



Reservoir Units of Yamama Formation in Gharaf oilfield, Southern Iraq

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Abstract

Reservoir unit classifications can be used in reservoir characterization of carbonate reservoirs where there is variability in the distribution of petrophysical properties. This requires the integration of geological and petrophysical data at different scales. In this study, cores and thin sections from Yamama Formation (Lower Cretaceous) at Gharaf oilfield, southern Iraq, were studied to identify reservoir units.

Nine reservoir units (units Y1 to Y9) were identified based on petrophysical evaluation by using interactive Petrophysics program (IP) software and depositional environments and related microfacies. The unit Y2 has the highest reservoir quality, which consists of grain-supported facies (packstone and grainstone) characterized by high values of effective porosity and oil volume. The second important reservoir unit is unit Y7 where oil exists in wells Ga-1, Ga-4, and Ga-5. By contrast, the unit Y6 is identified with no observable reservoir quality due to low porosity of mudstone microfacies. The computer processes interpretation (CPI) results show that unit Y1 has poor petrophysical properties except in wells Ga-3 and Ga-4 where reservoir properties are enhanced by fractures. Other units are characterized by different degrees of reservoir quality, and they are differentiated in terms of effective porosity, water saturation, clay volume, and facies types.

Keywords: Yamama Formation, Reservoir, Microfacies, Gharaf oilfield, Well logs.

الوحدات المكنية لتكوين اليمامة في حقل الغراف ، جنوب العراق

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الخلاصة:

يمكن استخدام تصنيفات الوحدات المكنية في توصيف المكامن الجيرية عندما يكون هناك تباين في توزيع الخواص البتروفيزيائية. يتطلب ذلك دمج البيانات الجيولوجية والبتروفيزيائية على مقاييس مختلفة. في هذه الدراسة ، تم دراسة اللباب والشرائح الرقيقة من تكوين اليمامة (الطباشيري السفلي) في حقل الغراف ، جنوب العراق ، لتحديد الوحدات المكنية.

حددت تسع وحدات مكنية (الوحدات من Y1 إلى Y9) استنادا إلى التقييم البتروفيزيائي باستخدام برنامج IP والبيئات الترسيبية وما يرتبط بها من سحنات مجهرية. تحتوي الوحدة Y2 على أعلى جودة مكنية ، والتي تتكون من السحنات ذات الاسناد الحبيبي (الحجر الجيري المرصوص و الحجر الجيري الحبيبي) و هي تتميز بقيمة عالية من المسامية الفعالة وحجم النفط. الوحدة المكنية الثانية من حيث الأهمية هي Y7 حيث يوجد النفط في الآبار Ga-1 و Ga-4 و Ga-5. وعلى النقيض من ذلك ، حددت الوحدة Y6 دون وجود كفاءة مكنية ملاحظة بسبب انخفاض مسامية سحنات الحجر الطيني المجهرية. تظهر نتائج التفسير المعالج

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بالحاسوب (CPI) أن الوحدة Y1 لها خصائص بتروفيزيائية ضعيفة ما عدا في الآبار Ga-3 و Ga-4 حيث تزداد خصائص المكمن بواسطة الكسور. تتميز الوحدات الأخرى بدرجات متفاوتة من الكفاءة المكنية ، وهي تتباين من حيث المسامية الفعالة ، وتشبع الماء ، وحجم الطين ، وأنواع السحنات.

Introduction

The lower Cretaceous carbonate succession includes significant hydrocarbon reservoirs in many parts of Arabian plate .In southern Iraq, these reservoir occur within Yamama Formation, and have extensive distribution in many oilfields. Several depositional and diagenetic factors control the reservoir quality of Yamama Formation. The available data in Gharaf oilfield allow the evaluation of these factors, which delineate reservoir characteristics.

This research was planned to utilize the core and wireline logs data from five wells, which penetrate complete succession of Yamama Formation. The study includes microfacies and wireline logs analyses as input for reservoir evaluation.

The Study Area

The Gharaf oilfield is located in DhiQar Governorate within the Dujaila area, about 35 km North of Rifaee and about 265 Km Southeast of Baghdad and 85 Km North of Nasiriyah city (Fig.1-1) . The area is characterized by almost flat land and covered with floodplain deposits that consist of mud, sand, and marshes, irrigation, drainage and rivers.

In the study area, wells Ga-1 , Ga-2 and Ga-3 were drilled during 1983 -1987 by the Iraq National Oil Company (INOC) ,whereas the wells Ga-4 and Ga-5 were drilled by Weatherford Company during 2011-2012. The geographic coordinate of these wells are shown in Table-1.

Aims of study

Evaluation the characteristics of Yamama Formation reservoir units by combining well logs, and available core data.

Table 1-The geographic coordinates of studied wells in Gharaf field

Well name	Eastern	Northern
Ga-1	602555	3514703
Ga-2	593659	3517488
Ga-3	597555	3517688
Ga-4	604011	3513573
Ga-5	602747	3514534

