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ORIGINAL PAPER

Hydrocarbon potential of Zubair Formation in the south of Iraq

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Abstract The main parameters of the possible source rock within Zubair Formation are satisfying, in terms of quantity, quality, and thermal maturity. Thirty-eight samples (15 cores 23 cuttings) are analyzed to determine the pyrolysis parameters as well as nine rock samples (6 core and 3 cuttings) are introduced to gas charmotagraphy/mass spectrometry (GC/MS) analysis. On the other hand, six oil samples were analyzed to determine the carbon isotopes, biomarkers, composition, and correlation. Quantitative analysis is done with GC/MS. In addition, 14 rock samples were subjected to infrared analysis. All these data are mainly obtained from Nassiriah, Gharraf, and Rafidain oil fields in Euphrates Subzone as well as from Rumaila North, Rumaila South, Zubair, and West Qurna oil fields in Zubair Subzone. Early-peak oil generation has been indicated from the Vitrinite reflectance (Ro) to the chosen samples in the Zubair Subzone (Ro maximum 0.81 %), while in the Euphrates Subzone, the maturity is indicated as immature-early oil generation (Ro maximum 0.69 %) due to shallow depths of Zubair Formation as well as the terrestrial supply of organic matters. On the other hand, the optical investigation revealed that the formation is within the mature zone dependent of color index. From the total organic carbon (TOC) values' point of view, shale intervals within Zubair Formation are generally good to excellent as source rocks, except in the lower parts, namely, the Lower Shale Member in the Zubair Subzone, which has fair amounts of the total carbon content. While the kerogen types are mainly type III gas prone, but type II/III oil-gas prone, and type II oil prone are available, which the later concentrated in the upper and lower sandstone members. The dominant type of organic matters was the amorphous organic material (AOM), which is principally related to oil prone source rock. On the other hand, the IR analysis also indicates the oil prone type II and type I kerogens in dependence on the A and C factors. The Rock-Eval pyrolysis shows that the organic geochemical properties presented an effective and/or potential source rock depending on the values of S1, S2, and S3 and their derivatives. This source rock has started the oil expulsion, where the S1/TOC values were mainly more than 0.2 mgHC/g TOC. The source-related biomarkers suggested that the reservoir oils of Zubair Formation and the source rock-extracted oils indicate the same origin, depositional environment, sulfur content, and maturity level. The depositional environment of the source rock is indicated as the anoxic, shallow marine offshore facies of the prodelta shale intervals, which is located within the multi-story sand bodies.

Keywords Zubair Formation · Hydrocarbon potential · South of Iraq

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Introduction

Lower Cretaceous deposits are of great importance especially in southern Iraq because they contain a great hydrocarbon accumulations and reserves (Al-Obaidi 2009). Zubair

Formation is one of the formations that is represented by the Late Berriasian-Albian cycle and can considered as an important reservoir in the south of Iraq and some of adjacent countries (Ibrahim 2001) due to good reservoir properties. It is worthy to mention that the shale components represent the source rock properties within the formation because these shale intervals contain some of the rare elements and pyrite, which that prove reductive and acidic depositional environment. This evidence is reinforcing the belief of forming the source rock within Zubair Formation (Idan 2012). This formation consists of a number of depositional cycles. Each cycle represents the growth of a deltaic lobe (construction phase), followed by a hiatus during which the delta margin was subjected to wave and tidal activity (destruction phase), succeeded by a marine transgressive shale by which the cycle was concluded. When the growth of the deltaic lobe is renewed over a shale base, a new cycle begins (Ali and Nasser 1989). The Zubair Formation is represented mainly by clastic facies sequences, while limestone is restricted to the upper part of the formation, which represents a transgressive phase (Aqrawi et al. 2010). The shale packages become thinner toward the western area of the study while the coarse clastic packages become thinner toward the eastern area (Jassim and Goff 2006). Such variation in the thicknesses must be due to progradation of the delta sand bodies. The formation thickness ranges from 500 m in Nassiriah oil field to 290 m in West Qurna oil field. The Zubair Formation passes laterally into the limestones of the Shuaiba Formation, in the eastern part of Iraq. In north of Iraq, specifically in Makhul, Bihassen, and Jambour fields, Zubair Formation passes into Sarmord Formation, then to Balambo Formation in high-mountain area in Kurdistan, north of Iraq (see Figs. 11-6, p. 126 in Ibid). Such change might be due to basin irregularities. The upper contact of Zubair Formation is marked by the appearance of the shale, which followed the Shuaiba Carbonates Formation, while the lower contact was defined by the appearance of Ratawi Limestone Formation (Buday and Jassim 1980). Many authors refer to that as both contacts of the formation are conformable (Owen and Nasr 1958; Al-Naqib 1967; and Ibrahim 1983). These contacts may be unconformable in other areas of Iraq, with attention to Shuaiba Formation which disappeared in Safawi oil field where Nahr Omer Formation is overlying Zubair Formation and also, the later is lying above the Yammama Formation in Kifl oil field (Ibrahim 2001). Zubair Formation in Iraq passes laterally into Gadvan Formation in NE of Iran, while toward the SW, it is equivalent to Biyadh Formation in KSA, while the Qatar, Hawar, and Ratawi formations are the equivalents (AL-Husseini 2000). Finally, the marly limestone of Jabal Abdulaziz Formation in Syria has the same age with Zubair Formation (Jassim and Goff 2006). The age of the formation have been studied by many researchers in different geographic locations; these studies showed many opinions to determine its real age. Haten (1960) in Al-Naqib (1967) mentioned that the Zubair Formation is diachronous and it is not related in a certain age. The age of the formation was primarily assigned by Owen and Nasr (1958) and Reulet (1971) to be Berrimian-Early Aption, while Hautirivian-E. Aptian is given by Van Bellen et al. (1959). And, Al-Naqib (1967), Abbo and Safer (1967), and Castro (1978) suggested Hautirvian-Aptian. Ibrahim (1983), Al-fars (1998), and AL-Husseini (2000) agreed that Hautirivian -Early Aptian is the certain age.

