

## THE ENVIRONMENTAL CONSTRAINTS OF LAKE BARDAWIL - NORTHERN COAST - EGYPT

#### **A THESIS**

Submitted to Faculty of Science, Cairo University

Presented by

### Mona Abd El-Naby Abd El-Monaem El-Miniawi

(B.Sc. in Geology – Chemistry) Faculty of Science, Cairo University

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

To
Geology Department
Faculty of Science, Cairo University



#### Approval sheet

Title of M.Sc. Thesis

## THE ENVIRONMENTAL CONSTRAINTS OF LAKE BARDAWIL - NORTHERN COAST - EGYPT

Name of candidate

## Mona Abd El-Naby Abd El-Monaem El-Miniawi

(B.Sc. In Geology – Chemistry) Faculty of Science, Cairo University

Submitted to Geology department Faculty of Science, Cairo University

#### Supervision committee:

Dr. M.A. El-Kammar Signature:

Assistant Professor, Faculty of science, Cairo University

Dr. M.A. El-Kashoutti Signature:

Assistant Professor, Faculty of science, Cairo University

Dr. M. M. Gomma Signature:

Assistant Professor, Desert Research Center

Prof. Dr. A. A. Sehim

Signature:

Head of Geology Department Faculty of Science, Cairo University

#### Note

The present thesis is submitted from Mona Abd El-Naby Abd El-Monaem El-Miniawi for the degree of Master of Science in geology, Cairo University. Beside the research work materialized in this, the candidate has attended graduate courses for one in the following topics:-

- Basic petroleum geology.
- Hydrogeology.
- Advanced studies in reservoir geology.
- Hydrogeochemistry.
- Stratigraphic and tectonic control of hydrocarbon and subsurface waters.
- Electric logs.
- Regional sedimentary basins and hydrocarbon deposits.
- Geochemical prospection for hydrocarbons.
- Field waters (connate oil waters).
- Statistics.
- German language.

She has successfully passed the final examination of these courses in October 2002.

Prof. Dr. A. A. Sehim

Head of Geology Department

#### **ACKNOWLEDGEMENT**

In fact, my prayful thanks, first of all our merciful great god who guides me through his light to finish this work.

The author wishes to express his deep gratitude to **the Geology Department**, Faculty of Science, Cairo University for the provided facilities during the progress of this thesis.

The author wishes his deep sense of gratitude to Dr. Mohammed El-Kammar and Dr. Mohammed El-Kashoutti for suggesting the point of research, supervising the work, field work, their continuous encouragement and faithful discussion during the progress of the work covered by the present thesis.

I am deeply indebted to **Dr. Mohammed Gomma**, Head of geochemistry department, Desert Research Center for his great help in analytical work and his staff.

Special thanks to **Dr. Ali Abd El-Motelib** for his great help and encouragement during the work of thesis.

Sincere thanks to **Eng. Nafel Hussein Nofal**, Bardawil lagoon executive Manager and his staff for their great help during the field work.

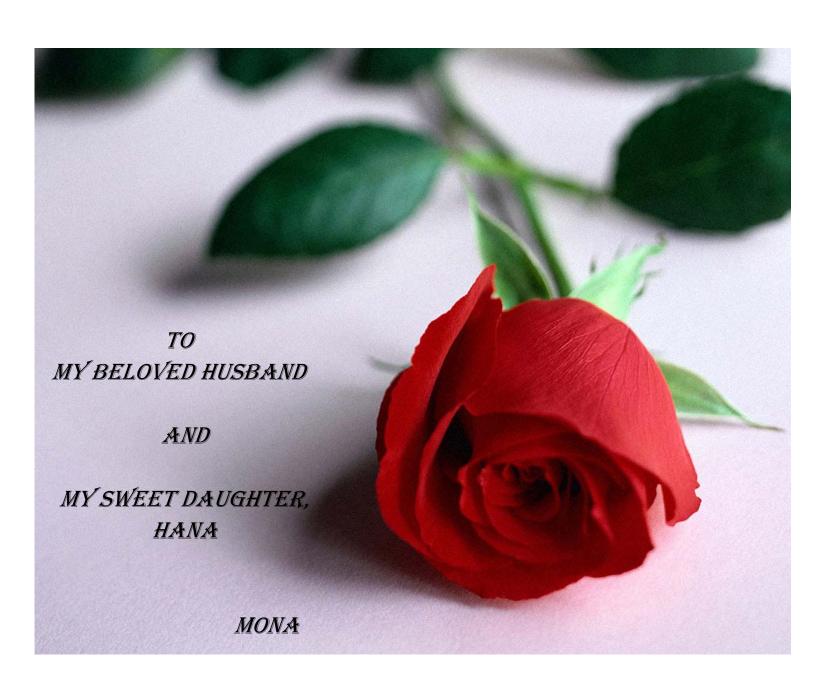
The author wishes to record his appreciation to the boundaries Guardians Forces, especially Major. Ali Ashmawy.

