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Tectonostratigraphic Framework and Depositional History Pattern of the Cretaceous Successions Period in Southern Iraq

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Abstract

Twenty oil wells were selected to study the tectonostratigraphic of the Cretaceous in southern Iraq, in order to develop a comprehensive description of the petroleum system in the region. That was conducted through an interpretation of the technical reports and the available information of the wells, which include sedimentary, stratigraphy, tectonic reports, and oil reservoir studies of the Cretaceous. Stratigraphically, a third order cycle was identified in the Cretaceous succession in southern Iraq, which also comprises seven and half cycles of the fourth order. Eight genetic stratigraphic sequences were also identified, as well as eight maximum flooding surfaces. The concept of the tectonostratigraphic boundary (TSB) and the tectonostratigraphic unit (TSU) has been adapted in this study. In the present study, the Cretaceous period in southern Iraq considers one tectonostratigraphic system (TSS) consisting of four main tectonostratigraphic categories. Each category consists of a set or group of secondary tectonostratigraphic units; these are TSU1A, TSU1B, TSU1C, TSU1D-TSU2A, TSU2B-TSU3A, TSU3B, TSU3C-TSU4A, TSU4B, and TSU4. These units are separated by five tectonostratigraphic boundaries presented from TSB1 to TSB5 by Sulaiy, Shuaiba, Mauddud, Khasib, lower part of Tanuma, and Shiranish. The lateral extensions of the TSUs that are close to the passive margin (northeast part of the study area) are hydrocarbon reservoirs. The lateral extensions TSUs that are far from the passive margin (southwest part of the study area) are hydrocarbon generator source. The intermediate unite is characterized as both a generator source and reservoir hydrocarbon. Vertically, the TSUs are characterized by improved reservoir properties with reduced depth due to the lack of compressional tectonic force, which leads to forming a good primary porosity. The transfer from north to south of the study area represents a trend of improvement in reservoir characteristics for the same reason as mentioned previously. Finally, the TSB represents a source generator hydrocarbon more than a reservoir.

Keywords: Cretaceous period; Southern Iraq; Tectonostratigraphic Unit; Petroleum system.

1. Introduction

Most previous geological studies focused on the lithology of subsurface formations, especially formations that produce oil (e.g. Mishrif, Zubair, and Nahr Umar formations). Most of these studies (for instance; Al-Ali et al., 2019; Alsultan, 2021; Al-Garbawi and Al-Shahwan, 2019; Menshed and Al-

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Mozan. 2021) include sedimentary and stratigraphy research, but these studies were isolated and had an absence of connection with tectonic and structural data. These studies adhered to the old tectonic concepts since Buday (1980). Lately, studies aimed to connect the available geological information with a single framework that can help to predict the oil production process, which is known as the petroleum system. This research aims to study the Cretaceous period in southern Iraq according to the petroleum system concept descriptively and focused. The Arabian passive margin is considered an important continental margin globally due to its natural resources, especially oil and gas. The Cretaceous sediments are among the important geological deposits. The current research focused on the sequences of the Cretaceous period to complete an image of this important period, by selecting 20 oil wells (Gn-1, Dn-1, Ak-1, Ks-1, Wk-1, UmQ-1, R-5, Rt-3, Rt-4, NNU-1, NNU-3, WQ-13, WQ-115, Mj-3, Mj-4, Snd-1, Rf-1, Am-2, Hf- 1, and Noor-1) distributed in three oil governorates in southern Iraq (Basra, Maysan, and Thi Qar), which are among the provinces that contain the largest giant oil-producing fields in Iraq, such as Rumaila, West Quran, Majnoon, Nahr Umar, Halfaya, and Ratawi (Fig. 1).

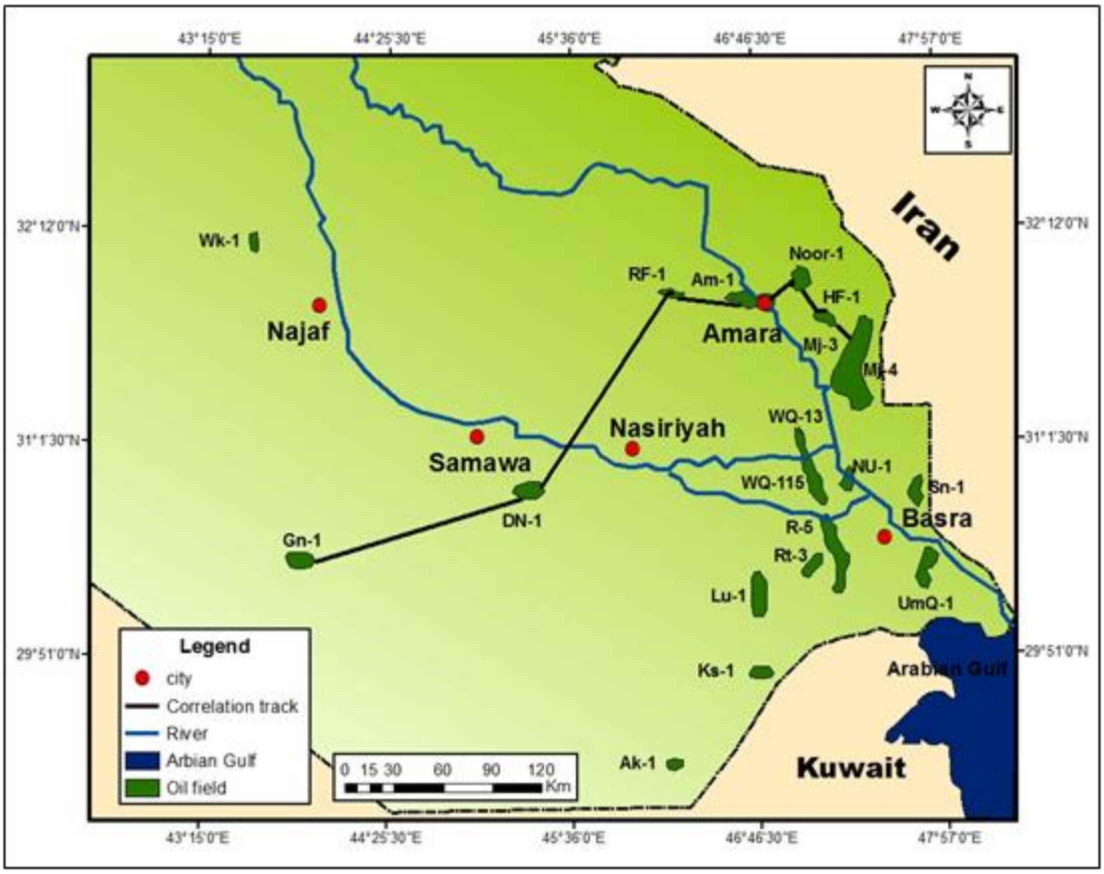

Fig.1. Location of the study area and the oil wells used in this study.

Sedimentary and stratigraphy information was collected from previous studies related to the proposed scenario of tectonic accidents in this period, based on studies of Numan (1997 and 2000), in order to reach a clear and comprehensive knowledge of the mechanism of sediment distribution and to identify the effects of tectonic movements on the physiology of sedimentary basin. The Lithology bonding method has been used as a philosophy for oil production for past years in Southern Iraq regions, which was based on the production of similar rock layers with neglect of the affective of lateral rocks microfacies variation. The concept of sequence stratigraphy was adopted to solve the problems of oil production, which used the environmental structural link method for genetic package rocks without taking its lithological variation (Homewood, 2000; Emery and Myers, 1996). So, the importance of the current study trying to draw an image of the vertical and lateral extension of the formations under study by dividing them into specific environmental zones that illustrate this idea and give an insight into the status of the sedimentary column of the Cretaceous period in southern Iraq. This study is based on the concepts of plate tectonics theory, instead of the geosynclines theory that was adopted by most of the previous studies. The geosyncline theory provides detailed information on the sedimentary, stratigraphy, and environmental characteristics of a region, but it is unable to give appropriate tectonic explanations. Davies et al. (2002) described the nature of sediments in the Arabian margin during the Early Cretaceous, and concluded that the sediments of this period extend into three longitudinal zones; these are the carbonates zone, the mixed of clastic and carbonates zone, and the clastic zone (Fig. 2).

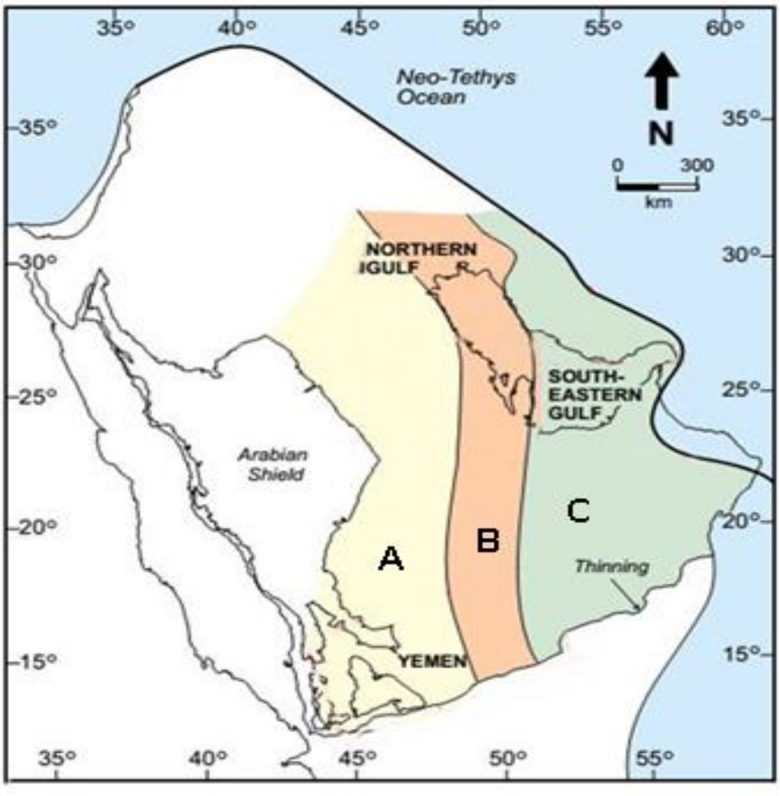

Fig.2. The three longitudinal zones of sedimentations in the Arabian margin during the Early Cretaceous (A) the carbonates zone; (B) the mixed of clastic and carbonates zone, and (C) the clastic zone (Davies et al., 2002).

2. The Tectonic Setting

Iraq represents the northern and northeastern margin of the Arabian plate. The Arabian plate represented the northeastern part of the African plate, It extended north and northeastwards over the central, southern and southeastern parts of Turkey (Kummel, 1970, Numan, 1997).The tectonic map of Iraq was updated many times during the period from 1984 to 2015 by many authors. Tectonically, many terminologies have been used by many authors, Buday and Jassim (1984) complied the first tectonic map of Iraq relied basically on the old principles of the geosynclinal theory, they used stable shelf and unstable shelf terminology, they have divided the Mesopotamian zone who forms aboard zone in Iraq into three subzones: the Tigris subzone in the north who is the most mobile unite of the Mesopotamian zone, the Euphrates subzone in the west and the Zubire subzone in the south. Based on plate tectonic theory, Numan (1997) put the tectonic division of Iraq. Jassim and Goff (2006) also compiled a tectonic map of Iraq using almost the same terminology but with slight differences, which did not depend on the Eugeosynclinal theory, but considered the Mesopotamian zone is part of the stable shelf. The last tectonic map updated was putting by Fouad (2015). The main part of Iraq is divided into two main parts, the first one is the Inner plateform (stable shelf) and the second part is the outer plate form (Unstable shelf), which is the Abu Jir-Euphrates active fault has represented the contact between the tow part Fouad (2007; 2015).

This study depended on the tectonic divisions of Iraq by Fouad (2015). According to this divisions, the study area extends within tow tectonic zones of the Arabian platform , the first area of the studied oil fields is located in the Inner platform and the second one in the outer plateform within the Mesopotamian Foredeep subzone (Fig.3).

