



## CHRONOSTRATIGRAPHICALLY BASED RESERVOIR MODEL FOR CENOMANIAN CARBONATES, SOUTHEASTERN IRAQ OILFIELDS

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### ABSTRACT

*The Cenomanian – Turronian sedimentary succession in the south Iraq oil fields, including Ahmadi, Rumaila, Mishrif and Khasib formations have undergone into high-resolution reservoir-scale genetic sequence stratigraphic analysis. Some oil-wells from Majnoon and West-Qurna oil fields were selected as a representative case for the regional sequence stratigraphic analysis. The south Iraqi Albian – Cenomanian – Turronian succession of 2nd-order depositional super-sequence has been analyzed based on the Arabian Plate chronosequence stratigraphic context, properly distinguished by three main chrono-markers (The maximum flooding surface, MFS-K100 of the upper shale member of Nahr Umr Formation, MFS-K140 of the upper Mishrif carbonates, and MFS-K150 of the lower Khasib shale member). Three 3rd-order genetic mega-sequences were embraced between the cited chrono-markers. The markers have been considered as regional key-surfaces for the Late Albian – Cenomanian to Early Turonian and Late Turonian to Early Coniacian stratigraphy of the south Iraqi oil fields. Eight 4th-order genetic meso-sequences (MS1 to MS8) have been established, comprising multiple 5th-order high-frequency (HF) lithofacies cycles, successively arranged in the mega-sequences without disturbance. MFS-K135 (this study), MFS-K140, MFS-K150 and Seven successive regional chrono-markers [MFS-K120, MFS-K125 (this study), MFS-K130, and MFS-K160 of upper Khasib shale member] started from lower Ahmadi shale member, identify these meso-sequences. Associated fifteen key-surfaces (K121, K122, K123, K124, K125, K126, K127, K128, K129, K131, K132, K133, K134, K141 & K142) have been described as well. The meso-sequence 1 signifies Ahmadi lithofacies buildups, whereas; the other meso-sequences represent Mishrif lithofacies buildups. The Rumaila carbonates come across the first HST-unit of the meso-sequence 2. The*

*meso-sequence 8 represents the Khasib carbonate facies buildups. The depositional super-sequence is terminated by type-1 sequence boundary SB-K150 at the top of the Mishrif Formation, created by maximum regression (MR). The study declares 15 reservoir syn-layers and 9 non-reservoir layers; each is essentially characterized by HF-single-lithofacies-cycle and lateral continuity pattern. This syn-layer model can be used as sequence steering technique for carbonates heterogeneity aspects, in the south Iraqi oil fields to control fluid dynamics in primary and secondary development projects.*

Keywords: Chronosequence stratigraphy; Chrono-marker; Synchronous Layering; Sequence steering technique; Reservoir optimization

## INTRODUCTION

The scope and work importance of this study is concentrated on the application of the high resolution sequence stratigraphic context of the AP-chronostratigraphic concepts for the Cenomanian multi-carbonates, from reservoir-scale key-surfaces to synchronous stratigraphic construction mainly in the Majnoon oil field (MOF) with relation to the nearby West-Qurna oil field (WQOF). The studied oil fields are displayed in Figure (1). The Early-Cenomanian to Late-Turonian carbonates succession was initially defined by Rabanit (1952) in Al-Siddiki (1975) at the Zubair well no-3, in the Zubair oil field (ZOF), southern Iraq (Fig. 1). ELF-Aquitaine (1995) and Al-Khayat (1998) studied the reservoir sequence stratigraphy and unit-layering system of the Cenomanian – Early Turronian succession in the Majnoon and West-Qurna oil fields. Both studies submitted eight decametric-scale sequences, which well separated by representative key markers from MFSs, to TSs and DSs (Fig. 2). The sequences from one to eight bounded by lower Ahmadi shale and lower shale member of Khasib Formation of Late Turronian specified with seven representative reservoir-units of the Mishrif Formation. The units were well correlated to the West-Qurna oil field (Al-Khayat, 1998). Eight chrono-sequences and reservoir-facies characteristics were determined via an updated 3-D geological study for the Mishrif Formation in the WQOF (Chevron and SOC study, 2006). According to Awadeesian (2010) and Awadeesian *et al.* (2015), the Mishrif reservoir in the North Rumaila oil field (NROF) synchronously subdivided and syn-layering model was introduced. This study is going to discuss the high resolution microfacies and sequence stratigraphy and declares a new reservoir characterization philosophy of synchronous modeling for proper fluid dynamics framework.

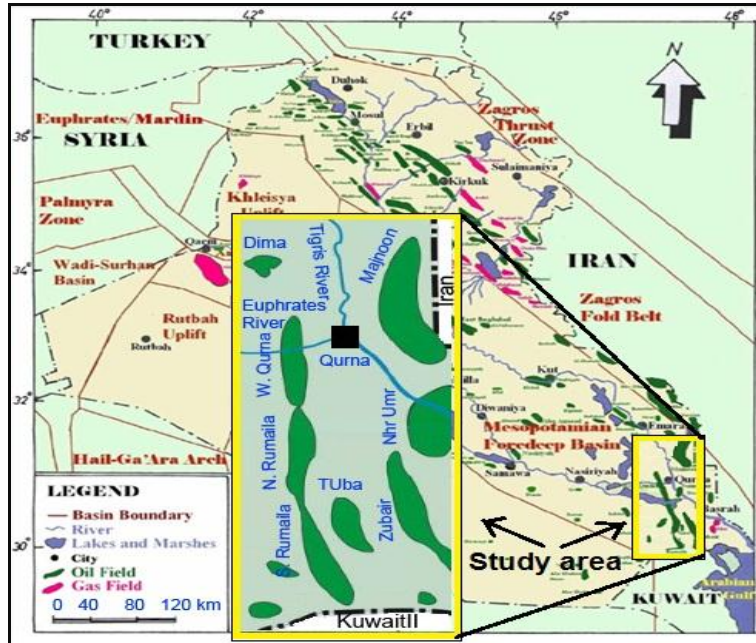


Fig. 1: Regional map of Iraq shows the studied oil fields, southeastern Iraq

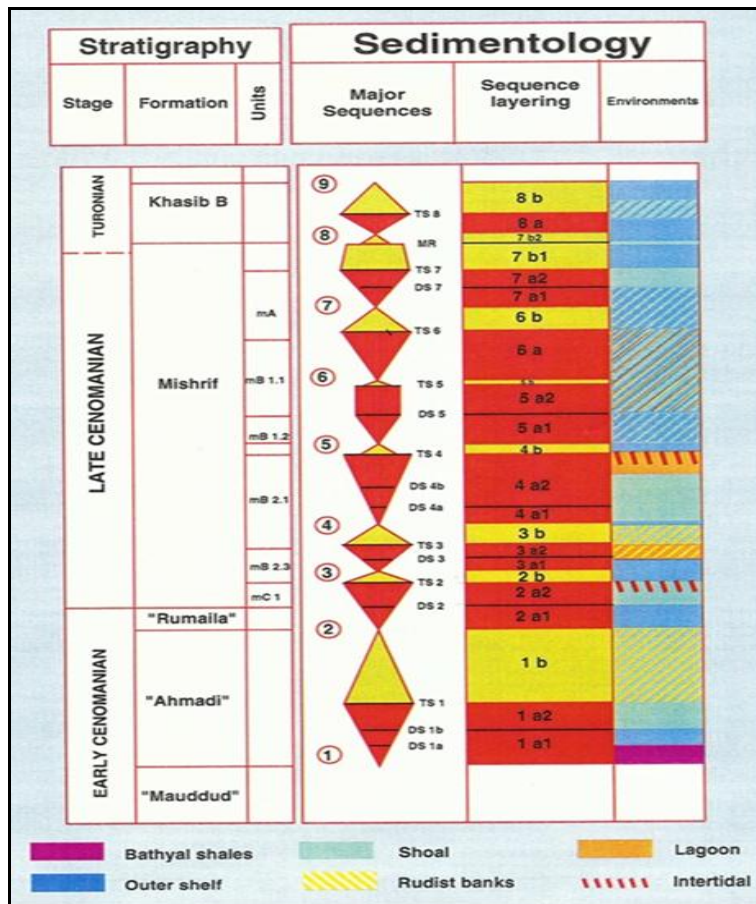


Fig. 2: Sequence stratigraphy of Ahmadi to Khasib succession, Majnoon Oil Field (ELF-Aquitaine, 1995)

## GEOLOGICAL SETTING

The geological setting of the study area is essentially considered a vital part of the tectono-sedimentary framework of the Mesopotamian fore-deep. The surface geology is characterized by non-structured stratigraphic cover of the Pliocene – Pleistocene sand-gravel to cobble of alluvium deposits belong to Dibdibba Formation covering of 100 – 200 m represents the final peneplanation-shelter with the recent maximum-regression. It was considered as a sequence boundary SB-1 of the last low stand system tract of the Neogene period (Sharland *et al.*, 2001 and 2004). The oil fields are characterized by simple elongated anticlinal structures almost of north-south trends (Fig. 1). The MOF in relation to the WQOF was considered as a reference field due its well-recovered succession. The both fields have a geometry of more than 40 Km long and 10 to 15 Km width on the top of the Mishrif Formation. The Mishrif Formation is a second most prolific oil reservoir in the southern Iraqi oil fields, of well-developed Rudistid bio-accumulated bank-shoal buildups. The petrophysical characterizations are well-improved with rims-buildup, located along the western southwestern flank-belt of the North-Rumaila field. During the Cenomanian age, the Mishrif paleohigh was clearly developed at the southeastern part of Iraq with gradual paleo-high deepening toward the northern part of Kuwait and to southwestern region of Iran. The western regional dip evidenced by well-developed outer to distal-outer shelf facies of the improved Rumaila intra shelf basin, the deteriorated-paleohigh part of the Cenomanian basin (Awadeesian, 1995 and 2002).

