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3D Facies Modeling of Mishrif Reservoir in Halfaya Oil Field

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Abstract

This research deals with the study of the types and distribution of petrographic microfacies and Paleoenvironments of Mishrif Formation in Halfaya oil field, to define specific sedimentary environments. These environments were identified by microscopic examination of 35 thin sections of cutting samples for well HF-9H as well as 150 thin sections of core and cutting samples for well HF-I. Depending on log interpretation of wells HF-1, HF-316, HF-109, IIF-115, and IIF-272, the sedimentary facies were traced vertically through the use of various logs by Petrel 2013 software in addition to previous studies. Microfacies analysis showed the occurrence of six main Paleoenvironments within Mishrif succession, represented by basin, slope, shoal, Rudist biostrome, back shoal, and lagoon. Mishrif Formation was divided into six reservoir units depending on well logs and CPI. These units are separated by low porosity and high-water saturation of barrier beds. The reservoir beds from top to bottom are MA, MB1, MB2, MCI, and MC2. The reservoir units MB1, MB2, and MCI are the most important in the field of interest due to good reservoir properties and being the principle oil-bearing units in Mishrif Formation.

Keywords: 3D Modeling, Mishrif Formation, Reservoir, Halfaya Oil Field.

موديل سحني ثلاثي الابعاد لمكمن المشرف في حقل الحلفاية النفطي

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قسم علوم الارض ، كلية العلوم ، جامعة بغداد ، بغداد ، العراق

الخلاصة

تضمن البحث دراسة التوزيع السحني والبيئات الترسيبية لتكوين المشرف في حقل الحلفاية النفطي في جنوب العراق وذلك بالاعتماد على فحص اكثر من (150) شريحة لنماذج الفتات الصخري لبئر حلفاية-1 و (38) شريحة لبئر حلفاية-9 الاقفي وكذلك بالاعتماد على تفسير سلوك المجسات في ابار (حلفاية-1 ، حلفاية-316 ، حلفاية-109 ، حلفاية-115 ، حلفاية-272) حيث تم تتبعها عموديا من خلال استخدام بريامج (petrel 2013) بالاضافة الى الدراسات السابقة. اظهر تحليل السحنات الدقيقة وجود ستة بيئات ترسيبية لتتابع المشرف تمثلت ب:- البيئة الحوضية، المنحدر، بيئة الرودست، الحاجز المتضحل، بيئة خلف الضحاحية وبيئة اللاغون. وقد تم تقسيم التكوين الى ست وحدات رئيسية (MA, MB1, MB2, MC1 & MC2) وقد وجد ان الودنين MB1 و MB2 هما اكثر اهمية كونهما اكثر سماكة وتتميزان بمواصفات بتروفيزياوية جيدة بالاضافة الى الاختلاف السحني حيث انها تمثل الوحدات الحاملة للهيدروكربونات في تكوين المشرف.

Introduction

Halfaya field is one of the important oilfields in Iraq, located about 35 km southeast Amara city. Mishrif Formation is the major reservoir in Halfaya field and one of the principle carbonate reservoirs in central and southern Iraq. Mishrif Formation was deposited during the Cretaceous period within the sedimentary subcycle (Cenomanian-early Turonian) as a part of the Wasia Group and widespread throughout the Arabian Peninsula [1]. The Mishrif Formation in Iraq represented the continuous deposition of shallow marine environments. The lower boundary of Mishrif Formation is appeared with change from basinal Rumaila Formation to shallow open marine environments with a conformable surface. While the upper boundary with the Khassib Formation is truncated by an unconformity surface separating the Middle from Upper Cretaceous. The thickness of the formation is about 400m [2]. The objective of this research is to build the environmental model and then examine the favorable facies distribution to guide the new geological well design. The important reservoir layers of Mishrif Formation consist of bioclastic and peloidal facies of shoal and shelf margin environments [3]. Bioclasts are derived mostly from rudist banks along the shelf margin to the east southern Mesopotamian Basin and at the crest of some giant structures, including Rumaila, Zubair and West Qurna oilfields [2]. These rudist reefs were eroded continuously during the deposition whilst the basin was shallowing-upward [4]. This extension of rudist into barrier facies may lead to the existence of large up-dip direction of hydrocarbon accumulations in the Mishrif Formation in areas beyond the known anticlines, *i.e.* it acts as a stratigraphic trap [2].

