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## Microfacies Analysis and Basin Development of Hartha Formation in East Baghdad Oil field, Central Iraq

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### Abstract

The Hartha Formation is one of the important formations deposited during Late Campanian age.

The present study deals with four boreholes (EB-53, 54, 55 and 56) within the East Baghdad oil field to diagnoses the microfacies and interpret the depositional environments.

Six major microfacies were recognized in the succession of the Hartha Formation. Their characteristic grain types and depositional texture enabled the recognition of paleoenvironment. There are Orbitoides wackestone-packstone, Orbitoides - miliolid wackestone, Peloidal and Pellets - echinoderm wackestone to packstone, Peloidal wackestone to packstone, Pelletal wackestone to packstone, and Planktonic foraminifera wackestone-packstone.

Four associations' facies were recognized in this succession, which are shallow open marine, deep open marine, semi-restricted, and restricted. The distribution of these associations led to the recognition of three major depositional stages in the studied succession.

The first stage is represented by the semi-restricted facies within the lower part of the Hartha Formation, which is characterized by Orbitoides - miliolid wackestone to the northwest direction and developed to shallow open marine and deep marine to the southeast direction. In the second stage, the sea level was rising to deposit the deep open marine facies represented by planktonic foraminifera wackestone-packstone microfacies above the semi-restricted facies, where the succession became characterized by Peloidal and Pellets - echinoderm wackestone to packstone microfacies of restricted association. The third stage is represented by the continuation of sea level rise. This caused the building of carbonate ramp of Shiranish Formation above the shallow open marine of Hartha Formation with conformable surface.

**Keywords:** Microfacies analysis, Basin development, Hartha Formation, East Baghdad, Central Iraq

**السحنات الدقيقة و تطور حوض تكوين الهارثة في حقل شرقي بغداد النفطي، وسط العراق**

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الخلاصة

يعتبر تكوين هارثة واحد من التكوينات المهمة التي ترسبت خلال العصر الكامباني المتأخر. تتناول الدراسة

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الحالية أربعة آبار (EB-53 و 54 و 55 و 56) ضمن حقل نفط شرقي بغداد لتشخيص السحنات الدقيقة وتفسير بيانات الترسيب.

تم التعرف على ستة سحنات دقيقة رئيسية في تتابع تكوين هارثة ؛ مكنت أنواع الحبيبات المميزة والنسيج الترسيبي من التعرف على البيئة القديمة لها. هذه السحنات هي:-

Orbitoides wackestone-packstone , Orbitoides – miliolid wackestone, Peloidal and Pellets – echinoderm wackestone to packstone, Peloidal wackestone to packstone, Pelletal wackestone to packstone and Planktonic foraminifera wackestone-packstone.

تم التعرف على أربع ترافقات سحنية في هذا التتابع ؛ البحرية الضحلة المفتوحة ، البحرية المفتوحة العميقة ، شبه مقيدة والمقيدة. أدى توزيع هذه الترافقات إلى تمييز ثلاث مراحل ترسيب رئيسية في التتابع المدروس :-

تمثل المرحلة الأولى في شبه المقيد في الجزء السفلي من تكوين الهارثة ، والذي يتميز بحجر جيرى واكي يحوي على Orbitoides و miliolid في الاتجاه الشمالي الغربي والذي تطور الى بيئة ضحلة البحرية مفتوحة والبحرية العميقة في الاتجاه الجنوبي الشرقي. في المرحلة الثانية ، كان مستوى سطح البحر يرتفع ليرسب الترافقات السحنية للبيئة البحرية العميقة المفتوحة التي تمثلها الفورامينيفرا المجهرية العالقة في صخور الحجر الجيري الواكي والمرصوص فوق ترافقات بيئة شبه المقيد حيث أصبح التتابع تتميز بالدمالق و شوكلات الجلد في صخور الحجر الجيري الواكي والمرصوص لمترافقة البيئة الترسيب المقيدة. في حين تمثل المرحلة الثالثة استمرار ارتفاع مستوى سطح البحر ، حيث ادى ذلك إلى بناء منحدر كربونات من تكوين الشيرانش فوق التتابعات البحرية المفتوحة الضحلة لتكوين الهارثة وبسطح متوافق.

## Introduction

The Hartha Formation is one of the important formations deposited during the Late Campanian age. It is the most heterogeneous from one place to another because of the complexities of sedimentary basin and the movements that influenced it [1].

The Hartha Formation was identified first in Zubair Field by Rabanit (1952, cited in [2]). The formation is composed of 200-250 m (656-820 ft) thick bioclastic -detrital glauconitic limestone with green or gray shaley interbeds. In certain places, the limestone is strongly dolomitized [2]. The formation was deposited for the greater part in a marginal-marine, fore-reef, neritic, and 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, while the upper boundary in the south of Iraq is conformable with the Shiranish Formation [3].

The aim of this study is to conduct a microfacies analysis to interpret the depositional environments and basin development.

The studied area is located in East Baghdad oil field which lies in the middle of Iraq, about 20 Km to the east from the center of Baghdad. The entire southern area of East-Baghdad project (Figure-1) has an area of 1201 Km<sup>2</sup> and contains three parts (S1, S2 and S3) [4].

