Analysis of Burial History for Mesopotamian basin, southern Iraq

Amna M. Handhal[1]*, Muwafaq F. Al-Shahwan[1] , Abdulla A. Al-Yaseri[2]
[1] Department of Geology, College of Science, University of Basra, Basra, Iraq,
[2] South Oil Company, Basra, Iraq

Abstract

In this study, different oil fields in Mesopotamian basin, southern Iraq (Siba, Zubair, Nahr - Umr, Majnoon, Halfaya, Kumait, and Amara) were selected for studying burial history. PetroMod software 1D was used for basin constructing and to evaluate burial history of the basin. Results showed that in the upper Jurassic to the Recent, Mesopotamian Basin exhibited a complex subsidence history over a period of about 152 Ma.There are different periods of subsidence: high, moderate, and slow. High subsidence occurred at upper Jurassic- mid Cretaceous and at Miocene due to Tectonic subsidence. Slow subsidence occurred at upper Cretaceous and moderate subsidence at Paleogene. In the upper Jurassic, rapid subsidence is driven under the effect of sediment load during Suaily deposited. The average total subsidence values of the basement during the deposition of Suaily Formation is reached about 200 m. The highest subsidence rates during this time are observed northeast of the study area. Rapid subsidence in the lower Cretaceous, during deposition of Yammama, Ratawi, and Zubair formations. The average tectonic subsidence value of the basements during the deposition of Yammam Formation is reached to 300 m. The highest subsidence rates are observed trend to south west of the study area.

Keywords: Backstripping, Total subsidence, Tectonic subsidence, Eroded thickness, Burial history.

تحليل تاريخ الدفن لحوض وادي النهرين، جنوب العراق باستخدام برنامج PetroMode 1D

امنة مال اللة حنظل*[1]، موفق فاضل جبر[1]، عبد اللة عبدالحسن الياسري[2]
[1] قسم علم الارض، كلية العلوم، قسم علم الارض، البصرة، العراق، [2] شركة نفط الجنوب، قسم الدراسات

الخلاصة:

في هذه الدراسةِ، اختيرت حقول نفط مختلفة من حوض وادي النهرين، جنوب العراق (سيبة والزبير ونهرعمر ومجنون وحلفاية وكميت وعمارة) لدِراسَة تأريخِ الدفنِ. استخدام برنامج PetroMod لبِناء موديل الحوض ولتَقييم تأريخِ دفنِ الحوض . بينت النَتائِجُ ان خلال الفترة (152 Ma) من الجوراسي الاعلى إلى المتاخرِ كان حوض وادي النهرين ذو تجلس معقّدِ . هناك فترات مختلفة مِنْ التجلس : عالي، معتدل، وبطيئ. التجلس العالي حَدثَ في الجوراسي الأعلى وطباشيري الاوسطِ وفي المايوسين بسبب التجلس التكتوني التجلس البطيئ حَدثَ في الطباشيري الأعلى والتجلس المعتدلِ في الباليوجين . التجلس السريعِ في الجوراسي الأعلى حدث تحت تأثيرِ حملِ الراسبِ أثناء فترة ترسب تكوين سلي. إنّ معدل قِيَمَ التجلس الكليّةِ للقاعدة أثناء ترسيب تكوين سلي وَصلت حوالي 200 متر. إنّ اعلى نِسَبَ تجلسِ في هذه الفترة تقع في المنطقة الشمالية الشرقيةَ من منطقةِ الدراسةَ. حدث التجلس السريع في الطباشيري الاسفلِ أثناء ترسيب تكاوين اليمامة ورطاوي والزبير. إنّ معدل قيم التجلس التكتوني للقاعدة أثناء ترسب تكوين اليمامة تُصَلُ إلى 300 متر. إنّ اعلى نِسَبَ للتجلس تتجه نحو المنطقة الجنوبية الغربيةَ من منطقةِ الدراسةَ.

*Email: amhgeo@gmail.com

Introduction:

The study area includes seven oil fields represent (Siba, Zubair, Nahr Umr, Majnoon, HalFaya, Kumait, and Amara) as shown in **figure (1)**. They are located in south part of Iraq between (30° 58′ - 32° 08′ latitude) and (46° 52′ - 47° 56′ longitude). At the present day, the basin forms a flat-lying area located between northern central Iraq and Kuwait [1]. The basin is covered by loess and Quaternary fluvial plain deposits of the Tigris and Euphrates Rivers. Anticlines and horsts lie beneath undeformeal or gentlly deformed Neogene cover and is frequently related to long-lived paleo-structures in the Basra area[1] . They may also related to movement of infracambrian of Harmuz salt [2]. From a tectonic view point,, the Mesopotamian basin was subdivided into three subzones: Zubair, Euphrates and Tigris subzones [3], The Mesopotamian zone is the eastern most unit of the stable shelf. It is bounded in the NE by the folded ranges of pesh-kuh in the east and Hemrin and Makhulin. The southern boundary is controlled by faults. figure two showed the stratigraphic column of southern Iraq. A sedimentary basin consists of strata of different lithologies deposited in different time interval [4]. The main data in the burial history studies are the thickness and the lithology of each layer and the time of the horizons separating the layers. In order to construct burial history curve, information on eroded thickness for individual stratigraphic succession was deduced from data on the thickness of geological formations.

A burial history usually has breaks or gaps in the stratigraphical record, either because of lack of deposition or because of erosion [4]. The development of the basin is modeled by adding layer on top of layer through the geohistory, eventually with periods of no deposition or periods with erosion [4]. The deposition history gives the geometry and material properties of the basin by processes on the basin surface; the water depth history, surface, temperature history and the heat flow history become boundary conditions for the equation of fluid flow and heat flow [4]. the geometry of basins is often complicated by additional processes, like faulting that breaks the geometrical continuity of the strata or thrust faulting that may even mess up the chronological order of the strata [4].

