 1: Lithostratigraphy correlation of the Late Cretaceous succession in Iraq, after [1; 7] with some modifications.

4. Material and Methods

The Nasiriyah oil field, which is located in the study area and is approximately 38 km northwest of the city of Nasiriyah at Latitude: 31.05799° and Longitude: 46.257269 (Figure 2 and Table 1), is approximately 34 km long and 13 km wide at Mishrif surface reflection [27]. The Iraqi National Oil Company (INOC) explored the Al-Nasiriyah field in 1975 using seismic analysis of the National Oil Company. In this study, subsurface sections of the Hartha Formation have been chosen for this investigation. 210 samples were also gathered from the studied area. Sampling intervals were typically 2 to 3 m. 200 hard carbonate rocks of the samples were studied by making thin sections. Different imperforate and perforate foraminifer species make up the foraminiferal assemblages of the Hartha Formation.

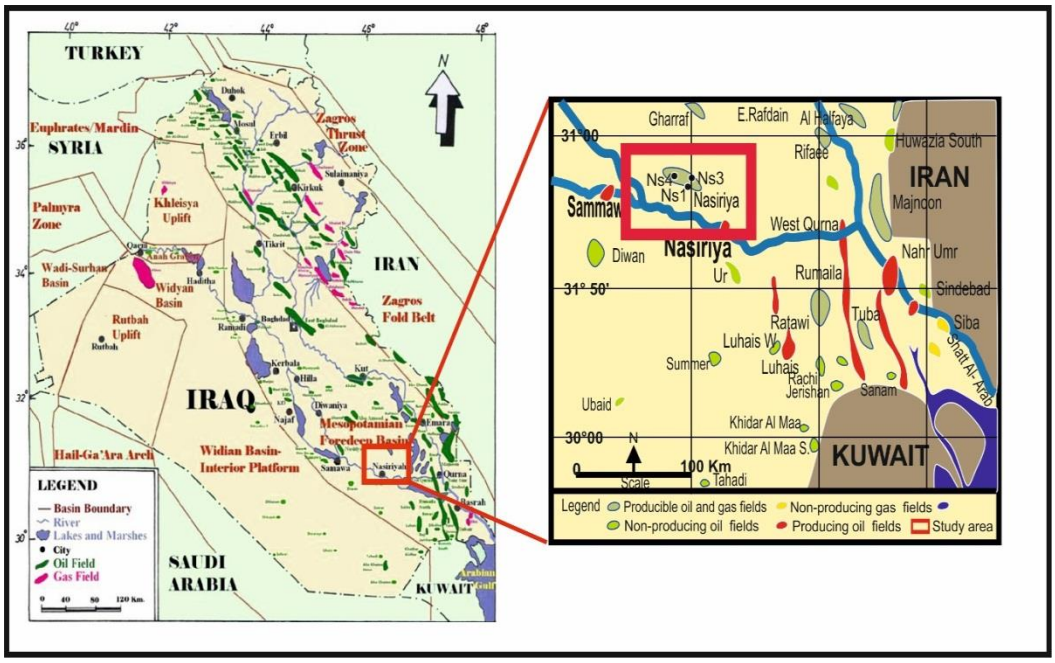

Figure 2: Location map of the studied area (Al-Nasiriyah oil field), After [28].

Table 2: Coordinates of three sections chosen in the studied area and thickness of Formation

Wells no.	Longitude	Latitude	Number of samples	Depth of Bottom of Hartha Fm.	Depth of Top of Hartha Fm.	Thickness of Hartha Fm.
Nasiriyah Ns1	46°0'43.383" E	31° 19'32.159"N	74	1642m.	1474m.	168 m.
Nasiriyah Ns3	46°2'21.734" E	31° 20'12.05"N	81	1625m.	1443m.	182 m.
Nasiriyah Ns4	45°55'33.887"E	31° 19'56.919"N	55	1588m.	1462m.	126 m.

5. Biostratigraphy and Biozone

The Hartha Formation, which is composed of limestones with areas of extensive dolomitization and marly limestone interbedded throughout, and whose thickness ranged from 126 to 182 meters, yielded a foraminiferal fauna made up of 16 species that belonged to 8 taxa. Common foraminifers of Hartha Formation in studied sections are consisted of *Orbitoides medius* (Plate 1, Figures A, and B), *Orbitoides* sp. (Plate 1, Figure C), *Orbitoides tissoti* (Plate 1, Figure D), *Orbitoides gensacicus* (Plate 1, Figure E), *Orbitoides apiculata* (Plate 1, Figure F),, *Omphalocyclus* sp. (Plate 1, Figures G and H), *Rotalia* sp. (Plate 2, Figure A), *Rotalia reichli*, *Rotalia skorensis* (Plate 2, Figure B), *Sulcoperculina* sp (Plate 2, Figure C), *Quinqueloculina* sp. (Plate 2, Figure D), *Triloculina* sp. (Plate 2, Figure E), *Lepidorbitoides* sp. (Plate 2, Figure F), *Lepidorbitoides minor* (Plate 2, Figure G), In addition to other fossils such as: Bryozoan fragment (Plate 2, Figure H), Crinoids (Plate 2, Figure I), *Lithothamnion* algae (Plate 2, Figure J), *Coralline* algae (Plate 2, Figure K), *Dasycladacean* algae (Plate 2, Figure L), Echinoid fragment (Plate 2, Figures M and N), Miliolid, Ostracods (Plate 2, Figure O), Shell fragment, Gastropoda shell(Plate 2, Figure P), Rudist debris (Plate 2, Figures Q, and R).

