

شبكة المعلومات الجامعية التوثيق الإلكتروني والميكروفيلو

بسم الله الرحمن الرحيم





MONA MAGHRABY



شبكة المعلومات الجامعية التوثيق الإلكتروني والميكروفيلو



شبكة المعلومات الجامعية التوثيق الالكتروني والميكروفيلم



MONA MAGHRABY



شبكة المعلومات الجامعية التوثيق الإلكترونى والميكروفيلم

جامعة عين شمس التوثيق الإلكتروني والميكروفيلم قسم

نقسم بالله العظيم أن المادة التي تم توثيقها وتسجيلها علي هذه الأقراص المدمجة قد أعدت دون أية تغيرات



يجب أن

تحفظ هذه الأقراص المدمجة بعيدا عن الغبار



MONA MAGHRABY



SOURCE ROCK EVALUATION AND HYDROCARBON CHARACTERIZATION OF ABU QIR OFFSHORE AREA, NILE DELTA, EGYPT

By

Yasmin Kadry Ali Mostafa

(B. Sc. In Geology and Chemistry)

A Thesis

Submitted for Partial Fulfillment for the Requirements of Master Degree of Science in Geology

To

Department of Geology, Faculty of Science, Ain Shams University

Supervisors

Prof. Dr. Samir Ahmed Awad

Prof. of Mineral and Sedimentary rocks, Geology Department, Faculty of Science, Ain Shams University.

Prof. Dr. Lobna Mohamed Sharaf

Prof. of Petroleum Geochemistry, Geology Department, Faculty of Science, Ain Shams University.

Dr. Mosaad Mohamed El Leboudy

Assistant Chairman for Exploration Gebel El Zeit Petroleum Company



Approval Sheet

Source Rock Evaluation and Hydrocarbon Characterization of Abu Qir Offshore Area, Nile Delta, Egypt

$\mathbf{B}\mathbf{y}$

Yasmin Kadry Ali Mostafa

A Thesis

Submitted for Partial Fulfillment for the Requirements of Master Degree of Science in Geology

<u>Supervisors</u>	Approved
Prof. Dr. Samir Ahmed Awad	
Prof. of Mineral and Sedimentary	• • • • • • • • • • • • • • • • • • • •
rocks, Geology Department, Faculty	
of Science, Ain Shams University.	
Prof. Dr. Lobna Mohamed Sharaf	
Prof. of Petroleum Geochemistry,	•••••
Geology Department, Faculty of	
Science, Ain Shams University.	
Dr. Mosaad Mohamed El Leboudy	
Assistant Chairman for Exploration	
Gebel El Zeit Petroleum Company	

Chairman of Geology Department
Dr. Karim W. Abdelmalik

ACKNOWLEDGMENT

The author wishes to express her deep thanks and sincere gratitude to Prof. Dr. Samir Ahmed Awad, Professor of Mineralogy and Sedimentary Petrology, Geology Department, Faculty of Science, Ain Shams University, for his generous help and support during this work.

The author also wishes to express her deep thanks and sincere gratitude to Prof. Dr. Lobna Mohamed Sharaf, Professor of Petroleum Geochemistry, Geology Department, Faculty of Science, Ain Shams University, for her supervision, suggesting the research point, valuable leading comments and critical reading and reviewing this manuscript.

The author wishes to express her deep thanks and sincere gratitude to Dr. Mosaad Mohamed El Leboudy, Assistant Chairman for Exploration and Board member in Gebel El Zeit Petroleum Company, for his supervision, scientific advice and critical reading and reviewing the work.

A special word of gratitude is due to StratoChem Services (SCS) company presented by Mr. Mohamed said (his soul rest In peace), and Mr. Tarek El Azhary, Head Managers of SCS company for their support during this work.

A special thanks is due to my all colleagues in SCS company for their help during progress of this work.

Thanks are also due to EGPC and Abu Qir Petroleum Company for information and publication and for acceptance to get the data needed for this work.

Last but not least, Grateful and true appreciation are expressed to my family for their true helpful patience and encouragement.

