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# Petroleum System Modeling of Halfaya Oil Field South of Iraq

**Shahad W. Al- Marsomy *, Thamer K. Al- Ameri**
Department of Geology, College of Science, University of Baghdad, Baghdad, Iraq.

**Abstract**

The petroleum system of Halfaya oil field shows that the hydrocarbon generation of these Formations such as Sha′uiba and Nahr Umr are immature and have generated few oil TR ≤ 50% which are neglected as compared to Formations below them which are very rich source rock. The Formations of Yamama, Ratawi and Sulaiy are mature with TR ≤ 100%. Other Formations such as Sargelu ,Najma,Zubair and Gotnia are with very high maturity with TR ≥ 100% and completely generated hydrocarbon and depleted after hydrocarbon are expelled and migrate to reservoir rock of structure traps and this study indicates that the major seals of Upper Jurassic are Gotnia and Allan Formations and of Middle Miocene is LowerFars fatha Formation.

**Keywords:** Petromod , Hydrocarbon generation , South Iraq , Hydrocarbon .

# موديل ألنظام ألنفطي في حقل حلفاية جنوب العراق

**شهد وديع ألمرسومي* ، ثامر خزعل ألعامري**
قسم علوم ألارض ، كلية ألعلوم ، جامعة بغداد ، بغداد ، ألعراق

**ألخلاصة :**

تمت دراسة النظام الهايدروكاربوني في حقل حلفاية النفطي في محافظة ميسان جنوب العراق .وأكدت الدراسة على ان نسبة تولد الهايدروكاربونات في تكويني الشعيبة ونهر عمر قليلة جدا حيث تصل نسبة التحول الهايدروكاربوني > من 50 % في حين أكدت الدراسة على ان تكوينات (الرطاوي ،اليمامة ،السلي )هي صخور مصدرية جيدة في تكوين الهايدروكاربونات حيث تصل نسبة التحول ≥ 100% في حين التكوينات (الزبير ،ساركلو ،نجمة ،القطنية )صخور مصدرية عالية جدا في تولد الهايدروكاربونات حيث نسية التحول ≤ 100% .أكدت الدراسة على ان هناك مظاهر تركيبية كفوالق وكسور ضمن الصخور المكمنية والمصائد التركيبية جعلت تكوين القطنية الذي يعود الى العمر الجوراسي وتكوين العلان يكون الحاجز العلوي للمحتوى الكاربوني في حين توقف تولد النفط ضمن تكوين الفارس الاسفل (تكوين الفتحة ).

## Introduction:

Petroleum system is a geologic system that encompasses the hydrocarbon source rocks and all related oil and gas which includes all of the geologic elements and processes that are essential if hydrocarbon accumulation is to exist [1]. Basin modeling provides insights into total Petroleum-system processes, which can optimize resource assessments and exploration efforts in under-explored basins [2].

The term "basin- modeling" has acquired a meaning referring mostly to simulating the thermal history of a basin for a given geologic and depositional history and, associated with it, the timing and volume of hydrocarbon generation as well as migration and accumulation. The total petroleum -

* Email: Shahad.wadie@Yahoo.com

system model of studied area is developed using Integrated Exploration system (IES) PetroMod software (one of the famous commercial modeling software. petroleum system model of Halfaya field area is developed using Integrated Exploration System [3].

**Basin Modeling Petromod Software**

The conceptual models are related to the concept of the "petroleum- system" [1]. It is a numerical formulation of the region history based on interpretation of combined geologic, geophysical, and geochemical data in a temporal framework, and it includes the principal elements (source rocks, reservoir rocks and seals) of the total petroleum system. Used in a one or two or three dimensional simulation computer program.

Petromod petroleum system modeling software combines seismic section, well and geologic information to model the evolution of sedimentary basin.

The construction model is based on the integrated sum of available geologic data such as stratigraphy within the province and to assign lithology's and age ranges. Assignment of strata to overburden, seal, reservoir and source intervals.

A well-defined conceptual model requires correct data input and proper analysis of the sequential geometrical arrangement of rock strata and their Chrono stratigraphy from the basis for the establishment of a time sequence for the most important geological events during basin evaluation; such events are the primary processes of deposition, non-deposition, uplift and erosion. However, it is useful for PetroMod generated total petroleum systems events chart and to tie the models to the assessment. Basin modeling that could improve predications of when and where oil and gas were generated in the subsurface.

**One dimensional Basin Modeling PetroMod 1D**

1D petromod modeling is used to determine burial and thermal history of source rock as well as timing of hydrocarbon generation. The essential inputs of maturating modeling are paleo – heat flow that source rock has been subjected to quantity and quality of organic matter in sediments [4] .It enables single-point data to be constructed from scratch or to be extracted directly from PetroMod 1D Calibration results such as heat flow histories can then be directly used by the 1D simulators, which enables calibration work in all packages to be performed much faster .

PetroMod 1D developed by Integrated Exploration System (IES) to determine burial thermal history hydrocarbon generation using well information such as depths, thickness and temperature. The data input for each well modeling in the studied area in Halfaya oil field HF161-Y161 are shown in table1.

