

PORE PRESSURE PREDICTION: A CASE STUDY OF BLOCK A, SABAH
INBOARD & BARAM BASIN, SABAH OFFSHORE

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“My dearest husband, parents, siblings, family and friends”

This is for all of you

Thank you, Allah, for giving me a chance to be your humble servant

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ABSTRAK

Memahami ramalan tekanan pori sangat penting dalam pelbagai peringkat proses petroleum. Masalah tekanan pori semasa penggerudian seperti insiden kawalan telaga, hilang peredaran telaga dan kerosakan reservoir yang sering membawa kepada penggerudian semula telaga yang mahal, pemberhentian penggerudian telaga, letupan bawah tanah dan kehilangan nyawa pengendali penggerudian di atas pelantar. Blok A yang terletak di kawasan perairan Sabah. Beberapa telaga telah digerudi dan telah mengalami tekanan pori yang tidak dijangka yang menyebabkan pemberhentian penggerudian telaga lebih awal dari yang dicadangkan dan mengakibatkan kegagalan mencapai objektif menggerudi telaga itu. Objektif kajian ini adalah untuk menganalisis geologi serantau untuk memahami mekanisme tekanan pori berlebihan dan bilakah tekanan pori berlebihan mula terjadi. Kedua, ramalan tekanan pori menggunakan data telaga terdekat di dalam Blok A, dengan menggunakan kaedah Eaton & Bowers dan menggunakan kaedah terbaik yang telah dioptimumkan berdasarkan interpretasi geologi dan model tekanan pori secara serantau. Dan akhirnya menganggarkan panjang maksimum ruang hidrokarbon untuk potensi prospek di Blok A yang masih ada di dalam lingkungan kedalaman tekanan pori yang tinggi. Skop kajian ini akan merangkumi kajian geologi termasuk stratigrafi urutan, tafsiran seismik, tafsiran & analisis fizikal seismik, pemendapan persekitaran kasar (GDE) dan evolusi struktur Blok A. Ramalan tekanan pori menggunakan data sedia ada dan menganggarkan maksimum panjang ruang hidrokarbon untuk melihat potensi prospek yang mengandungi gas dengan pori yang tinggi. Kajian geologi serantau memberi anggaran usia permulaan tekanan pori yang tinggi dalam kawasan Blok A. Hasil ramalan tekanan pori menunjukkan bahawa kaedah Eaton mempunyai keupayaan untuk meramal lebih baik rejim tekanan pori yang tinggi berbanding dengan kaedah Bowers. Dengan menggunakan kaedah Eaton, peta magnitud tekanan pori tinggi telah dihasilkan, dan menggunakan peta magnitud tekanan pori tinggi ini, panjang

maksimum ruang hidrokarbon telah dianggarkan untuk 3 potensi prospek gas tekanan pori yang tinggi. Model tekanan pori yang telah dibina dalam kajian ini, bukan sahaja boleh digunakan untuk meramalkan panjang maksimum ruang hidrokarbon untuk potensi baki prospek gas yang mempunyai tekanan tinggi, ini juga dapat memberi manfaat kepada pengiraan panjang maksimum ruang hidrokarbon untuk sebarang kemungkinan prospek lain yang berpotensi dan ia juga dapat digunakan untuk ramalan tekanan pori pada masa hadapan.

ABSTRACT

Understanding pore pressure prediction is critical in various stage of frontier in petroleum process. Pore pressure related problems during drilling such as well control incidents, lost circulation & reservoir damages which often leads to expensive sidetracks, well abandonments, underground blowout & the loss of life of the drilling operators on the rig. Block A located in Sabah Basins, a few wells have been drilled & encountered unexpected overpressure which led to early abandonments & resulting to failure on achieving well objectives. The objective of this study is to first interpreted regional geology to understand the overpressure onset and overpressure mechanisms. Secondly, predict pore pressure using available nearby wells data within Block A, by using Eaton & Bowers methods and best fit method that has been optimized based on geological interpretation and model the pore pressure regionally. And finally estimates maximum possible hydrocarbon column length model for Block A remaining potential of deep gas overpressured play. The scope of this study will include geological study including sequence stratigraphy, seismic interpretation, seismic facies interpretation & analysis, gross depositional environment (GDE) & structural evolution of Block A. The pore pressure prediction using available well data and estimating maximum possible hydrocarbon column length for remaining potential of deep gas overpressured play. The regional geological studies result gave the estimated age of overpressure onset within Block A area. The pore pressure prediction results show that Eaton method has ability to better predict the overpressure regime compared to Bowers method. Using the Eaton method, an overpressure magnitude map has been produced, and using this overpressure magnitude map, 3 potential deep overpressure gas prospects maximum hydrocarbon column length has been estimated. Pore pressure model that has been built within this study, not only can be used to predict maximum hydrocarbon column length for current remaining potential of deep gas overpressured

