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Assessment of the Lower Cretaceous source rock using PetroMod approach in West Qurna Oilfield- Southern Iraq

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Abstract

The L. Cretaceous succession is the main reservoir rock in the south of Iraq. Although the upper Jurassic Sargelu Formation is the main source rock in this area; however, the organic-rich interval within the studied succession, is contribute in these huge accumulations of petroleum. The pyrolysis parameters of the succession; Sulaiy, yamama, Zubair, and Nahr Umr formations showed that the main kerogen type is type III and II with moderate to good HI, which they refer to gas and/or oil prone especially in Zubair, Nahr Umr, and Sulaiy formations. The quantity parameters indicate potential source intervals in respect to (TOC). The maturity parameters suggest the threshold and peak of petroleum generation, which Tmax values ranged around 430-450 ºC, as well as the Ro values ranged 0.5 to 1.0. The Maturity factors is enhanced by PI (0.1 -0.4), which the main values are located in the oil window.The software modeling, namely PetroMod, assigned a transformation ratio up to 90% in respect to Sulaiy and Yamama formations, while it is around 5-30 % for Ratawi, Zubair, and Shuaiba formations. As though, Nahr Umr is less than 5% of transformation ratio. These facts indicates that Sulaiy and Yamama formations are within the peak oil generation, however, Ratawi, Zubair, and Shuaiba, and Nahr Umr formations are within the start.The generated oil migrates up dip toward the dome of West Qurna field, but the existence of longitudinal and transverse fault system in the area may lead to accumulate oil in the directions NE and SW for the field.

Keywords: Lower Cretaceous, south of Iraq, west Qurna oil field

تقييم الصخور المصدرية للعصر الطباشيري الاسفل باستخدام تقنية البترو–مود في حقل غرب القرنة النفطي – جنوب العراق

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الخلاصة

يعد تتابع صخور عصر الطباشيري الاسفل المكن الرئيسي في جنوب العراق. وبالرغم من ان تكوين الساركلو– العائد للجوراسي المبكر– هو الصخرة المصدرية الرئيسية في المنطقة الا ان الفترات الصخرية الغنية بالمادة العضوية ضمن التتابعات قيد الدراسة قد اسهمت بتوفير كميات كبيرة من النفط. لقد بينت نتائج تحليل النضوج للتكاوين سلي، يمامة، زبير، و نهر عمر ان الكيروجين هو من النوع الثاني والثالث مع معامل هايدروجيني متوسط الى جيد مما يشير الى صخور منتجة للغاز و/او النفط خصوصا في تكاوين الزبير، نهر عمر، والسلي. و بالاعتماد على محتوى الكاربون العضوي الكلي، دلت التحاليل الكمية على فترات صخرية واعدة ضمن التتابع. كما ان معاملات النضوج رشحت ان التتبعات المدروسة كانت ضمن عتبة النضوج

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وقمته، حيث تراوحت قيم Tmax بين 430–450 درجة مؤية وعليه فان Ro تكون بين 0.5 – 1.0. لقد عززت معاملات النضوج بمعامل الانتاج (0.1 – 0.4) حيث ان القيم الرئيسية وقعت في نافذة النفط.
ظهر من خلال تطبيق برنامج PetroMod الى ان نسبة التحول تصل الى 90% بالنسبة لتكويني السلي واليمامة، بينما كان التحول 5%–30% في تكاوين رطاوي، زبير، والشعيبة. هذا وان تكوين نهر عمر ذا قيمة تحول اقل من 5% . تشير كل هذه المعلمات الى ان تكويني السلي واليمامة هما في قمة العطاء النفطي، بينما تكاوين رطاوي، زبير، شعيبة، ونهر عمر فهم لا يزالون في المراحل المبكرة.
يهاجر النفط المتولد باتجاه اعلى الميل نحو قبة تركيب حقل غرب القرنة، لكن وجود انظمة الصدوع الطولية والمستعرضة في المنطقة قد يؤدي الى تجمع النفوط باتجاهات شمال شرق وجنوب غرب الحقل.

Introduction

The Basra region in southeast Iraq is well known for its giant oil fields. West Qurna is one of Iraq's largest oil fields, located north of Rumaila field, west of Basra, Figure-1. West Qurna is believed to hold 43 billion barrels of recoverable reserves, making it the second largest field in the world after Saudi Arabia's Ghawar oilfield. West Qurna oilfield locates within the Zubair Subzone, which it part of the Mesopotamian zone. Zubair Subzone characterized by many of elongated folds of NS to NW-SE directions. These folds, which finally enclosed in Late Cretaceous, characterized by linear and narrow anticlines with a little appearance to faulted basement rock. The fault system, which bounded the Zubair subzone is Takhadid-Qurna transversal fault from the north, and Al-Kuwait transversal to the south and southeast, western part is bounded by the extension of south Euphrates longitudinal fault [1], Figure-1. Previous seismic survey demonstrated that WQ-field is composed of an elongated double plunging asymmetrical anticline trending in a northwest-southeast direction [2]. On the other hand, Lower Cretaceous deposits especially in this area are of great importance because they contain a great hydrocarbon accumulations and reserves [3].

