Geological Modeling of Makhul Formation in Minagish Field: Integrating Sedimentological, Petrophysical, Geophysical and Well Test Data, an Example of a Tight and Complex Reservoir from Kuwait*

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Abstract

The Minagish Field in southwestern Kuwait (Figure 1), about 40 km west of the Burgan Field, was discovered in 1959. The field is an elongated anticline trending almost due north-south with a maximum size of 15 x 5 km (Figure 1), where the flanks dip 5-7. Recent interpretation of 3D seismic volume shows over 24 faults oriented mainly N-S and W-E, and some oblique to them (Figure 2). Normal displacements seem to predominate over reverse, and vertical displacements are generally subseismic (< 60 ft). The east and west flanks show higher dips (~ 3-7 degrees) than the north and south flanks which dip 2-3 degrees. The influence of faults as controls on the hydrocarbon accumulation is still controversial and depends on the unit under question.

The Berriasian Makhul Formation represents onset of open marine carbonate deposition overlying Late Jurassic Gotnia and Hith evaporites in Kuwait (Figure 4). The formation varies from 400’ to 900' in thickness, generally thickening towards the northeast. The lowermost part of the Makhul has been established as a source rock (Table 1) for the Lower Cretaceous Petroleum system. The middle and upper part of the Makhul had recorded numerous oil and gas shows during drilling, however, the reservoir was earlier considered too tight to be explored. Drilling, acquisition of core data, and testing of wells MN-A, MN-B and MN-C has allowed for more detailed description and interpretation of sedimentology and stratigraphy of this formation and has led to reassess the potential of this unit as a reservoir in Minagish Field.

Stratigraphy of Makhul Formation

Detailed description and interpretation of sedimentology and stratigraphy show that the Makhul Formation (Figure 3) can be broadly divided in three main zones, with a change from wackestone-packestone to mudstone toward the northeast. The lower Makhul consists of heavily bioturbated argillaceous lime mudstone and shale (Figure 6). The middle Makhul contains mostly argillaceous lime mudstone interbedded with turbiditic, very fine grainy lime mudstone-wackestone. The upper Makhul is composed of bioturbated to intensively bioturbated (Figure 5), very fine grainy lime mudstone-wackestone interbedded which is in areas is slightly dolomitized. These facies suggest depositional environments ranging from outer ramp to middle-outer ramp to outer-middle ramp settings for lower, middle and upper Makhul, respectively (Figure7).

Stratigraphically, the lower Makhul is described by an asymmetric base level fall cycle. Both lower and middle Makhul are described by complete base level asymmetric cycles. These complete cycles are described by a lower base level fall hemicycle larger than the capping base level rise hemicycle. Stepping pattern analysis shows that the middle Makhul steps seaward with respect to lower Makhul, and upper Makhul with respect to middle Makhul suggests a clear landward-stepping pattern signifying the upper Makhul had deeper water and lower energy deposition than the middle Makhul. Stepping patterns toward shallower conditions favor deposition of cleaner limestone in the middle Makhul and contrast with reservoir quality of the upper Makhul. Stratigraphic concepts helped to establish rock typing and associated quantitative log clustering and layering strategy.

Methodology

The methodology used to carry out the present study consisted of the following general workflow:

1) Geologic Study: Included data collection and data quality control, regional and local characterization of the Makhul Formation from external and internal sources, and generation of sedimentological and stratigraphic model of Makhul Formation in Minagish Area.

2) Geophysical Study: Include data collection and data quality control. Well to seismic calibration, seismic interpretation of faults and horizons of the 3D survey, and generation of velocity model. Major outputs for the model are depth structural grids at the top and base of Makul Formation, with faults sticks in depth. Additionally, use of attributes generation and analysis help to understand fault framework configuration. Finally, generation and analysis of seismic inversion cube helps to characterize and understand the 3D distribution of reservoir rocks and associated petrophysical properties such as porosity.

3) Petrophysical study: Includes data collection and data quality control. Generation of the log and mineral models, data clustering analysis and definition of major rock types. Interpretation of wells logs and generation of result curves such as PHIE, SW, and K. Main outputs to static model are quality control log curves, rock typing definition, and result curves for PHIE, SW, and K.

