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Sequence Stratigraphy of the Cenomanian - early Turonian Cycle in the Selected wells, Southeastern Iraq

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Abstract

Sequence stratigraphic cycle of Cenomanian-early Turonian is composed of (Ahmadi, Rumaila, and Mishrif) formations, which is bounded at top and base by unconformity surfaces. The lithofacies of this cycle in the southern Iraq indicate a normal lateral change facies from shallow water facies through deeper water and open marine sediments, Ahmadi Formation (early Cenomanian) characterized by open marine sediments during the transgressive conditions, and passes up into deep basinal sediments (Rumaila Formation) by conformably surface.

Rumaila Formation (middle Cenomanian) was deposited in the deeper part of the intrashelf basin, which comprises of a mainly basinal sediments, and includes an abundant of open marine fauna supportive of middle Cenomanian age. Rumaila Formation is represented time equivalent basin to the Mishrif Formation, and they deposited during highstand system tract. The Cenomanian-early Turonian cycle can be subdivided into three medium sequences displays coarsening upward cycles (Mishrif A, Mishrif B, and Mishrif C), which comprises of one reservoir pay zone dominated by rudistid packstone to grainstone or rudistid biostrome facies separated by barriers (dense non- porous) units (CR I and CR II). The microfacies analysis of the study wells assisted the recognition of five main environments (open marine, basinal, shallow open marine, Rudist biostrome, and lagoon).

Keywords: Sequence Stratigraphy, Mishrif Formation, Missan oil fields, southeastern Iraqi oil field

الطباقية التتابعية لدورة رسوبيات العمر السينوماني – التورني المبكر للابار النفطية المختارة، في جنوب شرق العراق

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الخلاصـــة

الطباقية التتابعية لرسوبيات عمر (السينوماني– التروني المبكر) تتالف من تكوينات (الأحمدي ، والرميلة ، والمشرف)، تكوين الأحمدي يتالف من رسوبيات البحر المفتوح وضمن طور سطح البحر الاغماري خلال العمر السينوماني المبكر(early Cenomanian)، وتتغير عموديا الى تكوين الرميلة والذي يمثل رسوبيات بيئة البحرية العميقة في الحوض الداخلي (intrashelf basin) خلال العمر السينوماني الاوسط، والتي تمتاز بوفرة المتحجرات الطافية الدالة على عمر التكوين، ويعتبر المكافئ الحوضي العميق لتكوين المشرف وترسبا ضمن طور سطح البحر العالي.

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البيئات الرسوبية التي تم تحديدها لدورة رسوبيات العمر(السينوماني– التروني المبكر) من خلال الفحوصات المجهرية هي خمسة (بيئة البحر المفتوح، البيئة الحوضية، الضحلة، البناءات الرودستية وبيئة المستنقع)، كما امكن تقسيمها الى ثلاث دورات رسوبية تراجعية تمثل رسوبيات التضحل نحو الاعلى (shallowing upward cycles) متمثلة بالوحدات الطباقية (Mishrif A, Mishrif B, and Mishrif C)، وان هذه الوحدات تفصلهما وحدات كتيمة تعرف (CR I and CR II).

1. Introduction

The study area is located in the southeastern of Iraq (Missan Province) which includes study wells (Dujaila -1, East Abu Amood -1, Amara -1, Halfaya-1 and Huwaiza-1), these five wells were chosen to cover most of the sedimentary basin from lagoonal environments through shelf margin to basin center, they consist of the (Cenomanian - early Turonian) formations, and penetrated by study wells at different depth and thickness. The basin analysis study for the (Cenomanian- Early Turonian) cycle, identify sedimentary facies distribution, then preparation of the geological model depend on the concepts of sequence, the area lies within the Universal Transverse Mercator (UTM) coordinates given in Table-1, Figure-1:

Table 1-Coordinates of the study area

Point	Northern (m)	Eastern (m)
A	3550014.13	628999
B	3496444.3	628007
C	3497081.67	763498.13
D	3522059.8	770875
E	3553864.57	746051.84

