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Petrophystics and Nannobiostratigraphy data from the Coniacian-Santonian interval of the Kometan Formation in the Bai Hassan-86 Oil Field, Northern Iraq: Implication for the Oceanic Anoxic Event

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Abstract

The late Turonian to early Campanian Kometan Formation is widespread in northern and central Iraq. The study section is located in Northern Iraq, northwest Kirkuk. This formation is composed primarily of limestone, dolomitic limestone, and black shale, with nodules of chert distributed throughout the formation. The lower contact of the formation with the Gulneri with the Mushorah Formations is unconformable. The current study used 80 thin sections that showed the presence of planktonic foraminifera and 55 samples. The black shale beds in the middle formation were determined through the Gamma log. And also five nannobiozones identified, they are *Eiffellithus eximius* Interval Zone (CC12) *Marthasterites furcatus* Interval Zone (CC13), *Micula staurophora* Interval Zone (CC14), *Reinhardites anthophorus* Interval Zone (CC15), *Lucianorhabdus cayeuxii* Interval Zone (CC16). Depending on planktonic foraminifera and the biostratigraphy of calcareous nannofossils, evidence of Bai Hassan-86 well determined the age of the Oceanic Anoxic Event (OAE3) was recorded in Upper Turonian – lower Santonian.

Keywords: Nannostratigraphic Study, planktonic; foraminifera, OAE3, Kometan Formation, Iraq.

البيانات البتروفيزيائية والطباقية الحياتية لمتحجرات النانو الكلسية من الحد الفاصل كونياسيان–سانتونيان لتكوين كوميتان في حقل باي حسن –86 النفطي , شمالي العراق : الاثار المترتبة على حدث نقص الاوكسجين المحيطي 3(OAE3)

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الخلاصة

تنتشر تتابعات تكوين كوميتان بشكل واسع في شمال ووسط العراق , خلال الفترة من ترونيان المتاخر الى الكامبانيان المبكر , تقع منطقة الدراسة في شمالي العراق , تحديدا في شمال غرب كركوك . ويتكون من تتابعات من الصخور الجيرية بشكل رئيسي والصخور الجيرية الدولومايتية والسجيل الأسود, كما سجل وجود عقد من الكلوكونايت موزعة في اغلب انحاء التكوين. يظهر سطح التماس السفلي لتكوين كوميتان مع تكوين كولنيري الذي يقع اسفل منه كسطح غير متوافق ، ويظهر سطح التماس العلوي مع تكوين مشورة غير متوافق أيضا.

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اعتمدت الدراسة الحالية على 80 شريحة صخرية رقيقة أظهرت وجود المنخربات الطافية و50 نموذج لغرض دراسة متحجرات النانو الكلسية , كما تم تحديد طبقات الطفل الأسود في وسط التكوين من خلال مجس كاما . تم دراسة متحجرات الفورامنيفيرا الطافية من خلال الشرائح الصخرية الدقيقة , كما تم تحديد خمس انطقة طباقية حياتية لمتحجرات النانو الكلسية وهي *Eiffellithus eximius* Interval Zone (CC12) *Marthasterites furcatus* Interval Zone (CC13), *Micula staurophora* Interval Zone (CC14), *Reinhardites anthophorus* Interval Zone (CC15), *Lucianorhabdus cayeuxii* Interval Zone (CC16), اعتمادا على ادلة متحجرات الفورامنيفيرا الطافية و النانو الكلسية لبئر باي حسن -86 تم توثيق حدث نقص الاوكسجين OAE3 وبعمر ترونيان المتاخر – سانتونيان المبكر .

1. Introduction

Major changes in the Earth system, particularly concerning the carbon cycle, have been identified as climatically influenced by oceanic anoxic episodes [1]. These events have been documented in the geological record, particularly in marine Cretaceous successions. Pelagic sediments rich in organic matter, such as black shales, were widely deposited during these events. These sediments are considered important mechanisms for organic carbon burial and, as a result, for buffering Cretaceous runaway super-greenhouse gas [2].

The Coniacian–Santonian limit signifies a time of marine sedimentation differentiation marked by carbonate and black shales rich in organic carbon (OC), which is thought to represent the final oceanic anoxic event (OAE3), versus the reddish limestones, white chalk, and claystone known as Cretaceous Oceanic Red Beds (CORBs) [3]. Based on the compiled geophysical and nannopaleontology proxy data of the study section. These excursions, each some few million years in duration, are characterized by regionally restricted calcareous nannofossils that best explain the accumulation during the OAE3.

This study examines over 95 different study sites and locations, which are divided into three primary levels of short amplitude carbon isotope excursions within OAE3. These excursions are constant across the region and linked to organic matter's long-term buildup. They referred to these levels, from oldest to youngest, as (OAE3a, OAE3b, and OAE3c) during the late mid-Coniacian at 86.9 Ma [4].

Average sedimentation rates were highest during the late Coniacian compared to the Santonian, which had the lowest rate of water interface. Oceanic anoxia linked to OAE 3 was absent during the Coniacian-Santonian interval until the earliest Campanian, where there was deposition of CORBs in this region of southern Tethys as opposed to the low and mid-latitudinal Atlantic Ocean [5].

By examining dinocysts in the southern Tethys, researchers discovered a widespread warm-to-hot greenhouse climate during this period, even though temperatures generally decreased. The Coniacian-Santonian period and the OAE3 event were not present in this region of the Tethys. Instead, the interval studied is more similar to CORBs, as indicated by [6].

