Sidi Rahman Oil Discovery in Egypt A Big Exploration Step in an Area of Lost Interest

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REVIEW

Converting an unattractive area, including numerous failed wells, into an oil attractive area is the challenge facing exploration when applying for an acreage previously relinquished by others, and finally achieving new hydrocarbon reserves. Since the first discovery during World War I (WWI), numerous oil fields were discovered in Egypt but none of them was found along the 1 200 km Mediterranean coastal strip, leaving the area unattractive for exploration. To build a new conceptual geomodel, not applied before, was imperative on the road to success. A small commitment for the first exploration phase of East Yidma Concession has triggered the needs to focus on a restricted area. Despite scarcity of data, a petroleum model has been reached. The presence of tough obstacles, including WWII mine fields and tourist sites along the coast, did not change the decision to focus on northwestern part of the concession. Poor seismic data and coverage was the reason to acquire seismic survey with a specific design, whose final results supported and updated the previously achieved petroleum model. High importance was given to evaluation of two completely separated plays with maximum elevation difference. Drazia-1 well was selected to test a deep rift-trough while Sidi Rahman-1, positioned on a tail of an old seismic line, aimed to penetrate a high stand structural ridge. Despite the results of conventional techniques and some non-conventional tools as acoustic spectroscopy that identified Sidi Rahman area as of low probability, it was decided to test the location. Drazia-1 proved oil accumulation down to 3 901 m (12 800 ft) in Barremian reservoir, while Sidi Rahman-1 tested the shallowest known oil at 1 914 m (6 280 ft) in Lower Cenomanian sandstone and 7 pay-zones down to 3 840 m (12 600 ft). The recent discoveries of INA re-triggered the interest and attracted international companies to invest in Egypt's Mediterranean coastal strip.

Key words: Egypt, Jurassic Rifting, Oil Exploration, Western Desert

1. INTRODUCTION

East Yidma Concession is located in the North Western Desert of Egypt (Fig. 1), with northern boundary facing the Mediterranean coastal line. The block was announced by the Egyptian General Petroleum Corporation "EGPC" during the International 2002 Bid Round, in its original acreage of 1 358 km². It is situated in the main trough of the Alamein Basin, which charged the hydrocarbons to the SW-Alamein-Razzak ridge (Fig. 1), with very favorable conditions regarding national pipelines network and El Hamra Terminal existence (Fig. 1) to facilitate future production. Nevertheless, international oil companies showed no interest to submit their offers for the block. Despite the fact that numerous oil fields have been discovered in Egypt since the first discovery during WWI, none of them was found along the 1 200 km Mediterranean coastal strip, making the area unattractive for exploration. Four companies (Phillips, Wepco, Kriti and Gharib) have explored different parts of East Yidma Block since the early 60s. This exploration has resulted with 1 600 km of 2D seismic profiles and four exploratory wells, mainly drilled off-structures and Plug & Abandon (P&A) as dry wells. Coeval with this, there were a lot of successes and hydrocarbon discoveries along Alamein-Razzak ridge, with almost constant oil-water contact (2 440 – 2 745 m), which is higher than the expected depth of the known reservoirs over East Yidma

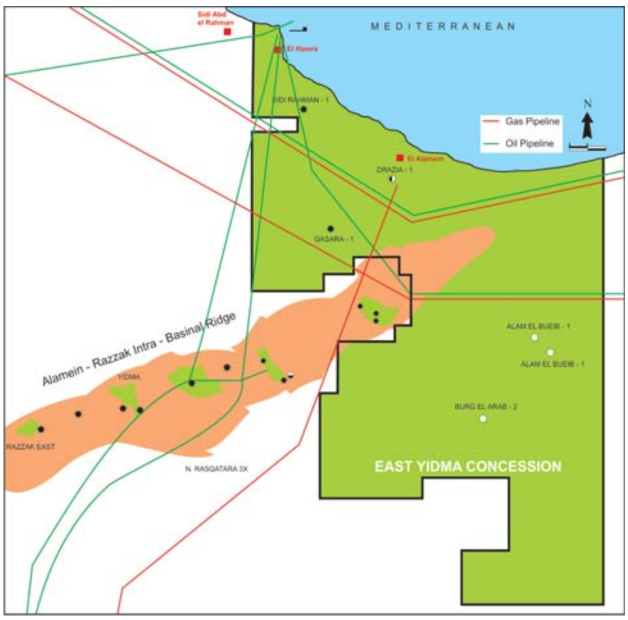

Fig. 1. Location map of East Yidma Concession, Western Desert - Egypt
Sl. 1. Lokacijska karta koncesije East Yidma, Zapadna pustinja - Egipat