## MATERIALS AND METHODS

Two main methodological work schedules have been applied as the followings:

### High-Resolution Microfacies Investigation

More than 500 thin sections from different core-levels of the Ahmadi to Mishrif succession have been studied. Microfacies investigation based on semi-quantitative rock-fabric and faunal analysis (Awadeesian *et al.*, 2015) were used to described allochemical components; biogenic (skeletal), and un-biogenic (non-skeletal) to lime-mud matrix or spary calcite cement buildup related to diagenetic processes and products. Detailed petrographic study based on Dunham (1962), Embry and Klovan (1971), Flugel (1982), Lucia (1995) and Awadeesian (2002) as well as; semi-quantitative method of Bacelle and Bosellini (1965) in Schulze *et al.* (2005) were used

to describe the faunal occurrences: (very-rare = < 10%, rare = < 20%, common = < 40%, and abundant = > 40%). The lime-mudstone facies is described of less than 10% allochems, whereas; the mud-dominated wackestone facies of 10 – 20 %, grain-dominated wackestone facies of 20 – 40 %, mud-dominated packstone facies 40 – 70 %, grain-dominated packstone facies 70 – 90 %, and grainstone facies is of more than 90% components.

### **Log-Facies and Synopsis**

Various log-facies-types and key-surfaces are recognized and determined by Gamma-Ray, Neutron-Sonic, Spontaneous Potential and Resistivity logs, using significant log-signatures, implicitly considered in the correlation panel. For first-run high resolution sequence stratigraphic analysis, it is very fruitful to take the high gamma-ray reading over 40 API-units with high-CNL-reading/ low-Density-reading; as a basic tool to start with. Accordingly; integrated matching of log-facies with condensed shale and lime-mudstone facies, bioturbated highly argillaceous and dense to delineate; maximum flooding surfaces (MFSs), as consistent chrono-markers and related key-surfaces.

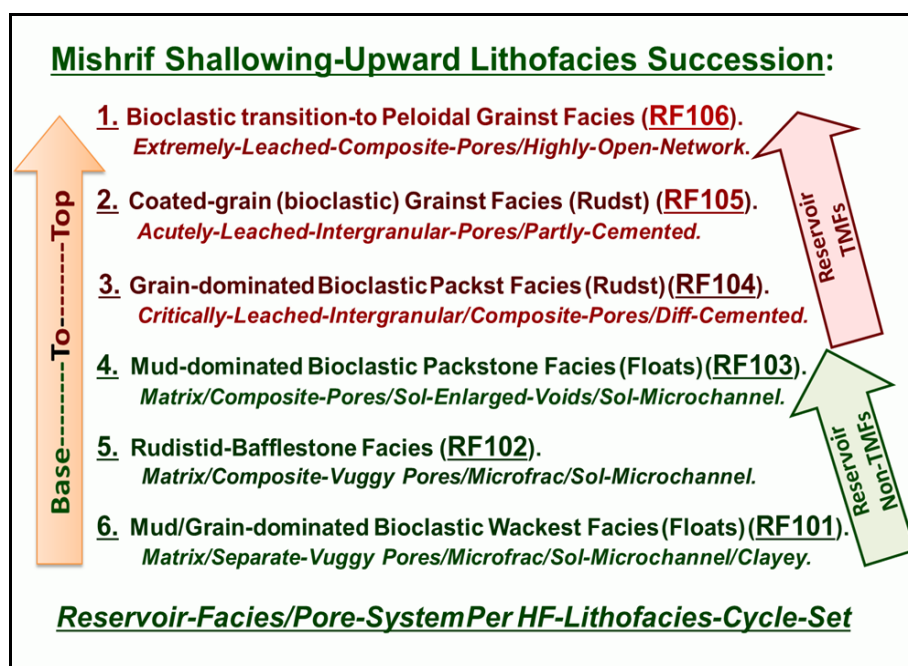
## **RESULTS**

### **Lithofacies Seccession**

Based on Chevron and SOC (2006) and Awadeesian (2008); six most important reservoir facies (RF) have been described from the recognized seventeen microfacies types for the studied succession (Fig. 3). All microfacies types have formulated to mud-or-grain-dominated textural buildups to determine the fining or coarsening upward rock-fabric system in each sequence. The figure illustrates the single high-frequency lithofacies shallowing-upward succession, with related rock-facies/ pore-system and characteristic cementation evolution. A complete reservoir facies cycle consists; one complete buildup of RF1 to RF6 succession described from non-to-semi troublemaker facies to acute TMFs. These latter types are highly responsible in creating water-bearing thief-zones during oil field development projects. The Cenomanian lithofacies successions described by this study are the descriptive rock-elements distinguished by specific allochem types, rock-fabric, sedimentary structures, depositional environment and early to late diagenesis using Dunham (1962), Embry and Klovan (1971) and Lucia (1995). The vertical lithofacies successions are marked by repeated shallowing-upward



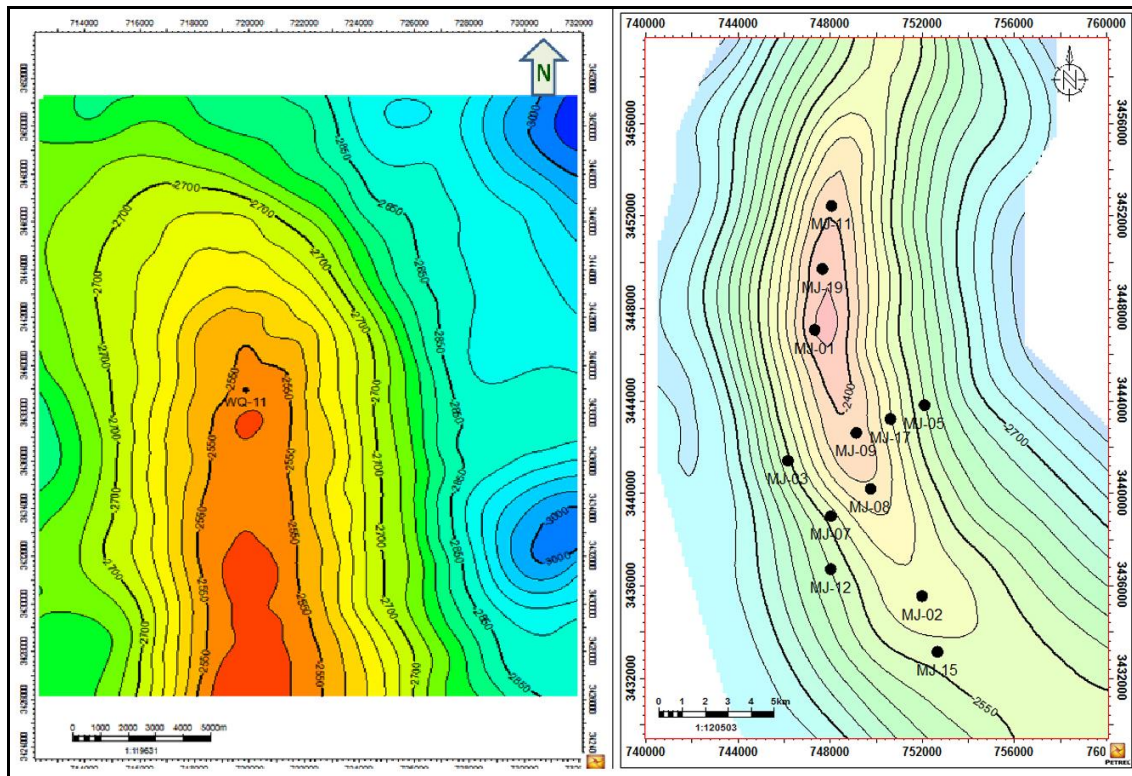
cycle. The single high-frequency (HF)-vertical lithofacies succession in a sedimentary cycle is indicated by vertical progression to coarser-grain-dominated lithofacies buildup of lithofacies tract genetically linked association that defines certain environmental settings. The ramp-crest lithofacies tract represents the depositional-profile from sea-level to the base of fair-weather wave-base, characterized by skeletal-shoals, oolitic-shoals lithofacies, algal-fenestral grain-dominated complexes, reefal-framestones or bindstones (Kerans and Tinker, 1997).



