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Application of Seismic Data Interpretation and Well Log Analysis for Evaluation of Matulla Formation, South Abu Zenima Oil Field, Gulf of Suez, Egypt.

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ABSTRACT

The objective of this study is to conduct a comprehensive geophysical evaluation of oil potential within the Late Cretaceous Matulla Formation in the Abu Zenima oil field using well logs and seismic data interpretation. The geophysical interpretation made use of a Pre-Stack Depth Migration (PSDM) seismic volume with 10 seismic lines covering the study area. Using PETREL software, a structural contour map was created for the top of Matulla Formation, revealing the existence of NW-SE normal faults. These faults play a crucial role in creating structural traps that are ideal for storing the hydrocarbon.

IP software was used to evaluate the petrophysical properties of four wells in the Matulla Formation. Based on this evaluation, isoparametric maps for gross thickness, shale volume, net reservoir, net/gross ratio, net pay, water saturation, and hydrocarbon saturation were developed and merged into the structural map. These maps are concentrated on the eastern side of the field due to the location of the provided wells.

Good net reservoir thickness (between 15 and 60 meters), a fair to good net/gross ratio (between 12% and 54%), shale volume (between 5% and 30%), good effective porosity (between 11% and 16%), high water saturation (between 50% and 100%), and hydrocarbon saturation (between 0% and 50%) are all displayed from the evaluation of Matulla reservoir. The maps suggest focusing on the southeast part of the area for more possible development locations. Furthermore, there are other possible exploration locations, especially in the upthrown block of the main producing block and the west blocks, based on the structural setting.

KEYWORD: Seismic Interpretation, Well log Analysis, Gulf of Suez Egypt.

INTRODUCTION

Due to its current production of over 85% of Egypt's total petroleum production, the Gulf of Suez has experienced intense activity in oil exploration (Alsharhan, 2003; Younes and McClay, 2002). Hydrocarbon exploration in the Gulf of Suez, Egypt, for more than 50 years has produced several major oil fields discoveries, such as Belayim 2.3 billion STB, Morgan more than one billion STB, and the fields of July and October more than 700 MSTB (Awni et al., 1990).

A good reservoir is found in the Matulla Formation, which is situated on the western side of Sinai and in the southern, central, and eastern parts of the Gulf of Suez. It is formed up of ferruginous sandstone interbeds with a poor to fair flow zone indication, very good to excellent permeability, and good to excellent porosity. The Coniacian-Santonian deposits of the Matulla Formation, which are characterized by a range of lithologies, lateral facies, and thickness variations as well as reservoir variations throughout the Gulf of Suez basin, are included in the Nezzazat Group. Several researchers have studied the sedimentology, palaeontology, depositional conditions, and structural setting of these deposits.

Location of the Study area

The studied area is located in the offshore central part of theGulf of Suez between longitudes: 33°7'24" E and 33°8'24" E and latitudes: 28°53'12" N and 28°54'47" N, South Abu Zenima Oil Field originally covered an area of about 150 km2 in a water depth of maximal 33 m. The field lies to the south of Abu Zenima city by about 6 km and to the west of Abu Rudies city by about 4.5 km (Fig. 1). surrounded by the producing Ras Budran development area in the east, Abu Rudies and Sidri oil field in the south east and by October, North October oil fields in the west.

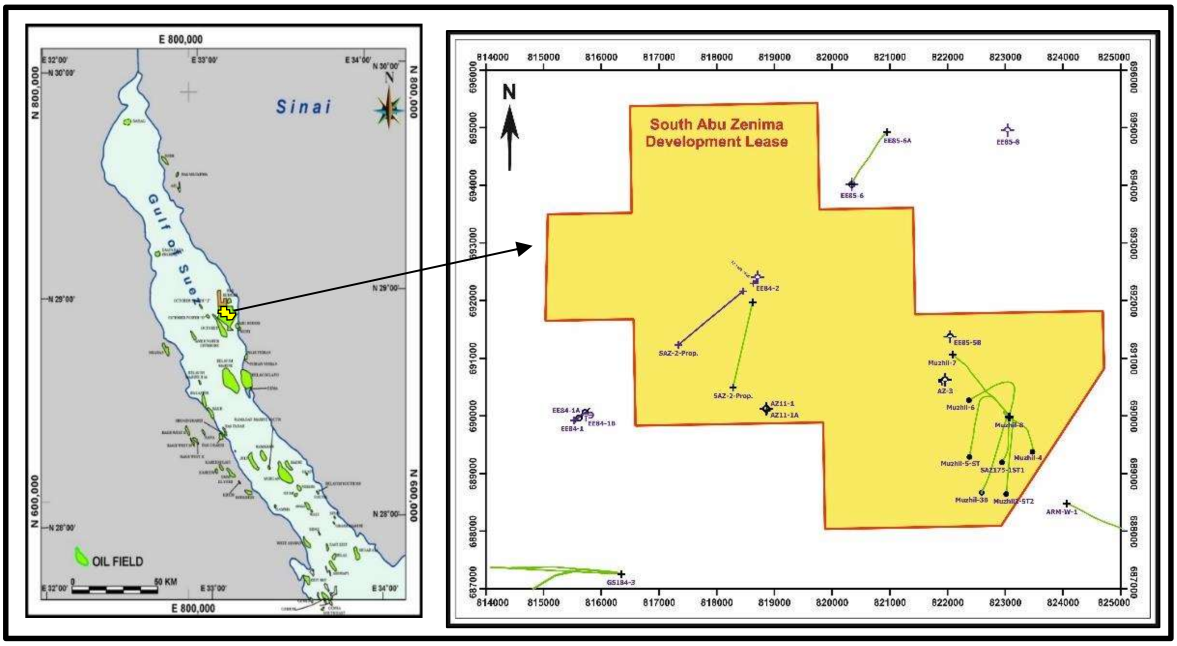

Fig. 1: Location Map of the study area

GEOLOGICAL SETTING

1. Lithostratigraphy

The stratigraphic column of the Gulf of Suez spans from the Pre-Cambrian to the present day (Fig. 2). This sequence is divided into three sections:

I. **Pre-rift sequence** (Said, 1962, 1990): Ranging from the Pre-Cambrian to the early Oligocene, starting with Paleozoic to Early Cretaceous rocks represented by the Nubian Sandstone. This is followed by the Late Cretaceous section, consisting from bottom to top of the Raha, Abu Qada, Wata, Matulla, Brown Limestone, and Sudr Formations, capped by the Esna Shale Formation (Paleocene) and the Thebes Formation (Eocene Carbonate) (Darwish and El Araby, 1993).