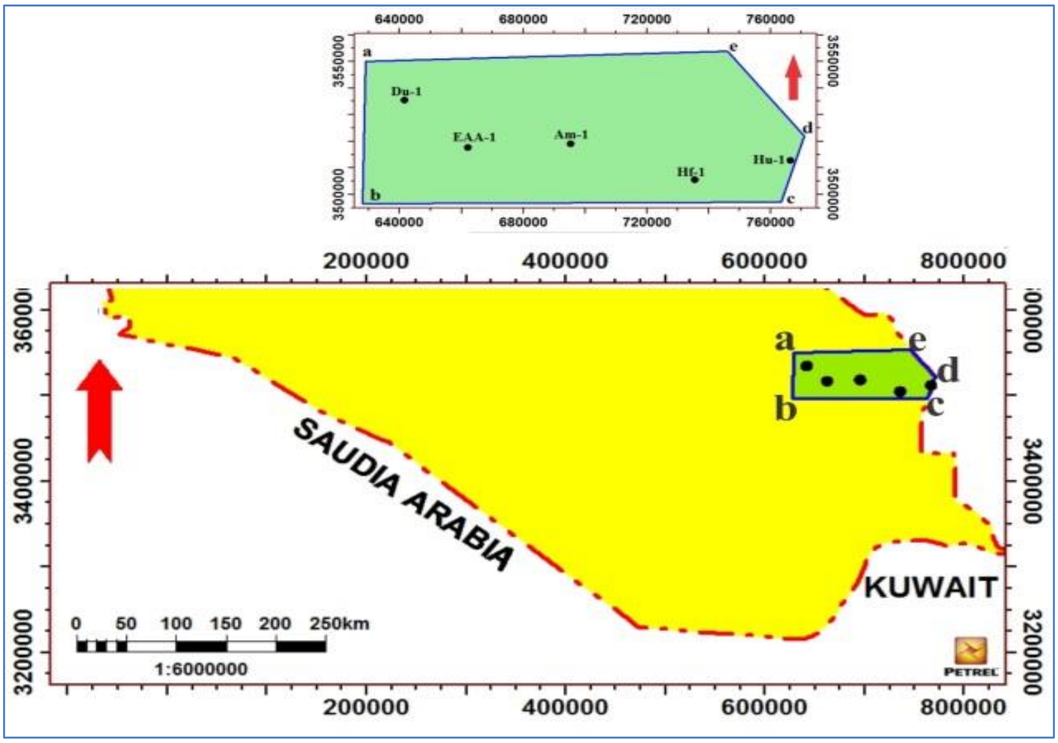


Figure 1- location map of the study area

2. Tectonic evolution

The intra-shelf basin development during the Cenomanian age is dominated by shallow water of carbonate ramps [1-3], that event was due to growth of Oman- Zagros peripheral bulge associated with obduction of the ophiolites, but the possibility resulted from compressional tectonic system along Arabian Plate margin Figure-2. Mishrif Formation is deposited above the high barrier or on the detached platform [4], which extend from south Kuwait to the southeastern Iraq, that is consistent with the model presented by [5] and in the figure above, which has been adopted in our current study.

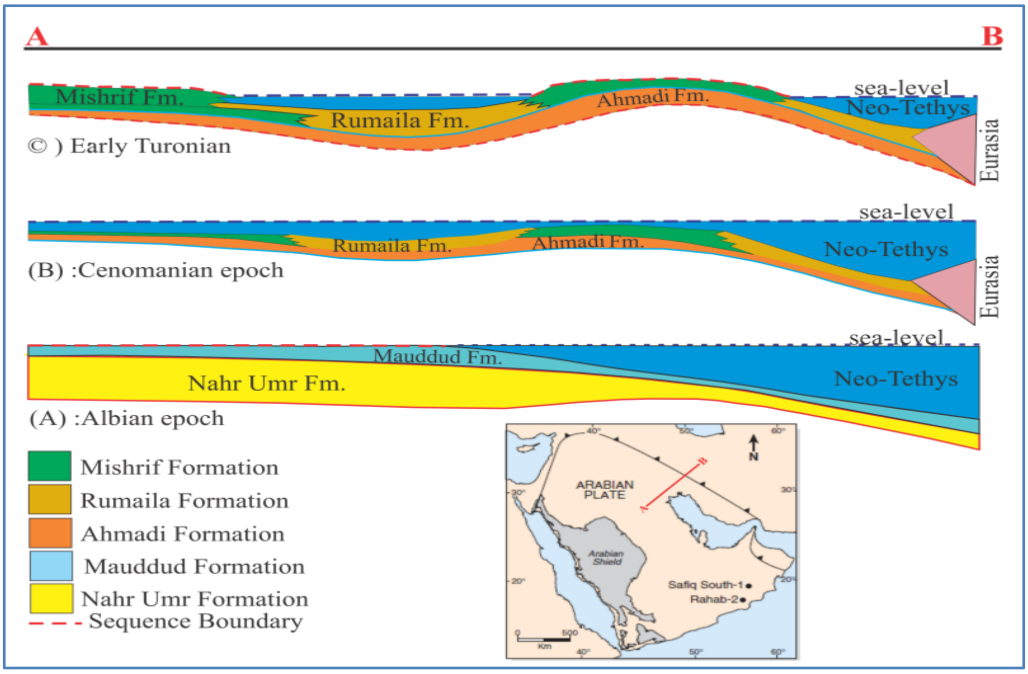


Figure 2-A scheme showing the stages of growth peripheral bulge Albian - Turonian.