**Fig. 3: A summary of the Mishrif carbonates reservoir facies characterization in the North-Rumaila, West-Qurna and Majnoon oil fields, Chevron and SOC (2006), and Awadeesian (2008)**

The Cenomanian multi-carbonates lithofacies succession in the studied fields is made up from open-marine buildup to climbing-shoals and bioaccumulated-banks terminated by lagoonal settings. The succession performs stratigraphic architecture of reservoir HF-lithofacies cyclicity and spatial-continuity pattern. The single HF-lithofacies cycle is distinguished by shallowing-upward buildup of mud to grain-dominated bioclastic (pilled-type) wackestone facies and Rudistid (in parts the Rudists of growth position and partly fragmental) bafflestone facies, well-progressed to grain-dominated bioclastic packstone facies of floatstone-rudstone texture and coated-grain (bioclastic) to peloidal grainstone facies buildup. The measured total porosity ( $\phi$ -total)

specify these carbonates are ranged from less-than 8% up to 25%, whereas; the absolute-permeability ( $K_a$ ) values ranged from [less than 0.1 to more than 500 millidarcy (mD)]; has taken into special consideration by this study. The general thickness of the concerned carbonates in the Majnoon oil field is more than 400m, including Ahmadi – Rumaila – Mishrif lithostratigraphic succession. The oil-well WQ-11 was used as prototype section for analogy with Majnoon oil field. The study has taken Majnoon-wells: MJ-1, MJ-2, MJ-3, MJ-5, MJ-8, MJ-9, MJ-11, MJ-12, MJ-15, MJ-17, & MJ-19, owing to availability of the logs and well data (Fig. 4).



**Fig. 4: Sub-surface structural contour maps on the top of the Ahmadi Formation in WQOF (Left) showing location of the oil-well (WQ11) at northern sector of the field; on the top of the Mishrif Formation in MOF**

### Lithostratigraphic Succession

**Ahmadi Formation:** The formation is of Early Cenomanian age comprises three sedimentary members; the lower and upper members are of condensed-shale facies, dominated by argillaceous lime-mudstone facies deposited in distal-outer ramp buildup. The middle non-shaly member is bioclastic wackestone-packstone facies, rarely argillaceous, deposited in middle-outer ramp buildup, moderate to good porosity-permeability system depending on depositional settings. At the northern part of the

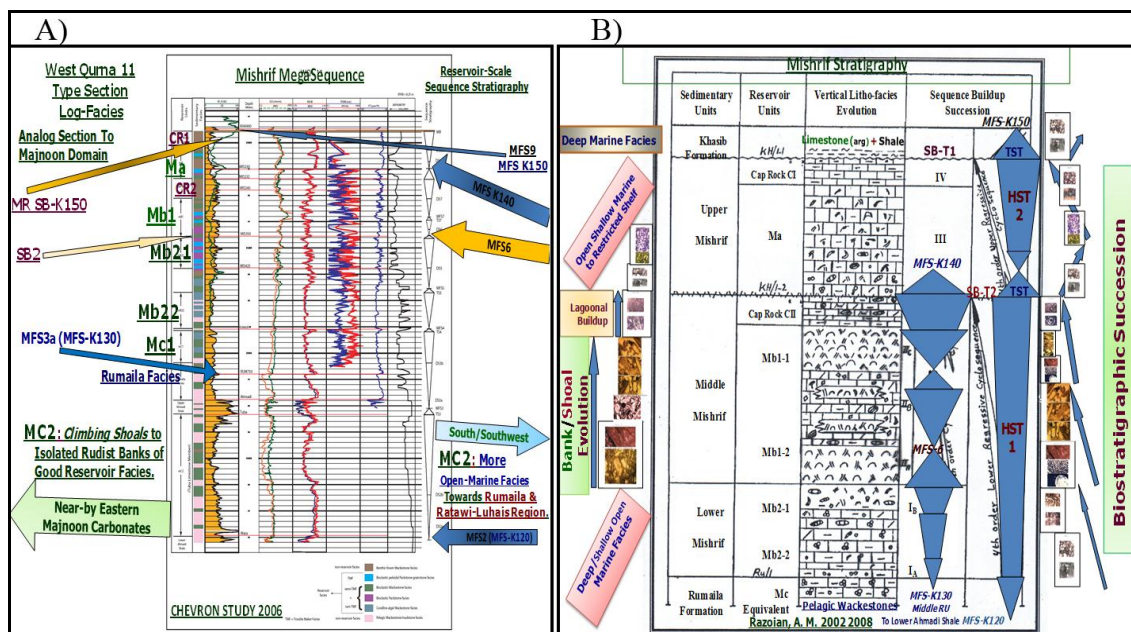
WQOF and MOF, this member specifies as a good reservoir facies/ poro-perm buildup, with 50 to 100 m thickness, whereas; it is non-reservoir-unit southwestwards to Rumaila – Ratawi and Luhais oil fields.

***Rumaila Formation:*** The formation is of Middle – Late Cenomanian, made-up by argillaceous pelagic mudstone facies of deep outer shelf buildup to shallow outer shelf facies of pelagic mud-grain dominated wackestone facies. The Formation is well developed to over 100 m thickness southwestwards of the study area, due to; the well-improved Rumaila intra-shelf-basin. At the MOF the Formation is less developed with thickness between 20 – 25 m.

***Mishrif Formation:*** The Mishrif Formation is of Late Cenomanian – Early Turronian age; represents the most specific carbonate buildup from standpoint of biostratigraphy and reservoir sequence stratigraphy in southern Iraq. The formation facies are improved along the paleo-high-development-settings, northeastwards from Rumaila area. Three lithostratigraphic units are identified as the Lower, middle and upper Mishrif members. The lower member is considered the gradual transitional phase from Rumaila Formation to fore-shoal facies of Mishrif carbonates, by upward-shallowing from pelagic mud-grain dominated wackestone to coralline algal wackestone-packstone/ bioclastic peloidal packstone facies. The middle Mishrif member is made-up of bioclastic wackestone/ bafflestone and bioclastic packstone/ grainstone facies of Rudistid-bank buildups, prograde to open shallow lagoonal benthic foram wackestone facies buildup. It is disconformably overlain by shallow-outer to restricted inner shelf facies of the upper Mishrif member, terminated by major regression of Middle Turronian (Figs. 5 and 6).

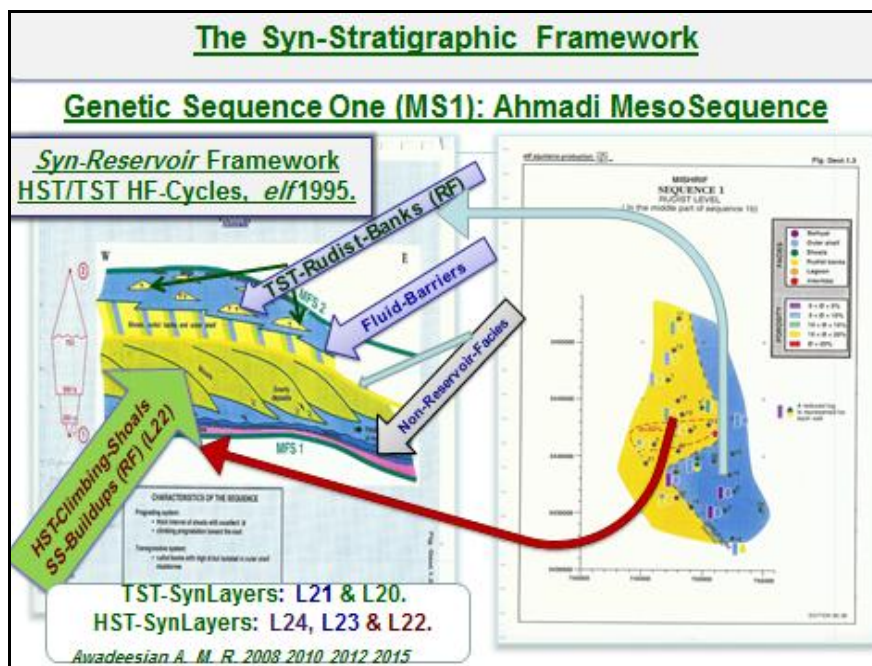
At the WQOF to MOF, the formation thickness is of 150 to over 400 m. Southwestwards of the study area, the formation degrades and completely disappears by the Rumaila intra-shelf basin.





**Fig. 5: A) Representative Sequence Stratigraphic buildup of the Mishrif – Ahmadi Succession, West-Qurna oil-well 11 (Chevron and SOC, 2006); showing by arrows reservoir-scale sequence stratigraphy and facies-change. B) Litho-Biostratigraphic and Sequence Stratigraphic buildup of the Mishrif Formation in the NROF and WQOF Awadeesian (2002 and 2008), modified in 2010**

**MFS-K140:** shaly lime mudstone facies at lowermost part of the Upper Mishrif litho-member. **Mb1:** Middle Mishrif (b), Rudistid-bioaccumulated-bank to open-lagoonal facies buildup, subdivided into Mb11 and Mb12. **MFS6** of (Chevron and SOC, 2006), **MFS-K130a** of (this study): the chrono-marker regionally crossing or terminating the bank. **Mb2:** Middle Mishrif (b), open shallow marine/ shoal facies buildup, subdivided into Mb21, Mb22/Mb23. **Mc:** the Lower Mishrif carbonates, the facies buildups depend on the depositional-setting of open-marine/ shoal facies buildups along West-Qurna and Majnoon oil fields, whereas; along the Rumaila and westwards regions more open marine facies buildup encounter. Subdivided into; **Mc1** and **Mc2**, the Latter equivalent to middle carbonates of Ahmadi formation. **MFS-K130** (Sharland *et al.*, 2004): consistent chrono-marker, crossing the lower-third part of the Rumaila Formation. **MFS-K120** (Sharland *et al.*, 2004): consistent chrono-marker of the lower Ahmadi shale member. **Ru/1:** lithostratigraphic key-marker indicates Rumaila Formation top. Progradational High Stand System Tract (HST). Retrogradational Transgressive System Tract (TST).