| Formation | Top(M) | Base(M) | Thickness (M) | Temperture(C) | Deposition From(Ma) | Deposition To (Ma) |
|---|---|---|---|---|---|---|
| Upperfars | 13 | 1388 | 388 | 37 | 10.8 | 8.9 |
| Lowerfars | 1388 | 1983 | 595 | 48.98 | 15.3 | 10.8 |
| Jeribe | 1983 | 1990 | 7 | 72.4 | 22.7 | 18 |
| Kirkuk | 1990 | 2314 | 324 | 73 | 24.2 | 28.4 |
| Jaddala | 2314 | 2528 | 214 | 73.4 | 62.9 | 51.1 |
| Aliji | 2528 | 2572 | 44 | 73.6 | 62.9 | 61.1 |
| Shiranish | 2572 | 2644 | 72 | 73.78 | 72.5 | 69.6 |
| Hartha | 2644 | 2693 | 49 | 81.2 | 78.7 | 72.5 |
| Sa'adi | 2693 | 2821 | 128 | 89 | 84.9 | 80.3 |
| Tanuma | 2821 | 2837 | 16 | 90 | 85.9 | 84.9 |
| Khasib | 2837 | 2916 | 79 | 91 | 91.8 | 85.9 |
| Mishrif | 2916 | 3311 | 395 | 93 | 94 | 92.3 |
| Rumila | 3311 | 3357 | 46 | 93.4 | 95.7 | 94 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Ahmadi | 3357 | 3375 | 18 | 93.76 | 97.2 | 95.7 |
| Mauddud | 3375 | 3540 | 165 | 102 | 101.4 | 99.4 |
| Nahr Umr | 3540 | 3796 | 256 | 109 | 109.6 | 101.4 |
| Shu'aiba | 3796 | 3990 | 194 | 114 | 120.7 | 113.2 |
| Zubair | 3990 | 4174.5 | 184.5 | 116 | 121 | 125.5 |
| Ratawi | 4174.5 | 4326 | 151.5 | 118 | 135.9 | 131 |
| Yamama | 4326 | 4414 | 88 | 120 | 143.1 | 135.9 |
| Sulaiy | 4414 | 4750 | 336 | | 148 | 143.1 |
| Gotnia | 4750 | 5170 | 420 | 129 | 154 | 148 |
| Najma | 5170 | 5570 | 400 | 137 | 160.1 | 154 |
| Sargelu | 5570 | 5720 | 150 | 145.4 | 183 | 160.1 |
| Allan | 5720 | 5730 | 10 | 148.4 | 184 | 183 |
| Total Depth | 5730 | | | | | |

**Table 1-** Formation tops and temperature of well HF161 – Y161 at Halfaya oil field .

**Model development**

**Chronostratigraphic units**

Chronostratigraphic units in the model are assigned absolute ages of deposition, and amounts and ages of erosion and/ or periods of non-deposition are defined table 2. The age of depositional and erosional events are designated based on the geologic time scale of [5], however, temporal correlation between depositional sequences in the basin and sequences on the Global Cycle Chart is imprecise. Lithology represented as end member rock types or as compositional mixtures was assigned to the facies in each unit.

The physical and thermal properties of the rock types and mixtures, including their thermal conductivities and heat capacities are either user – defined or software default values [6].

**Temperature and heat flow**

Determining the timing of petroleum generation and expulsion requires calibration of the thermal regime in each model location. Parameters used in the calibration include heat flow, thermal conductivity of the rock matrix, surface temperature, and sediment thickness (present and past). [6].Reservoir and bottom whole temperature data are provided from well logs and final geologic reports for Halfaya oil well in table 1 are used to estimate the present heat flow in studied area as in figure1. Reservoir and bottom –hole temperature data for well to estimate the present heat flow in the Mesopotamian basin.

A good fit between calculated and measured temperature values is achieved using estimated heat flow value equal to (45 mW/m$^2$) in studied areas, assuming a mean surface temperature of (27$^o$C) through the region.

Vitrinite reflectance, is the most widely used indicator of thermal stress, because it extends over a longer maturity range than any other indicator, and skilled organic petro chemist can make a large number of analysis in a relatively short time.

Vitrinite reflectance (%$R_o$) which integrates the effects of temperature over time is used to evaluate the Paleo thermal history of the regime. Computed Ro trend for the studied wells in south Iraq intersect the present – day surface at 0.25% Ro, indicating than erosion during late Cenozoic time generally was minimal less than 500m in this region . The amount of stratigraphic section removed during Mesozoic erosional episodes has not been reported, however sensitivity test indicate that Tertiary erosion, although locally intense had little impact on the Jurassic source rock maturation history [6].

**Table 2-** Chronostratigraehic units and ages of depositionaland erosional events in the study area.

| Geologic Age | Sequence Stratigraphic Unit | Deposition (Ma) | Erosion (Ma) |
|---|---|---|---|
| | | From – To | From – To |
| Late Miocene | Upper Fars(Iniana) | 10.8-8.9 | |
| Early –Middle Miocene | Lower Fars (Fatha) | 15.3-10.8 | |
| Middle Miocene | Jeribe | 22.7-18 | 13-23 |
| Oligocene | Kirkuk | 24.2-28.4 | |
| Upper –Lower Eocene | Jadala | 62.9-51.1 | |
| Paleocene –Lower Eocene | Aliji | 62.9-61.1 | 29-56 |
| Upper Cretaceous (Turonian) | Shiranish | 72.5-69.6 | |
| Upper Cretaceous (Campanian) | Hartha | 78.7-72.5 | |
| Upper Cretaceous (Lower Campanian ) | Sa′adi | 84.9-80.3 | |
| Upper Cretaceous(Coniacian) | Tanuma | 85.9-84.9 | |
| Upper Certaceous (Turonian ) | Khasib | 91.8-85.9 | |
| Upper Cretaceous (Lower Campanian ) | Mishrif | 94-92.3 | |
| Upper Cretaceous (Lower Campanian) | Rumila | 95.7-94 | |
| Upper Cretaceous (Lower Campanian) | Ahmadi | 97.2-95.7 | |
| Upper Cretaceous(Lower Campanian) | Mauddud | 101.4-99.4 | |
| Lower Cretaceous(Alibian) | Nahr Umr | 109.6-101.4 | 100-126 |
| Lower Cretaceous (Aptian) | Shu′aiba | 120.7-113.2 | |
| Lower Cretaceous (Baremian ) | Zubair | 121-125.5 | |
| Lower Cretaceous(Hautervian) | Ratawi | 135.9-131 | |
| Lower Cretaceous (Valanginian Berriasian) | Yamama | 134.1-135.9 | |
| Upper Jurassic | Sulaiy | 148-143.1 | |
| Upper Jurassic (Upper Kimmeridgian) | Gotnia | 154-148 | |
| Upper Jurassic (Lower Kimmeridgian) | Najma | 160.1-154 | |
| Middle Jurassic (Bathonian) | Sargelu | 183 -160.1 | |

**Model analysis**

**Burial – Thermal history**

The burial model reflects the gross geologic features of the basin and is consistent with the current understanding of the basin's geologic and tectonic history [7]. Subsidence that is the depth of burial changing with geologic time can be displayed in the form of a burial history diagram plotted as depth against age for a particular well or area. Burial history diagrams are useful as a background for showing temperature history and for estimating timing of hydrocarbon generation when vitrinite reflectance or other maturity Parameters are overlaid on the subsidence curves.