II. **Syn-rift sequence**: Extending from the Early to Late Miocene. The Early Miocene is represented by the Abu Zenima, Nukhul, and Rudeis Formations, known as Gharandal Group, which are primarily clastic. This is followed by the Ras Malab Group, extending from the Middle Miocene represented by the Kareem Formation, and the Late Miocene represented by the Belayim, South Gharib, and Zeit Formations.

III. **Post-rift sequence**: Starting from the Pliocene to the present.

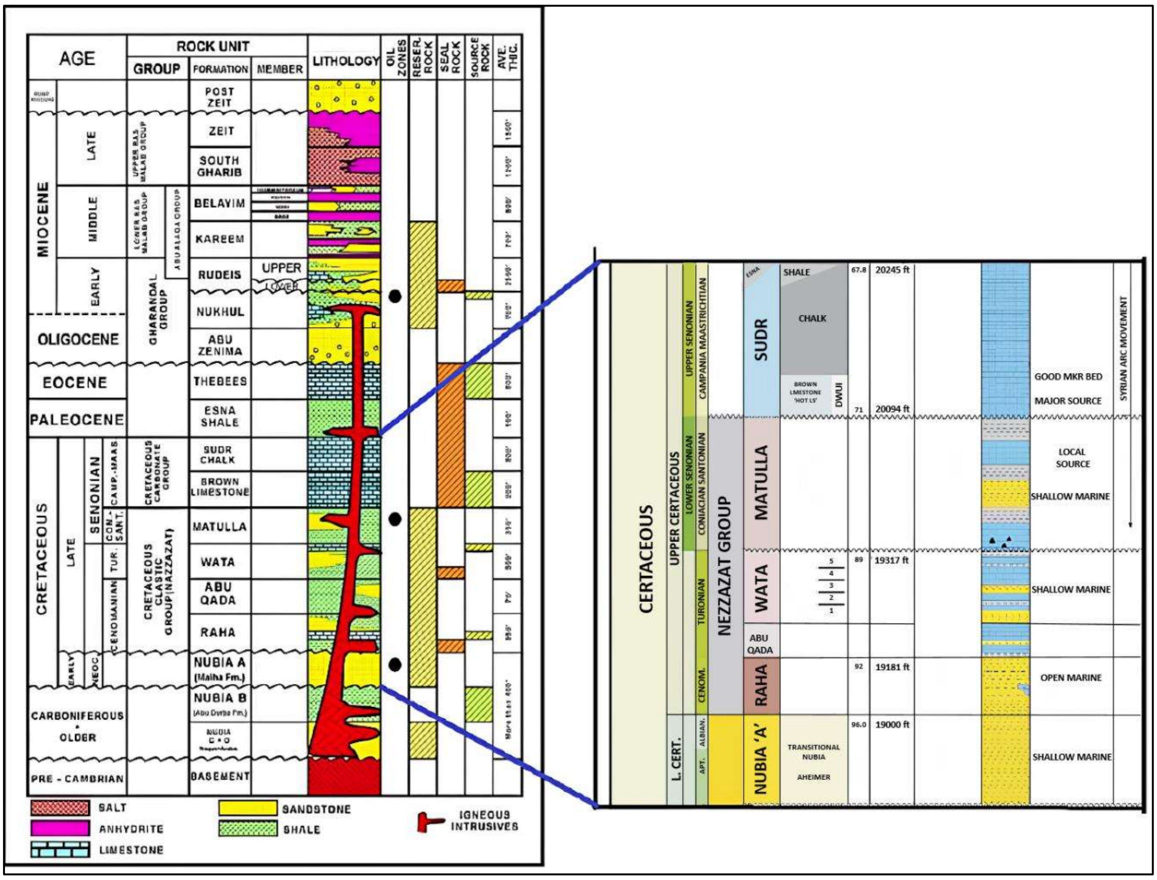

Fig. 2: Generalized stratigraphic succession of the Gulf of Suez.

2. Structure and tectonic setting

Due to its significance as a petroleum province, the Gulf of Suez's structure and tectonic setting have been extensively researched and documented. The structure and tectonic setting can be summarized as follows:

The current Gulf of Suez rift, along with the Red Sea oceanic basin and the Gulf of Aqaba, forms the Sinai triple junction. This geological formation began in the Oligocene period due to the northeastward displacement of the Arabian plate away from the African plate The rift originated as part of an extensional regime during the Late Oligocene to Early Miocene period. Throughout this time, magmatic eruptions occurred, coinciding with maximum tectonic subsidence, which may have continued until the Late Neogene. Magmatic eruptions occurred throughout this time period, coinciding with maximum tectonic subsidence, which may have lasted until the Late Neogene. From south to north, the Gulf of Suez is separated into three tectonic provinces: Zeit, Gharib, and Ataqa. Two large accommodation faults running NNE and SSW, often known as hinge zones, divide these provinces (Alsharhan, 2003). Included in the accommodation faults are the Morgan hinge zones and the Galala-Abu Zenima (Zaafarana) zone. The northern and central provinces are divided by the Zaafarana hinge zone, and the central and southern provinces are divided by the Morgan hinge zone. While the central province dips northeast, the northern and southern provinces dip southwest (Younes and McClay, 2002) (Fig. 3).

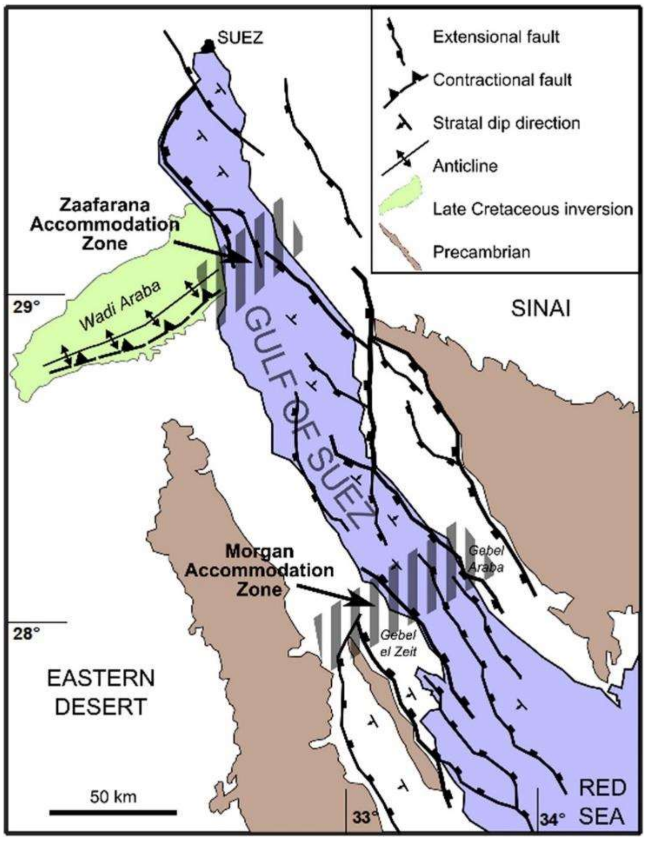

Fig. 3: The three tectonic provinces of the Gulf of Suez (after Younes and McClay, 2002).