**Fig. 6: Mesosequence One MS1 consisting HST reservoir syn-layer L22, TST reservoir synlayer L21 and L20. Each of these 3 reservoir units behaves different rock-facies/ pore-system characteristics and fluid-dynamics, during completion/ production stages**

### Sequence Stratigraphy

The most significant sequence stratigraphic terminology used by this study have basically been schemed to the genetic sequence concepts of Galloway (1989) and to syn-stratigraphic buildup specifically given by ELF-Aquitaine (1995), in order to; hold wide-range carbonate reservoirs dynamics understandings and controlling (Kerans and Tinker, 1997).

**Transgressive Surface (TS):** The TS identified by this study represents the first indication of the transgression episode; and has taken at the turn-around from base-level-fall to base-level-rise. It signifies a short period of subaerial exposure of micro to mega-vugs and solution enlarged-voids, differently cemented, progressed to 1 – 2 m lime-mudstone and mud-dominated wackestone facies partly argillaceous, glauconitic of indistinct biozone represents flooding surface (FS) of hard-ground character. The Gamma ray values between 20 to 50 API units and low neutron units were basically used to identify the TSs. The transgressive surface is directly overlies the top of coarsening-upward cycle, and properly taken as a candidate for potential sequence boundary (SB).

**Maximum Flooding Surface (MFS):** The MFS has taken as consistent chrono-stratigraphic marker characterized by; lime-mudstone argillaceous and shale facies, of non-characterized bioturbated zone. It has well taken at the turn-around from the maximum base-level-rise to the start of base-level fall. The use of the MFS key-marker is to separate the retrograde and prograde system tracts. The MFS characterize by the highest unit-value (30 – 70) API of gamma-ray-units of a specific maximum flooding interval, with lowest neutron unit reading. The MFS is a carbonate dead-line marker of a carbonate factory specified by bathyl shale/ shaly-lime mudstone facies.

#### **Downward-Shift Facies (DS)**

The DS is described; as synchronously prograded basinward-shift of local bank and shoal facies, close to the shelf margin in off-lapping depositional system. The DS is of mud-grain dominated benthic forams mudstone-wackestone facies of restricted/ open shelf lagoonal buildup. The facies identified by slightly compact low to moderate API-gamma units with high resistivity and low to moderate values of neutron-unit interval. The DS-surfaces distinctively separate high-frequency shallowing-upward cycles, ended by TS-surface.

The DS-surfaces are good correlatable stratigraphic key-markers for reservoir layering for lagoonal-offlap/ shoal-cycle (climbing shoals) of sea-ward stepping pattern.

**High Frequency Cycle (HFC):** The term "cycle" described by this study; as the basic building block for carbonate stratigraphic analysis. The HFC specifically refers to the smallest set of genetically related lithofacies deposited during a single-base-level-cycle, comparable to "parasequence" of Van Wagoner *et al.* (1988). The individual high frequency cycle defines the single vertical litho-facies succession, and the cycle-boundaries have taken at turn-around from base-level-fall to base-level-rise, regular to parasequences, high-frequency sequences, and composite sequences. The cycle-set implicitly used in the study; equivalent to Van Wagoner's parasequence set.

**High Frequency Sequence (HFS):** The HFS as the all attributes of the depositional sequences including transgressive, high stand and low stand system tracts and their high frequency cycles and cycle sets. The HFS has persistently taken by Kerans and Tinker (1997) as a basic building block for establishing a tight chrono-sequence with particular boundaries at the turn-around of two dimensional stacked cycles. The studied HFS is

characterized by; 4th to 5th-order eustatic-fluctuations of 10 – 400 thousands-years cycles (k.y.). The sequences consist of offlap and onlap surfaces, of multiple shoal-buildups and minimal tidal-flat caps progressed to bank(s) and open marine buildup.

**Cyclicity Hierarchy:** A cyclicity-hierarchy is defined as a basic step for constructing a 1D and 2D stratigraphic framework. The Albian-Cenomanian – Early-Turonian succession has considered regional dual lowstand-set unconformity-bound 2nd-order depositional super sequence (Sharland *et al.*, 2001 and 2004) of over 14 m.y duration. The cyclicity hierarchy system is of: 3rd-order cycles created by the sea-floor spreading mechanisms and high-frequency climatic to glacio eustacy, or long-term tectono-eustatic cycles of 1 – 3 m.y (Haq *et al.*, 1987 in Kerans and Tinker, 1997) or 1 – 10 m.y (Goldhammer *et al.*, 1991). The 4th-order cycle-packages; are largely tied to the eccentricity mechanisms during icehouse-periods as 100 k.y to 1 m.y sedimentary cycles, *whereas*; the 5th-order cycles, is defined 10 to 100 k.y sedimentary-units.

**Accommodation and Depositional Topography:** The single most important stratigraphic variable controls the rock record in a shallow marine setting; is the depositional topography, which is directly related to the variations in the accommodation. A 3-D volume-picture bounded by the water-sediment interface and sea level, widely defines the accommodation. High lithofacies diversity of high accommodation TST; preserves reefs to shoals topographies, whereas; low accommodation HST characterizes thin-HFC of less diverse vertical lithofacies. The abundance of shingled-grainstones and offlapping cycles are flourished as the accommodation decreases.

**Chrono-Sequence (CS):** The CS is particularly defined as progradational to retrogradational high-frequency sequence evolutionary sedimentary-trend, persistently bounded between two well-developed consistent maximum flooding surfaces (time-markers). It represents well-developed carbonate factory, as well-correlatable and mappable chrono-stratigraphic unit, consists one to several cyclic-bundles of petrophysically prime importance. The chrono-sequence has recognized for a particular sedimentary and faunal package of characteristic biostratigraphic zone(s), which in turn identifies a proper chronostratigraphic-unit. The unit is well bounded by either condensed sections/ or stilly-stand carbonate buildups; initiate and terminate the

sequential carbonate succession of intended chrono-sequence (Van Wagoner, 1995 in Kerans and Tinker, 1997). Refer to Figure (5A) for Cenomanian carbonates in WQOF. **The** sequence stratigraphic terminology used by Chevron and SOC (2006) and Awadeesian (2010) is mainly based-on; the Arabian chronosequence stratigraphic framework of Cretaceous (K) succession, as it is stated in Figure (5A & 5B): **MFS9** Chevron and SOC 2006, **MFS-K150** Sharland *et al.*, 2001 and 2004: characterized by the Lower shale member of Khasib formation. **MR (SB-K150)**: maximum regression (sequence-boundary type1 **SB-T1**) at the top of Mishrif Formation, equivalent to limonitic litho-marker KH/1-1. **CR1**: cap rock one, characterized by; shallow-shelf lagoonal facies, of dense compact limestone of very low porosity/ permeability buildup, between the top of Mishrif and the top of upper reservoir unit (**Ma**). **CR2**: characterized by; open-shelf lagoonal facies, of dense compact limestone, of very low porosity/ permeability buildup, between the base of Ma and the top of reservoir unit Mb1. The top of cap-rock2 is a regional disconformity (**SB-T2**); a facies change boundary, equivalent to KH/1-2 litho-marker.

## DISCUSSION

### Cenomanian Genetic Sequence Stratigraphy

Based on Galloway (1989), the genetic (G-sequence) stratigraphic context participated with the Arabian Plate (AP)-chronosequence stratigraphy principles given by Sharland *et al.* (2001 and 2004) and Awadeesian (2008 and 2015) have been applied on the studied 2nd Cretaceous carbonate factory in south Iraq. This study adapts three 3rd-order genetic G-sequences embraced between MFS1 to MFS3, MFS3 to MFS8, and MFS8 to MFS9 chrono-markers of the Albian-Cenomanian to Early Turronian 2nd-order depositional super-sequence (Fig. 5A), as the upper part of the Arabian plate (AP) tectonostratigraphic megasequence (AP8). The MFS1 represent MFS-K100 chrono-marker of the upper shale member of the Nahr Umr Formation, and the MFS2 signifies MFS-K110 of lower the Maaddud carbonates; and the both are not involved in this study. The MFS3 is the MFS-K120 chrono-marker of the lower Ahmadi shale, signifies the beginning of the studied carbonate factory. The AP-chronosequence stratigraphy of the southern Iraqi Albian-Cenomanian to Early Turronian succession 2nd-order depositional super-sequence, has been distinguished by three main chrono-markers: The AP/MFS-K100 of the upper shale of the Nahr Umr Formation, the AP/MFS-K140 of



the upper Mishrif carbonates, and the AP/MFS-K150 of lower Khasib shale. This super-sequence consists of three 3rd-order G-sequences embraced between the cited chrono-markers. The markers have been considered regional key-surfaces for the Late Albian-Cenomanian to Early Turonian and Late Turonian to Early Coniacian stratigraphic succession of the south Iraqi oil fields. Eight 4th-order genetic meso-sequences MS1, MS2, MS3, MS4, MS5, MS6, MS7 and MS8 have been established embracing 5th-order high-frequency lithofacies cycles. The meso-sequences successively arranged in one complete mega-sequence without disturbance. The second 3rd-order G-sequence MFS-K120 – MFS-K140 is described by SB-type 2 (K134) at the base of MFS-K140. The study submits; 30 regional-AP and local key-markers specified by MFSs, Downward-Shift Facies (DSs), Transgressive Surface (TSs) and sequence-boundaries; itemized as: MFS3 (MFS-K120), K121, K122, K123, K123a, MFS3.1 (MFS-K125), MFS4 (MFS-K130), K124, K125, MFS4.1, K126, K127, MFS4.2, K128, K129, MFS5, K130, MFS6 (MFS-K135), K131, K132, K133, K134, MFS8 (MFS-K140), K141, K142, SB-K150 (MR), MFS9 (MFS-K150), TS8 and MFS10 (MFS-K155) of upper shale member of the Khasib Formation. For the Cenomanian succession; the first itemized MFS-marker is MFS-K120 (Sharland *et al.*, 2001 and 2004), represents maximum full-depth sedimentation of Bathyal condensed section, mainly of shale and shaly lime mudstone facies buildup of the lower shale member of the Ahmadi Formation. The DS and TS surfaces are good evidence for sea-ward stepping (SS) and land-ward stepping (LS) depositional aspects respectively. Eight meso-sequences are successively covered the above mentioned super-sequence, refer; as in the formation correlation panel.

