

**PETROPHYSICAL ANALYSIS OF KADANWARI WELL NO
10 & 11, MIDDLE INDUS BASIN, PAKISTAN**



A thesis submitted to Bahria University, Islamabad in partial fulfillment of the requirement for the degree of BS in geology.

HABIB UR RAHMAN

IRSHAD HUSSAIN

SIBTE-E-HASSAN BUTT

**Department of Earth and Environmental Sciences
Bahria University, Islamabad**

2012

DEDICATION

“To our parents who have been by our side in every walk of life”

ABSTRACT

The main objective of research is to evaluate possible reservoirs in Well # 10 & 11 of Kadanwari gas field, which lies in Middle Indus basin, Pakistan. The said objective has been achieved by the petrophysical characterization of reservoir zones using wireline logs.

The methodology adopted to achieve the goal includes; Quality Check of the data set (complete suite of wireline logs), correlation of curves of different logs to demark the possible reservoir zones , measurement and computation of shale volume using gamma ray log, Resistivity of water using SP log, Porosity measurement by all porosity tools "neutron, Density and Sonic", Resistivity of invaded as well as un-invaded zones for the calculations and derivation of true resistivity and the saturation measurements using Archie's saturation equation.

The results of above mentioned analytical work done answered in positive, the zones marked through correlation of data show very good to fair hydrocarbon potential on the basis of evaluated clay volume, porosity and saturation component.

ACKNOWLEDGEMENT

(In the Name of Allah, the Most Merciful and Beneficent)

All praises are for Almighty Allah who blessed us with courage to cope with the odds of life and who enabled us to accomplish this project. We owe to the Holly Prophet (P.B.U.H) for the true guidelines of life.

We would like to pay our deepest gratitude to our loving parents, brothers, sisters and family for their prayers, encouragement and support. We are thankful to all of our friends who had provided us with the confidence and courage.

We are very much thankful to all the faculty members of the Department of Earth and Environmental Sciences, Bahria University for their valuable support and constructive ideas throughout our stay in the department.

We are glad to acknowledge the support and encouragement of our supervisor Mr. Mohsin Munir (OGDCL), PAKISTAN, for his heartiest contribution over the span of time to accomplishment of this project.

We would also pay our heartiest gratitude to Mr. Saqib Mehmood (Senior Lecturer), BAHRIA UNIVERSITY, PAKISTAN.

I would also like to pay regards and thanks from the core of our hearts to Mr. Ahsan Javed Deo, (OGDCL), PAKISTAN , for his encouraging help and guidance to complete this task.

Their needs to pay a bundle of special thanks to those special and true friends, who are around us like air. They have given us a boost in our lives and provided us a launching pad. Thank you so much!

Thank You All!

ABBREVIATIONS

d_h	Borehole diameter
d_i	Average diameter of invaded zone
R_m	Resistivity of the mud
R_{mf}	Resistivity of the mud filtrates
R_{mc}	Resistivity of the mud cake
R_w	Resistivity of the formation water
R_{wa}	Apparent resistivity of the formation water
R_t	Resistivity of the formation
R_{xo}	Resistivity of the flushed zone
R_{sh}	Resistivity of the shale
S_{xo}	Water saturation in flushed zone or invaded zone
R_i	Resistivity of invaded zone
V_{sh}	Volume of shale
R_{mfeq}	Equivalent mud filtrate resistivity
R_{weq}	Equivalent formation water resistivity
E_{ssp}	Estatic spontaneous potential
S_w	Saturation of water
S_h	Saturation of hydrocarbon
\emptyset	Porosity
BOEPD	Barrels of oil equivalent per day
CNL	Compensated Neutron Log
PEF	Photo-Electric Factor
LLS	Laterolog Shallow
LLD	Laterolog Deep
MSFL	Microspherically Focused Log

SP	Spontaneous Potential
Ec	Electrochemical Potential
(Em)	Shale or Membrane Potential
(Elj)	Liquid Junction Potential
(Ek)	Electro Kinetic Potential
B.H.T	Borehole Temperature
Φ_{av}	Average Porosity
Φ_n	Neutron Porosity
Φ_{den}	Density Porosity
Ma	Million Years
Fm	Formation
GR _{log}	Gamma ray reading of formation
GR _{min}	Gamma ray minimum
GR _{max}	Gamma ray maximum (shale)
ρ_{ma}	Matrix density
ρ_b	formation bulk density
ρ_f	fluid density
F	formation factor (a/ϕ_A^m)
A	turtuosity factor
M	constant, cementation exponent
K-10	Kadanwari well no 10
K-11	Kadanwari well no 11

