



AIN SHAMS UNIVERSITY
FACULTY OF SCIENCE
GEPHYRICS DEPARTMENT

**3D Structural Modeling and its Impact on Hydrocarbon
Reservoirs utilizing 3D Seismic Data Interpretation at West
Qarun Oil Field, Northwestern Desert, Egypt.**

By

Ahmed Ali Abd El-Salam Rayan
(B. Sc. In Geophysics)

A Thesis

Submitted in partial fulfillment of the requirements of Master Degree of
Science in Geophysics

Supervised by

Prof. Dr. Abdel-Khalek Mahmoud El-Werr

Professor of Geophysics,
Geophysics department,
Faculty of Science – Ain Shams University

Dr. Azza Mahmoud Abd El-Latif El-Rawy

Lecturer of Geophysics
Geophysics department,
Faculty of Science – Ain Shams University

**GEPHYRICS DEPARTMENT
FACULTY OF SCIENCE
AIN SHAMS UNIVERSITY
2017**

SUPERVISORS

Prof. Dr. Abdel-Khalek Mahmoud El-Werr

Professor of Geophysics,
Geophysics Department,
Faculty of Science–Ain Shams University

Dr. Azza Mahmoud Abd El-Latif El-Rawy

Lecture of Geophysics,
Geophysics Department,
Faculty of Science–Ain Shams University

ACKNOWLEDGMENTS

Firstly and before all, my complete praise is for Almighty God, Allah, lord of the universe, who guided and blessed me during the preparation of this work.

I would like to thank and express my great appreciation to **Prof. Dr. Abdel-Khalek Mahmoud El-Werr**, professor of Geophysics, Faculty of Science, Ain Shams University for his supervision, scientific advice and critical reading and reviewing all the work.

I would like to thank **Dr. Azza Mahmoud Abd El-Latif El-Rawy**, lecture of Geophysics, Faculty of Science, Ain Shams University, for supporting the idea, following the work, reading and reviewing the main scripts.

I would like also to thank **OAPCO** and **Sahara Oil & Gas Co.** for providing the data.

Dedication

This work is dedicated to my **family** who has been always supporting me. Especial dedication is to my **wife** whose support and devotion kept me going.

ABSTRACT

West Qarun Oil Field is located in Abu Gharadig basin of the northern Western Desert, Egypt. It lies between latitudes 29° 36' N and 29° 39' N and longitudes 29° 16' E and 29° 22' E.

The main purpose of this study is to evaluate West Qarun oil field by studying the subsurface geologic structural features and the interested reservoir markers (Middle, Lower Abu Roash "G" Member and Bahariya Formation) which are considered the main primary potential reservoirs in the study field.

To achieve these objectives, the current study started with the description of the geological setting of the area, including the stratigraphic sequence and dominating structures through a review for the pervious geological studies. Then, 3D seismic data interpretation was carried out by using Petrel (2013) to provide detailed information about the subsurface structural geometry of West Qarun oil field. The 3D seismic interpretation step started by fault pattern interpretation through the original seismic data in order to delineate the subsurface structural features using conventional and unconventional seismic interpretation (seismic attributes) methods, then horizon interpretation process including the interested reservoir markers. The depth structure maps which are constructed on the tops of Abu Roash "A", Middle Abu Roash "G", Lower Abu Roash "G", Bahariya and Alamein surfaces reveal that the West Qarun trap is an elongated NW-SE faulted anticline structural trap that constitutes over step-like fault pattern that has the same trend and downthrown towards the NE direction.

Then, comprehensive quantitative petrophysical review was carried out for the available wells in study area to determine the main petrophysical parameters for the main reservoir rocks like, net pay thickness, porosity, shale content, water and hydrocarbon saturation based on a number of equations and empirical formula. The well log data analysis has been done using Interactive Petrophysics (IP, 2013) Software.

Then, 3D structure model has been built through five processes (fault modeling, pillar gridding, make horizons, make zones and edit 3D grids). These processes should always be considered together and undergo several iterations to enhance the final structure model. The obtained 3D structure model confirms the interpreted structure from the seismic data.

Moreover, fault seal analysis has been done for the Middle and Lower Abu Roash “G” (A/R ‘G’) reservoirs, by using Allan’s Diagram method across the main normal fault planes (F-1, F-2 and F-a). Allan’s diagrams indicate that, the faults (F-1) and (F-a), which are located in the northern part of the study area are perfect seal in the Middle and Lower Abu Roash “G” reservoirs, while the fault (F-2), behaves as likely sealed in the Middle Abu Roash “G” and becomes a transmissive (leak) fault where the sealing is unlikely in the Lower Abu Roash “G”.