Summary

Stratigraphically, the lower Makhul is described as a complete base level fall asymmetric cycle. The lower part of this cycle is represented by at least 3 shallowing-upward non-symmetric subcycles, capped by a short term base-level rise hemicycle. The Upper Makhul is represented by another complete base-level fall asymmetric cycle. These cycles are described by a lower base-level fall hemicycle larger than the capping base-level rise hemicycle. The stepping pattern analysis of the upper Makhul with respect to lower Makhul suggests a clear landward-stepping pattern, suggesting deeper and lower energy depositional in upper Makhul cycle than the lower Makhul cycle. By understanding the implication of the stepping pattern analysis, it can be inferred that deposition of cleaner limestones can be associated

mainly with the middle part of the lower Makhul cycle. Additionally, some developments of fair petrophysical properties could be found in the middle part of the upper Makhul cycle.

Reference

Abdullah, F.H.A., and R.R.F. Kinghorn, 1996, A preliminary evaluation of Lower and Middle Cretaceous source rocks in Kuwait: Journal of Petroleum Geology, v. 19/4, p. 461-480.

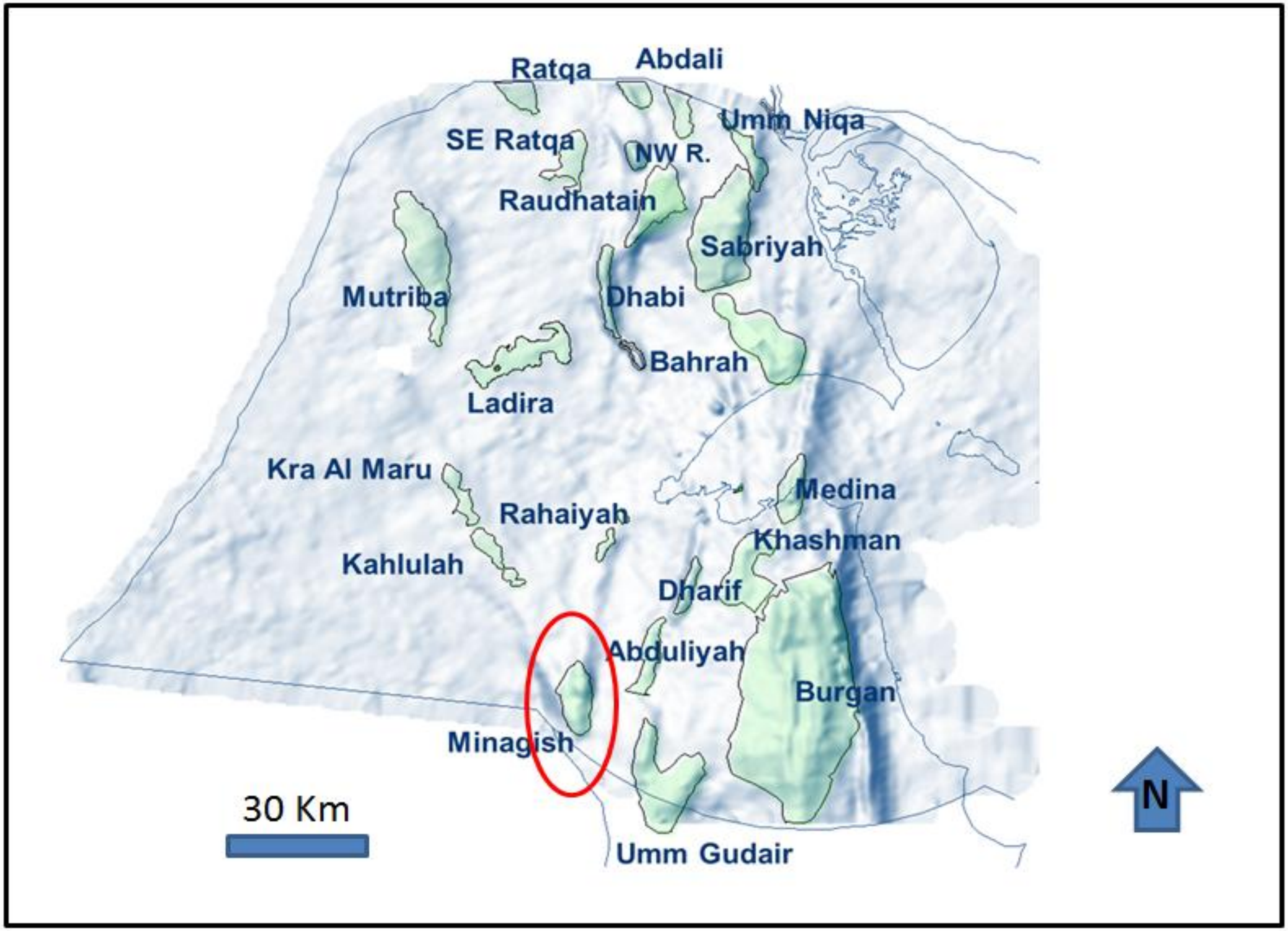

Figure 1. Location of study area.