- **Matulla Formation**

The Nezzazat Groups are composed of four formations (from top to bottom): Matulla, Wata, Abu Qada, and Raha, which are interbedded layers of shale, sandstone, siltstone, and limestone with substantial mechanical property variation. This research concentrated on the Lower Senonian Matulla Formation. Its average thickness is 140 m, and its lithology includes marls, limestones, and shales, as well as multiple sandstone units. The Matulla Formation unconformably overlies the Wata Formation. The upper section of the Matulla Formation is characterized by sandy shales that only grade into shales towards the top.

DATA AND APPLIED METHODOLOGY

The data for this study provided by EGPC and South Abu Zenima Oil Company include four wells drilled within the field; these wells include well tops, surveys, and logging data (Gamma ray, Resistivity, Density, Sonic, and Neutron), as well as ten pre-stack depth Seismic lines covering the area (Fig. 4).

1. Seismic Interpretation

Seismic interpretation involves analyzing seismic data to identify subsurface geological structures, such as faults and folds, which can indicate the presence of hydrocarbons. By examining seismic sections, geoscientists can create detailed structural maps that guide exploration and drilling efforts. Advanced techniques like Pre-Stack depth migration (PSDM) improve the accuracy of these interpretations. Integration with well log data further enhances the reliability of the findings. This process is crucial for effective hydrocarbon exploration and field development.

Interpretation of several 2D seismic sections would be done. Five dip seismic sections were interpreted as oriented towards the NE-SW direction, and five strike seismic sections were analyzed as oriented towards the NW-SE direction.

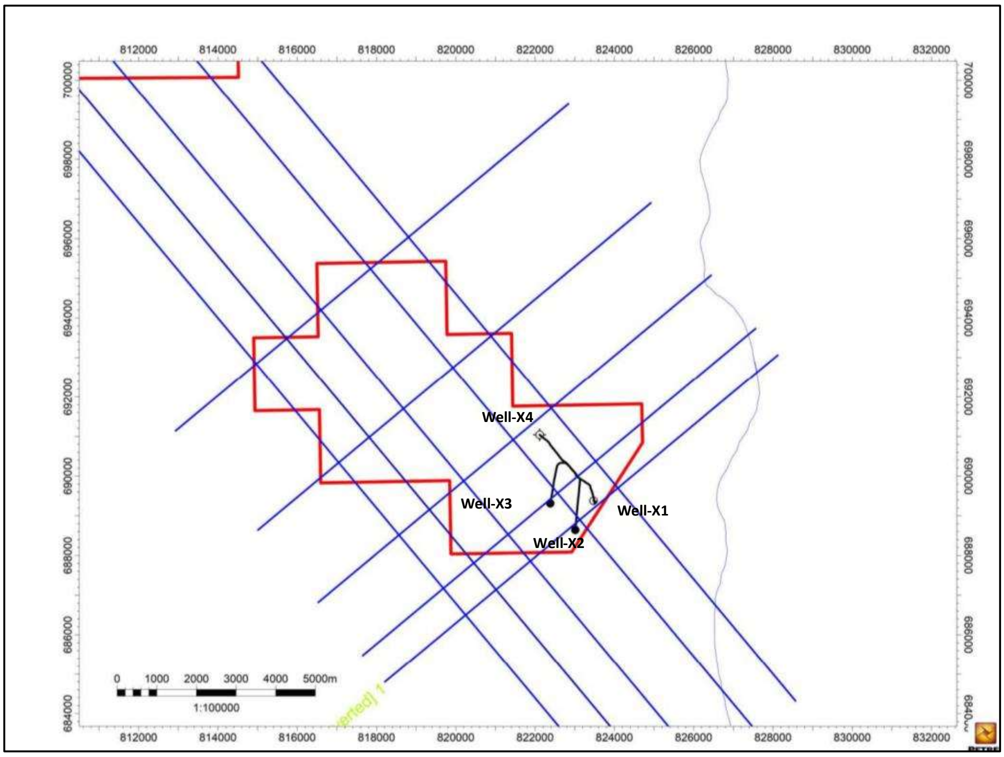

Fig. 4: Map showing the location of the studied seismic lines and wells covers Abu Zenima Oil Field.

The seismic horizon on top Matulla Formation was picked and guided by the provided well tops to detect the structural elements. The interpretation led to constructing structure depth map for top Matulla matching with the provided well tops.

(Fig. 4) shows the NE-SW dip seismic line, top Matulla is represented by a light blue color, and the interpretation shows the area is affected by several parallel normal faults with a NW-SE trend, this set of faults forms a group of step fault blocks, which would be excellent locations for hydrocarbon accumulations.

(Fig. 5) Represent The structural contour map for the top of the Matulla Formation reveals the presence of six normal faults (F1– F6) within the area, exhibiting a predominant NW-SE trend. These faults dissect the formation into five major blocks (Blocks A-E), each following the same fault trend and generally dipping towards the northeast, consistent with the central part of the Gulf of Suez, and bounded from the north by a major fault (F7) with NW-SE direction. The penetrated wells are concentrated in the eastern block (Block-A), which can be F-3, which is the main fault in the area with a throw reach to 400 m and toward the north The block is bounded from the west by F-2, making it a step block from Block-B.

