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Basin analysis study of block 53 in the Masilla Basin, Yemen, using a 1D-backstripping method

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ABSTRACT
Basin study of 1D-backstrripping analysis was performed on the sediments in in the four exploration wells (Bayoot S1, Bayoot Sw3, Sharyoof 2, and Sharyoof 9) from Block-53, Masilla Basin. 1D backstripping analysis resulted in many curves of the subsidence of the basement during the deposition of the stratigraphic units. The 1D basin models show that the Masilla basin exhibited a complex subsidence history over a period of about 155 Ma and includes three stages of subsidence. The first stage was occurred at 132-155 Ma and shows high subsidence rate about 6.2 cm per1000 years) and deposition rate about 6.13 cm per 1000 years in the southwest part of Block-53. This stage formed as a result of thinning in the curst during the lithospheric extension. The second stage of subsidence was occurred at 66-128Ma and shows decrease the subsidence rates in the range of 1.99- 1.11 cm/1000 years and deposition rates between 1.19 and 0.69 cm/1000 years during the post-rift deposits, which is represented by Qishn Clastic and Carbonate formations (.At the third stage, the subsidence and deposition rates are high in the southwest of block-53 and found to be about 9.3 cm/1000 years and 9.2 cm/1000 years, respectively . The rapid in the subsidence rates during this stage is primary related to the cooling of lithosphere and loading of the sediments

CONTENTS

1. Introduction:

Basin analysis used 1D- Backstripping method and used 1D-borehole stratigraphic data. It is a quantitative analysis of subsidence rates through time for a basin. The goal of 1D-backstripping is to produce a graphical representation of the vertical movement of a stratigraphic horizon in a sedimentary basin as an indicator of subsidence and uplift history in it (Van Hinte, 1978).The Masilla Basin is located in the Hadramaut region in east central Yemen (Figure. 1), which is one of several onshore Mesozoic basins in Yemen (Bosence.1997). Masilla area considered as one of the most important oil producing basins in Yemen (PEPA. 2013).

The stratigraphy and structures of the interior rift basins of Yemen, including Masila Basin have been studied by Redfern and Jones (1995). Redfern and Jones (1995) reported that the Masilla Basin formed during the Late Jurassic-Early Cretaceous period as a results of the breakup of Gondwana. The Block-53 is located in the Masilla basin between latitudes (15° 7 22' – 16° 07 5') N and longitudes (48° 826' – 48° 075') E, with area of 474 km ^{2}. It contains two oilfields, Sharyoof and Bayoot.

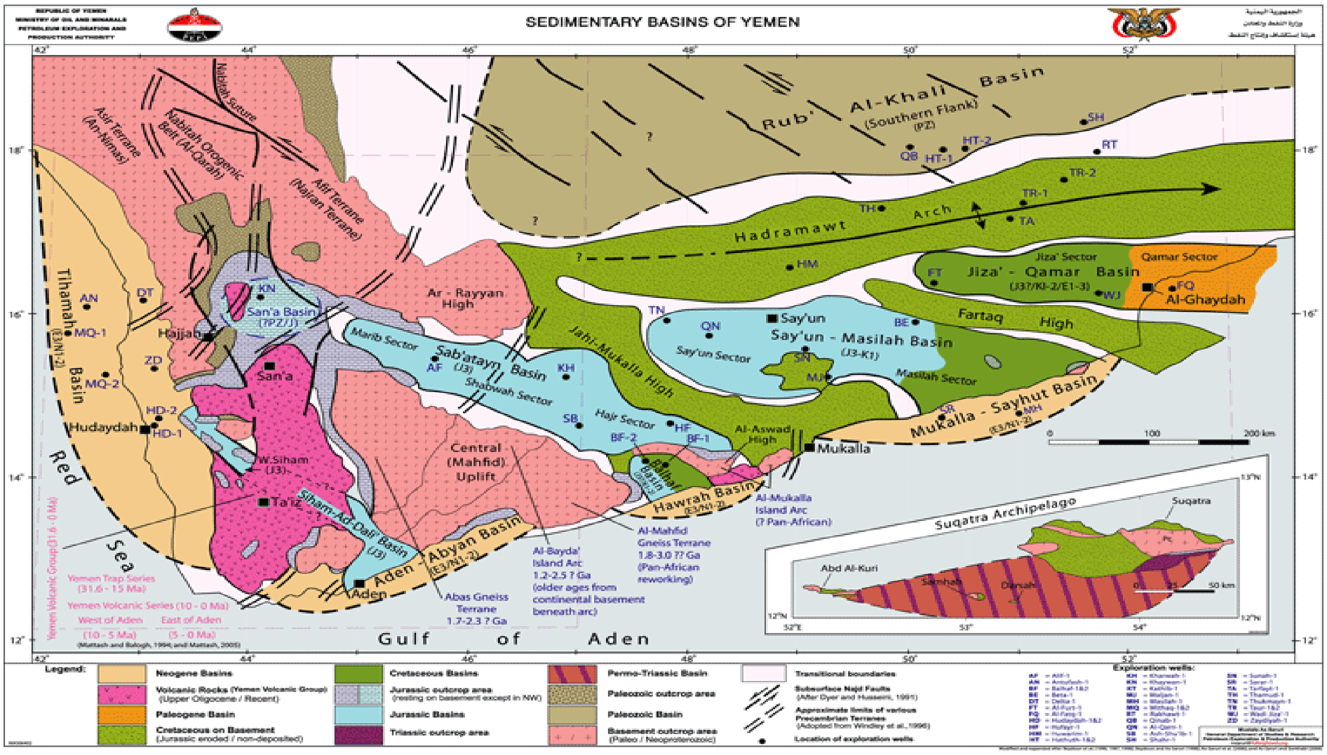

Figure. 1: Sedimentary Basins in Yemen (After As-Saruri, 2010)

Basin analysis uses the burial and thermal history in 1D and 2D to determine the oil and gas potential of a basin and to estimate reservoir porosities. Burial history curves from a number of locations can also be used to construct paleostructure maps at specific time slices. Combined with information on thermal maturity, this can be a powerful tool in evaluating the timing of oil migration and likely migration pathways in relation to the development of suitable traps (Allen and Allen, 2005). Similar studies were done in Yemen such as Al-Matary, A. M. and Hilal, A. (2012), on Block 10, and Al-Matary, A. M. and Sufian, H. (2014), on Block 7. They study the basin subdidence in these Blocks and produce the subsidence curves and rates there. This study mainly use 1D-Backstripping method to evaluate the geohistory of the Block 5 as apart of the Masila Basin.

Tectonic Setting and stratigraphy of Masilla Basin

The Masilah Basin is a rift Basin formed during the Late Jurassic (Kimmridgian) when the African-Arabian Plate was separated from the India-Madagascar Plate as a result of breakup of Gondwana (Beydoun et al., 1996). The structural trends of Say'un-Masilla Basin defined by major NW -SE and cross cutting E- W oriented faults. The Say'un-Masilla basin is divisible into two parts. The Say'un is more rift like in its configuration and subsidence manner than the Masilla, the deposits deposition with open marine conditions start extends into the Early Cretaceous (Beydoun, et. al. 1998). The Masilla basin contained similar early Syn-rift deposits but received less clastic sediment during the Jurassic; however, no salt formed because the basin remained open to ocean circulation in the Late Jurassic (Ahlbrandt, 2002).

