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Development of Diagenetic Traps Along the Hydrocarbon Migration Pathways

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Abstract

Oil accumulation in the secondary migration pathways may represent a huge potential for future exploration activities. The significant hydrocarbon available in the migration pathways is either absorbed by the rocks or accumulated in subtler traps style. The faults and heterogeneity along the migration pathways will act as barriers for the migrated hydrocarbon to be accumulate behind these barriers.

The diagenetic traps along the secondary migration pathways were developed in response to the presence of an equilibrium state between the buoyancy forces trying to move the oil through the rocks and the capillary pressures in the low permeable layer that resists these movements. The only requirement to develop such traps is for the capillary pressure to be greater than the migration buoyancy forces. Smaller pore throat sizes and larger oil molecules will greatly enhance the seal capacity and will resulted in longer oil columns.

The migration pathways sweet spots development can be outlined using the available core data to define the pore throat diameter, seismic data to define the amplitude variations and the basin modeling to define the migration route and the oil molecular sizes.

The Upper Thamama migration pathways, in east and central Abu Dhabi for example may represent the best potential areas for the secondary migration pathways oil accumulation. Some of the well-known stratigraphic traps in southern Arabia, which have been largely found by accident, are examples of the migration pathways traps. In Abu Dhabi, most of the known Middle Cretaceous stratigraphic traps and some Lower Cretaceous structural traps, in reality, are migration pathways hydrocarbon accumulations.

The improved technologies in seismic images, basin modeling, horizontal drilling, frac testing and steam injection will result in discovering a commercial volume of hydrocarbon that accumulated in the diagenetic traps along the migration pathways.

Extended Abstract

1. Play Concept

The secondary migration pathways represent the link between the mature source rock kitchens and the conventional traps (figure-1).