The analysis of foraminiferal content provided vertical and horizontal relationships between the provincial assemblages. One distinct biozone was identified after an investigation of the paleontological datum in the researched area revealed that the studied well contained a variety

of foraminiferal species, the larger foraminifers biozone was proposed: *Orbitoides'* species - *Omphalocyclus macroporus* assemblage zone (Late Campanian- Early Maastrichtian), this biozone divided in two range subzone: *Orbitoides medius* Partial Range Zone (Late Campanian) and *Omphalocyclus macroporus* Range Zone (Early Maastrichtian). The taxonomy followed here is based on that adopted by [6; 23; 29; 30; 31; 32; 33; 34; 35; 36; 37;38; 39; 40]. The biozones are discussed and described in the following manner:

5.1 *Orbitoides medius- Orbitoides tissoti - Orbitoides gensacicus -Orbitoides apiculatus - Omphalocyclus macroporus* Assemblage Zone:

Definition: This zone is identified depending on the range of extension of the four *Orbitoides* species and the range of extension of *Omphalocyclus macroporus*.
Age: Late Campanian- Early Maastrichtian.
Occurrence: This zone is found in the whole part of the Hartha Formation and measures around 168 m in thickness from depth 1642m to 1474m in Ns-1, and 182 m in thickness from depth 1625 m to 1443 m. in (Ns-3), and 126 m in thickness from depth 1588m. to 1462m. in Ns-4 (Figures 3; 4; 5, and 6).

Remarks and correlation: This zone is marked by index fossils *Orbitoides medius Orbitoides tissoti, Orbitoides gensacicus, Orbitoides apiculatus, Omphalocyclus macroporus* with other large foraminifera *Orbitoides* sp., *Rotalia* sp., *Rotalia reichli, Rotalia skorensis, Sulcoperculina* sp., *Lepidorbitoides* sp., *Lepidorbitoides minor* and small benthic foraminifera such as *Quinqueloculina* sp., *Triloculina* sp., *Idilina* sp. In addition to other fossils such as Bryozoan fragments, Crinoids, *Lithothamnion* algae, *Coralline* algae, *Dasycladacean* algae, Echinoid fragments, Miliolid, Ostracods, Shell fragments, Gastropoda shell, Rudist debris.

Many scientists from other nations have noted the coexistence of the Orbitoides assemblage, which supports the Campanian-Maastrichtian age; for biostratigraphic zonations, these benthic foraminifera are used [41]. The index species *Orbitoides medius* designated Late Campanian age in many parts of the world [42; 43; 44; 45; 23). Görmüş et al. [46] identified faunal assemblages represented by *Loftusia elongata*, *L. morgani*, *Orbitoides medius, O. megaloformis, O. gruenbachensis, O. apiculatus*, *Omphalocyclus macroporus, Siderolites calcitrapoides, Lepidorbitoides* sp., indicate Maastrichtian age. Many researchers, including [47], [48], and [34] regard *Loftusia elongata, L. morgani*, and *Siderolites calcitrapoides* as the most significant Maastrichtian fossils. These fossils are not documented in this study, so the assembly zone is thought to be the Late Campanian-Early Maastrichtian.

5.1.1 *Orbitoides medius* Partial Range Subzone

Definition: This subzone is defined from the first appearance of *Orbitoides medius* to the first appearance of *Omphalocyclus macroporus*.
Age: Late Campanian.
Occurrence: This subzone is found in the lower part of the Hartha Formation and measures around 73 m in thickness from depth 1642m. to 1569 m. in Ns-1, 86 m in thickness from depth 1625m. to 1539 m. in Ns-3, and 48 m in thickness from depth 1588m. to 1540 m. in Ns-4 (Figures 3; 4; 5, and 6).

Remarks and correlation: This subzone is marked by index fossils *Orbitoides medius* associated with other taxa like *Orbitoides* sp., *Orbitoides tissoti*, *Orbitoides gensacicus*, *Orbitoides apiculatus*, Rotalia sp., *Rotalia reichli, Rotalia skourensis, Sulcoperculina* sp. Other fossils that can be preserved include fragments of shell, Bryozoa, Echinoderm, Algae, Ostracoda, Gastropoda and rudist. Due to the quick evolution and wide range, of the genus

Orbitoides' distribution over that geological period and its demise during the Cretaceous-Tertiary transition, it is regarded as an index fossil for the Upper Cretaceous [49; 34]. *Orbitoides medius* zone is equivalent to *Orbitoides tissoti* zone which is described by [6], and equivalent to *Orbitoides tissoti - Orbitoides medius* zone which is described by [23], which is denoted Late Campanian. In this study, this *Orbitoides medius* biozone refers to the Late Campanian age.

5.1.2 *Omphalocyclus macroporus* Range Subzone

Definition: *Omphalocyclus macroporus* is marked by the total range of the nominate taxon, in addition to the last occurrence of all larger foraminiferal species and the first appearance of planktonic foraminifera of Shiranish Formation.