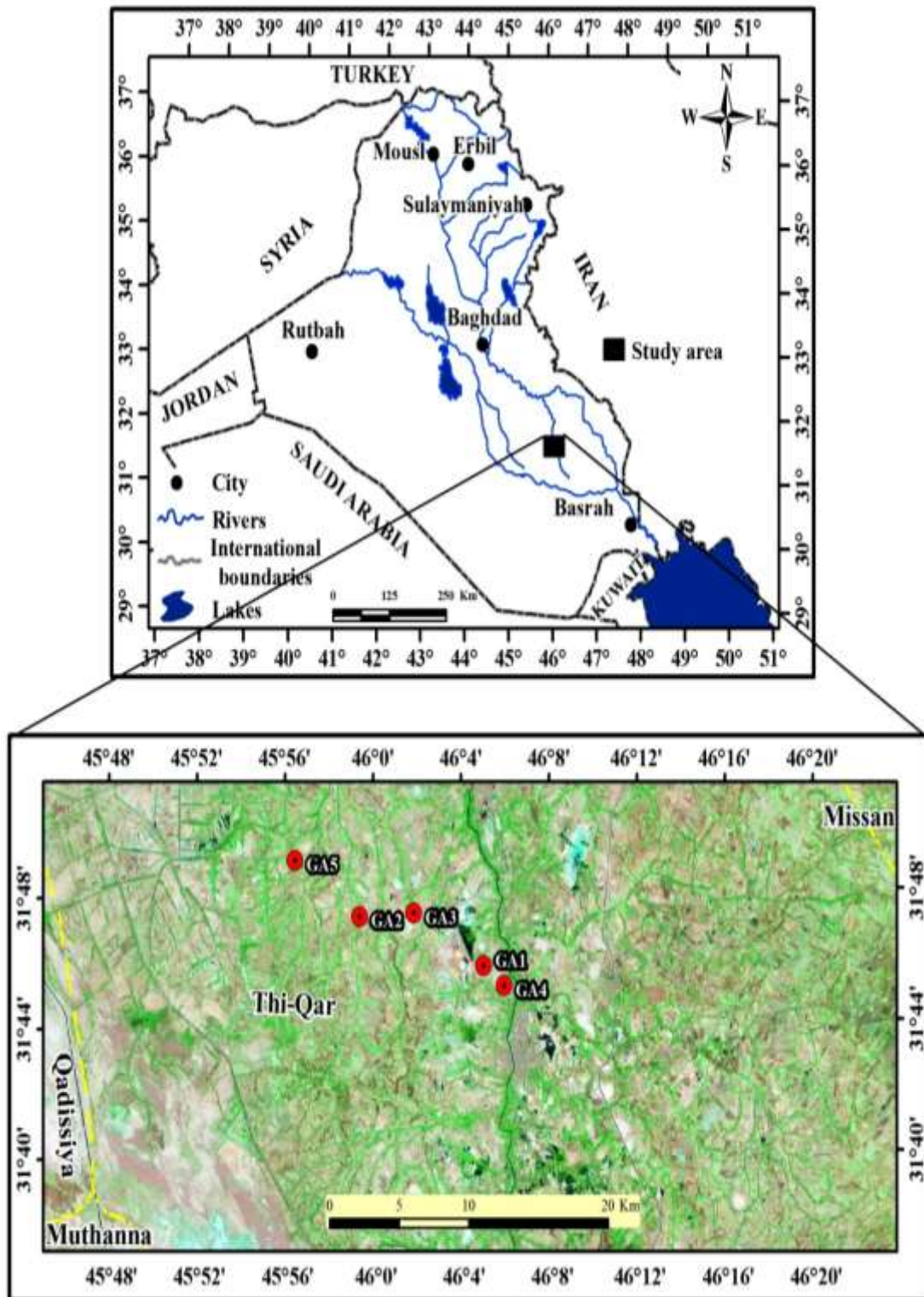


Figure 1-Location map of Gharaf oilfield with studied wells.

Geological setting

Tectonic

According to the tectonic subdivisions of [1], the Gharaf oilfield is located in the Mesopotamian Basin within the stable zone which is confined between the Arabian Shield in the West and Zagros mountains in the East. The Gharaf oilfield represents a broad, very open anticline, with dips on the flanks of the structure of approximately 1° . The fold axis trends NW-SE Figure- (1, 2) .This structural

trend coincides with similar anticline forming Rafidain and Dujaila oilfields, and it is parallel to the main Zagros trend, suggesting simple coaxial deformation [2].

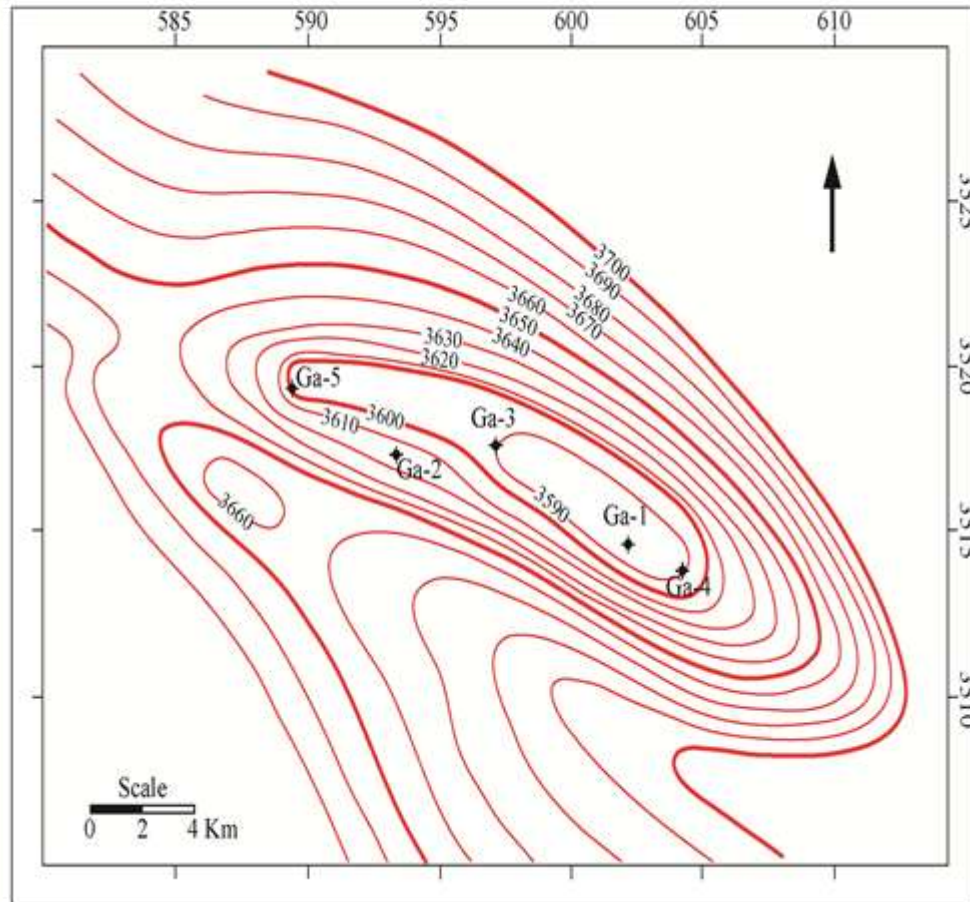


Figure 2-Structural contour map at top of Yamama Formation in Gharaf oilfield.

Stratigraphy

The type section of Yamama Formation outcrops in Saudi Arabia where it was described as fragmental limestone units [3]. In southern Iraq, [4] described the Yamama Formation in Ratawi oilfield (well Ratawi-1) as a succession of spicular and detrital limestone with thin beds of shale overlain by micritic and oolitic limestone. In Gharaf oilfield, the Yamama Formation consists of different limestone units such as vuggy limestone, fossiliferous limestone, chalky limestone, and argillaceous limestone.