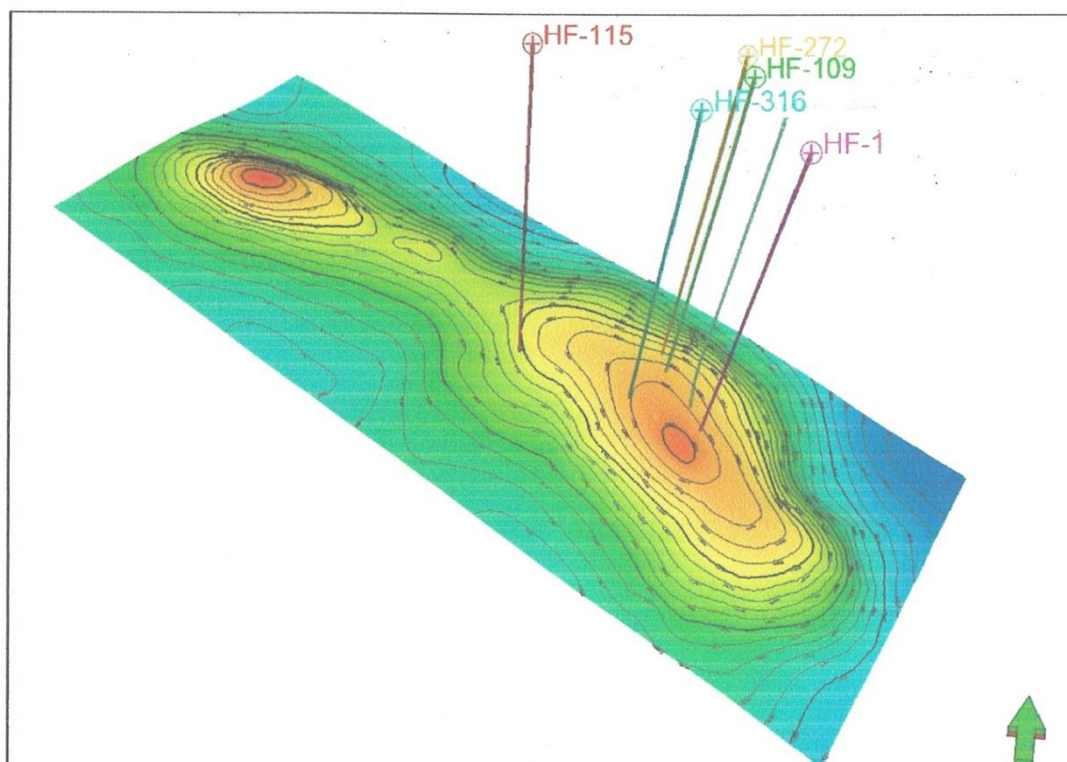


Figure1-Top of Mishrif Formation map showing the location of the studied wells.

Mishrif Facies Associations

The study of sedimentary facies is a largely important part of geological studies. In such research, it is important to start by investigating the sedimentary background of the studied region as well as using information based on previous studies to obtain real results. In the present study, the petrography and microfacies analysis of Mishrif Formation was performed depending on more than 150 thin sections of cut samples from HF-1. These thin sections were supplied by the Oil Exploration Company, while 38 thin sections were supplied by Missan Oil Company (M.O.C). Previous studies of facies were traced vertically with various logs using Petrel 2013 software. This study indicates the occurrence of six major depositional environments, which are: (1) basin environment, (2) slope, (3) shoal, (4) Rudist

biostrome, (5) back shoal, and (6) lagoon. These environments are diagnosed according to previously suggested standard microfacies models and depositional environment belts of carbonates [1].

Facies association of basin environment

The basinal environment is simply the end of the marine environmental spectrum that began at the maximum flooding surface and ended at the deepest part of that sedimentary basin. There is no unique depth that defines the basinal environment [5]. Based on a previous work [6], this association is composed mainly of micrite-bearing facies. This association consists of the wackestone dominated "shallower sub-basinal" and mudstone-dominated "sub-basinal" facies [6]. The microfacies analysis for well HF-1 shows that the environment is restricted within the lower part of Mishrif Formation at a depth of 3184 m, according to thin section (Fig. 8-C), where the fossils *Hedbergella* and *Oligostegina* were found. In addition, logs interpretation for the studied wells (Figures- 1, 2, and 3) shows a high value of gamma ray and low porosity values.

Facies association of slope environment

The slope association, which is represented by coarsening upward from basinal limestone to shallow marine packstone microfacies, reflects shallow depositional environments in response to progradation of a carbonate slope environment [4]. This association represents one of the most common facies associations in the study area of Mishrif formation. It is mainly composed of bioclastic or Foraminifera bioclastic wackstones and packstones microfacies. Other important fossil compositions in this facies association include benthonic Foraminifera (Fig.8-F), calcareous algae, corals (Fig.8-E), Echinoderms (Fig.8-B), sponge spicules, and Molluscs (Fig.9-F). From microfacies analysis of HF-1, it is clear that this facies is very common within the lower part of Mishrif Formation (Figures- 2, 3, and 4). Low gamma ray, high total porosity, and the types of pore systems appear to be the interconnected characteristics of the facies and, hence, good reservoir quality is envisaged.

Facies association of the shoal environment

The shoal association is composed of poorly sorted bioclastic packstone, grainstone, and rudstone microfacies. This unit is gradationally overlying and locally intercalated with the slope association. Bioclasts are predominantly composed of mollusks, mostly rudistid. Small rolled radiolitid rudists are abundant. Beddings that occur with few other sedimentary structures are present, although cross diagnosis occurs locally [4]. The mouldic pore spaces are surrounded by micrite or calcite cement, but still appear to have well-interconnected porosity. Reservoir characterization is represented by a moderate quality. According to the Logs interpretation, this environment is located within the reservoir units in the upper part of Mishrif Formation. Low GR, moderate DT, low density, and high total porosity are the main characteristics. This facies association consists of coarse to medium-grained rudist in a rudistid grainstone microfacies (Figure- 10-D).

Facies association of rudist biostrome environment

This facies association represents the most important reservoir unit in Mishrif Formation. It is made up of very coarse-grained, shelly, bioclastic rudstone and floatstone containing a more verified intact fauna as compared to the lithofacies association which has a shoal environment, dominated by radiolitid and caprinid rudists (Fig.9-B). Based on an earlier work [7], three sub-facies are recognized (rudist packstones, rudist grainstones and rudist rudstones), distinguished by the relative content of micrite and the coarseness of the rudist-derived material [2], as shown in Fig. 8-B. According to the log analysis, this facies is the main reservoir in Mishrif Formation, with very good petrophysical properties, high total porosity, and high hydrocarbon saturation, as observed in HF-1, especially at the intervals 2888m and 2968m.

Facies association of back shoal environment

Thin to medium-bedded and fine to very coarse-grained bioclastic packstone, wackestone, and grainstone characterize this association. These deposits represent a zone of sediment mixing between shoal and interior lagoon [4]. Back shoal facies association is characterized by low GR (20 API), medium density (2.45gm/cc), medium DT (70 μ s/ft), and medium porosity (13-15%), as illustrated in Figures-(2, 3, and 4). It consists of packstone microfacies containing benthic Foraminifera, mainly *Miliolid* sp (Figure-(9-C)). This lithofacies probably has a moderate reservoir quality.

Facies association of lagoon environment

The lagoon environment dominates into the upper part of Mishrif succession, below the upper unconformity surface that separates the Mishrif and overlying Khasib Formation, in addition to its dominance into the middle part of the Mishrif succession of Halfaya field that is deposited in a

restricted platform [6]. These units are characterized by high GR, medium resistivity, and low porosity. This facies association comprises benthonic foraminiferal wackestone microfacies and peloidal wackestone microfacies (Figure-10F).

