PERSATUAN GEOLOGI MALAYSIA

WARTA GEOLOGI

NEWSLETTER of the GEOLOGICAL SOCIETY OF MALAYSIA

Jilid 37
No. 1

JANUARY–MARCH
2011

Volume 37
No. 1

ISSN 0126 - 5539

PP2509/07/2011(028111)

PERSATUAN GEOLOGI MALAYSIA
GEOLOGICAL SOCIETY OF MALAYSIA

The Society was founded in 1967 with the aim of promoting the advancement of earth science particularly in Malaysia and the Southeast Asian region. The Society has a membership of about 600 earth scientists interested in Malaysian and other Southeast Asian region. The membership is worldwide in distribution.

Warta Geologi (Newsletter of the Geological Society of Malaysia) is published quarterly by the Society. Warta Geologi covers short geological communications and original research, as well as reports on activities and news about the Society. It is distributed free-of-charge to members of the Society. Further information can be obtained from:

GEOLOGICAL SOCIETY OF MALAYSIA
c/o Department of Geology,
University of Malaya
50603 Kuala Lumpur,
MALAYSIA
Tel: 603-7957 7036   Fax: 603-7956 3900
E-mail: geologicalsociety@gmail.com
URL: www.gsm.org.my

Cover photo: Sandstone of the Belait Formation, Tg Kubung, Pulau Labuan by Ng Tham Fatt

PGCE 2011

Petroleum Geology Conference & Exhibition

7 & 8 March 2011
Kuala Lumpur Convention Center

New Plays, New Ways, Innovative Technology

Co-organised by:

PERSATUAN GEOLOGI MALAYSIA 1967

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Petroleum Geology Conference & Exhibition 2011

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Introduction

This year the Geological Society Malaysia (GSM) and PETRONAS once again hosted another successful Petroleum Gelogy Conference & Exhibition or known more affectionately by its acronym, PGCE 2011. It was held at the prestigious Kuala Convention Centre (KLCC) on the 7th and 8th March 2011 with a record breaking number of more than 2000 participants. There were 43 technical papers presented, 60 technical posters were showcased and 43 companies exhibited with PGCE 2011.

Opening Ceremony

The day started with the Opening Ceremony on the Monday morning of 7th March 2011 at the Plenary Hall on level 3 of KLCC. After the doa recital and HSE briefing, the VVIP arrived and took their seats. Everyone was greeted by a very colourful, vibrant and energetic cultural performance by the PETRONAS Performing Arts Group (PPAG). It was then followed by the Welcoming Address by the President of GSM, Dr. Jacqueline Pereira . The Opening Address was delivered by Datuk Aziyah Binti Mohamed, Deputy Secretary of Natural Resource and Environment, Malaysia on behalf of YB Tan Sri Datuk Seri Panglima Joseph Kurup, Deputy Minister of Natural Resource and Environment, Malaysia. PGCE 2011 was then officially launched when Datuk Aziyah ceremoniously hit the 'gong', marking its opening. After the official launch, Mr. Suhail Al-Mazrouie, Deputy CEO of Mubadala Oil & Gas was invited to deliver the Keynote Address entitled " New Ways in Developing Business; A New Partnership Perspective". It was then followed by the PGCE Student Excellence Award, this year it is once again sponsored by PGS. 8 awards were given to outstanding students studying for a degree in Geology or Geophysics at Malaysian public universities. They were Johnny Yii Chiu Jin and Barman Bin Omoi from University Malaysia Sabah (UMS), Azrin Binti Azmi and Balqis Binti Nasruddin from University Kebangsaan Malaysia (UKM), Ling Hwei Chih and Yong Joy Anne from Universiti Malaya (UM) and Tan Hong Kiew and Muhamad Ariff Safwan Bin Abdul Ghani from Universiti Sains Malaysia (USM).

The Opening Ceremony ended with the morning tea before delegates were ushered into the Banquet Hall for the Keynote Paper by Mr. Jim Handschy of ConocoPhillips. His paper entitled "The Future of Hydrocarbon E&P-technology solutions for challenging environments and challenging reservoirs" mark the start of the parallel technical sessions.

Parallel Session

As previous years, PGCE 2011's main event is the technical paper presentation. There were 2 parallel sessions, one was Geology which was at the Banquet Hall and the other was Geophysics at the Plenary Theater. Geology sessions were 'Exploration Case Study & Petroleum System Analysis', 'Reservoir Characterisation & Modelling', 'Petroleum System Analysis' and 'Unconventional Play Type & Exploration Case Study' and Geophysics sessions were 'Specialised Geophysics', 'Seismic Intepretation & Specialised Geophysics', 'Geophysical Processing & Imaging' and ' Geophysical Acquisition, Processing & Imaging'. The turnout for both sessions was favourable.

Exhibition

The Exhibition was again held at Ballroom 1 & 2 with a record breaking 43 companies, societies and universities participating. All booth spaces were taken up and this year's exhibition shows the exhibitor's enthusiasm, innovation and creativity in designing their booth. There were a lot more short presentations at the boots where exhibitors had the chance to showcase their latest products and technologies to the interested visitors.

Sponsors

PGCE 2011 was fortunate to receive sponsorship from various oil and gas companies to ensure the smooth running of the event. There were four Platinum Sponsors, PETRONAS, PGS, ExxonMobil and Mubdala Oil & Gas, two Gold Sponsors, ConocoPhillips and Shell, seven Silver Sponsors, Lundin, BHPBilliton,Schlumberger, CGGVeritas, Total, Petrofac and JX Nippon Oil & Gas Exploration Corp. and six Bronze Sponsors, Mitsubishi, iPerintis, Murphy, Ikon Science, Offshore Works and Leap Energy.

Student's Program

PGCE 2011 also mark the first time a Student's Program was conducted. It was with collaboration with the European Association of Geoscientists & Engineers (EAGE). It received over whelming response from the students that we had to limit the number of those able to attend. Room 304 & 305 were packed to the brim with 200 eager students for the presentation session and then more than 100 more joined in for the Geoquiz session where a 32G Ipod was the prize to be won. The presentation session started off with a presentation by Azli Abu

Bakar a Geoscientist with PETRONAS with his paper entitled "What Petroleum Geoscientists Do". After the lunch break, the session continued with a "Developing a rewarding career in the oil & gas industry" by Peter Lloyd, Hon Prof of Heriot Watt University who had a long career with Schlumberger in the Asia Pacific. The students then had the opportunity to listen to Mr. Yusak Setiawan, an Exploration Manager of Murphy Oil on the "Introduction to oil and gas industry". The session broke up for the Afternoon Tea before continuing with a presentation by Shannon de' Groot, a Senior Student's Affairs Coordinator from EAGE on "How students can benefit from a professional society". The program ended with a high note as students were excited to participate in the GeoQuiz, jointly organize by UTP and EAGE. The students were all made to stand and answer 'YES and NO' questions, there was a dividing rope that separates the 2 answers, students choose their answer and stand on either side of the rope. Those who get the answer correct will stay on but those who gets the answer wrong will be eliminated. There was only one winner and he received a 32G Ipod for his effort for getting all the answers to the questions correct.

Ice Breaker

The first day ended with an 'Ice Breaker' session, where delegates and exhibitors get to mingle and network with each other over light refreshments. This year's ice breaker had an exciting entertainment performance featuring the PETRONAS Performing Arts Group (PPAG), where various upbeat cultural performances were presented. Some of the delegates also had the chance to participate in the dances.

Closing Ceremony

PGCE 2011 officially ended on the evening of the 8th March 2011 (Tuesday) with its Closing Ceremony. It was held at the Banquet Hall right after the final Geology paper was presented. During the Closing Ceremony, the Chairman of PGCE 2011, Mr. Abdul Manaf Mohammad gave his closing remark to the packed hall. In his closing remark he congratulated the team for another successful execution of PGCE and thanked all the sponsors and exhibitors for their continued support, he also hope that PGCE will continue to be more successful in the future and will be breaking more records in terms of paper participation, delegates and number of exhibitors. The highlight of the Closing Ceremony was of course the token of appreciation to all the exhibitors and sponsors and the Lucky Draw.

Pre and Post Conference events

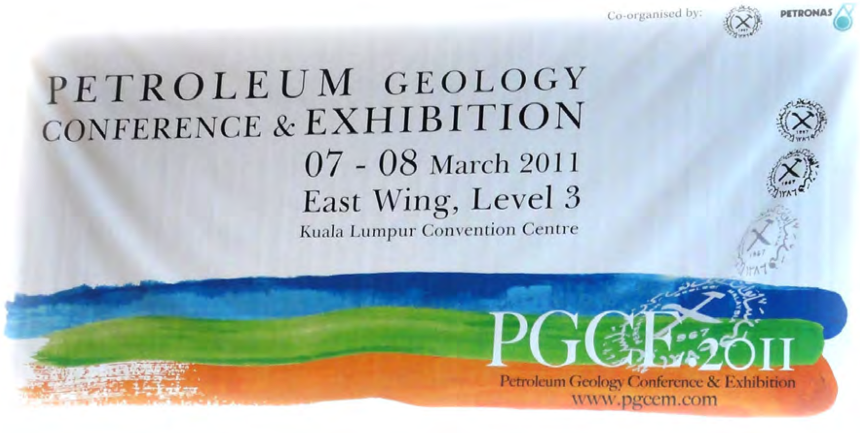
The Pre Conference Field Trip this year was held at two different locations from 1st to 4th March 2011. The 'Outcrop Observation on coastal deltaic facies of Nyalau, Lambir & Miri Formation along Bintulu-Miri road: An application for future exploration in Balingian and Baram Provinces" was lead by Mr. Othman Ali Mahmud, a Principal Geologist of PETRONAS and the "Fractured Granite & Meta Sediment Outcrops at Pulau Redang, Offshore Terengganu: An analogue for Fractured Basement in Malay Basin exploration was lead by Mr. Adrian Bal of Baker Hughes. Both field trips' seats were sold out months before the event started and the trips went on smoothly during the 4 days.

After PGCE 2011, there was the Post Conference course held at Impiana Hotel from 9th to 10th March 2011. This event also saw a pack audience of 30 eager to learn about the "Risk Analysis for Exploration Prospects" by Steve McIntyre of PetroRA.

Golf

PGCE 2011 would not have been complete if it didn't host its annual PGCE Friendly Golf Tournament. This year it was held at the Bangi Golf Resort on the 6th March 2011 (Sunday) and Tee off was at 8 a.m. A total of 36 flights were sold. Among those who participated in the tournament was PETRONAS' E&P Executive Vice President, YBhg Dato' Wee Yiaw Hin and CEO of PETRONAS' Exploration, Mr. Effendy Cheng Abdullah.

W Suraya Alssendra
Secretary, PGCE2011



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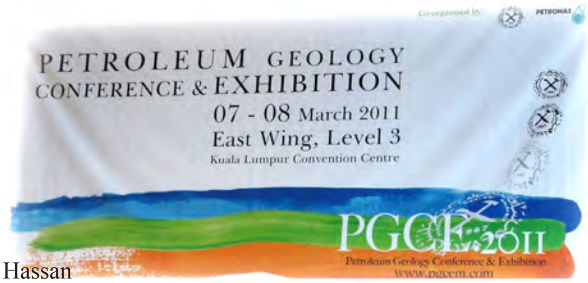
Front Row (Left to Right): Fatma Nazihah M Khatib, Ahmad Nizam Hassan, Zulkefli A Hamid, W Suraya Alssendra, Salina Safiullah, Abdul Manaf Mohammad, Aiman Hakimi Wong Abdullah, Low Cheng Foo, Nur Azah Zulkifli.
Back Row (Left to Right): M Farizanuddin Jaapar, Tengku Mohd. Syazwan Tengku Hassan, Anna Lee, Mazlan Madon, Awalludin Harun, Azli Abu Bakar, Mazlan Md Tahir, Garry Malo, Ali Andrea Hashim, Muzli Hussain, Ramlee A Rahman.



THANK YOU

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Universiti Teknologi PETRONAS	Welltec Oilfield Services

REGISTRATION, Sunday 6th March 2011

Registration Counters Level 3, Kuala Lumpur Convention Centre

OPENING CEREMONY, Monday 7th March 2011

8.00 AM	**REGISTRATION REOPENS**	**Registration Counters Level 3**
9.00 AM	**Do'a Recital** **HSE Briefing**	**Plenary Hall**
9.15 AM	**Arrival of VVIP** **Welcoming Performance by PETRONAS Performing Arts Group**	**Plenary Hall**
9.20 AM	**Welcoming Address by Professor Dr. Joy Jacqueline Pereira, President of the Geological Society of Malaysia**	**Plenary Hall**
9.30 AM	**OPENING ADDRESS by Yang Berhormat Tan Sri Datuk Seri Panglima Joseph Kurup (Deputy Minister of Natural Resource and Environment, Malaysia) (Sponsored by Conoco Phillips)**	**Plenary Hall**
9.40 AM	**Official Launching of PGCE2011 followed by montage presentation**	**Plenary Hall**
9.45 AM	**KEYNOTE ADDRESS - "New Ways in Developing Business: A New Partnership Perspective"** **by Mr. Suhail Al-Mazrouei, Deputy CEO, Mubadala Oil & Gas**	**Plenary Hall**
10.15 AM	**PGCE Student Excellence Award Presentation (Sponsored by PGS)**	**Plenary Hall**
10.30 AM	**Coffee Break at Exhibition Hall Foyer (Sponsored by JX)** **Exhibition Tour**	**Exhibition Hall @ Ballroom 1 &2**

Day 1 : 7th March 2011 (Monday) ORAL SESSIONS

11.00 AM **KEYNOTE PAPER: The future of hydrocarbon E&P - technology solutions for challenging environments and challenging reservoirs**

Jim Handschy (ConocoPhillips) Banquet Hall

PARALLEL SESSIONS

	GEOLOGY — Room 1 (Banquet Hall)	GEOPHYSICS — Room 2 (Plenary Theatre)
	Session 1: Exploration Case Study & Petroleum System Analysis **Session Chairmen: Vincent R. Drahaman (ExxonMobil) and Ali M Shariff (PCSB)**	**Session 2: Specialised Geophysics** **Session Chairmen: Robert Wong Hin Fatt (PETRONAS) and Anies Helmy Djamil (MUBADALA)**
11.30 AM	**Geology Paper 1**: Application of 3D basin modeling to address hydrocarbon charge risk in a frontier area, offshore Sarawak Basin, Malaysia – ***SR Iyer, SK Battacharya, Shahrul Amar Abdullah & P. Abolins (PCSB)***	**Geophysics Paper 1**: Mapping regional sedimentary horizons in the onshore Baram Delta, Sarawak, from magnetic and gravity data using Energy Spectral Analysis – ***S Markham, S Damte, I Kivior et al (Archimedes Consulting and JX Nippon Oil & Gas Exploration Corp)***

11.55 AM	**Geology Paper 2**: Appraisal While Development Campaign in the Jengka Field, North Malay Basin - ***Lai Kian Voon, M Yusof Abdullah, Kanok I et al. (PCSB, CPOC and PTTEP)***	**Geophysics Paper 2**: Efficiency of TDEM and EM-IP methods application for reservoir exploration in South East Asia – ***YA Agafonov, MM Salleh et al. (Irkutsk Electroprospecting Co. and Onyx)***
12.20 PM	**Geology Paper 3**: Pore Pressure Prediction of a Field in Southwestern Part of the Malay Basin A Basin Modeling Approach - ***Ismatul Hani Shada Idris, Peter Abolins, M Jamaal Hoesni (PCSB/PRSB)***	**Geophysics Paper 3**: Rotation of Borneo revisited – new inferences from gravity data and plate reconstructions – ***S Mazur, C Green, M Stewart, R Bouatmani, P Markwick (GETECH)***
1.00 PM	**LUNCH** Conference Hall 1, 2 & 3 **(Sponsored by Shell)**	
	GEOLOGY — Room 1 (Banquet Hall) **Session 3: Reservoir Characterisation & Modelling** **Session Chairmen: Hans-Jurg Meyer (Shell) and Andy Baker (Schlumberger)**	**GEOPHYSICS — Room 2** (Plenary Theatre) **Session 4: Seismic Interpretation & Specialised Geophysics** **Session Chairmen: Jesmee Zainal Rashid (PGS) and Mark T. Wheeler (ConocoPhillips)**
2.00 PM	**Geology Paper 4**: An Integrated Geoscience And Engineering Efforts Leading To Increased Development Planning Confidence – ***Liew Wei Long, Hanif Hashim, Ridzuan Tahir et al. (PMU and Petrofac)***	**Geophysics Paper 4**: Determination of AVO Attributes for Hydrocarbon Resources Region of Malay Basin: The Fluid Factors – ***TL Goh, Uzir Alimat, Shaidin Arshad, M Izzuljad AF (PRSB)***
2.25 PM	**Geology Paper 5**: From Depofacies To Lithofacies: A Way To Integrate Facies And Rock Types Into 3D Geocellular Models – ***Jairo Antonio Plata Torres (PCSB)***	**Geophysics Paper 5**: Soft Shale Complication in AVO interpretation in Sabah Basin – ***Alex Tarang, Yeshpal Singh (PCSB)***
2.50 PM	**Geology Paper 6**: An organic geochemical approach to address stratigraphic issues: A case study of the Layang-Layangan Beds, Labuan Island, NW Sabah Basin – ***Patrick Gou (Shell), Wan Hasiah Abdullah (U. Malaya)***	**Geophysics Paper 6**: An integrated approach to reservoir appraisal and monitoring using well log, seismic and CSEM data – ***L. MacGregor, J Tomlinson, S. Hili (OHM Rock Solid Images)***
3.15 PM	**Geology Paper 7**: Characterizing and Modeling Natural Fracture Networks in a Tight Carbonate Reservoir in the Middle East – ***DP Ray, A. Al-Shammeli, NK Verma et al. (Kuwait Oil Co. & Beicip-Franlab)***	**Geophysics Paper 7:** Seismic facies analysis of Group L and M reservoirs, Southeast of Malay Basin – ***Noor Iryani Jumari, Hamdan Mohamad, Nasaruddin Ahmad (PCSB)***
3.40 PM - TEA BREAK (Sponsored by CGG Veritas)		

	Session 5: Petroleum System Analysis **Session Chairmen: M Hasni M Hashim (PRSB) and Dr. Ould Ahmed Benan (TOTAL)**	**Session 6: Seismic Interpretation & Specialised Geophysics** **Session Chairmen: Hajime Kusaka (Nippon Oil) and Graham Hodgkiss (CGGVeritas)**
4.00 PM	**Geology Paper 8**: The onshore to offshore Dent Group, Eastern Sabah from sequence stratigraphic perspective: Implication to petroleum exploration – ***M Razali Che Kob, Sanudin Tahir et al. (PMU & U. Malaysia Sabah)***	**Geophysics Paper 8**: The Karap Mud Volcano Imaged on New 2D Seismic – Implications for Basin Analysis – ***FL Kessler (Curtin University), J Jong, Tran Quoc Tan, H Kusaka (JX Nippon Oil & Gas Exploration Corp.)***
4.25 PM	**Geology Paper 9**: Source of Coal Bed Methane – ***SK Bhattacharya & SQ Tunio (UTP)***	**Geophysics Paper 9**: Low relief structure – a favourable HC accumulation trap in Malay Basin – ***Ji Ping & Norhafizah Mohd (PMU)***
4.50 PM	**Geology Paper 10**: Sequence stratigraphic study of Block 16/19 and Zambezi Delta Block, Mozambique Basin, offshore Mozambique – ***Dyg Hasspariah Sapri & Othman Ali Mahmud (PCSB)***	**Geophysics Paper 10**: Conventional approach seems to be the best – ***Hijreen Ismail, M Izham Kassim, Khairul Hamidi Khalid (Petronas Carigali Muriah Ltd)***