The carbonate succession of Yamama Formation belongs to the Late Tithonian-Hauterivian sequence, which includes Sulaiy, Makhul, chia cara (including Karimia), Ratawi and Lower Sarmored formations [1]. The Berriasian-Valanginian time period spanned the deposition of Yamama Formation and its regional equivalents in the Arabian plate [5]. The shallow water carbonates of Yamama Formation covered large areas in the eastern shelf platform of the Arabian plate, and their deposition were affected by a moderate high, but falling, eustatic sea level [5].

In Iraq, the Yamama Formation is assigned a Berriasian-Valanginian age [4]. The upper and lower boundaries of the formation are conformable with the overlying Ratawi Formation and underlying Sulaiy Formation.

In Gharaf oilfield, the maximum thickness of the formation reaches 292 m in well Ga-4; minimum thickness is 269 m in well Ga-1.

Lithology

Determination of lithology is a prerequisite step in reservoir evaluation. Core examination was involved in this study in order to determine the lithology of Yamama Formation. The investigated succession is carbonate dominated, mainly limestone with limited dolomitic intervals. Diagenetic

features affected reservoir characteristics are also recognized at core scale. They include dissolution features such as vuggy and mouldic pores as well as fractures and stylolites (Pl.1).

Microfacies and depositional environments:

Four depositional environments similar to those described by [6] are recognized in Yamama Formation: Mid ramp, open marine, shoal, and restricted marine. Each of them is characterized by several microfacies based on texture and depositional energy. The microfacies were described using the classification scheme of [7].

The mid-ramp depositional environment of Yamama Formation is characterized by fine-grained bioclasticlimestones. The microfacies of these limestones are mudstone and wackestone that consist of fine unidentified bioclasts and echinoderm (Pl.2-A). Occurrence of potential pores is absent or rare. They can be moldic or isolated vugs if exist.

The open marine depositional environment is made of microfacies ranging in texture from wackestone to boundstone. Common microfacies are foraminiferal -echinoderm wackestone, foraminiferal-bioclasticwackestone, bioclasticpackstone, peloidal-bioclasticpackstone, and boundstone (Pl.2-B, C). This environment is characterized by good water circulation with deposition above fair weather wave base. Therefore, reefs are common in open marine depositional environment, and can be represented by coral boundstone [6]. The reservoir quality of open marine facies can be poor to moderate, and this depends on the size of dissolved skeletal grains and degree of connectivity of vuggy and moldic pores.

The microfacies of restricted marine depositional environment are lime mudstone, bioclasticwackestone, benthic foraminiferalwackestone, algal wackestone, foraminiferal-bioclasticwackestone (Pl.2-D, E), The main skeletal grains are dasyclad algae, benthic foraminifera, and bioclasts of different origin. The shoal depositional environment is typically a low energy setting with restricted water circulation [6].

Shoal facies are recognized in all studied wells. It is characterized by the accumulation of peloids, ooids, and skeletal grains. These grains occur separately or associated forming grainstone and packstone textures. The dominant microfacies include bioclastic-peloidalpackstone, peloidalpackstone-grainstone, oolitic-peloidalpackstone-grainstone, bioclastic-peloidalpackstone-grainstone, and echinoderm-peloidalpackstone-grainstone (Pl.2-F, G, H). The shoal depositional environment originates in storm-dominated mid-ramp and inner-ramp settings, and may be formed by storm induced but also by coast-parallel bottom currents [6]. The best reservoir quality of shoal facies is attributed to high proportion of interconnected interparticle pores and vugs, in addition to the scarcity or absence of lime mud and calcite cement.

Plate -I-

Core photos of Yamama Formation limestone showing different features:

A-Fossiliferous limestone with moldic and vuggypores (arrowed), Ga-4, 3711 m.

B-Limestone with bioturbation fabrics (arrowed), Ga-4, 3680.5 m.

C-Limestone showing stylolite (arrowed) and nodular fabric, Ga-4, 3676.5 m.

D-Horizontal fractures set in limestone, Ga-4, 3670.5 m.

E-Limestone with moldic pores, Ga-4, 3656 m.

F-Moldic pores (arrowed) in oil-impregnated limestone, Ga-5, 3680 m.

Plate -II-

Microfacies of Yamam Formation at Gharaf oilfield:

A-Wackestone including unidentified bioclasts , Mid-Ramp facies, well Ga-1 , 3782m, 5x.

B-Foraminiferal – echinoderm wackstone , open marine (Inner Ramp) facies, well Ga-4, 3782m, 5x.

C-Coral boundstone affected by cementation and micritization , open marine (Inner Ramp) facies, well Ga-5, 3800m, 5x.

D-Algal wackstone consisting manily of Dasycladacean algae bioclasts, restricted marine (Inner Ramp) facies, well Ga-1, 3750m, 5x.

E-Fossiliferous mudstone –wackstone with miliolid foraminifera (arrowed) and small skeletal grains, restricted marine (Inner Ramp) facies, well Ga-3, 3645m, 5x.

F-Bioclastic – peloidal packstone with abundant peloids and echinoderm bioclasts, shoal facies well Ga-4, 3676m, 5x.

G-Bioclastic –peloidal packstone with peloids and bioclasts and large micritized grains, shoal facies, well Ga-4, 3678m, 5x.

H-Peloidal packstone –grainstone consisting mainly of peloids with limited occurrence of micritized bioclasts, shoal facies, well Ga-5, 3680m, 5x.