The Kometan Formation widely appears as outcrops in northern and central Iraq during the Upper Turonian to Early Campanian [7]. Additionally, it can be subsurface found in the Kirkuk well (No.116), Demirdagh well (No. 29), Qarachoq well (No.1) and Najmah well (No.29) [2]. The formation was observed by [8] in the type section adjacent to the Northeastern Iraq villages of Kometan and Ain Dazah, located North of Rania town. The type section is estimated to be 36 m thick, consisting of thinly stratified limestone strata that are chalky and light gray [8]. Additionally, the partial silicificaticon process in certain of its impacts, occasionally taking the

form of scattered conglomerates and chert nodules. Nodules of Glauconite are present in a few beds at the lower part of the formation. The early Turonian-Santonian age of the formation was established by [8] based on the existence of crowds of fossils as *Gumbelina spp; Oligostegina; Globotruncana helvetica Bolli (at base); G.cf. renzi Gandofi; G.sigali Reichel; G. Lapparenti Coronata Bolli; G. Lapparenti bulloides Vogler; G. Lapparenti Brotzen ; G.lapparenti tricarinata (Quereau).* Additionally, they indicated that the bottom and upper boundary of the formation are unconformity. Several studies addressed determining the age of the formation, including [9], [10] and [11], which refer to Upper Turonian – Lower Campanian.

The conFigureuration has been studied by [12] and [13], and it was concluded that three depositional environments were distinguished along the studied sections, ranging from the continental shelf to the abyssal. The presence of pyrite throughout the Kometan Formation and glauconite in the upper parts of the formation, the embedding of all microfacies components in micritic groundmass and the absence of high energy deposition features such as oolite and coarse lithoclast, as [14] he study Bai Hassan oil well in northern of Iraq, and concluded that almost the whole parts of the formation in the well BH-86 contain hydrocarbon with different.

The objective of the present study is to utilize thin-section analysis to investigate the planktonic foraminifera to identify evidence for an anoxic event (OAE3). The systematic paleontology of calcareous nannofossils is conducted on the Kometan Formation to establish its biozone and ascertain the age of the formation and associated events, such as OAE3. The objective is to analyze the petrophysical characteristics of the Kometan Formation by examining the existing logs, specifically the Gamma Ray log, to identify the presence of black shale layers.

2. Methods and Materials

A detailed description of the Kometan Formation sequences of the study well was done, including determining the thickness and studying the properties of the contact surfaces, including their hardness, color, and other physical attributes, in addition to the sample collection.

The thickness of the formation reached about 200 meters. Twenty-two samples were selected from the Kometan Formation Bai-Hassan field. Thin sections were prepared for petrographic examination and diagnosis of planktonic Foraminifera fossils. These samples are used for the study of the calcareous nannofossils depending on the thin section (under transmitted-light microscope). The calcareous nannofossils are extracted using the method (H) [15]. It is an extraction method for microfossils that can be adequately examined. The sample preparation is to use decanting and smear methods to produce slides of calcareous nannofossils, which are as follows:

1-The sample preparation is decanting and smearing slides, which provide a method for producing slides of calcareous nannofossils. A small amount of the disaggregated sample is placed in distilled water, and drops of cellosize are added as a dispersant.

2-The cover slip is left to dry on a warm hotplate. Making permanent mounts allows the slide and residue to dry at a low temperature, away from possible sources of contamination.

3-Place a drop of mounting medium (e.g. Canada Balsam) on a clean cover slip and drop this over the residue. Allow it to dry before examining it with transmitted light.

On the other hand, the available logs were used to study the petrophysical properties, such as the Gamma-ray log to calculate the size of the shale and neutron log, the density and sound log to calculate the total effective porosity and secondary porosity through the use of modern software (Interactive & Petrophysics Didger 3.5) (IP.). The size of the shale, where these logs

were entered into a scanner to convert the information from their paper or image format to digital data inside the Las file format, makes dealing with them easier through the computer program (Neuralog V 2010.11).

The porosity was then calculated using Interactive Petrophysics v3.6 by petrophysical analysis of logs data mainly from common mathematical equations and some standard schemes (Schlumberger) applied to probe studies [16].

The thickness of the formation in the Bai Hassan well is about 200 meters, and it extends from depth (1725-1925) meters. The formation consists mainly of limestone and fossiliferous limestone, black shale, and Cherts nodules dispersed throughout the formation at some levels and near the bed's contact surfaces. The lower contact of the formation with the Gulneri Formation was unconformable, and the upper contact with the Mushorah Formation appeared unconformable; glauconite grain is present at both contacts.

3. Geological Setting

The Kometan Formation represent one of the formations which were situated in the lower part of the upper Cretaceous- lower Palaeogene (92-63 Ma.) part of the AP9 Tectonostratigraphic Megasequence [17] (Figure. 1).

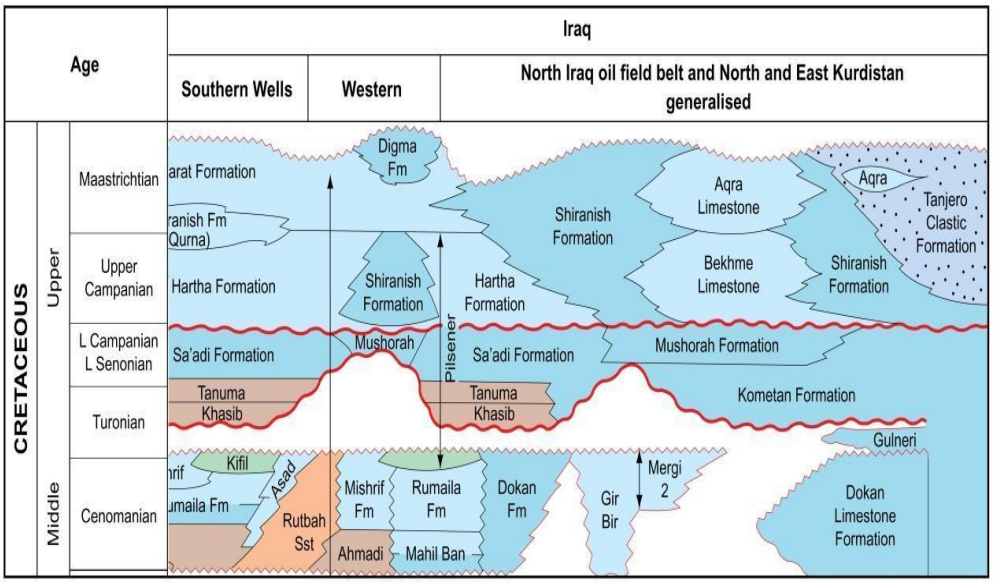

Figure 1: Schematic regional rock unit correlation [18]