Age: Early Maastrichtian

Occurrence: This subzone is found in the upper part of the Hartha Formation and measures around 95 m in thickness from depth 1569m. to 1474 m. in Ns-1, 96 m in thickness from depth 1539m. to 1443 m. in Ns-3 and 78 m in thickness from depth 1540m. to 1462 m. in Ns-4 (Figures 3; 4; 5, and 6).

Remarks and correlation: The faunal characterized in this zone are: *Orbitoides* sp., *Orbitoides tissoti*, *Orbitoides medius*, *Orbitoides gensacicus*, *Orbitoides apiculata*, *Omphalocyclus* sp., *Rotalia* sp., *Rotalia reichli*, *Rotalia skorensis*, *Sulcoperculina* sp., *Lepidorbitoides* sp., *Lepidorbitoides minor*, *Quinqueloculina* sp., *Triloculina* sp., *Idilina* sp., Besides other fossils including Bryozoan fragments, Crinoids, *Lithothamnion* algae, *Coralline* algae, *Dasycladacean* algae, Echinoid fragments, Miliolids, Ostracods, Rudist detritus. *Idilina* sp. *Lithothamnion* algae, *Coralline* algae are not recorded in Ns1. Ostracods and Gastropoda are not documented in Ns3. Many experts agree that the *Omphalocyclus macroporus* is Maastrichtian in age, in a variety of countries including Iraq [50; 51], Cuba [52], Switzerland [53], Libya [54], Tunis [55], and Iran [56]. *Omphalocyclus macroporus* biozone was defined as the Late Maastrichtian age in several areas, including Iran [57; 58; 59; 40]; South Turkey [60]; Iraq [61]. The appearance of *Orbitoides apiculatus* and *Omphalocyclus macroporus*, according to [61], implies Maastrichtian age; however their coexistence with *Siderolites calcitropoides* denotes Late Maastrichtian.

The Early Maastrichtian age of this biozone is determined in this work based on paleontological data and stratigraphic position. It is equivalent to the *Orbitoides apiculatus-O. medius* zone described by [23] and the *Omphalocyclus macroporus* zone determined by [6].