Plate -1-

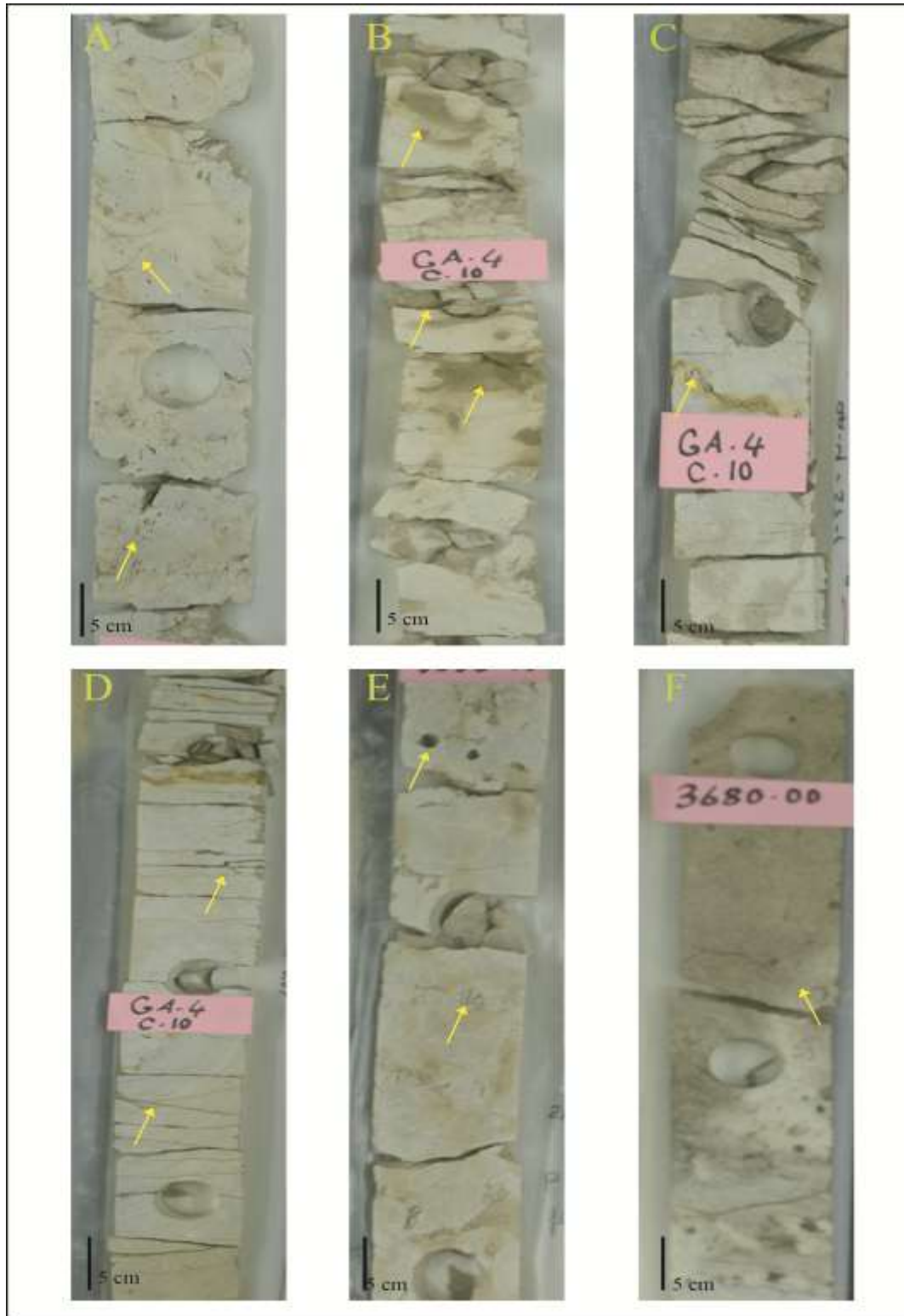
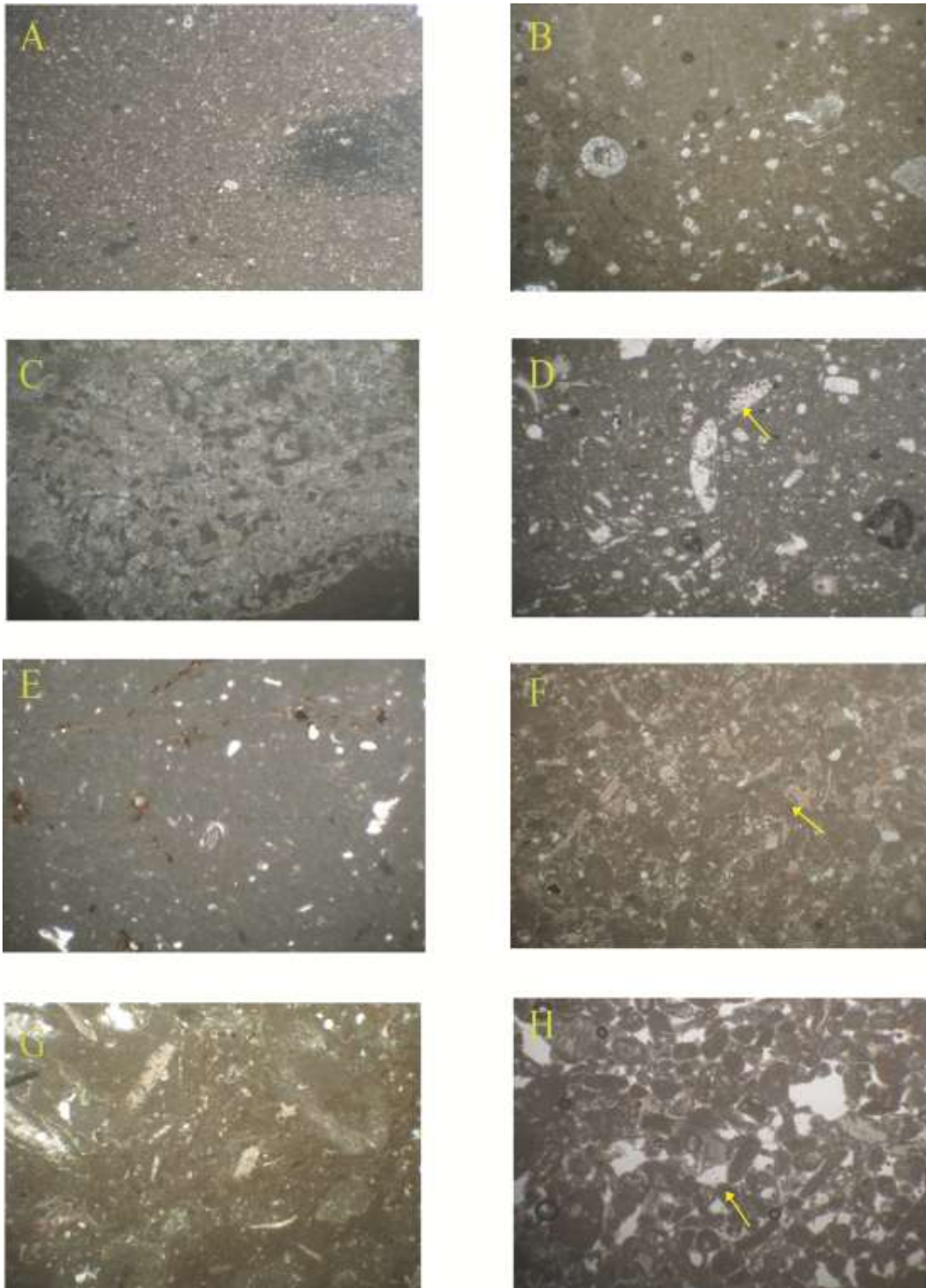