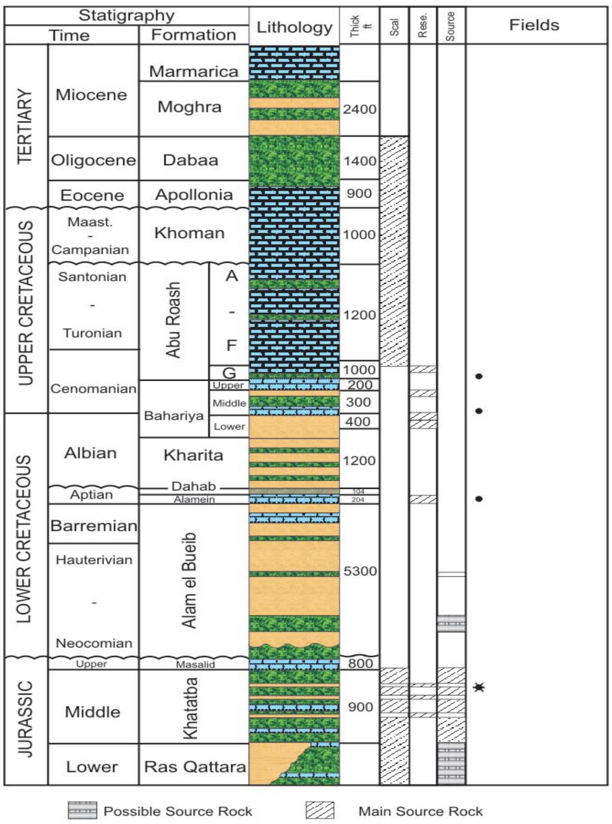

Fig. 2. General stratigraphic course of Western Desert -Egypt
Sl. 2. Generalni geološki stup Zapadne pustinje -Egipat

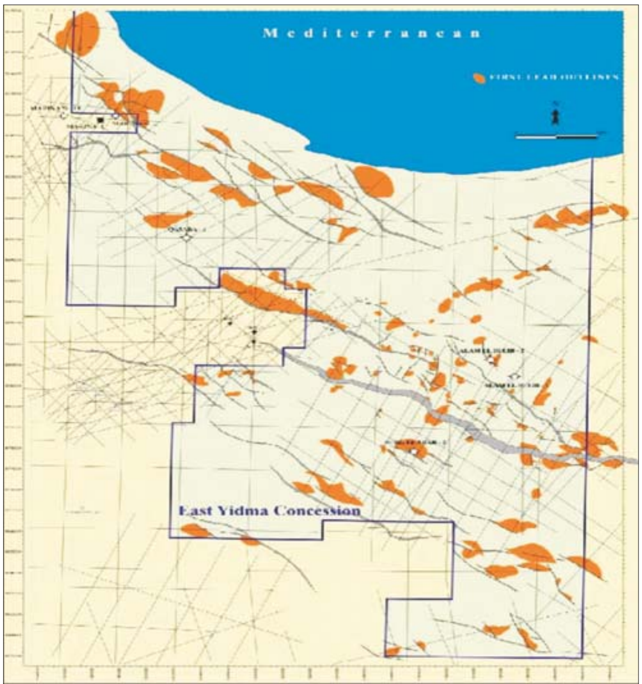

Fig. 3. First lead inventory based on old seismic vintages
Sl. 3. Prvi popis potencijalnih lokacija na osnovi starih seizmičkih podataka

