Evaluation of the Petrophysical Properties of Yamama Formation in Ratawi oil Field, South of Iraq

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Abstract
This paper contains studying of the Evaluation for the Petrophysical Properties of Yamama Formation in Ratawi Field which occurs in about 70 km to the west of Basrah city in Mesopotamia zone (Zubair subzone). The study includes a petrophysical evaluation and (3 Dimensions) geological model for each unit especially the three hydrocarbon units comprising the Yamama Formation in (5) boreholes which are Rt-3, Rt-4, Rt-5, Rt-6 and Rt-7 distributed on the crest and flanks of the Ratawi structure that are carried out in the present study. The formation's boundaries were determined using well logs, available core intervals and by Petrophysical data and it is found that it can be subdivided into three main reservoir units (YR-A, YR-B and YR-C), separated by two permeability barrier units, YB-1, and YB-2.

Keywords: Evaluation, Petrophysical Properties, Yamama formation.

تقييم الخواص البتروفيزيائية لتكوين اليمامة في حقل رطاوي النفطي جنوب العراق

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الخلاصة :
يحتوي البحث دراسة لتقييم الخواص البتروفيزيائية لتكوين اليمامة في حقل الرطاوي الذي يقع 70 كم الى الغرب من مدينة البصرة ضمن حزام الزبير التكتوني الثانوي، هذه الدراسة تشمل اجراء تقييم بتروفيزيائي مع عمل موديل جيولوجي ثلاثي الابعاد لكل وحدة وخاصة الوحدات الثلاثة الخازنة للهيدروكاربونات في تكوين اليمامة في خمسة ابار وهي Rt-3، Rt-4، Rt-5، Rt-6و Rt-7 موزعة عند القمة والسفوح لتركيب حقل الرطاوي. تم تحديد الحدود العليا والسفلى للتكوين باستخدام المجسات وفترات اللباب المتوفرة والمعطيات البتروفيزيائية حيث تم تقسيم التكوين الى ثلاث وحدات مكمنية رئيسية هي (YR-A, YR-B, YR-C) مفصولة بوحدتين غير نفاذتين هما (YB-1, YB-2).

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Introduction

The Yamama Formation, which is a heterogeneous carbonate reservoir, is one of the most important oil production reservoirs in southern Iraq, which was deposited during the Lower Cretaceous period within the main retrogressive depositional cycle (Berriasian - Aptian) south of Iraq, and from its stratigraphic position an age range of Late Berriasian to Early Valanginian age is expected, [1].

The Yamama Formation was defined by Steinke and Bramkamp in 1952, from outcrops in Saudi Arabia. They mentioned that the Yamama Formation represents the Thamama Group, along with the Buaib and Sulaiy Formations. Yamama Formation contains hydrocarbons at 26 structures in southern Iraq including West Qurna, North Rumaila, and Majnoon fields, and contains the most promising reservoir in Ratawi field, [2].

Formation Evaluation

There are a number of parameters that are needed by the exploration and evaluation team to determine the economic value and production possibilities of a formation. These parameters are provided from a number of different sources including, seismic records, coring, mud logging, and wireline logging. Log measurements, when properly calibrated, can give the majority of the parameters required. Specifically, logs can provide a direct measurement or give a good indication of :

- Porosity, both primary and secondary.
- Permeability.
- Water saturation and hydrocarbon movability.
- Hydrocarbon type (oil, gas, or condensate).
- Lithology.
- Formation dip and structure.
- Sedimentary environment.

These parameters can provide good estimates of the reservoir size. Logging can answer many questions on topics ranging from basic geology to economics; however, logging by itself cannot answer all the formation evaluation problems. Coring, core analysis, and formation testing are all integral parts of any formation evaluation effort, [3]. Log interpretation of the reservoirs for Yamama Formations was made after defining petrophysical properties of each unit by using GeoFrame software by Schlumberger which included log data for five boreholes (Rt-3, Rt-4, Rt-5, Rt-6, Rt-7) in Ratawi field, table-1.

A (3D) geological (static) model of a sample petroleum reservoir will be built depending on these petrophysical properties results. The software used is Petrel, which is a product of Schlumberger.

The ultimate objective of this Geophysical and Geological study is to construct 3D models of Yamama Formation in the Ratawi field for the consequent reservoir simulation study. The 3D Model is the grid that represents the structure, stratigraphy and reservoir properties (porosity and water saturation) in three direction (X , Y and Z), [4].

Cut-off Criteria

In general, cutoff is applied so that non-reservoir and/or non-pay intervals are excluded from the total reservoir intervals. Most simple way to find porosity cutoff limit is looking for porosity which is correlated with permeability of around 1 *md* in case of oil reservoir. When clear relation between porosity and permeability is observed on core measurement data, this approach can be followed.