According to [18], the lower part of Megasequence AP9 is represented by the (Khasib, Tanuma, and Sa'di formations) and (Kometan Formations) (Figure. 2). The isopach of the Upper Turonian - Lower Campanian (three) depocenters appear in a sequence: the initially is the lagoonal facies and the deep inner shelf of the (Khasib, Tanuma, and Sa'di formations) the secondly is the basinal facies and outer shelf of the Kometan Formation.

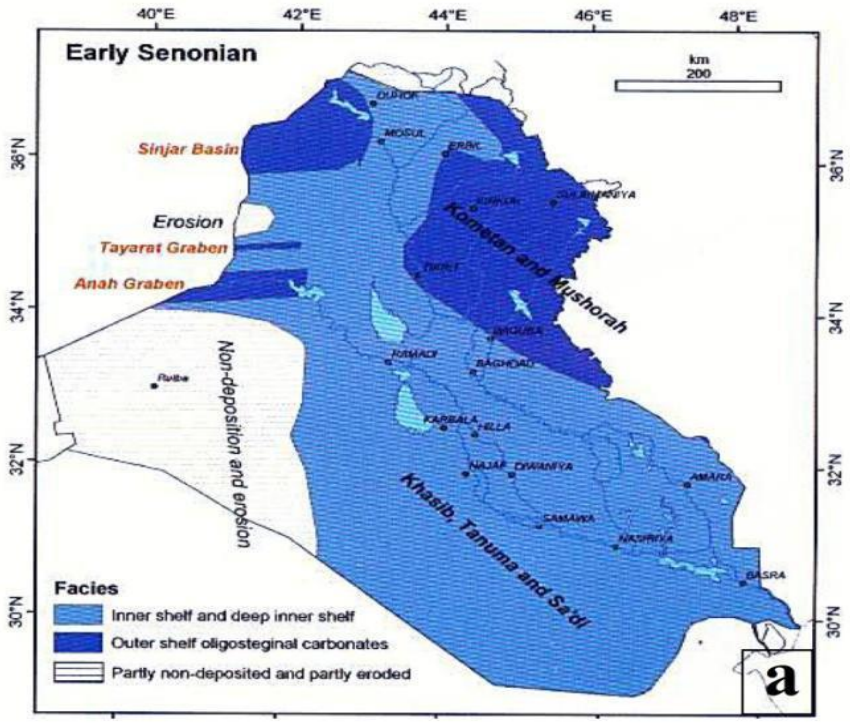

Figure 2 : Paleogeographic distribution of the lower Senonian rock units in Iraq [19].

According to [4], high organic carbon sediments from the Coniacian–Santonian era, particularly those with black shales rich in marine organic matter, are found in the Middle part of the Kometan Formation in this study. The same sediments are found in the South Atlantic, the Caribbean Sea, the United States, Venezuela, Columbia, Brazil, northern Namibia, Angola, Gabon, Ivory Coast, northwest Africa, and Morocco; they are also found in Libya and Egypt (Figureure 3).

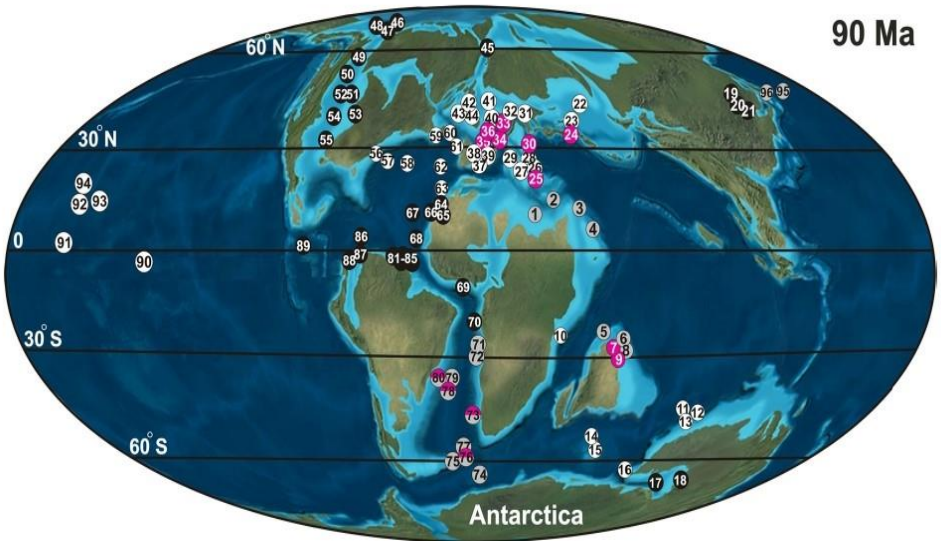

Figure 3: Palaeogeographic map at ca. 90 Ma Black circles represent areas with red circles denoting areas with red limestones/claystone, grey circles show sites with grey limestones/marls, and green/brown claystone split red/grey circles indicate sites with red claystone intercalations within green claystone/marl after [4].

5. Location of the study well

The samples used in this study were obtained from the well Bai Hassan oilfield, NW Kirkuk City, Northeastern Iraq. Tectonically, the studied well is located within the Foothill Zone [20] and [21] (Figureure 4).