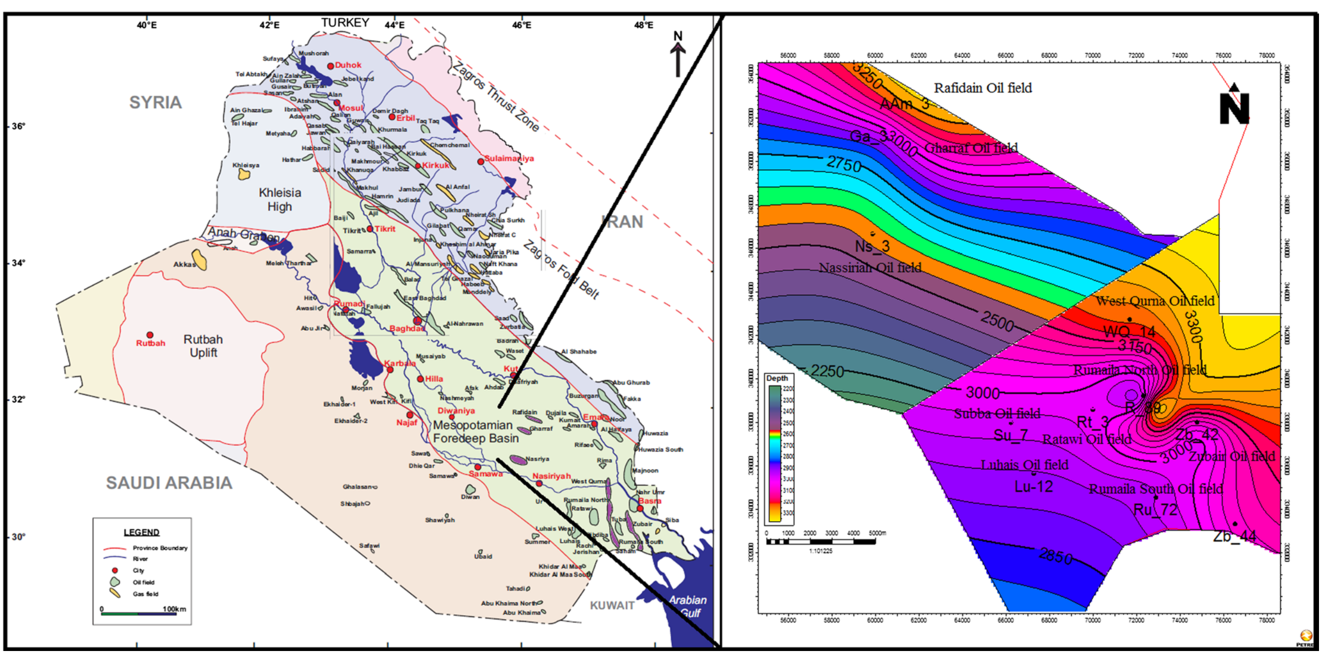

Fig. 1 The tectonical zonation and the area of study representing by target oil fields (Al-Ameri et al. 2011)

Finally, the palynomorphs evidences extended this formation up to the earliest Albian age (Al-Ameri and Batten 1997) with contacts of mostly gradational and conformable. The area of study lies in the Mesopotamian zone of the unstable shelf (Fig. 1, Buday and Jassim 1984). The Mesopotamian Zone is divided into three subzones, Zubair, Euphrates, and Tigris subzone. Zubair and Euphrates subzones are the project of this paper. This investigated area is marked by 30–32° latitude and 45°20′–48°20′ longitude. Zubair Subzone is characterized by many of elongated folds of NS to NW–SE direction representing by the giant oilfields in Basra province. These folds, which finally enclosed in Late Cretaceous, have been characterized by linear and narrow anticlines with a little appearance to faulted basement rock (ibid), and the interested oil fields of this subzone are as follows: Zubair (Zb), Rumaila North (R), Rumaila South (Ru),

Table 1 The subzones, members, wells names, depths, and results of Rock-Eval pyrolysis of shale samples of Zubair Formation (Geo-Mark Ins.)

No.	Subzone	Member	Well	Depth (m)	TOC	S1	S2	S3	Tmax	MI
1	Zubair	UpSstmbr.	R_27	3,214.16	1.03	2.98	5.12	0.38	424	2.89
2			R_36	3,179.64	1.8	0.25	1.24	0.36	425	0.14
3			RU_4	3,257.1	0.6	0.12	0.85	0.49	431	0.2
4			RU_10	3,126.5	9.1	2.56	36.57	1.12	430	0.28
5			WQ_2	3,251.78	0.26	0.05	0.16	0.26	–	0.19
6			WQ_2	3,255.78	3.8	0.89	7.63	0.57	430	0.23
7			Zb_45	3,338	1.36	7.17	8.37	0.46	415	5.27
8			Zb_45	3,362	2.17	0.41	4.21	0.33	431	0.19
9			Zb_45	3,391	3.06	0.36	7.25	0.36	432	0.12
10			Zb_109	3,203.5	0.49	0.05	0.3	0.34	443	0.1
11			Zb_109	3,233	0.4	0.05	0.29	0.16	437	0.13
12		UpShmbr.	RU_78	3,237	3.48	1.28	7.84	0.45	427	0.37
13			RU_78	3,249	2.58	0.05	0.15	0.32	–	0.02
14			WQ_1	3,056	0.28	0.19	0.76	0.38	432	0.68
15			WQ_1	3,104	0.52	0.42	0.92	1.47	431	0.81
16		MidShmbr.	RU_4	3,296.1	0.78	2.23	2.85	0.24	425	2.86
17			RU_4	3,309.3	25.4	5	68.62	3.82	434	0.2
18			RU_10	3,211.6	0.69	3.72	2.42	0.32	420	5.39
19			WQ_1	3,342	0.55	0.09	0.48	0.34	436	0.16
20			WQ_1	3,384	0.69	0.14	0.71	0.27	435	0.2
21		LSstmbr.	RU_4	3,387.5	4.23	0.47	8.16	0.45	437	0.11
22		LShmbr.	RU_4	3,417.6	0.77	0.14	0.74	0.26	434	0.18
23			WQ_1	3,424	32.58	0.37	0.11	0.25	0.33	0.01
24	Euphrates	UpZbfn.	Aam_3	3,328	1.01	0.54	1.56	0.94	433	0.53
25			Ga_1	3,010	0.17	0.24	0.22	0.23	–	1.41
26			NS_3	2,594	0.27	0.11	0.28	0.38	435	0.41
27			NS_3	2,624	1.06	0.37	1.89	0.6	436	0.35
28		MidZbfn.	Aam_3	3,448	1.84	0.52	3.63	1.32	429	0.28
29			Aam_3	3,590	0.58	0.28	0.63	0.69	431	0.48
30			Ga_1	3,130	0.65	0.25	0.75	0.29	433	0.38
31			Ga_1	3,198	1.81	0.22	2.01	0.6	425	0.12
32			NS_3	2,826	0.55	0.28	0.9	0.42	432	0.51
33			NS_3	2,922	3.18	0.54	4.61	0.88	436	0.17
34		LZbfn.	Aam_3	3,686	1.1	0.13	0.89	0.46	435	0.12
35			Aam_3	3,722	0.81	0.28	0.67	0.44	432	0.35
36			Ga_1	3,364	25.8	4.48	89.22	4.48	426	0.17
37			Ga_1	3,430	1.68	0.23	1.27	0.46	428	0.14
38			NS_3	3,050	1.65	0.44	3.53	0.49	430	0.27

MI (migration index)=S1/TOC

Table 2 The oil and the possible source rock samples went to the GC/MS

No.	Field/oil field	Well name	Member	Depth	TOC% of samples
Crude oil analysis					
1	Rumaila North	R-194	UpSstmbr.		
2	Rumaila South	Ru-228	UpShmbr.		
3	Rumaila South	Ru-263	LSstmbr.		
4	Zubair	Zb-14	UpSstmbr.		
5	Zubair	Zb-24	LSstmbr.		
6	Zubair	Zb-167	UpSstmbr.		
Rock extract analysis					
1	Rafidain	AAm_3	MidZbfn.	3,448.00	1.84
2	Gharraf	Ga_1	LZbfn.	3,364.00	25.8
3	Nassiriah	NS_3	LZbfn.	2,922.00	3.18
4	Rumaila North	R_27	MidShmbr.	3,214.16	1.03
5	Rumaila South	RU_4	MidShmbr.	3,309.30	25.4
6	Rumaila South	RU_10	UpSstmbr.	3,126.50	9.1
7	Rumaila South	RU_78	UpSstmbr.	3,237.00	3.48
8	West Qurna	WQ_2	UpSstmbr.	3,255.78	3.8
9	Zubair	Zb_45	UpSstmbr.	3,338.00	1.36

and West Qurna (WQ). The formation in Zubair Subzone is divided into the following:

- Upper shale member (UpShmbr).
- Upper sandstone member (UpSstmbr).
- Middle shale member (MidShmbr).
- Lower sandstone member (LSstmbr).
- Lower shale member (LShmbr).