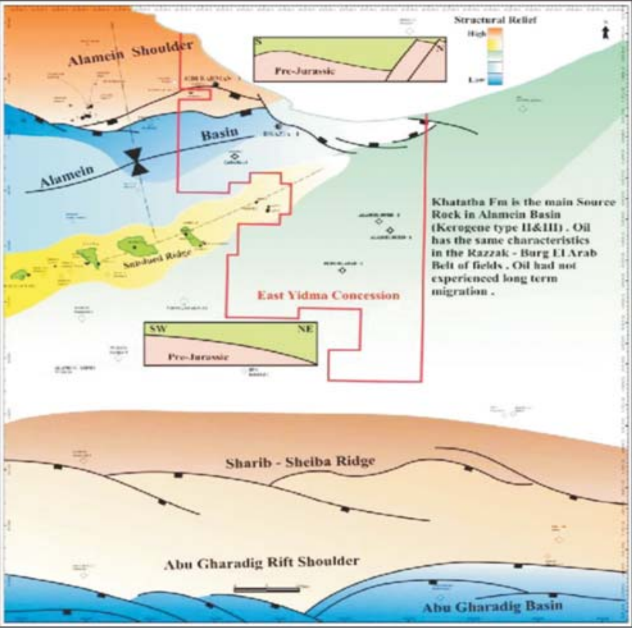

Fig. 4. Basinal segments and possible relief during the Jurassic time of rifting (Lines of schematic profiles are shown as doted lines)
Sl. 4. Bazenski dijelovi i mogući reljef u vrijeme jurske riftne faze (Linije shematskih profila prikazane su točkasto)

Block. This addressed a strong belief that the concession is the oil kitchen and the migration pathways bypassed the area, carrying the hydrocarbons beyond the concession. Basin as a kitchen and without traps?! It was a non-convincing way of approach. Differential basinal subsidence and subsequent tectonic phases should produce variable structural relief, especially if faulting played the main role as a rift-based model. New approach that has never been applied before was imperative to overcome the strongly established ideas; based on conceptual geomodel that the area hosts a thick mature source rock of the Middle Jurassic Khatatba Formation, preliminary work has been done to identify structural closures overlying the Jurassic-Lower Cretaceous Basin. Reservoir levels in the complete stratigraphic column from Cenomanian to Neocomian were regarded as possible pay intervals (Fig. 2), which can be fed by vertical and lateral migration, along fault conduits. After final assumption that structural shape was reached before hydrocarbon expulsion and favorable sealing conditions as a position of fault activity and proper juxtaposition, INA-NAFTAPLIN, as Operator, and RWE-Dea as Partner, submitted their offer to bid for the Concession. On April 16, 2003, EGPC declared INA and RWE's offer as the winning offer and East Yidma Concession was awarded to INA.

2. ON THE ROAD TO SUCCESS

At the time when INA was awarded the concession as Operator for the block, the available geological database was found of very poor quality and insufficient for routine approach. The concession was covered by 1 600 km of 2D seismic lines, with just 1 200 km lines available in seismic database. They are of poor to good quality, acquired in 13 vintages from 1969 to 1992, with different datum and replacement velocities and concentration of the lines around the four drilled wells, leaving the remaining parts of concession area completely uncovered. Preliminary interpretation of these old vintage seismic data resulted in the first lead outlines confirming abundance of possible closures in concession area (Fig. 3). However, the small commitment for the First Exploration Phase of just 150 km of 2D seismic lines triggered the needs to focus on a restricted area, with possible hydrocarbon potentials. A geomodel animating the relief architecture of the area during sedimentation of the Jurassic sequences and the hosted main source rocks in the northern Western Desert has been postulated. The reached model shows the northern rim of the concession, which faces the Mediterranean, as a stand-up high during the Jurassic Tethyan rifting (Fig. 4). At this stage of modeling and lacking a good database, it was a conceptual way to image the coastal strip as a rift-shoulder facing to the south the Jurassic Basin. This reversal image with recent geography was explained as an existence of asymmetric half-graben basin with southward dip polarity. Although the main fault dip polarity of the equivalent rift-basins in Egypt is due north,[1] southward fault-facing basins are also existing. Despite the rift shoulder's lack of source rock potentiality, the structural traps on its margin-edge with the basin have a good chance to be charged through the short-distance from the basin-side as a first trap-door.

