High Resolution Sequence Stratigraphy And Reservoir Characterization Of The Hartha Formation In Ahdab Oilfield

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Abstract

The Hartha Formation is one of the economically important formations which deposited during the Cretaceous period, and the most heterogeneous from one place to another because of the complexities of sedimentary basin and the movements that influenced it.

This research is interested in studying the Upper Campanian-Lower Maastrichtian succession (Hartha Formation) in Ahdab oilfield (Ad-1) which located in the middle of Iraq within the Mesopotamian basin (Tikrit-Amara Subzone). The present study includes two parts; the first is facies analysis and stratigraphic history, and the second is the study of petrophysical properties and reservoir characteristics for this succession.

Facies analysis enable the recognition of six main facies associations in the studied succession; these are basinal, open shelf margin, foreslope, rudistbiostorm, Shoal and restricted platform (lagoon). The Hartha succession represents deposition of two cycles of third order, these cycles where deposited during successive episodes of relative sea level rises and still stand.

There are nine petrophysical horizons observed in the studied succession named (I, II, III, IV, V, VI, VII, VIII and IX), four of them are good reservoir horizons which are: (III, IV, VI, and VIII). The dolomitized horizon as (II, V and VII) are matching with the still stand or regressed sea level, where during these stages the diagenesis processes (dolomitization and cementation) were active. The permeability-porosity relationship for the carbonate rocks showing a good match with the general facies and petrophysical properties for the studied succession.

Introduction

The Hartha Formation is one of the important formations which deposited during the Cretaceous, and the most heterogeneous from one place to another due to the complexities of sedimentary basin and the movements that influenced it.

The Hartha Formation was described at the first time in the Zubair Field by Rabanit (1952, cited in Bellen et al., 1959). The formation is composed of 200-250 m (656-820 ft) in thickness of bioclastic-detrital, glauconitic limestone with green or gray, shale beds. In some places, the limestone is strongly dolomitized (Bellen et al., 1959). The formation was deposited the greater part of in a marginal-marine, fore-
reef, neritic, shoal environment, but back-reef facies are found locally. The lower contact of the formation is unconformable and often is marked by the development of conglomeratic beds (Buday, 1980).

This research is interested to study the Upper Campanian-Lower Maastrichtian succession (Hartha Formation) in Ahdab oilfield (Ad-1) which located in the middle of Iraq within the Mesopotamian basin (Tiktit-Amara Subzone) (Fig. 1). This study includes two parts; the first is facies analysis and stratigraphic history, and the second is study of petrophysical properties and reservoir characterizations for this succession.

The studied succession is represented by the upper part of Sa'adi Formation, Hartha Formation and the lower part of Shiranish Formation (from the depth 2250-2450m), the Hartha Formation interval is ranged between (2263-2431.5m).

**Facies analysis**

At the Upper Campanian to Lower Maastrichtian the succession was deposited during five cycles, each one represented the rise-fall sea level event within Arabian plate according to Haq et al., 2005. In this study, comparison will be done between sea levels and microfacies with the petrophysical changes to develop a clear vision for the depositional history for the Hartha Formation. Six association facies are recognized in the studied section:-
Basinal facies association (Facies A)
Basinal deposits consist of thinbedded shale, marls and argillaceous to marly limestone. This association facies appeared in the lower part of the Shiranish Formation (from 2263 to 2250m) alternative with open shelf carbonate facies.

Open shelf margin facies association (Facies B)
This facies consist of mudstone to wackstone with small benthic foraminifera and calcispheres. This facies appeared in the depths (2438-2431) and (2341-2402.5).

Foreslope facies association (Facies C)
The echinoderm and rudist bioclastic packstone in addition less of benthic foraminifera are characterized the fore slopemicrofacies. This facies refer to the deposition in shallow water with high currents and high energy. This facies appeared in the depth(2410-2402.5 m).

Rudist biostorm facies association (Facies D)
The Rudist microfacies association facies consist mainly of rudiston and rudist packstone with bryozoan and red algae. This microfacies show a limited presences in the studied oilfield at the depth from 2307-2280m and 2431-2410m.

Shoal facies association (Facies E)
This facies consists of foraminiferal packstone to grainston. It is characterized by abundant foraminifera and echinoderm fragments, and the high degree of sorting, suggesting deposition in an environment of high energy. The facies (E) appeared in the depth from 2328 to 2307m, in addition to the depth from 2280 to 2275m where this part is observed by the logs only.

Restricted platform and lagoon facies association (Facies F)
This facies association consists mainly of Miliolids and pelletal wackstones and mudstone to wackstones. Refers to the deposition in a low energy environment (quiet lagoonal environment). The facies F shows in the depths (2341-2328m) and (2278-2265m).

Stratigraphic history
The stratigraphic history for the studied succession is described according to the facies analysis and depositional environments that have been deduced from facies association, addition to well-log sequence stratigraphic analysis.