Euphrates Subzone is represented by relatively small to medium monoclonal folds, separated with wide synclines between them, similar to box-fold shape. These folds are with NE ward gradual oriented fault system. This subzone was studied with Nassiriah (Ns), Gharraf (Ga), and Rafidain (AAm) oil fields. The formation is divided into three units in the Euphrates Subzone, which are the following:

- Upper Zubair Formation (UpZbfn).
- Middle Zubair Formation (MidZbfn).
- Lower Zubair Formation (LZbfn).

Material and methods

Cores, cuttings, and oil samples were collected from Zubair Formation and their suggested hard data source rocks from 12

Table 3 The factors A and C resulted from the IR analysis

No.	Field	Well	Depth (m)	2,860/cm	2,930/cm	1,630/cm	1,705/cm	A-factor	C-factor
1	North Rumaila oil field	R_27	3,219.16	48.383	46.362	52.056	49.597	0.65	0.49
2		R_36	3,165.5	83.214	79.014	58.162	64.478	0.74	0.53
3	South Rumaila oil field	Ru_4	3,272.79	73.54	71.547	48.075	57.877	0.75	0.55
4		Ru_4	3,368.3	68.802	65.383	67.611	72.27	0.66	0.52
5		Ru_4	3,415.6	59.341	57.186	38.616	47.451	0.75	0.55
6		Ru_4	3,417.6	101.968	101.507	95.829	99.761	0.68	0.51
7		Ru_10	3,206.5	50.702	45.157	40.067	48.446	0.71	0.55
8		Ru_78	3,226	65.339	62.098	47.812	56.044	0.73	0.54
9	West Qurna oil field	WQ_2	3,255.78	70.239	66.495	53.84	60.714	0.72	0.53
10		WQ_2	3,251.78	85.053	81.545	65.189	74.179	0.72	0.53
11	Zubair oil field	Zb_45	3,338	79.024	77.431	72.486	74.239	0.68	0.51
12		Zb_45	3,391	77.47	75.253	72.113	76.621	0.68	0.52
13		Zb_109	3,233	67.301	63.821	47.435	54.359	0.73	0.53
14		Zb_109	3,255	63.157	61.092	53.816	59.408	0.70	0.52

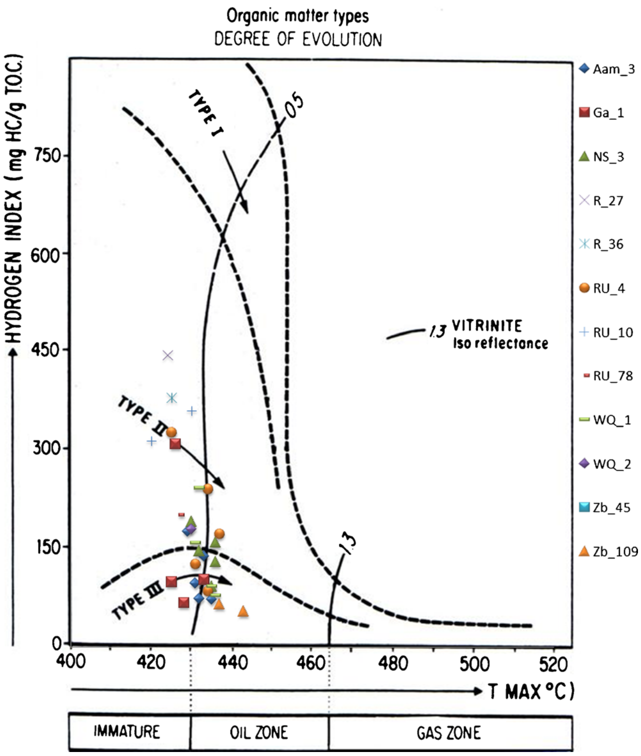

Fig. 2 The kerogen types, product zone, and maturity in terms of HI, Tmax, and Ro in Zubair and Euphrates Subzones (cross plot after Hunt 1996)

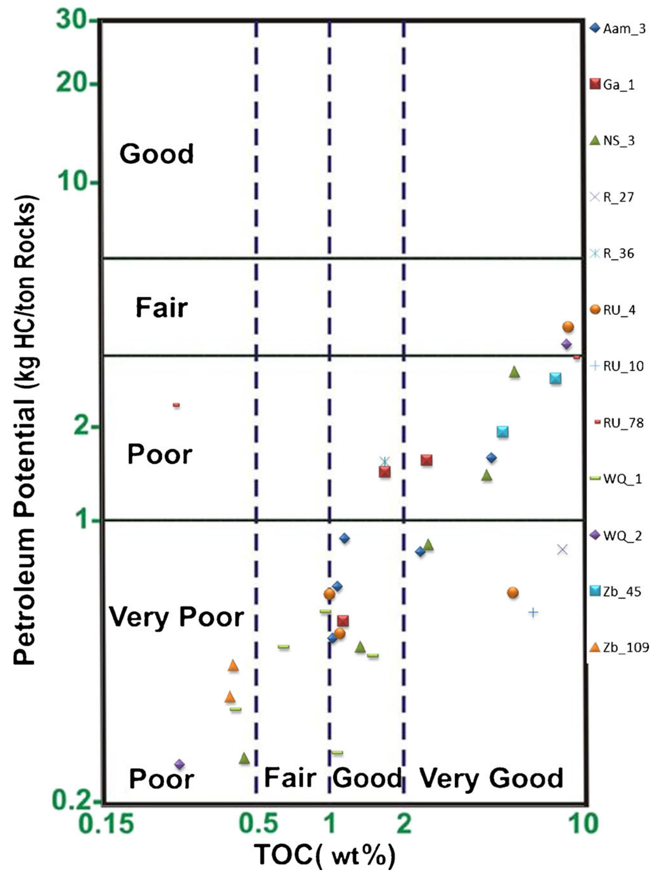

Fig. 4 Source rock potential interpretation by plotting PP vs. TOC modified from Ghori (2002) in Zubair and Euphrates Subzones, the cross plot assigned to the prospectivity of the Zubair Formation

wells in the Euphrates and Zubair subzone which are represented by Nasiriya and Basrah regions, respectively. These data were used to the different geochemical analysis as shown in the Tables 1, 2, and 3, for Rock-Eval pyrolysis, GC/MS, and IR, respectively.