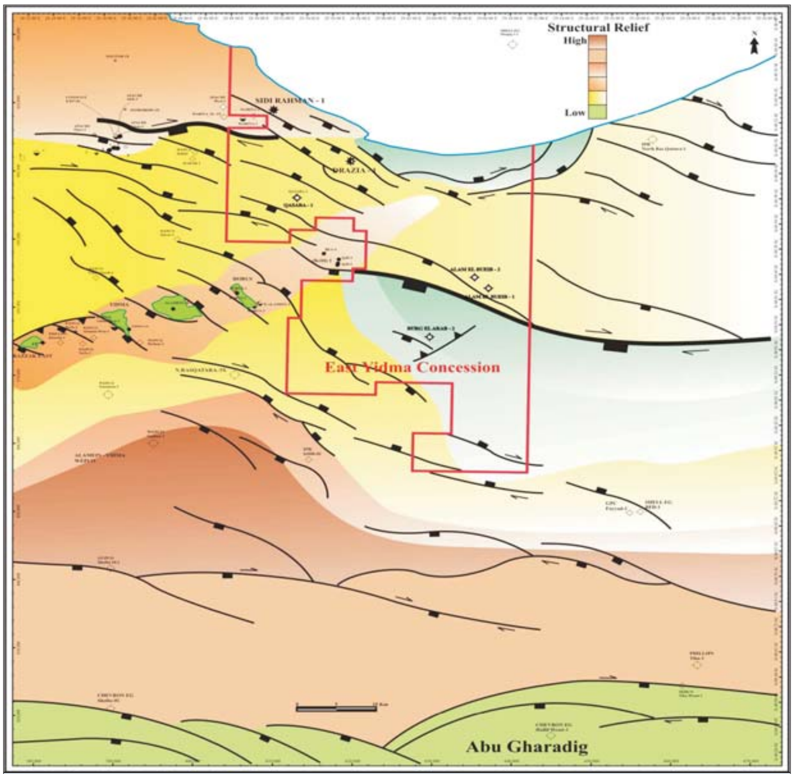

Fig. 5. Presentation of Late Cretaceous tectonic elements and main fault corridors for hydrocarbon migration
Sl. 5. Prikaz kasnokrednih tektonskih elemenata i glavnih rasjednih koridora za migraciju ugljikovodika

The shoulder faces due south the main trough of what is called Alamein Basin. The basin relief was roughly shallowing due south and keeping northward divergent sedimentary wedging (Fig. 4). This addresses the main role of the roughly E-W trending fault system, delimiting the rift shoulder, as the main tectonic element during the Alamein Jurassic basin development.

Divergent-sedimentary wedging toward the rift-shoulder faults stresses the main role of tectonic subsidence during rift development that exceeds sedimentation rate. General southward thinning of Jurassic sediments was interrupted by an ENE- trending ridge (Fig. 4). This intra-basinal ridge separated the basin into two rift segments. High source rock potentiality was expected for the northern rift segment, where thick Jurassic sediment accumulation occurs. Structural traps were formed during Senonian.[9,10] This required building of another model layer to see the concession area during this tectonic phase, which was dominated by WNW-transtensional faults, NW-extensional faults and NE-local thrusts (Fig. 5). During this phase, the Jurassic shoulder and intra-basinal ridge stood-up