5.15 PM - END DAY 1

5.30 PM - ICE BREAKER in Conference Hall 1, 2 & 3 (Sponsored by EXXONMOBIL)

Day 2 : 8th March 2011 (Tuesday) ORAL SESSIONS

	GEOLOGY — Room 1 (Banquet Hall) **Session 7: Exploration Case Study & Modelling** **Session Chairmen: Richard Jones (Lundin) and Gavin Lindsay (Baker Hughes)**	**GEOPHYSICS — Room 2** (Plenary Theatre) **Session 8: Seismic Interpretation and Specialised Geophysics** **Session Chairmen: Paul Carrol (BHP Billiton) and Jamlus Yasin (PCSB)**
8.30 AM	**Geology Paper 11**: Dynamic modelling of a North Sea saline formation for carbon sequestration – ***FE Watson, BJ Hedley, RJ Davies & SE Daniels (Durham University, UK)***	**Geophysics Paper 11**: Regional rock physics application for improved understanding of thief sands in offshore Sarawak basin – ***Yesphal Singh (PCSB)***
8.55 AM	**Geology Paper 12** : The possible significances of coals encountered in cored sections from the central Malay Basin; Implications for sequence stratigraphic interpretation and basin character – ***D Ince, Mazlan Madon, Abdul Hadi et el. (PCSB, PRSB & Orogenic)***	**Geophysics Paper 12:** Delineation Stratigraphic Features Using Spectral Decomposition and AVO in B Field, Malay Basin – ***Khairool Anwar Laksamana, Nguyen Huu Nghi, Goh Sing Thu (PMU)***
9.20 AM	**Geology Paper 13**: Habitat and C-14 Age Dating of Lignitic Terrace Sands – Implications for Uplift on the Borneo Coastline during the Holocene – ***F. Kessler (Curtin University) and John Jong (Nippon Oil Malaysia)***	**Geophysics Paper 13**: Integrated approach to identify stratigraphic prospect from sparse 2D seismic attributes (AVO), well correlation and geological model - a success case from Genale B-2X IN BLOCKS 3&4, Ogaden Basin, Ethiopia – ***Eadie Noor Fadzly, D. Suprapto, Amri Shahril Saadudin (PCSB)***
9.45 AM	**Geology Paper 14**: Characterization of Peat-forming Environments of Miocene Coal Using Biofacies in the Malay Basin, Malaysia – ***Shamsudin Jirin, RJ Morley, Mahani Mohamed & Sanatul Salwa Hasan (PRSB & Palynova)***	**Geophysics Paper 14**: Sequence stratigraphic study paves the way to the discovery of Kinabalu A-1 Well – ***Marianny Ismail, Othman Ali Mahmud et al. (PCSB)***

10.15 AM - COFFEE BREAK (Sponsored by TOTAL)

	Session 9 : Petroleum System Analysis Session Chairmen: Hoh Swee Chee (Murphy) and Lawrence Bernstein (Talisman)	Session 10: Geophysical Processing & Imaging Session Chairmen: Joseph Koh (Schlumberger) and Ridzuan Tahir (Petrofac)
10.45 AM	**Geology Paper 15**: Criteria For Discriminating Drilling-Induced Tensile Fractures From Natural Fractures In Basement Rocks – ***A. Bal & P. Zarian (Baker Hughes)***	**Geophysics Paper 15**: Azimuthal Anisotropic NMO Analysis for Amplitude Stripping Removal in Sumandak 3D Reprocessing – ***Mazlan Ghazali, E Padron, M Ferruh (PCSB)***
11.15 AM	**Geology Paper 16:** Impact Of Spatial Variability In Microfabrics On The Thermal Conductivity Of Subis Limestone – ***YS Lee (Earth Obs. Singapore), E Padmanabhan (UTP)***	**Geophysics Paper 16**: Multiple, diffractions and diffracted multiples in the South China Sea – ***Rosemary K Quinn (Talisman), Lynn B Comeaux (PGS)***
11.40 AM	**Geology Paper 17**: Oroclines and paleomagnetism in Borneo and South-East Asia – ***CS Hutchison (U. Malaya)***	**Geophysics Paper 17**: Deghost + Denoise + Demultiple + Velocity & Q Inversion + Depropagate = Seismic Imaging – ***Mehmet Ferruh Akalin (PCSB)***
12.05 PM	**Geology Paper 18**:Integrated Petrophysical Evaluation Of Thin Bed Formation: A Case Study From Field Offshore Malaysia – ***D. Maya & Nizam A Bakar (Baker Hughes)***	**Geophysics Paper 18:** Dip-dependent corrections for data reconstruction in true-azimuth 3D SRME – ***P Aaron, R van Borselen, R Hegge et al. (PGS)***
12.30 PM	**Geology Paper 19**: Typical Pore Pressure Regimes in the Malay Basin – Insight for other Basins Globally – ***R Swarbrick, S O'Connor, R Lahann et al. (GeoPressure)***	**Geophysics Paper 19:** Seismic imaging near and within the basement offshore Malaysia; including comparisons of imaging algorithms – ***N El-Kady, M Shah Sulaiman et al. (PCS, WesternGeco)***
	01.00 PM - **LUNCH (Sponsored by EMEPMI)** Conference Hall 1, 2 & 3	

	GEOLOGY — Room 1 (Banquet Hall) **Session 11: Unconventional Play-Type & Exploration Case Study** **Session Chairmen: Klaus Soffried (Halliburton) and Mazman Abu Bakar (PCSB)**	**GEOPHYSICS — Room 2** (Plenary Theatre) **Session 12: Geophysical Acquisition, Processing and Imaging** **Session Chairmen: David Betty (Paradigm) and UZMA**
2.00 PM	**Geology Paper 20**: Assessing fault seal risk and fault seal retention capacity in stacked clastic reservoirs – ***AJW Everts (LEAP Energy)***	**Geophysics Paper 20:** Broadband Marine seismic – Breaking the Limits – ***R Soubaras, C Nortfors (CGGVeritas)***
2.25 PM	**Geology Paper 21**: Labuan Outcrop Revisited: New Findings On Belait Formation Facies Evolution – ***M Rapi M Som, M Fauzi Kadir et al. (PRSB)***	**Geophysics Paper 21**: Seismic Imaging Below Shallow Gas Cloud – A comparison between PSTM, PSDM & 4C OBC datasets – ***Tan Boon Hua, Amy Marwani M Yusoff, G. Taslim (PCSB)***
2.50 PM	**Geology Paper 22**: Fabric Anomaly In Mud Clast Distribution In The Lambir Formation (Mid To Late Miocene), Sarawak – ***E Padmanabhan, M Pauzi AS (UTP, PCSB)***	**Geophysics Paper 22**: 4D Seismic Analysis of Reservoir Sands Overlying A Salt Structure – ***Haziqah Othman, Shuhadah Basaharudin, Salbiah M Sahad et al. (PRSB)***
3.15 PM	**Geology Paper 23**: An overview of the proven Pre-Tertiary karstified and fractured carbonate Basement play-type in the offshore northern Vietnam – ***Jamin Jamil, RM Borbajo et al. (PCSB)***	**Geophysics Paper 23**: 4D Seismic Interpretation in Angsi Field – ***Tan Chin Kang, Wahyudin Suwarlan, Kartina Ali, Fariz Fahmi (PCSB)***
	3.40 PM **- TEA BREAK (Sponsored by Petrofac)**	
	4.00 - 5.00 PM - **CLOSING CEREMONY** Banquet Hall	

PGCE.2011 — GEOLOGY POSTERS

P1 Major Controls on Deepwater Reservoir Distribution, West Africa
Amita Mohd Ali, Zainol Affendi Abu Bakar, Hasnol Hady Ismail et. al

P2 Shallow Seismic: An Analog Study of Fluvial Depositional System in the Malay Basin
W M Khairul Anuar W Sulaiman, M Rapi M Som and Faisal A. Alqahtani

P3 An Integrated Approach of Sedimentology, Biostratigraphy, Organic Petrological and Geochemical Analyses: A Case Study On Petroleum Source Rock Depositional Environments of Sebahat and Ganduman Formations, Eastern Sabah
Khairul Azlan Mustapha, Wan Hasiah Abdullah and Ralph L. Kugler

P4 Transgressive-Regressive Cycles in the Malay Basin: the Interplay of Tectonics and Sea Level Changes in a Silled Basin
Mazlan Madon

P5 High Resolution Biomarker Technique for Source Facies Interpretation of Malaysian Oils
Abdul Jalil Muhamad, Awang Sapawi A Jamil, and Nurfadhila M Sharef et al.

P6 Correlation of the Subis Limestones with Equivalent Limestone Bodies In Offshore Balingian Province, Sarawak, and Prupuh Limestones in Java.
Foo Yuan Han

P7 Salinity Stratification and its Effects on the Malay Basin Biofacies Assemblages
Mahani Mohamed, Shamsudin Jirin and Sanatul Salwa Hasan

P8 Development of New Correlations for Predicting Bubble Point Pressure and Bubble Point Oil Formation Volume Factor of Malaysian Crude Oils
B. Moradi, S.J. Hosseini, Birol M.R. Demiral et al.

P9 Sedimentology of Carbonate Buildup in Central Luconia, Sarawak, Malaysia
Noor Alyani Ishak, Dr. Zulfiqar Ali, Dr. Richard Bray et al.

P10 Sedimentary Facies, Depositional Environment and Sequence Stratigraphy of Miocene West Baram Delta Core, Offshore Sarawak.
Ummi Farah Mohamad Rosli, M Amri M Diah and Zulfiqar Ali

P11 A Natural Laboratory for Fractured Granitoid and Meta-Sediment Reservoirs at Redang Island, Terengganu.
Adriaan Bal, Hamdan Mohamad, Zulkifli A Hamid et al.

P12 The Possible Significances of Coals Encountered in Cored Sections from the Central Malay Basin; Implications for Sequence Stratigraphic Interpretation and Basin Character
David ince, Mazlan Madon, and Abdul Hadi A Rahman et al.

P13 Calibrating Carbonate Core Data to Wireline Data: Searching for a Relationship between Petrophysical Properties and Mappable Depositional Trends
Mehmet Altunbay, Adriaan Bal , Selim Belhaouas et al.

P14 Methodology in Surface Evaluation of the Fold and Thrust Belt Region
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P15 Sedimentology of Laayoune-Dakhla Area Western Sahara Desert, South Morocco
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PGCE.2011 — Welcoming Address

by Professor Dr. Joy Jacqueline Pereira,
President of the Geological Society of Malaysia

Good morning and welcome to the 34th Petroleum Geology Conference and Exhibition themed New Plays, New Ways, Innovative Technology. Better known as PGCE 2011, this event is co-organised by the Geological Society of Malaysia and PETRONAS.

Some of you may be aware that in the 1970s, PGCE was simply known as the "Petroleum Geology Seminar", one of the two flagship events of the Society, the other being the National Geoscience Conference, which has a longer history.

In the 1990s, the Geological Society invited PETRONAS to become co-organisers. Since then, the PGCE has evolved from participation of a few hundred delegates, to what we have today – more than 1300 delegates and 50 participating companies. There will be 46 technical paper presentation and 60 posters being displayed. In addition, for the first time ever, with the support of the EAGE, there are programmes that specifically target geoscience students from local universities. The success of PGCE as evidenced by the increased number of delegates and programmes is without a doubt due to the support of our co-organisers PETRONAS, an anchor industry player.

The Society is well aware of its responsibility in ensuring quality in the advancement of geoscience knowledge in the country. In this respect, we are embarking on an ambitious initiative to increase international recognition for our publications, to serve as the premier peer-reviewed record of geoscience knowledge on Malaysia. As such, I urge presenters in this event to support this effort and leave a legacy for the future by documenting your vast knowledge in our peer reviewed publications, the Bulletin of the Geological Society of Malaysia and Warta Geologi.

We are in a period where environmental pressures on the petroleum industry are increasing, particularly in the advent of climate change. Governments are increasing efforts to decouple economic growth from fossil fuel in an effort to mitigate climate change. In response to this, the petroleum sector is bringing in new technologies to off-set their carbon emissions. One such technology is carbon capture and storage. I have no doubts that geoscience knowledge can contribute much to the application of this technology in Malaysia, particularly with respect to identifying suitable rock formations for carbon storage. The Society would like to see an expansion of the corpus of knowledge of petroleum geoscience, to extend into these new areas.
Similar to the mining sector that now routinely includes social and environmental dimensions in their technical meetings; the PGCE should consider introducing sessions related to climate change mitigation and environmental issues, which draws on geoscience knowledge related to the petroleum sector. Such expansion, will not only serve the goescience community, but the country and society in general.

Before I end, I would like to thank Datuk Aziyah Bt Mohamed, Deputy-Secretary General of the Ministry of Natural Resource and Environment Malaysia, for making time to grace our event.

I also thank the Organising Committee, the sponsors and collaborators of PGCE 2011 for their contribution to this event. Your support has made this event spectacular.

I wish everyone a successful and productive discourse on New Plays, New Ways, and Innovative Technology.

Thank you very much.

PGCE.2011 — Opening Address

by Tan Sri Datuk Seri Panglima Joseph Kurup
(Deputy Minister of Natural Resource and Environment Malaysia)
delivered by Datuk Aziyah Bt Mohamed
(Deputy Secretary General of the Ministry of Natural Resource and Environment Malaysia)

A Very Good Morning and 'SELAMAT DATANG"

First and foremost, it gives me great pleasure to welcome all of you to Malaysia and to our capital city Kuala Lumpur. And I would like to extend Tan Sri Datuk Seri Joseph Kurup sincerest apologies for not being able to be present today. Tan Sri is honored and would like to thank the organizing committee for inviting him to deliver the opening remarks for this year's opening ceremony of the Petroleum Geology Conference & Exhibition.

Every year the Oil, Gas and Energy industry faces increasingly tough challenges to meet the demand of the ever growing consumer needs. Malaysia's rising economy brings is closer to being a net importer of oil rather than exporter. This means that the oil and gas industry has to not only be creative and innovative in its search for energy resources but to do so in a responsible and efficient manner. PGCE 2011's theme of " New Plays, New Ways, Innovative Technology" aptly describes the need for this. The geosciences community is now expected to discover new play types, exploring in much deeper reservoirs and in harsher environments, politically and geologically. There is naturally a need to find new ways and develop innovative technology that will support this.

The theme -New plays, new ways and innovative technology - is also relevant for us to tackle some of the emerging issues faced by the oil and gas sector. This is particularly relevant with respect to climate change mitigation, to fulfill the aspirations of the National Policy on Climate Change, which was launched by the Deputy Prime Minister last year on 30 August 2010. I am given to understand that petroleum geoscience serves as an important knowledge base for carbon capture and storage to reduce GHG emissions, and that capacity is being strengthened to apply this technology. I am also pleased to note that as part of PETRONAS' commitment as a socially responsible corporate citizen, a forum on the topic of climate change is being organized here today at the "Hot in Suria KLCC.

The Malaysian government, through the NKEA or National Economic Areas has identified the Oil, Gas and Energy industry as one of the 12 drivers of economic activity, which has potential to directly and materially contribute a quantifiable amount of economic growth to the Malaysian economy. NKEA came about as a means to reach the goal of achieving a high income status by the year 2020 and it shows the support of the government to each sector by providing sector specific policies and regulatory changes.

The oil, gas and energy industry contributes approximately 20% to the national GDP. The problems of declining production from maturing assets and decline in domestic natural gas production are a cause for concern. The solution NKEA hopes to provide is by intensifying the exploration and enhancing production activities of the domestic reserves, develop a strong regional oil field services and equipment hub and creating a strong presence in regional midstream logistics and downstream markets. NKEA targets to raise the total GNI (Gross National Income) contribution to RM 241 million by 2020, not an easy feed as this will require a yearly growth rate of 5% with the current base case natural percent decline of 2%. Through NKEA employment opportunities are also to increase with the creation of more than 53,000 jobs of which 21,000 will be high skilled qualified professionals such as engineers and geologist.

During the announcement of the Malaysian Budget 2011, the Malaysian government through our Prime Minister Datuk Seri Najib Tun Razak announced incentives to promote the development of oil and gas resources as a mean to stimulate the domestic exploration activities. This will potentially lead to additional petroleum revenue of RM 50 billion for Malaysia over the next 20 years. RM 146 million is being allocated to support the oil and gas sector and among the projects to be implemented are the oil field services and equipment centre in Johor with expected private investment

of RM 6 billion over the next 10 years. In addition to that, to meet the increase in gas demands, PETRONAS will be implementing a regasification project worth RM 3 billion in Malacca, which will be operational in the year 2012. The government and PETRONAS have also aligned the capital expenditure allocation of approximately RM 40 billion in domestic investment. In line with expanding the search of new type of plays, an allocation of new technology investment to tap un-worked deepwater and HPHT projects of RM 13 billion will be invested in 2011. This will focus on exploration and development of 4 deepwater projects, the Gemusut-Kakap, Kebabangan, Malikai and Jangas fields.

Tax incentives were also announced with the revision in the Petroleum Income Tax act that will encourage foreign investment for capital extensive deepwater projects and attract private sectors to smaller, marginal fields. Five new tax incentives were announced which were deduction of investment tax allowance of up to 60 to 100% of capital expenditure to encourage the development of enhanced oil recovery (EOR), high CO_2 gas fields, high pressure high temperature (HPHT), deepwater and infrastructure projects for petroleum operations and a 13% decrease of Petroleum Income tax (PITA) to improve commercial viability of marginal oil field development. Other incentives include, an accelerated capital allowance of up to 5 years from 10 years where full utilization of capital cost deducted could improve project viability, qualifying exploration expenditure transfer between non contiguous petroleum agreements with the same partnership or sole proprietor to enhance contractors' risk taking attitude, which will encourage higher levels of exploration activity and a waiver of export duty on oil produced and exported from marginal field development to improve project viability.

These incentives will see Malaysian Oil and Gas industry in a more strategic joint venture collaborations, increase in foreign acquisition of proven or marginal fields and rapid increase of investments in new technologies and enhanced oil recovery (EOR) to improve on the nation's reserves and reservoir management practices.

