ZIBELINE INTERNATIONAL PUBLISHING

Geological Behavior (GBR)

DOI: http://doi.org/10.26480/gbr.01.2020.01.08

ISSN: 2521-0890 (Print)
ISSN: 2521-0491 (Online)
CODEN: GBEEB6

RESEARCH ARTICLE

PETROLEUM SYSTEM OF SHOUSHAN BASIN, WESTERN DESERT, EGYPT

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ARTICLE DETAILS

Article History:

Received 01 January 2020
Accepted 06 February 2020
Available online 28 February 2020

ABSTRACT

The Western Desert is located in Egypt and it consists of a few extensional coastal rift-basins. It started as rifts and was formed during the Jurassic time in association with the opening of the Tethys Sea. There were three major tectonic events that occurred in Western Desert within Jurassic to Eocene time and resulted in NE-SW trend and NW-SE trend normal fault, and inversion of Western Desert basin due to rifting of Neo-Tethys followed by South America & Africa Atlantic rifting and Transpressional Syrian Arc event which had contributed to the formation of hydrocarbon trap. The generation, migration and accumulation of hydrocarbon started in the Late Cretaceous (95–90 Ma) and it continues to the present time. There is proven petroleum system named as Khatatba-Khatatba petroleum system within the Western Desert. The source of hydrocarbons is the Middle Jurassic Khatatba organicz-rich shales which contains type II- III and type III kerogen source migrated into Khatatba sandstones reservoir rock. Khatatba sandstones are mostly quartz arenite, which composed mainly of more than 95 % quartz. These sandstones have high porosity and high permeability with well sorted and are mostly subangular to subrounded grains. Masajid carbonate acts as regional seal within the basin. Hence, the Western Desert of Egypt has a significant hydrocarbon potential for exploration or development targeting on inversion structure.

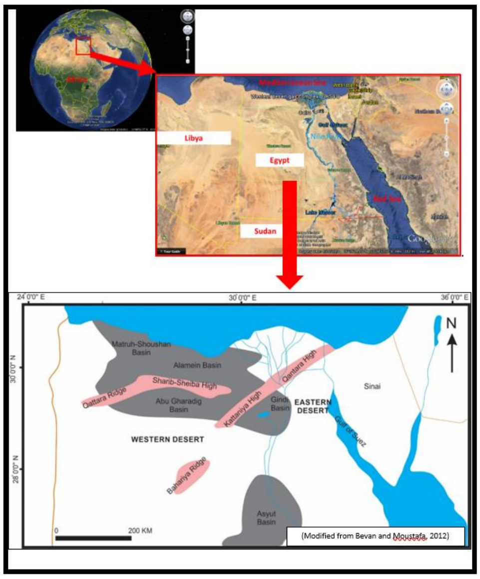
KEYWORDS

Petroleum System, Shoushan Basin, Lithofacies Play Types.

1. INTRODUCTION

The Western Desert (Figure 1) covers about 700,000 square kilometres which is equivalent to the size of Texas and is about two-thirds of Egypt's land area. Egypt borders the Mediterranean Sea to the north, the Red Sea to the east, Sudan to the south and Libya to the west. Western Desert consists of a few extensional coastal rift-basins including Alamein Basin, Abu Gharadig Basin and Matruh-Shushan Basin. The aim of this study is to identify petroleum system types (PSTs) and lithofacies play types of Shoushan Basin using the method as shown; and to evaluate the Khatatba-Khatatba (!) petroleum system (Doust and Summer, 2007). The integration of different types of data included geochemical data, well log, seismic data from literature review which provided a better understanding of the evolution and the hydrocarbon potential of Western Desert.

The stratigraphic succession of Western Desert can be divided into four tectono-sequences (Figure 2) which included Tectono-sequence 1: Paleozoic; Tectono-sequence 2: Jurassic-Coniacian; Tectono-sequence 3: Santonian–Late Eocene and Tectono-sequence 4: Late Eocene-Pliocene. Shoushan Basin evolved through two cycles namely Cycle 1: Margin Sag Basin (MS) and Cycle 2: Wrench Basin (LL) (Jong, 2019). There were three major tectonic events that occurred in Egypt while another important event was the sinistral or dextral rotation of the North Africa plate relative to Laurasia which had strong modifying effect on the local basin tectonic styles encountered in northeast Africa especially in Western Desert (Sedek and Al Mahdy, 2013).



(Modified from Bevan and Moustafa, 2012)

Figure 1: Location map showing significant sedimentary basins in Western Desert.

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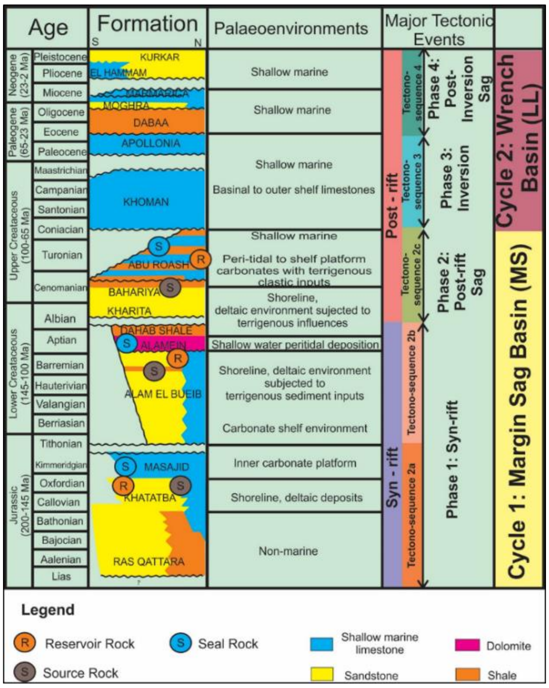

Figure 2: Phases and cycles of Shushan Basin on Stratigraphic Column (Jong, 2019).

