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Yamama Reservoir Characterization in the West Qurna Oil Field, Southern Iraq

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Abstract
Yamama Formation (Valanginian-Early Hauterivian) is one of the most important oil production reservoirs in southern Mesopotamian Zone. The Yamama Formation in south Iraq comprises outer shelf argillaceous limestones and oolitic, pelloidal, pelletal and pseudo-oolitic shoal limestones. The best oil prospects are within the oolite shoals. Yamama Formation is divided into seven zones: Upper Yamama, Reservoir Units YR-A & YR-B separated by YB-1, and YR-B Lower & two Tight zones: low (porosity, permeability and oil saturation) with variable amounts of bitumen. These reservoir units are thought to be at least partially isolated from each other.

Keywords: Yamama Reservoir, West Qurna oil field.

الخواص المكمنية لتكوين اليمامـة في حقل غرب القرنـة النفطي، جنوبي العراق

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الخلاصة
تكوين اليمامة (فالنجنينان–هوترفيان المبكر) واحد من خزانات إنتاج النفط الأكثر أهمية في منطقة جنوبي مابين النهرين. تكوين اليمامة في جنوب العراق يضم الرف الخارجي الحجر الجيري الصلصالي، والحجر الجيري الأوليتي، البيلويدي، البيلويتي، والحجر الجيري الضحل الأوليتي الكاذب. أفضل احتمالات وجود النفط تكون ضمن الحجر الأوليتي الضحل. ينقسم تكوين اليمامة الى سبع مناطق: أعلى اليمامة، الوحدات المكمنية YR-A وYR-B مفصولة بواسطة الوحدة العازلة YB-1، ووحدة YR-B السفلى ومنطقتين محكمتين: منخفضة (المسامية، النفاذية والتشبع النفطي) مع كميات متفاوتة من القار. ويعتقد أن هذه الوحدات المكمنية تكون معزولة على الأقل جزئياً عن بعضها البعض.

Introduction

The Yamama Formation is the main Lower Cretaceous carbonate reservoir in southern Iraq. The Yamama Formation belongs to the late Berriasian-Aptian cycle. This cycle is represented from shore to deep basin by the Zubair, Ratawi, Yamama, Shuiaba, and Sulaiy formations [2]. The formation is usually conformably overlain by the Ratawi Formation. In SE Iraq, at the Nasiriya, West Qurna, and Majnoon, fields, probable sequence boundaries have been identified within the Yamama Formation of the top of oolite facies. In southern Iraq, Yamama Formation composed of limestone, picked by appearance limestone which is below the last shale streak at bottom of Ratawi Formation.

The Yamama Formation is one of the most important oil production reservoirs in southern Mesopotamian Zone, especially in the West Qurna, North Rumaila, and Majnoon fields, that extends from Valanginian-Early Hauterivian within the main retrogressive depositional cycle (Berriasian-Aptian) south of Iraq [2].

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Area of study

West Qurna field is located in Basrah Governorate, in southern Iraq. The field is located 14 km west of Qurna city. Coordinate of the studied wells is located between lines easting (715-725) and northing (3409-3425) included four wells distributed a regular basin Figure-1.

Figure 1- A Location map of the study area

Yamama Stratigraphy

Yamama Formation is composed mainly of limestone passes into and overlies the Sulaiy Formation. It is 300-350m thick and thickens towards SW in the West Qurna area [4, 7] as shown in Figure-2. In SE Iraq, the formation comprises three depositional cycles [7]. Cycle tops contain oolitic grainstone inner-ramp facies which pass down into finer-grained peloidal facies and middle-ramp bioclastic/coral/stromotoporoid packstones-wackestones. Outer-ramp cycle bases comprise thick grey shales with stringers of chalky mircrite [6], Figure-3.