Plate -II-



Evaluation of Reservoir Units

Several studies subdivided the Yamama Formation in southern Iraq into reservoir units based on petrophysical properties [8-10]. In this study, the Yamama Formation in Gharaf oilfield is subdivided into nine reservoir units by combining well log petrophysical properties and microfacies data. The calculation and interpretation of petrophysical properties are done by using IP (Interactive Petrophysics) software. The results of computer processing interpretation (CPI) are shown in Figures (3-7). The main characteristics of these units are explained below:

Reservoir Unit Y1

This unit is located at the uppermost succession of Yamama Formation. Its thickness is approximately 41-53m. Although it consists of restricted marine mudstone and wackestone microfacies, the unit Y1 is characterized by high effective porosity (24.3 %) and residual oil volume in wells Ga-3 and Ga-4 Figures-(5, 6). This abnormal reservoir quality is related to the occurrence of fractures, which is indicated by high caliper log values reflecting borehole enlargement[11]. However, the same unit is considered a cap unit in other wells due to negligible effective porosity (0.01%) and high clay volume Figures-(3, 4, 7).

Reservoir Unit (Y2)

The unit Y2 is characterized by high reservoir quality, which is related to the dominance of packstone and grainstone shoal facies that have high effective porosity and low clay volume. High volume of moveable oil occur in wells Ga-1 and Ga-2 Figures-(3,4), whereas higher volumes of residual oil exist in wells Ga-3, Ga-4 and Ga-5 Figures-(3,7). The thickness of unit Y2 reaches 12m to 25m. The boundaries of this unit is marked by sharp log response representing remarkable changes in petrophysical properties as show in porosity and resistivity logs Figures-(3,7).

Reservoir Unit (Y3)

This unit consists of restricted and shallow marine facies succession, which have different thickness in each well Figures-(3-7). The total thickness of unit Y3 ranges between 35 to 49m. Effective porosity values vary between 0, 01-16.4%. The open marine facies of this unit show better reservoir properties than restricted marine facies as indicated by higher effective porosity values and low clay volume, in addition to the occurrence of moveable oil occur in wells Ga-2 and Ga-4 within open marine facies Figures.(4,6). Although similar facies is observed in both units Y3 and Y4 the contact between them is distinguished by sharp changes in porosity and resistivity logs pattern, which reflect the changes in reservoir properties associated with transition from open to restricted marine facies Figures-(3-7).

Reservoir Unit (Y4)

The unit Y4 is composed of interbedded succession of open and restricted marine facies Figures-(3-7). The thickness of this unit ranges between 33.5-52m. Higher values of effective porosity are recorded in wells Ga-2 (Figure-4), Ga-3 (Figure-5), and Ga-4 (Figure-6). However, the same wells have larger volumes of water than moveable or residual oil. Other wells have lower reservoir efficiency due to lower effective porosity and higher clay volume Figures-(3-7).

Reservoir Unit (Y5)

The reservoir unit Y5 consists of packstone and grainstone facies representing shoal depositional environment. It is overlain and underlain by mud-dominated facies of units Y4 and Y6 Figures-(3-7). The thickness of unit Y5 reaches 12m to 26m. Reservoir quality of unit Y5 is lower than unit Y2 although both of them have similar facies. This is related to the lower values of effective porosity and larger volumes of water in all wells except well Ga-4 (Figure-6).

Reservoir Unit (Y6)

This unit consists of mudstone and wackestone microfacies of mid-ramp environment. Based on microscopic study these microfacies show poor reservoir properties. Also, the CPI result based on microscopic observations and well logs data, the unit Y6 shows poor reservoir quality. It is distinguished by low effective porosity and high clay volume as indicated by borehole enlargement that caused sudden increase in caliper log values Figures-(3-7). The unit Y6 located between shoal facies of units Y5 and Y7. Therefore, this stratigraphic position results in sharp changes in log pattern at units contacts Figures-(3-7). The thickness of unit Y6 is 2-10m. It is considered as a cap unit for the underlying unit Y7.

Reservoir Unit (Y7)

As in unit Y2 and Y5, the reservoir unit Y7 is composed of shoal facies characterized by high effective porosity. Moveable oil occur in wells Ga-1 and Ga-4 Figures-(3,6), whereas residual oil has larger volume in wells Ga-5 Figure-7. The unit Y7 is considered a water bearing reservoir in wells Ga-2 and Ga-3 Figures-(4,5). The thickness of this unit ranges between 3-11m.

Reservoir Unit (Y8)

The unit Y8 is represented by a succession of open marine, restricted marine and shoal facies. Its thickness ranges between 43-67.5m. The unit can have high effective porosity as in wells Ga-2, Ga-3

and Ga-4 Figures-(4, 4, 6) with large volume of water and less of oil. Residual oil remarkably occurs in well Ga-5 well within shoal facies Figure-7.

Reservoir Unit (Y9)

This reservoir unit is located at the lowermost succession of Yamama Formation .It is made up of similar facies succession to unit Y8. However, the unit shows lower reservoir quality due to the higher clay volume and occurrence of limited volumes of residual oil Figures-(3-7).The thickness of unit Y9 ranges between 31.5-57m.

