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The Influence of Diagenesis Processes on the Reservoir Properties of Hartha Formation in Selected oil Fields, Northern Iraq

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ABSTRACT

The Hartha Formation reservoir was evaluated to be produced in the near future in Y oil and J fields, West of the Tigris River in northern Iraq. Due to geological data analysis of the Hartha facies and diagenesis could enhance oil production with minimized risks, this research tried to deal with data to support the oil production. The Hartha reservoir is subdivided into five-rock units, Har-1, 2, 3, 4 and 5. It is of Heterogenic facies limestone, dolomite, dolomitic limestone and argillaceous dolomite. The Hartha Formation is a clean carbonate; it has an effective porosity. It consists of lime mudstone-packstone skeletal grain. This conclusion is based on the lithology, core microfacies, cutting, thin section and log interpretation variability.

The study aims to characterize the depositional and diagenetic properties of the Hartha carbonate and their effects on the reservoir quality. This research indicated that the depositional setting is a gentle slope ramp including outer, mid and inner ramps. The dissolution and dolomitization in near-surface and marine environments formed secondary porosity types as a vuggy, cavern, and melodic. The fracture is a good reservoir in the upper part of the Hartha reservoir. The lower section is affected by other diagenetic processes causing a destructive effect on porosity such as compaction, Neomorphism and cementation. The measured and calculated porosity with an integration of the measured permeability in the Hartha Reservoir gave a good reservoir quality to the formation. These data are coming from the analysis of the primary and secondary porosity. The petrophysical cut-off provided an excellent result for the rock properties as the net to gross ratio of the most units of the Hartha Reservoir.

Keywords: Digenesis; Debris; Hartha; Reservoir; Rudest; Upper Campanian

تأثير العمليات التحويرية على الخصائص المكمنية لتكوين هارثة في حقول مختارة، شمال العراق

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الخلاصة

تقييم مكمن هارثة لوضع خطة انتاجية في المستقبل القريب في حقلي **Y**و **J** غرب نهر دجلة شمال العراق. اعتمادا على تحليل مجسات الآبار ،اللباب ،الشرائح الصخرية والفتات الصخري المتوفرة. ومرتسم (**MID**) والتباين في الخصائص السحنية والبتروفيزيائية قسم تكوين هارثة الى خمسة وحدات متكونة من الحجر الجيري والدولومايت والحجر الجيري المتدلمت والدولومايت الارجيلايتي حاوية على حبيبات هيكلية (قطع الرودست ،مونولبيدوربيس ، اوربيتويد) ذات مسامية فعالة عالية وحبيبات غير هيكلية (دمالق ، السرئيات)

النظام الترسيبي لمكمن هارثة منحدر قليل الميل ذو حاجز Barrier متكون من ثلاث بيئات (منحدر خارجي ، ومنحدر داخلي ، والمنحدر الاوسط) ان العمليات التحويرية في البيئات القريبة من السطح والبحرية شكلت نوعًا من المسامية الثانوية مثل (القالبية ،التكهف، الهزيمية ، والكسور) هي مكمن جيد في الجزء العلوي من تكوين هارثة في منطقة الدراسة ، وعلى العكس من ذلك ، فإن العمليات التحويرية الأخرى لها تأثير سلبي على المسامية مثل الانضغاط، اعادة التبلور والسمنتة.

1. Introduction

The oil fields Y and J are one of the giant producing reservoirs from the Tertiary pay zone in south Nineveh Governments, North Iraq. This study evaluates the oil reservoir by studying the main Cretaceous Hartha reservoir. The wells that are included in this study are (A, B, C, D) Y and J oil fields which penetrate Hartha Upper Cretaceous Reservoir (Figure 1)

The Y and J fields were discovered at the beginning of the last century through the surface survey done by the German team on the hydrocarbon seepage of the Fatha Formation (middle Miocene) [1]. The Upper Campanian Hartha reservoir is not producing till now, which has not been evaluated concisely to drilling to minimize risk production plan for the new 2nd pay; so the geological model from this study is important in future planning for new production [2].

The most significant part of the Y Field is located in the western part of the Tigris River, about 60 km south of Mosul city. The J field is located approximately 50 km southern part of Mosul city. The Y field consists of two domes separated by an NW-SE saddle axis, while the J field consists of one dome northwestern Y field. The dome in the southeast is broader and more developed than the dome in the northwest, the latter being narrow and inconspicuous. The dome in the southeast is 45 m higher than the dome in the northwest. According to the tectonic divisions of and Iraqi − Soviet team [3], the study area is located within the central faulting zone and in the Unstable Shelf corresponding o the Arabian−Nubian craton [4] [5] [6]. The studied boundary of the study area is shown in Figure 2. This study aims to make available petrophysical data the computer-processed interpretation (CPI) for the upper cretaceous "Hartha reservoir".

The first cretaceous well Y-1, drilled in 1982, penetrated the Cretaceous reservoirs, while the J-1 well was drilled in 1933 [2]. Final well reports of wells A, B, C, and D was conducted.

The depositional system of the Hartha reservoir is ramp facies, in which reservoir properties control by diagenesis enhancing or destroyed petrophysical properties geological data for better drilling and production and risks.

The Hartha reservoir was penetrated completely by nine wells in Y field and four wells in J field. (Figure 1). The reservoirs developed from medium compaction, moderate compaction, cementation, relatively strong dissolution and dolomitization.

