

Delineation of Organic Richness and Thermal History of the Lower Cretaceous Thamama Group, East Abu Dhabi: A Modeling Approach for Oil Exploration

Ahmed A. Taher
Abu Dhabi National Oil Company (ADNOC)

ABSTRACT

The source rocks of the Lower Cretaceous Thamama Group in east Abu Dhabi were identified by using wireline logs. This technique was applied to 33 wells which provided a well-sampled new regional pattern of source rock distribution and thickness. The Thamama Group includes rich source rocks in the Aptian Shu'aiba intra-shelf basin facies and a moderate source rock potential in the dense layers, especially those in the basal part of the Nasr Formation. The reconstruction of the burial and thermal histories indicates that the mature Thamama kitchens are mainly located in the eastern part of Abu Dhabi, adjacent to the foredeep basin and reached optimum maturity levels starting in the Eocene. Westward migration from these kitchens is mainly lateral and updip toward the main Thamama producing fields in central Abu Dhabi. The conclusion that the hydrocarbons migrated laterally is supported by oil to source rock correlation and the vertical distribution of hydrocarbons in the reservoirs.

INTRODUCTION

The Lower Cretaceous Thamama Group of eastern Abu Dhabi (Figure 1) includes several important hydrocarbon reservoirs. This sequence was deposited on a carbonate platform and varies in thickness from 2,500 to 3,000 feet (ft). The overlying Middle Cretaceous Nahr Umr shale and the basal part of the Nasr Formation are regional seals (Figure 2). Local seals also occur as intercalated dense carbonate layers.

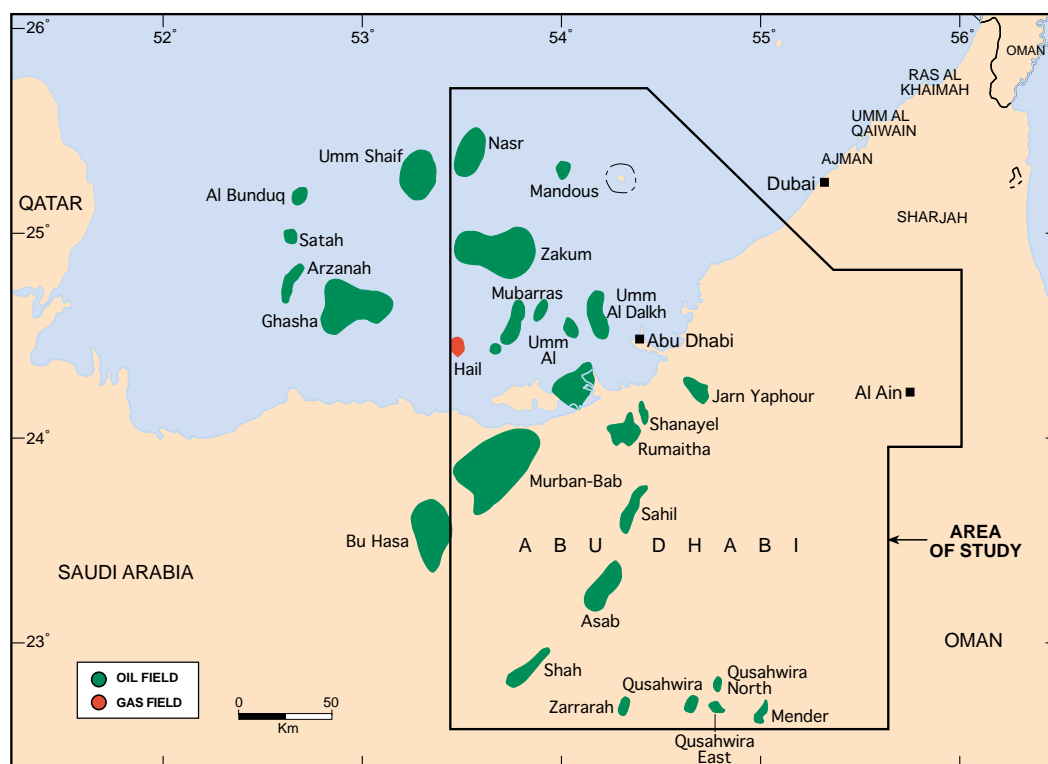


Figure 1: The study area is eastern Abu Dhabi, an area of approximately 50,000 square kilometers. Many of the giant oil fields in this area produce from the Lower Cretaceous reservoirs.

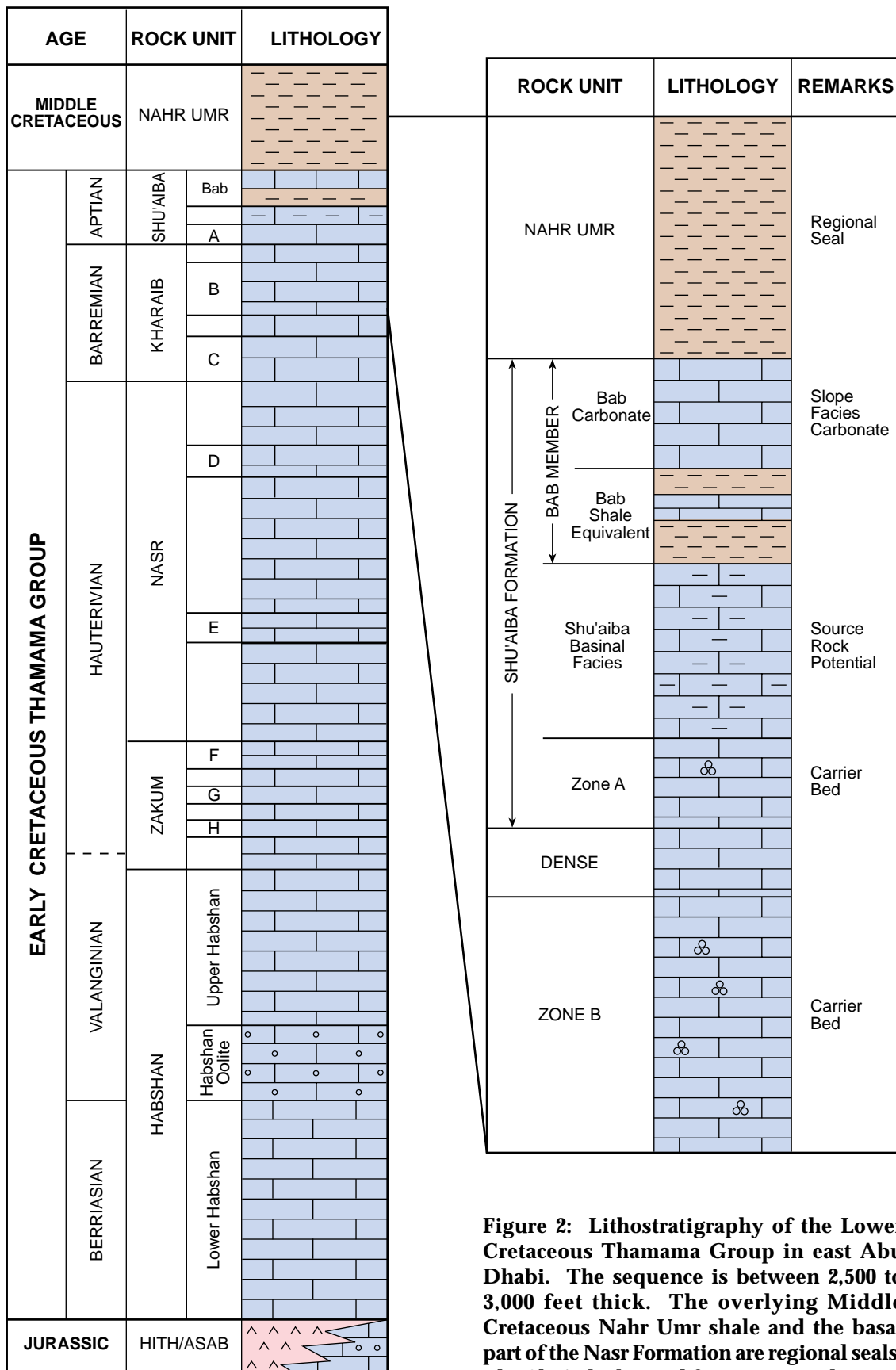


Figure 2: Lithostratigraphy of the Lower Cretaceous Thamama Group in east Abu Dhabi. The sequence is between 2,500 to 3,000 feet thick. The overlying Middle Cretaceous Nahr Umr shale and the basal part of the Nasr Formation are regional seals. The Shu'aiba basinal facies is a good source rock.

Several studies have concluded that the organic-rich Upper Jurassic Diyab Formation (also Dukhan Formation) is the source rock of the Thamama Group as well as the Jurassic Araej and Arab reservoirs (e.g. ADNOC, 1985; Hawas and Takezaki, 1995). In these studies, oil generated from the Diyab source rocks, in western Abu Dhabi, is assumed to migrate eastward through the Arab reservoir with the Hith anhydrite acting as a regional seal. Once the oil reaches the edge of the Hith anhydrite, in central Abu Dhabi, it then migrates vertically into the Thamama Group (Figure 3).

The conclusion that the Diyab sources the Thamama is questionable. Volumetric calculations indicate that the Diyab is insufficiently rich to account for all the oil attributed to it. Also Arab oil is less mature than Thamama oil at equivalent reservoir depth. Finally, structurally controlled migration pathways are inconsistent with the Diyab as the main source for the Thamama.

Based on a study of the petroleum geochemistry of Abu Dhabi, Lijmbach et al. (1992) concluded that the Lower Cretaceous Shu'aiba Formation and its Bab Member, and the Upper Jurassic Dukhan (Diyab) Formation are two of the five main source rocks of Abu Dhabi. In particular the analysis of oils indicates that the oil in the Shu'aiba reservoir, in Shah field, and the Lower Cretaceous Kharaib reservoir in Asab, Bu Hasa, Rumaitha, Sahil and Jarn Yaphour fields are sourced by the Lower Cretaceous Bab Member of the Shu'aiba Formation (Figure 1).

This paper presents a source rock and migration model for the Thamama reservoirs which is consistent with the study of Lijmbach et al. (1992). The model expands on an earlier study of the Aptian Shu'aiba stratigraphy and source rock potential by Azzam and Taher (1995). This new study includes well logs from 33 wells to develop a detailed distribution of the Lower Cretaceous source rocks. The model addresses the timing of hydrocarbon expulsion, migration pathways and high grades several areas for further exploration.

METHODOLOGY

Exxon Production Research Company (EPRCO) developed a technique which quantifies total organic carbon content (TOC) in source rocks (mostly shales and lime-mudstones) from well logs (Passey et al., 1990). In this paper, EPRCO's technique was used on 33 wells for source rock identification of Shu'aiba basinal facies and Thamama dense layers (Figure 2).

Implementation of Passey's method started with scaling the sonic and resistivity curves so that each 50 millisecond/ft (msec/ft) coincides with one logarithmic resistivity cycle. The porosity-resistivity curves overlie each other at baseline in a fine-grained (non-source rock) section over a significant depth range. In practice the baseline was extended into the Middle Cretaceous Tuwayil carbonate (Azzam and Taher, 1993).

In most cases the sonic baseline is 100 msec/ft and the resistivity baseline is 1.0 ohm-meter (Figure 4). The organic-rich intervals are generally recognized by the separation of the two curves as well as high gamma ray values (Figure 4). The magnitude of separation is linearly proportional to the volume of TOC and level of maturity (LOM). Using an algebraic expression to remove the LOM effect, the separation can then be converted to TOC values (Passey et al., 1990). The LOM is obtained from estimates of burial and thermal history.

In this study TOC values from cores and cuttings from three wells were compared with the log-derived TOC values (Figures 5 to 7). In most cases, the match was in general agreement which gives confidence in the applicability of this technique in wells where analysed rock samples are very limited, or not available.

The application of this method to deeply-buried horizons is less reliable because the resistivity increases greatly in the tight zones (porosity less than 3 to 4%) due to lack of electrically conducting fluid. Therefore this technique was not used to delineate organic richness in deeper horizons, such as the Habshan Formation of the Thamama Group.