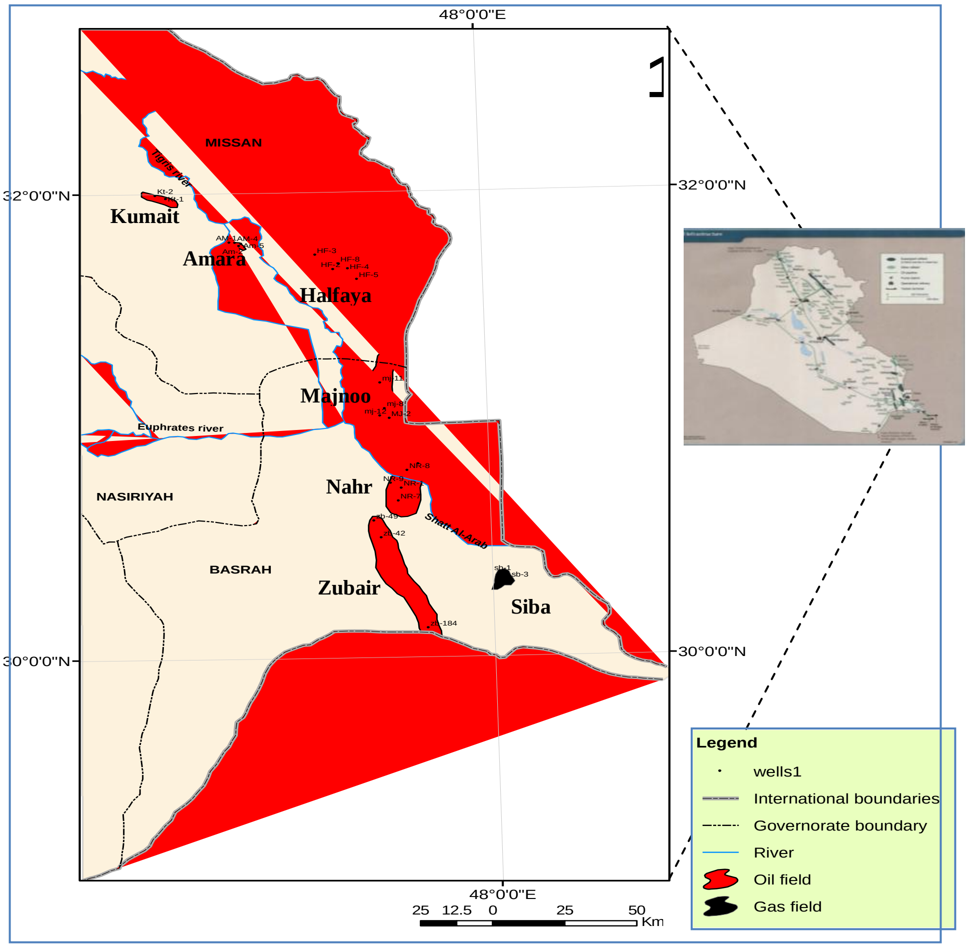

Figure 1- Map of the study area

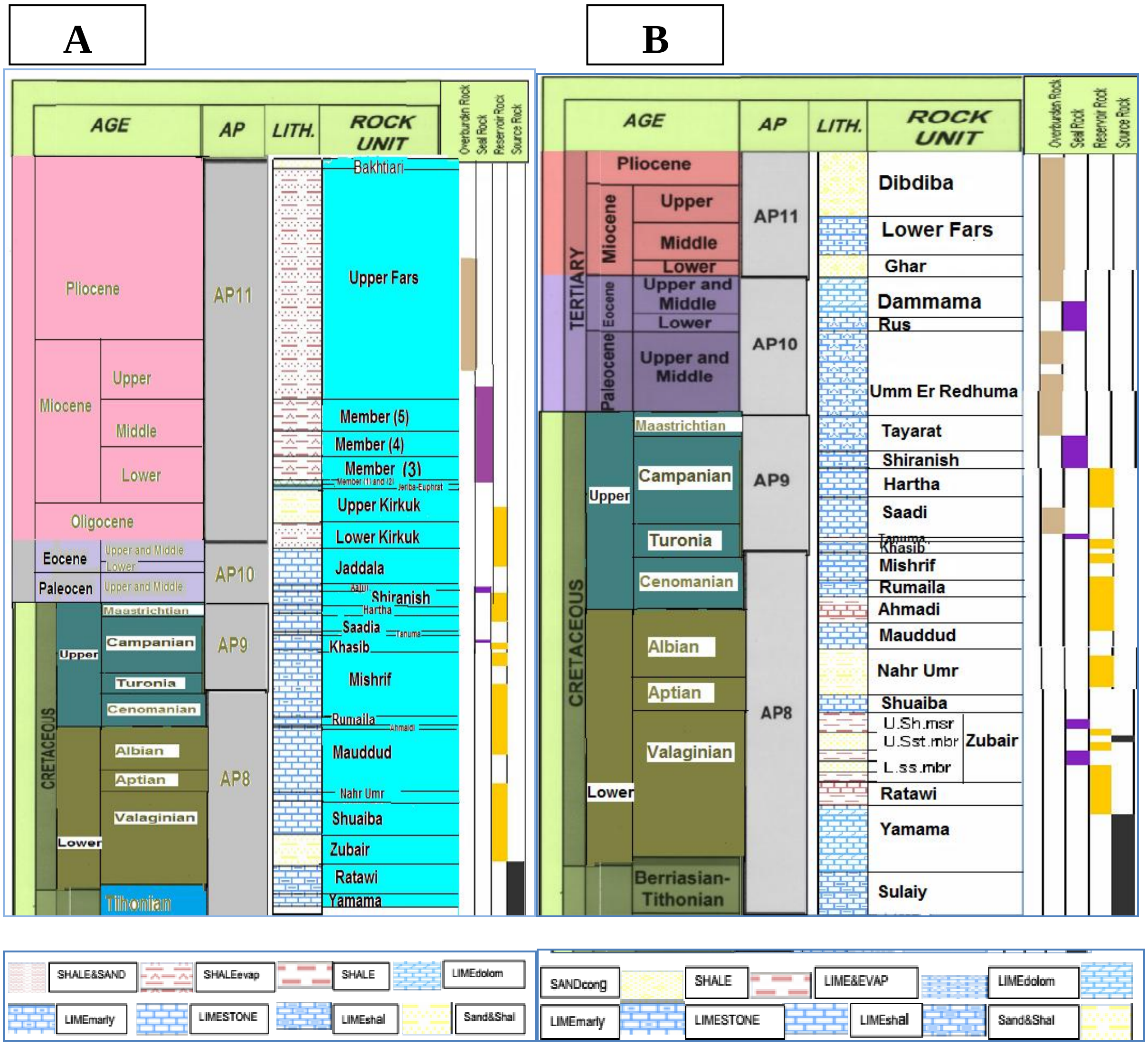

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Figure2- Stratigraphic column in southern Iraq.
A. Zubair oil field(Zb-42), B. Halfaya oil field(Hf-4)

PETRO MODE 1D software

PETRO MODE 1D software is a software package that fully integrates seismic, seismic-stratigraphyic, and geological interpretation with multi-dimensional simulation of thermal 3-phase fluid and petroleum migration histories in sedimentary basins. The steps of 1D modeling could by illustrated using Figure (3). It incorporates deposition, pore pressure calculation and compaction, heat flow analysis and temperature determination, the kinetics of calibration parameters such as vitrinite reflectance or biomarkers, modeling of hydrocarbon generation, adsorption and expulsion processes, fluid analysis, and finally migration [5]. The main basic units of this Package are

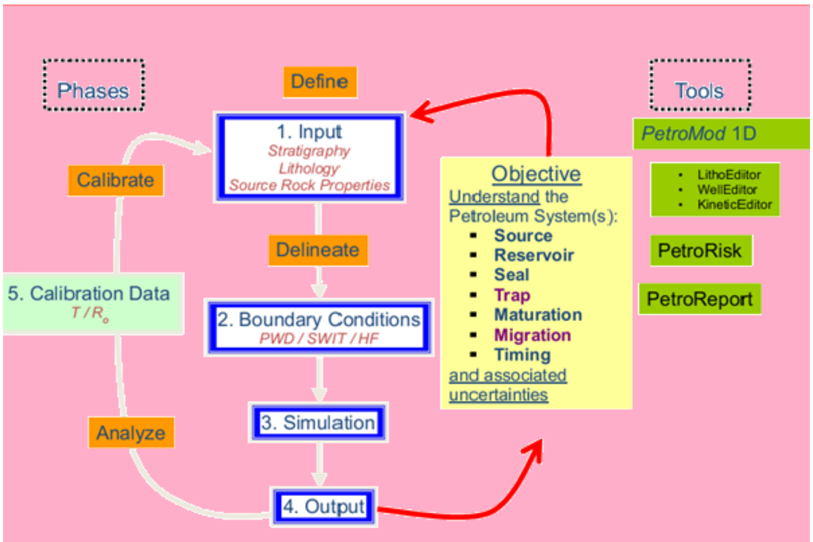


Figure 3- The workflow chart of PetroMode software (After Schlumberger, 2011)

Input

1) Deposition

Layer are created on the upper surface during sedimentation or removed during erosion. It is assumed that the geological events of deposition and hiatus are known, therefore, paleotimes of deposition can be assigned to the layers, the depositional thickness of a new layer is calculated via porosity controlled backstipping form present day thickness or impetrated form structural restoration programs [5].

a) Backstripping

The purpose of backstripping is to use the stratigraphic record to quantitively estimate the depth that basement would be in the absence of sediment and water loading. This depth provides a measure of unknown "tectonic driving forces" that are responsible for basin formation and for this reason have been termed the tectonic subsidence or uplifted of the basin by comparing backstripped curves to theoretical curves. For basin subsidence and uplift it has been possible to deduced information on the basin forming mechanisms. The aim of backstripping is to analysis the subsidence history of basin by modeling a progressive reversal of the depositional process [6]. The steps of backstripping are:

(1) Porosity determination:

Porosity can be measured using open hole well logs such as sonic, neutron, and density logs. These logs are commonly used to measure porosity. The measured porosity is then plotted against depth to estimate compaction. The relationship between these variables (i.e., porosity and depth) mostly exhibit linear relationship in the form: [7].

$$\phi_P = \phi_\circ e^{-cZ} \quad \textbf{(1)}$$

where

ϕ_P : porosity at depth (z)

$\phi_\circ$: initial porosity

c : coefficient determine the slope of porosity – depth curve

Figure (4) shows the exponential relationship between porosity and depth for different lithological units (shale, carbonate, and sandstone) for studied wells. From these relationships estimated values of $\phi_\circ$ and C were estimated.

(2) Age of lithologic units

The geological time scale preposed by [8] as well as Middle East geological time scale [9] were used to determine age of the studied formations.

(3) Sediment decompaction

The first step in backstripping is to reconstruct the original sediment thickness $T_\circ$ of growing sedimentary fill from the basin floor up – to – date stratigraphic boundaries in particular exposure or well logs [6]. To determine the $T_\circ$ the porosity (ϕ_P) and present – thickness (T_P) were used as show in the following equation: [10]

$$T_\circ = \frac{(1-\phi_P)}{(1-\phi_\circ)} \cdot T_P \qquad \textbf{(2)}$$

(4) Sediment accumulation rates

The average of the rate (R) at which the sedimentary rock accumulated during the time interval can be calculated from equation (3) below, if the time span (A) of the interval is expressed in million years and the thickness (T) in meters, then: [11]

$$R = \frac{T}{(10 * A)}\left(\frac{cm}{1000\,years}\right) \qquad \textbf{(3)}$$

This equation should be modified to express the uncorrected rate (UR) as[11]:

$$UR = \frac{T_P}{10 * A}\left(\frac{cm}{1000\,years}\right) \qquad \textbf{(4)}$$

where

T_p : present thickness

In other words, units should be restored to their original thickness $T_\circ$ to obtain comparable rates of fill (RF)[11].

$$RF = \frac{T_o}{10 * A}\left(\frac{cm}{1000\,years}\right) \qquad \textbf{(5)}$$

(5) Total subsidence

The total depth of basin is the sum of the thickness of the sediments and the water depth above that basin fill. The total subsidence is calculated as : [12]

$$S = \sum T^* + WD_i \qquad \textbf{(6)}$$

where

S = total subsidence, *WD* is the water depth and T^* is the decompacted thickness.

(6) Tectonic subsidence

Backstripping is a quantitative method of estimating tectonic subsidence, which is defined as the vertical movement of basement in the absence of both sediment loading and sea – level – change [13]. The calculation of basement subsidence in water, R1 (also called first reduction or accommodation), is a modification of the general backstripping equation of [14]:

$$R_1 = T_s + \Delta SL = T^*\left(\frac{\rho_a - \rho_s}{\rho_a - \rho_w}\right) + WD \qquad \textbf{(7)}$$

where

T_s : tectonic subsidence

ΔSL : eustatic sea level change

WD : paleodepth

ρ_a and ρ_w: densities of the asthenshpere (3.18 g/cm^3 at 1300 °C) and sea water (1.03 g/cm^3) respectively.