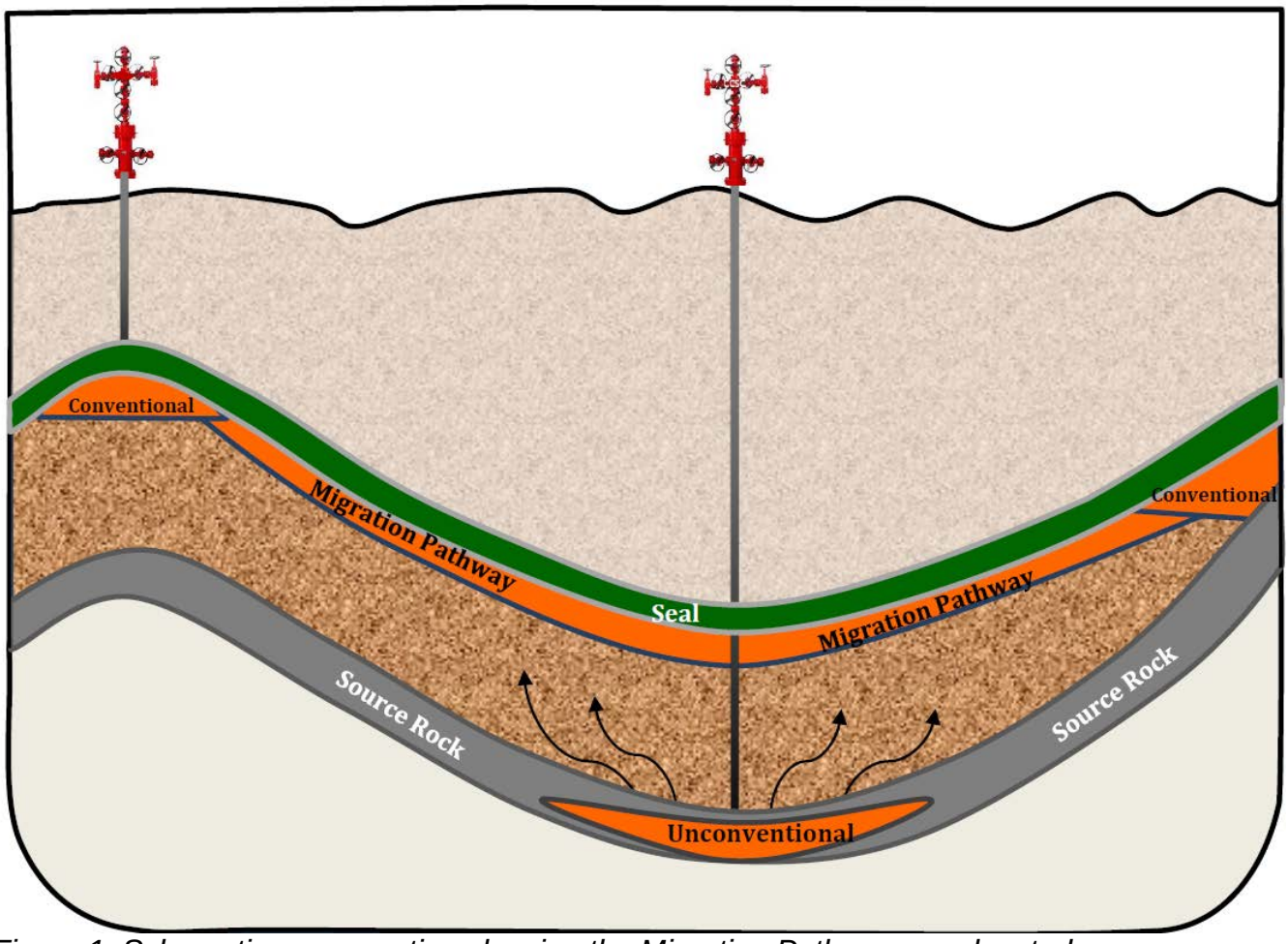

Figure 1: Schematic cross-section showing the Migration Pathways are located between conventional and Unconventional hydrocarbon resources.

Significant part of the generated hydrocarbon is available in the migration pathways. Some studies estimated that the hydrocarbons available in the migration pathways might represent more than 50% of generated oil (England, W. A., 1994).

The significant hydrocarbon volume entering the secondary migration pathway will be retained by the rocks and will be accumulated in subtle traps style that available along the migration pathways. Normally, oil migrates easier along the coarser grains part of a carrier bed and the presence of heterogeneities, permeability reduction, will causes hydrocarbons to be accumulated behind these heterogeneities.

The sweet spots along the migration pathways can be detected by using the seismic data to define the developed amplitudes variation along the migration pathways and these could be considered as an evidence for the development of possible sweet spots.

Some of the well-known stratigraphic traps in southern Arabia, which have been largely found by accident, are examples of the migration pathways traps. In Abu Dhabi, most of the known Middle Cretaceous stratigraphic traps and some Lower Cretaceous structural traps are in reality migration pathways hydrocarbon accumulations.

1. Trap Mechanism

Faults and diagenetic traps are the most known trap styles that can cause hydrocarbon entrapment along the migration pathways. The entrapment mechanism has resulted from the equilibrium state between the buoyancy forces that push the oil to migrate towards the up-dip direction and the capillary pressure in the tight and low permeability areas that resist these movements (Tissot and Welte, 1984). Also, the fault throne

2. Sealing Surfaces

It is well known that the oil generated from mature kitchens will be migrated in the up-dip direction. However, hydrocarbon migration routes are confined and limited vertically and laterally by the presence of sealing surfaces. Any lithology can serve as a seal for hydrocarbon accumulation, (Downey 1994). The only requirement is to have the capillary pressure of the tight lithological unit greater than the buoyancy pressure of the hydrocarbon accumulation. Therefore, a seal rock can be defined as one that has very small pore throats that are poorly connected to allow the passage of hydrocarbons (Downey 1994).

