

Hydrocarbon Potential of Eastern View Group Reservoir Rocks, Bass Basin, Australia

Natt Arian

Submitted in fulfilment of the requirements of the degree of
Doctor of Philosophy

February 2010

Australian School of Petroleum
Faculty of Engineering, Computer and Mathematical Sciences
University of Adelaide

ABSTRACT

Hydrocarbon exploration to-date in the Bass Basin has focused on Eocene reservoir rocks of the Upper Eastern View Group with limited success. This thesis focuses on the hydrocarbon potential of Middle and Lower Eastern View Group reservoir rocks which the results of this thesis suggest are closer and better connected to mature source rocks in the basin. This thesis employs several basin analysis techniques, particularly 3D basin modelling, to investigate the hydrocarbon charge history of the Bass Basin.

Sixteen 2D surveys providing ~20,000 km of reflection seismic data were interpreted in order to understand the structural setting of the Bass Basin and to constrain its morphology for input into 2D and 3D basin models. The seismic interpretation resulted in recognising a rotation in stress directions from the Early Eocene to the Late Eocene, which was associated with the creation of a new set of faults during the deposition of the Upper Eastern View Group and the Demons Bluff Formation. These faults are interpreted to have reactivated during the Miocene, with reactivation leading to hydrocarbon breach in accumulations within the northeastern part of the Bass Basin. Key horizons and faults interpreted from seismic data were depth-converted and input into PetroMod software for basin modelling.

Reservoirs of the Upper Eastern View Group demonstrate an average core porosity of 26% and an average permeability of ~200 mD. Thicker sand bodies in the Middle EVG exhibit an average log-derived porosity of 20%, even at depths greater than 3000 m. It is interpreted that these porosities are maintained at relatively great burial depth due to the occurrence of coarser-grained sands within lower sections of fining-upward sedimentary cycles. Coarser-grained sands have resisted compaction and cementation due to their grain texture and have preserved better intergranular porosity and reservoir quality.

The Demons Bluff Formation, is the regional seal overlying the Eastern View Group, and was analysed and found to have excellent sealing capacity. Some samples were interpreted to be capable of supporting in excess of 2 km oil column height.

The potential source rocks of the Bass Basin are interbedded coals and shales deposited mainly in freshwater lakes. Coaly source rocks of the Narimba (Early Eocene), Tilana (Palaeocene) and Furneaux (Maastrichtian) sequences are the key potential source rocks. The Otway Megasequence (Early Cretaceous) may also contain potential source rocks. Geochemical analysis suggests a Type II-III source rock for potential source rocks of the Early Eocene. Activation energy and kinetic reactions for source rocks of this age were modelled according to the results of geochemical analysis, while Palaeocene and other older source rocks were modelled as Type III source rocks to signify their terrestrial nature.

2D and 3D hydrocarbon generation models constructed for the Bass Basin suggest oil-prone source rocks of the Middle Eocene succession are immature and Early Eocene source rocks are partially mature for hydrocarbon expulsion. Source rocks of the Palaeocene and older are mature for hydrocarbon expulsion and have generated the majority of the gaseous hydrocarbons in the basin.

This thesis has highlighted the significance of fault conductivity in controlling the distribution of hydrocarbons within the Bass Basin. Migration modelling suggests faults were impermeable during the Late Palaeocene when hydrocarbon expulsion from the Early Cretaceous source rocks commenced. Impermeable faults, together with intraformational seals within the Lower and Middle Eastern View Group largely prevented vertical hydrocarbon migration into the Upper Eastern View Group. In the central and northeastern parts of the basin, the Upper Eastern View Group reservoirs were charged by Early Eocene source rocks, which commenced expulsion during the Pliocene. Fault reactivation during the Miocene may have resulted in breaching some deeper accumulations within reservoir sands of the Narimba and Tilana sequences and migration into reservoir sands of the Upper Eastern View Group.