ρ_s: density of sediment column, changes as the thickness of the stratigraphic section change due to compaction, which can be calculated for the column after the deposition of unit i by the following equation [14]:

$$\rho_{si} = \frac{\sum_{i=1}^{n}\left[\left(\phi_{i\rho w} + (1-\phi_i)\rho_g\right)\right]T^{*i}}{S^*} \qquad \textbf{(8)}$$

where

$$S^* = \sum_i^i T^{*i}$$

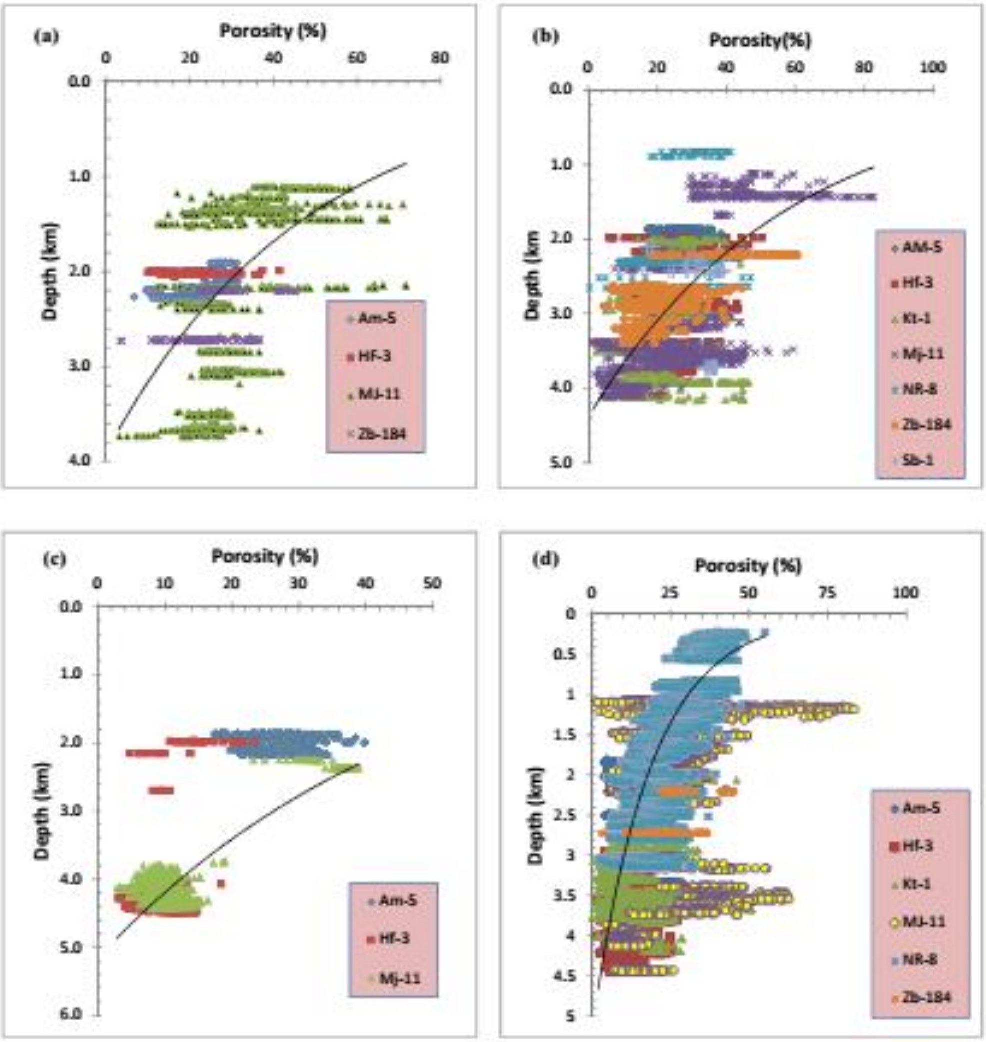


Figure4- Porosity – depth curve for **(a)** shale **(b)** sandstone **(c)** dolomite **(d)** and Limestone

ρ_g : grain density of unit and

ϕ_i : porosity of unit i

The tectonic subsidence for any interval of basin subsidence can be calculated by other formula proposed by [10]:

$$R_i = T^* \cdot \left[\left(\frac{\rho_m - \rho_s^*}{\rho_m - \rho_w} \right) + wd - \Delta SL \left(\frac{\rho_m}{\rho_m - \rho_w} \right) \right] \quad \textbf{(9)}$$

where

T^* : decompacted thickness (m)

wd : paleodepth water

ΔSL : changes in sea level (m)

ρ_m : mantal density (2.8 g/cm^3)

ρ_w : water density (1.04 g/cm^3)

ρ_s^* : corrected sediments density which is calculated as:

$$\rho_s^* = \phi_\circ \rho_w + (1-\phi_\circ)\rho_s \quad \textbf{(10)}$$

where

ρ_s : uncorrected sediments density (sand 2.65, limestone 2.71, shale 2.78, and evaporate 2.97) gm/cm^3.

Estimation of paleowater depths (wd) were obtained from a combination of benthic biofacies, litho stratigraphy, and paleo slope modeling [15]. The paleowater depths for the study wells were estimated depending on the depositional environments for each formation, Table (1), Fig. (5) and Fig. (6). Figs (7 to10) show the calculated total and tectonic subsidence for the study area.

Table 1- Environment and paleowater depth for each formation of studay area.

Formation	Environment	PWD	Formation	Environment	PWD
Mugdadiya(Baktiryi)	Alluvial sandy rivers and fans	1	Ahmadi		50
Injana (Upper Fars)	Fluvial facies	10	Mauddud	Carbonate ramp	100
Dibdibba	Alluvial fans	4	Naher Umr	Carbonate inner shelf	10
Fatha (Lower Fars)	Lagoon and Sabkha	3	Shuaiba	Carbonate ramp	100
Jeribe - Euphrate	Lagoon - inner shelf	10	Zubair	Inner shelf delta	10
Ghar	Littoral and delta	5	Ratawi	Carboante inner shelf	30
Upper - Kirkuk	reef	10	Yamama	Shoals	30
Lower Kirkuk	reef	15	Sulaiy	Inner shelf	30
Dammam	Shoals	10			
Jaddala	Outer shelf/ pelagic	200			
Rus	Lagoon/ Sebkha	3			
UmmEr Radhuma	Inner shelf	20			
Aaliji	Outer shelf	300			
Tayarat	Carbonate shelf	100			
Shiranish	Outer shelf/ Basinal	300			
Hartha	Carbonate shelf	200			
Sadia	Deep inner shelf/ Lagoon	30			
Tanuma	Deep inner shelf/ Lagoon	50			
Khasib	Deep inner shelf/ Lagoon	30			
Mishrif	Rudist reef	10			
Rumaila	Deep inner shelf	30			

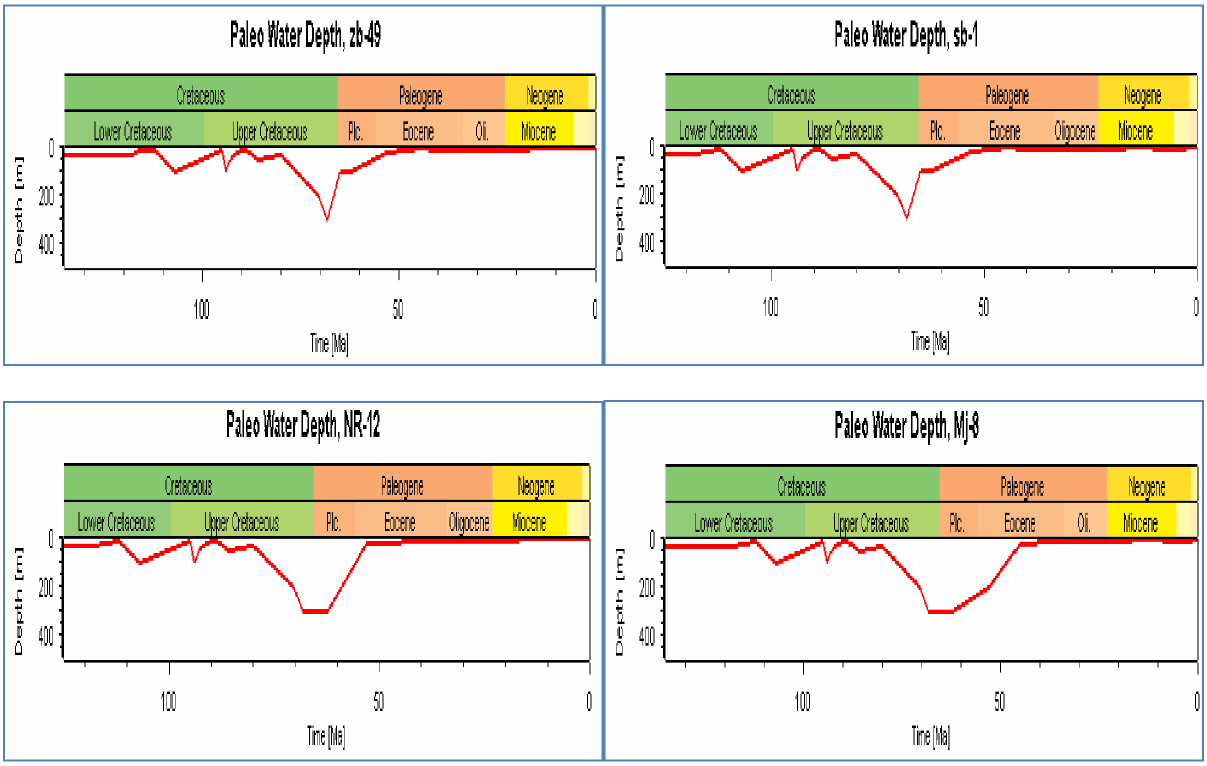


Figure 5- Paleowater depth for selected wells from Basra oil field.