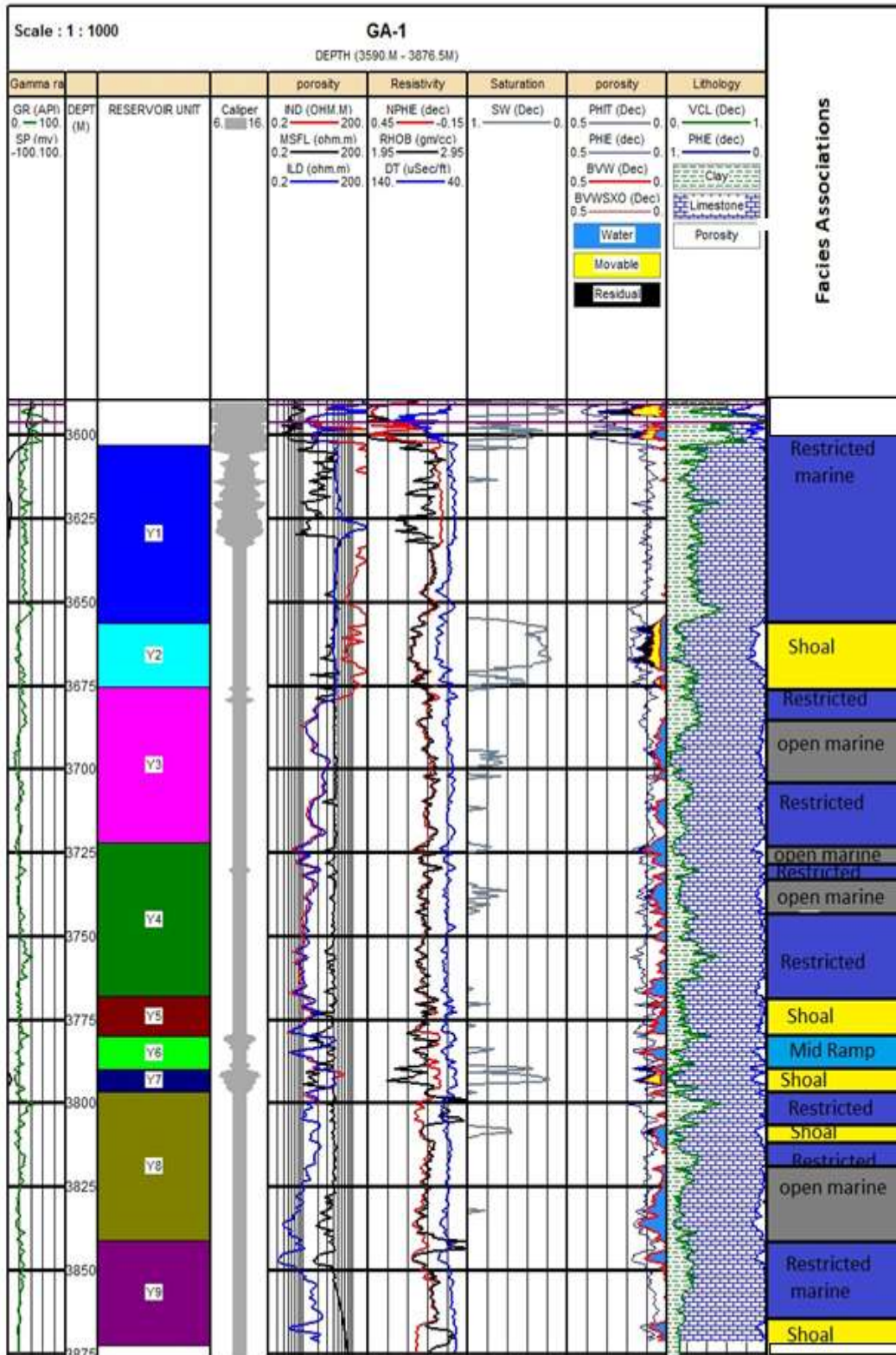


Figure 3-Computer Processes Interpretation (CPI) of Yamama Formation in GA-1 well.

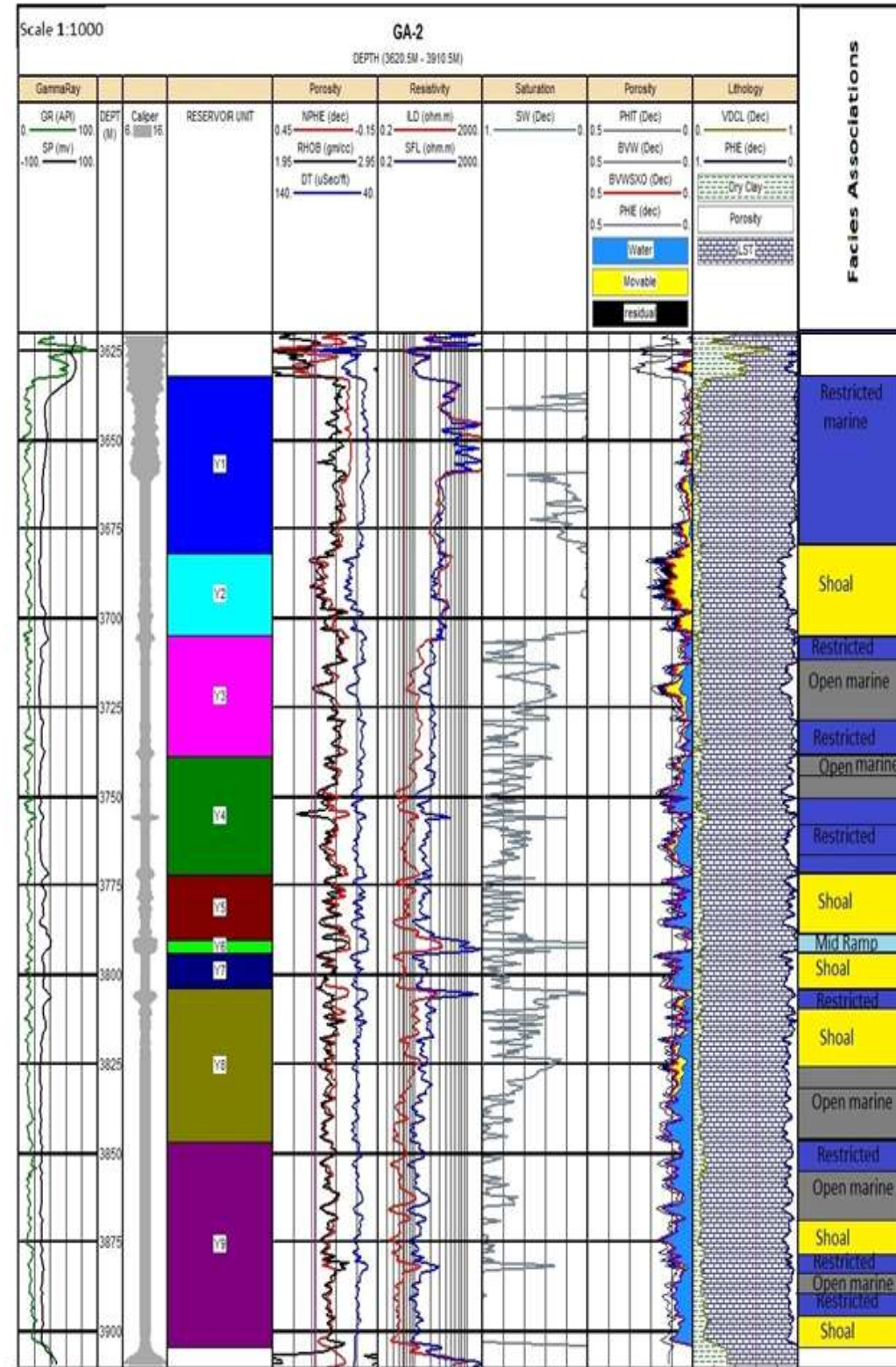


Figure 4-Computer Processes Interpretation (CPI) of Yamama Formation in GA-2well.