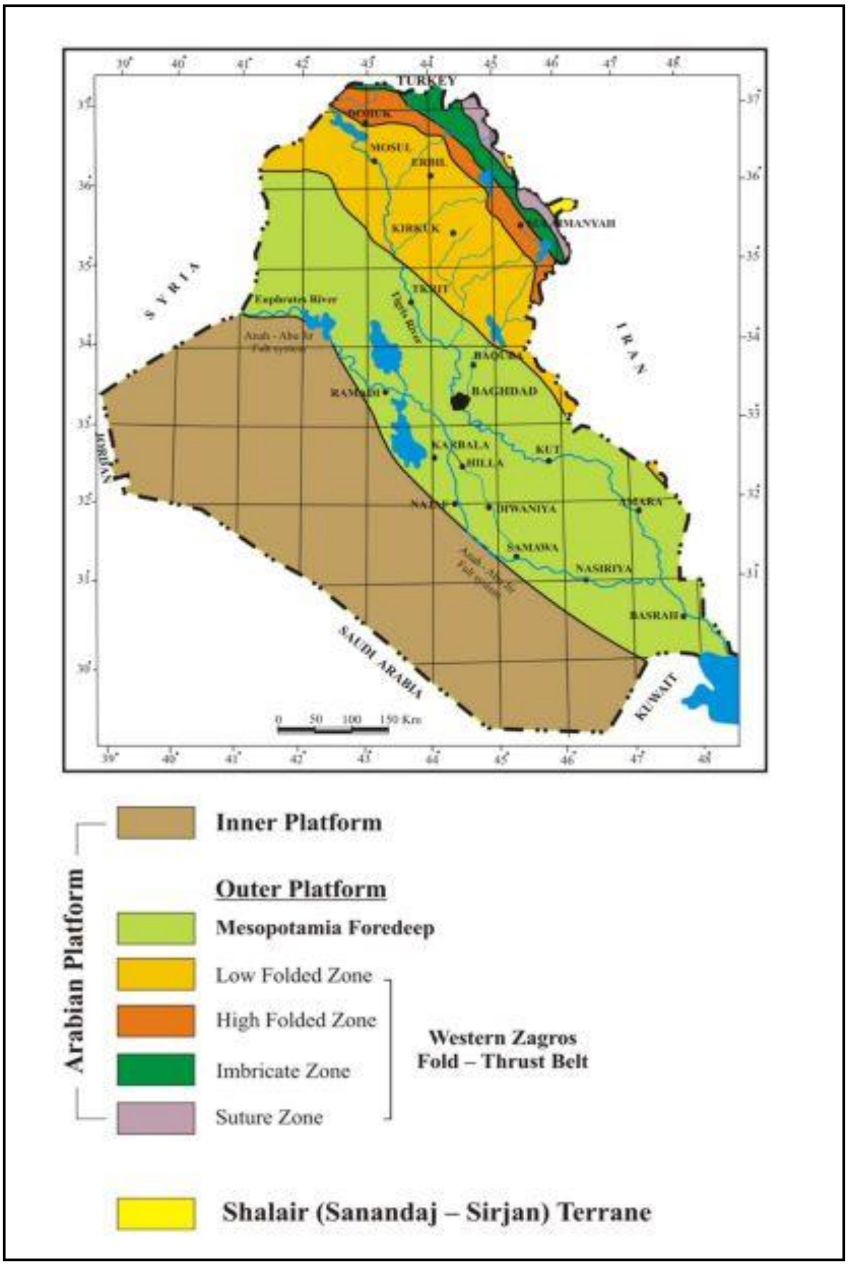

Fig.3. The tectonic divisions of Iraq after Fouad, (2015)

3. Materials and Methods

During the Cretaceous period, the Arabian plate was affected by two tectonic mega sequence phases (AP8, AP9). These two phases lasted for 86 million years. The (AP8) phase continued for 57 million years and was characterized by mixed carbonate siliciclastic sediments of the Lower Cretaceous period. The location of the Arabian plate during this period was the tropical position, while The (AP9) phase has lasted to 29 million years and dominated by carbonate sediments Sharland et al. (2000) (Fig.4).

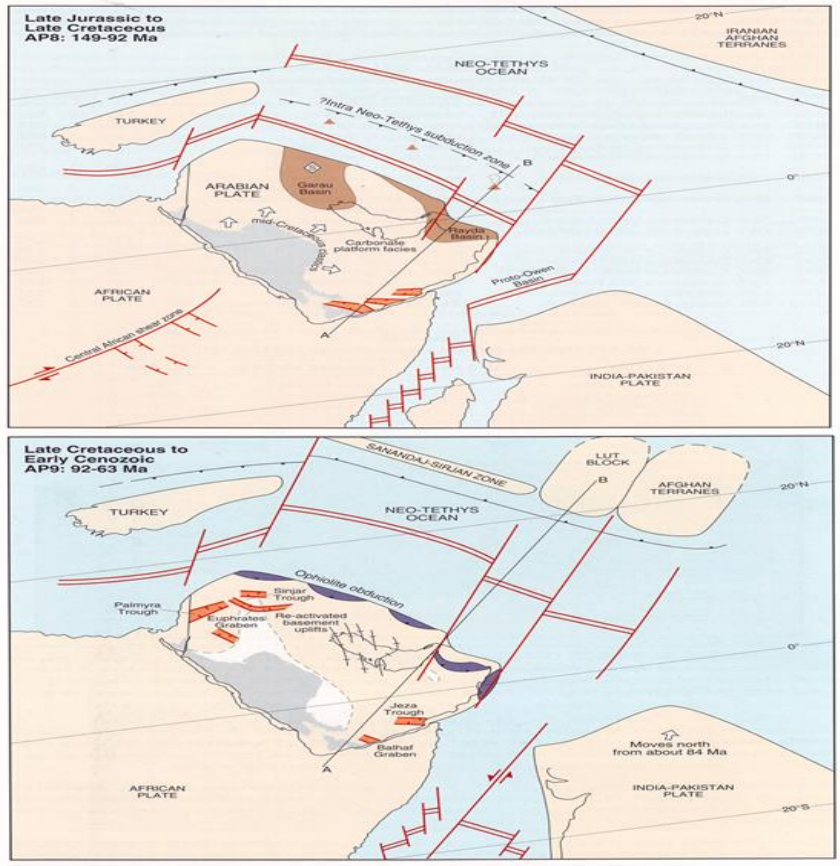

Fig.4. Two tectonic mega sequence phases (AP8, AP9) shown the Arabian plats position during the Cretaceous period Sharland et al.(2000).

The subduction of the oceanic crust of the Neo-Tethys appeared under the Turkish and Iranian plates at the end of the Jurassic period, which lead to a geodynamic inversion of the tectonic system from elongating to compression during the Cretaceous period Numan (2000).The tectonic movement is devided into two episodes as shown in Table 1.

Table 1. The tectonic movement phases in the Cretaceous period (Numan, 2000)

Episodes	Ages	Tectonic Movements
Late Cretaceous	End-Maastrichtian	Laramid
	End-Cenomanian	Second Austrian Alpine
Early Cretaceous	End-Albian	First Austrian Alpine
	Berriasian-Aptian	Young Kimmerian

The tectonostratigraphic evidence indicates that the extensional tectonism responsible for the separation of the Iranian and Turkish plates from the Arabian plate and the opening of the Neo-Tethys were generated in the Triassic period. The elongation conditions were affected on the two edges of the inactive plates on both sides of the new Tethys ocean during the Jurassic period. The signs of the subduction of the oceanic crust of the new Tethys under the Turkish and Iranian plats, they appeared at the end of the Jurassic period, and the result of this subduction was the occurrence of a geodynamic coup of the tectonic system from extensional tectonism to compression tectonism during the Cretaceous period (Numan, 2007). The compression forces had changed the preexisting listric normal fault into reverse faults, this mechanism exists in the foreland belt of northern Iraq (Numan and Al-Azzawi, 1993).

There are two basic types of continental margins, active and passive margins. Active margins are continental margins that coincide with either transform or convergent plate boundaries, and thus are seismically active. In contrast, passive margins are not seismically active and develop over the edge of a rift after the rift-drift transition (Condi, 1989; Van der Pluijim and Marshak, 2004).

According to Almutury and Alasadi (2008), the passive margin of Mesopotamian had been divided into two phases: First, is the opening phase, which is represented by divergent plate boundaries formed where the plates moved apart from one another. The second is the closing phase, characterized by convergent plate boundaries that formed where plates moved toward each other.

According to the Wilson cycle, the tectonic position of the Arabian plate during the Cretaceous period was part of the closed phase, specifically the subduction Set-up or Pre-collision Set-up mode. This situation is tectonically characterized by the zoon of the subduction oceanic crust of the new Tethys under the Iranian and Turkish plates, which made their edges active margins, while the edge of the Arabian plate remained passive margin (Numan, 2000) (Fig. 5).

A passive margin is defined as a continental margin within a single lithospheric plate and fused to adjacent oceanic crust. It includes continental shelf, continental slope, and continental rise Plummer et al. (2003). The passive margin was generally covered by shallow water, however, a number of deeper water intra-shelf basins had been formed during the Cretaceous (Murris, 1980).

On the tectonic side, the southern Iraq region in the lower cretaceous was part of the passive margin of the Arabian Plate, which represents the confluence of the continental crust with the oceanic crust. Southern Iraq occupies the largest part of the continental shelf area, which is structurally distinguished by containing half-graben basins, which are formed as a result of the presence of a number of Listric Normal Faults formed during the Triassic and Jurassic periods because of the tensile forces, However, during the lower Cretaceous, and as a result of the pressure forces, the movement on its levels changed to the reverse movement (Numan and Al-Azzawi, 1993).

The parts of the passive margin affected by Listerian faults are called Quasiplatform Foreland, and during the Cretaceous in Iraq, they were Submergence and generally uneventful from discontinuity. While the areas not affected by these faults, which currently occupy the Western Sahara region, are called the Stable Platform, during most of the Lower Cretaceous period was a positive region (Numan, 1997 and 2000).

The stable platform area was a source of the continental sediment in which the Sub-basins at the passive margin were filled. These basins played a prominent role in determining the quality of sediments and the nature of their distribution in southern Iraq, they worked to complicate the topographical shape of the bottom of the sedimentary basin represented by the passive margin of the Arabian plate. Perhaps this explains the nature of intense rock variation from one region to another within southern Iraq, which is evident in several oil wells in the study area.

During the Second Austrian Alpine movement, the upper Cretaceous period of the study area in southern Iraq was affected by the compression, which leads the uplift parts of the passive margin that led to confining sediments towards the stable shelf, and bringing marine sediments from high marine areas (Fig. 6). With the continuation of the second Austrian movement and the beginning of the Laramid movement, general parts of the passive margin were raised, forming the Foreland basin which was leaning towards the stable shelf area. The sedimentary basin was divided into Intra shelf basins consisting of Lagoonal environments confined in the western parts of the study area and open marine environments in the eastern parts. The sediments of this basin were diverse both horizontally and laterally, depending on the physiography of the sedimentary basin resulting from the intensity of the influence of both movements.