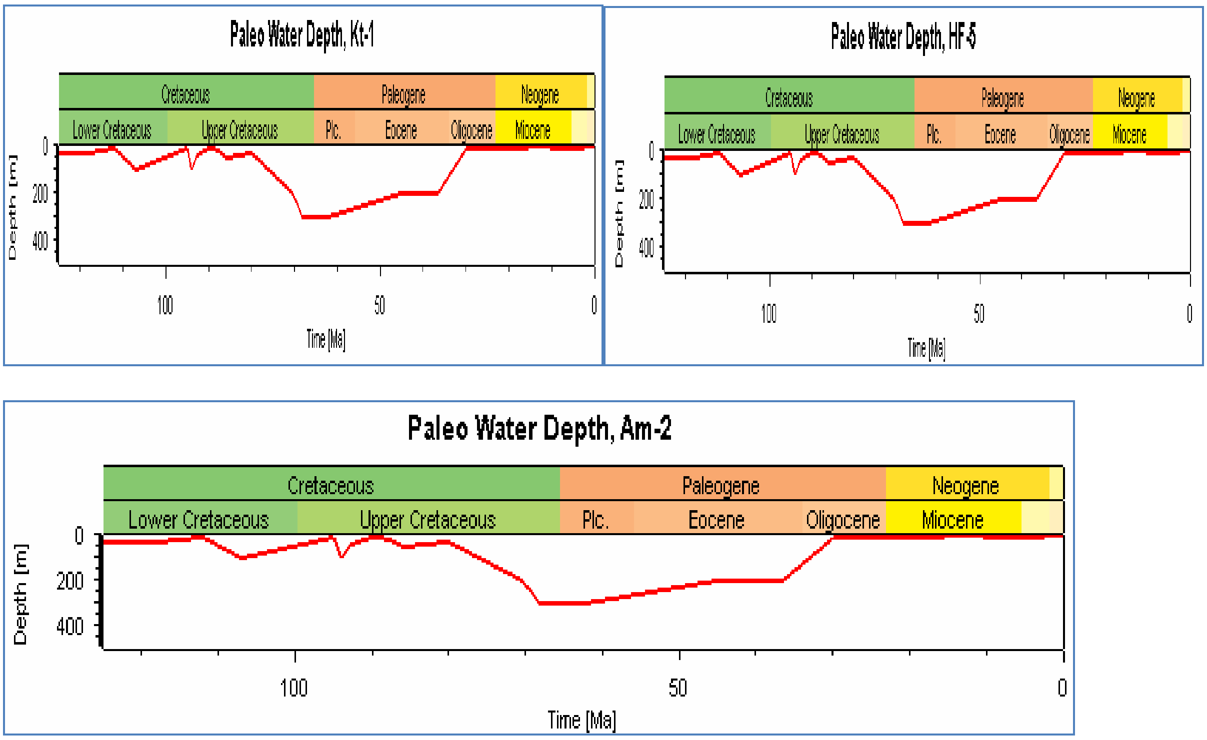


Figure6- Paleowater depth for selected wells from Amara oil field.

Zb-42

Fm.	Tp																								
Dibdba	364	To																							
Fatha	209	236.82	To																						
Ghar	124	131.49	136.66	To																					
Unconf.	0	0.00	0.00	0.00	To																				
Dammam	223	243.79	260.82	273.56	273.56	To																			
Rus	70	75.66	80.21	83.55	83.55	91.28	To																		
Umm-Er-Radh.	464	493.33	516.19	532.63	532.63	569.49	583.52	To																	
Unconf.	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	To																
Tayarat	204	213.64	220.96	226.12	226.12	237.38	241.56	281.31	281.31	To															
Shiranish	91	94.80	97.66	99.66	99.66	103.99	105.58	120.39	120.39	130.53	To														
Hartha	158	163.96	168.40	171.50	171.50	178.16	180.60	202.88	202.88	217.75	225.93	To													
Sadi	218	225.06	230.28	233.90	233.90	241.61	244.41	269.47	269.47	285.68	294.43	312.59	To												
Tanuma	25	26.08	26.85	27.37	27.37	28.44	28.83	32.12	32.12	34.14	35.20	37.35	41.16	To											
Khasib	63	64.79	66.10	67.01	67.01	68.93	69.62	75.73	75.73	79.60	81.66	85.87	93.46	94.50	To										
Unconf.	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	To									
Mishrif	151	157.10	161.17	163.81	163.81	169.07	170.87	185.02	185.02	192.78	196.62	203.94	215.68	217.16	221.05	221.05	To								
Rumaila	91	94.49	96.82	98.33	98.33	101.32	102.34	110.33	110.33	114.68	116.83	120.91	127.41	128.23	130.37	130.37	135.99	To							
Ahmadi	146	151.34	154.88	157.18	157.18	161.72	163.27	175.32	175.32	181.84	185.05	191.12	200.75	201.96	205.12	205.12	213.37	218.87	To						
Mauddud	139	143.80	146.98	149.03	149.03	153.08	154.45	165.13	165.13	170.86	173.67	178.98	187.33	188.38	191.11	191.11	198.20	202.91	211.26	To					
Naher Umr	258	262.32	265.43	267.55	267.55	271.95	273.51	286.75	286.75	294.64	298.70	306.72	320.24	322.02	326.71	326.71	339.52	348.47	365.26	384.77	To				
Shauaiba	98	100.92	102.84	104.07	104.07	106.48	107.30	113.57	113.57	116.88	118.50	121.52	126.22	126.80	128.31	128.31	132.22	134.78	139.27	144.04	154.46	To			
Zubair	377	381.63	384.94	387.18	387.18	391.81	393.45	407.08	407.08	415.04	419.09	426.99	440.04	441.73	446.17	446.17	458.06	466.21	481.14	497.91	537.94	557.20	To		
Ratawi	132	135.26	137.39	138.75	138.75	141.40	142.29	149.04	149.04	152.56	154.25	157.41	162.25	162.85	164.39	164.39	168.34	170.90	175.34	179.98	189.90	194.18	214.15	To	
Yamama	367	375.28	380.65	384.07	384.07	390.74	392.97	409.83	409.83	418.55	422.75	430.52	442.40	443.86	447.62	447.62	457.22	463.42	474.12	485.26	508.80	518.88	565.18	584.89	To
Sulaiy	237	241.79	244.89	246.86	246.86	250.68	251.96	261.56	261.56	266.49	268.86	273.22	279.86	280.67	282.76	282.76	288.07	291.50	297.37	303.44	316.17	321.58	346.02	356.24	390.88

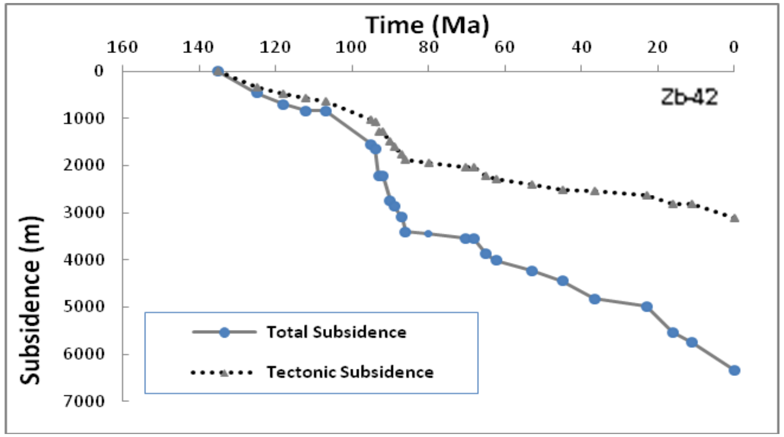


Figure 7- Matrix calculation of the decompacted thickness of the studied formation and the subsidence curves obtained from Zb-42 well .

Mj-11

Fm.	Tp																						
Dibdba	**1007**	To																					
Fatha	305	**391.6**	To																				
Ghar	132	151.2	**159.7**	To																			
Unconf.	0	0.0	0.0	**0.0**	To																		
Dammam	192	228.9	251.7	265.0	**265.0**	To																	
Rus	321	369.5	397.9	413.8	413.8	**442.8**	To																
Umm-Er-Radh.	81	91.2	97.0	100.2	100.2	105.9	**119.4**	To															
Unconf.	0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	To														
Shiranish	93	103.9	110.0	113.3	113.3	119.2	133.0	137.7	**137.7**	To													
Hartha	107	118.5	124.8	128.3	128.3	134.3	148.3	152.9	152.9	**159.0**	To												
Sadi	76	83.6	87.7	89.9	89.9	93.8	102.7	105.6	105.6	109.3	**114.4**	To											
Tanuma	43	48.9	51.9	53.4	53.4	56.1	61.9	63.8	63.8	66.2	69.3	**71.9**	To										
Khasib	50	54.6	57.0	58.3	58.3	60.6	65.8	67.4	67.4	69.6	72.4	74.7	**76.2**	To									
Unconf.	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	To								
Mishrif	**245**	**274.6**	**287.4**	**293.7**	**293.7**	**303.8**	**324.1**	**330.0**	**330.0**	**337.3**	**346.3**	**353.2**	**357.3**	**362.2**	**362.2**	To							
Rumaila	9	10.0	10.5	10.7	10.7	11.0	11.7	11.9	11.9	12.2	12.5	12.7	12.8	13.0	13.0	**13.9**	To						
Ahmadi	173	192.0	200.1	204.1	204.1	210.5	223.0	226.7	226.7	231.1	236.6	240.8	243.2	246.2	246.2	262.7	**263.4**	To					
Mauddud	177	195.1	202.7	206.4	206.4	212.4	224.0	227.4	227.4	231.4	236.5	240.3	242.5	245.2	245.2	260.1	260.7	**273.2**	To				
Naher Umr	185	194.5	199.3	201.8	201.8	206.1	215.1	217.9	217.9	221.4	225.9	229.4	231.5	234.1	234.1	249.3	249.9	264.0	**282.5**	To			
Shauaiba	165	179.6	185.6	188.5	188.5	193.1	202.1	204.7	204.7	207.8	211.6	214.4	216.1	218.1	218.1	229.0	229.5	238.5	249.1	**261.9**	To		
Zubair	302	313.4	319.0	321.9	321.9	326.8	337.1	340.1	340.1	344.0	348.9	352.6	354.9	357.7	357.7	373.5	374.2	388.3	406.0	429.3	**455.6**	To	
Ratawi	72	77.4	79.6	80.6	80.6	82.3	85.5	86.4	86.4	87.4	88.8	89.8	90.3	91.0	91.0	94.7	94.9	97.9	101.4	105.5	109.7	**119.0**	To
Yamama	193	206.7	212.3	214.9	214.9	219.1	227.2	229.4	229.4	232.1	235.4	237.9	239.3	241.0	241.0	250.3	250.6	258.1	266.7	276.8	287.1	309.6	**315.8**

