IBGM
GIF EVALUATIN - 2017
IRAQI BULLETIN OF GEOLOGY AND MINING
Global Impact Factor
0.936

Iraqi Bulletin of Geology and Mining *Vol.14, No.1, 2018* *p 31 – 46*

BASIN MODELING OF THE POTENTIAL SOURCED SARGELU FORMATION WITHIN ZAGROS FOLD BELT, NORTH IRAQ

Ahmed A. Najaf[1]

Received: 10/ 03/ 2017, Accepted: 07/ 09/ 2017
Key words: Sargelu Formation, Basin Model, Jurassic period, Thermal burial history

ABSTRACT

The attempts for determining the potentiality of Sargelu Formation adequately performed is by the application of various organic geochemical studies. The indications refer to this formation as being one of the most important source rocks and have its economic horizon generating the majority of oil and gas in Iraq. Basin modeling assist to declare the scope and will already perform the complementary view by acquiring all previous and current data, and create a new version of basin modeling, depending mainly on real and perfect studies that differ from the former studies that depends mainly on estimations because no rock samples were available, but in the undertaken study, rock samples (core and cuttings) were extracted from Butmah-15, Jabal Kand-1, Qara chuq-1 and Ajeel-8 oil exploratory wells.

One dimension petroleum-system modeling of key wells were developed using Integrated Exploration System (IES). PetroMod software to evaluate burial-thermal history, source-rock maturity, and the timing and extent of petroleum generation; interpreted well logs served as input to the models. The oil generation potential of sulfur-rich Sargelu source rocks was simulated using closed-system, Type IIs kerogen kinetics. Model results indicate that throughout northern Iraq generation and expulsion of oil from the Sargelu began and ended in the late Miocene.

At present, Jurassic source rocks might have generated and between 70 and 100 % of their total oil, or the model indicates that, the majority of Jurassic source rocks in Iraq have reached or exceed peak oil generation and most rocks have completed oil generation and expulsion except Jabal Kand-1, were defiantly unlike the other wells, is still generating today.

نموذج الحوض المصدري الاحتمالي لتكوين ساركلو ضمن حزام طية زاكروس، شمال العراق

احمد عسكر نجف

المستخلص

ان المحاولات لتحديد الاحتمالية لتوليد الهيدروكاربونات لتكوين ساركلو قد تم تنفيذها بكل دقة وذلك عن طريق تطبيق العديد من دراسات الجيوكيمياء العضوية. ان الدلائل تشير الى ان التكوين يعتبر من اهم الصخور المصدرية وللتكوين أفق اقتصادية كبيرة لكونه المولد لغالبية نفط وغاز العراق. ان نموذج الحوض يساعد في توضيح مدى الفهم واتمام شامل للمشهد الاستيضاحي لكل الدراسات السابقة والمعطيات الحديثة، وخلق رؤية حديثة لنموذج الحوض معتمدا على دراسات دقيقة وحقيقية تختلف عن الدراسات السابقة، وفي هذه الدراسة تم الاعتماد على نماذج صخرية (لباب وفتات) والمستحصلة من آبار استكشافية (بطمة-15، جبل قند-1، وعجيل-8).

[1] Department of Geophysics, Al-Karkh University of Science,
e-mail: drahmedaskar@yahoo.com

ان نظام الموديل النفطي ذو الاتجاه الواحد للابار قيد الدراسة تم تطويره باستخدام برامجيات الموديل النفطي وهو النظام الاستكشافي المتكامل لتقييم تاريخ حرارة الدفن والنضج للصخور المصدرية وكذلك توقيت وامتداد الزمن الجيولوجي للتوليد النفطي. مع تفسير للجس البئري كمعطيات في وضع وإنشاء الموديل. ان احتمالية التوليد النفطي لتكوين ساركلو المصدري الغني بالكبريت تمت محاكاته باستخدام النظام المغلق والكيروجين-II الكامن في هذا النوع من الصخور المصدرية. ان نتائج نموذج الحوض أوضحت انه من خلال التوليد والاستخلاص النفطي في مناطق شمال العراق وفي تكوين ساركلو بالتحديد بدات وانتهت في العصر الجيولوجي المايوسين المتأخر.

في الوقت الحاضر ان الصخور المصدرية لعصر الجوراسي ربما ولدت مابين 70 – 100 % من مجمل النفط المتولد او ان الموديل أو نموذج الحوض يوضح ان غالبية الصخور المصدرية للعصر الجوراسي في العراق قد وصلت الى او تزيد في قمة التوليد النفطي وان معظم الصخور قد استكملت التوليد وترحيل النفط باستثناء بئر جبل قند-1 حيث بالمؤكد لايشبه بقية الآبار التي وصلت الى قمم التوليد والترحيل النفطي، وهذا يعني ان التوليد مستمر الى يومنا هذا.

INTRODUCTION

Upper Jurassic carbonate source rocks are well known on the Arabian plate, especially on the Emirates, Qatar, Saudi Arabia, Kuwait, and southern Iraq. Much less is known about the Middle Jurassic sediments as possible source horizons so Sargelu Formation is one of the most important and promising source rock and is focused upon recently.

Petroleum system analysis integrates geological and geochemical data, and petroleum system modeling is the technology that organizes the oil exploratory wells of different depths a penetration through varieties related data management and processing tasks. (Al Ahmed, 2006) One Dimension for four wells of petroleum-system models of Tertiary, Cretaceous and Jurassic formations are Ajeel (Aj-8), Taq Taq (Tq-1), Jabal Kand (Jk-1) and Butmah (Bm-15), (Figs.1, 2 and 3). Representation of thermal burial history, timing and generation of HC and extent of oil and gas were the consequences that led to build and set up a suitable scenario for identification of the area that include the majority of oil reserves in Iraq.

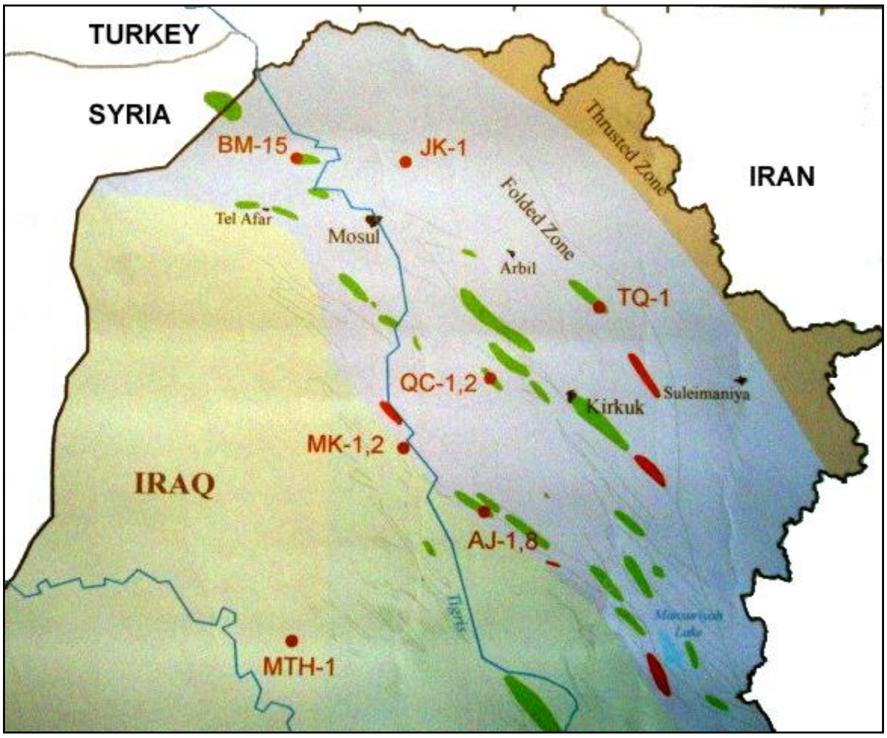

Fig.1: North part of Iraq shows the localities of the studied wells (modified from Chevron, 2009)