CONTENTS

	Page
ABSTRACT	ii
ACKNOWLEDGEMENT	iii
ABBREVAITONS	iv
CONTENTS	vi
FIGURES	x
TABLES	xii
GRAPHS	xiii

CHAPTER 1

INTRODUCTION

1.1 General Information	1
1.2 Location and access	2
1.3 Purpose and scope	3
1.3.1 Data set used	3
1.4 Physiography and climate	3

CHAPTER 2

REGIONAL SETTING

2.1 Regional information	4
2.2 Tectonic history and structural styles	5
2.3 Stratigraphy & petroleum system	9
2.4 Mesozoic	11
2.5 Triassic	11
2.5.1 Wulgai Formation	11
2.6 Jurassic	11
2.6.1 Shirinab Formation	11
2.6.2 Chiltan Formation	12
2.7 Cretaceous	12
2.7.1 Sembar Formation	12
2.7.2 Lower Goru Formation	13
2.7.2.1 upper Sand Shale And Marl Sequence	13
2.7.2.2 Basal Sands (Lower Goru Formation)	14
2.7.2.3 Talhar Shale (Lower Goru Formation)	14
2.7.2.4 Massive Sandstone (Lower Goru Formation)	15
2.7.3 Upper Goru Formation	15

	Page
2.8 Paleocene	15
2.8.1 Khadro Formation	15
2.8.2 Ranikot Formation	16
2.9 Eocene	16
2.9.1 Laki Formation (Sui Main Limestone and Shale)	16
2.10 Post Eocene	17
2.10.1 Siwalik	17
2.11 Stratigraphy of studied wells	18
2.12 Petroleum system of study area	19
2.12.1 Play type	19
2.12.2 Source rocks	20
2.12.3 Reservoir rocks	21
2.12.4 Seals	21
2.12.5 Traps	21
2.13 Exploration history	22

CHAPTER 3

WIRELINING LOGGING

3.1 Well logging	23
3.2 Creating well logs	23
3.3 Classification of logging tools	24
3.4 Lithology logs	25
3.4.1 Examples of lithology logs are	25
3.5 Porosity logs	25
3.6 Saturation (Resistivity) logs	26
3.6.1 Example of saturation log	26
3.7 Electrical logs	26
3.8 Spontaneous potential log	26
3.8.1 History	27
3.8.2 Application	27
3.8.3 Theory of measurement	27
3.8.4 Electrochemical component	29
3.8.4.1 Liquid Junction potential	29
3.8.4.2 Membrane potential	30
3.9 Resistivity Logs	32
3.9.1 Tools measuring the uninvaded zone (R_t)	32
3.9.2 Tools measuring the invaded zone (R_i)	33

3.9.3 Tools measuring the flushed zone (Rxo)	33
3.10 Induction Logging	33
3.10.1 Application	34
3.11 Laterolog	34
3.11.1 Application	35
3.12 Gamma ray Log	38
3.12.1 Application	38
3.12.1.1 Standard gamma ray applications	38
3.12.1.2 Natural gamma ray tool (ngt) applications	38
3.12.2 Theory of measurement	39
3.12.3 Naturally occurring gamma rays	39
3.12.4 Induced gamma rays	39
3.12.5 Interpretation.	40
3.13 Neutron log	42
3.13.1 Types of neutron detectors	42
3.13.2 Neutron log response	43
3.13.3 Borehole effects on the neutron log	43
3.13.4 Factors dealing with neutron log interpretation	43
3.13.5 Applications of the neutron log	44
3.13.5.1 Sidewall neutron log	44
3.13.5.1 Compensated neutron log	44
3.13.5.2 Quality control of neutron logs	45
3.14 Density log	47
3.14.2 Application	47
3.14.2.1 Density porosity determination	49
3.15 Sonic log	50
3.15.1 Application	50
3.15.2 Theory of measurement	51
3.15.3 Long spaced sonic tools	52