Extensional rift-basins of Western Desert started as rifts and they were formed during the Jurassic time in association with the opening of the Tethys Sea (Figure 3). Within the overall passive margin sequences, several half-graben basins formed due to extensional faults initiated in the Jurassic continued to subside through Createaceous. Western Desert consists of a few extensional rift-basins including Alamein Basin, Abu Gharadig Basin and Matruh Shushan Basin. The Mesozoic Egyptian margin was the southern margin of the Eastern Mediterranean basin, at the northern African plate boundary. It corresponds to the "Unstable Shelf" (Said, 1962). There are authors who considered the Egyptian segment as a passive margin with a NE-SW rifting (Keeley, 1994; Bevan and Moustafa, 2012). However, another interpretation suggested that North-West Egypt was an oblique margin associated with NW-SE opening direction (Garfunkel, 1998; Frizon de la Motte et al., 2011; Tari et al., 2012; Tassy et al., 2015). In this study, we follow the first interpretation.

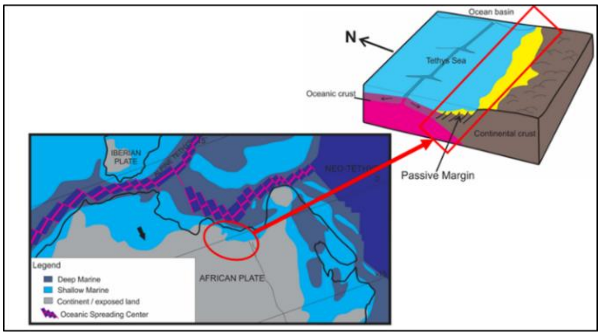

Figure 3: Location of Shoushan basin on a paleotectonic map of North Africa during the Middle Jurassic (Tassy et al., 2015; Ramberg et al., 2008).

2. Petroleum System Types (psts) And Lithofacies Play Types of Shoushan Basin

Some researchers proposed that by recognizing petroleum system types and reservoir lithofacies play types can facilitate prediction of hydrocarbon prospect (Doust and Simmer, 2007). By using the approach three main petroleum system types were recognized in Shoushan Basin and their classification were related to phases of basin evolution (**Figure 4**) (Doust and Summer, 2007). They are Early Syn-rift Transgressive Deltaic Petroleum System Type (Khatatba Formation), Late Syn-rift Transgressive Deltaic Petroleum System Type (Alam El-Bueib Member) and Post-rift Sag Shallow Marine Petroleum System Type (Abu Roash-G Member).

2.1 Early Syn-rift Tansgressive Deltaic Petroleum System Type (Khataba Formation)

Based on the plot of hydrogen index (HI) versus oxygen index (OI) on Van Krevelen diagram, Khatatba shale contains mixed kerogen types II-III. It consists of dark shale which contains TOC ranging between 3.60 and 4.20 wt.%. This indicates an excellent source rock (Peters and Cassa, 1994). The pyrolysis yield S1+S2 varies between 8.00 and 10.65 kg HC/ton rock and the productivity index (S1/S1+S2) of these rocks' ranges between 1.35 and 1.70. Therefore, the shale rock of the Khatatba Formation has an excellent source rock potential. The data of vitrinite reflectance measurements (Ro%) for the well Shushan-1X were plotted against depth (**Figure 5**) to indicate the phases of hydrocarbon generation and expulsion. The maturity profile in the burial history model of the well Shushan-1X (**Figure 6**) shows the different hydrocarbon bearing rock units. It indicates that the shale source rock of Khatatba Formation has entered the late mature stage of oil and gas generation window during the Late Cretaceous associate with vitrinite reflectance measurements between 1.0-1.3 Ro%.

2.2 Late Syn-rift Transgressive Deltaic Petroleum System Type (Alam El- Buieb Member)

Based on the plot of hydrogen index (HI) versus oxygen index (OI) on Van Krevelen diagram, Alam El-Bueib Member shales contain mixed kerogen types II-III. The shale section of Alam El-Bueib Member contains TOC varying from 1.85 to 2.40 wt.%, indicating a good source rock. The pyrolysis yield S1+S2 ranging between 3.60 and 4.50 kg HC/ton rock and the productivity index (S1/S1+S2) of this rock is generally less than unity, therefore the shale rock of the Alam El-Bueib Member has a good source rock generating potential. The burial history model of the different hydrocarbon bearing rock units indicate that the shale source rock of Alam El-Bueib Member entered the mid mature stage of oil generation window during the Late Cretaceous associate with vitrinite reflectance measurements between 0.7-1.0 Ro%

2.3 Post-rift Sag Shallow Marine Petroleum System Type (Abu Roash-G Member)

Based on the plot of hydrogen index (HI) versus oxygen index (OI) on Van Krevelen diagram, Abu Roash-G Member shale contains mixed kerogen types II-III. The organic richness of Abu Roash-G Member varies from 1.10 to 1.50 TOC (wt.%) reflects a medium to good source rock. The pyrolysis yield S1+S2 ranging between 0.85 and 1.10 kg HC/ton rock and the productivity index (S1/S1+S2) of this rock is generally less than unity, therefore the shale rock of Abu Roash-G Member indicates fair source rock generating potential. The burial history model of the different hydrocarbon bearing rock units indicate that the shale source rock of Abu Roash-G Member has entered the early mature stage of oil generation at Late Eocene associate with vitrinite reflectance values between 0.5-0.7 Ro%