As net pay intervals are not extracted only by porosity (φ) but water saturation (Sw) cutoff limit was applied, [5].

Cutoff Limits

The summary of the reservoir Gross thickness (**G**), Net Pay thickness (**N**), Net Pay Gross Thickness Ratio (**N/G**), Net Pay porosity (**φ**) and Net Pay water saturation (**Sw**) are presented in table-1 below.

Table 1-Log Interpretation Results (Cutoff calculations).

Well	*Unit*	*Gross Thickness (m) (G)*	*Net Pay Thickness in (m) (N)*	*Net Pay Gross Thickness Ratio (N/G)*	*Net Pay Porosity (M3/M3) φ*	*Net Pay Water Saturation (M3/M3) Sw %*
Rt-3	YR-A	119	30.125	0.253417	0.082112	20
	YR-B	84.5	45	0.532544	0.127582	21
	YR-C	40	18.625	0.465625	0.114532	32
Rt-4	YR-A	126	1.5	0.0119166	0.0770148	45
	YR-B	88	6.25	0.0710227	0.0788379	33
	YR-C	40	0.25	0.00625	0.0677977	46
Rt-5	YR-A	123	10.625	0.08647	0.0847003	31
	YR-B	93	3	0.0322581	0.0770241	40
	YR-C	48	—	—	—	—
Rt-6	YR-A	118	—	—	—	—
	YR-B	84	10.25	0.122024	0.0958757	28
	YR-C	43	—	—	—	—
Rt-7	YR-A	119.5	54.625	0.457113	0.0975994	10
	YR-B	81.5	65.5	0.803681	0.107139	93
	YR-C	58.5	12.375	0.211538	0.110773	90

Three reservoir zones of the Yamama Formation were separated by the tight zones. These tight zones were considered as the vertical flow barriers in the geological/reservoir model and each reservoir zone was interpreted to have individual Oil Water Contact (OWC) in the model. However, it was difficult to define the clear-cut OWC levels for the Yamama Formation, because pressure data was insufficient and only the lowest known oil for each separated zone can be recognized in the formation (the contact between the three reservoir units and the barrier below it) is L.P.O. (last prove oil), which is proven in the laterolog LLD and MSFL log value, especially the changing in facies lithology and low porosity value which were indicated in FDC/CNL log Density/Neutron log respectively.

As mentioned in well log data and reports they were utilized for petrophysical analysis and following construction of Geomodel. Detailed database of Well Logs, Core Data and Test Results were described. Other reports such as “Final Geological Reports", “Core Descriptions” were combined with well logs to divide the formation into zones and for interpretation of lithology, [6].
Figures-1, figure-2 and figure-3 were prepared for Net Pay Thickness (N) measured by meter for YR-A, YR-B, YR-C respectively.