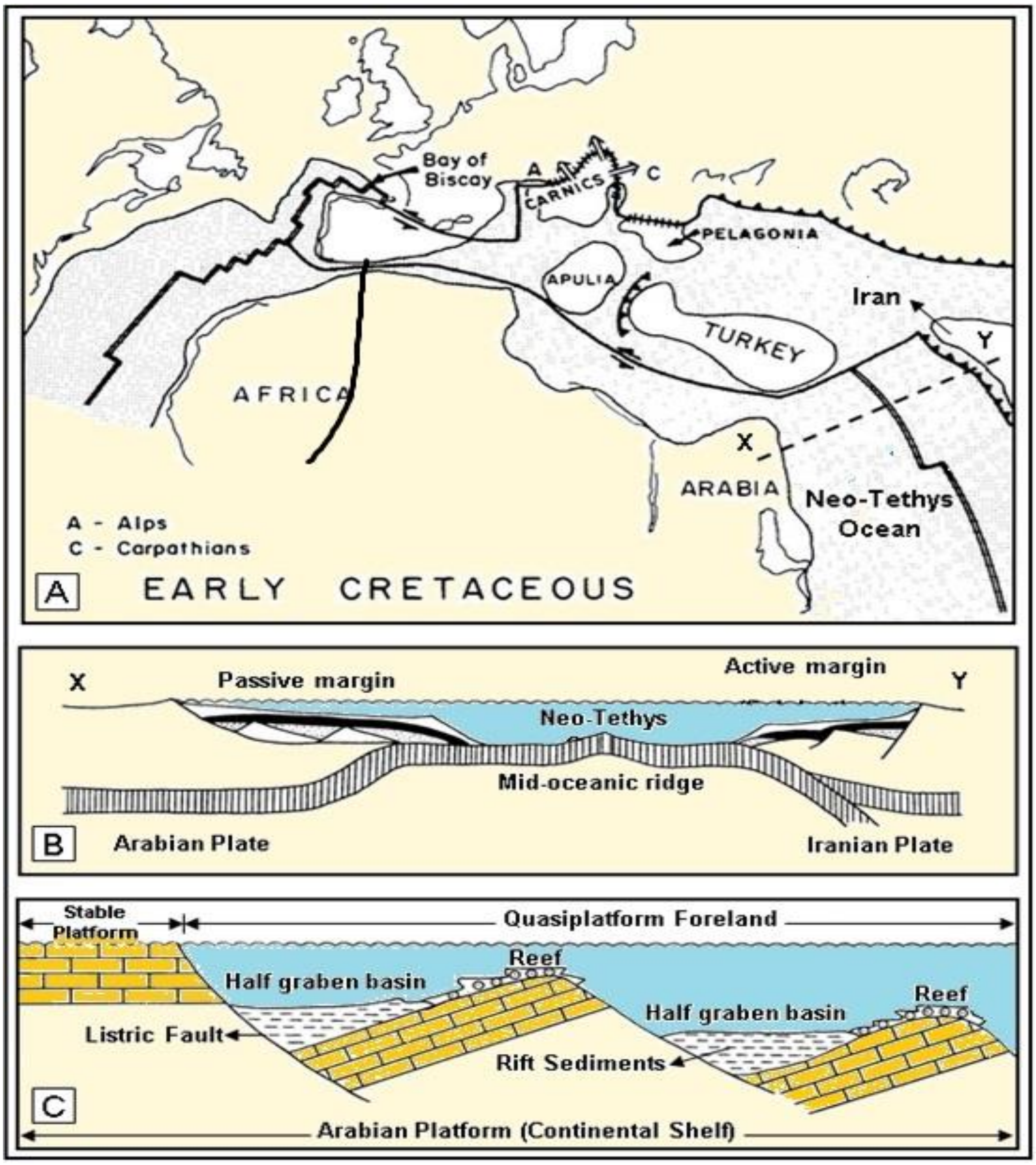

Fig.5. The tectonic position of the Arabian plate during the Lower Cretaceous. (A) The location of the Arabian plate relative to the other nearby tectonic plates (Rich, 1996); (B) The cross-section (X-Y) that extends from the Arabian plate to the Iranian plate through the new Tithes Sea (Modified from Numan, 2000); (C) A detailed cross-section on the passive margin of the Arabic plate (Modified from Mutlak, 1999).

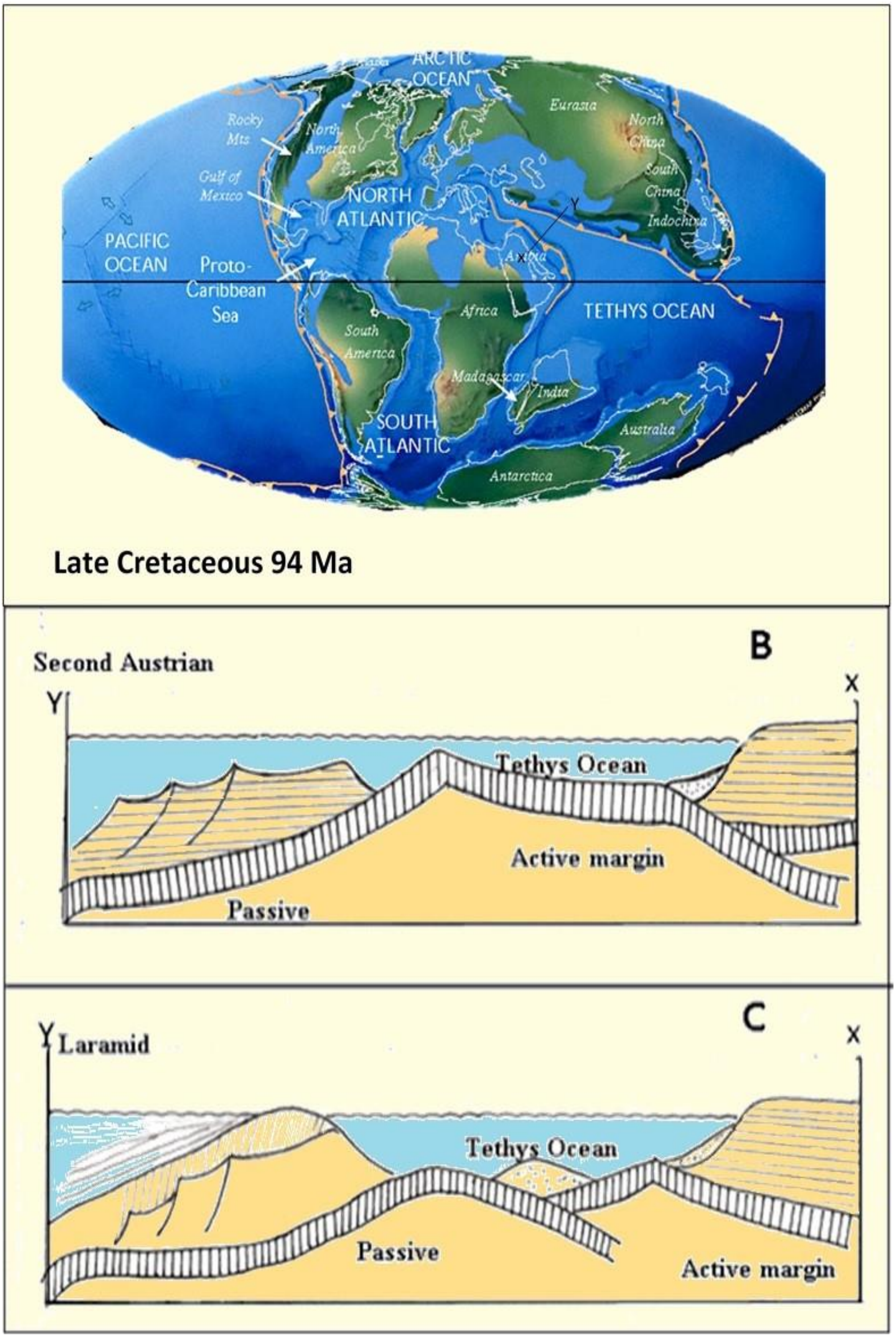

Fig.6. The tectonic position of the Arabian plate during the Upper Cretaceous. (A) Tectonic position of the Arabian Plat during the Upper Cretaceous (Rich et al., 1996); (B) Cross-section (X-Y) shows the position of the Arabian passive margin during the Austrian movement (current study); (C) Cross-section (X-Y) shows the position of the Arabian passive margin during the Lramidic movement (current study).

4. Sequence Stratigraphy

Several previous studies have been conducted on this field, where they concluded a detailed vision of facies, environmental sedimentation, and reservoir properties (e.g. Razoyan, 1998; Al Bayati, 2001; Zaibel, 2001; Razoyan, 2002; Shaawash, 2002; Al Mohammad, 2002; Mahawi, 2003; Al Ali, 2004; Handhal, 2006; Al Bayati et al., 2010; Al Bayati et al., 2011). The Cretaceous period in southern Iraq includes eleven sequence stages, in which seventeen formations were deposited (Suliy, Yamama, Ratawi, Zubair, Shuaiba, Nahr Umar, Mauddud, Ahmadi, Rumaila, Mishrif, Khasib, Tanuma, Saadi, Hartha, Shiranish, Tayarat) (Fig.7 and Table 2).

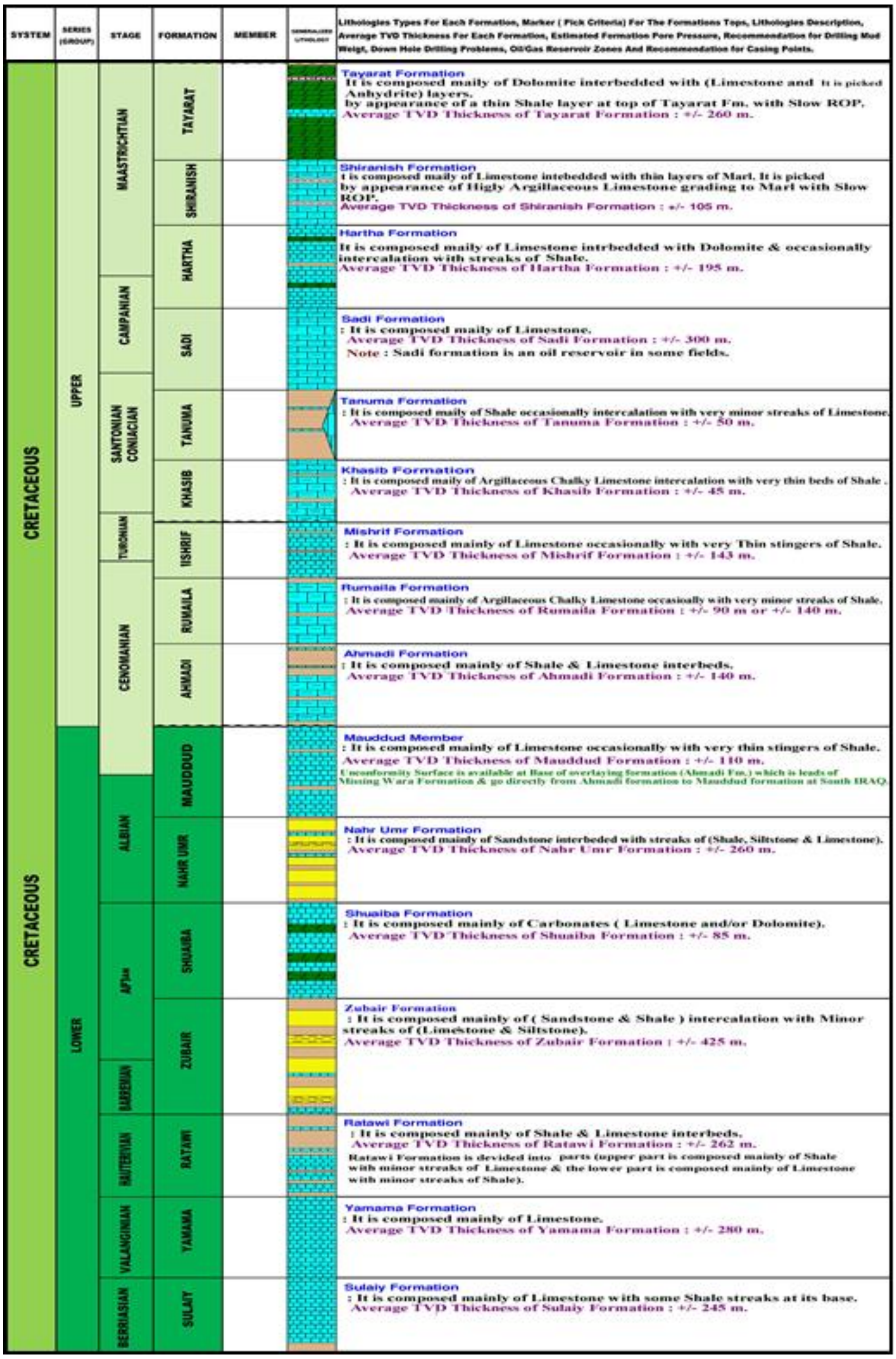

Fig.7. Illustrated the description of the lithology of the Cretaceous formations

Table 2. The lithological descriptions of formations depend on the final oil well reports.