Well-log sequence stratigraphic analysis is a methodology that permits a geologist and geophysicist to subdivide a stratigraphic section into a series of time related 3rd order depositional sequences and systems tracts (Vail and Wornardt, 1990). Abrupt changes in gamma-ray logs response are commonly related to sharp lithological breaks associated with unconformities and sequence boundaries (Krassay, 1998).

The study succession represents deposition of four cycles of the third order for all succession and two cycles third order for the Hartha Formation these cycles where deposited during successive episodes of relative sea level rises and stillstand (Fig. 2)

First cycle
The first cycle extends from the upper part of the Sa'adi Formation to the end of this formation, which represented by the basinal facies that deposed during the late stage of transgression period (HST). After this period, the sea fall happened (in the Middle of Campanian) to mark the contact (sequence boundary-SB1) between the Sa'adi Formation and the Hartha Formation.

Second cycle
This cycle was started with progress of the sea during the Upper Campanian to deposition of the lower part of the Hartha Formation. There are five steps for this transgression(TST) and rapid stillstand contributed the lower part of the Hartha
Formation; The first step deposited the facies D (rudistbiostorm) and then deposited the facies C (fore slopefacies) at the second step. The facies B (Open shelf margin facies) was deposited during the other three steps. The changing facies from rudist biostormto fore slope and then open shelf margin refers to deepening upward with high fluctuation in sea level. The log data showed a change in rock properties of the upper part of the facies (B), suggesting the maximum flooding surface (mfs). Therefore, the upper part of the facies B and the facies F(restricted platform and lagoon facies)are represent the high stand system tract (HST).

Third cycle

During this cycle the sea level rise has been slowed (transgression) leading to deposition of the facies E(platform margin sands facies - shoal) which refers to the deposition in high energy environment. And then deposition of the facies D (rudist biostorm facies) refers to deepening upward, the upper part of this facies marked the maximum flooding stage. The next stage was the high stillstand which deposited the facies E (shoal) and then restricted platform and lagoon facies. At the end of this cycle the regional regression sea was happened to mark the contact (sequence boundary-SB1) between the Hartha Formation and the Shiranish Formation.

Fourth cycle

The Shiranish Formation was deposited in this cycle during the transgression stage within the basinal environment.
Fig. 2 Stratigraphic section for the studied succession showing the facies analysis and stratigraphic events.
Reservoir characterization

The different characters of reservoir units such as lithology, types of porosity, permeability and types of fluids can be deduced from the study of geologic logs. In the present study the primary and secondary porosity as well as water and oil saturation were determined in addition to subdividing the succession.

The parameters of log interpretation are determined directly or inferred indirectly and measured by one of three types of logs:
1. Electric (Spontaneous Potential, Resistivity)
2. Radioactive (Gamma Ray, Density, Neutron)
3. Acoustic or sonic logs

The equations and parameters are used in this procedure (Fig.3) proposed by (Archie, 1942; Larionov, 1969; Wyllie et al., 1958; Morris and Biggs, 1967; Schlumberger, 1972; Coates and Dumanoir 1973; Schlumberger, 1989; Schlumberger, 1997; Doveton, 1999; Asquith and Krygowski, 2004).

The application of this procedure has been through two stages, at the first stage the studied succession divided into many horizons according to the petrophysical properties, in addition to comparison and correlation between the electrical and radioactive properties of these rocks on the one hand and the types of porosity on the other. The second stage represents the calculation of permeability and the comparison with the total porosity to determine the type of carbonates rocks fabric for each horizon.
The first stage:

There are nine petrophysical horizons observed in the studied succession named (I, II, III, IV, V, VI, VII, VIII, and IX) (Fig. 4):

Fig. 3 Diagram showing steps and parameters of petrophysical properties and reservoir characterization which used in the present study.
Horizon I
This horizon is represented the lower part of Shiranish Formation, therefore the values of SP (negative) and GR (maximum) logs shows the shale dominated rocks and alternative with carbonate rock.

Horizon II
At the depth 2265m the GR value decreasing and the SP value becoming positive to marked the upper contact of Hartha Formation. The interval of this Horizon is from 2265m to 2280m with two different parts are observed in this horizon: the first characterized by very poor porosity (massive carbonate rocks). The second (lower part) shows a very high porosity (approximately 35%) with high secondary and effective porosities, addition to intercrystalline type of porosity (BVW). Addition to that the lower partis appeared a negative SP values (sand line) and minimum GR values to refer to sand fabric.

Horizon III
The interval of this horizon is between 2280 to 2308 m with negative SP values (sand line) and moderate value of GR to referred to the carbonate buildup (rudistbiostorm according to microfacies analysis). This is good reservoir unit where the porosity ranging between 17% to 30% with high secondary and effective porosities percentages addition to the BVW values suggest the types of vugy and intergranular porous.

Horizon IV
The Horizon IV depth is ranging between 2308 to 2328m and this horizon has the same petrophysical and microfacies for the lower part (the second part) of the horizon II, where shows high porous zone with sand fabric, so that may be a good reservoir unit.