One-dimensional burial – thermal profiles as shown in figures 1 for Halfaya oil field HF161-Y161 demonstrate the effects of continuous burial that had been affected on source rocks temperature within stratigraphic section of Halfaya oil field. Present day are reaching at maximum burial temperature of 91C-140C at different depth for HF161-Y161. Profile for this well show that the temperature of source rocks of Mesozoic age present at maximum burial temperature due to burial and tectonic subsidence through time of sedimentary basin.

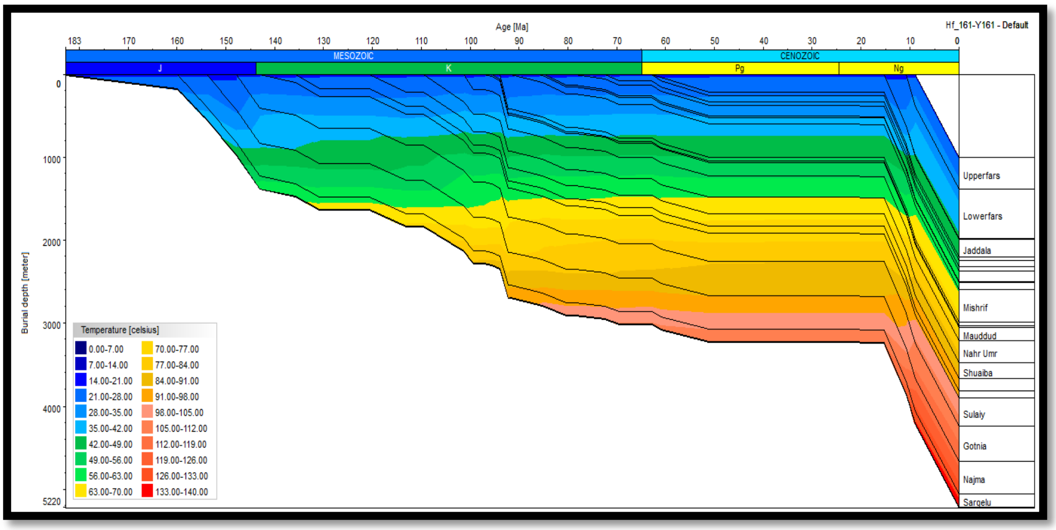


**Figure 1-A-** Burial thermal history of source rock formations in Halfaya oil field, well (HF161 – Y161)

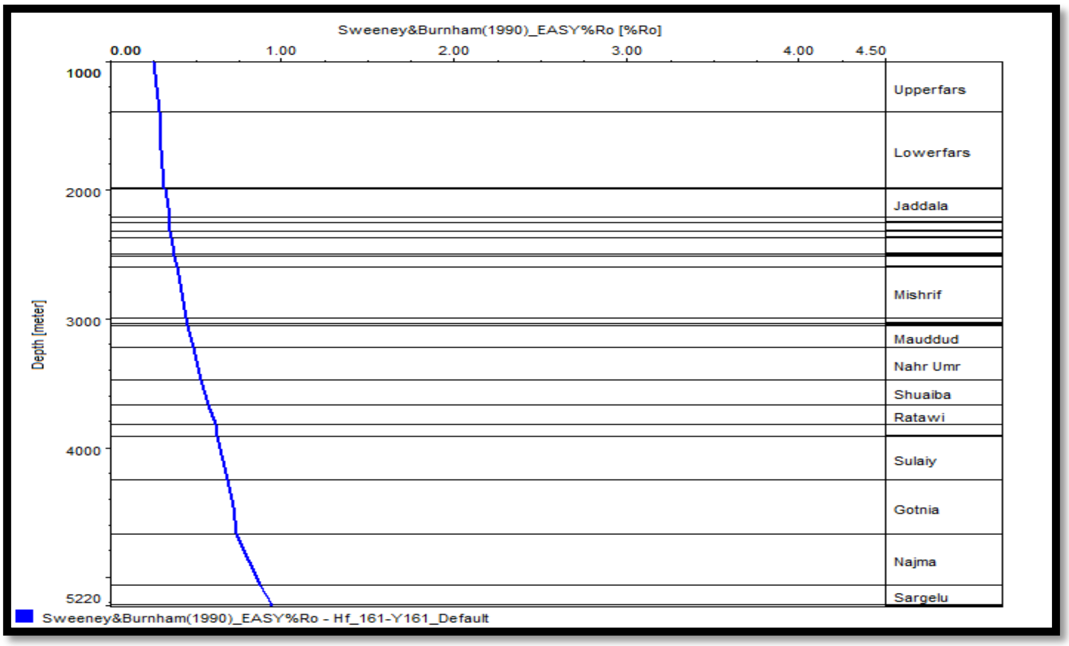


**Figure 1-B-** Burial thermal history of source rock formations in Halfaya oil field, well (HF161 – Y161)

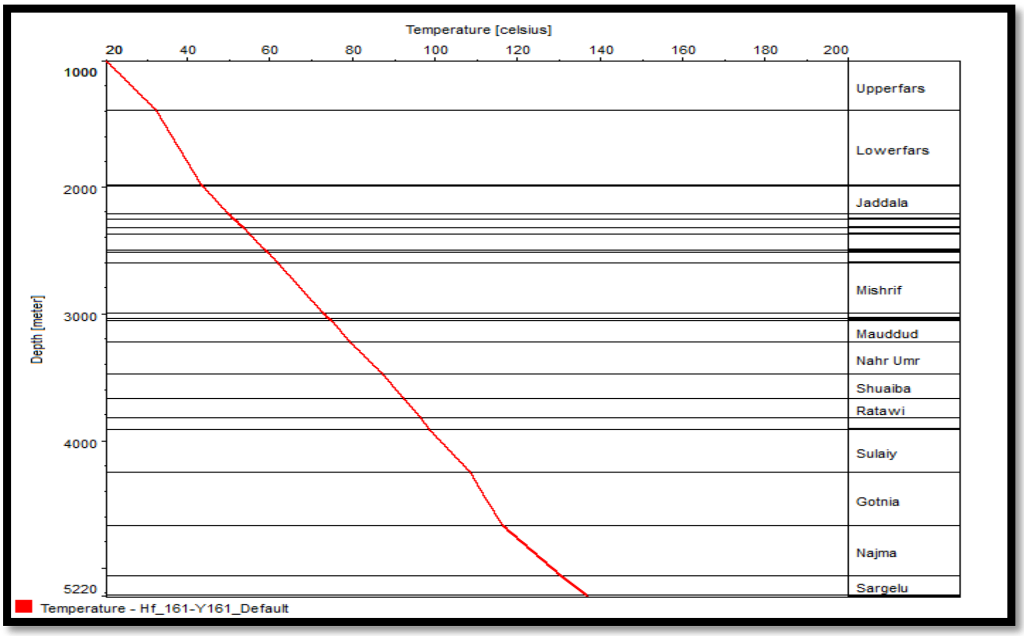


**Figure 1-C-** Burial thermal history of source rock formations in Halfaya oil field, well (HF161 – Y161)

**Timing of oil generation:**

Transformation ratio (TR) is the difference between the original hydrocarbon potential of a sample before maturation and the measured hydrocarbon potential divided by the original hydrocarbon potential. And could be measured by Bitumen/ Total organic carbon (TOC), [2,8] . Oil transformation (TR) ratio and the temperatures of petroleum generation are modeled for Halfaya oil field, well HF161-Y161. Vitrinite reflectance curve are used for depicting thermal stress and for comparision . TR curves represent the fraction of oil that is generated at agiven moment in geologic time. Temperture during oil generation are modeled with integrated heat flow, conductivity decompacted thickness calculation. The value of Transformation ratio could range from (0-1.0) or could be converted percentage which eepresented the beginning and end of oil generation respectively according to time generation for source rock unit in study well HF161-Y161 of the Halfaya oil field figure 2, 3, 4, 5, 7, 8, 9, 10 , 11 and 12 could be clarified the follows:-

**Upper Jurassic**

**At Sargelu formation** figure 2TR curve indicate that oil generation commenced with TR ≥ 10% in age of Upper Gretaceous (95 Million Years ago) and deposit temperature of 90 C° with calculated vitrnite reflection of 5.5%Ro. Peak oil generation is continued from this point to reach TR=90% at age of Neogene (50Million Years ago)and deposit temperature of 105C°with calculated vitrinite reflectance of 0.75%Ro. End generation with 100% had performed at age of early Neogene (25 Million Years ago).And this formation consider high mature source rock

**At Najma