CONTENTS

Chapter. No.	Subject	Page
Chapter 1		
1	INTRODUCTION	1
1.1.	Generalities	1
1.2.	Previous Related Work	2
1.3.	Objectives of the Present Study	6
1.4.	The Study Framework	6
Chapter 2		
2	SAMPLING AND METHODOLOGY	7
2.1.	Sample Preparation	8
2.2.	Determination of Total Organic Carbon Content (TOC)	8
2.3.	Rock Eval Pyrolysis	9
2.4.	Determination of the Types of Hydrocarbon Generated	13
2.5.	Maturity and Kerogen Analysis Techniques	14
2.6.	Oil Analysis Techniques	15
2.6.1.	API gravity determination	15
2.6.2.	Gas chromatography (GC) technique	15
2.6.3.	MPLC technique	21
2.6.4.	GC/MS (biomarker) analysis technique	21
2.7.	Gas Analysis Techniques	27
2.8.	Thermal Burial History Modelling	27
2.8.1.	Geothermal gradient	28
2.8.2.	Modeling procedures	30
Chapter 3		
3	GEOLOGIC SETTING OF THE NILE DELTA AND	22
2.1	THE STUDY AREA	33
3.1.	Regional Geology of the Nile Delta	33
3.2.	Stratigraphy of the Nile Delta and the Study Area	37
3.2.1.	Eocene and Oligocene cycles	38
3.2.2.	Miocene cycle	38
3.2.3.	Pliocene and Pleistocene cycles	42

Chapter 4

I ict	οf	Conte	nte
Lisi	UI -	Come	u

4	SOURCE ROCKS EVALUATION	46
4.1.	Guidelines of Source Rock Evaluation	46
4.1.1.	Quantity of organic matter	46
4.1.2.	Petroleum generating capability	46
4.1.3.	Types of organic matter	47
4.1.4.	Thermal maturity of organic matter	48
4.2.	Results and Discussion	48
4.2.1.	Source rock analyses	49
Chapter 5		
5	CONDENSATES AND GASES CHARACTERIZATION	71
5.1.	Condensate Characterization	72
5.1.1.	Maturity of the condensates	90
5.2.	Gases Characterization	92
Chapter 6		
6	HYDROCARBON GENERATION AND EXPULSION	100
6.1.	Guidelines	100
6.2.	Thermal Burial History Modelling	100
6.2.1.	Modeling procedures	101
6.2.2.	Vitrinite reflectance (Ro)	101
6.2.3.	A graphical method for modeling	102
6.3.	Discussion and Results on Modelling of the Drilled Wells	102
6.3.1.	Burial history	103
6.3.2.	Thermal history	105
6.3.3.	Hydrocarbon potentialities	122
SUMMARY	AND CONCLUSIONS	125
REFERENC	CES	131

LIST OF FIGURES

Fig. No.	Subject	Page
Fig. 1.1	Location map of the studied wells in Abu Qir, North	
	Abu Qir and West Abu Qir fields, Western offshore Nile	
	Delta, Egypt.	1
Fig. 2.1	LECO CR 12.	9
Fig. 2.2	Rock-Eval II.	9
Fig. 2.3	Schematic of program showing the evolution of hydrocarbons and CO ₂ from a rock sample during heating (increasing time and temperature from left to right). Important measurements include S1, S2, S3 and Tmax. Hydrogen and oxygen indices are calculated	
	shown (Peters 1986).	10
Fig. 2.4	Modified Van Krevelen diagram showing three types of	
	kerogen at different maturity levels.	13
Fig. 2.5 Fig. 2.6	C ₇ Kinetic scheme, Modified after Mango (1994). Ring Preference (RP) at C ₇ (adapted from Mango, 1994). RP is dictated by deposition environment (kerogen structure, catalyst type and oxidative state).	18
	Data for end members are plotted.	18
Fig. 3.1	Outline map for four main alignments control over the evolution of the Nile Delta with the study area in Abu	
Fig. 3.2	Qir, North Abu Qir and West Abu Qir fields, Western Nile Delta, Egypt (Sarhan et al., 1996). Generalized stratigraphic column of the Nile Delta,	36
<i>8</i>	Egypt (Modified by Omran, 2001, after El-Heiny and Morsi in 1992).	37
Fig. 4.1	Depth versus TOC wt% for Kafr El Sheikh Formation from NAF-1, NAF-101, WAQ-1X and WAQ-4X wells in North Abu Qir and West Abu Qir fields, western Nile	
	Delta, Egypt.	51
Fig. 4.2	Depth versus total generating potential for Kafr El Sheikh Formation from NAF-1, NAF-101, WAQ-1X	
	and WAQ-4X wells in North Abu Qir and West Abu Qir	52
Fig. 4.3	fields, western Nile Delta, Egypt. Depth versus Quality index for Kafr El Sheikh Formation from NAF-1, NAF-101, WAQ-1X and	52
	WAQ-4X wells in North Abu Qir and West Abu Qir	53

