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Basin Modelling of The Yamama Formation In Ratawi Oil Field South Iraq

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prepared by

Ali Hussein Zaghir

Supervised by

Dr. Amer Jassim Al Khafaji

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بِسۡمِ ٱللَّهِ ٱلرَّحۡمَٰنِ ٱلرَّحِيمِ
قَالُواْ سُبۡحَٰنَكَ لَا عِلۡمَ لَنَآ إِلَّا مَا عَلَّمۡتَنَآۖ إِنَّكَ
أَنتَ ٱلۡعَلِيمُ ٱلۡحَكِيمُ ﴿٣٢﴾ سورة البقرة

Certification of the Supervisor

I certify that this undergraduate dissertation entitled

“ Basin Modelling Of The Yamama Formation In Ratawi Oil Field South Iraq “

was prepared under my supervision at the College of Science / University Babylon in partial fulfillment of the requirements for Bachelor's degree.

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Abstract

The Yamama Formation is an important reservoir as well as a good source of rocks in many of the oilfields of the southern Mesopotamian Basin, Iraq. The formation represents a regressive cycle deposited in a shallow carbonate ramp that was under clastic influence from the nearby land. This setting is a determining factor in the organic matter content. Geochemical pyrolysis, palynofacies, biomarkers, and carbon isotope analyses were conducted on 152 samples from 27 oil wells. The formation represents a regressive cycle deposited in a shallow carbonate ramp that was under clastic influence from the nearby land. Based on pyrolysis analyses, the source rocks have poor to excellent hydrocarbon potential. The kerogen types of the Yamama source are varied, including II, II/III, III, and I. This is due to the varied depositional environments and related organic matter sources (continental to marine). The studied samples also showed a variety in distribution between oil-prone kerogen type II, distal sub-oxicanoxic–anoxic, and the dysoxic–anoxic marine carbonate environments of (IX) and (VIII) zones of Tyson Ternary, which reflect the wide variations in the sediment depositional paleo-environments. The difference in the variations of normal alkanes of light alkanes in the range of n-C13 to n-C19 of the gas chromatography analyses, as well as the verities of the biomarker ratio of the tricyclic terpanes, hopane, and homohopane, indicate differences in the depositional setting. Similarly, the carbon stable isotope compositions of 13C (‰) saturated and 13C (‰) aromatic hydrocarbons, as well as the canonical variable value for Yamama source rock extracts, correspond to a variety of organic matter sources, ranging from open marine to terrestrial with plants. The Tmax values for most Yamama source samples range from 430 ◦C to 451 ◦C, the C27 Ts/Tm, C29 sterane the 20S/(20 S + 20 R) and ββ/(ββ+αα) stereoisomer, and trichromatic steroids 3 [TAS3]) ratios, indicating that the studied samples are in the range “immature to

oil window”, and that Tmax of 430–450 ◦C corresponds to an early to peak oil window stage. The Yamama source intervals entered the early oil window in the Late Cretaceous ranging from 80 to 62 Ma and completed oil generation in the early Eocene to Late Miocene approximately 80 to 62 Ma, according to 1D-Burial, thermal history modeling, and the timing of oil generation of selected wells covering the studied area (58–7 Ma). This confirms that these source intervals have completed petroleum generation and have contributed significantly to the supplies of crude oil and gas to surrounding reservoirs.

Chapter One

Introduction

1.1. Introduction

The Yamama Formation of the Valanginian age was introduced to the Arabian stratigraphy by (Steinke and Bramkamp, 1952) in Saudi Arabia to be distinguished from the Ratawi Formation. By extension, the formation name has been applied to the upper part of a more or less continuous pellety limestone sequence which underlies the shaly Ratawi Formation in the Ratawi well of southern Iraq, and also Burgan 113 in Kuwait.

In southern Iraq, the Yamama Formation is one of the major Lower Cretaceous carbonate reservoirs. At the same time, the Formation contains important source rocks that may be responsible for the generation of some of the oil stored in the Cretaceous reservoirs in the area, (Fig. 1); (Sadooni, 1993). The Yamama Formation is formed of shallow water carbonates containing large benthonic foraminifera, and red and green algae with some horizons of oolitic packstone and grainstone. The Yamama carbonates grade upward into the shale and fine sand of the Ratawi Formation, which is considered the caprock of the Yamama reservoir units.

The Yamama Formation is underneath the Upper Jurassic to Lower Cretaceous Sulaiy Formation which consists mainly of sub-basinal chalky and argillaceous limestone. The Jurassic-Cretaceous boundary in southern Iraq passes through the upper part of this Formation, (Sadooni, 2018), Fig 3.2 (see Fig. 3.3). Jurassic-early Cretaceous in Iraq, Kuwait, and Saudi Arabia. Modified after (Sharland et al., 2011). The Yamama source potential has been investigated by many workers such as (Al-Marsoumi et al., 2005; Abeed et al., 2011; Abeed et al., 2013; Al-Khafaji et al., 2019). They concluded that the Yamama source rocks were deposited in alternating suboxic to anoxic depositional conditions basin and that they have very good hydrocarbon indices with moderate to higher levels of thermal maturity (Chafeet et al., 2020). evaluated the source rocks potential and palynofacies of Early Cretaceous formations (Nahr Umr, Zubair, and Yamama) in Suba oilfield, southern Iraq, and suggested that the Yamama Formation has a good hydrocarbons potential in that area.