The tectonics setting of Bai Hassan well is located within the Unstable Shelf. The structure extends in a northwest-southeast direction length of 35 km and a width of 3.5 km, where it is in a crescent shape and is located in the syncline between the Kirkuk structures on one side and the Qara Chouk structures on the other. The Bai Hassan well is located on the northern Dome of Daoud, separated from the southern Katha Dome by a fault that directly affects the tectonics of the Bai Hassan well [20]. The well located at 44° 24′ 28″ N and 36° 48′ 18″ E .

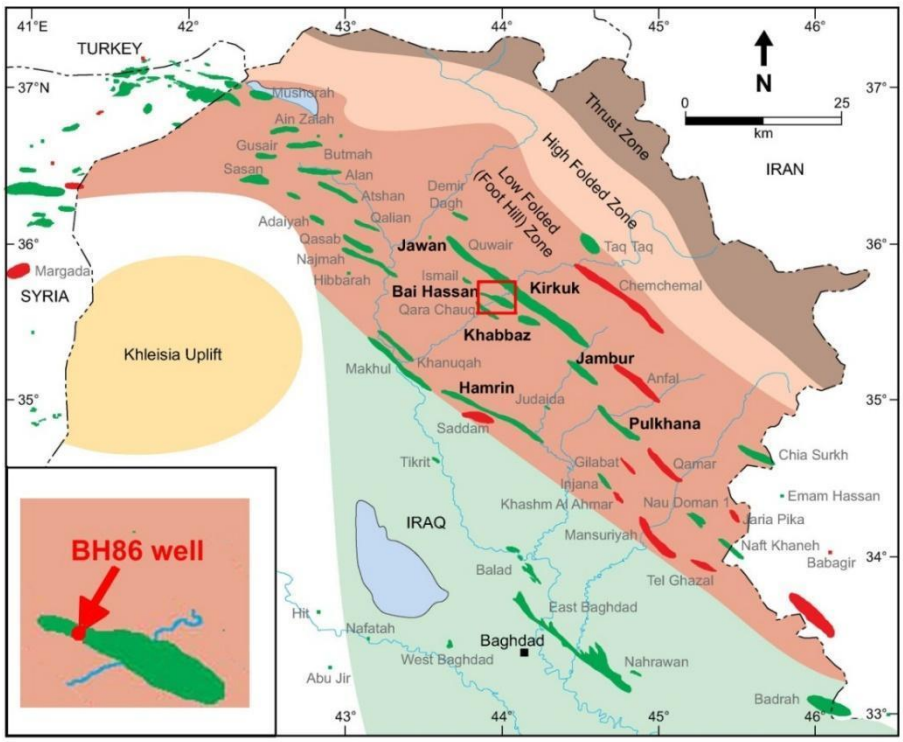

Figure 4: location of the studied section [21]

6. Result and Discussion

1-Nannobiostratigraphy

The five following biozones are recognized based on the stratigraphic distribution of the studied species. (Figure.5) (Figure. 6) :

- *Eiffellithus Eximius* Interval Zone (CC12)

Definition: The initial occurrence determines the biozone of *Eiffellithus Eximius* and the first occurrence of *Marthasterites furcatus*

Thickness: (25) meters samples (Bh1)

Correlation and Discussion: There is a correlation with the biozone (CC12) (*Lucianorhabdus maleformis* biozone) by [22] and the corresponding upper part of UC8 biozone, which [23] is researching; as a result, we proposed the Late Turonian [24] , And equivalent with lower part of *Marthasterites furcatus,* described by [25] Santonian age. From previous studies, *Lucianorhabdus maleformis* (late Cenomanian- early Turonian) descriptions are [26].

- *Marthasterites furcatus* Interval Zone (CC13)

Definition: The initial occurrence determines the biozone of *Marthasterites furcatus* to the first occurrence of *Micula staurophora*.
Thickness: (55) meters samples (Bh2)
Correlation and Discussion: There is a correlation with the biozone (CC13) (*Marthasterites furcatus* biozone) by [22], and a correlation of (UC9) biozone, which is studied by [23] is researched; as a result, we proposed the Late Turonian [24], the name *Marthasterites furcatus* biozone has been used by several authors with different definitions for the lower part of the zone [25], and correlated upper part of UC9 biozone which is studied by [26].

- *Micula staurophora* Interval Zone (CC14)

Definition: The initial occurrence determines the biozone of *Micula staurophora*to first occurrence of *Reinhardites anthophorus*.
Thickness: (35) meters samples (Bh3)
Correlation and Discussion: There is a correlation with the biozone (CC14) (*Marthasterites decussate* biozone) by [22] and correlated with (UC10) biozone, which is studied by [23]; as a result, we proposed the Coniacian [24].

- *Reinharditesanthophorus* Interval Zone (CC15)

Definition: The initial occurrence determines the biozone of *Reinhardites anthophorus* to the first occurrence of *Lucianorhabdus cayeuxii*.
Thickness: (70) meters samples (Bh4)
Correlation and Discussion: There is a correlation with the biozone (CC15) (*Reinhardites anthophorus* Biozone) by [22], and correlated upper part of (UC10) and lower part of (UC 11) biozones, which is studied by [23] is researching; as a result, we proposed the Early Santonian [24].

- *Lucianorhabdus cayeuxii* Interval Zone (CC16)

Definition: The initial occurrence determines the biozone of *Lucianorhabdus cayeuxii* to the first occurrence of *Calculites obscurus*.
Thickness: (12) meters samples (Bh5).
Correlation and Discussion: There is a correlation with biozone (CC16) (*Lucianorhabdus cayeuxii* Biozone) by [22] and correlated lower part of (UC11) and upper part of (UC12) biozones, which is studied by [23] is researching; as a result, we proposed the Late Santonian [24].