Evaluation parameters of a prospect which are the representative elements of petroleum system include essentially aerial extent and amplitude (thickness) of the structure, the source type and the reservoir facies, the seals and the entrapment mechanism to form an effective trap. These elements of petroleum system were evaluated and four new locations (A, B, C and D) were detected. The locations A, B, C and D proposed as plays for future exploration and development activities and drilling in West Qarun Oil field with respect to their seismic structural highs and suitability of petrophysical parameters in the Middle, Lower Abu Roash “G” Member and Bahariya Formation reservoirs.

Key Words: West Qarun Oil Field, Western Desert, Tectonic Trends, 3D Seismic interpretation, Petrophysical Properties, 3D Structure Model, Fault Seal Analysis, Locating Promising Prospects.

TABLE OF CONTENTS

<u>Subject</u>	<u>Page</u>
Table of Contents	i
List of Figures	v
List of Tables	ix
Chapter 1: Introduction	1
1.1 Location of the Study Area	1
1.2 Objectives of the Study	1
1.3 Available Data	2
1.4 Methodology	3
1.5 Concession History	3
Chapter 2: Regional Geologic Setting	5
2.1 Introduction	5
2.2 Surface Geology	6
2.3 Stratigraphy	10
2.3.1 Pre-Cambrian Basement	13
2.3.2 Paleozoic	13
2.3.2.1 Cambrian-Ordovician	13
2.3.2.2 Silurian	14
2.3.2.3 Devonian	15
2.3.2.4 Carboniferous	15
2.3.2.5 Permian	15
2.3.3 Mesozoic	16
2.3.3.1 Triassic	16

2.3.3.2 Jurassic	16
2.3.3.3 Cretaceous	17
2.3.3.4 Cenozoic	20
2.4 Structural Setting	21
2.5 Tectonics	28
2.5.1 Late Carboniferous - Liassic Rifting Episodes	28
2.5.2 Late Jurassic-Early Cretaceous Rifting Episodes	29
2.5.3 Late Santonian Basin Inversion	30
Chapter 3: 3D Seismic Data Interpretation	32
3.1 Introduction	32
3.2 Available Data	34
3.2.1 Seismic Acquisition	35
2.3.1.1 Seismic Acquisition Parameters	36
3.2 Seismic Processing	38
3.2.2.1 Main Processing Sequence	39
3.3 Work Flow of Seismic Interpretation	40
3.3.1 Data Importing	41
3.3.2 Fault Interpretation Process	41
3.3.2.1 Conventional Method for Fault Interpretation	42
3.3.2.2 Seismic attributes Fault Interpretation	48
3.3.3 Horizon Interpretation Process	57
3.3.4 Mapping Interpretation Process	64
3.4 Tectonic Inference of the Study Area	69
Chapter 4: Well Log Analysis	70
4.1 Introduction	70

4.2 Available Data	71
4.3 Work Flow	72
4.3.1 Qualitative Correlation	73
4.3.2 Quantitative Analysis	76
4.3.2.1 Determination of formation temperature	76
4.3.2.2 Determination of shale volume	77
4.3.2.3 Determination of formation porosity	86
4.3.2.4 Determination of the formation water resistivity	92
4.3.2.5 Determination of fluid saturations	95
4.3.2.6 Determination of lithologic components	96
4.3.2.7 Petrophysical parameters cut-off estimation	104
4.3.3 Lateral Distribution of Petrophysical Parameters	111
4.3.3.1 Shale percentage map	111
4.3.3.2 Effective porosity map	114
4.3.3.3 Net pay map	117
4.3.3.4 Water saturation map	120
4.3.3.5 Hydrocarbon saturation map	123
Chapter 5: 3D Structural Modeling and Fault Seal Analysis	127
5.1 3D Structural Modeling	127
5.1.1 Introduction	127
5.1.2 Work Flow of the 3D Structural Modeling	128
5.1.2.1 Fault Modeling	129
5.1.2.2 Pillar Gridding	130
5.1.2.3 Make Horizons	132
5.1.2.4 Make Zone	134

5.1.2.5 Edit 3D Grid	135
5.2 Fault Seal Analysis	137
5.2.1 Introduction	137
5.2.2 Controlling Factors of Fault Seal Analysis	137
5.2.3 Recognizing Mechanisms of Fault Seal	138
5.2.4 Methods used for Evaluating of Fault Seal Analysis	139
Chapter 6: Petroleum System and Prospect Detection	146
6.1 Introduction	146
6.1.1 Source Rocks	147
6.1.2 Maturation	148
6.1.3 Reservoir Rocks	148
6.1.3.1 Abu Roash “G” Sandstone	149
6.1.3.2 Bahariya Sandstones	149
6.1.4 Traps	150
6.1.5 Seal Rocks	151
6.1.5.1 Vertical Seal	151
6.1.5.2 Lateral Seal	151
6.2 Prospect Detection	151
Summary and Conclusion	155
Reference	164
Arabic Summary	