formation** figure 3 TR curve indicate that oil generation commenced with TR ≥ 10% in age Upper Cretaceous (92 Million Years ago) and deposit temperature of 88 C° with calculated vitrnite reflection 0.50 % Ro. Peak oil generation is continued from this point to reach TR=50% at age of Paleogene age (52Million Years ago)and deposit temperature of 80 °C with calculated vitrinite reflectance of 0.60 %Ro. End generation with 100% had performed at age of early Neogene (15Million Years ago). And this formation consider high mature source rock.

**At Gotnia formation** figure 4 TR curve indicate that oil generation commenced with TR ≥ 10 % in age Upper Cretaceous (78Million Years ago) and deposit temperature of 80 C° with calculated vitrnite reflection 0.48 % Ro. Peak oil generation is continued from this point to reach TR=50% at age of Neogene age (60Million Years ago)and deposit temperature of 110 °C with calculated vitrinite reflection of 0.7 0 %Ro. End generation with 100% had performed at age of early Neogene (13Million Years ago). And this formation consider high mature source rock.

**At Sulaiy formation** figure 5 TR curve indicate that oil generation commenced with TR ≥ 10 in age of Neogene (13Million Years ago) and deposit temperature of 90C° with calculated vitrnite reflection

0.47 % Ro. Present time is generation with temperature 100 C° and vitrnite reflection 0.65% Ro and TR=65 % at age of early Neogene. And this formation consider mature source rock.

**Lower Cretaceous**

**At Yamama formation** figure 6 TR curve indicate that oil generation commenced with TR≥10 in age of Neogene (10Million Years ago) and deposit temperature of 78C° with calculated vitrnite reflection 0.45% Ro.Present time is generation with temperature 98 C° and vitrnite reflection 0.60% Ro and TR=40% at age of early Neogene. And this formation consider mature source rock.

**At Ratawi formation** figure 7 TR curve indicate that oil generation commenced with TR≥ 10 in age of Neogene (9Million Years ago) and deposit temperature of 70C° with calculated vitrnite reflection 0.50 % Ro. Present time is generation with temperature 90 C° and vitrnite reflection 0.55 % Ro and TR=38% at age of early Neogene. And this formation consider mature source rock.

**At Zubair formation** figure 8 TR curve indicate that oil generation commenced with TR ≥10% in age of Paleogene (35Million Years ago) and deposit temperature of 75C° with calculated vitrnite reflection 0.8 0 % Ro. Present time is generation with temperature 85 C° and vitrnite reflection 0.90 % Ro and TR=100% at age of early Neogene. And this formation consider high mature source rock.