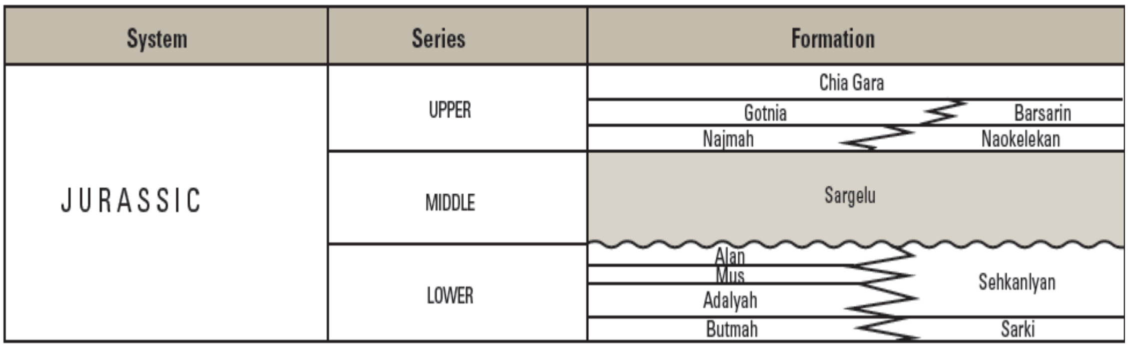

Fig.2: Jurassic stratigraphy within the study area of north Iraq Pitman, 2004

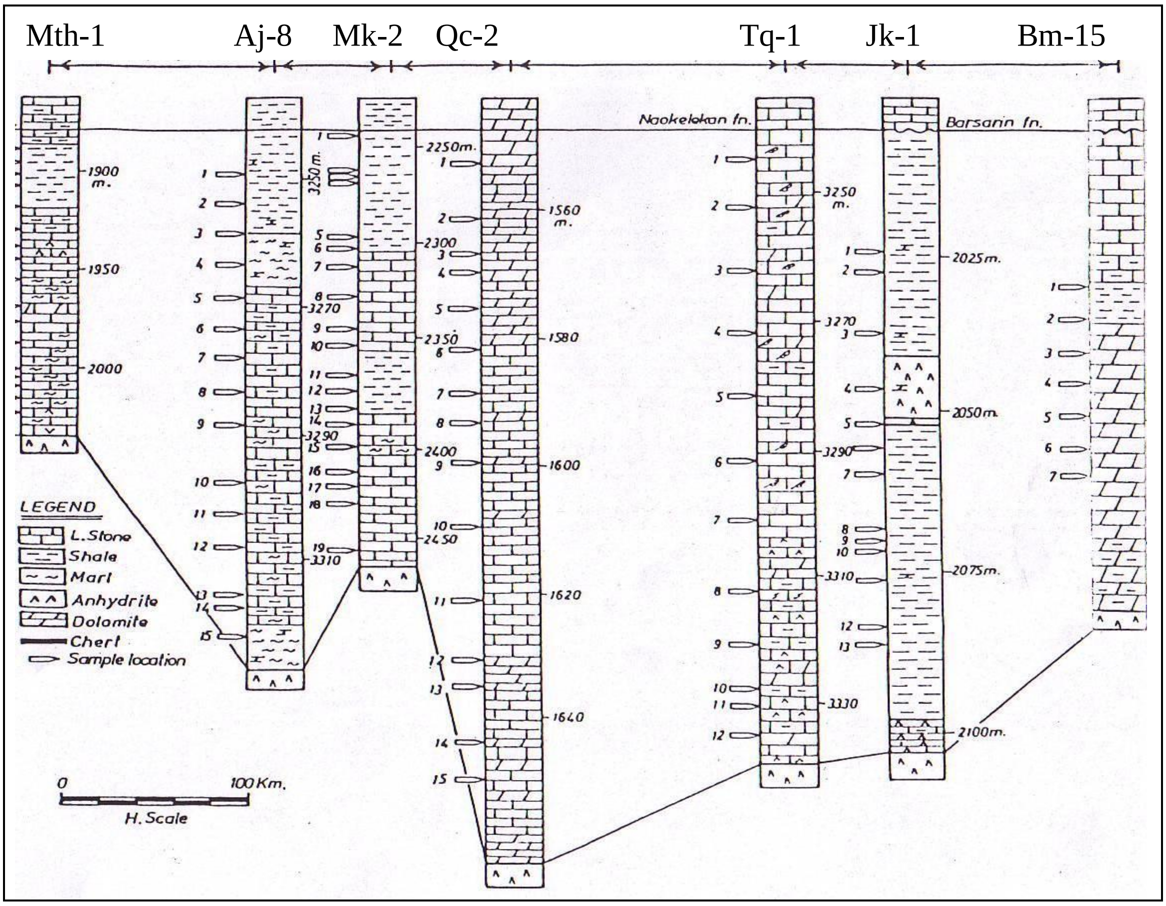

Fig.3: Stratigraphy of Sargelu Formation (Al Ahmed, 2006)

Each model is a numerical formulation of the burial-thermal history developed to simulate burial-thermal history, source-rock maturity, at the model (well) location based on interpretation of combined geologic and geochemical data in a temporal frame work, and it includes the principal elements (source rocks, reservoir rocks, and seals) of the total petroleum system. In the regional 2D model, thermal maturity and petroleum generation and expulsion histories were simulated on 1D profile and model results were extracted for the top Middle Jurassic insights into total-system process, which can optimize resource assessments and exploration efforts in under-explored basins. Basin model simulation take into interpretations gained from geologic models and are based on knowledge of the source rocks.

Historically, it has been difficult to assess petroleum resources in the Mesopotamian Basin and Zagros Fold Belt because data on the source rocks and reservoir rocks were not available. Several studies have documented stratigraphy and sedimentology of Jurassic source rocks, (Pitman, 2004).

Sargelu Formation is first described by (Wetzel, 1950) at type locality in Surdash anticline, near Sulaimaniyah district northeastern Iraq (Bellen *et al*., 1959). Barsarin – Banik sections are also sections for the Sargelu Formation.

Lithology of the Sargelu Formation at type locality consists of thin layers of bituminous, dolomitic limestone and black papery shale with streaks of thin black chert in upper parts in almost all cropping sections. These sections show similarity between surface and wells. They have higher percentages of shale, but toward the west, sandy admixture has been observed, which represent change to Muhaiwir Formation. Outcrops is silicified, but silicification is absent in boreholes (Buday, 1980). The thicknesses of Sargelu Formation as noticed in Banik and Barsarin section are (14 – 48) m respectively, and (148) m in type locality at the Sargelu village. On the other hand, the thickness noticed during the study of boreholes ranged between (100 – 200) m.

Sargelu Formation is a product of euxinic marine environment, with some inlayers showing either shallowing or better aireated condition. The shallower and better aireated environment occurred mainly on the stable area (Buday, 1980). Fossils recognized in outcropped section referred mainly to Middle Jurassic age.

They are Jurassic ammonite's *stephanoceras, perisphinctes, posidonia ornati* that occurred in the upper parts of the Sargelu Formation at Barsarin section, according to our field collections.

The age of the formation is determined according to the global range biozone for the extracted palynomorphs, from the studied samples and age assignment is suggested to be late Bathonian-Bajocian-Callovian (Al Ahmed, 2001). During the late Mesozoic and early Cenozoic, sedimentation in the area of the present Mesopotamian Basin and Zagros fold belt was controlled by local tectonics, eustatic sea-level changes, and climate variations. From Jurassic through Late Cretaceous time, sea-level fluctuations in conjunction with slow subsidence led to the formation of large, but shallow intrashelf basins on the passive margin of the Neo-Tethys Ocean and the Arabian Plate (Stoneley, 1987; Alsharhan and Nairn, 1997; Murris, 1980).

