Petrophysics of the Northern Browse Basin

Irma Savitri Widiasri

(B.Sc in Mathematics
Institut Teknologi Bandung, Indonesia)

This thesis is submitted in partial fulfillment of the requirements for the
Master of Science (Petroleum Geoscience)

Australian School of Petroleum
The University of Adelaide

November, 2007

ABSTRACT

The Northern Browse Basin, located on the North West Shelf of Australia, is a gas province with minor oil accumulations. Significant gas discoveries have been made within the Caswell Sub-basin, including the Scott Reef, Brecknock, Brecknock South and Brewster Fields. This area is a focus of exploration for the Chevron Australia Business Unit (Chevron ASBU). With the increasing potential for commercialization of the long-discovered gas in the Northern Browse Basin, Chevron ASBU's interest, and the aim of this project, is to identify any additional unrecognized gas reservoirs in the Late Triassic to Late Cretaceous rocks of the Northern Browse Basin. The section of interest covers the Nome, Plover, Lower Vulcan, Upper Vulcan, Echuca Shoals, Jamieson, Woolaston, Fenelon/Gibson and Puffin Formations. Petrophysical analysis of well logs was undertaken to identify unrecognized potential reservoirs.

A stepwise methodology was undertaken in this study. Log editing, pre-calculation and environmental corrections were first performed. A deterministic method was then used in the petrophysical analysis. The lowest of the estimates from the gamma ray and the density-neutron combination was taken as the shale volume. The Raymer-Hunt-Gardner sonic porosity transform was then used to calculate the porosity, with calibration to core data. Water saturation was determined using the dual water method for shaly sand.

A major uncertainty of this study was the determination of formation water resistivity (*Rw*). Formation water resistivity was determined using Pickett plots and assumed to be the same through the entire Late Triassic-Late Cretaceous sequence analyzed in each well. The resultant *Rw* values describe the salinity distribution within the study area. Salinity generally increases from southwest to northeast, with a range from 12,000 to 80,000 ppm.

Twelve out of the 16 analyzed wells were interpreted to contain potential net pay, which was encountered in the Puffin, Jamieson, Echuca Shoals and Upper Vulcan Formations. In the Puffin Formation, significant potential net pay was interpreted in Gryphaea-1, Discorbis-1 and

Kalyptea-1ST1, with the greatest thickness of 127 m being identified in Kalyptea-1ST1. Potential net pay in this formation has good reservoir quality, with an average of 17% shale volume, 20% porosity and 50% water saturation. Potential net pay in the Jamieson Formation averaged 25 m in thickness and 20% porosity. A half of the wells that encountered the Echuca Shoals Formation are interpreted to contain potential net pay in that unit, with the maximum thickness being 61 m in Adele-1. A very significant potential net pay of 430 m was interpreted in the Upper Vulcan Formation in Heywood-1. The Upper Vulcan Formation has good reservoir quality with an average of 125 m net pay thickness and 10% porosity in five out of seven wells.

This project was a reconnaissance study for possible unrecognized reservoirs in the Northern Browse Basin. It has identified many possible potential reservoirs and follow-up study should focus on re-analyzing the intervals highlighted here. A reservoir by reservoir analysis, especially when picking the parameter, such as *Rw*, would reduce the uncertainties. A probabilistic method of log analysis e.g. Multimin in Geolog (which was briefly attempted here), should be investigated as a replacement for deterministic methods such as the one used in this study.

STATEMENT OF CONFIDENTIALITY

Due to confidentiality agreement between Chevron Company and the Australian School of Petroleum, this thesis is not available for public inspection or borrowing until 5 November 2010.

ACKNOWLEDGEMENTS

I am grateful to the Almighty Allah SWT for all blessing and favor that made this thesis possible.

I would like to express my gratitude to Chevron IBU for supporting this project. A special thanks to Christopher Davin and Randall Cooper for giving me the opportunity to undertake this program. My appreciation is to Chevron ASBU for providing the essential data for this project. Particularly, I thank Justyn Wood and Michael Wilson for their assistance during my internship in Perth and their advice during the project. Many thanks also to Occam Technology Pty Ltd of Adelaide for supplying additional data.