Basin models predict trapped hydrocarbons within reservoirs of the Middle Eastern View Group where mature source rocks exist, while the majority of the Upper Eastern View Group reservoirs under the regional seal were left without hydrocarbon charge. Deeper troughs such as the Yolla, Cormorant and Pelican troughs in the Cape Wickham Sub-basin (western part of the Bass Basin) are predicted to have the

most accumulations in the basin. Few accumulations are predicted in the Durroon Sub-basin (eastern part of the Bass Basin).

The basin models suggest several new and untested plays within the Bass Basin which may increase its prospectivity, notably by implementing a new exploration strategy targeting quality reservoirs of the Middle Eastern View Group.

Regional assessment and modelling of the carbon dioxide (CO₂) storage potential of the Bass Basin was also undertaken and suggests the basin has the potential to provide excellent CO₂ storage. Since many reservoirs of the Upper Eastern View Group have not received hydrocarbon charge, CO₂ storage in these reservoirs will not interfere with hydrocarbon exploration.

This thesis dedicated to:

My mother
My beloved wife Hêro,
My children,
My real friend Hugh Pope, and
My homelands Australia and Kurdistan

Statement of Authenticity and Availability

This is to certify that, to the best of my knowledge and belief, this thesis contains only my original work towards the PhD, except where due references and/or acknowledgments have been made in the text to all other materials used in this thesis.

I give consent to this copy of my thesis, when deposited in the library of the University, being made available for loan and photocopying.

Natt Arian

ACKNOWLEDGMENTS

I would like to express my thanks and appreciation to those who have provided assistance during the course of my PhD, especially to my supervisors Dr. Peter Tingate, Professor Richard Hillis and Dr. Geoffrey O'Brien.

Peter has been a great supervisor, who made himself available for discussion and advice at almost any time. He has corrected several of my manuscripts, especially the thesis manuscript during times of high workload while working for Geoscience Victoria.

Richard, as a supervisor, and as head of Australian School of Petroleum, is highly appreciated for advice, assistance and encouragement. Apart from direct PhD project advice, he has been excellent in facilitating fortnightly stress group meetings, postgraduate retreats and other occasions for PhD students and postdoctoral fellows.

Geoff engineered the original proposal for my PhD project and positioned it on track. His continued supervision and assistance, despite his interstate location, is also greatly appreciated...

I would also like to extend many thanks to the ASP postgraduate coordinator Mr. Andy Mitchell, who managed my seismic project and provided continuous support and assistance during the course of the project, especially with seismic depth conversion formulas.

I kindly thank Mr. Aaron Cummings, who made his 2D seismic project available for this project, and who gave permission to use the two uppermost seismic horizons he had interpreted.

A big thank you goes to Minerals Resource Tasmania (MRT) for generously sponsoring my PhD project and supplying important financial and logistical support.

Many thanks go to Geoscience Australia (GA) and the Department of Primary Industries Victoria (VicDPI), with whom I established an excellent relationship, and who showed interest in my PhD project, and provided financial and logistical support. GA provided financial support for a Mercury Injection Capillary Pressure (MICP) to be undertaken by ASC consultants, which contributed to seal capacity evaluation. VicDPI provided financial support for a fault evaluation study to be undertaken by JRS Petroleum which was integrated into migration modelling. VicDPI also made their office and computers available for 3D simulation and calibration runs.

Integrated Petroleum Systems (IES) and Schlumberger Ltd have directly and indirectly supported my PhD project by providing software licences. IES provided an academic license for PetroMod software to be used within the ASP, and kindly provided a free license to be used on my own laptop which made life much easier for me. Schlumberger provided GeoFrame and Petrosys licenses.

The Australian School of Petroleum (ASP) and all its staff and postgraduate students are thanked for creating a friendly working environment which made research an enjoyable experience. Maureen, Maxine and Judith from administration get special thanks for their continuous daily support. The ASP IT helpdesk Mr. Ian West, is also thanked for his great effort in providing daily IT needs, particularly with the remote computer used for 3D modelling simulations.

I also sincerely thank everyone who has supported me in one way or another during my PhD, especially my wife for her support and love, my children for understanding my limited time for family life, my relatives and circle of close friends for support and encouragement.