Horizon V
This horizon depth is ranging between 2328 to 2358m, this horizon is subdivided into two sub horizons:-
  The first is characterized by decreasing the porosity from the 10% in the upper part to becoming 5% in the lower part. The second sub horizonis comprised of massive rocks (dolomitized limestone), with the porosity values is very low (An approximately zero).

Horizon VI
The interval depth of this horizon is ranging between 2358and 2400m, and divided into five parts, the first and third parts are good porous units with porosity values about (20%) (as primary porosity) and the value of BVW refer to intergranular to intercrystalline porous types. The fifth part is same the first and third parts except that it has a secondary porosity. While the second and fourth parts are separated among the first, third and fifth parts, characterized by low porosity values (less of 5%).

Horizon VII
Depth of the horizon F is ranging between 2400 and 2412m. The porosity values for this horizon is very low (less than 5%) with moderate values for GR and SP, which refer to the massive limestone.

Horizon VIII
The horizon H depth is ranging between 2412 and 2431m. The SP and Gr values refer to the sand fabric for this horizon, and the porosities values are high (about 25%) with good effective porosity. These petrophysical properties refer that the horizon is a good reservoir rock.
Horizon IX

This horizon is represented by the upper part of Sa'adi Formation. The SP value refers to the shale rocks (shale line), while the GR is not clear as indicator to shale composition, this may be due to the type of clay in that rocks.

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<th>Formation</th>
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Fig. 4 Stratigraphic section for the studied succession showing the petrophysical properties and reservoir characterization.
The second stage:- The permeability values are calculated by using the Coates and Dumanoir method (1973), this method is a complex method for calculating permeability. The results of applying this method showed identical behavior with the behavior of the effective porosity (Fig.5). Which confirms that it is an accurate method to calculate the permeability, as it supports the positive relationship between effective porosity and permeability.

According to Nelson (1994) and Akbar et al. (1995), the permeability-porosity relationship in the carbonate rocks showing the different types of carbonate fabric and porous (Fig.6), as follow:-
1. The horizon II shows two type of fabric, the first is moldic grainstone and the second mudstone to wackstone.
2. The horizon III shows vuggy dolomite wackstone to packstone with coccolith chalk pore.
3. The horizon IV shows fine grained coccolith chalk pore.
4. The horizon V shows massive limestone (mudstone to wackstone).
5. The horizon VI shows moldicpackstone to grainstone.
6. The horizon VII shows mudstone to wackstone.
7. The horizon VIII shows vuggy dolomitic wackstone to packstone.

Fig.5: Comparison between the effective porosity-depth and the permeability-depth.
Conclusions

1. The Hartha Formation in the Ahdab oilfield consists of five association facies which are: open shelf margin, fore slope, rudist biostorm, shoal and restricted platform (lagoon) association facies.

2. This formation deposited during two stratigraphic cycles:
   a. The first cycle was started with progress of the sea during the Upper Campanian to deposition of the lower part of the Hartha Formation. There are five steps for this transgression and rapid stillstand contributed the lower part of the Hartha Formation; The first step deposited the facies D (rudistbiostorm) and then deposited the facies C (foreslopefacies) at the second step. The facies B (Open shelf margin facies) was deposited during the other three steps. The changing facies

Fig. 6 Schematic poro–perm plots for carbonate rocks, based on Nelson (1994) and Akbar et al. (1995), showing the types of studied rocks.
from rudistbiostorm to fore slope and then open shelf margin refer to deepening upward with high fluctuation in sea level. The log data showed a change in rock properties of the upper part of the facies (B), suggesting the maximum flooding surface (mfs). Therefore, the upper part of the facies B and the facies F (restricted platform and lagoon facies) represent the highstand system tract (HST).

b. The second cycle happened during the sea level rise has been slowed (transgression) leading to deposition the facies E (platform margin sands facies - shoal) which refers to the deposition in high energy environment. And then deposition of the facies D (rudist biostormfacies to refer to deepening upward, the upper part of this facies marked the maximum flooding stage. The next stage was the high stillstand which deposited the facies E (shoal) and then restricted platform and lagoon facies. At the end of this cycle the regional sea regression was happened to marked the contact (sequence boundary- SB1) between the Hartha Formation and the Shiranish Formation.

3. There are eight petrophysical horizons observed in the studied succession named (I, II, III, IV, V, VI, VII, VIII and IX), four of which are good reservoir horizons are: (III, IV, VI, and VIII).

4. The dolomitized horizons as (II, V and VII) are matching with the stillstand or sea level regression, where during these stages the diagenesis processes (dolomitization and cementation) are active.

5. The permeability results of applying the Coates and Dumanoir (1973) method showed identical behavior with the effective porosity. Additional to thepermeability-porosity relationship in the carbonate rocks showing a good match with the general facies and petrophysical properties for the studied succession.

References