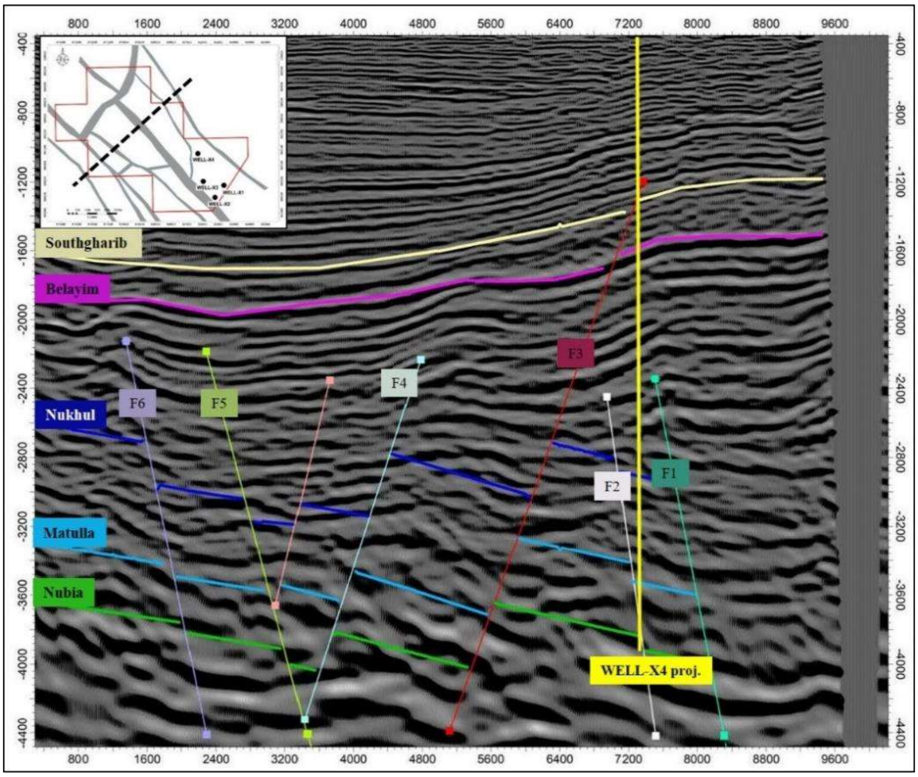

Fig. 5: Depth Structure Contour map on Top Matulla Formation

named the main block; the main block is the main producing block in the area. This block is a major horst block, dipping to the northeast bounded from the east by F-1 and from the west by F-3.

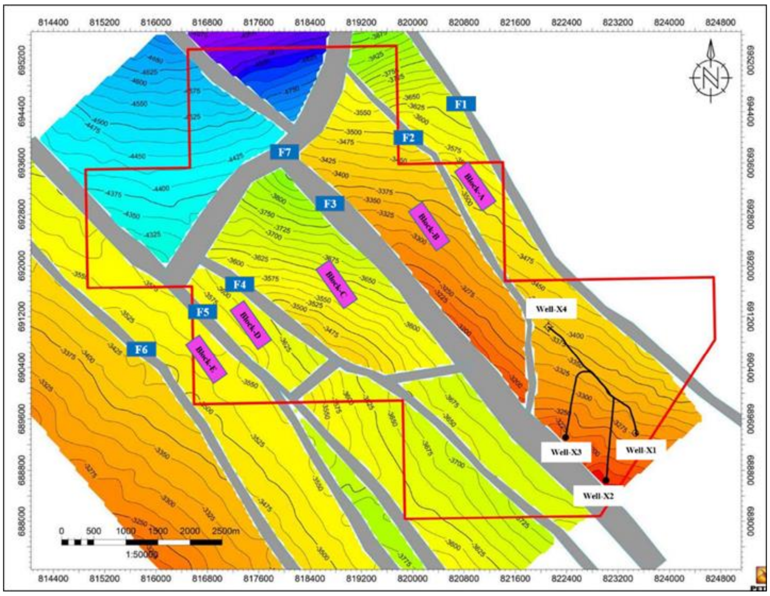

Fig. 6: NE-SW Seismic section Showing the horizon and fault interpretation within the area.

The map also reveals another horst block (Block-B) with a V-shape in the upthrown section of the main producing block from the east and bound in the updip direction by F3 in the west. This block has not been penetrated by any wells and is bounded to the north by a major fault

(F-7) trending NE-SW. This makes Block-B a promising target for further exploration activities.

Further west, between F-3 and F-4, another step block, Block-C is a downthrown of Block-B that offers exploration opportunities in its updip region.

Block-D is considered the least significant block in the area due to its geological position. As a Graben block, it is situated in a depressed fault-bounded area, with faults F-4 and F-5 marking both its eastern and western boundaries. This structural setting typically implies a lower potential for hydrocarbon accumulation compared to horst blocks or more structurally favorable areas.

In the far west, the area's structure rises again, forming Block-E, which is upthrown relative to Block-D. This upthrown position suggests that Block-E might be more prospective for exploration and development compared to Block-D. The upthrown nature of Block-E indicates that it might have experienced less subsidence and deformation, potentially preserving better reservoir quality and higher hydrocarbon potential.

2.Well log Analysis

Well log analysis involves the examination of data recorded from boreholes to determine the petrophysical properties of the surrounding geological formations. This analysis helps in identifying lithology, porosity, fluid saturation, and other key reservoir characteristics. Tools used in well logging include gamma ray, resistivity, and sonic logs, among others. By integrating well log data with other geological and geophysical information, geoscientists can make informed decisions about hydrocarbon exploration and production.

The available data comprises a complete set of logs, including caliper, gamma ray, shallow and deep resistivity, density, and Neutron logs for four wells in the field. Well-log analysis represents the most critical stage in evaluating petrophysical characteristics such as effective porosity, shale content, and water and hydrocarbon saturations. This study exclusively utilized the Computer Processed Interpretation (CPI) method for petrophysical evaluation. CPI offers significant advantages in terms of efficiency and accuracy, making it the preferred approach for this research. Interactive Petrophysics software (IP) was employed for this study to ensure precise and comprehensive analysis.

For the evaluated wells, the petrophysical cut off values of the reservoir zone are: < 0.40 for the shale content, > 0.08 for the effective porosity, and < 0.60 for the water saturation.

Vertical distribution of petrophysical characteristics

The litho-saturation cross plots are constructed for the Matulla Formation in all studied wells in the study area using the IP software (Fig. 7-10). In each cross plot, the calliper (GR) log is displayed in Track 1. Formation Top and Bottom are displayed in Track 2. Tracks 3 and 4 exhibit the measured reference depth and true vertical depth (TVDSS). Track 5 shows deep, medium, and shallow resistivity logs (RD, RM, and RS). Track 6 displays density (DEN), neutron (CNL), and photoelectric (PEF) logs. Track 7 presents the Calculated Water Saturation. Track 8 and 9 demonstrate the flags of the net reservoir and net pay zones. Track 10 demonstrates the effective porosity (Φe). Track 11 displays the results of mineralogical and fluid components in volume percentage (decimal).

