

Ain Shams University
Faculty of Science
Geophysics Department



Fluid and Lithology Prediction Utilizing Quantitative Well logging and Seismic Data Interpretation, West Delta Deep Marine Concession, Egypt.

Thesis submitted for the award of the Ph. D in Science
(Geophysics)

By

Eman Mohamed Abd El Rahman Morsey
M.Sc. in Geophysics
Faculty of Science – Ain Shams University, 2013

To

Geophysics Department
Faculty of Science
Ain Shams University

Supervised by

Prof. Dr. Nasser M. Abou Ashour
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

Cairo – 2019

Acknowledgements

My greatest appreciation is to the Almighty God for His grace, mercy and love towards me throughout my life. His guidance and protection have led me this far .

I would like to express my deepest gratitude to my thesis Supervisor Professor Dr. Nasser, for the guidance he provided during this study. His encouragement, criticisms, patience and support have been invaluable throughout the course of the project .

I would also like to thank Dr.Abd Allah, Assistant Professor in department of Geophysics, for his encouragement and advice throughout the formation evaluation chapter of this thesis .

I would like to state my greatest respect and appreciation to my advisor, Dr. Azza, Lecturer in department of Geophysics, for her guidance, expertise and patience during my graduate years and this study. Her thoughts about my thesis helped me to shape my study. The discussions that I have done with her and her encouraging attitude to me made this research possible.

I also thank all the staff of Geophysics Department. I have enjoyed my time with them and truly appreciate their supporting and encouraging.

I owe many thanks to RASHPETCO company for providing the data.

Finally, I am very grateful to my family for their love, support and encouragement. The goal of furthering my education would have remained a dream without their unwavering support. I am really lucky to have you all in my lifetime.

Thank you and God bless you all.

Abstract

Offshore Nile Delta gas reservoirs are dominated by slope-channel systems of Plio-Pleistocene age. The area of study is Sienna Field which is located in the eastern portion of the West Delta Deep Marine (WDDM) concession, approximately 120 km North-East of Alexandria, Egypt. Sienna channel consists of unconfined channel system in Kafr El Sheikh. The challenges in the data set of this field is the discrimination of hydrocarbon bearing sands from shales and more importantly, the separation of gas sands from brine saturated sandstones.

The primary objective of this thesis is How can make discrimination between lithology and fluid using rock physics analysis and advanced seismic interpretation method as AVO inversion, Extended Elastic Impedance (EEI) and Artificial Neural Networks (ANN).

Reservoir characterization is aimed at identifying hydrocarbon bearing reservoirs, delineating them and subsequently, determining the distribution of relevant physical properties such as lithology, porosity, permeability, water saturation and pore pressure, which will make for an easy determination of the reservoir's economic potential. The detailed petrophysical analysis revealed the presence of a gas-bearing sandstone interval ranged from 1 to 14 m of net pay zone with good reservoir characteristics in terms of good porosity (18-36%), shale volume (12-40%) and water saturation (20-52%). AVO simultaneous inversion inverts pre-stack seismic into elastic properties; compressional impedance, shear impedance and density.

Based on petrophysical analysis and rock physics modeling, an integrated approach is adopted to discriminate between lithologies and fluid

saturation in Sienna channel. These estimated elastic parameters were cross-plotted to discriminate between the lithology and fluid content in the target zone. Cross plots clearly separate the shale, brine sand, and gas-bearing sand clusters, which was not possible through conventional petrophysical analysis. These data clusters have been exported to the corresponding well for the purpose of interpolation between wells and to analyze the lateral and vertical variations in lithology and fluid content in the reservoir zone intervals.

The Extended Elastic Impedance (EEI) is used to derived petrophysical properties and distribution of reservoir facies to create relationship between these attributes and well log data. The results show that EEI is worthy effort to highlight the difference between reservoir and non-reservoir to identify hydrocarbon pay zones.

Neural network analysis is one of these algorithms use the information from multiple wells and seismic data to train a neural network to predict properties away from the well control. The low values of training error and validation error make reliable prediction of physical and seismic rock properties. It suggests that reservoir properties can be estimated from seismic data using neural network analysis and thereby helps in better understanding of the lateral variations of reservoir properties away from the wells. Probabilistic neural network (PNN) predicted results show lateral variation of physical and seismic rock properties in reservoir and non-reservoir parts at the study area. High porosity, low V_{sh} , low density, low water saturation, high Young modulus, high shear, low bulk modulus, high μ - ρ , low λ - ρ , low V_p/V_s ratio, low poisson's ratio, and good permeability are traced corresponds to Sienna channel which indicated to good pay zone with gas content.