**At Shu′aiba formation** figure 9 TR curve indicate that oil generation commenced with TR ≤ 10% in age of Neogene (9Million Years ago) and deposit temperature of 70C° with calculated vitrnite reflection 0.50 % Ro. Present time is generation with temperature 90 C° and vitrnite reflection 0.60. % Ro and TR=10% at age of early Neogene.And this formation consider immature source rock

**At Nahr Umr formation** figure 10 TR curve indicate that oil generation commenced with TR≤ 10% in age of Neogene (8Million Years ago) and deposit temperature of 80C° with calculated vitrnite reflection 0.55 % Ro. Present time is generation with temperature 90 C° and vitrnite reflection 0.55% Ro and TR=5% at age of early Neogene. reflection 0.50 Ro and this is considered immature source rock.

Hydrocarbon generation has been distributed within the whole petroleum system of Jurassic and Tertiary of the major seals of Upper Jurassic Gotnia Anhydrite formation and Allan Limestone formation and Middle Miocene Lower Fars Fatha Anhydrite formation.

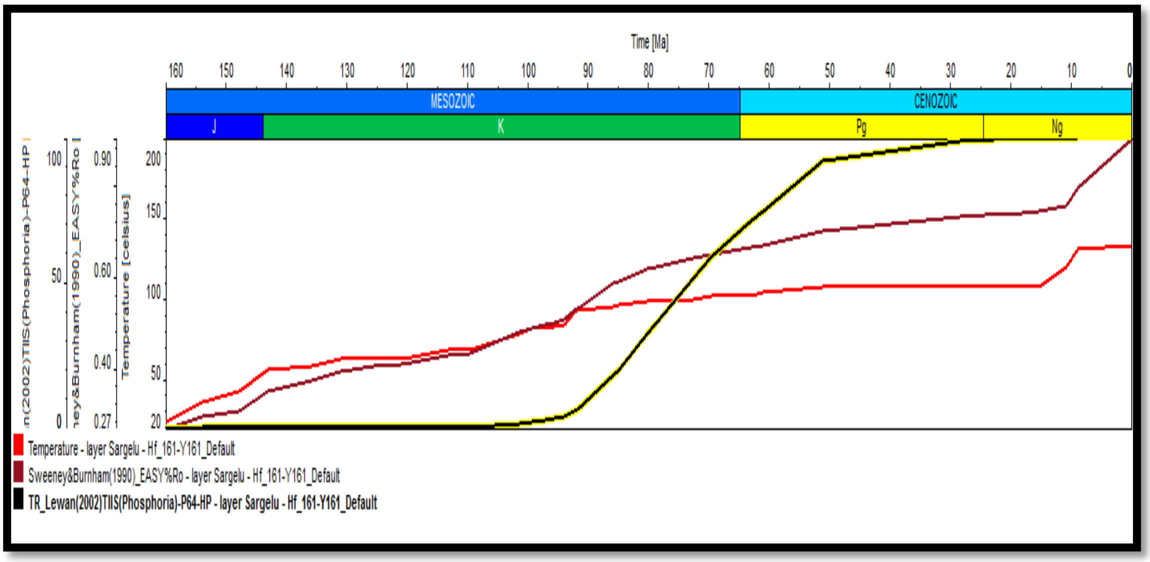


**Figure 2-**Transformation Ratio and timing of oil generation of Upper Jurassic Sargelu formtaion in Halfaya oil field , Well( HF161- Y161).

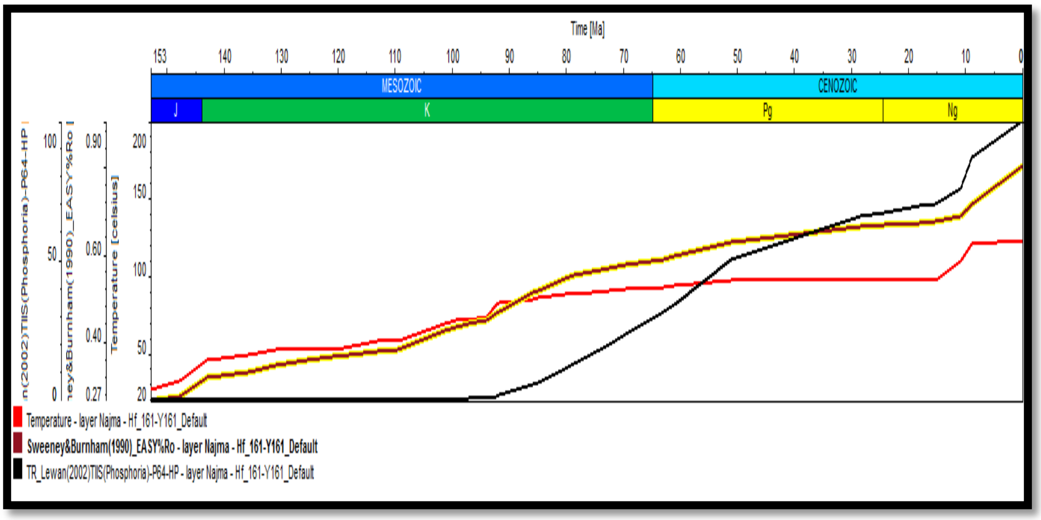


**Figure 3-** Transformation Ratio and timing of oil generation of Upper Jurassic Najma formtaion in Halfaya oil field, Well (HF161- Y161).

