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# Microfacies Analysis and Stratigraphic Development of the Mishrif Formation in the Eastern of the Mesopotamian Zone, Southeastern Iraq

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**Abstract**

Mishrif Formation is the most important succession in the southern part of Iraq and has extensive distribution in the Arabian Plate. The present study focuses upon the sequence stratigraphy and development of Mishrif Formation basin in four oil fields within the eastern part of the Mesopotamian Zone are:- Halfaya (Hf-1), Noor (No-1) and Abu Ghirab (AG-3) and Fauqi oil fields (Fq-1).

There are several types of microfacies were distinguished in the succession of the Mishrif Formation. Their characteristic of the grain types and carbonate texture enabled to interpret of five facies associations (depositional environments) were observed in this formation, they are: deep marine, shallow open marine, Shoal, rudist biostorm, and shallow restricted associations facies.

The stratigraphic development of Mishrif succession in the studied oil fields was summarized by three depositional stages during the Cenomanian-Early Turonian cycle:-

First stage:- the basin of Rumaila Formation during this stage was continued to deposition the lower part of Mishrif Formation within the deep marine environment. The end of deposition in this basin (Rumaila basin) was represented by shallow open marine associated facies in the studied area. The High stand sequence distinguished by deposition the deep marine facies and the shallow open marine as two cycle in the southwest, while to the northeast one cycle. The end of the first stage was finished by the shoal facies in all studied area to mark a sequence boundary type II (prograde stage A).

Second stage:- the basin was developed from shoal to biostorm facies association with slow sea level rise. The deposition of the open marine associated facies within the biostorm-shoal sequence marked the mfs surface. The final step of this stage was shown the shallowing up-ward by overlaying the shallow open marine association facies upon the biostorm and shoal. At the end of this period, the lagoon/restricted facies were spread in the studied area to mark the prograde stage B as sequence boundary type II.

Third stage:- the sea level raised in the southwest direction as open sea association facies, while to the northeast the restricted facies was dominated. This sequence appeared the shoal facies underly the open sea facies marked the mfs surface to start the final high stand deposition overly the restricted facies. This stage is representing the prograde stage C for the Mishrif Formation, where ended the deposition to mark the unconformable surface (SBI) with Khasib Formation.

**Keywards:** Microfacies Analysis, Stratigraphic Development, Mishrif Formation, Mesopotamian Zone

## تحليل السحنات الدقيقة و التطور الطباقي لتكوين المشرف في الجزء الشرقي لنطاق بين النهرين، جنوب شرق العراق

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**الخلاصة**
يمثل تكوين مشرف تتابع مهم في جنوب العراق وله انتشار واسع في الشرق الأوسط. حيث تركز الدراسة الحالية على التتابع الطباقي وتطور حوض تكوين المشرف في اربعة حقول نفطية مهمة في شرق منطقة بلاد الرافدين في العراق هي: - حقل نفط حلفاية (Hf-1) وحقل نفط نور (No-1) وحقل ابو غراب النفطي-AG) (3وحقل نفط الفكة (Fq-1) .
هناك عدة أنواع من السحنات الدقيقة تم تمييزها في تتابع تكوين المشرف. مكنت أنواع المكونات الحبيبية والنسيج الترسيبي من التعرف على ست مترافقات سحنية (البيئات الترسيبية) ضمن هذا التتابع ، وهي: البحرية العميقة والبحرية الضحلة المفتوحة والحاجز البحري والبيوستورم والضحلة المقيدة.
تم تلخيص التطور التتابعي للتكوين المشرف في الحقول النفطية المدروسة من خلال ثلاث مراحل من تطوير الحوض خلال دورة السنومانين الى االتوروني المبكر.
المرحلة الأولى: - خلال هذه المرحلة استمر حوض تكوين الرميلة في ترسيب الجزء الأسفل من المشرف في بيئة بحرية عميقة. ان نهاية حوض الرميلة أُشرت بظهور سحنة البيئة البحرية الضحلة المفتوحة في المنطقة المدروسة. تم تمييز نظام الوثبة المرتفع بتعاقب من السحنات البحرية العميقة و البيئة البحرية المفتوحة الضحلة كدورتين في الجنوب الغربي ، بينما إلى الشمال الشرقي فقد تميزت بدورة ترسيبية واحدة. تم الانتهاء من المرحلة الأولى من خلال انتشار بيئة الحاجز البحري الضحل في جميع المناطق المدروسة لوضع علامة على حد طباقي من النوع الثاني .
المرحلة الثانية: - تتمثل بتطور الحوض من الحاجز البحري الضحل إلى البايوستورم السائدة مع إرتفاع بسيط بمستوى سطح البحر. ان وجود مترافقة السحنة البحرية المفتوحة ضمن تتابع الحاجز البحري الضحل/البايوستورم يؤشر اعلى مستوى لسطح البحر (mfs) . وظهرت الخطوة الأخيرة من هذه المرحلة في تضحل نحو الاعلى من خلال ظهور مترافقة السحنة البحرية الضحلة المفتوحة التي تعلو سحنة البايوستورم والحاجز البحري. في نهاية هذه الفترة ، انتشرت سحنة الحاجز البحري/ السحنة اللاغونية في المنطقة المدروسة للإشارة إلى مرحلة تراجع المسطبة الجيرية كحد طباقي من النوع الثاني.
المرحلة الثالثة: - ان ارتفاع مستوى البحر من اتجاه الجنوب الغربي لترسيب سحنة بحرية مفتوحة ، بينما في الشمال الشرقي تم فقد شاعت سحنة البحر المقيدة. لقد اظهر تتابع هذه المرحلة تعاقب سحنة الحاجز البحري تحت سحنة البحر المفتوح ، لتؤشر اعلى مستوى لسطح البحر وبداية ترسيب تتابع الوثبة العليا فوق السحنة المقيدة. تمثل هذه المرحلة ج التراجعية لتكوين المشرف حيث انتهى الترسيب بتراجع بحري و تكون حد طباقي غير متوافق من النوع الاول مع تكوين الخصيب