Well	Formation	Thickness(m)	Lithology
Noor-1	Shiranish	82	- Lower part (35m) limestone. - Upper part (47m) marly limestone.
	Hartha	32	- Interbedded chalky and detrital limestone, in part(upper) Glauconite.
	Sa'adi	131	-The lower part (28m) Oolitic detrital limestone. - Upper part (103m) limestone, in part shaly and marly limestone.
	Tanuma	25	- Interbedded shale (limestone and shale) and limestone.
	Khasib	65	- Interbedded limestone and chalky limestone with shale in one bed (2m).
	Mishrif	383	- Limestone, in part chalky limestone(in the lower and middle) and in part Rudist (in the upper).
	Rumaila	46.5	-Interbedded limestone and detrital limestone, in part(middle)shaly limestone.
	Ahmadi	16	- Limy shale, in top beds of marl (2m), in the lower part bed of limestone (2m).
	Mauddud	193	Limestone.
	Nhar Umr	203	-The lower part(50m) interbedded Shaly sandstone and Sandstone -Upper part(153) Limestone
	Shuaiba	188.5	- Interbedded Marley Limestone and Limestone and Dolomitic Limestone.
	Zubair	Zero	None deposit.
	Ratawi	321	Interbedded Shale and Limestone and Shaly Limestone
	Yamama	78.5	- Interbedded Shale and limestone in last (25m) from upper part confirms from shaly Limestone
	Sulaiy	318	-Interbedded shale and sandstone
Mj- 4	Shiranish	139	-Lower part (50m) marly limestone, in part shale. -The middle part (40m) shaly limestone, in part shale. -Upper part (49m), in the lower interbedded marly and shaly limestone in the upper pure limestone.
	Hartha	136	-The lower part (32m) shaly limestone. -The middle part (50m) interbedded detrital and chalky limestone in the lower.in the upper interbedded dolomite and shale.
	Sa'adi	108	-The lower part (15m) Oolitic limestone. -The middle part (62m) interbedded marl and limestone. -Upper part (37m) marly limestone and detrital limestone.
	Tanuma	29	Shale in part thinning bed of limestone.
	Khasib	44	Limestone, in part shale.
	Mishrif	244	-Lower part (115m) limestone. -Upper part (129m) detrital limestone.
	Rumaila	12	Shally limestone.
	Ahmadi	171	-The lower part (25m) interbedded shale and limestone. -The middle part (45m) interbedded marly limestone and limestone container chert. -Upper part (101m) interbedded chalky and detrital limestone, in the top of formation shale bed (10m).
	Mauddud	180	- Marley Limestone and Limestone and Shaly Limestone intermittent Shale.
	Nhar Umr	178	- Limestone.
	Shuaiba	196	- The lower part(70m) interbedded Sandstone and Shale and Shaly Sandstone and it contains one-bed Limestone.
	Zubair	Zero	- None deposit

	Ratawi	477	- Lower part(315m) Marly Limestone and Shaly Limestone and Shall intermittent three beds of Sandstone. - Upper part (162m) Limestone.
	Yamama	66*	Interbedded Marl and Limestone and Shaly Limestone.
	Sulaiy	205	Limestone.
	Shiranish	70	-The lower part (-) shaly chalky limestone. -Middle part (--) marl. -Upper part (--) in the lower marly limestone, in the upper shaly limestone.
	Hartha	34	- Chalky and detrital limestone, in part, thinning bed of shale.
	Sa'adi	124.5	-The lower part (75m) in the lower interbedded shale and Oolitic chalky limestone.in the upper interbedded limestone and chalky limestone. -Middle part (36m) marl. -Upper part(23.5m) chalky detrital limestone.
	Tanuma	14.5	-Lower part (7m) shale. -Upper part (7.5m) interbedded shale and shaly limestone.
	Khasib	84.5	-The lower part (15m) chalky and detrital limestone. -Upper part (69.5m) in the lower interbedded shale and shaly limestone and in the upper interbedded detrital and shaly limestone.
HF-2	Mishrif	404	-Lower part (95m) chalky limestone, in part detrital limestone (15m) in the lower. In part container Gypsum. -Middle part (95m) interbedded chalky and shaly limestone. -The upper part (214m) interbedded Rudest and detrital limestone.
	Rumaila	49	-The lower part (23m) interbedded chalky and limestone, in part shaly limestone. -Upper part (26m) limestone.
	Ahmadi	18	Interbedded shale and chalky limestone, in the bottom, consisting of limestone (5m).
	Mauddud		No information.
	Nhar Umr		No information.
	Shuaiba	180	Interbedded Shaly Limestone and Limestone.
	Zubair	Zero	None deposit.
	Ratawi	355	Interbedded Shaly Limestone. Upper part(12m) interbedded Shale and Sandstone.
	Yamama	43	Interbedded Shaly Limestone and Limestone.
	Sulaiy	419	Inter bedded Shaly Limestone and Shale
	Tayarat	202	-Lower part (160) dolomite. -Middle part (24m) shaly limestone and 5m in the top is clay. -Upper part (18m) dolomite.
	Shiranish	173	Shally marly Limestone.
	Hartha	220	-The lower part (35m) interbedded limestone and shaly limestone. -The middle part (74m) consists of marly limestone in the bottom (55m) and shaly limestone in the top (19m), in part chalky limestone. -Upper part (111m) dolomite, in part the dolomite container shale. in the top part consist of chalky limestone (16m).
Rt- 4	Sa'adi	194.7	-The lower part (50m) interbedded limestone and shaly limestone and chalky limestone. -Middle part (30m) marly limestone. -Upper part (114.7m) chalky limestone.
	Tanuma	56.8	Shale with one meter only limestone
	Khasib	48.5	-The lower part (22m) interbedded shale and shaly limestone in the bottom and shale and limestone in the top part. -Upper part (26.5m) limestone.
	Mishrif	136	Limestone, in the bottom, found Gypsum, in part shaly and marly limestone, in the middle (thinning) tow to one bed.

	Rumaila	99.5	-Lower part (61m) limestone, in part shaly limestone. -Upper part (38.5m) shaly limestone.
	Ahmadi	138.5	Interbedded thick beds Marl and chalky limestone, in part thin bed of shale
	Mauddud	126	Limestone.
	Nhar Umr	239.5	The lower part(147m) Sandstone intermittent thin bed of Shale. The upper part (92.5m) interbedded Shaly Limestone and Shaly Sandstone and Shale.
	Shuaiba	86.6	Limestone and Shaly Limestone, rare dolomitic Limestone.
	Zubair	439.4	Interbedded Shale and Sandstone, in the last 25m interbedded Limestone and Shale.
	Ratawi	365	Interbedded Shaly Limestone and Limestone intermittent Shale.
	Yamama	170	Limestone.
	Sulaiy	50*	Marley Limestone and Shaly Limestone.
WQ -13	Tayarat	130	-Lower part (27m) limestone, in part thin bed of dolomite (4m). -Upper part (103m) mostly marl, in part thinning beds of limestone.
	Shiranish	111.5	-The lower part (20m) shaly limestone -Upper part (91m) interbedded dolomite and limestone, in part thin beds of shaly limestone and Glauconite at the top.
	Hartha	176	-Lower part (80m) limestone. -Middle part (75m) dolomite. -Upper part (21m) limestone.
	Sa'adi	120	-Lower part (21m) limestone. -Upper part (99m) interbedded shale and chalky limestone.
	Tanuma	47	-Lower part (20m) marl. -Upper part (27m) interbedded shale and limestone.
	Khasib	53.5	Interbedded shale and shaly limestone, in part bed of shale (5m).
	Mishrif	240	-The lower part (150m) interbedded chalky limestone and limestone, in part found Rudest. -Upper part (90m) limestone.
	Rumaila	30.2	Limestone.
	Ahmadi	155.7	-The lower part (15m) shaly and marly limestone. -The middle part (127m) interbedded chalky limestone and limestone, in the lower found Gypsum. -Upper part (13.7m) shale with limestone.
	Mauddud	158.5	Limestone.
	Nhar Umr	214	The lower part (112m) interbedded Shale and Sandstone with two beds of Limestone. The upper part (102m) interbedded Shale and Limestone.
	Shuaiba	101	Interbedded Limestone and dolomitic Limestone.
	Zubair	Zero	None deposit.
	Ratawi	487	Interbedded Limestone and Shale. intermittent Limestone. The last 47m on top represent by a limestone bed.
	Yamama	353	Limestone.
	Sulaiy	15*	Limestone.
Am-2	Shiranish	79	-Lower part limestone and chalk -Middle part Marl -Upper part marly limestone
	Hartha	56	-Interbedded shaly limestone and chalky limestone
	Sa'adi	136	-Lower part detrital limestone and shale. -Upper part interbedded marl and shale limestone and chalky
	Tanuma	17	Shale and shaly limestone.
	Khasib	78	Interbedded chalky and detrital limestone.
	Mishrif	407	Interbedded chalky limestone with shaly limestone, in the lower part (5m) there is one bed of shale

	Rumaila	14	-Limestone.
	Ahmadi	25	Interbedded shale with limestone.
	Mauddud	385.5	In lower part interbedded Shaly Limestone and Shale fallow by Limestone in the upper part.
	Nhar Umr	71	Interbedded Shale and thick bed of Sandstone.
	Shuaiba	171.5	Limestone.
	Zubair	Zero	None deposit.
	Ratawi	455	The lower part (237m) interbedded Limestone and Shale. In the bottom (5m) bed Sandstone. Upper part (148m) interbedded Limestone and Shale, an intermittent thin bed of Sandstone.
	Yamama	117	Limestone and Shaly Limestone.
	Sulaiy	160	Limestone.
Dn-1	Tayarat	110	Interbedded dolomite and dolomitic limestone, in part shale container fauna
	Shiranish	170	-Shale and shaly limestone.
	Hartha	295	-Lower part is interbedded dolomitic chalky limestone and dolomite. -Middle part dolomite with Anhydrite. -Limestone with pyrite.
	Sa'adi	205	Dolomitic chalky limestone and shale limestone in the upper.
	Tanuma	50	Shale in part shaly limestone with glauconite.
	Khasib	32	-Lower part shale. -Upper part shaly limestone.
	Kifl	26	Interbedded Limestone container anhydrite and shale.
	Rumaila	55	-Lower part dolomitic chalky limestone. -Upper part limestone.
	Ahmadi	135	-Lower part interbedded shale and limestone. -Upper part shale container fauna, in part, interbedded limestone and chalky limestone.
	Mauddud	27	- Limestone and Shaly Limestone and Shale.
	Nhar Umr	190	- Shale and Siltstone and Shaly Limestone and Sandstone.
	Shuaiba	35	- Dolomite contains Anhydrite.
	Zubair	480	- Shale and Sandy Siltstone.
	Ratawi	105	- Limestone and Dolomite and thin bed of Shale, intermittent of a thin bed of Limey Sandstone.
	Yamama	25	- Chalky limestone.
	Sulaiy	95	- Chalky Limestone and arggelous Limestone and porous Limestone.
Rf-1	Shiranish	57	Interbedded marl and marly limestone.
	Hartha	139	-The lower part (45m), in the lower (17m), interbedded marl and chalky limestone, in the upper (28m) interbedded shale and chalky limestone. -Upper part (94m) interbedded chalky and foraminiferal limestone.
	Saadi	149	-The lower part (98m) interbedded shale and chalky limestone in part found foraminifera limestone. - Middle part (32m) marl with limestone. -Upper part (19m) chalky and detrital limestone.
	Tanuma	52	-Lower part (18m) marl with one thin bed shaly limestone. -The middle part (16m) shaly limestone. -Upper part (18m) limly marl.
	Khasib	58.5	-The lower part (8m) chalky and Oolitic limestone. -The middle part (18m) interbedded shale and Oolitic chalky limestone. -Upper part (32.5m) interbedded chalky and Foraminifera limestone.
	Mishrif	293.5	-Interbedded chalky and Foraminifera limestone, in part in the lower found a thin bed of marl and shaly limestone.
	Rumaila	56	-The lower part (25m) chalky limestone. -Middle part (15m) marly limestone.