Fig. 4.4	fields, western Nile Delta, Egypt. Modified Van Krevelen diagram for Kafr El Sheikh Formation from NAF-1, NAF-101, WAQ-1X and WAQ-4X wells in North Abu Qir and West Abu Qir	
Fig. 4.5	fields, western Nile Delta, Egypt. Vitrinite Reflectance (Ro%) versus HI diagram showing the type of kerogen for Kafr El Sheikh Formation from NAF-1, NAF-101, WAQ-1X and WAQ-4X wells in North Abu Qir and West Abu Qir fields, western Nile	54
Fig. 4.6	Delta, Egypt. Depth versus vitrinite reflectance (Ro%) for Kafr El Sheikh Formation from NAF-1, NAF-101, WAQ-1X and WAQ-4X wells in North Abu Qir and West Abu Qir	55
Fig. 4.7	fields, western Nile Delta, Egypt. Depth versus TOC wt% for Sidi Salim Formation from NAF-1, NAF-101 and WAQ-1X wells in North Abu Qir	56
Fig. 4.8	and West Abu Qir fields, western Nile Delta, Egypt. Depth versus total generating potential for Sidi Salim Formation from NAF-1, NAF-101 and WAQ-1X wells in North Abu Qir and West Abu Qir fields, western Nile	58
Fig. 4.9	Delta, Egypt. Depth versus Quality index for Sidi Salim Formation from NAF-1, NAF-101 and WAQ-1X wells in North Abu Qir and West Abu Qir fields, western Nile Delta,	59
Fig. 4.10	Egypt. Modified Van Krevelen diagram for Sidi Salim Formation from NAF-1, NAF-101 and WAQ-1X wells in North Abu Qir and West Abu Qir fields, western Nile	60
Fig. 4.11	Delta, Egypt. Vitrinite Reflectance (Ro%) versus HI diagram showing the type of kerogen for Sidi Salim Formation from NAF-1, NAF-101 and WAQ-1X wells in North Abu Qir and	01
Fig. 4.12	West Abu Qir fields, western Nile Delta, Egypt. Depth versus vitrinite reflectance (Ro%) for Sidi Salim Formation from NAF-1, NAF-101 and WAQ-1X wells in North Abu Qir and West Abu Qir fields, western Nile	62
Fig. 4.13	Delta, Egypt. Depth versus TOC wt% for Qantara Formation from NAF-101 well in North Abu Qir field, western Nile	63
Fig. 4.14	Delta, Egypt. Depth versus total generating potential for Qantara	65
	Formation from NAF-101 well in North Abu Qir field,	66

western Nile Delta, Egypt.