I hope that the many opportunities and incentives being offered will be fully utilized by the oil companies and service providers alike. As mentioned earlier the need to be innovative and creative stems from the fact that it has been increasingly challenging to discover big oil fields. With that in mind, I implore that we work together to make sure that we will achieve our common goal in ensuring the growth of the industry. The Petroleum Geology Conference & Exhibition is the perfect avenue for us to discuss and propagate knowledge, through the wide spectrum of attendance, from oil companies, service providers, academicians and government officials. I'm confident that these 2 days will prove to be a beneficial experience for all. Lets take this opportunity to network and absorb as much knowledge as we can from each other.

I am sincerely pleased that the Petroleum Geology Conference & Exhibition is here again this year. Many congratulations to the organizing committee, exhibitors, sponsors and participants for successfully organizing this event for the petroleum geoscience community. The commitment shown by everyone present here today brings confidence to our common goal of finding "New Ways, New Plays, Innovative Technology" to the oil and gas industry.

Welcome to PGCE 2011, I wish all the participants a successful and engaging session.

Thank you.

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QUESTION 16
Dinosaur skeletons have never been found in SE Asia


PGCE 2011

PGCE 2011 — Abstract of Papers

GEOLOGY PAPER 1

APPLICATION OF 3D BASIN MODELING TO ADDRESS HYDROCARBON CHARGE RISK IN A FRONTIER AREA, OFFSHORE SARAWAK BASIN, MALAYSIA

S.R. Iyer[1], S.K. Bhattacharya[2], Shahrul Amar B Abdullah[1] & Peter Abolins[1]

[1]Petronas Carigali Sdn Bhd, Level 10, Tower 2, Petronas Twin Towers, KLCC, 50088- Kuala Lumpur, Malaysia.
[2]Universiti Teknologi PETRONAS, Malaysia.

SUMMARY

Analysis of offset wells in a frontier exploratory area located in offshore Sarawak identified hydrocarbon generation, migration timing with respect to trap formation, and migration fairways into the drilled prospects as the key uncertainties in exploration. A semi constrained 3D basin modeling study was undertaken based on regional 2D depth maps and calibration from offset wells to address the uncertainties. Three source rock units viz. Rift, Cycle-I and Cycle-II, from older to younger sequence, below a major regional unconformity were modeled, constraining the boundary conditions with regional geological understanding. Four geological scenarios were run, to account for uncertainties in mapping the top of basement, and also in fixing the duration of erosion for the unconformity, which has a direct impact on timing of deposition of the regional top seal.

Source rock maturity and transformation ratio based on modeling suggest that Cycle-I source is in optimum window in the study area for charging the identified traps. The older Rift source is expended by around 20 Ma, with possibility of charging only the deeper Cycle-I traps. Cycle-II source over major part of the study area is in immature to early oil stage. It can be an effective source in the southern and western parts of the study area where maturity is adequate due to deeper depth of burial.

The distribution of hydrocarbon accumulation modeled is validated by two of the offset wells with hydrocarbon discovery. Compositional kinetics indicates dominantly vapor phase for the accumulation in discovery well location, consistent with samples recovered through MDT. Modeling results suggest significant hydrocarbon generation and expulsion in the study area. However, the total hydrocarbon accumulated is relatively small compared to the quantity expelled, as the peak migration timing predates the major unconformity over which the regional top seal section was deposited. Reducing the duration of erosion and early deposition of top seal has increased the volume accumulated, but the parameter remains a key uncertainty due to limited well control.

In the absence of direct evidence from well data, the present study has improved the understanding of the frontier area and aided in preparation of play fairway map to risk leads/prospects. The current base model can be refined by incorporating additional data from future exploratory activities. The present approach is a very useful tool in screening new exploration blocks and their ranking.

INTRODUCTION

Exploration in frontier basins is prone to high risks due to uncertainties in the presence of petroleum system elements. Burial history, facies distribution, and the regional structural setting, plays a major role in the process of hydrocarbon generation, migration timing with respect to trap formation, and migration fairways into traps. 3D Basin modeling, constrained by regional maps and well data, provides a method for integrated understanding of the complex system of hydrocarbon generation, migration, and entrapment in an area. A fully constrained model serves as an ideal tool for derisking of prospects. However, it is not always the case as input data are scarce, especially in frontier exploratory basins.

The study area is located in offshore Sarawak basin (Fig.1), where several exploratory wells have been drilled with varied success. Analysis of the wells suggests the presence of adequate reservoir and valid structural trap. The key exploration risks perceived for this area are: (a) lack of adequate generation due to poor source rock characteristics and its distribution; (b) unfavourabe migration timing with respect to trap timing, and (c) inadequate hydrocarbon migration fairways into the drilled prospects.

The quality and distribution of source rocks in the area is uncertain, as the well penetrations are few and restricted to the shallower sections. 3D basin modeling of the area was utilized primarily to address maturation history of the predicted source units, hydrocarbon migration timing, and migration fairways into identified leads and prospects.

GEOLOGICAL BACKGROUND & METHODOLOGY

The generalized stratigraphy and petroleum system in the area are depicted by Figs. 2 & 3. Regional depth maps of six horizons covering an area of around 40,000 sq km with biostratigraphic calibration from two deep wells (Krebs, 2006) were used to build the 3D model. Sequences A to E defined by the surfaces were split into layers (Fig. 4), assigned facies

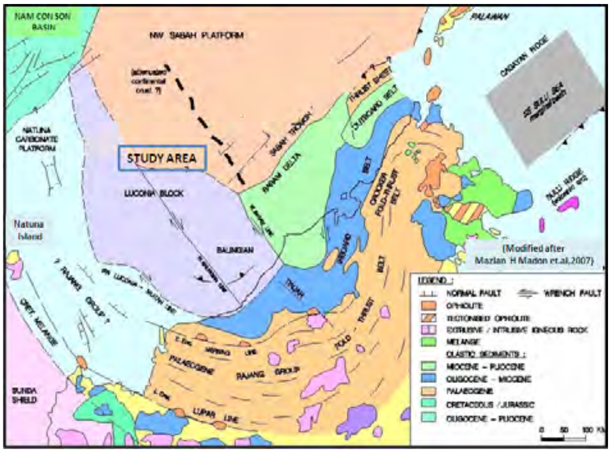

Figure 1: Regional geological map showing study area.

and boundary conditions, constrained by well data and regional geological understanding.

Three source sequences have been postulated viz. Rift, Cycle-I and Cycle-II. The Rift source, presumed to be lacustrine, is not widespread and its presence is likely in the deeper part of half grabens. The rift source predicted is speculative due to lack of well penetrating this sequence in the whole basin. Cycle-I source, similarly has no well penetrations in the area. However, good source rocks have been observed in this unit in the shallower parts of the basin. Based on Cycle-I palaeogeography, the study area is located in shallow marine setting with predicted presence of coaly source. So far, marine source has not been reported in the area. Fair source presence has been observed in Cycle-II in some of the drilled wells. Type III kerogen was assigned for Cycle-I and Cycle-II source, and Type I for the Rift source. TOC and HI inputs for Cycle-I and Cycle-II were based on maximum value observed in well samples (Abolins, 1996). The heat flow assigned was optimized with calibration from key wells.

The reservoir targets in the area are primarily in Cycle-I to Cycle-III section dominated by clastics. Occasional limestone stringers straddling the MMU can also form potential reservoir targets. Post MMU hemipelagics form the regional seal. The traps in the area are dominantly three way dip fault closures.

Four geological scenarios were modeled, due to uncertainties in mapping the basement top, and also the duration of the regional unconformity (MMU). The parameters after optimization runs are summarized in Table-1.

DISCUSSION OF RESULTS

Temperature and EASY% Ro calibration of the model with well results is shown by Fig. 5. Maturity of the three source layers and their transformation ratio extracted from four locations, two corresponding to the drilled wells A & B, and two over pseudo wells E & F spread over the area were analyzed.

Maturity of the Rift source indicates wet to dry gas stage over major part of the study area with main to late oil stage over the high trends. The transformation ratio (TR) suggests that the rift source is completely expended by around 20 Ma in all the four scenarios much earlier than the deposition of regional top seal. Hydrocarbon charge from this source in Cycle-I traps is possible, but no accumulations have been observed in modeling outputs of Cycle-I reservoir layers.

Cycle-I source over major part of the area is in main to late oil stage (Fig. 6). Wet to dry gas stage is seen towards the southern and western parts of the area where the overburden is more. The transformation curve indicates that around 55 to 70% of the kerogen is expended by around 15 Ma close to the regional unconformity and the critical moment (TR 50%) is between 16 to 22 Ma. After 15 Ma, the generation slows down due to the intervening unconformity, and continues up to the present day. Analyzing the results, it emerges that the peak generation and expulsion predates the unconformity over which the regional top seal section was deposited. Effectiveness of intraformational shale in Cycle-I and Cycle-II as seal is questionable, as the net to gross sand increases upward in the overall coarsening up sequence, and also due to the likely breaching of traps through intense faulting evident in the data. Thus, the timing of deposition of the post MMU sequence and the time when it becomes an effective seal to hold hydrocarbons underneath are very critical in determining the size of the accumulations. At the present stage, the age of the unconformity could not be constrained over the study area due to limited well control, and remains an uncertainty. The thickness of eroded section also could not be estimated with confidence.

Cycle-II source over major part of the study area is in immature to early oil stage. Higher maturity of kerogen to oil and gas stage is observed towards southern and western parts of the study area from where hydrocarbon charge is probable. Overall, this source unit shows low transformation ratio and is not projected as an effective source for the area.

Hydrocarbon accumulation map output for the four scenarios shows entrapment primarily in Cycle-II upper reservoir straddling the regional unconformity and is validated by accumulation in the discovery well location D (Fig.7). Minor entrapment is seen in Cycle-II lower reservoir in shallow basement case. Compositional kinetics run on Scenario-IV suggests a dominantly vapor phase consistent with MDT results of well D. The trend of hydrocarbon accumulation observed is NNW-SSE to NW-SE (Fig.8) and follows the regional structural trends (Iyer, 2010). This hypothesis needs validation based on future discoveries in the study area.

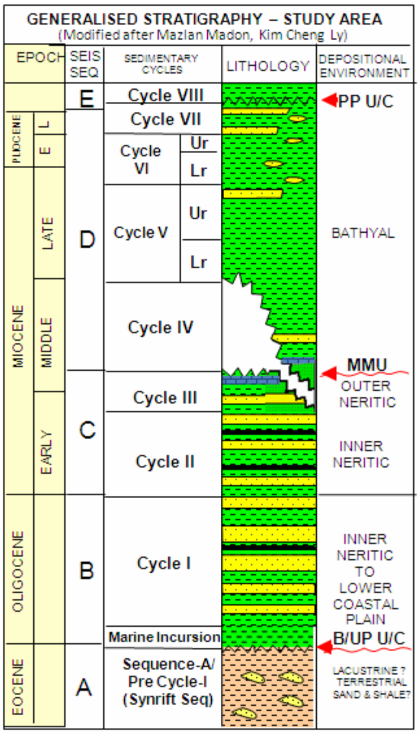

Figure 2: General stratigraphy.

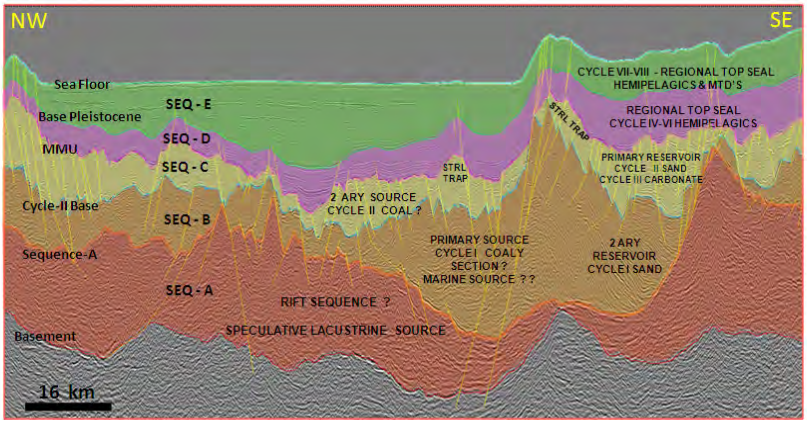

Figure 3: Representative NW-SE profile depicts the mapped horizons, sequences, and petroleum system elements in the study area.

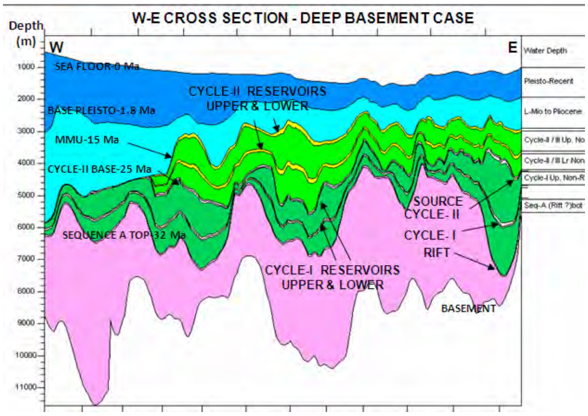

Figure 4: W-E Cross section through the 3D model shows splitting of the sequence into petroleum system element layers & age assignment.

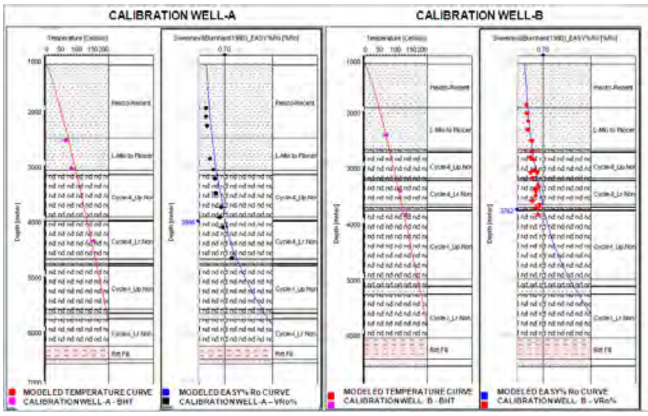

Figure 5: Modeled temperature and EASY % Ro curves show good match with the observed values at calibration wells A & B.

Petroleum System summary chart was prepared based on modeling results from the four likely scenarios (Fig.9). As the inputs are not fully constrained, volumes from modeling outputs cannot be considered as true estimates. However, it gives an insight into the relative volumes and what can be expected in a qualitative sense. 3D Basin Modeling suggests generation and expulsion of significant volumes of hydrocarbons in the study area. However, total volume accumulated is small due to significant hydrocarbon losses resulting from late deposition of regional seal. Reducing the duration of unconformity to around 2.5 Ma (Scenarios II & IV) has increased the hydrocarbon sum accumulated, but not significantly, as peak generation and expulsion predates the regional unconformity and deposition of top seal sequence.

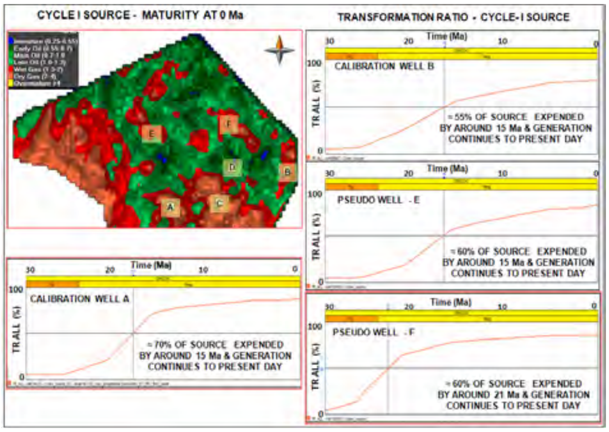

Figure 6: Present day maturity map of Cycle I source indicates main to late oil stage over most of the area except to the south and west where it is in wet & dry gas stage. TR extract from calibration wells and pseudo well locations suggest that 55-70% of kerogen is expended by 22 to 16 Ma. Generation slows down from 15 Ma due to the regional unconformity and continues to present day.

CONCLUSIONS

The main conclusions based on 3D Basin Modeling in the study area are-

Cycle-I is the most effective source for this area charging Cycle-II reservoirs. Charge from Rift source is possible for Cycle-I traps not breached by later tectonics. Cycle-II can be a source in the southern and western parts even though the overall maturity for this unit is low over the study area.

Significant volumes of hydrocarbon have been generated and expelled from predicted source units in this area. As peak generation and expulsion predates the regional top seal deposition, only medium to small sized discoveries can be expected.

WAY FORWARD

The present study is a semi constrained base model in a frontier area to address the migration timing and the migration fairways with data available from few key wells and regional 2D maps as input. The main limitations to the modeling input are quality and distribution of source, regional facies distribution, age/duration of unconformity, eroded thickness estimation and effective timing of the regional seal formation. Nevertheless, the migration timing, migration fairways and HC accumulation output from the model can be used as an effective tool for risking and ranking of leads/prospects. Further improvements can be made by incorporating fault map and additional data from future exploratory activities in the area to constrain the inputs.

ACKNOWLEDGEMENTS

The authors are grateful to PCSB and PMU Management for permission to publish the results of the study. The authors also thank Mr. Effendy Cheng B Abdullah, Mr. Idris B Ibrahim, Mr. Jamlus B Md Yassin, Mr. Ali B M Shariff, and Mr. Mazman B Abu Bakar for facilitating the study. Thanks are due to the Technical professionals-PCSB for their review and criticism.

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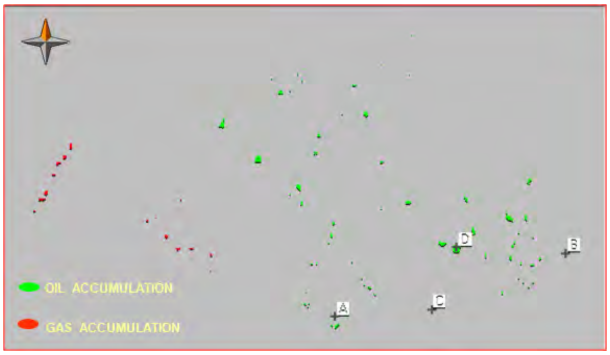

Figure 7: Representative modeling output showing hydrocarbon accumulation at Cycle II upper reservoir straddling MMU. Accumulation at discovery well location D in all the scenarios validates the study.

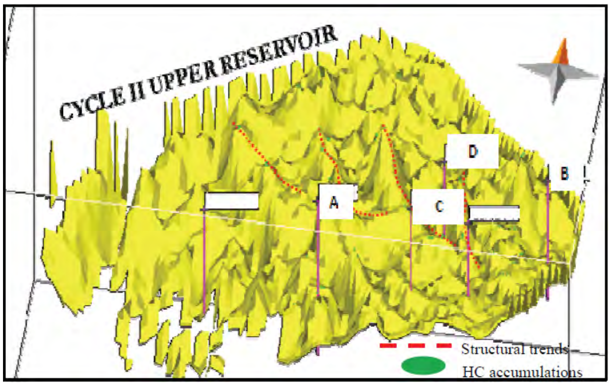

Figure 8: Three dimensional view of Cycle II upper reservoir surface shows preferential hydrocarbon accumulation along NW-SE regional structural trends.