play, it is also can benefit future maximum hydrocarbon column length for any other potential play and it can be used for future drilling pore pressure prediction.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	ACKNOWLEDGEMENT	iv
	ABSTRAK	v
	ABSTRACT	vii
	TABLE OF CONTENTS	ix
	LIST OF TABLES	xi
	LIST OF FIGURES	xii
	LIST OF ABBREVIATIONS	xvi
	LIST OF SYMBOLS	xvii
	LIST OF APPENDIXES	xviii
1	INTRODUCTION	1
	1.1 Introduction	1
	1.2 Statement of Problem	2
	1.3 Objectives	3
	1.4 Hypothesis	3
	1.5 Scope of Study	4
	1.6 Significance of Study	4
	1.7 Chapter Summary	5
2	LITERATURE REVIEW	6
	2.1 Block A Background	6
	2.2 Geological Overview, Sequence Stratigraphy & Depositional System	10
	2.3 Basic Pore Pressure & Overpressure Mechanisms	17

2.4	Basin Analogues for Block A Pore Pressure Study	21
2.5	Pore Pressure Prediction Method	26
2.6	Chapter Summary	29
3	METHODOLOGY	30
3.1	Data Requirement	30
3.2	General Methodology Overview	31
3.3	Geological Interpretation	31
3.4	Pore Pressure Prediction	33
3.5	Maximum Hydrocarbon Column Length Prediction	36
3.6	Chapter Summary	37
4	RESULT AND DISCUSSION	38
4.1	Geological Interpretation	38
4.2	Pore Pressure Prediction	48
4.3	Maximum Hydrocarbon Column Length Prediction	64
4.4	Chapter Summary	74
5	CONCLUSION	75
5.1	Conclusions	75
6	RECOMMENDATION	77
6.1	High Case and Base Case Scenario	77
	REFERENCES	78

LIST OF TABLES

TABLE NO.	TITLE	PAGE
Table 4.1	Summary of maximum hydrocarbon column length	73
Table 5.1	Summary of hypothesis and the outcome from the study done	76

LIST OF FIGURES

FIGURES NO	TITLE	PAGE
Figure 2.1	Sabah initial 3-year exploration period (Said, 1982)	7
Figure 2.2	Sabah Pre-PSC discovery (Said, 1982)	8
Figure 2.3	Sabah 2-year exploration extension period (Said, 1982)	8
Figure 2.4	Sabah 2-year exploration extension period (Said, 1982)	9
Figure 2.5	Approximate location of Block A within Northwest Borneo geological provinces. Block A are located within Baram Delta & Champion Province	11
Figure 2.6	Schematic cross-section showing the development of Northwest Borneo and Sabah Basin & location of Block A	12
Figure 2.7	Integrated Chronostratigraphic nomenclature of Northwest Borneo (Balaguru & Lukie, 2012)	14
Figure 2.8	Chronostratigraphy and Petroleum System of Offshore Northwest Sabah (Balaguru & Lukie, 2012)	15
Figure 2.9	Map of northern Borneo showing location of the three major delta systems province offshore Northwest Sabah, Brunei and Northeast Sarawak (Tingay et al., 2005) and approximate location of Block A	16
Figure 2.10	Schematic of pressure vs. depth	17
Figure 2.11	During burial of a sediment, the pore pressure increases by following the hydrostatic pressure gradient (from point A to point B) because the fluid can escape to the surface during compaction. As subsidence continues, the permeability of the sediment declines and fluid starts to be retained (point B, the fluid retention depth). The pore pressure then rises along the pressure-depth path parallel to the of the lithostatic gradient (B to C) (Osborne & Swarbick, 1997)	19

