



AIN SHAMS UNIVERSITY
FACULTY OF SCIENCE
GEPHYRICS DEPARTMENT

"Geophysical Study on some Salt Dome Structures in the Southern Part of the Gulf of Suez, Egypt"

A Thesis Submitted in Partial Fulfillment of the Requirements for
The Master Degree of Science in Geophysics

By

Camellia Saber Mahran Moftah Mahran

(B. Sc. In Geophysics)

Supervised by

Prof. Dr. Abdel-Khalek Mahmoud El-Werr

Professor of Geophysics,

Geophysics Department,

Faculty of Science, Ain Shams University

Dr. Abd Allah Mahmoud El Sayed

Associate Professor of Geophysics,

Geophysics Department,

Faculty of Science, Ain Shams University

Dr. Ahmed Mohamed Sobhy Helaly

Associate Professor of Geophysics,

Geophysics Department,

Faculty of Science, Ain Shams University

GEPHYRICS DEPARTMENT

FACULTY OF SCIENCE

AIN SHAMS UNIVERSITY

Cairo, Egypt

2016

SUPERVISORS

Prof. Dr. Abdel-Khalek Mahmoud El-Werr

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

Dr. Abd Allah Mahmoud El Sayed

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

Dr. Ahmed Mohamed Sobhy Helaly

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

ACKNOWLEDGEMENTS

First and above all, I would like to express my great thanks to "ALLA" who supplied me with strength and patience to complete this work.

"Thanks GOD".

I wish to express my gratitude and deep appreciation to Dr. Abd El K halek El Werr, Professor of Geophysics, Geophysics Department, Faculty of Science, Ain Shams University, for his supervision, encouragement, kind help, valuable advice and revising the manuscript of the present work.

I would like to express my special gratitude to Dr. Abdulla Mahmoud El Sayed, Assistant Professor of Geophysics, Geophysics Department, Faculty of Science, Ain Shams University, for helping me and learning me how to use also Techlog software.

I am greatly appreciated to Dr. Ahmed Sobhy El Hilaly, Assistant Professor of Geophysics, Geophysics

Department, Faculty of Science, Ain Shams University for his supervision.

I am greatly indebted to. Dr. Sallah Abd El Wahab, Professor of Geophysics, Geophysics Department, Faculty of Science, Ain Shams University for his great support, help and valuable advices.

Thanks are extended to Gulf of Suez Petroleum Company (GUPCO) and its friendly teamwork for providing the data required for this work, especially Mr. Essam Ahmed, Dr. Hatem Farouk, Ahmed Ismail, Samy Kamal, Wael Alla El Den and my dear friend Mahmoud Abu El Nasr.

Special thanks to Dr. Wafik M. Meshref for his kind help.

I am very grateful to my friends Ismail El Wakef, Mohamed El Arabi and Mohamed Abd El Dayem, for there huge support and help in the present work.

*There is no enough words in the world to my best friend
Wael Raafat who have always had my back, supported me,
wiped my tears, thank you for always giving me the extra push I
need, for supporting me in my dreams and believing in me even
when I didn't believe in myself and thank you for being my rock.*

*Last but not least, grateful and true appreciation is
expressed to my family for their help, patience and
encouragement, but no words of thanks and feelings are
sufficient.*

Thanks to GOD

ABSTRACT

The area under study lies in the southern part of the Gulf of Suez, Egypt. Integrated geophysical study has been carried out in the study area for estimating and recognizing the geological features, especially Salt Dome Structures and fault element trends, then focusing our study on Hilal Oil Field which lies between latitudes $27^{\circ} 46' \text{ N}$ and $27^{\circ} 51' \text{ N}$ and longitudes $33^{\circ} 42' \text{ E}$ and $33^{\circ} 47' \text{ E}$.

This work is concerned in the interpretation of gravity anomalies in the southern part of the Gulf of Suez to detect the major predominant trend of the regional structural features.

In addition, petrophysical properties and subsurface structural geological features using formation evaluation of well logs and seismic reflection data interpretation, respectively, at Hilal Oil Field have been achieving. The formation evaluation involves measurements and corrections of the fluid resistivity, rock resistivity, shale content, porosity values and fluid saturations. Where, different quantitative interpretation steps that had performed by using the computer technique and a number of distribution and saturation maps (porosity, shale content, water and net pay of hydrocarbon saturation) as well as, the Litho-saturation crossplots was constructed to show the horizontal and vertical distribution of the hydrocarbon occurrences in the study area.