3. Case Histories from the Middle and Lower Cretaceous in Abu Dhabi

The middle Cretaceous source rock is the Shilaif formation. The maximum Shilaif source thickness and richness was found in the central Abu Dhabi. Shilaif is highly mature in the deeper onshore synclines and in the Rub' Al Khali basin. The Shilaif generated oil has migrated upward into the Mishrif formation carrier bed. However, in the areas where Mishrif is absent, the Shilaif generated oil will migrate downwards into the Mauddud formation, which act as an alternative carrier bed for the Shilaif generated oil.

a. Mishrif Migration Pathway Hydrocarbon Exploration Potential

Oil generated from Shilaif kitchens in western synclines and the Rub' Al Khali basin will be migrate vertically into the Mishrif carrier bed. Then oil will laterally was migrated through highly porous and permeable Mishrif reservoir until a permeability barrier interrupts its migration pathway. The height of oil column, in such traps, increases proportionally with the increase a barrier tightness and this is represented by the equilibrium state between the capillary pressure and the buoyancy forces that will try to overcome these barriers.

In west onshore Abu Dhabi, several sweet spots were detected along the Mishrif oil migration pathways. The Mishrif stratigraphic discovery (figure-2) represents a diagenetic trap accumulation along the Mishrif migration pathway. No structural or stratigraphic closure was detected in this discovery. However, the **L** structural closure, that is located directly to the north of this discovery, was found to be dry at Mishrif level. This prove that the Mishrif oil was trapped behind the barriers and could not continue to migrate in the up-dip direction into the well-developed Mishrif reservoir in the structure **L**.

Mishrif accumulated oil will spill toward the high permeable trend possibly to the northwest of K discovery (figure 2).