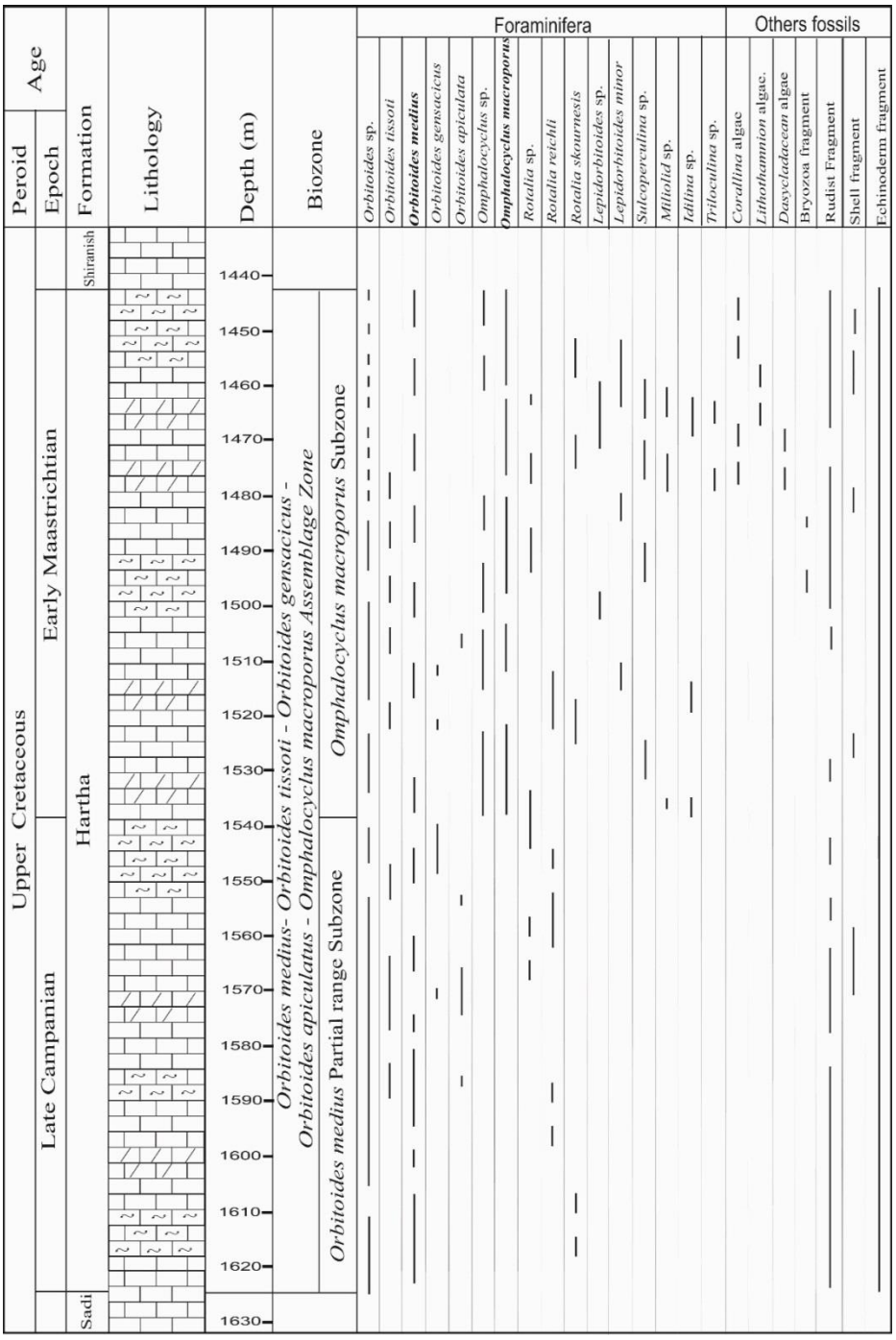

Figure 3: Biozone and biostratigraphic distribution of foraminifers and skeletal grain of Hartha Formation in well Ns1.

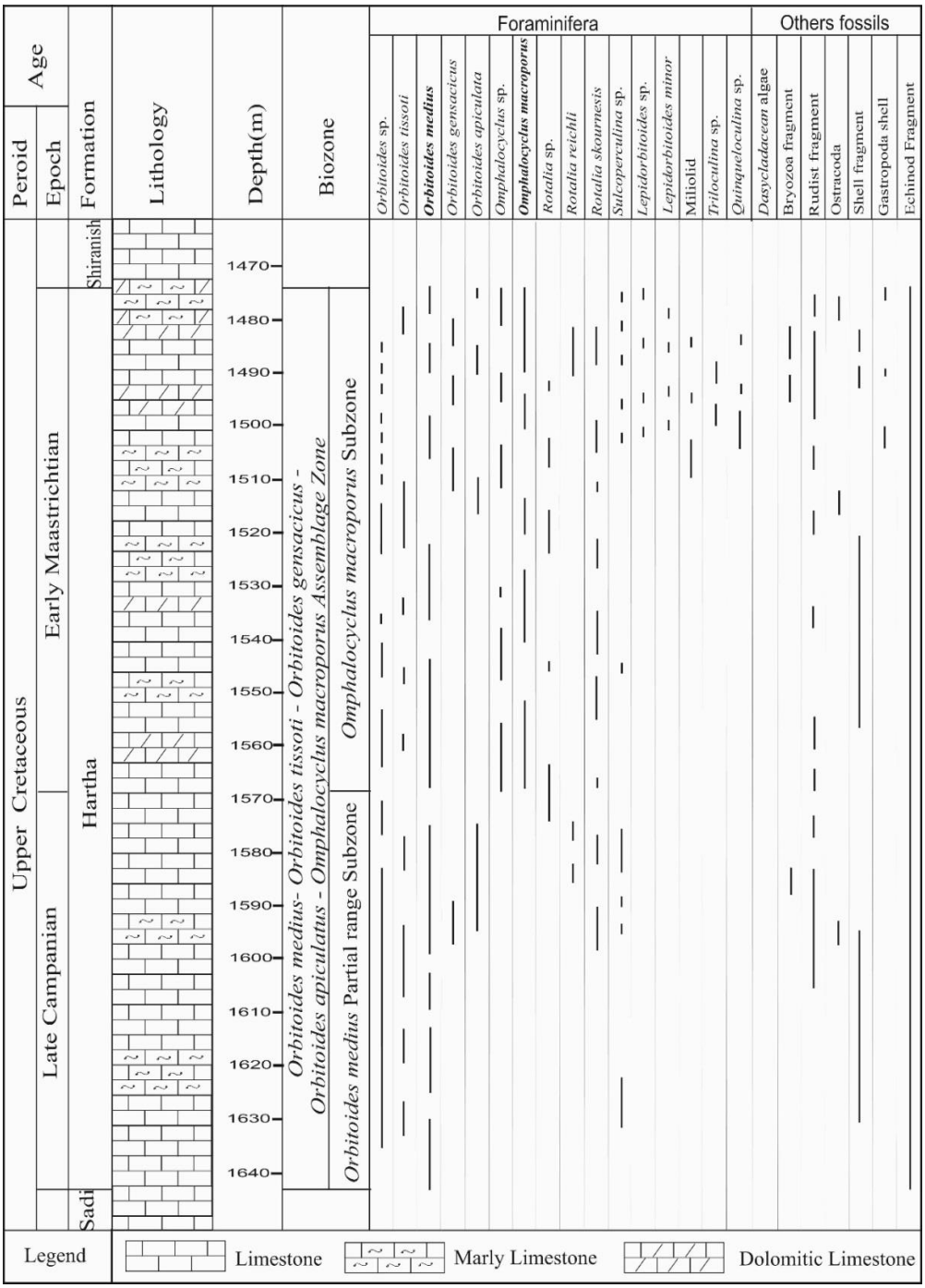

Figure 4:- Biozone and biostratigraphic distribution of foraminifers and skeletal grain of Hartha Formation in well Ns3.

The Hartha Formation is underling by Sadi Formation, in this study documented where the first appearance of *Orbitoides* species. And the upper contact is with Shiranish Formation determined where the first appearance of planktonic foraminifera. Hence, there is no evidence of large foraminiferal biofacies. The lower and top formations, respectively, were determined by [2] and [7] to be Sadi and Shiranish formations, and these investigations considered the same formation as the underlying and overlying formations.