Stratigraphy

Early Cretaceous started (the upper most) with Sulaiy Formation, which unconformably overlying the Gotnia evaporites Formation (Calovian-Early Tithonian). The later is represents final stand of the upper Jurassic sequences, as well as a regional seal of the lower Cretaceous petroleum system [4].*Sulaiy Formation* (Tithonian- Valanginian) composes of mainly alternating argillaceous, dolomite, and pyrite rich limestone [5]. It is conformable with Yamama Formation.*Yamama Formation* (Berriasian- Valanginian) comprises argillaceous to oolitic, pelloidal, dolomitic Limestone [6].

Ratawi Formation lie conformably on Yamama Formation consists of dark Shale and beds of oolitic, detrital, fossiliferous Limestone in the lower parts of the formation [7]. *Zubair Formation* (Hautirivian- Early Aptian) comprises of alternating sand shale beds, which reflect the multi-story of deltaic environment [8]. *Shuaiba Formation* (Aptian) contains oolitic, fine-grained organodetrital Limestone, with thin Shale bed in the upper parts [4].

Nahr Umr Formation (Alpian) comprises of black shales interbedded with medium to fine grained sandstone with lignite, amber, and pyrite [9**].**

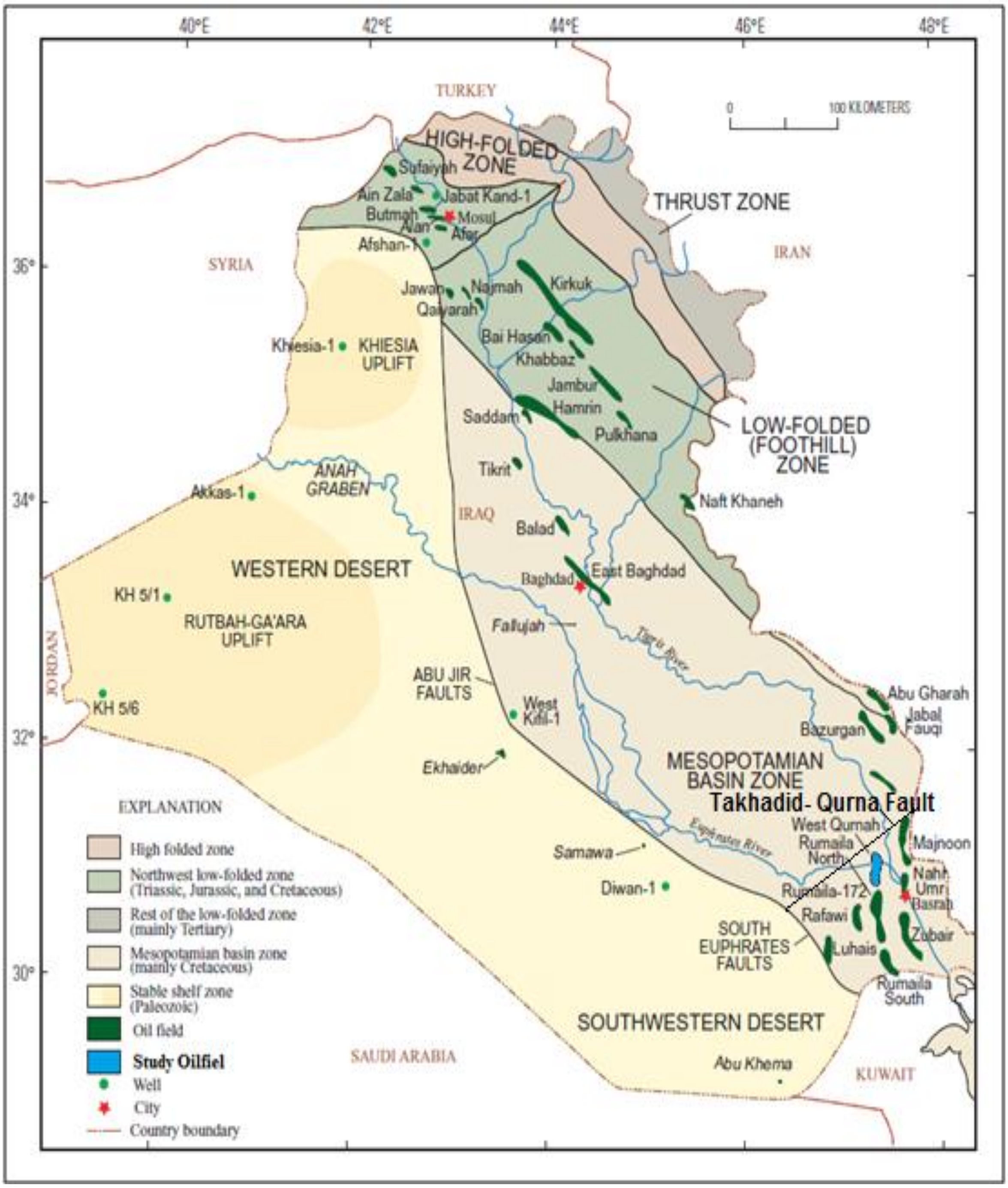

Figure 1- Map showing location of Mesopotamian Basin and Zagros fold belt. The Zubair subzone bounded in Iraq with Takhadid-Qurna and South Euphrates faults [5]

Source Rocks

The main source rock in the total petroleum system of Iraq is undisputedly the middle Jurassic Sargelu Formation. Nevertheless, the lower Cretaceous rock also proofed the ability to petroleum production especially in south of Iraq [7]. As shown below in Figure-2, the lower Cretaceous source rocks may contribute in oil production. This paper work to proof this assumption using the tools of organic geochemistry and PetroMod approaches.