Organic-rich sediments, which gave rise to the (Jurassic) Sargelu and Naokelekan source rocks, accumulated in these basins under anoxic conditions, and high-energy carbonates (i.e., bioclastic and oolitic) were deposited along the basin margins on the carbonate-evaporite shelf. In the Late Jurassic, depositional conditions culminated in the formation of thick evaporites (anhydrite and salt), which presently form a semi-permeable regional seal (i.e. Gotnia Formation) above the Jurassic source facies. The distribution of Cretaceous reservoirs in the southern Mesopotamian Basin was influenced by the nature of these evaporites (Murris, 1980; Beydoun *et al*., 1992).

MODEL SETUP

Model development using Integrated Exploration System (IES) Petromod software (Note: use of brand name is for descriptive purposes only and does not constitute endorsement by the U.S. Geological Survey). Petromod is a finite-element, basin simulator that describes thermal histories, source rock maturity, and petroleum generation and migration in one, two and three dimensions (1-D, 2-D, and 3-D, respectively) (IES, 2004). The generalized nature of the input data and the lack of adequate data for model calibration precluded analysis of 3-D model results on a field-by-field basis; however, on a regional scale, the 3-D model providing valuable insights into timing from petroleum-system models were utilized in the USGS (2000) World Petroleum Assessment.

Each studied well have a worksheet that includes the following data:

1. Formation names of all major unit overlying the Sargelu formation.
2. The top and bottom depths of each unit including the Sargelu Formation.
3. The beginning and ending ages of deposition for each unit. (The stratigrphic chart of the Arabian plate published by Sharland and others. GeoArabia pub 2 in 1991 is the best source for ages.
4. The estimated amount of section eroded from each unit and the beginning and ending age of each period of erosion. Information for even unit that were deposited but are no longer present is also included. Unit with large erosional loss only are important.
5. The Lithology of each unit.
6. The petroleum system elements (Source rock, reservoir rock, seal rock, over burden rock) that best characterizes each unit.
7. The total organic carbon contents of each source rock interval. A source rock such as the Sargelu Formation can be subdivided into generative and non-generative interval.
8. The type of organic matter (Type 1, Type II, Type III sulfur-rich-s, Type IV) that best describe each source rock interval. This information should be entered in the column "Petroleum Kinetics". The sulfur content of each source rock interval would be helpful also.
9. The initial hydrogen index of each source rock interval will be determined later.
10. Latitude and longitude for each well and the name of the field where the well is located.
11. Vitrinite reflection and/ or measured temperature dated that is available for each well.

- **Chronostratigraphic Units and Lithologie**s

The chronostratigraphic units in the 1D model were assigned absolute ages of deposition and amounts and ages of erosion... The ages of depositional and erosional events were designated based on the geologic time scale of (Sharland and others, 2001) as the best references. Lithologies represented as end-member rock types or as compositional mixtures of rock types were assigned to each unit using software default parameters.

MODEL CALIBRATION

Determining the timing of petroleum generation and expulsion required calibration of the present and past thermal regime at each model location. Parameters used in the thermal calibration includ heat flow, thermal conductivity of rock matrix, surface temperature and sediment thickness (present and past) (final well report for each oil exploratory well. Bottom-hole temperature data in combination with a geothermal gradient of 23 °C/Km (Pitman *et al*., 2004) were used to estimate the present heat flow in the area of the wells. The resulting temperature profiles computed for the models are displayed in Figure 4.

Vitrinite reflectance (% Ro) determined from Tmax values was used to evaluate the paleothermal history at each well location. Although Ro values estimated using this method have a high degree of uncertainty, they do provide a first approximation of the effects of temperature through time. Calibration of the paleothermal regime was based on matching Ro values computed from Tmax with values calculated using the Easy Ro method of Sweeney and Burnham (1990).

A good correlation between computed and calculated values (Figures 4, 5, 6, 7 and 8) was achieved by varying the estimated amount of erosion at each well locality and the paleoheat flow until a close match was achieved. The best calibration of the Ro data required between 1,700 and 1,900 m of erosion during the late Tertiary. It is noteworthy that pre-Tertiary erosion had little impact on source-rock maturity.

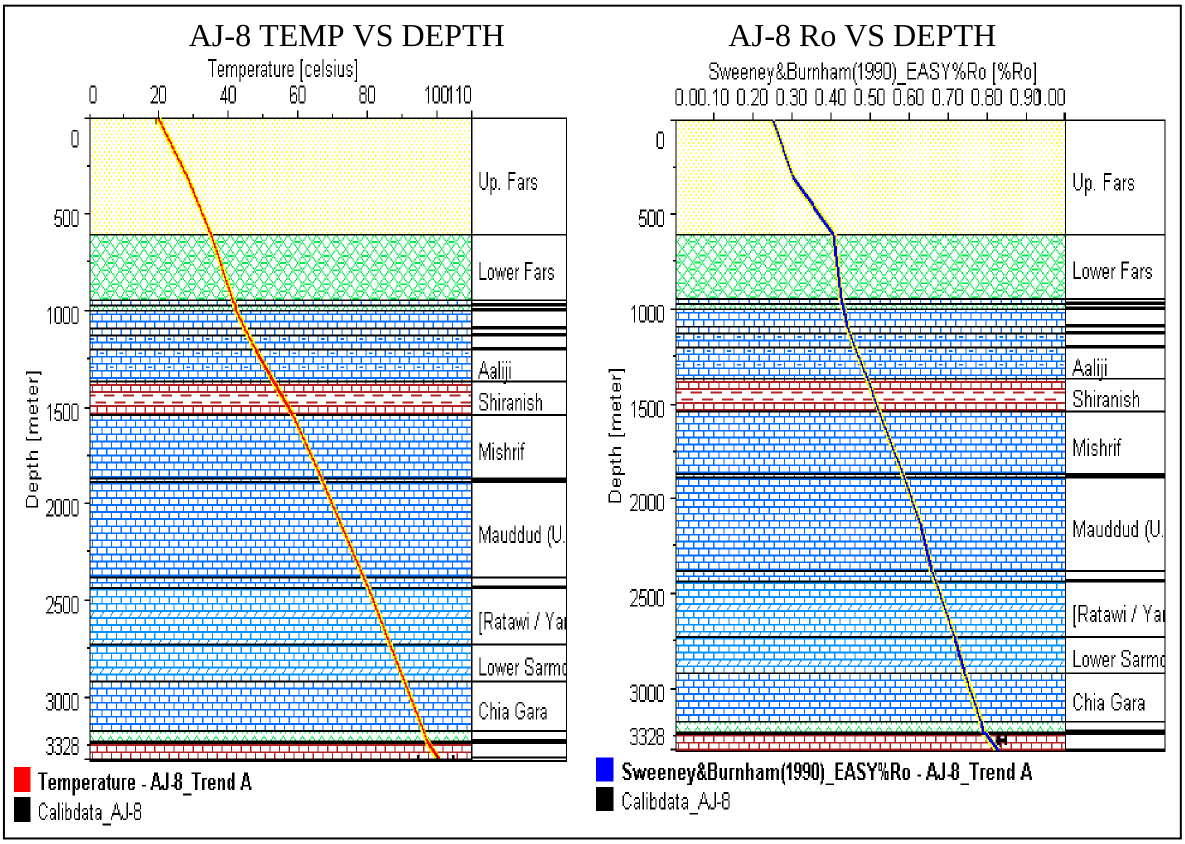

Fig.4: Computed temperatures and vitrinite reflectance of Ajeel-8
(Al Ahmed, 2006)