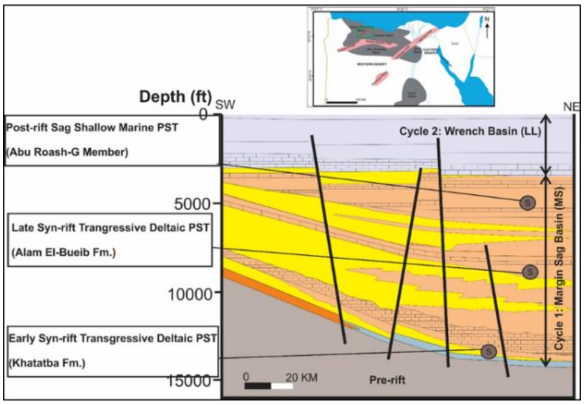

Figure 4: Three petroleum system types (PSTs) recognized in Shoushan Basin, Western Desert and their relation to phases of basin evolution (Shalaby et al., 2014).

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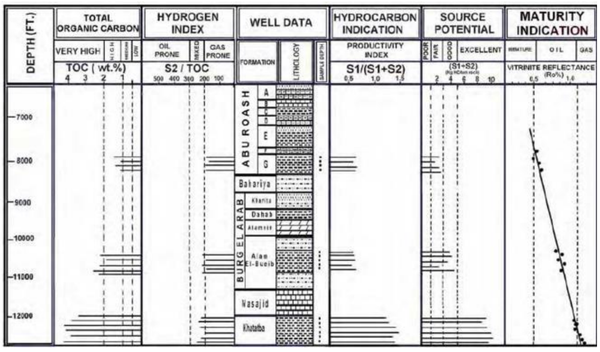

Figure 5: Idealized geochemical log to the well Shushan-1X, showing Rock-Eval pyrolysis data, total organic carbon and vitrinite reflectance measurements (Younes, 2012).

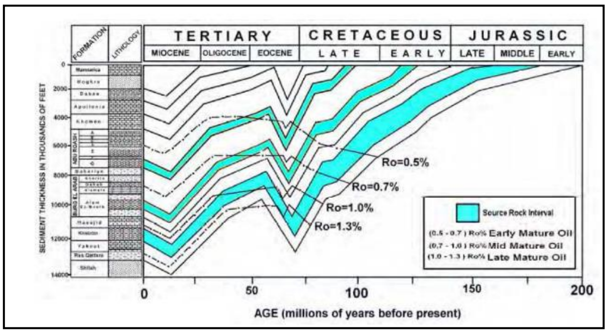

Figure 6: Burial history model of the well Shushan-1X and stages of hydrocarbon generation windows (Younes, 2012).

Each of the three PSTs outlined in Shoushan Basin has an associated suite of reservoir lithofacies as is discussed below (**Figure 7**). Useful generalizations can be made about the relationship between reservoir, seal and charge by placing these lithofacies within the context of overall stratigraphic sequence that characterizes the PSTs.

2.3.1 Early Syn-rift transgressive deltaic PST Reservoir Lithofacies Plays

A reservoir lithofacies occurs in association with Early Syn-rift transgressive deltaic PST which is transgressive delta. The associated fluvial and deltaic reservoir sands are commonly interbedded with coal and shale which are Types II-III source rocks. The hydrocarbon in this reservoir is thought to be laterally charged from in situ gas and oil-prone interbedded coal and coaly shale (Types II-III source rocks). Laterally extensive transgressive marine carbonate associated with the early syn-rift typically overlie the lateral extent of the deltaic reservoir sands. This marine carbonate provides an excellent top seal.

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2.3.3 Post-rift Sag shallow marine PST Reservoir Lithofacies Plays

A reservoir lithofacies occurs in association with Early Post-rift shallow marine PST which is marine carbonate. Marine carbonate of Abu Roash Formation represents the dominant reservoir in post-rift marine PST. The hydrocarbon is charged from the intercalated oil/gas-prone source rock at the deeper part of post rift sag PST. The reservoir is associated with shelf platform carbonates build-ups during the post-rift sag during marine transgression. The top and lateral seals are often marine shales that may inhibit vertical migration of oil charge from deeper oil/gas-prone source rock of the post rift sag PST. The Petroleum System Types and lithofacies play types recognized at Shoushan Basin, Western Desert could be the analog for exploration in similar rift basin in the world especially in Western Desert.

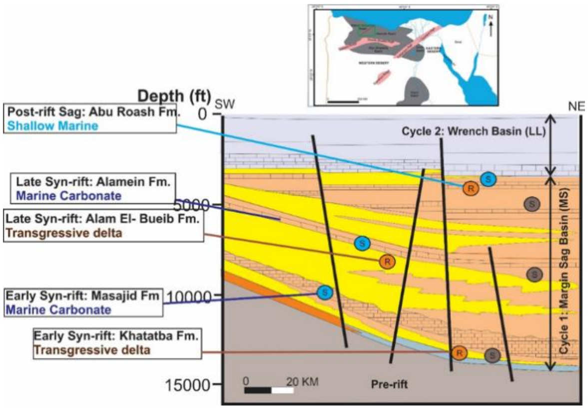

Figure 7: Schematic diagram showing major lithofacies reservoir plays belongs to the three petroleum system types (PSTs) for Shoushan Basin, Western Desert (Shalaby et al., 2014).