(A) Albian. Passive margin sedimentation of Nahr Umr and Mauddud formations followed by initial differentiation into intra-cratonic basins and platforms.

(B) Emergence and development of interior basin and commence progradational pattern of the Mishrif shallow water carbonate platforms.

(C) Early Turonian age. Development of initial peripheral bulge and exposure of the top Mishrif Formation, Modified after [5].

3. Microfacies Analysis

Microfacies are the total of all paleontological and sedimentological criteria which can be classified in the thin-section [6], the study of the carbonate microfacies is characterized by complex of biolithofacies buildup, and the relationship with the diagenetic processes.

3. Facies Association

A depositional environment can be defined in terms of physical, biological, chemical, or geomorphic variables [7]. Thus, sedimentary environment is a geomorphic unit in which deposition takes place. The diagnosis of the microfacies of the Cenomanian - early Turonian succession and comparing with the standard microfacies of Wilson [8], which contributed to identification five facies associations (open marine, basin, shoal, rudist biostrome, and lagoon), Figures-(3, 4).

3.1 Pelagic mudstone microfacies

Note the homogeneous texture of the matrix. The matrix is a fine-bioclastic micrite, is defined as the type of limestone, which basic consists of calcite fine crystalline. This microfacies is association with open marine and basinal sediments, these microfacies started with deep basin deposits supported by pelagic lime mudstone that contains calcispheres, sponge spicules and rare of planktonic foraminifera, plate (1-a). These facies zones represent of the Ahmadi and the Basal Rumaila formations.

Mudstone microfacies in the Rumaila Formation is characterized by high organic-rich lime mudstone containing a pelagic biota such as (Oligosteginids, *Hedbergella sp.*, and other planktonic foraminifera), these microfacies spread over most of wells (EAA-1 and Du-1) plate (1- b).

3.2 Bioclastic wackestone microfacies

These microfacies composed of skeletal and non-skeletal grains with mud-supported, and associated with back reef or with open lagoon environments, it consists of wackestone with benthic foraminifera such as Plate (1- c), or concentrations of their skeletal grains with rudistid debris.

3.3 Bioclastic packstone microfacies

Packstone microfacies are characterized by the diversity of skeletal grains such as algae, benthic foraminifera, coral, rudist, echinoderms and mollusks. They are deposited in fore- reefs or shallow marine environments, these sediments sited at the shelf margin according to [8], such as Plate (1- d).

3.4 Bioclastic grainstone microfacies

Grainstone is grains-supported and mud-free consists of skeletal and non-skeletal carbonate grains. The absence of mud has various causes: deposition of grains in high-energy environments, and contain the groundmass, which consists of sparry cement Plate (1- e). These microfacies associated with shoal facies sediments and spread in the most of the Mishrif Formation in the wells (Am-1and Hf-1) at depth (3025-3045m) and (2900-2944m) respectively, and in the uppermost of the wells (Du-1 and EAA-1), they culminate of the coarsening upward cycle.

3.5 Rudstone microfacies

Rudstone almost entirely composed of large rudistid fragments, and related to distinctly bedded structures, that is growth into lenslike or reeflike form, rudstone have structures originate from in situ accumulations of organisms such as rudistid build-up to mound structures, it seems sensible to use term (buildup).

This microfacies is made up of very coarse-grained bioclastic rudstone containing a more diverse intact fauna than lithofacies association shoal, dominated by rudistid debris; Plate (1- e). These are spread in the most of (Hf-1, Am-1 and Hu-1) wells, and uppermost of the Mishrif Formation in the (EAA-1and Du-1) wells.