The litho-saturation of Well-X1 (**Fig. 7** and **Table 1**) shows the petrophysical parameters of Matulla Formation, which extend between depths 3299 and 3418 TVDSS and consist of mainly carbonate, shale and sandstone. The gross thickness is 119 m with a reservoir thickness of 43 m. the Vsh is 10%, while Porosity is 16%, the Net pay in this well is 15 m with water saturation 51% and hydrocarbon saturation 49%. The Matulla formation in WELL-X1 exhibits fair conditions for reservoir potential.

Table 1: Reservoir and pay Summary of Well-X1

Reservoir Summary								
Matulla	**Top (TVDSS)**	**Bottom TVDSS**	**Gross (TVDSS)**	**Net (TVDSS)**	**N/G (TVDSS)**	**Av Phi**	**Av Sw**	**Av Vcl (Ari)**
	3299	**3418**	**119**	**42.69**	**0.359**	**0.16**	**0.709**	**0.096**
Pay Summary								
Matulla	**Top (TVDSS)**	**Bottom (TVDSS)**	**Gross (TVDSS)**	**Net (TVDSS)**	**N/G (TVDSS)**	**Av Phi**	**Av Sw**	**Av Vcl (Ari)**
	3299	**3418**	**119**	**14.72**	**0.124**	**0.181**	**0.511**	**0.022**

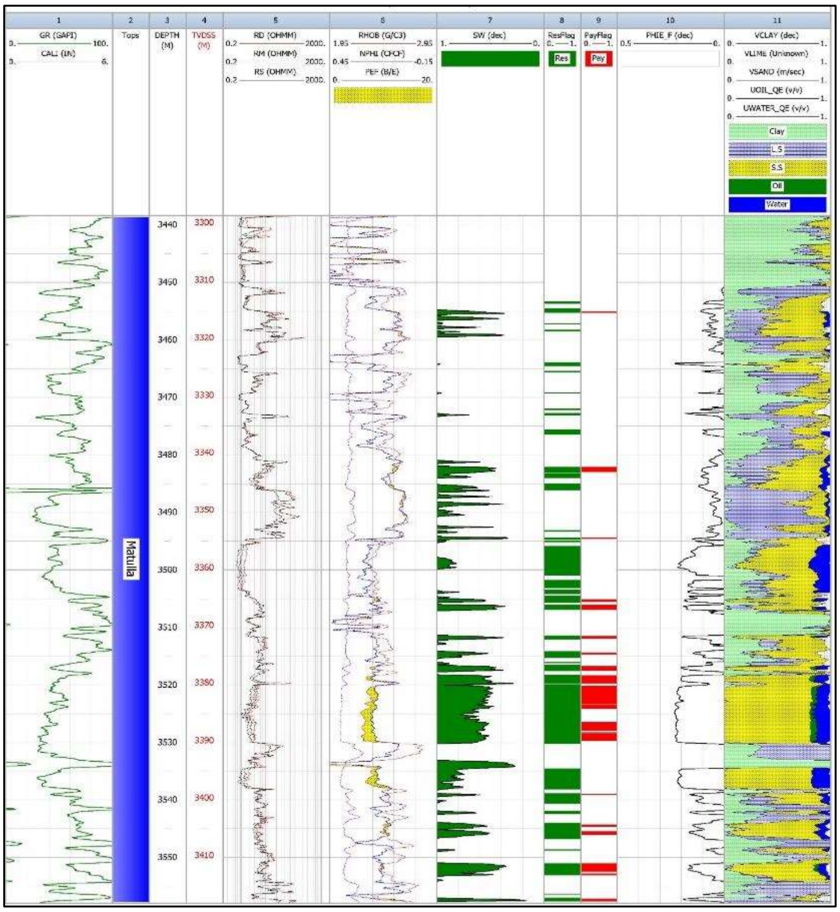

Fig. 7: Computer processed interpretation (CPI) of Well-X1

(Fig. 8 and Table 2) represents the vertical distribution of the different petrophysical parameters in the sediments of Matulla Formation in Well-X2 well. Matulla Formation in this well has good reservoir conditions, where the gross thickness of Matulla is 113 m, the shale volume is about 12% and 53 m reservoir thickness, and effective porosity is about 15.5%. The net pay is 28 m with 20% water saturation and 80% hydrocarbon saturation.

Table 2: Reservoir and pay Summary of Well-X2 well

Reservoir Summary								
MATULLA	Top (TVDSS)	Bottom TVDSS	Gross (TVDSS)	Net (TVDSS)	N/G (TVDSS)	Av Phi	Av Sw	Av Vcl (Ari)
	3155.79	3268.63	112.84	53.49	0.474	0.156	0.535	0.121
Pay Summary								
MATULLA	Top (TVDSS)	Bottom TVDSS	Gross (TVDSS)	Net (TVDSS)	N/G (TVDSS)	Av Phi	Av Sw	Av Vcl (Ari)
	3155.79	3268.63	112.84	28.39	0.252	0.167	0.206	0.08