3. KHATATBA-KHATATBA (!) PETROLEUM SYSTEM

Petroleum system includes all related essential elements (source rock, reservoir rock, seal rock, overburden rock, trap) and processes (generation-migration-accumulation) needed for oil and gas to accumulate and preserve (Magoon and Dow, 1994). Khatatba-Khatatba (!) petroleum system is one of the proven petroleum systems which has been identified in Shoushan Basin (**Figure 22**).

3.1 Source Rock

Source rock evaluation conducted includes quantity and quality of organic matter in addition to thermal maturity or burial heating of organic matter buried in sedimentary succession (Waples, 1994). The source rock of Khatatba-Khatatba (!) petroleum system is the organic-rich carbonaceous shale which contains mainly type III kerogen (gas prone) and types II–III kerogen (oil and gas prone) from Middle Jurassic Khatatba Formation (Shalaby et al., 2014). The Khatatba source rock samples have high TOC content (1.0–32.5 wt.%), which meet the standard as a source rock with good to excellent hydrocarbon-generative potential (**Figure 8**).

Kerogen type within the Khatatba source rocks was also characterized by Rock-Eval pyrolysis analysis. Khatatba source rocks show HI values in the range of 63–261 mg HC/g TOC. Most of the studied samples are plotted in the low hydrogen index area, ranging between 63 to 200 mg HC/g TOC (type III) and some of the samples plotted at relatively higher hydrogen index range between 201 to 261 mg HC/g TOC (types II–III) (Figure 9).

Khatatba samples that contain type III kerogen would be expected to generate gas while the samples with hydrogen index >200 mg HC/g TOC would generate gas and limited components of liquid hydrocarbon. T-max indicates that the studied samples have reached the main stage of hydrocarbon generation. However, the hydrogen index may be influenced by the maturity of samples. So, the van-Krevelen diagram reflects the present-day hydrocarbon generation potential and not the original hydrocarbon generation potential of the source rocks.

It is recommended that Khatatba Formation can be an effective source rock for hydrocarbon generation in the Western Desert (El Nady, 2013). The oils from the Western Desert are derived from source rocks contain a significant proportion of higher plant material (Mostafa et al., 1998). The features include high abundance of n-alkane in the C21-C31 range, high Pr/ Ph ratios and dominance of C29 tetracyclic steranes (Mostafa et al., 1998).

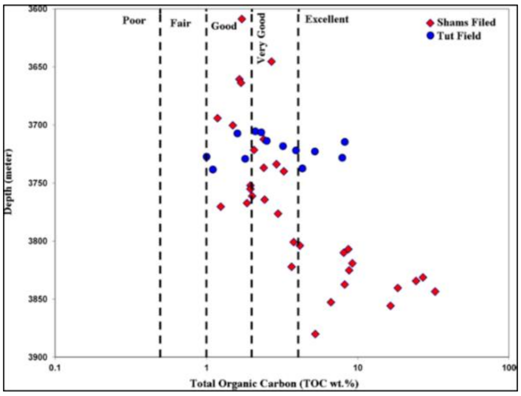

Figure 8: Distribution of total organic carbon content (TOC weight percent) versus depths (in metres) for Khatatba samples in the Shoushan Basin. Most of the samples plotted show good to excellent source rocks (Shalaby et al., 2014).

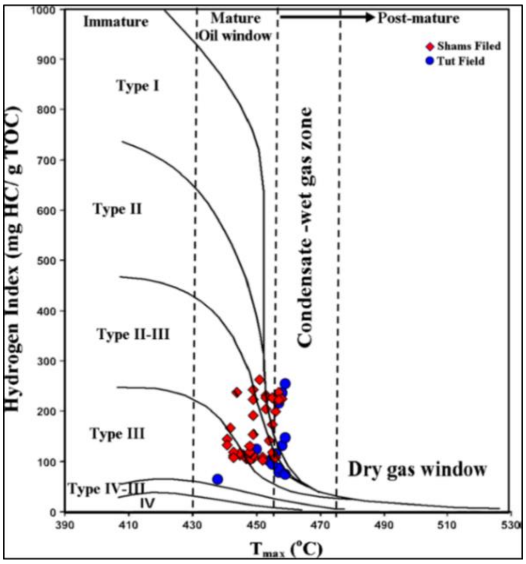

Figure 9: Hydrogen index versus pyrolysis T-max for the Khatatba source rock, showing kerogen quality and thermal maturity stages (Shalaby et al., 2014).

3.2 Reservoir Rock

The Middle Jurassic Khatatba sandstones were recognized as reservoir rocks in the Shoushan Basin. Khatatba sandstone is mostly quartz arenite (**Figure 10**), which is composed mainly of more than 95 % quartz with fine to coarse grained, moderate to well-sorted, and sub-angular to sub-rounded grain (**Figure 11**). The quartz grains are mostly monocrystalline. Petrophysical analysis based on core plug samples from the Khatatba sandstones shows porosity values ranging from 1 % to 17 % and measured permeability values range from 0.05 mD to 1,000 mD (**Figure 12**). Porosity and permeability range from good to poor are due to several reasons. Secondary porosity recognized in the Khatatba sandstones is resulted from fracturing and dissolution of calcite and quartz (**Figure 13**). The dissolution contributed to substantial enhancement of sandstone porosity and permeability thus reservoir quality.