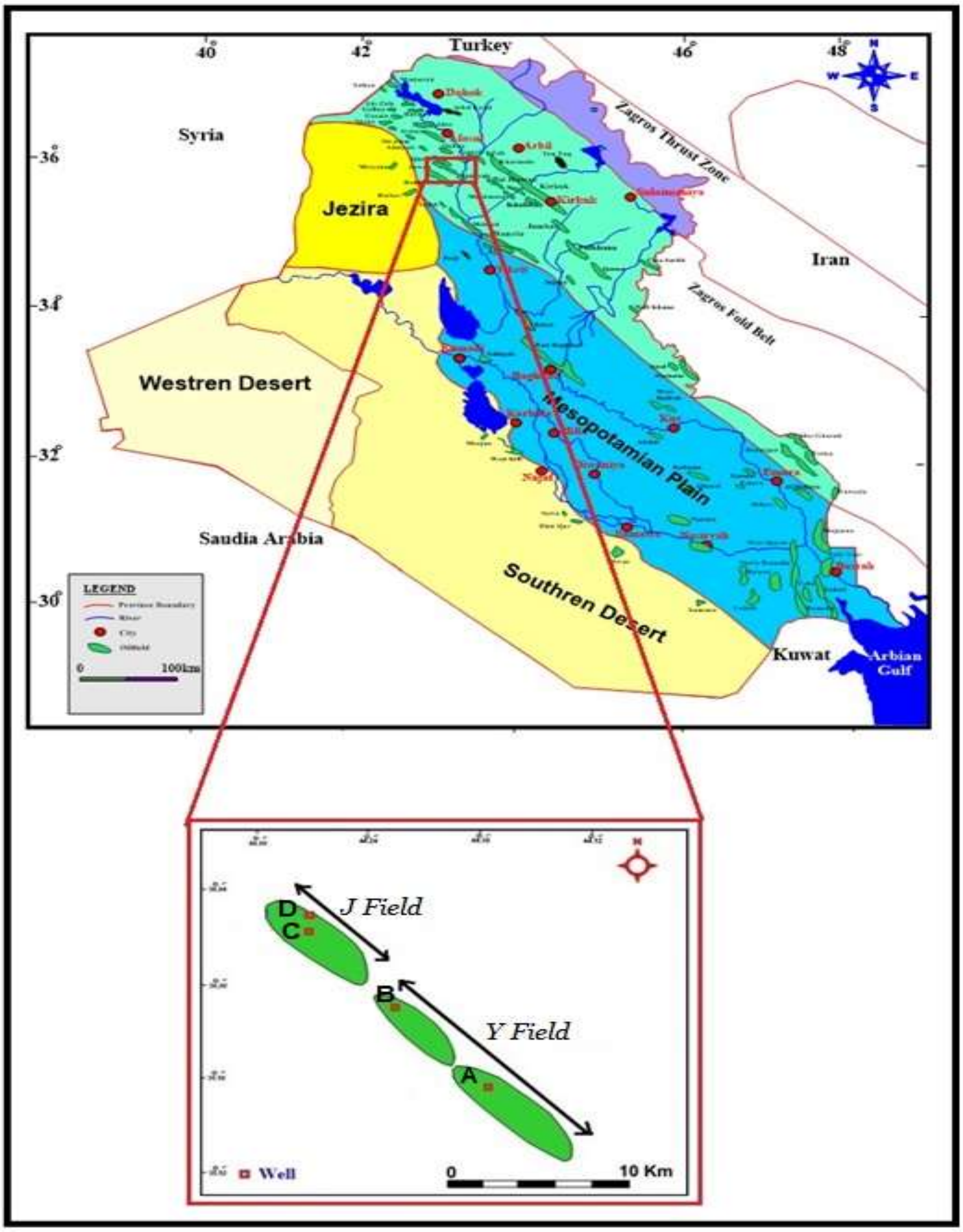

Figure 1-Location map of Y and J fields [7].

2- GEOLOGICAL SETTING

Rabanit (1952) [8] was the first who described this formation in Zubair-3 well. [3], [4], [9], and [10] described the formation and its equivalents in central and southern Iraq. Other studies involved the sedimentology and stratigraphy of the formation. The studied wells (A, B, C and D) are located within the central faulting zone according to the divisions stated by [11]. It is also located in the Unstable Shelf area relative to the Arab-Nubian craton, which contains feet. Foothill zone subdivisions [12] [13]and (Figure 1)

Y and J field is located in the northern part of Iraq.

Y is the largest part of the Y field lies to the west of the Tigris River, 60 km south of Mosul. Consists of two domes, separated by a saddle.

The dome in the southeast is broader and more developed than the dome in the northwest, the latter being narrow and inconspicuous, and the dome in the southeast is 45 meters higher than the dome in the northwest. The first well Y-1 was drilled in 1982, and penetrated to Cretaceous Reservoir. the J field is located of about 50 km south of Mosul and about 15 km northwest of the city of Y. well J -1 was drilled in 1933.

The Hartha reservoir overlain unconformably by the Shiranish Formation and underline the Sadi Formation, of the four wells section of the Y and J fields

3- Materials and Methods

The methodology of the present study included the following analyses:

In these wells, where samples were available, there were log data (gamma-ray, density) for reconstructing not cored intervals.

1- Digitizing well logs by using Nuro software.

2- determine porosity from core and log by using Tech-log software

3- Core and thin-section analyses were combined to identify porosity types and their related diagenetic stages that enhance and destroy porosity, with particular regard to the porosity evolution

4- Porosity texture evolution and reservoir quality using "staining Alizarin red S" to differentiate calcite from dolomite.

4- Objectives of the study

The following goals are targeted:

1- studying the depositional and diagenetic characteristics of these carbonate formation and their controls on the reservoir quality.

2- Analyzing the facies and interpreting the petrography, as a tool to the depositional setting environment, which controls the reservoir properties diagenesis effective on reservoir between two wells

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3- Constructing the Hartha Formation in vertical and horizontal stratigraphic correlation in two wells (Y & J)

5- Diagenesis Development

The analysis of reservoir pore development is important in evaluating the carbonate Hartha reservoir's efficiency in assessing production.

The initial porosity of the reservoir is mainly controlled by the characteristics of the initial sediment and the sedimentation conditions, and the development of pores in the late-stage primarily depends on the severity of late diagenesis, like a fracture.

Diagenesis is affected by the Hartha Formation environment, which is the Inner - Middle- Outer Ramp [2] [14]

The pore types in the Hartha Formation throughout the studied core samples in wells A and B consist of a mixture of primary and secondary types (Table-1). Intercrystalline, vuggy and cavern porosity are the dominant porosity types in the studied samples, followed by interparticle and fracture porosity (Figure 2). These porosity are characterized by fabric selective pore types, including intercrystalline and interparticle. The vuggy and cavern are considered non-fabric selective porosity types. The origin of porosity type in the Hartha reservoir can be considered a mixture of primary and secondary porosity depending on pore type identification from core samples. The N-M cross plot is illustrated in Figures 2 and 3.