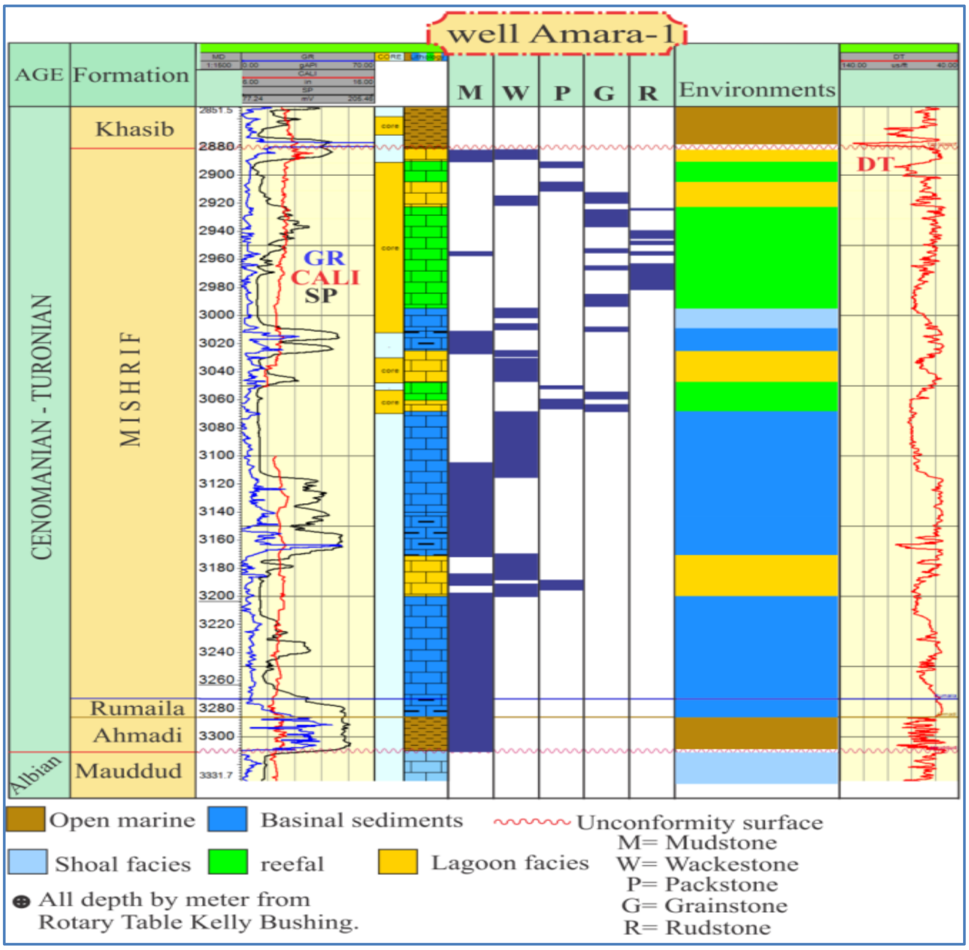


Figure 3-Description of the Cenomanian – early Turonian succession based on thin-section (cores & cutting) and well logs at well Amara-1

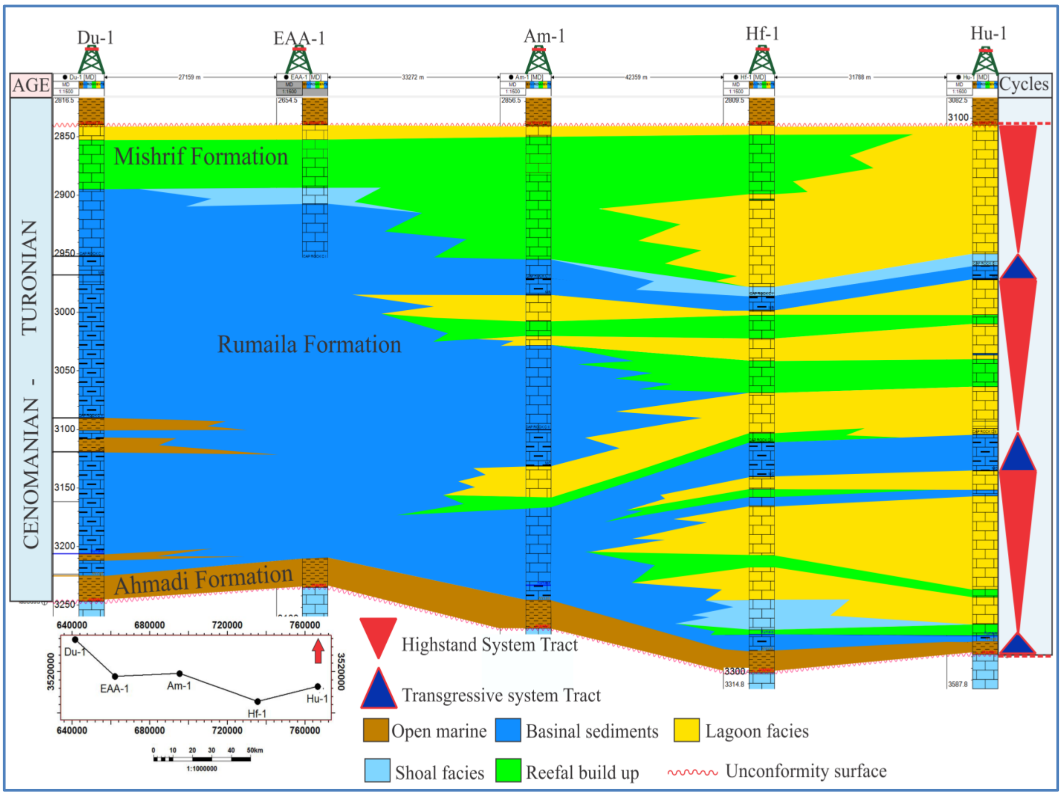


Figure 4-Cross section of the Cenomanian – early Turonian succession of the study wells.