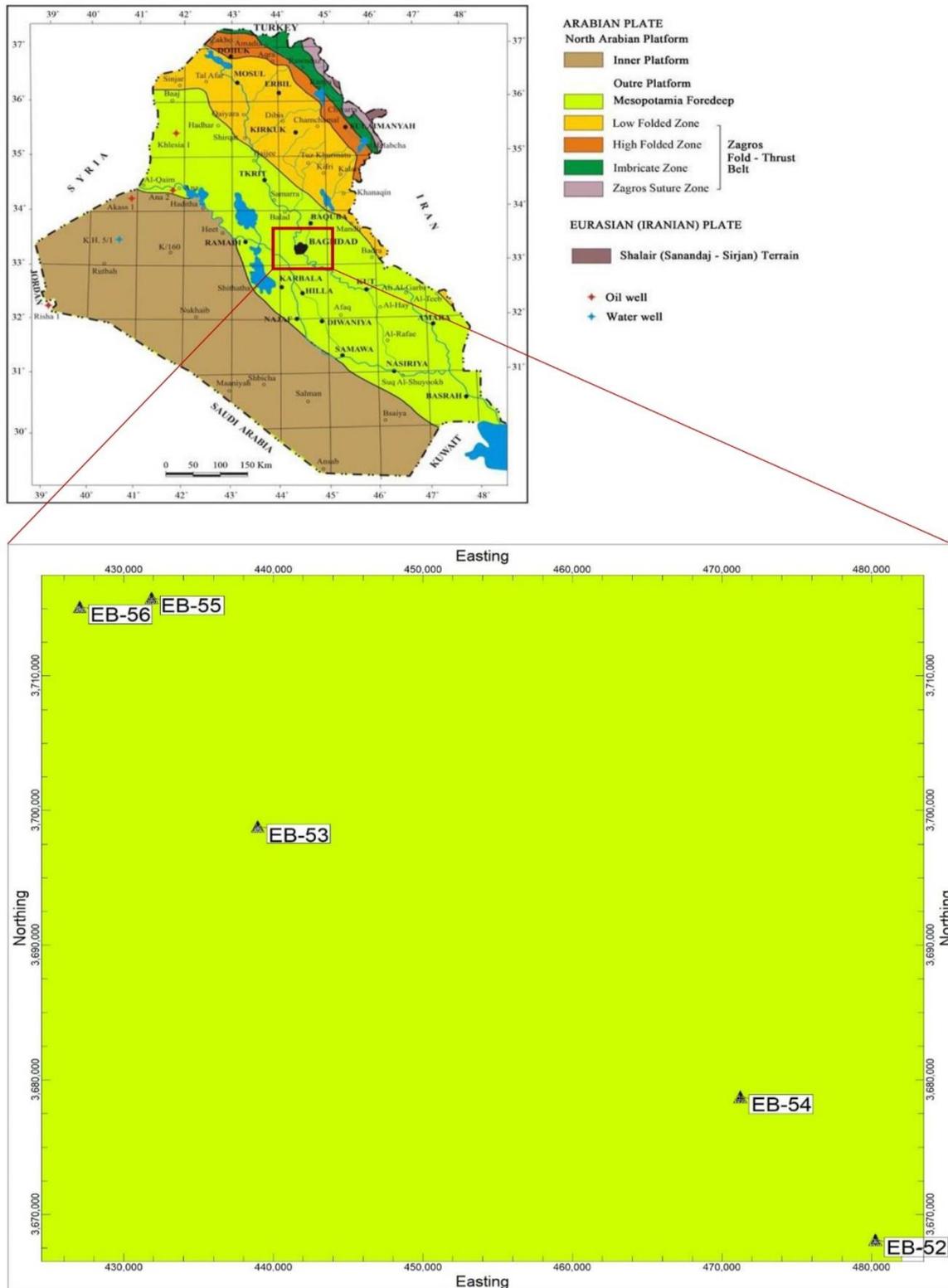


Figure 1-Location and tectonic map of the study area [5].

**Stratigraphic setting**

The Upper Campanian-Maastrichtian cycle includes enormous formations in the geological evolution of Iraq. The cycle begins with a widespread transgression and is almost covering the whole country, being occurred after the termination of sea rising [3].

The sediment of the Upper Campanian- Maastrichtian cycle was relatively thoroughly studied, due to their importance for oil industry in both northern and southern parts as well as in the neighboring

countries [6] (Figure-2).

Formations of the cycle are approximately contemporaneous, being replaced by each other. Local changes in age within the Upper Campanian- Maastrichtian time span occur mainly where intertonguing of the facies bound formations exists [7].

Many attempts have been made to classify rock units belonging to this period depending on its lithofacies and biofacies as well as its depositional location in paleogeography. The most important among these attempts was Buday's division (1980), which mixed these units according to resemblance facies and paleogeographic location and divided them into groups depending on their depositional environment, as in the following:

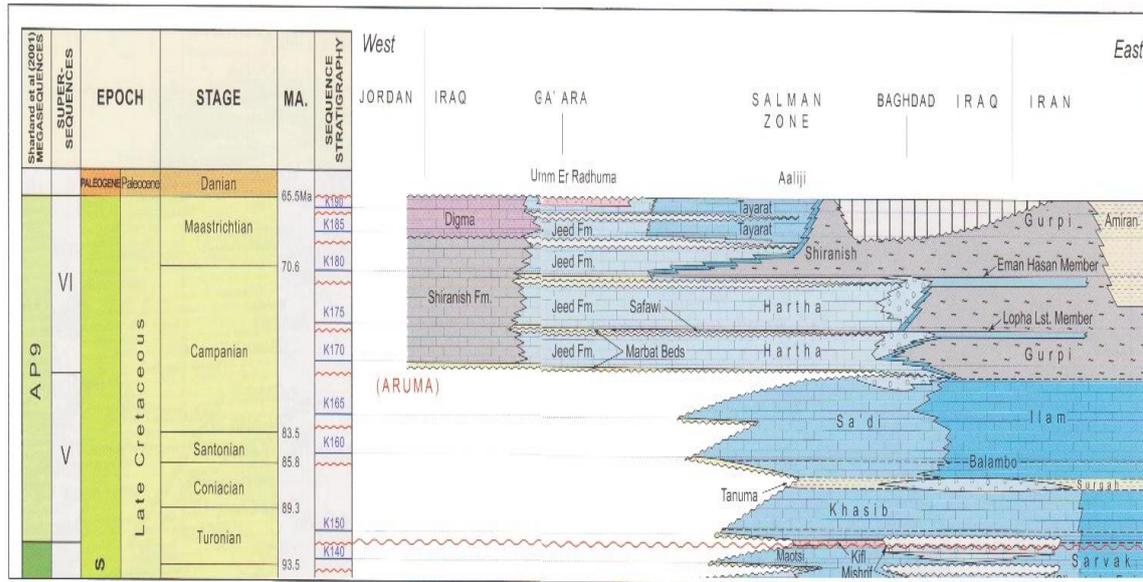


Figure 2-Early Cretaceous chronostratigraphic cross section [6].

- 1- Hartha Facies: representing fore-reef deposits which are subdivided into:
  - a- Hartha Formation.
  - b- Tayarat Formation.
  - c- Mushak- Dibs member.
- 2-Aqra - Bekhme Facies: representing reefal deposits.
- 3-Shiranish Facies: representing off-shore deposits which are subdivided into:
  - a- Shiranish Formation.
  - b- Jebab Formation.
- 4-Digma Facies: representing series of marl limestone interbedded with phosphate beds.
- 5-Tanjero Facies: representing miogeosyncline deposits.
- 6-Hadiena facies: representing geosynclinal ridge deposits.

Those divisions did not mention Qurna Formation and used Mushak-Dibs member instead of Pilsner Formation.

The Hartha Formation was defined by Rabanit in 1952 from well Zubair-3 in the Mesopotamian Zone of the south of Iraq [8]. It comprises organic detrital and glauconitic limestones with beds of grey and green shale. Limestone are locally strongly dolomitized. Beds of chalky limestone occur frequently. Oolitic beds were found in some wells. Nodules, lenses and beds of anhydrite often occur in the formation along the southwestern side of the Mesopotamian Zone. Argillaceous limestone occurs more frequently in the east parts of the Mesopotamian Zone where the formation passes into the Shiranish Formation. In northern Iraq, the Hartha Formation now includes parts of the Pilsner Formation. According to Bellen *et al.*, (1959)[2], the Pilsner facies comprise organic detrital limestone, with beds of argillaceous limestones containing fossil debris, and medium-grained dolomite.

Anhydrite and oolitic limestone beds and lenses are recorded in the Hartha Formation between Ramadi and Makhual. In northwestern Iraq, oolitic limestones occur [9]. These facies were deposited in lagoons in the interior of the Hartha carbonate platform to the west side of the Mesopotamian Zone.

In the Rutba area, west of Iraq, the Hartha Formation consists of beds of marl and dolomite with "Birds eye" texture, indicating a supratidal-subtidal depositional environment. South of Rutba, the upper 35m of the original type section of M'sad Formation was reassigned to the Hartha Formation. The formation thins to the north of Rutba and is totally truncated below an unconformity at the base of the Tayarat Formation on the northwestern rim of the Ga'ara depression. The formation consists predominantly of carbonates in the west near Rutba and marl in the east [7].

The lower contact of the formation is usually an unconformable, often marked by a basal conglomerate with Khasib Formation. The upper boundary in the south of Iraq is conformable and the formation is often overlain by pelagic sediments of the Shiranish Formation [3].

The Hartha Formation is thickest within the Salman Zone, south of Ramadi (400m), whereas near Mousl, the thickness is 100-200m [7].

The Hartha Formation was deposited in a fore reef to shoal environment. Locally, lagoonal back reef facies occur around the margins of the Stable Shelf. Reef facies may be presented around the Khlesia High, as indicated by the reef limestone debris in the detrital limestone beds in some wells in the formation [7].

### Methodology

#### - Field Work

1- Five oil wells were selected for the study area that contains the largest amount of thin sections. They were then described according to properties such as identify texture, grains size, and type of pores between the grains, in addition to the determination of depositional environments.

2- Sampling was performed by taking rock samples from the cutting and core from Hartha Formation (Figures- 1 and 2). Sampling and thin section preparation were conducted per meter.

#### - Laboratory Work

The petrographic study was based on investigating more than 150 thin sections from cores and/ or cutting of the studied wells. Microfacies analysis of the Hartha Formation was based on the classification of Dunham (1962) [10], by using a transmitted light microscope.

### Microfacies Analysis

Data from the detailed study of more than 200 thin sections, in addition to cores and cuttings, from 4 boreholes (EB-53, 54, 55, and 56) in Hartha Formation within the study area were used to interpret the different subenvironments of the studied succession. The facies architectures were also studied to describe the sedimentary framework of the basin. Depositional environment can be defined in terms of physical, biological, chemical, or geomorphic variables [11].

Six major microfacies, described below, were recognized in the succession of the Hartha Formation; their characteristic grain types and depositional texture enabled the recognition of paleoenvironment.

