CHAPTER VII
SUMMARY AND CONCLUSIONS

The present study of about eight wells in the East of Khalda area, Northern Western Desert, deals with the subsurface evaluation of Abu Roash "G" Member and Bahariya Formation as well as seismic analysis including velocity and seismic stratigraphy analysis for nine stratigraphic tops (Dabaa, Apollonia, Khoman, Abu Roash, Bahariya, Kharita, Alamein, Alam El-Bueib and Masajid Formations) in four of the studied wells in the study area.

-Geologic setting.

The study area lies in the northwestern part of the Western Desert to the south of Matruh City. It is located to the East of Khalda oil field in a low area (Meleiha Basin), and surrounded by the Matruh Basin to the north, Nasr Platform to the northeast and Qattara Ridge to the southwest. The predominant structural trends are NW-SE of alternating anticlinal and synclinal structures dissected by dip slip faults. Most of these initiated during the Late Cretaceous to Early Tertiary.

The surface is cropped out with rocks ranging in lithology from gravels to sands intercalated with clays aging from Pleistocene-Recent to Miocene. Stratigraphically, the subsurface rocks ranging in age from Lower Miocene to Lower Cretaceous or even Jurassic in some of the studied wells. The main oil producing reservoirs are the Bahariya and Alam El-Bueib Formations.
- Well logging analysis.

Such analysis is diversified into calculation of the average formation porosity; water and hydrocarbon saturation, lithologic composition of the analyzed rock units as well as the matrix parameters, water resistivity and volume of shale. Moreover, the mathematical equations for environmental corrections, calculations and well formation evaluation were determined.

The author used many computer programs for data entry, environmental corrections and graphical and computational approaches involved in the estimation of the different petrophysical parameters (shale content, matrix volumes and types, fractional porosity and fluid saturation) and formation evaluation techniques. The main advantage of the computer in well logging analysis is giving the chance to calculate each petrophysical parameter using large number of methods. This is done to cover the different conditions, which may affect the validity of parameter estimation. Then, the resulted values are weighted to choose the proper value, which is the least, affected by any other parameter.

a) Shale parameters of the studied rock units have been determined using frequency cross plots between M values and the logging readings. Shale volume is determined through the use of single and two-curve shale indicators. The different values of Vsh are corrected and calibrated to give the optimum values required for further interpretation. The shale content ranges from 7 % to 33 % for Abu Roash "G" Member and 29 % to 38 % for Bahariya Formation.

b) Matrix fractions have been evaluated using different methods. A statistical technique is carried out to compute the probabilities by which the occurrences of a given rock type at each depth in the studied formations can be determined.
c) Porosity is differentiated into total and effective porosity, through the graphical and computational approaches. Both approaches yield corporate estimation of the corrected porosity. Regarding Abu Roash "G" Member, the total porosity (4T) ranges from 10 % to 20 % and the effective porosity (Oeff.) ranges from 9 % to 19 %. Moreover, the total and effective porosity of Bahariya Formation ranging from 11 % to 21 % and 11 % to 19 %, respectively.

d) Also, the determination and discrimination of the fluid saturation (water saturation Sw and hydrocarbon saturation Sh) are carried out for both clean and shaly zones. Water saturation of Abu Roash "G" Member is ranging from 63 % to 100 %, while the total hydrocarbon saturation ranges from 0 % to 37 %. Bahariya Formation contains a range of 59 % to 99 % of water and 1 % to 41 % of hydrocarbons.

The well log crossplots are used to identify the matrix parameters, water saturation, water resistivity, and shale volume, total and effective porosity and the matrix composition.

1- Mono-porosity crossplots of resistivity logs (deep and shallow) and porosity tools (sonic, density and neutron) are used to determine the matrix parameters (ATma, pbma and 4Nma), waters saturation (Sw and Sxo) and water resistivity (Rw). A number of frequency crossplots relating Rxo vs. Rt. are used for the determination of water resistivity.