These samples are subjected for organic geochemical analysis with pyrolysis for source rock evaluations and

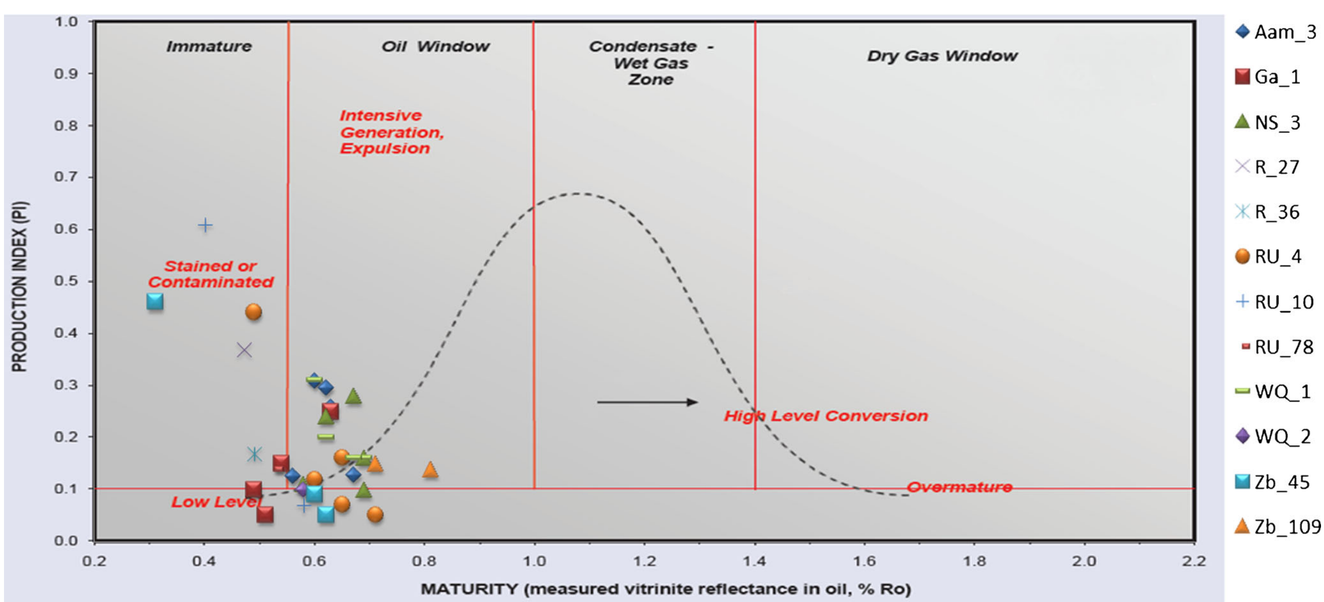

Fig. 3 The production index (transformation ratio) vs. calculated Ro as an indicator to maturity, which refers to onset of generation and expulsion in Zubair and Euphrates Subzones and indicates that Zubair Formation entered the oil window

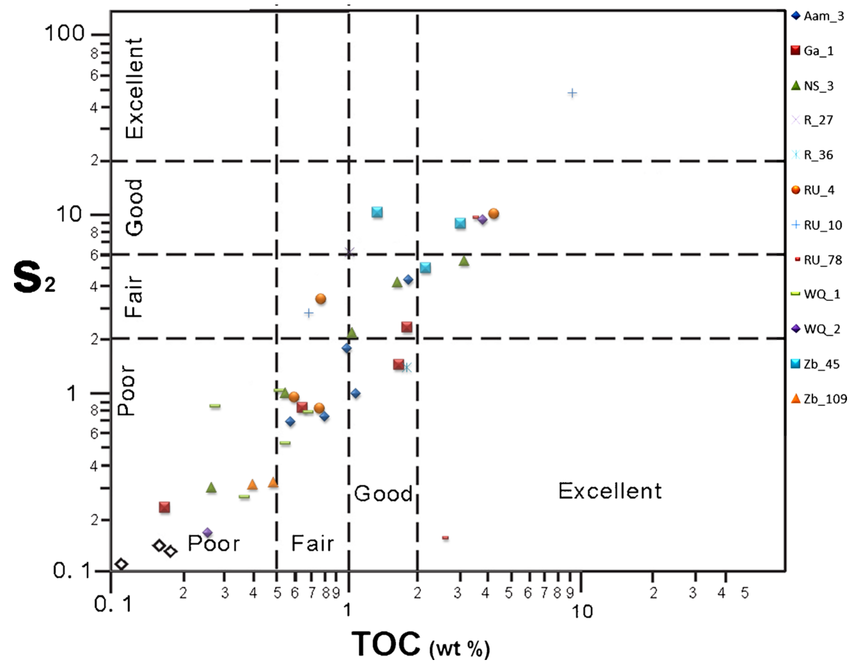

Fig. 5 The relation between TOC vs. S2 values to evaluate the source rock potentiality in Zubair Formation in the studied area (Akinlua et al. 2005)

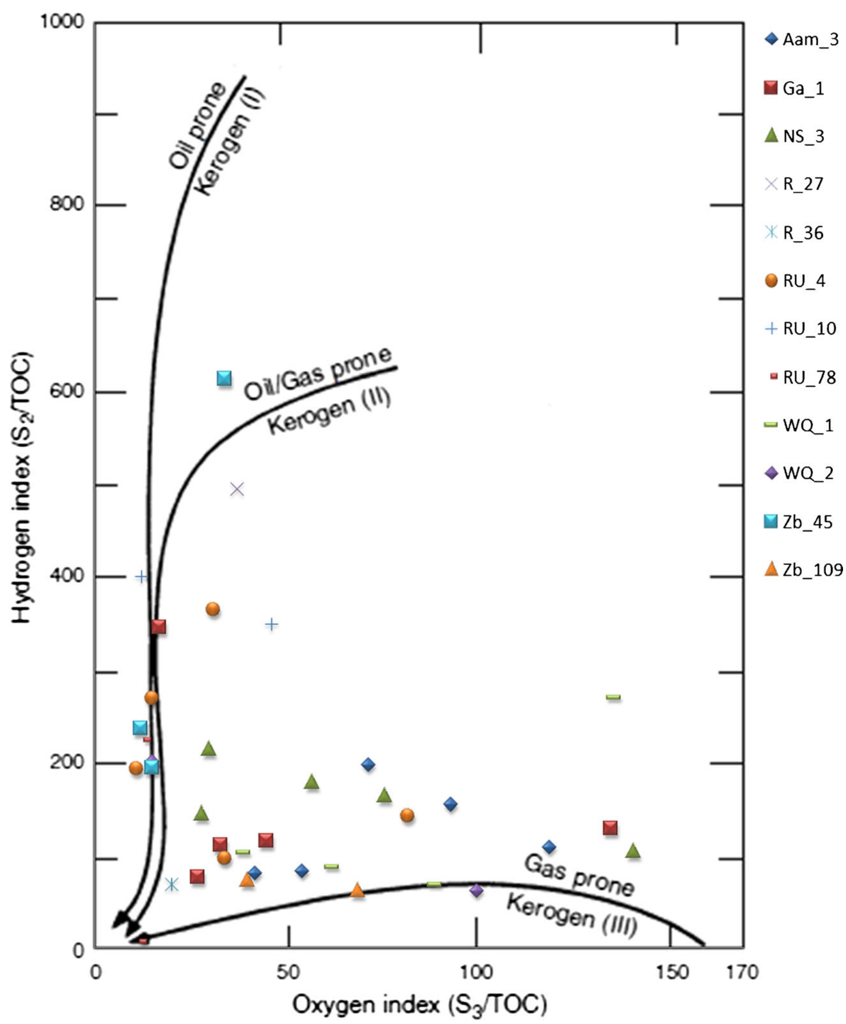

Fig. 6 The kerogen types in the study area depending on hydrogen index vs. oxygen index (Tissot and Welte 1984a, b)

with gas chromatography/mass spectrometry for oil analysis and biomarkers in Geomark Research Ltd in Houston, Texas, and with FT-IR analysis as well as microscopy is aided by petrographic and palynological slides that are prepared from these rock samples in the laboratories of the department of geology, College of Science, University of Baghdad.