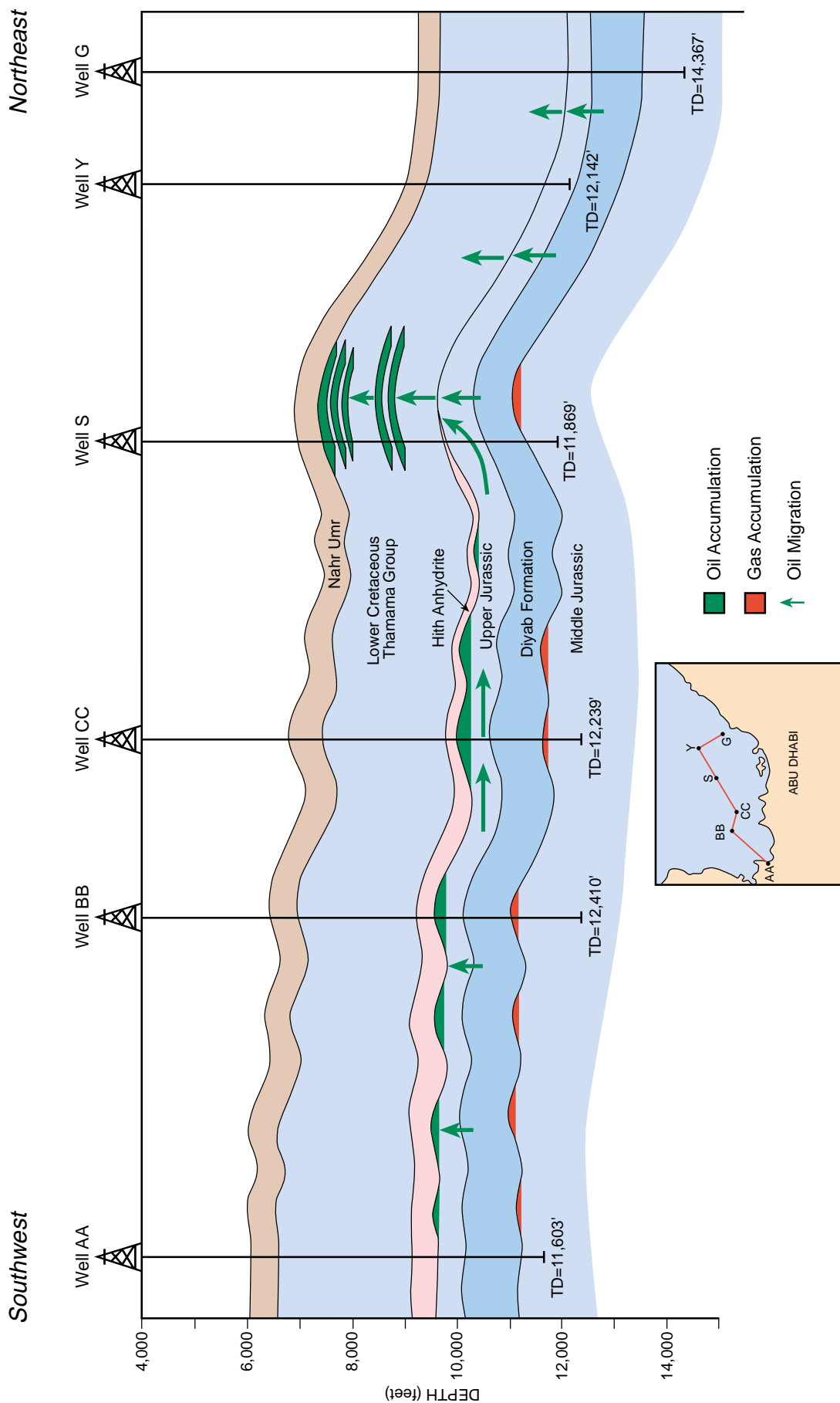


Figure 3: In the traditional model oil generated by the organic-rich Upper Jurassic Diyab source rock migrates laterally from west Abu Dhabi until the edge of the Hith anhydrite and then vertically into the Lower Cretaceous Thamama reservoirs. In this study the Thamama Group is sourced by the Lower Cretaceous source rocks located to the east.

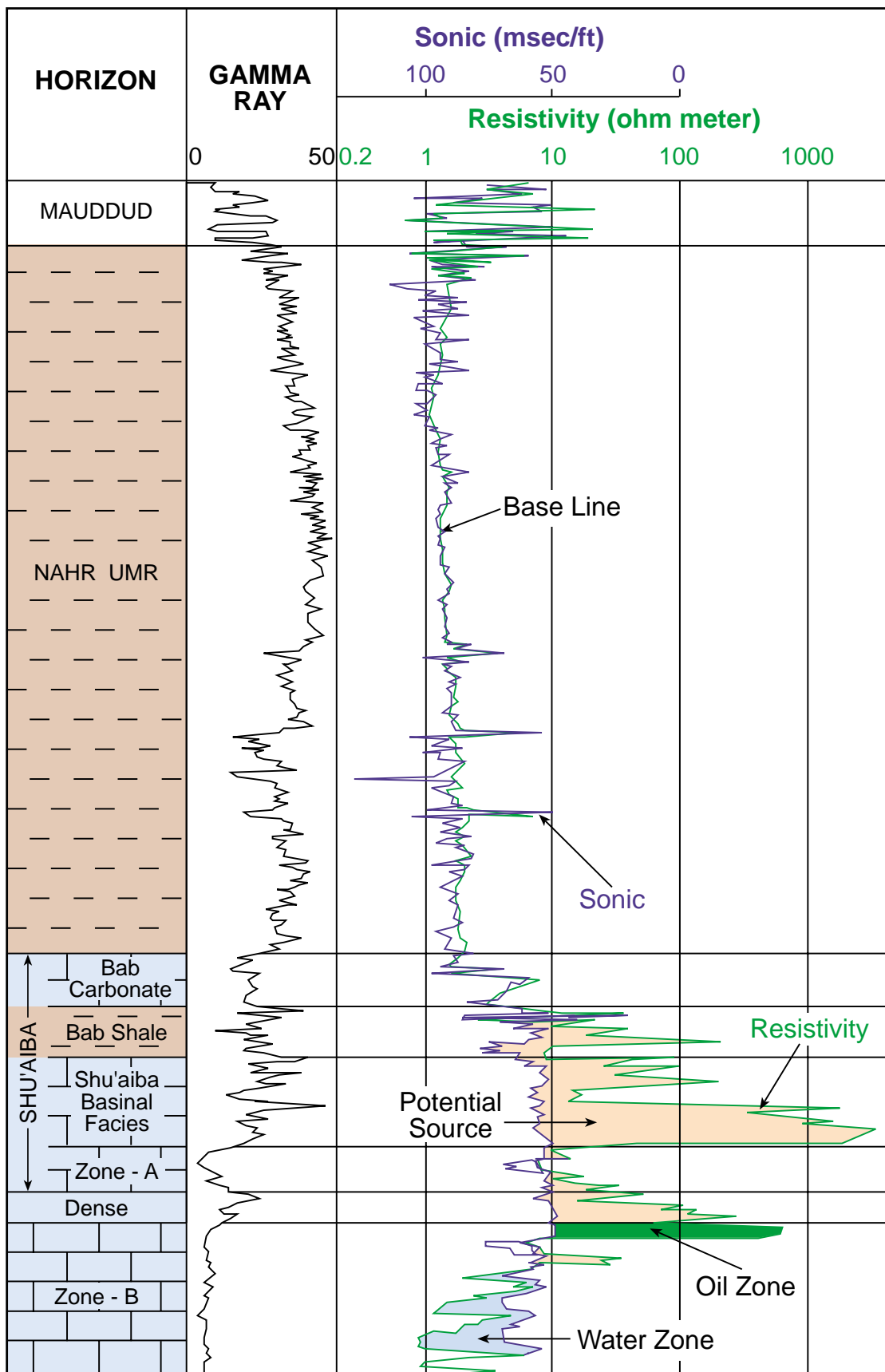


Figure 4: Overlay of the sonic and resistivity logs shows separation which corresponds to organic-rich Shu'aiba basinal facies and dense layers.

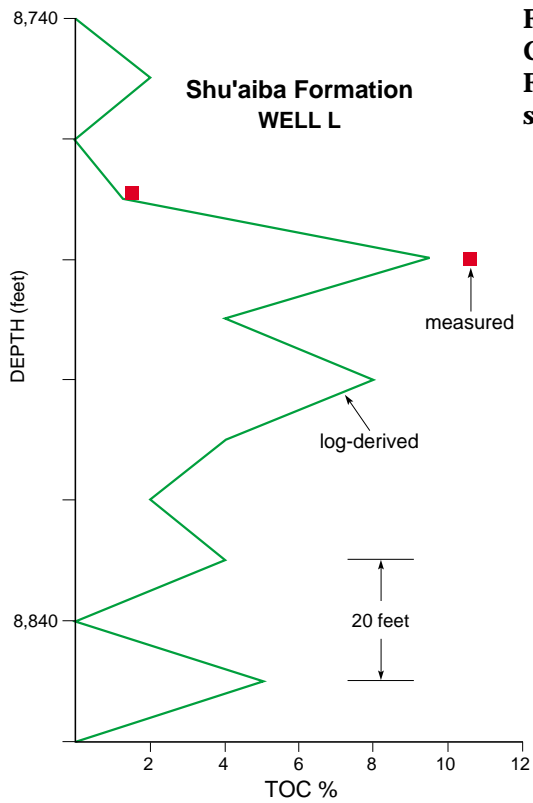


Figure 5: Comparison of Total Organic Carbon content in the Shu'aiba Formation measured by log and core sample in well L.

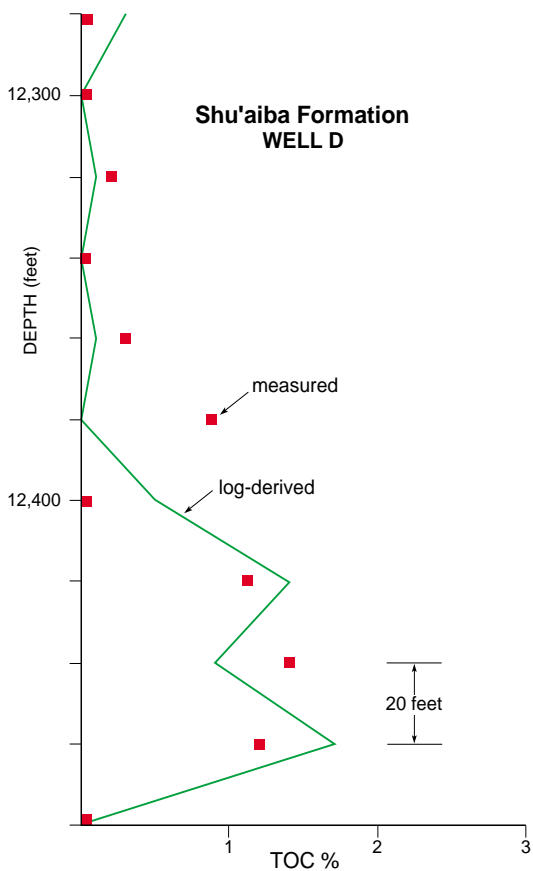


Figure 6: Comparison of Total Organic Carbon content in the Shu'aiba Formation measured by log and core sample in well D.

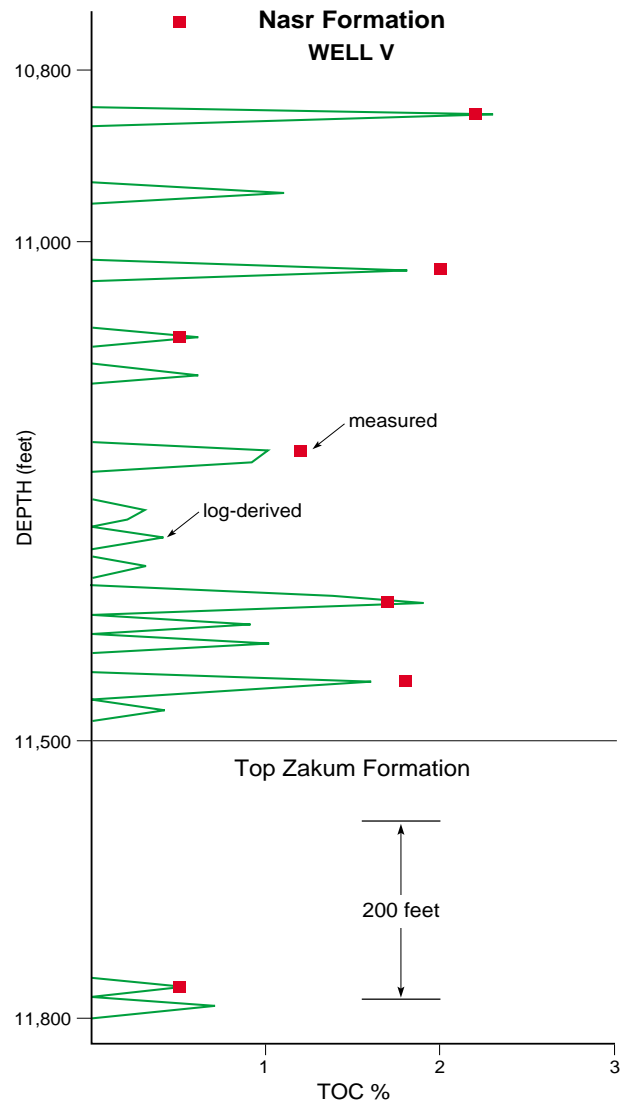


Figure 7: Comparison of Total Organic Carbon content in the Nasr Formation measured by log and core sample in well V.

SOURCE ROCK POTENTIAL

Shu'aiba Basinal Facies

The Shu'aiba Formation in the study area is subdivided into four lithological rock units: (1) Thamama Zone-A; (2) Shu'aiba basinal facies (Shu'aiba shelf facies time equivalent); (3) Bab shale equivalent and (4) topmost Bab carbonate unit (Figures 2 and 8). The main organic-rich intervals in the Shu'aiba Formation are found in the Shu'aiba basinal facies and in some intervals within the Bab shale equivalent.

The Shu'aiba basinal facies consists of pelagic lime-mudstone with abundant planktonic microfossils. The regional distribution of the Shu'aiba basinal facies indicates that it was deposited in an intra-shelf basin that was surrounded by Shu'aiba carbonate shelf sediments (Figure 9; Murris, 1980). This resulted in restricted water circulation, anoxic conditions and deposition below wave base (Figure 8); all factors which are conducive to the formation of oil-prone source rocks (Creany and Passey, 1993).

The highest Shu'aiba TOC values exceed 4% by weight and occur in the central part of the study area (Figure 10). This area coincides with the thickest Shu'aiba source rock of approximately 100 ft (Figure 11). As the Shu'aiba basinal facies unit becomes thicker shelfward, the TOC and net source thickness decrease progressively, reaching a minimum value of less than 2% and 25 ft near the shelf margin. In contrast the thickness of the Shu'aiba Formation increases from about 100 ft in the central part of the study area to 300 ft at the slope facies area.