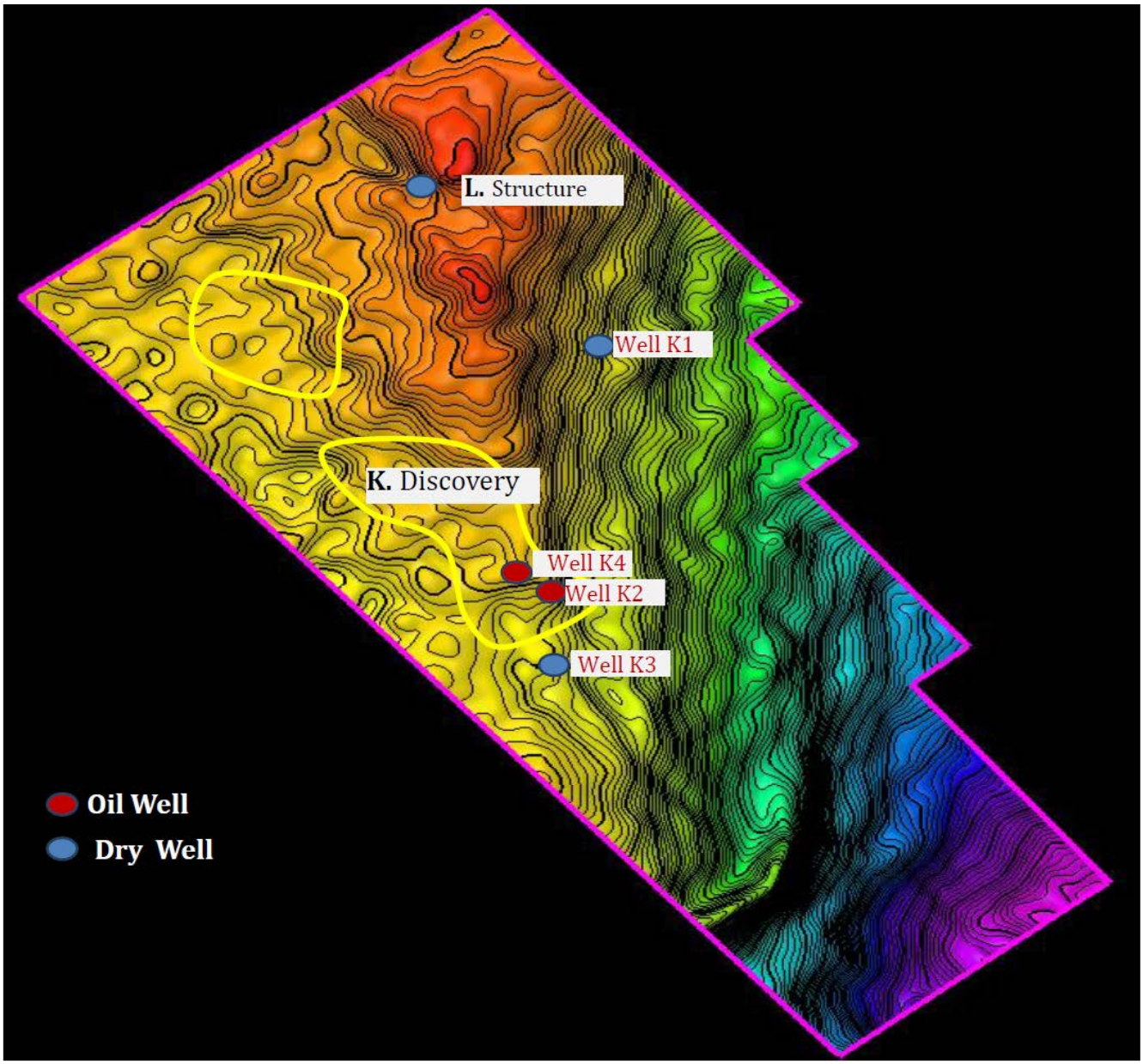

Figure 2: Mishrif migration pathway discovery

b. Mauddud Migration Pathway Hydrocarbon Exploration Potential

The absence of Mishrif carrier bed directly over the Western syncline kitchen caused the highly pressurized Lower Shilaif generated oil to migrate downward into the Mauddud formation. Mauddud formation acts as an alternative carrier bed for the Shilaif generated oil. Since the Mauddud thickness is limited and the Shilaif generated oil is huge, the migrated Shilaif oil filled the Mauddud formation in Ghurab

syncline then pushed out the excess oil and fill all west onshore Abu Dhabi (figure 3). This model was supported by the high hydrocarbon shows while drilling and by high hydrocarbon saturation in the interpreted logs in all wells drilled in west onshore area.

- *Mauddud Play Concept*

Shilaif source rock generated oil in western onshore syncline could not migrated out into the surrounding structures due to the absence of a carrier bed directly over the Shilaif kitchen.

Therefore, the enclosed hydrocarbon system resulted into a highly pressurized Shilaif kitchen and this facilitated the downward migration into the Mauddud formation.

Since Mauddud limited thickness (~20 ft.) in Ghurab Syncline cannot contain all Shilaif generated oil, it was pushed out into Mauddud layer in all west onshore Abu Dhabi (figure 3).