Great thanks to my teacher Mr. Mohammed El-Shazly Mahmoud, head of the research sector, the general co. for research and ground water, for his valuable guidance during this work.

Thanks from my deep heart to the responsible of the sedimentologic lab. **Mr. Ahmed El-Essawi** for his great help during my Laboratory work.

Thanks to all my colleagues and friends for their encouragement and help with special thanks to my sister **Miss. Mai Abd-El Naby** for her great help during my field work and **Mr. Amir Mohammed Hassan** in his reading and reviewing the thesis.

Finally, my special gratitude is expressed to my beloved husband, Mr. Mohammed Attia Ali and his parents, my father, my mother and my sisters due to their great help and encouragement during the progress of this work.



## LIST OF CONTENTS

## CHAPTER 1

## **INTRODUCTION**

		Page
1.1	Introduction	1
1.1.1	The hydrosphere as a part of the Eco-global system	3
1.2	Aim and scope of the present study	5
1.3	Methodology	5
1.4	Previous works	7
1.5	Physiographic	9
1.5.1	Climate	9
1.5.1.1	Water and Air Temperature	9
1.5.1.2	Evaporation	11
1.5.1.3	Relative humidity	12
1.5.1.4	Wind speed	12
1.5.1.5	Water current speed	13
1.5.1.6	Rainfall	13
1.5.2	Landforms of Lake Bardawil area	14
1.6	Hydrogeological setting of Lake Bardawil setup area	18

## **CHAPTER 2**

## **GEOLOGY**

2.1	Introduction	20
2.2	Tectonic setting of North Sinai	20
2.3	Stratigraphy of North Sinai	23
2.3.1	Precambrian	26
2.3.2	Paleozoic	26
2.3.3	Mesozoic	26
2.3.3.1	Triassic	26
2.3.3.2	Jurassic	28
2.3.3.3	Cretaceous	30
2.3.4	Cenozoic	33
2.4	structure of North Sinai	37
2.5	Geologic History of North Sinai	37
2.6	Geologic History of Lake Bardawil	41
	CHAPTER 3	
	WATER CEMISTRY	
	AND WATER QUALITY	
	WILLRYOALIII	
3.1	Introduction	43
3.2	Origin and significance of major ions	43

3.2.1	Calcium	43
3.2.2	Magnesium	43
3.2.3	Sodium	44
3.2.4	Potassium	44
3.2.5	Chloride	44
3.2.6	Bicarbonate	44
3.2.7	Sulfate	45
3.3	Physical characteristics of Lake Bardawil water	45
3.4	Chemical characteristics and quality of Lake Bardawil water	46
3.4.1	The total dissolved solids (TDS)	46
3.4.2	Sodium, potassium and Chloride	48
3.4.3	Magnesium	52
3.4.4	Calcium and Bicarbonate	52
3.4.5	Sulfate	54
3.4.6	Heavy Metals Distribution	59
3.4.6.1	Distribution of Cobalt, Nickel and Lead	60
3.4.6.2	Distribution of Transition metals	64
3.5	Hypothetical salts	72
3.6	Hydrochemical Coefficients	74
3.7	Ion dominance and water types	78
3.8	Hydrochemical facies and genetic classification by Graphical methods	78
3.8.1	The trilinear system (Piper diagram)	79
3.8.2	Durov graph classification	79
3.8.3	Schoeller graph classification	82

