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Facies Analysis and Paleoenvironmental Assessment of the Upper Campanian Hartha Formation in Y and J Fields Northwestern Zagros Basin, Iraq

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Abstract

The Upper Campanian Hartha Formation represents potential Cretaceous hydrocarbon-bearing reservoir rocks across the Y and J oilfields northwestern Zagros Basin, northern Iraq. The study objective is depositional environment which affects reservoir properties by tool, lithofacies, core, thin section, and logs, using petrel (V.2016) and strat software, facies distribution, grains, and diagenetic processes control and enhance reservoir properties which can plan platform production and minimize risks in choosing production wells location at two fields scale. The current study is concerned with lithofacies and microfacies of the Hartha Formation within two fields in northern Iraq. Several subsurface well-log data, core, and cutting samples have been used in order to prepare thin sections that were subjected to sedimentological (lithofacies, and grain-size) examination. The petrography investigation revealed five rock-units including Hr. 1, 2, 3, 4, and 5, the thickness of 89 m in the Y-A field and increasing to up to 140 m in the J-B field might be due to erosion or tectonic uplift of the topography in Y subbasin. Which is locally sub-basin within study fields western banks of Tigris river as gentle slope ramp depositional condition with Spectrum microfacies from lime-mudstone to packstone texture with rudest and benthic debris enhances by diagenesis, dolomitization, dissolution moldic porosity, fracture; dolostone is more effective in the upper section of the formation in A than B Wells. Many factors, such as cementation, compaction, and pore-filling autogenic minerals, decrease reservoir quality, and their effects are similar in wells A and B.

Keywords: Bioclastic packstone; Hartha Formation; Ramp depositional condition; Rudest debris; Upper Campanian

1. Introduction

The two fields were discovered at the beginning of the last century by the German team conducting a surface survey during the detection of the Middle Miocene Fatha Formation (Lower Fars) and the presence of oil seepage on the surface (Nobel and Evans, 1919). There are few detailed studies on Cretaceous carbonate facies (Chatton and Hart, 1961 and Al-Sammarai, 2010). The Upper Campanian Hartha Formation has not produced hydrocarbons within the study area till the present day, while Tertiary reservoir rocks produced hydrocarbons only in the Y field. The Cretaceous Hartha Formation represents the main reservoirs across the Aqra sub-basin, which is part of the NW-SE trending major

Cretaceous land basin. Furthermore, to plan new production and development methods in these fields need to build a geological model is important.

The studying of Hartha ramp facies and diagenesis could improve geological data, allowing for better drilling and production and minimizing risks in selection producing well locations. The large of Y field is located in the western part of the Tigris River, about 65 km south of the city of Mosul. Consists of two domes in axial direction NW-SE separated by a saddle. The southern dome is structurally wider and larger than the northern dome. The First well in Y field was drilled at 1982 in the Cretaceous reservoirs. The J field, which consists of a single dome, is located 50 km south of the city of Mosul, northwest of field Y, and the First well in J field was drilled at 1933. The Hartha Formation was completely penetrated within nine wells in field Y and in four wells of field J.

According to the tectonic divisions of Ditmar (1979) and Iraqi -Soviet team, the study area is located within the central faulting zone, within the unstable shelf corresponding to the Arabian -Nubian craton (Aqrawi, 1998) (Fig.1). The first description of the Cretaceous Hartha Formation was made by Rabanit (1952), while Van Bellen et al. (1959) redescribed the formation in the Zubair-3 well. Many researchers have described the formation and its equivalents in central and southern Iraq (Al-Naqib, 1967; Al-Omeri and Sadek, 1975; Chatton and Hart, 1961). Other researchers concerned the sedimentology, stratigraphy, and depositional environments of this formation (Ahmed, 1996; Al-Ali, 1989; Al-Na'aimi, 1994; Hammoudi, 1990; Nasir, 1996; Chaseb and Mahdi, 2020).

The Hartha Formation is unconformably overlain by the Shiranish Formation, with glauconite grains and high gamma-ray readings as depositional conditions change from shoal to basinal facies. The contact between these formations was recognized by facies change, in which gamma-ray reading is significantly decreased from a shallow depositional environment of Hartha dolomitic limestone reservoir rocks into the deep depositional environment Shiranish marly limestone rocks. Furthermore, the formation is underlined by the Santonian sub-basinal Sadi Formation, which consists of oligosteginal limestones (Figs. 2 and 3).