CHAPTER 4

PETROPHYSICAL ANALYSIS

4.1 Petrophysical analysis	53
4.2 Raw log curve	53
4.3 Log quality check	54
4.4 Marking of possible potential zones	54
4.5 Borehole environment correction	54

4.6 Volume of shale by using gamma ray log	55
4.7 Porosity	56
4.7.1 Effective porosity	56
4.8 Resistivity of water (R_w)	57
4.9 True resistivity (R_t)	58
4.10 Water saturation (S_w)	58
4.11 Saturation of hydrocarbon	59
RESULT	60
DISCUSSION	86
CONCLUSION	87
RECOMMENDATIONS	88
REFERENCES	89
APPENDICES	92

FIGURES

Figure 1.1 (a).Location map of the study area (modified after Nisar Ahmed)	1
Figure 1.1(b).Satellite view of the area understudy with location of wells (10,K-11) (modified after Ahmad. N and Chaudhry. S)	1
Figure 1.2. Road access to the study area.	2
Figure 2.1. Tectonic map of Pakistan modified after Maqsood (2003).	4
Figure 2.2. Middle Jurassic modified from Scotese and others, 1980	7
Figure2.3. Early Cretaceous (modified from Scotese and others, 1980).	7
Figure2.4. LateCretaceous (modified from Scotese and others, 1980).	8
Figure 2.5. Latest Cretaceous (modified from Scotese and others, 1980).	8
Figure 2.6. Middle Eocene (modified from Scotese and others, 1980).	8
Figure 2.7. Late oligocene (modified from Scotese and others, 1980).	8
Figure 2.8. Generalized stratigraphy of lower indus Basin (modified from Raza, et al, 1990).	9
Figure 2.9. Depositional sequence/trend of southern Indus basin	10
Figure 3.1. Logging operation (after “Well logging basics” by “Baker Hughes INTEQ” 1992)	24
Figure 3.2. SP circuit diagram	28
Figure 3.3. Liquid junction effect	29
Figure 3.4. Membrane potential	30
Figure 3.5. Idealized sp log	31
Figure 3.6. Ideal resistivity log	37
Figure 3.7. Idealized gamma ray log	41

Figure 3.8.	Schematic diagram of CNL	45
Figure 3.9.	Idealized neutron log	46
Figure 3.10.	Idealized density log	48
Figure 3.11.	A typical density logging tool	50
Figure 3.12.	Schematic diagram of a sonic log	51
Figure 3.13.	Long space sonic log	52
Figure 4.1.	Work flow chart	53

TABLES

Table 2.1 Stratigraphy of studied formations	19
Table 4.1 Shows the zone depths of both wells (k-10, k-11)	54
Table 4.2 Shows the interpretation of well no 10	59
Table 4.3 Shows the interpretation of well no 11	60

Graphs

Graph 4.1. Correlation between depth & shale volume	62
Graph 4.2. Correlation between depth & effective porosity	63
Graph 4.3. Correlation between depth & water saturation	65
Graph 4.4. Correlation between depth & hydrocarbon saturation	66
Graph 4.5. Correlation between depth & shale volume	67
Graph 4.6. Correlation between depth & effective porosity	68
Graph 4.7. Correlation between depth & water saturation	69
Graph 4.8. Correlation between depth & hydrocarbon saturation	70
Graph 4.9. Correlation between depth & shale volume	71
Graph 4.10. Correlation between depth & effective porosity	72
Graph 4.11. Correlation between depth & water saturation	73
Graph 4.12. Correlation between depth & hydrocarbon saturation	74
Graph 4.13. Correlation between depth & shale volume	75
Graph 4.14. Correlation between depth & effective porosity	76
Graph 4.15. Correlation between depth & water saturation	77
Graph 4.16. Correlation between depth & hydrocarbon saturation	78
Graph 4.17. Correlation between depth & shale volume	79
Graph 4.18. Correlation between depth & effective porosity	80
Graph 4.19. Correlation between depth & water saturation	81
Graph 4.20. Correlation between depth & hydrocarbon saturation	82
Graph 4.21. Correlation between depth & shale volume	83
Graph 4.22. Correlation between depth & effective porosity	84
Graph 4.23. Correlation between depth & water saturation	85
Graph 4.24. Correlation between depth & hydrocarbon saturation	86