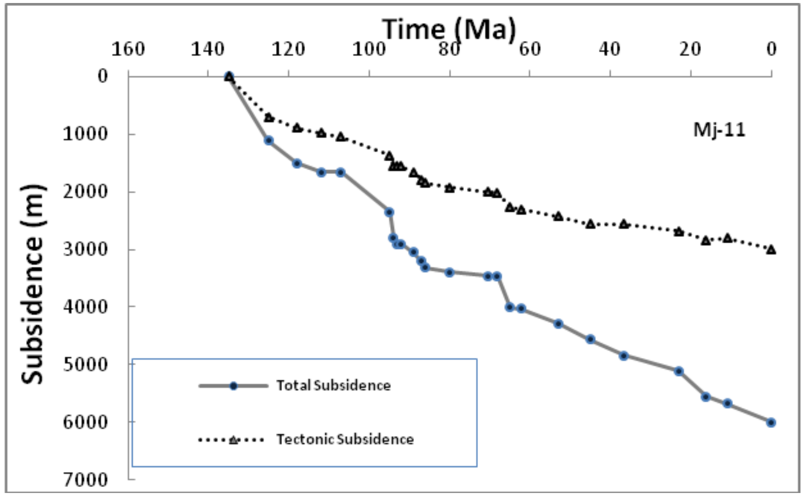
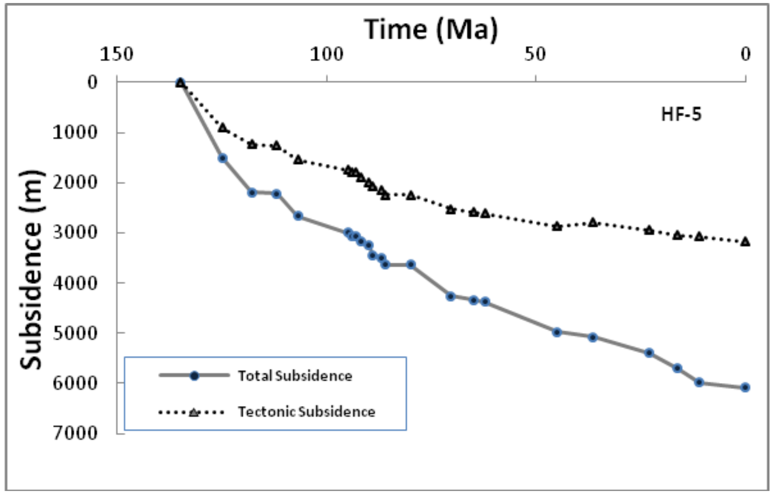


Figure 8- Matrix calculation of the decompacted thickness of the studied formation and the subsidence curves obtained from Mj-11 well .



HF-5

Fm.	Tp																					
Anjanah	**1401**	To																				
Fatha	501	**700.2**	To																			
Jeribe-Euphrate	15	18.6	**22.3**	To																		
Kirkuk Group	347	404.4	438.7	**439.9**	To																	
Jaddala	228	264.0	295.4	296.7	**334.1**	To																
Aliji	43	49.0	54.2	54.4	60.3	**66.1**	To															
Unconf.	0	0.0	0.0	0.0	0.0	0.0	**0.0**	To														
Shiranish	74	83.9	92.2	92.5	102.0	111.1	113.3	**113.3**	To													
Hartha	53	59.7	65.3	65.5	71.8	77.8	79.2	79.2	**81.7**	To												
Sadi	134	149.7	162.5	163.0	177.3	190.7	193.7	193.7	199.4	**203.9**	To											
Tanuma	20	23.3	25.7	25.8	28.4	30.6	31.1	31.1	32.1	32.8	**34.9**	To										
Khasib	87	96.2	103.5	103.8	111.8	119.1	120.8	120.8	123.9	126.3	133.3	**134.5**	To									
Unconf.	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	To								
Mishrif	416	477.0	512.5	513.7	545.9	571.5	576.9	576.9	586.4	593.6	613.1	616.2	630.3	**630.3**	To							
Rumaila	50	56.6	60.4	60.6	64.0	66.6	67.2	67.2	68.2	68.9	70.9	71.2	72.7	72.7	**81.1**	To						
Ahmadi	19	21.5	22.9	23.0	24.2	25.2	25.4	25.4	25.8	26.1	26.8	26.9	27.5	27.5	30.6	**31.0**	To					
Mauddud	388	434.8	461.0	461.9	485.1	503.2	506.9	506.9	513.5	518.5	531.8	533.9	543.4	543.4	598.1	606.0	**609.1**	To				
Naher Umr	56	58.8	60.9	60.9	63.0	64.8	65.2	65.2	65.8	66.4	67.8	68.1	69.2	69.2	76.1	77.2	77.7	**89.6**	To			
Shauaiba	196	216.6	227.9	228.2	238.1	245.6	247.2	247.2	249.9	252.0	257.5	258.3	262.2	262.2	284.1	287.2	288.4	317.4	**322.4**	To		
Zubair	200	207.9	213.5	213.7	219.3	224.1	225.1	225.1	226.9	228.3	232.1	232.7	235.5	235.5	253.0	255.7	256.7	284.5	289.8	**311.9**	To	
Ratawi	163	177.8	185.7	186.0	192.8	198.0	199.1	199.1	201.0	202.3	206.1	206.6	209.2	209.2	223.7	225.8	226.5	245.0	248.1	260.2	**274.6**	To
Yamama	58	63.0	65.7	65.8	68.1	69.9	70.3	70.3	70.9	71.4	72.6	72.8	73.7	73.7	78.5	79.2	79.4	85.6	86.6	90.6	95.3	**99.7**

Figure 9- Matrix calculation of the decompacted thickness of the studied formation and the subsidence curves obtained from HF-5 well .

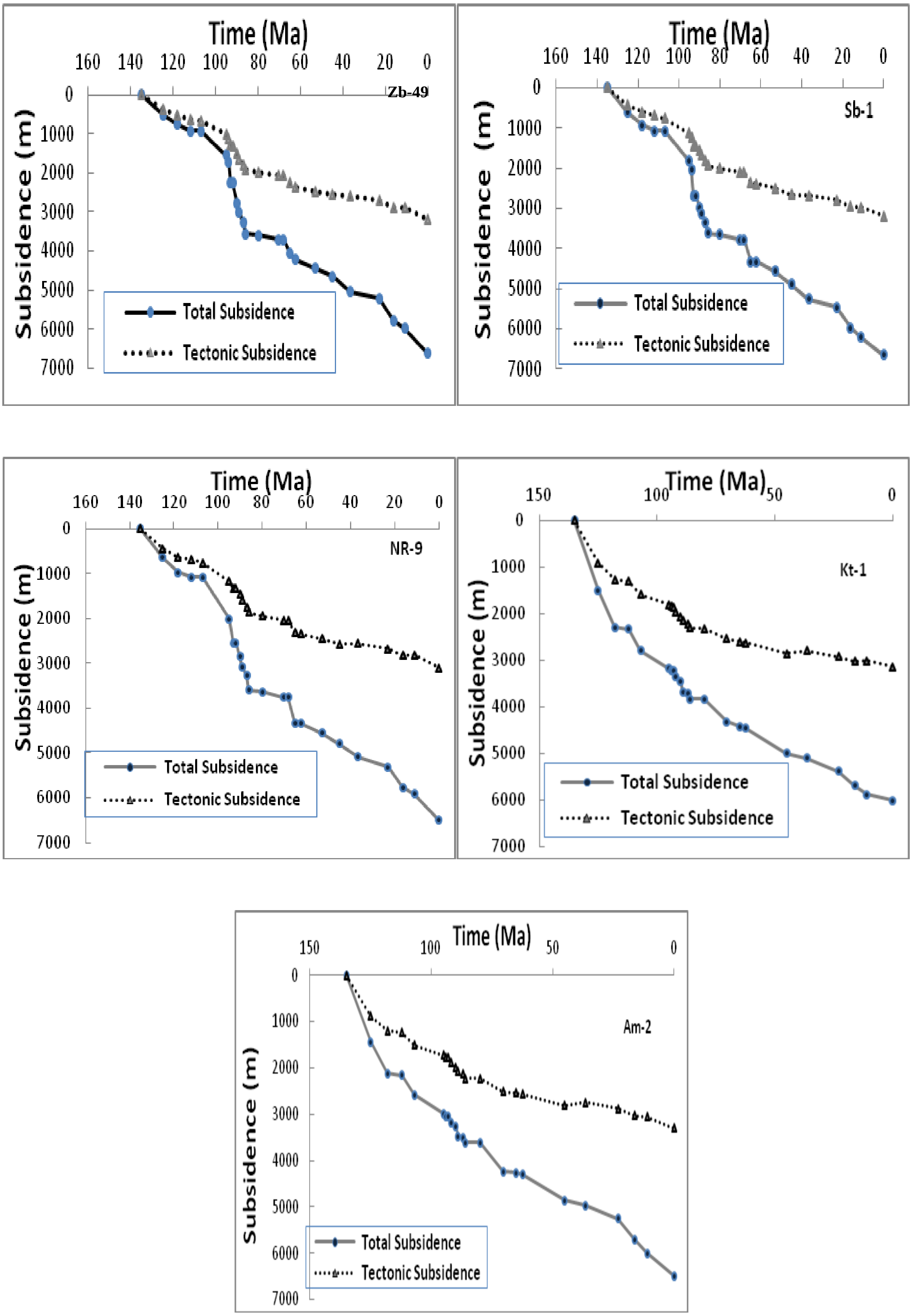


Figure10- Subsidence results for the selected well in the study area.

By comparing paleowater depths for Basra and Amara oil fields, it could be noted that during the period of lower - upper Cretaceous, Amara area have deep environments which reflect transgression conditions with continuous deposition while in Basra area the case was reversed, because formations of these period were deposited in a shallow water depth that reflect regression condition. At the end of Oligocene - Miocene, sea was closed in Amara area, and evaporates was deposited (Jeribe and Fatha formations) followed by clastic material (Dibdibb and Injana formatins). These conditions were increased heat flow and sedimentary subsidence. In Basra area, the basin was closed gradually in Eocene where the clastic formation was deposits. By comparing subsidence of Basra and Amara oil fields, they are different in tectonic and sedimentary subsidence, burial history, sedimentary, and erosion rates, it was seen that the burial depth was greater in the east and north east in compared with the south and west south of the study area.