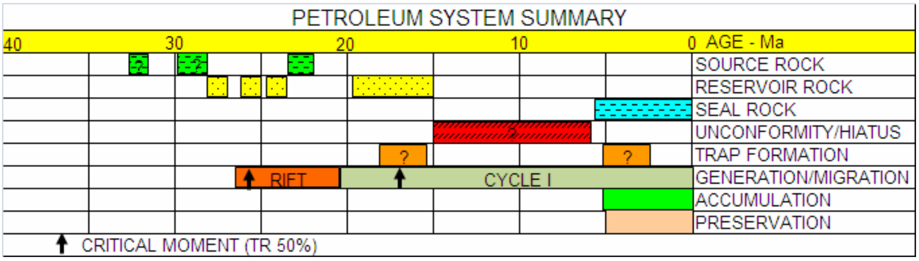

Figure 9: Petroleum System Summary chart for the study area.

Table-1. Geological Scenarios and Basin Modeling Inputs

SCENARIO		SOURCE			RESERVOIR				NON RESERVOIR				REMARKS
		RIFT	CYCLE I	CYCLE II	CYCLE I		CYCLE II		CYCLE I		CYCLE II		
					LOWER	UPPER	LOWER	UPPER	LOWER	UPPER	LOWER	UPPER	
I DEEP BASEMENT	THICKNESS RANGE-M	12 - 200	17- 300	5 -180	17-173	7-120	4 - 162	5 - 180	28 - 1500	151-1555	36 -1458	41-1720	Optimised version after initial calibration runs
	QUALITY	T I source, TOC - 3%, HI- 400	T III source, TOC - 3%, HI- 250	T III source, TOC - 3%, HI- 250	Wacke sst-70%, Sltst-30%		Wacke sst-90%, Sltst-10%		Shale-70%, Sltst-20%, Sst-10%		Shale-70%, Sltst-15%, Sst-15%		
II DEEP BASEMENT	THICKNESS RANGE-M	12 - 200	17- 300	5 -180	17-173	7-120	4 - 162	5 - 180	28 - 1500	151-1555	36 -1458	41-1720	Same inputs as in I, Reduce duration of erosional MMU from 10 to 2.5 Ma
	QUALITY	T I source, TOC - 3%, HI- 400	T III source, TOC - 3%, HI- 250	T III source, TOC - 3%, HI- 250	Wacke sst-70%, Sltst-30%		Wacke sst-90%, Sltst-10%		Shale-70%, Sltst-20%, Sst-10%		Shale-70%, Sltst-15%, Sst-15%		
III SHALLOW BASEMENT	THICKNESS RANGE-M	3 - 150	17- 300	5 -180	17-173	7-120	4 - 162	5 - 180	17 - 900	151-1555	36 -1458	41-1720	Assign Sequence A top as Basement top, subdivide Cycle I lower non reservoir into lower rift section and upper Cycle I non reservoir section
	QUALITY	T I source, TOC - 3%, HI- 400	T III source, TOC - 3%, HI- 250	T III source, TOC - 3%, HI- 250	Wacke sst-70%, Sltst-30%		Wacke sst-90%, Sltst-10%		Shale-70%, Sltst-20%, Sst-10%		Shale-70%, Sltst-15%, Sst-15%		
IV SHALLOW BASEMENT	THICKNESS RANGE-M	3 - 150	17- 300	5 -180	17-173	7-120	4 - 162	5 - 180	17 - 900	151-1555	36 -1458	41-1720	Same inputs as in III Reduce duration of erosional MMU from 10 to 2.5 Ma
	QUALITY	T I source, TOC - 3%, HI- 400	T III source, TOC - 3%, HI- 250	T III source, TOC - 3%, HI- 250	Wacke sst-70%, Sltst-30%		Wacke sst-90%, Sltst-10%		Shale-70%, Sltst-20%, Sst-10%		Shale-70%, Sltst-15%, Sst-15%		

GEOLOGY PAPER 2

APPRAISAL WHILE DEVELOPMENT CAMPAIGN IN THE "J" FIELD, NORTH MALAY BASIN

Lai Kian Voon[1], M. Yusof Abdullah[2], Kanok I.[3], Fazili Ilias[1], Bukhari I.[1], Puvanat C.[3] & Liau Min Hoe[1]

[1]Petronas Carigali Sdn Bhd, Level 11, Tower 2, PETT, KLCC, 50088 Kuala Lumpur, Malaysia.
[2]Carigali-PTTEPI Operating Company
[3]PTTEP

SUMMARY

The conventional approach to develop a field is from Exploration to Appraisal and finally Development Phase. This paper describes a case study for an unconventional approach in the Malaysia – Thailand JDA area where the appraisal program was carried out while the development campaign is ongoing. Once production has commenced, drilling from the well head platform will be difficult as some production wells needed to be shut-in for safety reason during the drilling operations.

This appraisal-while-development approach was carried out in the "J" Field to appraise the hydrocarbon potential of the "J" East fault block. Various strategies and technical justifications had been carried out to convince the management to approve this approach. The appraisal well was eventually drilled, which discovered 86m of net gas sand and encountered two new depositional sequences based on the seismic re-interpretation. Appraisal-while-development concept allowed CPOC to appraise the upside potential and convert the well to development well, leading to cost optimization and immediate contribution to the total field production.

INTRODUCTION

The "J" field is located in the Malaysia-Thailand Joint Development Area (MTJDA) to the north of the Malay Basin. The prominent structures in JDA areas are tilted strata against north-south trending transpressional normal faults & curvy ended faults which are related to dextral wrench deformation from Early Miocene through Late Miocene. A total of five exploration wells and one appraisal well, Well A (2007) had been drilled in the "J" Field, where the latter discovered significant gas reserves with low CO2 content in shallow reservoirs.

APPRAISAL STRATEGY

The development wells were drilled in two batches. The first batch comprised 9 wells where 4 wells drilled into "J" North Fault Block (JNFB) and 5 wells drilled into "J" Main Fault Block (JMFB) (Fig. 1). Post-drill analysis indicated that the deeper reservoirs in JNFB are not correlatable to the appraisal well drilled in 2007. Seismic re-interpretation was carried out and found the appraisal well was drilled into "J" East Fault Block (JEFB) instead of JNFB. The significant gas show at deeper zone possible a new sequence undiscovered earlier. Appraisal well was planned to be drilled into JEFB in order to optimize the platform capacity and the objective to increase the reserves for "J" Field. (Fig. 2)

CHALLENGES

The seismic attribute analyses were not convincing to support well targeting due to fault shadow effects. Various scenarios needed to be planned to mitigate the risk involved due to this. In the event of negative outcome in the proposed well, an alternate down-hole target for a side track well needed to be determined in the JMFB or JNFB. The unknown pressure regime in JEFB also posed a risk for well planning, as over pressured zone in JEFB could undermine the integrity of the development wells and even the platform.

RESULTS AND RECOMMENDATION

One appraisal well was drilled parallel to the fault based on the new seismic interpretation. Seismic velocity was used to predict the pore pressure as input to the drilling operation and casing design. This appraisal well was meant to appraise the shallow and deep reservoirs. The appraisal well discovered 86m of net gas sand which was able to correlate with the appraisal well drilled in 2007. Two new deposition sequences were found in Z7 & Z8 which can be correlated to the "M" Field (South East of JEFB) (Fig. 3).

The distribution of the reservoir Z7 & Z8 will be a new challenge when calculating the reserves. One more appraisal well was recommended to be drilled away from the fault shadow area to appraise the extension of the gas bearing sand's distribution.

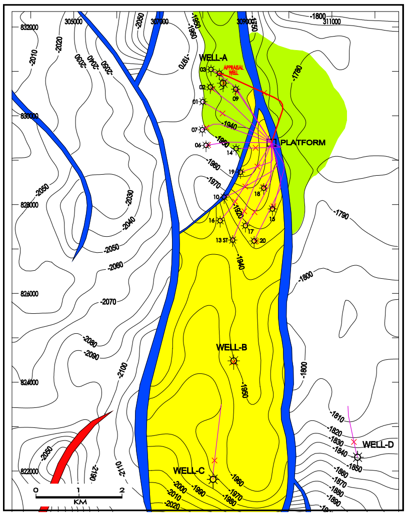

Figure 1: Depth structure map for "J" Field. Development campaign focuses at JNFB and JMFB and appraisal on JEFB.

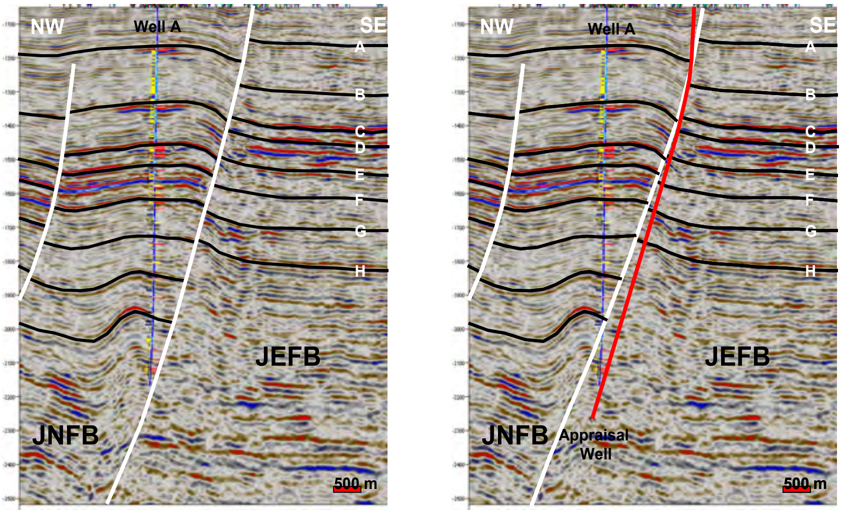

Figure 2: Seismic section along the well A and appraisal well. (Left) Pre-drilled interpretation. (Right) Post-drilled Interpretation.

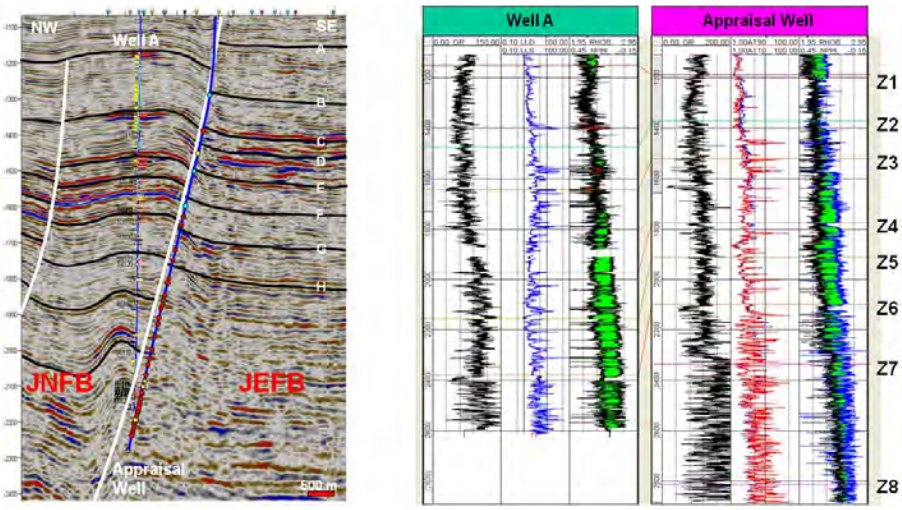

Figure 3: Post-drilled result with seismic section and well log correlation. (Left)Seismic Section along Well A & Appraisal Well. (Right) Well Correlation.

CONCLUSION

This case study is meant to share the success story by using 'appraisal-while-development' approach. The appraisal well drilled from the well head platform can be converted to be producer well once significant gas bearing sands are encountered.

ACKNOWLEDGEMENT

The authors would like to thank Carigali-PTTEPI Operating Company Sdn. Bhd (CPOC), Malaysia-Thailand Joint Authority (MTJA), Petronas Carigali Sdn. Bhd (PCSB) & PTTEP International Ltd for the support of this study & their permission to publish of this work.

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GEOLOGY PAPER 3

PORE PRESSURE PREDICTION OF A FIELD IN SOUTHWESTERN PART OF THE MALAY BASIN: A BASIN MODELING APPROACH

Ismatul Hani Shada Binti Idris[1], Peter Abolins[1] & M Jamaal B Hoesni[2]

[1]Petronas Carigali Sdn Bhd, Level 16, Tower 2, Petronas Twin Towers, KLCC, 50088 Kuala Lumpur, Malaysia.
[2]Petronas Research Sdn. Bhd., Lot 3289, Off Jalan Ayer Itam, Kawasan Industri Bangi, 43000 Kajang, Selangor.

SUMMARY

Pore pressure prediction has become crucial in various stages of frontier exploration, development, exploitation and drilling. Various methods are commonly used in predicting formation pore pressure, for example by using seismic velocity, wireline log-based pore pressure prediction, and geomechanics study. Basin modeling is an emerging approach in predicting pore pressure. Thus the development of a pore pressure prediction workflow using basin modeling provides an alternative approach. This project demonstrates a case study on the application of basin modeling for pore pressure prediction in the southwestern part of the Malay Basin. This study involves 1D, 2D and 3D basin modeling to evaluate the pressure distribution and behaviour. This study also considers the role of faults in controlling pressure distribution. Therefore, several faults have been incorporated into the 3D model. Lithology variations also occur, perhaps controlling the various pressure profiles. It is believed that both faults and facies control the pressure distribution. The pressure evaluation in this project was carried out mainly from 2D simulation. Porosity and permeability calibration was carried out to match the measured pressure data to the model. The final results of 2D simulation show a good calibration between the measured data and the model.

INTRODUCTION

Basin Modeling has become an integral part of the petroleum exploration process. It provides a primary platform for integrating different data types and techniques and for evaluating the interdependencies of the various physical and chemical processes affecting rocks and fluids in the subsurface. Quantitative models for rock property and pressure evolution in different geological settings are among the important challenges for the basin modelers.

This project will study a typical exploration scenario where Well A-1 has been drilled and was a discovery well. Unexpectedly high overpressures were encountered from quite shallow depth all the way down to Total Depth (TD). Well C-1 and Well D-7 are planned as appraisal wells. Using all the measured data from Well A-1, can basin modeling provide a reliable pre-drill pore pressure prediction?

GEOLOGICAL SETTING

The study area is located at the southwestern part of the Malay Basin. It is an east-west trending elongated inversion anticline feature. The structure is dissected and is compartmentalized by several north-south trending normal faults (Figure 1). The observed pressure data from seven wells have been used in the pressure against depth plot (Figure 2); these are A-1, B-1, C-1, D-4, D-5, D-6 and D-7. Based on the pressure profile shown in Figure 2, nearly all of the wells are overpressured.

The pressure profile varies between fault blocks as shown in Figure 2. This figure illustrates the degree of variability of the overpressure in the study area. Different fault blocks show different overpressure trends. The overpressure may start deeper and ramp up rapidly or, alternatively, some of the overpressure may start shallow and ramp up gradually with depth. This demonstrates that pressure behavior is a complex dynamic system that needs to be thoroughly studied. Block C shows an example of overpressure starting slightly at deeper level but ramps up quickly with depth. Other wells from other fault blocks have much shallower overpressure and gradually increase with depth.

PROJECT METHODOLOGY

The study began with 1D thermal calibration. It was done to obtain the heat flow (HF) trend for the field and was achieved by matching calculated temperature and VRo to the measured data. The HF trend obtained from the 1D model was incorporated in 3D basin model construction. A 2D section was extracted from the completed 3D basin model. Pore pressure calibration was done mainly in the 2D model. Pressure calibration was done for Well A-1. Using all parameters to calibrate pressure at Well A-1, pore pressure at pseudo well C-1 and D-7 were predicted. The three parameters used in the calibration process were the porosity-effective stress relationship, porosity-permeability relationship and fault transmissibility.

CONCLUSIONS

The results of this project have demonstrated a good agreement between the pressure model to the measured data at Block A and D of the study area. 2D and 3D pressure models extracted at drilled well, A-1, has shown a good calibration (Figure 3). The parameters used for calibration at Well A-1, were then applied to other pseudo wells, which are Well C-1 and D-7. Well D-7 shows a good calibration but not so good in Well C-1 which showed a slight underestimation of pressure, perhaps suggesting an additional cause for overpressures (Figure 4).

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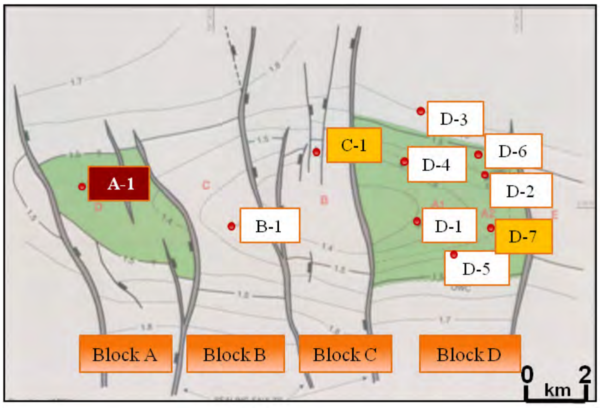

Figure 1: Map showing location of fault blocks and wells drilled in the study area.

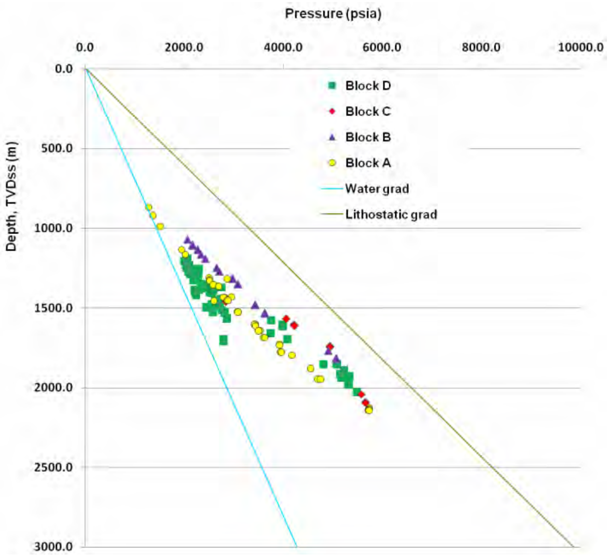

Figure 2: Pressure against depth plotted on a fault block basis.

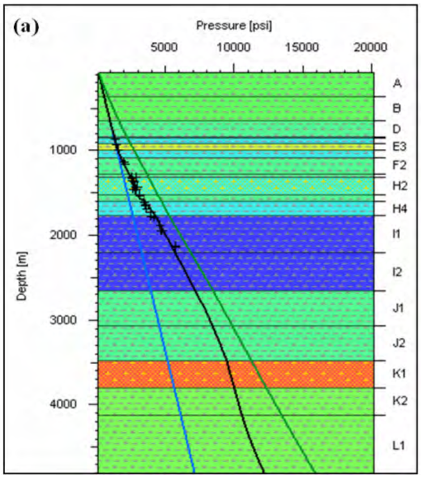

Figure 3: Result of pore pressure calibration at drilled well, A-1.