The cements recognized in the Khatatba sandstones were quartz overgrowth, calcite and authigenic kaolinite were the main culprits which resulted in poor porosity and permeability in Khatatba sandstone. Quartz cement in the sandstones occured mainly as partial syntaxial overgrowths around monocrystalline quartz grains which reduced the porosity and resulted in low permeability reservoirs (**Figure 14**). Furthermore, calcite acted as the predominant cementing agent in poikilitopic form and it completely sealed the effective porosity and this resulted in low permeability in Khatatba sandstones reservoirs (**Figure 15**). In addition, kaolinite had blocked the pore throats and resulted in poorly connected pores and thus low permeability reservoirs (**Figure 16**).

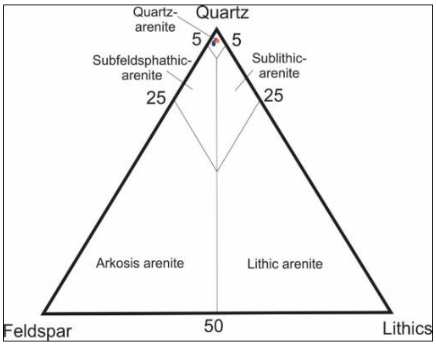

Figure 10: QFL triangular diagram shows the type of Khatatba sandstone classification (Pettijohn et al., 1987).

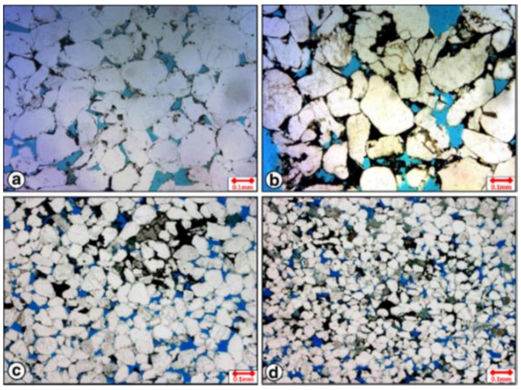

Figure 11: Thin section photomicrographs of Khatatba sandstone: a & b, Coarse-grained quartz with good intergranular porosity (blue colour). c, Medium-grained quartz and well sorted with good intergranular porosity (blue colour). d, Well sorted fine-grained quartz with good intergranular porosity (blue colour). (Shalaby et al., 2014).

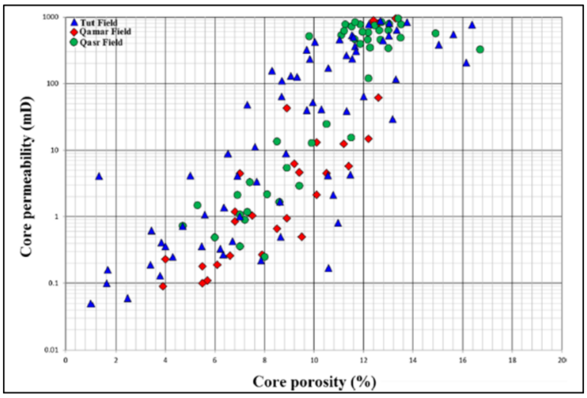

Figure 12: Cross plot of core plug permeability versus porosity of the Khatatba sandstones in three fields, Shoushan Basin, Western Desert (Shalaby et al., 2014).

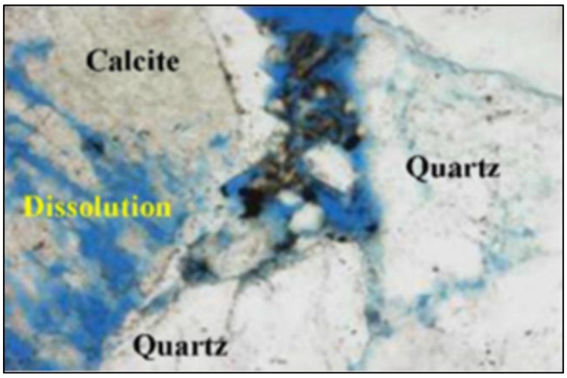

Figure 13: Thin section photomicrographs of sandstones in the Khatatba Formation shows fracturing and dissolution of calcite and quartz (Shalaby et al., 2014).

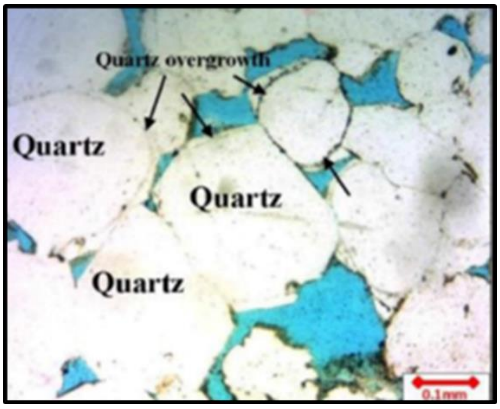

Figure 14: Thin section photomicrographs of sandstones in the Khatatba Formation shows syntaxial quartz overgrowth around monocrystalline quartz grains which reduce porosity and permeability (Shalaby et al., 2014).

