Subsurface Geological setting and Reservoir Characterization of East Zeit oil Field, Gulf of Suez, Egypt.


*Geology Department, Faculty of Science, Al Azhar University, Cairo, Egypt.
**General Petroleum Company, Cairo, Egypt.
***East Zeit Petroleum Company, Cairo, Egypt.

ABSTRACT

East Zeit Oil field is located in the southern part of the Gulf of Suez province (offshore). Two sandstone sub-reservoir units Shagar and Markha (the main reservoir is Markha Member) within Kareem Formation are hydrocarbon producing units in this field. The present work is devoted to the study the subsurface setting and reservoir characteristics to evaluate the hydrocarbon potentials of Markha Member based on 3D seismic data and well logs data. Subsurface structural setting was studied through construct structure contour maps that raveled the area is affected by two fault systems: Longitudinal fault system, trending northwest-southeast (Clysmic trend) and cross fault system, trending east northeast-west southwest. The vertical and horizontal variations of reservoir parameters are studied through constructing the lithosaturation cross plots and iso-parametric maps, revealed the reservoir thickness, average effective porosity, shale content, water saturation and hydrocarbon saturation. For Markha Member as main reservoir in Kareem Formation in the study area the reservoir thickness map shows that the reservoir thickness in this unit ranges between 10 and 240 ft., effective porosity map shows that the reservoir porosity ranges between 9% and 12.5 %. The shale content map shows that the shale content ranges between 10% and 32%. The water saturation map shows that the water saturation ranges between 20% and 54%. And hydrocarbon saturation map shows that it ranges between 46% and 80%. As a result of the present study, based on the Subsurface and Petrophysical evaluation gained from this study; the author recommends to drill new development wells in three locations that are proposed to be new prospects in Markha Member of Kareem Formation. These locations are found within three way dip closure trap and characterized by good petrophysical parameters. Also the author recommends making more exploration and prospecting in the center of northern part of the study area.

Keyword: subsurface Structure and reservoir characterization of East Zeit field
INTRODUCTION

East Zeit field is located in the southern part of the Gulf of Suez province (offshore) Figure (1). The study area is bounded by latitudes 27º 30' and 30º 00' N and longitudes 32º 10' and 34º 00'E and occupies an area of about 27 km² and around 245 ft of water depth. East Zeit field located along a major structure trend called the B-Trend which is characterized by its formation from several oil fields. The aims of the present study are to reveal the structural setting and evaluate the reservoir characterization.

METHODOLOGY

The present study is based mainly on the use of the available wireline logs of eight wells namely (EZA-1A, EZA-9,EZA-11 and EZC-2) and ten 3D seismic lines distributed in the study area, as shown in Figure (1).

Figure (1): Location map of the East Zeit Oil field.
Stratigraphic Setting

According to (Said, 1962 and 1990) the stratigraphic setting of the Gulf of Suez is characterized by three main depositional phases relative to the Miocene rifting events namely; pre-rift phase (Early Paleozoic to Eocene); Syn-rift phase (Early to Middle Miocene) and post-rift phase (Late Miocene to Pliocene). (Darwish and El Araby, 1993), pointed out pre-rift phase (Early Paleozoic to Eocene); It includes Qebliat group (Araba and Naqus formations), Ataqa group (Um Bogma and Abu-Durba formations), El Tih group (Qiseib and Malha formations), Nazzazat group (Raha, Abu-Qada, Wata and Matulla formations) and El Egma groups (Sudr Chalk, Esna Shale, Thebes and Mokattam formations). Syn-rift phase (Early to Middle Miocene); The Syn-Rift sediments represented by Gharandal Group (Nukhul and Rudeis formations) and Ras Malaab Group (Kareem, Belayim, South Gharib and Zeit formations). And post-rift phase (Late Miocene to Pliocene); The Post Zeit Formation (Pliocene-Recent Sediments) are composed mainly of clastic, carbonates and evaporites intercalations which conformably overlie the Late Miocene evaporates. Figure (2) showing the stratigraphic succession penetrated by the studied wells, ranges from Precambrian (Basement Rocks) to Pliocene-Pleistocene (post Zeit Formation).