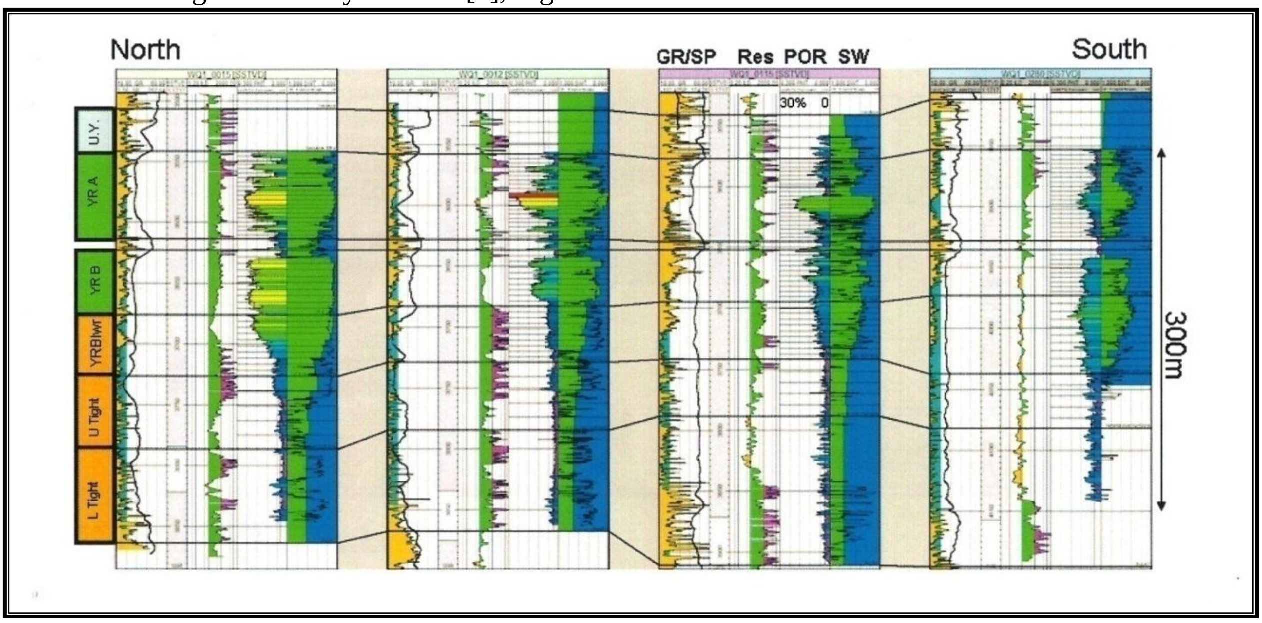

Figure 2- Stratigraphic cross section of the Yamama Formation in the West Qurna field.

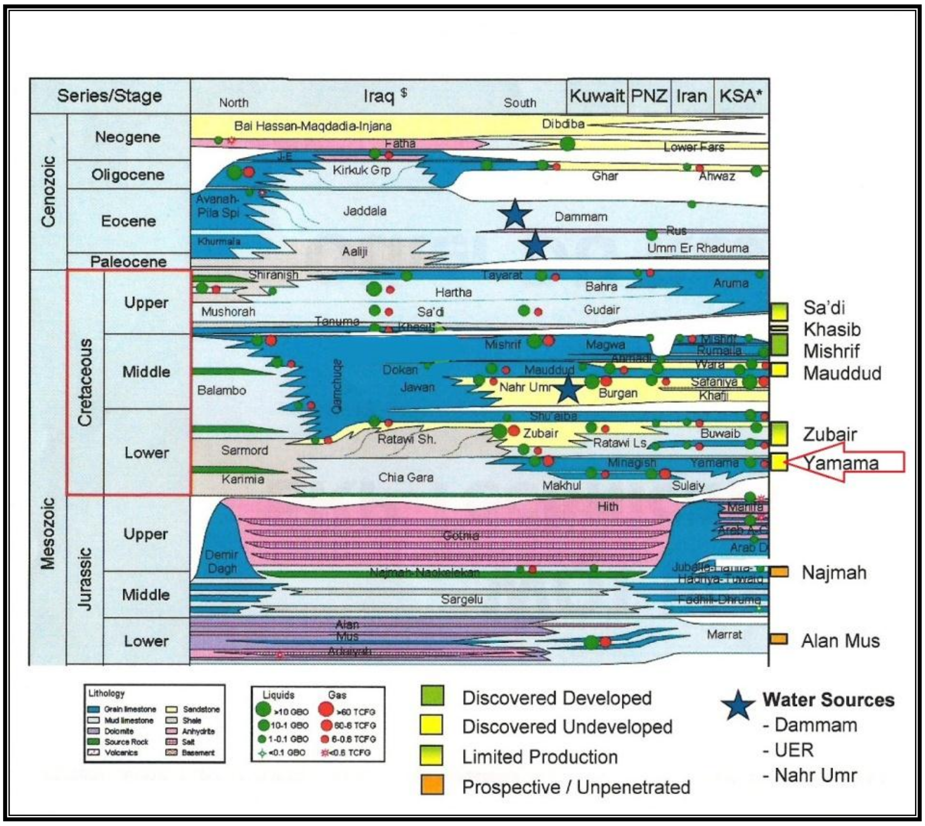

Figure 3- Stratigraphic column of the West Qurna hydrocarbon reservoirs.

Yamama Paleogeography

In Late Tithonian-Valanginian time the Southern Neo-Tethys opened with the separation of the Bisitoun (Avroman) microplate from Arabia. The Upper Berriasian to Lower Valanginian palaeogeography (Yamama Formation) is summarized in Figure-4. The intra-shelf basin comprised inner and outer shelf (basinal) areas [4].

The Mesopotamian Zone witnessed repeated open marine incursions leading to deposition of alternating shallow water carbonates and outer shelf marls. Sedimentation began with deposition of the transgressive Sulaiy and Yamama formations and ended with deposition of the Ratawi Formation during a highstand [3] as in Figure-5. The Yamama Formation in south Iraq comprises outer shelf argillaceous limestones and oolitic, pelloidal, pelletal and pseudo-oolitic shoal limestones.