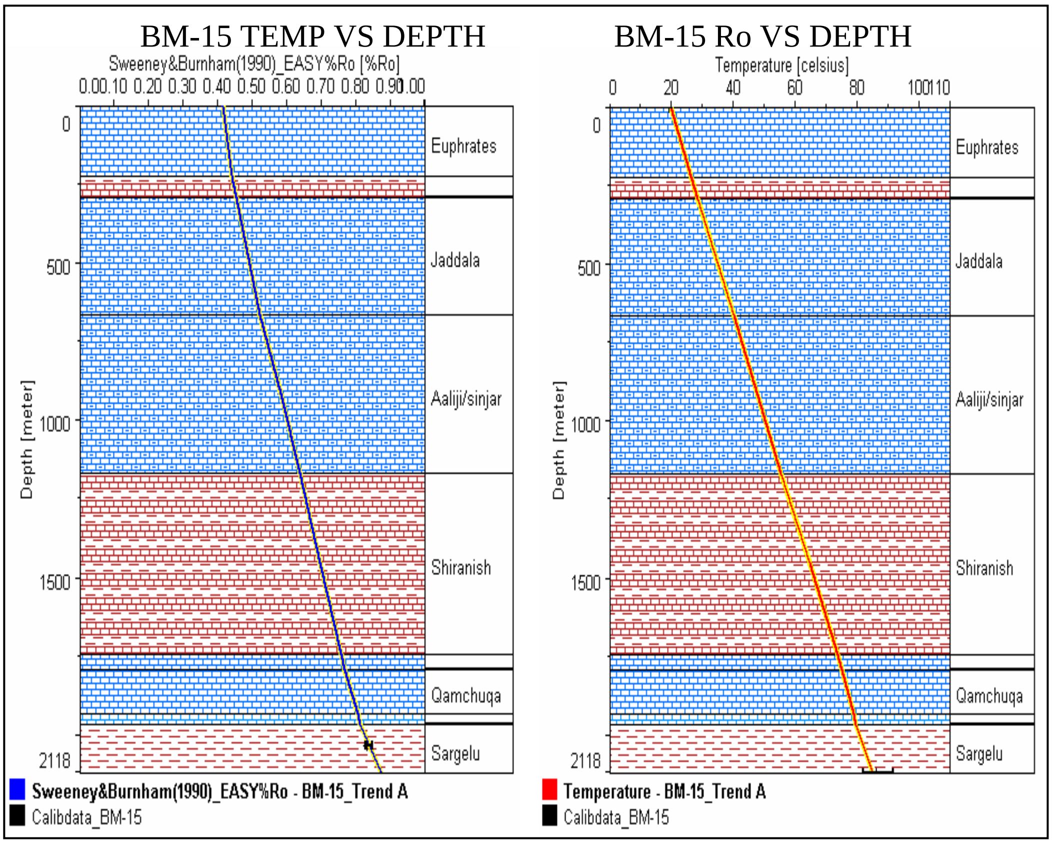

Fig.5: Computed temperatures and vitrinite reflectance of Butmah-15 (Al Ahmed, 2006)

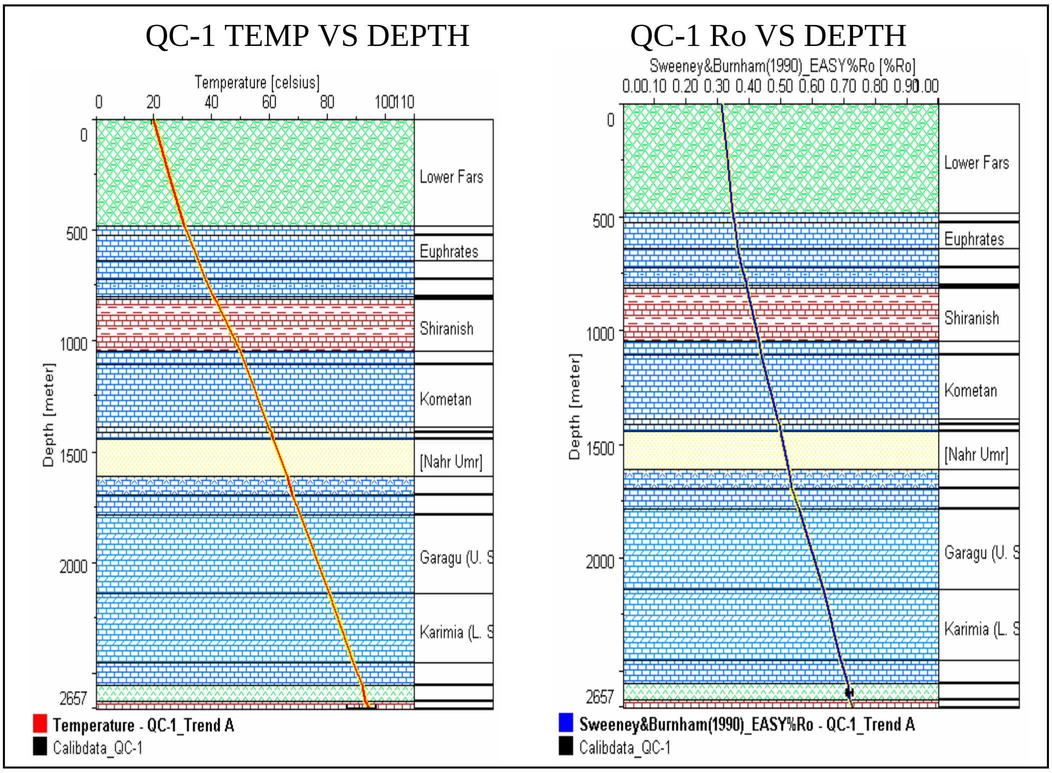

Fig.6: Computed temperatures and vitrinite reflectance of Qara Chuq-1 (Al Ahmed, 2006)

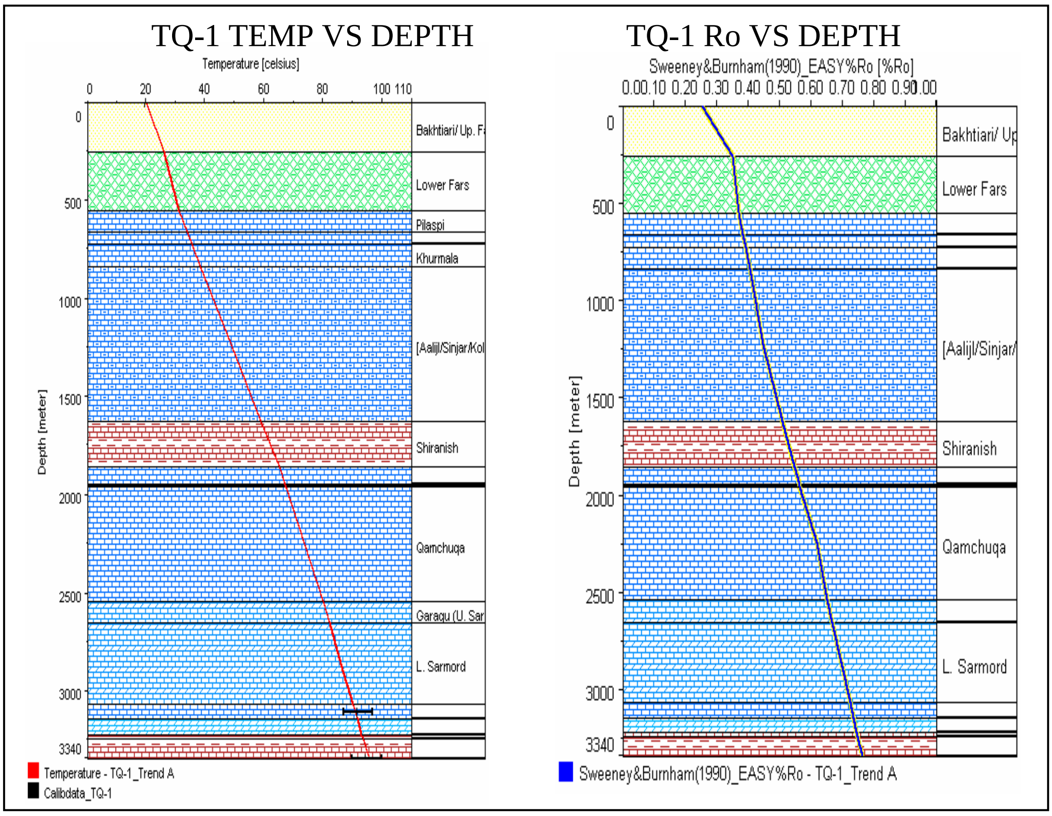

Fig.7: Computed temperatures and vitrinite reflectance of Taq Taq-1 (Al Ahmed, 2006)