Material and Method

Many of pyrolysis results collected from Oil Exploration Company (OEC) and South Oil Company (SOC) inverted to this paper, in addition to the analyst samples in Geo-Mark Research Ltd in Houston-Texas. The collected data were precisely from WQ_1, WQ_2, WQ_13, WQ_15, and WQ_60. These results used as tools to evaluate the Lower Cretaceous rocks and thus, to identify the ability to petroleum generation. On the other hand, the modelling output, burial histories, and conclusions prepared by 1D PetroMod program. Input data consist of formation depths, ages, bottom hole temperatures, as well as the mean of TOC and HI to each formation. The ages of depositional and erosional events were designated Table-1, based on the chronostratigraphic units and modified from [8].

Source Rock Evaluation:

Source rock data obtained consist of TOC, S1, S2, S3, and Tmax °C as well as, HI and production index (PI). Results are presented on figures below to interpret the maturity, oil generation, and expulsion for the formations within the interval of interest.

The plots indicated the presence of mixed kerogen type II and III, as well as type I is available Figure-3. Hydrogen index range of 36 to up to 500 mg HC/g TOC that suggest oil and gas prone. Tmax (430°C and higher) indicates that successions are in the start and peak of maturity in respect to depth and temperature Figure-3. Maturity, depending on the values of Tmax, and Ro is often indicates the threshold of generation, but can say the L. Cretaceous is started oil and/or gas production, which the PI also assigns (0.1–0.4) to the result of oil window as indicated from Figure-4 [10].

Fair to good petroleum potential results of 2-38.11 kg HC/ton rock indicate good generated hydrocarbons from some strata Figure-5. These generated hydrocarbons were expelled to the reservoir within the same succession according to migration index (MI). MI of 0.1–0.2 could be considered for oil expulsion [10] and hence, the highest values of MI (0.3 and more, which they 60 % of the analyzed samples) could rate strata of the lower Cretaceous as high expulsion efficiency Figure-6. Finally, the geochemical log Figure-7 indicates the best intervals from Sulaiy, Zubair, Nahr Umr, and Yamama formations descendingly, which the parameters of quantity, quality, and thermal maturity are.

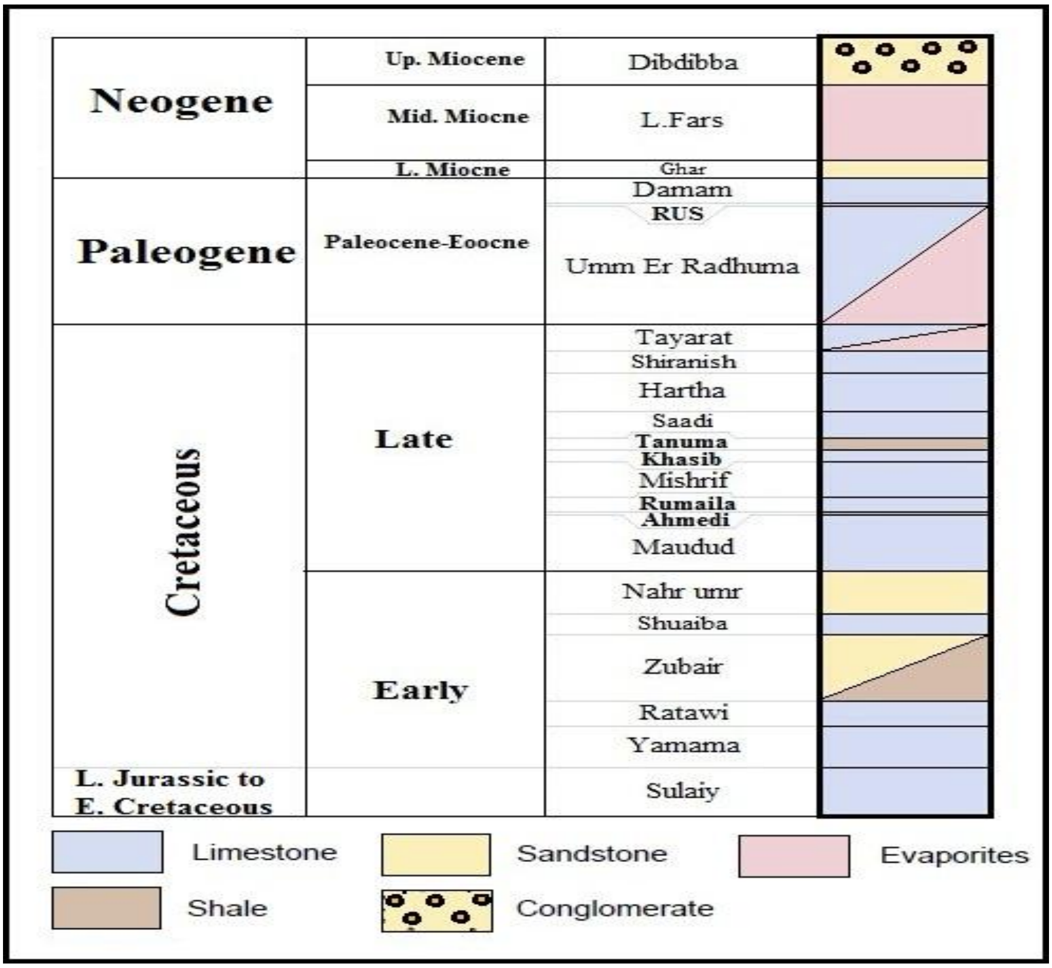

Figure 2- A stratgraphic section to the succession of the Cretaceous and Cenozoic in West Qurna Oilfield.