			-Upper part (16m) pure limestone.
	Ahmadi	18	-Lower part (5m) limestone. -Upper part (13m) shaly marl.
	Mauddud	30	Interbedded Shale and Limestone.
	Nahr Umr	70	Sandstone.
	Shuaiba	130	Dolomitic Limestone.
	Zubair	310	Sandstone and shale.
	Ratawi	160	Shaly Limestone and Shale.
	Yamama		No information.
	Sulaiy		No information.
	Shiranish	100	-Shally limestone with glauconite.
	Hartha	375.5	-Dolostone, in the middle part(14m), interbedded dolostone and Anhydrite.
	Sa'adi	112	-Interbedded chalky limestone and Foraminifera limestone.
	Tanuma	20	-Interbedded shaly marl and limestone.
	Khasib	75.5	-The lower part (38m) interbedded Foraminfra limestone and shale chalky limestone. -Upper part (37.5m) limestone and Foraminifera limestone.
WK-1	Kifl	28	-Interbedded limestone and Anhydrite.
	Mishrif	248.5	-The lower part (78m) chalky Foraminifera limestone with glauconite. -The middle part (100m) interbedded chalky and limestone in the lower and interbedded shale and chalky limestone in the upper. -Upper part (70.5m), in the lower part (10m) marl, in the upper (60.5m) interbedded limestone and dolostone.
	Rumaila	21	Interbedded limestone and shaly limestone.
	Ahmadi	12	Marl
	Tayarat	294	Dolomitic limestone with chalky and shally limestone in some part.
	Shiranish	460	Shally marl, in the middle part (28m) chalky limestone and (31m) shale.
	Hartha	1211	-Lower part (280m) dolomitic limestone. -The middle part (554m), in the upper (22om), interbedded Anhydrite and dolomitic limestone. In the lower (110m) nearly Anhydrite only with a thin bed of limestone. -Upper part (377m) chalky limestone with (20m) shale in the middle.
Gn-1	Saadi	395	-Lower part (41m) marly limestone, -Upper part (35m) chalky dolomitic limestone.
	Tanuma	15	-Shale
	Khasib	77	-Chalky limestone.
	Kifl	34	-Limestone
	Rumaila and Ahmadi	486	The lower part (147m) interbedded chalky limestone and shale. -Middle part (96m)limestone with marl in the upper. -Upper part (243m) mixed chalky and dolomitic limestone.
	Tayarat	461	-Generally, consist of dolostone, in some part especially in the bottom found Anhydrite and shaly chalky limestone, and in the top found beds of shale.
	Shiranish	82	Interbedded marly limestone and limestone.
KS-1	Hartha	196	-The lower part (75m) interbedded marl and chalky shaly limestone. -Middle part (25m) dolostone, -Upper part (96m) interbedded chalky limestone and limestone, in part thin bed of shale.

	Sa'adi	405	-Lower part (85m) marl, in the bottom (5m) chalky limestone. -Middle part (50m) marly limestone. -Upper part (270m) interbedded limestone and chalky limestone.
	Tanuma	60	-Shale
	Khasib	31	-Interbedded shale and limestone, in the top (5m) chalky limestone.
	Mishrif	127	-The lower part (47m) interbedded chalky limestone shale. -Middle part (40m) chalky limestone and in the bottom (5m) clay. -Upper part (40m) pure limestone.
	Rumaila	69	-Shally limestone, in part (8m) chalky limestone.
	Ahmadi	80	-The lower part (40m) interbedded thin bed of shale and tick bed of marl. -The middle part (25m), (20m) shale, and (5m) clay. -Upper part (15m) mixed shale and marl.
	Wara	46	-Lower part (18m) shale. -Upper part (28m) sand with glauconite container in the middle (5m) marl.
UmQ-1	Tayarat	264.8	Dolostone, in part thin beds of Evaporite.
	Shiranish	106.5	-Lower part (73m) Marl. -Upper part (33.5m) marly limestone.
	Hartha	121.5	Limestone
	Sa'adi	340.5	-The lower part (197.5m) interbedded marly limestone and chalky limestone. -Upper part (143.5m) chalky limestone.
	Tanuma	19	-Lower part (10m) shale. -Upper part (9m) shaly limestone.
	Khasib	54.5	Interbedded shaly limestone and chalky limestone, in part thin bed of shale.
	Mishrif	133.5	Interbedded limestone and chalky limestone, in the upper beds of marly limestone.
	Rumaila	91	Interbedded chalky limestone and marly limestone and limestone.
	Ahmadi	142.5	-Lower part (10m) shale with marl. -The middle part (105m) interbedded chalky limestone and limestone. -Upper part (27.5m) shale with marl

Generally, the Cretaceous period is characterized by rising eustatic sea level (Haq et al. 1988a). The contact between the lower and upper Cretaceous sequences is conformable except for the sequences of the far southwestern parts of Iraq where the unconformable contact is represented by the deposition of the Wara Formation in the form of a tongue (Razoyan, 1995). Whereas the contact is unconformable between the lower and early Tertiary due to the loss of sediments of this period towards the wells of the Amara region. This sequence ends with the deposition of the Tayarat Formation and then Aalijy Formation, which is the conformable contact between the Lower Cretaceous and the late Jurassic. The Cretaceous period has three unconformity surfaces. The first separates Mauddud Formation from Ahmadi Formation. The second separates Mishrif Formation from Khasib Formation. The third separates the Tayarat Formation from Umm Erduma Formation (Figs. 8 and 9).

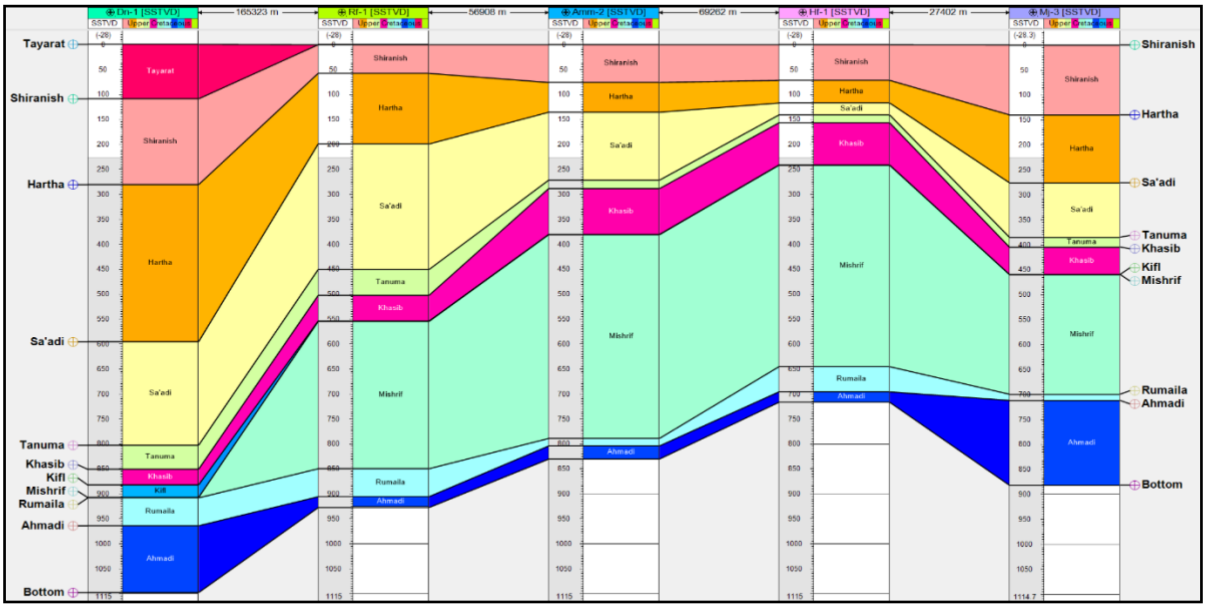

Fig.8. Stratigraphic correlation section for the Upper Cretaceous formations in oil wells (Dn-1, Rf-1, Amm-1, Hf-1, Mj-1)

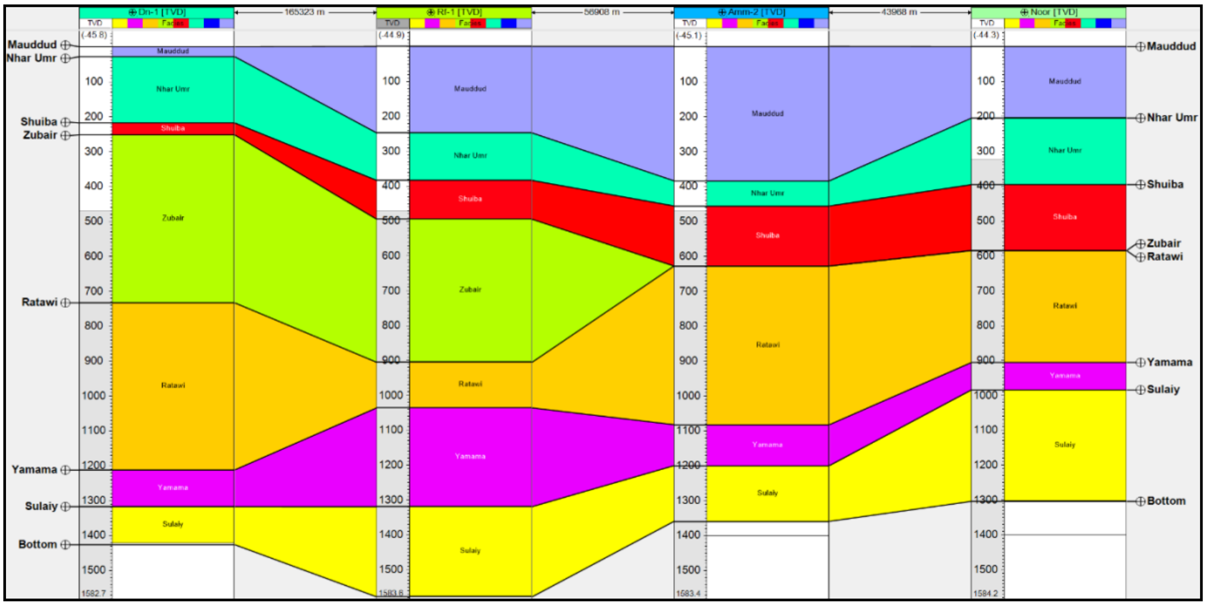

Fig.9. Stratigraphic correlation section for Lower Cretaceous Formations in oil wells (Gn-1, Dn-1, Rf-1, Amm-1, Hf-1, Noor-1).

Generally lower cretaceous is characterized by shallowing upward cycles, while the upper cretaceous represents deepening upward cycles, the stratigraphic setting of the Cretaceous period was illustrated and summarised by Razoyan (1995) (Fig. 10).