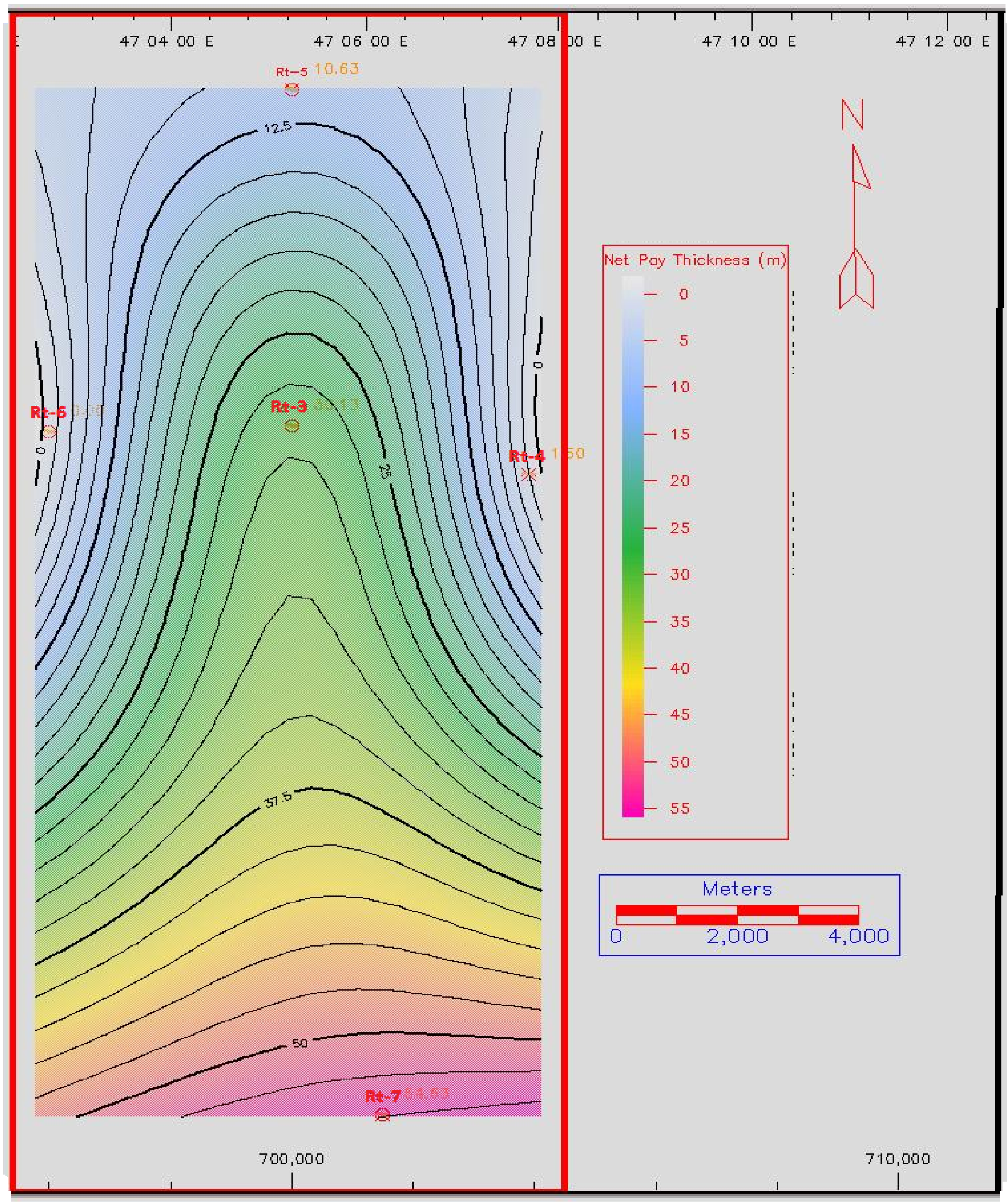

Figure 1-Net Pay Thickness (N), for YR-A.