***The Mesosequence One (MS1):*** The first Cenomanian genetic-sequence is encountered between the chrono-markers (MFS3, MFS-K120) of the lower Ahmadi shale member and (MFS3.1, MFS-K125) of the upper Ahmadi shale member, with key-surfaces (K121 to K123a), (Fig. 6). The MS1 is aptly characterized by long HST-facies buildup manifested by (K122 and K123a) key-surfaces and medium to long TST-facies buildup (K123a and top of Ahmadi Formation). The MFS-K125 is described by this study as a local stratigraphic term terminated sequence MS1. The (Mc2) limestone of the Ahmadi; is described as multi-carbonates of progradational-HST followed by retrogradational-TST. The DS-shoals are progressed to backstepping-shoals and isolated Rudist-banks in

outer-shelf lime-mudstone. The well-developed SS climbing-shoals, particularly encountered in the syn-layer L22 between the key surfaces K122 and K123a of good to very-good reservoir characteristics, of good oil bearing reservoir in the MOF and at the central-northern sectors of the WQOF. The MS1; is a good synchronously-based example for Cenomanian carbonate reservoirs production optimization in field development agenda, as per HST-TST reservoir-syn-layering. The back-stepping shoals of syn-layer L21, is completely differs from the lower climbing-shoals of L22 and from the upper isolated Rudistid-banks of the syn-layer L20, by; facies/ pore per poro-perm buildup, which highly controls fluid-dynamics of the Cenomanian reservoirs. This reservoir syn-layer is useful in the oil-well completion programs for the Ahmadi and Mishrif Formations.

**Mesosequence Two (MS2):** This sequence is clearly bordered by the chrono-markers MFS3.1 (MFS-K125) and MFS4 (MFS-K130) of the middle Rumaila facies, embraces K124 and K125 key-surfaces. The sequence comprises the Rumaila shallowing-upward open shallow marine facies buildup, obviously embraced from MFS-K125 to K124. The Mc1-lithounit is well encountered between K124 and K125, as well-developed fore-shoals of good poro-perm buildup, ended by TS2 (K125) and open marine facies TST-buildup, lower Mb2-3 unit, specified by low poro-perm.

**Mesosequence Three (MS3):** The sequence is delimited by MFS4.1 and MFS4.2 chrono-markers, embracing the K126 and K127 key-surfaces. The sequence comprises the upper part of Mb23-lithounit MFS3 to K127 (HST)-buildup and the lower part (TST-buildup) of the Mb21-lithounit bounded between K127 and MFS4.2. The prograded lagoonal benthic foram wackest facies of the HST-buildup highly affected the Rudist-banks, with well-developed fore-shoals and Rudist-banks in TST-buildup.

**Mesosequence Four (MS4):** This meso-sequence is bounded between the chrono-markers (MFS4.2) and (MFS-K135) embraces the K128, K129 and K130 key-surfaces. The sequence comprises the upper part of Mb21 litho-unit MFS5 and SB-K130 representing long HST-buildup, with good-FPPS, and the lower part of Mb1 major-unit specified by relatively short open shallow marine facies TST-buildup with low (FPPS) between SB-K130 and MFS-K135 markers.

**Mesosequence Five and Six (MS5 and MS6):** This sequence is bordered between the [MFS6 (MFS-K135)] and [MFS8 (MFS-K140)] chrono-markers, embracing the K131, K132, K133 and K134 key-surfaces. The sequence comprises the upper part of Mb1 major-litho-unit; characterized by medium HST-buildups between the MFS-K135 to K134 key-surfaces, involving the lower part of the Ma major-unit represent short (TST)-buildup between the K134 and MFS-K140 key-markers. The interval encountered between the key-surfaces K133 and K134, characterized by lagoonal facies setting signatred as: Cap rock II (CRII), as a terminal-phase for the lower major Mishrif-unit.

**Mesosequence Seven (MS7):** The sequence is expressly bounded between MFS-K140 and MFS-K150 chrono-markers, embraces K141, K142, and MR key-surfaces of long (HST)-buildup, truncated by regional unconformity as a maximum regression (MR) of sequence boundary type-1, at the top of Mishrif formation. The MFS-K140 to K141 interval represents the litho-unit Ma2, whereas; the interval K141 – K142 represents Ma1 litho-unit. The interval K142 to MR key-markers, is of restricted/open-shelf-lagoonal setting, and manifested as cap rock I (CRI), representing the terminal-phase of the Cenomanian mega-sequence.

**Mesosequence Eight (MS8):** This Late Turronian – Coniacian Khasib sequence has identified; between the MFS-K150 and MFS10 (MFS-K155) of upper Khasib shale chrono-markers, with TS8 key-surface. This mesosequence represents medium-HST-buildup of open shallow marine and fore-shoal facies; Kh-B (MFS-K150 – TS8) unit of good reservoir characteristics at northeastern part of the field.

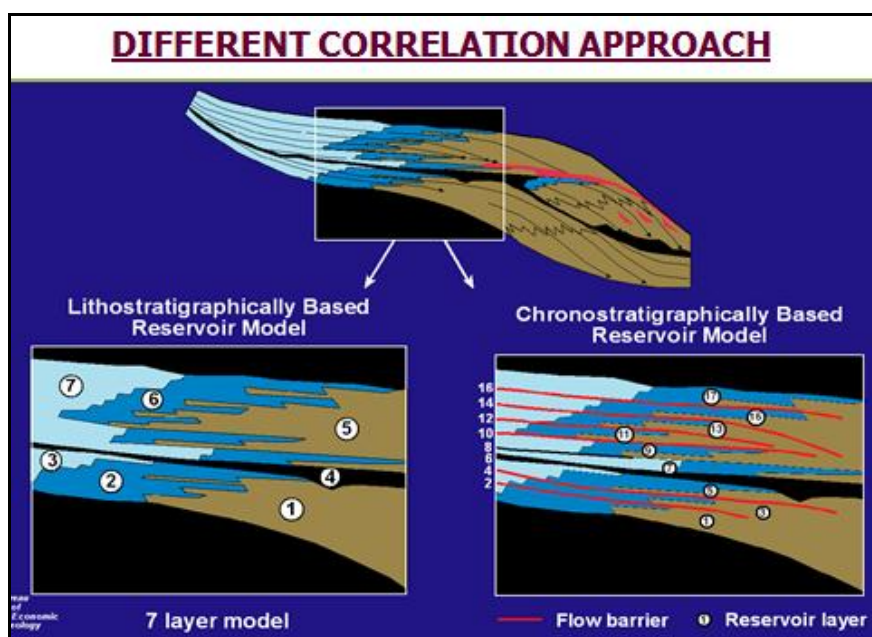
### **Reservoir SYN-Layering Model**

To construct synchronous reservoir architecture for better understanding of the Mishrif reservoir dynamics: the following chronostratigraphically-based reservoir subdivision has introduced for Majnoon oil field. A 24 syn-layer model has established for the studied wells, as illustrated in the correlation chart between the wells MJ-11, 19, 1, 9, 8, 12, 2 and 15.

**The Syn-Layers Terminology:** MR – K142 = **L1** = CR1, K142 – K141 = **L2** = Ma1, K141 – MFS-K140 = **L3** = Ma2, MFS-K140 – K134 = **L4**, K134 – K133 = **L5** = CRII, K133 – MFS6 = **L6**, MFS6 – K132 = **L7**, K132 – K131 = **L8**, K131 – MFS-K130 = **L9**,

MFS-K130 – K130 = **L10**, K130 – K129 = **L11**, K129 – K128 = **L12**, K128 – MFS4 = **L13** (L11, L12 and L13 upper Mb21), MFS4 – K127 = **L14** (lower Mb21), K127 – K126 = **L15** (Mb23), K126 – MFS3 = **L16**, MFS3 – K125 = **L17** (base of Mb23, Open Marine Facies), K125 – K124 = **L18** (Mc1), K124 – Top of MFS2 = **L19** (Rumaila facies). *The Ahmadi Syn-Layers*: MFS-K120a (MFS2) – K123a = **L20**, K123a – K123 = **L21**, K123 – K122 = **L22**, K122 – K121 = **L23** = Open Marine Facies, K121 – MFS-K120 = **L24** = Bathyal condensed section.

*The Reservoir Syn-Layers Buildup*: The Mishrif – Ahmadi carbonates reservoir-syn-layering buildup is accomplished according to chronostratigraphic scheme given by the Bureau of Economic Geology, Austin University, in Kerans and Tinker (1997); that clearly based on downward facies change and flooding surfaces (Fig. 7). These surfaces characterized by barrier-flow fonts across the basin, and finally presented in the correlation panel.