## Introduction

The Mishrif Formation is representing an important succession in the southern Iraq and has extensive distribution in the southern part of the Arabian Plate. The Mishrif Formation deposited during Cenomanian-Early Turonian period within the shallow marine carbonates environment as a part of the Wasia Group [1]. In central and southern Iraq, the Formation was described in many oil fields such as, Buzergan, Amara, Halfaya, Majnoon, Rumaila, West Qurna, and Nasiriya as well as other oil fields [2].

The aim of this study is to interpret the sequence stratigraphy and basin development of the Mishrif Formation in the four important oil fields in the south of Iraq are:- Halfaya oil field (Hf-1), Noor oil field (No-1) and Abu Ghirab oil field (AG-3) and Fauqi oil field (Fq-1) .

The Halfaya field is located to the south of Iraq in Maysan governorate, about 35 kilometers southeast Amara city (Figure-1). The structure, which is composed of two domes laying from northwest to southeast direction and gentle elongated anticline about 38km long and 12km wide.

Noor oil field is located to the southeast of Iraq about 15 km northeast Amara city in the Maysan province (Figure-1). The field structurally is representing an anticline with NW- SE trending, and is about 18.9 km long and 5.9 Km wide.

While the Abu Ghirab and Fauqi oil field are a complex of fields located around 175 kilometers (km) north of Basra city, close to the border with Iran within the Maysan oil field.

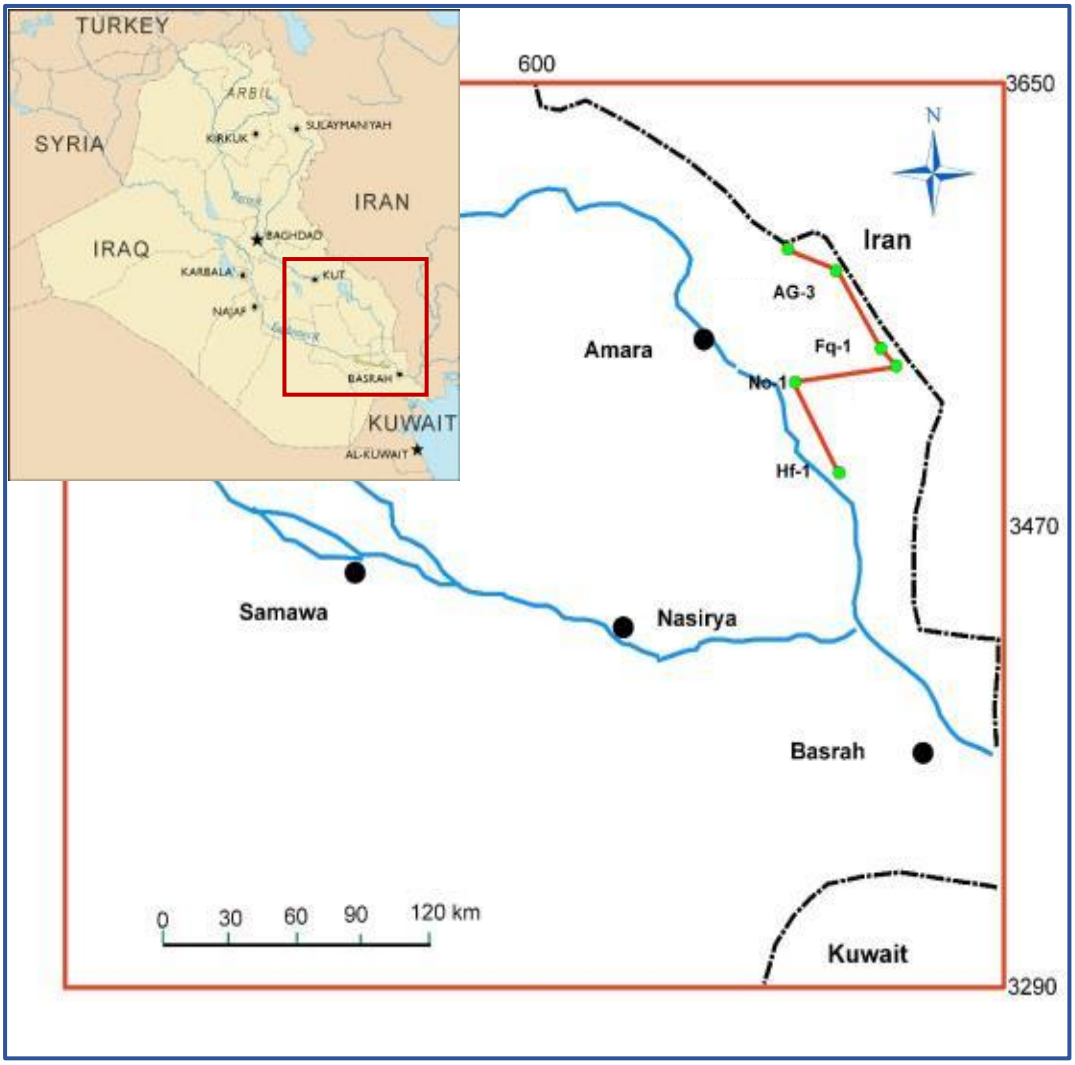



**Figure 1-**Location map of the study area

**Stratigraphic setting**

The lower contact of Mishrif Formation is conformable surface, where change the depositional environment from the basinal Rumaila Formation to shallow open marine facies. While the upper contact with the Khasib Formation is represented an unconformity surface separating the Middle from Late Cretaceous[2]. Gir-bir Formation in the north and the Balambo Formation east-northeast are equivalent formations of the Mishrif Formation within the same basin of the Dokan Formation [2] (Figure-2).

