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The Late Cretaceous X Reservoir Petrophysics Properties and its Oil Geochemistry in the Nameless Oilfield, Mesopotamian Basin, South Iraq

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Abstract

The X Formation, which dates from the Late Cenomanian to the early Turonian, is the largest carbonate reservoir in Iraq's South Mesopotamian Basin. There are two shallowing-up depositional periods in it, which begin with deep water mudstone associated with wackestone, which gradually shallows into rudist and is dominated by big foraminifera shoals and barriers, which are followed by lagoonal and intertidal facies. The identification of five distinct reservoir rock types, including mB2, mB1, CRII, mA, and CRI, was based on a combination of sediment types and diagenetic processes that influenced porosity types. The formation oil geochemical studies point to a Lower Cretaceous marine carbonate source depositional environment that is early mature and anoxic.

Keywords: X reservoir, Depositional System, Porosity, Reservoir units, Biomarkers, Nameless field, Iraq

الخصائص البتروفيزيائية لخزان X العصر الطباشيري المتأخر والكيمياء الجيولوجية للنفط في حقل نفط "بدون اسم"، حوض بلاد ما بين النهرين الجنوبي، العراق

الخلاصة:

يعتبر تكوين X، الذي يعود تاريخه من العصر السينوماني المتأخر إلى أوائل العصر التوروني، أكبر خزان كربونات في حوض جنوب بلاد ما بين النهرين بالعراق. هناك فترتان ترسيبيتان ضحلان، تبدأان بحجر طيني في المياه العميقة مرتبط بالحجر الجيري، والذي يتحول تدريجياً إلى روديست ويهيمن عليه مستنقعات وحواجز فورامنيفيرا كبيرة، تليها سهول بحيرة ومدية. أدى تكامل أنواع الرواسب والعمليات التحويرية التي أثرت على

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أنواع المسامية إلى التعرف على خمسة أنواع مختلفة من صخور المكمن، وهي ؛ mB2 و mB1 و CRII و mA و CRI. تشير تحليلات الجيوكيميائية لنفط التكوين إلى أنها نشأت أساسًا من بيئة ترسبات مصدرية من الكربونات البحرية منخفضة النضج من العصر الطباشيري السفلي، في بداية نضوجها الحراري وبيئة مختزلة.

1. Introduction

The Nameless oilfield is considered one of the promising fields located around 70 kilometers northwest of Basra. The oilfield is structurally part of an asymmetrical elongated anticline [1]. Which may have been produced by salt intrusion. The Field is approximately 40 kilometers long and 10 kilometers wide, Figure (1) A and B.

In terms of stratigraphic succession, the Cretaceous epoch in Iraq and the Middle East is regarded a one-of-a-kind sedimentary period. Some of the period layers are key source rocks that produced large amounts of hydrocarbons, while others, such as the X Formation, operated as excellent hydrocarbon repositories. The X Formation in southern Iraq dates from the late Cenomanian to early Turonian. During the Upper Cretaceous (Cenomanian–Early Turonian), it was part of a larger carbonate platform system that stretched from Iraq to Oman across the Arabian Plate [1].