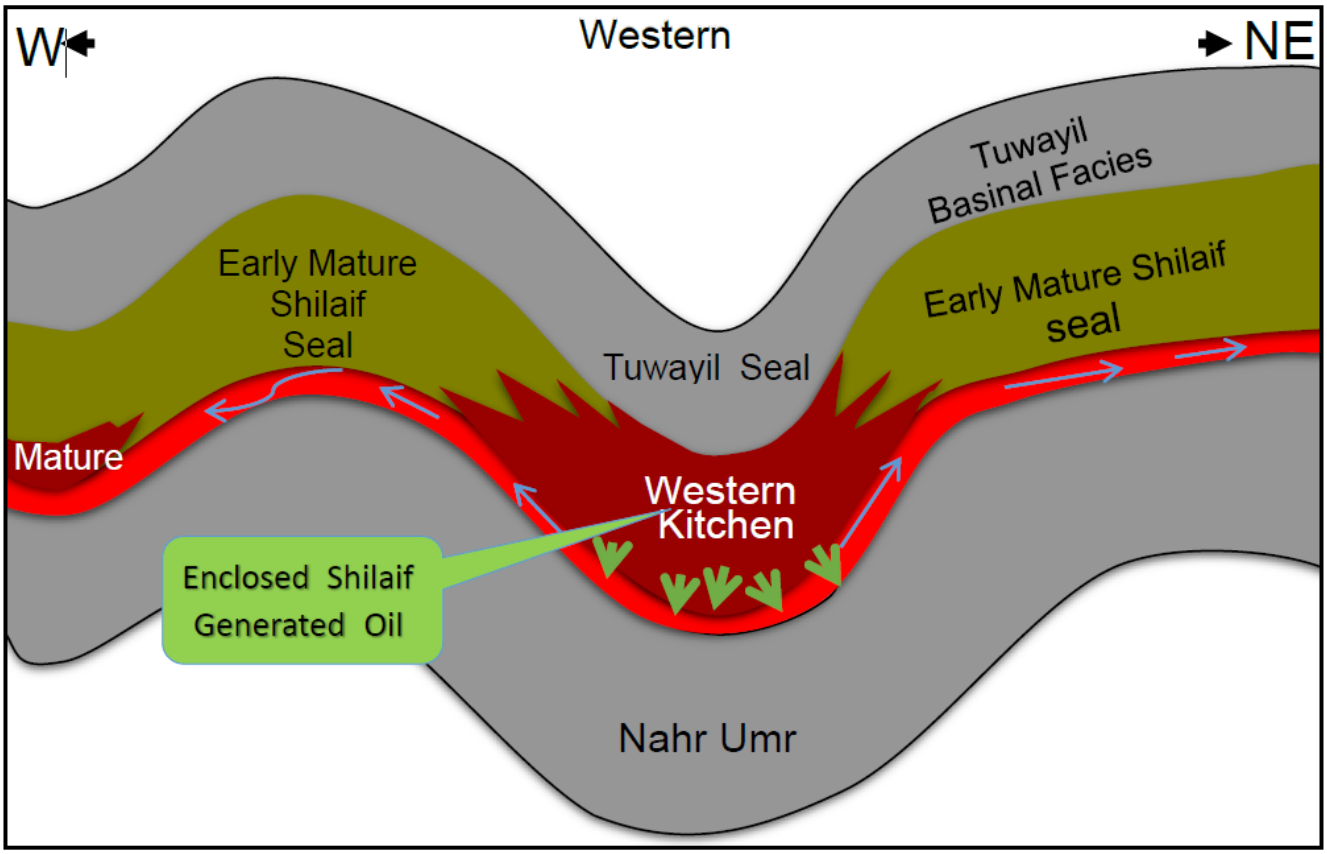

Figure-3: Mauddud migration accumulation play concept.

c. Thamama Reservoirs Migration Pathways Hydrocarbon Potential

The Upper Thamama secondary migration pathways in Abu Dhabi have a high potential for discovering additional hydrocarbon resources. The present day active migration pathways model supports this potentiality. Also, the late Tertiary tilting was resulted in the segmented of the paleo supper giant field that is located in the northeast onshore Abu Dhabi. Hydrocarbons spilled out of this Paleo-structure were re-migrated and filled most of the prominent Abu Dhabi fields that located in the migration pathways (figure-4). In addition to filling the structural closures, spilled oil can be trapped behind the barriers that resulted from the presence of segmented faults or reduction in permeability along the migration pathways.