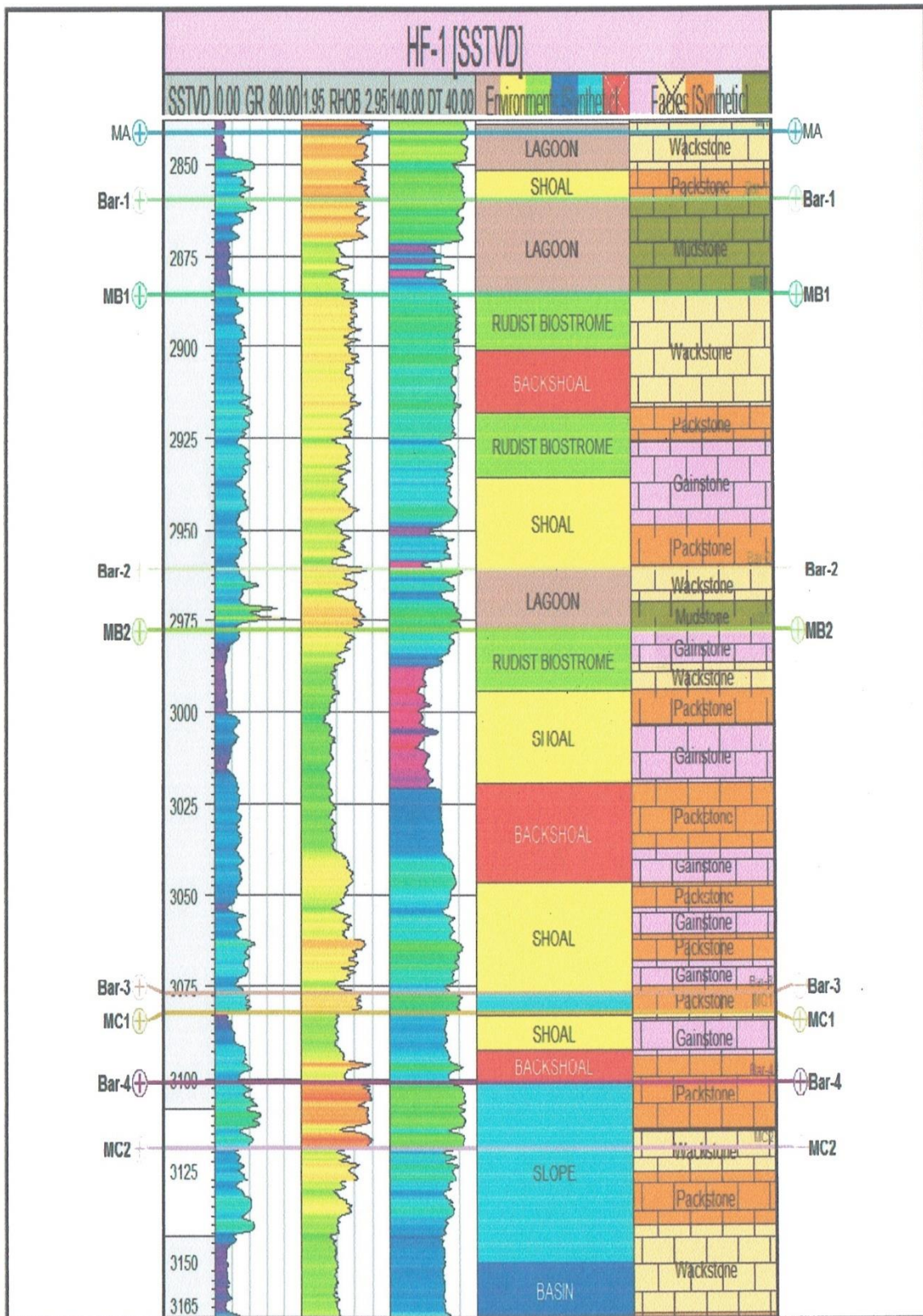


Figure2-Depositional environments of Mishrif Formation in well HF-1.