The value of the calculated effective porosity in well A is greater than 20% in the entire formation interval, except the lower part of the fourth unit. In the well B, the effective porosity, despite the shale volume compaction, the porosity in the first to the third unit has good quality (17%). In comparison, the fourth and fifth units in the lower part of the formation have porosity in the Fair range (13-15%). In well (C), the magnitude of calculated effective porosities has very good range, while this result is dropped to a good range in the lower part of the formation. In well (D), porosity in the first to the third unit is good quality, while the fourth and fifth units in the lower part of the formation have porosity in Fair.

Moreover, a great match between the logs and core readings for wells A and C (Table1), (Figures. 4, 5, 6 and 7).

Table 1-Porosity types were observed in the Hartha reservoir.

Well No.	Formation	Core Number	Recovery core	Depth (m.)	Φ core	Φ log	Pores Type
A	Hartha	16	100%	769	18	17	Intercrystalline
				770	20	18	Vuggy+Cavern
				772	19	19	Intercrystalline
				773	22	17	Fracture
				775	21	17	Vuggy+Cavern
				776	21	16	Intercrystalline+Interparrtical
C		21	93%	699	18	16	Intercrystalline
				700	26	21	Vuggy+Cavern
				701	22	19	Intercrystalline
				702	37	28	Vuggy+Cavern
				703	27	22	Vuggy+Cavern
				704	31	19	Vuggy+Cavern
				705	27	25	Vuggy+Cavern
				706	25	22	Vuggy+Cavern

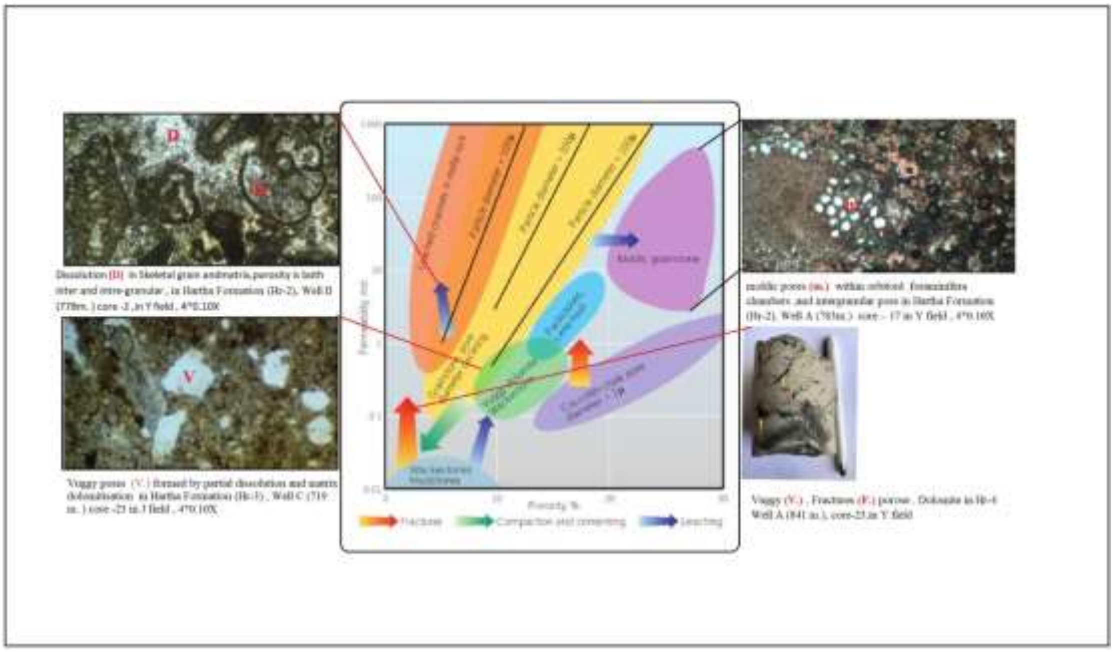

Figure 2-Permeability-porosity relationship for carbonate rocks following Danham classification.