2- Depleting of oxygen results from organism mortality

The oceans are losing oxygen, and oxygen minimum zones are expanding due to climate warming (lower O2 solubility). This trend is challenging for most marine taxa that are not well adapted to O2 depletion. Several species possess adaptations to O2 depletion that are rare amongst eukaryotes, and some foraminifera can calcify even under anoxic conditions. They are important archives for paleoceanographic reconstruction in O2-depleted environments [27].

The anoxic waters, however, probably developed due to high surface productivity associated with the plate-tectonic movement of these oceanic plateaus across the highly fertile equatorial belt during Cretaceous time [1].
Marine anoxia is characterized by the oceans being severely depleted in dissolved oxygen, making them toxic and thus having devastating impacts on the organisms inhabiting them. One such event, known as an OAE, during such scenarios, organic matter is buried at an elevated rate, producing distinctive layers of black shale in the geological record; persistent low-oxygen layers increase in number and size with enhanced warming of the oceans, with ongoing global warming, it is predicted that oxygen minimum zones warmer water holds less oxygen, and increased surface temperatures can lead to stronger stratification of ocean layers [28]. Additionally, global warming can enhance biological activity in surface waters, resulting in

more organic matter sinking to the depths, where it consumes oxygen as it decomposes, a process evident during OAE. [29].
Diversity in calcareous nannofossils, planktonic foraminifers, and other organisms appears more significantly regulated by the growth of suitable habitats during periods of high sea level and high temperature, as well as the abundance of calcareous nannofossils are a clear gradation of climate was recorded, from hot in the Turonian to warm in the Coniacian. A gradual cooling in the early Santonian is accompanied by a rising sea level and a warm climate, with increased CO_2, black shale and a decrease in O_2 [30].

This is consistent with what was stated in the current study of the Kometan Formation, where recorded black shale beds in the middle part of the Bai Hassan well in depth about (1825-1895) m. with occurrence evidence as of dwarfism planktonic foraminifera, elongate of the planktonic foraminifera chamber, presence accumulation of thin shells (Filament allochems), it is synchronized with rising temperatures from sea level changes and the sediments form under Conditions of oxygen loss. Therefore, it was proven that the OAE3 occurred throughout the age range of late Turonian to early Santonian. This is the period that coincided with high sea levels and high temperatures.

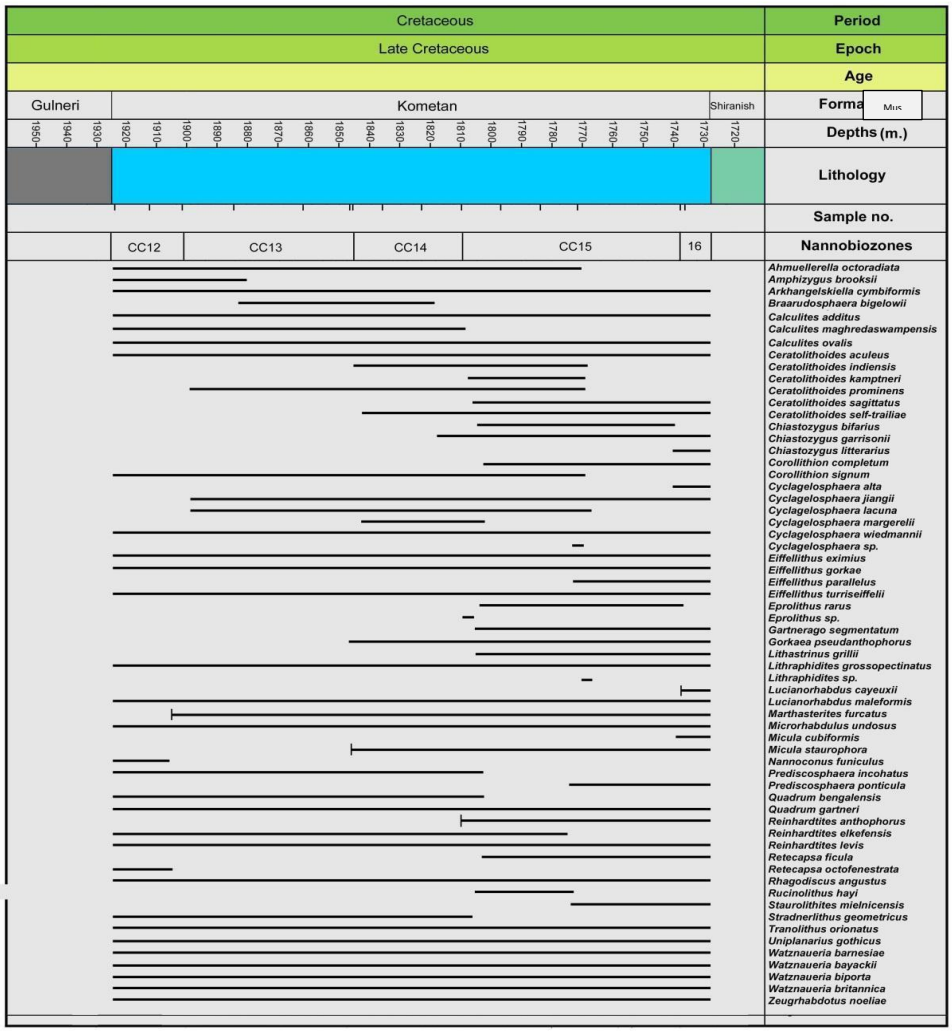

Figure 5: Nannobiozones of Calcareous Nannofossils of study section

Figure 6: Local Correlation diagrams for the study section's biozones of calcareous nannofossils

7. Study of rock characteristics by using Gamma-ray logs

The current study focused on the Bai Hassan oilfield on the North Daoud Dome, which is visible on the surface and contains many major faults [13]. The Bai Hassan well was studied based on the available log values used to determine the black shale volume through modern software (Interactive and Petrophysics Didger 3.5).