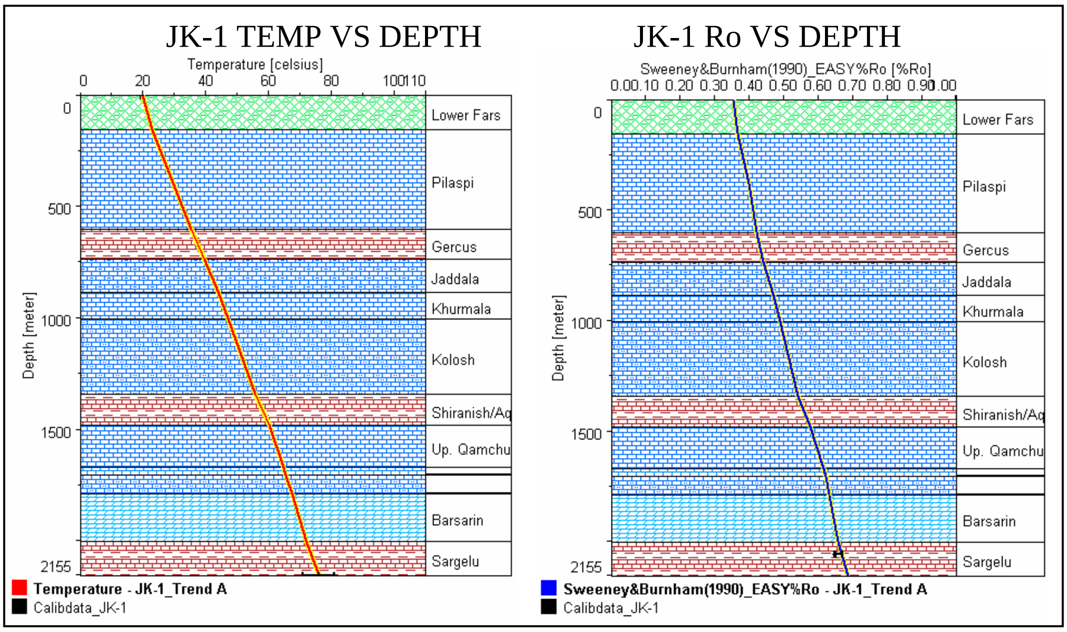

Fig.8: Computed temperatures and vitrinite reflectance of Jabal kand-1 (Al Ahmed, 2006)

MODEL RESULTS

- **Source Rock Maturation and Petroleum Generation**

Modeled vitrinite reflectance at the top of the Middle Jurassic source rock in the Zagros Fold Belt is shown in Figure 9. The model simulations indicate that source-rock maturity varies across the region.

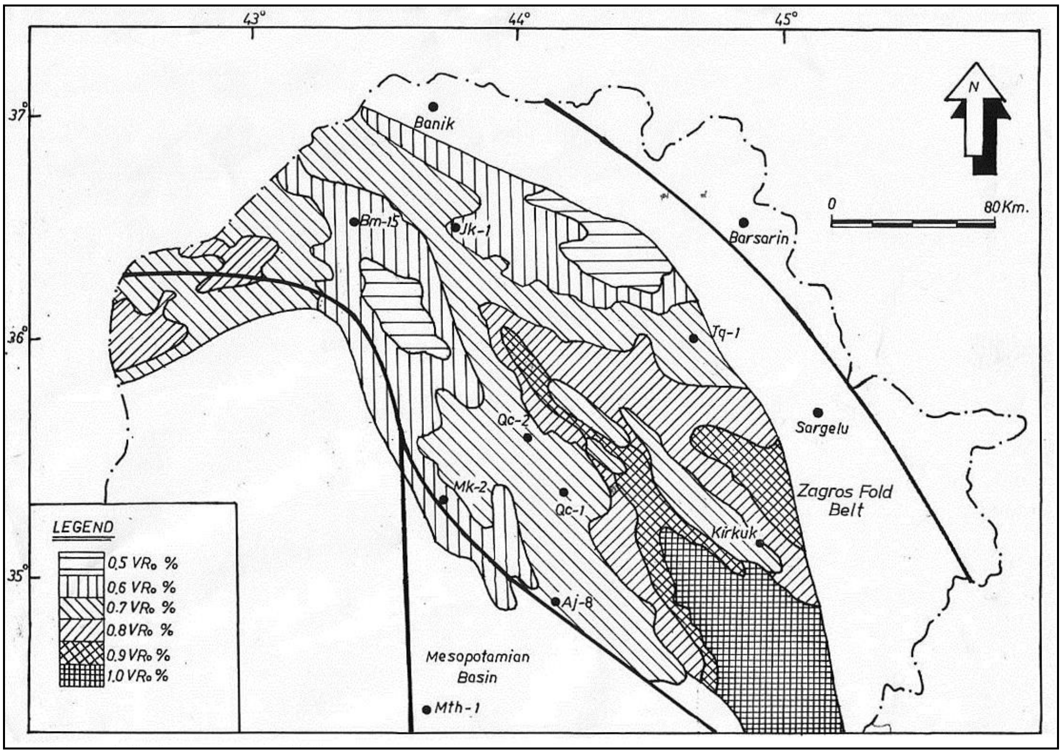

Fig.9: Modeled thermal maturity of Sargelu Formation calculated by VR◦ (modified from Pitman, 2004)

Vitrinite reflectance (% Ro), which integrates the effects of temperature over time, was used to evaluate the paleothermal history of the Mesopotamian Basin and Zagros fold belt. Measured Ro values for six widely-spaced wells (P.G.A., 2000) provided the input for the analysis. Calibration of the paleothermal regime required matching measured Ro values for each well with values of Ro calculated using the Easy Ro method of Sweeney and Burnham (1990). A reasonable correlation between measured and modeled values was achieved by adjusting the estimated amount of stratigraphic section eroded at each well location

At present, there is a systematic decrease in thermal maturity from SE – NW, to illustrate the gradual inclination in maturation indices, (Internal report, OEC. 1997), (Al Ahmed, 2006). Across the fold belt paralleling the trend of the regional structure which indicates that source rock maturation was predominantly controlled by burial. Jurassic source rocks have high maturity (indicate range in maturities) near the surface in the thrust zone. These maturities provide evidence that uplift and erosion took place after source rock maturation, and are consistent with studies that have documented an early oil phase generated and expelled in the thrust belt prior to late Cenozoic tectonism. (Dunnington, 1959; Pitman, 2004). Oil and gas transformation ratios (TR) of petroleum generation were modeled for the wells (Bm-15, Jk-1, Tq-1, Aj-8) to simulate the timing of major petroleum events (generation onset and completion) and the extent of oil and gas generation at each well location (Figs.10 and 11).