List of Figures

Figure No.	Figure Caption	Page No.
1-1	Location map of West Qarun study area	2
2-1	Western Desert location map	5
2-2	Geological map of Egypt	8
2-3	Subdivision of Egypt area in the four principal units	9
2-4	Generalized litho-stratigraphic column of the northern part of the Western Desert	12
2-5	The tectonic elements in the Western Desert, Egypt	24
2-6	Pulling the Western Desert Apart	27
3-1	Location base map of boreholes and seismic lines for West Qarun area	35
3-2	Inline 511775 vertical seismic section	43
3-3	Crossline 110775 vertical seismic section	44
3-4	Arbitrary line vertical seismic section	45
3-5	Horizontal depth slice at 6700 ft depth level near the top of Middle Abu Roash "G"	46
3-6	Horizontal depth slice at depth of 6900 ft near the top Lower Abu Roash "G"	47
3-7	Horizontal depth slice at depth 7100 ft near the top Bahariya Formation	47
3-8	Variance attribute map on top Middle Abu Roash "G" surface	51
3-9	Variance attribute map on top Middle Abu Roash "G" surface superimposed by fault polygons	51
3-10	Variance attribute map on top Lower Abu Roash "G" surface	52
3-11	Variance attribute map on top Lower Abu Roash "G" surface superimposed by fault polygons	53
3-12	Variance surface attribute map on top Bahariya surface	54
3-13	Variance surface attribute map on top Bahariya surface superimposed by fault polygons	54
3-14	Fault polygons overlaying each other for the main three interpreted surfaces	55
3-15	Ant-track attribute map on top Middle Abu Roash "G" surface	56

3-16	Ant-track attribute map on top Lower Abu Roash “G” surface	56
3-17	Ant-track attribute map on top Bahariya surface	57
3-18	Seismic arbitrary line passing through the available wells in West Qarun oil field	58
3-19	Interpreted inline 511775 seismic section	61
3-20	Interpreted inline 517575 seismic section	62
3-21	Interpreted crossline 113675 seismic section	63
3-22	Interpreted crossline 110775 seismic section	64
3-23	Depth structural map on top Abu Roash “A” Member	66
3-24	Depth structural map on top Middle Abu Roash “G” reservoir	67
3-25	Depth structural map on top Lower Abu Roash “G” reservoir	67
3-26	Depth structural map on top Bahariya Formation	68
3-27	Depth structural map on top Alamein Formation	68
4-1	Stratigraphic correlation passing through the interested wells in the study area (AA')	75
4-2	The neutron-density crossplot clay indicator	79
4-3	The neutron-density cross plot of Bahariya Formation in WQ34/15-1 well	80
4-4	The neutron-density cross plot of Bahariya Formation in WQ34/15-2 well	81
4-5	The neutron-density cross plot of Bahariya Formation in WQ34/15-3 well	81
4-6	The neutron-density cross plot of Bahariya Formation in WQ34/15-10 well	82
4-7	The neutron-density cross plot of Lower Abu Roash "G" in WQ34/15-1 well	82
4-8	The neutron-density cross plot of Lower Abu Roash "G" in WQ34/15-2 well	83
4-9	The neutron-density cross plot of Lower Abu Roash "G" in WQ34/15-3 well	83
4-10	The neutron-density cross plot of Lower Abu Roash "G" in WQ34/15-10 well	84
4-11	The neutron-density cross plot of Middle Abu Roash "G" in WQ34/15-1 well	84
4-12	The neutron-density cross plot of Middle Abu Roash "G" in WQ34/15-2 well	85

4-13	The neutron-density cross plot of Middle Abu Roash "G" in WQ34/15-3 well	85
4-14	The neutron-density cross plot of Middle Abu Roash "G" in WQ34/15-10 well	86
4-15	Formation water resistivity value of Bahariya Formation derived from Schlumberger Chart Gen-9	93
4-16	Formation water resistivity value of Abu Roash "G" Member derived from Schlumberger Chart Gen-9	94
4-17	UMAPP/RHOMAPP cross-plot of Bahariya Formation in WQ34/15-1 well	98
4-18	UMAPP/RHOMAPP cross-plot of Bahariya Formation in WQ34/15-2 well	98
4-19	UMAPP/RHOMAPP cross-plot of Bahariya Formation in WQ34/15-3 well	99
4-20	UMAPP/RHOMAPP cross-plot of Bahariya Formation in WQ34/15-10 well	99
4-21	UMAPP/RHOMAPP cross-plot of Lower Abu Roash "G" in WQ34/15-1 well	100
4-22	UMAPP/RHOMAPP cross-plot of Lower Abu Roash "G" in WQ34/15-2 well	100
4-23	UMAPP/RHOMAPP cross-plot of Lower Abu Roash "G" in WQ34/15-3 well	101
4-24	UMAPP/RHOMAPP cross-plot of Lower Abu Roash "G" in WQ34/15-10 well	101
4-25	UMAPP/RHOMAPP cross-plot of Middle Abu Roash "G" in WQ34/15-1 well	102
4-26	UMAPP/RHOMAPP cross-plot of Middle Abu Roash "G" in WQ34/15-2 well	102
4-27	UMAPP/RHOMAPP cross-plot of Middle Abu Roash "G" in WQ34/15-3 well	103
4-28	UMAPP/RHOMAPP cross-plot of Middle Abu Roash "G" in WQ34/15-10 well	103
4-29	The log analysis results in WQ34/15-1 well	107
4-30	The log analysis results in WQ34/15-2 well	108
4-31	The log analysis results in WQ34/15-3 well	109
4-32	The log analysis results in WQ34/15-10 well	110
4-33	Shale percentage distribution map of Bahariya reservoir	112
4-34	Shale percentage distribution map of Lower Abu Roash reservoir	113