Table 1- The ages of depositional and erosion events were designated based on the chronostratigraphic units (modified from [4,9]).

Layer	Deposition from (Ma)	Deposition to (Ma)	Erosion (Ma)
Lower Fars	15.3	10.8	
Ghar	22.1	17	1.7
Dammam	36	33.7	11.6
Rus	48.8	47.8	11.8
Umm ErRathuma	62.9	51.1	2.3
Tayarat	69.6	66.9	4
Shiranish	72.5	69.6	
Hartha	78.7	72.5	
Sadi	84.9	80.3	1.6
Tanuma	85.9	84.9	
Khasib	91.8	85.9	
Mishrif	94	92.3	0.5
Rumaila	95.7	94	
Ahmadi	97.2	95.7	
Mauddud	101.4	99.4	2.2
Nahr Umr	109.6	101.4	
Shuaiba	120.7	113.2	3.6
Zubair	127.4	120.7	
Ratawi	135.9	131	3.6
Yamama	143.1	135.9	
Sulaiy	148	143.1	
Gotnia	154	148	
Najmah	160.1	154	

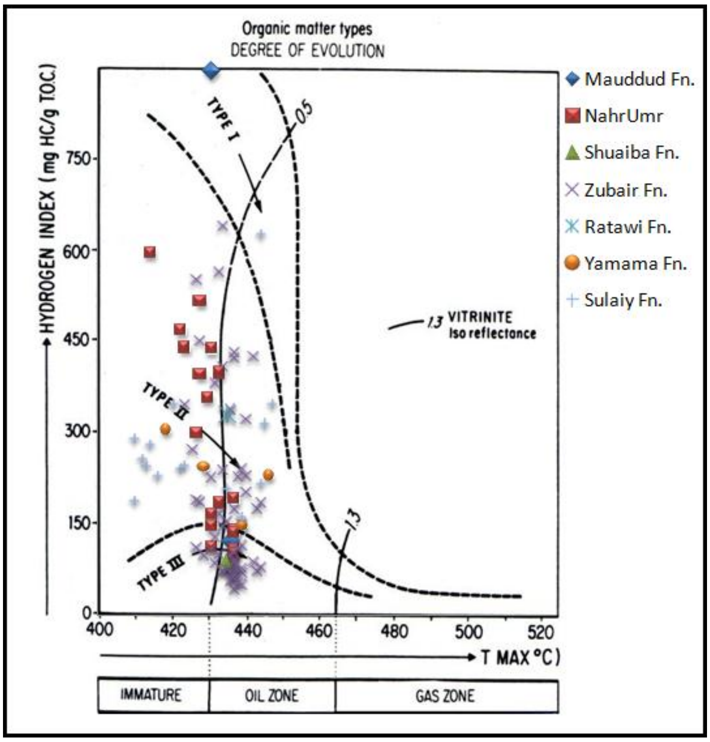

Figure 3- The kerogen types, product zone and maturity in terms of HI, Tmax, and Ro in Lower Cretaceous formations [10].