Oolitic reservoir units are present in several NW-SE trending depocentres [7]. The equivalent Minagish Formation in Kuwait [3]; was deposited as a transgressive unit in an inner shelf environment.

The formation is of Berriasian-Valanginian age [1]. From its stratigraphic position an age range of Upper Berriasian to Lower Valanginian age is likely (140 to 136 Ma.). In Kuwait the Yamama Formation is assigned a Berriasian age [3]. The Yamama Formation was deposited in alternating oolitic shoal and deep inner shelf environments, probably controlled by subtle structural highs within a carbonate ramp [7].

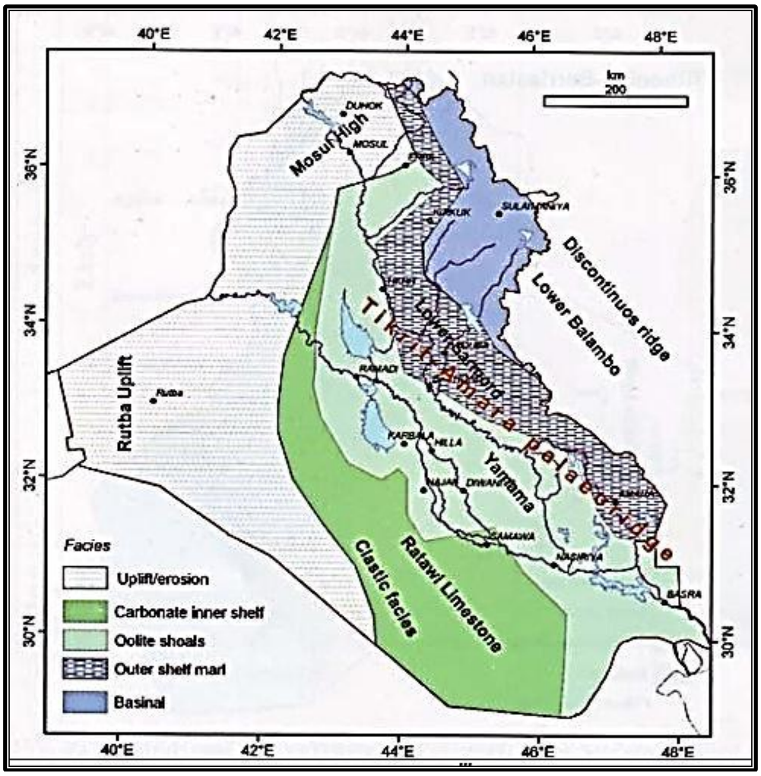

Figure 4- Palaeogeography of the Yamama Formation [4].

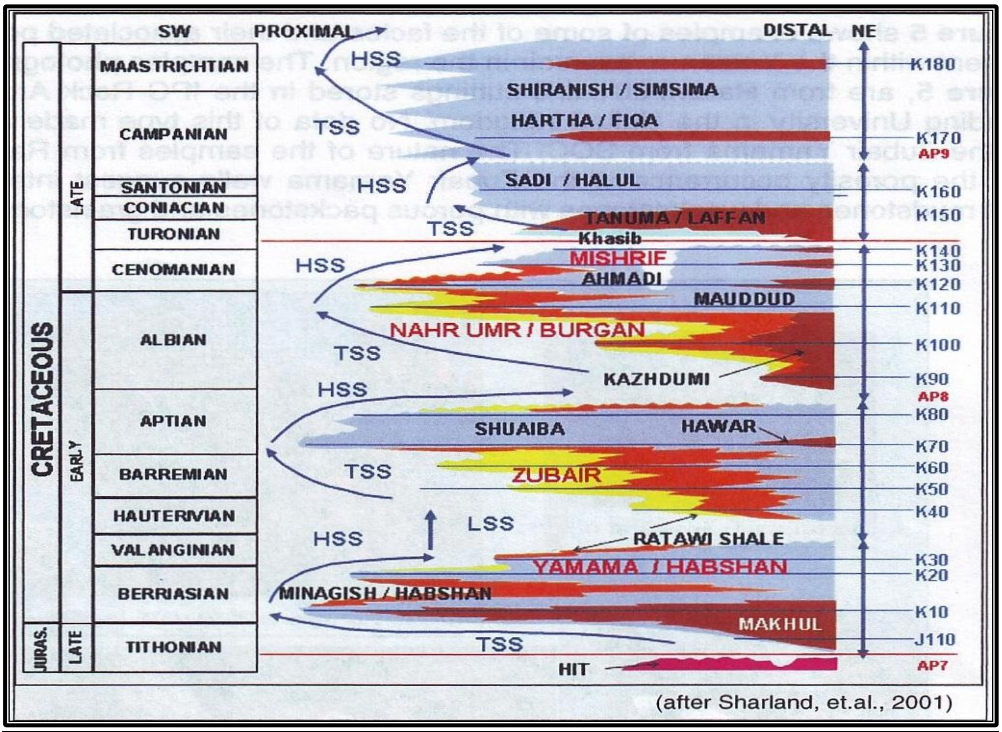

Figure 5- Sequence stratigraphy of the Cretaceous age [8].