#### - Microfacies (A): Orbitoides wackestone-packstone

This microfacies includes Orbitoides - bearing limestone with few shell fragments of echinoderm and calcareous algae. *Orbitoides tossoti* is an index species of shallow warm water within middle shelf [12]. Hence, this microfacies could be represented by shallow open marine waters within middle shelf environment (Plate 1-1).

#### - Microfacies (B): Orbitoides miliolid-wackestone

This facies is mainly composed of Orbitoides and miliolid in addition to shell fragments (mollusk), echinoderms, pellets, and calcareous algae. The microfacies reflects a semi restricted marine environment (Plate 1-2).

#### -Microfacies (C): This part included Rotaliidae and Siderolites with echinoderm wackestone-packstone

The main constituents are Rotaliidae and Siderolites with shell fragments of mollusks and echinoderms, in addition to few Nezzazata and red algae. This microfacies reflects a shallow open marine environment (Plate 1-3)

#### - Microfacies (D):- Peloidal and Pellets - echinoderm wackestone to packstone

This microfacies consists mainly of peloids with rudist fragments, calcareous algae, and milliolid being the least abundant. It can be divided into:-=

- Peloidal wackestone to packstone with rounded grains, which are inferred from their bifurcated size and ovoid shape, with the dominance of relatively coarse to fine (sand sized) and moderately sorted

peloids .

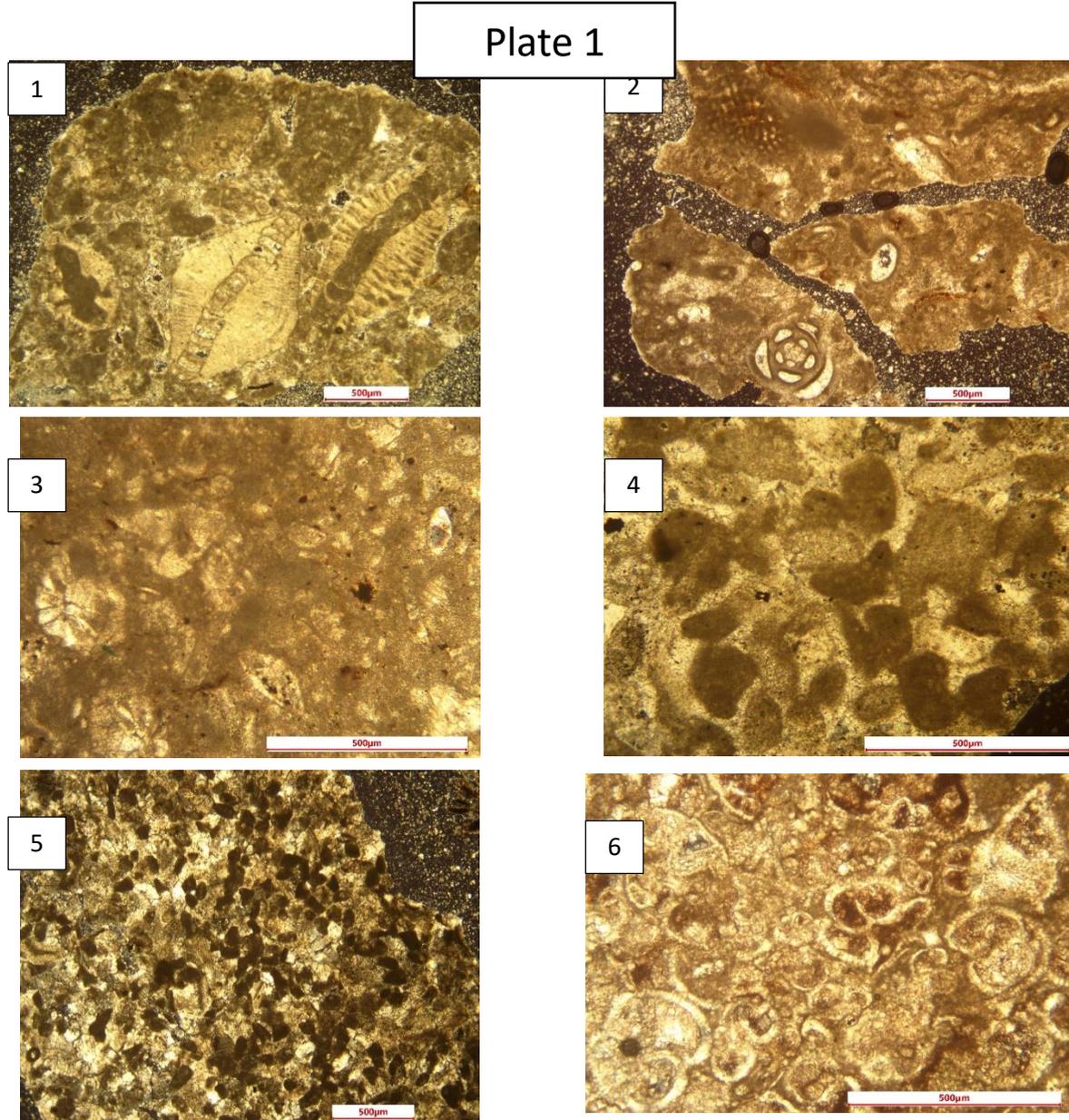
- Pelletal wackestone to packstone is characterized by the abundance of a uniformly small size of the particles and by their consistent shapes (silt sized well sorted pellets).

Microfacies (D) =represents deposition in a restricted environment, which developed during the deposition of the Hartha Formation. The environment became more restricted (lagoonal) and is represented mainly by gypsum and anhydrite (Plate 1-5).