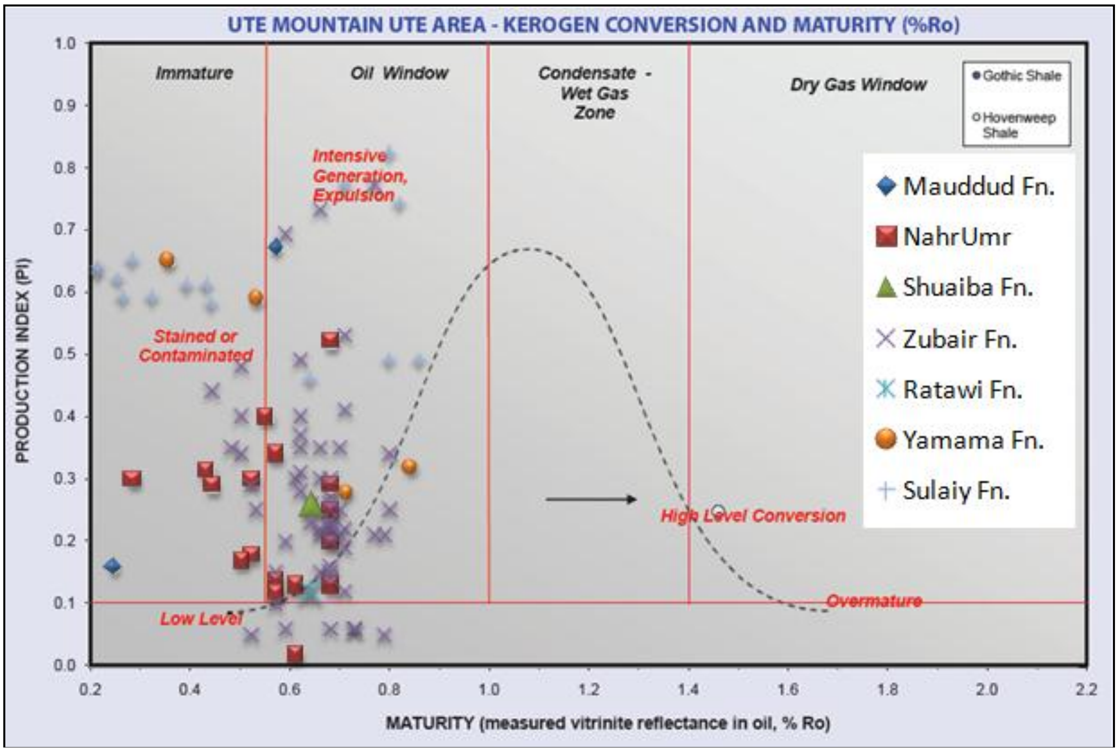

Figure 4- The Production Index (Transformation Ratio) versus calculated Ro, which it is refer to onset of generation and expulsion in Lower Cretaceous formations.

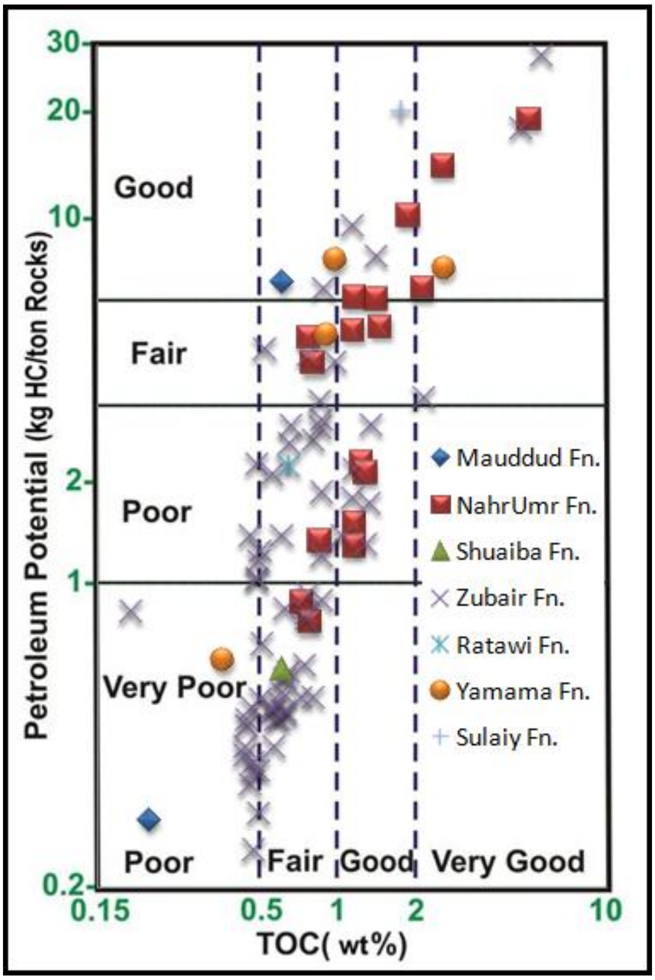

Figure 5- Source rock potential interpretation by plotting PP vs. TOC modified from [11] in Lower Cretaceous formations, the cross plot assigned to the prospectivity of the formations.

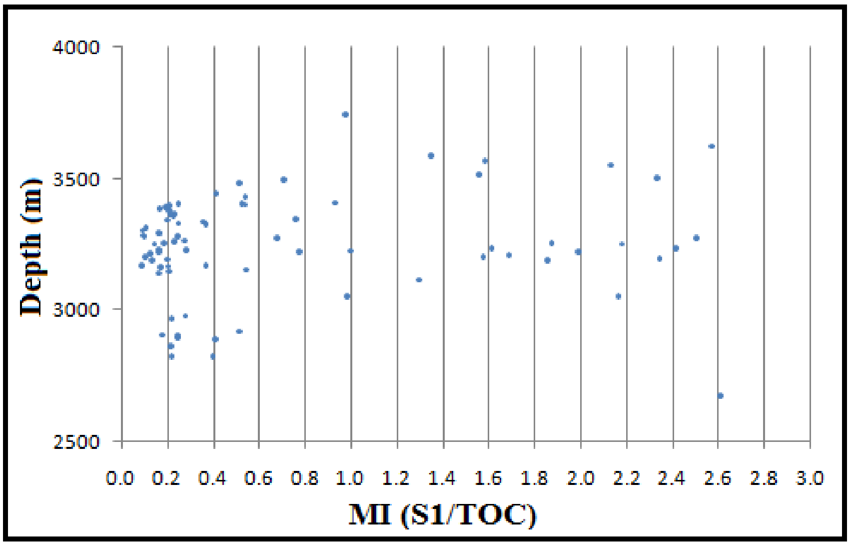

Figure 6- Cross plot of depth versus migration index (SI/TOC or Expulsion efficiency diagram), show the good efficiency of the studied formations.