1.2. Previous studies

Previous studies by Iraqi and international oil companies operating in Iraq over the last few decades (e.g., (Beydoun et al., 1992), as well as some recent studies (e.g. (Pitman et al., 2004; Al-Khafaji et al., 2021), indicate that the majority of the hydrocarbons accumulated in the Cretaceous and Tertiary reservoirs in the Middle and South of Iraq may have been generated by the Middle Jurassic Sargelu and Najmah formations.

However, the huge quantities of hydrocarbons trapped in these reservoirs appear to be considerably higher than the Sargelu and Najmah formations can yield. Therefore, other mature source formations may have contributed to supplying oil to these reservoirs. This study is recognized as one of the most significant organic geochemical investigations since it addressed one of the most important formations in central and southern Iraq, the Yamama formation, which is regarded as one of the most probable source rocks for hydrocarbon generation and may have contributed to the generation and expulsion of hydrocarbons into neighboring reservoir

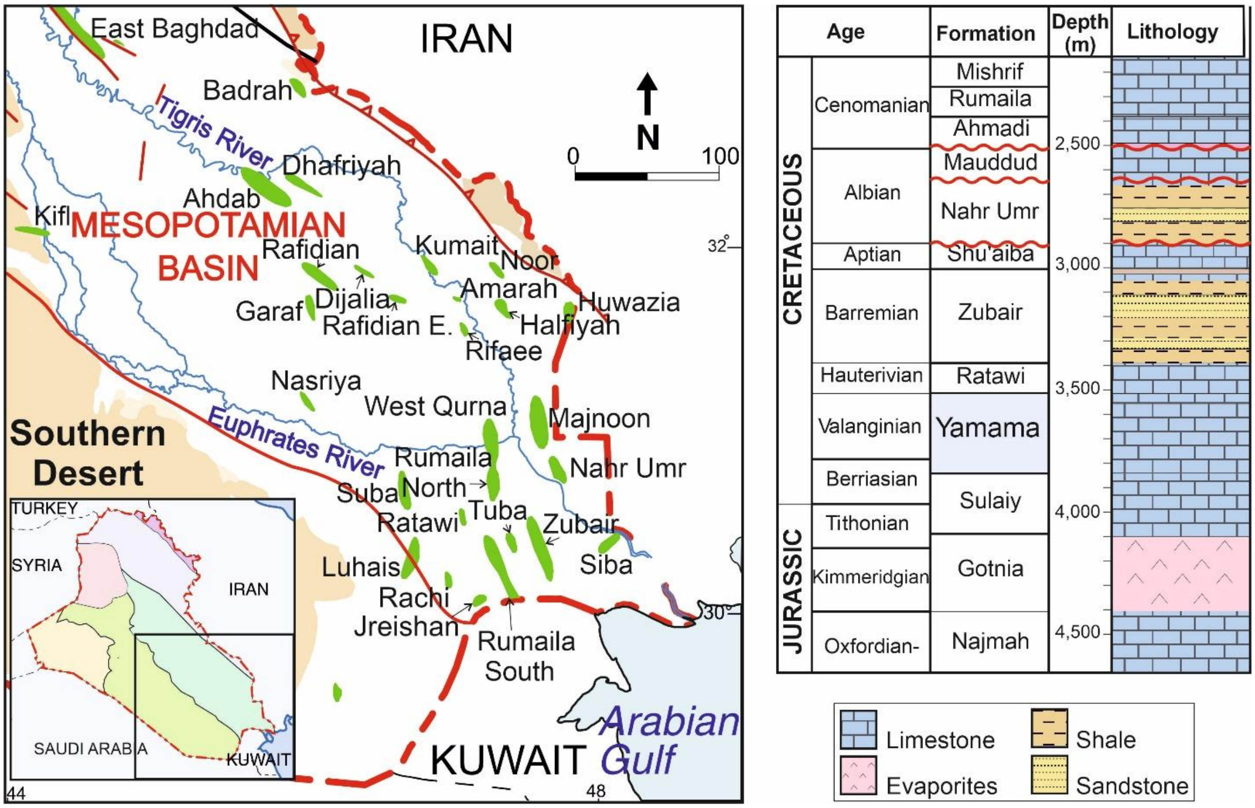

Fig. 1. Left. The major oil fields in central and southern Iraq are also shown on a map of the study area. Right. Stratigraphic section of the well Rumaila North (Ru72), Southern Mesopotamian Basin, Iraq.

Chapter Two

Methodology

2. Methodology

2.1. Preliminary information was compiled and consisted of reviewing wells and research, including internal reports, geological and reservoir studies, and the archives of the Iraq Ministry of Oil and its services com- panies, along with information from the Oil and Gas University.

2.2. Wire-line logs were collected that cover most of the excellent section for Yamama wells, which were selected because of the availability of open-hole logs for identifying each reservoir unit in Yamama Formation, includ- ing the compensated neutron log (CNL), density log, sonic log, spontaneous potential log, resistivity logs, gamma-ray log, and calliper logs. Tese logs identify the formation tops and thickness and have also been used in stratigraphic correlation. Tese logs are also crucial for identifying the separator boundaries between the formations that return to the reservoir.

2.3. Detailed core examinations and thin sections were collected for facies analysis and diagenesis evaluation. Then, these components within the sedimentary section of the formation were divided into primary and secondary facies and distributed within their environments according to the divisions2 to draw sedimentary environment models for the study area. The steps for sampling and making a thin section are listed below:

(a) Describing the study samples through feld observations.