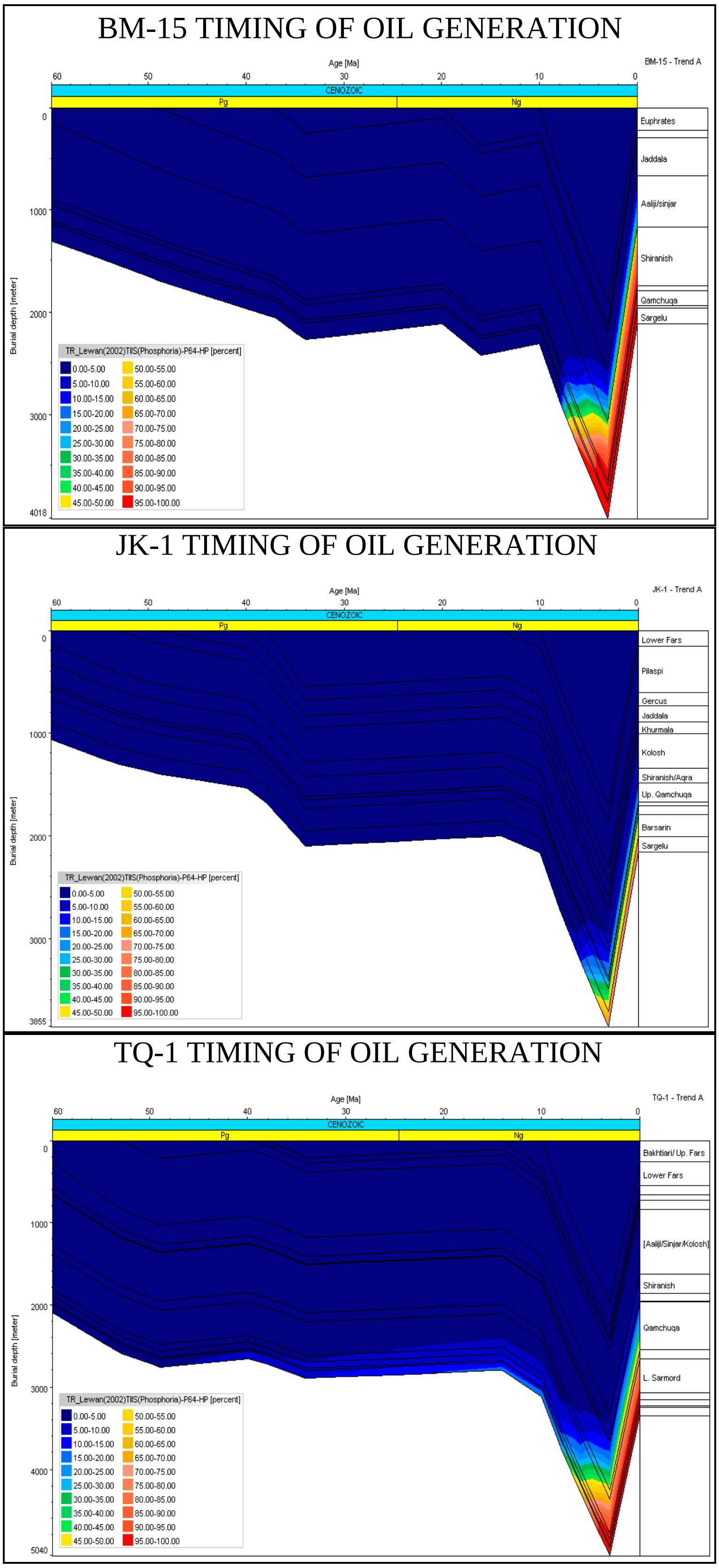

Fig.10: Burial – Timing of Petroleum Generation for Butmah-15, Jabal kand-1 and Qarachuq-1 oil exploratory wells (Al Ahmed, 2006)

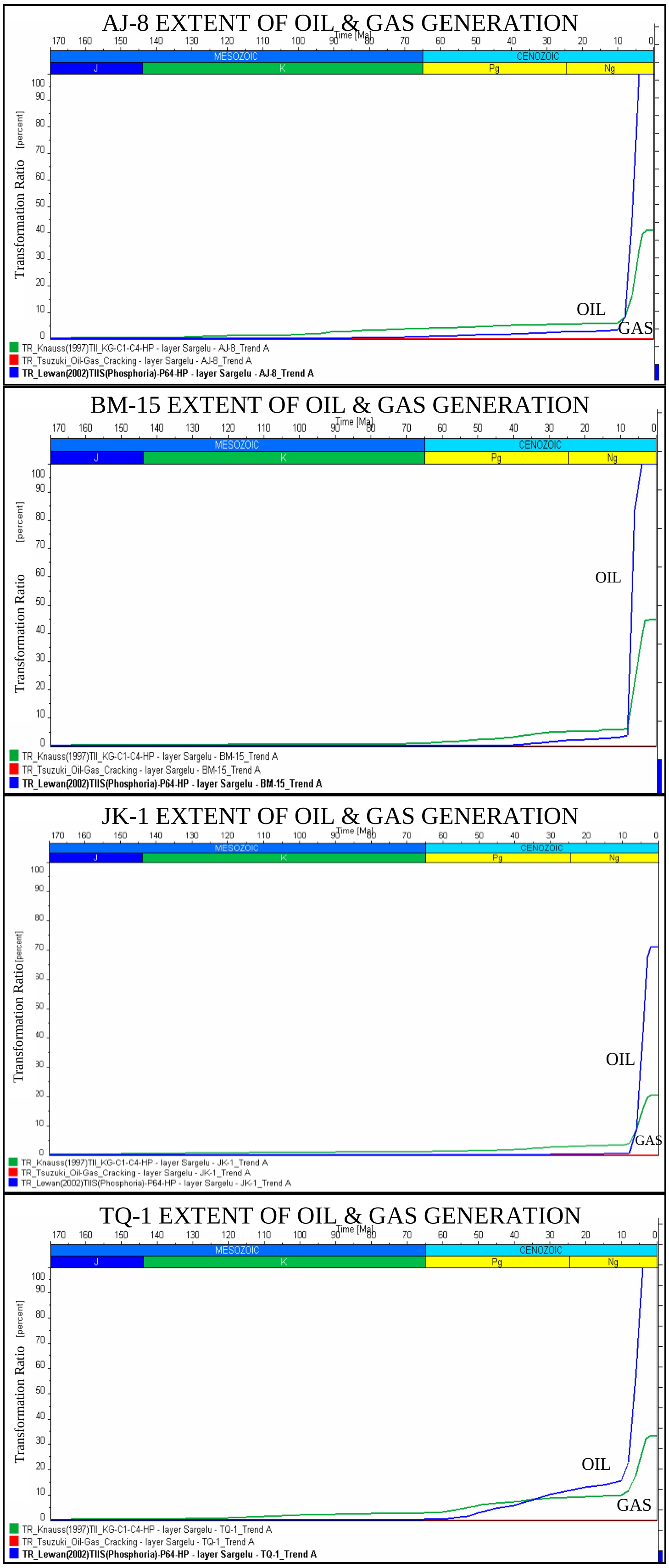

Fig.11: Transformation Ratios (Burial history Curve) for each Oil Well (Al Ahmed, 2006)

TR curves represent the fraction of petroleum that was generated from a source rock at a given moment in geologic time. The beginning, peak, and end of oil generation correspond to TRs of 0.1%, 50%, and 95 – 100 %, respectively are shown below the onset, peak, and end of generation in the model wells shown in (Table 1) are illustrated in (Fig.6).

Table 1: The beginning, peak, and end of oil generation in Jurassic source rocks to indicate the TR from beginning to End of oil generation of Sargelu Formation.

No. of sample	**Well name**	**TR of oil**		
		Beginning	**Peak**	**End**
1	Bm-15	0.1	98.0	100
2	Jk-1	0.1	68.5	89.8
3	Taq-1	0.1	79.5	100
4	Aj-8	0.1	74.8	100

The transformation ratios mentioned in Table 1 is taken from the upward values related with the geological time before Millions years ago compared with the calculated Transformation Ratio Schedule (1) and (2).

Schedule 1: Transformation ratio beginning and completed for both Butmah-15 and Ajil-8 and Jabal Qand-1 oil exploratory wells

Butmah-15 Transformation Ratio of Oil

Time (Ma)	**TR_Iraq_T2S_Lewan (%)**	**TR_Lewa**
0	100.0	100
2	100.0	100
3	100.0	100
4	100.0	100
6	98.0	83.63
8	7.1	3.91
10	5.7	3.13
15	5.2	2.83
16	5.0	2.73
20	4.2	2.29
25	3.8	2.05
30	3.0	1.65
34	2.1	1.13
35	1.8	0.95
37	1.3	0.69
40	0.9	0.5
45	0.5	0.27
49	0.3	0.16
50	0.3	0.14
55	0.1	0.06
60	0.1	0.03
63	0.0	0.01
65	0.0	0.01
70	0.0	0