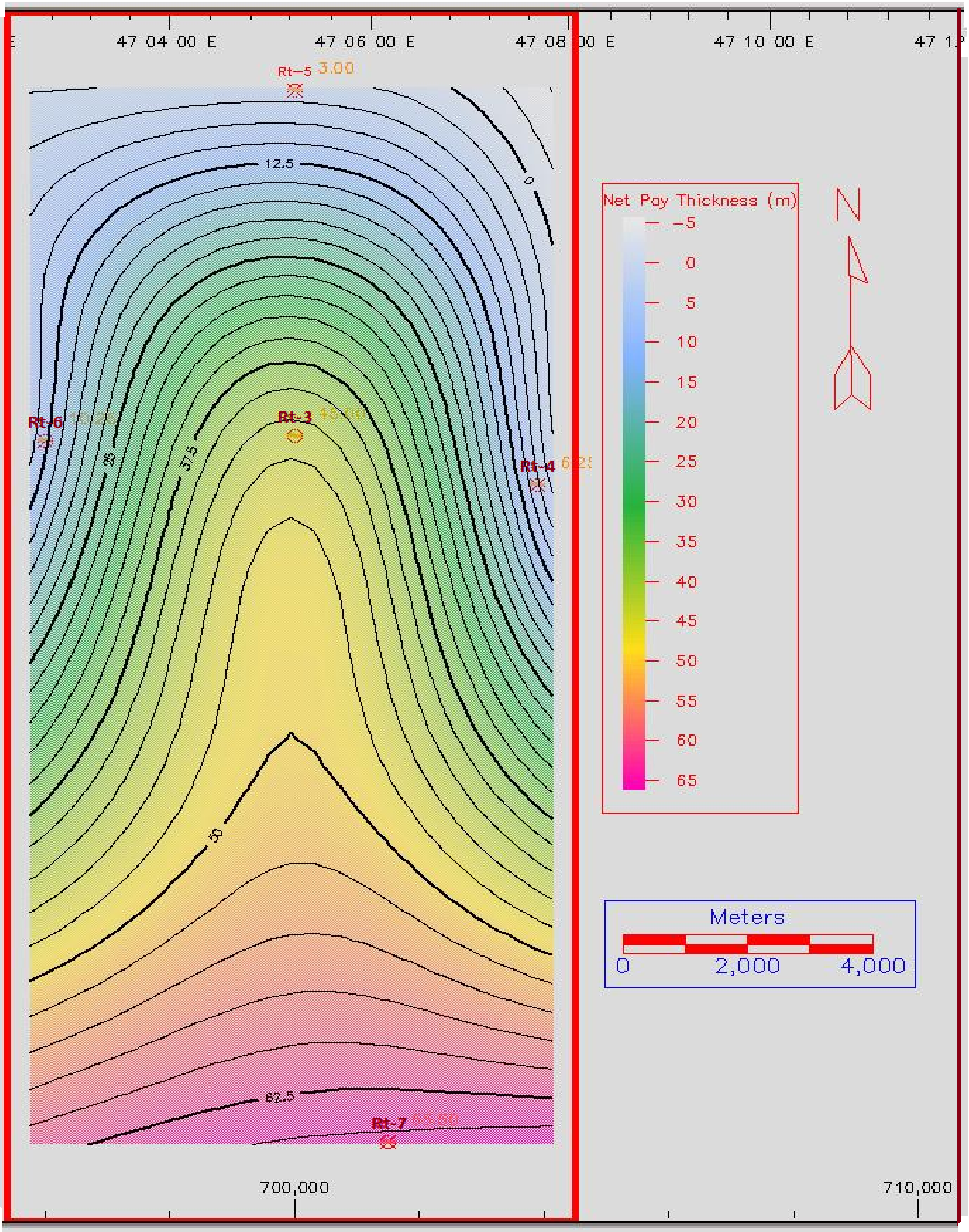

Figure 2-Net Pay Thickness (N), for YR-B.

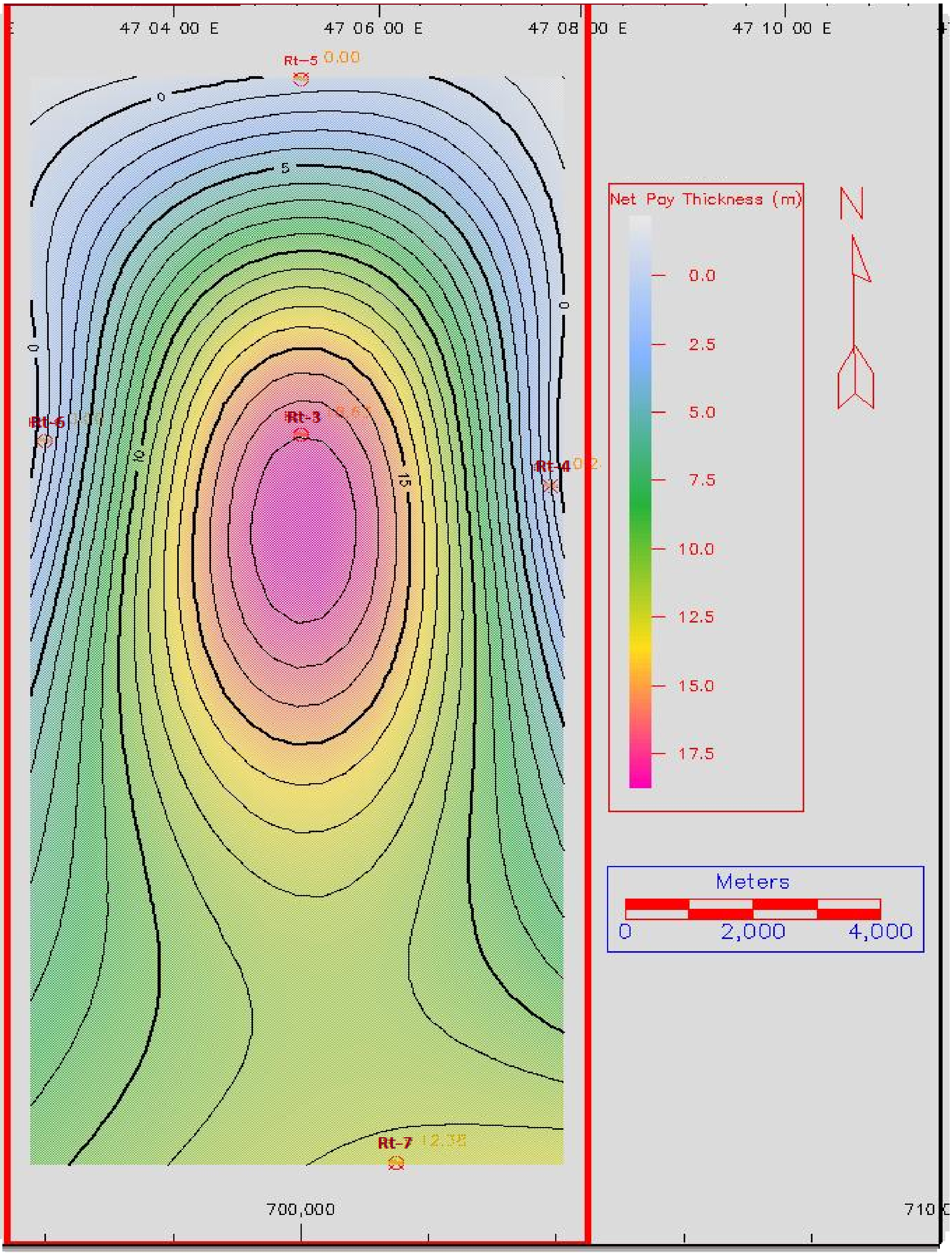

Figure 3-Net Pay Thickness (N), for YR-C.