# CHAPTER 4 MODELING OF WATER CHEMISTRY DATA

4.1	Introduction	84
4.2	Multivariate statistical methods	84
4.2.1	The hierarchical cluster analysis (HCA)	84
4.2.2	Correlation analysis (Pearson coefficient matrix)	89
4.2.3	The principal component analysis (PCA)	92
4.3	The hypothetical saturation index of the minerals	97
4.3.1	The saturation index of gypsum and Anhydrite	98
4.3.2	The saturation index of calcite, Aragonite and CO <sub>2</sub>	101
4.3.3	The saturation index of Dolomite	101
4.4	The simulated evaporation of water	105
	CHAPTER 5 SUMMARY AND CONCLUSIONS	
	Summary and conclusions	108
	References	113
	List of Appendices	121

## LIST OF FIGURES

Figure No.	Description	Page No.
1.1	Location map of the study area	2
1.1' A	The distribution of the collected water samples during summer	6
1.1' B	The distribution of the collected water samples during winter	6
1.2	Histogram of the air temperature (°C) during the whole year in North Sinai	10
1.3	Histogram of the evaporation (mm/day) and evapotranspiration (mm)	
	during the whole year in Northern Sinai	12
1.4	Histogram of wind speed in (km/h) of the Mediterranean Sea area	13
1.5	Histogram of the Rainfall during the whole year in North Sinai (mm/day)	14
1.6	Mean annual rainfall (1994-1995) in Lake Bardawil (mm)	15
1.7	Mean annual rainfall in Lake Sinai (mm)	16
1.8	Land form classification of north Sinai	17
1.9	Hydrogeological basins of north Sinai peninsula	19
2.1	Geological map of north Sinai	21
2.2	Tectonic map of north and central Sinai	22
2.3	Lithostratigraphic column of north Sinai	24
2.4	Chronostratigraphic section of north, central and offshore of Sinai	25
2.5	Triassic Sequence of Gebel Arif El Naga	27
2.6	Geological map of Gebel Magharah	29
2.7	Lithostratigraphic section of Jurassic and Cretaceous at Gebel Magharah	31
2.8	Lithofacies relationships of the upper Cretaceous (Senonian),	2.4
	Paleocene and Eocene Formations in Sinai	34
2.9	Tectonic Framework of Gulf of Suez-Red Sea Rift system	38

2.10	Geological Cross Section of the Sinai Peninsula	38
2.11	Structural zones of the Sinai Peninsula	39
2.12	Structural map of North Sinai showing the en-echelon fold belts	40
3.1	The distribution pattern of the pH of Lake Bardawil water in summer	45
3.2 A	The distribution pattern of total dissolved solids of Lake Bardawil	47
	water in summer	47
3.2 B	The distribution pattern of total dissolved solids of Lake Bardawil	47
	water in winter	4/
3.3 A	The distribution pattern of sodium of Lake Bardawil water in summer	49
3.3 B	The distribution pattern of sodium of Lake Bardawil water in winter	49
3.4 A	The distribution pattern of potassium of Lake Bardawil water in summer	50
3.4 B	The distribution pattern of potassium of Lake Bardawil water in winter	50
3.5 A	The distribution pattern of chloride of Lake Bardawil water in summer	51
3.5 B	The distribution pattern of chloride of Lake Bardawil water in winter	51
3.6 A	The distribution pattern of magnesium of Lake Bardawil water in summer	53
3.6 B	The distribution pattern of magnesium of Lake Bardawil water in winter	53
3.7 A	The distribution pattern of calcium of Lake Bardawil water in summer	55
3.7 B	The distribution pattern of calcium of Lake Bardawil water in winter	55
3.8 A	The distribution pattern of bicarbonate of Lake Bardawil water in summer	56
3.8 B	The distribution pattern of bicarbonate of Lake Bardawil water in winter	56
3.9 A	The distribution pattern of sulfate of Lake Bardawil water in summer	57
3.9 B	The distribution pattern of sulfate of Lake Bardawil water in winter	57
3.10	Lithologic nature of the bottom sediments of Lake Bardawil	58
3.11 A	The distribution pattern of cobalt of Lake Bardawil water in summer	61
3.11 B	The distribution pattern of cobalt of Lake Bardawil water in winter	61