The M-N and Matrix Identification Plot (MID) methods are used. The rocks in the Bai Hassan -86 well consist of limestone (calcite) and dolomitic limestone and are affected by dolomization. The middle unit Ko2 is characterized by a high concentration of points in the black shale area within the limestone rocks' fractures, indicating the formation of gas (Figure.7) (Figure.8).

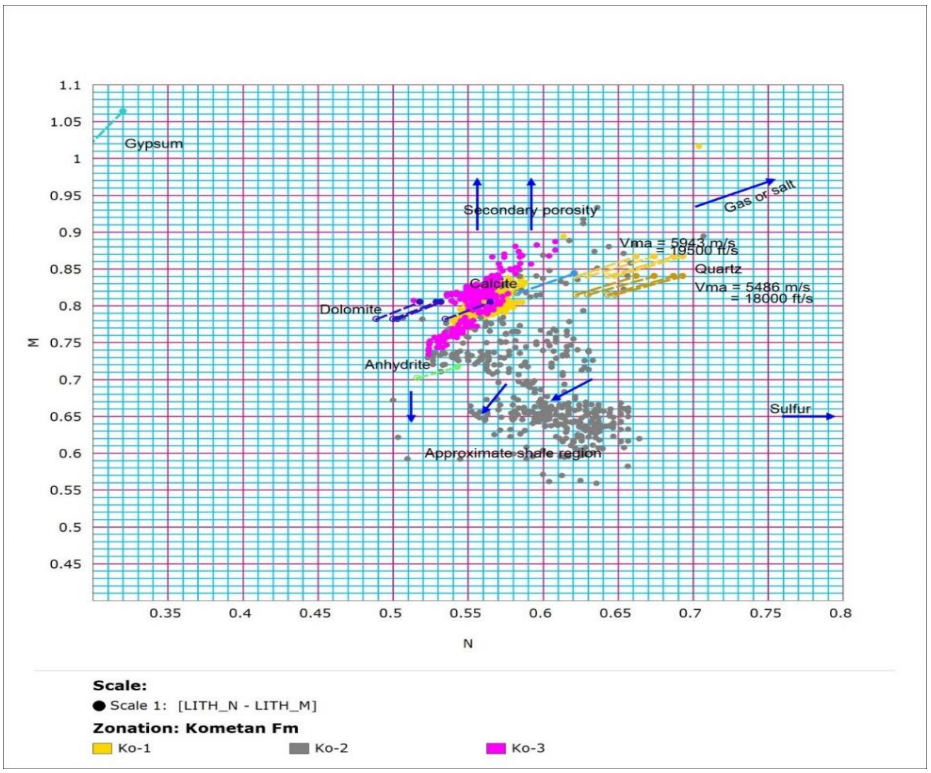

Figure 7: Mineral profile by M-N method for well Bai Hassan.

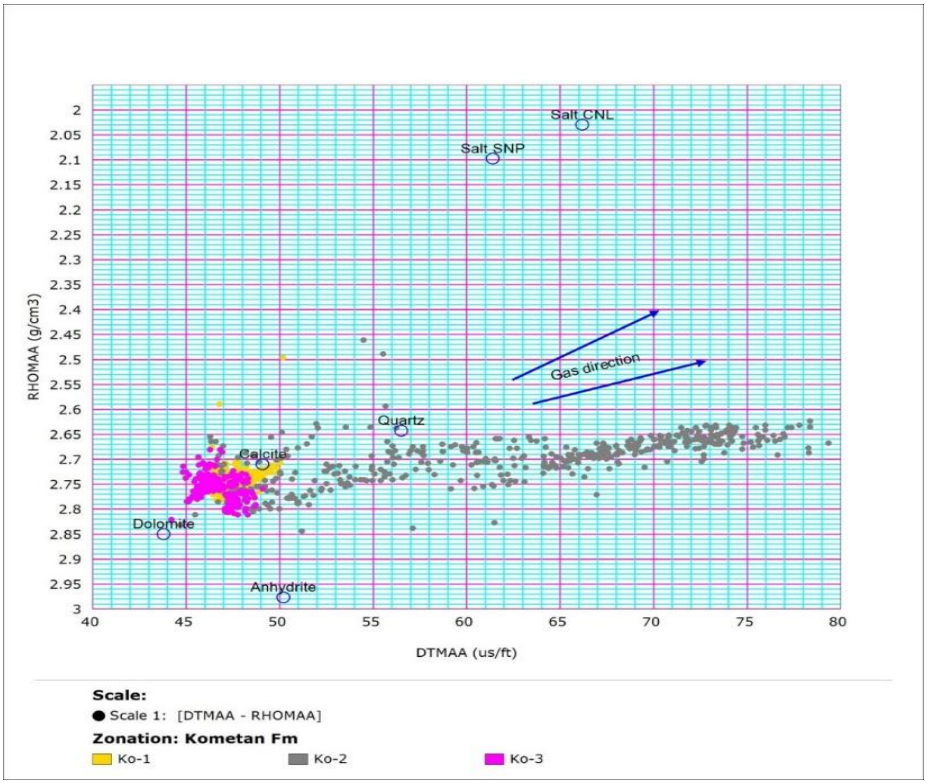

Figure 8: MID lithology profile for well Bai Hassan

8. Oceanic Anoxic Event (OAE-3)

The Cretaceous is the last and longest period of the Mesozoic Era, where the earth experienced some major geological events, such as oceanic anoxic events [31], which are episodes of oxygen depletion in the water column, primarily resulting in the deposition of

organic-rich sediments known as black-shales, The OAE3, known through (Coniacian-Santonian), is the youngest Oceanic Anoxic event [32], [1]. OAE-3 have been documented in the geological sedimentary record, particularly in Cretaceous marine sediments, as complex paleoenvironmental phenomena and climatically influenced major geological perturbations of the earth system, especially the earth's carbon cycle and these complex geological events are characterized by global organic deposits [3], [33], and [34], the Coniacian-Santonian OAE3 evolution is less well-studied than compared with the Early Cretaceous (OAE1) and middle Cretaceous (OAE2) [35], according to [36] these events are linked to global warming due to the release of CO_2 from large-scale volcanoes and the dissociation of methane hydrates [37]. The geographical distribution of the OAE3 suggests that the Coniacian–Santonian oceanic anoxic events are restricted to the Atlantic and proximate basins [38].