- Figure 2.12 Pressure-temperature diagram illustrating the magnitude of overpressure produced by aquathermal pressuring. For example, if a fluid with density of 0.99 g/cm^3 is heated from 54.4 to 93.3 degree Celsius, the pressure of the fluid will rise along an isochore, or line of constant volume, which is appropriate for a fluid with that density. The rise in pressure is very large (8000 psi, or 55 MPa). (Osborne & Swarbrick, 1997) 20
- Figure 2.13 Residual stresses due to uplift and erosion 21
- Figure 2.14 Schematic sections through the Baram Delta province, including the top of overpressure and border between inner- and outer-shelf overpressure provinces. The vertical exaggeration is 6. The onset of overpressure in the outer shelf is coincident with the top of the prodelta shales, whereas overpressures in the inner-shelf commence in the overlying deltaic sequences 23
- Figure 2.15 (a) Pore-pressure prediction in outer-shelf well A containing disequilibrium compaction overpressures. Pore pressure is accurately estimated using an Eaton exponent of 3.0 (black curve). (b) Pore-pressure prediction for inner-shelf well B containing vertically transferred overpressures. Pore pressure is reasonably estimated using an Eaton (1972) exponent of 6.5 (black curve). However, sharp pore-pressure increases are underestimated (e.g., at 1700 m [5577-ft]). An Eaton (1972) exponent of 3.0 underestimates pore pressure (gray curve). (c) Pore-pressure prediction for inner-shelf well C containing vertically transferred (1750–2350 m, 5741–7710 ft) and disequilibrium compaction overpressures (>2350 m, >7710 ft). Pore pressure appears to be more accurately estimated using an Eaton (1972) exponent of 6.5 (black curve) and underestimated using an Eaton (1972) exponent of 3.0 (gray curve) 23
- Figure 2.16 Typical Velocity vs. Density signatures and their associated, causal mechanisms of overpressure generation (Hoesni, 2004) 25
- Figure 2.17 (Left) Velocity vs. density data plotted for Well A. Estimated borehole temperatures also plotted. Deviation is observed from the primary compaction curve of Gardner (red line) and Bowers (2001) (blue line) for shales at temperatures of 120°C , although more significantly at

160°C. This signature of increasing velocity and density is identified by Hoesni et al. (2007) as suggestive of chemical compaction/cementation effects. (Right) Velocity vs. density data plotted for Well B. Deviation is observed from the primary compaction curve of Gardner (red line) and Bowers (2001) (blue line) for shales at temperatures of 120°C. This signature of increasing velocity and density is identified as suggestive of load transfer effects (refer to Figure 2.16)	25
Figure 2.18 (a) The unloading parameter “U”, (b) Normalized unloading curve (Bower, 1994)	28
Figure 3.1 General methodology for Block A pore pressure study	31
Figure 3.2 Detail methodology for geological interpretation to define overpressure mechanisms over Block A	33
Figure 3.3 Detail methodology for pore pressure prediction to model pore pressure over Block A	34
Figure 3.4 Velocity and density logs showing the physical properties of normally compacting rocks (blue trend lines), undercompacted rocks (orange trend lines) and unloading (red trend lines) (Chopra and Huffman, 2004) where the overpressure starts for this well	35
Figure 3.5 Detail methodology on maximum hydrocarbon column length prediction	36
Figure 4.1 Seismic cross-section from NW to SE within Block A	40
Figure 4.2 Classification of clinoforms based on geometric configuration	41
Figure 4.3 Block A map with shelf edge for stratigraphic age that has been interpreted	42
Figure 4.4 Block A map with shelf edge for stratigraphic age overlay with wells info on overpressure onset age	43
Figure 4.5 Top Stage IVA/LIU map shows structural highs/uplift in the middle of Block A	45
Figure 4.6 Structural highs polygon/area (blue colour) overlay on overpressure onset wells data	46
Figure 4.7 Overpressure onset map	47
Figure 4.8 Pore pressure prediction using Eaton’s method	49
Figure 4.9 Velocity vs. Depth plot	50