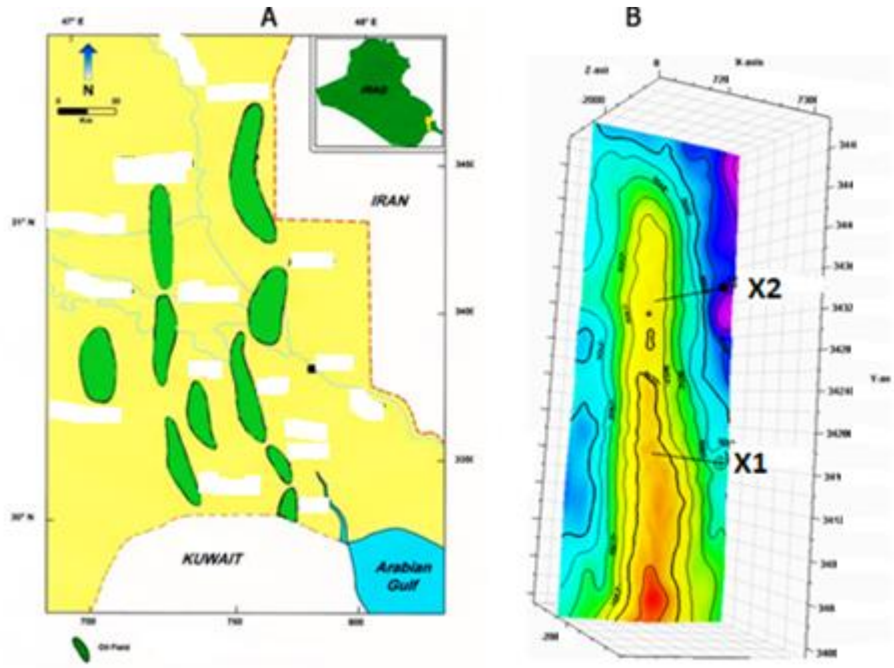

Fig. (1): (A). Map of South Mesopotamian Basin shows the location of the Nameless. (B); Structural map of Nameless oil field with the location of the studied boreholes wells (X1 and X2).

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Because of their excellent reservoir qualities and extensive distribution, The X sediments are one of the Mesopotamian Basin's most significant oil reserves. After the Y1 Formation, this formation is the second-largest oil deposit in southern Iraq, accounting for up to 30% of Iraq's oil reserves, [2] . It also evolved a distinct lithological architectural, which was deposited in several sedimentary contexts on a carbonate shelf. The mB2, mB1, CRII, mA, and CRI manufacturing units are divided into many production units (from oldest to youngest) that are roughly 200 meters thick. The mB2 component is the most prevalent in the Nameless Oilfield.

The Late Tithonian-early Turonian HST of the X Formation is the second-order sequence of the (AP8) of Arabian Plate sequence stratigraphy (148 to 92MA), Figure (2). According to [3], the Transgressive System Tract (TST) includes the Underlying Y2 Formation, whereas the Highstand Systems Tract includes the Y3 and X Formations (HST). The Y3 Formation that conformable and gradational transition with the overlying X Formation is primarily composed of chalky and marly limestones [5]; [6]; [7]).

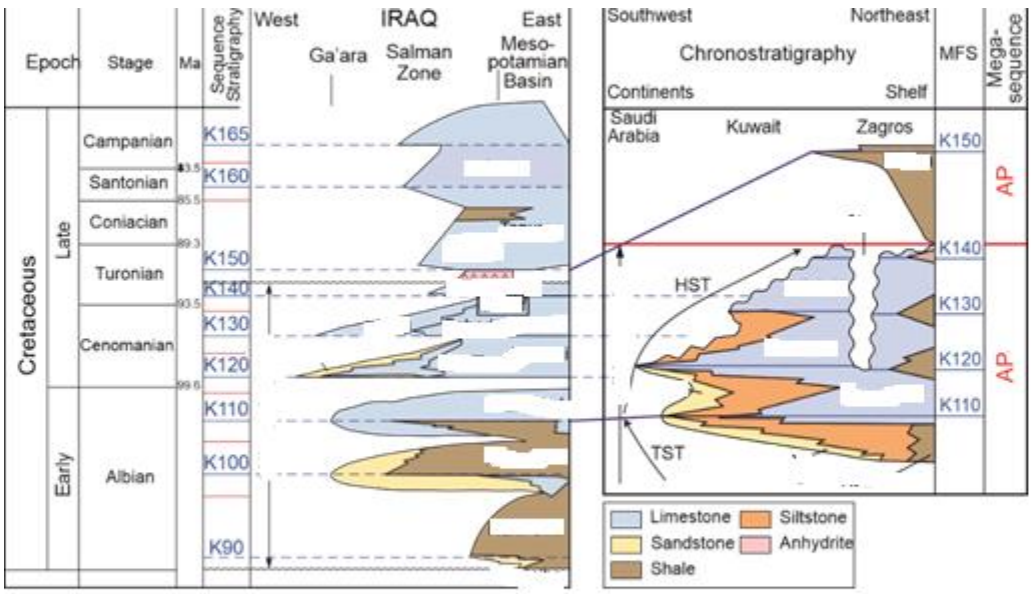

Fig. (2) Regional chronostratigraphy and stratigraphy of the X Formation in the Arabian Plate including southern Iraq, modified from [3], modified after [4]