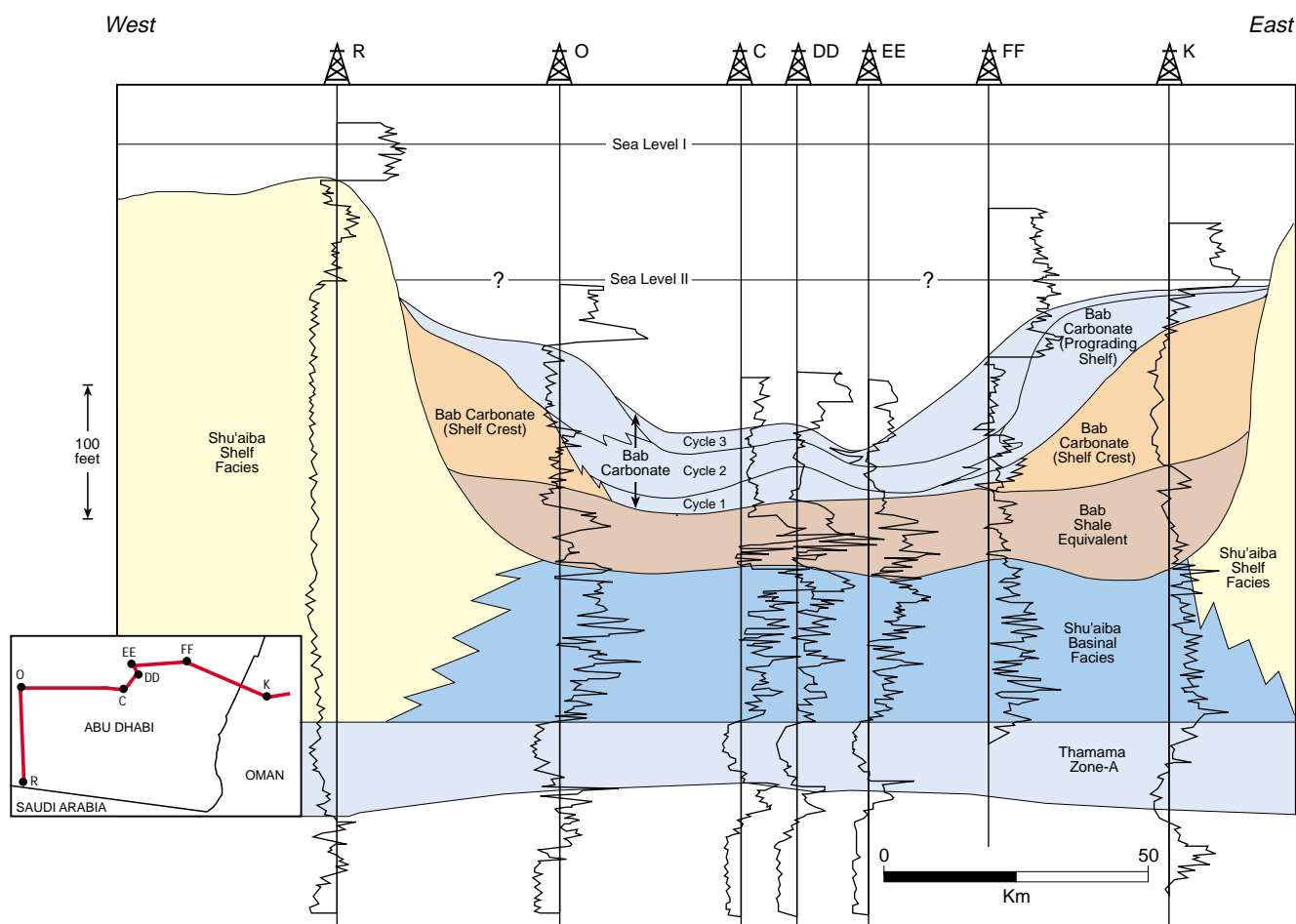


Figure 8: Schematic of the depositional model of the Shu'aiba basinal facies. Logs are gamma ray.

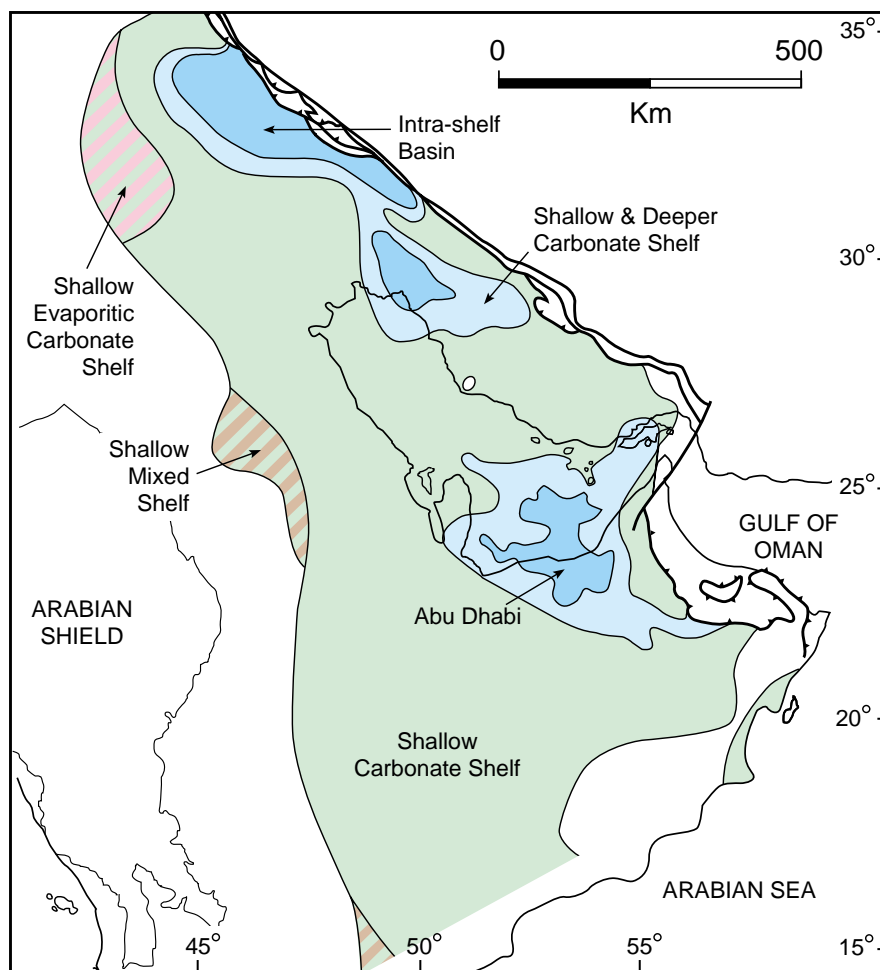


Figure 9: During the middle to late Aptian (Early Cretaceous) Abu Dhabi was located in an isolated intra-shelf basin (Murriss, 1980).

Relatively low TOC values of 1.4% by weight are found in the northeast onshore area, adjacent to the foreland basin. The sediments here are highly mature and only possess residual organic carbon.

The organic richness and thickness of the Shu'aiba Formation are comparable to the world's most prolific source rocks which are frequently less than 100 ft thick and have average TOC values of more than 2% by weight (Creany and Passey, 1993). In addition, Rock-Eval analysis of Shu'aiba cutting and core samples identified good to excellent Type II with some intervals of Type I source rocks (Lijmbach et al., 1992).

Thamama Dense Layers

The Thamama Group was deposited on a broad carbonate platform along the margin of the Tethys Ocean. The facies consist of a porous shelfal carbonate that cyclically alternate with argillaceous dense layers. The dense layers are isochronous and may have been deposited during periodic rises in relative sea level.

The volumetric calculations of oil migrated from the Thamama dense layers (Table 1) suggests that some of the oil that accumulated in the Thamama reservoirs may have originated from these muddy dense layers.

The low source potential (TOC less than 1.4%) determined from the model is compensated by the presence of many source layers that can efficiently expel oil (Figure 12). The effective source thickness

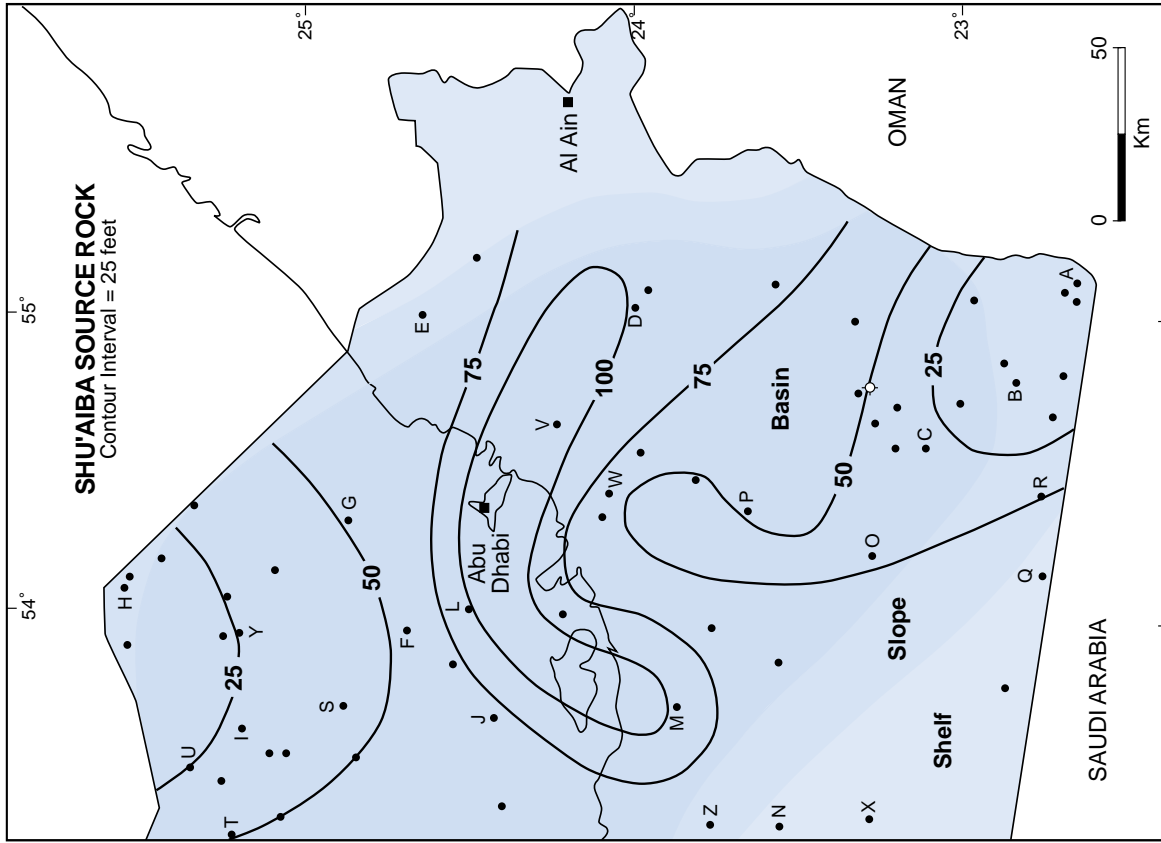


Figure 11: Net source rock thickness of the Shu'aiba Formation exceeds 100 feet in the central part of Abu Dhabi beneath the capital city. A comparison to the TOC distribution (Figure 10) shows that this area is a prolific hydrocarbon kitchen.

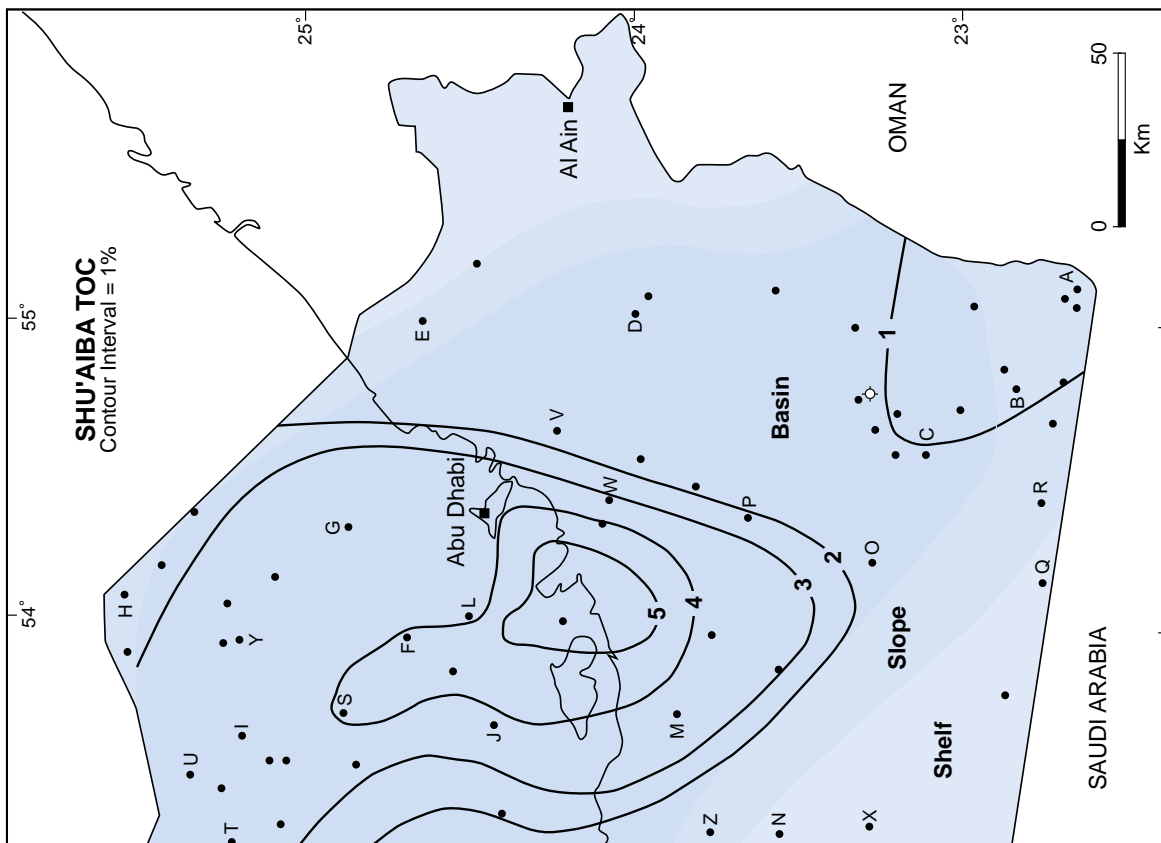


Figure 10: Average log-derived Total Organic Carbon of the Shu'aiba Formation shows increase from 1 to 2% in the slope area (light blue) to 5% in the center of the basin (darker blue).