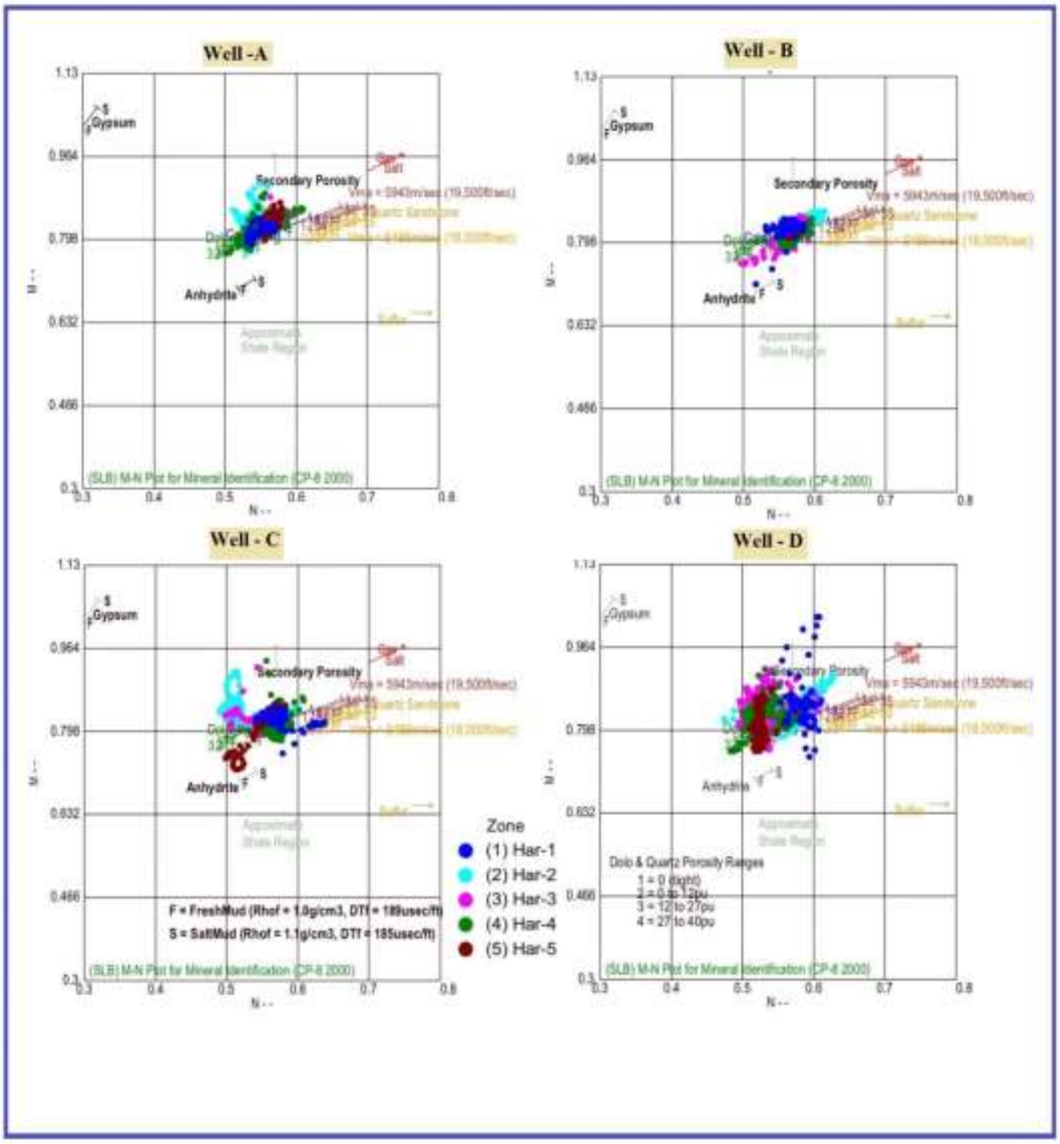

Figure 3-N-M cross plot of the Hartha reservoir throughout the studied wells

7- Porosity

According to the type porosity in the Hartha reservoir (Table-1), core and thin section " primary and secondary porosity" type (Intercrystalline, Fracture, Interpartical, Vuggy, Cavern)، and quantity by density and netrune log (secondary porosity), and primary porosity from sonic log [15].

Figures 5 and 6 shows porosity matching and permeability different in track (4 and 7) of wells A and C log and core sample correlated, as well as laboratory measured permeability by plug samples using steady state gas permeability technique [16].

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The porosity is determined stochastically within each lithological facies for calculating petrophysical parameters. It shows that the average weighted porosity in the Hartha Formation, Y and J oil fields are as follows:

- First unit; the average weighted porosity of the wells studied for Y and J fields ranged between 17%-23%, and this ratio is considered good and ideal for the reservoir. In addition, most of the porosity is of the secondary porosity type represented by cavern and vuggy. (Figures 4, 5, 6 and 7)

- Second unit is good at wells (A,B), at a rate of (18-24) %, and somewhat decreases towards the J field at the wells - (C,D), at a rate of (13)%. (Figures 4,5,6 and 7)
- While in the third unit in Y field (A,B) it is good (18-23) % and worsens in J field to become (14-17)%. (Figures 4,5,6 and 7)
- It becomes medium in the fourth unit at (A,B) at a rate of (15-19) %and good in well- (C) at a rate of (25%) and is somewhat lower in well- (D) , where it is (14%) unlike the previous units. (Fig.-4,5,6 and 7)
- It is good in the fifth unit at (A) and (B), up to (21%), and somewhat decreases at well (C) to (14%), and worsens significantly at well – (D) to become 6%. (Figures 4,5,6 and 7)

The magnitude of the measured permeability in the Hartha Formation throughout the studied intervals are heterogeneously distributed from the top to the bottom of the formation. In well-A, the measured permeability ranged by core analysis from (0.03) mD to (510.43) mD with an average of (21.37) mD. in Well-C the permeability values have the same range but with different magnitudes. The minimum permeability in well- C is (0.02) mD and the maximum permeability is (844.50) mD with an average permeability of (29.42) mD. However, the magnitude of permeability is widely distributed but in term of reservoir quality it considered as good permeability for the Hartha Formation. (Figures 4 and 5).