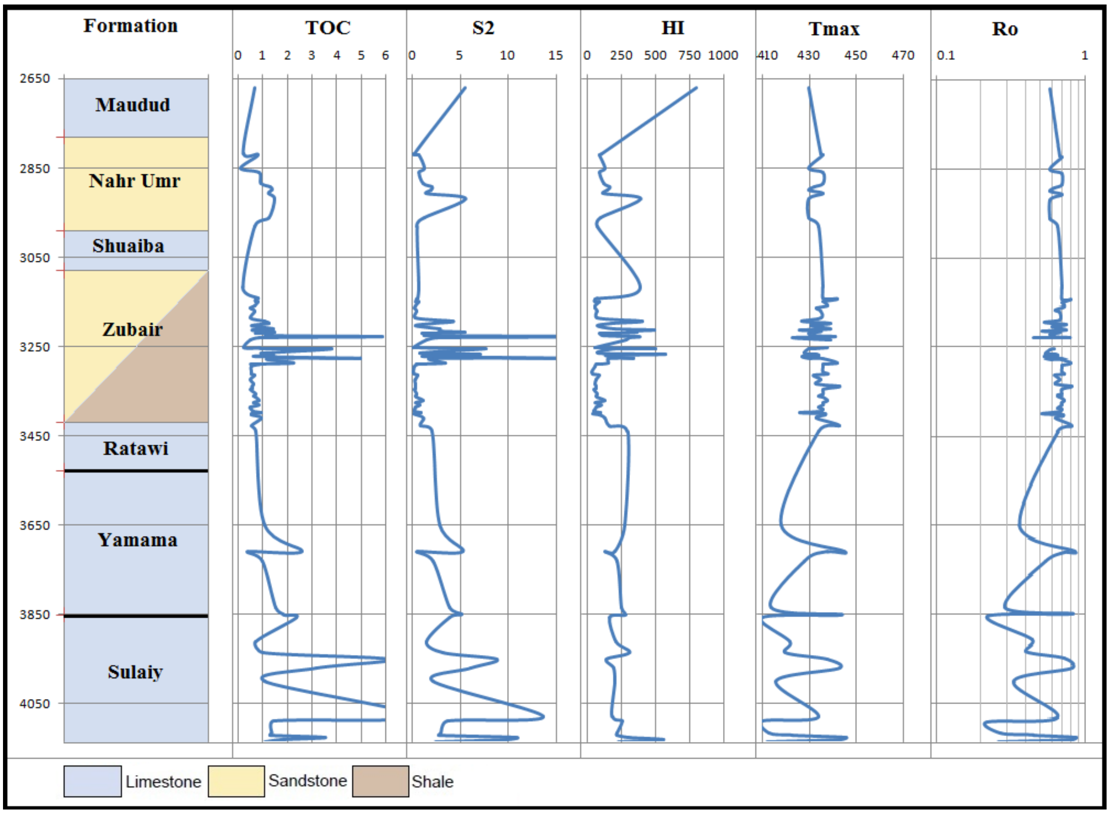

Figure 7- a geochemical log shows the studied intervals in terms of TOC, S2, HI, Tmax, and Ro.

Basin modelling Results

The Figures-8 and 9 illustrate the temperature needed to prove the thermal maturity in the studied oilfield, which appear satisfy in the proposed source rock intervals within the studied succession. Maturation history based on Ro calibration for the burial history (Figure-9, dark red curves) represents that Nahr Umr, Shuaiba, Zubair, and Ratawi formations are in the early oil window, while Yamama and Sulaiy formations are in the peak.

The transformation ratio (TR) and the temperatures of hydrocarbon (HC) generation, which are modeled for the oilfield, represent the timing and extent of HC generation from the prescribed source rock at the burial history location. Figure-8 explains the TR of the succession as expected, the most extensive HC generation occurred at the location where SR is most deeply buried in the studied oilfield.

The longitudinal and transverse fault system in this area may act as conduit to the generated oil drops to migrate NE and SW within Takhadid-Qurna transverse fault as explained in Figure-1.