Fig. 4.15	Depth versus Quality index for Qantara Formation from NAF-101 well in North Abu Qir field, western Nile	67
Fig. 4.16	Delta, Egypt. Modified Van Krevelen diagram for Qantara Formation from NAF-101 well in North Abu Qir field, western Nile	67
Fig. 4.17	Delta, Egypt. Vitrinite Reflectance (Ro%) versus HI diagram showing the type of kerogen for Qantara Formation from NAF-101 well in North Abu Qir field, western Nile Delta,	68
Fig. 4.18	Egypt. Depth versus vitrinite reflectance (Ro%) for Qantara Formation from NAF-101 well in North Abu Qir field, western Nile Delta, Egypt.	69 70
Fig. 5.1	Bulk composition for condensate samples recovered from Kafr El Sheikh and Abu Madi reservoirs in Abu Qir, North Abu Qir and West Abu Qir fields, western Nile Delta, Egypt.	72
Fig. 5.2	Whole oil gas chromatogram for AQ PII-17 condensate from Kafr El Sheikh reservoir in Abu Qir field, western Nile Delta, Egypt.	75
Fig. 5.3	Whole oil gas chromatogram for NAQ PI-1 condensate from Abu Madi reservoir in North Abu Qir field,	
Fig. 5.4	western Nile Delta, Egypt. Whole oil gas chromatogram for NAQ PI-5 condensate from Abu Madi reservoir in North Abu Qir field,	75
Fig. 5.5	western Nile Delta, Egypt. Whole oil gas chromatogram for WAQ-1 condensate from Abu Madi reservoir in West Abu Qir field, western Nile Delta, Egypt.	76 76
Fig. 5.6	Plot of Phytane/n-C ₁₈ vs. Pristane/n-C ₁₇ for condensate samples recovered from Kafr El Sheikh and Abu Madi reservoirs in Abu Qir, North Abu Qir and West Abu Qir fields, western Nile Delta, Egypt (Modified after	
Fig. 5.7	Shanmugam, 1985). Thompson alteration vector for light hydrocarbon data (Thompson, 1979) for condensate samples recovered from Kafr El Sheikh and Abu Madi reservoirs in Abu	77
	Qir, North Abu Qir and West Abu Qir fields, western	78

	Nile Delta, Egypt.	
Fig. 5.8	Relationship between the Primesum and P3 (Mango,	
8	1996) for condensate samples recovered from Kafr El	
	Sheikh and Abu Madi reservoirs in Abu Qir, North Abu	
	Qir and West Abu Qir fields, western Nile Delta, Egypt,	
	see appendix A.	78
Fig. 5.9	Ring Preference (RP) at C7 (Mango, 1994). The end	, 0
1 16. 5.7	members are isoalkanes (3RP), cyclopentanes (5RP),	
	and cyclohexanes + toluene (6RP) for condensate	
	samples recovered from Kafr El Sheikh and Abu Madi	
	reservoirs in Abu Qir, North Abu Qir and West Abu Qir	
	fields, western Nile Delta, Egypt.	79
Eig 5 10	, 2,1	19
Fig. 5.10	Plot of two light hydrocarbon Mango Parameters (1987),	
	2-methylhexane + 2,3-dimethylpentane vs. 3-	
	methylexane + 2,4-dimethylpentane, derived from gas	
	chromatography for condensate samples recovered from	
	Kafr El Sheikh and Abu Madi reservoirs in Abu Qir,	
	North Abu Qir and West Abu Qir fields, western Nile	90
Ei~ F 11	Delta, Egypt.	80
Fig. 5.11	Carbon isotopic composition of aromatics vs. saturates	
	(after Sofer in 1984) for condensate samples recovered	
	from Kafr El Sheikh and Abu Madi reservoirs in Abu	
	Qir, North Abu Qir and West Abu Qir fields, western	0.1
E' 5 10	Nile Delta, Egypt.	81
Fig. 5.12	Plot of δ^{13} C of Aromatic Hydrocarbon Fraction vs.	
	Pristane/Phytane ratio (Chung et al., 1992) for	
	condensate samples recovered from Kafr El Sheikh and	
	Abu Madi reservoirs in Abu Qir, North Abu Qir and	0.1
D: 5.10	West Abu Qir fields, western Nile Delta, Egypt.	81
Fig. 5.13	Plot of Pristane/Phytane ratio vs. Canonical Variable	
	(CV) (Sofer, 1984) for condensate samples recovered	
	from Kafr El Sheikh and Abu Madi reservoirs in Abu	
	Qir, North Abu Qir and West Abu Qir fields, western	
	Nile Delta, Egypt.	82
Fig. 5.14	Steranes distribution (m/z 217) for condensate samples	
	recovered from Kafr El Sheikh and Abu Madi reservoirs	
	in Abu Qir, North Abu Qir and West Abu Qir fields,	
	western Nile Delta, Egypt.	84
Fig. 5.15	Terpanes distribution (m/z 191) for condensate samples	
	recovered from Kafr El Sheikh and Abu Madi reservoirs	
	in Abu Qir, North Abu Qir and West Abu Qir fields,	
	western Nile Delta, Egypt.	85