The stratigraphy of the Masilla basin as obtained from the previous studies of the Geology of Yemen which is a part of the Arabian shield that consists of a Proterozoic crystalline basement overlain by a Paleozoic sedimentary sequence as Ghabar Group and Kuhlan Formation (Bathonian/ Callovian) then the Amran and

Mahara Groups (Mesozoic sediments). In the eastern part of Yemen such as the Masila basin, the Mesozoic sediments were covered by extensive formations (Hadhramaut Group) composed of the Paleocene-Eocene limestone, marl and gypsum.

The following summarizes the stratigraphy and Basin evolution of the Masilah Basin based on published studies by Haitham and Nani (1990) Bosence et al. (1996), Redfern and Jones, 1995, Bosence (1997), Putnam et al. (1997), Beydoun et al. (1998, 1996, and 1993), Beydoun and As-Saruri (1998), Watchorn et al. (1998) Cheng et al. (1999), Canadian Oxy Oil Company (1999), Total Oil Company (1999) and As-Saruri et al. (2010). (Figure.2):

Pre-rift sequence

Kuhlan Formation: In Early to Late Jurassic time, sandstone was deposited widely across the Yemen and thick sediments developed in lows of pre-Jurassic topography. This thick sandstone deposit is known as the Kuhlan Formation

Shuqra Formation: Late Jurassic in age and includes predominantly a platform carbonate with reef build–ups.

Syn-Rift Sequence

Madbi Formation: The Upper Jurassic Madbi Formation is widely exposed in the Masilah Basin and has been penetrated by wells in the study area. It comprises muddy limestones and chalks with shaly horizons. An occasional rich, but low-diversity Nano-fossil assemblage supports a relatively deep, partly restricted environment (Brannan et al.1999).

Naifa Formation: During late Upper Jurassic to Early Cretaceous time, the rifting system of the Masilah Basin continued, but the subsidence becomes slower. It was accompanied by the accumulation of carbonates in shallow marine shelf deposits (Naifa Formation).

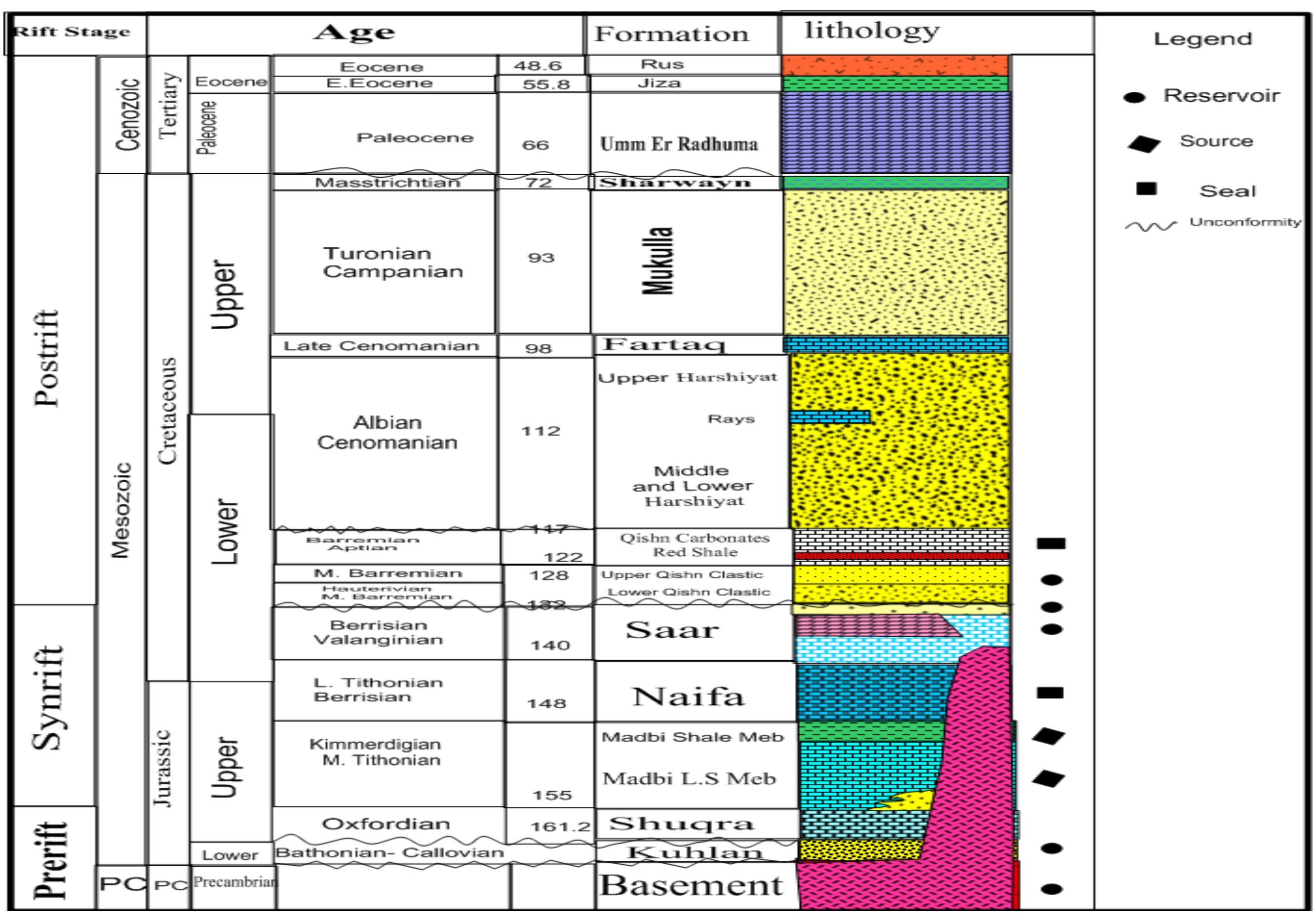

Figure. 2. Stratigraphic column of the Masila Basin

Sa'ar Formation: During Early Cretaceous the sea level rose on a flat ground, resulting in marine transgression and sedimentation of widespread shallow marine carbonates (Sa'ar Formation). These deposits unconformably overlie the Naifa Formation.

Post-rift sequence

Qishn Formation: In late Early Cretaceous, braided plain to fluvial and shallow marine sediments were deposited in the Masilah Basin (mainly basal Lower Qishn Clastic Member). This basal unit was followed by the deposition of shale and carbonate shallow marine sediments accumulated in Barremian-Aptian time (upper shale and carbonate members of Qishn Formation).

Late Lower Cretaceous – Tertiary Formations: During the Late Early Cretaceous time regressive and transgressive sedimentation took place. This pattern selected in interbedded clastic Harshiyat Formation and carbonate rocks of Fartaq Formation. A similar pattern of sedimentation occurred in the Late Cretaceous time, where fluvial systems (Mukalla Formation) prograde southeast in the Masilah Basin. Marine transgression culminated in Late Cretaceous time, where carbonate deposits developed (Sharwen Formation). In the Late Paleocene, the sea level rose and resulted in the formation of transgressive shale deposits (Shammer Member) at the base of the Umm Er-Radhuma Carbonate Formation, followed the shale of the Jeza Formation. Jeza deposits continued to accumulate in the Early Eocene followed by the deposition of anhydrite (Rus Formation) in the Middle Miocene.

2. Materials and Method

This study depends on data collected from four wells (two from Sharyoof field and two from Bayoot Field) in the block 53 of the Masilla Basin (Figure 3 and Table 1 and 2).