Figure 4.10 Pore pressure prediction using Bowers' method	51
Figure 4.11 Pore pressure prediction for southern part	55
Figure 4.12 Pore pressure prediction for middle part	56
Figure 4.13 Pore pressure prediction for northern part	57
Figure 4.14 Overpressure onset map overlay with overpressure magnitude per wells tested	58
Figure 4.15 Overpressure magnitude map	59
Figure 4.16 Tectonic uplift for Stage IVA and erosional for Stage IVB and Stage IVC Lower	60
Figure 4.17 Faults that can function as seal or vertical fluid transfer	61
Figure 4.18 Comparison between Block A and Brunei	62
Figure 4.19 Proper comparison between Block A and Brunei	63
Figure 4.20 Location of possible deep overpressure prospects on the magnitude map	64
Figure 4.21 Polynomial function 3 rd order is used for depth conversion for prospect mapped	65
Figure 4.22 (Above) map of prospect REM DW1. (Below) seismic cross-section shows prospect REM DW1	66
Figure 4.23 Pore pressure prediction for prospect REM DW1	67
Figure 4.24 (Above) map of prospect REM DW2. (Below) seismic cross-section shows prospect REM DW2	68
Figure 4.25 Pore pressure prediction for prospect REM DW2	70
Figure 4.26 (Above) map of prospect GRA D1. (Below) seismic cross-section shows prospect GRA D1	71
Figure 4.27 Pore pressure prediction for prospect GRA D1	72

LIST OF ABBREVIATIONS

DRU	- Deep Regional Unconformity
DST	- Drill-Stem Test
FIT	- Field Integrity Test
GDE	- Gross Depositional Environment
LIU	- Lower Regional Unconformity
LOT	- Leak-Off Test
MDT	- Modular Dynamic Test
NCT	- Non- Compacted Trend
PSC	- Production-Sharing Contract
RFT	- Repeat Formation Test
SRU	- Shallow Regional Unconformity
UIU	- Upper Regional Unconformity
VES	- Vertical Effective Stress
2D	- Two-Dimensional Space
3D	- Three-Dimensional Space

LIST OF SYMBOLS

A, B	-	Virgin Curve Parameters
°C	-	Degree Celcius
P	-	Pore Fluid Stress
S	-	Vertical Overburden Stress
V	-	Velocity
σ	-	Effective Stress Acting on The Rock Frame

LIST OF APPENDIXES

APPENDICES NO	TITLE	PAGE
A	List of wells Block A with data availability	82
B	List of time and depth maps per stratigraphic sequence	83
C	Overpressure onset map	93
D	List of wells Block A time depth relation	94
E	Depth conversion polynomial function third order	95
F	Block A wells pressure data	96
G	Block A wells pore pressure prediction Bowers method	106
H	Block A wells pore pressure prediction Eaton method	116
I	Overpressure magnitude per well Eaton method overlay with overpressure onset map	141
J	Overpressure magnitude map Eaton method	142
K	Maximum hydrocarbon column length prediction	143

CHAPTER 1

INTRODUCTION

1.1 Introduction

Understanding pore pressure is critical in various stages of frontier hydrocarbon exploration, development, exploitation & drilling. The benefits of understanding pore pressure are not only to successful exploration & development drilling, but also it is one of the most important safety elements that should be considered before drilling a well. Pore pressure related problems during drilling such as well control incidents, lost circulations & reservoir damages which often leads to expensive sidetracks, well abandonments, underground blowouts & the loss of life of the drilling operators on the rig.

Even though so many wells have been drilled over time especially within matured basin, pore pressure prediction was observed to always been wrongly predicted and was normally been underpredicted, thus, this means the understanding of pore pressure prediction over matured basin especially, has been overlooked.

To understand pore pressure of the area, geological setting of the area needs to be understood. A few elements of geological understanding, especially depositional environment, including structural elements and this, will help on overpressure onset prediction. Area definition by geological setting and the first mechanisms overpressure generation understanding will help to better predict on overpressure magnitude thus optimization of the pore pressure model can be done. The wells data of the area will

also be used to determine pore pressure, using a few methods to test (Tau, Eaton & Bowers), use one of the method which best fit the pressure of Block A and will be design according to geological understanding to further optimize the pore pressure model.