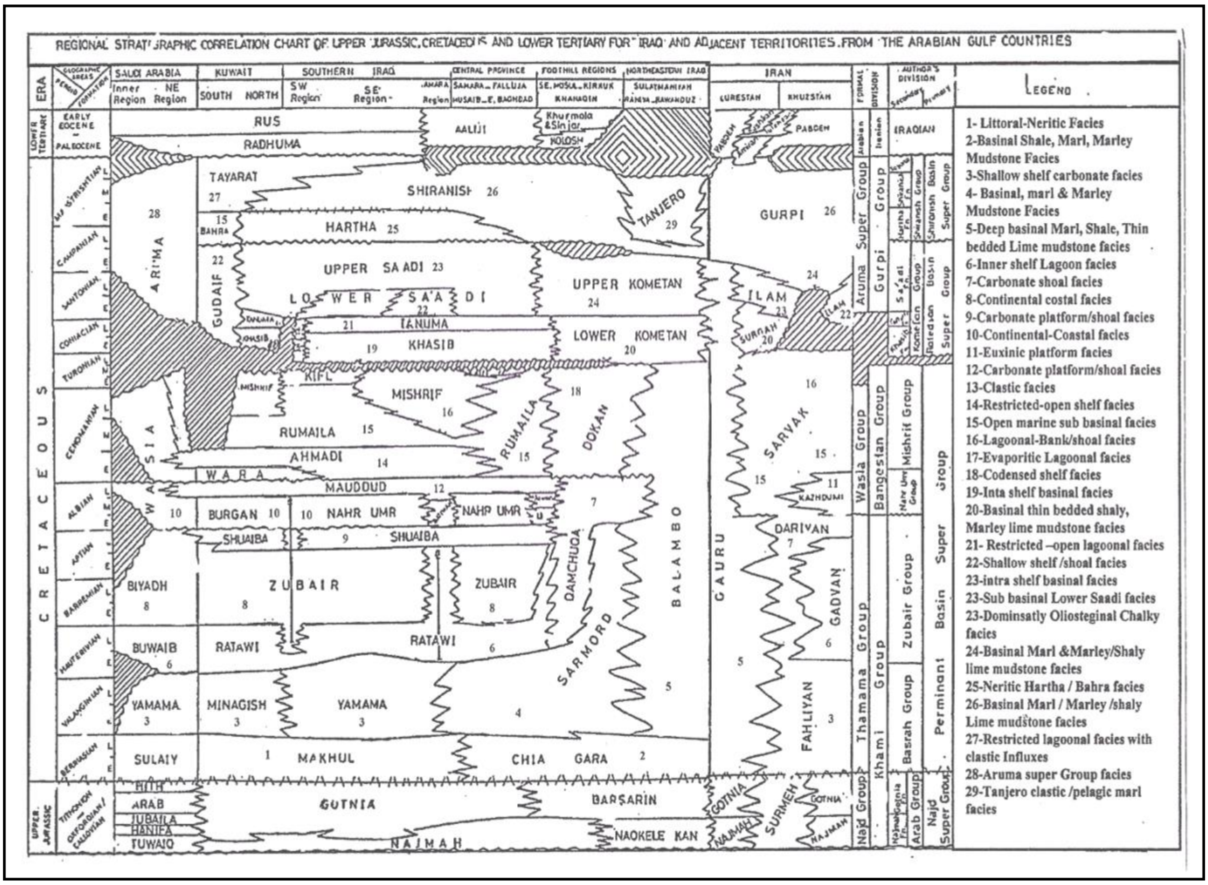

Fig.10. Represents the vertical and horizontal stratigraphic variation section with sedimentary environments of the Cretaceous Formations Razoyan (1995).

5. Results

According to the changes of the sedimentary environments in determining the extent of deepening and shallowing of the sedimentary basin and, since the variation of the sedimentary environments is important evidence in determining the accommodation space, It is a function for base-level transient cycle heterogeneity. This study has recognized:

- There are eight maximum flooding surfaces (MFS).
- The high system tract (HST) is represented by the Yamama, Ahmadi, Mishrif, Tanuma formations, the lower part of the Saadi, Hartha, and Tayarat formations.
- The transgressive system tract (TST) is represented by the Ratawi, Shuaiba, Mauddud, Rumaila, and Khasib, the upper part of the Saadi formation and Shiranish formation.
- The low stand system tract (LST) is represented by Zubair and Nahr Omr formations.
- The Cretaceous period is divided into one cycle from the third order, and seven and a half cycles from the fourth order.
- The Cretaceous period includes seven genetic stratigraphic packages (GSS) (Fig.11).

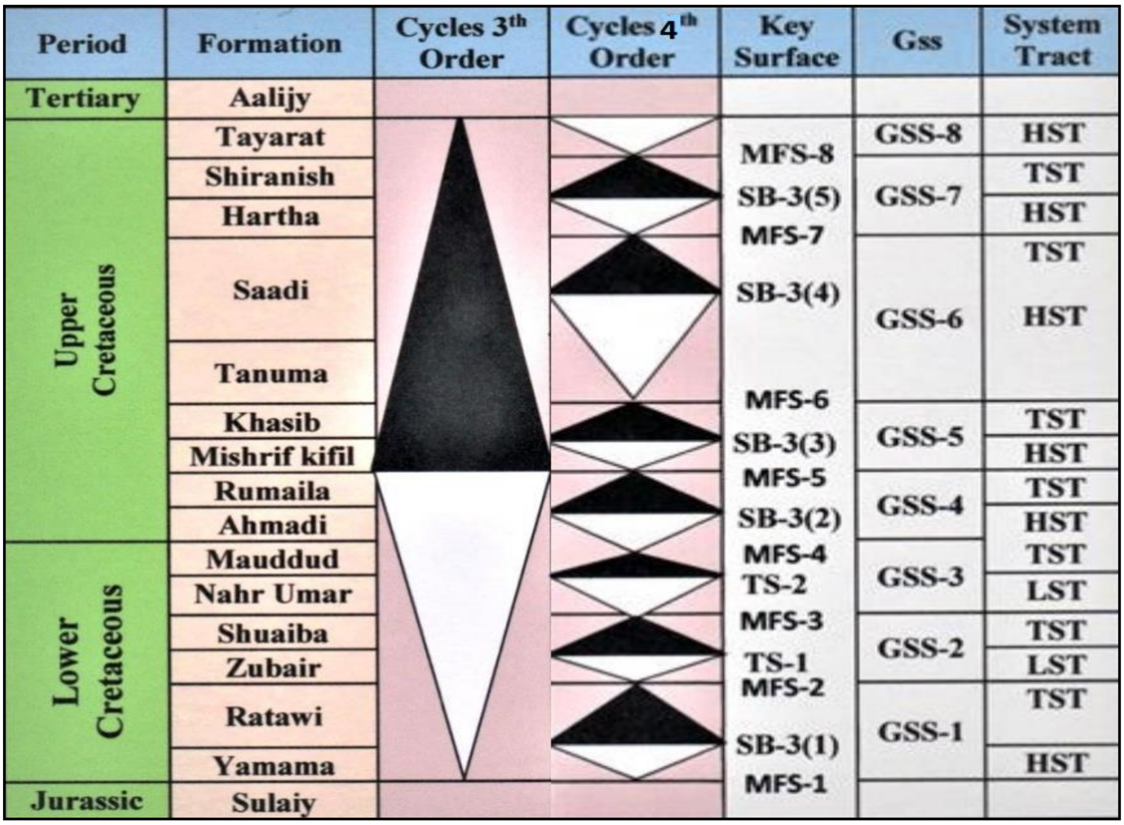

Fig.11. General sequence stratigraphic framework for Cretaceous southern Iraq

The concepts of plate tectonic theory give more realistic explanations of the stratigraphic situation in southern Iraq, especially when the structural nature of the sedimentary basin is taken into regard. The interpretation of the phenomenon of horizontal variation in sedimentation between marine, mixed and continental sediments is due to the tectonic position of the southern region of Iraq at the northeastern margin of the Arabian Plate, which was the passive margin, and characterized by the presence of sub-basin result from many of listric faults. The effect of marine on the northeastern side of the passive margin of the Arabian plate is represented by the accumulation of high-thickness limestone sediments in the eastern regions of this edge, while the continental effect of the platform on the southwestern side deposited the clastic sediment in the western regions in the passive margin of the Arabian plate, which was not separated from the African plate at that time. This combined effect produced clastic sediment in the western desert and southern parts of the stable platform area in Iraq, which is represented by Zubair - Nahr Umr formations, while the platform areas far from the Western Desert toward the east were characterized by alternating clastic and limestone in Ratawi, Zubair, and Nahr Umr formations. The basin area was characterized by limestone sediments of the continental shelf in Sulaiy, Yamama, Ratawi, Shuaiba, Nahr Omar, and Mauddud formations. As a result, three sedimentary zones were formed; these zones are the marine limestone deposits, the mixed carbonate-clastic deposits, and the continental deposits. The boundaries between these zones are represented by relatively wide areas rather than sharp lines. The boundaries were characterized by their horizontal movement during the lower Cretaceous due to the dominated one of the marine or continental effect on the other (Fig. 12 and Table 3).

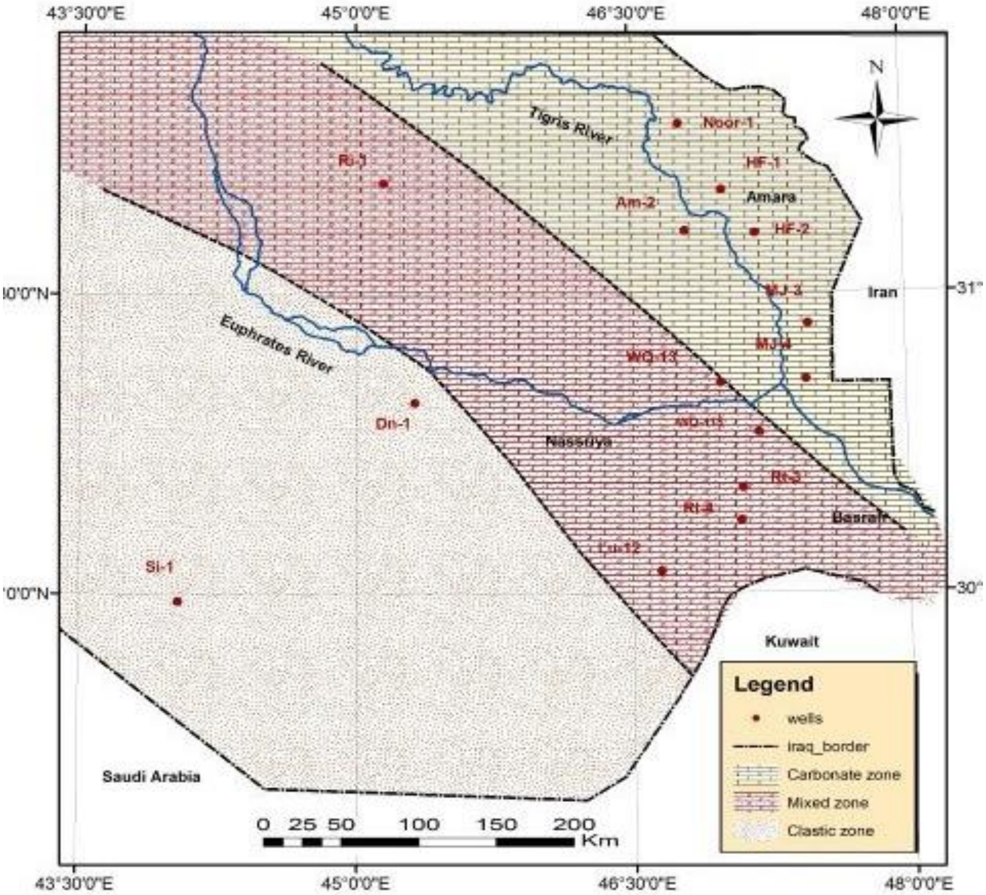

Fig.12. The three depositional border zones of limestone, mixed, and clastic in the Lower Cretaceous.

Table 3. The high fluctuation of the formation thicknesses in the three zones of limestone, mixed, and clastic in the Lower Cretaceous due to the combined effect of the marine and continental factors.

Tectonic Movements	**Stage and Substage**	**Formations**	**The thickness of formation in the clastic zone in meters (Si-1, Dn-1)**	**The thickness of formation in Mix zone in meters (Lu1, WQ115, Rt3, Rt4)**	**The thickness of formation in the carbonate zone in meters (WQ13, Am2, Hf1, HF2, Mj3, Mj4, Rf1, Noor1)**
First Austrian Alpine	Late Albian	Mauddud	31	100.7	226.5
	Early Albian	Nahr Umr	295	210	178.8
Young Kimmerian	Late Aptian	Shuaiba	35	86.6	178.3
	Barremian-Early Aptian	Zubair	440	399.2	Zero
	Hauterivian	Ratawi	127.5	268	384
	Valanginian	Yamama	35.5	233	171
	Berriasian	Sulaiy	93	254	286

The dominance of the continental factor occurred firstly in the Young Kimmerian movement that led to the uplift of the passive margin as a result of the Arabian and Iranian plates convergence, then the marine regressive led to the dominance of the continental factor and shift the boundary between the three zones towards the east. Opposite of that, during the second tectonic movement (First Austrian Alpine movement) the marine factor is dominant because of the subjection of the ocean crust under the Iranian plate. Thus, the discharge of stresses resulting from the forces of pressure, this unloading of the strains led to subsidence in the passive margin and increased its depth in addition to the sea progress towards the stable platform, leading to a shift in the boundary between the three regions towards west land. It should be noted that the first movement caused alternation between the high thickness of the clastic and limestone formations. The second movement is the First Austrian Alpine movement that created alternation between the claystone and limestone with fewer thicknesses within the same formation (Nahr Omar), this movement ended with relative quiet in a short time and Mauddud Formation deposited. It can be concluded that the first movement was more active than the second one, in terms of the higher thickness in the first movement compared to the second.