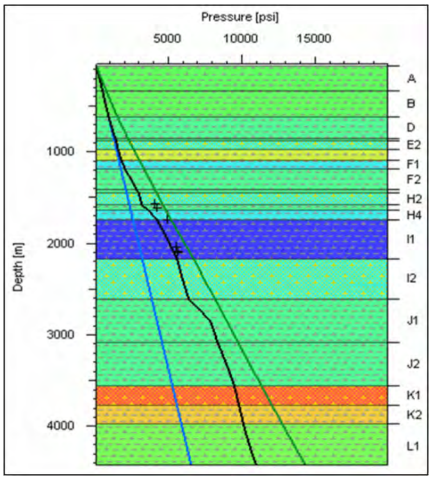

Figure 4: Result of pore pressure prediction at pseudo well, C-1.

GEOLOGY PAPER 4

AN INTEGRATED GEOSCIENCE AND ENGINEERING EFFORTS LEADING TO INCREASED DEVELOPMENT PLANNING CONFIDENCE

Liew Wei Long[1], Hanif Hashim[2], Ridzuan Tahir[2], Zahari Mokhtar[2], Amirul Kusyairi[2], Natasya Pawanteh[2] & Meor Hassan[2]

[1]Field Development, PETRONAS Resource Development, PMU, PETRONAS,
Level 28, Tower 1, Petronas Twin Towers, KLCC, 50088 Kuala Lumpur, Malaysia.
[2]Petrofac (PM 304) Malaysia Ltd, Level 50, Tower 2, Petronas Twin Towers, KLCC, 50088 Kuala Lumpur, Malaysia.

Successful field development planning requires effective mitigation of geological uncertainties through integration of available G&G data and this has been the case for Jambu Liang faulted anticline (Figure 1) which is currently operated by Petrofac Malaysia. Jambu Liang faulted anticline initiated by Cendor development in 2006 has been very prolific despite initially thought to be marginal. Following the success of Cendor, in 2008/2009 Petrofac resume the appraisal of fault blocks to the west and this appraisal campaign has lead to a potential new development of the West D fault block. For an effective development of the fault block, understanding reservoir characters and distribution especially in the prolific Group H reservoir which is geologically complex, is crucial. Amongst the challenges inherent in the block is how to effectively delineate reservoir quality and sand continuity especially at poor seismic quality areas where most seismic response has been attenuated by presence of shallow gas (Figure 2).

In 2008/2009, appraisal wells were diligently planned and drilled to test seismic bright spots and areas with attenuated reflectors. The wells encountered potentially developable sands and hydrocarbon amounts at the West D fault block within the attenuated areas. Well data acquired such as image logs and core has provided good calibration points at the poor seismic areas addressing issues such as structural uncertainties and depositional trends. Comparing and correlating stratigraphic events in cores and image logs from the wells enables the Group H reservoirs to be better characterized with a robust stratigraphic framework established across the fault blocks. Evidence via integrating well data and seismic (Figure 3) indicates that the fluvially influenced West D and tidally influenced Cendor could possibly belong within one depositional system. This interpretation suggests that the H reservoir may be continuous within the Jambu Liang structure; notwithstanding the geological interpretation for the geologically complex H sand continues to evolve and shall be enhanced from time to time.

It is envisaged that future development opportunities in PM304 will be tied-into the planned Cendor Phase 2 facilities in phases and achieve development economies of scale. West D is planned to be the next field for development post Cendor Phase 2 based on the ongoing technical assessments stemming from the integrated subsurface geoscience, reservoir engineering and phase development strategy. The Cendor field has been on production since 2006 and experience gained from the field in addition to phase 2 development strategies shall be incorporated to mitigate the inherent subsurface risks and uncertainties throughout the Jambu Liang structure.

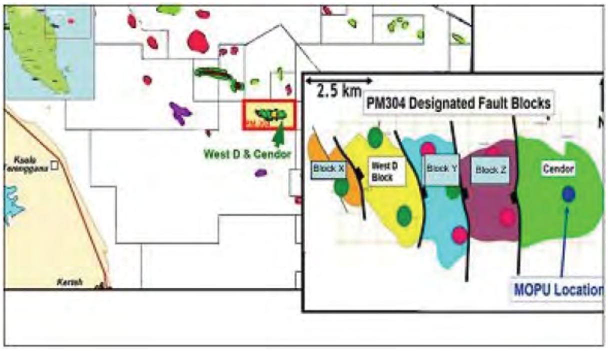

Figure 1: Field location.

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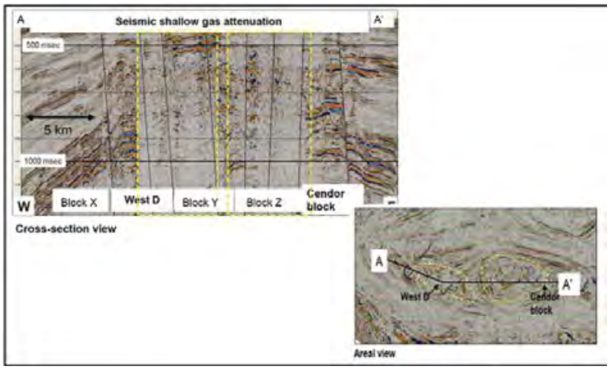

Figure 2: Seismic attenuation.

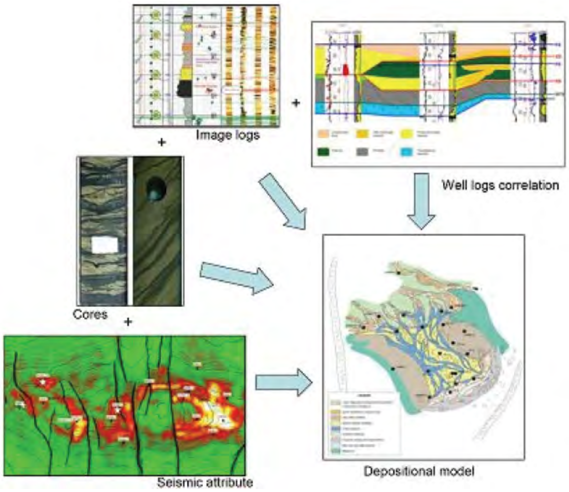

Figure 2: Integrated workflow.

GEOLOGY PAPER 5

FROM DEPOFACIES TO LITHOFACIES: A WAY TO INTEGRATE FACIES AND ROCK TYPES INTO 3D GEOCELLULAR MODELS

Jairo Antonio Plata Torres

Petronas Carigali Sdn Bhd, Level 11, Tower 2, Petronas Twin Towers, KLCC, 50088 Kuala Lumpur, Malaysia.
jairo_plata@petronas.com.my

3D geological facies modeling has been confused in the past with 3D petrophysical rock types (PRT) modeling. The efforts made by sedimentologists trying to understand the 3D geometry of facies and their distribution in the reservoir, sometimes are not well used by modelers who base their facies definition on petrophysical cutoffs which normally don't follow sedimentological concepts.

There are many important implications when determining facies using petrophysical cutoffs: 1. Even though petrophysical properties are initially delineated by sedimentation processes, they are normally altered by diagenetic processes (Morad, et al 2010). This causes mismatches between core described facies and facies based on petrophysical cutoffs. 2. It is not possible to capture the log signature of the facies which is linked directly with their 3D shapes (Serra, 1986). This causes, for example, that sandstones deposited in canalized systems which normally exhibits a bell or cylinder GR signature can be treated as those deposited in fan shapes which exhibit funnel log signatures. 3. There is a bias when selecting core plug for determining petrophysical properties (Terzaghi, 1965). Normally the sampling is concentrated in medium to high quality reservoir rocks and shales are not sampled. This causes that during clustering in crossplots for defining facies, data is not representative of the bad rock quality facies.

This paper presents a methodology for facies modeling integrating core facies definition, conceptual geological models (depofacies and petrophysical rock types. Two field cases, one in South America and the other in South East Asia are used to apply this methodology.

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GEOLOGY PAPER 6

AN ORGANIC GEOCHEMICAL APPROACH TO ADDRESS STRATIGRAPHIC ISSUES: A CASE STUDY OF THE LAYANG-LAYANGAN BEDS, LABUAN ISLAND, NW SABAH BASIN

Patrick Gou[1,2] & Wan Hasiah Abdullah[1]

[1]Geology Department, Faculty of Science, University of Malaya, Kuala Lumpur, Malaysia
[2]Sarawak Shell Berhad, Geological Services, Locked Bag No. 1, 98009 Miri, Sarawak

The three main geological units on Labuan Island which is located within the NW Sabah Basin include the Temburong, Setap Shale and Belait Formations. The Temburong Formation (deep marine turbidites) is the oldest, followed by Setap Shale (outer neritic to littoral) and Belait Formations (fluvial and shallow marine). The sediments are generally divided into two phases of sediment deposition by a major unconformity known as the Lower Miocene Te5 unconformity (after Brondijk, 1962), or more popularly referred to in the petroleum industry as the Deep Regional Unconformity, or DRU (Levell, 1987).

This study is centred on the Layang-Layangan Beds that lie beneath the sandstone and conglomerate ridge of the fluvial Lower Belait Formation. Previous authors have assigned the Layang-Layangan Beds to all of the three major geological formations on Labuan Island; Belait Formation (Wilson & Wong, 1964; Lee, 1977; Albaghdady et al., 2003), Setap Shale Formation (Liechti et al., 1960), and Temburong Formation (Madon, 1994). This confusion is not surprising as the Tertiary sediments in the NW Borneo region can be very difficult to tell apart based on field observations or conventional geological methods alone.

Geochemical results from the analyses of the Labuan sediments, which included thermal maturity related-data derived from Source Rock Analyzer (SRA), organic petrography and gas chromatography-mass spectrometry (GC-MS) were able characterise the different sediments as each of them have significant differences in their geochemical properties to produce unique geochemical profiles. The Layang-Layangan Beds display similarities in its geochemical profile with the overlying Belait Formation, while the Temburong Formation has a different and distinct geochemical profile compared to the Layang-Layangan Beds and Belait Formation. However, the Setap Shale and Temburong Formations are geochemically quite similar to a certain extent.

Consequently, the existence of the DRU on Labuan Island that is thought to separate the Layang-Layangan Beds and the Lower Belait Formation is put into question since this regional unconformity surface is supposed to represent a drastic change in depositional environment (deep marine to fluvial), which appears to be a lot more subtle and gradual as indicated by the geochemistry data.

The geochemical analysis workflow to characterise outcrop geology as demonstrated in this study is relatively cheap and simple, and should be considered when other geological methods do not give convincing results. In addition to that, it serves as a good and reliable independent method to verify ambiguous geological interpretations.

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GEOLOGY PAPER 7

CHARACTERIZING AND MODELING NATURAL FRACTURE NETWORKS IN A TIGHT CARBONATE RESERVOIR IN THE MIDDLE EAST

Dipak Singha Ray[1], Adnan Al-Shammeli[1], Naveen K. Verma[1], Saad Matar1, Vincent de Groen[2], Ghislain de Joussineau[2]*, Thierry Le Maux[2] & Waleed Al-Khamees[1]

[1]Kuwait Oil Company, Kuwait

[2]Beicip-Franlab, Paris, 232 Avenue Napoléon Bonaparte, 92502 Rueil-Malmaison Cedex, France.

*ghislain.dejoussineau@beicip.com

Fractured reservoirs are challenging to handle because of a high level of heterogeneity (Nelson, 2001; Bourbiaux et al., 2005). In particular, natural fracture networks have a significant impact on the reservoir performance as they affect well productivity (Narr et al., 2006). Therefore, understanding their significance through fracture characterization is helpful in well placement and field development.

This paper presents an overview of efforts in building a 3D stochastic fracture model for reservoir characterization of a Middle Eastern tight carbonate field. This model is generated in FracaFlowTM through the analysis and integration of well data pertaining to fractures like cores (including oriented core), bore hole images (BHI), well logs, mud losses, production logging and well test data together with 3D Q-Seismic data [structural and seismic attributes and seismic facies analyses (Abdul et al., 2010)].

The impact of lithology on fracture occurrence was quantified based on rock-typing and distributed in a 3D geological model using a high resolution sequence stratigraphic framework. The length, dip angle and orientation of fractures as well as the shale content of the facies where they are present were defined to sort the tectonic fractures from the non-tectonic ones. It was found that multiple sub-vertical sets of diffuse fractures are generally associated with cleaner limestone units. Altogether, three sets of diffuse fractures were identified from borehole image data: N20°E, EW and N170°E. Large-scale fracture corridors, including sub-seismic faults identified from seismic analysis, were calibrated with core and BHI fractures through fracture data analysis workflows. The model finally incorporates two scales of tectonic fractures: diffuse fractures and large-scale fractures that have a direct bearing on well and field production behavior.

The fracture calibration was also performed using the dynamic data set such as production log and well production data. Permeability at wells was computed in the DFN (Discrete Fracture Network) model and matched with the real build-up data. These data were then used to propagate 3D fracture properties (fracture porosity, fracture permeability and equivalent block size or shape factor) in the upscaled geological model for constructing a full reservoir simulation model. The model proved to be very reliable as few changes of the fracture properties were needed to obtain a good history match.

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GEOLOGY PAPER 8

THE ONSHORE TO OFFSHORE DENT GROUP, EASTERN SABAH FROM SEQUENCE STRATIGRAPHIC PERSPECTIVE: IMPLICATION TO PETROLEUM EXPLORATION

M Razali Che Kob[1], Sanudin Tahir[2], A Fahrul Januri[1], Harminza Mansor[1], Nuraman Nusral[1], M Idrus Ismail[1], Robert Wong Hin Fatt[1] &Azani Manaf[1]

[1]Petroleum Management Unit, PETRONAS
[2]Universiti Malaysia Sabah

The prospective Sandakan sub-basin has been less explored even though some oil and gas discoveries has been made in addition to the numerous thermogenic gas show encountered in most of the exploration wells in the offshore Eastern Sabah. The gas and condensate was tested with flow rate as high as 15mmcfg and 500 bc/d in one of the wells, however the discovery of commercial size has yet to be made. The probable reason for this lack of success is insufficient seal integrity due to very high percentages of sand vs. shale.

Field observation of the Dent Group outcropping in Dent Peninsula shows the occurrence of thick shale belonging to Sebahat Formation, the equivalent to the main reservoirs in the offshore. This formation together with younger Ganduman and Togopi Formations are collectively known as the Dent Group of Middle Mioecene to Pleistocene. The Group consists of post-rift sedimentary packages, overlying the older syn-rift Segama Group. It consists of fluviodeltaic to marine sediments, characterized by strong southeastward progradation into the offshore area.

The onshore to the offshore correlation of the Dent Group is achieved through application of sequence stratigraphy. The group can be divided into 2 mega-sequences that consist of several higher order composite sequences, namely Composite-Sequence 1 and 2. The older Composite-Sequence 1, consists of lithological units that has been described as Sebahat and Ganduman formations, while the younger, Composite-Sequence 2 consists of the Togopi Formation.

The occurrences and distribution of the lithofacies of the Dent Group can be explained through subdivision of the sequence into composite systems tracts. The lowstand sequence set of Composite-Sequence 1 mostly sub-cropping in the offshore area, while the Sebahat Formation in the onshore represents the transgressive sequence set. The Ganduman Formation is interpreted as the highstand sequence set of the sequence.

The transgressive Sebahat Formation offers a new look for its sealing capacity as well as reservoir potentials. The thick Sebahat shale outcropping on the Dent Peninsula is occurring in the offshore as well, and potentially sealing. On the offshore seismic sections, this shale is observed overlying the transgressive carbonate and thick lowstand sequence set of Composite-Sequence 1, which contain good reservoir facies. The facies of the lowstand sequence set is interpreted to consist of turbidites forming the fan-system and stacks of shoreface deposits forming the lowstand set of prograding wedges.

GEOLOGY PAPER 9

SOURCE OF COAL BED METHANE

Swapan Kumar Bhattacharya & Saleem Qadir Tunio

University Technology PETRONAS, Bandar Seri Iskandar, 31750 Tronoh. Malaysia.
swapan_b@petronas.com.my

Commercial viability of a coal bed methane project exclusively depends on the available source of methane. By default it is expected that the source of methane is bacterial / thermal actions on organic biomass during coalification process. Carbon isotope signatures and chemical composition of the produced gases are not always favourable supports to the coal origin of the available methane. Moreover, all the major successful coal bed methane projects are geographically located over one or the other petroliferous basins. Does it mean that the coal bed methane has some intricate source relation with occurrence of petroleum?

Critical review suggests as such methane generation from coal is difficult because average molar H/C for coal is around 0.8 (Hunt, 1995) whereas molar H/C for methane is 4.0. Therefore, even if it generates some methane it may not be commercial because of non-availability of sufficient hydrogen in coal. However, it is possible for coal / organic biomass to generate methane if deficient hydrogen is compensated by water. Conversion of organic matter to methane is represented by the following reaction:

$$C_6H_{12}O_6 \;=\; 3CH_4 + 3CO_2$$

The chemical potentials at STP for the simple carbohydrate $C_6H_{12}O_6$, methane, and carbon dioxide are −218.720, −12.130, and −94.260 kcal/mol, respectively. The thermodynamic affinity for the reaction accordingly is 100.42 kcal/mol and therefore permitted by the second law. Although, thermodynamically it is possible but this reaction cannot represent methane generation from coal because coal is dominantly aromatic with lots of free carbons and always have low hydrogen concentration. Kenney (2002) experimentally showed that free carbon and hydrogen from water catalytically can be combined to form CH_4. Fischer-Tropsch synthesis also shows similar combination to form petroleum but these reactions do not take place spontaneously in natural conditions.

Methane is generated in the process of coalification using either biogenic or thermogenic process. Biogenic methane is initially generated by some aerobic bacteria while the sample is in peat / swamp condition. Trapping of this early biogenic methane in coal is not possible because this is generated before proper gellification / coalification process starts. Next, methane generative stage commences with anaerobic methanogens during lignite stage and possibly continues till high volatile bituminous stage of coal. Although it is said that bacterial methane is generated by methanogens using coal of any maturity but it is

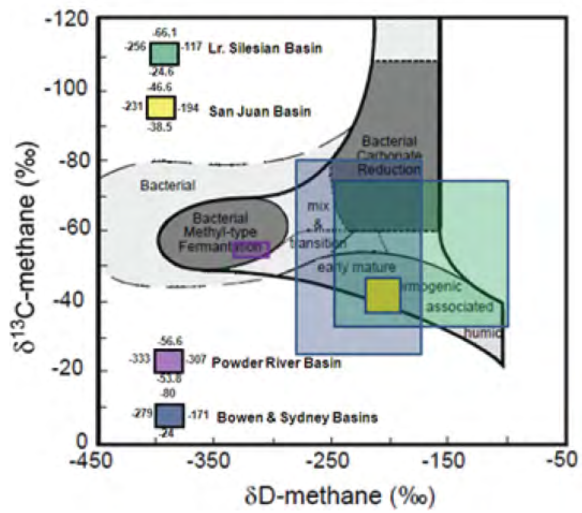

Figure 1: Modified after Whiticar, 1996

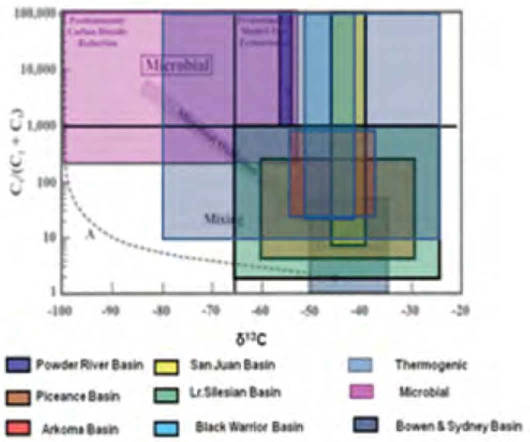

Figure 2: Bernard Plot, modified after Whiticar, 1996.

difficult to accept because methanogens can reduce only low molecular weight carbon compounds.