Table 1
Parameters Used in Volumetric Calculations

Thamama Dense Layers

DRAINAGE AREAS	MATURE AREA square kilometer	NET SOURCE Thickness meter	S2 kilogram per ton	OIL GENERATION (%)	OIL MIGRATION Efficiency (%)	VOLUMES OF OIL GENERATED Billion Barrels
Wells-D, C & B	7,400	58	1.5	85	50	2.2
Wells-D, P & O	7,800	64	1.6	90	50	1.8
Well-Q	3,500	76	2.0	75	50	0.3
Wells-D, V, W, M & N	15,500	106	1.6	95	50	34.8
Wells-G, F & S	10,100	40	1.7	85	50	10.0
Wells-L & J	3,600	56	2.0	65	50	0.8
Well-Y	1,400	46	1.7	65	50	0.3
Most Likely Total						50.2

Shu'aiba Basinal Facies

DRAINAGE AREAS	MATURE AREA square kilometer	NET SOURCE Thickness meter	S2 kilogram per ton	OIL GENERATION (%)	OIL MIGRATION Efficiency (%)	VOLUMES OF OIL GENERATED Billion Barrels
Wells-D, C & B	5,100	24	2.5	60	40	4.5
Wells-D, P & O	6,500	21	2.5	60	40	6.9
Well-Q	1,200	17	2.5	60	40	4.0
Wells-D, V, W, M & N	13,000	30	11.0	75	40	25.3
Wells-G, F & S	7,800	18	9.5	70	40	5.6
Wells-L & J	2,600	24	3.5	40	40	2.2
Well-Y	1,000	9	7.5	50	40	0.5
Most Likely Total						49.0

Volume = Area (sq km) x Net Source Thickness x Rock Density (2.7 gm/cc)

Source Potential = S2 x .75 (Oil Index) x (% Oil Generation - % Source Rock Saturation) x (.6 kg/ton)

Oil Predicted-In-Place = Volume x Source Potential x .02 x % Oil Migration

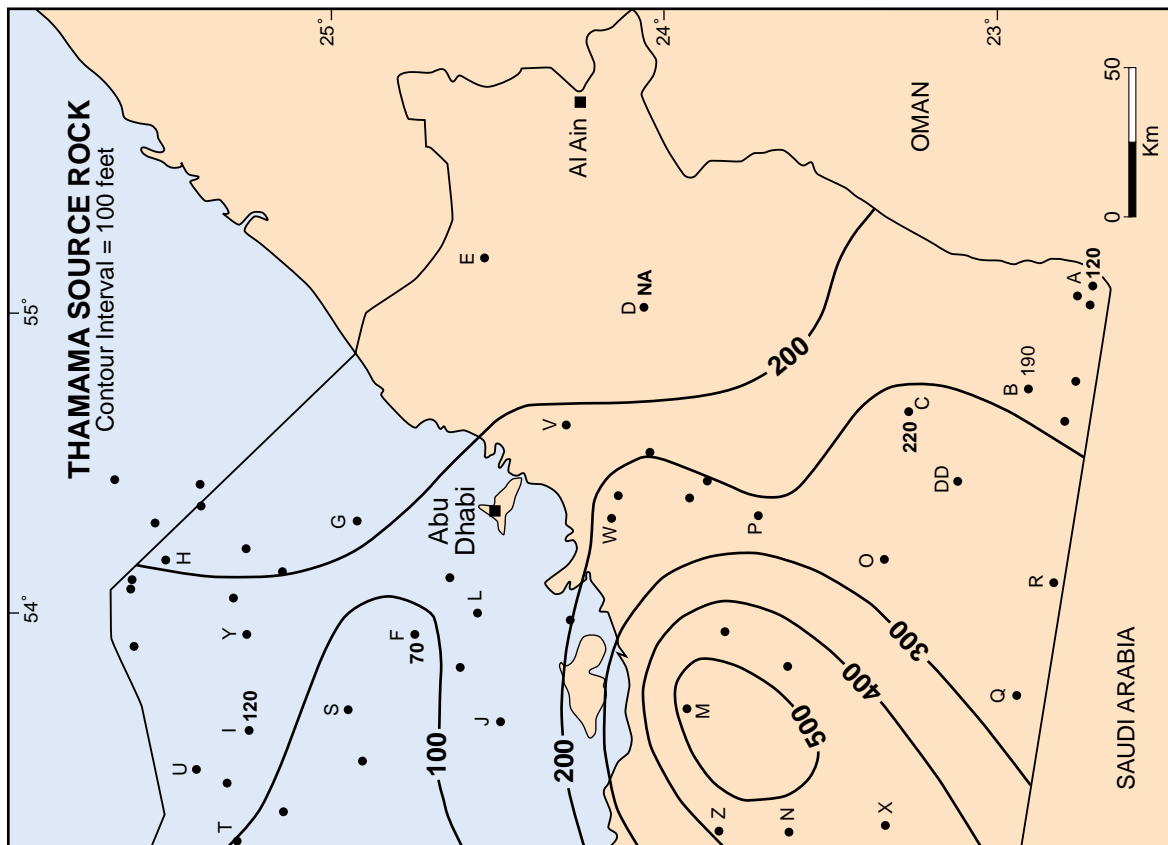


Figure 13: Net source rock thickness of the Thamama Dense Layers exceeds 500 feet in central onland Abu Dhabi. This source rock is not as organic-rich as the Shu'aiba basal facies; however, it is nearly five times thicker (Figures 10 and 11).

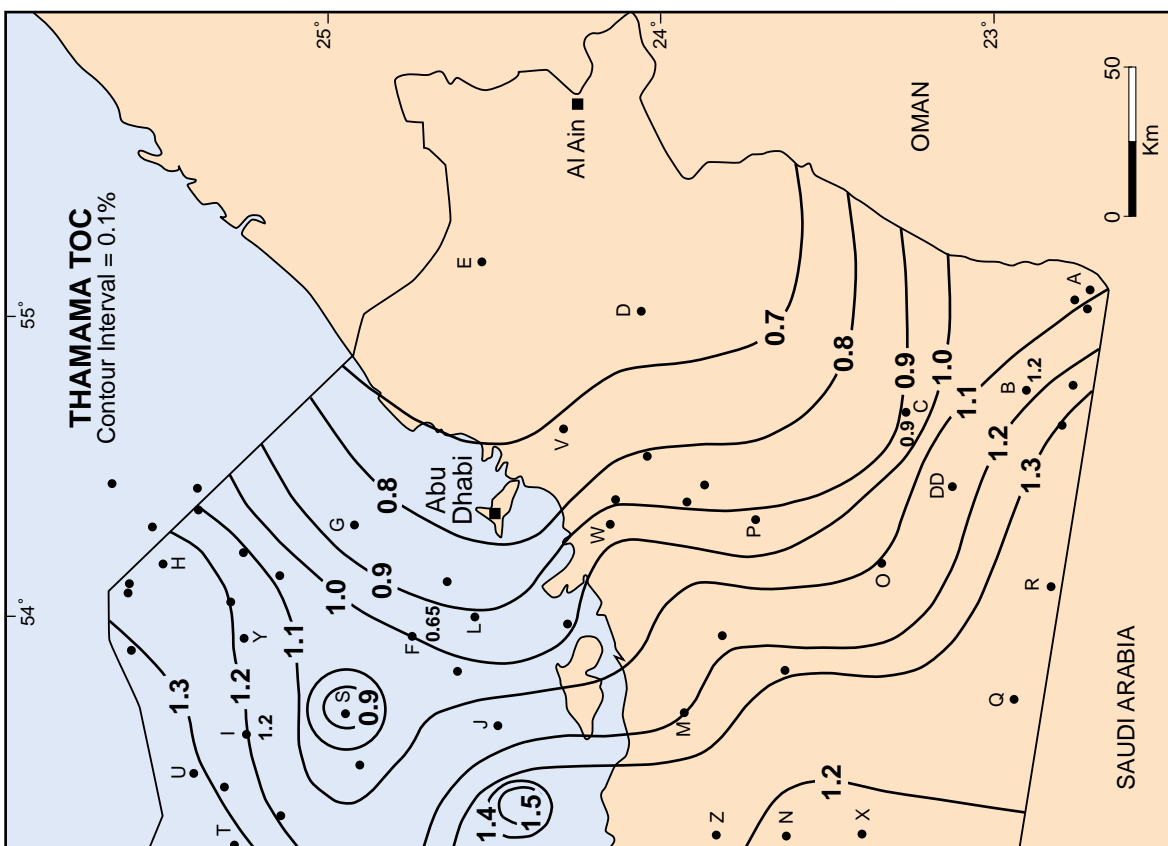


Figure 12: Average log-derived Total Organic Carbon of the Thamama Dense Layers shows increase from less than 1% in the east to just over 1% to the west.

varies from 100 to 500 ft (Figure 13). The maximum source thickness is found adjacent to the Falaha Syncline, while the minimum is located in the north offshore area. The TOC values range between 0.7% and 1.3% by weight (Figure 12). A gradual decrease of source rock potential from west to east is mainly related to the increase of thermal maturity in the eastern part of the study area. The organic matter in this area only possesses residual organic richness.

Lower Thamama: Speculative Intra-shelf Basins

The oolitic, high energy belts of the Asab, Habshan and Zakum formations consist of several shoaling-upward cycles that prograde laterally eastwards into its time equivalent slope and basinal facies (Figure 14). The basinal facies, especially in eastern onshore Abu Dhabi, may have some source potential. However, this remains speculative.

The Salil Formation, along the slope, and the Rayda Formation, in the basin, in southeast onshore Abu Dhabi and surrounding areas, are thicker than the Habshan platform carbonate. These two formations may be reworked sediments rather than a condensed section. This may explain the poor potential of the Salil and Rayda samples that were analyzed.

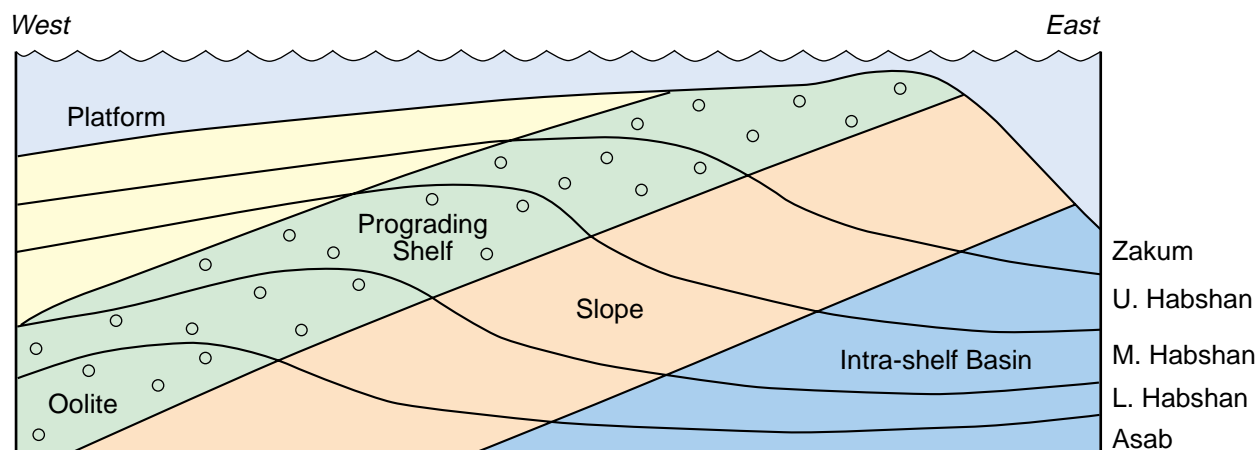


Figure 14: Schematic depositional model of eastern Abu Dhabi during the Early Cretaceous Tithonian and Hauterivian time.