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Six facies and twenty-one microfacies make up the X Formation [4], (1) Mid-ramp facies, which are mud-dominated rocks and refer to the basin's deeper section as follows: (a) Mid-distal ramp: Planktonic foraminifera and a few bioclast fragments can be found towards the mid-distal ramp's end. (b) Proximal ramp: In addition to bivalve and echinoderm fragments, the proximal ramp is rich in rudist.

(2) Rudist bioherm facies, occupied by rudist and debris grains. (3) Shoal facies consist of Echinoderms, corals, bivalves, algae, and tiny benthic foraminifera. (4) Back shoal facies, which comprises rudist packstone or wackestone, benthic foraminifera, and bivalves, were the back-shoal facies. (5) Lagoon facies content small benthonic foraminifera from packstone and wackestone, such as alveolinids, miliolids, and textularids, make up the fifth lagoon facies. (6) Intertidal facies are a preponderance of mud that is insufficiently fossiliferous and contains thin units of algal wackestone describes. [8].

There is a lot of studies out there about the petroleum geochemistry of this formation (e.g., [9]; [10]). However, the purpose of this study is to link the qualities of formation oils to their depositional settings. It will also try to understand how the reservoir quality of X reservoir rock types has evolved over time in this field, taking into consideration facies depositional facies, and diagenetic overprints.

2. **Methods and Materials**

Two borehole wells in the Nameless Field (x1 and x2) had their Gamma Ray, Neutron, Density, and Sonic logs analyzed and interpreted. A polarized-light microscope was used to examine 35 thin sections from X Formation cored intervals to evaluate their microfacies [11]. The principal diagenetic process, porosity, and permeability using the [12] classification. All of the data was shown on well logs in order to identify important system tracts and depositional environments in which the studied rocks originated, Figure (1).

This study was carried out according to the procedure outlined below.

Texture, color, sedimentary structures, hardness, grain size, diagenetic characteristics, visual porosity, inclusions, and oil shows are all lithological characters that can be identified in the accessible core samples from the two examined borehole wells. Petrographic analysis of tiny sections cut from these cores.

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These were investigated under a polarized-light microscope to determine their microfacies [11], principal diagenetic process, that affected the porosity and permeability according to the [12] classification.

To identify horizontal and vertical facies changes, important system tracts, and depositional locations in which the studied rocks were deposited, all data were displayed on borehole well logs. Facies analysis, elecrofacies, and determined porosity were used to divide the X Formation into reservoir units. Then, for third-degree sequence stratigraphy, link these to the system tracks.

Multiple biomarkers and non-biomarkers analyses, such as GC, GC/Ms, Carbon isotope, and bulk properties were used to investigate the geochemical characteristics of X Formation crude oils at the GeoMark research facility in Houston, Texas, USA.

3. Results and Discussion

3.1. Depositional system tracts

The X Formation is divided into two depositional cycles, each of which constitutes a 3rd order stratigraphic sequence, Figure (3). [5], [1].