Preliminary Yamama Sequence Stratigraphy
Unit YR-A

- Proximal higher energy inner ramp.
- Peritidal, lagoonal, and offshore marine.
- Leaching is present but not as strong as in YR-B.

Unit YR-B

- Dominantly shallow open marine, peritidal, and lagoonal.
- Lower energy proximal inner ramp.
- Lagoonal, algal biostromes and offshore marine.
- Leaching common
- .

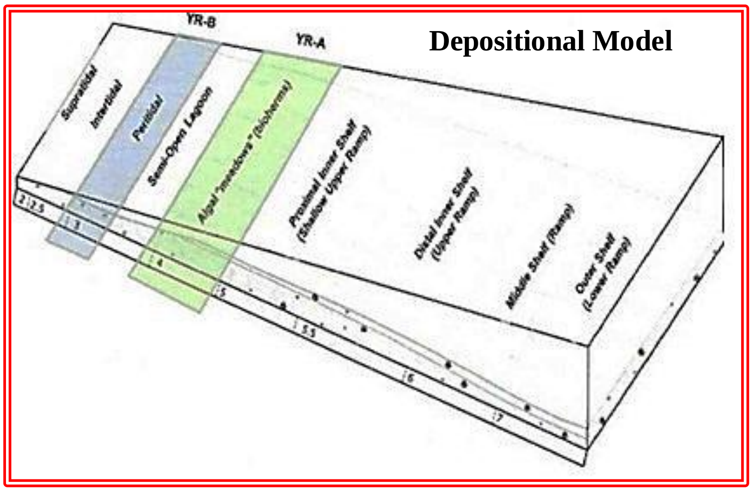

Figure 6- Depositional basin of the Yamama Formation.

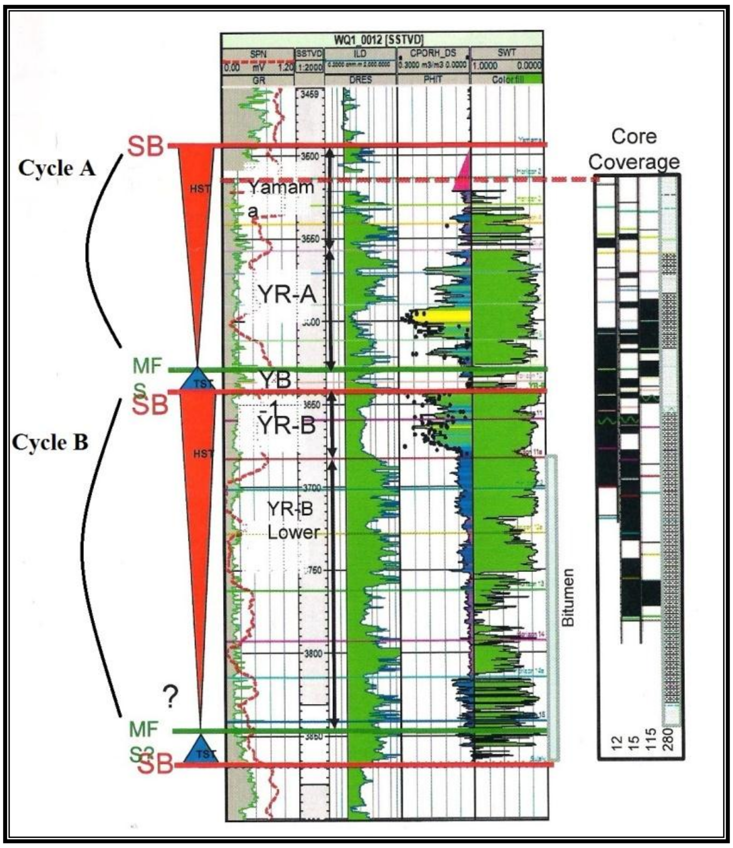

Figure 7- Stratigraphic column of the Yamama Formation.

Quality of the Yamama Reservoir:

The formation comprises two carbonate units each with basal reservoir oolitic limestones overlain by lime mudstone seals [7].

Reservoir Unit YR-A

This unit shows a wide variation in both lithology and thickness. In wells with high total Yamama thickness, this unit is thick also. Note that the unit attains its greatest thickness (100 m) at the well Ratawi-3.