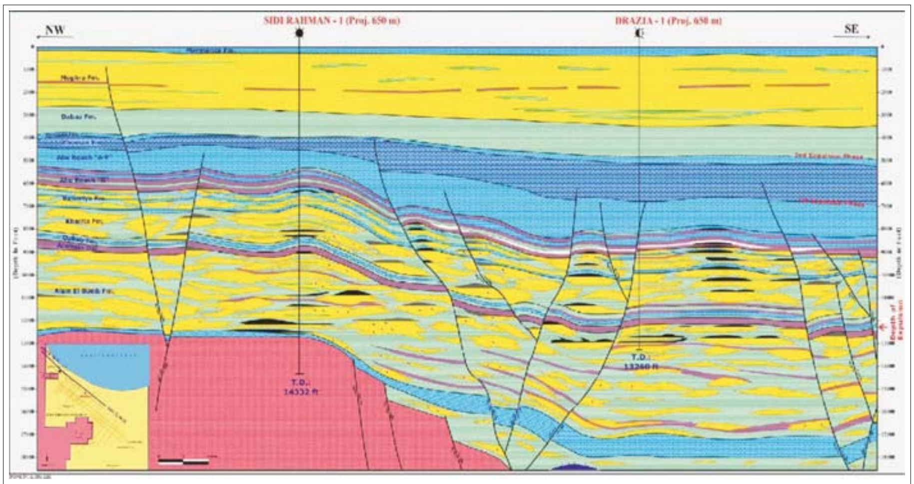

Fig. 6. NW-SE geological cross section (based on seismic lines 0402 Ij 38-32 & Ij 38-31 & well data)
Sl. 6. Geološki poprečni profil sjeverozapad - jugoistok (na osnovi seizmičkih profila 0402 Ij 38-32 & Ij 38-31 i podataka bušenja)

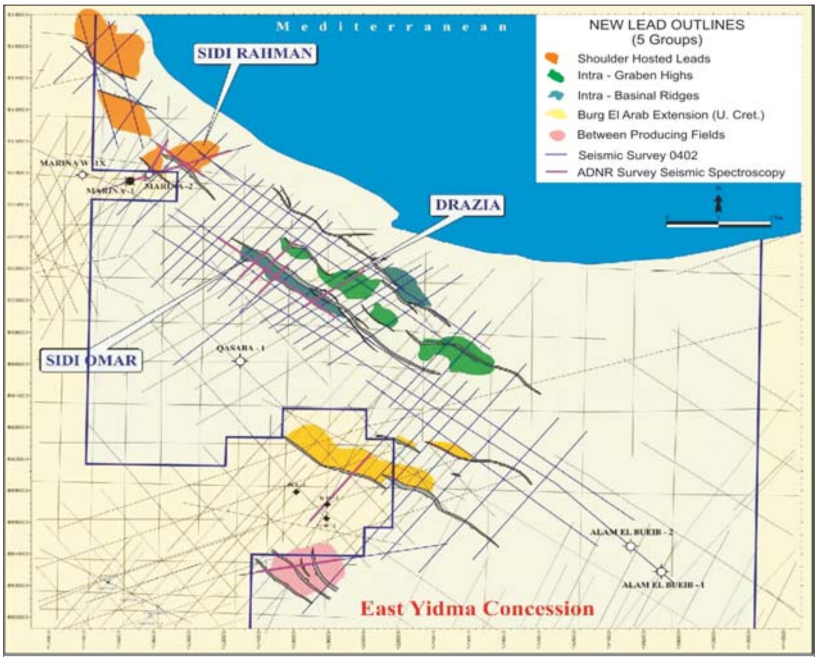

Fig. 7. Final lead inventory after acquiring new 2D seismic
Sl. 7. Konačni popis izglednih lokacija poslije snimanja 2D seizmike

as highs. On the contrary, two local deeps were postulated in reflection to displacement on two WNW and E-W curvilinear master faults. These newly developed deeps kept the northeastern and central eastern parts of concession areas as low-stand. Domination of NW and WNW-trending faults with extensional-transtensional regimes and their existence sub-perpendicular to the main Jurassic trough- axis gave access for migratory paths in lateral and vertical directions. These fault corridors were imaged as the main hydrocarbon carriers for charging the Jurassic rift-shoulder hosted leads, intra-basinal hosted leads and other structural highs within the northern Jurassic basinal segment. This charging concept concurs with the existence of several old discoveries along the intra- basinal ridge. This ridge was activated during Senonian tectonics as strike-slip belt hosting en echelon anticlines of the oil fields and it plunges due ENE within the Alamein Basin (Fig. 5). Within the scope of limited budget for the 2D seismic program, the exploration effort in the first phase was given to the northern half of the concession. The area encompasses possible extension of the intra-basinal ridge oil fields, basin-shoulder hosted highs and northern rift segment, with thick Jurassic accumulation of sediments and possible existence of other petroleum elements like good quality reservoirs, favorable timing of hydrocarbon expulsion and migration with proper sealing conditions (Fig. 6).