Evaluation of Reservoir Units

The Yamama Reservoir is composed of limestone. Shale or argillaceous thin beds are often intercalated throughout the Yamama Formation. Porous layers are dominant in the middle zone of Yamama which were described as pseudo oolitic or equivalent to packstone or grainstone. Oil impregnation is limited to such porous zones, but fracture systems play role as a conduit of fluid flow. The digitized log data and depth normalization were carried out by shifting and adjusting log curves referring Density-Neutron logs as standard curves. All Gamma ray curves measured simultaneously with Density-Neutron were regarded also as reference curve even though GR behavior is not so clear within clean limestone reservoirs.

The zones YR-A, YR-B and YR-C are the oil-bearing intervals in the Ratawi field. The top and bottom of each oil-bearing zone are sharp lithological boundaries. The thickness of each zone is more or less constant and correlation among the wells is generally easy, table-2

Table 2 Tops of the Lithostratigraghic Units and Thickness for Yamama Formation in Ratawi field (measured in meter from (R.T.K.P. Rotary Table Kelly Bosh)). .

Top of Sulaiy	YR-C	YB-2	YR-B	YB-1	YR-A	R.T.K.P	Well no.
3803	3763	3749.5	3665	3653	3534	34.1	Rt-3
269	40	13.5	84.5	12	119		Unit Thickness
3952	3914	3900	3812	3801	3675	35.73	Rt-4
277	38	14	88	11	126		Unit Thickness
3960	3912	3900	3807	3796	3673	27.7	Rt-5
287	48	12	93	11	123		Unit Thickness
3919	3876	3857	3773	3761	3643	24.5	Rt-6
276	43	19	84	12	118		Unit Thickness
3939	3880.5	3868.5	3787	3775	3655.5	39.0	Rt-7
283.5	58.5	12	81.5	12	119.5		Unit Thickness

YR-A: The Net Pay thickness for this unit is (30.125, 10.625) m, and Net Pay Water Saturation (20, 31) % in (Rt-3, Rt-5) wells respectively table-2, this unit has no oil-bearing in (Rt-4, Rt-6, Rt-7) wells.
YB-1 : High Positive deflection for SP. log, low Sonic log , and GR. log shows distinctive increasing but not higher than the above unit.
YR-B: The Net Pay thickness for this unit is (45, 6.25, 3, 10.25, 65.5) m, and Net Pay Water Saturation (21, 33, 40, 28, 9) % in (Rt-3, Rt-4, Rt-5, Rt-6, Rt-7) wells respectively table-2.
YB-2: The log response to this unit is the same to the unit YB-2.
YR-C: The Net Pay thickness for this unit is (18.6, 12.37) m, and Net Pay Water Saturation (32, 9) % in (Rt-3, Rt-7) wells respectively table-1, this unit has no oil-bearing in (Rt-4, Rt-5, Rt-6) wells. The petrophysical properties of the unit are of poorer quality as compared to YR-A and YR-B. Its petrophysical properties become less distinctive with depth, with the cutoff and the net pay results of each reservoir unit of formation show that YR-A have poor petrophysical properties except in (Rt-3, Rt-5) which contains oil. YR-B is considered as the major reservoir unit which had been confirmed by the Petrophysical analysis of Yamama rocks which revealed that YR-B unit has the best Petrophysical properties comparing with the other two units (highest porosity, lowest water saturation and the best Net Pay Thickness) in all studied wells (Rt-3, Rt-4, Rt-5, Rt-6, Rt-7) and represent the principal oil bearing unit in the Formation. And YR-C has good petrophysical properties in two wells (Rt-3, Rt-7).

Structural contour map

Structural modeling - Making complex horizon and zones with possible pitchout zones. [7]. Contour maps can be made by computer from the surface and correlated borehole. [8]. Contour maps for exploration may depict geologic structure as well as thickness of formations. They can show the formations taper off or stop abruptly, [3].

In this study, structural modeling represents building structural contour map for each reservoir unit in Yamama formation (YR-A, YR-B, and YR-C) using Petrel software.