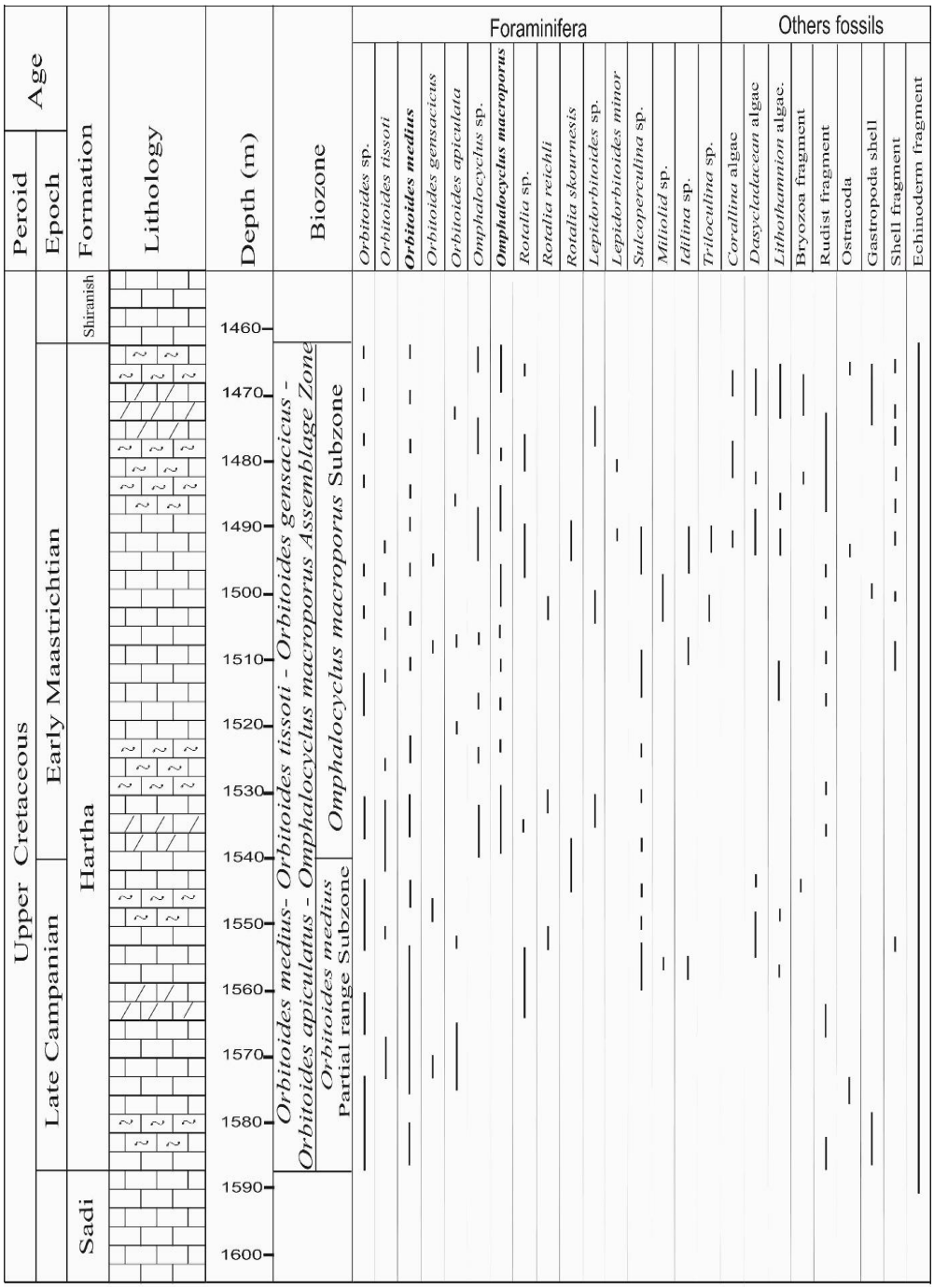

Figure 5: Biozone and biostratigraphic distribution of foraminifers and skeletal grain of Hartha Formation in well Ns4.