Methanogens spontaneously generate methane using CO2 or methyl type fermentation of some methyl compound.

$CO_2 + 8H+ + 8\ e^-$ —> $CH_4 + 2H_2O$ ----------------- (1)

CH_3COOH —> $CH_4 + CO_2$ ------------------- (2)

The formation of methane by microbes using CO2 of reaction type-(1) gets all the hydrogen from water and it generally takes place in marine conditions (Whiticar et al., 1996) whereas, the hydrogen availability in reaction type – (2) is disputable. Initially it was suggested that only one hydrogen is introduced from water (Whiticar et al., 1986) now it has been suggested that all the hydrogen in methane is made available from water (Waldron et al., 1999). All these changes confuse the interpretation using hydrogen isotopes. However, interpretation using combined carbon and hydrogen isotopes is more satisfactory.

Thermogenic methane starts generation during late lignite stage and continues to high volatile bituminous stage whereby methoxy groups from lignins are separated. Finally, during bituminous to anthracite coalification jump (Vro exceed more than 2.0) aromatic condensation reactions dominate to generate some amount of methane.

From all of the above, it is apparent that anoxic bacterial methane may be the main source of coal bed methane because thermogenic methane cannot be commercial as coal is deficient in hydrogen.

Table-1 shows coal bed methane data from available eight basins of the world and Figures-1 and 2 show modified (Whiticar et al., 1996) plots for characterization of coal bed methane. Isotope values for carbon and hydrogen (Figure 1) suggest methane in Powder River Basin of USA generated as biogenic whereas San Juan Basin of USA show thermal genesis and Lr. Silesian Basin of Poland show mixing influence of biogenic and thermal genesis.

This is further verified with Bernard plot (Figure 2) using wettability versus carbon isotope composition. Here also samples from the Powder River Basin matches with biogenic origin of the gas. Gases of San Juan Basin USA and Lower Silesian Basin of Poland suggest thermogenic origin and Piceance Basin of USA suggest mixing of thermogenic and biogenic source.

Data as available from the Australian basins (Faiz, 2009) are also reviewed and it appears that the gases from Surat Basin, Bowen Basin and Sydney Basins of Australia all suggest mixing of biogenic and thermogenic source.

Results of the above four basins confirms methane generation only from the Powder River Basin to be of biogenic and others are all mixed thermogenic or pure thermogenic. If bacterial methane is the only source of coal bed methane then in the other three basins commercial methane generation from coal is difficult to explain.

Table-1

Approximate range in Carbon & Hydrogen isotope for different types of petroleum gas

Gas Type	$\delta^{13}C$	δD
Dry Bacterial	-110 to -60	-250 to -150
Wet Thermogenic	-60 to -30	-300 to -120
Dry Thermogenic	-40 to -15	-150 to -70

Ref. Petroleum Geochemistry & Geology By J. M. Hunt Part 2 Chapter-7 Table 7-1 Page 189

Measured ranges of Carbon & Hydrogen isotopes from Coal Bed Methane projects in Different Basins

Sample	$\delta^{13}C$	δD
Powder River Basin	-56.6 to -53.8	-333 to -307
San Juan Basin	-46.6 to -38.5	-231 to -194
Piceance Basin	-60.3 to -29.1	Not Available
Arkoma Basin	-56.0 to -38.0	Not Available
Black Warrior Basin	-51.0 to -41.9	Not Available
Lr. Silesian Coal Basin	-66.1 to -24.6	-256 to -117
Bowen & Sydney Basins	-80.0 to -24.0	-279 to -171

Ref. Composition & Origin of Coal Bed Gas by Dudley D. Rice

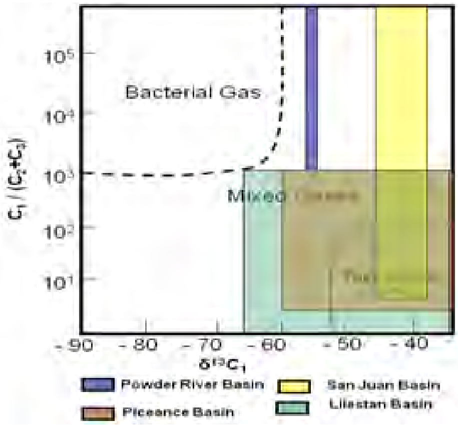

Figure 3: Revised Bernard Plot comparing gas wetness and δ13C of methane to characterize origin of gas. (Modified after Hunt, 1995). Areas of bacterial, mixed and thermogenic sub-divisions have been taken Claypool & Kvenvolden (1983).

Critical review of successful CBM projects reveal most of them are geographically lying over producing petroliferous basins. The available data of coal bed methane is now plotted in the same way as to characterize the petroleum natural gas (Figures 3 and 4). Both Bernard and Schoell plots suggests the coal bed methane can also be originated in the same way as petroleum natural gas.

Thus, methane from coal bed and petroliferous reservoirs is indistinguishable. Further, since successful projects are associated with petroliferous basins, it is most possible that the source of methane in coal bed is the same source rock in individual petroliferous basins.

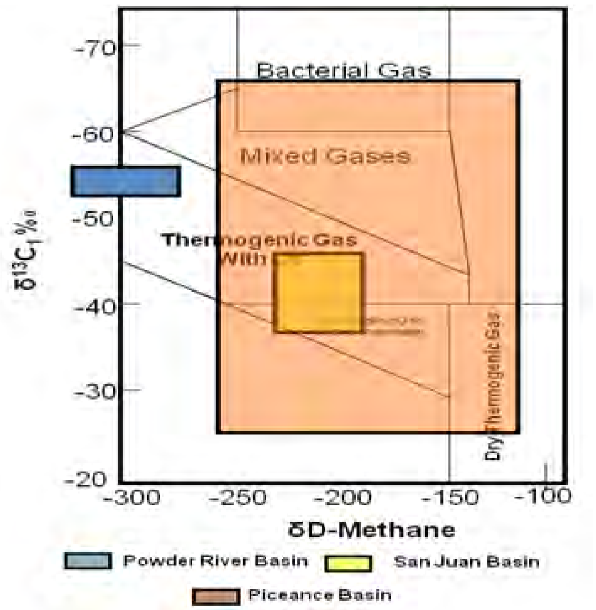

Figure 4: Scholl's plot of δD-methane versus δ13C1 for characterizing the origin of natural gases (Modified after Hunt, 1995). Values of Coal Bed Methane from San Juan Basin, Powder River Basin and Lr.Silesian Basin are superposed.

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GEOLOGY PAPER 10

SEQUENCE STRATIGRAPHIC STUDY OF BLOCK 16/19 AND ZAMBEZI DELTA BLOCK , MOZAMBIQUE BASIN, OFFSHORE MOZAMBIQUE

Dayang Hasspariah Binti Sapri & Othman Ali Bin Mahmud

PETRONAS Carigali Sdn Bhd, Level 16 Tower 2, PETRONAS Twin Towers, KLCC, 50088 Kuala Lumpur, Malaysia

Block 16/19 and Zambezi Delta Block (ZDB) are located in the offshore Mozambique about 350 km to the north of Maputo the capital of Mozambique (Figure 1). Sasol Petroleum International (Pty) Limited is the operator for Block 16/19 and Petronas Carigali Mozambique Exploration and Production (PCMEP) is the partner with 35% working interest. Zambezi Delta Block was operated by PCMEP but relinquished in 2009 due to unsuccessful exploration.

In Block 16/19, a commercial gas discovery has been made by the successful drilling of Well-F in 2008. The discovery of Well-F add to the number of commercial gas discoveries in Mozambique which prior to that discovered onshore fields of Temane in 1956 and Pande in 1961.

In order to further explore the hydrocarbon potential of this area, a regional study with sequence stratigraphic approach was carried out in 2009. The main objective of this study is to construct stratigraphic framework of the region and try to establish regional stratigraphic correlation between Block 16/19 and Zambezi Delta Block. The established stratigraphic framework and regional correlation will facilitate future exploration work activity of Block 16/19. In addition, the study was also aimed to identify any upside potential and presence of stratigraphic play in the area.

The method used in this study is based on Exxon's techniques (Van Wagoner et. a., 1990) which defined Sequence Boundary (SB) as a product of relative sea level falls. Seismic data and well data (logs, cores & biostratigraphic data) were used to identify major bounding surfaces in order to establish a framework in which genetically related facies can be studied and a realistic depositional model can be constructed. Sequence stratigraphic interpretation such as identification of sequence boundaries, maximum flooding surfaces, reflector terminations (onlap, downlap, toplap and truncation) were done on hardcopy of several selected key seismic lines prior to extend the

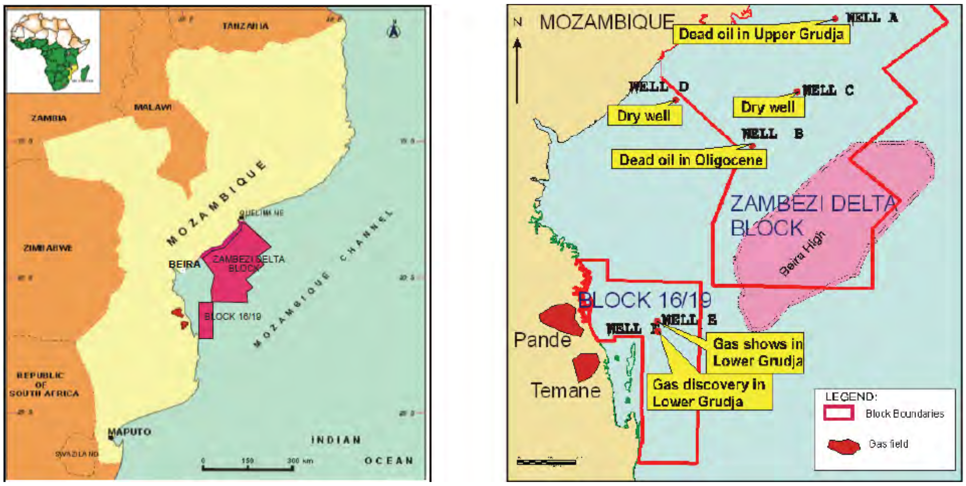

Figure 1: Location map of Block 16/19 and Zambezi Delta Block.

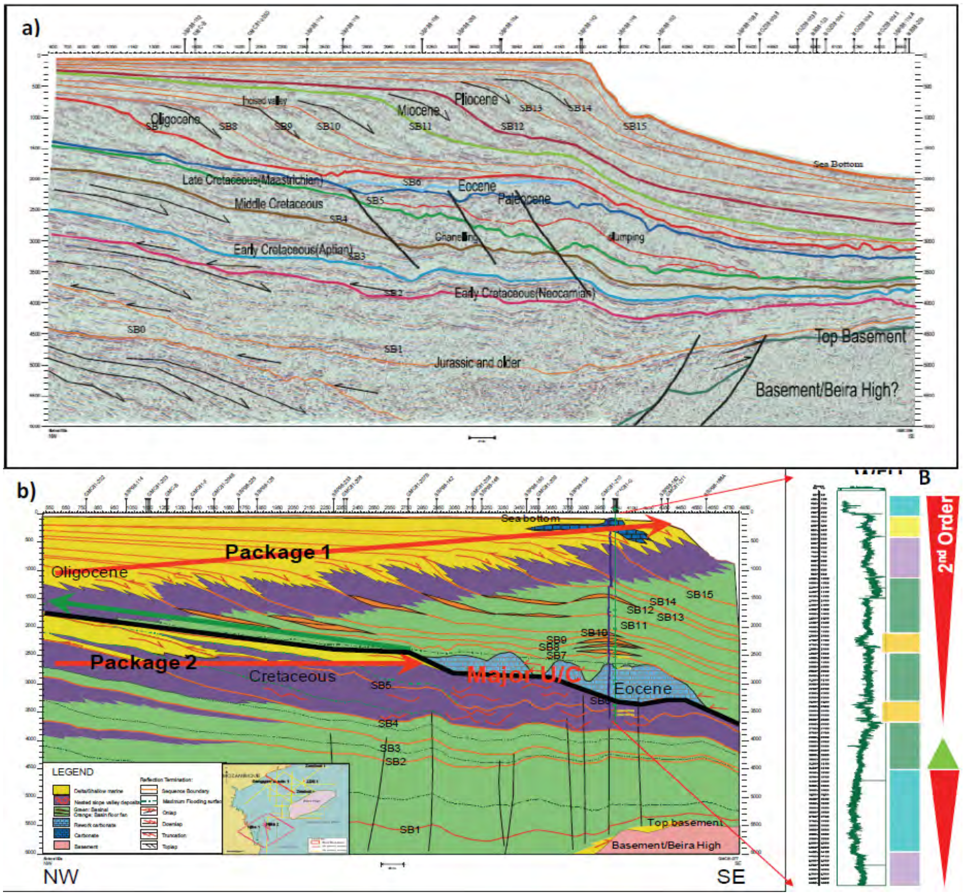

Figure 2: a) Identified third order sequence boundaries in the study area b) The third order sequence boundaries form two packages of prograding mega sequences of 2nd order.

interpretation to the rest of the available seismic data.

The tectonic setting and basin evolution of the Mozambique Basin is very much related to the break-up of Gondwanaland. The rifting events during Permo-Early Jurassic times divide Gondwanaland into East Gondwana (Madagascar, India, Antarctica and Australia) and West Gondwana (Africa and South America). The extensive separation and drifting of East Gondwana from West Gondwana resulted in north-south relative motion between Madagascar and Africa. After the sea-floor spreading ended, a passive margin developed along the western coast of Madagascar and eastern coast of Africa. The Mozambique basin is located at the eastern part of African continent formed as a passive margin and start receiving sedimentation in Mesozoic which later overlain by rapid deltaic sedimentation towards Tertiary (ENH, 2000).

The study has recognized seventeen sequence boundaries (SB) in Block 16/19 and Zambezi Delta Block area of which ten are the existing SBs based on previous interpretations and another seven are new SBs introduced in this study. All identified sequences are of the third order sequence which formed two mega prograding sequences of second order (Figure 2). The two mega prograding events are found to be corresponded to two episodes of shelf edge development during Cretaceous and Tertiary (Figure 3). New potential play has been identified and the study has also established regional stratigraphic well logs correlation between Block 16/19 and Zambezi Delta Block.

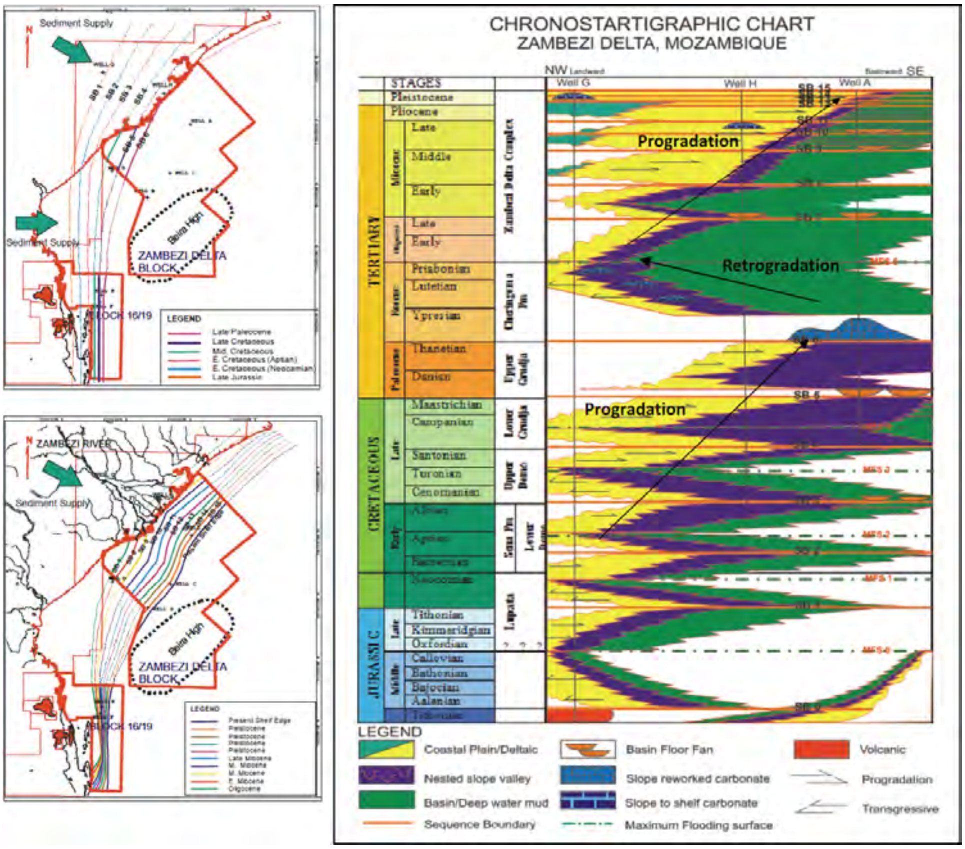

Figure 3: The paleoshelf edge development and the chronostratigraphic model for Zambezi Delta (modified after Othman et al., 2003).

This paper shall discuss the approach, the methodology and the result of the study, which is the refinement of previous sequence stratigraphic interpretation carried out in 2003.

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GEOLOGY PAPER 11

DYNAMIC MODELLING OF A NORTH SEA SALINE FORMATION FOR CARBON SEQUESTRATION

Francesca E. Watson[1,2]*, Benjamin J. Hedley[2], Richard J. Davies[2] & Susie E. Daniels[1]

[1]Geospatial Research Ltd., Dept. of Earth Sciences, Durham University, Durham DH1 3LE, UK.
[2]Dept. of Earth Sciences, Durham University, Durham DH1 3LE, UK.
*f.e.watson@durham.ac.uk

Carbon capture and storage has been proposed as a way of stabilising greenhouse gas emissions in order to meet global greenhouse gas emissions targets. A thorough characterisation of potential CO_2 storage sites is required prior to CO_2 injection. European Directive 2009/31/EC (European Parliament, 2009) states that this should include dynamic modelling of the proposed storage site. This paper describes the results of the dynamic modelling carried out on a deep saline formation in the UK North Sea.