(b) Modelling the study samples, photographing and describing the samples during collection, then storing them in special bags.

(c) Making thin slides of the selected samples.

(d) Examining the thin slides under a microscope and obtaining a clear picture of each important slide using a special microscope.

4. Upscaling the petrophysical parameters and facies results to build the facies models.

5. Applying sofware programs to obtain the following aspects:

• Didger 3 sofware was used to read the values of all open hole logs mentioned above with depth for each metre for the study area. Additionally, the program was used to draw many graphics and maps related to the study area.

• Excel was used to calculate the petrophysical properties of the reservoir.

• ArcMap, Photoshop, and Paint were used to draw many graphics and maps related to the study area.

• Te Weka-3.6 program with Excel was used to determine the values of electrofacies for the study area to obtain the intervals of facies for the study area that had no core by open hole logs.

• Te Petrel 2017 program was used as follows:

(a) Tabulate the results of the petrophysical and facies analysis and make a correlation between the studied wells.

(b) Make 2D and 3D models for the facies model after generating upscaling for these properties and make surface maps for the reservoir units (Fig2.1,2.2)

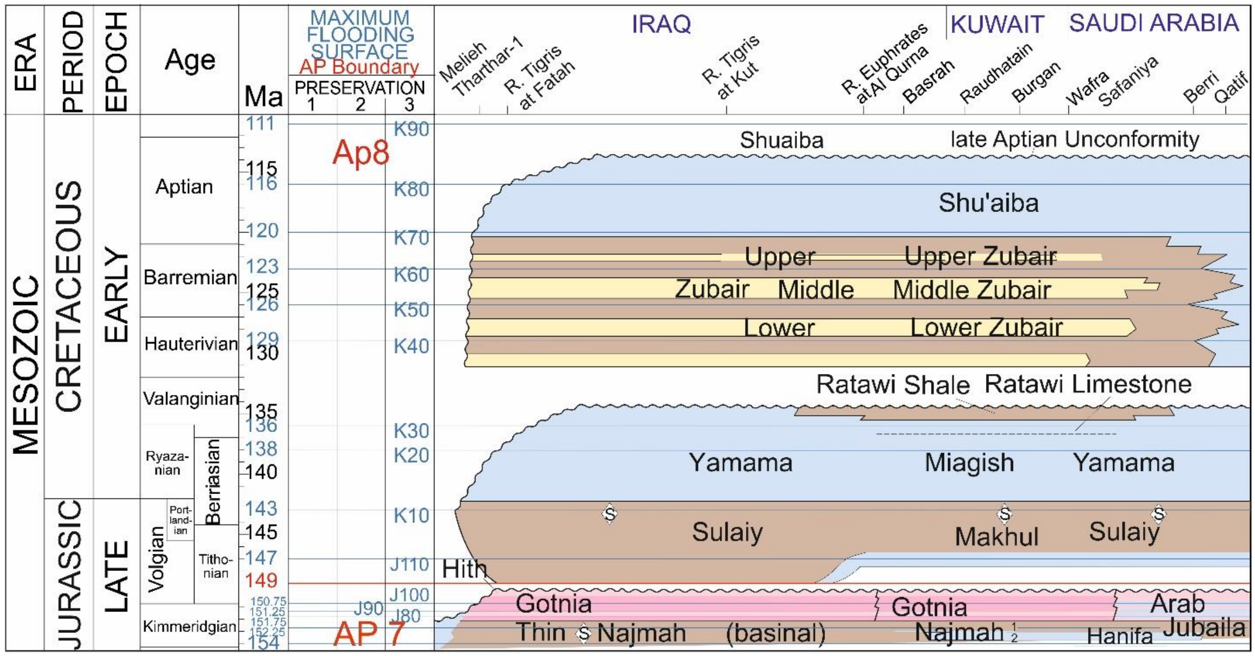

Figure 2.1. Equivalents to the Yamama Formation in Iraq and the neighboring Arab countries were modified (Al-Khafaji et al, 2022) by using Didger 3 software.