Figure (2): Stratigraphic Column of the East Zeit field (modified after Zeitco 2010)
Kareem Formation

According to Stratigraphic Sub-Committee (1974), Kareem Formation is the base most part of Ras Malaab group; it represents (in its lower part) the oldest stable evaporite development in the Gulf of Suez region. Its type section is at Gharib North well No. 2. Kareem Formation consists of clastic sediments with evaporite beds, as an oil reservoir target in the Gulf of Suez, Kareem Formation overlies conformably Asl Member of Rudeis Formation and underlies conformably Baba Member of Belayim Formation. In the study area; Two sandstone sub-reservoir units Shagar and Markha (the main reservoir is Markha Member) within Kareem Formation are hydrocarbon producing units in this field. Figure (3): Isopach map of Kareem Formation; shows thickness distribution in the study area ranges from 0 ft to 1200 ft that increase in northeast trend. Figure (4): Stratigraphic correlation of some wells of the study area, showing the field succession and their thickness distribution in the study area (Basement, Nubia, Thebes, Nukhul, Rudeis, and Kareem), hanged on top Belayim evaporites (as the famous marker in the study area).

Figure (3): Isopach map of Kareem Formation in East Zeit oil Field.
Figure (4): Stratigraphic correlation of some wells of the study area.
Structural Setting

In the present study the structural setting was studied by interpretation of seismic profiles and construct the Structure contour maps as following.

Depth Structure Contour Map, Top Nubia Formation

Bayoumi (1983) pointed that the structure of the Gulf of Suez area were developed due to its subjection to three phase of tectonism, NW-SE fractures which took place in response to the Clysmic Cycle (Early Cambrian to Early Carboniferous). Structure contour map, top Nubia Formation Figure (5). As shown in this map, the Nubia Formation is affected by the major faults NW-SE (Clysmic fault trends) and minor faults with WNW-ESE trend. These features are also shown on seismic profile 1336 Figure (6).

Figure (5): A structure contour map, top Nubia Formation (after Zeitco 2010).
Figure (6): Interpreted seismic profile 1336. It is dip section and takes the NE-SW direction. This profile illustrates a set of normal faults that separate the field into two Domes.

**Depth Structure Contour Map, Top Nukhul Formation**

Nukhul Formation still affected by the major faults NW-SE (Clysmic fault trends) and minor faults with WNW-ESE trend. As shown on Structure contour map, top Nukhul Formation Figure (7) and in interpreted seismic profile 1372 Figure (8).

Figure (7). A structure contour map, top Nukhul Formation, *(after Zeitco 2010)*.
Figure (8): Interpreted seismic profile 1372. It is dip section and takes the NE-SW direction. This profile illustrates a set of faults that separate the field into two Domes.

**Depth Structure Contour Map, Top Kareem Formation**

Kareem Formation still affected by the major faults NW-SE (Clysmic fault trends) and minor faults with WNW-ESE trend. As shown on Structure contour map, top Kareem Formation Figure (9) and in interpreted seismic profile 1388 Figure (10).

Figure (9). A structure contour map, top Kareem Formation.
Figure (10): Interpreted seismic profile 1388. It is dip section and takes the NE-SW direction. This profile illustrates a set of normal step faults that separate the field into one Dome and step tilted fault blocks.

**Depth Structure Contour Map, Top South Gharib Formation**

South Gharib Formation is not affected by any faults and it represents the salt dome in the study area. As shown in structure contour map, top South Gharib Formation Figure (11) and interpreted seismic profile 1412 Figure (12).

Figure (11). A structure contour map, top South Gharib Formation.
Figure (12): Interpreted seismic profile 1412. It is dip section and takes the NE-SW direction. This profile illustrates the salt dome of South Gharib Formation is not affected by any faults.

**Depth Structure Contour Map, Top Zeit Formation**

Zeit Formation is not affected by any faults and it represents a dome in the study area. As shown in structure contour map, top Zeit Formation Figure (13) and interpreted seismic profile 842 Figure (14).