Insufficient and scattered seismic data triggered all exploration efforts, which were at this stage directed towards achieving specific design for a new seismic program. The presence of tough obstacles, including mine fields area that witnessed the Alamein Battle of WWII, quarries, coastal resorts, archeological heritage and environmentally protected areas, could not change the decision to focus activities on the northwestern part of concession. After a few modifications, sometimes even encountering unpredictable problems in the field, the final layout of 465 km of 2D seismic lines was brought up (Fig. 7). Prior to the main acquisition activity, the Egyptian Armed Forces have carried out mine clearance with the aim to deliver safe corridors for human resources and equipment required for operations.

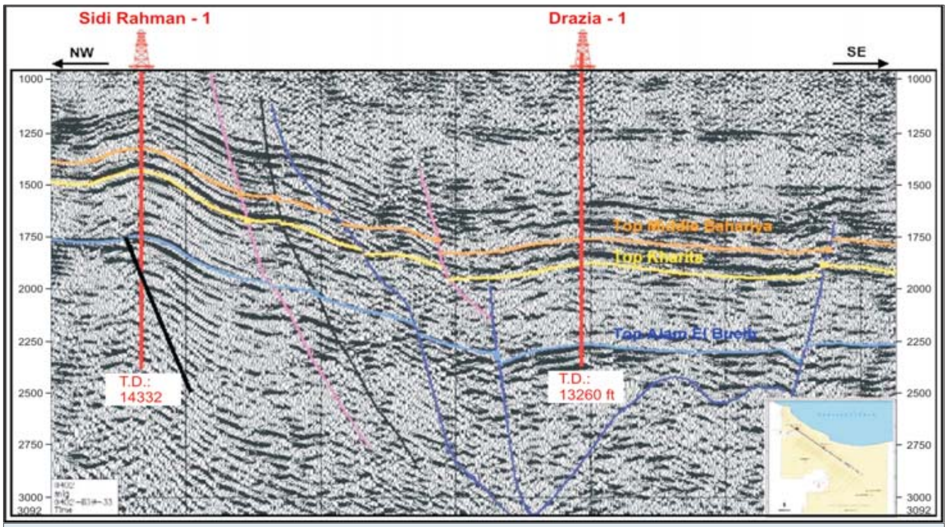

Fig. 8. Seismic line shows folding and thrusting in rift-shoulder (Sidi Rahman-1), against transtensional and extensional faulting in the basin (Drazia-1)
Sl. 8. Seizmički profil pokazuje boranje i navlačenje u rubnom dijelu rifta (Sidi Rahman-1), nasuprot divergentnom i ekstenzijskom rasjedanju u bazenu (Drazia-1)

Compagnie Generale de Geophysique (CGG) acquired 39 seismic lines of 465 km using mainly vibrators and, in sabkha areas, explosives as a source of energy. The newly acquired seismic data helped in understanding the area, where the typical asymmetric rift basin is delineated with its northern rift shoulder. Several structural traps were identified within the basin as intra-basinal ridges and doubly plunging anticlines. In addition, several traps were formed on the shoulder by interference of flexural- bending of the rift margin and strike-slip regime (Fig. 8).

Consequently, all exploration efforts during prospect generation were directed to evaluate two completely different and

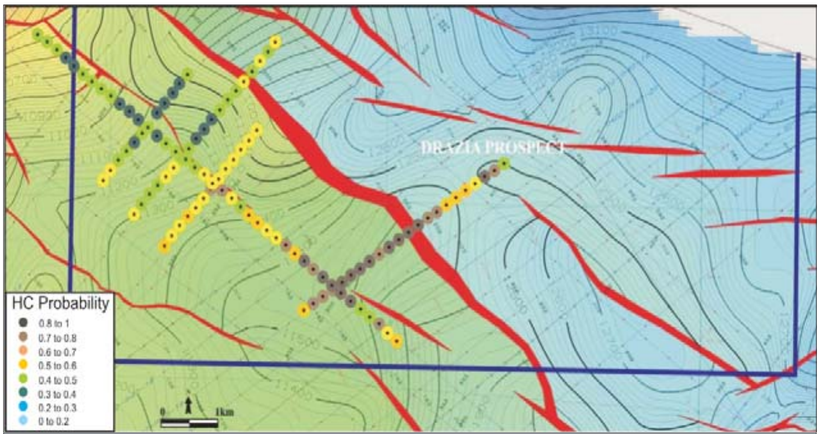

Fig. 9. Top Alam El Bueib depth map & probability of success based on acoustic spectroscopy
Sl. 9. Strukturna karta po krovini formacije Alam El Bueib i vjerojatnost uspjeha na osnovi akustičke spektroskopije