The structural contour map shows that Yamama structure is composed of elongated semi-symmetrical anticline, (with Rt-3 is in the crest). The long axis of the anticline shows N-S trend. The size of the structure is approximately 29.5 km long and 14.9 km wide at the top of each reservoir unit. The dip of the east flank at the top of the formation is about 2.4°, and the western dip at the top of the formation is about 2°. The dip increasing towards the eastern and western flanks reaches 1.8°, but the northern and southern flanks shows lesser dip around 1.5°. No fault was interpreted at the Yamama Formation, figure-4.

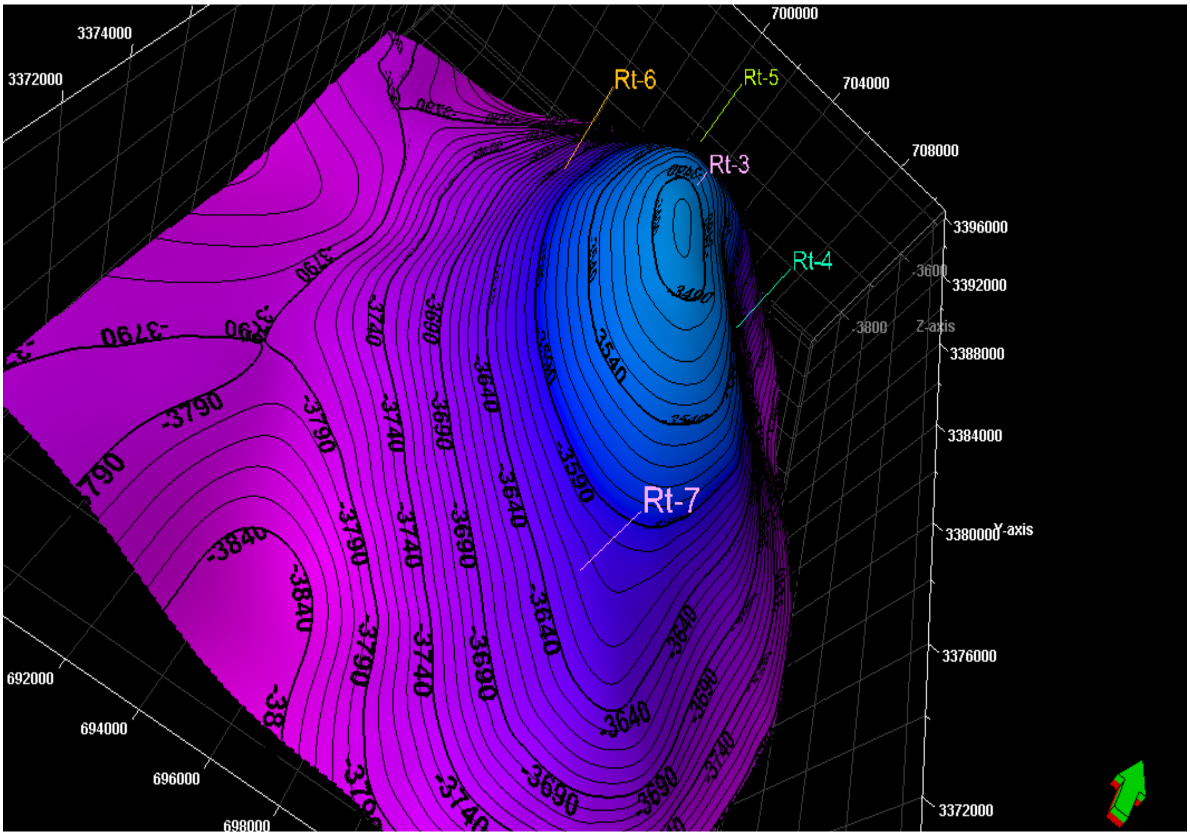

Figure 4- structural contour map on top of the Yamama Formation in Ratawi field.

Property Modeling

If all the structure and petrophysical grids for each zone are used as individuals then a considerable amount of work is required to combine structures with fluid contacts to create models and then to discount those models by Porosity, water saturation. Each of these operations is prone to errors and each set of operations must be performed for each zone, a time consuming process.

Since the structures were linked together in a 3D Grid in a previous step, it is a simple process to link the zone average petrophysical grids to the zones of that 3D Grid. This is done using the *Geometrical modeling* process. Geological modeling was a process of filling the 3D cell grids with petrophysical properties. The modeling was carried out considering the geological concept of each reservoir and the trends suggested by any geological or geophysical information as well as the well data as constraints. [6].

Petrophysical property modeling is the process of assigning petrophysical property values (porosity, water saturation, etc.) to each cell of the 3D grid. Petrel offers several algorithms for modeling the distribution of petrophysical properties in a reservoir model [9].

Reservoir Model has been created in PETREL software with grid size of X, Y and Z directions and cell size of 100m X 100m cell. Porosity and water saturation maps have been generated based on well values.