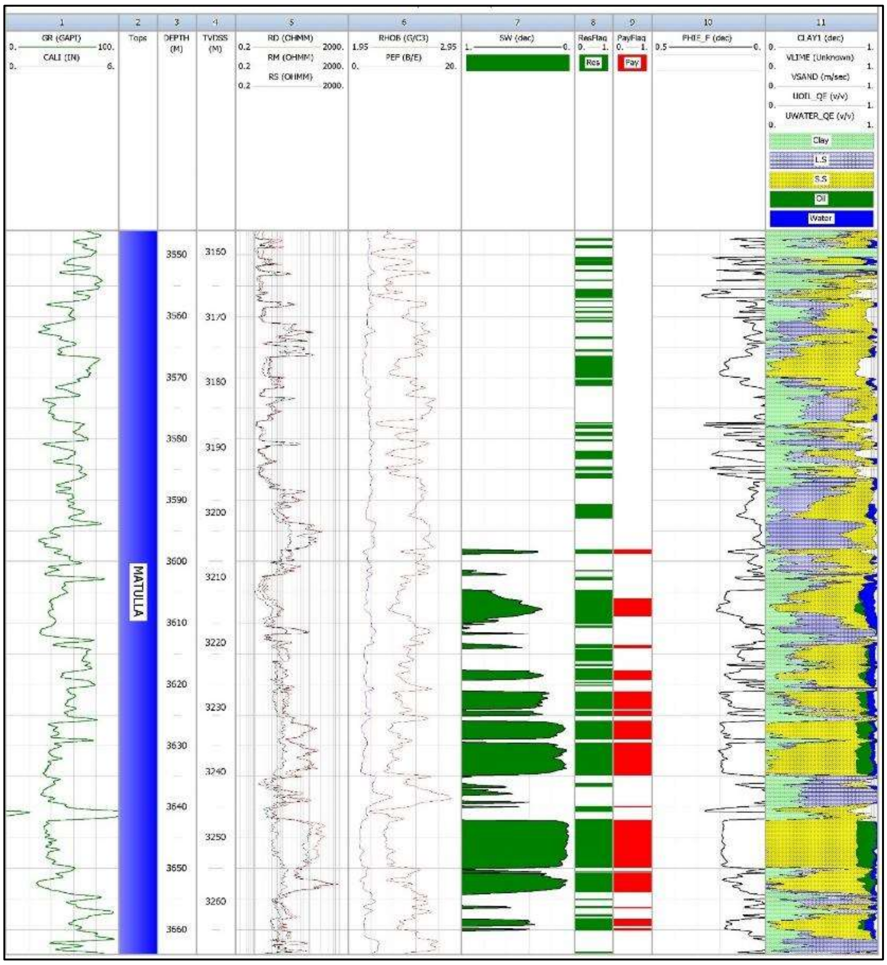

Fig. 8: Computer processed interpretation (CPI) of Well-X2

Litho-saturation cross plot of WELL-X3 Well extends from 3220 to 3327 m, with a gross thickness 106 m and a reservoir thickness of 25 m and net pay thickness 7 m. Litho-saturation cross plot illustrates lithology mixed from sandstone, shale, and limestone (Fig. 9 and Table 3). The value of shale volume is 10%. The effective porosity is about 15%, water saturation is 43%, and hydrocarbon saturation is about 57 %. Accordingly, Matulla Formation in Well-X3 Fair Reservoir Possibility.

Table 3: Reservoir and pay Summary of Well-X3 well

Reservoir Summery								
Matulla	Top (TVDSS)	Bottom TVDSS	Gross (TVDSS)	Net (TVDSS)	N/G (TVDSS)	Av Phi	Av Sw	Av Vcl (Ari)
	3220.37	3327.08	106.7	25.76	0.241	0.15	0.696	0.106
Pay Summary								
Matulla	Top (TVDSS)	Bottom TVDSS	Gross (TVDSS)	Net (TVDSS)	N/G (TVDSS)	Av Phi	Av Sw	Av Vcl (Ari)
	3220.37	3327.08	106.7	6.73	0.063	0.179	0.433	0.039

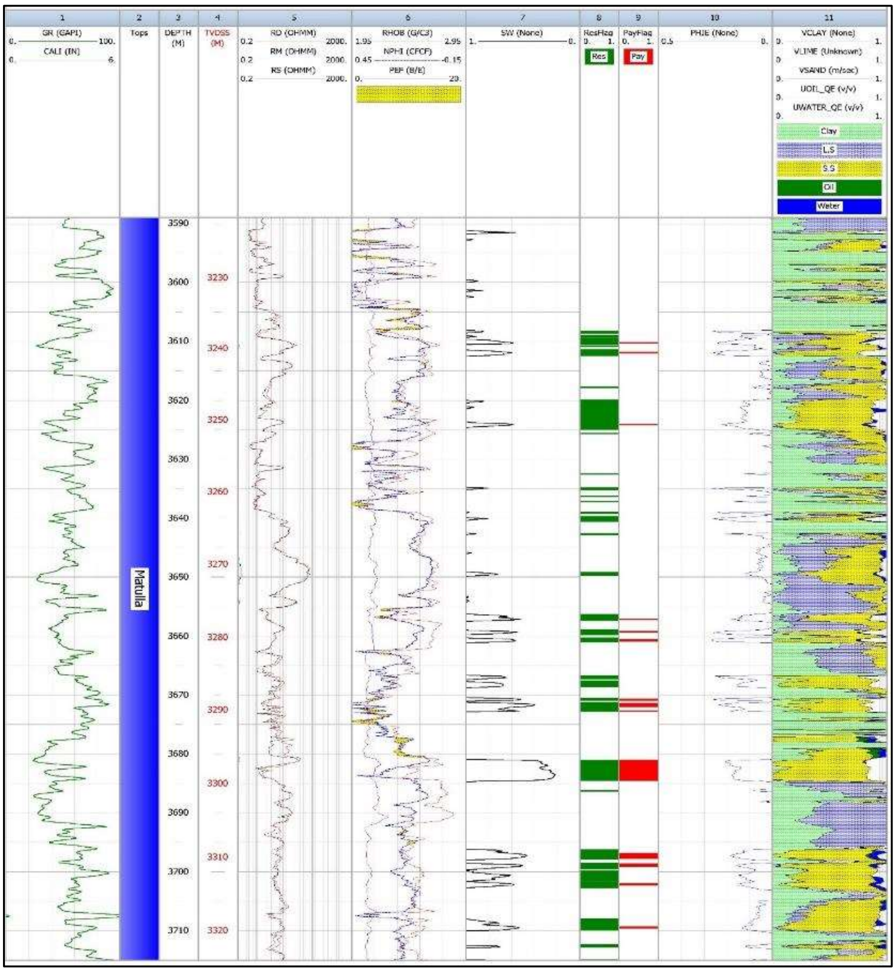

Fig. 9: Computer processed interpretation (CPI) of Well-X3

WELL-X4 well extends from 3381 to 3507 m (Fig. 10 and Table 4) and consists of mixed lithology from sandstone, shale, and some streaks of limestone. The shale content is 5%, porosity is about 13 %. Water saturation in Matulla formation has reached to 43%. The net pay in this is very low reaching to 1.5 m which makes Matulla in this well is bad reservoir.