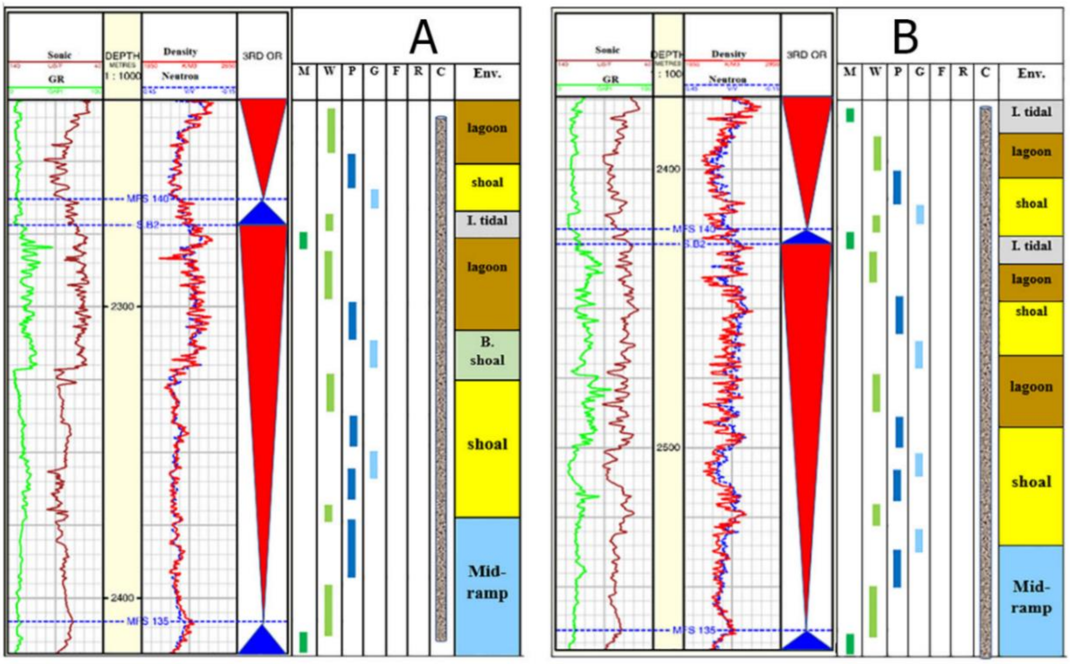

Fig. (3) Sequence stratigraphic subdivision, depositional cycles and main the depositional environments, based on the wireline log analysis only of the two wells from NamelessField.

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As a transgression system tract, the first cycle begins at the top of the underlying Y3 Formation. It is characterized by wackestone-floatstone and mudstone from an open shallow marine depositional environment, depending on the depositional environment's hydrodynamic circumstances. The K135 cycle reflects the first cycle of the Maximum Flooding Surface, which may be recognized as clay seams in cores and, less occasionally, as an increase in the micritic composition of rocks. The Highstand Systems Track corresponds to sediments in the form of bioherm accumulation or shoal deposits above this MFS (HST). They are covered by lagoonal deposits, and tidal sediments complete the cycle. The disturbance of these typical facies sequences is most commonly manifested in the sequence structure. This is indicated by the presence of exposed surfaces, subaerial sediments, and washout of previously deposited sediments [4], [14].

3.2.Facies association

The X Formation rocks investigated can be divided into six distinct facies associations. They are strewn over the two significant sedimentary periods mentioned above. The contents of both cycles are the identical, but the facies and periodicity are different. The bottom cycle begins with mudstone and peloidal-bioclastic wackestone sediments coarsening upward into a subtidal shoal containing bioclastic debris, big foraminifera, and algae from mid-ramp sediments. The shoal transforms into a barrier shoal with coarser rudist debris and other shell fragments as system energy and shallowing increase, Figure (4).

The X Formation top section is represented by the second cycle. It's linked to a new regional deluge that engulfed the Arabian plate's whole eastern parts. Unit mA, which contains the MFS K140, is included in the cycle [3]. The occurrence of calcareous mudstone with planktonic foraminifera distinguishes this surface [14]. The cycle shallows up into another bioclastic shoal, which then transforms into Y4 Formation lagoonal and sabkha deposits [15].