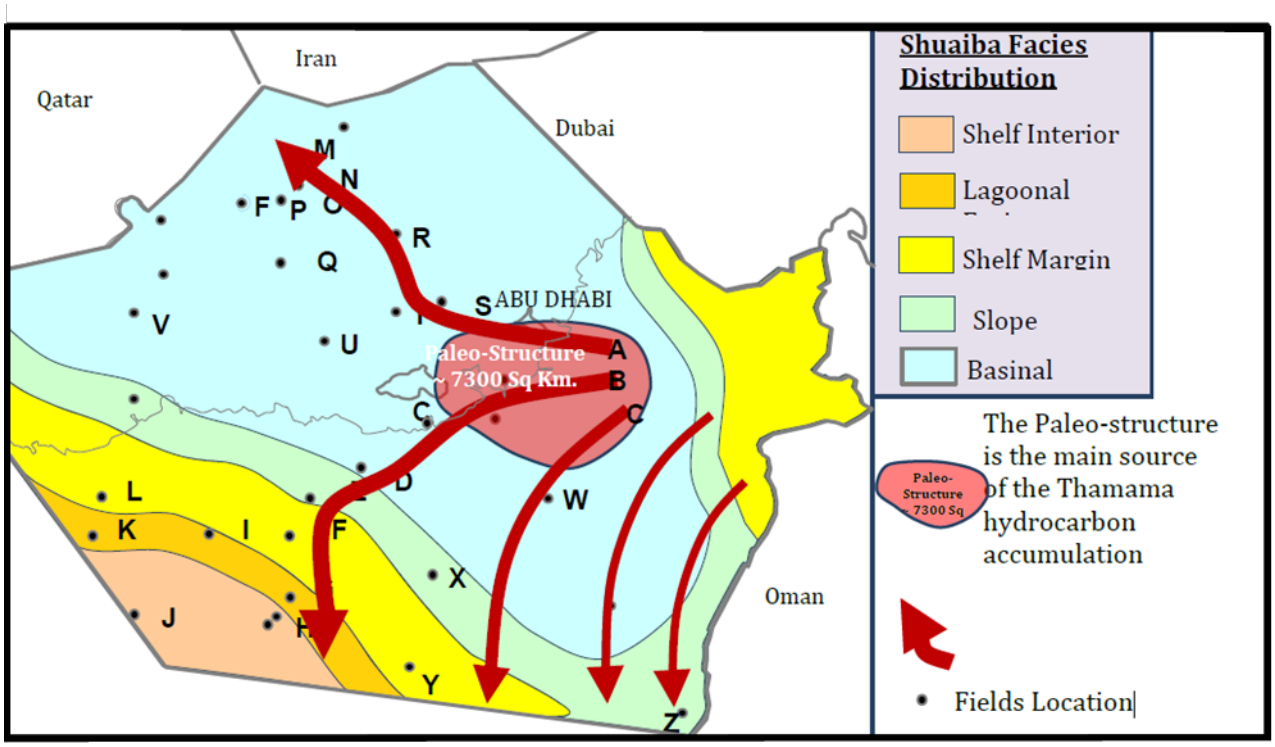

Figure 4: Thamama hydrocarbon migration pathways. These migration routes are the place for the Shuaiba and Thamama reservoirs hydrocarbon exploration potential.

Some of the well know fields are in reality a hydrocarbon accumulation behind the segmented faults. The field C (figure 5) represents oil accumulations in the

secondary migration pathways. In this field, the trap mechanism has developed in response to the presence of faults and heterogeneities and permeability reduction along the hydrocarbon migration pathways. The OWC for example, is crossing the structure contour lines and the oil accumulated was behind the tight sediment.