I would particularly like to thank my supervisor, Prof. Richard Hillis and my co-supervisor, Dr. Bruce Ainsworth, for their technical guidance and valuable advice. I would also like to thank Sigit Sutiyono for support. Thanks also to Andy Mitchell and Zuraidah for assistance with Geolog.

Most importantly, I am indebted to my parents, my beloved family, and my great friends in Indonesia and Australia who give me never-ending support, caring and great motivation. Thanks to all the staff and students of the Australian School of Petroleum for a wonderful year and experience.

TABLE OF CONTENTS

Abstract i
Statement of Confidentiality iii
Acknowlegments iv
Table of Contents v
List of Symbols vii

1 Introduction 1
1.1 Background 1
1.2 Study Area 1
1.3 Study Objectives 2
1.4 Data 2
1.5 Chevron Interest 2
2 Regional and Petroleum Geology of the Northern Browse Basin 4
2.1 Geological Summary and Stratigraphy 6
2.1.1 Caswell Sub-basin, Browse Basin 6
2.1.2 Ashmore Platform, Vulcan Sub-basin 9
2.2 Petroleum System 10
2.2.1 Caswell Sub-basin, Browse Basin 10
2.2.2 Ashmore Platform, Vulcan Sub-basin 11
2.3 Exploration History 12
3 Methodology 15
3.1 Raw Data 15
3.2 Log Editing 16
3.3 Well Correlation 18
3.4 Pre-Calculation and Environmental Corrections 18
3.5 Interpretation/Analysis 26
3.5.1 Parameter Picking 27
3.5.2 Bad Hole Identification 28
3.5.3 Shale Volume 31

3.5.4 Porosity 32
3.5.5 Formation Water Resistivity Determination 35
3.5.6 Water Saturation 36
3.5.7 Net Sand - Net Reservoir - Net Pay Summaries 38
4 Petrophysical Results 39
4.1 Formation Water Salinity 39
4.2 Petrophysical Properties within Each Formation 40
4.2.1 Puffin Formation 45
4.2.2 Fenelon/Gibson Formation 46
4.2.3 Woolaston Formation 47
4.2.4 Jamieson Formation 48
4.2.5 Echuca Shoals Formation 49
4.2.6 Upper Vulcan Formation 50
4.2.7 Lower Vulcan Formation 51
4.2.8 Plover Formation 51
4.2.9 Nome Formation 52
5 Discussion 54
5.1 Uncertainties 54
5.2 Multimin Method 55
6 Conclusions and Recommendations 59
6.1 Conclusions 59
6.2 Recommendations for Further Work 61

References 62

Appendix 1 Abbreviations
Appendix 2 Pre-Calculation Data for Each Well
Appendix 3 Documentation of Log Editing in Each Well
Appendix 4 Documentation of Parameter Picking in Each Well
Appendix 5 Net Pay-Reservoir-Sand Summaries
Appendix 6 Log Interpretation of Each Well (in CD)

LIST OF SYMBOLS

a : Constant, equal to 1
C : Porosity factor
CEC : Cation exchange capacity
C_t : Conductivity of the uninvaded formation
C_w : Conductivity of formation water
C_{wb} : Conductivity of bound water
C_{we} : Equivalent conductivity of the water in the pore space
Δt_{ma} : Sonic matrix
$GR_{\max}$: Gamma ray shale (GAPI)
$GR_{\min}$: Gamma ray matrix (GAPI)
m : Cementation exponent
n : Saturation exponent
ϕ_{cwb} : Porosity of clay bound water
ϕ_e : Effective porosity
$\phi_{e_{\max}}$: The maximum value of effective porosity
ϕ_{fw} : Porosity of free water
ϕ_h : Porosity of hydrocarbon
ϕ_t : Total porosity
ϕ_{tsh} : Shale total porosity, equal to volume of clay bound water
Q_v : CEC of the rock per unit pore volume
R_0 : True formation resistivity where the pore space is 100% water saturated (ohmm)
R_t : True formation resistivity (ohmm)
R_{xo} : Formation resistivity in flushed zone (ohmm)
R_w : Formation water resistivity (ohmm)
S_{wb} : Bound water saturation
S_{we} : Effective water saturation
S_{wt} : Total water saturation
Vsh : Shale volume
V_w : Bulk volumes of formation water
V_{wb} : Bulk volumes of bound water