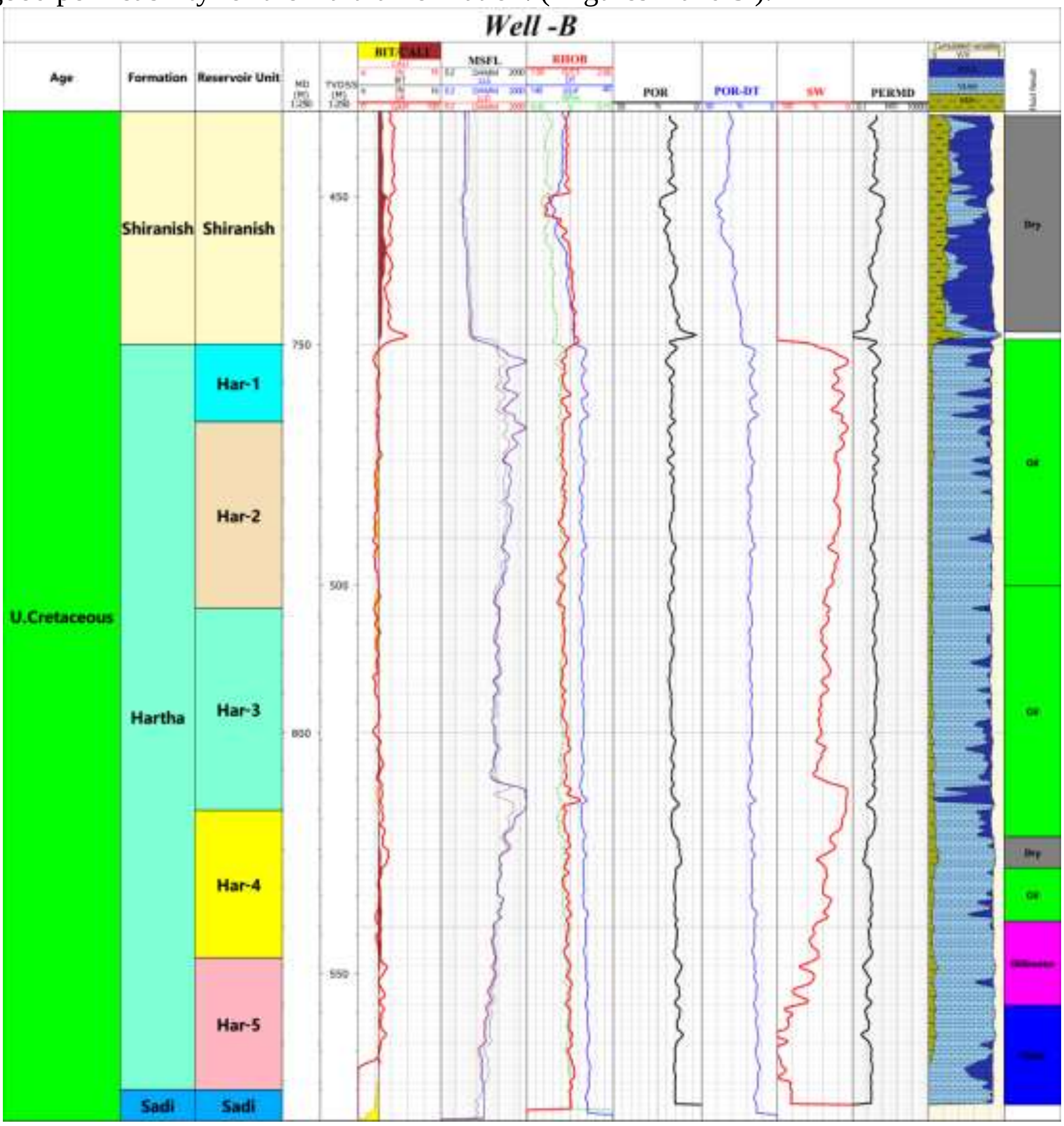

Figure 4 - Composite wireline log data and CPI of well -A

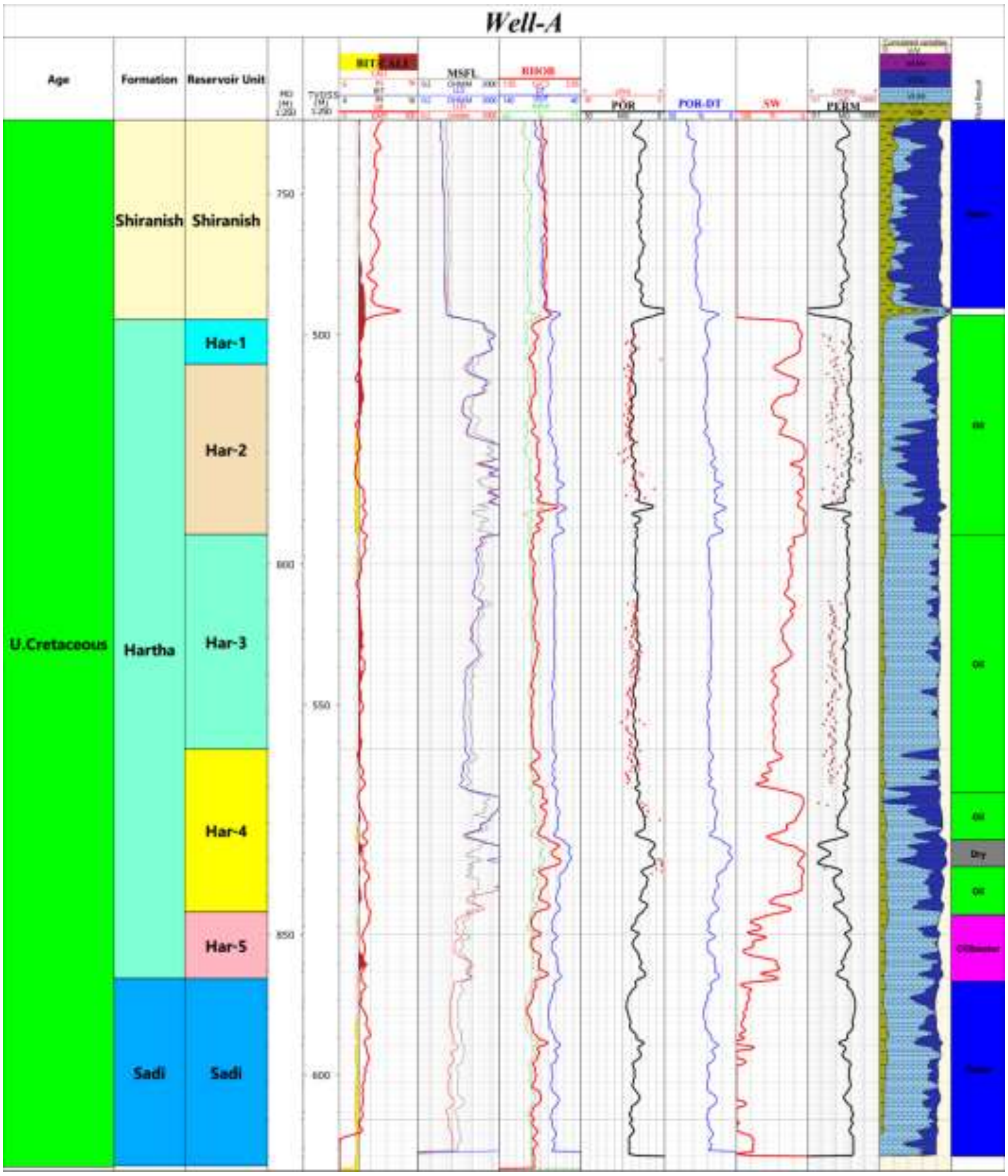

Figure 5-Composite wireline log data and CPI of well -B

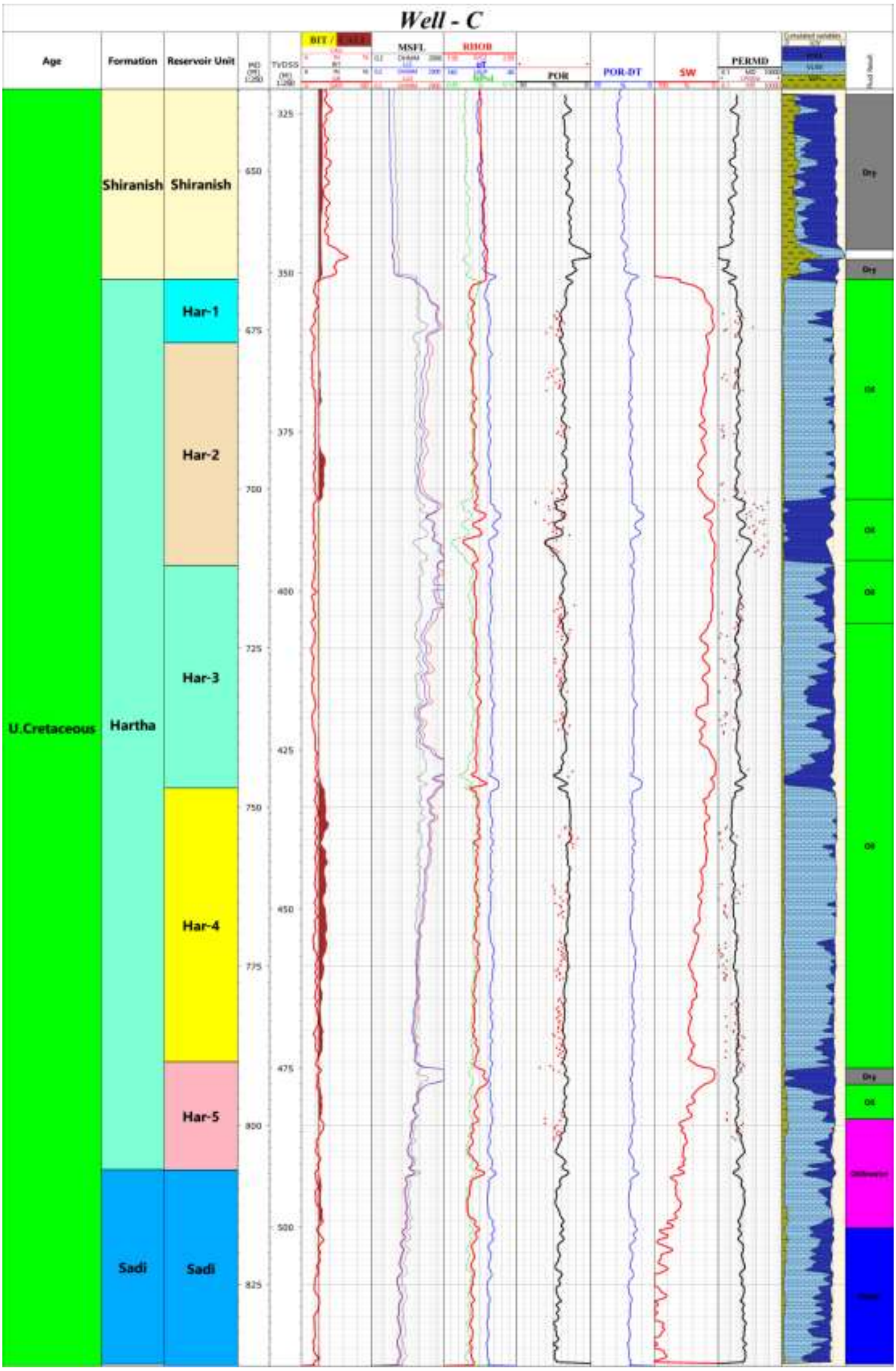

Figure 6 - Composite wireline log data and CPI of well -C

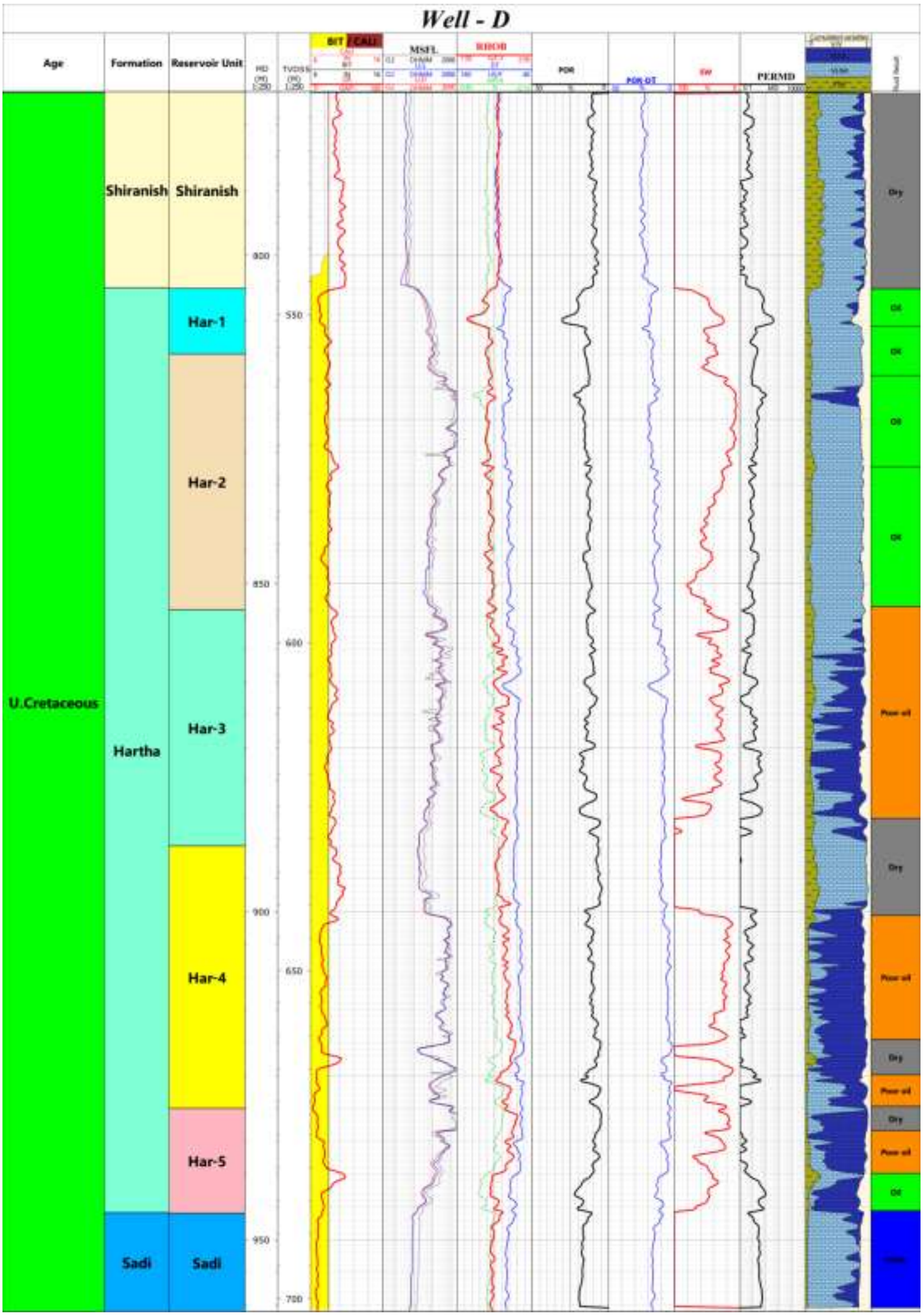

Figure 7- Composite wireline log data and CPI of well -D

8. Diagenesis Process Type

The diagenesis of the Hartha carbonate reservoir includes the processes between deposition of formation and burial. They include cementation, compaction, stylolite, dissolution, micritization, neomorphism, dolomitization and fracturing (Table -2).

The cementation, compaction, and pressure solution in the studied wells negatively influence reservoir porosity. Recrystallization has little effect on the physical properties of the reservoir. Dissolution, decomposition and tectonics are among the main processes in the studied wells that improve the properties of the Hartha reservoir, and they are also major influencing factors in the reservoir pores.

Micritization

The Micritization process mainly includes the formation of the Micratic cover that covers skeletal grains and some intraclast, because of microalgae activities, which creates holes or gaps on the grain wall and fills with micrite. This process significantly affects the biological components in Hartha Formation facies (Plate-3; B).

- **Dissolution**

Dissolution is a very important constructive diagenesis. From the microfacies observation, it was found that the major dissolution in the third stage of the carbonate development, respectively, corresponds to the syngenetic diagenetic stages, the middle, and the late diagenetic stages