Table 4: Reservoir and Net Summary of Well-X4 well

Reservoir Summery								
Zone Name	**Top (TVDSS)**	**Bottom TVDSS**	**Gross (TVDSS)**	**Net (TVDSS)**	**N/G (TVDSS)**	**Av Phi**	**Av Sw**	**Av Vcl (Ari)**
	3381.41	**3507.97**	**126.56**	**15.7**	**0.124**	**0.126**	**0.832**	**0.05**
Pay Summary								
Zone Name	**Top (TVDSS)**	**Bottom TVDSS**	**Gross (TVDSS)**	**Net (TVDSS)**	**N/G (TVDSS)**	**Av Phi**	**Av Sw**	**Av Vcl (Ari)**
	3381.41	**3507.97**	**126.56**	**1.55**	**0.012**	**0.148**	**0.427**	**0.015**

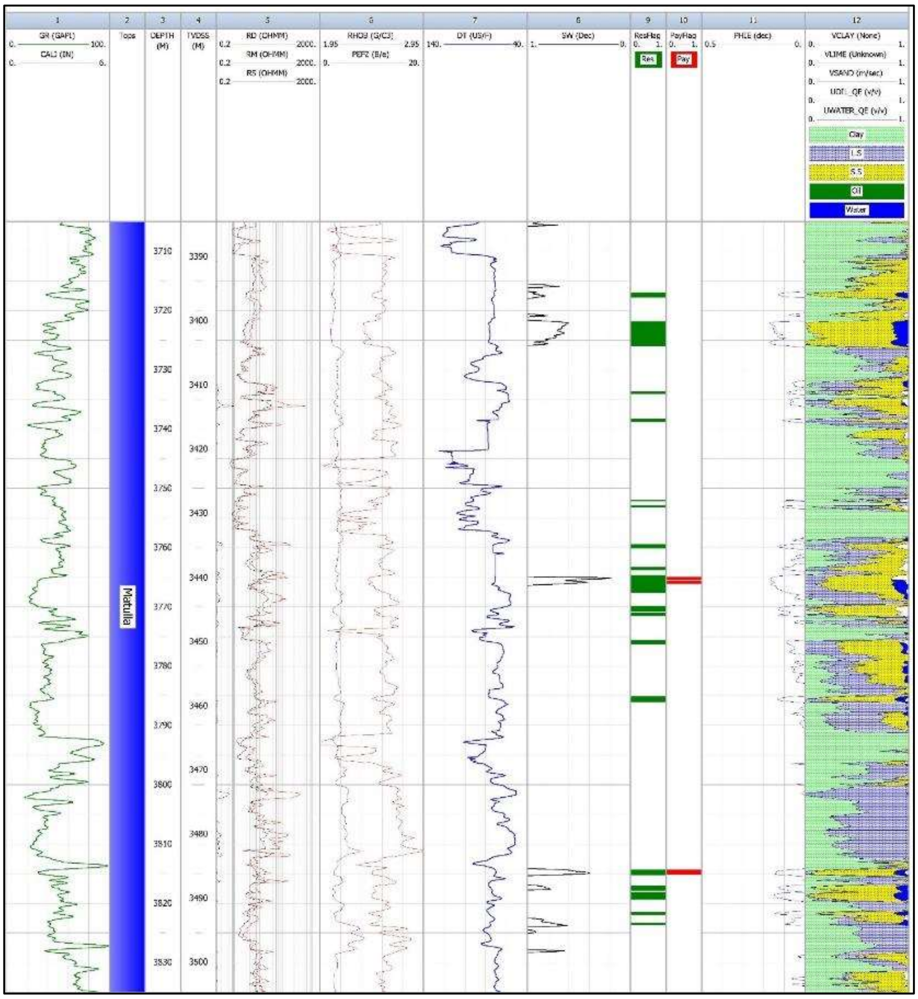

Fig. 10: computer processed interpretation (CPI) of Well-X4

In general, the Matulla Formation exhibits varying reservoir potential across different wells. While some wells show fair to good potential with significant hydrocarbon saturation and effective porosity, others display lower net pay and higher water saturation, indicating poorer reservoir conditions. These variations highlight the importance of site-specific evaluations for accurate reservoir characterization and development planning.

Lateral variations of petrophysical characteristics

The lateral variation of petrophysical characteristics was studied using constructed isoparametric maps. Analyzing these petrophysical parameter maps is crucial for understanding their lateral variation and identifying the factors that control them, which may be stratigraphic, structural, or a combination of both.

Due to the concentration of the wells in the eastern part of the study area, the iso-parametric map constructed in this block to provide the remaining oil potentiality in this block Fig. 11 & Fig. 12.

The resulting parameters show net reservoir thickness range from 15 to 60 m, which indicates the thickness of the reservoir rock that contains economically producible hydrocarbons and show increase in the gross thickness toward the south of the main block.

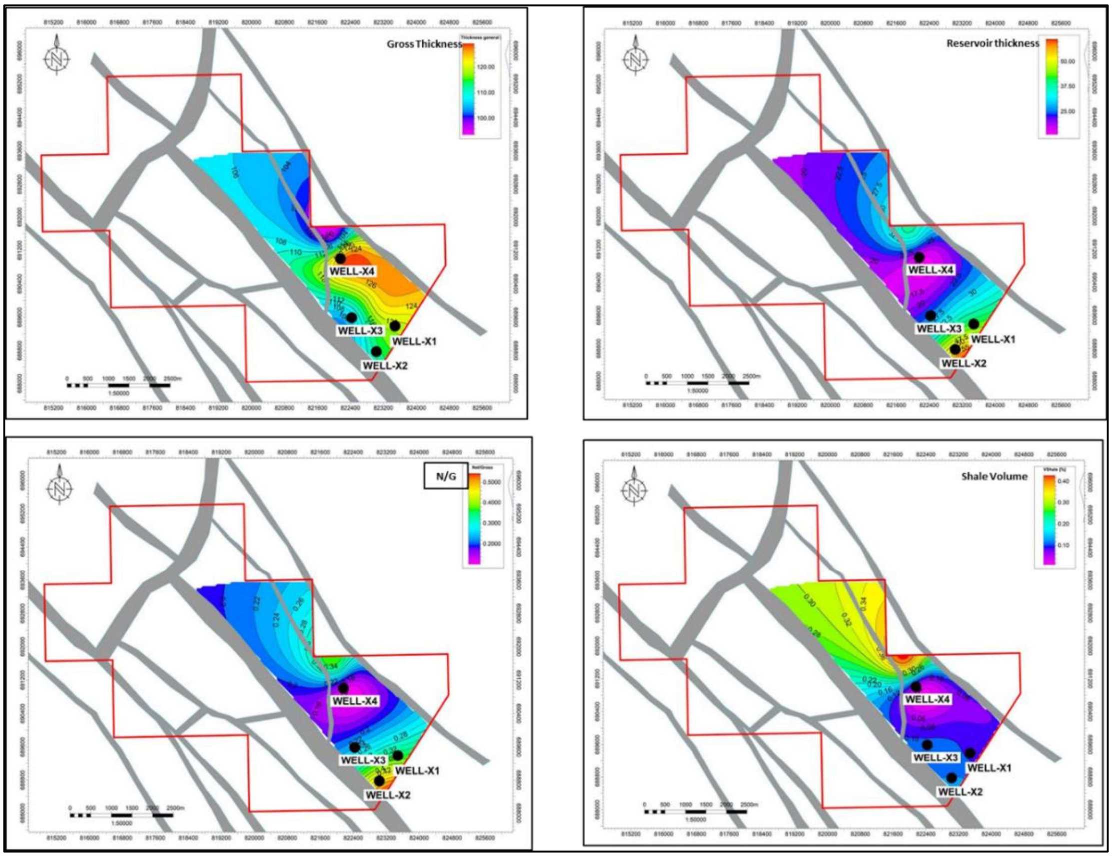

Fig. 11: Iso-paramtric maps (Gross- Net reservoir- Net to Gross- Shale Volume) with structure pattern of Matulla Formation.