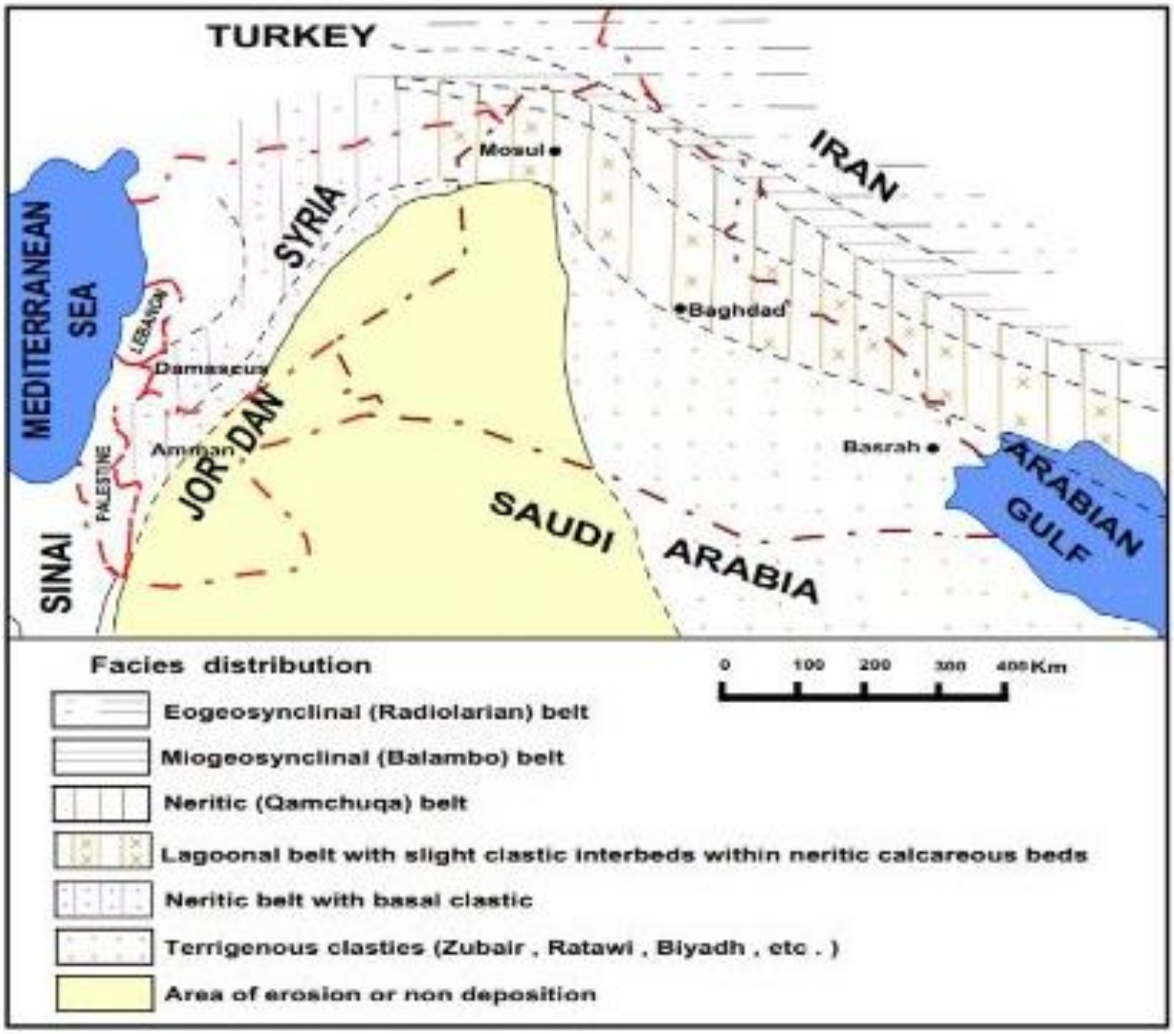

Figure 2.2 Paleogeography map of the Late Berriasian—Aptian period, modifed form4 by using Didger 3. Te

miogeosynclinal furrow indicate that in northeastern Iraq the boundary of Balambo trough was formed by ridge indicated by shallow water carcareous sediments in the wider Surkev–Norbab–Avroman area. On the area of

unstable shelf, and on the marginal parts of the stable shelf,—three zones, with diferent sedimentary sequences, can be distinguished in this fgure: (a) Te neritic belt, is relatively broad zone connected with the ridge separating the miogeosynclinal furrow from the basinal areas of the platform. (b) Te lagoonal belt occupies the rest of the Foothill Zone, and the Mesopotamian Zone. Te sediments of the basin are characterized by

terrigenous supply, mainly in the basal parts of the sequence Garagu facies and show lagoonal in layers too. (c) Te sandy zone occupies the rest of the Mesopotamian Zone (the Euphrates Block). Te zone is characterized by prevalently terrigenous clastic sedimentation, pelitic and calcareous at the beginning i.e. by the reduced Yamama

and the Ratawi Formations and mainly by the mighty Zubair sands. Te area extends over the stable shelf on and to the east of the Abu Jir Subzone too.

Chapter Three

Results and Discussions

3.1Formation 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.(Halliburton, Energy Service, 2001)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, table٣-1.

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), (Turner A. K. and Gable C. W., 2008)

3.1.1. Cut-off Criteria

In general, cutoff is applied so that non-reservoir and/or non-pay intervals are excluded from the total reservoir intervals. A 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 a 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. (Schlumberger, 2010)

3.1.2. Cut off 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 3-1: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, [The Ratawi Field 2009].Figures-1, figure٣-2 and figure٣-3 were prepared for Net Pay Thickness (N) measured by meter for YR-A, YR-B, YR-C respectively.