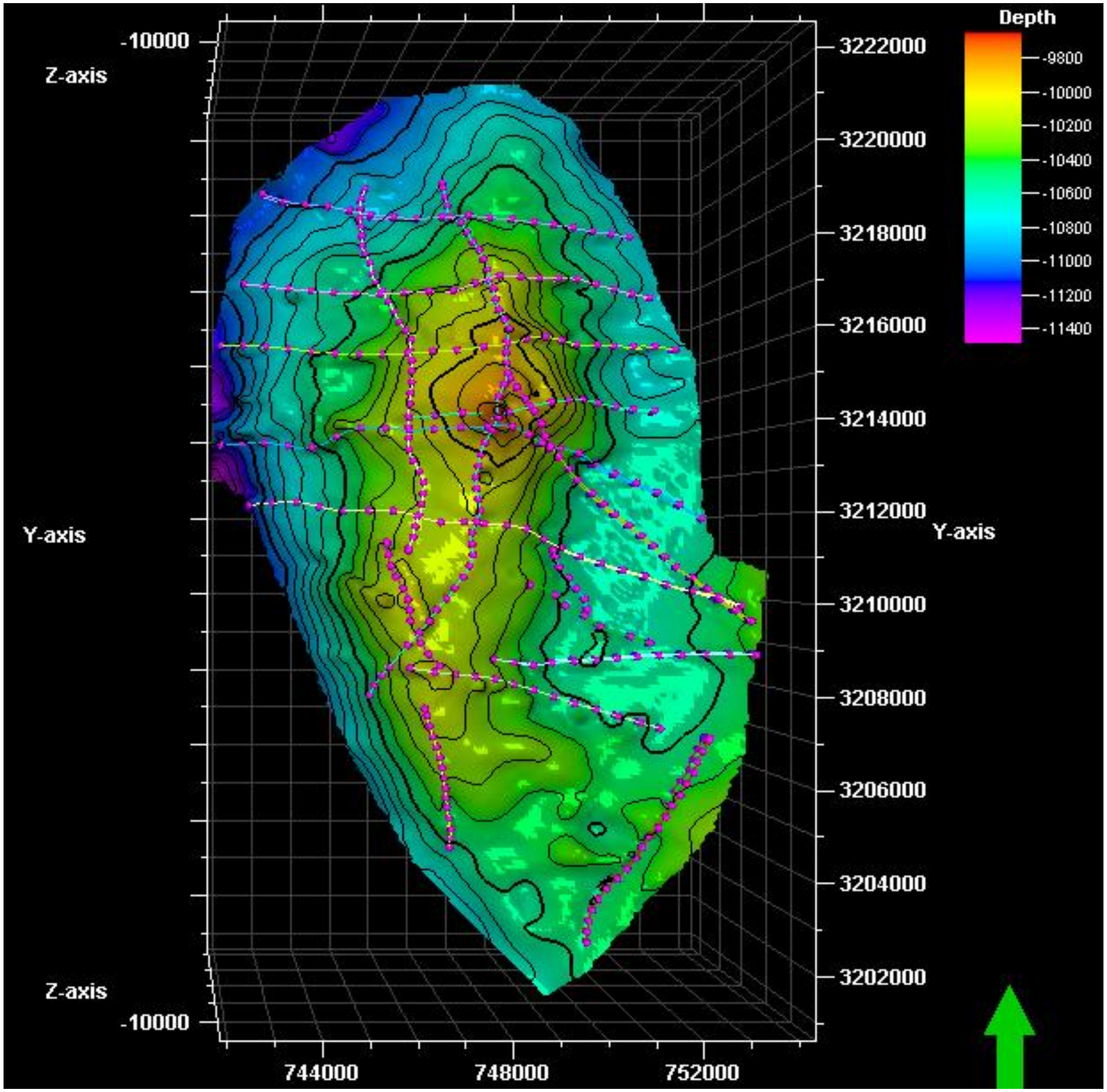

Figure 2. Structural configuration of Mahkul top in the Minagish Field.