Fig. 5.16	Tricyclic and Tetracyclic terpanes distribution (m/z 191) for condensate samples recovered from Kafr El Sheikh	
	and Abu Madi reservoirs in Abu Qir, North Abu Qir and	86
Ei~ 5 17	West Abu Qir fields, western Nile Delta, Egypt.	80
Fig. 5.17	Pristane/Phytane vs. DBT/Phenanthrene cross-plot	
	(Hughes et al., 1995) for condensate samples recovered	
	from Kafr El Sheikh and Abu Madi reservoirs in Abu	
	Qir, North Abu Qir and West Abu Qir fields, western	0.0
T: # 40	Nile Delta, Egypt.	88
Fig. 5.18	C ₂₇ -C ₂₉ monoaromatic steroids (MAS) ternary diagram	
	for condensate samples recovered from Kafr El Sheikh	
	and Abu Madi reservoirs in Abu Qir, North Abu Qir and	
	West Abu Qir fields, western Nile Delta, Egypt.	89
Fig. 5.19	Plot of C_4/C_3+C_4 Mester vs. Dinosteroid Index for	
	condensate samples recovered from Kafr El Sheikh and	
	Abu Madi reservoirs in Abu Qir and West Abu Qir	
	fields, western Nile Delta, Egypt.	90
Fig. 5.20	Sterane maturity parameters, $C_{29} \alpha\alpha\alpha 20S/(20S+20R)$	
	and $C_{29} \alpha\beta\beta/(\alpha\alpha\alpha + \alpha\beta\beta)$ for condensate samples	
	recovered from Kafr El Sheikh and Abu Madi reservoirs	
	in Abu Qir and North Abu Qir fields, western Nile	
	Delta, Egypt.	91
Fig. 5.21	Steroid maturity parameters, $C_{21} + C_{22}$	
	monoaromatic/total monoaromatic steroids vs. $C_{20} + C_{21}$	
	triaromatic/total triaromatic steroids for condensate	
	samples recovered from Kafr El Sheikh and Abu Madi	
	reservoirs in Abu Qir, North Abu Qir and West Abu Qir	
	fields, western Nile Delta, Egypt.	91
Fig. 5.22	A cross-plot of light-to-heavy ratio (LHR) vs. gas	
0	wetness ratio (GWR) (Haworth et al., 1985) provides a	
	prediction of the hydrocarbon type in potential reservoir	
	intervals for gas samples recovered from Kafr El Sheikh	
	and Abu Madi reservoirs in Abu Qir, North Abu Qir and	
	West Abu Qir fields, western Nile Delta, Egypt.	94
Fig. 5.23	"Bernard" diagram (Modified from Bernard, 1978 by	
1 18. 0.20	Faber and Stahl, 1984) to classify using the combination	
	of their molecular ratios, $C_1/(C_2+C_3)$. And their carbon	
	isotopic ratio ($\delta^{13}C_{CH4}$) for gas samples recovered from	
	Kafr El Sheikh and Abu Madi reservoirs in Abu Qir,	
	North Abu Qir and West Abu Qir fields, western Nile	
	Delta, Egypt.	95
Fig. 5.24	A plot of δ^{13} C _{Methane} vs. C ₂ / C ₃ (After Xu Yongchang	96
115. J.44	A DIOLULU C Methane VS. C2 / C3 [ALE] AU LUITECHAITE	フい