**Fig. 7: Different Correlation approach given by Bureau of Economic Geology, Austin University, in Kerans and Tinker (1997); the chrono-based reservoir model showing syn-deposited-layers (reservoir layers) bounded by flow-barriers**

A) **L2 (K142 – K141.1)**: The layer; is mainly made-up; of mud/ grain-dominated bioclastic wackestone facies and grain-dominated bioclastic packstone/ Rudist-bafflestone graded to floatstone/ grainstone facies, HST-Rudistid-banks and back-

shoals buildups, Figures (8, 10, 11 and 13-1). The buildups are good to very-good facies/ poro-perm system (FPPS), and well-improved around the area MJ-5, 17, 9, 19 and MJ-11. The buildups; deteriorate toward the southwest around MJ-12 by lagoonal-setting of dense benthic foram wackestone facies. It signifies upper Ma-unit of south oil company terminology.

**B) L3 (K141 – MFS-K140.1):** This layer; is mainly made-up of mud/grain-dominated bioclastic wackestone facies and grain-dominated bioclastic packstone (floatstone) graded to grainstone facies of open shallow marine/ fore-shoals buildups (Figs. 8, 10, 11 and 13-1). The buildups are of good to very-good FPPS, well-improved around the area of MJ-5, 17, 9, 19 and MJ-11. The back stepping-shoals; retrograde towards MJ-9, 8, 3 to MJ12 at the southwestern part of the field declining the lagoonal-facies, middle Ma.

**C) L6 (K133 – MFS6):** This layer; is mainly made-up of grain-dominated bioclastic wackestone facies to grain-dominated bioclastic packstone (floatstone)/ grainstone facies buildup, Figures (6, 7, 8, 10, 11, 12 and 13) represent; bank/back-shoals/lagoonal-setting. Good to very-good FPPS and well-improved around MJ-5, 17, 9, 19, 10 and MJ-11. The backstepped fore-shoals-buildups from MJ-5, 17, 9 and 10 to MJ-8, and southwest to MJ-12, are dismantled by well-developed benthic foram wackestone facies. While; towards MJ-10 and MJ-11: fore-shoals well-developed. It signifies upper Mb1-unit.

**D) L7 (MFS6 – K132):** The layer; is mainly made-up of grain-dominated bioclastic wackestone facies to grain-dominated bioclastic packstone (floatstone)/ grainstone facies, bank/back-shoals buildups (Figs. 6, 7, 8, 10, 11 and 13). The buildups of good to very-good FPPS, and well improved around the area joined by oil-wells MJ-5, 17, 9, 10, 19 and MJ-11. The backstepping-shoals-buildups; are significantly deteriorated from MJ-5, 17 and 9 to MJ-8, by lagoonal facies buildups, and southwestwards to MJ-12, at which the shoals completely deteriorated, represents upper Mb1-unit.

**E) L8 (K132 – K131):** Characterized by; grain-dominated bioclastic wackestone facies and grain-dominated bioclastic packstone/ grainstone facies, represent; HST-Rudistid-banks/back-shoals buildups, (Figs. 6, 7, 8, 10 and 13). These buildups are of



good to very-good FPPS, well-improved around the area joined by MJ-3, 5, 17, 9, 19 and MJ-11. The backstepping of the back-shoals buildups is from the area bounded by MJ-5, 17 and MJ-9, towards MJ-8 and southwest at the vicinity of MJ-12. The whole buildup dismantled into multiple HF-cycles by well-developed lagoonal facies. The detection of the MFS6-marker; is very important for separating/or compiling the L6, L7 and L8 units, characterizes the middle Mb1-unit.

**F) L9 (K131 – MFS-K130):** During deposition of this layer, the shelf-progradation started from MJ-3, 12, and 15 areas northeastward to MJ-5, 17, 9, and 19; created good chances for bank/shoal development, with open marine facies influence at the lowermost part almost around the whole Majnoon field. Well intertounge with lagoonal facies at the southwestern part. The upper part of the unit is characterized by well-developed grain-dominated bioclastic packstone and coated grain (bioclastic) grainstone facies buildups, with improved FPPS. The grainstone-shoals climb toward east-northeastwards, with well-developed 3-separate-buildups; the first located within MJ-8, 12, 15 and MJ-16, whereas; the second & third areas within MJ-17, 9, MJ-1 and MJ-19 created; shelf-edge dismantling (Figs 6, 7, 8 and 11). It signifies lower Mb1-unit.

**G) L11 (K130 – K129):** The upper-part of this layer; is specifically composed of downward shift climbing-shoals towards east-northeastward of the field. It characterized by; well-developed grain-dominated bioclastic packstone facies, progressed to; coated grain (bioclastic) grainstone facies buildups with improved FPPS, of variable reservoir qualities, non-cemented types of Figure (8).

Well-improved prograded benthic foram wackestone and lime-mudstone facies buildups at the uppermost part of the unit, towards (MJ-12). The lower part consists of regular non-climbing-shoals throughout the field, comprised same former facies-buildup. It is considered by ELF-Aquitaine (1995); extensive reservoir-drain (d2) in the Buzurgan field (Amara-region), and of good reservoir characteristics over Majnoon field, as well, represents upper Mb21-unit.

**H) L12 (K129 – K128):** Characterized by; well-developed grain-dominated bioclastic packstone facies progressed to coated grain (bioclastic) grainstone facies plate 3, with improved facies/ poro-perm system over Majnoon oil field. It is considered an extensive reservoir-drain (d3) by ELF-Aquitaine (1995). The facies progressed to

backstepping-shoals, with open marine facies towards the southwestern area of the field, created variable reservoir-qualities. It denotes middle Mb21-unit.

**I) L13 (K128 – MFS4):** This reservoir layer; which is considered the lower part of Mb21unit, expressly characterized by: well developed grain-dominated bioclastic packstone facies and coated grain (bioclastic) grainstone facies (Fig. 8), with improved facies/poro-perm system. It is progressed to; backstepping-shoals intertounge with open marine facies towards the area of MJ-5, 17, 9, 3, 1, and MJ-2, of variable reservoir qualities. Good shoal-buildups within MJ-15, 12, 7, 13 and 16 areas, and between MJ-19 and MJ-11 as well, with continuous good reservoir characteristics.

**J) L14 (MFS4 – K127):** The layer mainly made-up of mud/ grain-dominated bioclastic wackestone facies and grain-dominated bioclastic packstone (floatstone)/bafflestone to grainstone facies (Figs. 6, 7 and 8).

Well-developed TST-Rudistid-banks/ fore-shoals; improved toward the southwestern area of the field. Good facies/ poro-perm system, good reservoir quality. The L14 is considered the lower-most part of the Mb21-unit.

**K) L15 (K127 – K126):** Characterized by; mud/ grain-dominated bioclastic wackestone facies and grain-dominated bioclastic packstone (floatstone) to grainstone facies, Figures (6, 7, 10 and 11) of thin-moderately-developed HST-Rudistid-banks and shoals. The buildups are well-intertounge with improved benthic foram wackestone facies over the entire Majnoon oil field. Characterized by; moderate FPPS, poor to medium reservoir quality, represents upper Mb23-unit.

**L) L18 (K125 – K124):** It is essentially made-up of grain-dominated bioclastic wackestone facies/ grain-dominated bioclastic packstone (floatstone)/ grainstone facies, non-cemented types of Figure (8, 10, 11 and 13). Represent HST-prograded-shoals, climbing toward the northeastern areas. The buildups are of good to very-good FPPS characteristics. The reservoir characteristics; are highly degraded toward the east of the line joining MJ-5, 10, 18, 1, 19, and MJ-13, 16, 6, 2, 15, due to; well-developed open marine facies, whereas; at MJ-11 represents the area of well-developed shoals to Rudistid-banks. Characterized by; good shoal-buildups of good FPPS, nearly of continuous belt within MJ-12, 14, 5, 17, 9 and MJ-10 area. The

shoal/Rudistid-bank buildups; are highly controlled by open marine facies within MJ-5, 17, 10 and MJ-19, it represents Mc1-unit.

**M) L20 [MFS-K125 (MFS2) – K123a]:** Non-stacked TST-Rudistid-banks-buildups of isolated-setting in the outer-shelf lime mudstone facies, good FPPS and discontinuous-reservoir-framework. The description of HF-lithofacies cycle-set of mud/ grain-dominated bioclastic-wackestone/ grain-dominated bioclastic packstone/ bafflestone facies, and pelagic-lime-mudstone facies buildups; it is of prime importance for oil-well-completion program, represents Mc21-unit. Refer to Figures (6, 7, 10 and 11).