Fig.1. Location map of Y and J fields (modified from Aqrawi, 1998)

Within the studied area, the depth of Hartha reservoir at 660 – 800 m (Fig.4). General stratigraphic correlation and stratigraphy with thicknesses and tops of the Hartha Formation are presented in Table 1 and illustrated (Figs. 2, 3 and 4). Table 1 showed that the Hartha Formation is thicker in J-B well in the J field than Y-A well in the Y field. The upper part of the late Turonian–Danian mega sequence (AP9) including Tayarat, Tanjero, Aqra, Bekhme, Digma, and Hadiena formations (known only from a narrow outcrop which runs east-west from the Ora area into the Chalki-Banik area) represents the equivalent of the Hartha Formation. The geological framework of the Hartha Formation in the Majnoon oilfield in southern Iraq was modeled by Mahdi (2020). Geological evolution throughout Turonian to Eocene of the Y Tertiary basin northern part of Iraq contributed to the construction of foreland basin northern edge of the Arabian plate as a result of overloading the crust by a thrust sheet and convergent or compression on the N-E margins of an Arabian plate with Iranian plate (Jassim and Goff, 2006). The facies and petrographic evaluation of Hartha Formation within Y and J fields in this study are aimed to determine the depositional and diagenetic features evaluation of carbonate facies and their impact on the reservoir quality of this formation, horizontal and vertical stratigraphic correlation construction, in the A and B wells.

2. Materials and Methods

- Several core and cutting samples were used to prepare thin sections in the North Oil Company (NOC) laboratory in order to identify petrographic and microfacies were used together in order to determine the facies types and associated diagenesis features as well as their depositional circumstances. prepared thin sections were analyzed using OPTIKA B-383POL-Italy type microscope and linked with a canon camera to get the best figure outputs.
- Digitizing of acquired well-logs by using Neuralog software and facies distribution modeling with petrel version 2016 software
- Evaluating of the Hartha Formation in the current study required several parameters, including reservoir well-logs such as gamma-ray (GR), density (FDC), and neutron (CNL) well-logs integrated with core and cutting sample from A, B wells in Y and J oilfields, respectively.

Table 1. Top Hartha Formation of A and B Wells in Y and J Fields, respectively

Wells	A			B		
	RTKB- 269 m			RTKB- 316 m		
	Top	Th.(m)		TOP	Th.(m)	
Formation	RTKB(m)	MSL(m)		RTKB(m)	MSL(m)	
Shiranish	501	-232	266	421	-105	246
Hartha	767	-498	89	667	-351	140
Hr-1	767	-498	6	667	-351	10
Hr-2	773	-504	23	677	-361	35
Hr-3	796	-527	29	712	-396	35
Hr-4	825	-556	22	747	-431	43
Hr-5	847	-578	9	790	-474	17
Sadi	856	-587	25.3+	807	-491	73
T.D.	881.3	-612.3		976	-660	
Spudded-in on	9/6/1982			6/5/1983		
Well Completed on	14-7-1982			19-6-1983		
Location	SE Plunge of Y			Near to the crest of J Field

Fig.2. Generalized stratigraphy of Hartha Formation and Equivalent formations In Iraq (modified after Harland et al., 1990)

Fig.3. Stratigraphic column of the Hartha Formation in the study area

3. Results

3.1. Facies and Depositional Model

Core and thin section examinations, integrated with textural investigations in petrography as a tool to establish a depositional Model environment. According to Readings (1981), lithofacies are a combination of facies relationships that are already assessed. Generally, the Hartha Formation is thicker

in the J field than at Y field (Table 1). Microfacies investigation and petrographic components that are diagnostic in thin sections of acquired samples in two boreholes (Y-A and J-B), control reservoir depositional condition.

In the current study, several different skeletal and non-skeletal components such as benthic fossils and rudest debris (Tables 2 and Figs. 7 and 8) were recognized based on the main classification of Dunham (1962) with an expanded classification of Randazzo and Zachos (1984).

Fig.4. Stratigraphic rock units of the Hartha Formation in the A and B wells

3.2 Microfacies of the Hartha Formation

Based on the textural variations of Hartha Formation carbonates and types of skeletal grains, (Figs. 8 and 9), different microfacies are distinguished. They range from mudstone to packstone microfacies, and can be subdivided as explained below:

3.2.1. Lime mudstone microfacies

This facies mainly consists of a matrix with a homogeneous micritic texture containing few skeletal granules (less than 10%) including a limited number of benthic foraminifera such as (*Peneroplis*) (*Miliolid*) as well as small pieces of detritus and Echinoderms, affected by diagenesis processes, some parts of the micrite are incorporated into fine sparite crystals.

3.2.2. Dolomitised bioclastic wackestone/ packstone microfacies

These facies are found in all wells in the study area and widely in the second and third units composed of carbonate grains are mainly Rudist debris Echinoderm, Orbitoid fragments and interclasts, peloids. Matrix is entirely replaced by fine crystalline euhedral dolomite. Porosity is predominately moldic, Vuggy, cavern, fracture (Figs. 8 and 9), This facies are divided into sub microfacies.

3.2.3. Bioclastic wackestone submicrofacies

wackestone facies are defined as facies that contain skeletal grains of more than 10% and a homogeneous micrite matrix (Dunham, 1962). consists foraminifera such as *Orbitoides* sp. and *Monolepidorbis* sp.

3.2.4. Bioclastic foraminifera packstone submicrofacies

Rich benthic foraminifera Bioclastic Carbonate grains packstone consist of the large foraminifera of the Rudist (Especially in the two wells Y-A and J-B) , Monolepidorbis, echinoderms and (miliolids and orbitoids), (Figs. 8 and 9).