Table 1. Shows the selected wells, their location and total depths.

Well name	Well Symbols	Total depth (m)	Elevation above sea level (m)
Bayoot S 1	BS1	3007.5	907.4
Bayoot Sw3	BSw3	3443.97	950.75
Sharyoof 2	Sh-2	1658	927
Sharyoof 9	Sh-9	1655	923.07

Table 2: Names of stratigraphic units and the present depth to the top of these Formations (in m).

Units Name	Bayoot S 1	Bayoot Sw3	Sharyoof 2	Sharyoof 9
Umm Er Radhuma	9.2	9.2	6.15	6.26
Sharwayn	278	302	224	247
Mukalla	297	332	250	272
Fartaq	769	795	649	642
Harshiyat	807	834	0.684	674
Unconformity	1608.4	1661.89	1353	1347.5
Qishn Carbonate	1608.4	1661.89	1353	1347.5
Qishn Clastic	1732.8	1790.76	1454	1451.5
Unconformity	2011.5	2073.75	1599	1588.5
Saar	2011.5	2073.75	1599	1588.5
Naifa	2550	2517.54	-	-
Madbi	2842.3	2833.78	-	-
Kuhlan	3007.5	3013.41	-	-
TD	3026	3443.97	1658	1655

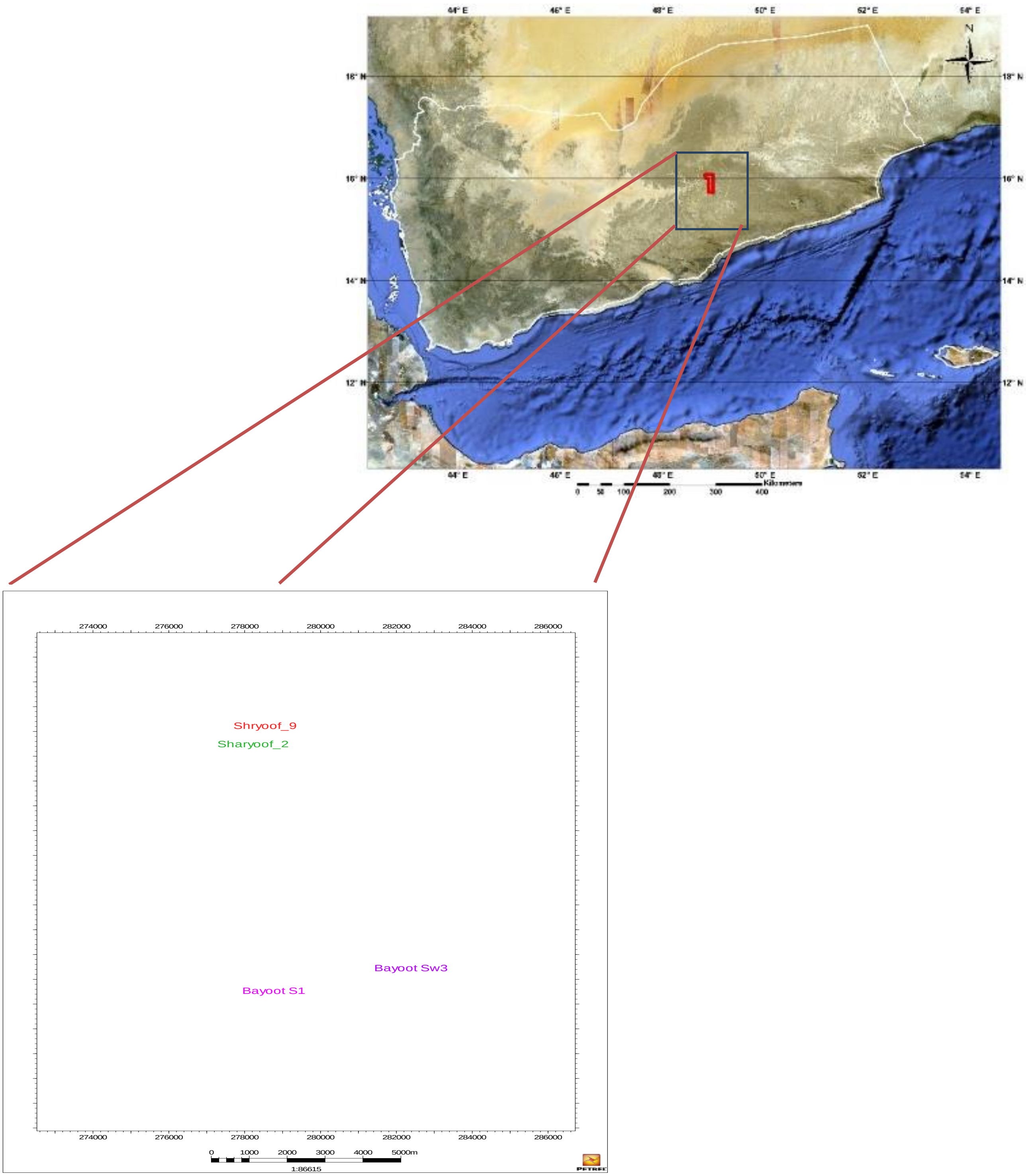

Figure. 3: Maps show the location of the studied area; block-53, in the Masila basin.

1-D Basin analysis

The method used in study basin analysis was 1D Backstripping method was applied to determine the tectonic subsidence and uplift history of block 53. It is a technique employed to analyze the subsidence history of a basin by modeling a progressive reversal of the depositional process (Sclater & Christie 1980) and to estimate tectonic subsidence, vertical movement of basement in absence sediment loading and sea level change. The backstripping procedure con-sists first of removing units of stratigraphy from the top downwards.

To do this analysis corrections must be made for sediment compaction in response to burial and for subsidence arising from the isostatic response to sediment loading (Van Hinte, 1978).

a) Sediment Accumulation

The sediment accumulation through time.

b) Compaction Correction

Sedimentary unit compact after deposition so that the thickness of the interval that preserved today is smaller than the unit's thickness at the time of deposition.

c) Paleobathymetry

The water depth at the time of deposition determines its position relative to a datum (such as present-day sea level). The final subsidence curve incorporates changes in paleowater depth in addition to the corrections made for compaction history.

Input parameters for airy (1D) backstripping

The biostratigraphic age must be converted into numerical age; so it used the updated version of International Union of Geological Sciences (2022) for this conversion. No specific paleo-bathymetric data were available; instead, the standard paleowater depth of common lithology is used (Fluegel, 2004).

Flex-Decomp (Badley's Company2000) is a software that deals with the problem of removing a laterally varying load from a lithosphere. This program is used here to calculate several parameters such as compaction constant, (C), initial porosity ($\emptyset_o$), and density of units, (ρs) as shown in Table 3. In this regard, four wells were selected to calculate the total subsidence of the basement rocks in the (block 53) in Masila Basin and plotit against the age to the base of the studied formation in each.

The first step of backstripping is determining the sediment thickness and porosity for each unit, then making the correction of the compaction effect to reconstruct the original thickness of the unit, and finally calculating the amount of subsidence and sedimentation rates.

1. **Determine sediments porosities**

There are many different ways to calculate the porosity, but most of them rely on the assumption that porosity decrease with burial depth. In this study, the porosity of the studied Formations derived from well logs and from equation (1).