The target formation for CO_2 sequestration is the Permian Rotliegend sandstone, Central North Sea, approximately 40 km west of the Central Graben and 200 km north east of the Teeside industrial processing region, northeast England. The seal is the overlying Permian Zechstein salt. Seismic data show that the Rotliegend sandstone dips to the north east and pinches out to the southwest, forming a stratigraphic trap on a regional scale. Local dip closures within the Rotliegend sandstone have also been identified as possible locations for carbon dioxide injection, in addition to the stratigraphic closure.

The site is not penetrated by wells but the structure is defined by 2D reconnaissance seismic data tied to adjacent exploration wells. Horizons interpreted from the seismic survey have been used to build a 2D dynamic model. The model consists of a layer of Rotliegend sandstone approximately 100 m thick underneath a layer of Zechstein salt which is approximately 600 m thick. Both the Rotliegend and Zechstein layers are considered to be homogeneous due to the absence of resolvable internal seismic structures. The topography of the interface between the sandstone and the salt has been imported from the seismic interpretation of the top Rotliegend surface. The base of the Rotliegend sandstone has been modelled as both a flat and a dipping planar surface. This takes into account different interpretations of the location of the bottom of the Rotliegend which is difficult to distinguish in the seismic data. The model has been populated with rock and fluid properties using data from literature, sonic logs and results from core flood experiments.

Modelling has been performed using TOUGH2-MP (Zhang et al., 2008), the parallel version of the TOUGH2 numerical code for modelling multiphase fluid and heat flow in porous media. It has been used in conjunction with the ECO2N equation of state module (Pruess, K., 2005) which models mixtures of H_2O-CO_2-NaCl designed specifically to represent conditions applicable to CO¬2 storage in deep saline formations.

Several models have been developed to explore the effect of different parameters on the behaviour of the injected CO_2 and the response of the reservoir to CO_2 injection. Best and worst case scenarios with respect to rock and fluid properties and reservoir geometry have been assessed. Also different injection scenarios have been considered for instance different well positions, injection rates and number of wells.

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GEOLOGY PAPER 12

THE POSSIBLE SIGNIFICANCES OF COALS ENCOUNTERED IN CORED SECTIONS FROM THE CENTRAL MALAY BASIN; IMPLICATIONS FOR SEQUENCE STRATIGRAPHIC INTERPRETATION AND BASIN CHARACTER

David Ince[1], Mazlan Madon[1], Abdul Hadi A Rahman[2], Ahmad Munif Bin Koraini[2], Mahani Mohamed[1], Sanatul Salwa Hasan[3] & Samsudin Jirin[3]

[1]Petronas Carigali Sdn Bhd
[2]Orogenic Resources Ltd
[3]Petronas Research Sdn Bhd

Cores recently acquired from E Group sections from the central Malay Basin, have been the subject of detailed and integrated sedimentological and palaeontogical studies in order to provide the basis for improved understanding of reservoir sequences. These studies have included detailed core description and dense sampling for combined micropalaeontological and palynological analysis. The results of these programs have revealed significant results that allow the coals to be confidently assigned to a particular phase of relative sea level and, furthermore, shed light on the nature of the overall receiving basin. Models have been developed to account for the sequences observed. These may apply more generally to the Malay Basin sections, although variations on this basic theme may occur.

The coals studied have been shown to be of both freshwater and brackish origin, based on the palynological and micropalaeontological content. In all cases they represent phases of drying out of the basin, some being correlatable over wide areas. They are usually underlain by variably well-developed seat earths which show high levels of bioturbation/pedoturbation and also contain marine to brackish microfaunas. As such these seat earths often represent the most saline/marine sediments in a given sequence. This is a feature of many seat earths in the Malay Basin that we have been able to study in addition to those from Sepat. The coals are generally rootleted, and the seat earths are pale grey in colour indicative of the soil zone leaching that creates such deposits. Peat accumulation is invariably terminated by a flooding event, although this may be freshwater, or brackish, based on the palaeontology and level of bioturbation. One of the coals studied occurs as a split seam, with an enigmatic conglomeratic lithology present in the intervening interval.

The conclusion drawn from these observations is that at various stages of the fill of the Malay basin the areas was prone to regular drying out, with the establishment of widespread coal forming peats. River channels formed at the same time as these peats and dissected the area, which is thought to have been low relief, but occasionally flood events breached the channel margins and killing the peat mires, at least locally. Peat accumulation was brought to a close by flooding of the basin, either with fresh or brackish water. This suggests there to have been some form of barrier to the basin, preventing or restricting the ingress of saline water. The presence of brackish water coals may approximately locate the palaeo-coastal belt for a given cycle and the upward change in coal character indicates increasingly freshwater conditions. This in turn suggests that peat facies belts may have been migrating basin-wards during phases of falling sea levels, resulting in the establishment of more widespread peats. Reservoir sandstones in the cored sections were most probably deposited within fluvially dominated shallow water deltas or sub deltas in a lacustrine setting.

These observations can be combined to allow a simplified cycle to be developed for the coal bearing intervals in the fill of the Malay Basin. Given that the seat earths appear to be the most marine parts of the section it is considered that the coal forming peats began to form with the onset of falling sea levels, with both the brackish and freshwater peats migrating basin-wards with the coastal belt. Basin-wards migration would have halted at the onset of transgression and thus the S.E. limit of a given coal would delineate the regressive maximum for a particular cycle. Thus the bases of coal beds are likely to be significantly diachronous. The tops of coal beds may also be diachronous. Variations in the make-up of sequences occur, probably as a result of subtle interactions between sea level, subsidence in the receiving basin, and the tectonic or sedimentary factors creating a barrier at the S.E. end of the basin. Such short term changes in sea level, and consequently in the geomorphology of the

Sunda Shelf, are unsurprising. Recent research (Sathiamurthy and Voris, 2006) using Digital Elevation Models has shown the possible response of the area to glacio-eustatic fall in sea level during the Last Glacial Maximum, some 21ka BP, when sea levels were some 116m lower than at present, with the development of former low-lying, potential lake, areas on the exposed shelf which formed Sundaland. Repetition of such changes is considered likely to have resulted in the accumulation of the strongly cyclical sequences typical of parts of the Malay Basin succession.

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GEOLOGY PAPER 13

HABITAT AND C-14 AGE DATING OF LIGNITIC TERRACE SANDS – IMPLICATIONS FOR UPLIFT ON THE BORNEO COASTLINE DURING THE HOLOCENE

Franz L. Kessler[1] & John Jong[2]

[1]Curtin University of Technology, Miri, Sarawak, franz@curtin.edu.my
[2]JX Nippon Oil Exploration (Malaysia), Ltd., Miri, Sarawak, johnjong@noex.com.my

Quaternary terrace deposits are very common along the Borneo coastline (H.D. Tjia 1983), often in conjunction with mangrove swamp environments, and these have been preserved on land, where terraces saw uplift in respect to the sea-level (Liechti et al., 1960; Hutchison, 2005). The terrace deposits lie above a marked angular unconformity that may have originated as an intra-tidal abrasion surface (Kessler, 2005).

The young terrace deposits lacing the Miri coastline from Miri to Bekenu (Figure 1) are formed by lignitic sands (Figure 2), fossil wood, and conglomeratic beds that contain reworked quartz pebbles derived from the older Tukau Fm below. The only fossils, other than wood, are Callianassa-style burrows (Figure 3), and are indicative for an inter-tidal to estuarine environment.

Field observations (in the context of stratigraphy, buried wood and compaction) suggested that the sediments might be young, and possibly younger than 50,000 years, which would bring the sediment into the window of C-14 analysis. Accordingly, ten (10) lignitic sand and fossil wood samples in ten coastal profiles were sent for C-14-based age determination; with the results indicate an age range from Late Pleistocene to Early Holocene of 28,570 to 8,170 years.

The presence of Quaternary tectonism is particular interesting from the angle of petroleum geology. Significant Quaternary tectonism would have considerable impact on the trapping of hydrocarbons (breach and spill); hence it is an important question to be resolved. Given the terraces are block-faulted; implication is that the Miri Hill, in its present form, emerged during the Holocene. So-far, with the Holocene tectonics being confirmed for the Miri Hill, the question remains how much the oilfield below Miri City and undrilled prospects further east of the Miri Hill have been affected by these young movements.

Figure 1: Elevation and profiles of the terraces in the surroundings of Miri.

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Figure 2: Cross-bedded lignitic sands, with quartz pebble conglomerates.

Figure 3: Laminated lignitic sandstones containing Calianassa-type burrows.

GEOLOGY PAPER 14

CHARACTERIZATION OF PEAT-FORMING ENVIRONMENTS OF MIOCENE COAL USING BIOFACIES IN THE MALAY BASIN, MALAYSIA

Shamsudin Jirin[1], R. J. Morley[2], Mahani Mohamed[1] & Sanatul Salwa Hasan[1]

[1]PETRONAS Research Sdn Bhd, Lot 3288 & 3289 Off Jalan Ayer Itam, Kawasan Institusi Bangi, 43000 Kajang, Selangor, MALAYSIA

[2]PALYNOVA, 1 Mow Fen Rd, Littleport Cambs, UK and Dept of Geology, Royal Holloway, University of London, Egham UK

Coals are common in many Miocene paralic sedimentary successions in the Malay Basin. Four types of peat-forming environment associated with coal precursors can be recognized by using high resolution biofacies analysis, and each has a different significance in terms of depositional environment and sedimentary facies interpretation. They are 'basinal', 'watershed' or 'kerapah', 'brackish/marine' and 'freshwater alluvial' peats.

Basinal peats occur behind mangrove swamps, and form during the period of stable sea level and everwet climate. They begin as topogeneous peats and develop into domed, ombrotrophic peats at a later stage. Currently, they represent the most widespread type of peat in the Southeast Asian region, occurring widely in Sarawak, Brunei, Malay Peninsula, Sumatra and Kalimantan and frequently form thick coals in Malay Basin successions.

Watershed or Kerapah peats form on low lying watersheds and other poorly drained areas where mineral influx minimal. They form when the climate is everwet and rainfall exceeds runoff. Unlike basinal peats, they develop independently of sea level change and thus can form at any time during eustatic sea level cycle provided the climate remains everwet. Today such peats occur locally in Sarawak and Central Kalimantan. In the Malay Basin they were probably more common during periods of sea level lowstand and coals thought to be from Kerapah peats may have occurred commonly on low lying interfluves.

'Brackish/marine' peats are very rare at present, but were probably common in the Miocene. Today they form in brackish settings which are subject to sediment starvation and limited nutrient availability, such as on carbonate substrates. However, a thick, and widespread coal formed at the end of Malay Basin Seismic Group E (about 9.0 Ma) on clastic sediments, and biofacies analysis suggests that this formed as a peat on exposed low relief area subject to subtle interaction of brackish water, probably at a time when sea levels fell.

Freshwater alluvial peats could occur within alluvial plain settings such as abandoned fluvial channel and flood plains. These peats may be considered as ephemeral compared the previous three types, and thus coals derived from freshwater alluvial peats tend to be much thin and limited areal distribution.

The means of differentiating these four coal types, and their significance to depositional interpretation, will be discussed.

GEOLOGY PAPER 15

CRITERIA FOR DISCRIMINATING DRILLING-INDUCED TENSILE FRACTURES FROM NATURAL FRACTURES IN BASEMENT ROCKS

Adriaan Bal & Pedram Zarian

Baker Hughes Inc.

To date, a number of reservoir evaluation workflows have been developed and commonly used in exploration and production of fractured basement reservoirs. Identification of fractures from available borehole image logs has often been an integral part of such workflows. There have been, however, few critical analyses of methodology efficacy, especially in view of successful discrimination between natural fractures and drilling induced fractures in borehole image logs. In hard-rock reservoirs all hydrocarbon storage is in the open natural fractures, while drilling induced fractures are also open but do not contribute to the producibility of the reservoirs.

Moreover, differentiating between different fracture types is of great importance for correct determination of principal stress orientation as well as for correct assessment of a number of fracture attributes used in reservoir modeling (e.g. fracture density, length and spacing). Therefore, poor fracture interpretation can result in severe errors in total reserves estimates.

This study, using examples from basement fractured reservoirs of Southeast Asia, illustrates the problems and pitfalls facing the borehole image interpreter in discriminating between drilling-induced tensile fractures and natural open fractures. Particular attention is given to complex situations where drilling induced tensile fractures resemble natural open fractures because of the significantly inclined fracture traces on the borehole image logs. Different discrimination criteria are thoroughly re-evaluated and the validity of automated interpretation routines investigated.

GEOLOGY PAPER 16

IMPACT OF SPATIAL VARIABILITY IN MICROFABRICS ON THE THERMAL CONDUCTIVITY OF SUBIS LIMESTONE

Y.S. Lee[1] & E. Padmanabhan[2]

[1]Tectonics Group, Earth Observatory of Singapore, Nanyang Technological University, N2-01a-14, 50 Nanyang Avenue, Singapore 639798.
[2]Geoscience and Petroleum Engineering Department, Universiti Teknologi Petronas, Tronoh, Perak
eswaran_padmanabhan@petronas.com.my

SUMMARY

There are several facies in the Subis Limestone Formation. These include the skeletal rudstone, coral boundstone, mudstone and algal bindstone facies. The facies assemblage suggests a shallow biohermal depositional environment. Every facies is characterized by differences in fabric. This suggests also variation in the depositional environment. The resultant variation in microfabrics influences the thermal conductivity for each type of microfacies. Presence of corals, burrows, stylolites including differences in mineralogy between each facies appear to decrease the thermal conductivity values to varying extends. The mudstone facies has the highest thermal conductivity values among all other facies tested. The results of this study also suggest an inverse relationship between porosity and thermal conductivity values. This finding has some important bearing on the reservoir potential and stability of carbonates in general.

INTRODUCTION

Subis Limestone (Late Oligocene to Early Miocene) is believed to be an isolated bioherm built up in the midst argillaceous sediments. Tectonism created a shallow shoal environment which deposited coralline algae and large foraminifera (Banda, 2000). The Subis Fm. interfingers with Nyalau Fm. (Haile, 1962) and is surrounded by Sibuti Fm. (Hutchison, 2005). Continuous uplifting caused coral-algal reefoid growth in shallow shelf zone.

Limestone in Mount Subis has a lot of micro-variations. Such spatial and temporal variability suggests a complicated facies development model for Subis Limestone. Thermal conductivity in rocks is a function of the nature of the composites (fabric), rock type, mineralogy, porosity (air, liquid) and temperature. It is important to know possible variations in thermal conductivities in limestones as this will have the tendency to influence, for example, the stability of buried gas clathrates or even bore hole heat dissipation.

Therefore, the objective of this study is to evaluate the impact of spatial variability in the Subis Limestone on critical properties such as thermal conductivity. Such knowledge is very useful in order to characterize carbonate reservoirs better.

MATERIALS AND METHODS

Subis Limestone is located 65km south-west from Miri, Sarawak, Malaysia. An active quarry (DeBestone) at Subis Limestone was visited and four outcrops in the quarry were investigated. Two representative samples were taken from each rock type. Macroscopic study, microscopic study, and thermal conductivity were conducted on selected samples. Textural classification was done according to Embry and Kovan (1971). Thermal conductivity of the carbonate rocks were estimated according to Padmanabhan (2010).

Table 1: Thermal conductivity of the different facies in the Subis Limestone.

Facies	Thermal Conductivity (W m-1 k-1)
Mudstone	17.57
Skeletal rudstone	6.21
Coral boundstone	8.60
Coral boundstone	12.9
Algal Bindstone	14.05

RESULTS AND DISCUSSION

Spatial Distribution of the Facies

The facies identified in the study area are skeletal rudstone, coral boundstone, mudstone and algal bindstone. All these facies interfinger into each other (Fig. 1).

Substrate Dependency for the Distribution of Burrows

The spatial variability in the distribution of burrows has been attributed to the type of substrate (Bathurst, 1975). In this study, burrows were only detected in some localities and are attributed largely to the presence of mud-matrix.

Fabric Modifications with Corals as Coarse Fragments in Matrix

Corals are restricted in spatial distribution. All corals in Subis Limestone belong to hermatypic type. There might have a variety reasons that cause spatial and temporal variability in the presence of corals. Temporal changes in the environment of deposition are linked to eustatic sea-level changes. The fabric created by coarse fragments of corals (> 2µm) being incorporated into the matrix is reflected by a more porous matrix compared to mud-dominated or other types of microfacies. As porosity inadvertently increases, the thermal conductivity associated with the new composite internal structure decreases accordingly.

Influence on Thermal Conductivity

All the facies have different thermal conductivity values (Table1). According to Clauser and Huenges (1995), a variety of factors can affect the thermal conductivity of the rocks. Each facies showed that they have different mineralogy and fabrics. Presence of corals, burrows, stylolites and differences

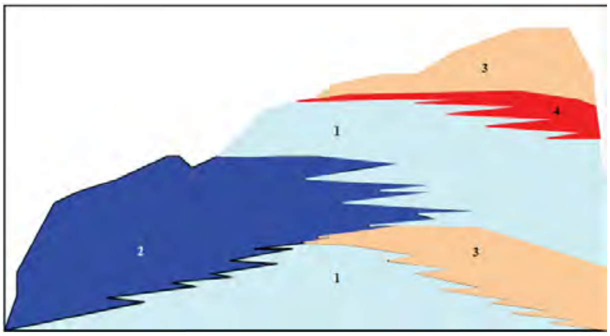

Figure 1: Spatial and temporal variability of the distribution of the various facies observed in the study area. 1 = Skeletal rudstone; 2 = Coral boundstone; 3 = Mudstone; 4 = Algal bindstone.

in bio-indices, including differences in mineralogy and fabrics between each facies appear to decrease the thermal conductivity values. The results show conclusively that thermal conductivity is inversely proportional to the porosity. It is therefore, possible to reclassify the carbonates based on thermal conductivity values as the linkages between high thermal conductivity values, porosity and subsequently, the reservoir potential is apparent. However, this is part of an ongoing study and the results for such a relationship will be discussed in another paper.

CONCLUSIONS

There is spatial and temporal variability in the distribution of facies in the Subis Limestone. Variations in the presence of stylolites and coral fragments are easily seen. The study indicates that this section of the Subis limestone strongly resembles a regressive reef sequence. The spatial and temporal variability of the micro-fabrics is linked to differences in thermal conductivities measured for these carbonate rocks. The study indicates that thermal conductivity in carbonates is inversely related to the porosity. This finding has some important bearing on the reservoir potential and stability of carbonates in general and is being currently pursued as a long term study.

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GEOLOGY PAPER 17

OROCLINES AND PALEOMAGNETISM IN BORNEO AND SOUTH-EAST ASIA

Charles S. Hutchison

Professor Emeritus, Geology Department, University of Malaya, 50603 Kuala Lumpur, Malaysia.