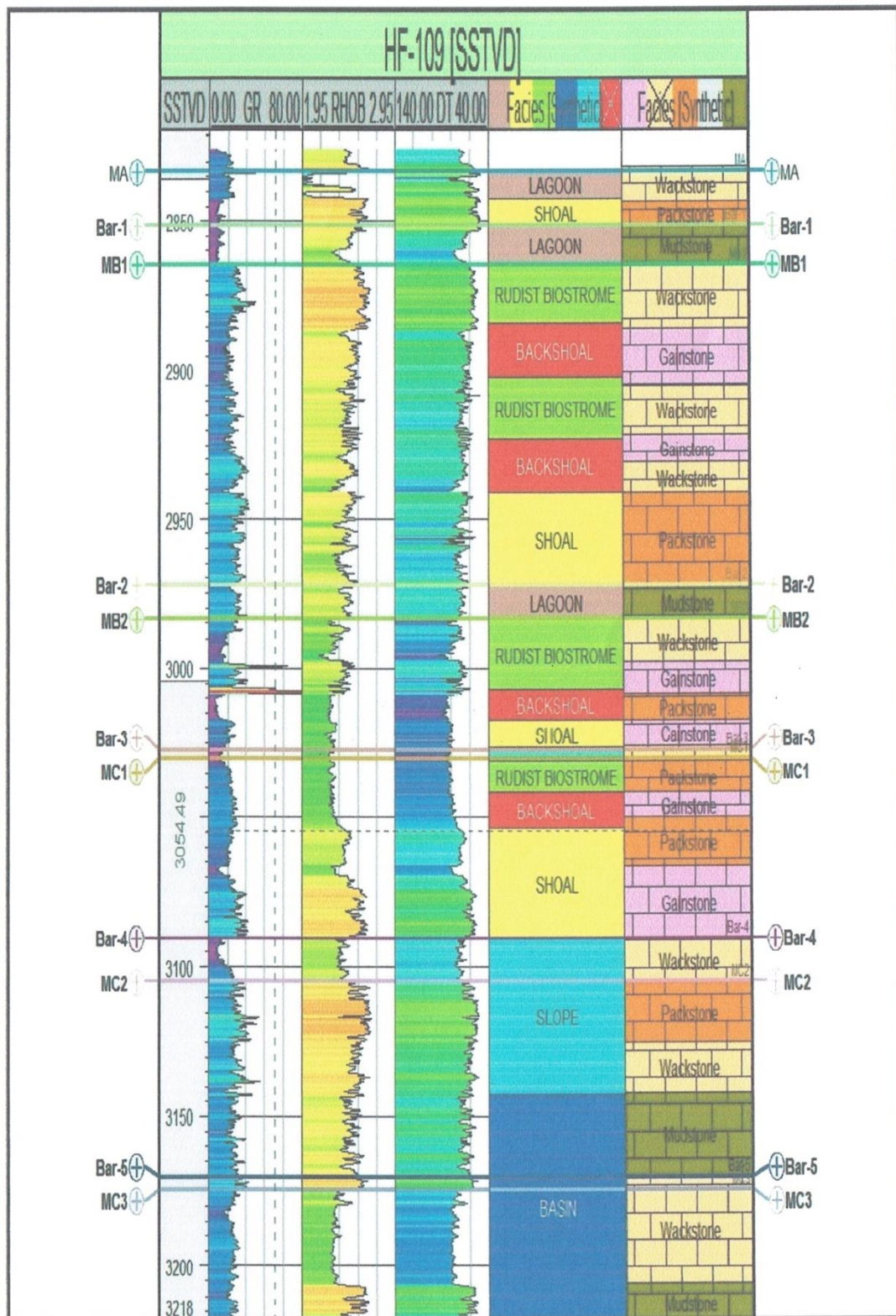


Figure 3-Depositional environments of Mishrif Formation in well HF-316.

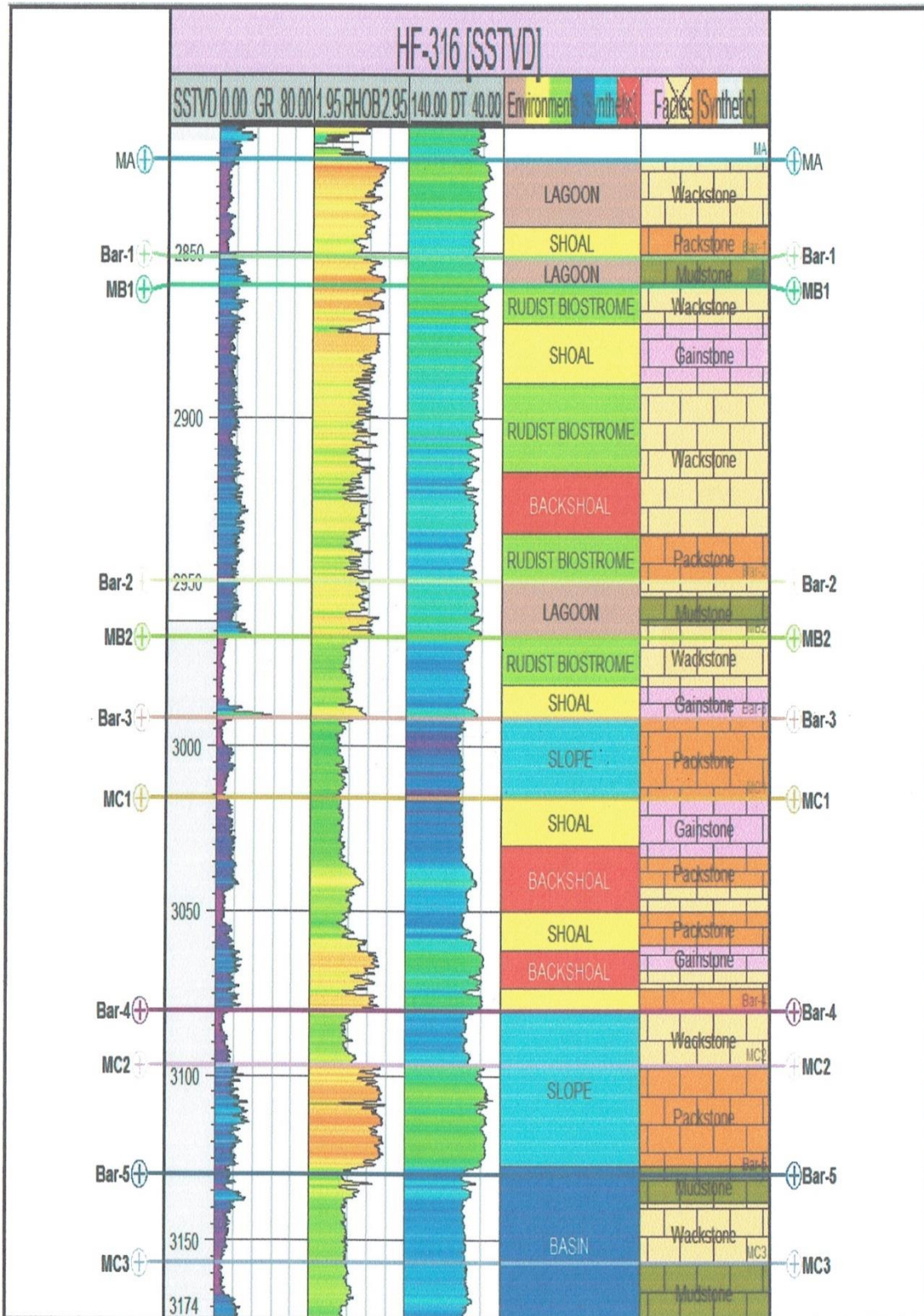


Figure 4-Depositional environments of Mishrif Formation in well HF-109.

3D Facies and environmental model

Facies modeling shows distributed discrete facies throughout the model grid. Normally, by analyzing these data, upscaled well logs are observed with discrete properties in the model grid and possibly defined trends within the reservoir [8, 9]. Mishrif is divided into 6 depositional environments according to the thin sections, logs interpretation, and previous studies [10]. These environments are represented by Basin, Slope, Shoal, Back Shoal, Rudist Biostrom and Lagoon, which were generally interpreted for each well.