$\emptyset_N = \emptyset_o e^{-CZ}$ (Van Hinte, 1978).

Where $\emptyset_N$ present- day porosity of the unit, $\emptyset_o$ is the initial porosity, C is the compaction constant for each lithology, and Z is the burial depth of the unit.

Table.3 Required Backstripping parameters used to calculate the subsidence rate.

Units Name	Layer NO.	Age to Base	Present-day porosity Φ_n	Compaction Constant c	Matrix Density ρ km^2
Umm Er Radhuma	**1**	**66**	**0.64**	**0.71**	**2.71**
Sharwayn	**2**	**72**	**0.544**	**0.55**	**2.72**
Mukalla	**3**	**93**	**0.277**	**0.29**	**2.66**
Fartaq	**4**	**98**	**0.214**	**0.69**	**2.71**
Harshiyat	**5**	**112**	**0.13**	**0.41**	**2.69**
Unconformity	**6**	**117**	**0**	**0**	**0**
Qishn Carbonate	**7**	**122**	**0.22**	**0.65**	**2.71**
Qishn Clastic	**8**	**128**	**0.185**	**0.33**	**2.67**
Unconformity	**9**	**132**	**0**	**0**	**0**
Saar	**10**	**140**	**0.158**	**0.69**	**2.71**
Naifa	**11**	**148**	**0.115**	**0.7**	**2.71**
Madbi	**12**	**155**	**0.062**	**0.68**	**2.71**

2. Sediment decompaction

The first step in backstripping is to reconstruct the original sediment thicknesses (To) of the growing sedimentary fill from the basin floor up to dated stratigraphic boundaries in particular exposures or well logs

$$Td = \frac{(1-\emptyset N)TN}{(1-\emptyset o)}$$ (Van Hinte, 1978).

Where T_d decompacted thickness, $\emptyset_N$ present-day porosity of the unit, $\emptyset_o$ initial porosity and T_N present-day thickness.

1. Sediment Accumulation Rates

Sediment accumulation rates are a measure of the speed of deposition. In general, the rate of sediment accumulation at any interval of time can be calculated from this equation

$$Rf = \frac{To}{10A}\ cm/1000year$$ (Van Hinte, 1978)

2. Total Subsidence

The total depth of a basin is the sum of the sediments thickness and the water depth above that basin fill. It calculated from this equation

$$S = \sum T_d + Dw$$ (Angevine et al., 1990)

Where S is the total subsidence and (Td) is the decompacted thickness, D is the water depth.

3. Tectonic Subsidence

The tectonic subsidence of the basement rocks subsidence can be calculated from these equations

$$ho = z\frac{(\rho a-\rho s)}{(\rho a-\rho w)} + D$$ (Angevine et al,1990)

Where Z is the thickness of decompacted sedi-ment column, h_o amount of tectonic subsidence, p_a is the density of the astheno-sphere (3.330 kg/m^3); p_s is the density of sedim-entary, p_w is the density of water (1.030 kg/m^3); and D_w is the depth of water for unit p_s can be calculated for the column after the deposition of unit i, following this equation

$$\rho s = \frac{\sum_{i=1}^{N}[\varphi i\rho w + (1-\varphi i)\rho g]Ti}{z}$$ (6) (Steckler & Watts,1978)

4. Subsidence Rate

It can calculated from dividing the total subsid-ence or tectonic subsidence in meters by age of any unit

$$Rs = \frac{S}{10A}\ cm/1000years$$ (7) Van Hinte ,1978

3. Results and Discussion

The result of backstripping by using equations (1and 2) for all selected wells shown and discus-sed separately as follows:

Sharyoof-2

Results of the decompacted thickness and porosities of the studied rock units in the Sharyoof-2 well shown in (Figure. 4) and the curves in (Figure.5), while the results of tectonic, total subsidence and sedimentation rates and the values of tectonic subsidence and total subsid-ence shown in (Table 4). 1904.94 m sediments deposited (Figure.4). During the Valanginian to Maastrichtian deposited 1904.94 m (Figure. 4), the subsidence starts at Early Cretaceous (140-132 Ma) with a relatively low subsidence rate. The rate of total subsidence (0.53 cm/1000 years) and tectonic subsidence (0.32 cm/1000 years), while the value of total subsidence 69.8m and tectonic subsidence 42m. This is coupled with the of deposition 59.8 m of Saar Formation (Figure. 4). Time span of about five millions years represented by the surface of un conformity, erosion, or non-deposition before the deposition of Qishn formation occurred. In Hauterivian to Aptian, the tectonic subsidence rate was increased (0.78-0.57cm/1000years) and the total subsidence rate (1.38-0.996 cm/1000 years) is relatively continued due to sediment loading effects, the value of total subsidence (168.5m- 116.6m) and tectonic subsidence (94.8m- 67m). During this time, 158.5 m of Qishn Clastic, and 106.6 m of Qishn Carbonate sediments, dominantly limestone and sandstone deposited. Time span of about six millions years is represented by the surface of unconformity, erosion, or non-deposition before the deposition of Harshiyat Formation occurred.

Sharyoof 2

FM	Thickness									
Umm Er Radhuma	224	T								
	0.6465	Φ								
Sharwayn	26	26.24								
	0.565	0.569								
Mukalla	399	439	453.3							
	0.277	0.2978	0.32							
Fartaq	35	38.5	44.6	45						
	0.1963	0.27	0.37	0.376						
Harshiyat	669	704.6	759.8	797.3	831.5					
	0.13	0.174	0.234	0.27	0.31					
Unconformity	0	0	0	0	0	0				
	0	0	0	0	0	0				
Qishn Carbonate	101	102	103	104	105.3	106.6	106.6			
	0.22	0.2278	0.236	0.245	0.254	0.263	0.263			
Qishn Clastic	145	147	149	151.3	154	157	157	158.5		
	0.185	0.196	0.208	0.22	0.234	0.249	0.249	0.256		
Unconformity	0	0	0	0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	0	
Saar Carbonate	59	59.13	59.2	59.3	59.4	59.53	59.53	59.7	59.8	59.8
	0.087	0.089	0.09	0.092	0.094	0.096	0.096	0.098	0.1	0.1
∑	1658	1516.47	1568.9	1156.9	1150.2	323.13	323.13	218.2	59.8	59.8

	Initial Thickness	T =thickness(m)
	Present Thickness	Φ=porosity
	Restored Thickness	

Figure. 4: Backstripping and Decompacted results for Sharyoof -2 well in Block-53.

The basin during Late Albian to Early Cenomanian (112-98 Ma) continue to subside with increasing rate of subsidence, with total subsidence rate (8.59 cm/1000years) and tectonic subsidence rate (4.64 cm/1000years), while the value of total subsidence 841.5m and tectonic subsidence 454.85m. This coupled with deposition of 831.5 m of sandstone Harshiyat Formation.

During late Cenomanian (98-93 Ma), the subsidence rate was markedly decreased with total subsidence rate (0.59 cm/1000years), and tectonic subsidence rate (0.37 cm/ 1000 years), while the value of total subsidence 55m and tectonic subsidence 34m. In this time, 45 m of Fartaq Formation sediments deposited. During late Turonian to Campanian (93-72 Ma), basin subsided at a relatively high rate with total subsidence rate (6.435 cm/1000years) and tectonic subsidence rate (3.5 cm/1000years), while the value of total subsidence 463.3m and tectonic subsidence 252.52m. This coupled with the deposition 453.3 m of Mukalla Formation sediments. In the late Maastrichtian (72-66 Ma), the subsidence rate decreased with total rate (0.549 cm/1000years) and tectonic subsidence rate was (0.36 cm/1000years), while the value of total subsidence 36.24m and tectonic subsidence 24m. In this time, 26.24 m of Sharwayn Formation sediments deposited.