- **Microfacies (E):** Planktonic foraminifera wackestone-packstone.

This microfacies is composed of planktonic foraminifera (*Globogerinelloids* sp. and *Golobotruncana*) and other small benthic foraminifera. This microfacies represents an environment ranging from an open shelf to a deep open marine (Plate 1-6).

The Figures- 3, 4, 5 and 6 are showing the microfacies distribution in studied wells.



1. Orbitoides wackestone-packstone; EB-55(1872)
2. Orbitoides - miliolid wackestone; EB-56(1648)
3. Rotaliidae and Siderolites with echinoderm wackestone-packstone; EB-56(1746)
4. Peloidal - echinoderm wackestone to packstone; EB-56(1642)
5. Pellets – bioclasts packstone; EB-56(1626)
6. Planktonic foraminifera wackestone-packstone; EB-56(1708)

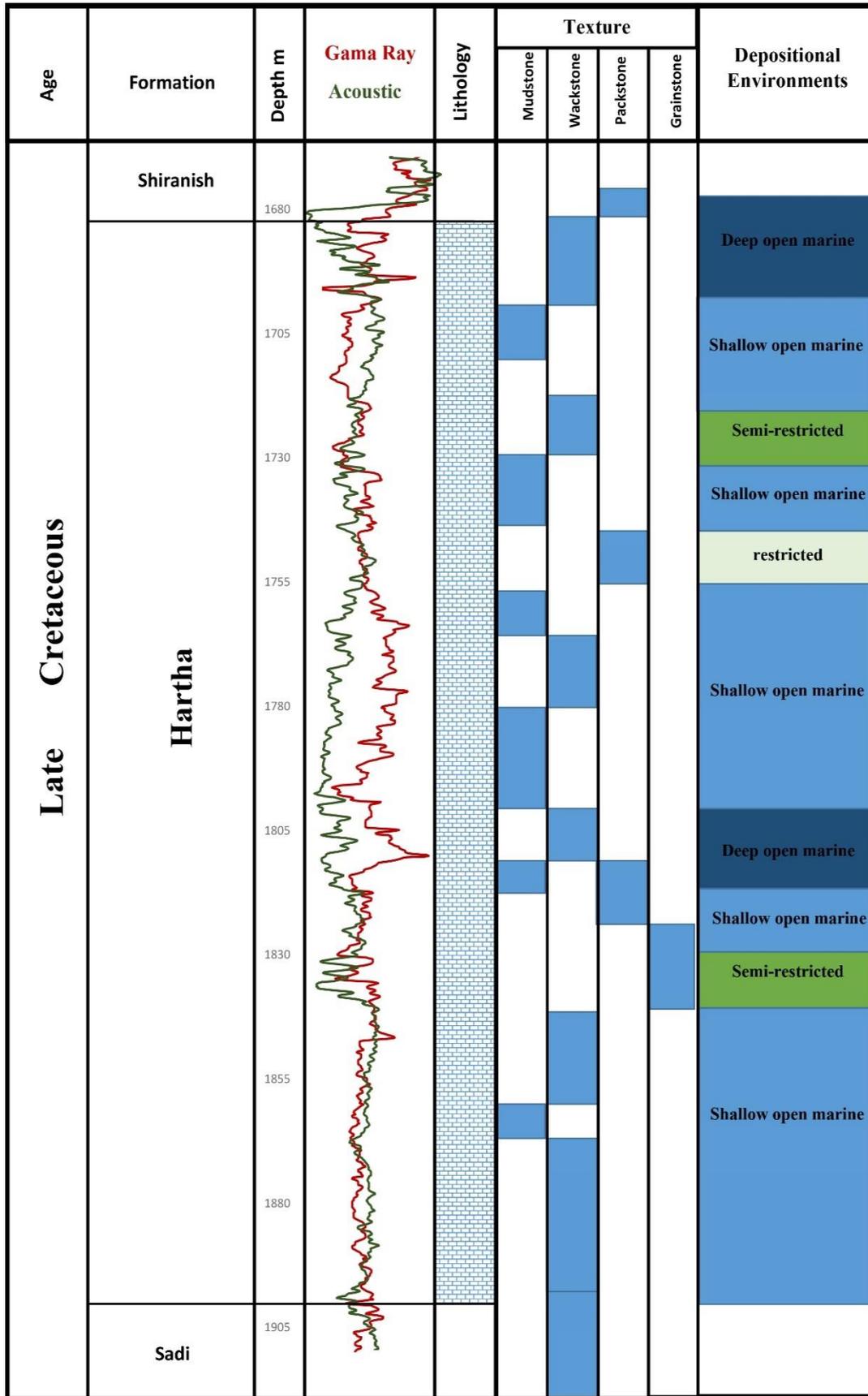


Figure 3-Shows variation of depositional environment of the Hartha Formation, along with age and texture characteristics for EB-53.