The 3D environment model of the Mishrif Formation was built by analyzing the microfacies for HF-1, the available thin section in OEC, and previous studies, as well as the logs data. HF-1 is considered as a key well to study paleo-environments of other wells. As Also, the interpretations of well logs are used to analyze microfacies for these wells. After layering of reservoir units of Mishrif Formation was performed, the layers for each reservoir unit were recognized with specific facies and environment.

Rudist biostrom and shoal facies which have good reservoir properties represent the reservoir unit and the oil bearing zones, as seen in the MB2 unit and the upper part of MC1, while back shoal facies has moderate reservoir properties, as in MCI. The lagoon facies in the top of Mishrif at the uppermost MA unit is characterized by bad reservoir porosity.

Figure- 5 shows the final facies and environmental model for Mishrif Formation, which are matched with the property models in the Halfaya field. Figures- 6 and 7 show the facies and environmental models, respectively, for each unit of Mishrif Formation.

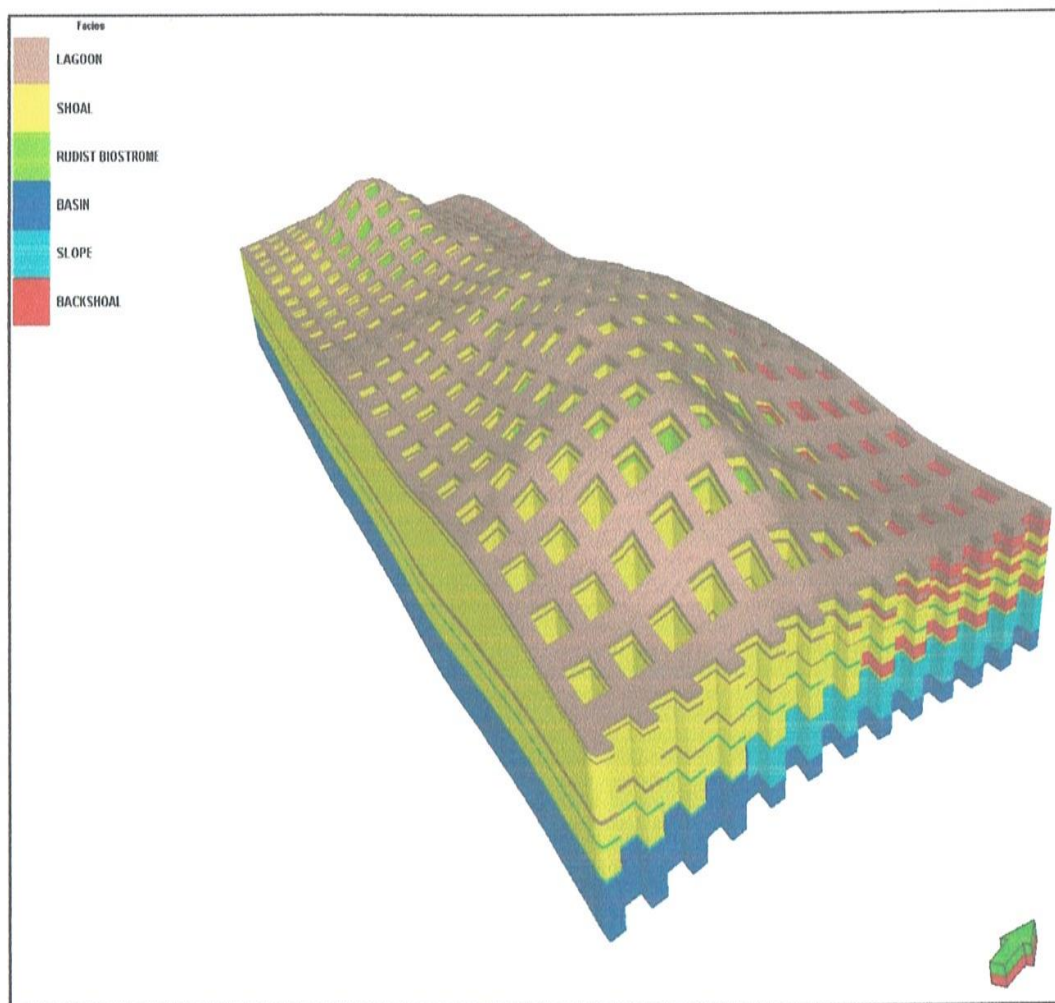


Figure 5-3D Environmental model for Mishrif Formation of Halfaya oil field.