Keyword: Reservoir characterization, AVO inversion, Petrophysical cross-plots, Extended Elastic Impedance, Probabilistic neural network.

Contents

Acknowledgments	II
Abstract	III
Contents	V
List of Figures	IX
List of Tables	XX
Chapter 1: Introduction	1
1.1 Location of the Study Area	1
1.2 Exploration History	2
1.3 Objectives and Methodology	3
1.4 Available Data	5
Chapter 2: Geologic Setting	7
2.1 Introduction	7
2.2 Bathymetry of the Area	8
2.3 Subsurface Stratigraphy	9
2.3.1 Pre-Miocene	9
2.3.2 Miocene	11
2.3.2.1 Early Miocene - Qantara Formation	11
2.3.2.2 Middle Miocene - Sidi Salim Formation	12
2.3.2.3 Late Miocene - Qawasim Formation	12
2.3.2.4 Late Miocene - Early Pliocene Abu Madi Formation	13
2.3.3 Pliocene	14
2.3.3.1 Early to Late Pliocene-Kafr El Sheikh Formation	14
2.3.3.2 Late Pliocene to Early Pleistocene - El Wastani Formation	15
2.3.3.3 Pleistocene to Holocene - Mit Ghamr / Bilqas Formations	15
2.4 Structural Setting	16
2.4.1 NE-oriented Qattara-Eratosthenes (Rosetta) trend	16
2.4.2 NW-oriented Misfaq-Bardawil (Temsah) Trend	17

2.4.3 East-West Faults	18
2.5 Tectonic Evolution of the Nile Delta	20
2.6 Tectonic Evolution of the Study Area	32
2.7 Sienna Field	33
<hr/>	
Chapter 3: Well Data Analysis for Reservoir Evaluation and Characterization	37
3.1 Introduction	37
3.2 Available Data	38
3.3 Petrophysical properties Evaluation of the studied wells	38
3.3.1 Shale Volume (Vsh) calculations	38
3.3.2 Effective Porosity (PHIE) calculations	40
3.3.3 Water Resistivity (Rw) calculations	42
3.3.4 Water Saturation (Sw) calculations	43
3.3.5 Determination of Net Pay Thicknesses	44
3.4 MDT Interpretation	46
3.5 Lithologic Identification	47
3.5.1 RHOB-NPHI Cross-plot Identification	47
3.5.2 PEF-RHOB Cross-plot Identification	47
3.6 Clay Minerals Identification	50
3.6.1 Th - K Cross-plot	5
3.6.2 PEF - K Cross-plot	52
3.6.3 PEF - Th/K Cross-plot	53
3.7 Litho-Saturation Cross-plots	54
3.8 Nuclear Magnetic Resonance (NMR)	58
3.8.1 Theoretical Background	59
3.8.2 Applications	61
3.8.2.1 Porosity Determination	63
3.8.2.2 Permeability	66
<hr/>	
Chapter 4: Reservoir Characterization by AVO Analysis and Modeling	70
4.1 Introduction	70
4.2 AVO Theory	95

4.2.1 Aki-Richard Approximation	97
4.2.2 Shuey's Approximation	98
4.2.3 Hilterman's Approximation	98
4.2.4 Fatti et al.'s Approximation	99
4.3 AVO Classification	100
4.4 Seismic Data Quality Control	102
4.4.1 Frequency Filtering	104
4.4.2 Amplitude Balancing	105
4.4.3 Events Alignment (Trim Statics)	107
4.5 Wavelet extraction	108
4.6 AVO Analysis	111
4.7 Inversion	113
4.7.1 Initial Model Building	115
4.7.2 Inversion Parameters Optimization	116
4.7.2.1 Wavelets Set	116
4.7.2.2 Constraining Relationships	117
4.7.2.3 Pre-whitening Method	118
4.7.2.4 Scalars	118
4.7.3 Inversion Outputs	120
4.8 AVO combination indicators	129
Chapter 5: Petrophysical Cross-plot for Lithology and Fluid Discrimination	
5.1 Introduction	106
5.2 Seismic Rock Properties	107
5.2.1 Basic rock properties	107
5.2.2 Elastic Properties	110
5.2.3 Anisotropic Properties	112
5.3 Gross-plots Analysis	113
5.3.1 Petrophysical properties versus basic and elastic seismic properties	113
5.3.2 Basic Rock Properties versus Elastic Rock Properties	125
Chapter 6: Extended Elastic Impedance for Lithology and Fluid Discrimination	
	130