4. Sequence Stratigraphy

Standard carbonate microfacies models are widely used to interpret paleoenvironment, but they do not treat how carbonate platforms are affected by relative sea level change, a realization of how the carbonate factory responds to relative sea level changes and the role played by other environmental factors towards influencing the formation of carbonate platforms, which allows differentiating platform type and helps establish depositional sequence and system tract models.

The sequence stratigraphic defined: depositional sequences bounded by subaerial unconformities and their marine correlative conformities [9-11].

4.1 Systems tract

Systems tracts can be seen to be comprised of a number of distinct depositional packages. They were observed in the depositional basins were not uniform and continuous but occurred in a series of discrete 'packets'. These packages generally were arranged in a predictable style in the majority of sequences they observed on seismic section, these packages are known as ***systems tract***.

4.1.1 Lowstand systems tract

Shoreline are moving, and rarely remaining stationary for long periods of time, and will migrate depending upon eustatic, tectonic, subsidence, and rate of depositional supply [12], when sea-level has dropped below the shelf margin, platform is now subaerially exposed and unable to produce sediments.

4.1.2 Transgressive systems tract

A rapid relative sea-level rise and can force the loci of terrigenous sediment to retreat known the transgressive system tract, and can form deposits an aggradational to backstepping, or retrogradational stacking pattern [11]. The transgressive conditions consist of deepening upward cycle [13].

4-1-3 Highstand systems tract

Highstand conditions deposition occurs in the late eustatic rise, a stillstand, and the early eustatic fall [11]. During that phase, shallow marine sedimentation rates commonly exceed subsidence and the eustatic rise, thus leading to deposition of aggradational to progradational stacking pattern to shelf, shelf margin, and slope [14]. According to Van Wagoner [11], a downlap surface records maximum flooding surface, separates the transgressive system tract and highstand system tract [14], and record the regional progradation of shelf margin toward center basin.

4.2 Originated and development (Cenomanian-Early Turonian) cycle

In order to study development of this cycle in southeastern Iraq in a more detail, structural proposed model is constructed to show the vertical and horizontal facies change, and additional the determination of the main factors which control on the intrashelf sedimentary basin (tectonic and sea level change). This cycle was divided into three stages Figure-5:

Stage (A)

The tectonic setting contributed to the emergence of the passive margin in the east and northeast Arabian Plate, and making it facing of the Neo-Tethys [1]. The abrupt discontinuity of the Mauddud sediments, and followed by the open marine sediments (Ahmadi Formation) during transgressive conditions, on the gentile slope of the carbonate platform model, characterized by the no-facies change with wide extension and the quiescent tectonic.

Stage (B)

As a result of the up growth of compressional tectonic system (initial collision), which produce the peripheral Bulge in the middle Cenomanian, along of the southeastern Arabian plate edge, which was deposited of the Mishrif Formation, and formed a coral barrier and rudistid biostrome [5, 15]. This stage is distinguished by beginning of the emergence an intrashelf basin, which shows a moderate slope resulting of wide extension of the Mishrif Formation.

Stage (C)

The continuation of the compressional tectonic system, contributed to the development of the sedimentary basin, and appearance of the facies change (differentiated basin), marly limestone facies of the Rumaila Formation passes to the bioclastic shoal, reef, and back-reef facies (Mishrif Formation).

The highstand system tract causes to growing of the carbonate factory, and accompanied the progradation facies towards the basin center. In the last regressive cycle with continuance of the progradation shelf margins (rudistid biostrome) to become overlie basinal sediments in the (Dujaila-1 and East Abu Amood-1) wells, while the lagoonal facies progradation, and overlie the reefal buildups in the (Amara -1 and Halfaya -1) wells. The Cenomanian-early Turonian sequence ended with appearance of the erosional surface in the middle Turonian, resulted of compressional tectonic system that causes ophiolite obduction along the northern and northeastern of Arabian plate [1].