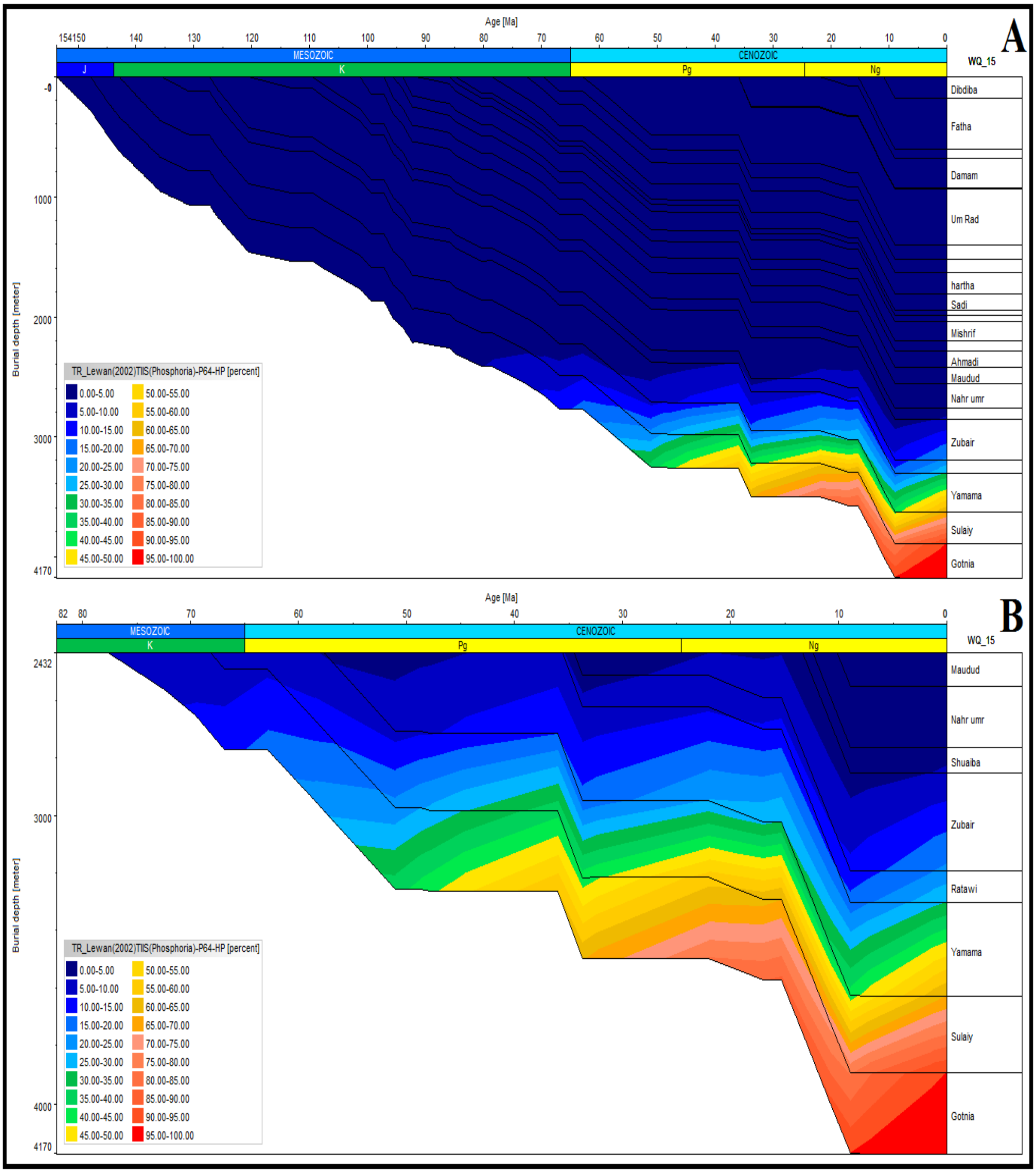

Figure 8- A- Represents the burial history curves, superimposed by the transformation ratio (TR) representing TR of the organic matters into HC.
B- Close section to the L. Cretaceous succession in WQ_15 well.