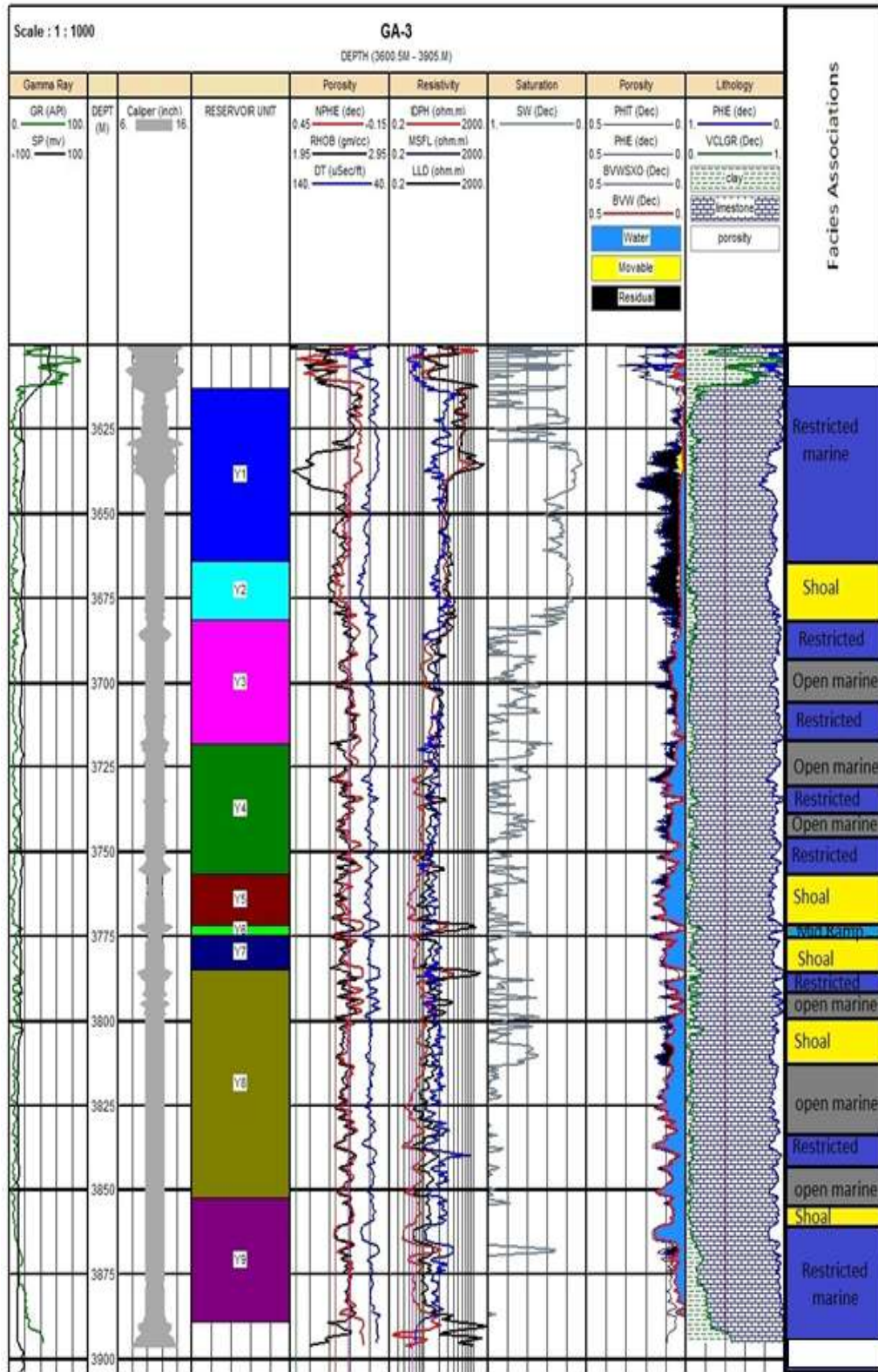


Figure 5-Computer Processes Interpretation (CPI) of Yamama Formation in GA-3 well.