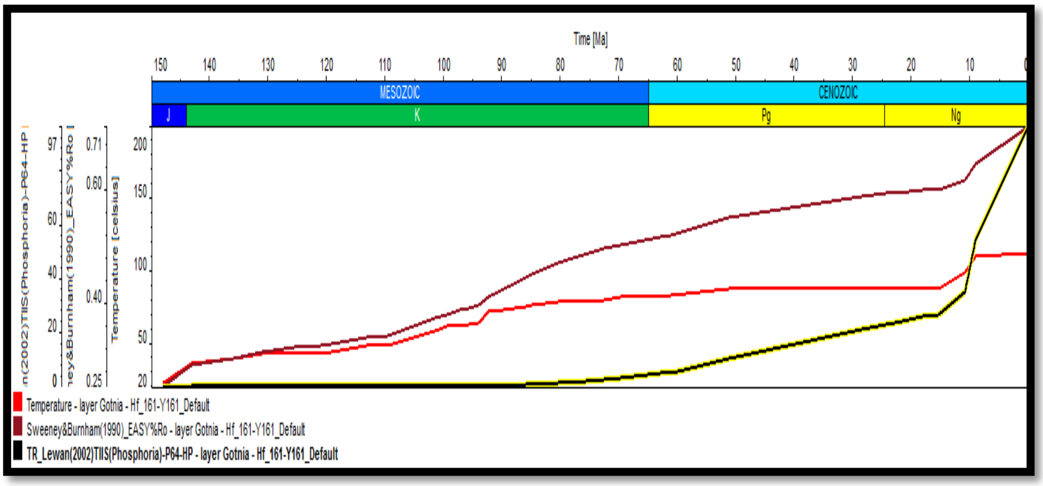


**Figure 4-** Transformation Ratio and timing of oil generation of Upper Jurassic Gotnia formtaion in Halfaya oil field, Well (HF161- Y161).

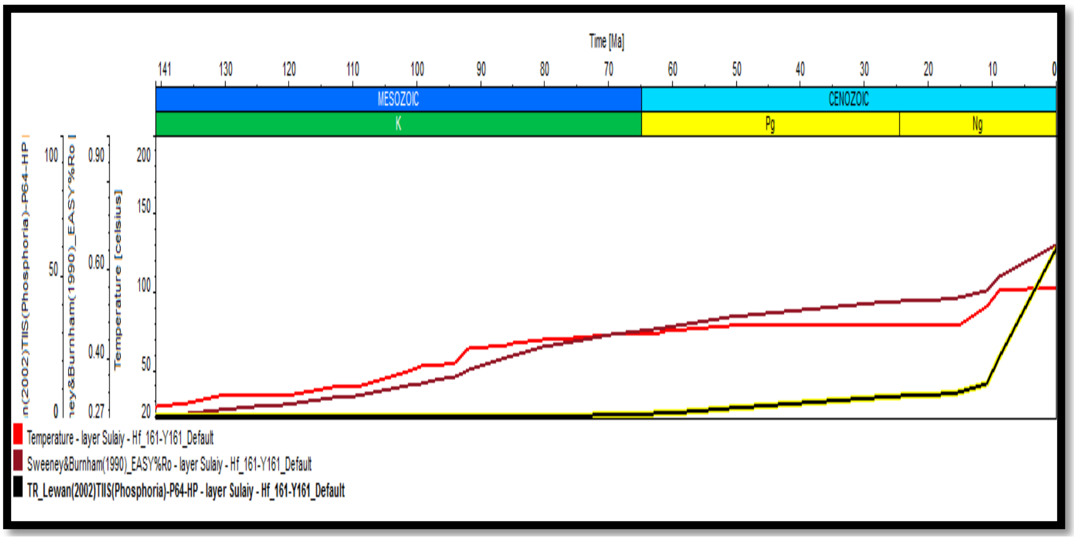


**Figure 5-** Transformation Ratio and timing of oil generation of Upper Jurassic Sulaiy formtaion in Halfaya oil field , Well (HF161- Y161).

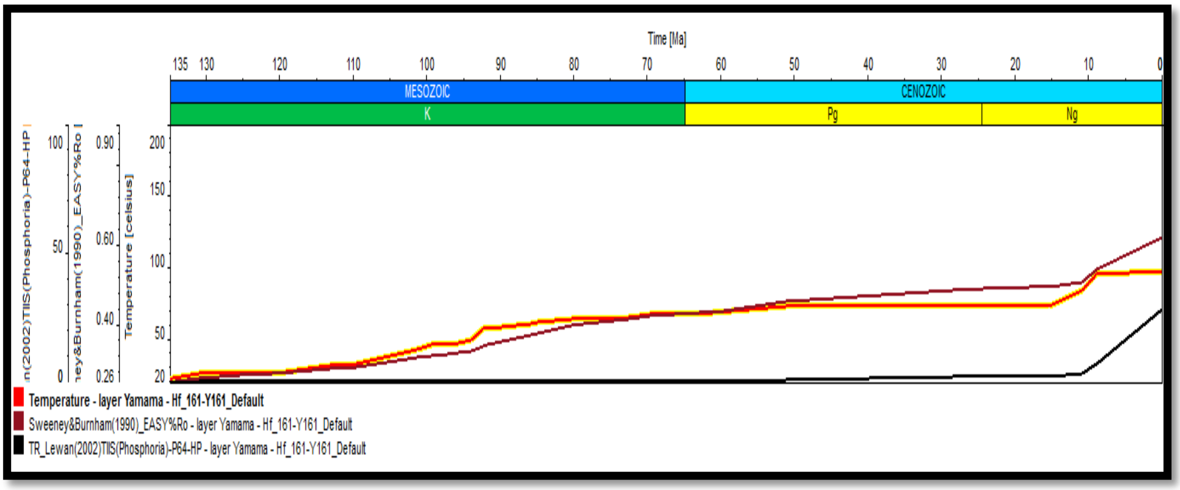


**Figure 6-** Transformation Ratio and timing of oil generation of Lower Cretaceous Yamama formtaion in Halfaya oil field, Well (HF161- Y161).