There are remaining potential exploration in the deep gas overpressured play at Block A. Using optimized pore pressure model, the maximum column length prediction over remaining potential deep gas overpressured play can be better predicted. This pore pressure prediction will be done over Block A area, offshore Sabah.

1.2 Statement of Problem

Well T-1 was drilled within Block A and early abandonment needs to be done due to overpressure surprise encountered at the deeper depth, 9580 ft of AHBDF which reflects overpressure greater than 0.53 psi/ft. Well TDW-1 was drilled nearby a decade later and was abandoned 600 ftss shallower due to overpressure encountered at depth 13585 ft of AHBDF which reflects overpressure to a maximum 2895 psi above hydrostatic near TD. The example shows pre-drill evaluation failed to predict overpressure that will be encountered by the wells. These scenarios have led to early wells abandonment, hence may likely fail to achieve wells objectives. The strategy is to re-visit wells data over Block A area, understand the geological settings & mechanisms of overpressure generation and model the pore pressure for Block A.

A few remaining potential of deep gas overpressured play has been identified within Block A. In an overpressured system, there is a risk that the top seal may be breached by the high pressure, thus leads to a reduced hydrocarbon column or at worst, a completely blown trap. Optimized pore pressure modelling can be a key to a successful exploration campaign.

1.3 Objectives

The objectives of the pore pressure prediction are:

- i. To interpret geology over Block A, understand the first mechanisms of overpressure generation and use these understandings with overpressure observed in wells within Block A.
- ii. To predict pore pressure by using Block A wells data and come out with optimized method of prediction/model, based on geological understanding
- iii. To estimate maximum possible hydrocarbon column length for Block A remaining potential of deep gas overpressured play, based on optimized method of prediction/model.

1.4 Hypothesis

The hypotheses of this study are predicted as below:

- i. Overpressure onset starts at shelf edge for the outer shelf, shallow onset overpressures in the inner shelf are in regions that have been uplifted or below maximum flooding surface events & vertical transfer of the porous units within inner shelf. Faults is one of the mechanisms for pressure seals.
- ii. Two methods to test on predicting pore pressure (Eaton & Bowers) underpredicts overpressure magnitude. Optimization needs to be done to better predict pore pressure, based on the overpressure regime.
- iii. Maximum possible hydrocarbon column length for Block A remaining potential of deep gas overpressured play, could be estimated based on optimized model in (ii).

1.5 Scope of Study

The scope for this study includes:

- i. Geological interpretation of the area includes sequence stratigraphy, seismic facies interpretation & analysis, gross depositional environment (GDE) & structural evolution of Block A.
- ii. Pore pressure prediction of Block A based available wells data by testing two methods (Eaton & Bowers), choose one of the best method to best represent the pore pressure model and optimize the pore pressure model to match the actual well data based on geological observation.
- iii. Estimation of column length for remaining potential of deep gas overpressured play, based on Block A pore pressure regimes. Test the maximum column length with available deep gas overpressured play discovery fields within Block A.

1.6 Significance of Study

Pore pressure prediction is normally being done per wells basis and did not normally been done as regional scope. As such, regional overview of pore pressure has been neglected, hence overpressure surprise was not being expected for previous planned wells. Even if it's been done as regional scope, only a few basin pore pressure studies examples found in the literature. This study is not only for reference for the future planned wells, it's supposed to function as part of additional literature to pore pressure studies and understanding overpressure over local basin area and how it affects the risking on the remaining potential of deep gas play.

1.7 Chapter Summary

An effort to pursue pore pressure study has been initiated due to very limited understanding on pore pressure prediction of Block A, understanding the mechanisms of overpressure, designing optimized pore pressure model and to evaluate the remaining potential of deep gas play. The study will be done by defining sequence stratigraphy of Block A, develop gross depositional environment (GDE), horizon & structural interpretation, testing a few different pore pressure prediction methods with wells data available, select best method and optimized the pore pressure model based on geological observation & predict column length of the remaining potential of deep gas play. The study not only as part of pore pressure understanding improvement over Block A, it is also served as additional literature of pore pressure study over local region as well as additional value to determine column length on the remaining potential of deep gas play.