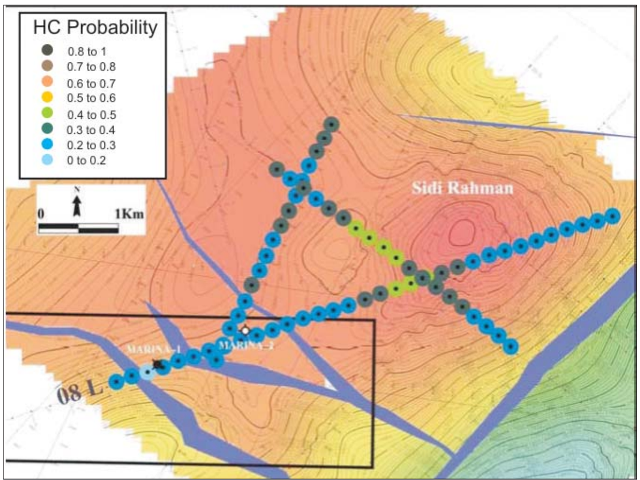

Fig. 10. Top Jurassic depth map & probability of success based on acoustic spectroscopy
Sl. 10. Strukturna karta po krovini jurskih stijena i vjerojatnosti uspjeha na osnovi akustičke spektroskopije

separated plays. Although prospect ranking is routinely based on geological and geophysical evaluation, it was decided to incorporate a new tool for hydrocarbon reservoir detection, using acoustic/seismic spectroscopy method.[8] This technology uses the naturally occurring broadband seismic signal at the surface to locate the occurrence and define the lateral distribution of hydrocarbon. The survey was acquired by ADNR Exploration GmbH, after selecting certain profiles across the leads in order to test the accumulation possibility and cross-check the postulated accumulation risk. A total of 229 data points was recorded on specific shot points of the acquired 2D seismic survey. Several of them were cited on producing and dry well locations, with the purpose of calibration and hydrocarbon net pay thickness prediction. Analyzed data points with probability ratio of hydrocarbon accumulation were posted on structural maps and geoseismic sections in order to establish the relation between geology and survey results. Simultaneously, and with the aim to respect the already established concept and to test the different plays, two possible drilling locations were chosen based on conventional seismic interpretation. One was to test a deep rift-trough and the other was positioned on the tail of an old seismic line to penetrate the high stand structural rift shoulder. The Acoustic Spectroscopy Survey has independently confirmed high probability for hydrocarbon accumulation on intra graben prospect that would become Drazia prospect (Fig. 9). Contrary to this, low probability results over the Sidi Rahman prospect, on high stand shoulder (Fig. 10) were not in complete agreement with exploration evaluation.

Despite the results that identified Sidi Rahman prospect as of low probability and several unsuccessful neighboring wells, it was decided that the two commitment exploratory wells of the first exploration phase should be Drazia-1 and Sidi Rahman-1.

Drazia-1 was spudded as the first well reaching the final depth of 4 056 m (13 308 ft) in Neocomian-Barremian Alam El Bueib Formation. Hydrocarbon shows were encountered while drilling Bahariya, Kharita, Dahab, Alamein Dolomite and Alam El Bueib formations and they were associated with high gas readings, from C1 to nC5. Petrophysical analysis has indicated good reservoir characteristics for shallow targets, as well as for Alam El Bueib Formation as deep target. Four intervals were found to be hydrocarbon bearing within Alam Al Bueib, proved by Reservoir Description Tool (RDT) samples that recovered gas and condensate with different API (40°-50°) and present down to 3 954 m (12 972 ft). Three hydrocarbon bearing intervals (3 943 – 3 950 m, 3 910.5 – 3 911.2 m and 3 865.8 – 3 869.7 m) were selected for further evaluation by Drill Stem Test (DST) in the near future. Post drilling reinterpretation revealed differences in structural shape for the mapped horizons that are attributed to 2D seismic uncertainties caused by poor seismic coverage. The planned 3D seismic acquisition will help in better defining the image of structure architecture and open prospectivity potential to any valid structure, from the deepest to the highest points in the area.