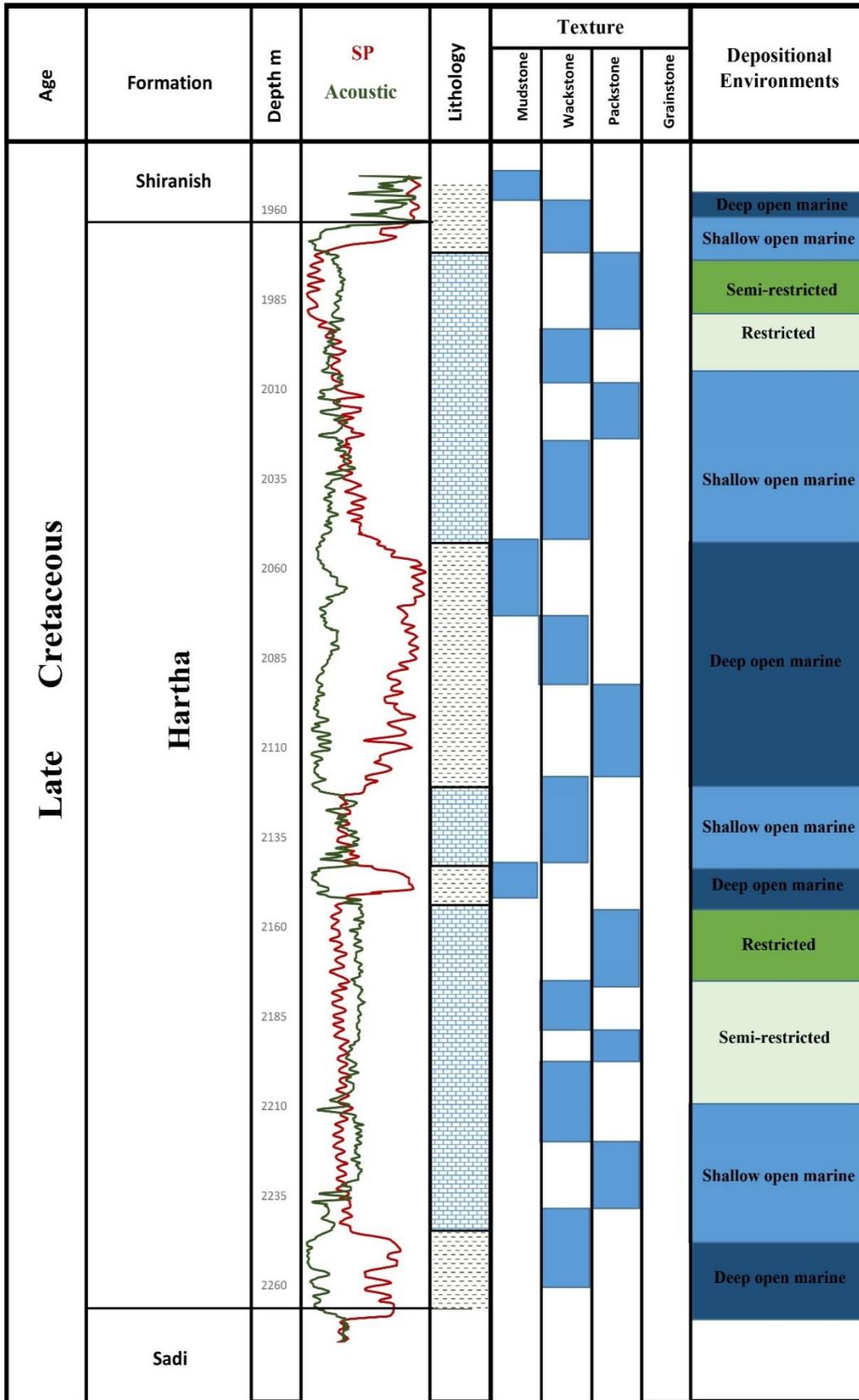


Figure 4-Variation of depositional environment of the Hartha Formation, age and texture characteristics for EB-54.