REFERENCES

- Ahmed Satti, I., Wan Yusoff, W. I. and Ghosh, D. (2015). *Overpressure in the Malay Basin and prediction methods*. <https://doi.org/10.1111/gfl.12149>
- Balaguru, A. and Lukie, T. (2012). *Tectono-Stratigraphy and Development of the Miocene Delta Systems on an Active Margin of Northwest Borneo, Malaysia*. Talisman: Petroleum Geoscience Conference & Exhibition 2012.
- Behaki, W. A., Sukapradja, A., Siregar, R. C., Wisnu Y, R., Djaelani, S. and Sjafwan, B. A. (2012). *3D Pore Pressure Prediction Model in Bentu Block – Central Sumatra Basin*. AAPG International Convention and Exhibition, Singapore, 16-19 September 2012.
- Berton, F. and Vesely, F. F. (2016). *Seismic expression of depositional elements associated with a strongly progradational shelf margin: northern Santos Basin, southeastern Brazil*. Brazilian Journal of Geology, vol.46 no.4 São Paulo Dec. 2016.
- Bowers, G.L. (1994). *Pore pressure estimation from velocity data: Accounting for overpressure mechanisms besides undercompaction*. IADC/SPE Drilling conference proceedings, p 515-530.
- Bredehoeft, J.D., R.D. Djevanshir, and K.R. Belitz (1988). *Lateral fluid flow in a compactin sand-shale sequence, south Caspian Sea*. American Association of Petroleum Geologists: AAPG Bulletin, v. 72, p. 416-424.
- Chopra S. and Huffman A. (2006). *Velocity determination for pore pressure prediction*. Arcis Corporation, Calgary, Alberta, Canada; Fusion Petroleum Technologies, Houston USA. CSEG RECORDER April 2006, Vol. 31 No. 4.
- Dickinson, G. (1953). *Geological aspects of abnormal reservoir pressures in Gulf Coast, Louisiana*. American Association of Petroleum Geologists: AAPG Bulletin, v. 37, p.410-432.
- Eaton, B. A. (1972). *Graphical method predicts geopressures worldwide*. World Oil, v. 182, p. 51–56 In: Tingay, M., Hillis, R., Swarbick, R., Morley, C. and Damit, A.R. (2009).

Origin of overpressure and pore-pressure prediction in the Baran Province, Brunei.
AAPG Bulletin, V.93, No. 1 (January 2009), p. 51-74.

Eaton, B. A. (1975). *The Equation for Geopressure Prediction from Well Logs.* Society of Petroleum Engineers of AIME, SPE 5544, 11 p.

Fjær, E., Holt, R.M., Horsrud, P., Raaen, A. M. and Risnes, R. (1992). *Petroleum Related Rock Mechanics.* Elsevier Publications, Second Edition 2008.

Hoesni, M.J. (2004). *The origin of overpressure in the Malay Basin and its influence on petroleum systems.* Unpublished PhD thesis, University of Durham. In: O'Connor, S., Swarbick, R., Hoesni, J. and Lahann, R. (2011). *Deep pore pressure prediction in challenging areas, Malay Basin, SE Asia.* IPA, 2012 – 35th Annual Convention Proceedings, 2011, IPA11-G-022.

Idris, I. H. S. and Wijnands, F. (2014). *Geological Understanding is the Key to Predicting Pore Pressure.* International Petroleum Technology Conference (IPTC), Kuala Lumpur, Malaysia. IPTC-18054-MS.

Johnson, H.D., Kudd, T., and Dundang, A. (1989). *Sedimentology, and reservoir geology of the Betty Field, Baram Delta Province, offshore Sarawak, NW Borneo:* Geological Society of Malaysia Bulletin, v. 25, p. 119-161.

Madon, M.B.H., Meng, L.K., and Anuar, A., (1999). *The Sabah Basin,* in Marcian, M.H., and Mansor M.I., eds., *The Petroleum Geology and Resources of Malaysia.* Malaysia: Petronas Special Publication, p. 500-542.