	and Shen Ping, 1996) provides information about the genetic origin for gas samples recovered from Kafr El Sheikh and Abu Madi reservoirs in Abu Qir, North Abu Qir and West Abu Qir fields, western Nile Delta, Egypt.	
Fig. 5.25	Natural gas genetic classification diagram using $\delta^{13}C$ and δD (after Coleman et al., 1995) of methane for gas samples recovered from Kafr El Sheikh and Abu Madi reservoirs in Abu Qir, North Abu Qir and West Abu Qir	0.6
Fig. 5.26	fields, western Nile Delta, Egypt. The stable carbon and hydrogen isotopic composition (δ^{13} C and δ D) (Schoell, 1983) of methane provide information about its genetic origin for gas samples recovered from Kafr El Sheikh and Abu Madi reservoirs in Abu Qir, North Abu Qir and West Abu Qir fields, western Nile Delta, Egypt.	96 97
Fig. 5.27	The stable carbon isotopic composition (δ ¹³ C) of methane versus Wetness % (Schoell, 1983) provides information about its genetic origin for gas samples recovered from Kafr El Sheikh and Abu Madi reservoirs in Abu Qir, North Abu Qir and West Abu Qir fields, western Nile Delta, Egypt.	97
Fig. 5.28	Inferred thermal maturity (equivalent vitrinite reflectance %Ro) of the generative source based on the stable carbon isotopic relationships between ethane versus methane (A) and ethane versus propane (B), Type II kerogen model (Berner and Faber, 1996) for gas samples recovered from Kafr El Sheikh and Abu Madi reservoirs in Abu Qir, North Abu Qir and West Abu Qir fields, western Nile Delta, Egypt.	99
Fig. 5.29	Inferred thermal maturity (equivalent vitrinite reflectance %Ro) of the generative source based on the stable carbon isotopic relationships between ethane versus methane (A) and ethane versus propane (B), Type III kerogen model (Berner and Faber, 1996) for gas samples recovered from Kafr El Sheikh and Abu Madi reservoirs in Abu Qir, North Abu Qir and West Abu Qir fields, western Nile Delta, Egypt.	99
Fig. 6.1	Burial burial history curves of NAF-1 and NAF-101 wells.	107
Fig. 6.2	Burial burial history curves of WAQ-1 and WAQ-4 wells.	108

Fig. 6.3	Temperature versus depth plot of NAF-1 and NAF-101 wells.	109
Fig. 6.4	Temperature versus depth plot of WAQ-1 and WAQ-4 wells.	110
Fig. 6.5	Maturity versus depth plot of NAF-1 and NAF-101 wells.	111
Fig. 6.6	Maturity versus depth plot of WAQ-1 and WAQ-4 wells.	
Fig. 6.7	Cumulative hydrocarbons versus time plots of the Kafr	112
Fig. 6.8	El Sheikh Source Rocks in NAF-1 and NAF-101 wells. Cumulative hydrocarbons versus time plots of the Kafr	113
Fig. 6.9	El Sheikh Source Rocks in WAQ-1 and WAQ-4 wells. Cumulative hydrocarbons versus time plots of the Sidi	114
	Salim Source Rocks in NAF-1 and NAF-101 wells.	115
Fig. 6.10	Cumulative hydrocarbons versus time plots of the Sidi Salim Source Rocks in WAQ-1 and WAQ-4 wells.	116
Fig. 6.11	Cumulative hydrocarbons versus time plots of the Qantara Source Rocks in NAF-1 and NAF-101 wells.	117
Fig. 6.12	Cumulative hydrocarbons versus time plots of the	
Fig. 6.13	Qantara Source Rocks in WAQ-1 and WAQ-4 wells. Cumulative hydrocarbons versus time plots of the Tinah	118
Fig. 6.14	Source Rocks in NAF-1 and NAF-101 wells. Cumulative hydrocarbons versus time plots of the Tinah	119
1 1g. 0.14	Source Rocks in WAQ-1 and WAQ-4 wells.	120