OAE3 is a short-term phenomenon occurring in ancient oceans, deep and shallow environments. That event is characterized by warm climates followed by gradual cooling periods [39]. The most important evidence in the current study, which was compared with local and regional studies, is:

1- The researcher [40] in his study of the Valles-San Luis Potosi platform in Mexico [41], and [42] in studies of them at the Gulneri Formation in Northeastern Iraq, [43] in his research at Madingo formation in West Africa, and [44] the survey in Tanzania, and study [45] found it genera of planktonic foraminifera as (Heterohelix, Globigerinelloides, Archaeocretacea and Schackoina) reflect evidence of the occurrence of a lack of oxygen through its resistance to this deficiency, and record occurrence radiolaria, calcisphere, addition to conclude of dwarfism planktonic foraminifera. In [42] the Gulneri Formation in Northeastern Iraq, and [46] that since his study in Colorado and Suggest [47] in his study of the Valles-San Luis Potosi platform in Mexico, that the elongate of the planktonic foraminifera chamber is evidence of the event (OAE3).

2- [42] study of the Gulneri Formation in Northeastern Iraq and [48] a study in Central Mexico concluded the peak accumulation of thin shells (filament allochems) is evidence of the OAE3.

3- Southeastern [49], the study in China identifies condensed section, including glauconite and the sediments formed under Conditions of oxygen loss consist mainly of lamellar structures. They contain laminations that are dark in color have total organic matter, and lack benthic organisms is evidence of OAE3.

From the above, all the driving evidence recorded in previous studies indicates the event (OAE3) and the age, and this was consistent with many of the pieces of evidence that were recorded in the current study, where the presence of black shale (Figure.9a) and organic materials was diagnosed, as in the (Figure. 9b), and occurrence genera of planktonic foraminifera as (*Heterohelix)* (Figure.-9c), *(Globigerinelloides)* (Figure.-9d) *(Archaeocretacea)* (Figure.-9e) *and (Schackoina)* (Figure.-9f), and record occurrence radiolaria (Figure.-9g), Calcisphere (Figure.-9h), presence of accumulation of thin shells (Filament allochems) (Figure.10a), and include Glauconite (Figure.10b), addition to Conclude of Dwarfism planktonic Foraminifera (Figure.-10c), also the presence of diagnosed elongate of the planktonic foraminifera chamber (Figure. 10d), and the sediments form under conditions of oxygen loss consist mainly of lamellar structures they contain laminations that are dark in color (Figure. 10e).