After that the subsidence rate is increased with total subsidence (4.875cm/1000years) and tectonic subsidence (2.7 cm/1000years), while the value of total subsidence 234m and tectonic subsi-dence 129.84m. This coupled with deposition 224 m of Umm Er Radhuma Formation

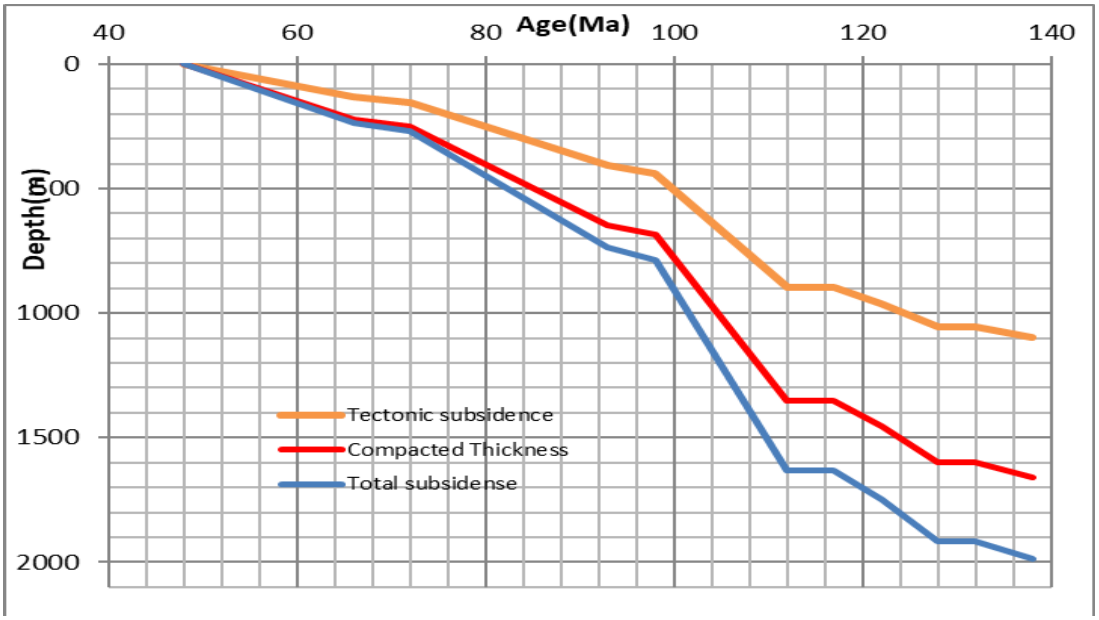

Figure. 5: Subsidence curves of Sharyoof 2 well in Block-53

Table 4. Calculated rates of subsidence, sedimentation and subsidence value in the Sharyoof-2 well.

Formation	Sharyoof-2 cm/1000 Years			Sharyoof 2	
	Rate of			Subsidence value (m)	
	sedimentation	Total subsidence	Tectonic subsidence	Total	Tectonic
Umm Er Radhuma	4.7	4.875	2.7	234	129.84
Sharwayn	0.398	0.549	0.36	36.24	24
Mukalla	6.3	6.435	3.5	463.3	252.52
Fartaq	0.48	0.59	0.37	55	34
Harshiyat	8.48	8.59	4.64	841.5	454.85
Unconformity	0	0	0	0	0
Qishn Carbonate	0.91	0.997	0.57	116.6	67
Qishn Clastic	1.3	1.38	0.78	168.5	94.8
Unconformity	0	0	0	0	0
Saar Carbonate	0.45	0.53	0.32	69.8	42

Sharyoof -9

Results of the decompacted thickness and porosities of the studied rock units in the Sharyoof-9 well shown in (Figure.6) and the curves in (Figure.7) while the results of tectonic, total subsidence and sedimentation rates and the values of tectonic subsidence and total subsi-dence shown in (Table 5).

Starting in the Valanginian age and continued to Maastrichtian. During this time, 1930.5 m sediments were deposited (Figure 3.3), the subsidence starts at Early Cretaceous (140-132 Ma) with a relatively low subsidence rate. Total subsidence rate (0.52 cm/1000 years) and the tectonic subsidence (0.36 cm/1000 years), while the value of total subsidence 68.5m and tectonic subsidence 47.4m. This coupled with the deposition of 58.5 m of Saar Formation (Figure.6). Time span of about five millions years is represented by the surface of unconformity, erosion or non-deposition before the deposition of Qishn Formation occurred.

Sharyoof 9

(grey)	Initial Thickness	T =thickness(m)
(pink)	Present Thickness	Φ=porosity
(white)	Restored Thickness	

FM	Thickness									
Umm Er Radhuma	247	T								
	0.64	Φ								
Sharwayn	25	25.2								
	0.544	0.5476								
Mukalla	370	382	394.4							
	0.31	0.332	0.353							
Fartaq	32	35	39.8	40						
	0.214	0.283	0.37	0.375						
Harshiyat	673.5	713.7	779.2	832.3	901.4					
	0.13	0.179	0.248	0.296	0.35					
Unconformity	0	0	0	0	0	0				
	0	0	0	0	0	0				
Qishn Carbonate	104	105.3	106.7	108.2	109.9	111.6	111.6			
	0.253	0.262	0.272	0.282	0.293	0.304	0.304			
Qishn Clastic	137	139.3	141.65	144.5	147.4	150.9	150.9	152.4		
	0.204	0.217	0.23	0.245	0.26	0.277	0.277	0.284		
Unconformity	0	0	0	0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	0	
Saar Carbonate	57.5	57.63	57.8	58	58.13	58.3	58.3	58.4	58.5	58.5
	0.092	0.094	0.096	0.098	0.1	0.102	0.102	0.104	0.106	0.106
∑	1646	1492.73	1631.55	1398	1679.43	320.8	320.8	210.8	58.5	58.5

Figure. 6: Backstripping and Decompacted results for Sharyoof-9well in Block-53.