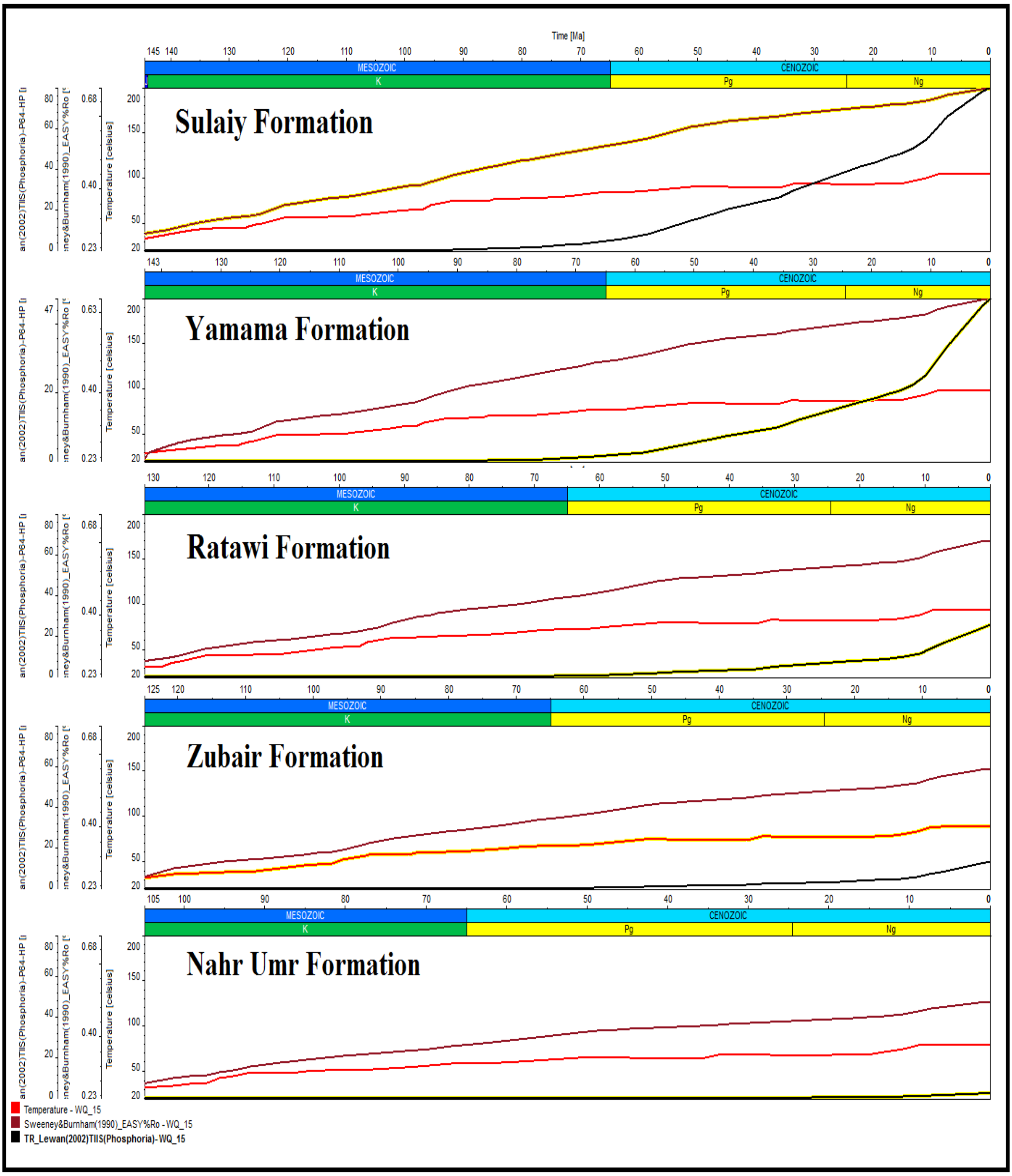

Figure 9- Temperature (the red curves), vitrinite reflectance (the dark red curves), and transformation ratio (the black curves) in well WQ_15.

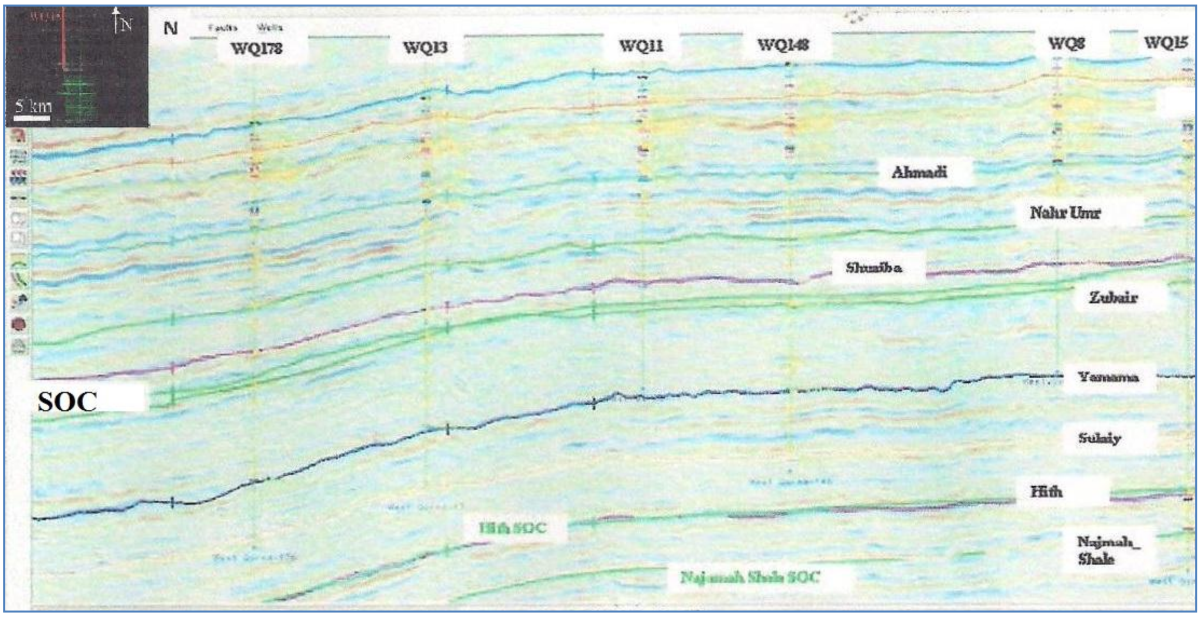

Figure 10- Seismic profile across width of West Qurna oil field passing through wells WQ-15 to WQ-172, (after SOC interior reports).

Results and Conclusions:

The L. Cretaceous source rock intervals are within the studied formations of the same succession. Data of the pyrolysis analysis showed the organic matter of the interested intervals are type II and III, as well as type I is available, which refer to oil and gas prone source rocks.

The derivatives indicate good parameters to produce oil from the organic-rich intervals, which the main source rocks are within Sulaiy, Zubair, Nahr Umr, and Yamama formations in descending order. The source rock intervals have high migration efficiency, which the MI factor qualifies them to expel the oil up dip or toward low-pressure strata.

The software modeling shows that Nahr Umr, Shuaiba, Zubair, and Ratawi formations are within the start of hydrocarbon generation. However, Yamama and Sulaiy formations are in the peak, with respect to the transformation ratio.

The resulted oil from the proposed SR may migrate up dip toward the dome of the target oilfield Figure- 10. Moreover, the longitudinal and transverse fault system may act as conduit to transport far away to neighboring area. As a result, the migrated oil may accumulate in directions NE, SW through Takhadid-Qurna transverse fault. In this case, the recommendation of this paper came to intensify the new well drilling in the surrounding area, especially near the locations of Majnoon, Bazurgan, Ad-dima, Nahr Umr oilfields Figure-1, as well as, the high resolution seismic survey is necessity for more details in subsurface study.

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