Figure (13): A structure contour map, top Zeit Formation.
Figure (14): Interpreted seismic profile 842. It is strike profile and NW-SE aligned. This section illustrates a set of minor normal faults (ESE-WNW) which are cintersected between Clysmic faults.
Reservoir Characteristics

The petrophysical evaluation has been done using the available well log data for four wells (EZA-1A, EZA-9, EZA-11 and EZC-2), using the available digital well log data. The available well log data are tabulated in Table (1), and cutoff limits used in the field evaluation are tabulated in Table (2). Based on the petrophysical analysis the Markha Member forms the main reservoir in the study area.

Table (1), the available and used well log data.

<table>
<thead>
<tr>
<th>Well name</th>
<th>Depth interval TVDSS(FT)</th>
<th>Available well logging tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>EZA-1A</td>
<td>7962-8488</td>
<td>CALI,GR,RES-DEEP,RES-SLS,DEN,NEU,DT,PEF</td>
</tr>
<tr>
<td>EZA-9</td>
<td>8107-8635</td>
<td></td>
</tr>
<tr>
<td>EZA-11</td>
<td>8489-9118</td>
<td></td>
</tr>
<tr>
<td>EZC-2</td>
<td>7854-8393</td>
<td></td>
</tr>
</tbody>
</table>

Table (2), Cut-off limits used in the field evaluation.

<table>
<thead>
<tr>
<th>Cutoff</th>
<th>Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porosity</td>
<td>10%</td>
</tr>
<tr>
<td>Water saturation</td>
<td>60%</td>
</tr>
<tr>
<td>Shale content</td>
<td>35%</td>
</tr>
</tbody>
</table>
Table (3), Shows the petrophysical Characteristics of Markha Member.

<table>
<thead>
<tr>
<th>Well Name</th>
<th>Reservoir Thickness (ft)</th>
<th>Effective Porosity (%)</th>
<th>Volume Of Shale (%)</th>
<th>Water Saturation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EZA-1</td>
<td>187</td>
<td>11.5</td>
<td>18.7</td>
<td>28</td>
</tr>
<tr>
<td>EZA-9</td>
<td>126</td>
<td>11</td>
<td>17</td>
<td>43</td>
</tr>
<tr>
<td>EZA-11</td>
<td>72.5</td>
<td>10</td>
<td>25</td>
<td>33</td>
</tr>
<tr>
<td>EZC-2</td>
<td>149</td>
<td>10.1</td>
<td>15.2</td>
<td>39.5</td>
</tr>
</tbody>
</table>

Markha Member

The vertical and horizontal variations of Markha Sandstone reservoir parameters are studied through constricting the litho-saturation cross plot and iso-parametric maps.

Lithological Identification Cross-Plots

Identification of lithology is of a particular importance in formation evaluation process. Logs can be used as indicators of lithology. The most useful logs for this purpose are density and neutron Figure (15) shows the neutron-density cross plot (lithological identification cross-plot) for Markha Member (the main reservoir) of Kareem Formation in all wells. As shown in this figure the Markha Member is characterized by the presence of sandstone, shale and limestone.
Figure (15), lithological identification cross-plot of Markha Member of Kareem Formation in the studied wells.

**Markha Gross Reservoir Distribution Map**

Figure (16) shows that, the net reservoir of Markha Member ranges between 20 and 240 ft. The gross reservoir has its maximum thickness towards the western part of the study area and decreases toward northeastern part of the study area.
Figure (16): Gross reservoir map of the Markha Member in the study area
Markha Effective Porosity Distribution Map
Figure (17) shows the effective porosity distribution of Markha Member in the study area ranges between 9% and 12.5%. The maximum values occur in the western part and minimum values occur in the north-eastern part of the area. In general, the map shows that the Markha Member is of wide quality ranging from poor to very good reservoir.

Figure (17): Iso-Effective porosity map of the Markha Member.
Markha Shale Content Distribution Map

Figure (18) shows that, the shale content distribution of the Markha Member in the study area which varies from 10% to 32%. The maximum values occur in the northern part and minimum values occur in the south-eastern part of the study area. In general, this map shows that the Markha Member is shaly sandstone.

Figure (18): The shale content distribution map of the Markha Member.
Markha Water Saturation Distribution Map

Figure (19) shows that, the water saturation distribution of the Markha Member in the study area is observed within the ranges between 20% and 54%. It is decreases in the northwestern and central parts and increases towards the eastern part.