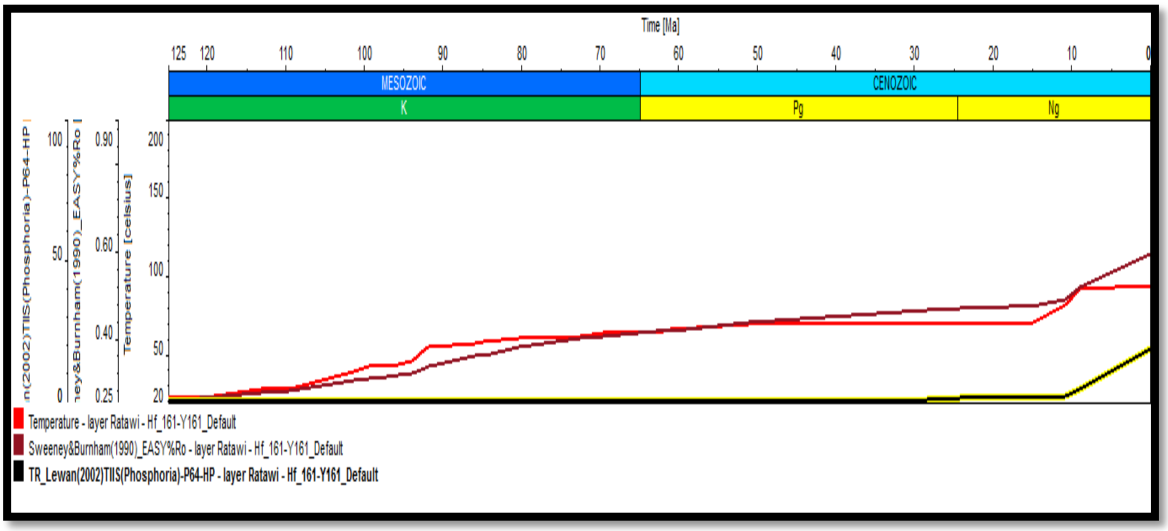


**Figure 7-** Transformation Ratio and timing of oil generation of Lower Cretaceous Ratawi formtaion in Halfaya oil field, Well (HF161- Y161).

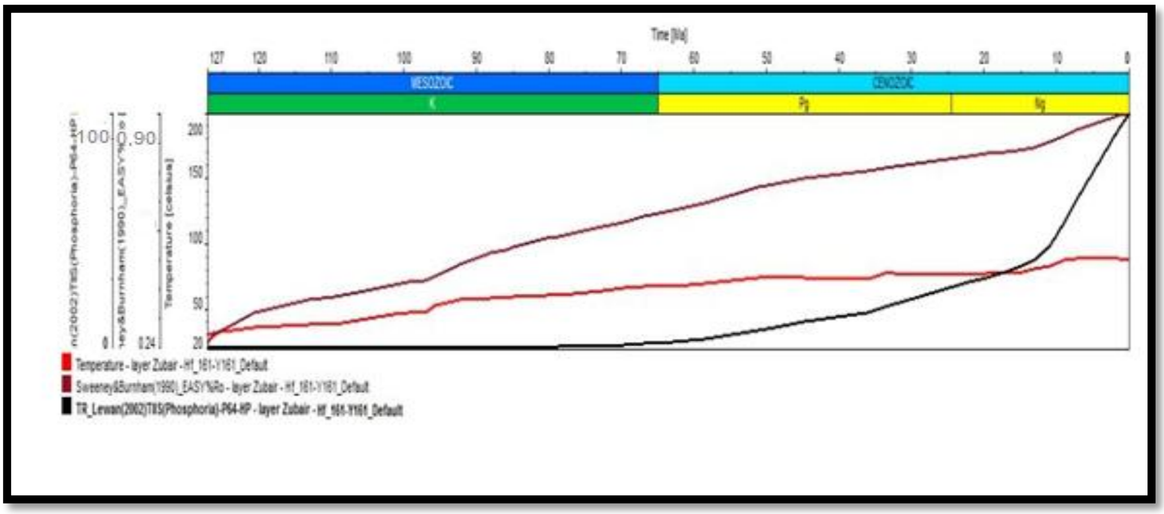


**Figure 8-** Transformation Ratio and timing of oil generation of Lower Cretaceous Zubair formtaion in Halfaya oil field, Well (HF161- Y161).

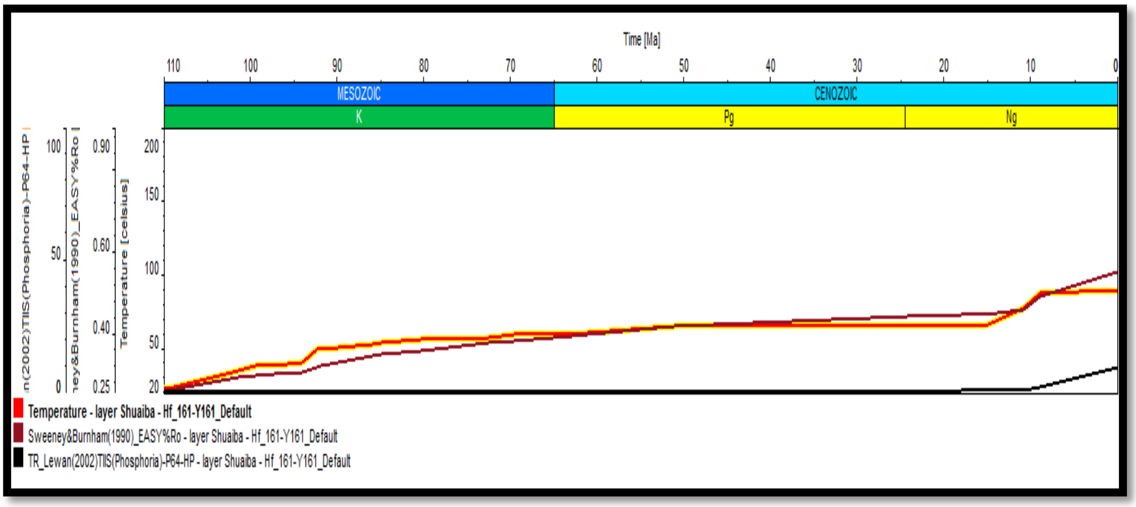


**Figure 9-** Transformation Ratio and timing of oil generation of Lower Cretaceous Shu′aiba formtaion in Halfaya oil field, Well (HF161-Y161).