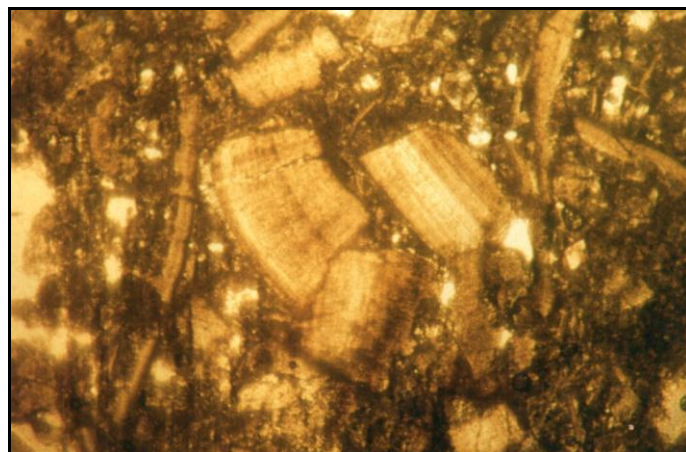
**N) L21 (K123a – K123):** The layer; is made-up of mud/ grain-dominated bioclastic wackestone facies and grain-dominated bioclastic packstone (floatstone)/ grainstone facies, of well-developed TST-Rudistid-banks/ fore-shoals (Figs. 7, 8, 10, 11 and 13). These buildups are of variable facies-poro-perm-system, of moderate/good reservoir qualities. The lime-mudstone-facies/ benthic foram wackestone facies buildup separate L20 and L21 units, is of prime importance for completion programs, Mc22-unit.

**O) L22 (K123 – K122):** This layer; is essentially made-up of grain-dominated bioclastic wackestone facies/ grain-dominated bioclastic packstone (floatstone) facies, and coated-grain bioclastic grainstone facies (Fig. 8) of well-developed HST-prograded-shoals buildups, downward climbing toward northeastern area of the field. The buildups are of good to very-good FPPS, good reservoir characteristics. The cyclicity hierarchy of the downward-shift shoals northeastward from the wells MJ-3, 12, 15, to MJ-10, 9, 8, 2 and MJ-5; is of vital-importance for development of MS1. The separating of L-20, L-21 and L-22 depends on K123 character; which is very important for completion and production programs; it signifies the Mc23-unit.

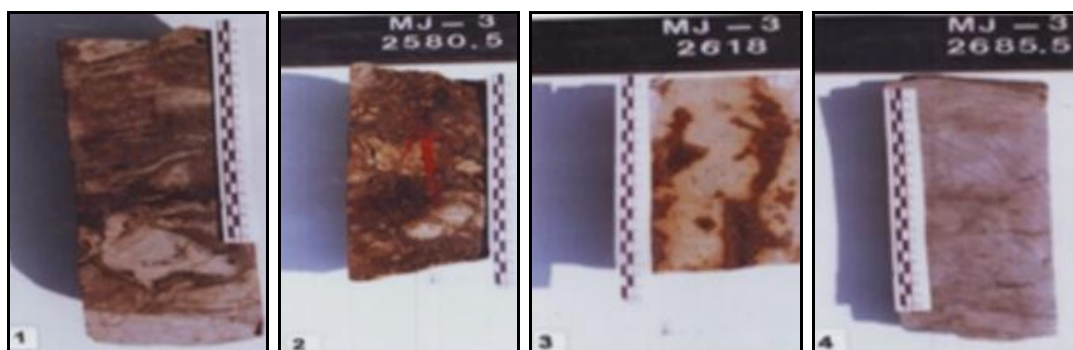
***The Most Important Cenomanian Microfacies:*** types from the well-recovered core-intervals and good thin-sections of the mentioned oil-wells have petrographically studied; and presented in the following photomicrographs as in their depositional order (Figs. 8, 9, 10 and 11). Figure (8) displays different sized Rudist and Mollusks debris, smaller-than 2 mm, worn, angular, poorly to moderately sorted, rarely transported, disoriented in micritic matrix, with micro-stylolite. Well-developed separate vugs open with improved solution micro-channel, enlarged the micro-stylolite, oily at the lower-

right part. Figure (9) represent the microfacies at MOF. Figure (10) displays bafflestone facies, with large partitioned Rudist fragment, Caprinid or Eoradiolite of more than 15 cm in length, the Rudists behave good capability in trapping micritic-matrix to below the wave-base. It represents bioaccumulated-bank of the reservoir-layer L6, signifies patch-bank/ inner shelf lagoonal setting, north to northeastward from Rumaila, West-Qurna to Majnoon and Buzurgan region. Well-developed intra-bioclastic pores of open network, inparts cemented by equi-mosaics with solution micro-channel oily impregnated at the lower left hand side. **2 and 3:** Bafflestone facies; solitary hexacoral, subsidiary organic-builder of Mishrif carbonates with intra-bioclastic pores cemented by equi-mosaics, represent bank/inter-bank buildup. Rudistid bioclastic packstone-grainstone (floatstone/ rudstone) facies in Figure (11) is explained as: **1:** Echinoid plates (**a**) with cyntaxial-rim cement and the Rudist fragment (**b**) with isopachous-rim, most of the bioclasts are less than 2mm in size; well rounded, moderately sorted, normally packed. Shoal facies of L13 with good vugular pore system, selectively dissolved and well cemented, of micro-meso pores (5 up-to 20 microns) in size. The cementation is highly considered as fluid-obstacle. Oil-well Mj-3: 2756 m **2:** Peloidal bioclastic grainstone facies, the Rudist and Mollusk-debris are with isopachous-rims, the Echinoids with cyntaxial-rim. The micritized bioclasts moderately/ well-sorted, normally/tightly packed. Well-developed separate vug porosity, selectively dissolute of micro to meso pores (from 5 to 20 micron), oily impregnated. The interparticle pores differently cemented by fine/medium equi-mosaics, represent reservoir layers L21 and L22 of good poro-perm buildup, oil bearing, when non-cemented. WQOF, WQ-16: 2447.20 m. **3:** Grain-dominated bioclastic packstone (floatstone) facies; most of the bioclasts of less than 2mm in size. The facies represents bank-flank, from the North-Rumaila shelf margin toward West-Qurna and Majnoon fields, differently improved rock-fabric/ poro-perm buildup. The intensive dissolution created composite vug-porosity of open channel-network system, partly cemented. Good pore-channel-network creates troublemaker facies in water-encroachment efficiency within L6 and L7 (Awadeesian, 2002). Mishrif (Mb1)-unit in NROF, NR-36: 2277.35 m. **4:** Coated grain (bioclastic) grainstone (rudstone) facies; more than 10% of the bioclasts are larger-than 2mm in size, of well-developed composite-vug and interparticle pores, partly cemented by equimosais lining intragranular pores with isopachous-rims of bank to shoal facies. The pore-network is of open channel pathways; within the main Rudist-bank/shoal

(Mb1) unit, of serious TMFs of well-connected pore-pattern of 5 upto 50 and 100 microns, Awadeesian (2002). The presented oil-droplets; is the crude oil-in-water divertor injected into core plugs of TMFs, are blocking the pore throats. **4a.** NROF, NR-292: 2410.25 m, **4b.** NR-253: 2337.00 m, and **4c.** NR-253: 2337.60 m.



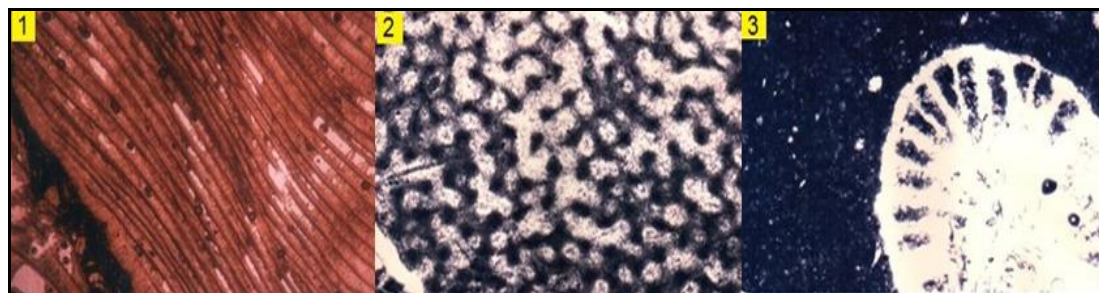
**Fig. 8: Grain-dominated bioclastic wackestone (floatstone) facies at the base of L6 at the Rumaila field, (WQ&MOF). Reservoir facies RF101. (WQOF): Oil-well WQ-114: 2401m, X12.5; ———: scale-bar = 1mm**



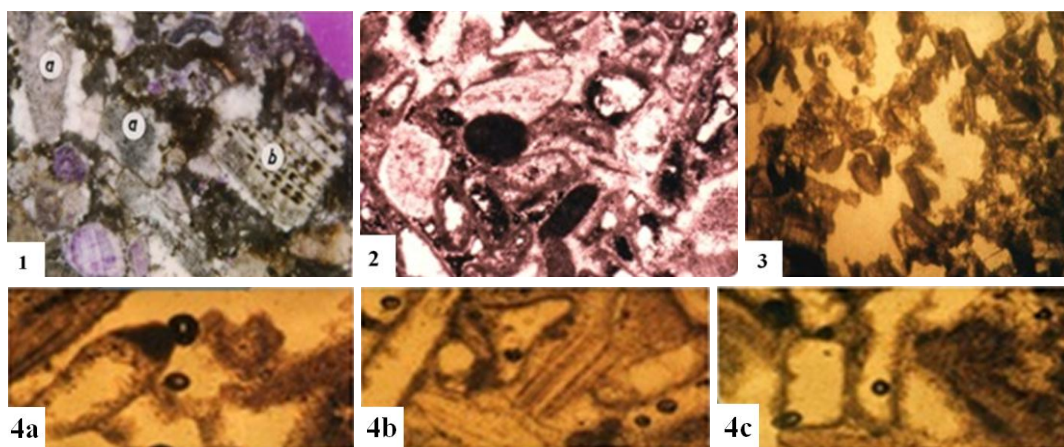
**Fig. 9: Mishrif Carbonates at MOF:**

**1)** *Radiolitid Rudist* in growth position, with *Condrodonta shells* of low depositional-energy setting of the biostromal facies. Mud to grain-dominated floatstone/ rudstone facies with micro to meso fractures, oily impregnated. Reservoir facies RF101 to RF102. Oil-well Mj-3: 2688.9 – 2689.10 m, *lower Mb1*, reservoir-layer (L9). **2)** Mud-to-grain dominated floatstone/ rudstone facies, back-shoal/ biostromal facies, oily impregnated, RF101 to RF102 Mj-3: 2580.5 – 2580.68 m, *upper Ma*, reservoir (L2). **3)** Micro-meso/ mega-vugs and solution-enlarged-voids, mottled structure, lagoonal facies, oily, solution-channel/ fracture. Mj-3: 2618 – 2618.18m, *upper Mb1*, L6/7. **4)** Dense-compact argillaceous lime mudstone/ wackestone, lagoonal barrier facies. Mj-3: 2618 – 2618.18m, lagoonal part of the *upper Mb1*. All photographs; — : scale-bar = 2 cm.