Petrophysics model was built using geostatistical methods. The petrophysics models include :

Porosity

Porosity model was built depending on the results of porosity logs (density, neutron, and sonic logs) which have been interpreted in the GeoFrame software obtained in chapter three. After the process of scaling up of well logs .

The geostatistical algorithm (Statistical sequential Gaussian simulation algorithm) represents a statistical method which fits with the amount of available data, [10], figure-5 shows porosity model of the three reservoirs together.

Water Saturation (Sw)

Using the results of water saturation that export from GeoFrame software the water saturation model was built for each reservoir unit of the Yamama formation in the Ratawi field. The same geostatistical method was used in the porosity model (Statistical sequential gaussian simulation algorithm). [7].

Figures-6 shows the distribution of water saturation models of the three reservoirs (YR-A, YR-B, and YR-C). The water saturation model matches the environments and porosity models, and as these Sw models compared with the porosity model in the previous section it shows that in YR-A the porosity has high value and low Sw is near Rt-3 in the crest and to the north near Rt-5 well, the highest porosity and lowest Sw is in YR-B especially around Rt-3 and Rt-7 as opposed to the area around Rt-4, YR-C has the highest Sw and lowest porosity in the three reservoir except around Rt-3 and Rt-7. And it can be deduced that generally, Yamama formation in Ratawi field has distinctive reservoir property at the crest of the structure reducing downward and towards the flanks of the structure.

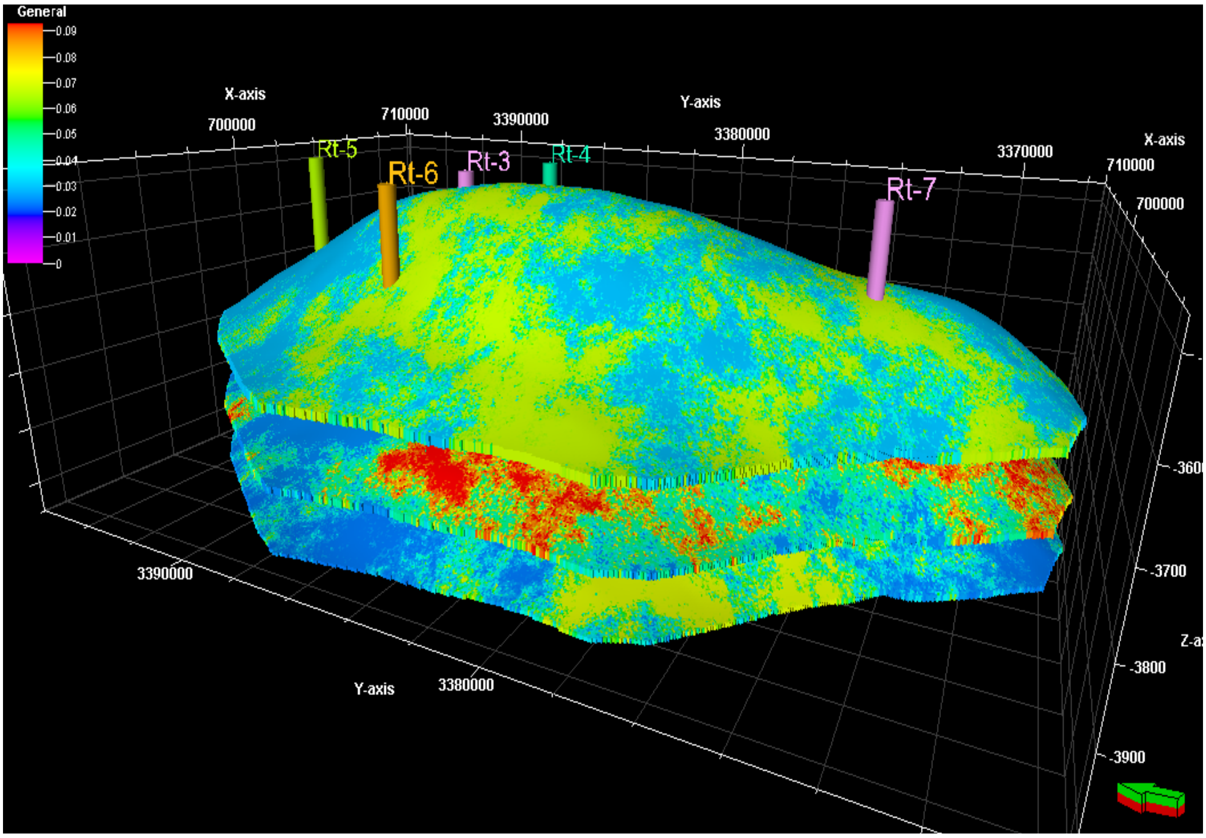

Figure 5-The porosity model of the three reservoirs (**YR-A, YR-B, YR-C**) in Ratawi field.