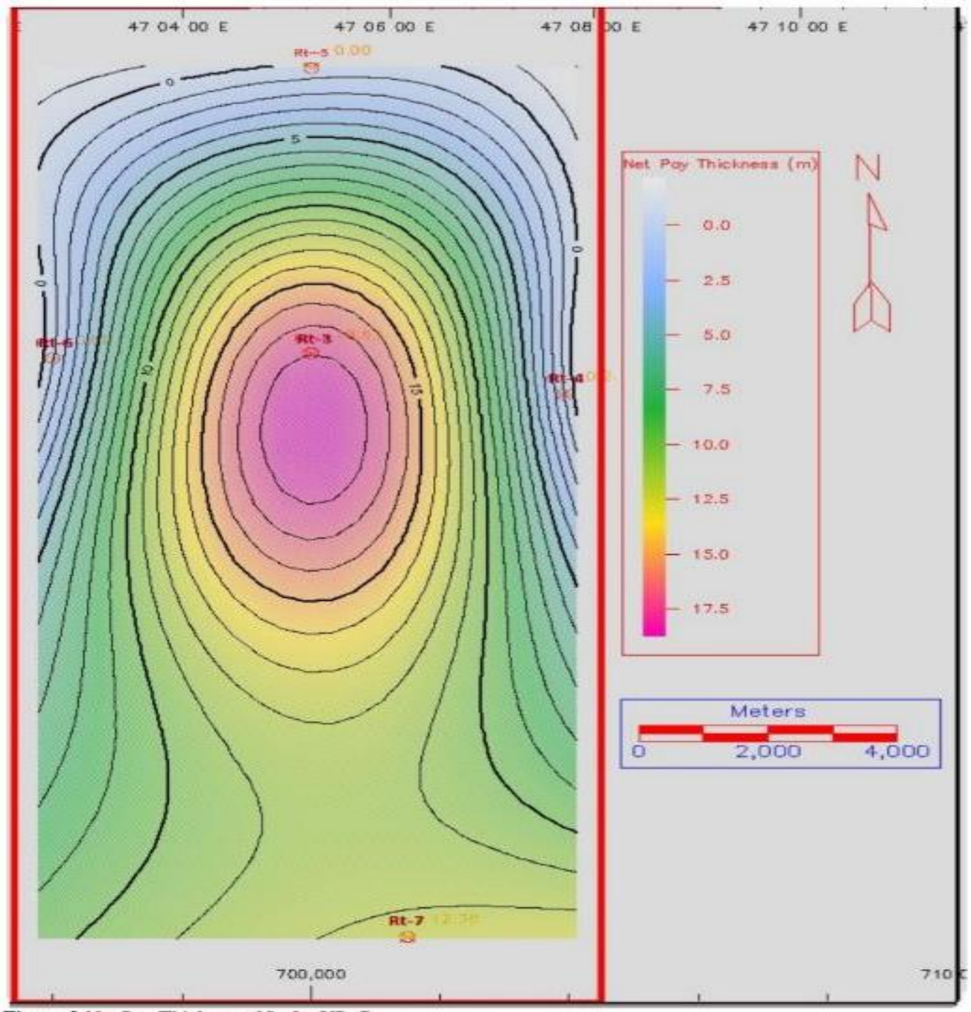

Figure 3.1-Net Pay Thickness (N), for YR-A.

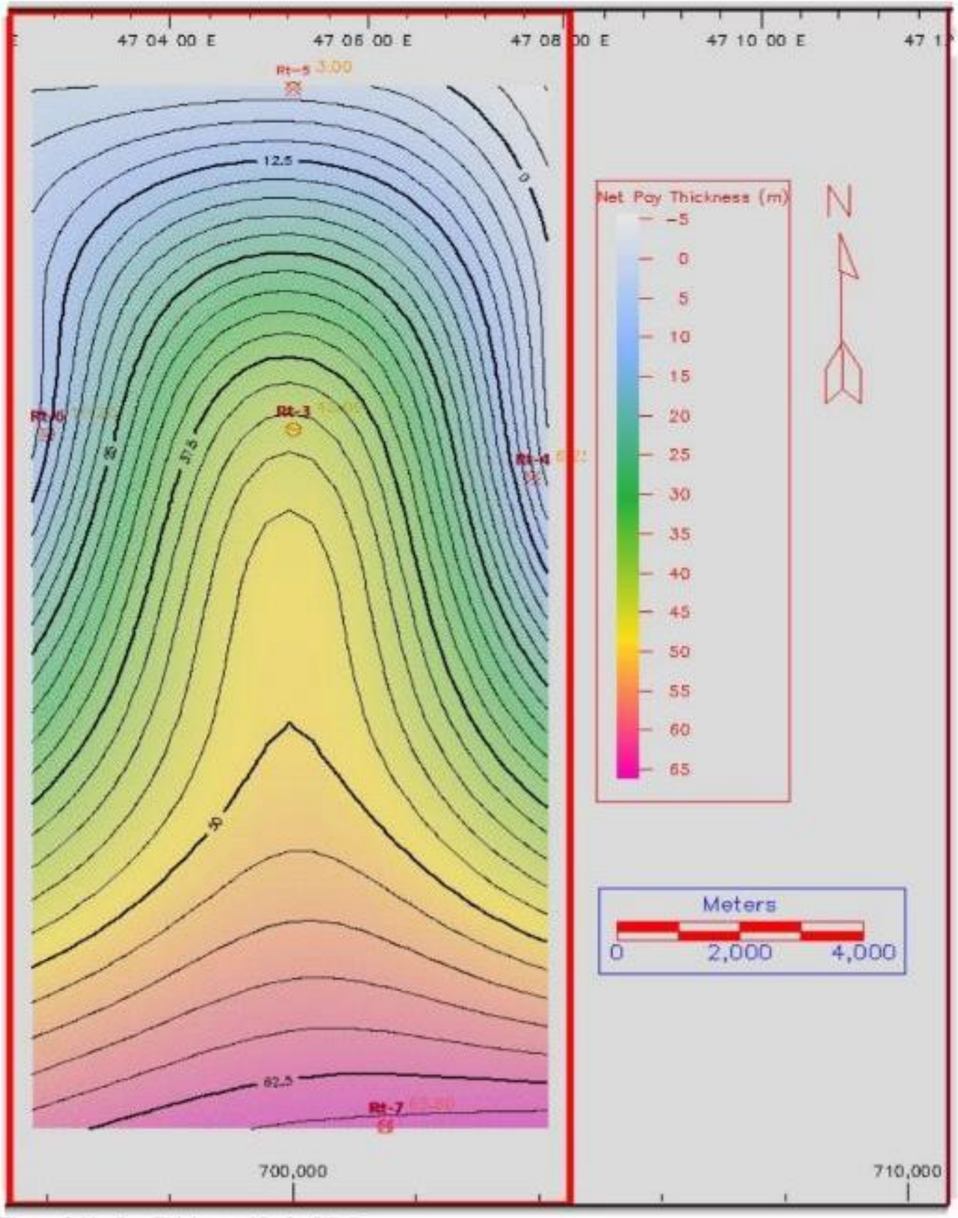

Figure 3.2-Net Pay Thickness (N), for YR-B.