Source rock assessment

Source rock analyses were performed on 38 core and cutting samples (Table 1) from the Zubair Formation from wells R_27, R_36, Ru_4, Ru_10, Ru_78, WQ_1, WQ_ 2, Zb_45, and Zb_109 in Zubair subzone and AAm_3, Ga_1, and NS_3 in Euphrates subzone. Source rock assessments were based on Durand (1980a, b) Tissot and Welte (1984a, b), Tyson (1995), and Hunt (1996).

Rock-Eval pyrolysis of Zubair Formation sources

Source rock data obtained comprised TOC content in percentage by weight (wt%) and Rock-Eval results (S1, S2, and S3 in milligram hydro- carbon (HC) to grams of rock; maximum temperature (Tmax) °C; HI (mg HC/g TOC) and production index (PI)=S1/(S1+S2)). Results are presented on diagrams of hydrogen index vs. Tmax (Fig. 2), PI vs. Ro (Fig. 3), and petroleum potential (PP) vs. TOC (Fig. 4) to interpret the oil-window matches for the formation and the hydrocarbon generated within the oil zone. And, the other cross plots was used to enhance the results as seen in the next figures (Figs. 5, 6, 7, 8, 9).

The plots indicate the presence of mixed kerogen types II and III with hydrogen index range of 61 to 615 mg HC/g TOC that suggest oil and gas prone. Oil-window maturities of Tmax range between 415 and 443 °C that achieve production index of 0.05–0.61, which the values 0.04–0.40 are for the oil generation and 0.5–0.7 are for migrated oil according to Hunt (1996). Very good PP of 0.2–93.7 kg HC/t rock concur with very good generated hydrocarbons from some strata. These generated hydrocarbons were expelled to the reservoir strata within the same formation according to migration index of 0.02–5.39 mg HC/g TOC (Table 1). MI of 0.1–0.2 could be considered for oil expulsion (Ibid), and hence, the highest MI of 0.3–0.8 (40 % of the analyzed samples) could rate strata of the Zubair Formation as of high expulsion efficiency.

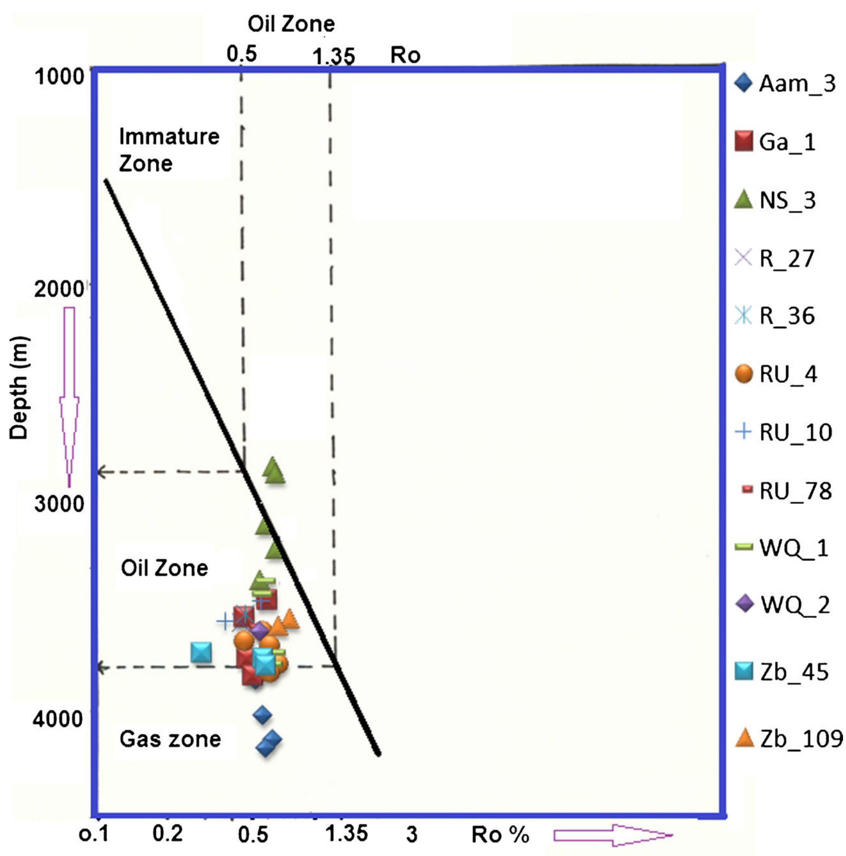

Fig. 7 The values of Ro are representing mainly the oil zone maturity (Al-Haba and Abdulla 1989)

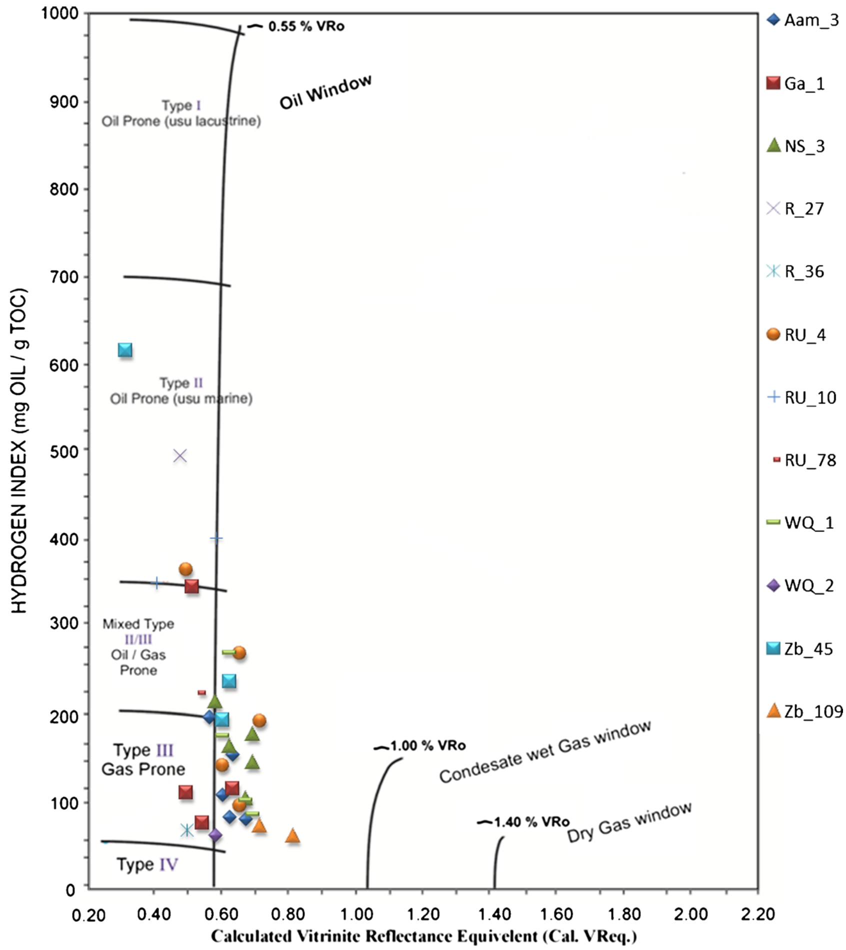

Fig. 8 The relation between HI and calculated Ro with respect to kerogen types (Ghori 2002). As obvious, most of the points are within the mature zone in respect to Ro