Figure (19): Iso-Water saturation distribution map of the Markha Member.
Markha Hydrocarbon Saturation Distribution Map

Figure (20) shows that, the hydrocarbon saturation distribution of the Markha Member in the study area is observed between 46% and 80%. It decreases in the eastern part and increases in the central and northwestern parts. The hydrocarbon distribution pattern indicates that the hydrocarbon potential of Markha Member reservoir quality is promising towards central and northwestern parts of the study area.

Figure (20): Hydrocarbon saturation map of the Markha Member in the study area.
Computer Processed Interpretation (C.P.I.) Plot for the Markha Member in.

Figure (21) is the computer processed interpretation (C.P.I.) plot for the Markha Member in EZA-11 well. As is shown in this figure, the Markha Member is encountered at depths 8716 to 9119 ft TVDSS. The gross thickness is 404 ft. The gamma ray curve indicates the presence of shale and sandstone penetrated in the well. The resistivity separation curves indicate the presence of hydrocarbon accumulation, where a high reading of the resistivity curves. The neutron and density value confirms the gamma ray readings and indicates the presence of shale and sandstone in the unit. Water saturation curve shows low water saturation in the net-pay interval and high water saturation in the rest of the unit. Effective porosity curve indicates that the effective porosity in reservoir interval ranges between 8% and 12%. Shale content curve indicates that the shale content in reservoir interval ranges between 18% and 30%.

Figure (21): computer processed interpretation (C.P.I.) plot for Markha Member in EZA-11well.
Computer Processed Interpretation (C.P.I.) Plot for the Markha Member.

Figure (22) is the computer processed interpretation (C.P.I.) plot for the Markha Member in EZC-2 well. As is shown in this figure, the Markha Member is encountered at depths 8122 to 8393 ft. The gross thickness is 271 ft TVDSS. The gamma ray curve indicates the presence of shale and sandstone penetrated in the well. The resistivity curves indicate the presence of hydrocarbon accumulation, where a high reading of the resistivity curves. The neutron and density value confirms the gamma ray readings and indicates the presence of shale and sandstone in the unit. Water saturation curve shows low water saturation in the net-pay interval. Effective porosity curve indicates that the effective porosity in reservoir interval ranges between 8% and 12%. Shale content curve indicates that the shale content in reservoir interval ranges between 0 and 25%.

Figure (22), Computer processed interpretation (C.P.I.) plot for the Markha Member in EZC-2 well.
Petroleum System

According to Magoon and Dow (1994), the source rock evaluation is the drive to the petroleum system and all related oil and gas accumulation. It also includes all the essential elements and processes needed for oil and gas accumulation to exist. The essential elements are the source rock, reservoir rock, seal rock, and overburden rock, and the processes include trap formation and the generation-migration-accumulation of petroleum. All essential elements must be placed in time and space such that the processes required forming a petroleum accumulation can occur.

Source Rock

The source rock potential in the southern Gulf of Suez has been studied by many authors (Shaheen and Shehab, 1984; Darwish et al., 2004). The main source rocks identified in the Gulf of Suez could be listed as: Brown Limestone, Sudr Chalk, Thebes carbonates and Rudeis Formation shale (lower Rudeis). The Brown Limestone is considered as the main and primary source rock of the Gulf of Suez. In the study area; the main source rock considered as the Brown Limestone while Rudeis Formation is ranked second for the possibility of sourced the hydrocarbon feeding inside the reservoirs in the area. Figure (23) shows that Upper Senonian brown limestone thickness in the study area is observed within the range of (100 to 220 ft). As is shown in this map the Upper Senonian brown limestone thickness decreases towards the northwestern part of the study area, and increases gradually towards the southeastern part recording its maximum thickness of 220 ft in the southeastern part.

Figure (23) Isopach map of the Upper Senonian Brown limestone.
Reservoir Rocks

Alsharhan, (2003), mentioned that, the sandstones of the Kareem Formation form one of the most important reservoir lithologies in the southern of the Gulf of Suez Sub-Basin and produce and/or test oil from many oilfields (including Morgan, Belayim Land and Belayim Marine, Amal, Kareem, Badri, Zeit Bay, East Zeit, Shoab Ali, Hilal, Sidki, Geisum, Ashrafi, GH376, Bahr, Warda, Kheir, Hareed, and Esh El Mellaha). In the study area, based on the Petrophysical evaluation of the reservoir units of Kareem Formation (Shager and Markha members). The main reservoir in the study area is Markha Member. Its lithology is sandstone, shale and limestone. Figure (16) show the thickness map of the gross reservoir As is shown in the map the net reservoir has its maximum thickness towards the western part of the study area and decreases toward north-eastern part of the area under investigation.