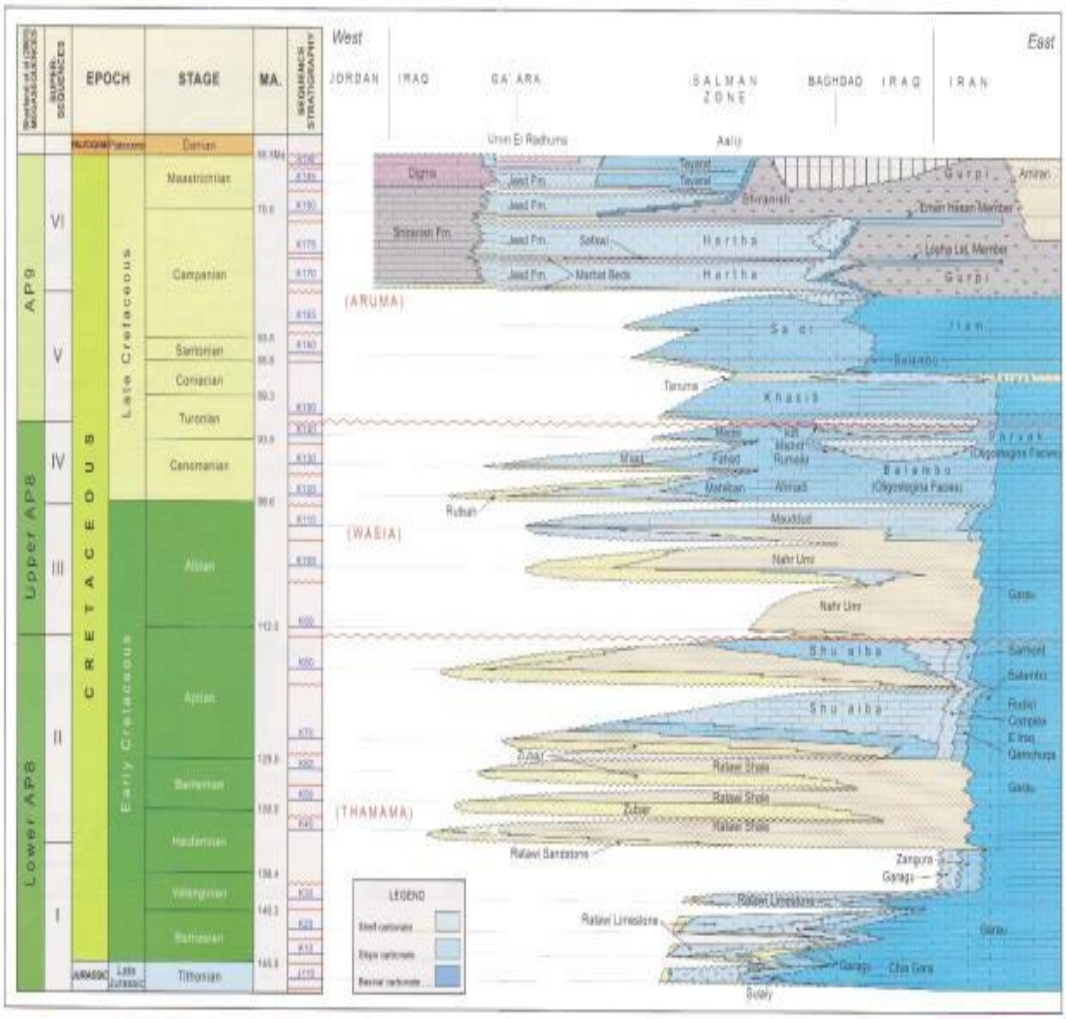



**Figure 2-**Chrono-stratigraphic cross section of the Cretaceous sequence in northern part of Arabian Plate [2].

The top Mishrif off lapping forms between the AP9 and AP8 megasequence boundary at ~92 Million years [3]. The Rumaila/Mishrif High Stand System Tract represents the 3rd order sequence which is driven by both eustasy and subsidence [2]. The Mishrif is considered to be a progradational succession deposited within the marine shelf environment. The transgressive shales and marly limestones of the Ahmadi and Rumaila Formations, rudist reefs and other related build-ups are represented the deposition of the Mishrif basin [1].

The Late Cenomanian to Early Turonian cycle was represented a period of generally suitable conditions world-wide for high organic productivity and the eustasy was the major element controlling the growth, development and location of the sequence [4]. The Mishrif Formation was deposited during two major sedimentary cycles abruptly terminated by the unconformity which separates the Mishrif from the overlying Khasib Formation [2].

Mishrif Formation is a rudist bearing carbonate deposits. It is equivalent to the Gir-Bir Formation and chalky marly limestones of Dokan Formation in the North. The latter was deposited to the east in deeper environment and interabasinal parts in this basin [5].

Wasia Group in Saudi Arabia is the time equivalent to the Mishrif (Cenomanian part) because of the same assemblages of foraminifera. In the southeastern Iran, the same fossil assemblages was recorded in the upper unit of the Sarvak Formation [6] (Table-1).