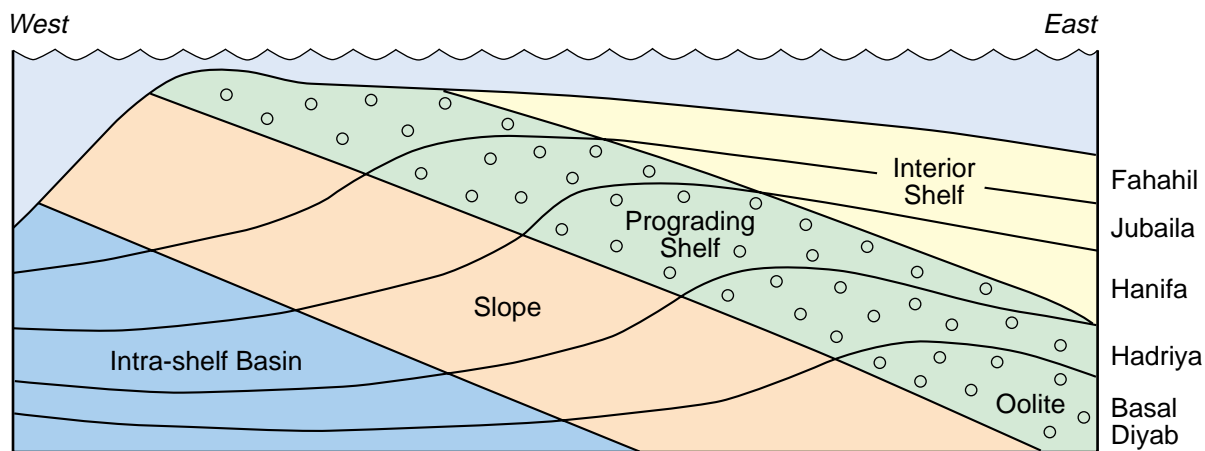


Figure 15: Schematic depositional model of eastern Abu Dhabi during the Late Jurassic Oxfordian and Kimmeridgian time. Comparison with the Early Cretaceous (Figure 14) shows a complete reversal in the orientation of the basin.

Upper Jurassic Diyab Formation

The carbonates of the Upper Jurassic Diyab Formation were deposited on a platform, prograding shelf and slope (Figure 15). The Diyab intra-shelf basin is surrounded by its time equivalent shelf facies. The basin was restricted and anoxic bottom water conditions developed progressively westward reaching a maximum thickness in western Abu Dhabi. The organic-rich basal part of the Diyab is believed to be a synchronous event over most of Abu Dhabi and may have generated the oil in the Hanifa reservoir in east Abu Dhabi.

The analytical data of the Diyab source rock support the proposed depositional model. The average Diyab TOC decreases gradually from more than 2% in the west to less than 0.5% in the east (Figure 16). The eastward decreasing Diyab organic richness through time resulted from the shallower conditions due to sediment fill of the basin.

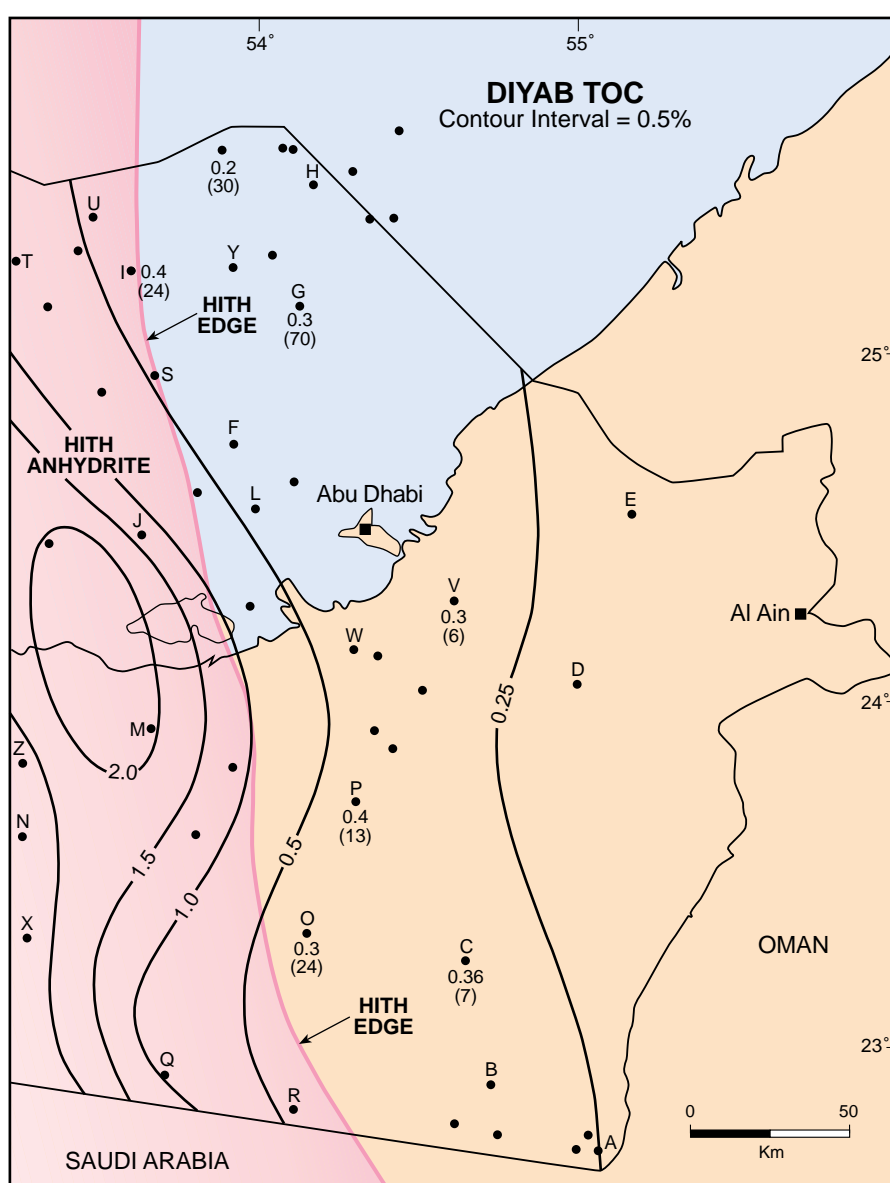


Figure 16: Average Total Organic Carbon of the Upper Jurassic Diyab Formation shows increase from 0.25 % in the east to over 2% to the west. The numbers in parenthesis indicate the number of analyzed rock samples. The Upper Jurassic Hith anhydrite terminates to the east of the region colored in pink.

MATURATION OF THE THAMAMA SOURCE ROCKS

Methodology

The delineation of mature kitchens was based on modeling the study area with both the Lopatin/Waples algorithm (Waples, 1980) and the graphical method based on the Arrhenius equation (Hunt et al., 1991). Initially the burial history of the area was reconstructed from 28 wells. In Figure 17 four examples are shown. The 28 wells are spaced adequately to sample maturity variations. The input data for the reconstruction of the burial history profiles consists of present-day depth maps of the key horizons, formation thicknesses, age and formation temperature.

Unconformities were also accounted for in the burial reconstruction. The paleo-thickness of the partly eroded Aruma and Wasia groups were estimated. In southeast onshore Abu Dhabi, however, a significant time gap of upto 45 million years (Ma) occurs. This was modeled in order to obtain the best fit to the Shu'aiba and Lower Thamama maturity boundaries.

The burial history reconstruction is accompanied by a thermal reconstruction of the key wells. The input data consists of geothermal gradients, rock conductivity and fluid distribution. The geothermal gradient data in the study area show a gradual increase in temperature gradients southwards that ranges between 1.5° Fahrenheit/100 ft (°F) in the north offshore and 2.3° F/100 ft in the south onshore. The high geothermal gradient in the south onshore is probably related to shallow basement depth, rock conductivity and fluid distribution.

The maturation modeling was also calibrated with available optical and statistical data to render it more effective in predicting maturation boundaries in the study area where no analytical data are available.

Shu'aiba Formation

The time temperature index (TTI) and timing of hydrocarbon generation can be determined from the reconstruction of the burial and temperature histories. The TTI values are utilised to delineate the maturity boundaries of the Shu'aiba source rocks. The maturity map (Figure 18) indicates that the formation is at present mature for oil generation over most of the area. The maturity increases toward the northeast onshore foreland basin and the Falaha Syncline in the southwest. The immature state of the southeast onshore and north offshore areas are mainly related to shallow burial depth and low geothermal gradient, respectively.

Thamama Dense Layers

The thermal modeling of the base Zakum formation (Top Valanginian, Figure 2) shows a similar maturity pattern as the Shu'aiba Formation, but with higher maturity values due to increasing depth of burial (Figure 19). The north offshore and southeast onshore areas are within the oil generation threshold, while the Falaha Syncline and northeast onshore areas are in the gas window. The remainder of the study area is within the peak oil generation window.

Timing of Hydrocarbon Charge

The thermal modeling of the Shu'aiba source rock showed that major expulsion of petroleum commenced as early as Eocene (40 Ma) from the Falaha Syncline and foreland basin. At present, the northwestern offshore and southeastern onshore have not reached the oil expulsion phase, while the central part of the study area is at optimum oil generation from Late Miocene time to present day.

Hydrocarbon charge in the kitchen of the Falaha Syncline commenced during early Eocene (50 Ma) from the highly mature kitchens in the northeast onshore and Falaha Syncline. At present, the Thamama source potential is within the expulsion phase over most of the study area.

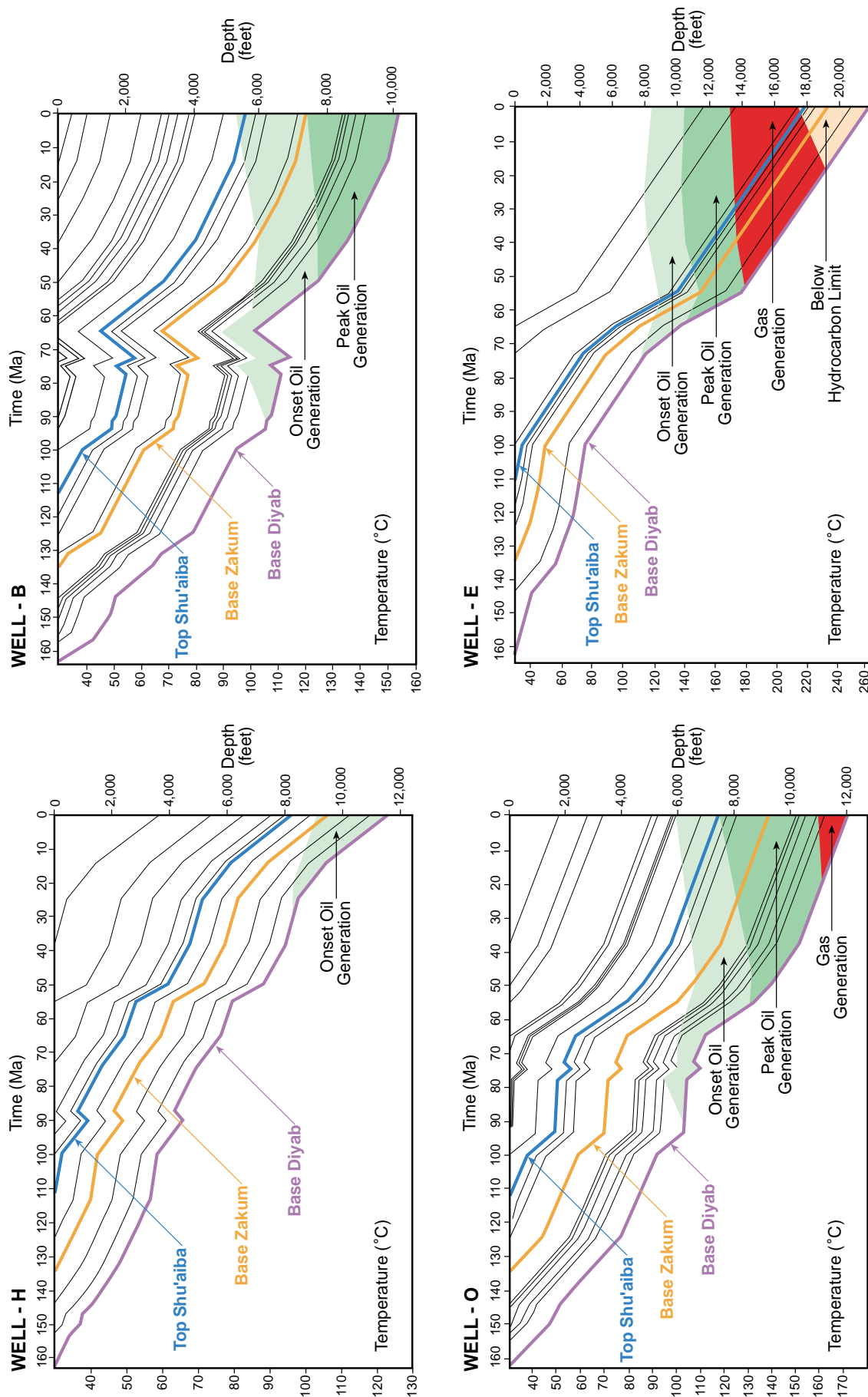


Figure 17: Burial history and oil hydrocarbon generation curves for 4 representative wells from 28 wells (see Figures 18 and 19 on facing page). The Shu'aiba source rocks in wells H (north) and B (south) are immature. In well O the Shu'aiba is presently in the early oil generation phase. At well E the Shu'aiba started generating oil during the Eocene (65 Ma) and is currently in the gas window.