Seal Rocks

The pre-rift Cretaceous carbonates, Esna shale and Thebes limestone formations act as a vertical seals over the Cretaceous sandstones. Within the syn-rift sequence; the Miocene evaporates are always considered to be the ultimate seal in the Gulf of Suez (Rashed, 1990). In the study area, the cap rock is represented by the evaporate series of south Gharib Formation (Figure 24) and shale evaporate of Belayim Formation (Figure 25).

Figure (24): Seal map of the South Gharib Formation.
Petroleum Traps

Traps are any arrangement of rock regardless of origin that permits significant accumulation of oil or gas, or both, in the subsurface and includes a reservoir rock and an overlying or up dip seal rocks. Several mechanisms for hydrocarbon entrapment are recorded in the southern Gulf of Suez. These are structural, stratigraphic and combination traps, as described in detail by Saoudy (1990). In the study area, three way dip closure is developed along an NW-SE (Clysmic fault), that is bisected by small NE-SW faults. The closure is well defined on top the Kareem Formation down to the Rudeis Formation. Figure (26) is a structure contour map on top Kareem Formation, as shown in this map the Kareem Formation is affected by the major normal faults NW-SE (Clysmic fault trends) and minor normal faults with WNW-ESE trend along which the trap is formed. Based on the digital data of EZA-
In well 14, we used the pressure data to detect the oil-water contact. As shown in figure 27, the oil-water was detected in the Markha Member at depth 8580ft TVDSS.

Figure (26). Structure contour map, at top Kareem Formation in the study area.
Prospect Evaluation

According to Magoon and Dow (1994), prospects were first used by exploration geologists to describe present day structural or stratigraphic features that could be mapped and drilled. A series of related prospects are called Play. As a result of the present study using subsurface and petrophysical evaluation, three locations are proposed to be prospects in Lower Kareem Markha member as shown in figure (28). These locations structurally are located within a three way dip closure that is very attractive place for hydrocarbon accumulation. Petrophysically, these locations are characterized by the following: The first location, the red colored area, is located in the south of central part of the study area (the reservoir is 100-120 ft, the effective porosity is about 12%, the shale content is about 17%, the water saturation is about 40%, the hydrocarbon is about 60%). The second area is the black area, is located in the western part of the study area and characterized by the following; (the reservoir is about 210 ft thick, the effective porosity is about 11%, the shale content is about...
19%, the water saturation is about 25%, the hydrocarbon is about 75%). The third area is the yellow area, is found in the southeast of central part of the study area and is petrophysically characterized by the following; (the reservoir is 140-170 ft, the effective porosity is about 16%, the shale content is about 15%, the water saturation is about 35%, the hydrocarbon is about 65%.

Figure (28): New generated prospect map on top Lower Kareem Markha Member, showing the proposed locations in the study area.
Conclusion

As result of this study it can be conclude that: the area is affected by two fault systems: Longitudinal fault system, trending northwest-southeast (Clysmic trend) and a trending east northeast-west southwest faults. Kareem sandstone (the main reservoir is Markha Member) is thick with thickness ranges between 20 and 240 ft, good pores with effective porosity ranges between 9 and 12.5 %. shaly sandstone with shale content ranges between 10 and 32%, that can store a lot of the hydrocarbon where the water saturation becomes under the water saturation cutoff limit (60%). The area has all criteria to make it have considerable hydrocarbon potentials. It is characterized by having the hydrocarbon generating source rock, seal rocks, reservoir rocks with reasonable porosity and structure closure. Also, as result of the present study, based on subsurface and Petrophysical evaluation, three locations are proposed to be new prospect. These areas are found on three dip way closure and character by good Petrophysical parameters.

Acknowledgement

The authors indebted to East Zeit Petroleum Company (Zeitco) for permission to use the seismic profiles and well logs data presented in this study.

References