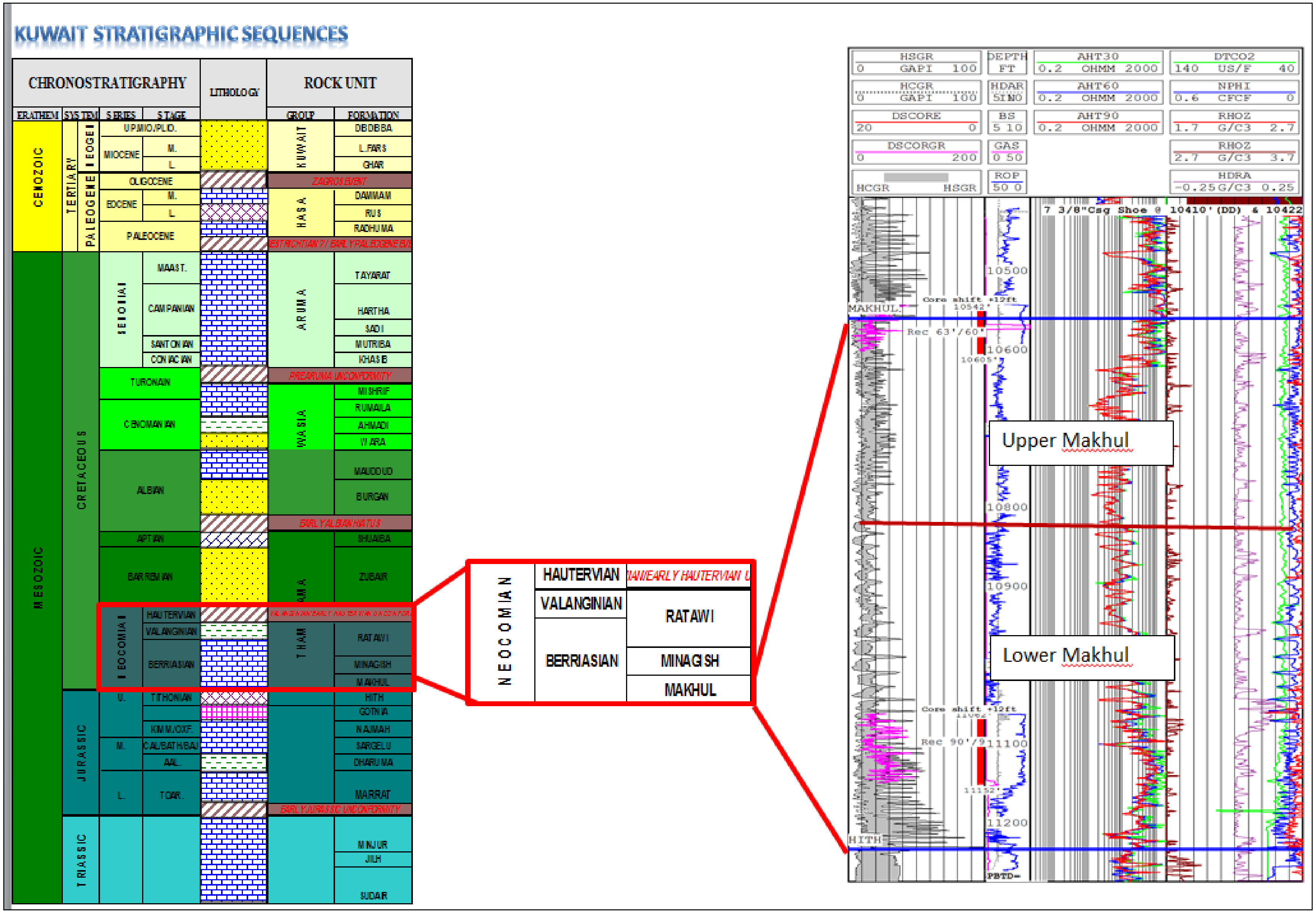

Figure 3. Generalized stratigraphic column for Kuwait showing position of Makhul Formation.

Figure 4. Projected Late Tithonian-Early Berriasian depositional conditions for the Makhul Formation in the Kuwait area.