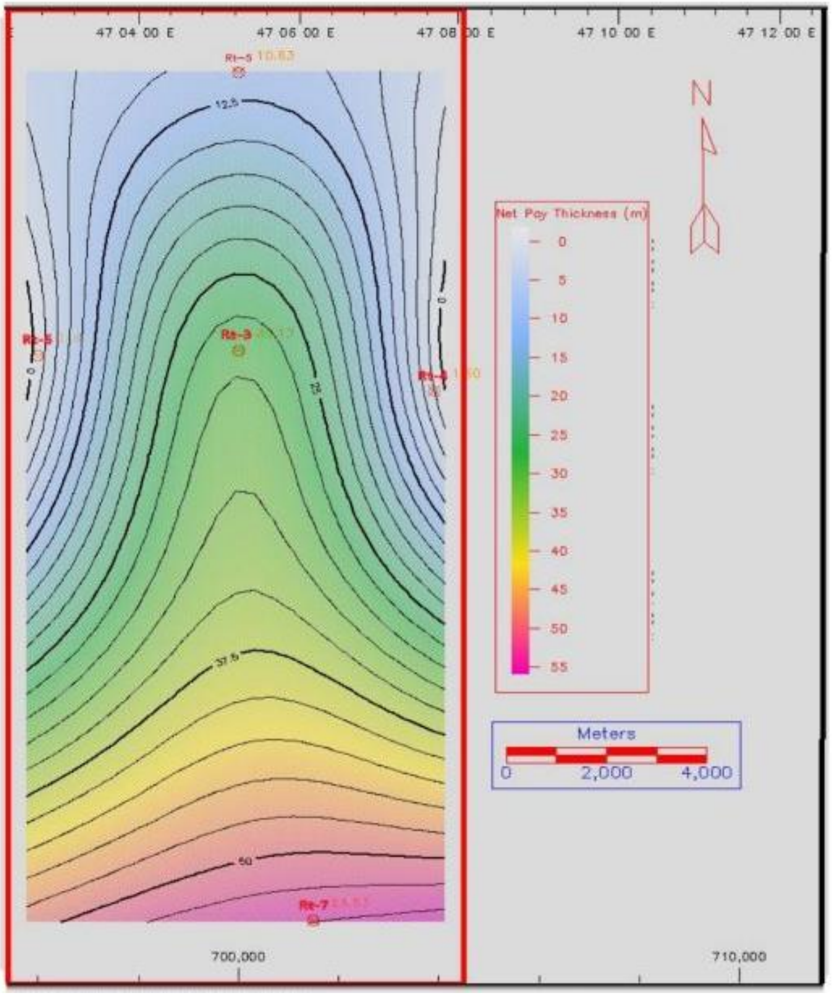

Figure 3.3-Net Pay Thickness (N), for YR-C.

3.2. 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-be aring 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, table٣-2

Table3-2: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).

3.3. Structural Contour Map

Structural modeling - Making complex horizon and zones with possible pitchoutzones.0T0T[Schlumberger, 2008].Contour maps can be made by computer from the surface and correlated borehole. [Pack, S., 2000]. Contour maps for exploration may depict geologic structure as well as thickness of formations. They can show the formations taper off or stop abruptly, [Halliburton, Energy Service, 2001.]. 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.