GC/MS analysis of Zubair Formation source rock and oil

The results of the GC/MS analysis showed that the oil and the rock extract samples (Table 2) were from the same origins, which are anoxic reduced shallow marine depositional environments, consisting of deltaic sand lobes inter-fingering with prodelta shale layers. And, the analysis indicates the same origin and level of maturity and the absence of biodegradation effect as shown in the Figs. 10, 11, and 12, which presented the amount of C27, C28, and C29 located in marine and non-marine shale. On the other hand, Pr/Ph vs. C29/C27 ratios showed anoxic depositional conditions and C29 20S/R vs. TAS3 showed to the maturity for both samples types, which led to the previous conclusions.

Infrared analysis of Zubair Formation source rock

Ten samples underwent to IR analysis, and as seen from the Fig. 13, maturity levels appear to be higher as the values of A and C factors decrease: accordingly, all the analyzed samples were located within the mature zone (Ro>0.4 %), and all the organic matters appeared to be mostly of type II to III kerogen (Table 3).

Palynofacies

Palynological assemblages of Zubair Formation are dominated by amorphous organic material (AOM), with a low abundance of palynomorphs might be due to masking. Diagnostic palynomorphs are mainly characterized by the dominance of AOM, low abundance of palynomorphs, alternative

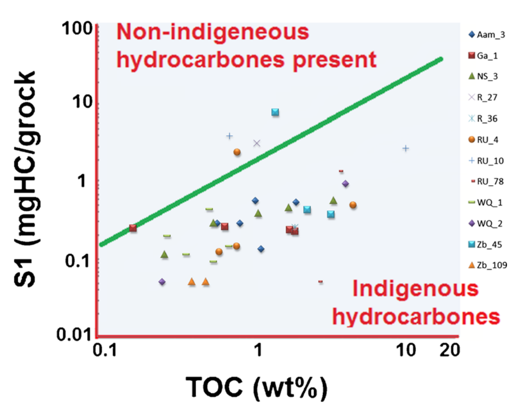

Fig. 9 S1 vs. TOC identifying migration or contaminants hydrocarbon and showing the limitation of this phenomenon in the study area (Hunt 1996)

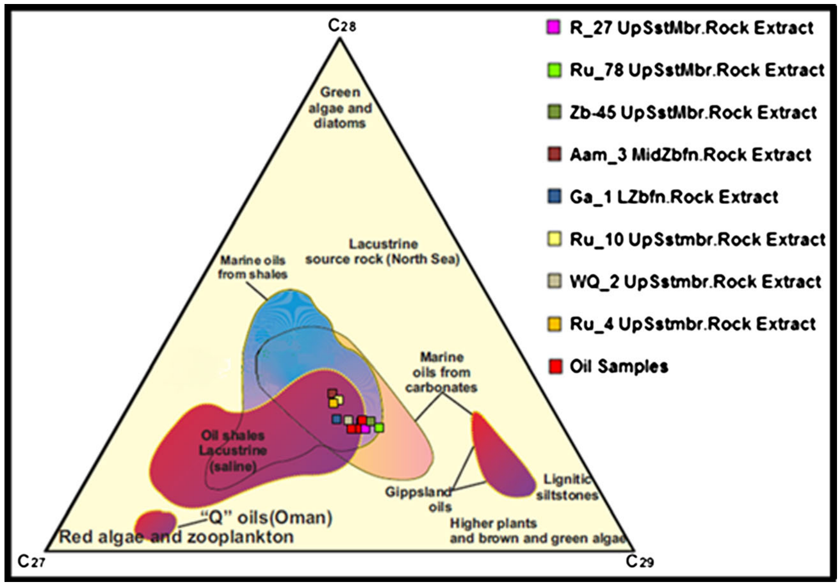

Fig. 10 Ternary plots of the relative amounts of C27, C28, and C29 show the distribution of the analyzed samples of oil and rock extract between the marine and non-marine shale (a plot after Moldowan et al. 1985, in Peters et al. 2005a, b)

abundance in phytoclasts, and steadily rich in opaque materials. The depositional environment is interpreted to be distal suboxic–anoxic to dysoxic–anoxic. This may indicate a stratified shelf basin as well as the sediments may represent a starved basin (cf. Tyson (1984) in Tyson 1993). Maturation based on thermal alteration index (following Staplin (1969)) indicates the presence of mature organic matter of yellow orange (2) to dark yellowish brown (−3) in respect to the AOM for the formation. Palynofacies could be based on Al-Ameri and Batten (1997) who have recorded, by palynological studies for Rumaila North Oil Field (well R 26), Zubair Oil Field (well Zb-43), and West Qurna Oil Field (WQ-1), four palynofacies types that may infer to indicate swamp and marsh environments on delta top and platform conditions of delta front, prodelta, and open marine, respectively. Other wells of this study are recorded by palynological analysis to have been undergoing the same environmental laws within similar palynofacies types. Swamps and marsh as near to shore line of early Cretaceous prevailed in the western Iraqi Desert and Saudi Arabian region, and open marine conditions dominated in easternmost Iraq and Iran, with more varied deltaic environments in between, within Iraq and Kuwait. The repetition of the palynofacies types reflects transgressive and regressive phases during the deposition of the detrital sediments of the Zubair Formation and hence formed Barrier Island which led to reducing circulation. Accordingly, anoxic conditions leading to the preservation of abundant organic matters along with the palynomorphs were created (Fig. 14; Al-Ameri et al. 2010).

Discussion

Migration and accumulation of the generated and expelled oil to the reservoirs of the Cretaceous-Tertiary total petroleum system (TPS) could be assigned for their source rocks by biomarker interpretations. These could be performed by crude oil analysis within instrument of gas chromatography for the alkanes, pristanes, and phytanes while more concentrated analysis are performed by combined GC/MS.