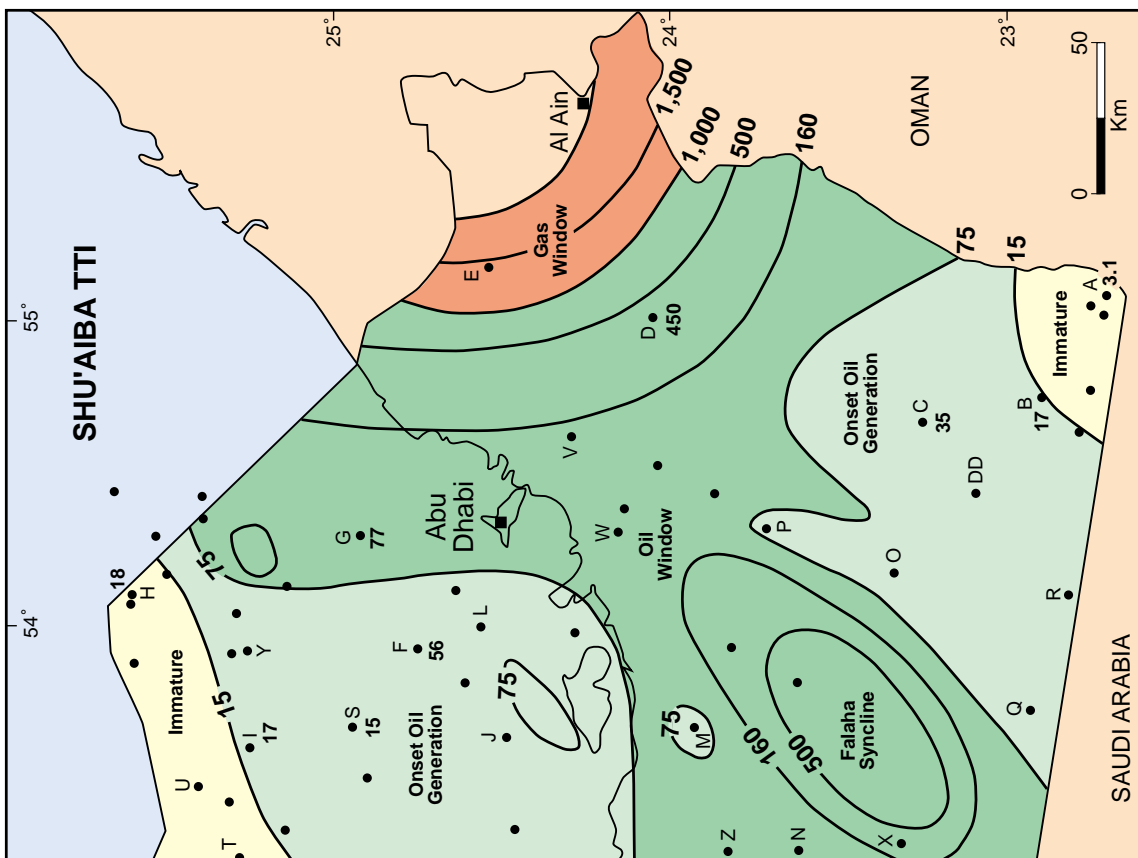


Figure 18: Present-day maturation map of the basal facies of the Shu'aiba Formation (Lower Cretaceous, Aptian) indicates peak oil generation from the Falaha Syncline to the southwest of the study area.

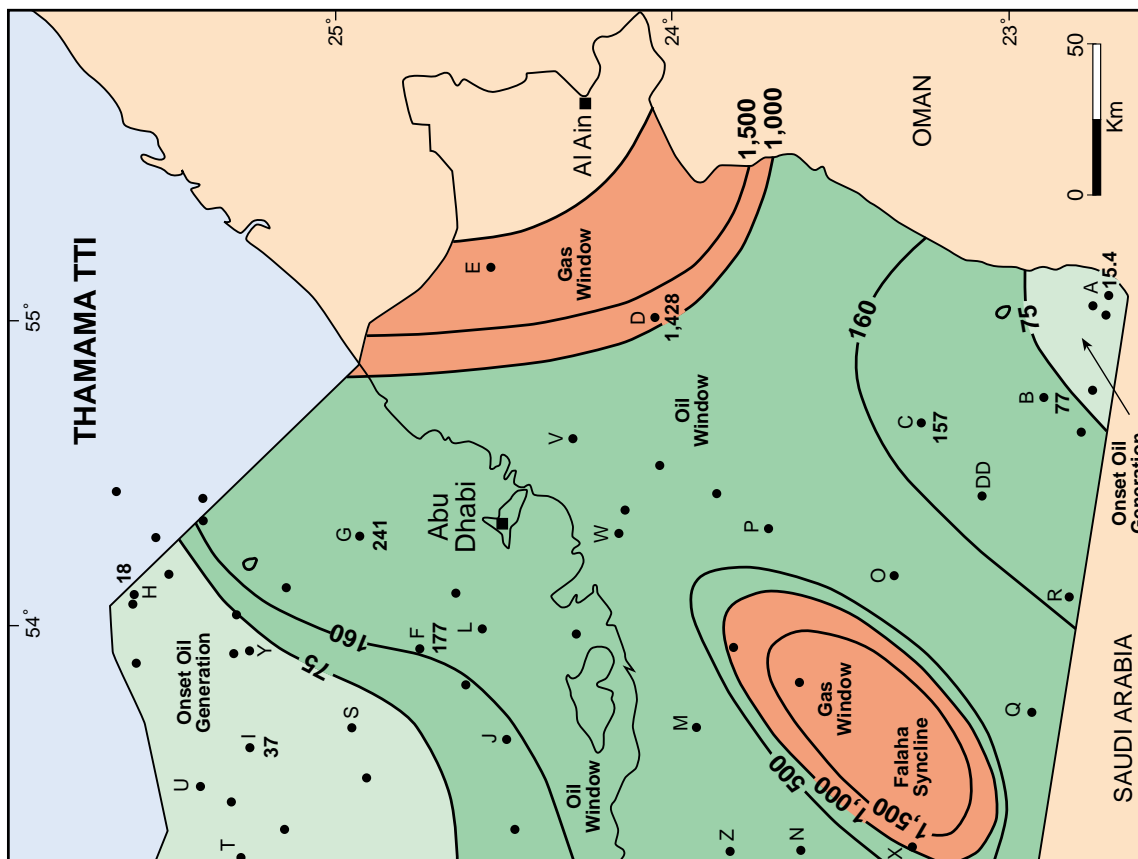


Figure 19: Present-day maturation map of the Thamama Dense Layers at the base of the Zakum formation (Lower Cretaceous, Top Valanginian) indicates oil generation over most of the area. The Falaha Basin to the southwest is in the gas generation window.

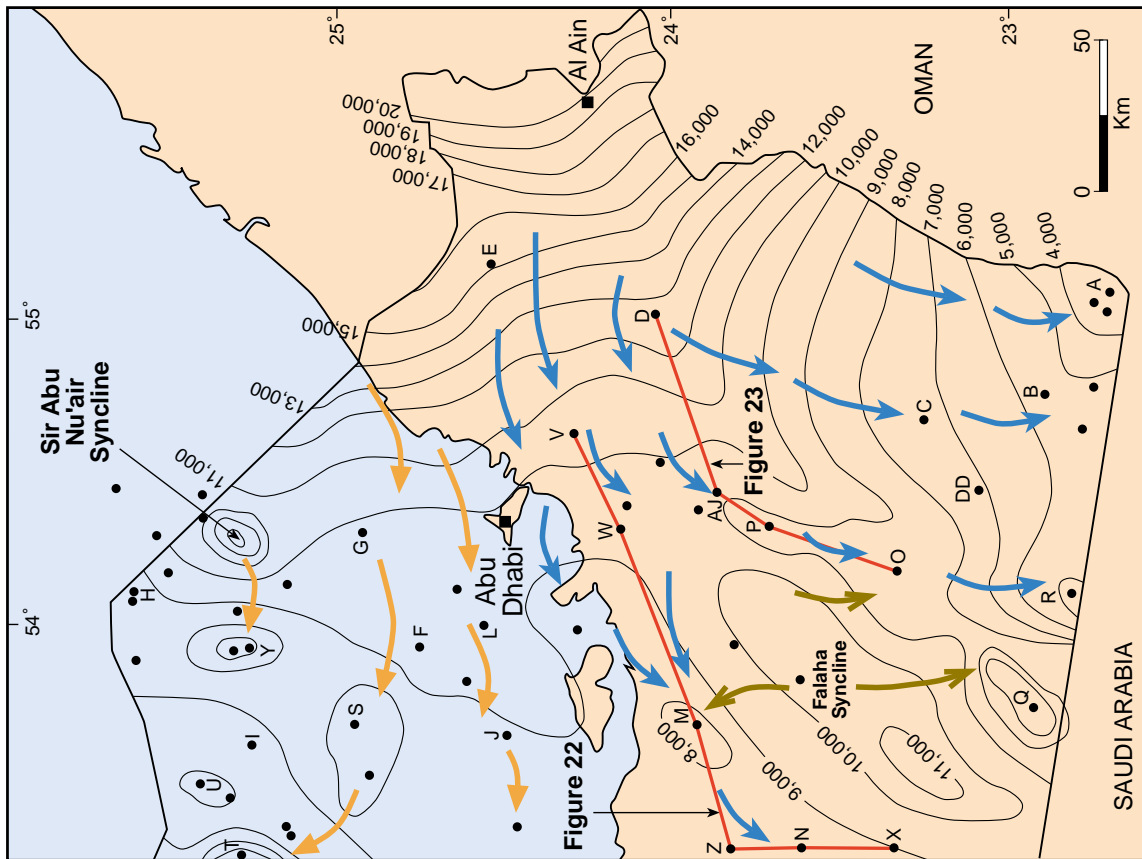


Figure 21: Structure map of the Lower Cretaceous Thamama Zone B shows the regional tilting to the east Abu Dhabi foredeep. Migration in late Tertiary is mostly westwards.

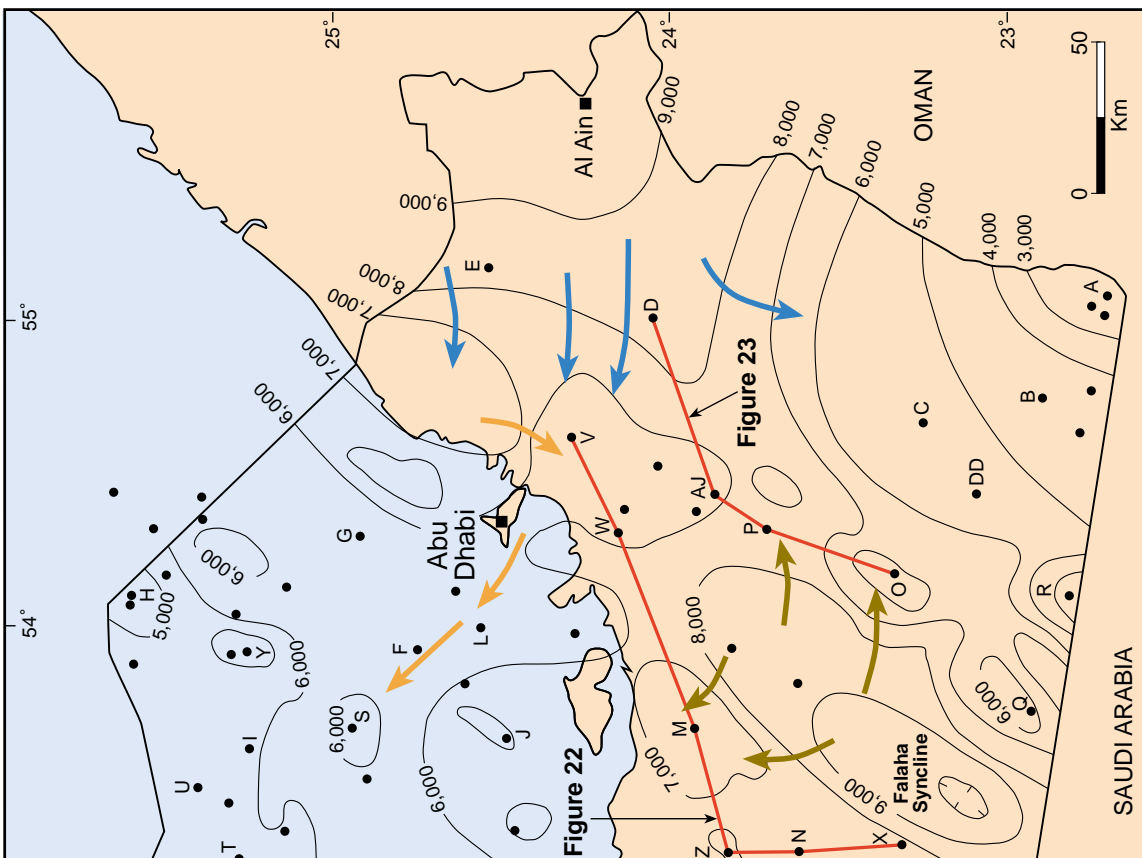


Figure 20: Structure map of the Lower Cretaceous Thamama Zone B at Eocene time. Zone B is the main Lower Cretaceous carrier bed beneath the Middle Cretaceous Nahr Umr regional seal. Migration patterns are from the east and the Falaha Syncline.

HYDROCARBON MIGRATION

The Thamama Zone B is the first good carrier bed below the Nahr Umr regional seal (Figure 2). This zone adequately defines the main migration routes in the upper part of the Thamama Group. Paleostucture maps of this zone were reconstructed by adding or subtracting isopachs to its present-day depth configuration. These maps may be inaccurate in the areas away from well control. The migration patterns for the lower part of the Thamama Group may be similar to Thamama Zone-B in this area.

The structure map of Zone-B in Late Eocene and present times are shown in Figures 20 and 21. Petroleum expelled during the Eocene from the mature kitchen in northeast onshore Abu Dhabi would migrate towards wells V and W and spill northwestward towards the giant offshore S field. The Late Tertiary tilting (Figure 21) further enhanced migration from the east offshore towards the S field and shifted the east onshore migration pathways towards M and N fields. Oil spilling from S field would migrate northwest toward T field at the Upper Thamama level and possibly toward the U field at the Lower Thamama level.