Mitchum R.M., Vail P.R., Sangree J.B., (1977a). *Seismic stratigraphy and global changes in sea level, part 6: stratigraphic interpretation of seismic reflection patterns in depositional sequences.* Payton C.E. (ed.). *Seismic stratigraphy: application to hydrocarbon exploration* , 26:117-133.

Mitchum R.M., Vail P.R., Thompson S., (1977b). *Seismic stratigraphy and global changes in sea level, part 2: the depositional sequence as a basic unit for stratigraphic analysis.*

- Payton C.E. (Ed.). *Seismic stratigraphy: application to hydrocarbon exploration* , 26:53-62.
- Morley, C. K., P. Crevello, and Z. H. Ahmad (1998). *Shale tectonics and deformation associated with active diapirism: The Jerudong anticline, Brunei Darussalam*. *Journal of the Geological Society (London)*, v. 155, p. 475–490.
- O'Connor, S., Swarbick, R., Hoesni, J. and Lahann, R. (2011). *Deep pore pressure prediction in challenging areas, Malay Basin, SE Asia*. IPA, 2012 – 35th Annual Convention Proceedings, 2011, IPA11-G-022.
- Osborne, M.J and Swarbick, R.E. (1997). *Mechanisms for generating overpressure in sedimentary basins: a re-evaluation*. American Association of Petroleum Geologists: AAPG Bulletin 81, p. 1023-1041.
- Pore pressure (2017). Retrieved from http://www.glossary.oilfield.slb.com/Terms/p/pore_pressure.aspx
- Safronova P.A., Henriksen S., Andreassen K., Laberg J.S., Vorren T.O. (2014). *Evolution of shelf-margin clinoforms and deep-water fans during the middle Eocene in the Sørvestsnaget Basin, southwest Barents Sea*. AAPG Bulletin , 98(3):515-544.
- Said, Ahmad (1982). *Overview of Exploration for Petroleum in Malaysia Under the Production-Sharing Contracts*. Petronas, Malaysia: 10441-MS SPE Conference Paper.
- Sandal, S. T. (1996). *The geology and hydrocarbon resources of Negara Brunei Darussalam: Bandar Seri Begawan, Syabas*, 243 p. In: Tingay, M., Hillis, R., Swarbick, R., Morley, C. and Damit, A.R. (2009). *Origin of overpressure and pore-pressure prediction in the Baran Province, Brunei*. AAPG Bulletin, V.93, No. 1 (January 2009), p. 51-74.
- Schreurs, J. (1997). *Geology of Brunei deltas, exploration status updated*. Brunei: Oil & Gas Journal, v. 95, no. 31: http://www.ogj.com/articles/article_display.cfm?ARTICLE_ID=20397&p=7§ion=ARCHI&subsection=none&c=none&x=y.

- Tan, D. and Lamy, J. (1990). *Tectonic evolution of the NW Sabah continental margin since the Late Eocene*. Sabah Shell Petroleum Company Ltd: Geological Society of Malaysia, Bulletin 27, November 1990, pp. 241-260.
- Tingay, M., Hillis, R., Morley, Chris., Swarbick, R. & Drake, S. (2005). *Present-day stress orientation in Brunei: a snapshot of 'prograding tectonics' in a Tertiary delta*. Brunei: Journal of Geological Society, London, Vol. 162, 2005, pp. 39-49.
- Tingay, M., Hillis, R., Swarbick, R., Morley, C. and Damit, A.R. (2009). *Origin of overpressure and pore-pressure prediction in the Baran Province, Brunei*. AAPG Bulletin, V.93, No. 1 (January 2009), p. 51-74.
- Van Rensbergen, P., C. K. Morley, D. W. Ang, T. Q. Hoan, and N. T. Lam (1999). *Structural evolution of shale diapirs from reactive rise to mud volcanism: 3-D seismic data from the Baram Delta, offshore Brunei Darussalam*. Journal of the Geological Society (London), v. 156, p. 633–650
- Yassir, N. and Addis, M.A. (2002). *Relationships between pore pressure and stress in different tectonic settings*. In: Huffman, A.R., Bowers, G.L. (Eds.), *Pressure Regimes in Sedimentary Basins and their Prediction*: AAPG Memoir, pp. 79–88.