Rocks of Zubair Formation are deposited in subsiding deltaic deposits of favorable conditions for the preservation

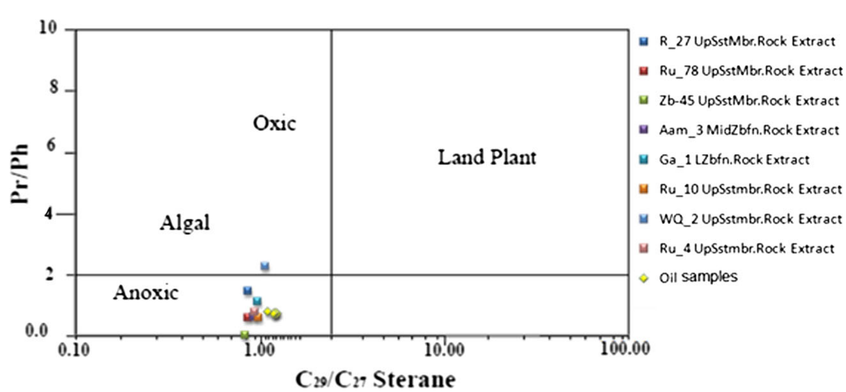

Fig. 11 Pr/Ph vs. C29/C27 ratios cross plot show anoxic condition of deposition for the analyzed oil and rock extracts samples (Othman 2001)

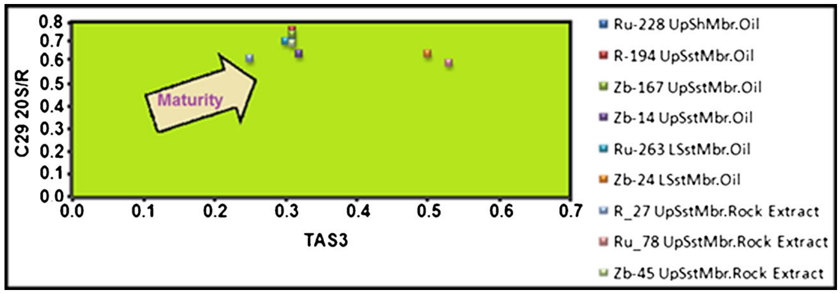

Fig. 12 The analyzed oils and rock extracts are in the mature zone (Peters et al. 2005a, b)

of the accumulated organic matter, albeit mostly in a biodegraded state (Al-Ameri and Batten 1997). The TOC content is between 0.52 and 25.8 % for most of the analyzed samples. Biodegradation and thermal alteration of the organic matter led in particular to the abundant amorphous organic matters that indicate oil prone (following Tyson 1995). The composition of this material is similar to oil prone kerogen type A of Thompson and Dembicki (1986) and is considered to be mature, the thermal alteration index being 2.5 (Staplin 1969; see Batten 1996a, b), and hence capable of generating liquid hydrocarbons.

Chemistry of the Zubair Formation organic matters in the area of interest is based on the results of pyrolysis analysis techniques (Table 1). Analyzed samples are plotted on the diagrams of hydrogen index (S2/TOC=mg HC/g rock) vs. maximum temperature (Tmax °C). The positions of the intersect points in the figure could indicate that Zubair Formation is a source rock of kerogen types II and III and of early-mature organic matter content with 415–443 °C Tmax and hydrogen index of up to 300 mg HC/g rocks for the Zubair subzone, while Euphrates subzone has a Tmax range 425 to 436 °C, which indicates less of maturity. The petroleum potential (mgHC/g Rock) of Zubair Formation in Zubair subzone varies between 0.2 and 73.62, while it is between 0.39 and 93.7 in Euphrates subzone that led to the petroleum potential assessment of fair to good source rock.

Zubair oil geochemistry is mainly saturated hydrocarbons on the basis of C15+. Plotting the analysis result from gas chromatography (GC) and GC/MS of wells of the study area (Table 4) on diagrammatic presentation of global standard parameters suggested by Peters et al. (2005a, b) and Zumberge et al. (2005) could assess the following oil-source relations:

The pristane/phytane value (Pr/Ph) plot can be used to infer reductive condition in the source rock depositional environment (Hunt 1996 and Peter et al. 1999). In Fig. 11, the Zubair Formation oils are plotted in the area of algal marine, reducing environments. Both Pr-nC17 and Ph-nC18 decreases with thermal maturity of oil and increase with degree of biodegradation. The Pr/Ph ratios of the Zubair oils vary between 0.73 and 0.83 (Table 4) and hence could indicate anoxic source rock deposition by comparison with the less than 1.0 of Peters et al. (2005a, b), while Pr/Ph >1 indicates that the oil is rich in lipids and waxes organic matter as showed in the rock extracts analysis of the Zubair Formation.

Sterane triangle plots of gas chromatography/mass spectrometry of the analyzed oil on the triangle of C27-C28-C29 ratios are used to interpret depositional environment and type of source rock and to classify crude oil into groups (Peters et al. (2005a, b). Accordingly, the resultant diagram (Fig. 10) is showing that the Zubair Formation oil and rock extract samples are in the area of marine shale source rock.

Terpane biomarker ratios of C22/C21, C24/C23 could assess source lithology by comparison with Peters et al. (2005a, b). Accordingly, the values of the analyzed samples of Zubair Formation (Table 4) are lying in shallow marine carbonate source rock area with interfingering of shale and marl.

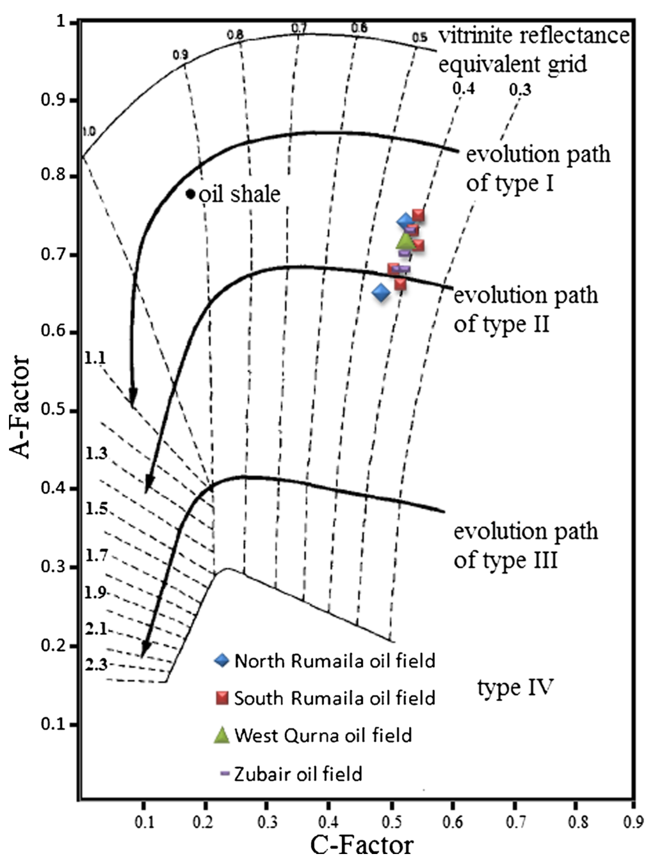

Fig. 13 Kerogen type and maturity levels as determined from A factor and C factor relationship for the study area (Ganz and Kalkreuth 1987b)