6.1 Introduction	130
6.2 Theoretical Background	131
6.2.1 Elastic Impedance (EI)	132
6.2.2 Extended Elastic Impedance (EEI)	132
6.3 EEI Workflow	136
<hr/>	
Chapter 7: Neural Network (NN) for Lithology and Fluid Discrimination	157
7.1 Introduction	157
7.2 Theoretical Background of Neural Network	158
7.2.1 NN Development History	159
7.2.2 Application	161
7.3 Neural Network structure	161
7.3.1 Artificial Neuron Components	163
7.3.2 Types of neural networks	169
7.4 Neural Network workflow in the Study Area	171
7.4.1 Probabilistic neural network	172
7.4.1.1 PNN methodology	175
7.4.1.2 Data Preparation for Training	175
7.4.1.3 PNN Validation	181
7.5 Petrophysical Prediction result	182
7.5.1 Porosity Prediction	183
7.5.2 Shale volume (Vsh) Prediction	191
7.5.3 Density Prediction	197
7.5.4 Water saturation (Sw) Prediction	203
7.5.5 Bulk modulus Prediction	209
7.5.6 Shear modulus Prediction	215
7.5.7 Young modulus Prediction	221
7.5.8 Mu-Rho Prediction	227
7.5.9 Lambda-Rho Prediction	233
7.5.10 Vp/Vs ratio Prediction	239
7.5.11 Poission's ratio Prediction	245
7.5.12 Permeability Prediction	251

7.6 Facies Classification	257
Summary and Conclusions	266
Reference	271
Arabic summary	

List of Figures

Figure (1.1) : Map for the study area.	2
Figure (1.2): Processing summary from the final processing report Western Geco Schlumberger.	5
Figure (2.1): Bathymetry map of the Nile Delta (after Dolson,2005)	8
Figure (2.2): General stratigraphic column and hydrocarbon system of the Nile Delta (After Raslan, 2002)	10
Figure (2.3): Main fault trends of the Nile Delta modified from (Abd Aal et al., 2000)	17
Figure (2.4): Tectono-stratigraphy column of the Nile Delta. (after Dolson et al., 2005)	25
Figure (2.5): Interpreted distribution of crustal type and key basement fabric within the East Mediterranean Basin (EMB) (after Longacre et al., 2007)	26
Figure (2.6): Structure restoration features of the Nile Delta (1–15); distribution of Pliocene formation in the offshore Nile Delta region (Hanafy, et al., 2017)	28
Figure (2.7): The faults, anticlines, and convergence arcs effect on Nile Delta (after Abd-Allah, et al., 2012)	33
Figure (2.8): Evolution stages of Sienna channel (Sharaf, et al., 2014)	34
Figure (2.9): 3D schematic diagram showing the depositional model of turbidite slope channels (After Reading and Richards 1994).	34
Figure (2.10): Western sub basin Pliocene channels (Samuel et al., 2002)	36
Figure (3.1): Pickett's crossplot to determine formation water resistivity (Rw)	43
Figure (3.2) MDT Plot for Sienna-1, Sienna-2 and Sienna-Dd in the Study Area	47