Conventional seismic data interpretation was very difficult for estimation of the subsurface geological features due to the complex geology of the Gulf of Suez that is arising from the broken rock blocks with different types of faults. That is why unconventional seismic interpretation (seismic attributes) has been used for solving this complexity and it was very useful approach.

Different types of seismic attributes such as Dip of Maximum Similarity, Smoothed Dip of Maximum Similarity, Trace Envelope, Wavelet Envelope, Similarity, Similarity Variance, Dip Variance, Instantaneous Lateral Continuity, Event Continuity ... etc., have helped us to detect the reflection horizons and the normal faults within the

salt border. Event Continuity and Instantaneous Phase attribute were the best in subsalt layers detection.

All the previous studies, structures, well-logs analysis and seismic structural interpretation were tied together to get a complete understanding of the hydrocarbon potentiality in the area under study.

Key words:

Gulf of Suez, Hilal oil field, Salt domes, Gravity, Well logging analysis, seismic attributes, subsalt detecting.

LIST OF CONTENTS

Subject	Page number
ACKNOWLEDGMENTS	
ABSTRACT	
LIST OF CONTENTS	8
LIST OF FIGURES	VI
LIST OF TABLES	IX
 CHAPTER 1: INTRODUCTION	 1
1.1 Location of the study Area	1
1.2 Previous Exploration Works	2
1.3 Aim and Objectives	4
1.4 Available Data	4
1.5 Methodology and Techniques	5
 CHAPTER 2: REGIONAL GEOLOGIC SETTING	 7
2.1 Regional Overview	7
2.2 Tectonic Framework	9
2.2.1 Tectonic Evolution	9
2.2.2 Megatectonic And Evidences Of Movement	12
2.3 Current Structural Setting Of The Gulf Of Suez Basin	13
2.3.1 Northern Province	14
2.3.2 Central Province	15
2.3.3 Southern Province	15
2.4 Stratigraphy	16
2.5 Hilal Oil Field	18
2.6 Structural Geology	20
2.6.1 Descriptive structural geology	20
2.6.2 Tilting	21
2.6.3 Faulting	21
2.6.4 Unconformities	23
2.6.5 Salt Doming	24
2.7 Stratigraphy	24
2.8 Hydrocarbon Potential	29
 CHAPTER 3: GRAVITY	 32
3.1. Introduction	32
3.2. The Gravity Technique	33
3.3 Gridding	34
3.4 Qualitative Interpretation Of Gravity Data	35
3.5 Data Separation	39
3.6 Enhancement Of Gravity Anomalies	46

CHAPTER 4: WELL LOGGING ANALYSIS	51
4.1 Introduction	51
4.2 Available Well Data for our study	52
4.3 Evaluation of Petrophysical Properties	52
4.3.1 Determination of Volume of Shale Content (Vsh)	53
4.3.1.1 Gamma Ray Log (GR Log)	53
4.3.1.2 Neutron-Density logs	53
4.3.2 Determination of Porosity (Φ)	54
4.3.2.1 Density Log (Φ_D)	55
4.3.2.2 Neutron Log (Φ_N)	55
4.3.2.3 Sonic Log (Φ_S)	56
4.3.2.4 Determination of Total Porosity (Φ_T)	58
4.3.2.5 Determination of Effective Porosity (Φ_E)	58
4.3.3 Determination of Water Saturation (S_w)	59
4.3.3.1 Determination of Total Water Saturation by Dual Water Equation	62
4.3.3.2 Determination of Effective Water Saturation by Indonesia Equation	63
4.3.4 Determination of Hydrocarbon Saturation (S_h)	63
4.4 Lithology Determination And Interpretation	64
4.4.1 Neutron- Density Crossplots	65
4.4.2 M- N Crossplots	71
4.4.3 Histogram of gamma ray	78
4.4.4 Litho-saturation Crossplots	83
CHAPTER 5: SEISMIC DATA INTERPRETATION	86
5.1 Introduction	86
5.2 Available Seismic Data in the Study Area	88
5.3 Seismic Data Interpretation	91
5.3.1 Seismic Data Interpretation Technique	91
5.3.2 Seismic Data Interpretation Outputs	94
5.3.2.1 Interpretation of seismic sections in the Study Area	94
5.3.2.1.1 Interpreted seismic section (Crossline-1610)	96
5.3.2.1.2 Interpreted seismic section (Crossline-1592)	98
5.3.2.1.3 Interpreted seismic section (Crossline-1572)	99
5.3.2.1.4 Interpreted seismic section (Crossline-1530)	100
5.3.2.2 Interpretation of Seismic Maps	101
5.3.2.2.1 Depth structure map on the top of the Basement Complex	102
5.3.2.2.2 Depth structure map on the top of Nubia Formation	103
5.3.2.2.3 Depth structure map on the top of Kareem Formation	104
5.3.2.2.4 Depth structure map on the top of Zeit Formation	105