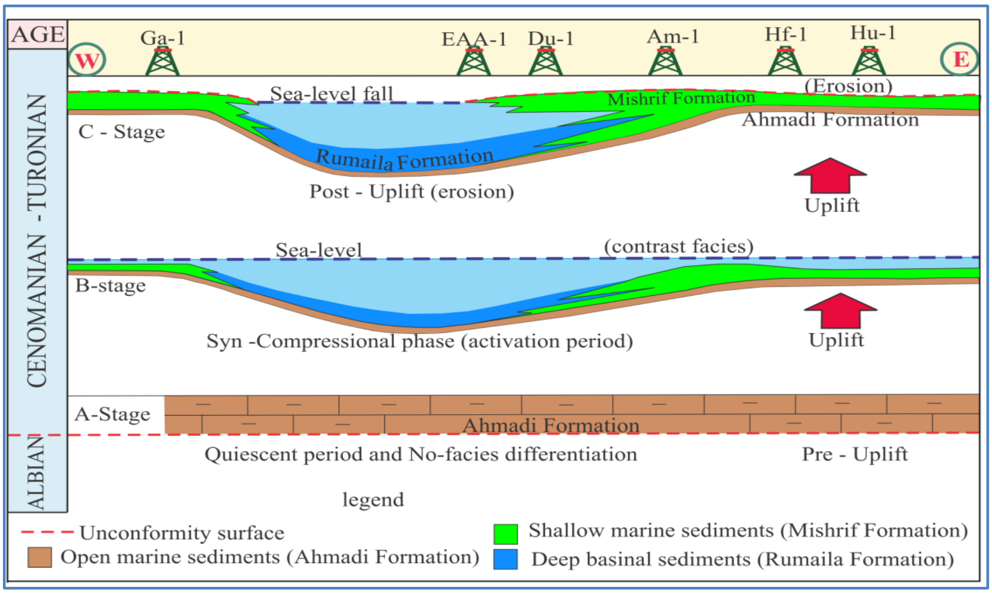


Figure 5-The Cenomanian-Early Turonian cycle divided into three tectonic phases: (A) represents the quiescence tectonic where the sedimentation characterized by no-facies change. (B) Mention to the beginning of the compressional tectonic system that contributed to the appearance of (Bioclastic grainstone or rudistid Biostrome) of the Mishrif Formation.

(C) Ended the tectonic setting by appearance of sequence boundary associated with ophiolite obduction in the (middle Turonian) age.

4.3 Stratigraphic Cenomanian - early Turonian cycle

The Cenomanian - early Turonian megasequence started by transgressive system tract (Ahmadi Formation), and terminated in the highstand system tract (Mishrif Formations), the megasequence subdivided into three main mesosequences Figures-(4, 6), because all most sequences display coarsening upward cycles, that described through thin section and wireline logs information for the study wells, these units consist of (Mishrif A, Mishrif B, and Mishrif C), separated by compacted rock (CR I and CR II) units.

- Mishrif A

This unit represents upper regressive cycle, which ends by the emergence of regional unconformity surface; Mishrif A is characterized by the abundant of benthonic foraminiferal packstone, that indicate to open lagoon environment in (Am -1, Hf-1 and Hu-1) wells.