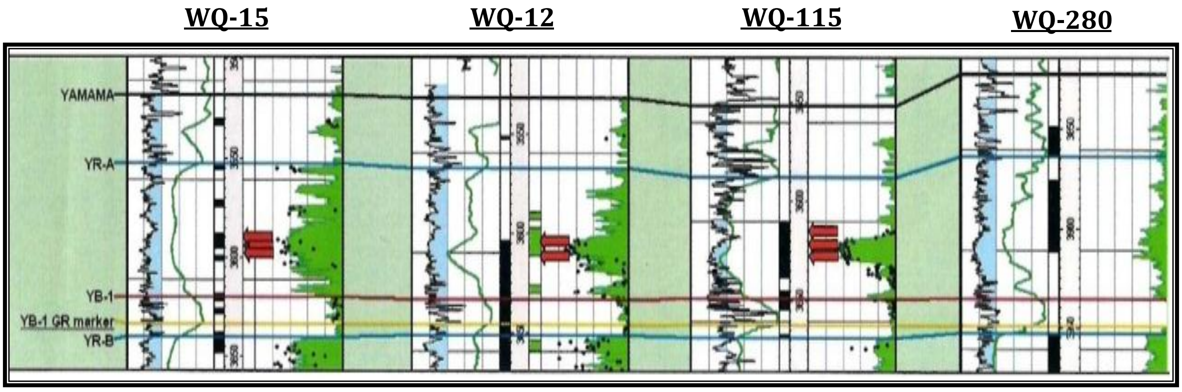

Figure 8- Correlation of the Reservoir Unit YR-A in the wells (West Qurna-15, 12, 115, and 280) at West Qurna field**.**

The unit consists of algal limestone with benthonic foraminifera, corals, and stromatoporoids such as West Qurna-15. The lithologic character of the unit may change with the location of the well on the structure. In general, crestal wells have purer sections of the unit than flanking wells, as in Figure-8 and plate-1. The gravity of unit YR-A oil is 32.7°API in the West Qurna-15. The Yamama Formation has been tested at rates of up to 9000 bbl. /day in West Qurna field.

Microfacies:

1. Peloid Packstone-Grainstone

Some sections of the Yamama Formation are made peloidal-bearing limestone. The peloids are of different shapes, size, and sorting. This facies is prevalent mostly in the middle part of the basin, mainly in the West Qurna, adjacent to the oolite shoal and slightly to its east.

Two mechanisms are suggested to explain the origin of these grains. They were either fecal pellets formed in a low-energy sheltered environment (plate-1) or they were originally ooids but were transported by currents and waves from the oolite shoals and distributed over the basin, where they accumulated in local depressions and underwent such diagenetic processing as micritization and borings [7].

2. Large foraminifera Wackstone-Packstone

This facies is made of rocks ranging in texture from wackstone to packstone and containing large benthic foraminifera, such as *pseudocyclammina* spp., *Orbitolina* spp., and *Everticyclimmina* spp. (plate-1). Commonly, the foraminifera were either micritized or encrusted or replaced by pyrite [7].

Large foraminifera flourish in shallow, normal marine environments and fore reef areas. Thus, some of these (notably *Orbitolina* spp.) may be found, in association with green algae, in hypersaline sheltered lagoons. This facies may indicate a transgressive system tract.

3. Stromatoporoids-Sponge-Coral Boundstone

Thin sections examined from the crestal wells of the West Qurna oil field (e.g., WQ-12, 15, and 115), revealed the presence of rocks made stromatoporoids, coral (plate-1), and some calcisponges. Stromatoporoids are found in reefal and lagoonal environments. Calcisponges have the ability to produce hard reefal skeletons. They also may trap lime-mud sediments, forming either mud mounds or algal-spongy reefs. Some patch reefs probably flourished on local highs within the Yamama basin [7].