Figure (3.3): RHOB-NPHI Cross Plot for Sienna-1.	48
Figure (3.4): RHOB-NPHI Cross Plot for Sienna-2.	49
Figure (3.5): RHOB-NPHI Cross Plot for Sienna-Dd.	49
Figure (3.6): PEFZ-RHOB Cross Plot for Sienna-1.	49
Figure (3.7): PEFZ-RHOB Cross Plot for Sienna-1.	50
Figure (3.8): TH-K Cross Plot for Sienna-1	51
Figure (3.9): TH-K Cross Plot for Sienna-2	51
Figure (3.10): TH-K Cross Plot for Sienna-Dd	52
Figure (3.11): PEF-K Cross Plot for Sienna-1	52
Figure (3.12): PEF-K Cross Plot for Sienna-Dd	53
Figure (3.13): PEF-TH/K Cross Plot for Sienna-1	53
Figure (3.14): PEF-TH/K Cross Plot for Sienna-Dd	54
Figure (3.15): Petrophysical model used by ELAN plus application (redrawn from manual of Schlumberger Techlog software)	55
Figure (3.16): Litho-saturation cross-plot for Sienna-1 well.	56
Figure (3.17): Litho-saturation cross-plot for Sienna-2 well.	57
Figure (3.18): Litho-saturation cross-plot for Sienna-Dd well.	58
Figure (3.19): Pulse echo sequence and refocusing (Allen, D., et al., 1997).	60
Figure (3.20): Example of a well-sorted water-wet sandstone formation.	62
Figure (3.21): Two examples of varying T2 distribution indicating different permeabilities (Allen, D., et al., 1997).	62
Figure (3.22): NMR T2 time distributions identifying free fluid, clay-bound and capillary bound water components depending on Cutoffs.	63
Figure (3.23): Distribution of the porosity over T2 values.	64
Figure (3.25): Porosity Distribution for Sienna-2 well.	64
Figure (3.26): NMR Output for Sienna-1 well.	68
Figure (3.27): NMR Output for Sienna-2 well.	69
Figure (3.28): NMR Output for Sienna-Dd well.	70
Figure (4.1): Ray paths for a plane wave that is incident on an interface and splits into four separate modes.	73
Figure (4.2): Classification of AVO. (after Rutherford and Williams, 1989 and Castagna et al, 1998).	78
Figure (4.3): Intercept versus gradient crossplot displaying location of AVO classes. (after Rocky et al, 2014).	79
Figure (4.4): Seismic pre-stack data conditioning workflow, the wiggles represent the seismic traces. (After Yehia, I. 2014).	81

Figure (4.5): Amplitude spectra of seismic gather volume before (top) and after (bottom) applying the low-pass filter displayed in transparent yellow in the top graph.	82
Figure (4.6): Comparison between AVO response for the top reservoir at Sienna-2 well on the AVO synthetic (right) and raw seismic gather (left).	83
Figures (4.7): shows an example of the application of the event alignment.	84
Figure (4.8): The best extracted wavelets per well in both time (top) and frequency (bottom) domains.	87
Figure (4.9): Show an AVO class 3 response, according with their gradient characteristics and cross plot results at top of gas zone.	89
Figure (4.10): The effect of conditioning the layering to the horizons.	92
Figure (4.11): LnZs vs. LnZp plot on the left and LnDn vs. LnZp on the right.	94
Figure (4.12): Inversion analysis of Sienna-1.	96
Figure (4.13): Inversion analysis of Sienna-2.	96
Figure (4.14): Inverted P-impedance section at Sienna-1 location.	97
Figure (4.15): Inverted P-impedance section at Sienna-2 location.	97
Figure (4.16): Inverted P-impedance section at Sienna-Dd location.	98
Figure (4.17): Inverted S-impedance section at Sienna-1 location.	98
Figure (4.18): Inverted S-impedance section at Sienna-2 location.	98
Figure (4.19): Inverted S-impedance section at Sienna-Dd location.	99
Figure (4.20): Inverted Density section at Sienna-1 location.	99
Figure (4.21): Inverted Density section at Sienna-2 location.	99
Figure (4.22): Inverted Density section at Sienna-Dd location.	100
Figure (4.23): Inverted Vp/Vs ratio section at Sienna-1 location.	100
Figure (4.24): Inverted Vp/Vs ratio section at Sienna-2 location.	100
Figure (4.25): Inverted Vp/Vs ratio section at Sienna-Dd location.	101
Figure (4.26): show the product of AVO attribute ($A*B$).	104
Figure (4.27): show the second type of AVO attribute combination $\text{Sign}(A) \times B$.	104
Figure (4.28): show the fourth type of AVO attribute combination $(A - B)/2$	104
Figure (4.29): show the sixth type of AVO attribute combination Poisson's ratio indicator, $4(A + B)/9$.	104
Figure (5.1) : Static measurement for Poission's ratio.	108
Figure (5.2): Vp/Vs ratio and lithology (Li and Zhang, 2011).	109