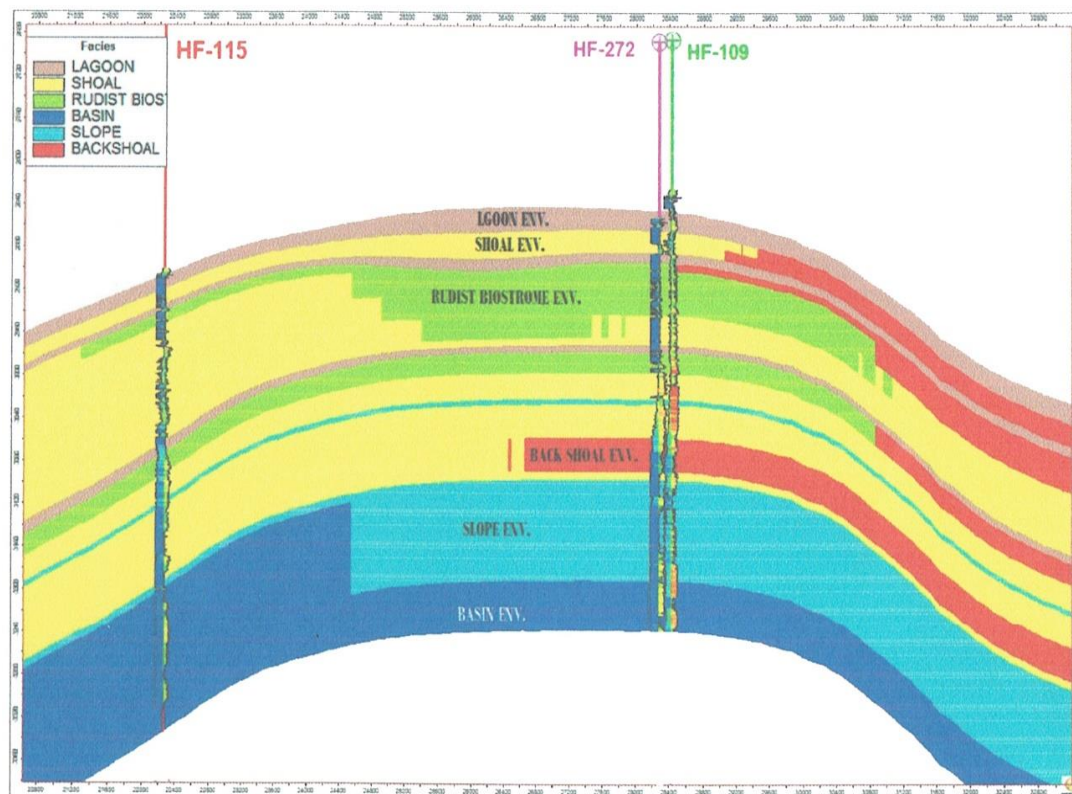


Figure 6-Horizontal section of distribution in the main depositional environments of Mishrif Formation in Halfaya oil field.

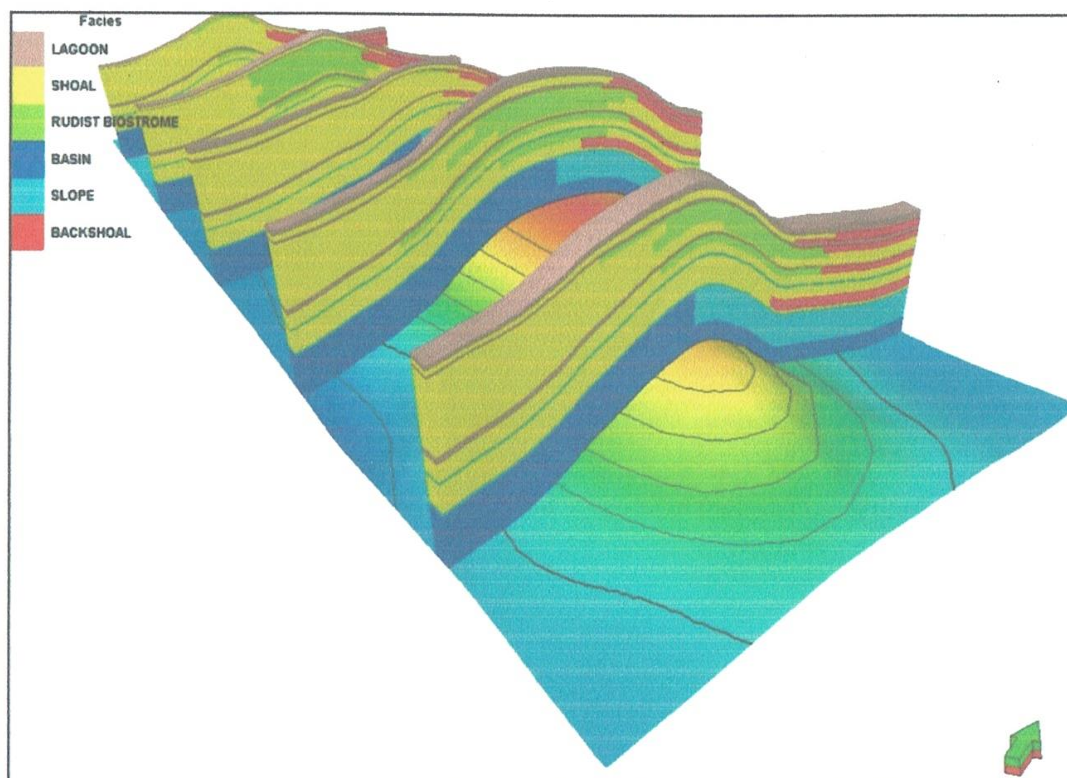


Figure7-Vertical sections of distribution in the main depositional environments of Mishrif Formation in Halfaya oil field