**Table 1-**Mishrif Formation and equivalent in Iraq and adjacent area after [5] [7]

| AREA / AGE | IRAQ | | | KUWAIT | SAUDI ARABIA | IRAN |
|---|---|---|---|---|---|---|
| | NORTH | MIDDLE | SOUTH | | | |
| TURONIAN | GULNERI FN. | KIFL FN. / MAOTSI FN. | KHASIB FN | GUDAIR FN. | WASIA FN. | SARVAK FN. |
| CENOMANIAN | DOKAN FN. | FAHAD FN. | MISHRIF FN. | MAGWA FN. | | |
| | QAMCHU -QA Fn. | MAHILBAN FN. | RUMAILA FN. | AHMADI FN. | BURGAN | |
| ALBIAN | MAUDDUD FN. | | | | | |

**Microfacies and Paleoenvironments**

The carbonate textures and microfacies were described following the classification of Dunham [8], and rudist and coral bearing carbonate rocks were classified according to Embry and Klovan's classification [9]. While the microfacies were compared with the models of microfacies standard and depositional environment of carbonates as association facies according to standard of microfacies and depositional model for Wilson [10] and Flugel [11].

**Association Facies**

Five association facies are recognized in the Mishrif succession such as; deep marine, Shallow open marine, Shoal, Rudist biostrom and Shallow restricted marine Figures-(3, 4, 5 &6).

**Facies Association One (Deep marine**)

Deep marine facies association consists of fine grained skeletal lime mudstones to wackstones. Planktonic foraminifera are the skeletal grains which consist mainly of such as, *Hedbergella*. The bioclasts are mostly fine and unidentifiable, Spicules and less of echinoderms were also presented (Pl.1-a).

**Facies Association Two (Shallow open marine)**

The shallow open marine association facies represent the most common facies in the Mishrif succession in the study area. It consists mainly of foraminiferal bioclastic as wackstones and packstones, the bioclasts are very fine size and in some cases coarser. Other important compounds included in this facies association are calcareous algae, coral, echinoderms, sponge spicules, and molluscs (Pl.1-b,c and d).

**Facies Association Three (Shoal)**

The shoal association facies is referred to deposition in high energy environment within intertidal conditions. This Facies consist of medium to coarse grained Rudist and Pelloids (Pelloidal packstones to grainstones) consisting mainly of pelloids, (Pl.1-e).

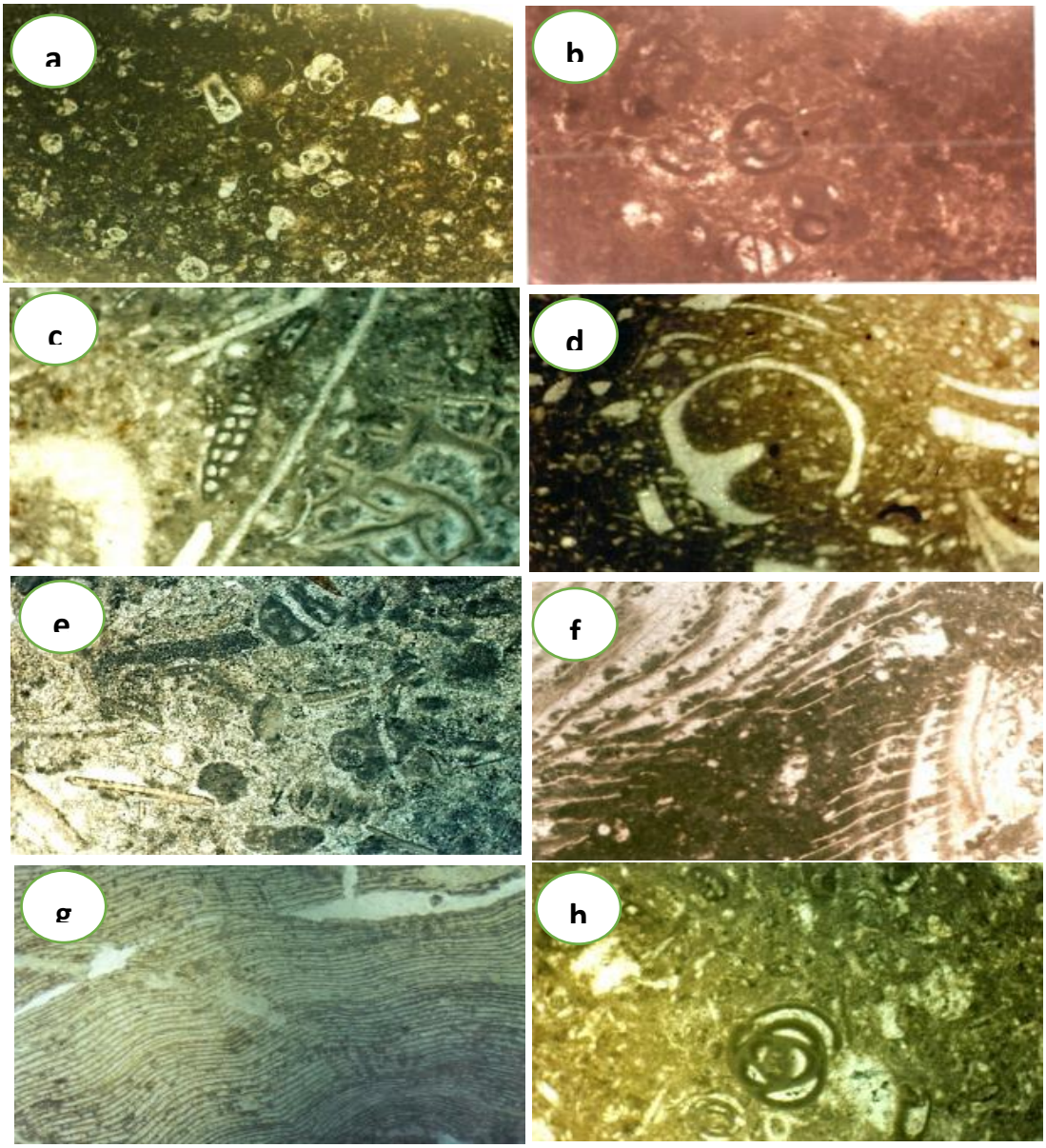
**Facies Association Four (Rudist Biostrom)**