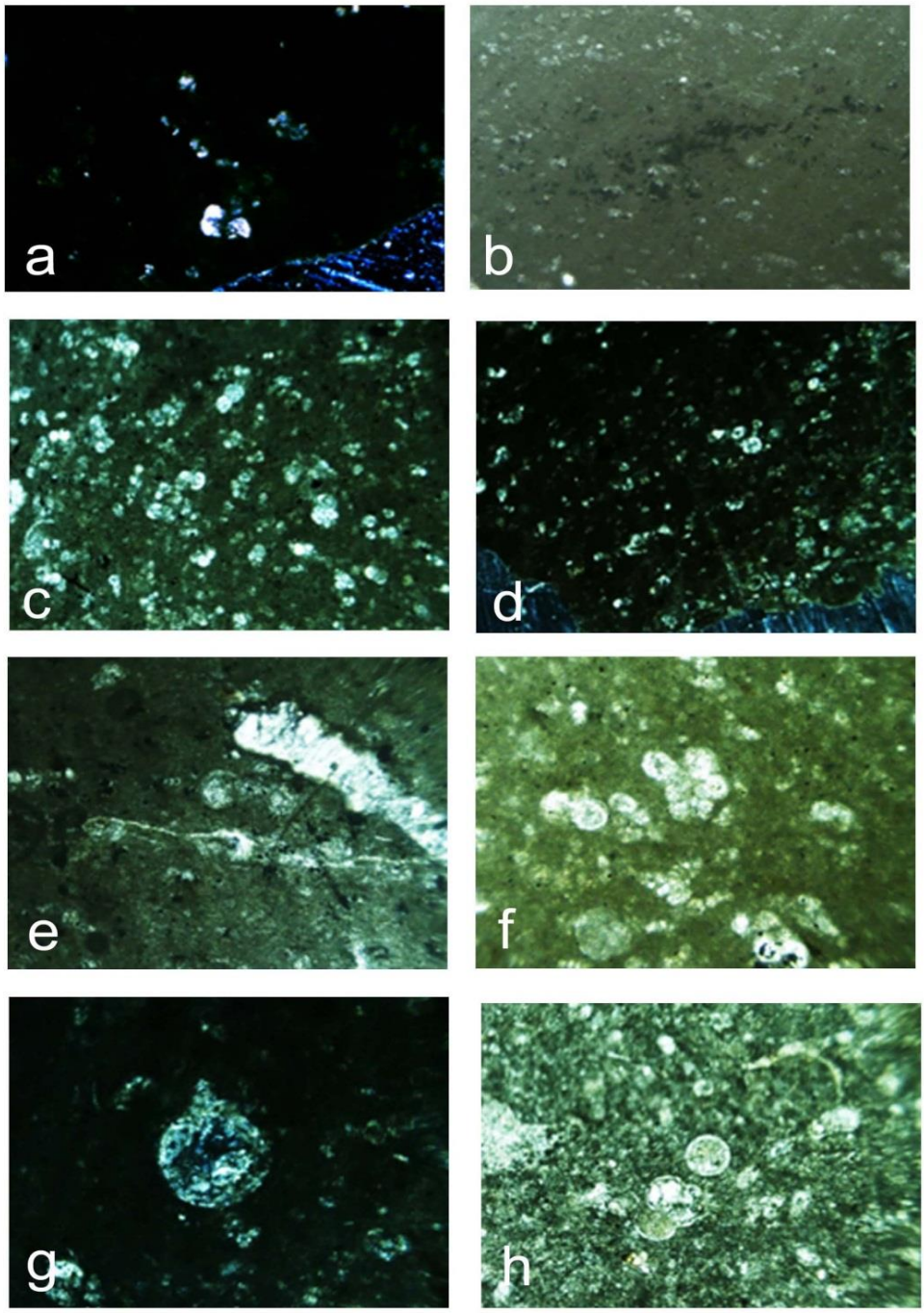

Figure 9: Microscopic Image for Microfacies for study section

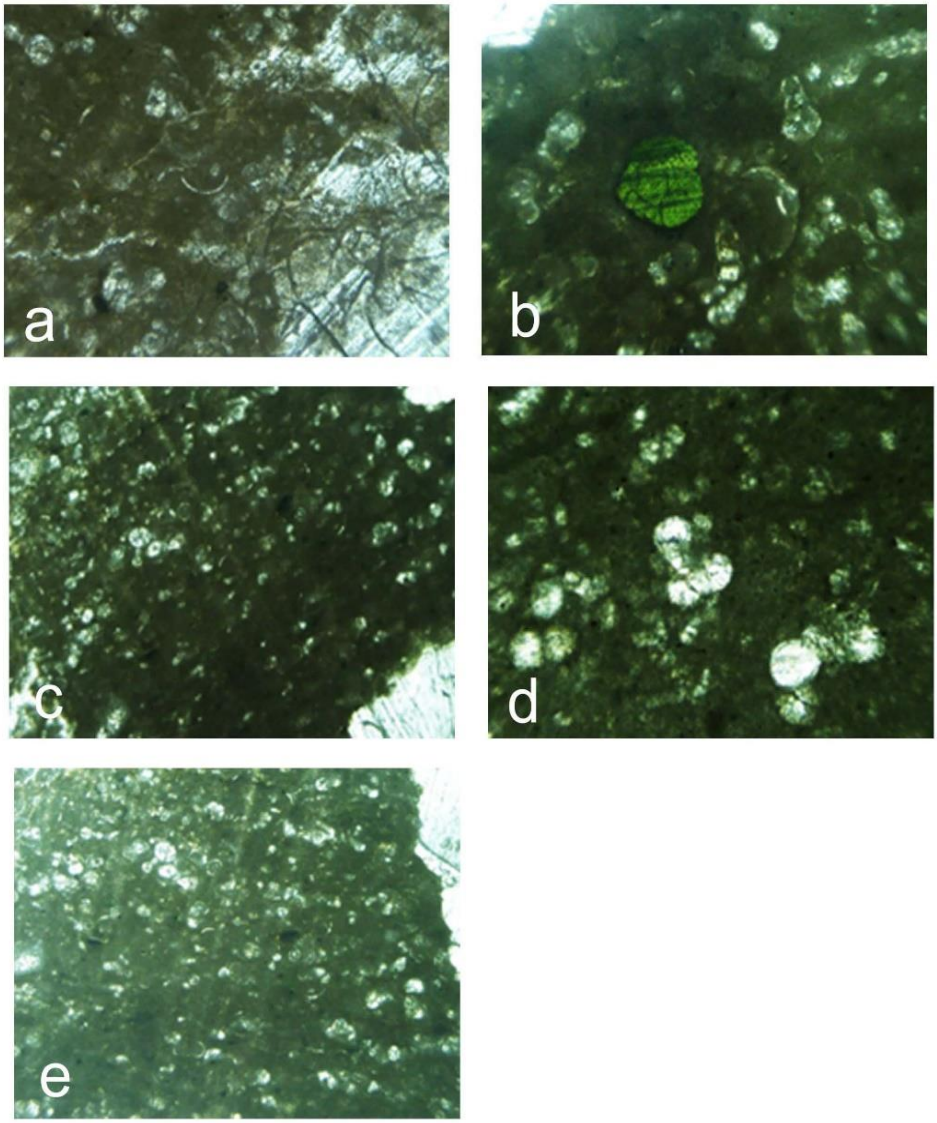

Figure 10: Microscopic Image for Microfacies for study section

Conclusions

1- The age of the Kometan Formation in Bai Hassan well is late Turonian to early Campanian based on biostratigraphic ranges of the information calcareous nannofossils biozones, which were arranged as follows, oldest to youngest :

Eiffellithus eximius Zone Interval Zone(CC12)

Marthasterites furcatus Interval Zone(CC13)

Micula staurophora Interval Zone (CC14)
Reinhardites anthophorus Interval Zone(CC15)
Lucianorhabdus cayeuxii Interval Zone(CC16)

2- The methods of the M-N and the Matrix Identification Plot (MID), the rocks in the Bai Hassan-86 well consist of limestone and dolomitic limestone and are affected by dolomization. The middle unit Ko2 is characterized by a high concentration of points in the black shale area within the limestone fractures, indicating gas formation.

3- The middle unit of the Bai Hassan-86 well, located at a depth of approximately 1825-1895 m in the Kometan Formation, contains black shale. Planktonic foraminifera evidence, specifically Heterohelix, Globigerinelloides, Archaeocretacea, and Schackoina, suggests the presence of dwarfism in planktonic foraminifera. Additionally, elongated chambers of planktonic foraminifera and an accumulation of thin shells known as filament allochems were observed.

4- According to calcareous nannofossils biozones in unit Ko2 of the Bai Hassan, the OAE3 was recorded in late Turonian – early Santonian.

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