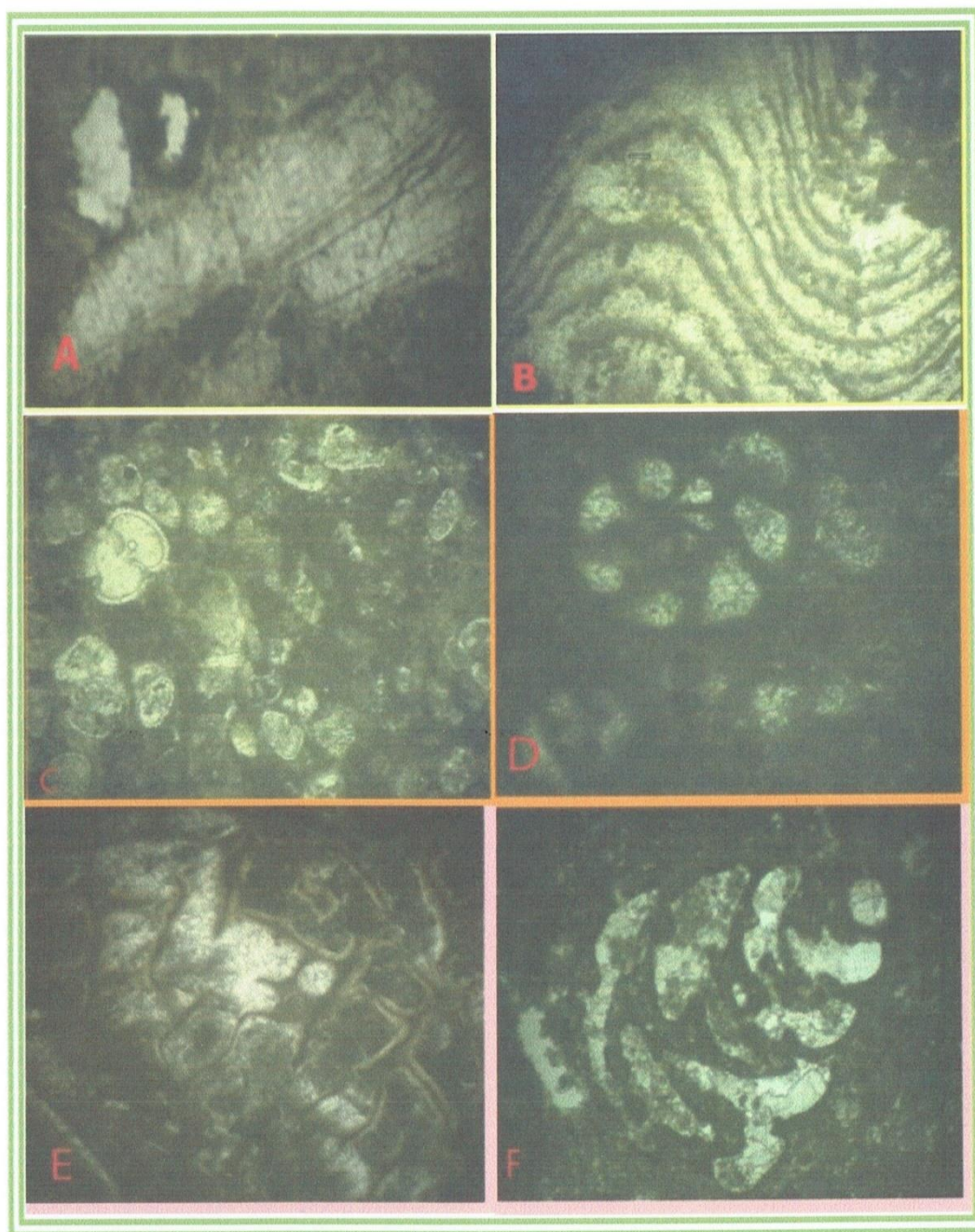


Figure 8-Microfacies of Mishrif Formation in Halfaya Oil Field.

- A. Rudist fragments in rudist packstones, HF-1, 3000 m, [4x],
- B. Echinoderm fragment, Dolomitic, HF-1, 2896 m, [10x].
- C. Hedbergella in Bioclastic Wackestones, HF-1,3184 m, [10x].
- D. Foraminifera, Grainstone (Lagoon), HF-1, 2968 m, [10]

Coral, Bioclastic Grainstone, HF-1, 2988 m, 25x.

Miliolid in Miliolidic Mudstone to Wackestone, HF-1, 2932 m, [25x].

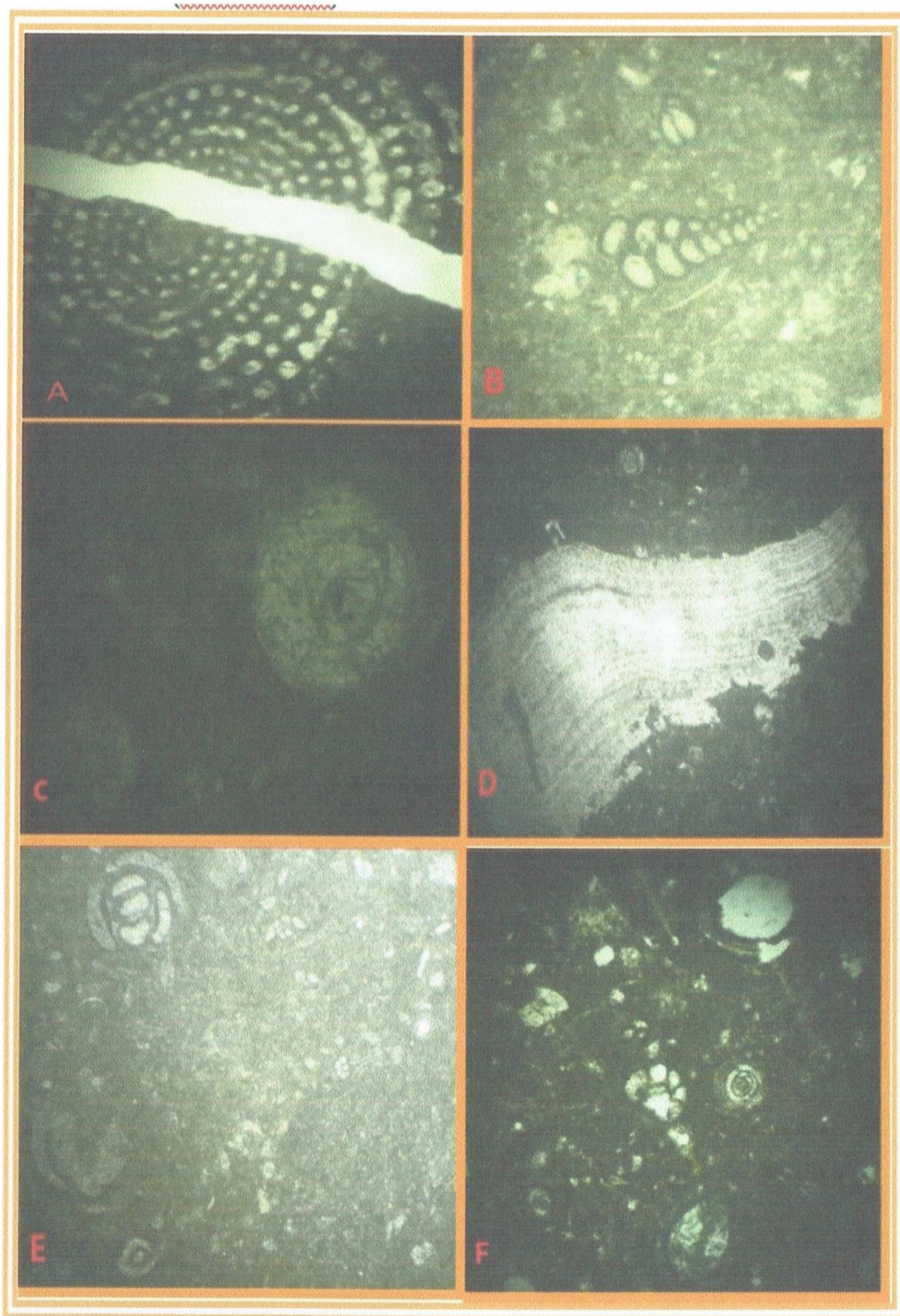


Figure 9-Microfacies of Mishrif Formation in Halfaya Oil Field.