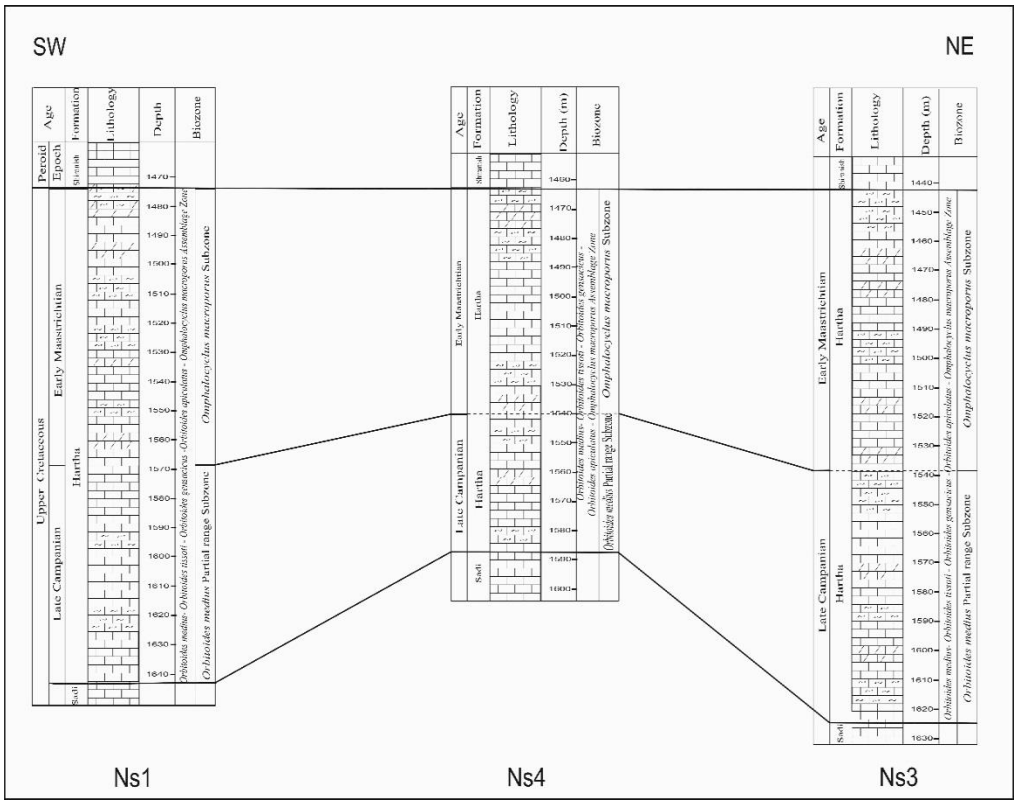

Figure 6: Biozone correlation of Hartha Formation in studied wells Ns1, Ns3, and Ns4.

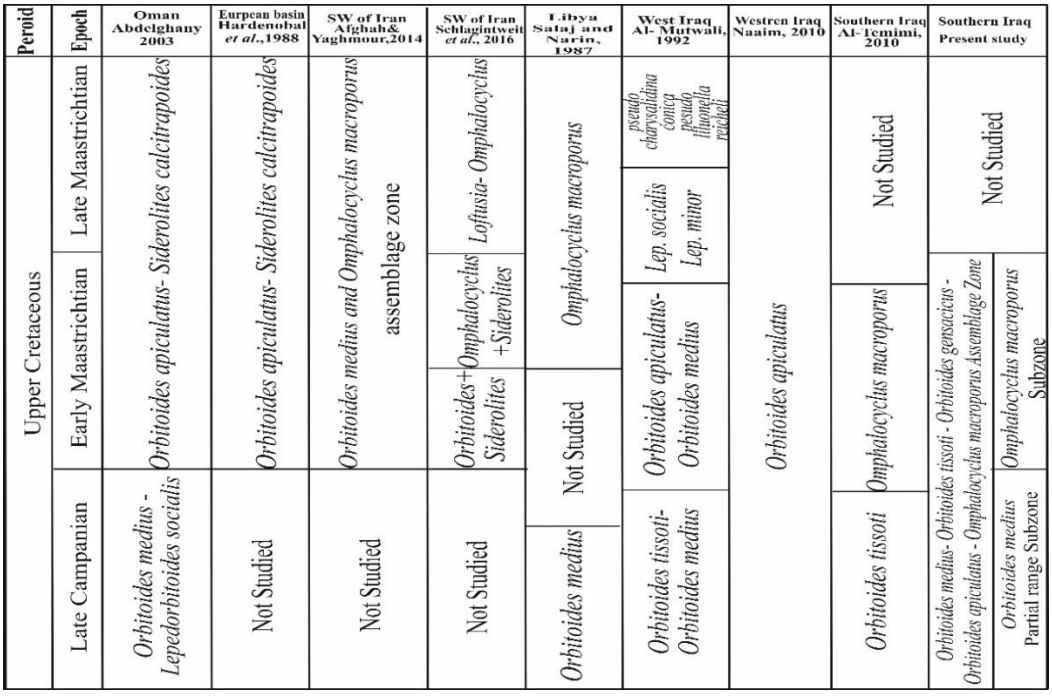

Figure 7: Correlation chart showing the Foraminiferal biostratigraphic zones of the Upper Cretaceous in the studied section with the foraminiferal zonation commonly used in Iraq and different countries.