(7) Eroded thickness

The eroded thickness can be estimated using the following equations:

$$Eroded\ thickness = T_{\circ} * \frac{age\ of\ erosion}{age\ of\ deposition} \qquad \textbf{(11)}$$

$$Eroded\ thickness = R_F * 10 * age\ of\ erosion \qquad \textbf{(12)}$$

This equation used to calculate eroded thickness and as input value for **PetroMod** software.

Results and Discussions

After running **PeroMod**, many results for the evaluation of petroleum system are obtained such as vitrinite reflectance, thermal conductivity, porosity, heat flow, migration properties, permeability, all types of pressure, burial history, thermal history...etc.

Burial history

With respect to the study area, the subsidence rates for Basra province are: Fig. (11)

1) Moderate to rapid subsidence during period (135-112 Ma) which represents the deposition of Suaily, Yammama, Ratawi and Zubair formations.

2) Rapid subsidence during period (107-95Ma) which represents the deposition of Nahr – Umr and Shuaiba formations and during period (23-5Ma), the deposition of Ghar, Fatha, and Dibdibba formations, were occurred.

3) Very rapid subsidence during period (95-86 Ma) which represents the deposition of Mauddud, Ahmadi, Rumaila, Mishrif, Khasib and Tanuma formations.

4) Moderate to rapid subsidence during period (68.2-45.0 Ma) which represents deposition of Tayarat, Um-Er-Radhuma and Rus formations.

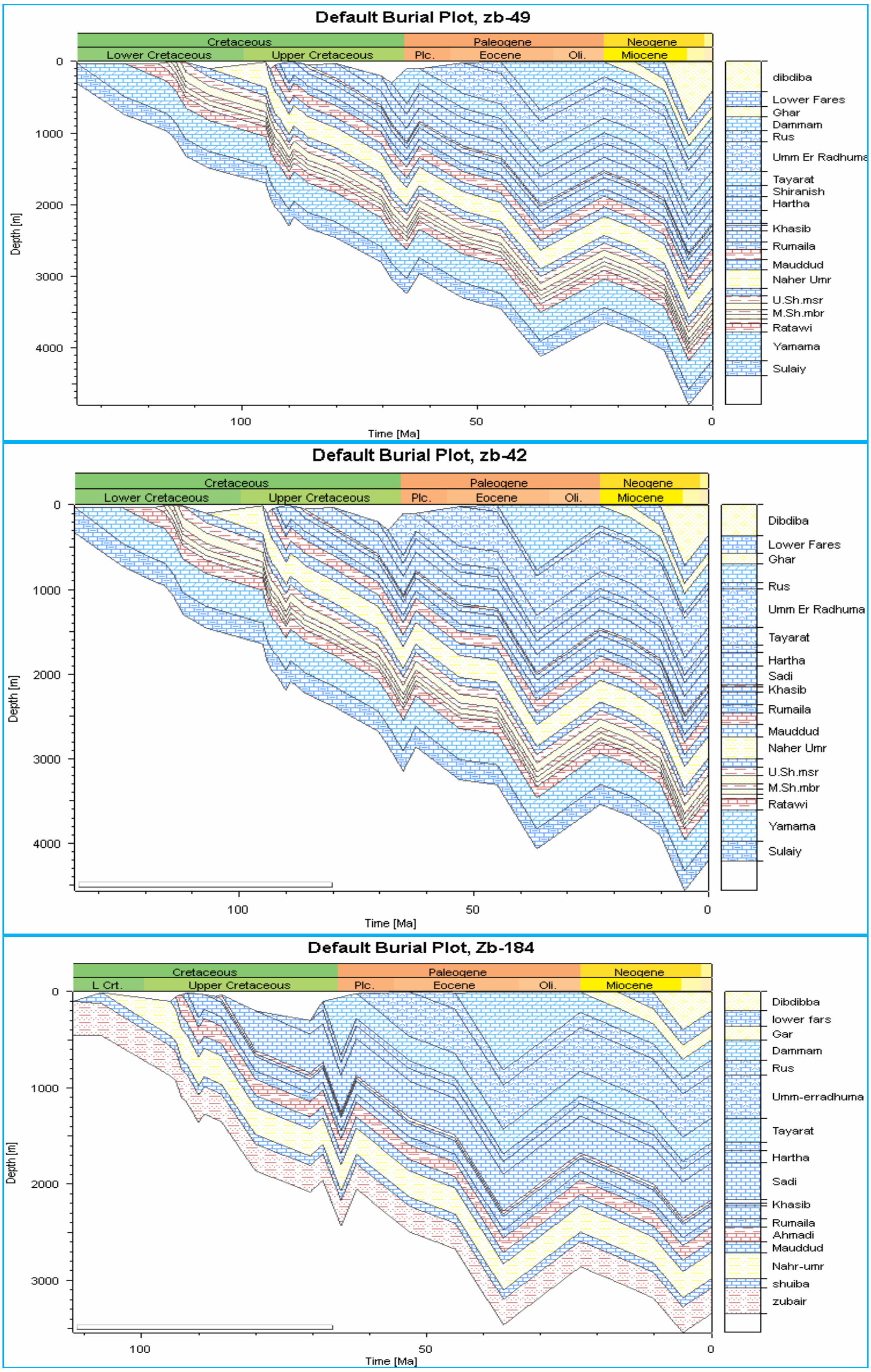


Figure 11- Burial history for the study area.

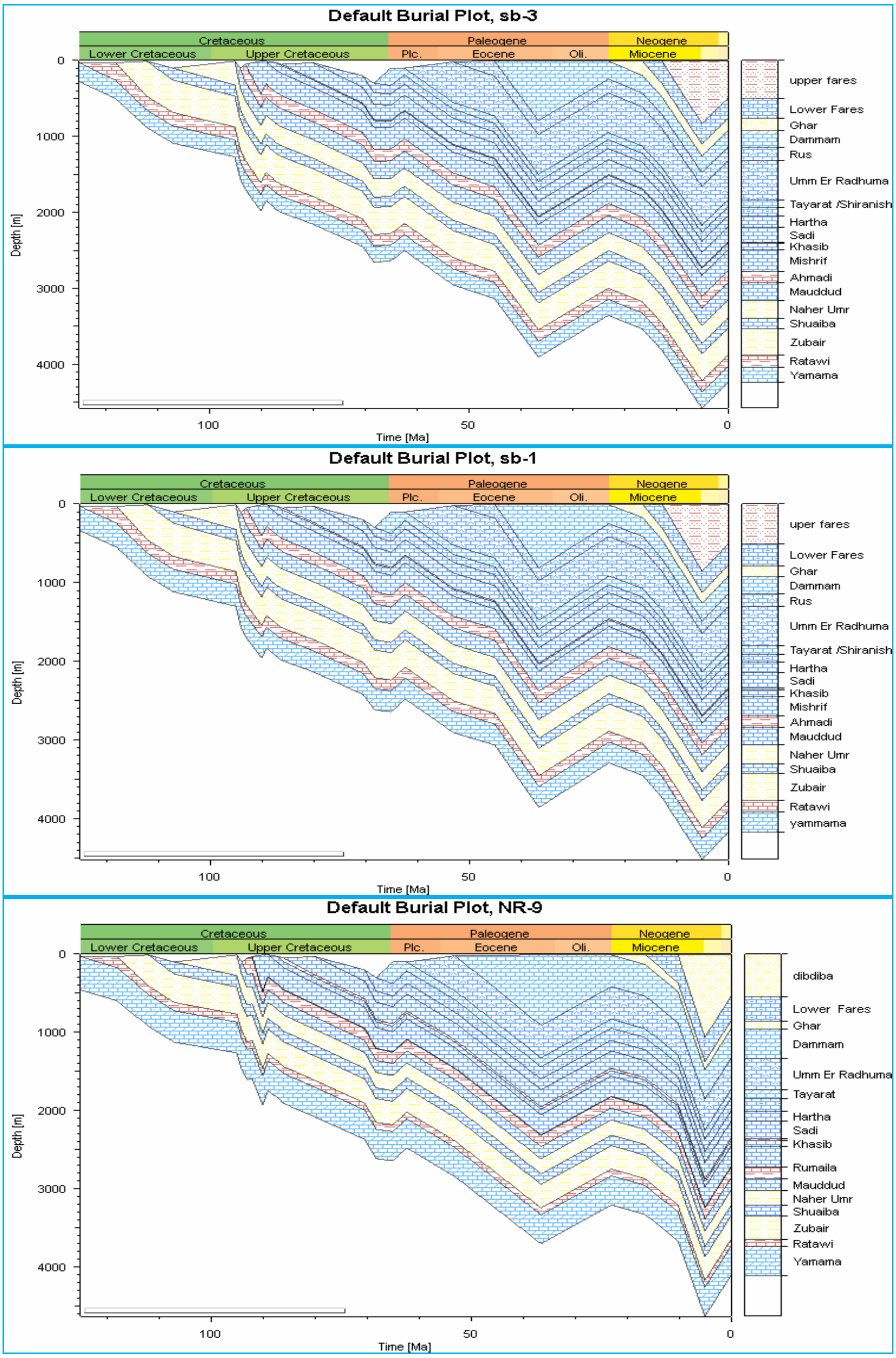


Figure 11- Continue ...