- A. *Cisalveolina* in foraminiferal, bioclastic wackestone, Hf-1, 2908.60 m, [25X].
- B. *Sproplectemina-Iraq* sp, Grainstone, HF-1, 2968 m, [10x],
- C. Miliolids, Packstone, HF-1, 2906 m, [10x].
- D. Rudist fragments, Grainstone, HF-1, 2972 m, [10x],
- E. Miliolid Lagoon env, HF-1, 2906 m, [1 Ox].
- F. Miliolidic Mudstone to Wackestone, HF-1, 2932 m, [10x],

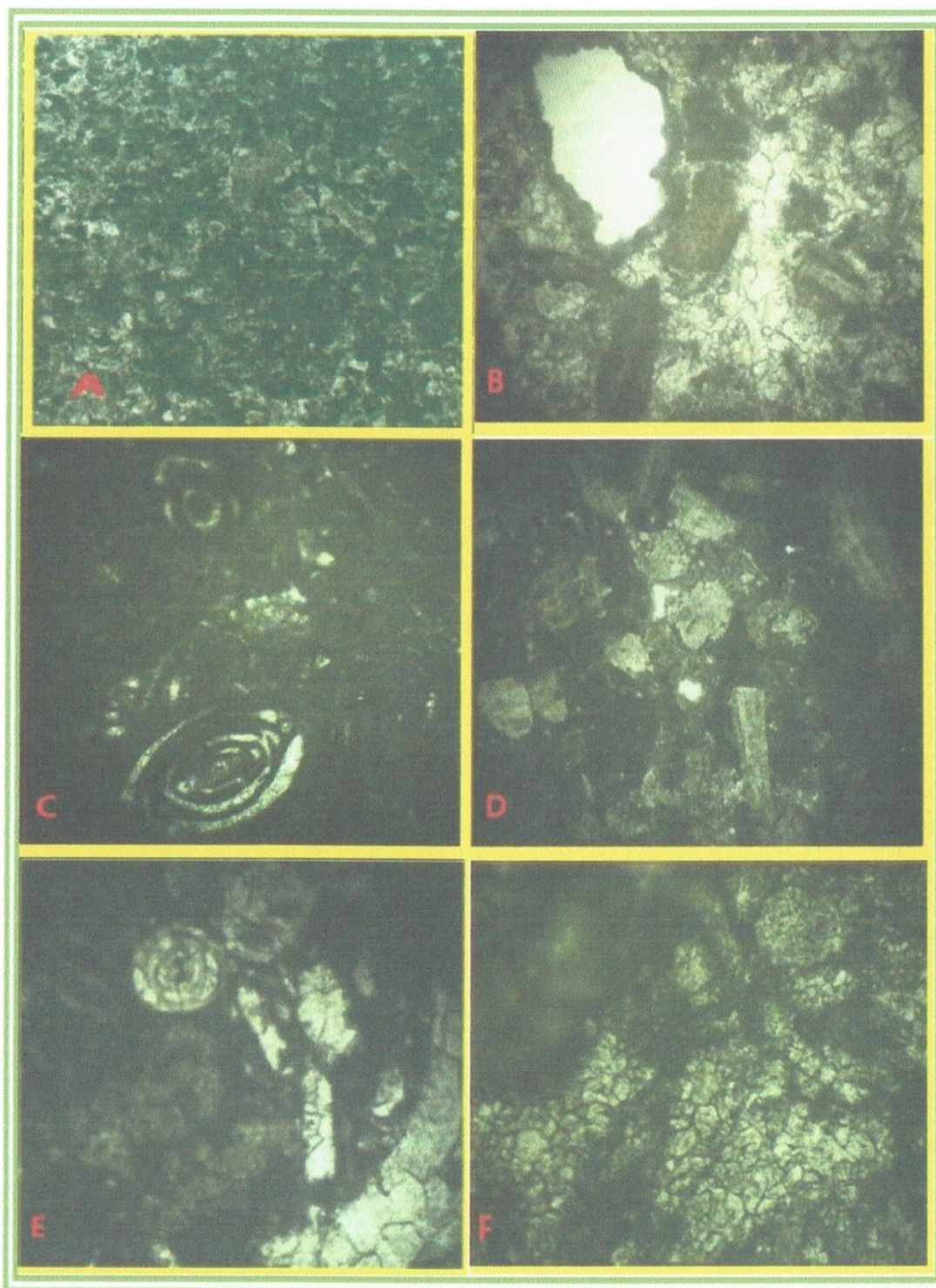


Figure 10-Microfacies of Mishrif Formation in Halfaya Oil Field.

- A. Pelloids in pelloidal packstones HF-1, 2905m, [X25].
- B. Echinoderm & Rudist fragments, HF-1, 2896m, [4x].
- C. Ovalveolina sp, Lagoon environment, HF-1,2910m, [4x].
- D. Rudist fragments, Bioclastic Grainstone, HF-1, 2892m, [10x].
- E. *Miliolid* (Lagoon environment), HF-1, 2872m, [10x]
- F. Bioclastic (slope environment), HF-1, 2900m, [10x]

Conclusions

The microfacies indication of Mishrif Formation was studied vertically through the utilization of various logs, the examination of the available thin sections in OEC, and the findings of previous studies. The results distinguished the existence of six main paleoenvironments, which are the Basin, Slope, Rudist biostrome, Shoal, Back shoal, and Lagoon environments.

Rudist biostrom and shoal facies have good reservoir properties that represent the reservoir unit and oil bearing zones, as seen in the MB2 unit and the upper part of MCI, while back shoal facies has moderate reservoir properties, as in MCI. The lagoonal facies in the top of Mishrif at the uppermost MA unit is characterized by bad reservoir porosity. We recommend the utilization of 2D and 3D seismic data since they are very important for building advanced Facies models.

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