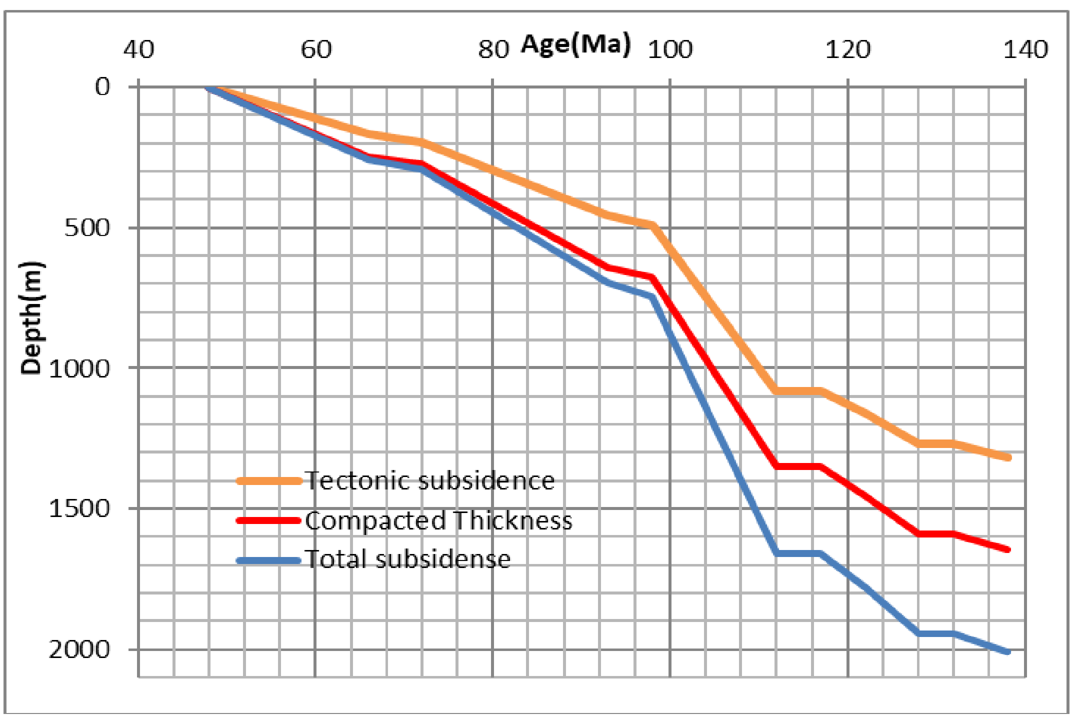

Figure. 7: Subsidence curves of Sharyoof- 9 well in Block-53.

Table 5. Calculated rates of subsidence, sedimentation and subsidence value in the Sharyoof-9 well.

Formation	Sharyoof-9 cm/1000 Years			Sharyoof 9	
	Rate of			Subsidence value (m)	
	sedimentation	Total subsidence	Tectonic subsidence	Total	Tectonic
Umm Er Radhuma	5.15	5.35	3.5	257	168
Sharwayn	0.38	0.53	0.39	35.2	26
Mukalla	5.5	5.6	3.64	404.4	262.4
Fartaq	0.43	0.54	0.38	50	35.6
Harshiyat	9.2	9.3	6	911.4	586.9
Unconformity	0	0	0	0	0
Qishn Carbonate	0.95	1.03	0.7	121.6	81.4
Qishn Clastic	1.25	1.33	0.88	162.4	107.5
Unconformity	0	0	0	0	0
Saar Carbonate	0.44	0.52	0.36	68.5	47.4

In Hauterivian to Aptian the, tectonic subsidence rate was increased (0.88- 0.7 cm/1000years) and the total subsidence (1.33-1.03cm/ 1000 years) is relatively continued due to sediment loading effects, the value of total subsidence (162.4 m-121.6m) and tectonic subsidence (107.5m - 81.4m). During this time, 152.4 m of Qishn Clastic, and 111.6 m of Qishn Carbonate sediments, dominantly limestone and sandstone deposited. Time span of about six millions years is represented by the surface of unconformity, erosion, or non-deposition before the deposition of Harshiyat Formation occurred. The basin during Late Albian to Early Cenomanian (112-98 Ma) continue to subside with increasing rate of subsidence with total subsidence (9.3 cm/ 1000years) and tectonic subsidence (6 cm/1000years),while the value of total subsidence 911.4m and tectonic subsidence 586.9m. This coupled with deposition of 901.4 m of sandstone Harshiyat Formation. During (98-93 Ma), the subsidence rate was markedly decreased with total subsidence rate (0.54 cm/1000years), and tectonic subsidence rate (0.38 cm/1000 years) ,while the value of total subsidence 50m and tectonic subsidence 35.6m. In this time, 40 m Fartaq Formation sediments deposited. During late Turonian to Campanian (93-72 Ma), basin subsided at a relatively high rate with total subsidence rate (5.6 cm/1000years) and tectonic subsidence rate (4.59 cm/1000 years),while the value of total subsidence 404.4m and tectonic subsidence 262.4m. This coupled with the deposition 394.4 m of Mukalla Formation sediments. In the late Maastrichtian (72-66 Ma), the subsidence rate decreased with total subsidence rate (0.53 cm/1000years) and tectonic subsidence rate (0.39 cm/1000years),while the value of total subsidence 35.2m and tectonic subsidence 26m . In this time, 25.2 m of Sharwayn Formation sediments deposited. After that the subsidence rate is increased with total subsidence (5.35 cm/1000years) and tectonic subsidence (3.5 cm/1000years), while the value of total subsidence 257m and tectonic subsidence

168m.This is coupled with the deposition of 247 m of Umm Er Radhuma Formation.

Bayoot S1

Results of the decompacted thickness and porosities of the studied rock Units in the Bayoot S1 well are shown in (Figure. 8) and the curves in (Figure. 9) while the results of subsidence, sedimen-tation rates and the values of subsidence are shown in (Table 6). Starting in the Callovian age and continued to Cam-panian. During this time 3656.05 m sediments were deposited (Figure.8). The subsidence starts at the Middle Jurassic, in during Kimmeridgian (155 Ma) through Tithonian (148 Ma) total subsidence rate (2.84 cm/1000 years) and tectonic subsidence rate (1.67 cm/ 1000 years), while the value of total subsidence 420m and tectonic subsidence 247.8m. In this time 410 m sediments was deposited Madbi Formation (Figure 3.5). During Tithonian- Berriasian (148-140 Ma) continue to subside with increasing rate of subsidence, with total subsidence rate (4.27 cm/1000y) and tectonic subsidence rate (2.5 cm/ 1000 year), while the value of total subsidence 597.8m and tectonic subsidence 350.9m. During this time, 587.8 m of sediments dominantly carbonate was deposited Naifa Formation. Early Cretaceous (140-132 Ma) total subsidence rate (6.2 cm/1000 years) and tectonic subsidence (3.63 cm/1000 years), while the value of total subsidence 819.8m and tectonic subsidence 479.68m.This is coupled with the deposition 809.8 m of Saar Formation. Time span of about five millions years is represented by the surface of unconformity, erosion, or non-deposition before the deposition of Qishn Formation occurred. In Hauterivian to Aptian, the subsidence rate rapidly decreased with total subsidence (2.56 -1.2 cm/ 1000years) and tectonic subsidence rate (1.5 - 0.74 cm/1000 years), while the value of total subsidence (312m- 141.3m) and tectonic subsidence (185.16m- 86.15m). During this time, 302 m of Qishn Clastic, and 131.3 m of Qishn Carbonate sediments, dominantly limestone and sandstone deposited.