3.2.5. Bioclastic packstone peloidal microfacies

This facies include the peloids, echinoderms, and Rudist debris foraminifera affected by diageneses processes such as dissolution, compaction.

4.2. Depositional Model

Lithofacies-Microfacies investigation as a distinct order of the Hartha Formation showed the abundance of benthic fossils and rudist debris in the carbonate platform, and suggest the gentle ramp type platform with a moderate slope. Planktonic foraminifera comprising oligostegina facies at the bottom of Hartha Formation gradually progressed from the outer ramp depositional environment of Sadi Formation to the middle ramp environment of Hartha Formation, indicating that a sub-basinal within the sedimentary basin has reached the onset of a marine regression during the Late Campanian Period (Jassim and Goff, 2006), in which the Hartha Formation deposited.

The Hartha Formation deposited mostly during the late Campanian tectonic event known as the Santonian Event, within a ramp carbonate platform setting (Fig. 5). The depositional environments of the Hartha Formation range from Inner-middle- to outer ramp platform conditions. While AL-Haj (2020), suggested four regional depositional conditions of the ramp-type of a carbonate platform. Consequently, the name "Hartha" designated for the neritic limestone complexes, deposited on the shelf mostly during the Upper Campanian-Maastrichtian transgressive Cycle In the Y field zone, the Hartha Formation is abruptly ended by a deep Shiranish Formation facies, where it was deposited in a shoal environment with a gentle slope in the Y oil field as rudist not well developed (Fig. 5). The Rudist as evidence indicator is not developed as Hartha Formation within central and southern Iraq with the rudist debris not proper high bank depositional model, genetically or environmentally related. Through the study of facies association, the presence of Benthic fossils, and the presence of rudist debris were proved.

Fig.5. Model of the Hartha Formation showing the environmental effects of the Y Basin

Table. 2. Facies Petrography parameters and diageneses of rock unit in well Y-A and J-B

Formation	Facies code	Facies characteristic	Interpretation of depositional environment	Oil Shows
Shiranish	Har-1	Packstone, pack/Wackstone	Deep Basin, Outer Ramp	Heavy Oil flow surging and bitumen in the Lower part, in well Y-A
	Har-2	wack/packstone	Inner Ramp Shoal (786-789)	
			Inner Ramp	
Hartha	Har-3	Packstone	Shoal Inner –Mid Ramp	oil flow to surface in well J-B
			Shoal Inner –Mid Ramp Shoal (723-726) (735-738)	
	Har-4	wacke/packstone	Mid Ramp Shoal (830-834)	
Sadi	H-5	wacke/packstone	Deep Middle Ramp	
			Outer Ramp	

4.3. Diagenesis Processes

The Hartha reservoir properties are influenced by sub-environment diagenesis processes, such as higher dolomitization processes effect appearance in the upper part of the studied formation within A than B Wells (Fig.5), in which improving porosity (ratios and types) such as moldic near-surface diagenesis, vuggy, and cavern in addition to dolomitization (Figs. 7 and 8), and bioclastic packstone of rudist debris fragments (marine vadose), autogenic glauconite, oil impregnation, destroyed properties. Sub-environment meteoric and marine sucrose dolomites are mixing models is explain dolomitization processes that effect on Hartha formation rocks (Longman, 1980). The main reservoir property controlling factors such as fractures and micro-open fractures represents secondary porosity formed during diagenesis stages (Plate 1: A and B) (Plate 2: A, B, C, D, E and G).

Fig.6. Lithofacies and their lateral variation within A and B wells

Plate-1 A and B: Core photography; Fractures; Cavern; Vuggy with oil impregnation in dolomite rock samples within Y-A well core-23, depth 841 m. ,4*0.10 x

Plate 2. A) Glauconite concentration in the contact between Hartha and Shiranish formations, Y-A well 765m; B) Vuggy porosity formed by partial dissolution and dolomitization, impregnation oil, J-B well, 719m ;C) Bioclastic packstone of rudist debris fragments, J-B well, 783m; D) Peloidal-packstone microfacies impregnation oil, J-B well, 674m; E) Microfracture healed silicate, Y-A well, 789m; F) Intergranular porosity within moldic porosity in Large benthonic foraminifera *Monolepidorbis* sp. and oil impregnation, Y-A well, 783m. 10*0.25 PX, G) Drusy cement in micro sutured dolomite, Y-A well, 820 m. core – 20; H) Calcisphere wackestone microfacies Bottom of the Hartha Formation (Hr-5), Well J-B (945 m.)

Fig. 8. Petrographic microfacies, diagenesis and porosity type of well - B in J field

5. Conclusions

The objectives of this study in the Y and J fields North Iraq heterogeneity carbonite in sub-basin Y area are:

- Several factors. facies association petrographic and diageneses process which controls Reservoir variation in two wells.
- Low angle slope carbonite Ramps setting (Inner-middle ramp) of Hartha Reservoir the upper part is a good reservoir.
- Dolomitization in Y field more than J field which enhanced reservoir quality of the Hartha Formation.

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