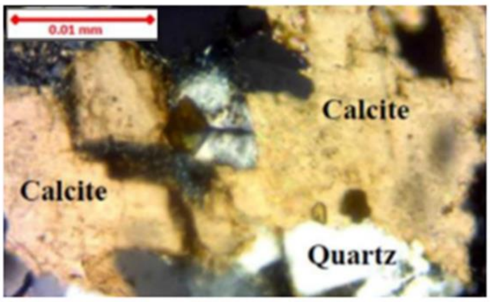

Figure 15: Thin section photomicrographs of sandstones in the Khatatba Formation shows calcite developed in the intergranular pore and blocked the pore spaces (Shalaby et al., 2014).

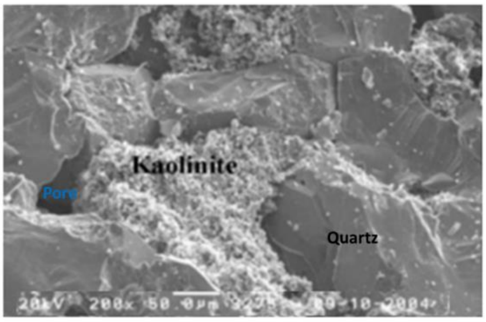

Figure 16: SEM photomicrograph showing intergranular pore occluding clusters of kaolinite between quartz grains (Shalaby et al., 2014).

Upper Safa Member which is one of the four members constituting the Middle Jurassic Khatatba Formation in Shushan Basin in Obaiyed Field consists of mainly shale with two major sandstone reservoir intervals, namely unit A and unit B, which are pay zones for gas production (Abdel-Fattah, 2015). In terms of depositional facies, the reservoirs are interpreted to be composed of fluvial channel sands (unit A) and tidal channel sands (unit B) based on gamma ray curve signatures.

The fluvial channel deposits of unit A are composed of single and multi-story channels and are characterized by a cylindrical, bell-shaped, and smooth or slightly serrated appearance on the gamma ray log. This interval is mainly made up of coarse to fine-grained sandstone at the base with thin beds of siltstone and shale at the top. The unit A exhibits a fining-up sequence. The presence of a characteristically cleaning-down succession in unit A facies indicates channel fill deposits (Rider, 1990; Abdel-Fattah and Slatt, 2013). The well log analysis indicates that the best reservoir characteristics is observed in unit A, which has high porosity, low shale content, good net pay thickness, and low water saturation (**Figure 19**). **Figures 17 and 18** show different architectural channel fill elements of unit A. These elements have cylindrical, bell-shaped, and smooth or slightly serrated appearance on the gamma-ray log (Cant, 1992).

Their sharp bases indicate generally downcutting into clay or silt-rich floodplain sediments (Juhász et al., 2004). Gamma ray log shapes record the presence of two types of channels: single-story and multi-story. Single-story channels are expressed as a cylindrical-shaped signature with a sharp base and a slightly fining-upward trend towards the top **(Figure 17 and 18**). Multi-story channels are expressed as a boxcar or cylindrical shape (rarely irregular) with thinner individual sandstone bodies and fining-upward trends. The slightly fining-upward trend in the uppermost parts of motifs, the presence of isolated sand bodies within thick overbank fine units, and the sharp erosional basal contact are all characteristics of a single-story channel. Multi-story channels are identified by their rather thinner individual signatures and by their superimposed nature on each other, with small thicknesses of fine-grained material between (Juhász et al., 2004).

Unit B is composed of tidal channel deposits, which are characterized by a generally irregular-shaped gamma ray log motif. It is composed of thinly interbedded siltstone and fine-grained sandstone. In such environments, reservoir quality is driven by the amount of sand within the channel fill. As the sand content increases and the shale content decreases, the porosity and permeability increase. Facies of unit B is generally characterized by irregularly shaped motif in the gamma-ray logs (**Figure 17 and 18**). The thick irregular-shaped motif in the gamma ray log, with erosional top and intervening fine-grained sandstone and siltstone signature, indicates floodplain deposits (Cant, 1992). The irregular shape of the gamma ray log curve is due to presence of interbedded mudstone and sandstone (Cant, 1992). An irregular-shaped log with gamma ray value increasing upwards to a lower value indicates increasing clay content. This type of sandstone is characteristics of the tidal channel in the delta plain. The productivity of these reservoirs is quite poor, and the main reason attributed for the poor performance is due to poor reservoir properties (**Figure 20**).

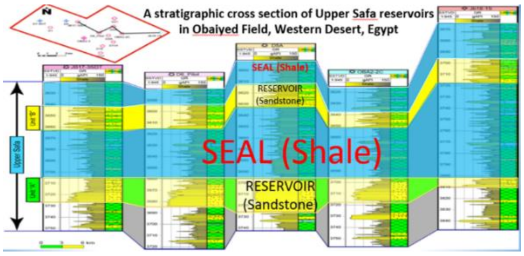

Figure 17: A stratigraphic cross section showing the Upper Safa reservoirs (unit A and unit B) in Obaiyed Field, Western Desert, Egypt (Abdel-Fattah, 2015).

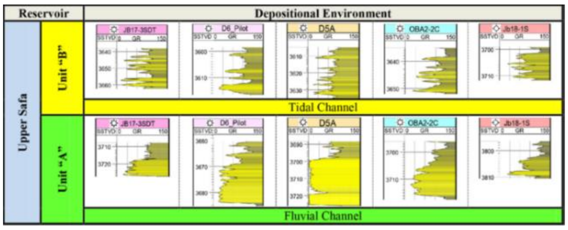

Figure 18: The gamma ray log and depositional environments of the Upper Safa reservoirs (unit A and unit B) (Abdel-Fattah, 2015).