Ajil-8 TR of oil

Time (Ma)	TR_Iraq_T2S_Lewan (%) (wrong freq	TR_Lewan(2002)TIIS(Phosphoria)-P64-HP
0.0	100.0	100
2.0	100.0	100
3.0	100.0	100
4.0	100.0	100
6.0	74.8	45.57
8.0	22.6	8.37
10.0	9.3	3.56
14.0	7.8	3.01
15.0	7.6	2.96
15.5	7.6	2.93
16.0	7.5	2.91
20.0	7.1	2.74
25.0	6.6	2.57
26.0	6.5	2.53
30.0	6.1	2.37
34.0	5.7	2.2
35.0	5.5	2.15
40.0	4.9	1.91
45.0	4.3	1.67
49.0	3.8	1.47
50.0	3.7	1.42
55.0	3.0	1.19
60.0	2.5	0.98
63.0	2.2	0.87
65.0	2.0	0.8
70.0	1.6	0.64
75.0	1.3	0.5
80.0	1.0	0.39
82.0	0.9	0.36
85.0	0.8	0.31
90.0	0.5	0.21
91.0	0.5	0.19
95.0	0.2	0.07
96.0	0.1	0.06
98.0	0.1	0.05
100.0	0.1	0.04
102.0	0.1	0.03
110.0	0.1	0.02
114.0	0.0	0.02
120.0	0.0	0.01
127.0	0.0	0

Schedule 2: Transformation ratio beginning and completed for both Qara Chuq-1 and Jabal Qand-1 oil exploratory wells

Qara Chuq-1 TR of Oil			Jabal Kand-1 Transformation Ratio of Oil		
Time (Ma)	TR_Iraq_T2S_Lewan (%)	TR_Lewa	Time (Ma)	TR_Iraq_T2S_Lewan (%)	TR_Lewa
0	100.0	100	0	89.8	71.04
2	100.0	100	2	89.7	71.01
3	100.0	100	3	87.8	67.8
4	100.0	100	4	68.5	45.38
6	79.5	56.08	6	16.0	8.97
8	38.2	22.95	8	1.5	0.8
10	27.2	15.74	10	0.9	0.51
14	24.6	14.13	14	0.8	0.45
15	24.3	13.95	15	0.8	0.44
20	22.7	13	20	0.7	0.39
25	20.7	11.77	25	0.6	0.33
30	18.0	10.18	30	0.5	0.24
34	15.2	8.52	34	0.3	0.16
35	14.4	8.03	35	0.2	0.13
38	12.0	6.68	38	0.2	0.08
40	10.9	6.05	40	0.1	0.07
45	8.7	4.77	45	0.1	0.05
49	6.1	3.35	49	0.1	0.04
50	5.3	2.91	50	0.1	0.03
53	3.2	1.72	53	0.1	0.03
55	2.1	1.16	55	0.1	0.02
60	0.9	0.5	60	0.0	0.02
63	0.7	0.37	63	0.0	0.01
65	0.6	0.32	65	0.0	0.01
70	0.5	0.24	70	0.0	0.01
75	0.4	0.22	75	0.0	0.01
80	0.4	0.2	80	0.0	0.01
82	0.3	0.18	85	0.0	0.01
85	0.3	0.16	90	0.0	0.01
87	0.3	0.15	95	0.0	0.01
90	0.2	0.13	100	0.0	0.01
94	0.2	0.11	102	0.0	0.01
95	0.2	0.1	110	0.0	0
100	0.1	0.08	114	0.0	0
110	0.1	0.03			
120	0.0	0.01			
127	0.0	0			
130	0.0	0			
132	0.0	0			

The timing and extent of oil and gas generation events in the area of study are only approximate due to the complex fold geometries in the region; nevertheless they can be estimated from the transformation ratios. For example, in oil well JK-1, the Sargelu source rock, based on the model results, has generated approximately 70% of its oil, compared to the same source rock in the other wells which has generated all of its oil. The Sargelu in JK-1 was never as deeply buried (see burial history curve for JK-1 Fig.6) and unlike the other wells, is still generating today. In the northern fold belt, oil generation and expulsion are relatively recent events, and occurred in the Paleogene to early Neogene from about 6 Ma to present-day.

- **Petroleum Migration and Accumulation**

Total Petroleum Systems(TPS) of north of Iraq contain a plenty of excellent hydrocarbon plays discovered since the fifties of the last century, overlying with several types of hydrocarbon seeps according to the complex structural features in folded zone. Surface oil seeps associated with faulted anticlines and fractured traps in the Zagros fold belt due to folding confirm that petroleum has migrated out of the system, however, not all surface petroleum loss was related to the Zagros orogenic event (Dunnington, 1959; Beydoun *et al.*, 1992). The complex facies relations (lithologic variations and unconformities) characterize these formations and groups further complicate flow-path simulations In the Mesopotamian Basin, Jurassic, and Cretaceous and Tertiary structure surfaces at different time periods, including present day, were geometrically very similar, thus calculated migration paths on the present Middle Jurassic surface provide a proxy for the present flow paths on the structure surfaces of Cretaceous units containing the major carrier beds. Simulated flow paths on the Middle Jurassic structure surface in the Zagros fold belt are only approximate due to the complex structure of the region; nevertheless, the flow paths are consistent with the present-day structure of the area, and thus are considered to be reasonable.

Faults were major conduits that channeled petroleum flow from source to Miocene and younger traps, (Internal well reports, OEC) and seal fracturing enhanced vertical petroleum flow. A major fault extends across the Tigris River and in response to folding, the fault plane accumulated oil. This oil which is presently under high pressure due to rapid burial of the sedimentary section was injected into unconsolidated Tertiary reservoir rocks Fig.12.

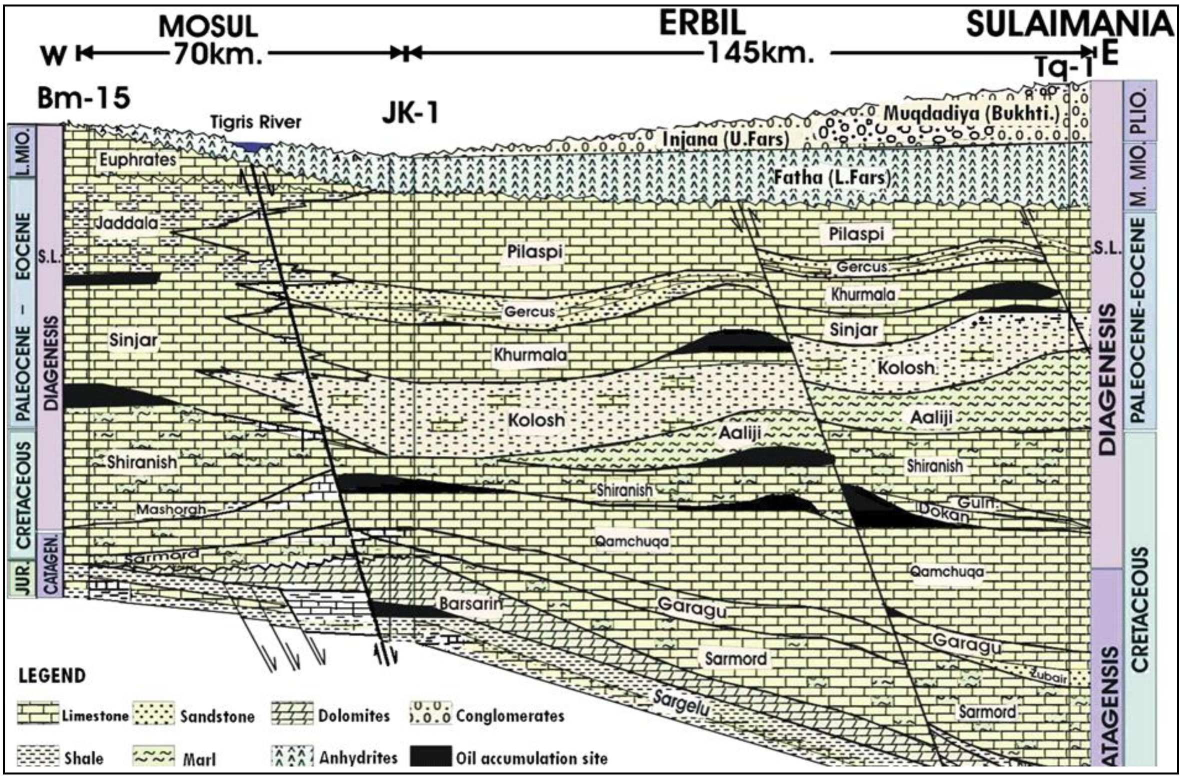

Fig.12: Tectonically and lithologically section for the studied area (designed by collection of well data from final well report of Bm-15, Jk-1 and Tq-1 oil exploratory wells). Showing the probable conclusion of total petroleum system (Generation, Migration and Accumulation) of this study based on the data recovered from the final well reports of OEC)

CONCLUSIONS

Oil and gas fields in the northern part of Mesopotamian Basin and Zagros fold belt are located over the modeled area of petroleum charge, which is consistent with a total petroleum system dominated by upward migration. In Zagros Fold Belt, faults were conduits declared by so many previous geophysical studies, that channeled petroleum flow from source to Miocene and younger estimated traps, and seal fracturing augmented upward flow. Fields in close proximity to modeled migration pathways filled earliest to form extensive reservoirs, before the late Miocene and as early as Late Cretaceous. Beginning in the late Miocene, petroleum migration shifted from a local to a regional flow pattern in response to a northeast change in regional structural dip caused by sediment loading in the Zagros foredeep.