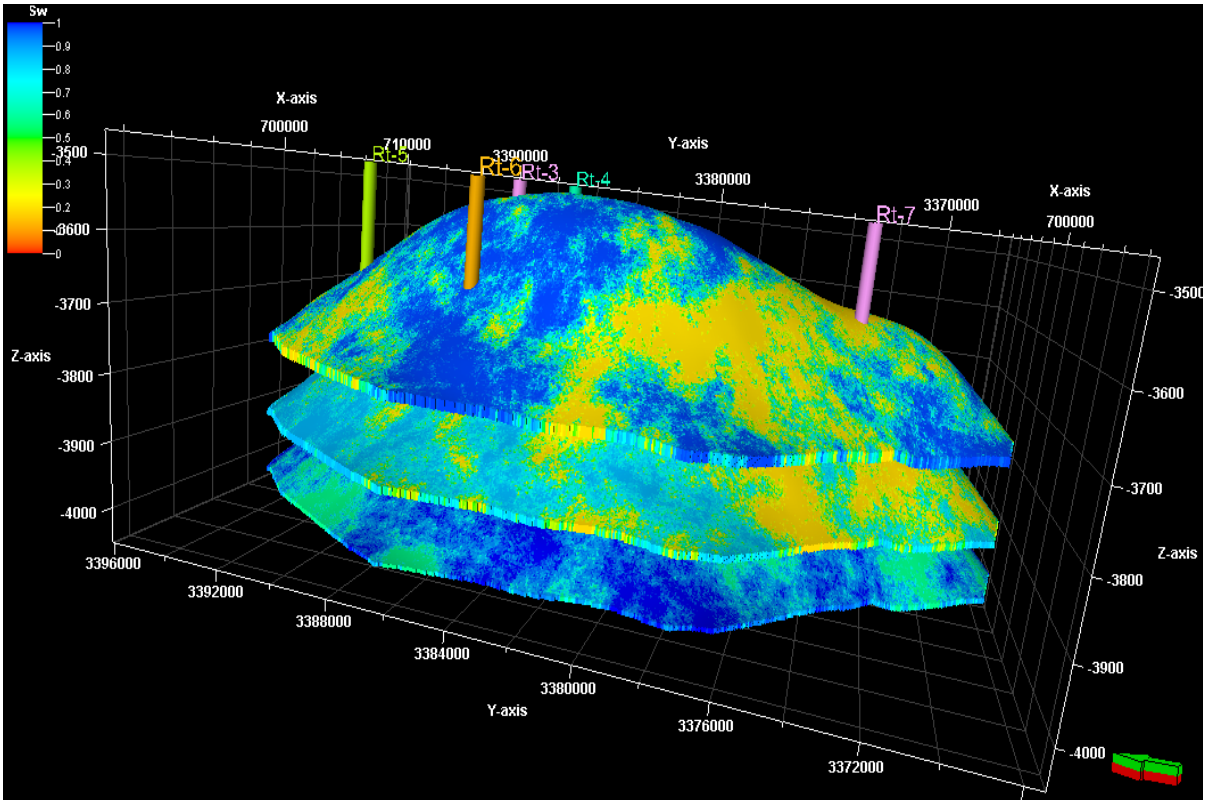

Figure 6- The water saturation model of the three reservoirs together (**YR-A, YR-B, YR-C)** in Ratawi field.

Conclusions

1. YR-B is considered as the major reservoir unit that has been confirmed by the Petrophysical analysis of Yamama rocks which revealed that YR-B unit has the best Petrophysical properties comparing with the other two units (highest porosity, lowest water saturation and the best Net Pay Thickness) in all studied wells (Rt-3, Rt-4, Rt-5, Rt-6, Rt-7) and represent the principal oil bearing unit in the Formation. And YR-C has good petrophysical properties in two wells (Rt-3, Rt-7). RT-3, 4, 5, 6 and 7 produced oil.
2. The structural contour map from 3D geological model shows that the Yamama structure is composed of elongated semi-symmetrical anticline, (with Rt-3 is in the crest). The long axis of the anticline show N-S trend. The size of the structure is approximately 29.5 km long and 14.9 km wide at the top of each reservoir unit.

Recommendations

1- Drilling a well between (Rt-3, Rt-7) if possible because the information and data are insufficient at the Sothern part of the field.

2- Taking core samples for YR-A because that it is not available, and for YR-C because they are very few and not enough for petrography microfacies study.

3- The 3D geological model that has been produced in this study will be more accurate with a 3D seismic survey.

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