Bayoot S 1

Initial Thickness	T =thickness(m)	
Present Thickness	Φ=porosity	
Restored Thickness		

FM	Thickness									
Mukalla	472	T								
	0.293	Φ								
Fartaq	38	38.15								
	0.225	0.228								
Harshiyat	801.4	846.6	905							
	0.213	0.255	0.303							
Unconformity	0	0	0	0						
	0	0	0	0						
Qishn Carbonate	124.4	126.6	129	131.3	131.3					
	0.293	0.305	0.318	0.33	0.33					
Qishn Clastic	278.7	284.6	290.4	298	298	302				
	0.186	0.203	0.22	0.24	0.24	0.25				
Unconformity	0	0	0	0	0	0	0			
	0	0	0	0	0	0	0			
Saar Carbonate	538.5	559.8	588.9	629.8	629.8	695.5	809.8	809.8		
	0.158	0.19	0.23	0.28	0.28	0.348	0.44	0.44		
Naifa	292.3	318.5	378.7	587.8	587.8	587.8	587.8	587.8	587.8	
	0.115	0.188	0.317	0.56	0.56	0.56	0.56	0.56	0.56	
Madbi	165.2	179.4	207	410	410	410	410	410	410	410
	0.645	0.124	0.254	0.624	0.624	0.624	0.624	0.624	0.624	0.624
∑	2711	2354	2499	2057	2057	1995	1808	1808	997.8	410

Figure. 8: Backstripping and Decompacted results for Bayoot S1 well in Block-53

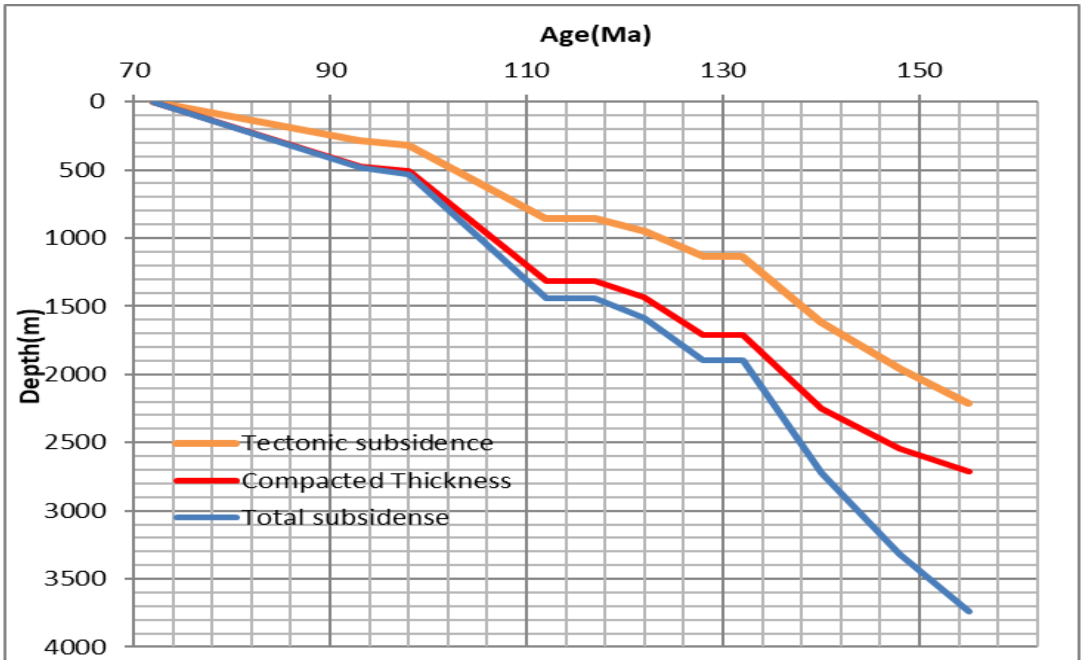

Figure. 9: Subsidence curves of Bayoot S1 well in Block 53

Table 6. Calculated rates of subsidence, sedimentation and subsidence value in the Bayoot S1well.

Formation	Bayoot S1 cm/1000 Years			Bayoot S1	
	Rate of			Subsidence value	
	sedimentation	Total subsidence	Tectonic subsidence	Total	Tectonic
Mukalla	6.6	6.7	3.94	482	283.76
Fartaq	0.4	0.52	0.35	48.15	32.1
Harshiyat	9.2	9.3	5.55	915	543.9
Unconformity	0	0	0	0	0
Qishn Carbonate	1.12	1.2	0.74	141.3	86.15
Qishn Clastic	2.5	2.56	1.5	312	185.16
Unconformity	0	0	0	0	0
Saar Carbonate	6.13	6.2	3.63	819.8	479.68
Naifa	4.2	4.27	2.5	597.8	350.9
Madbi	2.77	2.84	1.67	420	247.8

Time span of about six millions years is represented by the surface of unconformity erosion, or non-deposition before the deposition of Harshiyat Formation occurred. The basin during Late Albian to Early Cenomanian (112-98 Ma) continue to subside with increasing rate of subsidence with total subsidence (9.3 cm/1000years) and tectonic subsidence (5.55

cm/1000years), while the value of total subsidence 915m and tectonic subsidence 543.9m. This coupled with deposi-tion of 905 m of sandstone Harshiyat Formation. During (98-93Ma), the subsidence rate markedly decreased with total subsidence rate (0.52 cm/1000years), and tectonic subsidence rate (0.35 cm/1000years), while the value of total subsidence 48.15m and tectonic subsidence 32.1m. In this time, 38.15 m of Fartaq Formation sediments deposited. During late Turonian to Campanian (93-72 Ma), basin subsided at a relatively high rate with total subsidence (6.7 cm/1000 years) and tectonic subsidence (3.94 cm/1000years), while the value of total subsid-ence 482m and tectonic subsidence 283.76m. This coupled with the deposition of 472m of Mukalla Formation sediments.

Bayoot Sw3

Results of the decompacted thickness and porosities of the studied rock units in the Bayoot Sw3 well are shown in (Figure.10) and the curves in (Figure.11), while the results of subsidence , sedimentation and the values of subsidence are shown in (Table 7). During the Callovian age and continued to Campanian 3482.9 m sediments were deposited (Figure 10). The subsidence starts at the Middle Jurassic, in during Kimmeridgian (155 Ma) through Tithonian (148 Ma) total subsidence rate (2 cm/1000 years) and tectonic subsidence rate (1.2 cm/1000years), while the value of total subsidence 300m and tectonic subsidence 178.2m.In this time 290 m sediments was deposited Madbi Formation (Figure 11).

Bayoot SW3

(grey)	Initial Thickness	T =thickness(m)
(pink)	Present Thickness	Φ=porosity
(white)	Restored Thickness	

FM	Thickness									
Mukalla	463	T								
	0.334	Φ								
Fartaq	39	39.2								
	0.22	0.223								
Harshiyat	827.9	860.6	904.6							
	0.21	0.24	0.277							
Unconformity	0	0	0	0						
	0	0	0	0						
Qishn Carbonate	128.9	130.4	131.9	133.6	133.6					
	0.21	21.9	0.228	0.238	0.238					
Qishn Clastic	283	289.3	306.3	315.5	315.5	321				
	0.175	0.193	0.214	0.237	0.237	0.25				
Unconformity	0	0	0	0	0	0	0			
	0	0	0	0	0	0	0			
Saar Carbonate	443.8	460.8	483.7	514.8	514.8	560	632.7	632.7		
	0.178	0.217	0.254	0.299	0.299	0.356	0.43	0.43		
Naifa	316.2	349.5	425	698.8	698.8	698.8	698.8	698.8	698.8	
	0.149	0.23	0.367	0.615	0.615	0.615	0.615	0.615	0.615	
Madbi	179.6	188	206.4	276	276	276	276	276	276	290
	0.062	0.104	0.184	0.39	0.39	0.39	0.39	0.39	0.39	0.42
∑	2681	2318	2458	1939	1939	1856	1608	1608	974.8	290

Figure. 10: Backstripping and Decompacted results for Bayoot Sw3 well in Block-53