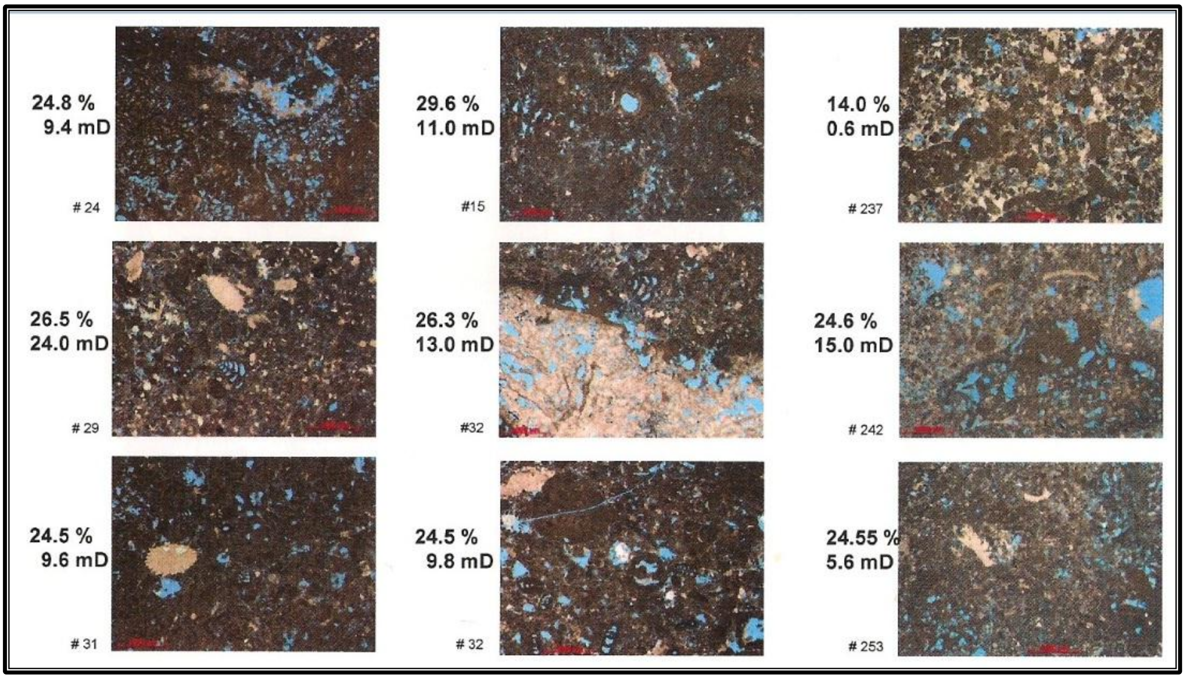

Plate 1- Packstone, peloids, benthic forams, algae, corals, sponges, bryozoans in the (WQ-15/depths 3590m, 3594m, and 3598m) and (WQ-12/depths 3604m and 3611m) and (WQ-115/depths 3615m, 3622m, and 3627 m).

Reservoir Unit YR-B

This unit shows a wide variation in lithology. Moreover, it may contain oil, bitumen, or water. In West Qurna oil field, YR-B unit is composed of limestone containing peloids, pseudo-oolites with stromatoporoids, and corals such as West Qurna-15 as in Figure-9 and Plate-2.
The oil of unit YR-B has a gravity of 36.4°API and 1.1-5 mole % H_2S by oil volume in the West Qurna-15.

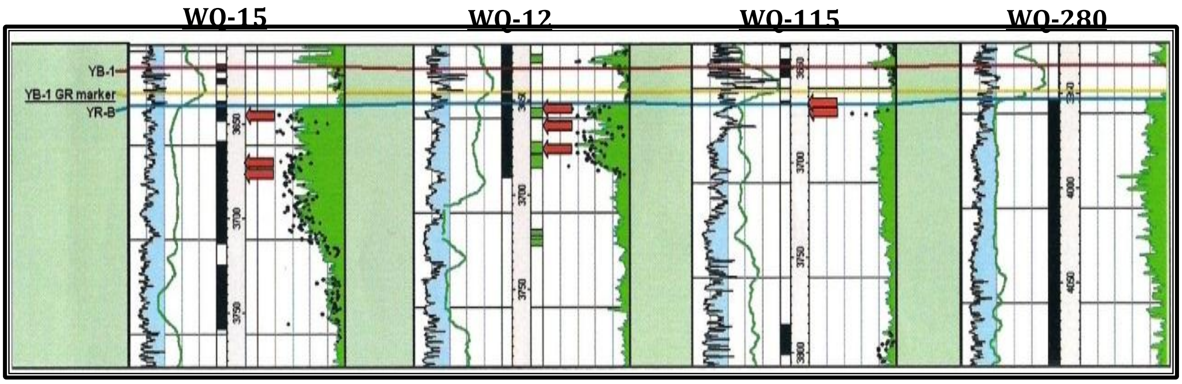

Figure 9- Correlation of the Reservoir Unit YR-B in the wells (West Qurna-15, 12, 115, and 280) at West Qurna field**.**

Microfacies:

1. Oolitic Packstone-Grainstone

Ooids are the most important nonskeletal grains for the interpretation of the depositional environment. An oolite shoal appears to extend over the earlier Upper Jurassic oolitic shoal of Najmah Formation and parallel to eastern margin of the Yamama basin [7]. Some of these ooids were transported later by currents and waves to other parts of the basin, oolite shoals indicate highstand system tract.

The ooids form part of a regressive cycle, with size decreasing and sorting deteriorating downward. No skeletal components were found with this type of oolite except some echinoderm plates (plate-2). In the lower part of the section, the facies changes into a mixture of ooids, peloids with shell fragments, and algal debris. The majority of ooids nuclei were algae fragments.

2. Lithoclastic Wackstone-Packstone

In its type locality, the Yamama Formation has been described as fragmental limestone (Powers *et al.*, 1966). This facies consists of lithoclasts variable in sizes and shapes. Some of these lithoclasts are genuine intraclasts and consist of typical Yamama lithologies (plate-2). Others are diagenetic in origin and may be attributed to the action of micritization or pressure solution in the form of stylobreccia. Primary intraclasts were formed either due to erosive effects of waves and currents or due to gravitational flow of some of the unconsolidated sediments o local slopes provided by the growing structures [7].