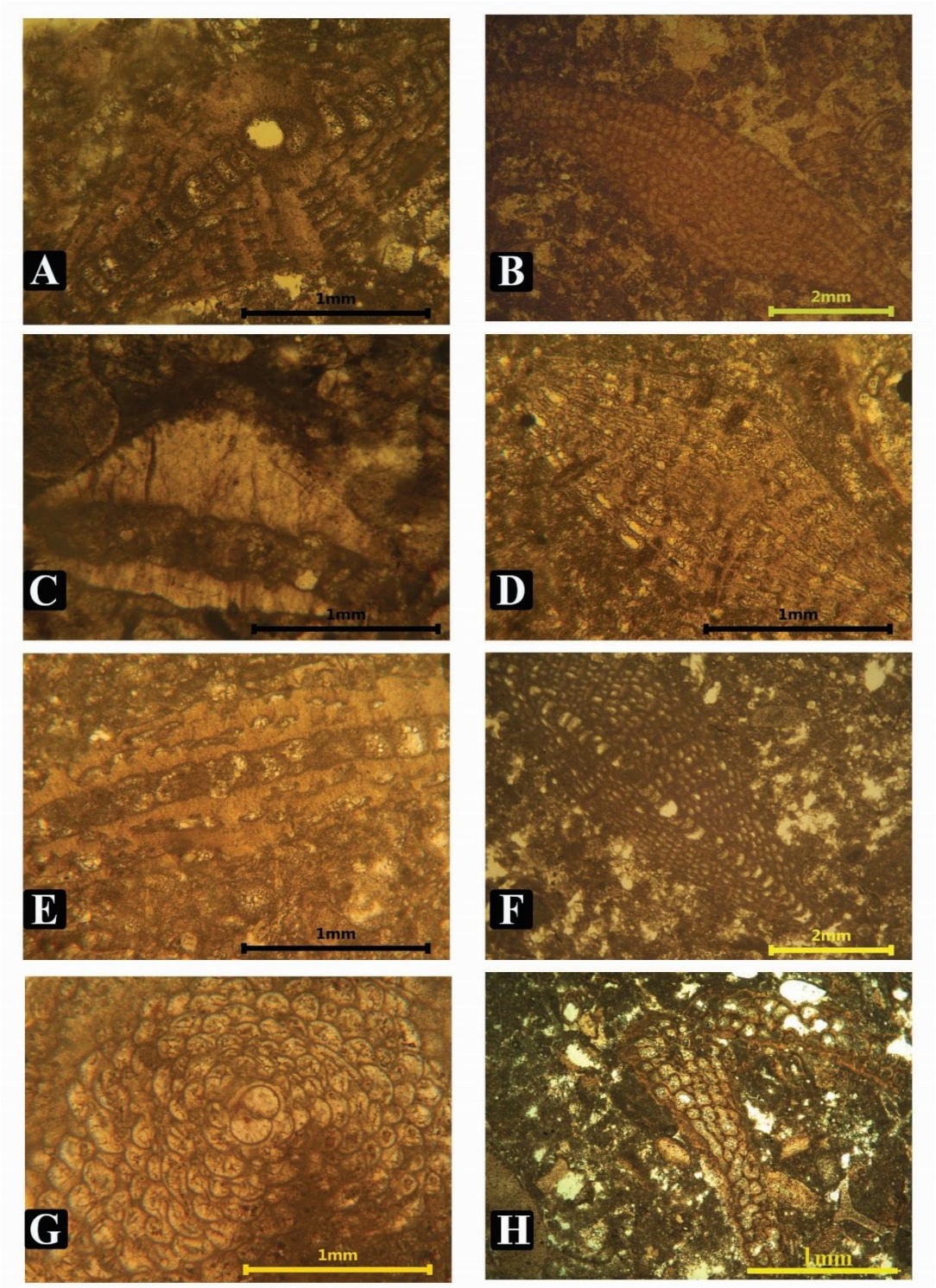

Plate 1: All figures from Hartha Formation (Late Campanian- Early Maastrichtian): Figure A: *Orbitoides medius*, Ns1; depth (1590) m. Figure B: Subaxial section *Orbitoides medius*, Ns4; depth (1562) m. Figure C: *Orbitoides* sp. Ns1; depth (1560) m. Figure D: *Orbitoides tissoti*, Ns3; depth (1487) m. Figure E: *Orbitoides tenacious*, Ns4; depth (1508) m. Figure F: *Orbitoides apiculata*, Ns3; depth (1572) m. Figure G: *Omphalocyclus macroporus*, Ns1; depth (1480) m. Figure H: *Omphalocyclus* sp. Ns3; depth (1513) m.