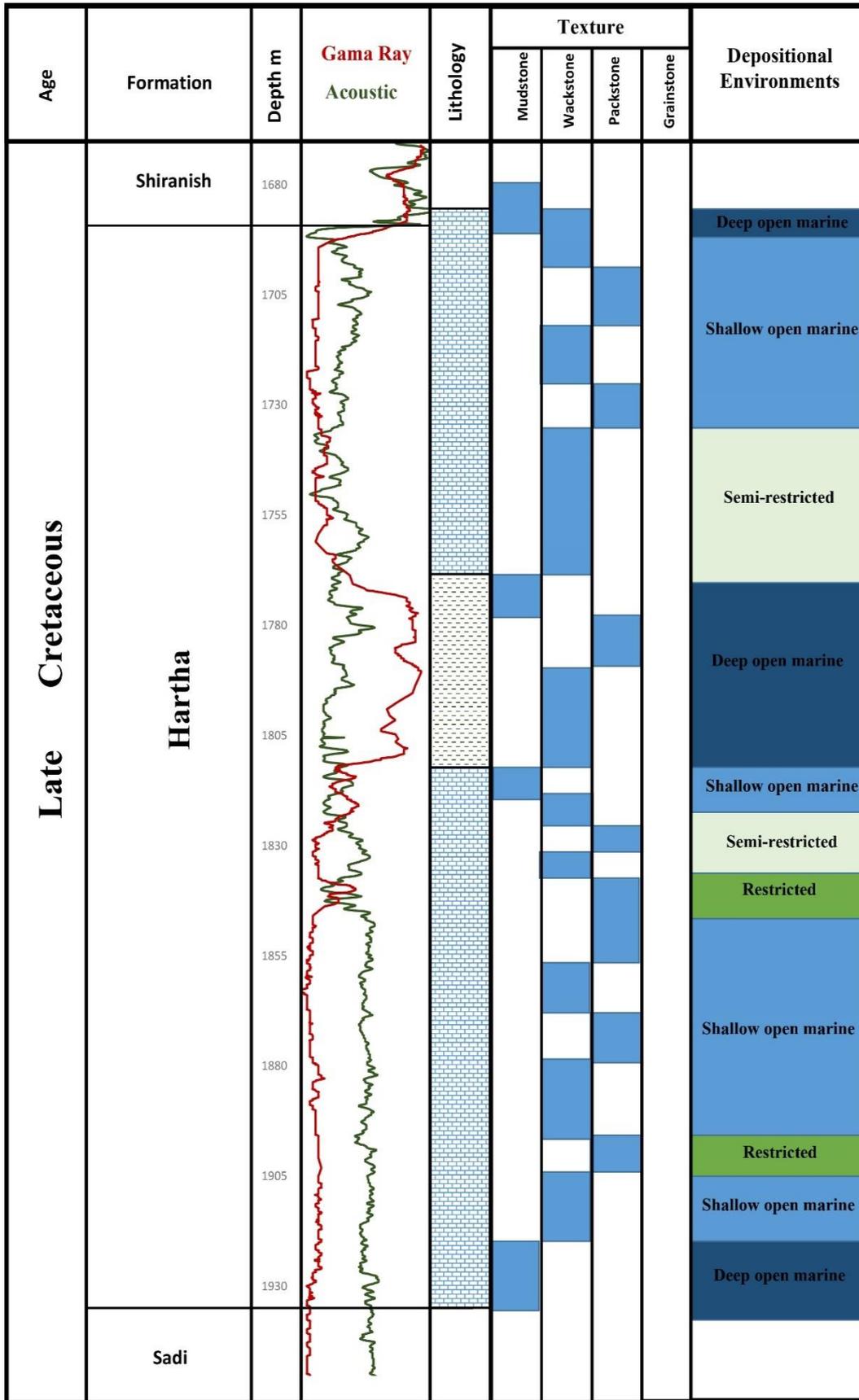


Figure 5-Variation of depositional environment of the Hartha Formation, along with age and texture characteristics for EB-55.

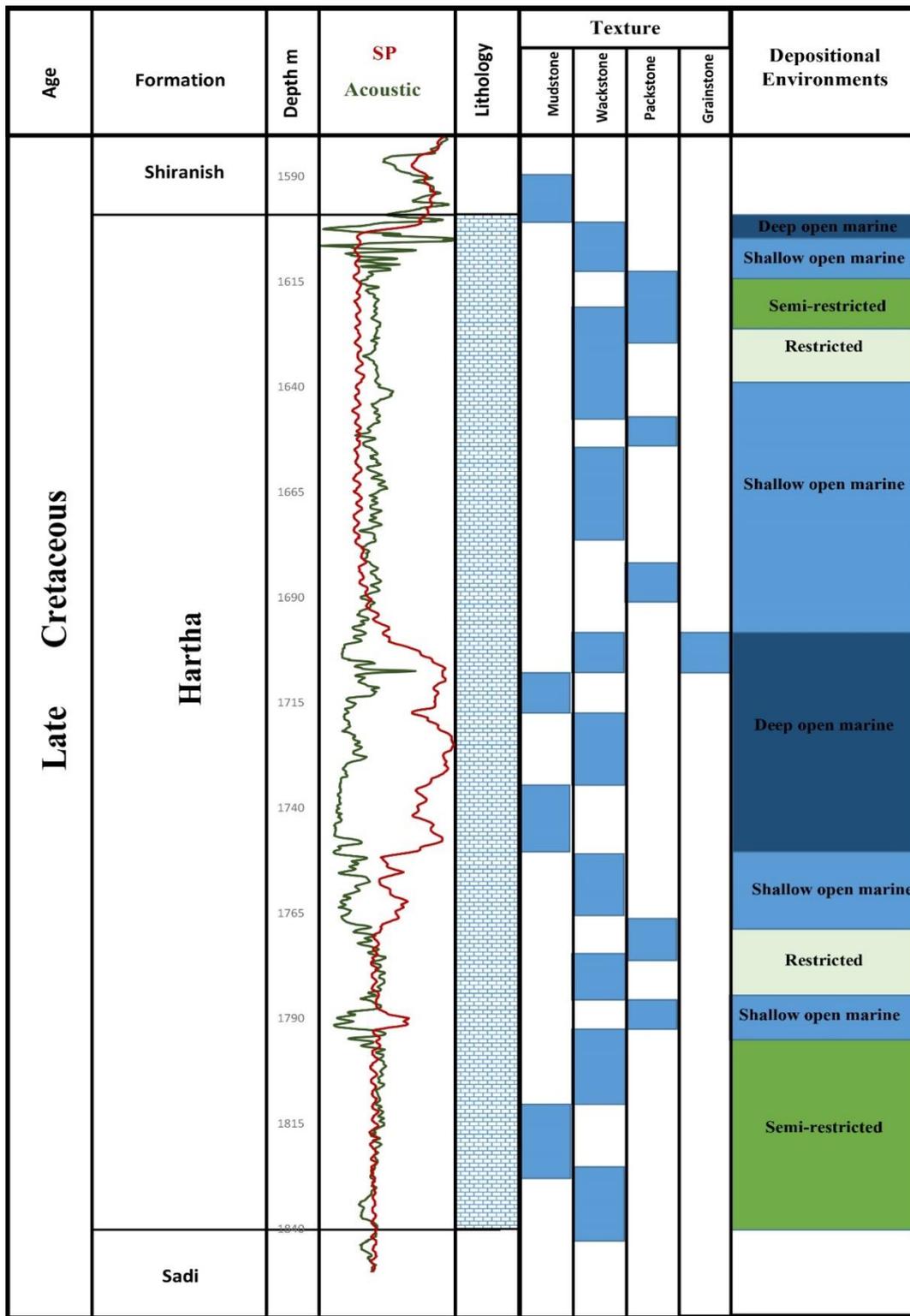


Figure 6-Shows variation of depositional environment of the Hartha Formation, along with age and texture characteristics for EB-56.