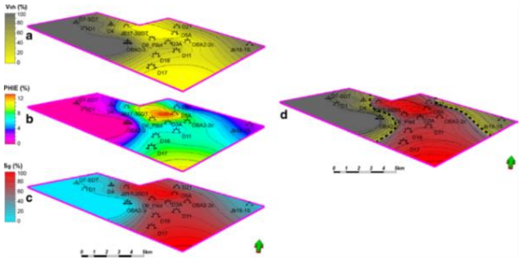

Figure 19: Iso-parametric maps of the Upper Safa reservoirs (unit A) from well data analysis showing lateral variations in petrophysical characteristics: a shale volume (Vsh), b effective porosity (PHIE), c gas saturation (Sg), and d cutoff area (shale volume <40 %, effective porosity >6 %, and gas saturation >40 %) (Abdel-Fattah, 2015).

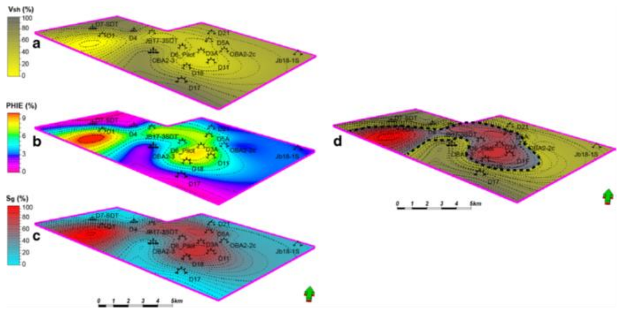

Figure 20: Iso-parametric maps of the Upper Safa reservoirs (unit B) from well data analysis, showing lateral variations in petrophysical characteristics: a shale volume (Vsh), b effective porosity (PHIE), c gas saturation (Sg), and d cutoff area (shale volume <40 %, effective porosity >6 %, and gas saturation >40 %) (Abdel-Fattah, 2015).

3.3 Seal Rock

The carbonate rocks of the Masajid Formation within these overburden rocks act as regional top seals for Khatatba-Khatatba (!) petroleum system in the basin (Shalaby et al., 2014). The interbedded shale beds within the Khatatba Formation serve as good local top seals (**Figure 17**).

3.4 Overburden

The overburden rock of Khatatba-Khatatba (!) petroleum system included the successions that overlie the Khatatba source rock formed from Upper Jurassic time to Tertiary time.

3.5 Traps

The structural traps of Khatatba-Khatatba (!) petroleum system formed during Late Cretaceous to Early Miocene consist of the inverted hanging walls of tilted blocks and folds related to the inversion of these former half-grabens. However, stratigraphic traps are possible to exist in Khatatba Formation as proposed Khatatba Formation consisted of fluvial channel deposits and tidal channel deposits (**Figure 17**) (Abdel-Fatteh, 2015).

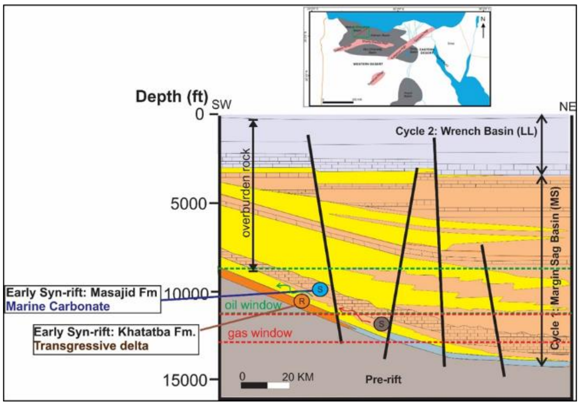

Figure 21: Schematic northwest–southeast geo-seismic cross section showing petroleum system elements and process across Shoushan Basin (Shalaby et al., 2014).

3.6 Generation- Migration – Accumulation

Khatatba Formation entered the oil window during Late Cretaceous to Eocene times while at the present time it lies within the gas window (El Nady, 2013). The models (**Figure 22**) show the onset of the oil window (corresponding to 0.50–0.60 %Ro) of the Khatatba source rocks occurred during the Late Cretaceous (95–75 Ma). Hence, the generation and migration of Khatatba Formation started in the Late Cretaceous (95–90 Ma) and continued to the present (Shalaby et al., 2014). The Khatatba source rock reached the main oil window at the end of the Late Cretaceous, and the gas window occurred in the Tertiary. However, accumulation of hydrocarbon (mainly gas) started after Late Cretaceous when trap was formed due to Syrian Arc Inversion is preserved until today.

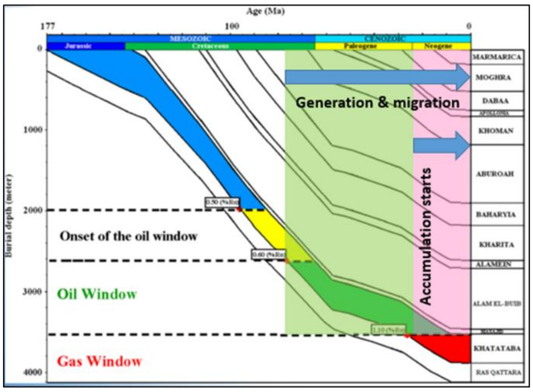

Figure 22: Burial history curves with hydrocarbon generation zone for the Khatatba Formation in Shams Field, Shoushan Basin (Shalaby et al., 2011).