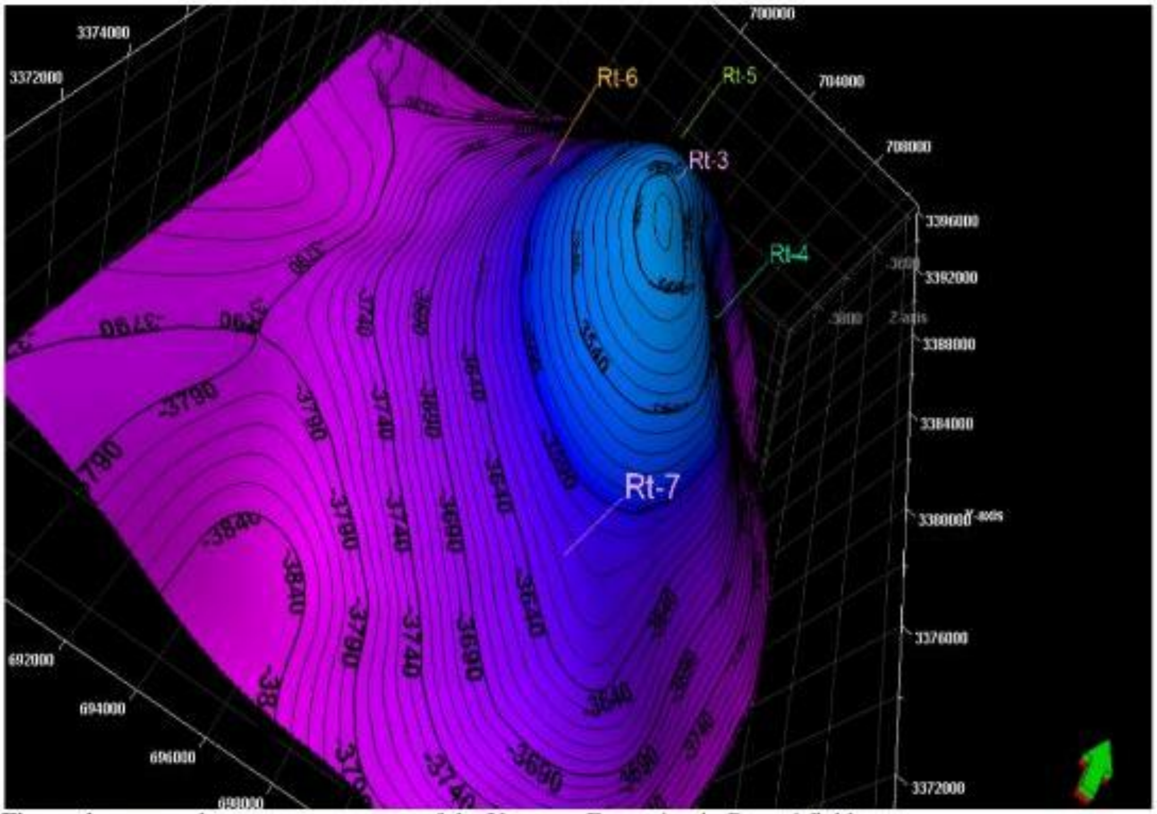

Figure.3.4.: structural contour map on top of the Yamama Formation in Ratawi field.

3.4. 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 petrophysicalproperties. 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.

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. 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. 2TPetrophysics model was built using geostatistical methods. The petrophysics models include :

3.4.1 Porosity

Porosity model was built1 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) Trepresents statistical method which fits with the amount of available data,figure3-5 shows porosity model1 of the three reservoirs together. (P., 2003)

3.4.2 Water Saturation (Sw)

Using the results of water saturation that export from GeoFrame software the water saturation1model was built for eachreservoirunit1of the Yamama formation1in the Ratawi field same geostatistical method was used in the porosity model (Statistical sequential gaussian simulation algorithm). (Schlumberger, 2008)

Figures3-6 shows the distribution of water saturation model of the three reservoirs (YR-A, YR-B, and YR-C). The water saturation model matches the environments and porosity models, and1T as these Sw models compared with the porosity model in the 1Tprevious 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.

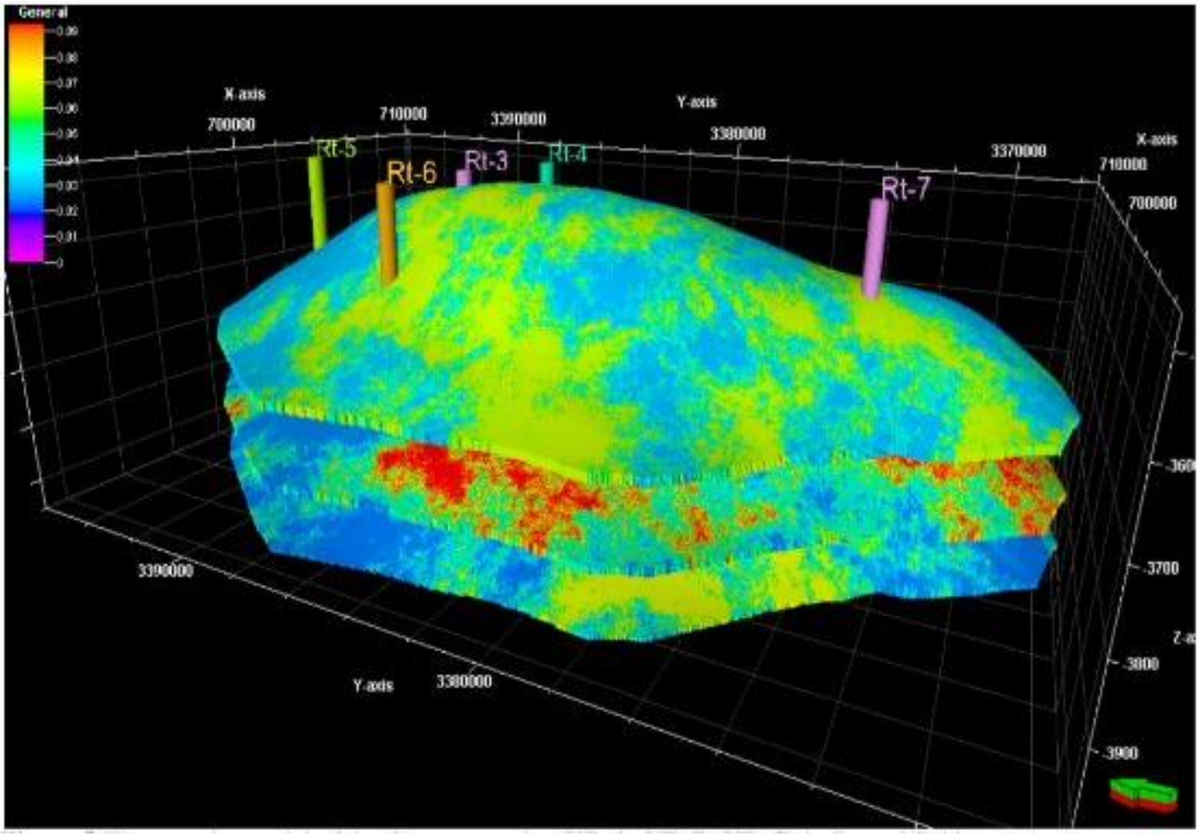

Figure 3.5-The porosity model of the three reservoirs (YR-A, YR-B, YR-C) in Ratawi field.