3.12 A	The distribution pattern of nickel of Lake Bardawil water in summer	62
3.12 B	The distribution pattern of nickel of Lake Bardawil water in winter	62
3.13 A	The distribution pattern of lead of Lake Bardawil water in summer	63
3.13 B	The distribution pattern of lead of Lake Bardawil water in winter	63
3.14 A	The distribution pattern of iron of Lake Bardawil water in summer	65
3.14 B	The distribution pattern of iron of Lake Bardawil water in winter	65
3.15 A	The distribution pattern of cadmium of Lake Bardawil water in summer	66
3.15 B	The distribution pattern of cadmium of Lake Bardawil water in winter	66
3.16 A	The distribution pattern of zinc iron of Lake Bardawil water in summer	68
3.16 B	The distribution pattern of zinc of Lake Bardawil water in winter	68
3.17 A	The distribution pattern of copper of Lake Bardawil water in summer	69
3.17 B	The distribution pattern of copper of Lake Bardawil water in winter	69
3.18 A	The distribution pattern of manganese of Lake Bardawil water in summer	70
3.18 B	The distribution pattern of manganese of Lake Bardawil water in winter	70
3.19 A	Locations of cross-section of hypothetical salts over Lake Bardawil in	· · · · · · · · · · · · · · · · · · ·
	summer	72
3.19 B	Locations of cross-section of hypothetical salts over Lake Bardawil in	
	winter	73
3.20 A	Hypothetical salts of water samples of Lake Bardawil during summer	
	along SW-NE cross section.	73
3.20 B	Hypothetical salts of water samples of Lake Bardawil during winter	
	along SW-NE cross section.	73
3.21 A	Hypothetical salts of water samples of Lake Bardawil during summer	
	along SE-NW cross section.	74

3.21 B	Hypothetical salts of water samples of Lake Bardawil during winter	7.4
	along SE-NW cross section.	74
3.22 A	Locations of cross-section of hydrochemical coefficients over Lake	7.5
	Bardawil in summer	75
3.22 B	Locations of cross-section of hydrochemical coefficients over Lake	7.5
	Bardawil in winter	75
3.23	Histograms of the hydrochemical coefficients comparison between	7.0
	summer and winter	76
3.24 A	Piper graph classification of Lake Bardawil water samples during summer	80
3.24 B	Piper graph classification of Lake Bardawil water samples during winter	80
3.25 A	Durov graph classification of Lake Bardawil water samples during summer	81
3.25 B	Durov graph classification of Lake Bardawil water samples during winter	81
3.26 A	Schoeller graph classification of Lake Bardawil water samples	83
	during summer	83
3.26 B	Schoeller graph classification of Lake Bardawil water samples	83
	during winter	63
	Q-mode dendrogram using Average Linkage (between groups) of the	87
4.1	analysed samples from Lake Bardawil during summer	0/
	Q-mode dendrogram using Average Linkage (between groups) of the	07
4.2	analysed samples from Lake Bardawil during winter	87
4.3 A	The geographical pattern of the Q-mode cluster groups during summer	88
4.3 B	The geographical pattern of the Q-mode cluster groups during winter	89
4.4 A	Scree plot of the component numbers during summer	92
4.4 B	Scree plot of the component numbers during winter	93
1.5 A	Histograms of the seven components matrix in summer	93

4.5 B	Histograms of the seven components matrix in winter	96
4.6 A	The distribution pattern of gypsum saturation index of Lake Bardawil	22
	in summer	99
4.6 B	The distribution pattern of gypsum saturation index of Lake Bardawil	
	in winter	99
4.7 A	The distribution pattern of anhydrite saturation index of Lake Bardawil	
	in summer	100
4.7 B	The distribution pattern of anhydrite saturation index of Lake Bardawil	
	in winter	100
4.8 A	The distribution pattern of calcite saturation index of Lake Bardawil	
	in summer	102
4.8 B	The distribution pattern of calcite saturation index of Lake Bardawil	
	in winter	102
4.9 A	The distribution pattern of CO <sub>2</sub> saturation index of Lake Bardawil	102
	in summer	103
4.9 B	The distribution pattern of CO <sub>2</sub> saturation index of Lake Bardawil	102
	in winter	103
4.10 A	The distribution pattern of aragonite saturation index of Lake Bardawil	104
	in summer	104
4.10 B	The distribution pattern of aragonite saturation index of Lake Bardawil	104
	in winter	104
4.11 A	The distribution pattern of dolomite saturation index of Lake Bardawil	
	in summer	106
4.11 B	The distribution pattern of dolomite saturation index of Lake Bardawil	
	in winter	106

4.12 A	The distribution pattern of the evaporation percentage of Lake Bardawil	
	water in summer	107
4.12 B	The distribution pattern of the evaporation percentage of Lake Bardawil	
	water in winter	107