**Fig. 10: Bafflestone facies (1); Fig. 1: Oil-Well NR-186: 2363.35 m X8.5. — : scale-bar = 2.5cm. Fig 2: 2292.50 m X25. Fig.3: 2325.15 m X8.5. — : scale-bar = 2 cm, at Oil-Well WQ-20**

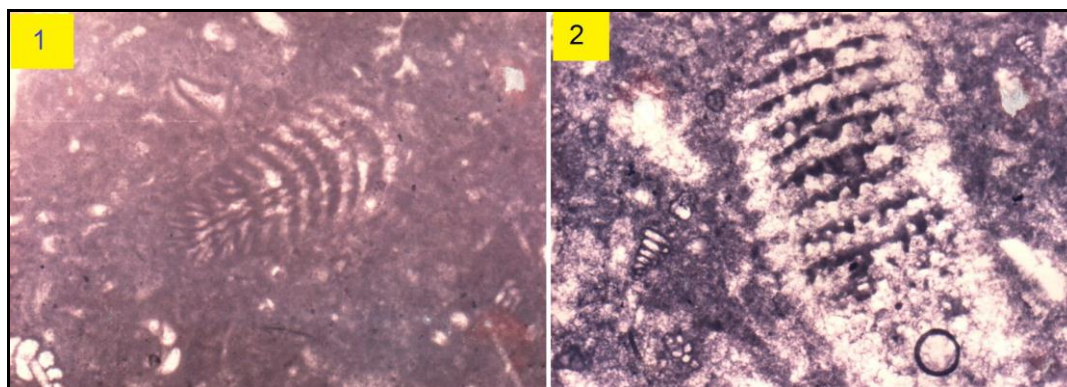


**Fig. 11: Rudistid bioclastic packstone-grainstone (floatstone/ rudstone) facie:**  
**1:** Echinoid plates (a) with cyntaxial-rim cement and the Rudist fragment (b) with isopachous-rim, most of the bioclasts are less than 2mm in size; well rounded, moderately sorted, normally packed. Oil-well Mj-3: 2756 m X20. — : scale-bar = 2 mm.  
**2:** Peloidal bioclastic grainstone facies in (WQOF), WQ-16: 2447.20m X12. — : scale-bar = 2 mm.  
**3:** Grain-dominated bioclastic packstone (floatstone) facies; NROF; NR-36: 2277.35 m X12.5. — : scale-bar = 2 mm.  
**4:** Coated grain (bioclastic) grainstone (rudstone) facies (NROF); NR-292: 2410.25 m, **4b.** NR-253: 2337.00 m, and **4c.** NR-253: 2337.60 m. All of 30X. — : scale-bar = 2 mm.

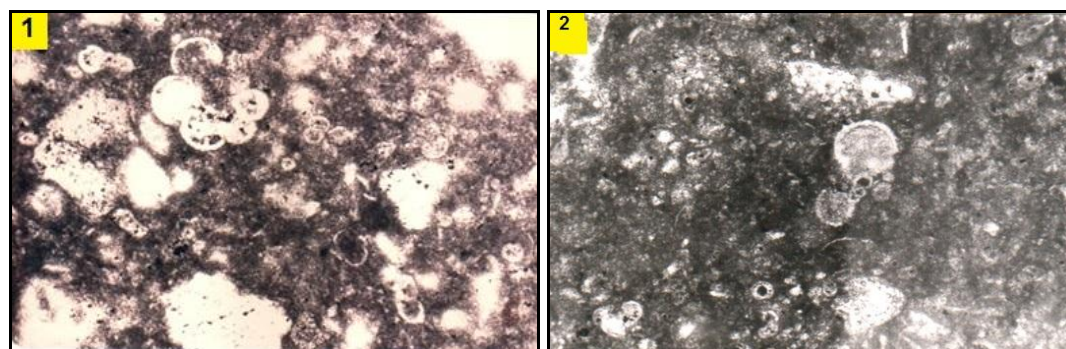
### The Non-Reservoir Units

The non-reservoir layers are identified by; benthic foram wackestone facies of dense, compact, argillaceous buildup of restricted/ open-shelf lagoonal setting. That is specified either cap-rock CRII; separating the lower from the upper Mishrif sequences or CRI the terminator of the Mishrif carbonates before the creation of MR. They represent; low poro-perm buildup as barriers and fluid-obstacles separate reservoir-units (Figures 12 and 13). The non-reservoir units identified are: L1: MR - K142 = CRI of

Benthic Foram Wackestone Facies. L4: MFS-K140 – K134 of Open Marine Facies. L5: K134 – K133 = CRII of Benthic Foram Wackestone Facies. L10: MFS-K130 – K130 of Open Marine Facies. L16: K126 - MFS3 of Open Marine Facies. L17: MFS3 - K125 = Base of Mb23 of Open Marine Facies. L19: K124 - Top of MFS2 = Rumaila Open Marine Facies. L23: K122 – K121 of Open Marine Facies. L24: K121 – MFS-K120 of Bathyal Condensed Shale Section.



**Fig. 12: Non-Reservoir Facies: *Taberina bingistani*, with *Nezzazata gyra*, and Textularids, in a benthic foram wackestone facies, dense argillaceous. This larger benthonic index-foram has taken a good bio-indicator for low energy open inner-shelf lagoonal eco-zone, of shallow subtidal setting. It represents low poro-perm buildup. (NROF) Oil-Well/ NR-36: 2249 m, X12.5. — : scale-bar = 2.5 mm**



**Fig. 13: Non-Reservoir Facies: Mud-grain dominated pelagic wackestone facies; with *Hedbergella planispira* and *Hedbergella IRK sp1*, *Hedbergella washitensis*, *Oligostegina spp*, moldic pyrite, argillaceous, of low poro-perm buildup, 65X. Oil-Well WQ-20: 2372-2374 m. — : scale-bar = 20  $\mu$**

#### Vocabs used by this study

**MFS-K125:** The second chrono-marker of the Cenomanian succession for the southern Iraqi oil fields as considered by this study, characterized by shale/ shaly-lime-mudstone

facies of condensed-section of the upper shale member of Ahmadi formation, consistent and persistent correlative key-surface.

**MFS-K135:** A Cenomanian consistent chrono-marker considered by this study as well, 1-2 m thickness of lime-mudstone facies, dense/ compact texture, phi of less-than 5%, and Ka of less-than 0.2 mD crossing or terminating the main Rudistid-bioaccumulated bank of the lower Mb1-unit in North-Rumaila and West-Qurna oil fields. The marker is equivalent to MFS6 of Chevron and SOC (2006) and Awadeesian (2008).

**MFS-K155:** *A local MFS(10); for the upper Khasib shale-member in south Iraq oil fields.*

The MFS1 of ELF-Aquitaine, is equivalent to the chrono-markers (MFS2 of Chevron and SOC 2006, and to MFS-K120 of Sharland 2001, and to MFS3 of this study), characterizes the lower Ahmadi shale member, *whereas*; MFS2 is equivalent to (MFS3 of Chevron, MFS-K125 of Sharland and to MFS3.1 of this study) of the upper Ahmadi shale member.

## CONCLUSIONS

1. Thirty regional-(AP) and local key-markers have resolved by specific MFSs, DSs, TSs and sequence boundaries; itemized as: MFS3 (MFS-K120), K121, K122, K123, K123a, MFS3.1 (MFS-K120a), MFS4 (MFS-K130), K124, K125, MFS4.1, K126, K127, MFS4.2, K128, K129, MFS5, K130, MFS6 (MFS-K135), K131, K132, K133, K134, MFS8 (MFS-K140), K141, K142, SB-K150 (MR), MFS9 (MFS-K150), TS8 and (MFS10 of upper-shale of Khasib formation).
2. Seven 4th-order genetic-mesosequences from MS1 to MS7 have been established for the Cenomanian – Early Turronian mega-sequence MFS-K120 to MFS-K150, each containing 5th-order HF-lithofacies cycles.
3. Fifteen reservoir syn-layers and nine non-reservoir-layers have been identified, as a chrono-sequence-model: for the Mishrif – Rumaila and Ahmadi succession.
4. This new Mishrif reservoirs model, by genetic sequence stratigraphic context; will construct valuable synchronous reservoirs dynamics architecture.
5. It is highly recommended; to take into consideration the oil well completion, to be based-on; selective-syn-completion program attended with syn-layer-modeling technique.

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