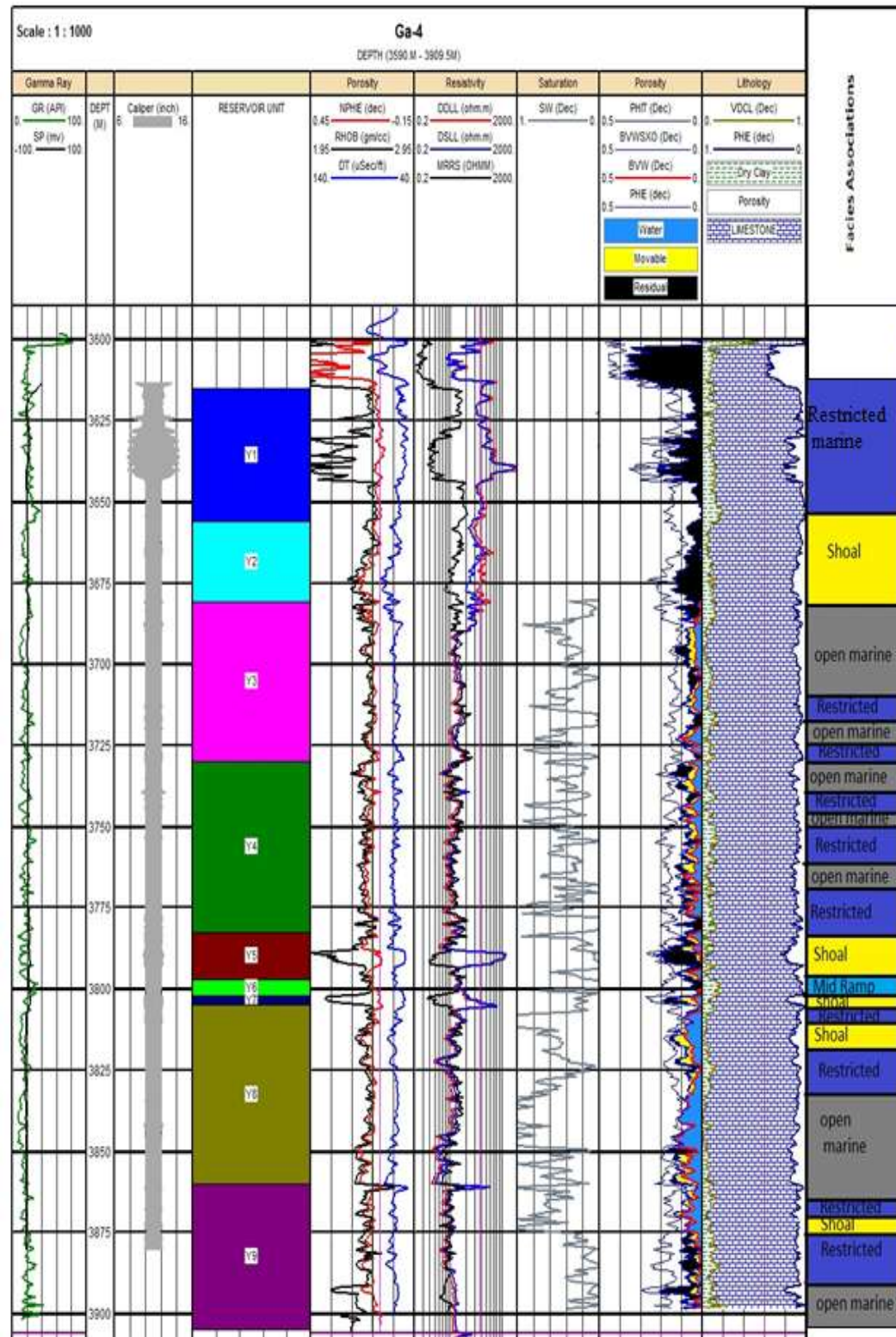


Figure 6-Computer Processes Interpretation (CPI) of Yamama Formation in GA-4well.

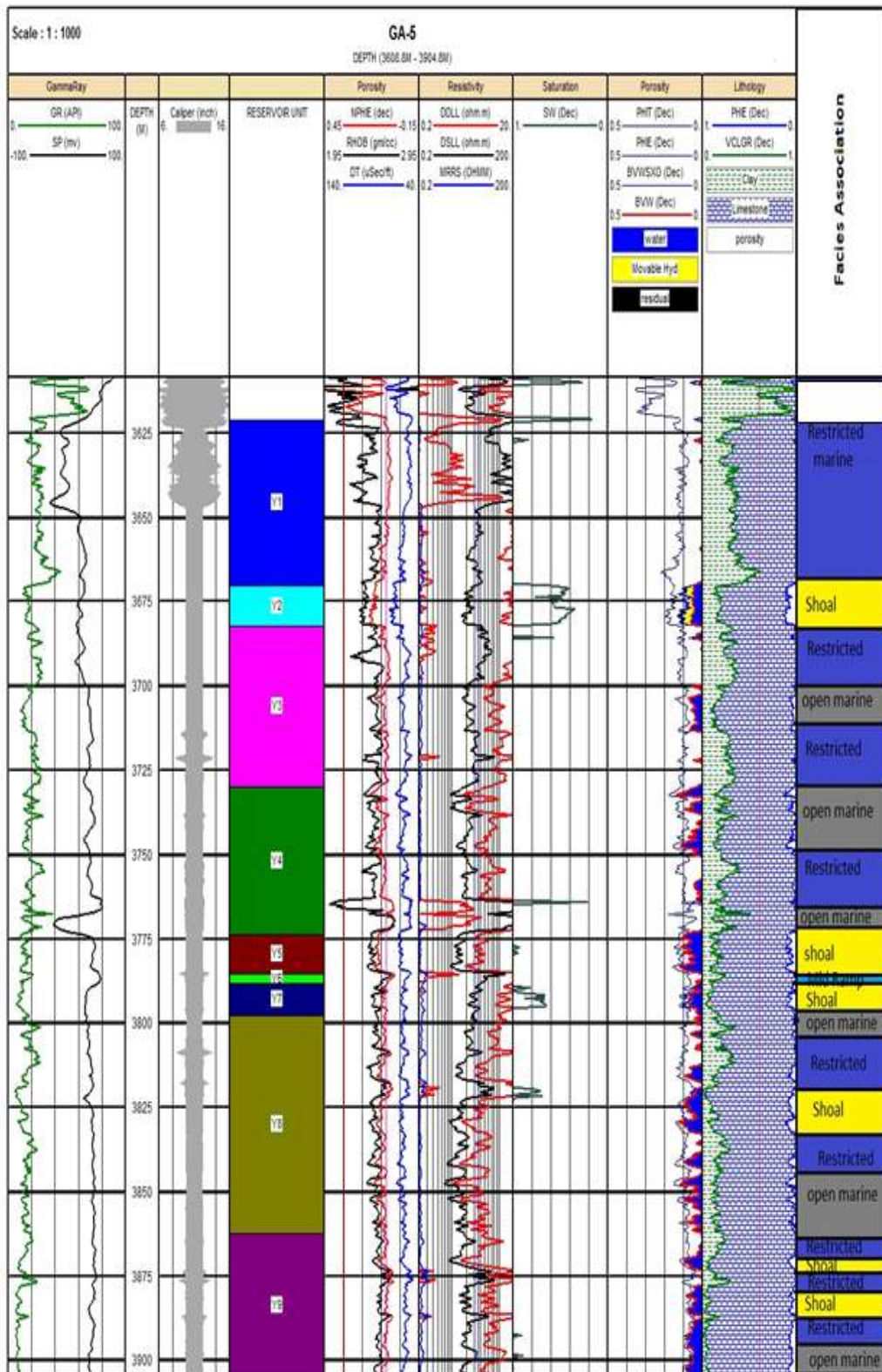


Figure 7-Computer Processes Interpretation (CPI) of Yamama Formation in GA-5well.

Conclusions

This study includes identification of reservoir units of the Lower Cretaceous Yamama Formation at Gharaffield, southern Iraq. Nine reservoir units were defined from analyses of depositional facies, and petrophysical properties derived from well logs. The CPI results combined with microfacies data show that unit Y2 is the major reservoir unit characterized by high effective porosity, low water saturation

and clay volume comparing with units. Although units Y5 and Y7 have similar shoal facies with unit Y2, they exhibit lower reservoir quality due to lower values of porosity and volume of oil. Possible reason for this change in reservoir characteristics is related to calcite cementation, which decreases the porosity of shoal microfacies. However, the reservoir properties of these facies are enhanced by dissolution.

Fracturing enhanced the effective porosity of clay-rich, restricted marine mudstone and wackestone of unit Y1 in wells Ga-3 and Ga-4. Similar depositional textures of mid-ramp facies have cap properties in unit Y6 due to low porosity. The units Y3, Y4, and Y8 have low reservoir quality, and can be water-bearing units or have low volumes of oil.

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