Primary hydrocarbon migrated from the Khatatba source rock to Khatatba sandstones via microfracture pathways as a result of overpressure was due to hydrocarbon generation. Secondary migration of hydrocarbon was from the active Khatatba source rock and it accumulated at shallower traps via vertical migration pathways through faults and carrier beds (**Figure 21**). The critical moment of the system (**Figure 23**) is during Middle Miocene, when no major tectonic and stratigraphic changes occurred after this moment.

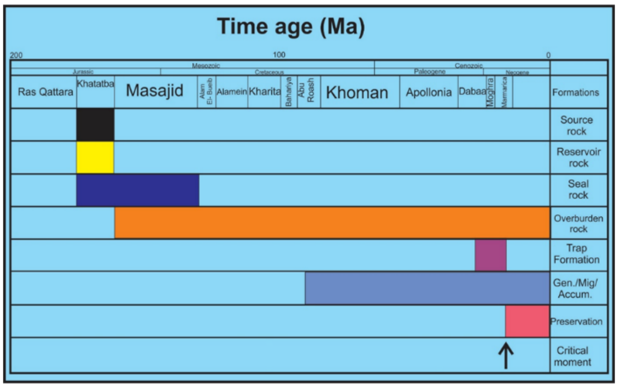

Figure 23: Events chart of the Khatatba-Khatatba (!) petroleum system in the Shoushan Basin showing the essential elements and processes (generation, migration and accumulation).

4. OPPORTUNITIES AND CHALLENGES FOR HYDROCARBON EXPLORATION

4.1 Opportunities

4.1.1 *Structural Play: Inversion structure*

Exploration or development in the Western Desert can target on inversion structures and fault traps. However, petroleum system study in new prospects basin must be analyzed due to the uniqueness of every basin. Inversion events may also cause tertiary migration. At the faulted trap, fluid might spill at spill point under several conditions as introduced` included juxtaposition spill point, gouge failure spill point or filled to seal capacity and lead to leakage or tertiary migration (Sales, 1997). These spill points are known as "Cryptic" spill points which cannot be seen on seismic or reconstructed from the structural/stratigraphic framework of the trap.

There are several proven inversion structures which contain hydrocarbon including Razzak Inversion Structure, Mubarak Anticline and Kattaniya High (Bevan and Moustafa, 2012). In Kattaniya High case (**Figure 24**), inversion resulted in the formation of inverted hanging wall half-graben anticline which created a closed structure for hydrocarbon accumulation. However, inversion may cause hanging wall anticline reservoir to become breached and source-rocks "switch off" from oil window to shallower depth.

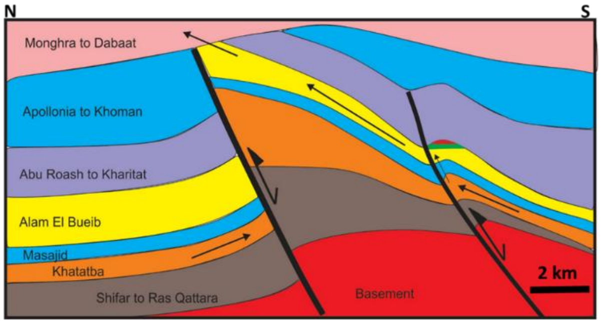

Figure 24: Inversion structure and fault trap of Kattaniya High (Bevan and Moustafa, 2012).

4.1.2 Stratigraphic Play: Facies changes (pinch out) and isolated sand bodies (channel)

Since the reservoirs of Khatatba Formation are interpreted to be composed of channel sands, the trend of channels reservoir sand bodies is expected to be perpendicular to the shoreline and it thins laterally away from channel axis. Furthermore, the individual channels may be separated by floodplain mudstone. This reservoir is expected to have good horizontal flow properties but limited vertical flow between beds due to individual channel was separated by floodplain mudstone horizon. In addition, meandering channel may result in the formation of point bar. Point bars of meandering channel could form lateral accretion which contains mud-draped surfaces which can be barriers baffles or barriers to fluid flow (Pranter et al., 2007). Hence, waterflooding should be parallel to the baffles/barriers in the point bar sandstone which has the highest sweep efficiency.

4.2 Challenges

4.2.1 Drilling Issue

Drilling issue might occur when penetrating carbonate section above the target reservoir such as Masajid Formation. Masajid formation was karstified during Late Jurassic due to tectonic uplift of Jurassic succession (Keeley et al., 1990; Keeley and Wallis, 1991) and may lead to large or even total losses during drilling. These voids are usually localised and their geometry and patterns are hard to predict. Hence, it is important to design drilling path away from voids and fracture, and remedial measures are needed to be ready for countering mud losses when drilling wells or using non-conventional drilling technique such as Pressurized Mud Cap Drilling (PMCD). Furthermore, wellsite geologist should also be aware during drilling operation through carbonate section.

5. CONCLUSION/RECOMMENDATION

Three main petroleum system types were recognized in Shoushan Basin and their classification were related to phases of basin evolution. They are Early syn-rift transgressive deltaic Petroleum System Type (Khatatba Formation), Late syn-rift transgressive deltaic Petroleum System Type (Alam El-Bueib Member) and Post-rift Sag Shallow Marine Petroleum System Type (Abu Roash-G Member). There is a proven petroleum system which has been identified in Shoushan Basin named as Khatatba-Khatatba (!) petroleum system. Opportunities for hydrocarbon exploration in Shoushan Basin are structural play and stratigraphic play while the challenge could be the mud losses issue while penetrating carbonate sections.

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