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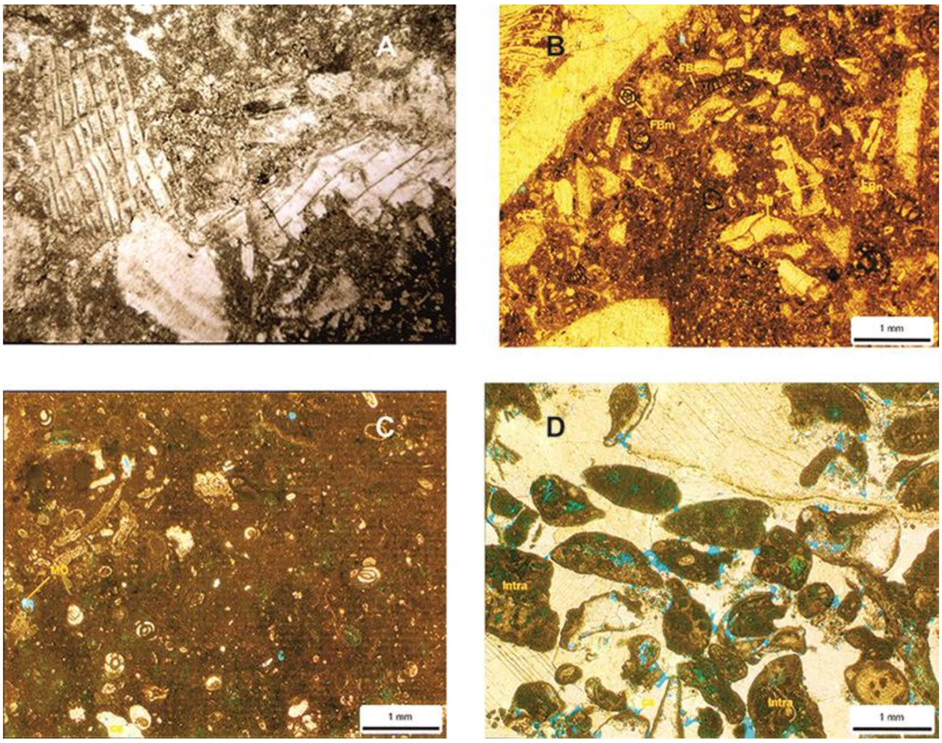

Fig. (4) Photomicrographs of the main microfacies in the X Formation carbonate in the x1 well, (A) Rudist-dominated shelf made mainly of large rudist debris and other shell fragments. (B) Bioclastic packstone/wackestone of rudist fragments, miliolids, textularia, ovalveolina, Nezzezata, rotalids, echinoderm fragments and bivalves, (Lower cycle, HST, 2340m). (C) Bioclastic packstone - wackestone of benthic foraminifera including milliolids, Nezzazata, Praealveolina, planktonic foraminifer tests and bivalve shell fragments, (Lower cycle, TST, 2390). (D) Allogeneic lime mudstone with scarce skeletal grains such as benthonic and planktonic foraminifera, echinoderms, and bivalve shell fragments, (Second cycle, HST, 2240m).

3.3. Diagenetic processes

Throughout the Cretaceous, the Arabian Plate, encompassing southern Iraq, was in a tropical climatic zone. This meant that a significant volume of fresh water was available. Several diagenetic characteristics of Cretaceous carbonate deposits, notably the X Formation [1] may be traced back to this. Freshwater sediments [15] meteoric water percolation [14] and karst landforms [1] are some of these. As a result, freshwater activity, such as dissolution and precipitation through cracks and joints, is responsible for the majority of the diagenetic characteristics of the investigated strata. When exposed to subaerial exposures, At the top of shallowing-

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up sequences, these features are more pronounced. The bulk of the porosity and permeability of the Formation was formed as a result of these processes. As a result, these facies have high porosity and permeability, making them ideal reservoir rock types.

3.4.Porosity types

The X formation's porosity and permeability patterns such as rock types and reservoir quality are closely linked to its facies distribution and diagenetic overprints. The X Formation rock types were established using [1] a formula dependent on depositional facies type and diagenetic processes that have been overprinted. The Transgressive System Tract's wackestone-packstone facies has the greatest intergranular porosity (TST). The Highstand System Tract (HST) has many types of porosity, including moldic porosity, vuggy porosity, enlarged-cemented intragranular, and cavern porosity, Figure (5).