By late Miocene time, the majority of fields in the Mesopotamian Basin and Zagros fold belt was associated with active source rock and modeled petroleum pathways. Therefore, it is plausible that these fields received an initial petroleum charge during this period or additional charge if they were filled earlier. In the fold belt, extensive exhumation of reservoir and seal rock during the Holocene (2,000 m of erosion has been estimated) led to local accumulations of surface petroleum. Oil accumulations along fault traces indicate that additional petroleum was lost through faults. Evaluate the source-rock generation potential of prospects in the Zagros fold belt Fig.12.

Model results indicate that throughout northern Iraq generation and expulsion of oil from the Sargelu began and ended in the late Miocene. Jurassic source rocks might have generated and between 70 and 100% of their total oil, or the model indicates that, the majority of Jurassic source rocks in Iraq have reached or exceeds peak oil generation and most rocks have completed oil generation and expulsion except Jabal Kand-1, were defiantly unlike the other wells, is still generating today.

Jurassic source rocks in the Mesopotamian Basin are highly mature with peak oil generation and expulsion beginning in the late Paleocene. At present, most source rocks in the Mesopotamian Basin (Sargelu Formation), have reached or exceeded peak oil generation (TR $\geq$ 0.5) and completed oil generation and expulsion (TR $\geq$ 0.95), except Jabal kand-1 the transformation ratio attained 71.4%. This type of study could indicate the unique phenomenon that took place in rare basin in the world ,so we are on systematic ,supergiant and promising oil and gas fields and also can serve the oil companies deals with exploration sector for more investigation and could open a new horizon for further detection and explore more and more virgin areas.

It is so clear that set-up suitable model by making use of the consequences that forms the ultimate interpretation lead to the scenario available to establish relatively acceptable diagram, at least to open horizon for the coming researchers to make use of this foundation revealed in this manuscript, for more accomplishments with another developed software.

ACKNOWLEDGMENT

I want to express my sincere thanks, to Ms. Janet K. Pitman of USGS for her efforts in setting up the models, and for her advices. Appreciation for the role of North Oil Company for providing me with core and cutting samples, so much faith for the memory of my supervisor Prof. Dr. T.K. Al Ameri whom passed away in 2016.

REFERENCES

Al Ahmed, A.A.N, 2001. Palynofacies Indications of Depositional Environment and Source Potential for Hydrocarbon, Middle Jurassic (Sargelu Formation) Northern Iraq. Msc Thesis, (unpublished) Faculty of Science-University of Baghdad, 100pp (in Arabic).

Al Ahmed, A.A. Najaf, 2006. Organic Geochemistry, Palynofacies and Hydrocarbon Potential of Sargelu Formation (Middle Jurassic), North Iraq. Unpublished Ph.D. thesis, 120pp.

Al sharhan, A.S. and Nairn, A.E.M., 1997. Sedimentary Basins and Petroleum Geology of the Middle East. Elsevier, the Netherlands, 843pp.

Bellen, R.C., Van Dunnington, H.V., Wetzel, R. and Morton, D., 1959. Lexique Stratigraphic International. Asie, Fasc. 10a, Iraq, Paris, 333pp.

Beydoun, Z.R, Hughes Clark, M.W. and stoneley, R., 1992. Petroleum in the Mesopotamian Basin. A late Tertiary foreland basin overprinted on to the outer edge of a vast hydrocarbon-rich Paleozoic – Mesozoic passive-margin shelf. In: R.W. Mac queen and D.A. leckie (Eds.), foreland Basin and Fold Belts. AAPG Memoir 55, p. 309 – 339.

Buday, T., 1980. The Regional Geology of Iraq. Vol.1. Stratigraphy and Paleogeography. In: I.I., Kassab and S.Z., Jassim (Eds.). GEOSURV, 445pp.

Dunnington, H.V., 1958. Generation, Migration, Accumulation and Dissipation of Oil in Northern Iraq. In. G.L. Weeks (Ed), Habitat of oil. Tulsa, Oklahoma. AAPG, Bulletin, p. 1194 – 1251.

Murris, R.J., 1980. Middle East: Stratigraphic evolution and oil habitat. AAPG Bulletin: Vol.64, p. 597 – 618.

IES Integrated Exploration Systems, 2004. PetroMod, 1D/ PetroCharge Express, and Petro Risk Software. IES, Bastionstrasse, Vol. 11 – 19, 52428 Juelich, Germany, www.ies.de.

Pitman, J.K., Steinshouer, D. and Lewan, M.D., 2004. Petroleum Generation and Migration in the Mesopotamian Basin and Zagros Fold Belt of Iraq Result from a Basin-Modeling Study, Gulf Petrolink Bahrain, Vol.9 No.4, p. 41 – 72.

Sadooni, F.N., 1997. Stratigraphy and Petroleum Prospects of Upper Jurassic Carbonates in Iraq. Petroleum Geoscience, Vol.3, p. 233 – 243.

Sadooni, F.N. and Aqrawi, A.A.M., 2000. Cretaceous Sequence Stratigraphy and Petroleum Potential of the Mesopotamian Basin, Iraq. In Middle East Models of Jurassic/ Cretaceous Carbonate Systems, SEPM Special Publication, No.69, p. 315 – 334.

Sharland, P.R., Archer, R., Casey, D.M., Davies, R.B, Hall, S.H., Heward, A.P., Horbury, A.D. and Simmons, M.D., 2001. Arabian Plate Sequence Stratigraphy. Geo Arabia special publication 2, Gulf petrolink, Bahrain, 371pp.

Stoneley, R., 1987. A Review of Petroleum Source Rocks in Parts of the Middle East. IN J. Brooks (Ed.) classic petroleum provinces: Geological society special publications 50, p. 293 – 298.

Sweeney, J.J. and Burnham, A.K., 1990. Evaluation of a Simple Model of Virinite Reflectance Based on Chemical Kinetics, AAPG. Bulletin, Vol.74, p. 1559 – 1570.

U.S. Geological Survey World Petroleum Assessment, 2000. Description and Results: U.S. Geological Survey Digital Data Series DDS-60, version 1.1, four CD-ROM set.

About the author

Dr. Ahmed Askar Najaf Al Ahmed Head of the Geophysics Department, Al-Karkh University of Science in Baghdad, Iraq. Assistant Professor of Petroleum Geology, environmental pollution and industrial chemistry for the College of Science-Al-Nahrain University since 2006. He received his Ph.D. in Petroleum Geology and Master Degree from University of Baghdad and the BSc from University of Mosul. The scope of interest involves exploration for oil and gas in the northern Iraq. Active Member of the American Association of Petroleum Geologists (AAPG) since 2009, and member of European Association of Geoscientists and Engineers (EAGE) also he is an expert of OAPEC (Organization of Arab Petroleum Exporting Countries). His main researches exceeds than 25 research papers focused on Hydrocarbon exploration (organic geochemistry).

e-mail: drahmedaskar@yahoo.com