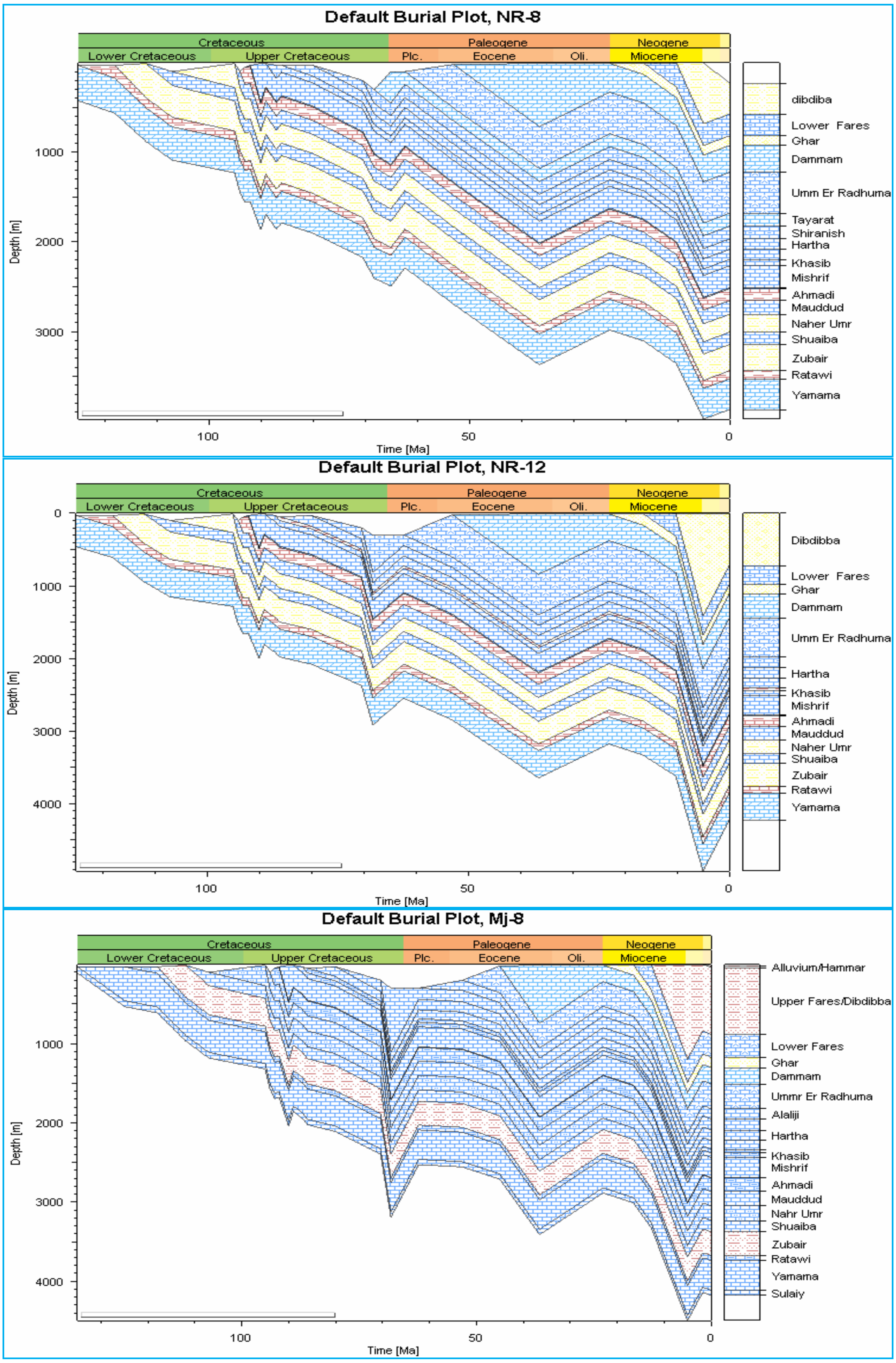


Figure 11- Continue ...

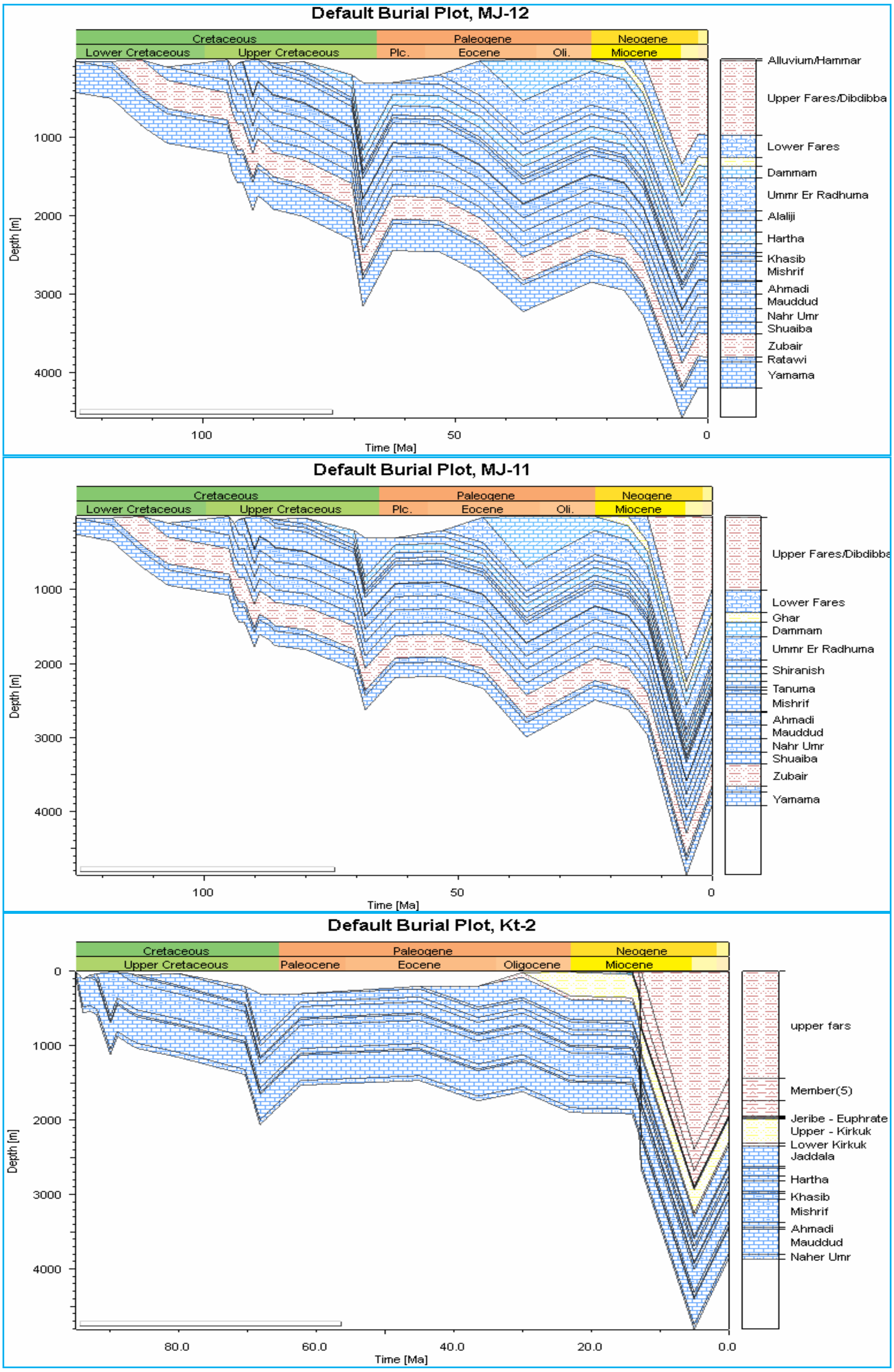


Figure 11- Continue ...

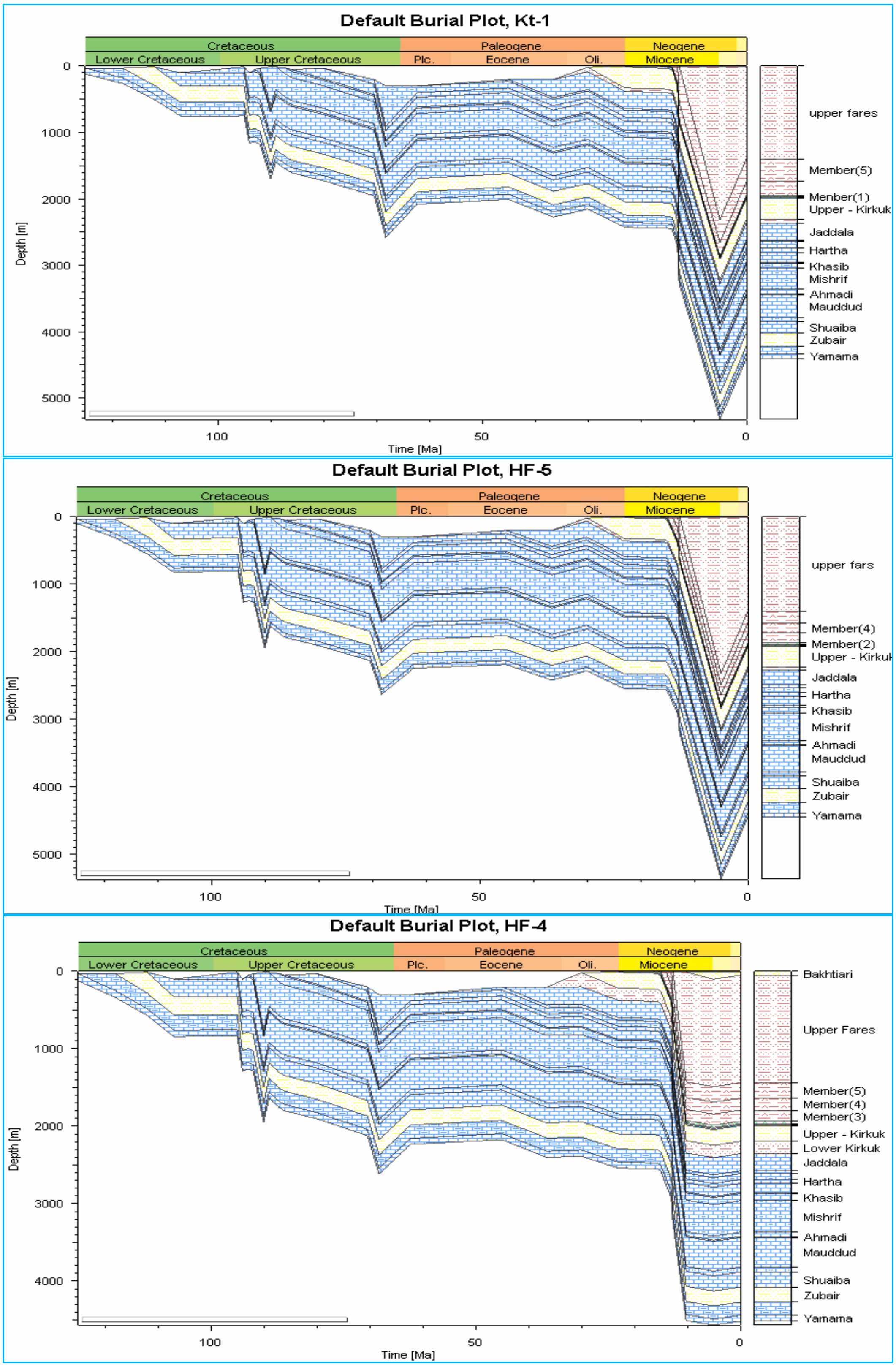


Figure 11- Continue ...