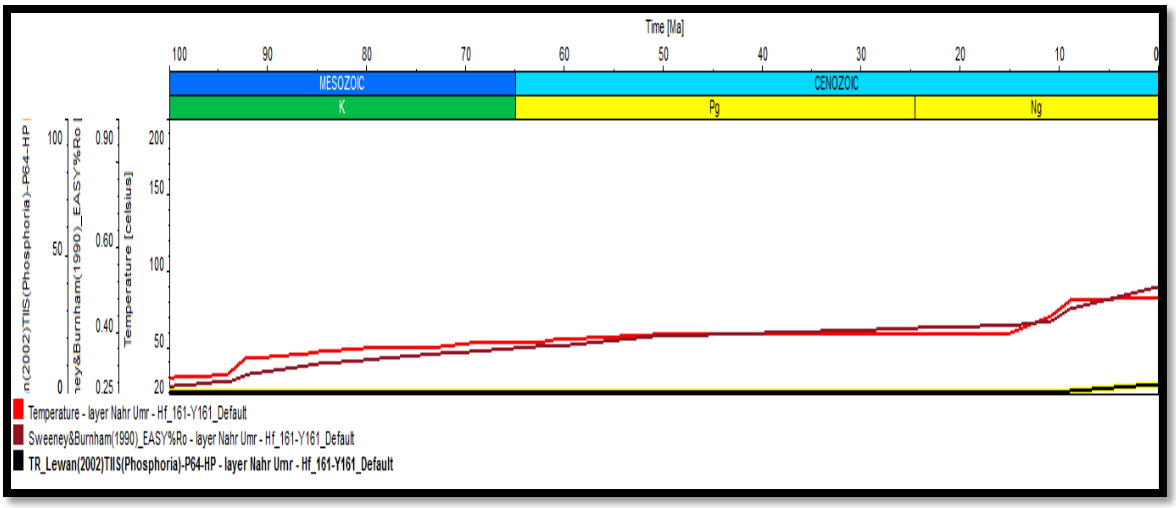


**Figure 10-** Transformation Ratio and timing of oil generation of Lower Cretaceous Nahr Umr formtaion in Halfaya oil field, Well (HF161-Y161).

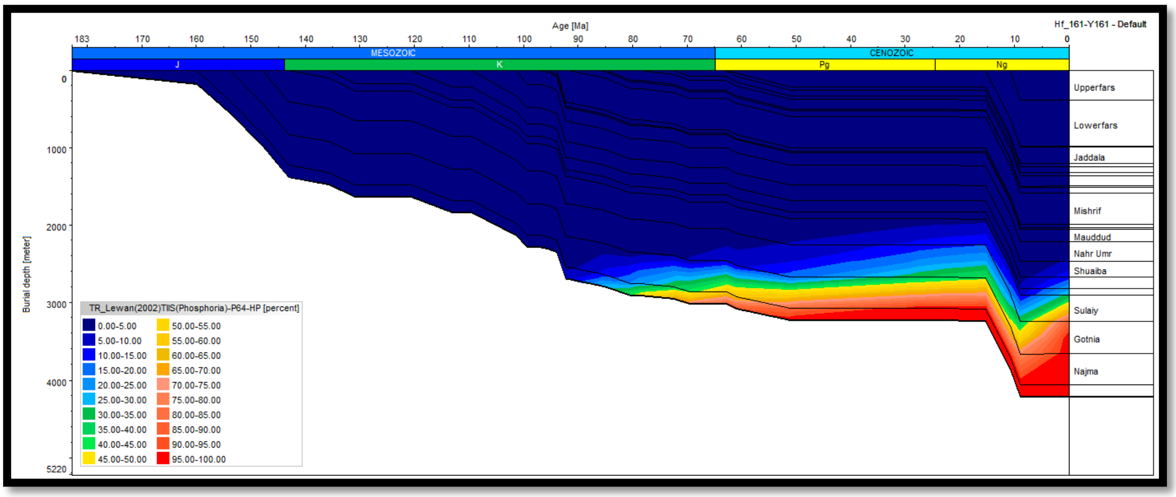


**Figure 11-** Timing and Extent of oil Generation of Halfaya oil field , Well( HF161 – Y161)

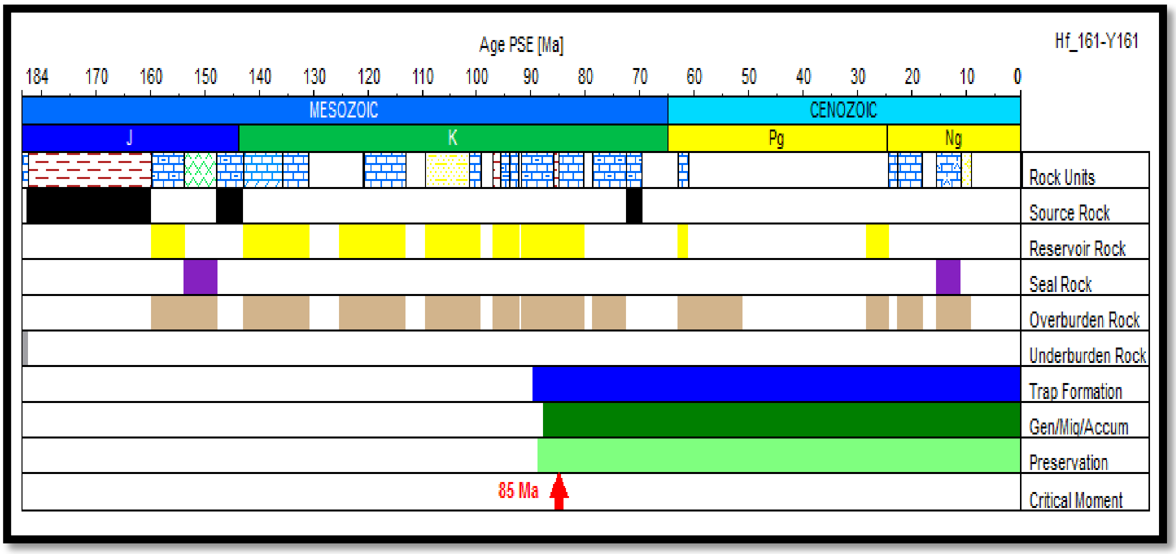


**Figure 12-** Events Chart showing the timing of the essential elements and processes in the total petroleum system in studied area well (HF161-Y161).

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