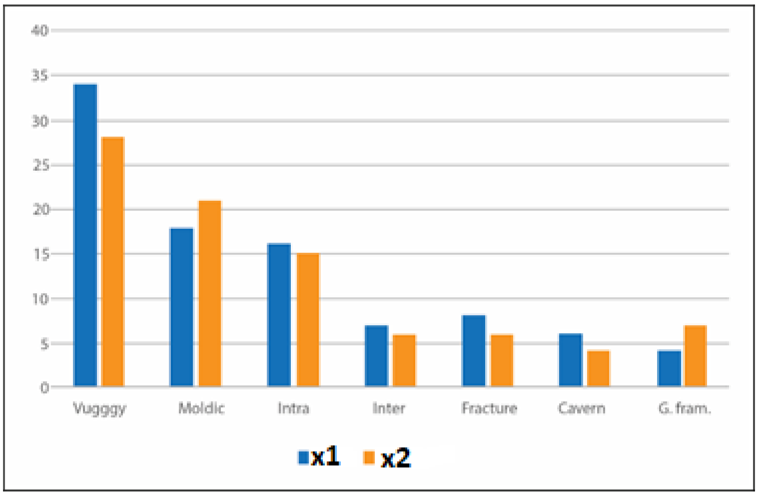

Fig. (5) Histogram showing the type and percentage of each porosity type in the two studied wells from x1.

They're mostly found in shoal and lagoonal depositional environments, which are more susceptible to meteoric freshwater impact than other areas of the basin. because the shoals are greater and the lagoons are closer to dry land. Another forms of porosity that are less common include those related to tectonic processes, such as fissures created by the Hormuz salt's upward movement. [14], or caves and karst structures

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caused by freshwater percolation during the formation's subaerial exposure [1]; [14].

3.5.Reservoir rock types

When the primary depositional microfacies creating the X Formation rocks were combined with its overprinted diagenesis, distinct porosity types resulted, allowing the formation's reservoir rock types to be identified in the investigated wells. This is a crucial stage in determining the X Formation's reservoir characteristics (e.g., [4]) By adding permeability and production statistics to these units, they may be utilized to define the reservoir's flow units. The following are the primary reservoir rock types, in order of best to worst:

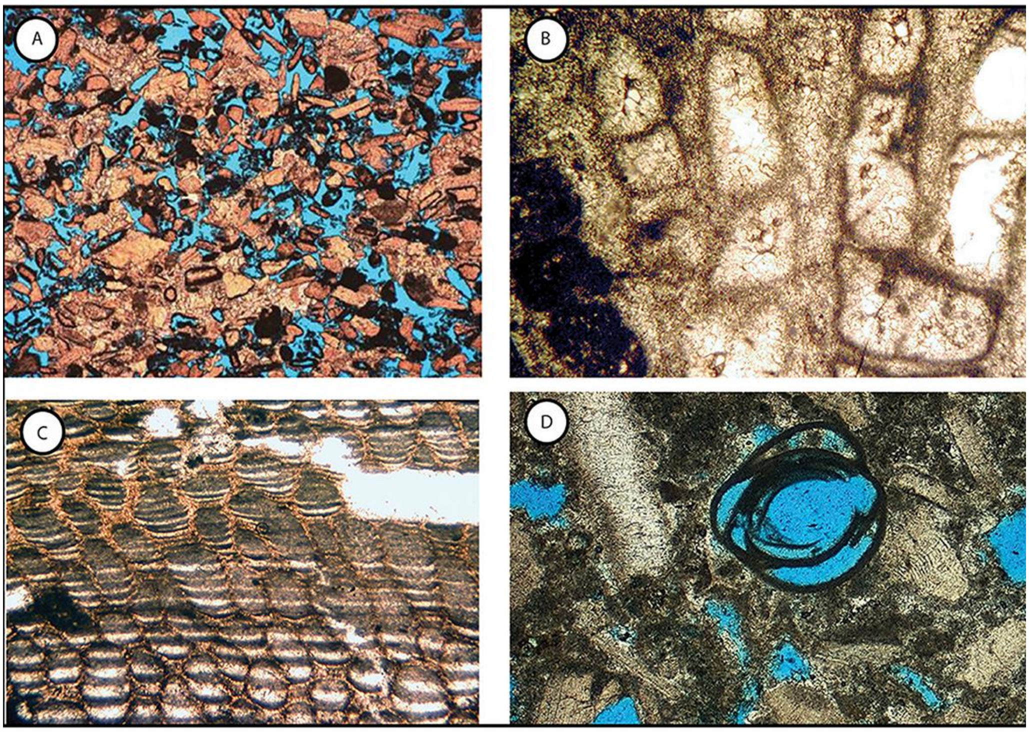

Fig. (6) Examples of the porosity types in the studied rocks (A) Intergranular porosity in grainstone made predominantly of skeletal fragments probably rudist. This is the best reservoir rock type and is the main oil producer in the formation (B) Intragranular porosity inside a big rudist shell. The pores are enhanced by dissolution with some cement lining them (C) Framework porosity which is found mostly in the rudist shelf. The rudist was probably in growth position. The pores are also enhanced by dissolution (D) moldic porosity resulted from the dissolution of a foraminifera skeleton. Only the micritized walls of the shell are left.

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- RT1: this type of rock class comprises grainstone and grainstone (bigger than 2 mm), [11] with vuggy porosity, moldic, and cavern porosity, and rudstone with moldic, vuggy, and cavern porosity. This kind of reservoir rock contains mA and mB2 units and shows better reservoir units which have higher porosity more than 26% percentage and permeability estimate of 70mD values.
- RT2: this rock type is made up of grainstone and packstone with moldic porosity and intragranular porosity. This tyoe comprises the mA, mB1, and mB2 units, which represent excellent reservoir units which have a good porosity more than 22%, and permeability that of more than 300 mD characteristics.
- RT3: This type comprises of vuggy and intergranular porosity packstone and wackestone. It comprises the unit’s mA, mB1, and mB2. It reflects medium-quality units which have medium porosity with more than 22% percentage and medium permeability which have more than 100mD values.
- RT4: Wackestone with fracture porosity makes up this rock type. The mA, mB1, and mB2 units indicate low quality units with low porosity with 10% percentage and permeability with about 50mD values.
- RT5: mudstone with no apparent porosity is included in this rock category. It is generally found in cap rocks or may be is a source rocks and has no observable porosity about 5% or permeability with value about 0.5mD characteristics, therefore it is classified as a cap rock, Figure (6).

3.6. Organic Geochemistry

The pristane/nC17 against phytane/nC18 ratio, Figure (7A), the pristane/phytane and stable carbon isotope ratio, Figure (7B), and the V/ (Ni + V) ratio for the studied crudes may all be used to establish genetic links between type of organic matter, and the depositional settings. They point to a non-biodegradable, mostly marine algal organic matter that was maintained under reducing conditions in our case. [16].

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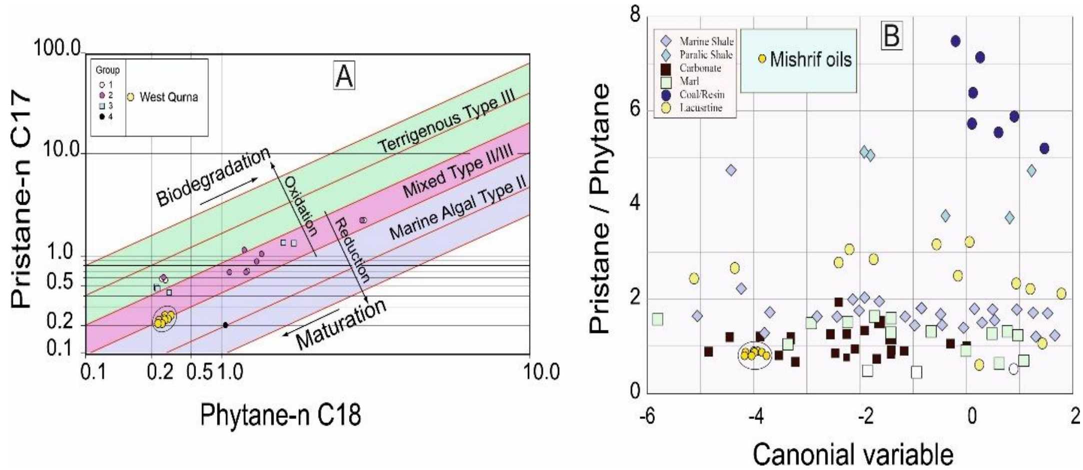

Fig. (7) A. Pristane-n C17 and Phytane-n C18 plot of the analyzed oil deposits of mainly kerogen type II/S, anoxic paleoenvironments and early mature source of the X Formation oil for Nameless oilfield in southern Iraq, [16]. B. Canonial Variable (CV) versus Pristane/Phytane diagram show that X Formation crude oil samples from Nameless oilfield have low values for the canonical variable (CV) and pr/ph, consistent with the anoxic, marine source-rock depositional environment. CV <0.47 indicates mainly non-waxy marine oils, [13].