In terms of reservoir quality, the net/gross ratio (which varies between 12% and 54% in the south and between 11% and 16% in the north of the block) provides information on the percentage of reservoir rock that contributes to hydrocarbon productivity in relation to overall thickness. The effective porosity (which varies between 11% and 16% in WELL-X1 and

WELL-X2) shows how much of the reservoir rock is accessible for fluid storage (hydrocarbons).

Furthermore, the amount of fine-grained sedimentary rocks in the reservoir, which may have an impact on permeability and fluid flow, is shown by the shale content, which varies from 5% in the south to 30% in the north of the block. The calculated water saturation of the reservoir ranges from 20% to 100%, which is rather high, especially in the north. This water saturation indicates the percentage of pore space that is contain of water. Hydrocarbon production has been promoted by lower water saturation levels. Consequently, the computed hydrocarbon saturation extends within the range of 0 to 80%; this parameter indicates the percentage of pore space that is filled with hydrocarbons and is an important factor in

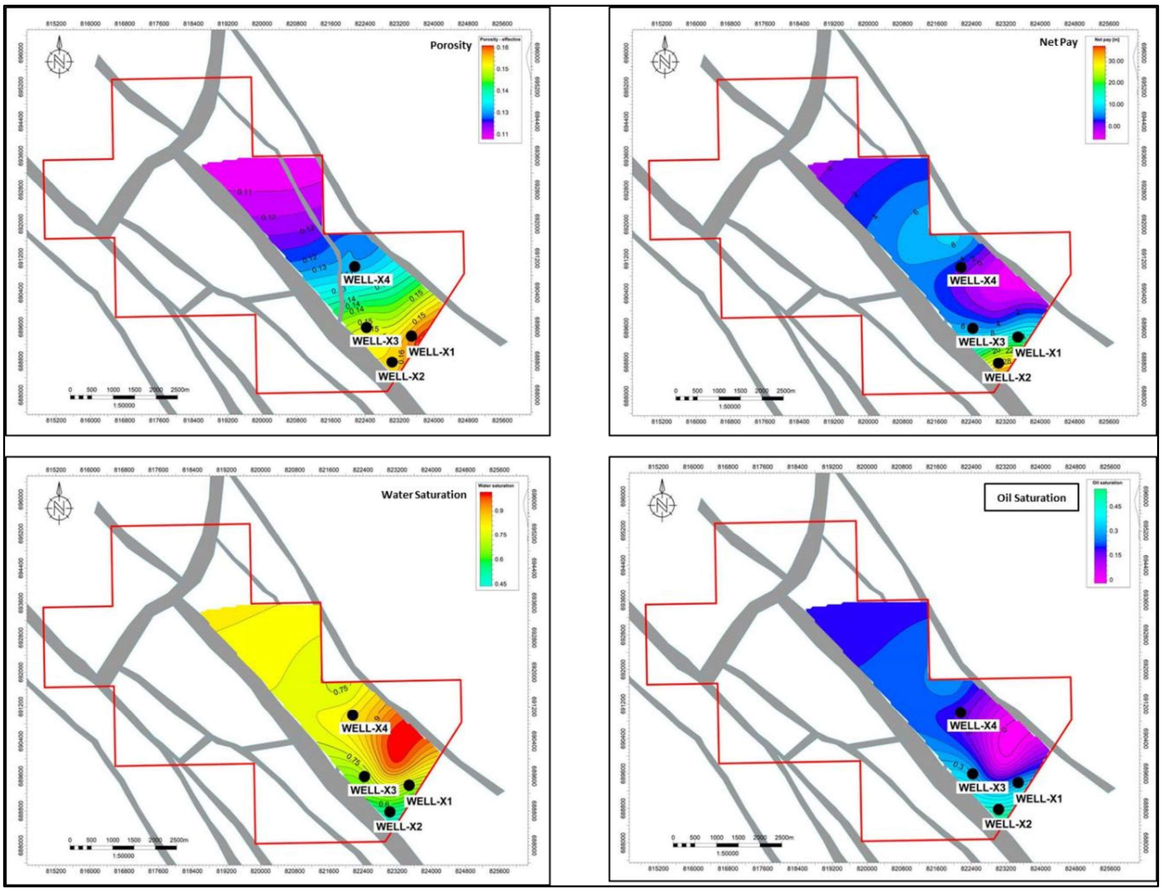

Fig. 12: Iso-paramtric maps (Porosity- Net Pay- Net to Gross- Sw- Shc) with structure pattern of Matulla Formation.

determining the economic viability of a reservoir. Finally, the net pay is indicating that the most valuable part of the block in the south with 30 meter around WELL-X2.

The iso-parametric maps generated for the estimated reservoir characteristics of the Matulla Formation in the Abu Zenima field give useful information. These maps indicate that the southwest section of the main block of the Abu Zenima field, specifically the region between

WELL-X2 and WELL-X3, is an appropriate location for future development activities and additional targets.

CONCLUSIONS

The study of Mautlla Reservoir was conducted in two stages:

- First, seismic interpretation of ten seismic lines was performed, resulting in the creation of a depth structural map for the reservoir showing the Formation dissected by several normal faults into several blocks with general dipping NE and the identification of promising hydrocarbon-bearing blocks based on structural setting.
- Second, well log analysis was carried out on the provided wells to determine the petrophysical parameters of the reservoir in the main block in the east part, this analysis led to the creation of litho-saturation plots and reservoir summaries for the studied wells, as well as the generation of iso-parametric maps for various petrophysical parameters.
- Finally, the integration of the structural and isoparametric maps were integrated to accurately characterize the reservoir and assess its hydrocarbon potential.

The study recommended to drilling more development wells in the updip areas of the main block to optimize hydrocarbon recovery, Additionally, new exploration opportunities exist in the upthrown areas of the main block, and promising targets on the western side of the Abu Zenima oil field warrant further exploration activities.

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