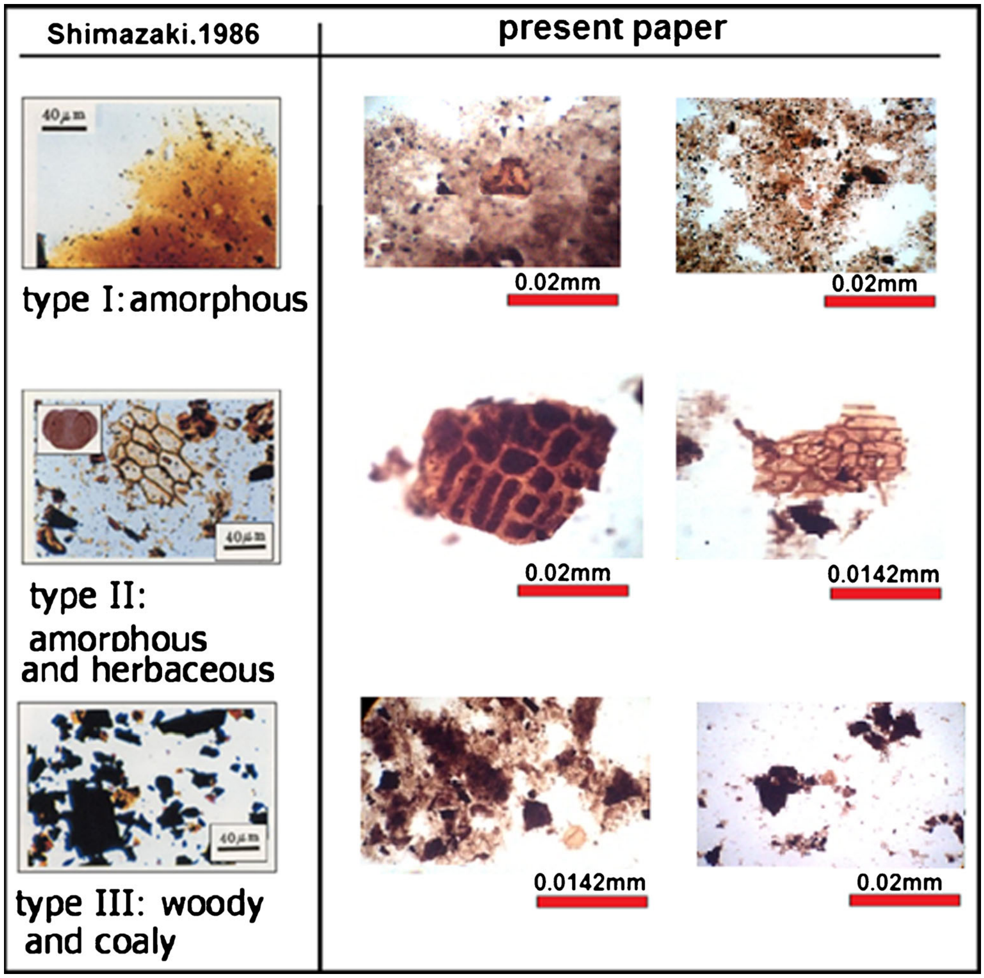

Fig. 14 Kerogen types by (Shimazaki 1986) in the optical study compared to the palynofacies of this paper. It is important to be explained that the type one AOM is the dominant in the Zubair Formation

Table 4 The well name, sample type, and GC/MS analysis were made to samples of oil and rock extracts to illustrate the source rock potentiality

Well	Sample type	Member	Depth (m)	Pr/Ph	Pr/n- C17	Ph/n-C18	Sat.	Aro.	NSO	Asph.	C22/ C21	C24/ C23	C26/ C25	C29/H	C31R/H	C35S/ C34S
Ru-228	Oil	UpShMbr.		0.76	0.18	0.28	43.2	36.9	12.7	7.2	1.02	0.3	0.75	1.41	0.35	1.11
R-194		UpSstMbr.		0.73	0.19	0.31	45	36.7	11.4	6.9	0.95	0.33	0.76	1.33	0.37	1.03
Zb-167		UpSstMbr.		0.77	0.21	0.32	45.4	37.4	10.3	6.9	0.94	0.34	0.76	1.32	0.37	1.06
Zb-14		UpSstMbr.		0.81	0.2	0.31	45.4	36.5	12.6	5.6	0.92	0.35	0.77	1.32	0.36	1.08
Ru-263		LSstMbr.		0.76	0.18	0.28	38	38.9	13.5	9.7	1.05	0.29	0.69	1.48	0.36	1.12
Zb-24		LSstMbr.		0.83	0.18	0.26	62.3	30.6	6.6	0.6	1.02	0.32	0.8	1.52	0.37	0.99
R_27	Rock Extracts	UpSstMbr.	3,214.16	1.5	1	0.45					1.71	0.34	0.83	1.55	0.35	1.02
Ru_78		UpSstMbr.	3,214.16	0.64	0.11	0.17					0.89	0.28	0.88	1.49	0.36	1
Zb_45		UpSstMbr.	3,338	0	0	0.42					1.38	0.39	0.82	1.37	0.35	1.06
Aam_3		MidZbfn.	3,448	0.69	0.17	0.23										
Ga_1		LZbfn.	3,364	1.17	0.3	0.34										
Ru_10		UpSstmbr.	3,126.5	0.64	0.14	0.17										
WQ_2		UpSstmbr.	3,255.78	2.31	0.51	0.21										
Ru_4		MidShmbr.	3,309.3	0.83	0.5	0.48										

Oleanane derives from Beta-amyrin and other land plant triterpenoids through a sequence of diagenetic reactions involving defunctionalization of the precursor molecules and skeletal rearrangement of the pentacyclic ring system (Rullkotter et al. 1994). Land-plant triterpenoids are biomarkers of angiosperms and restricted to fossil OM in late cretaceous and younger geological materials (Moldowan et al. 1994).

The oleanane/hopane ratio in the analyzed samples are very low (from 0.0 to 0.01) which may be interpreted due to the oil sources are older than the late cretaceous and they are empty from any angiosperm content.

Conclusions

1. The TOC of Zubair Formation approximately ranges between 1 and 24 %
2. The main type of organic matter is the AOM, followed by the opaque matters and then the phytoclasts and palynomorphs, which they represent in general the distal proximal anoxic shelf environment.
3. The maim kerogen type in Zubair Formation are the types: III, mixed type II/III, and type II kerogen.
4. The pyrolysis present in the Zubair Formation is entered in the threshold of oil generation and expulsion, which is represented by the values of MI (more than 0.2 mg HC/g TOC).
5. The relation between S1 vs. TOC has indicated that oil of Zubair Formation is indigenous within the studied area.
6. Maturity parameters indicate that the Zubair Formation is mainly within the early-peak oil window in Zubair Subzone, while in the Euphrates subzone, they show less maturity than former. Zubair Formation in Euphrates Subzone occurs in the immature-early oil window, while Nassiriah oilfield had a frequent results of maturity where Ns_3 shows higher maturity between the rest. It is worth mentioning that Nassiriah oilfield is the nearest to Abo-Jir faulting zone.
7. The high prospectivity of the formation clearly appears in the sandstone members. This result may indicate to thin organic-rich marine shale beads deposited in the prodelta zone of offshore facies.
8. The biomarker analyses indicate that the oil and related source rock are from the same origin, environment, and maturity as well as the absence of biodegradation effect.
9. All the results have supported the anoxic shallow marine environment, which belongs to offshore facies of prodelta sediments.

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