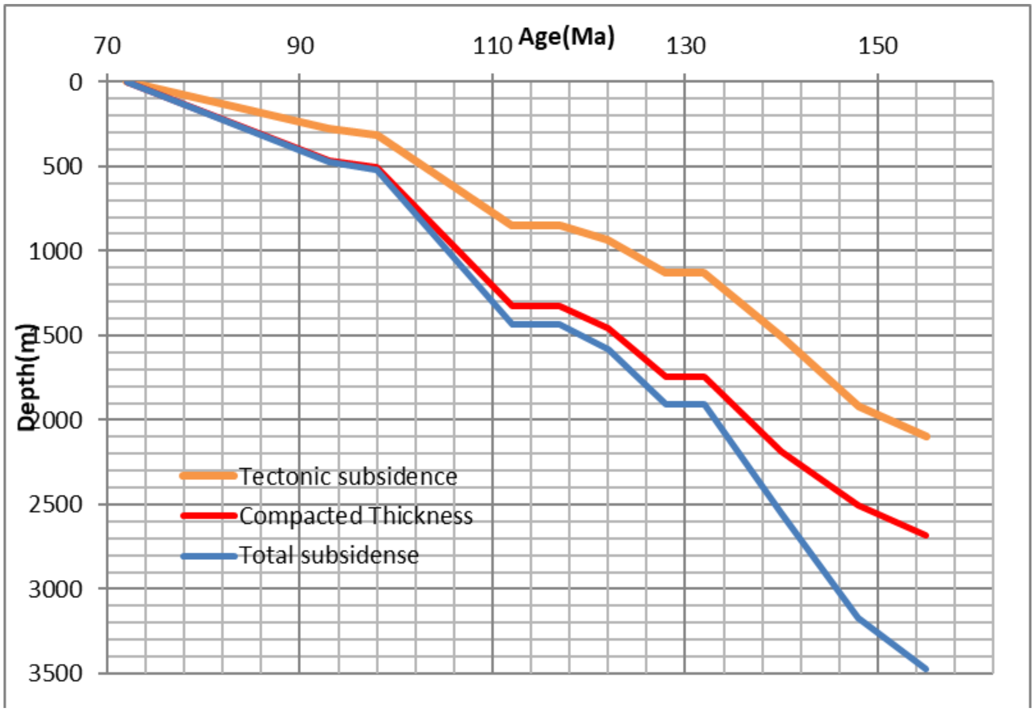

Figure. 11: Subsidence curves of Bayoot Sw3 well in Block 53.

Table 7. Calculated rates of subsidence, sedimentation and subsidence value in the Bayoot Sw3 well.

Formation	Bayoot Sw3 cm/1000 Years			Bayoot Sw3	
	Rate of			Subsidence value	
	sedimentation	Total subsidence	Tectonic subsidence	Total	Tectonic
Mukalla	6.4	6.6	3.9	473	278.54
Fartaq	0.4	0.53	0.35	49.2	32.74
Harshiyat	9.2	9.3	5.5	914.6	534.67
Unconformity	0	0	0	0	0
Qishn Carbonate	1.14	1.2	0.75	143.6	87.49
Qishn Clastic	2.6	2.7	1.6	331	196.18
Unconformity	0	0	0	0	0
Saar Carbonate	4.8	4.9	2.9	642.7	376.97
Naifa	5	4.42	3	618.8	415.3
Madbi	1.96	2	1.2	300	178.2

During Tithonian- Berriasian (148-140 Ma) continue to subside with increasing rate of subsidence, with total subsidence rate (4.42 cm/1000year) and tectonic subsidence (3 cm/1000year), while the value of total subsidence 618.8m and tectonic subsidence 415.3m. During this time, 698.8 m of sediments dominantly carbonate depositedNaifa Formation. Early Cretaceous (140-132 Ma) total subsidence rate (4.9 cm/ 1000 years) and the tectonic subsidence (2.9 cm/1000 years), while the value of total subsidence 642.7m and tectonic subsidence 376.97m. This coupled with the deposition of 632.7 m of Saar Formation. Time span of about five millions years is represented by the surface of unconformity, erosion or non-deposition before the deposition of Qishn Formation occurred.

In Hauterivian to Aptian, the subsidence rate rapidly decreased with total subsidence (2.7 -1. 2 cm/ 1000years) and the total subsidence (1.6 - 0.75 cm/1000 years), while the value of total subsidence (331m- 143.6m) and tectonic subsidence (196.18 m- 87.49m). During this time, 321 m of Qishn Clastic, and 133.6 m of Qishn Carbonate sediments, dominantly limestone and sandstone deposited. Time span of about six millions years is represented by the surface of uncon-formity erosion, or non-deposition before the deposition of Harshiyat Formation occurred. The basin during Late Albian to Early Cenomanian (112-98 Ma) continue to subside with increasing rate of subsidence with total subsidence (9.3 cm/1000years) and tectonic subsidence (5.5 cm/1000years), while the value of total subsidence 914.6m and tectonic subsidence 534.67m. This coupled with deposition 904.6 m of sandstone Harshiyat Formation. During (98-93 Ma), the subsidence rate was rapidly decreased with total subsidence rate (0.53 cm/1000years), and tectonic sub-sidence rate (0.35 cm/1000years), while the value of total subsidence 49.2 and tectonic subsidence 32.74. In this time, 39.2 m of Fartaq Formation sediments deposited. During late Turonian to Campanian (93-72 Ma), basin sub-sided at a relatively high rate with total subsidence (6.6 cm/1000years) and tectonic subsidence (3.9 cm/1000years), while the value of total subsidence 473m and tectonic sub-sidence 278.54m. It coupled with the deposition of 463 of Mukalla Formation sediments.

4. Summary and Conclusion

This study aimed to study basin analysis of Block-53, Masilla basin by using 1D back-stripping. This study depended on data collected from four wells. The methodology of the research principally depended on the following steps:

Data of the selected wells were collected from final reports, composite logs and diff-erent other logs (LAS and ASCI).The present study based on the analysis of the well logs of four wells. Data analysis and interpretation to calculate the present porosity that used in the calculation of backstripping by Flex-Decomp. Masilla basin is one of the Mesozoic basins, which formed as results of the rifting that started during Kimmeridgian.

The rate of sedimentation in the Block-53 increasing from the North to Southeast with highest accumulation rates 9.2 cm/1000 years.

All of the subsidence diagrams in Block-53 show two stages of subsidence. The first stage of subsidence (132-155Ma) occurred during the deposition of Sa'ar, Naifa and Madbi Formations, formed by the thinning in the curst, during a lithospheric extension. The average rates of total subsidence for all wells (3.04, 4.35 and 2.42 cm/1000years), tectonic subsidence (1.8, 2.75 and 1.44 cm/1000years) and the average rate of deposition for all wells (2.96, 4.2 and 2.37 cm/1000years).

The second stage of subsidence (66−128Ma), coupled with the deposition of Qishn Clastic, Qishn Carbonate, Harshiyat, Fartaq, Mukalla, Sharwayn and Umm Er Radhuma Formations. Subsidence generated by the cooling of lithosphere and the sediments and water loading. The average rates of total subsidence for all wells (1.99, 1.11, 9.12, 0.545, 6.33, 0.54 and 5.11 cm/1000years), tectonic subsidence (1.19, 0.69, 5.42, 0.36, 3.745, 0.375 and 3.1 cm/1000years) and the average rate of deposition for all wells (1.9, 1.03, 9.02, 0.43, 6.2, 0.39 and 4.9 cm/1000years).

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