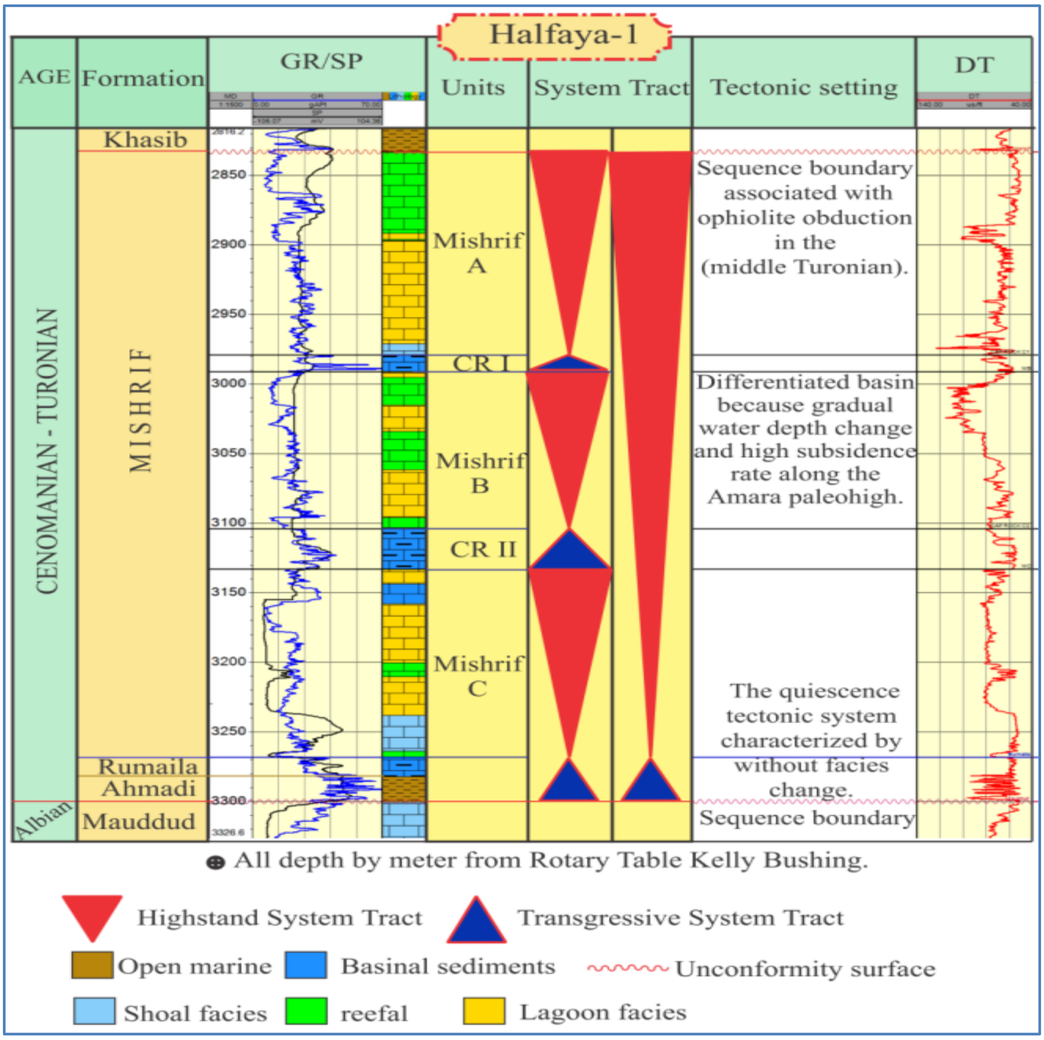


Figure 6-Vertical succession of the Cenomanian – early Turonian subdivided into three regressive mesosequences, at well Halfaya-1

- Compact Rock (CR I)

This unit is located below the (Mishrif A) unit and can be distinguished by a high GR and low DT logs, Figure-6. The stratigraphic unit consists of lime mudstone and free of fossils with pyrite.

- Mishrif B

The stratigraphic unit was deposited in the differentiated basin, because represents of lateral biofacies change from deep basin sediment as (Du-1 and EAA-1) wells, to the rudistid biostrome with open shelf lagoon facies at (Am-1, Hf-1, and Hu-1) wells, Figure-4.

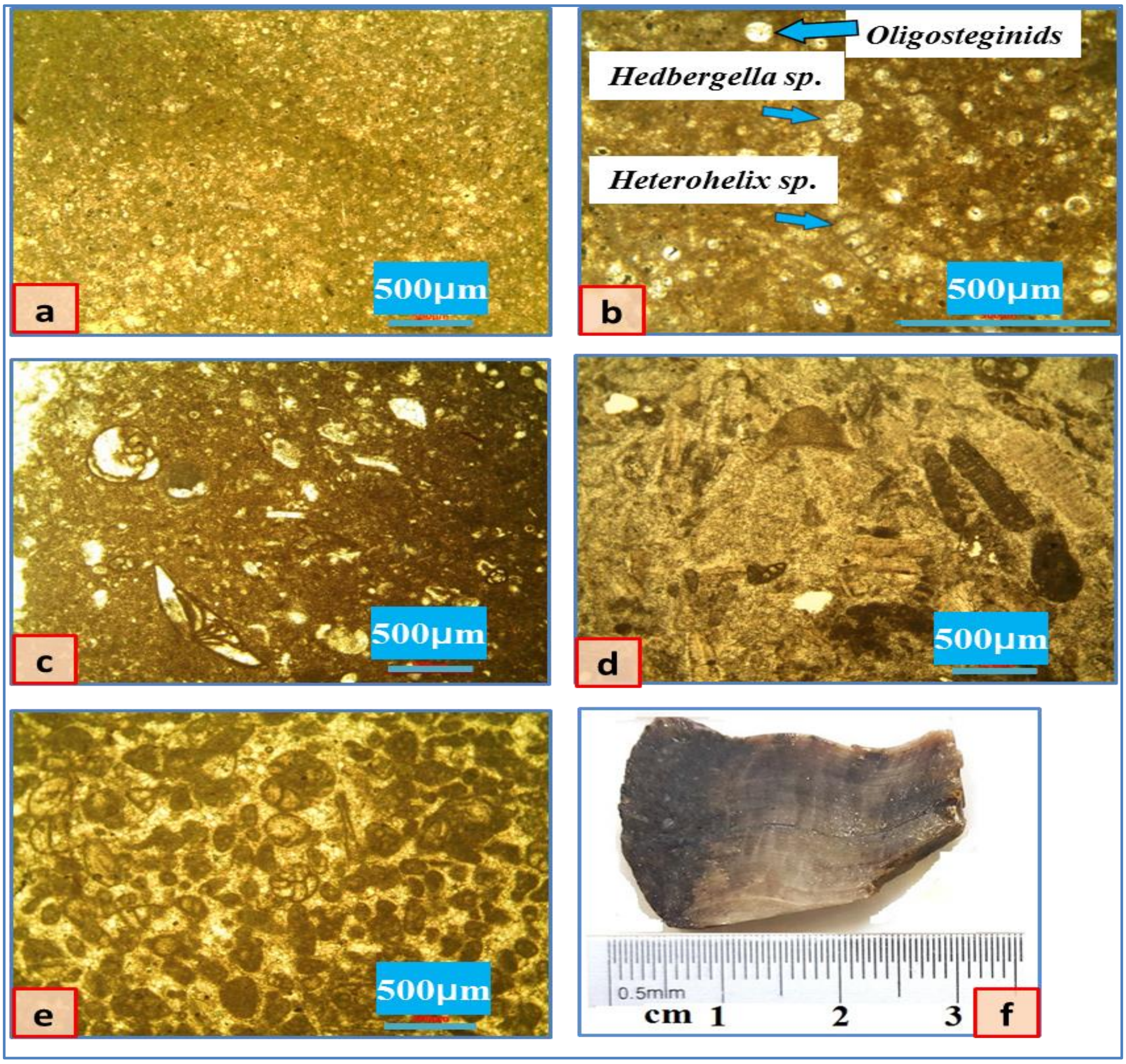
- Compact Rock (CR II)