4-35	Shale percentage distribution map of Middle Abu Roash reservoir	114
4-36	The effective porosity distribution map of Bahariya reservoir	115
4-37	The effective porosity distribution map of Lower Abu Roash reservoir	116
4-38	The effective porosity distribution map of Middle Abu Roash reservoir	117
4-39	Net Pay thickness map of Bahariya reservoir	118
4-40	Net Pay thickness map of Lower Abu Roash reservoir	119
4-41	Net Pay thickness map of Middle Abu Roash reservoir	120
4-42	The water saturation distribution map of Bahariya reservoir	121
4-43	The water saturation distribution map of Lower Abu Roash reservoir	122
4-44	The water saturation distribution map of Middle Abu Roash reservoir	123
4-45	The hydrocarbon saturation distribution map of Bahariya reservoir	124
4-46	The hydrocarbon saturation distribution map of Lower Abu Roash reservoir	125
4-47	The hydrocarbon saturation distribution map of Middle Abu Roash reservoir	126
5-1	Fault model in a 3D view	130
5-2	100*100 m 3D gridding skeleton	132
5-3	Final Horizon Model in a 3D view	133
5-4	Zonation model in a 3D view	135
5-5	Final 3D structure model of West Qarun field in a 3D view	136
5-6	Schematic presentation showing Allan diagram based on seismic data and wellbore information	140
5-7	Depth structural map on top Middle Abu Roash “G” reservoir	142
5-8	Allan diagram for the NW-SE normal major fault (F-1)	143
5-9	Allan diagram for the NW-SE normal fault (F-a)	144
5-10	Allan diagram for the NW-SE normal major fault (F-2)	145
6-1	Petroleum maturation diagram	148
6-2	Complex combination and structural trap	150
6-3	Prospect identification on top Lower Abu Roash “G” reservoir	152

List of Tables

Table No.	Table Caption	Page No.
3-1	The spread parameters	36
3-2	The source parameters	37
3-3	The receiver parameters	38
3-4	Main processing sequence	39
4-1	available wire-line logs of WQ34/15-1 well	71
4-2	The available wire-line logs of WQ34/15-2 well	71
4-3	The available wire-line logs of WQ34/15-3 well	72
4-4	The available wire-line logs of WQ34/15-10 well	72
4-5	The determined petrophysical properties for Bahariya reservoir in the studied wells	105
4-6	The determined petrophysical properties for Lower Abu Roash "G" reservoir in the studied wells.	105
4-7	The determined petrophysical properties for Middle Abu Roash "G" reservoir in the studied wells	106

CHAPTER 1

INTRODUCTION

1.1 LOCATION OF THE STUDY AREA

The West Qarun development concession is located in Abu Gharadig basin of the northern Western Desert, about 220 km southwest of Cairo city. The block comprises a gross area of 46.2 km². It is bounded from the south by Sitra platform and from the north by Ras Qattara uplift and from the east by Kattaniya high and from the west by Siwa platform. It lies between latitudes 29° 36' N and 29° 39' N and longitudes 29° 16' E and 29° 22' E (Figure 1-1). This part of Abu Gharadig basin is considered to be valuable for all petroleum companies due to the availability of petroleum system elements.

1.2 OBJECTIVES OF THE STUDY

The objectives of study is to evaluate West Qarun oil field by studying the subsurface geologic structural features through picking and identification of the horizon packages including interested reservoir markers (Bahariya Formation, Lower and Middle Abu Roash “G” Members) which are considered the main primary potential reservoirs in the study field. Then, petrophysical evaluation of the studied intervals for reservoir characterization, constructing of 3D structural model using 3D seismic data and fault seal analysis were carried out.

Finally, integrating the seismic and petrophysical results to obtain the detailed information about the field for the development stage to increase