In the Eocene the M, N, O and Q fields were sourced from the nearby Falaha Syncline (Figure 20). The Late Tertiary (Late Miocene) tilting provided a second migration pathway from the east into M and N fields (Figure 21). The Cretaceous source rocks to the east, at this time, produce mainly volatile oils such as found in M field.

Figure 22 shows a structural cross-section along the migration pathway from well V, near the eastern kitchen to well X near the Falaha Syncline. In the M field, five oil and gas upward cycles reflect the presence of effective intra-formational seals. These are (1) Habshan oil; (2) Zones G and F oil and gas; (3) Zone-E highly under-saturated oil; (4) gas with some oil in Zone-D and Zone-C; and (5) Thamama Zones-A and -B which have a common oil-water contact.

Oil spilled from M field into N field migrated vertically upward into the Shu'aiba Formation and filled the structure from the top down to Thamama Zone-B. A limited amount of oil migrated southwards into the first culmination within the X structure, but further south, the X structure is wet.

Evidence for recent filling (probably after the Tertiary tilting) of the N structure is further supported by the nearly identical porosity values in both the oil column and water leg. The average porosity is usually higher in the oil column than in the water leg if earlier oil emplacement occurred.

In the Late Tertiary, oil generated in the Well-D area would migrate directly southeast towards P and O fields (Figure 23). This is confirmed by an API oil gravity trend where the highest maturity oils are found nearest to this mature kitchen, while the low maturity oils are found further from the source area and at shallower depth.

The O field shows a vertical segregation of two major cycles below the Nahr Umr and basal Nasr Formation regional seals (Figure 23): (1) Zone-F to Habshan-2; and (2) oil bearing Zone A to Unit-7 and water-bearing Zones D and E. The absence of oil in Zones D and E is due to the absence of intra-formational seals. Also these zones are not within the structural closure as defined at the top of Zone-A.

In the northeast offshore area the Y structure was probably sourced by the Sir Abu Nu'air syncline.

CORRELATION OF SOURCE ROCK AND OIL

Oil to Source Rock Correlation

In Figure 24 Triterpane Fragmentograms of 2 oil samples from the Arab reservoir (wells Q and N), 2 oil samples from the Cretaceous Shu'aiba and KharaiB reservoirs (wells N and O) and one sample each from the Shu'aiba basinal facies (well V) and Upper Jurassic Diyab (well BB) are compared. The Shu'aiba basinal facies (well V) correlates with the Shu'aiba and KharaiB oils (wells N and O). The Arab oil samples (wells Q and N) are most probably sourced from a highly-matured Diyab Formation. Lijmbach et al. (1992) also concluded that the oils in the KharaiB reservoirs in fields O, N, W, P and V originated from Shu'aiba/Bab Member.

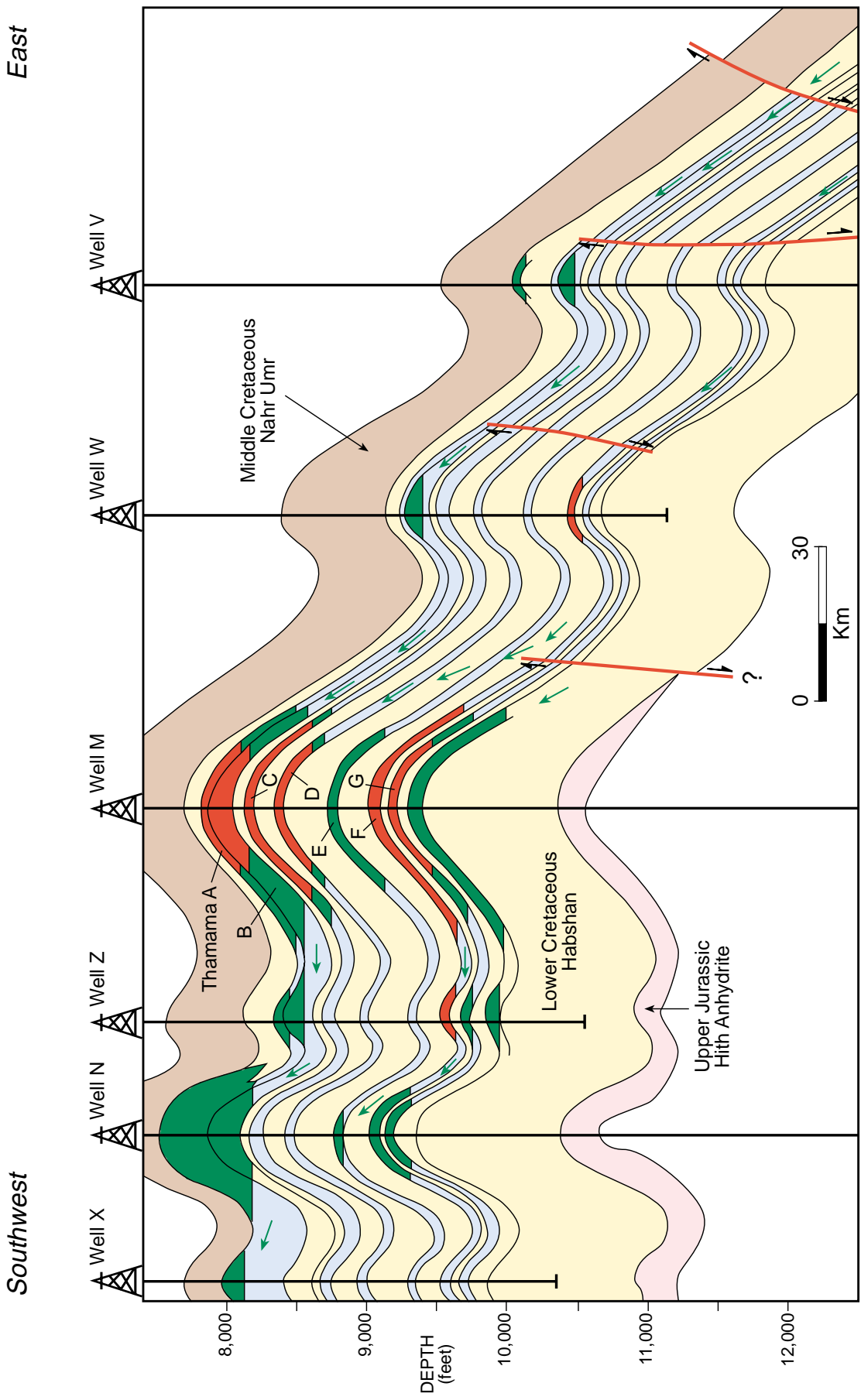


Figure 22: Structural cross-section (see Figures 20 and 21) shows effectiveness of intra-formational seals. In M field 5 independent reservoirs are: (1) Habshan; (2) Zones G and F; (3) Zone-E; (4) Zones D and C; and (5) Thamama Zones A and B.

Downloaded from https://pubs.geoscienceworld.org/geoarabia/article-pdf/2/1/65/4552016/taher.pdf by guest

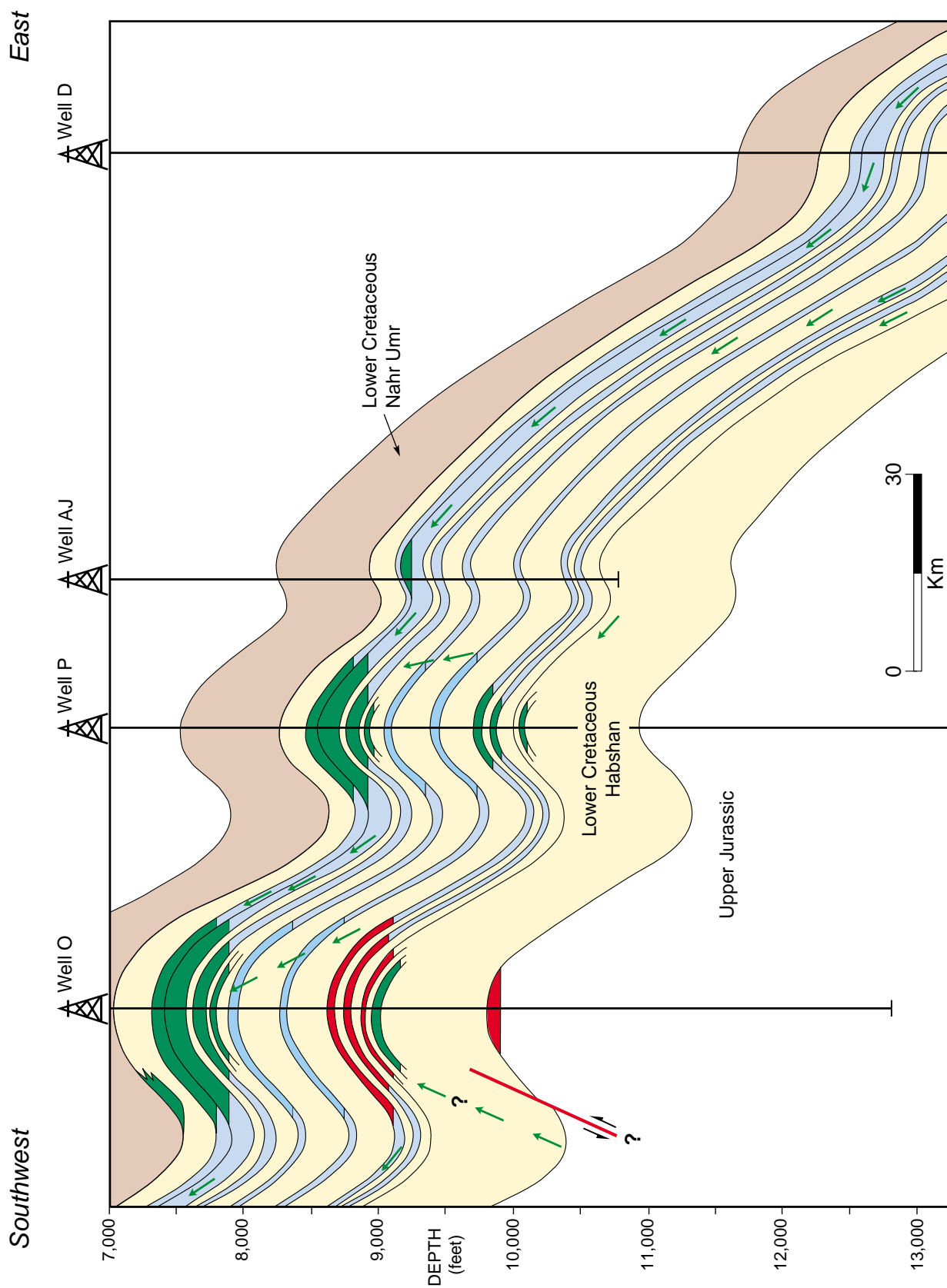


Figure 23: Structural cross-section (see Figures 20 and 21) shows vertical segregation of two major cycles below the Nahr Umr and basal Nasr Formation regional seals in O field.

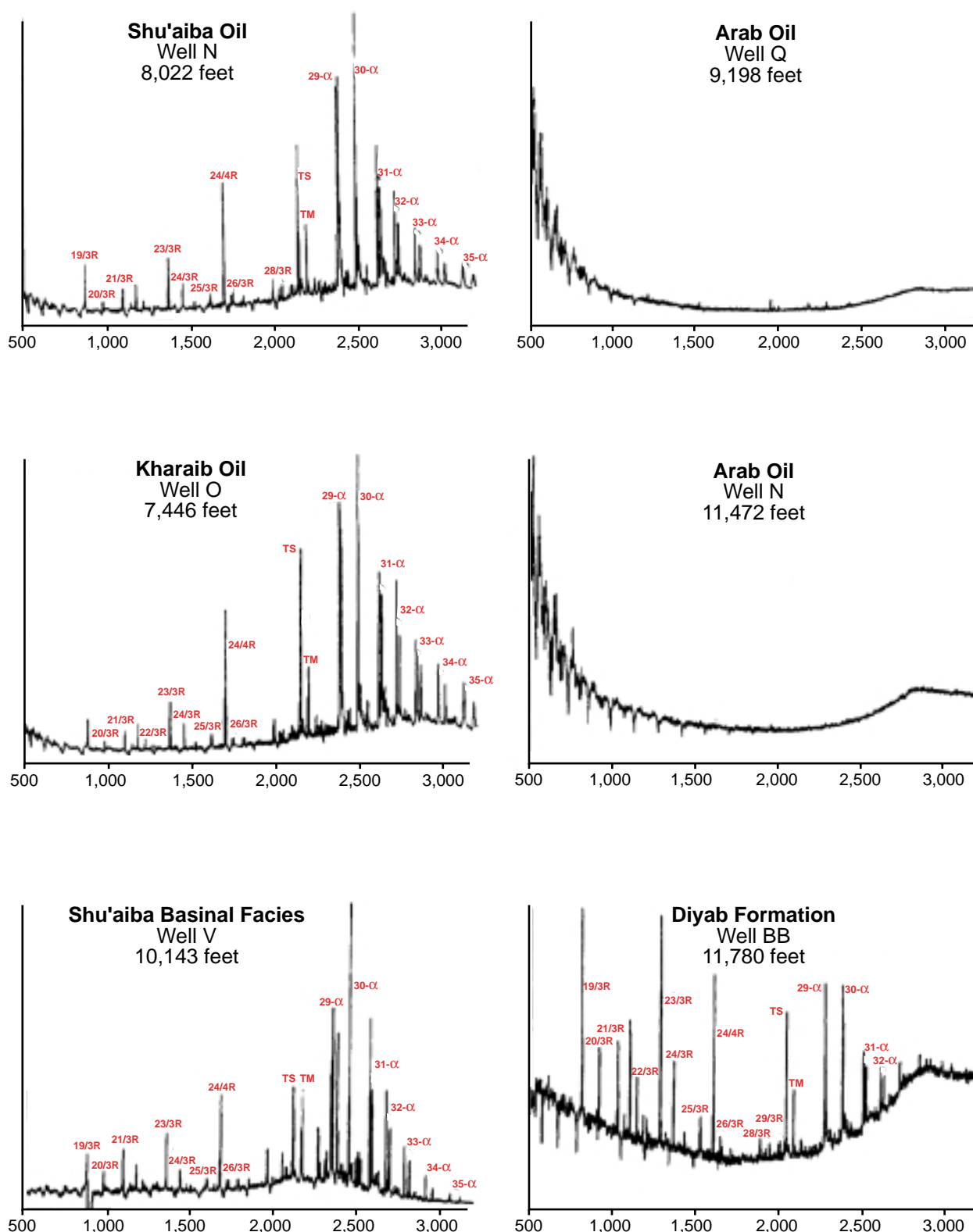


Figure 24: Triterpane Fragmentograms of Upper Jurassic Arab oils and Diyyab source rocks do not correlate with the Lower Cretaceous Shu'aiba and Kharai oils. The Cretaceous oil correlate with the Shu'aiba basinal facies.