This unit is located below the unit (Mishrif B) and can be distinguished by a high (DT and GR) logs, Figure-6. The stratigraphic unit consists of lime mudstone (micrite) and free of fossils.

- Mishrif C

The stratigraphic unit represents lower regressive cycle, which deposited during early highstand system tract, and comprises the transitional sediments from deep marine facies at wells (Du-1, EAA-1 and Am-1) to the rudistid packstone - grainstone, with abundant of benthonic foraminiferal grainstone in the lagoonal facies at wells Hf-1 and Hu-1.

PLATE (1)



a- Pelagic mudstone microfacies, with abundant of *Calcispheres,* Well (Dujaila-1), at depth (3214m).

b- Pelagic lime mudstone containing a (*Oligosteginids*, *Heterohelix sp*., and *Hedbergella sp*.). Well (Dujaila-1), at depth (3214m).

c- Bioclastic wackestone microfacies with diversity of skeletal grains such as (benthonic foraminifera (*Nezzazta* *sp*.), in the open lagoon marin facies at well (Halfaya-1, depth 2915 m).

d- Bioclastic packstone microfacies consist of diversity of skeletal grains such as (benthic foraminifera, rudist fragments, echinoderms and mollusks), in shoal marine sediments. (Halfaya-1, 3000.5m).

e- Peloidal grainstone with scattered open space and vugs structures filled in spary cement. (Shoal facies). (well Amara-1, depth 2884 m).

f- Rudstone microfacies almost entirely composed of large rudistid fragments, well (Amara-1), at depth 2972m.

5. Discussion

Cenomanian-early Turonian succession is composed of (Ahmadi, Rumaila, and Mishrif) formations. The intra-shelf basin development during the Cenomanian age by dominated shallow water of carbonate ramps that event was due to growth of Oman- Zagros peripheral bulge, the Mishrif Formation is deposited above the high barrier or on the detached platform. The Mishrif Formation consists of shallowing upward cycle, and associated with continuation of the compressional tectonic system led to the emergence of the unconformity surface at the top the Mishrif Formation, and overlying by the Khasib Formation.

Petrographic study and microfacies analysis assist to recognition of five main environments (open marine, basin, shoal, Rudist biostrome, and lagoon).

The open marine facies consists mainly pelagic lime mudstone that contains calcispheres, sponge spicules and rare of planktonic foraminifera, The basinal facies consists of the calcareous sediments with pelagic organisms plus fine detritus moved off from adjacent shallow shelves, Shoal facies is represented by packstone- grainstone benthic foraminifera and concentrations of skeletal grains with rudistid debris, the Rudist biostrome consists of masses of organic rudstone facies, and this facies is made up of very coarse-grained bioclastic rudstone and floatstone, lagoonal facies consists of benthonic foraminiferal wackestone and mudstone with miliolids and peloidal.

6. Conclusions

The Cenomanian-early Turonian succession can be subdivided into three mesosequences displays coarsening upward cycles (Mishrif A, Mishrif B, and Mishrif C), which comprises of one reservoir pay zone dominated by rudistid packstone to grainstone or rudistid biostrome facies separated by barriers (dense non- porous) units (CR I and CR II). The porosity increases toward the rudistid reefal build up and shallow water microfacies more than the lagoonal facies, and decrease toward the basinal facies of the reservoir units. The upper reservoir unit (Mishrif A) is located above the deep marine succession at wells (Du-1 and EAA-1), but the lower and middle reservoir units disappear there.

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