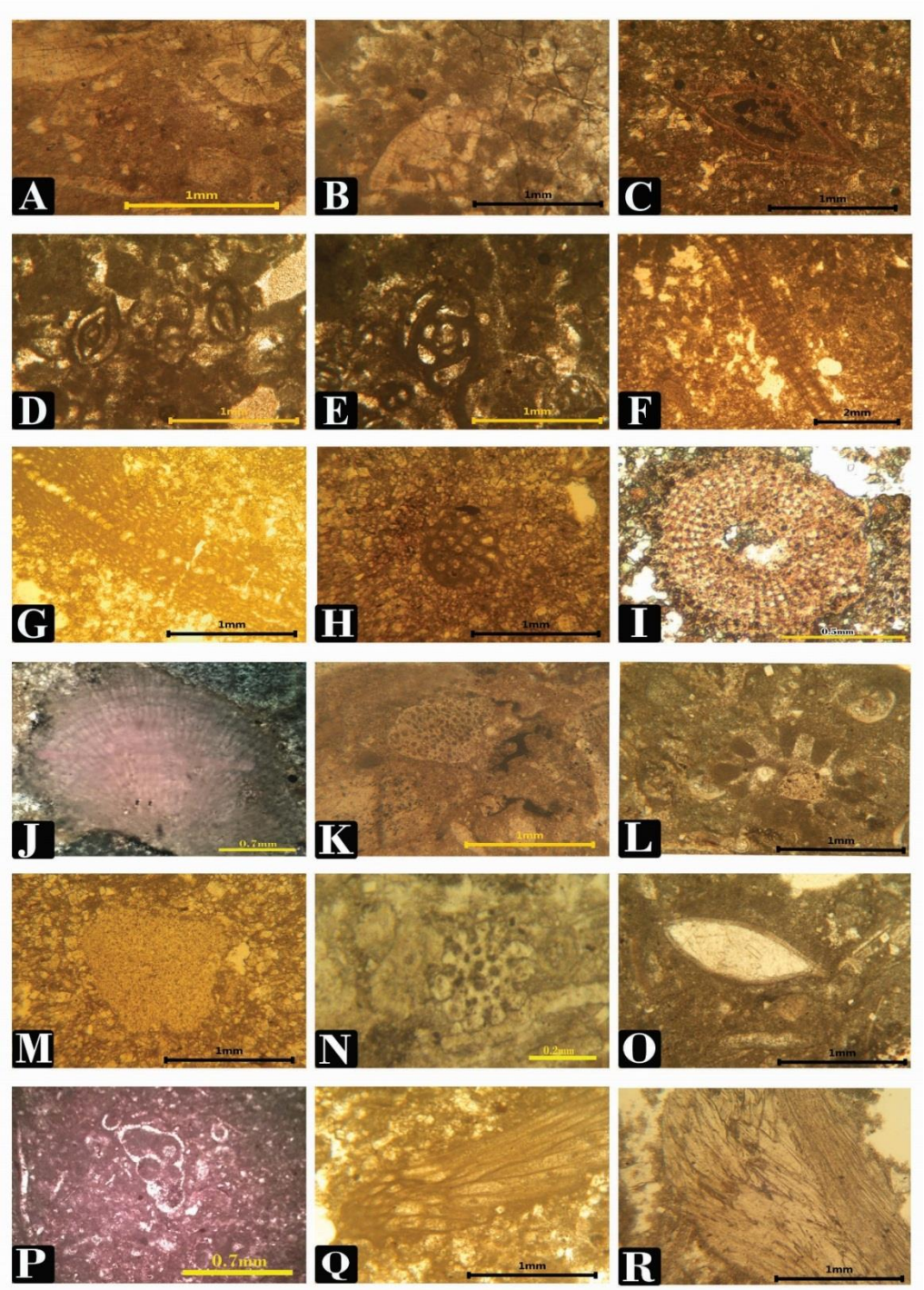

Plate 2: All figures from Hartha Formation (Late Campanian- Early Maastrichtian): Figure A: *Rotalia* sp. Ns3; depth (1488) m. Figure B: *Rotalia skorensis*, Ns4; depth (1502) m. Figure C: *Sulcoperculina* sp. Ns3; depth (1464) m. Figure D: *Quinqueloculina* sp. Ns1; depth (1500) m. Figure E: *Triloculina* sp. Ns3; depth (1466) m. Figure F: *Lepidorbitoides* sp. Ns1; depth (1494) m. Figure G: *Lepidorbitoides minor*, Ns1; depth (1494) m. Figure H: Bryozoan fragment, Ns4; depth (1470) m. Figure I: Crinoids, Ns3; depth (1524) m. Figure J: *Lithothamnion* algae, Ns3; depth (1464) m. Figure K: *Coralline* algae, Ns4; depth (1492) m. Figure L: *Dasycladacean* algae, Ns3; depth (1478) m, Figure M: Echinoid fragment, Ns3; depth (1516) m. Figure N: Echinoid Spin, Ns4; depth (1436) m. Figure O: Ostracods, Ns4; depth (1494) m. Figure P: Gastropoda shell, Ns4; depth (1472) m. Figure Q: Rudist fragment, Ns3; depth (1600) m. Figure R: Rudist Fragment, Ns3; depth (1572) m.

6. Conclusions

The Hartha Formation is primarily composed of carbonates and comprises limestone that is interbedded with marly limestone and dolomitic limestone, in the wells that were being studied, the Formation's thickness ranged from 126 to 182 meters.

The carbonate succession of the Hartha Formation is underlain by the Sadi Formation, which is distinguished by the lack of Orbitoides species, while overlain by fossiliferous limestone rich in planktonic foraminifera of the Maastrichtian age, which represents the Shiranish Formation.

The three sections (Ns1, Ns3, and Ns4) yielded several larger foraminiferal species, including *Orbitoides medius*, *Orbitoides tissoti*, *Orbitoides gensacicus*, *Orbitoides apiculata*, *Rotalia* sp., *Rotalia reichli*, *Rotalia skorensis*, *Sulcoperculina* sp., *Lepidorbitoides* sp., *Lepidorbitoides minor*, *Sulcoperculina* sp., and *Omphalocyclus macropora*, which confirms the Late Campanian- Early Maastrichtian age of the investigated deposits.

According to the distribution of index foraminifers of the Hartha Formation in these sections, thirteen benthic foraminifer's species belonging to eight genera were recognized, all of which were previously described. One biozone was identified within Hartha Formation. It is represented by one large benthic foraminiferal assemblage biozone, *Orbitoides medius- Orbitoides tissoti - Orbitoides gensacicus -Orbitoides apiculatus - Omphalocyclus macroporus*, which can be subdivided into two range subzones, *Orbitoides medius* Partial Range Zone (Late Campanian) and *Omphalocyclus macroporus* Range Zone (Early Maastrichtian). The age of the Hartha Formation is determined to be (Late Campanian- Early Maastrichtian) at studied wells.

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