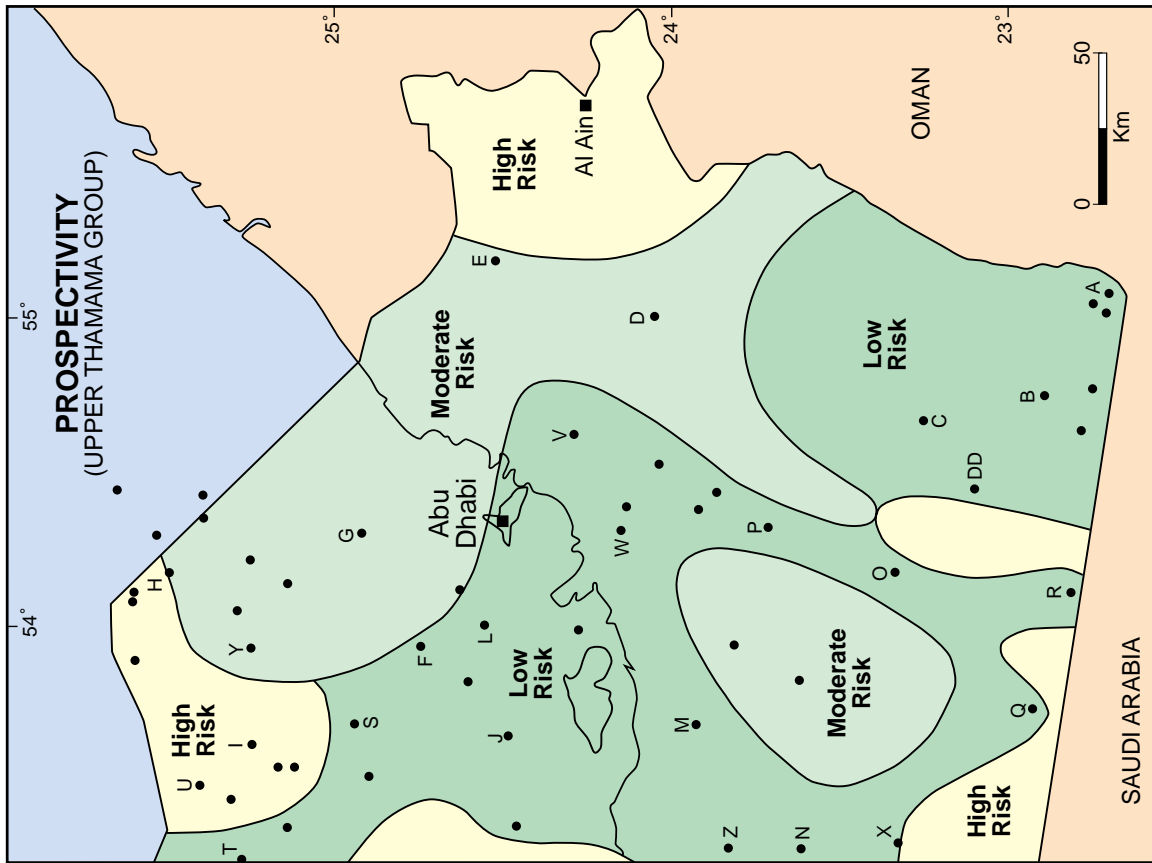


Figure 26: Exploration prospectivity is considered low risk in the major generative areas and migration pathways. Exploration risk is high in the immature areas (Figure 25).

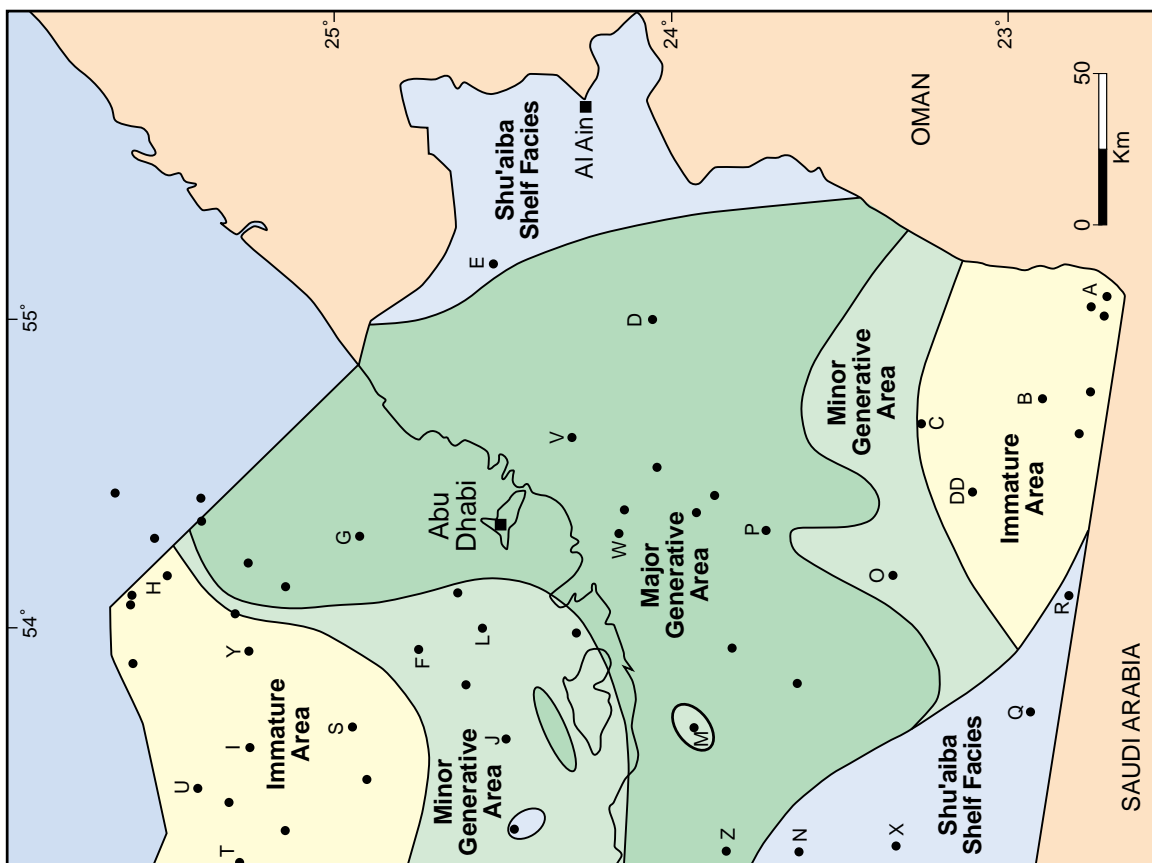


Figure 25: Hydrocarbon generative area for the Shu'aiba basinal facies.

Volumetric calculations were performed using Piggot's method (1982) and Goff's equation (1983). The area of mature kitchens is estimated at around 37,000 sq km and 49,000 sq km for Shu'aiba basinal facies and Thamama dense layers, respectively. These mature kitchens were subdivided into seven drainage polygons that appear to be in different structural positions and isolated from each other. Based on the outlined assumptions (Table 1) the predicted oil-in-place which migrated from the Shu'aiba basinal facies and accumulated in the Shu'aiba and Kharai reservoirs amounts to 50 billion barrels. The oil migrated from Thamama dense layers amounts to 49 billion barrels.

PROSPECTIVITY AND CONCLUSIONS

The Shu'aiba basinal facies is a prolific oil-prone source rock. The Thamama dense intervals have moderate to lean organic richness. The Shu'aiba and Thamama basinal facies source rocks are generally mature over much of the study area. The oils in the Thamama reservoirs are mainly sourced from its basinal facies. The main kitchens are the Falaha Syncline and the eastern Abu Dhabi foreland basin. Westwards migration to the structures located in central Abu Dhabi started in Eocene time.

The present-day regional hydrocarbon distribution can be explained by a fill and spill migration mechanism. The oil generative areas of the Shu'aiba and Thamama dense layers source rocks and the areas that are located in the migration pathways are highly prospective. Figures 25 and 26 highlight the major generative areas which can be considered low risk. Northeast onshore Abu Dhabi and Falaha Syncline are considered less prospective areas due to the increased depth of burial and thermal cracking in these synclines (Figure 26). Eastern offshore Abu Dhabi is considered moderate risk.

ACKNOWLEDGMENT

The author gratefully acknowledges the management of Abu Dhabi National Oil Company (ADNOC) for permission to publish this paper. Thanks also to many colleagues in ADNOC Exploration Division who provided significant stimulating discussions during the preparation stages of this paper.

REFERENCES

- Abu Dhabi National Oil Company 1985. *Habitat of Hydrocarbon in Abu Dhabi, United Arab Emirates*. Proceedings of the Seminar on Source and Habitat of Petroleum in the Arab Countries, Kuwait 7-11 October 1984. Organization of Arab Exporting Countries (OAPEC), p. 7-72.
- Azzam, I.N. and A.K. Taher 1993. *Sequence Stratigraphy and Source Rock Potential of the Middle Cretaceous (Upper Wasia Group) in West Abu Dhabi*. Proceedings of the 8th Middle East Oil Show, Bahrain, March 3-6, 1993, SPE 25577, p. 475-487.
- Azzam, I.N. and A.K. Taher 1995. *Sequence Stratigraphy and Source Rock Potential of the Aptian (Bab Member) in East Onshore Abu Dhabi: A Model Approach to Oil Exploration*. Proceedings of the 9th Middle East Oil Show, Bahrain, March 11-14, 1995, SPE 29802, p. 305-317.
- Creaney, S. and Q.P. Passey 1993. *Recurring Patterns of Total Organic Carbon and Source Rock Quality within a Sequence Stratigraphic Framework*. American Association of Petroleum Geologists Bulletin, v. 77, p. 386-401.
- Goff, J.C. 1983. *Hydrocarbon Generation and Migration from Jurassic Source Rocks in the East Shetland Basin and Viking Graben of the Northern North Sea*. Journal of the Geological Society of London, v. 140, p. 445-474.
- Hawas, M.F. and H. Takezaki 1995. *A Model for Migration and Accumulation of Hydrocarbons in the Thamama and Arab Reservoirs in Abu Dhabi*. In M.I. Al-Husseini (Ed.), GEO'94, Middle East Petroleum Geosciences. Gulf PetroLink, Bahrain, v. 2, p. 483-495.

- Hunt, J.M., M.D. Lewan and R.J.C. Hennen 1991. *Modeling Oil Generation with Time-Temperature Index Graphs based on the Arrhenius Equation*. The American Association of Petroleum Geologists Bulletin, v. 75, p. 795-807.
- Lijmbach, G.W.M., J.M.A. Buiskool Toxopeus, T. Rodenburg and L.J.P.C.M. Hermans 1992. *Geochemical Study of Crude Oils and Source Rocks in Onshore Abu Dhabi*. 5th Abu Dhabi Petroleum Conference, 18-20 May, 1992. SPE 24513 (ADSPE 305), p. 395-422.
- Murris, R.J. 1980. *Middle East: Stratigraphic Evolution and Oil Habitat*. The American Association of Petroleum Geologists Bulletin, v. 64, p. 597-618.
- Passey, Q.R., S. Creaney, J.B. Kulla, F.J. Moretti and J.D. Stroud 1990. *A Practical Model for Organic Richness from Porosity and Resistivity Logs*. The American Association of Petroleum Geologists Bulletin, v. 74, p. 1777-1794.
- Piggot, N. 1982. *Volumetric Assessment of Petroleum Generation in Basins*. British Petroleum Exploration School, GCB/22/82.
- Waples, D.W. 1980. *Time and Temperature in Petroleum Formation: Application of Lopatin's Method to Petroleum Exploration*. The American Association of Petroleum Geologists Bulletin, v. 64, p. 916-926.
-

ABOUT THE AUTHOR

Ahmed A. Taher is a Geologist with the Abu Dhabi National Oil Company (ADNOC) since 1982 and has worked as an Explorationist for the ADNOC Concession areas. He received his BSc in Geology from UAE University. He is a member of the Society of Explorationists in the Emirates (SEE). Ahmed is particularly interested in the statistical modeling of source rocks and its maturation regime.



Paper presented at the 2nd Middle East Geosciences Conference and Exhibition, GEO'96, Bahrain 15-17 April 1996

Manuscript Received 25 September 1996

Revised 3 February 1997

Accepted 15 February 1997