Table of Contents

CHAPTER 1	1
1. Introduction	1
1.1. The Bass Basin	1
1.2. Bass Basin Structure	2
1.3. Petroleum Geology of the Bass Basin	4
1.3.1. Accommodation cycles and sequence stratigraphy.....	5
1.3.2. Source rock geochemistry.....	7
1.3.3. Reservoir rocks	8
1.3.4. Seal evaluation.....	10
1.4. Previous exploration	11
1.5. Main issues	13
1.6. Objectives, Aims and Scope	14
CHAPTER 2	16
2. 2D Seismic Interpretation	16
2.1. Introduction	16
2.2. Data sets and methods	17
2.2.1. Data.....	17
2.2.2. Methods.....	21
2.3. Basin architecture	25
2.3.1. Redefinition of basin boundaries.....	26
2.3.2. Structural elements	28
2.4. Seismic stratigraphy in the Bass Basin	30
2.4.1. Basement	32
2.4.2. Crayfish Equivalent Megasequence (Early Cretaceous “possibly latest Late Jurassic-Early Cretaceous”).....	34
2.4.3. Otway Megasequence (Early Cretaceous)	35
2.4.4. Durroon Megasequence (Early Late Cretaceous “Turonian to Campanian”)	37
2.4.5. Bass Megasequence (Late Cretaceous-Early Eocene).....	38
2.4.6. Aroo Sequence (Early-Middle Eocene).....	42
2.4.7. Flinders Sequence (Middle Eocene - late Early Oligocene)	44
2.4.8. Torquay Sequence (Late Oligocene-Recent)	45
2.5. Preparation of 3D Surfaces and Faults	46
2.5.1. Gridding.....	46
2.5.2. Depth conversion	46
CHAPTER 3	57

3. Porosity Trends and Regional Reservoir Quality in the Bass Basin	57
CHAPTER 4.....	71
4. 2D Generation, Expulsion, Migration and Accumulation Modelling	71
4.1. 2D Generation, Migration and Accumulation Modelling in the Central Bass Basin.....	71
4.2. 2D Generation, Migration and Accumulation Modelling across the Bass Basin86	
4.2.1. Hydrocarbon Generation and Expulsion	87
4.2.2. Hydrocarbon Migration and Accumulation	89
4.2.3 General sense of the basin's petroleum systems	93
CHAPTER 5.....	95
5. 3D Petroleum Systems Modelling.....	95
CHAPTER 6.....	122
6. Implications for Petroleum Prospectivity.....	122
CHAPTER 7.....	127
7. CO₂ Storage potential of the Bass Basin.....	127
7.1. Geological Storage of Carbon Dioxide.....	128
7.2. Initial screening and ranking of the Bass Basin.....	129
7.3. Seal analysis.....	130
7.3.1. Seal Thickness and Geometry.....	132
7.3.2. Mercury Injection Capillary Pressure (MICP) Analysis	134
7.4. Fault Risk Evaluation under the Present-day Stress Regime.....	141
7.5. Regional reservoir quality	142
7.5.1. Sands of the Upper EVG.....	143
7.5.2. Sands of the Middle EVG.....	145
7.6. Potential CO₂ storage in saline aquifers of the Upper EVG.....	146
7.7. Modelling Possible CO₂ Migration and Entrapment.....	151
CHAPTER 8.....	158
8- Conclusions.....	158
8.1. 2D Seismic and Structural Interpretation	158
8.1.1. Structural and Depositional Evolution	158
8.1.2. Structural Styles	159
8.2. Regional Reservoir Quality.....	160
8.2.1. The Middle EVG.....	160
8.2.2. The Upper EVG.....	160

8.3. Seal Integrity and Capacity.....	161
8.3.1. Regional Seal.....	161
8.3.2. Intraformational seals.....	161
8.4. Petroleum plays and prospectivity	161
8.4.1. Generation and Expulsion.....	162
8.4.2. Migration pathways	162
8.4.3. Accumulations.....	163
8.5. Fault Conductivity Prediction.....	164
8.6. Potential CO₂ Storage and Sequestrations	164
8.7. Recommendations for future work	166
9. References	168
APPENDICES	176