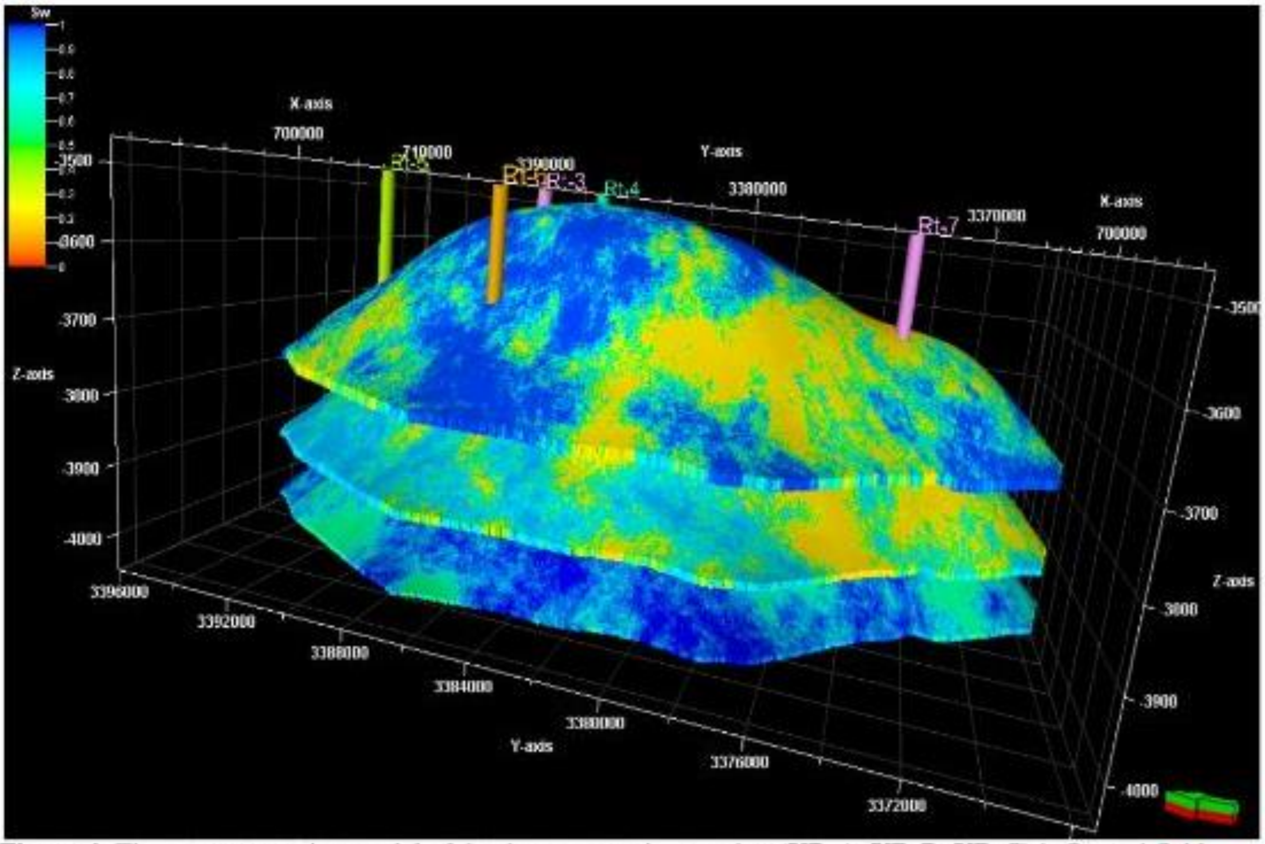

Figure3. 6- The water saturation model of the three reservoirs together (YR-A, YR-B, YR-C) in Ratawi field.

Chapter Four

Conclusion

4. Conclusions

1. The boundary of the contact between the upper and lower Yamama Formation of the Ratawi field, as well as the internal boundaries, have been redefined using well log data, facies data, and various reservoir data, and new limits were given according to the data of the results mentioned earlier.

2. It was found by examining the thin sections that the wells in the Yamama Formation contained a percentage of skeletal grains, which include calcareous algae, some benthonic foraminifera, echinoids, and a few sponge spicules and molluscs, which can distinguish the study area by containing an abundance of these skeletal grains. While the non-skeletal grains were represented by oolites, pseudoolites, and peloids, some pellets were rarely observed.

3. Seven primary facies and several subsidiary facies were found, deposited in various settings and modi- fed by diagenesis. Facies at noncore depths could be checked by comparing them to their well logs. After comparing the microscopy results with the well logs, the following main limestone facies were identifed: mudstone, mudstone–wackestone, wackestone, wackestone–packstone, packstone, packstone–grainstone, and grainstone facies.

4. The Yamama Formation environments in the Ratawi Feld were divided into several environments depending on the facies and electro facies characteristics of the formation (lagoon environment, open marine environ- ment, shoal environment, and slope environment).

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