-The first stage of dissolution mainly took place syngenetically that are commonly developed in fine silty dolomite. Since the development took place very early, after a long-buried, all the dissolution pores were almost filled

-The second stage of dissolution occurs during the middle diagenetic phase in a buried environment. The dissolution commonly took place along the stylolites and was closely related to the filling with organic matter (Figures 13 and 14). This kind of dissolution is quite common along the stylolites,

-The third stage of dissolution is the most constructive diagenesis phase. The typical dissolution includes one of the fissures filled with calcite or gypsum in the early stages and the intracrystal pores in the coarse crystals dolomite.

The diagenetic evolution history of the Hartha shows that wells A and C experienced multi-stage diagenesis with complex and diverse diagenetic types (Palette 2C and Plate 3C)

- **Cementation**

Cementation is one of the diagenesis types representing a form of destructive diagenesis. The early diagenetic cementation leads to reduced primary porosity. The primary dissolution pores were filled by early cementation (granular, blocky and drusy) (Plate 2A and B), (Plate 3E).

- **Compaction**

In the Hartha carbonate reservoir, the compaction affects the fabric of the Hartha Formation. Stylolite is direct evidence of pressure solution. Quite developed, which is mainly embodied in the form of developed stylolite at the zigzag (Plate 1A and B).

- **Neomorphism**