The previous microfacies studies recognized micro interment within the same rock type, Benthonic lime mudstone microfacies concentrated within south and southwest from the platform, while Pelagic limestone and mudstone microfacies toward the northeast region. So is the sandstone in the southern and southwestern regions, which is represented by the dunes, while in the north-eastern areas, it becomes a river and deposits of the delta. also, within the Basra regions, it showed interference between clastic and limestone represented by a group of rocks, Limey Sandstone, Sandy limestone and conversely, Sandy shale, Limey shale, Shaly limestone, and Shaly sandstone.

5.1. Berrisian to Valanginian (144-132) Million Years

This period included the deposition of Sulaiy and Yamama formations in oilfield Si-1 and Dn-1 which are located in the region of the continental platform. The main structures (West Qurna, Rumaila, Zubair, etc.) in the unstable shelf province probably were growing during the Yamama deposition, leading to facies differentiation within the same structure. These formations have a relatively small thickness of about 35 meters for Sulaiy and 93 meters for Yamama. Moving to the wells in the east, which are located within the Basrah area, especially in the wells (Lu-12, WQ-115, Rt-3, Rt-4), the thickness of the two formations increases to several hundred meters, where the thickness of the Sulaiy is about 254 meters and Yamama is around 233 meters. Finally, the wells located within the north of Basra and Amara (HF-2, Am-2, Noor-1, Mj-3, Mj-4, WQ-13, Rf-1), Sulaiy Formation continue to have a high thickness of about 286 meters while Yamama Formation thickness is reduced to an about 171 meters. After this period the convergence occurred which led to the activation of the listric faults group responsible for the formation of the sub-basin, this reflects on the nature of the deposition of the Yamama Formation, which is deposited within a group of the secondary depositional basin (Al-Mohammed, 2002). The present study indicated a high thickness of Yamama formation within the Basrah area and that thickness decreases in Amara and Western desert, which indicates that the center of the basin is located within the Basrah oilfield (WQ-115). While Yamama Formation consists of limestone in the open sea area (Al-Bayati, 2001), these sediments shallowed to contain the remains of evaporators within Western desert.

5.2. Hauterivian to the Barremian (132-121) Million Years

During this period, a mix of lithofacies was presented by Ratawi and Zubair Formation deposits, where Ratawi is thinning in the wells (Si-1, Dn-1) with a thickness of 127 meters this thickness is increased to reach 384 meters in the Amara region. In contrast, Zubair Formation is thickening in wells

(Si-1, Dn-1) about 440 meters, while disappearing completely in the east Amara Oilfields, reflecting the combined effect of the marine and continental factors.

5.3. Aptian to Albian (121-99) Million Years

The beginning of this period is still within the Young Kimmerian tectonic movement, was the sedimentation of the Shuaiba Formation, which decreased its thickness in a well (Dn-1) to 35 meters, while disappeared in the well (Si-1). In Basrah area wells the thickness is about to 86 meters, while in the east of Amara Oilfields the thickness reaches 178 meters. It should be noted that these overlap with the unity of the Halfaya (Patio) in the area of Basrah and towards the Amara area Al-Bayati (2001). This is attributed to the prevalence of marine influence in the fields of north Basra and the Amar area (Mj-3, Mj-4, WQ-13, Rf-1, HF-1, HF-2, Am2, Noor-1) then disappear towards the (Si- 1) completely. Within this same period, disconformity occurred between the Aptian and Albian, which separates Shuaiba Formation from Nahr Omr Formation. Thus a new tectonic movement begins within the Lower Cretaceous is the First Austrian alpine movement, and here the effect of this movement is evident within the sediments of the Nahr Omar Formation itself, where it form clastic facies with a thickness of nearly 400 meters in a well (Si-1) and 190 meters in a well (Dn-1), while its thickness about 210 meters in the Basrah wells (Lu-12, Rt-3, Rt-4, WQ-115). The lower part is characterized by the deposition of sandstone interfering with Shale while the upper part is characterized by precipitation of limestone interfering with the Shale. It is noted in this region that the thickness of the lower part increases toward the wells (Si-1, Dn-1) versus decrease in thickness towards the wells north of Basra and the Amara region (HF-1, HF-2, Am-2, Noor-1, Mj-3, Mj-4, WQ-13, and Rf-1). The upper part, oppositely deposited, with increased thickness towards the Amara area, and decreased towards the wells (Si-1, Dn-1). After this, the marine influence (sea level rise) continues until the end of the Albian period, accompanied by the sedimentation of the lime Mauddud Formation, which ranges from 30 meters in a well (Si-1) to 226 meters in the north Basrah and Amara fields. The existence of a regional disconformity separates between the Aptian formation and alpine formation related to a wide decline in sea level that was followed by a rise in sea level that reached its peak at the end of Albian (Haq et al., 1988). Al-Fares et al. (1998) explained the pre-Albian disconformity because of the subsequent far-field stress after the opening of the center of the South Atlantic, this opening caused the uplift to raise the western part of the Arabian Craton, leading to transport of the deltaic sands and the transitional marine sediment from west and southwest to the east of the platform.

5.4. Cenomanian – Early Turonian (88-99.6) Million Years

This period included the deposition of Wara, Ahmadi, Rumaila, Kifl, and Mishrif Formations, the rate of sediment production was controlled by the tectonic factor more than the marine factor. Wara and Ahmadi Formations were deposited in the southwestern parts of the study area, particularly in well (Ks-1). Unconformity occurred between the sequences of the Mauddud and Wara Formations, this is indicated by the presence of glauconite mineral in the upper part of it, while this was not recognized between the Mauddud and Ahmadi Formations. These formations represented the intra-shelf basin development during the Cenomanian age by dominating shallow water of carbonate ramps that event was due to the growth of Oman- Zagros peripheral bulge (Al-Zaidy and Al Shwaliay, 2018). The beginning of the second Austrian tectonic movement had a massive effect on raising the passive margin, thus reducing the production of limestone deposits in the southwestern parts, while sedimentary shelf sediments were allowed to deposit (Wara Formation). Also, Ahmadi Formation was deposited in the same area, represented by restricted shallow marine sediments consisting of marl and shale, specifically within wells (Ks-1, AK-1, Gh-1, UmQ-1, Dn-1, Wk-1). In the middle of the study area wells (Rt-1, Rt-2, WQ-13, WQ-115, NNU-1, NNU- 2, R-5), it is observed that Ahmadi Formation is represented by the shallow water lithofacies of gypsum in well WQ-13, and dolomite in the well NNU-1. It should be noted that the average formation thickness is 172.54 meters (Table. 4). This thickness is attributed to the increased growth of the Amara uplift area, which was working to trap the sediments, thus increasing the sedimentation rate. On the other hand, Ahmadi Formation was deposited in wells (Hf-1, Mj-3, Mj- 4, Am-2, Snd-1, Rf-1, Noor-1) located east of the study area within the open marine environment represented by the detrital limestone facies. With the continuation of the second Austrian movement, the Amara bank was uplifting continuously as a result of the compression process increase towards the passive margin, which led to the formation of the sub-basin environments in the western regions and thus sedimentation of the Rumaila Formation consisting of marl, chalky limestone, and shale, with a large thickness about 129.5 meters, while it starts to shallow towards the wells of the central and eastern region of the study area to deposit in the form of a chalky limestone with limestone containing gypsum crystals. Mishrif Formation was characterized by a large thickness in all wells of the study area, where the highest thickness reached 408 meters in the well (Am-2). It had a succession of chalky limestone and shale, this high thickness expanded the eastern region towards the edge of the passive margin and prevented its lithofacies from spreading laterally, so it deposited as a form of rudeist limestone with shally limestone and limestone containing gypsum crystal, while the thickness of the formation is thinning towards the southwestern parts to disappear in wells (Dn-1, Gn-1) to deposit Kifl Formation instead of it with a small average thickness (30) meters from Marly limestone and anhydrite, which is considered a complement to the upper part of the Musharraf Formation, indicating the calm and shallow of the restricted water that allowed the deposition of thin layers of gypsum. This period ended with a regional discontinuity that occurred during the global regressive marine extended from Saudi Arabia, Kuwait, and southern Iraq to the northern Iraq regions (Mosul and Kirkuk) (Razoyan, 1995). It should be noted that the beginning of this discontinuity was the end of the second Austrian tectonic movement

5. 5. The Middle Turonian - Middle Campanian (76.2-88) Million Years

The deposition of the sedimentary cycle (Khasib, Tanuma, and Saadi Formations), this period coincided with the beginning of the lrmidain tectonic movement activity, which was a compressive movement that worked to complete the uplift of the passive margin, that resulted from a regional inclination in the southwestern parts of the study area Thus, it prevented the sediments influx from the stable shelf area. With the deposition of the lower part of Khasib Formation (Late Turonian-Early Conacian), a relative calm occurred for the second Austrian tectonic movement with the continuation of the global marine regressive, which resulted in the deposition of relatively homogeneous sequences of formation in all wells of the study area, up to 57 meters in the eastern regions represented by chalky limestone and Shaly limestone. While the average thickness of the Formation was 53 meters in the central region wells, where it represented chalky limestone and marly limestone, as well as the presence of dolomite. the average thickness of the formation is about 57 meters within the wells of the eastern region, represented by the successions of limestone and shale. The diversity in the Khasib Formation lithofacies is believed to have resulted from the geochemical variation of marine waters due to the relative distance to the passive margin, as well as the variation of the local sea-level changes.

After that, the Armada tectonic movement became active and its effect appeared on the sedimentation of the upper part of the Tanuma Formation (Oolitic limestone facies), while its deposition within the quieter environments towards the stable shelf. The effect of this movement extended with the deposition of the lower part of the Saadi Formation represented by the open marine environment lithofacies towards the edge and the basinal environments in the middle and the sub basinal environments toward the west of the study, and therefore the effect of this movement on this system was shallowing upward. while the upper part of the Saadi Formation was deposited within the deepening upward system, which included sedimentation of chalky limestone of planktonic foraminifera, especially within the wells of the western study area where the formation average thickness is about 284 meters.

5. 6. Late Campanian - Maastrichtain (65.5-76.2) Million Years

During this period, three formations were deposited under the effect of the laramide tectonic movement, these Formations are Hartha, Shiranish, and Tayarat. Hartha Formation that was deposited by the uplifting process, whose effect is evident by the dominance of the deposition of the dolomitic limestone, marly limestone, and the shale towards the middle and western wells of the study area, represented by the Neritic facies' environment at an average thickness 200 meters, while the chalky limestone for open sea environments is deposited towards the wells of the study area close to the edge of the passive margin, whereas Shiranish Formation was deposited with the end of the movement effect within a basin environment represented by the dominance of marly limestone and shale with a system of deepening upward and in conjunction with it deposition Tayarat Formation in the central parts and the western part of the study area with a system of shallowing upward. As a result of this sedimentary distribution in the passive margin during the Upper Cretaceous, three main sedimentary zones were formed: The open marine environment zone towards the passive margin, the Shallow water zone in the mid-region (Amara dome), and the Restricted water zone toward a stable shelf (Table.4). The thickness and facies of the sediments of this zone are characterized by lateral and vertical heterogeneity depending on the dominance of the intensity of the movement and this affected the variance of the thicknesses of the Formations (Rumaila, Ahmadi, Kifl, Mishrif, Upper Tanuma, Saadi, Hartha, Shiranish, and Tayarat). While the relative calm of the movement and the dominance of sea-level change affected precipitation of Khasib and Lower Tanuma Formations.