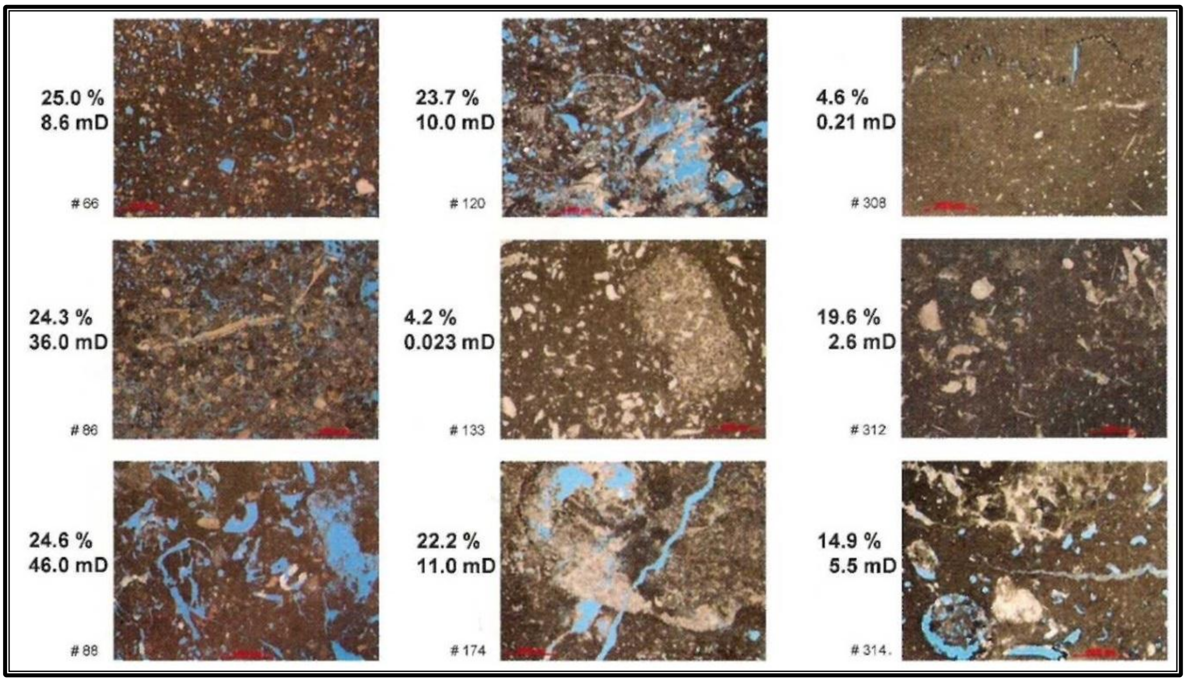

Plate 2- Packstone, wackestone, early leaching & calcite cement in the (WQ-15/depths 3645m, 3670m, and 3676m) and (WQ-12/depths 3655m, 3662m, and 3675m) and (WQ-115/depths 3669m and 3672m).

Porosity Types

The Yamama Formation is characterized by relatively low porosity values as compared to other Cretaceous reservoirs of the Middle East. This may be due to the relatively low-energy system under which the formation was deposited. The porosity readings range between 4.2 and 29.6% and are of three main types: intergranular porosity within the organic buildups and oolite shoals, matrix porosity in chalky texture, and dissolution porosity.

1. Intergranular porosity within the organic buildups and oolite shoals is the main porosity type associated with the grain-supported sediments of the patchy reef sediments and the oolite shoals that are concentrated mainly at the crestal wells and the high areas. Some of the original intergranular porosity is enlarged by later dissolution. Such porosity types are found in the West Qurna-15.
2. Matrix porosity in chalky texture is common in the mud-supported sediments. As previously stated, some of the lime-mudstone fades is formed of well-sorted micrite grains. Thick lime-mudstone sediments are recorded from some wells in West Qurna oil field. These sediments show medium porosity readings (around 8% in the unit YR-A) and (around 10% in the unit YR-B).
3. Dissolution porosity may result from the enlargement or widening of original primary intergranular porosity or some of the fossils such as algae or bio-clasts, plate-1. This enlargement or widening may be caused by meteoric water, but the presence of the permeability barriers between the reservoir units may prevent the free percolation of meteoric water [5]. Suggested that brines charged with organic acids may cause pore enlargement.

Relationships between Porosity & Permeability

The permeability barriers that consist of argillaceous mudstone were believed to be deposited in an outer ramp in the deeper part of the basin. Well test permeability greater than **2** Darcy in some YR-B tests, indicates enhanced (excess) permeability in-situ. The porosity readings range between (4.2 and

29.6%), where the porosity average in the unit YR-A (8%) and the porosity average in the unit YR-B (10%), Figure-10.