This process includes recrystallising the intergranular micritic matrix and fossil skeletons to sparse calcite in different degrees, called Aggrading Rrecrystallize (Folk, 1974). The enlargement in the crystal size appears in most parts of the Hartha Formation facies (Plate 3D).

- **Dolomitisation**

The petrographic feature of the dolomite were studied on core and thin section identification. Dolomitisation in Hartha reservoir is increase upwards from the cycle bottom and the most significant type as pen contemporaneous dolomite may also have different development patterns dolomite texture type of according [17] are Sutured mosaic Dolomite , Floating rhombs fabric in dolomitic limestone and vuggy porosity impregnation oil. (Table 2), (Plates-2 ;A,E,F and Plates- 3;A,F) , Dolomitized Intercrystal porosity Sucrosic dolomite bioclastic the genetic models of dolomite were put forward for the study area, that is, reflux and mixing modelas texture and no evaporate.

Table 2- Paragenetic sequences of diagenesis affecting the Hartha Reservoir

Diagenetic Stage		Syngenetid		Early	Middle	Late	Plates Number
Diagenetic environment		Meteoric environment	Mixing Zone	Shallow burial	Middle burial	Deep burial	
Type of diagenesis	Micritization						3-B
	Dissolution						1-A , 2-C,3-C
	Cementation						2-B,2-A
	Compaction						
	Stylolite						1-B
	Neomorphism						
	Dolomitization						2-F,3-F,3-D
	Dissolution 2						2-C,2-D,3-A
	Fracture						1-A,3-E
Bitumen							1-C

Improve the reservoir properties (blue)

Reduce the reservoir properties (green)

Plate-1:

A- Vuggy (V.), Fractures (F.) porous, Dolomite in Har-4 (841 m.), core-23, Well –A

B- Fine-grained limestone affected by stylotization (S.) ، in Hr-2 (691 m.)، core-20، Well – C