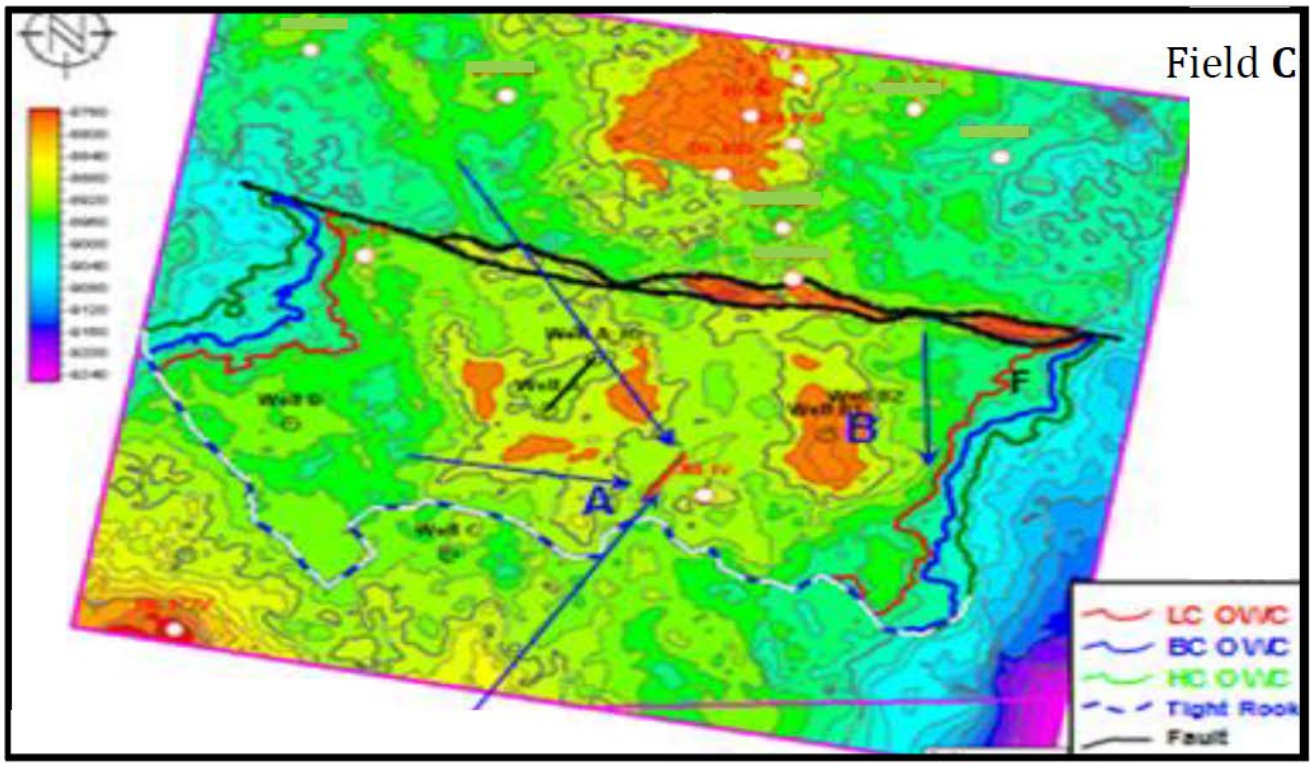

Figure 1: represents oil accumulations in the secondary migration pathways

Conclusions

Oil accumulation in the secondary migration pathways may represent a huge potential for future exploration activities.

The traps mechanism along the migration pathways were developed in response to the presence of an equilibrium state between the buoyancy forces trying to move the hydrocarbon through rocks and the capillary pressures in the low permeable layers that resist this movement.

A rock-sealing surface holds back hydrocarbon only until the hydrocarbon exerts sufficient buoyancy pressure to pass through the water wet rock pores, or membrane seal. Fundamentally, the quality of lateral seal is determined by the minimum pressure required to displace brine water from pores or fracture, thereby allowing leakage.

The Mishrif stratigraphic discovery in west onshore Abu Dhabi (figure-4) represents an oil accumulation along the Mishrif migration pathway. No structural or stratigraphic closure was detected in this discovery and the limit of the Mishrif oil entrapment in this area is controlled by the Mishrif heterogeneities.

The significant Shilaif generated oil in the western Kitchen will be migrated downward into the Mauddud carrier bed. Shilaif oil filled Mauddud formation in the western syncline, and then pushed the oil out to migrate into the Mauddud formation all over west onshore Abu Dhabi.

Upper Thamama oil accumulations were spilled from the Paleo-structure that is located in the northeast onshore Abu Dhabi and the spilling still active until present day.

Several well-known structures located along the Upper Thamama migration pathways, especially migration route B (figure 4), are stratigraphic traps developed in response to the presence of heterogeneities or segmented faults along these migration routes (figure 5). No definite OWC can be found within these kind of traps and they are expected to be a part of semi-continuous trap that extends from east Abu Dhabi Island into the central Abu Dhabi ridge.

Therefore, the Upper Thamama migration pathways are filled with hydrocarbon and all porous and permeable areas are expected to be filled with hydrocarbon and can be considered potential areas for future exploration activities.

2. Acknowledgments

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