CHAPTER 6: SEISMIC ATTRIBUTES	108
6.1 Introduction	108
6.2 Classification Of Seismic Attributes	108
6.2.1 Trace Attributes	109
6.2.2 Multi-Trace Attributes	109
6.2.3 Geometric Attributes	109
6.2.4 Physical Attributes	111
6.2.4.1 Wavelet Attributes	112
6.2.4.2 Instantaneous Attributes	113
6.2.4.2.1 Post-Stack Instantaneous Attributes	116
6.2.4.2.2 Pre-Stack Instantaneous Attributes	122
6.3 Applications Of Seismic Attributes	123
6.3.1 Fault Detection Attributes	123
6.3.2 Subsalt Detection Attributes	131
Summary and Conclusion	136
Reference	141
Arabic Summary	\

LIST OF FIGURES

Fig. 1.1	Hilal Oil Field location map in the southern part of the Gulf Suez	1
Fig. 1.2	Hilal Oil Field platform	3
Fig. 2.1	Generalized stratigraphic column of the Gulf of Suez	9
Fig. 2.2	Gulf of Suez major tectonic features and troughs (Meshref 1990)	11
Fig. 2.3	Gulf of Suez Rift Structural Provinces (modified after Mostafa, 1976 & Rashed 1990)	14
Fig. 2.4	Geologic Cross Section Across B – Trend Showing South Gharib And Salt Thickening On Downdip Side Of Uplifted Tilted Fault Block (Meshref)	18
Fig. 2.5	Geologic Cross Section Across Hilal Field Showing Evaporite Seal For Both Miocene And Pre – Miocene Porosities (Meshref)	20
Fig. 2.6	Structure cross section of Hilal Oil Field (after EGPC, 1996)	28
Fig. 2.7	Stratigraphic column of Hilal Field (after EGPC, 1996)	31
Fig. 3.1	Bouguer gravity anomaly map Southern Gulf of Suez	37
Fig. 3.2	3D view of the Bouguer gravity anomaly map at the southern part of the Gulf of Suez	38
Fig. 3.3	Vector map of the Bouguer gravity anomaly at the Southern part of the Gulf of Suez	39
Fig. 3.4	Vector map of the residual gravity anomaly at depth 2 km at the southern part of the Gulf of Suez	43
Fig. 3.5	Vector map of the residual gravity anomaly at depth 4 km at the southern part of the Gulf of Suez	44
Fig. 3.6	Vector map of the second vertical derivative gravity anomaly at depth 2 km at the southern Gulf of Suez	48
Fig. 3.7	Vector map of the second vertical derivative gravity anomaly at depth 4 km at the southern Gulf of Suez	49
Fig. 3.8	3D view second vertical derivative gravity anomaly map at depth 2 km	50
Fig. 3.9	3D view second vertical derivative gravity anomaly map at depth 4 km	50
Fig. 4.1	Well location map for the studied wells in Hilal oil field	52
Fig. 4.2	Shale zone in GH404-2 well	54
Fig. 4.3	Pickett cross plot in Hilal A9A well	60
Fig. 4.4	Pickett cross plot in Hilal A9 well	60
Fig. 4.5	Pickett cross plot in Hilal A4 well	61
Fig. 4.6	Pickett cross plot in Hilal A16 well	61
Fig. 4.7	Density- Neutron cross plot in GH404-2 well	66
Fig. 4.8	Density- Neutron cross plot in GH404-2A well	67
Fig. 4.9	Density- Neutron cross plot of Nubia Formation in GH404-2A well	67
Fig. 4.10	Density- Neutron cross plot in Hilal A16 well	68
Fig. 4.11	Density- Neutron cross plot of Nubia Formation in Hilal A16 well	69