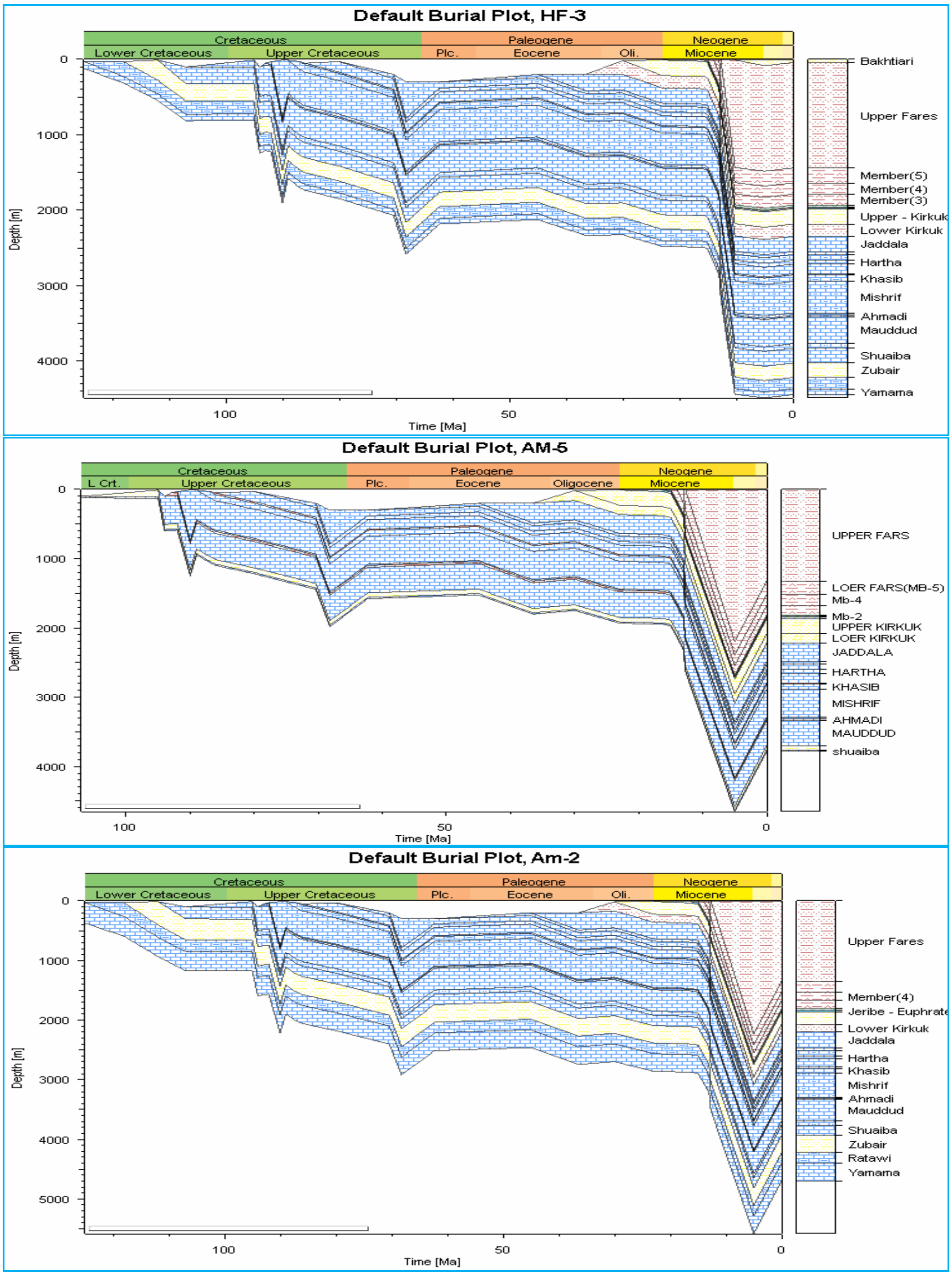


Figure 11- Continue ...

5) Slow subsidence during period (86-68.2 Ma) which represents deposition of Saadi, Hartha and Shiranish formations.
6) Slow subsidence in period (36-23 Ma) which represents deposition of Dammam Formation.
In Amara province Fig (11):

1) Rapid subsidence in period (135-118 Ma) which represents deposition of Yamamma, Ratawi formations.

2) Very rapid subsidence in period (112-86 Ma) which represents deposition of Shuaiba, Nahr Umr, Mauddud, Ahmadi, Rumaila, Mishrif, Khasib and Tanuma formations.

3) Moderate to rapid subsidence in period (62.3-23 Ma) that represents Aliji, Jaddala, Kirkuk group and Jeribe-Euphrates formations.

4) Moderate to slow subsidence in period (118-112 Ma) that represent Zubair Formation, however, in periods (86-80 Ma) and (70.4-62.3 Ma) Sadi and Shiranish formations were represents.

5) rapid subsidence in period (23-5 Ma) that represents deposition of Fatha (lower Fars) and Injana (upper Fars) formations.

The rates of sediment accumulation for the studied formations are shown fig (7 to10) . The highest accumulation rates direction the Amara oil field. The rates of the total subsidence of the basement during all stages are shown in fig7. The highest rate of tectonic subsidence commenced at 23 Ma associated with the extensional rifting of the basin. In the lower Cretaceous, high subsidence was driven under the effect of sedimentary weight. After that, slow subsidence happened in the upper cretaceous that was driven by mechanical extension and rifting at this time. In the Tertiary, the dynamic loading by static loading, caused by the developing huge accumulative sediments, leading to very high rates of subsidence, and the development of Mesopotamian Basin. This stage was followed by a high rate of sedimentation during the Late oilgocen to Early Miocen. This rate of tectonic subsidence could be interpreted in terms of dynamic re-rifting during this time. The pattern of total subsidence seems to be identical at the period extends from L. Cenomenian to Miocene. Moreover the tectonic subsidence was graphical represented.

Conclusions

The differences between tectonic subsidence and total subsidence at Wells study area are reducing with the age decreasing. It indicates that the new strata have smaller compaction than that of old strata. The subsidence rates are different in various periods. There is a fast subsidence period of 13 Ma. The stratigraphic section of the study area contains many periods which are different in tectonic and sedimentary subsidence, burial history, sedimentary, and erosion rates, it was seen that the burial depth was greater in the east and north east in compared with the south and west southern of study area. A rapid subsidence period appeared from 135to 112 Ma, and then the subsidence rate rapidly increased until 86 Ma. After 86 to 62 Ma, the subsidence rates became slow, and then the subsidence become moderate until 23Ma. After 23Ma, the subsidence rates become rapid. The general trend is that these subsidence rates are larger in early time than that of late times. The highest accumulation rates direction the Amara oil field. The rate of tectonic subsidence increase within the fields of Amara (Halfa, Kumait, Amara) and relavely decreases in Basra oil fields (Siba, Zubair, Nahr Umr, Majnoon).

References

1. Aqrawi, A.A.M, Horbury, A.D., Goof, J.C, Sadooni, F.N, **2010** *The petroleum geology of Iraq*. Seientific press Ltd, pp:424.
2. Jassim. S.Z., **2006**: Palaeozoic Megasequences APl-AP5. 1n: Jassim S.Z. and Goff, J.C. (Eds), *Geology of Iraq*. Dolin. Prague and Moravian Museum, Brno, Czech Republic, pp.91-102.
3. Buday, T. and Jassim, S.Z., **1984**. Tectonic map of Iraq. Scale 1;1,000,000. Directorate General of Geological Survey and Mineral Investigation,Baghdad.
4. Wangen, M. **2010** *Physical principles of sedimentary basin analysis*. Cambridge univ. pp:527.
5. Hantschel,T. and Kauerauf, A.I. **2009**; *Fundamentals of basin and petroleum system modeling*; Springer, pp :476.
6. Al- Matary,A. M., and Ahmed, H. M. **2011** Basin analysis study of block 10 in the Say'un - Masilah Basin,Yemen, using a 1D backstripping method. *Arab J Geosci*.
7. Allen, P. A. and Allen, J.R. **2005**; Basin analysis. Blackwell publishing, second edition, pp :549.
8. Al- Sharlhan, A. S. and Nairn, A. E. M.**1997** *Sedimentary basins and petroleum geology of the Middle East*. Elsevier**,** The Netherlands, 843P.
9. Al-Husseini M. I., **2008**. Middle East geological Time Scale. GeoArabia Journal of Middle East Petroleum Geosciences.
10. Angevine, C.L.; Hellen, P.L. and Paola, C. **1990**: Quantitative sedimentary basin modeling, AAPG.Bull. Cont. Edu.Course Notes Series, 32,133p.
11. Van Hinte,J.E. **1978** Geohistory analysis-application of micropaleontology in exploration geology. AAPG, 62(2), pp:201-222.
12. Beicip Franlab petroleum consultants, **2002**, GENEX, 1D Basin Modeling WWW.beicip.com.
13. Watts,A.B. and Ryan, W.B.F., **1976**: Flexure of the lithosphere and continental basin tectonophysics, 36, pp:25-44.
14. Steckler, M.S. and Watts, A.B. **1978** Subsidence of the Atlantic- type continental margins off New york: Earth and planetary science letters, 41. Pp:1-13.
15. Kominz, M.A. and Pekar, S.F. **2001** Oligocene eustasy from two dimensional sequence stratigraphic backstripping. Geological society America, v.113, pp:291-304.