Figure 5. Core showing intensely bioturbated lime mudstones and wackestones in MN-141. Upper Makhul interpreted as outer to middle ramp.

Core 2, Box 6 : 10750.7 - 10751.4 ft | Core 2, Box 6 : 10752.9 - 10753.5 ft | Core 2, Box 7 : 10755.3 - 10756 ft

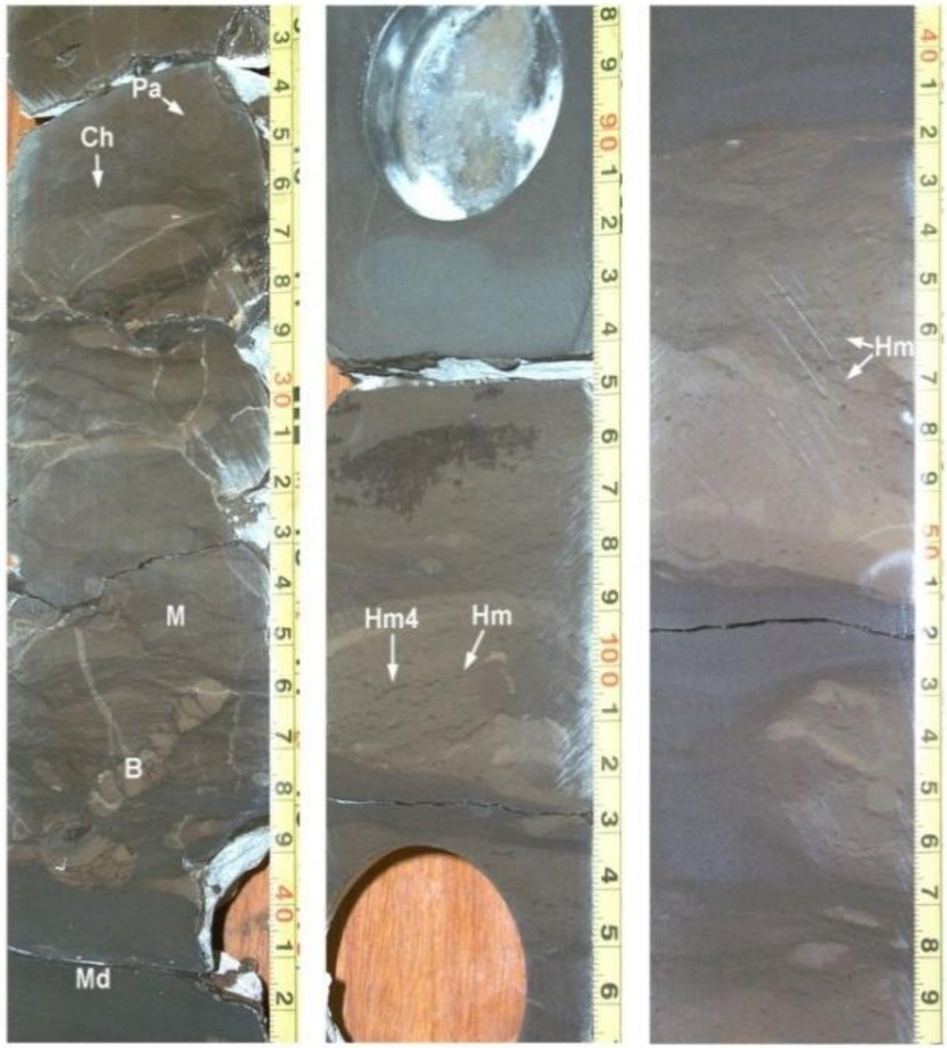

PLATE 34A | PLATE 34B | PLATE 34C

Figure 6. Core showing bioturbated lime mudstones and wackestones interbedded with slightly dolomitic argillaceous lime mudstones in MN-138. Lower Makhul interpreted as middle ramp.