C- C-Bitumen (B.) Dolomite in unit Hr-4 (833m.) ، core-22 ، Well -A

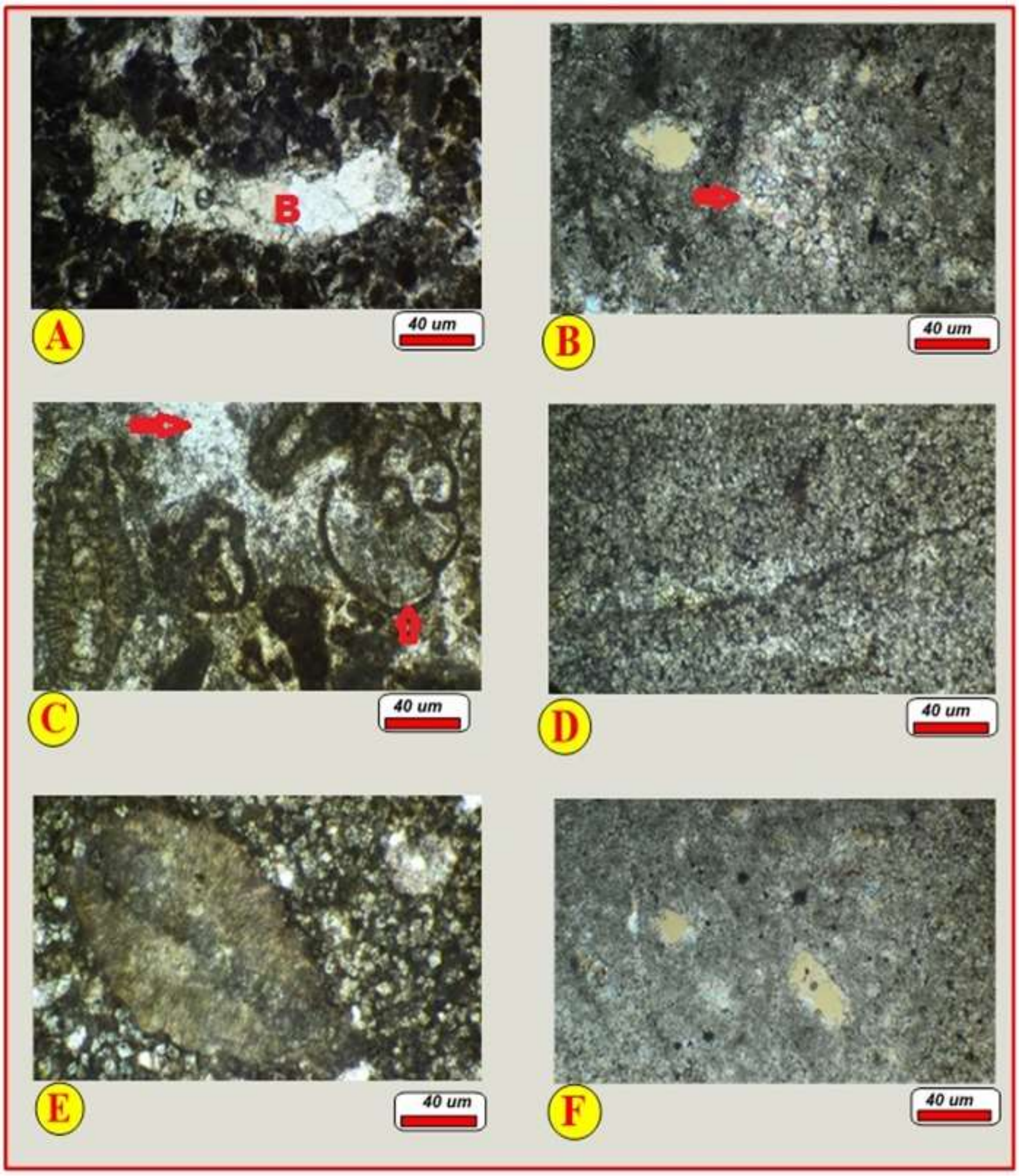

Plate-2

A- Blocky cement (B) in Hartha Formation (Har-2), Well –D (838 m.),core -18, (4 X).
B- Granular cement in Hartha Formation (Har-2) Well –A (792m.),core -18, (4 X).
C- Dissolution in Skeletal grain and matrix, porosity is both inter and inter-granular, locally filled with euhedral dolomite blocky and granular cement in Hartha Formation (Har-2), Well -B (778m.) core -2, (4 X).
D- Sutured mosaic Dolomite and porosity is limited to open Fracture present in Hartha Formation (Har-3) , Well -D (870 m.) core -21, (4 X).
E- Floating rhombs fabric in dolomitic limestone and vuggy porosity, impregnation oil in Hartha Formation (Har-4), Well - C (841 m.) core – 23, (4 X).
F- Sucrosic dolomite bioclastic wackestone microfacies in Hartha Formation (Har-2), Well -A (790m.) core - 18, (4 X).

PLATE-3

A- Dolomitized Intercrystal porosity dominates and may be enlarged by dissolution in Hartha Formation (Har-2), Well -D (889m.), (4 X)

B- Micritization in skeletal grains in Hr-4 (783-784 m.) core-30, Well – C, (4 X)

C- Vuggy pores formed by partial dissolution and matrix dolomitization, Rudist debris (R) in Hartha Formation (Har-3) , Well -C (719 m.) core -23, (4 X)

D- Neomorphism of skeletal grain in Monolepidorbis spp. and Peloidal packstone microfacies. in Hartha Formation (Hr-2), Well - D (838m.) Core-18, (4 X)

E- Lime Mudstone with Micro fracture healed silicate (Drusy cement (D)) in Hartha Formation (Har-4) Well -A (842 m.), core -23, (4 X)

F- bioclastic packstone, showing many rudist debris foraminiferas and Echinoids fragments. Micrite matrix is partially replaced by scattered dolomite rhombs in Hartha Formation (Hr-2), Well -A (784,m.) core - 17 (4 X)

9. CONCLUSIONS

The object of this study in the Y and Y Fields North Iraq heterogeneity carbonate in sub-basin Y area

1. Several factors Facies associated petrographic and diageneses process controls reservoir variation in four wells.
2. The upper part of the Hartha reservoir (Har-1, Har-2 and Har-3) has a good porosity as most of the porosity types are secondary in origin and formed during diagenesis, cavern dissolution and the dolomitazation.
3. The magnitude of measured and calculated porosity with an integration of the measured permeability in the Hartha reservoir throughout the studied intervals indicate a good reservoir quality. These data come from primary and secondary pores, including intercrystalline, interparticle, vugs, caverns and fractures. The petrophysical cut-offs provided an excellent result for the rock properties. The net to gross ratio of most units of the Hartha reservoir is equal to one or close to one except for the fourth unit in D and the fifth unit in B.

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