Sidi Rahman-1 well is the second commitment well drilled in East Yidma Concession, with the aim of testing completely different play than Drazia-1 well. Sidi Rahman-1 was bottomed within the Pre-Cambrian basement, reaching the final depth of 4 384 m (14 383 ft). Oil shows, associated with high gas readings, were encountered while drilling Bahariya, Kharita and Alam El Bueib sandstones.

Petrophysical interpretation indicated good porosity and oil saturation within Bahariya and Kharita formations, which was confirmed by Side Wall Cores (SWC) and Reservoir Description Tool (RDT).

Several intervals of Alam El Bueib Formation indicated existence of oil saturation, but with low porosity and permeability.

Four DST operations were performed on Sidi Rahman-1 well. Alam El Bueib section (2 806.6 - 2 809 m) was the first tested interval. Total liquid volume of 4.61 m^3 (29 bbl), consisting of oil, mud filtrate and brine water, was obtained from the reservoir.

Build up pressure did not reach radial flow, and it was not possible to calculate reservoir parameters. Therefore, the test was considered as non-conclusive and unreliable.

The second DST was conducted over interval (2 546.9 – 2 548.7 m), in Kharita Formation, with average rate on choke 32/64", 508 m^3/d (3 195 bbl/d) of 49.1° API and 5% water cut. M. Bahariya interval (1 915.4 – 1 918.4 m) (DST-3) recovered 209 m^3/d (1 314 bbl/d) with 0.2% water cut.

The last DST-4 operation was performed during well completion. On choke 20/64", the well was flowing 167 m^3/d (1 050 bbl/d), with 48.4° API and no water cut. Sidi Rahman-1 tested the shallowest known oil at 6 284 ft and seven pay-zones down to 12 600 ft in the coastal area where only tails of seismic surveys exist, leaving the exploration teams of petroleum companies in a gray medium.

In November 1942, the German Army was defeated in two crucial battles and this determined the outcome of WWII. The battles of Stalingrad and Alamein made it impossible for the Germans to conquer oil fields with sufficient quantities of petroleum to keep their warfare protected and the fuel supply of their armored divisions undisturbed. At the outset of the crucial battle of Alamein, the fuel reserves of the German African Corps were practically zero. Until the end of the war, all operations were carried out under conditions of constant shortages of fuel for the armored units. Today, more than sixty years after, INA knows that oil lies beneath the Alamein fields of death. Thousands had died in the struggle to find and conquer some remote oil fields. Fortunately, they did not have a geological concept or the world might have looked very different today.

Following the winding road in search for success, INA Egypt Exploration Team has turned the "unattractive" coastal strip to INA's Development Lease.

3. CONCLUSION

Mediterranean coastal strip of Egypt, covered with poor seismic data where only tails of seismic lines exist, hindered the geoscientists to reveal its secrets for a long time. New conceptual way of thinking imaged this coastal area as a flexural-bend shoulder of a south dip polarity basin. The shoulder stood up high during most of basin life history and started to receive starved sediments during latest Jurassic while rift basin was continuously subsided. Late Cretaceous tectonics was influenced by the basin shoulder structural and lithologic anisotropy. Shoulder was shaped by transpressional regime of thrusting and doubly plunging anticlines. Basin-ward, transtensional regime formed corridors for hydrocarbon migration through the NW and WNW extensional and transtensional faults. This optimal petroleum system environment finally revealed its secrets and brought the new INA discoveries. Sixty years after WWII oil started to flow from beneath the mine fields and war remnants. The newly announced petroleum province on map of Egypt attracted other international oil companies to invest in the area aiming to change the name of "Alamein garden of evil" to "Garden of wellheads".

4. REFERENCES

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