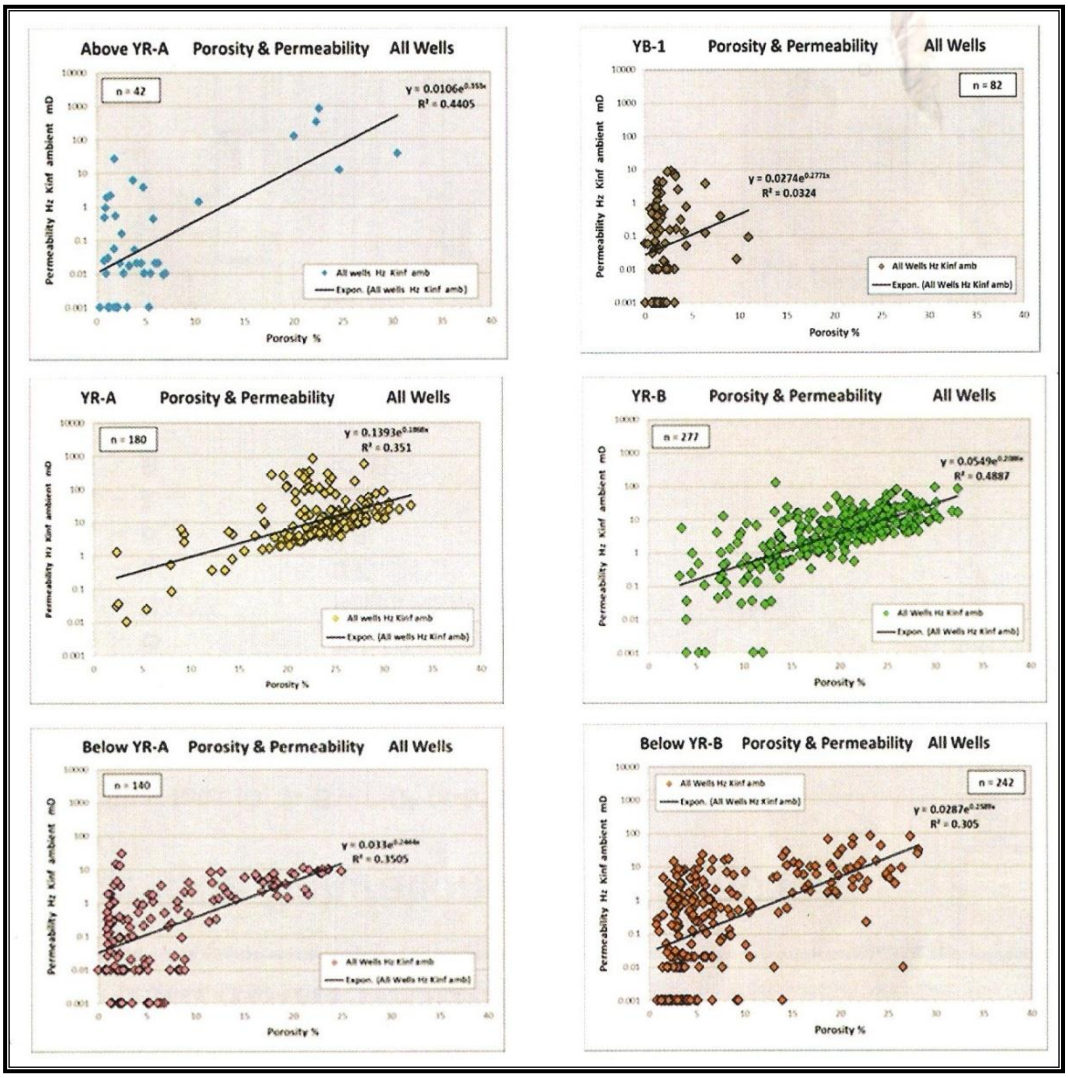

Figure 10- Relationships between Porosity & Permeability of the units Yamama Formation in West Qurna field.

Conclusions

The Yamama Formation is divided into seven zones: Upper Yamama, Reservoir Units YR-A & YR-B separated by YB-1, and YR-B Lower & two Tight zones: low (porosity, permeability and oil saturation) with variable amounts of bitumen.

The main structures (West Qurna, Rumaila, Zubair, etc.) in the unstable shelf province probably were growing during the Yamama deposition, leading to facies differentiation within the same structure.

The Yamama Formation in south Iraq comprises outer shelf argillaceous limestones and oolitic, pelloidal, pelletal and pseudo-oolitic shoal limestones. The best oil potential is mainly within the oolitic shoal and the cleaner reefal facies. The gravity of unit YR-A oil is 32.7°API. The oil of unit YR-B has a gravity of 36.4°API, and 1.1-5 mole % H_2S by oil volume in the West Qurna-15. The porosity readings range between (4.2 to 29.6%), where the porosity average in the unit YR-A (8%) and the porosity average in the unit YR-B (10%).

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