The X Formation oils have high C22/C21 and C35S/C34S hopanes 1.21 and 1.13, respectively, as well have low C24/C23 tricyclic terpanes with an average of 0.28, which might imply that the carbonate source was marine. Anoxia marine carbonate source rock habitat was suggested by high norhopane/hopane ratios of 1.49 and C35S/C34S hopane ratios [16]. The X Formation oils was obtained from Berriasian-Tithonian Sulaiy source rocks, according to the Sofer, (1984) plot of aromatic and saturated fractions values, Figure (8A). (See, for example, [17]; [18]).

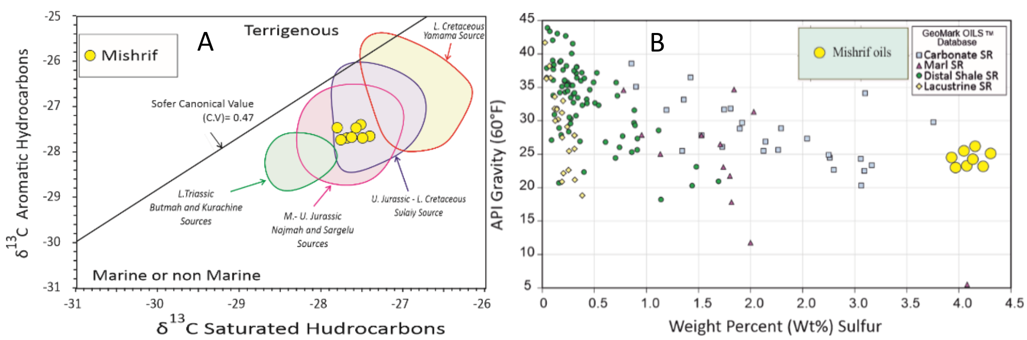

Fig. (8) A. A plot showing the stable carbon isotope ratio values of aromatic saturated fractions [13]for analyzed X Formation crude oils and the Cretaceous Y5 and Y6 source rocks of [18](B). B. A plot of the API Gravity and weight % sulfur of the X Formation crude oils from Nameless oilfield, southern Iraq. Other data points

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are from GeoMark Research OILS™ database [10]

3.7. Maturity of the X Formation crude oils

The characteristics of several biomarkers can be utilized to predict crude oil maturity. For the examined samples, the C27 Ts/Tm sterane ratio averaged 0.22, C29 20S/R ratio averaged 0.63, and TAS3 (CR) ratio averaged 0.33, indicating early mature source rock. API gravity values of 250 on average, sulfur content about 4.5 on average, and V/ (Ni + V) ratio have 0.22 on average confirm this [16], Figure (8B).

4. Conclusions

The X Formation is divided into two depositional cycles, each of which begins with a type 2 sequence border and two system tracts (TST and HST). Each cycle begins with deeper facies and progresses upward to a limited lagoon or intertidal zone. The formation's lithofacies include mudstone, bioclastic, and poloidal rock suites with rudist, foraminifera, and green algae. Microfacies types and over-printed diagenetic processes impacting these facies are highly linked to porosity kinds and distribution. Cavern porosity moldic, vuggy, and developed from the impact of freshwater in the top portion of the HST and lagoonal sediments because of relatively high elevation or proximity to the dry land Tectonic impact or karstification by freshwater percolation create fracture and cavern porosity. Microfacies and porosity types were combined to identify five reservoir rock types, ranging from good reservoirs to rocks with no discernible porosity.

The X Formation oils were non-biodegradation and early mature, deposited in a reducing marine environment, according to detailed analyses of eight crude oil samples from the studied Formation. The oil characterization matches that of Late Jurassic and Early Cretaceous source rocks.

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