Table 4. The average thickness to the Upper Cretaceous formations within each of the three regions

Period	Stage and Sub stage	Formation	The average thickness of Restricted water Zone Wells (Wk1, UQ1, KS1, AK1, Gn1, Dn1)	The average thickness of Shallow water Zone Wells (Rt3,4, WQ13,115, R5, NNu1,3)	The average thickness of Open marine Zone Wells (Am2, Noor1, Hf1, MJ3,4, Rf1, Snd1)	Tectonic Movement
Upper Cretaceous	Maastrichtian	Tayarat	293.56 m	193.41	Zero	Laramidian Movement
	Maastrichtian	Shiranish	174.08	173.928	93.75	
	Late Campanian- Maastrichtian	Hartha	379.833	216.357	97.142	
	Early Santonian- Late Campanian-	Saadi	284.75	183.6	133.285	
	Late Coniacian	Tanuma	31.08	40	56.857	
	Late Turonian- Early Coniacian	Khasib	56.33	73.54	57.42	
	Late Cenomanian	Kifl	30	Zero	Zero	Second Austrian Alpin
	Late Cenomanian	Mishrif	134.5	308.17	300.21	
	Early- Middle Cenomanian	Rumaila	129.5	85.84	20.83	
	Early Cenomanian	Ahmadi	84.1	172.54	71.33	
	Early Cenomanian	Wara	46	Zero	Zero	

As a result of this sedimentary distribution in the passive margin during the Upper Cretaceous, three main sedimentary zones were formed: The open marine environment zone towards the passive margin, the Shallow water zone in the mid-region (Amara dome), and the Restricted water zone toward a stable shelf (Fig.13).

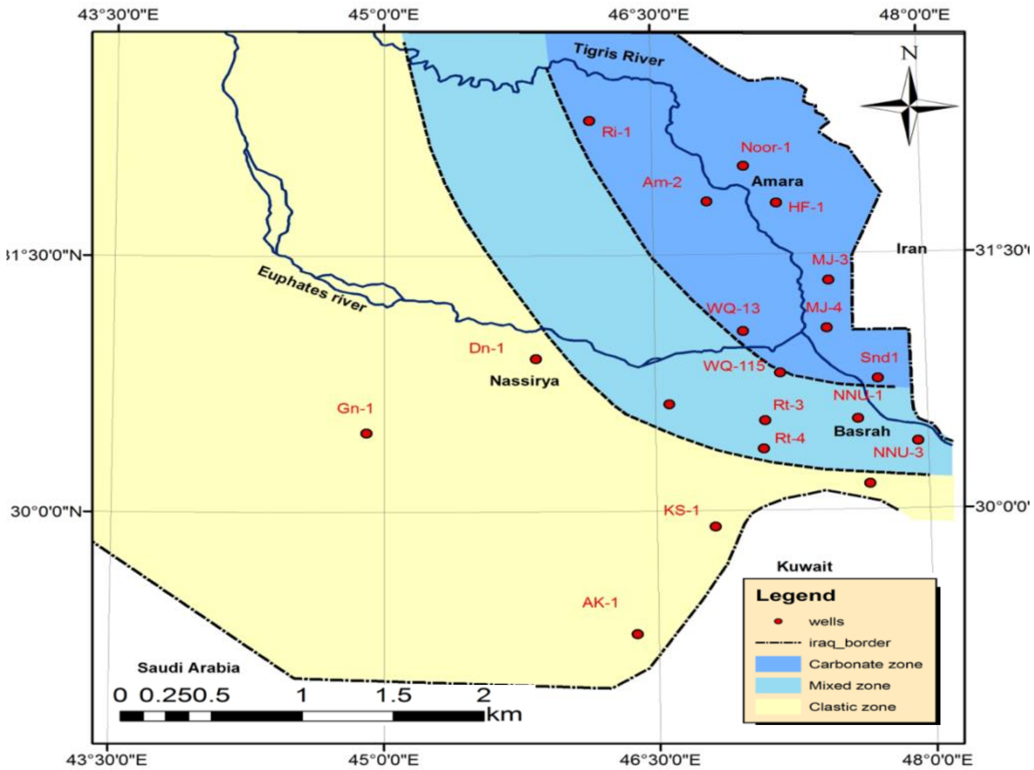

Fig.13. The boundaries between the three deposit regions of the Upper Cretaceous (Modified after Al Bayati, 2011).

6. Discussion

The comprehensive overview of all the available data on the Cretaceous period in southern Iraq has reached two basic definitions:

- The tectonostratigraphic boundary (TSB) is defined as the boundary between phases or kinetic stages and represents the sediments that are deposited away from the impact of movement, as well as this limit may include part of a formation or several formations.
- The tectonostratigraphic unit (TSU) is a layer or set of layers that are deposited by the effect of motion. It represents a confined layer between two tectonic borders.

According to the previous two definitions, the present study gives approximate results close to Al-Bayati et al. (2010) and Numan (2000 and 2011) (Fig.14).

Fig.15. Summarizes the main results in the present study. The results show the presence of five stratigraphic boundaries of TSB that are represented by TSB1 to TSB5. The five TSBs are represented by Sulaiy, Shuaiba, Mauddud, Khsib, and the lower part of Tanuma-Shiranish formations. Each one of these TSBs boundaries has a set of four units TSU, which it has, in turn, secondary sub-units illustrate as follows:

•TSU 1= (A – B – C – D)

•TSU 2= (A – B)

•TSU 3= (A – B – C)

•TSU 4= (A – B – C)

It is obvious from Figure 8 that the boundaries are gradually extended through the area during the Cretaceous period and do not have a sharp limit. Additionally, these boundaries could disappear from some features during sedimentary periods, such as TSU 1D, which extends through the clastic and mixed zones, as well as with the two unites TSU 2A and TSU 2B, which are conjunction in the mixed zone.

Decreasing the movement forces with time leads to form the primary porosity of the upper TSU units and leads to moderate deposition rates of these units, which helped to accumulate the organic substance insufficient amount in them. The average sedimentation rate is considered a good condition to aggregate the organic substance.

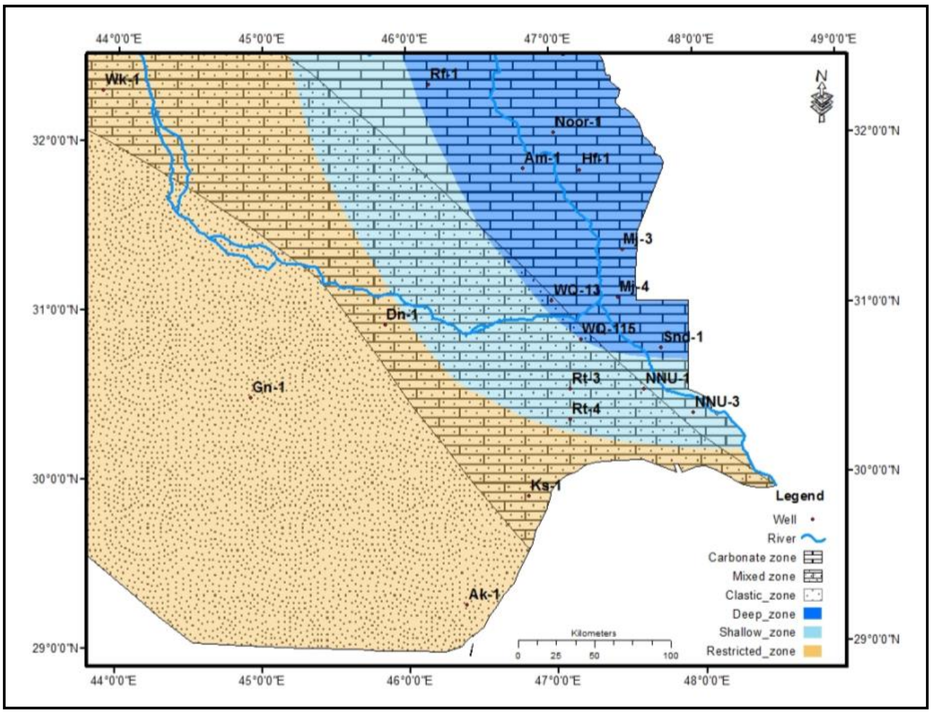

Fig.14 . A comparison between the Lower and Upper Cretaceous zones.

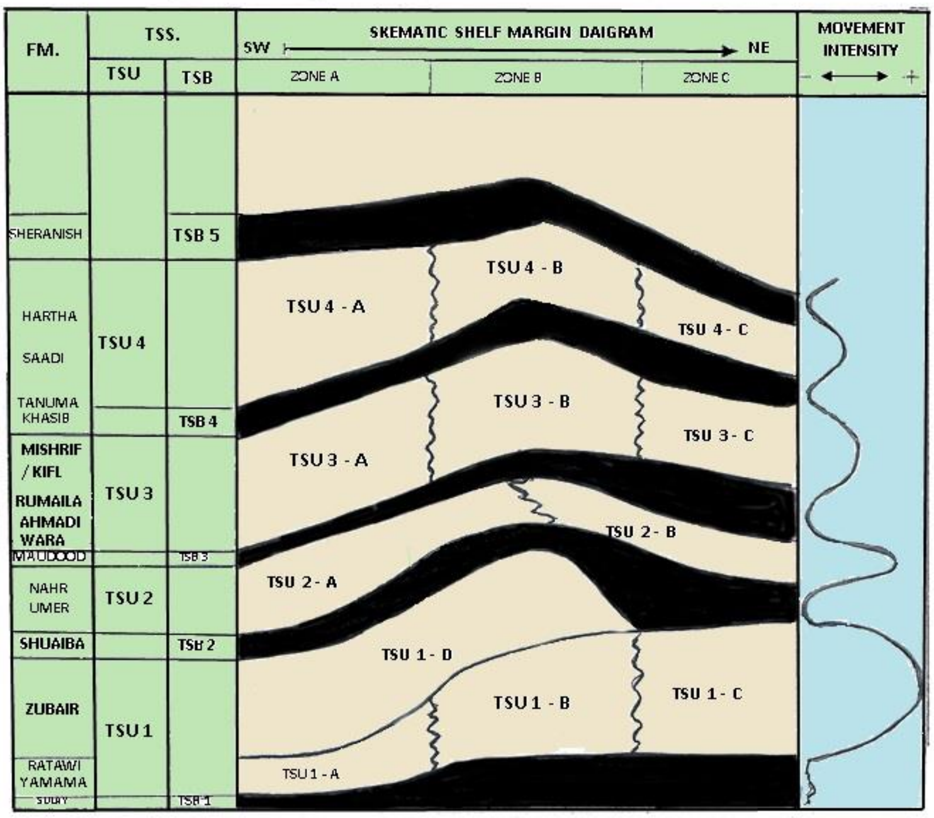

Fig.15. Tectonic stratigraphic system of the Cretaceous period in Southern Iraq

7. Conclusions

- The Cretaceous period in southern Iraq was divided into four main categories of TSU units. Each category contains a set of subunits or secondary that is confined between five boundaries of TSB.
- The lateral extension of TSU close to the passive margin from the northeast to the southwest part of the study area, which represents a transfer form of TSU units from a reservoir to a generator source and then to generator hydrocarbons. The transition from north to south represents the improvement of reservoir characteristics in the TSU units.
- Vertically, the TSU units were characterized by improved reservoir properties with decreasing depth.
- Each TSU unit needs an isolated oil-producing model because it cannot be produced laterally or vertically from one layer or formation by concerned it in one system.
- The lateral boundary between the TSU units is gradual limits rather than sharp limits. There is a relative convergence in their specifications for the central and south-western regions, compared with the north-eastern regions of the study area, which reflects the variation or similarity of the producing models of these units.
- Tectonostratigraphic boundary (TSB) is considered as a generator source more than producing hydrocarbons. Therefore, it does not have a significant lateral variation compared to the TSU units.

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