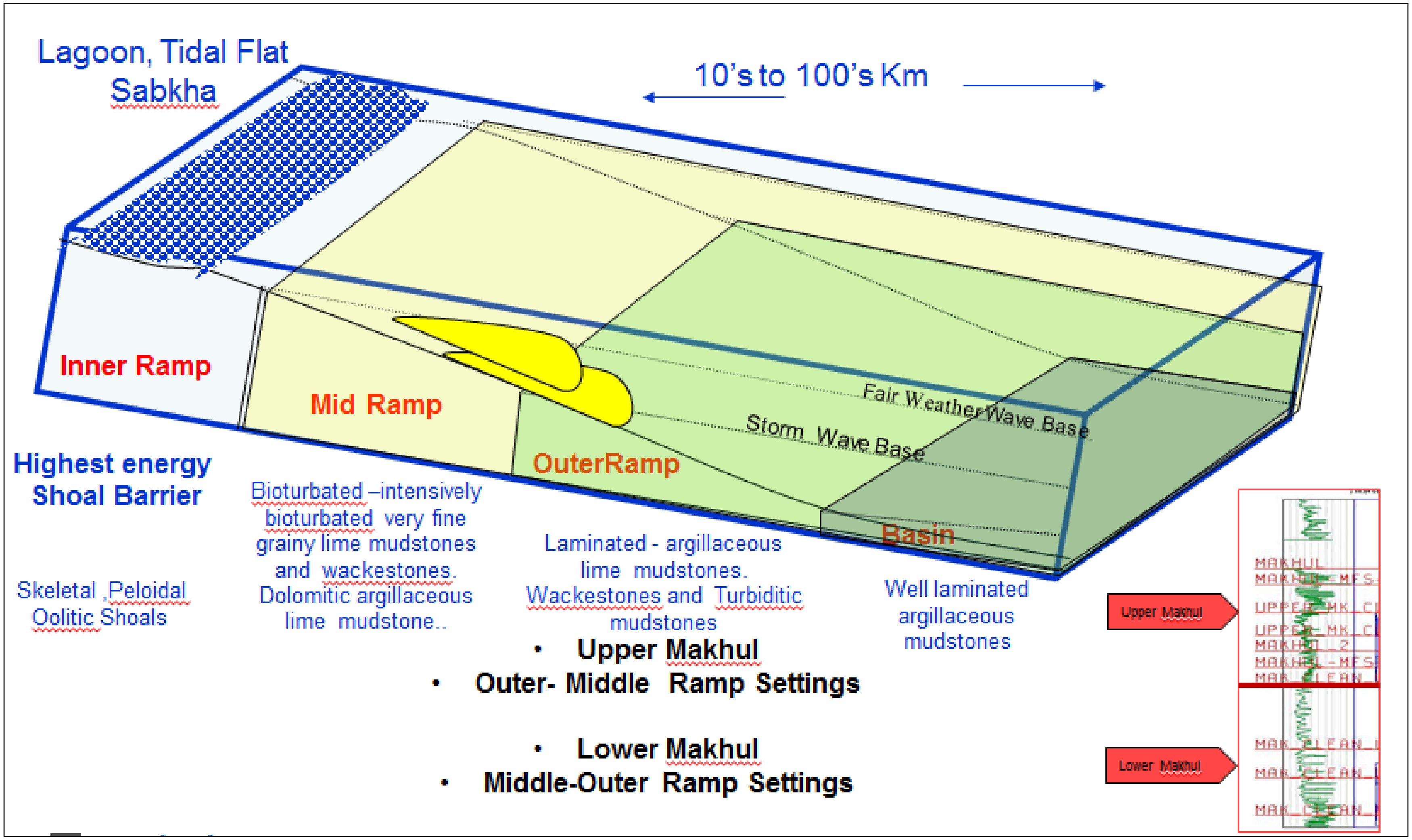

Figure 7. Schematic depositional environments interpreted for Makhul as middle to outer ramp setting for the lower Makhul and outer-middle ramp settings for the upper Makhul.

Formation	Field Name	Richness	Type	Maturity	General
Sulaiy	*Raudhatain*	Good to very good	II Marine	Mature	Good source rock in northern parts of Kuwait, becomes fair in Minagish Field
	Minagish	Fair	II Marine	Very early mature	
	Riqua	Excellent?	II Marine	Mature	
Minagish	*Raudhatain*	Fair to good	II-III, III Marine	Very early mature	Very good source rock in Ash-Shaham, the oolitic and deeper parts in Raudhatain is also good
	Minagish	Fair to good	II-III, III Marine	Very early mature	
	Ash-Shaham	Very good?	I-II Marine	Mature	

Table 1. Summary of source rock potential for lower Cretaceous units in some oil fields in Kuwait (Abdullah and Kinghorn, 1996).