**Depositional model**

The studied succession was deposited during the Late Campanian age. The cycle begins with a widespread transgression and almost covering the whole country which occurred after the termination of sea rising [3]. This cycle started with the regional unconformity above the Sadi Formation, and continued during the following three major depositional stages observed in the studied succession:

### The first stage

This stage is represented by the semi-restricted facies within the lower part of the Hartha Formation, which is characterized by *Orbitoides* - miliolids wackestone to the northwest direction and developed to shallow open marine and deep marine facies to the south east direction (Figure-7). During this stage, the lower part of Hartha Formation is overlying the unconformity surface with Sadi Formation. This facies association is underlying the deep marine association in the northwest and restricted associations in the southeast.

### The second stage

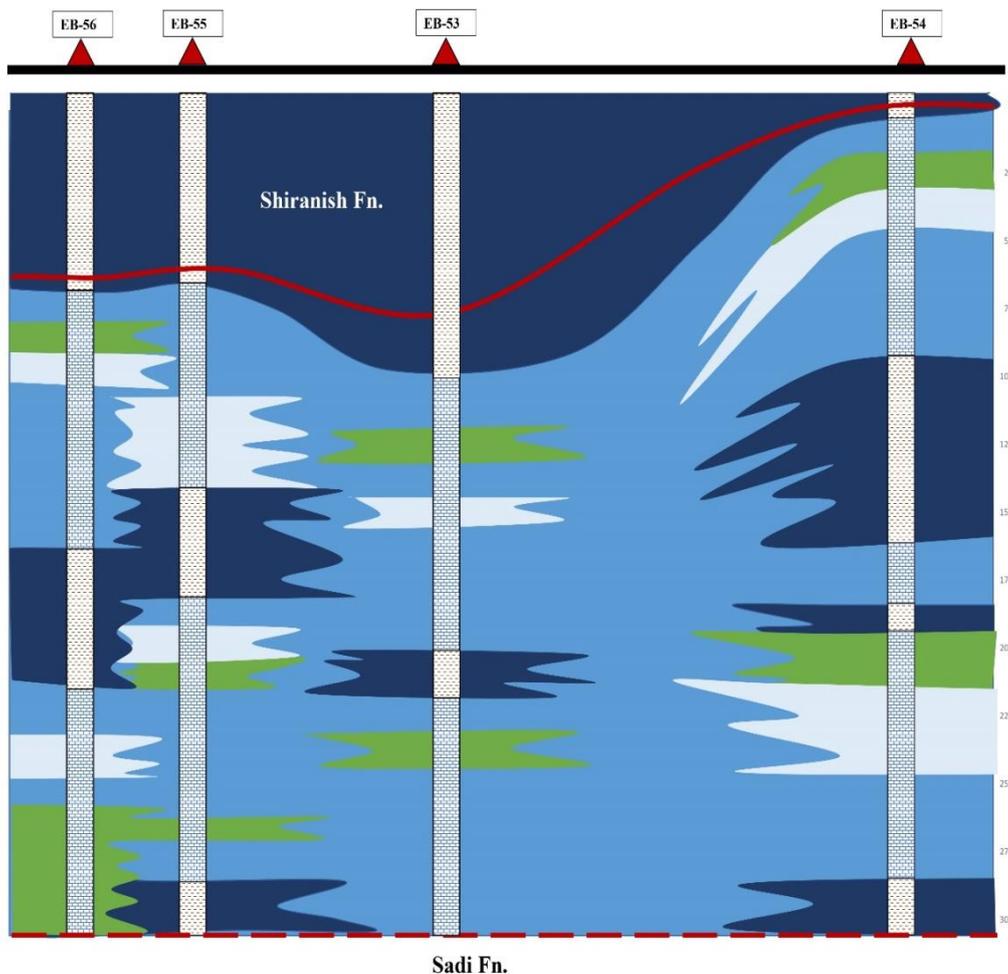
During this stage, the sea level was rising to deposit the deep open marine microfacies which is represented by planktonic foraminifera wackestone-packstone microfacies above the semi-restricted microfacies. The succession became characterized by peloidal and pellets - echinoderm wackestone to packstone microfacies - of restricted association. While to the southeast, the succession is characterized by deepening upward by appearing the rothliidae and siderolites with echinoderm wackestone-packstone microfacies underlying the planktonic foraminifera wackestone-packstone.

### The third stage

This stage is represented by the continuation of sea level rise that led to the building of carbonate ramp of Shiranish Formation above the shallow open marine of Hartha Formation with conformable surface.

The Hartha depositional stage is represented by shallow open marine with semi-restricted microfacies which appeared in all studied bore holes (Figure-7). The semi restricted facies is recorded in other locations and associated with peloidal and miliolid microfacies.

At the end of the third stage, the sea level was arising to mark the end of the deposition of the studied succession with regional transgression with Shiranish Formation.



**Figure 7**-Cross section showing facies association distribution for Hartha Formation in studied the wells (Eb53, Eb54, Eb55 and Eb56) within East Baghdad oil field

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