Generally all types of microfacies in this association are highly porous and permeability, this facies association was recognized at Hf-1, No-1, AG-3, and Fq-1 wells. This microfacies consist of rudistone and rudist packstones (Pl.1-f,g).

**Facies Association Five (Shallow Restricted marine )**

This association consists of benthonic foraminiferal wackstones and mudstone to wackstones. The benthonic foraminifera are including Miliolids, *Nezzazata*, Alviolinids, *Textularia*, and Others. The others fossils include sponge spicules, Algae, Rudist fragment, and Molluscs. The matrix is fine lime mud (Pl.1-h).

**Plate 1**




(a) planktonic foraminifera in foraminiferal wackstones ,Hf-1, 3200m ,X10
(b) Miliolds *and Nezzazata* in benthonic foraminiferal wackstones , AG-3, 3820m , X40.
(c) Coral , and Shell fragments in bioclastic foraminiferal packstones Hf-1, 2988m, C-9, X35.
(d) Molluscs shell fragments (pelecypodes) in bioclastic wackstone ,Hf-1, 3170m , X35.
(e) bioclastic grainstones , Hf-1 m,3000.50m ,X50.
(f) Rudist in rudistone, No-1, 3342.64m ,X 35.
(g) Rudstone (Rudist biostrom) Hf-1 , 2888.75m C-3,X40.
(h) Miliolids and shell fragments, in foraminiferal bioclastic packstones, No-1, 3365.75m,X40.