2- Dia-porosity crossplots (sonic-density, neutron-density and neutron-sonic) are applied to determine the shale volume (Vsh) and effective porosity (4eff.) of the studied formations.

3- Tri-porosity crossplots, on the other hand, are used to identify the lithologic constituents of the studied rock units. These plots show
that the interpreted lithology of the Abu Roash "G" Member is calcite and dolomite with considerable amounts of silica and shale. Also, the Bahariya Formation is interpreted as silica, shale and calcite with decreasing proportions of dolomite and anhydrite.

- Velocity analysis.

Sonic logs are considered the main source of velocity measurements in the study area. Calibrations are executed for the extraneous factors affecting the sonic log readings. Drift curve between the sonic log and the check shots is an essential product for the process of calibration, with the indication of both the magnitude and sign of drift of each well.

Average and interval velocities of the units; Dabaa, Apollonia, Khoman, Abu Roash, Bahariya, Kharita, Alamein, Alam El-Bueib and Masajid Formations in four of the studied wells in the study area are calculated and plotted in a number of two-dimensional plots and gradient maps. Consistent style of variation of the high and low velocity anomalies are found across the studied rock units.

The drift between time-depth curves derived from velocity analysis and those derived from well data are calculated and plotted for the wells: Sultan-1, Ashour-1, 1G-24-2 and IF-24-1, respectively. These drifts are positive sometimes and negative in other times, and in both reflecting conflicting systems of sedimentation.

Moreover, four reflectivity logs are constructed for Sultan-1, Ashour-1, 10-24-2 and IF-24-1 using the log data of the four wells to study the vertical changes in the reflection characteristics of the comparable stratigraphic units. The cyclic nature of sedimentation plays a prominent role in the magnitudes of the produced reflectivity and the polarities of the resulted reflection coefficients of the included boundaries take a certain and prominent arrangement, particularly in complete sections.
Concerning the structure of the study area, the available forty seismic lines scattered in the area are interpreted in terms of structural features. The result is the mapping of these features in terms of faults (dip-slip) on the top of Abu Roash, Bahariya, Alamein and Masajid Formations. The faults are oriented NW-SE, these faults are running parallel to each other in the form of Synthetic step-like faults or antithetic in the form of graben or horst belts. Intersections of these horst belts by fault elements of crossing trends transform them into block faults of varying sizes and parameters.

- Seismic stratigraphy.

About four seismic sections have been selected from forty sections covering the study area and processed for seismic stratigraphy, aided by lithologic logs, velocity logs and reflectivity logs. Seismic stratigraphic analysis is subdivided into seismic sequence analysis and seismic facies analysis.

Seismic sequence analysis includes the use of the interval velocities in defining the seismic sequence boundaries and identification of the termination phenomena either at the top or at the base of the sequence.

Also, seismic facies analysis is carried out by recognizing the seismic reflection characteristics (configuration, continuity, amplitude, frequency and interval velocities) and then identifying the reflection configuration patterns (parallel-sub-parallel, divergent, prograding, sigmoid, oblique, shingled, hummocky, chaotic and reflection free) on the seismic sections and transferring them into seismo-facies maps. Moreover, the lithologic well data have been used to thaw a number of isopach maps (thickness variation maps), ratio maps (clastic/non-clastic and sand/shale ratio maps) and lithofacies maps to study the depositional environment of the rock units in the investigated area. The depositional
environments ranged from alternating neritic shale/limestone to shallow marine elastics transported mainly by wave action, fluvial or nearshore elastics to, deep marine, hemipelagic deposits, and fluvial or nearshore elastics to stable shelf marine deposits.

**Subsurface evaluation.**

Integrated subsurface geological-formation evaluation system, cumulating the well depth data and the conclusions arrived through the well logging analysis, resulted in the interpretation of thickness variations of Abu Roash "G" Member and Bahariya Formation through the construction of isopach maps for the two studied formations, lithofacies analysis as well as interpreting structural features using seismic data.