Fig. 4.12	Density- Neutron cross plot in Hilal A9 well	69
Fig. 4.13	Density- Neutron cross plot in Hilal A9A well	70
Fig. 4.14	Density- Neutron cross plot of Nubia Formation in Hilal A9A well	71
Fig. 4.15	M-N cross plot in GH404-2 well	73
Fig. 4.16	M-N cross plot of South Gharib formation in GH404-2 well	74
Fig. 4.17	M-N cross plot in GH404-2A well	74
Fig. 4.18	M-N cross plot of South Gharib formation in GH404-2A well	75
Fig. 4.19	M-N cross plot of Nubia formation in GH404-2A well	76
Fig. 4.20	M-N cross plot in Hilal A16 well	76
Fig. 4.21	M-N cross plot of Nubia formation in Hilal A16 well	77
Fig. 4.22	Histogram of gamma ray for well GH404-2	78
Fig. 4.23	Histogram of gamma ray for well GH404-2A	79
Fig. 4.24	Histogram of gamma ray for well Hilal A16	79
Fig. 4.25	Histogram of gamma ray for Nubia formation in well Hilal A16	80
Fig. 4.26	Histogram of gamma ray for well Hilal A4	81
Fig. 4.27	Histogram of gamma ray for Nubia formation in well Hilal A4	81
Fig. 4.28	Histogram of gamma ray for well Hilal A9	82
Fig. 4.29	Histogram of gamma ray for well Hilal A9A	82
Fig. 4.30	Lithology, oil, and gas pattern used in lithosaturation crossplot	83
Fig. 4.31	Lithosaturation crossplot for Nubia formation in Hilal A16 well	84
Fig. 4.32	Lithosaturation crossplot for South Gharib formation in Hilal GH404 2A well	85
Fig. 5.1	Study area location map seismic lines base map	89
Fig. 5.2	Interpreted seismic section (Crossline-1610)	98
Fig. 5.3	Interpreted seismic section (Crossline-1592)	99
Fig. 5.4	Interpreted seismic section (Crossline-1572)	100
Fig. 5.5	Interpreted seismic section (Crossline-1530)	101
Fig. 5.6	Depth structure map on top Basement Complex	103
Fig. 5.7	Depth structure map on top Nubia Formation	104
Fig. 5.8	Depth structure map on top Kareem Formation	105
Fig. 5.9	Depth structure map on top Zeit Formation	106
Fig. 5.10	3D view of the picked formations in Hilal oil field	107
Fig. 6.1	Real and imaginary parts of the complex trace	117
Fig. 6.2	Real and complex sinusoids	118
Fig. 6.3	Trace Envelope Attribute showing the salt border	124
Fig. 6.4	Dip of maximum similarity attribute depth slice at depth level 5528 ft e showing the salt border and major fault	125
Fig. 6.5	Dip variance depth slice attribute at depth level 5528 ft showing minor faults	126
Fig. 6.6	Instantaneous lateral continuity depth slice attribute	127
Fig. 6.7	Similarity depth slice attribute	129
Fig. 6.8	Similarity variance depth slice attribute	130
Fig. 6.9	Smoothed Dip of Maximum Similarity depth slice attribute	131
Fig. 6.10	Seismic section crossline 1607 amplitude	132

Fig. 6.11	Seismic section crossline 1607 event continuity indicator attribute	133
Fig. 6.12	Instantaneous phase attribute slice at depth 10400 ft	134
Fig. 6.13	Vertical arbitrary line A with clear subsalt picking of Nubia Formation top	135

LIST OF TABLES

Table 6.1	Types and uses of Geometric Attributes	111
Table 6.2	Types and uses of Wavelet Attributes	113
Table 6.3	Types and uses of Instantaneous Attributes	114
Table 6.4	Classification Of Seismic Attributes	115

CHAPTER 1

INTRODUCTION