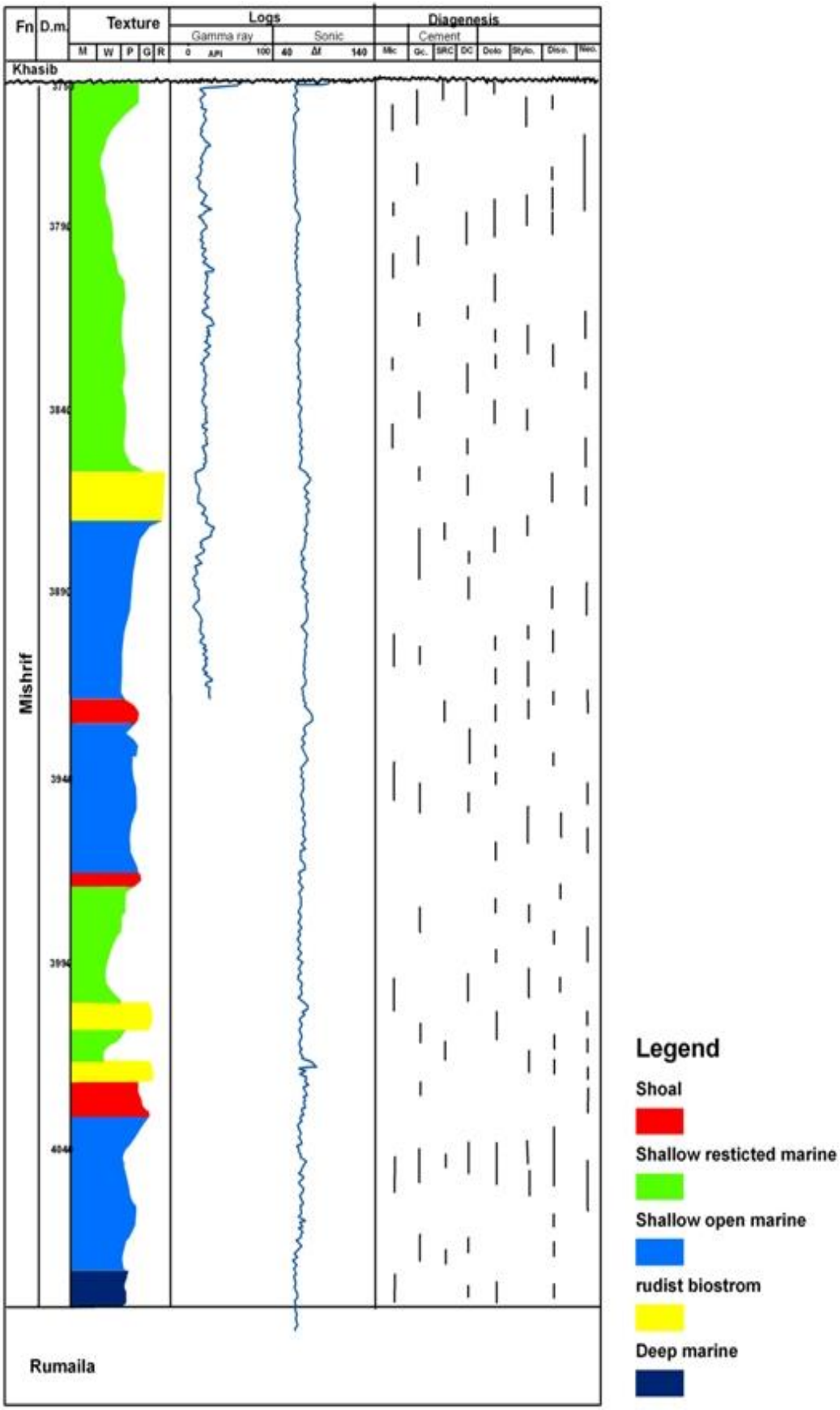



**Figure 3-**Stratigraphic Column of the Mishrif Formation at AG-3 showing the facies associations.

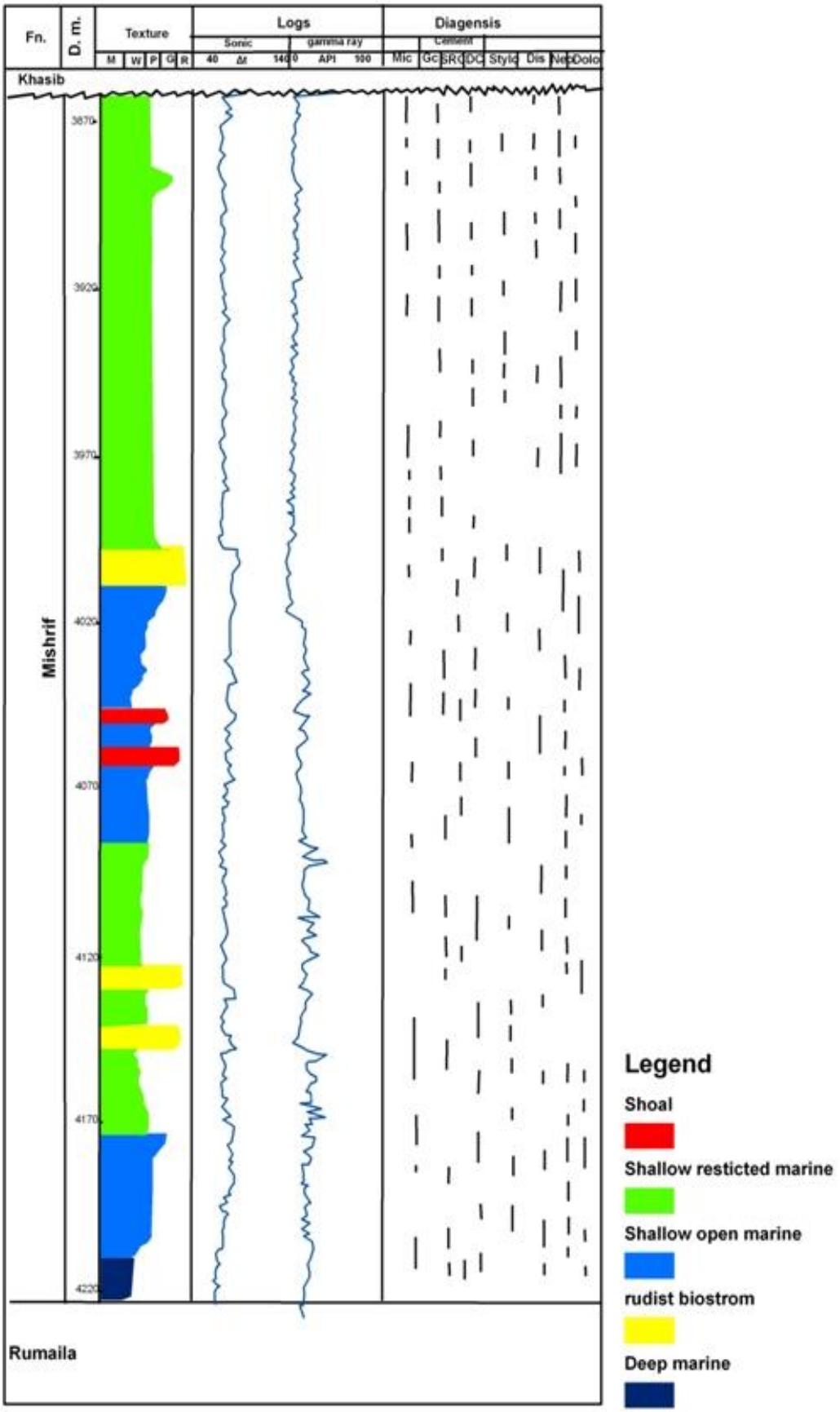



**Figure 4-**Stratigraphic Column of the Mishrif Formation at Fq-1showing the facies associations.

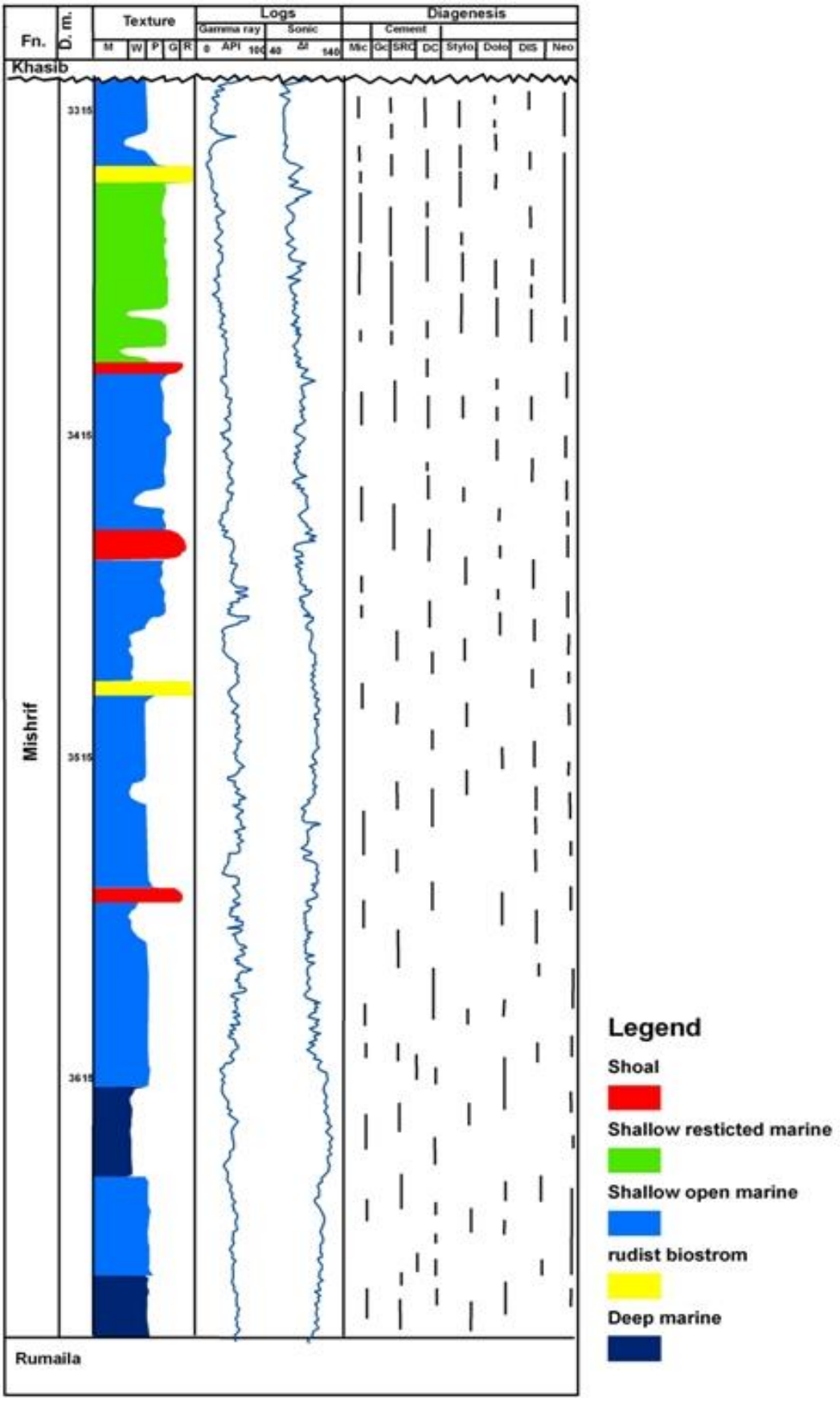



**Figure 5-**Stratigraphic Column of the Mishrif Formation at No-1 Showing the facies associations**.**

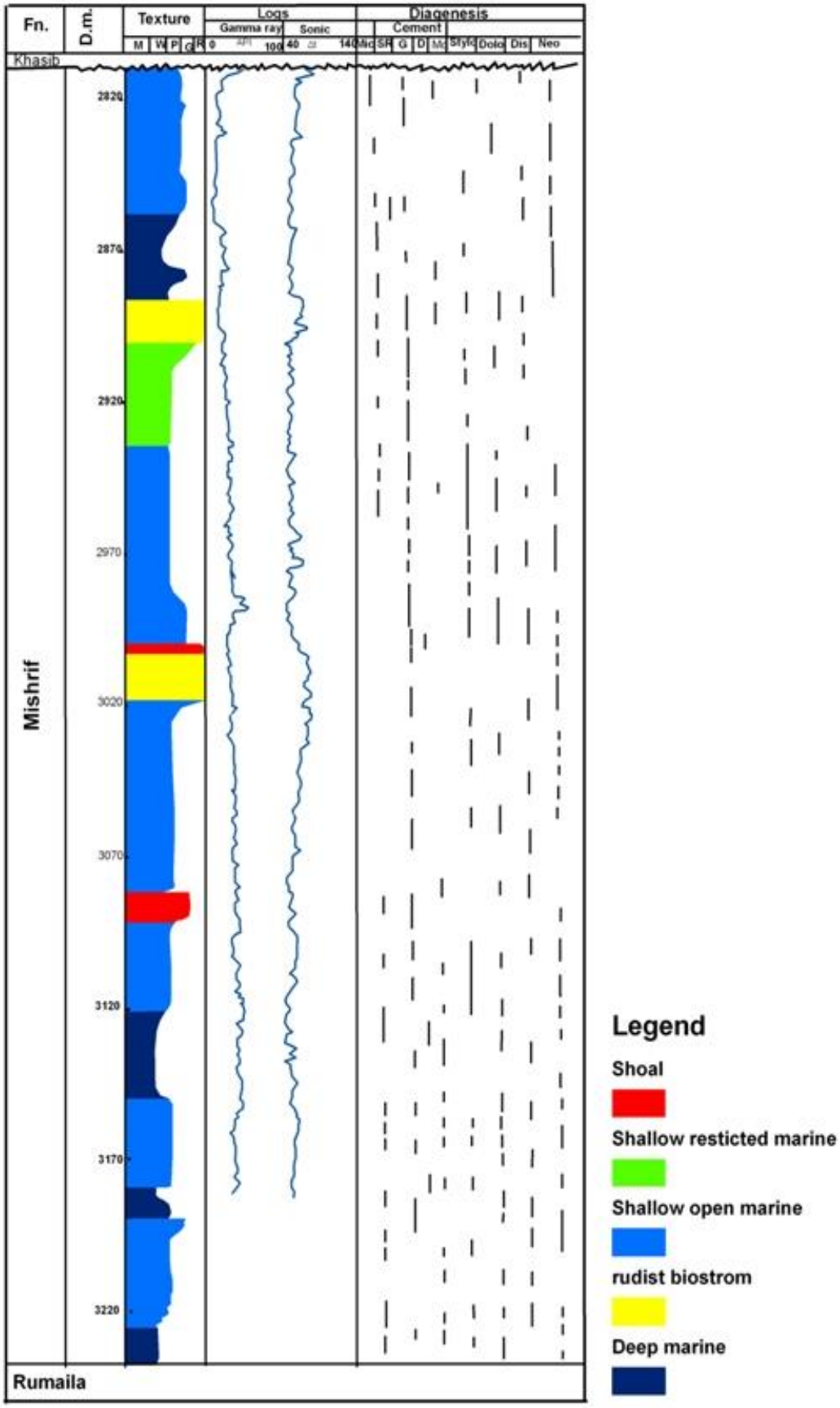



**Figure 6-**Stratigraphic Column of the Mishrif Formation at Hf-1 Showing the facies associations.

**Stratigraphic Development**

Stratigraphic development of the Mishrif succession in the studied oil fields was summarized by three depositional stages during the period from Cenomanian-Early Turonian (Figure-7):-