Concerning thickness variation, the isopach map of Abu Roash "G" Member, exhibits observable thickening to the northeast and a marked thinning to the south of the study area. On the other hand, isopach map of Bahariya Formation is similar to that of Abu Roash "G" Member, where the maximum thickening is observed to the north and northeast of the study area.

Regarding lithofacies analysis, a number of distribution maps for the rock components (shale, sandstone and carbonates), ratio maps (sand/shale ratio and clastic/non-clastic ratio), and lithofacies maps as well as a number of two dimensional plots relating pbmaa versus Vsh or ATmaa versus Vsh are constructed to determine the depositional environments of the minerals forming Abu Roash "G" Member and Bahariya Formation. Lithofacies analysis of Abu Roash "G" Member reveals that, this unit was deposited under shallow marine environment, while Bahariya Formation was deposited under fluvio-marine to shallow marine environment.
Hydrocarbon potentiality.

The oil potential described in the present work is based on the determined petrophysical parameters, which can be represented vertically or horizontally.

*Vertical distributions of the petrophysical parameters* were represented by a number of litho-saturation crossplots of Abu Roash "G" Member and Bahariya Formation in the studied wells. Such plots show that, Abu Roash "G" Member consists mainly of carbonates, shale and sandstone. Bahariya Formation composed mainly of sandstone, shale and carbonates.

*Horizontal distributions of the petrophysical parameters* were represented by a number of iso-parametric maps to illustrate the distribution of the total and effective porosities, and the distribution of the fluids (water and hydrocarbons) saturating the pore spaces.

The total porosity gradient map of Abu Roash "G" Member shows the increase of porosity to the northeast and northwest. The effective porosity gradient map of Abu Roash "0" Member exhibits the same trends of variation. The total porosity gradient map of Bahariya Formation illustrates the increase of porosity toward the south and northwest. The effective porosity gradient map shows the increase of porosity system in the same directions.

Water saturation map of Abu Roash "G" Member shows a southeast-southwest increase in percentage associated with a decrease in the hydrocarbon saturation. Regarding Bahariya Formation, the water saturation distribution map indicates a gradual increase to the east and the northwest directions, while the hydrocarbon saturation distribution map show gradual decrease in the same direction.

Source rocks, in the study area, are identified by using different electrical logs (gamma ray, resistivity, density and sonic) in the form of a
number of two dimensional plots to differentiate the source and non-source rocks, as well as illustrating the vertical distribution of the estimated total organic content (TOC), total organic matter (TORG) and the discriminate factor of the studied rock units in the investigated area.

1. Organo-source analysis of Abu Roash "G" Member reveals that, this unit contains fair amounts of organic carbon content. Most of the data points are of negative discriminate factor, indicating that, this unit is non-source in the majority of the studied wells.

1. Organo-source analysis of Bahariya Formation reflects that, this formation contains good amounts of organic carbon content. Most of the data points are of positive discriminate factor, indicating that, this unit is a source in the most of the studied wells.

A number of iso-parametric maps are drawn to illustrate the distribution of the total organic carbon and the total organic matter of the studied rock units in the investigated area.

The total organic carbon distribution map of Abu Roash "G" Member shows a considerable increase toward the north and the southeast parts and decreases to the northeast and the southwest. The total organic carbon distribution map of Bahariya Formation, illustrates a noticeable increase to the southern and northwestern portions of the map, and decreases to the east and the southwest of the studied area.

From the preceding discussion, it is clear that Abu Roash "G" Member can be considered as fair source rock; while, Bahariya Formation, is good source rock. Moreover, Bahariya Formation, which is composed, of highly porous sandstone with shale and limestone intercalation, is considered as a good reservoir rock.
The hydrocarbon potentiality of the study area is good especially at Lotus-1X, IF-24-1 and Sultan-1X wells.

Based on structural, stratigraphical and hydrocarbon content analysis, it is recommended to explore in the northwest and the southwest directions of Lotus-1X well.