Figure (5.3): Guideline plot for Vp/Vs ratio versus Poisson`s ratio (Avseth. 2005)	109
Figure (5.4) : a- Young`s modulus: E, b- Bulk modulus: K, c- Shear (rigidity) modulus: μ , d- Axial modulus: ψ .	110
Figure (5.5): Ratio Difference cross-plot (left) showing fluid and lithology discrimination capability, (after Goodway (2001).	111
Figure (5.6): LMR cross-plot (right) with classifications of rocks λ and μ : Lamé parameters, ρ : density (after Perez and Tonn, 2010).	112
Figure (5.7): Cross-plots between DTCO (compressional slowness) and Gamma Ray, effective porosity, and water saturation.	116
Figure (5.8): Cross-plots between DTSM (shear slowness) and Gamma Ray, effective porosity, and water saturation, respectively.	117
Figure (5.9): Cross-plots between Vp/Vs ratio and Gamma Ray, effective porosity, and water saturation, respectively.	118
Figure (5.10): Cross-plots between Poission's ratio and Gamma Ray, effective porosity, and water saturation, respectively.	119
Figure (5.11): Cross-plots between Bulk Modulus (K) and Gamma Ray, effective porosity, and water saturation, respectively.	120
Figure (5.12): Cross-plots between Young Modulus and Gamma Ray, effective porosity, and water saturation, respectively.	121
Figure (5.13): Cross-plots between Shear Modulus (SMG) and Gamma Ray, effective porosity, and water saturation.	122
Figure (5.14): Cross-plots between Lambda-Rho ($\lambda\rho$) and Gamma Ray, effective porosity, and water saturation, respectively.	123
Figure (5.15): Cross-plots between Mu-Rho ($\mu\rho$) and Gamma Ray, effective porosity, and water saturation, respectively.	124
Figure (5.16) : DTCO versus VP/VS ratio cross-plot	125
Figure (5.17): Acoustic (P-) impedance versus S-impedance cross-plot.	126
Figure (5.18): Acoustic impedance versus VP/VS ratio cross-plot.	127
Figure (5.19): VP/VS ratio versus Poisson`s ratio cross-plot.	128
Figure (5.20): LMR cross-plot.	129
Figure (5.21): LMR Ratio-Difference cross-plot	129
Figure (6.1): Extended elastic impedance angles can range from - 90° to +90°, at which values $\sin^2 \theta$ is physically impossible.	133
Figure (6.2): Comparisons between elastic parameters and equivalent EEI curves for particular well.	135
Figure (6.3): Intercept and Gradient calculation from a linear regression of the amplitudes across near-mid-far stacks.	137

Figure (6.4): Cross-correlation analysis for the Porosity at three wells.	138
Figure (6.5): Cross-correlation analysis for the Vsh at three wells.	138
Figure (6.6): Cross-correlation analysis for the Density at three wells.	138
Figure (6.7): Cross-correlation analysis for the Sw at three wells.	139
Figure (6.8): Cross-correlation analysis for the Bulk Modulus at three wells.	139
Figure (6.9): Cross-correlation analysis for the Shear Modulus at three wells.	139
Figure (6.10): Cross-correlation analysis for the Young Modulus at three wells.	140
Figure (6.11): Cross-correlation analysis for the Mu-Rho at three wells.	140
Figure (6.12): Cross-correlation analysis for the Lambda-Rho at three wells.	140
Figure (6.13): Cross-correlation analysis for the Vp/Vs at three wells	141
Figure (6.14): Cross-correlation analysis for the Possion's ratio at three wells.	141
Figure (6.15): The EEI logs against equivalent well log targets.	142
Figure (6.16): a-Inversion analysis for REEI-porosity at Seinna-2 well, b-Inverted porosity section at Sienna-2 location, c-. Inverted porosity section at Sienna-1 location.	146
Figure (6.17): a-Inversion analysis for REEI-Vsh at Seinna-Dd well, b-Inverted Vsh section at Sienna-Dd location, c-. Inverted Vsh section at Sienna-1 location.	147
Figure (6.18): a-Inversion analysis for REEI-density at Seinna-1 well, b-Inverted Density section at Sienna-1 location, c-. Inverted Density section at Sienna-2 location.	148
Figure (6.19): a-Inversion analysis for REEI-Sw at Seinna-1 well, b-Inverted Sw section at Sienna-1 location, c-. Inverted Sw section at Sienna-2 location.	149
Figure (6.20): a-Inversion analysis for REEI-bulk modulus at Seinna-1 well, b-Inverted bulk modulus section at Sienna-1 location, c-. Inverted bulk modulus section at Sienna-2 location.	150
Figure (6.21): a-Inversion analysis for REEI- Shear modulus at Seinna-2 well, b-Inverted shear modulus section at Sienna-2 location, c-. Inverted shear modulus section at Sienna-Dd location.	151