**First stage:-** this stage was represented the deposition in the basin of Rumaila Formation and continued to deposition the lower part of Mishrif formation within the deep marine environment. The end of this basin (Rumaila basin) was represented by the shallow open marine associated facies in the studied area. The High stand sequence distinguished by deposition the deep marine facies and the shallow open marine as two cycle in the southwest, while to the northeast one cycle. The first stage was finished by deposition of the shoal facies in all studied area to marked a sequence boundary type II (prograde stage A).

**Second stage:-** during this stage the basin was developed from the shoal to biostorm dominated facies with slow sea level rise. The deposition of the open marine associated facies within the biostorm-shoal sequence marked the mfs surface. The final step of this stage was shown the shallowing up-ward by overlaying the shallow open marine association facies upon the biostorm and shoal. At the end of deposition this sequence, the lagoon/restricted facies were spread in the studied area to formed the prograde stage B as sequence boundary type II.

**Third stage:-** the sea level was raised in the southwest direction as open sea association facies, while to the northeast the restricted facies was dominated. This sequence appeared the shoal facies underly the open sea facies marked the mfs surface to start the final high stand deposition overly the restricted facies. This stage is representing the prograde stage C for the Mishrif Formation, where ended the deposition to mark the unconformable surface (SBI) with Khasib Formation.

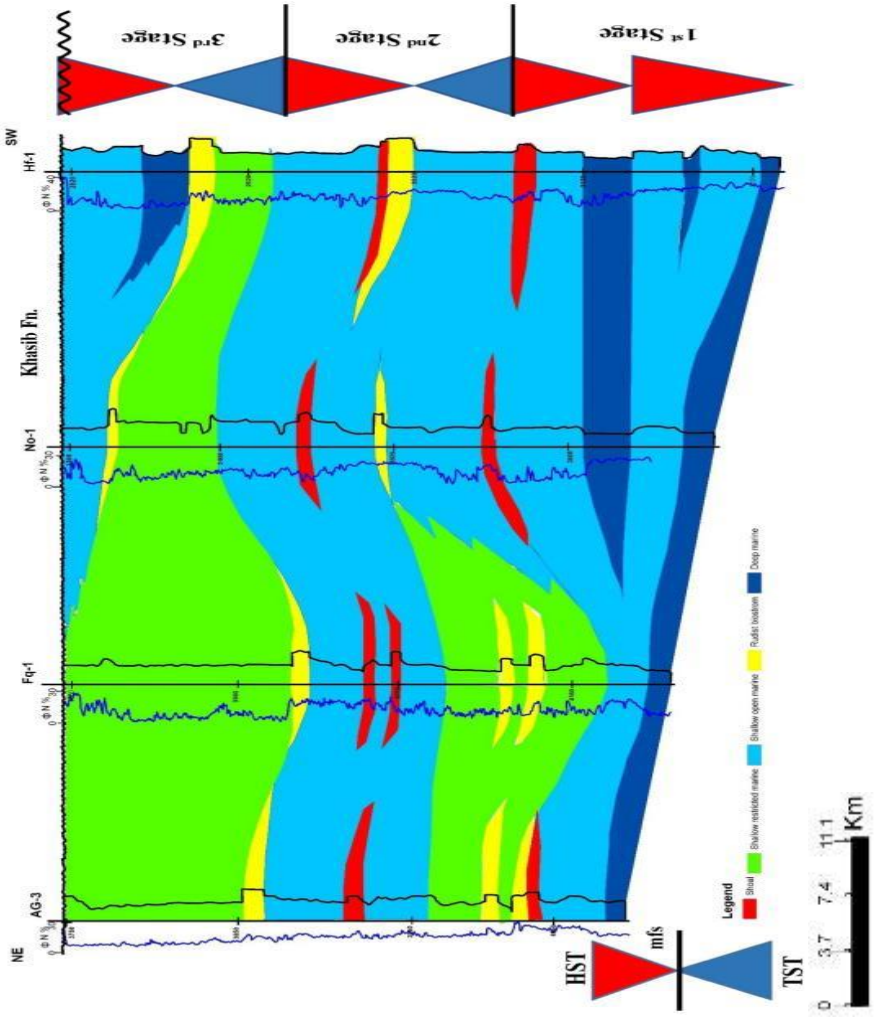



**Figure 7-**Stratigraphic cross section of the Mishrif Formation in the study area

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