Figure (6.22): a-Inversion analysis for REEI- Young modulus at Seinna-Dd well, b-Inverted Young modulus section at Sienna-Dd location, c- Inverted Young modulus section at Sienna-1 location.	152
Figure (6.23): a-Inversion analysis for REEI-Mu-Rho at Seinna-Dd well, b-Inverted Mu-Rho section at Sienna-Dd location, c-. Inverted Mu-Rho section at Sienna-1 location.	153
Figure (6.24): a-Inversion analysis for REEI-Lambda-Rho at Seinna-2 well, b-Inverted Lambda-Rho section at Sienna-2 location, c-. Inverted Lambda-Rho section at Sienna-Dd location.	154
Figure (6.25): a-Inversion analysis for REEI-Vp/Vs at Seinna-1 well, b-Inverted Vp/Vs section at Sienna-1 location, c-. Inverted Vp/Vs section at Sienna-Dd location.	155
Figure (6.26): a-Inversion analysis for REEI-possion's ratio at Seinna-Dd well, b-Inverted Sw section at Sienna-Dd location, c-. Inverted Sw section at Sienna-2 location.	156
Figure (7.1): (a) schematic view of the node of (a) a neural network and (b) a biological neuron.	158
Figure (7.2): Neural network development Time Line (Al-Mahasneh, 2017).	159
Figure (7.3): McCulloch and Pitts neuron model and its equation.	159
Figure (7.4): The biological and the mathematical neuron.	163
Figure (7.5): Schematic of Artificial Neuron (After Mohaghegh, 2000).	163
Figure (7.6): shows sample transfer functions.	166
Figure (7.7): shows the most commonly used activation functions.	166
Figure (7.8): some type of neural Network (Fjodor , 2017).	169
Figure (7.9): Feed-Forward and Recurrent neural network.	170
Figure (7.10): Signle-layer and multi-layer FFN.	170
Figure (7.11): The data-driven statistical interpretation (after Schultz et al).	172
Figure (7.12): Prediction curve derived by the PNN and MLFN (Hampson, et al, 2001).	175
Figure (7.13): Assuming the case of three seismic attributes, each target log sample is modeled as a linear combination of attribute samples at the same time.	177
Figure (7.14): a. A comparison between the target log (left) with the seismic attribute (right) emphasizes the difference in frequency	178

content, b. Using a five-point convolutional operator to relate the seismic attributes to the target log.

Figure (7.15): Illustration of cross-validation.	182
Figure (7.16): Training data for 3 wells.	183
Figure (7.17): Cross-plot of porosity and 1/inverted, using points within the analysis windows from all 3 wells (upper) and applying of the single attribute (1/inverted) transform for three wells (lower).	184
Figure (7.18): The results of stepwise regression in graphical form.	186
Figure (7.19): Applying the multiattribute transform using 6 attributes.	187
Figure (7.20): The validation results for the multiattribute analysis.	187
Figure (7.21): The prediction errors for each well.	187
Figure (7.22):Applying the PNN using 6 attributes.	188
Figure (7.23): The validation result for the PNN.	188
Figure (7.24): Application of the derived transforms to the 3-D volumes at Sienna-1 location.	190
Figure (7.25): A data slice through the porosity volume estimated using the PNN.	191
Figure (7.26): Training data for 3 wells.	192
Figure (7.27): Cross-plot of Vsh and computed porosity, using points within the analysis windows from all 3 wells (upper) and applying of the single attribute (computed porosity) transform for three wells (lower).	192
Figure (7.28): The results of stepwise regression in graphical form.	193
Figure (7.29): Applying the multiattribute transform using 3 attributes (upper). The normalized correlation coefficient for all the wells is 0.57. The validation results for the multiattribute analysis (lower). This is the same as upper except that the multiattribute transform for each well has been rederived with the well data removed from the analysis. The normalized correlation for all wells is 0.52.	194
Figure (7.30):Applying the PNN using 3 attributes. The normalized correlation coefficient for all the wells is 0.87. The validation result for the PNN. The normalized correlation for all the wells is 0.47.	195
Figure (7.31): Application of the derived transforms at Sienna-1 location.	196
Figure (7.32): A data slice through the Vsh volume estimated using the PNN.	197