Oroclinal bending of Borneo is interpreted to result from indentation and collision by the continental promontory of the Miri Zone–Central Luconia Province of northern Sundaland into southern Sundaland. The collision caused strong compression and uplift of the intervening Sibu Zone Upper Cretaceous–Eocene Rajang-Embaluh Group turbidite basin that was floored by oceanic crust of the Proto South China Sea. Timing of the collision is indicated by uplift of turbidite formations to be overlain by Upper Eocene–Lower Oligocene carbonates [Sebuku and Melinau Limestone] and intrusion of tin-mineralised granites into the turbidites at the south-east maximum inflexion of the orocline, a region of complicated juxtaposition of both shallow and deep water formations. The West Crocker Formation (Late Oligocene to Early Miocene) post-dates the uplift of the turbidite zone, but the Eocene Trusmadi Formation, at the foothills of Mount Kinabalu, was an integral part of the Rajang Group of the Sibu Zone into Sabah.

The oroclinal model, requiring clockwise rotation of the north-west limb, is given no support from the paleomagnetic data that instead demonstrate about 50° of Cenozoic anti-clockwise rotation. Unfortunately not a single outcrop of the strongly oroclinally bent Sibu Zone was measured for paleomagnetism in the north-west limb. Limited support was given for the required anti-clockwise rotation in the north-east limb. Previous syntheses emphasised anti-clockwise rotation, or stable non-rotation of the greater Borneo region (Murphy, 1998) as a coherent entity, without any internal deformation (e.g. Hall, 2002). Dick Murphy rejected the Tertiary paleomagnetic data for Borneo because a stable single entity did not agree with the active Tertiary tectonism that characterises the island. The single entity models have ignored the oroclinal shape defined by the areal geology of the island, known since early Dutch publications [the tectonic zones of Van Bemmelen, (1949)]. "Orocline" was not then in the geological dictionary, and we had to wait for Warren Carey (1955) to coin the term and for Marshak (2004) to define orocline characteristics and origins.

The northern Thailand–Myanmar north–south-trending geology fabric results from indentation by a promontory of continental India at the Assam-Yunnan oroclinal syntaxis, resulting in paleomagnetically-determined clockwise rotation. The bend of Peninsular Malaysia and Sumatra, from north–south changing to west–east towards Borneo in the south, has remained difficult to model because of widespread remagnetisation. But this is now demonstrated to be part of the Borneo orocline

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GEOLOGY PAPER 18

INTEGRATED PETROPHYSICAL EVALUATION OF THIN BED FORMATION: A CASE STUDY FROM FIELD OFFSHORE MALAYSIA

Diego Maya & Nizam Abu Bakar

Baker Hughes Inc,25th Floor Menara Tan & Tan, 207 Jalan Tun Razak, 50400 Kuala Lumpur, Malaysia
Diego.Maya@baker.huges.com; MohdNizam.AbuBakar@baker.huges.com

Asset managers generally consider reasonable precise and accurate volumetrics to be important before taking decisions about exploring and producing hydrocarbon reservoirs. One of the many uncertainties that affect volumetrics is the true hydrocarbon saturation of thin bedded sand-shale sequences. Uncertainties related to thin bedded sequences may affect reservoirs by up to 50%, and often even more.

Modelling net pay in low-resistivity thin bedded pay zones is challenging. In wells drilled near perpendicular to bedding, conventional resistivity instruments measure the resistivity along bedding, the horizontal resistivity. The horizontal resistivity is dominated by the shale conductivity and consequently the true resistivity, ergo sand saturation, is significantly underestimated. In contrast, the measurement of the resistivity perpendicular to bedding, vertical resistivity is more sensitive to the resistive hydrocarbon bearing sand laminae.

Horizontal and vertical resistivity has been recorded in this local case study. A robust petrophysical model is constructed and shale and thin-bed sand volume, and true resistivity, was calculated. When integrated with the conventional Thomas Steiber porosity model, a more accurate computation is obtained. Zones with low resistivity anisotropy may point to disturbed low productivity zones. The borehole resistivity image tool allows the identification and quantification of thin laminations; this information is integrated with petrophysical results in order to have a consistent earth model.

This paper discusses the integration of multi-component induction and borehole resistivity images into one enhanced and consistent earth model which allows accurate saturation modelling of thin bedded sand-shale sequences in a local Southeast Asia example. Conventional LWD resistivity showed low resistivity zones, potential misinterpreted as water bearing. The vertical resistivity computed by the multi-component induction tool clearly identified high resistivity intervals interpreted as hydrocarbon bearing zones. The petrophysical model quantified thin bed sand volume and true hydrocarbon saturation. The image data acquired in this well confirmed the laminated model and contributes to net-to-gross calculations. The results show net increase in pay of XX% (with no cut-offs) and XX% when conventional cut-offs are applied.

GEOLOGY PAPER 19

TYPICAL PORE PRESSURE REGIMES IN THE MALAY BASIN – INSIGHT FOR OTHER BASINS GLOBALLY

Richard Swarbrick[1], Stephen O'Connor[1], Rick Lahann[1], Jamaal Hoesni[2], Bitrus Pindar[1], Sam Green[1] & Steve Jenkins[1]

[1]GeoPressure Technology Ltd, Stockton Road, Durham, DH1 3UZ, England
[2]Petronas Carigali Sdn Bhd, Level 16, Tower 2, Petronas Twin Towers, KLCC, 50088 Kuala Lumpur, Malaysia.

The Malay Basin is a Tertiary trans-tensional rift basin located in offshore Peninsular Malaysia and is one of the most prolific hydrocarbon-producing basins in Southeast Asia. Over 12 km of fine-grained Tertiary sediments were deposited during the last 35 Ma, leading to development of overpressure in the deeper parts of basin (Hoesni et al., 2003). On the Basin Flank (Resak-Beranang – Regime A), reservoir sediments are normally pressured to depths in excess of 3.0km, on account of a high sand/shale ratio. Beneath Regime A sediments, a strong pressure transition zone is expected (e.g. Beranang-1; Mohamad et al., 2006), with attendant challenges for pre-drill prediction and safe well planning. Shale-prone sediments, both shallow (e.g. on continental slopes) and deep (e.g beneath Regime A) which have been isolated from fluid escape by low-permeability shales correspond to Regime B, which is characterised by having high overpressures. Pressure prediction in Regime B characterised by Well LA-3, works satisfactorily if reservoirs are limited in their vertical relief and/or there are no open faults connecting stacked or cross fault reservoirs.

Where temperatures exceed approximately 100-120^{o}C additional pressure generation mechanisms commonly involve clay mineral diagenesis and hydrocarbon generation reactions are present (Regime C). These processes influence rock properties, notably porosity, thereby requiring modification to the standard rock property-effective stress relationships used to predict pore pressures. In the Malay Basin the depth these isotherms are shallow due to the high geothermal gradient of 45-60^{o}C/km

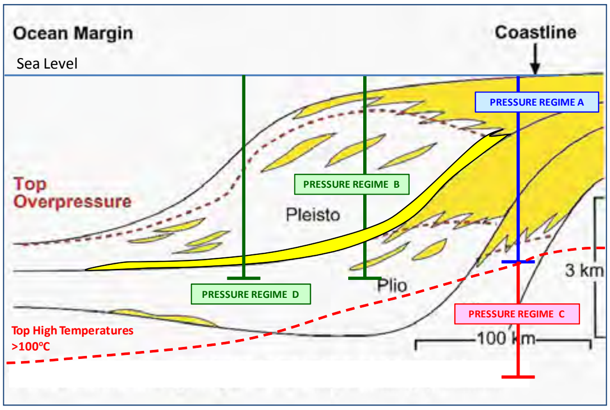

Figure 1: Location of Pressure Regimes A-D in a typical deltaic environment.

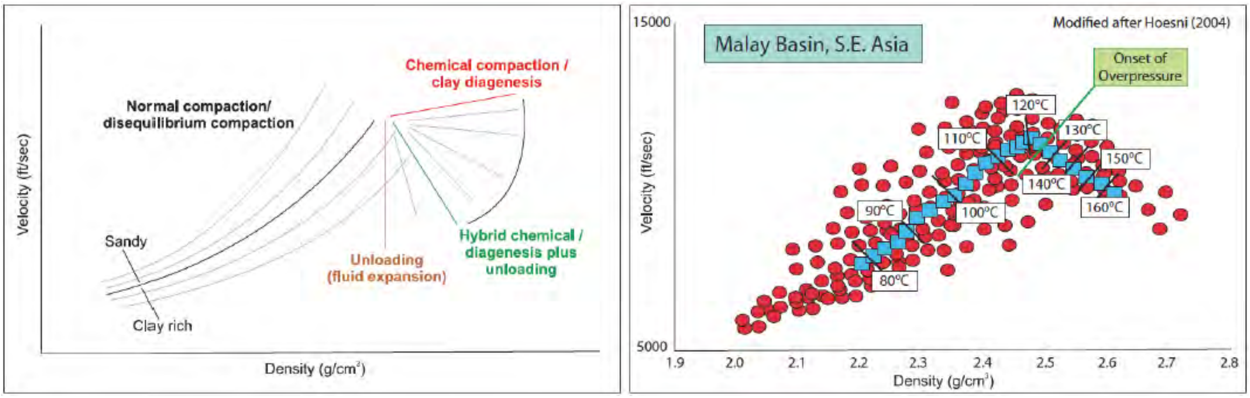

Figure 2: Secondary overpressure generation mechanisms typical of Regime C can be detected using velocity and density analysis (Modified after Hoesni, 2004).

(Madon, 2007). Finally where reservoirs are connected within the delta (perhaps laterally draining to the surface, or confined within low-permeability sediments but with high relief) lateral fluid movements once again render traditional approaches to shale-based pore pressure prediction more challenging. Regime D can therefore be found at any depth range. The range in fluid pressures in parts of the Malay Basin at the same depth (and in reservoirs of the same age) suggests that Regime D is likely in this Basin.

Although it is vital to be aware that there is no short-cut to accurate fluid pressure prediction, these Regimes are observed in many environments world-wide including Tertiary Deltas such as the Niger Delta and Gulf of Mexico.

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GEOLOGY PAPER 20

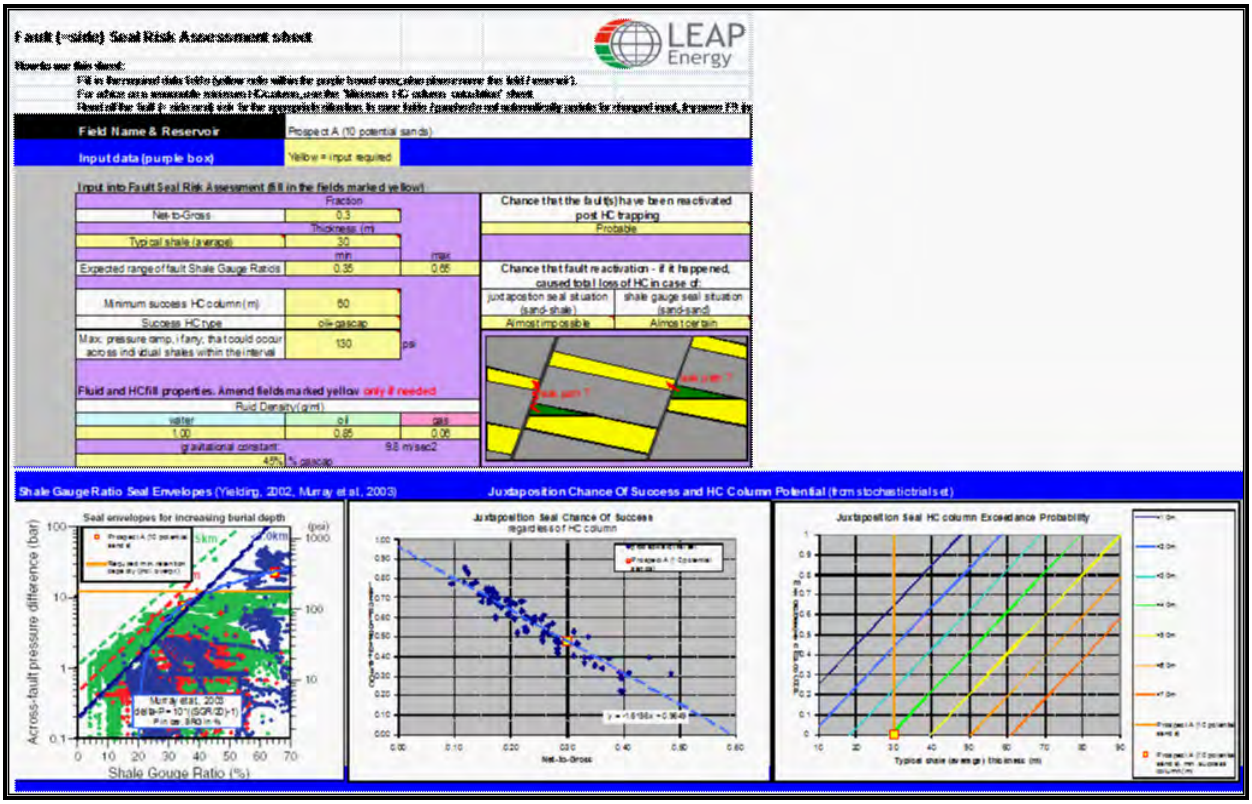
ASSESSING FAULT SEAL RISK AND FAULT SEAL RETENTION CAPACITY IN STACKED CLASTIC RESERVOIRS

Arnout J.W. Everts

LEAP Energy Partners Sdn Bhd, Suite 46-3, Level 46, Menara Citibank, 165 Jln Ampang, 50250 Kuala Lumpur, Malaysia

The prospectivity of structural or combination traps in stacked clastic reservoir settings typical of many of the known hydrocarbon provinces in Southeast Asia such as Baram Delta and Balingian province, often critically hinges on the presence of a working fault side seal. A thorough understanding of the key controls on fault seal risk and retention capacity and from there, a consistent methodology to access these factors across a prospect portfolio, are essential to achieve a balanced prospect ranking and an accurate assessment of prospect success volumes.

Faults in a clastic reservoir typically seal through either one of a combination of the following mechanisms: juxtaposition of reservoir against non-reservoir, the development of impermeable gauge within the fault zone either because of clay smear, mixing of sand and shale in the fault gauge, or through grain size reduction within the fault zone (cataclasis). Fault seals can be breached if pressure buildup exceeds retention capacity or in cases of fault movement post hydrocarbon emplacement. The objective of this paper is demonstrate how stochastic simulation of juxtaposition relationships along faults in combination with reference to literature published data on retention capacity of shaly fault gauges (e.g., Yielding et al., 1997; Yielding, 2002; Freeman et al., 2008) can be used to generate quantitative insights in the relationship between measurable reservoir properties such as net-to-gross ratio and typical thickness of reservoir sands and intervening shales, and the chances of fault seal success as well as the likely retainable hydrocarbon column in a success outcome. Quantitative estimates of the chances of success and the expected range of retention potential can be done for a single reservoir-seal pair, but they can easily be expanded to predictions for a series of stacked reservoirs using binomial distribution theorem. The paper will show how a simple but elegant toolkit incorporating these relationships can be used (Figure 1) to successfully replicate the hydrocarbon distribution of known discoveries (Figure2, Figure 3) e.g., in Balingian province. A tool like this can be used to assess the fault seal success Chance Factors, i.e., the chances of fault seals being able to retain a hydrocarbon fill equal or exceeding the P90 area, in a consistent manner across a prospect portfolio. Whilst the methodology and toolkit described here considers the complete "outcome tree" of success and failure cases, it can also be shown that under certain specific circumstances many of the outcomes have extremely low probability of occurrence. For example, the retention capacity of shaly fault gauge should always be in the range of some 50psi or more even if the net-to-gross ratio is relatively high, which means that failure on Shale Gauge seal is unlikely unless there are significant pressure ramps or the fault re-activates post-hydrocarbon emplacement. By removing the low probability outcomes for specific cases



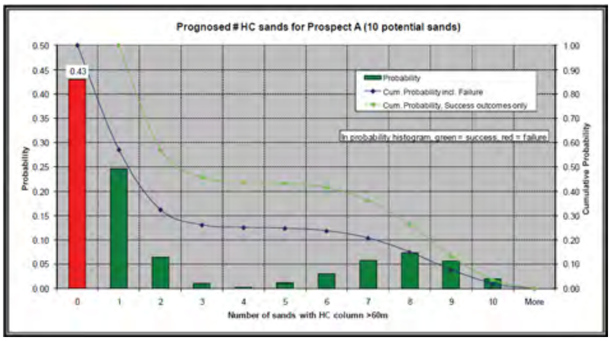


Figure 2: Fault seal Chance of Success (cos) prediction for Field A, for an aggregate of 10 potential reservoir zones. This simulation of fault seal success considers all possible seal mechanisms and aggregates the individual chance factors. Simulated fault seal results compare well with the findings in fields nearby to Prospect A where only 10 to 40% of the sands have significant HC fill (column length >60m).

under consideration, we can simplify the "outcome tree" to a set of simple rules that can guide an operator to identify leads prospects with a high chance of fault seal success.

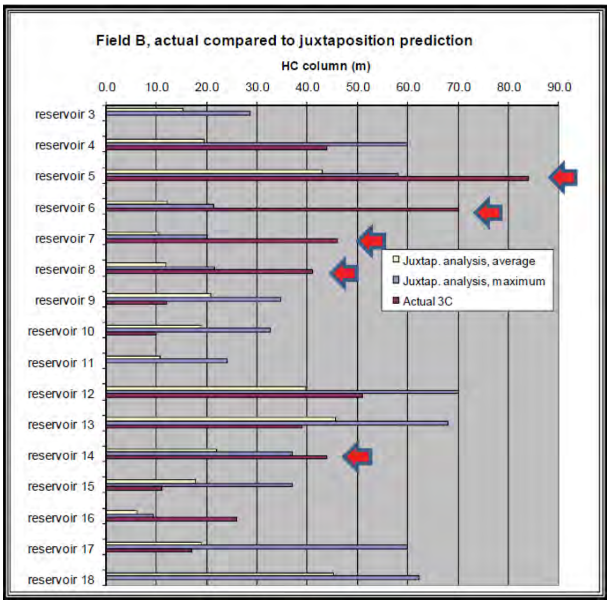


Figure 3: Predicted potential for juxtaposition seal for Field B, compared to actual well results. Note that the trends in predicted column height match the actually observed HC columns fairly well, suggesting juxtaposition seal is one of the key sealing mechanisms in Field B. The red arrows mark reservoirs where other seal mechanisms (e.g., shale fault gauge) may play a role as actual HC columns are significantly beyond the estimated juxtaposition seal retention capacity.

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GEOLOGY PAPER 21

LABUAN OUTCROP REVISITED: NEW FINDINGS ON BELAIT FORMATION FACIES EVOLUTION

M Rapi B M Som* & M Fauzi B A Kadir, Siti Syareena M Ali, Shamsuddin Jirin, W M Khairul W Sulaiman, Norshida Mohsin & Shahriza Salwani M Shah

PETRONAS Research Sdn. Bhd., Bangi, 43000 Kajang, Selangor, Malaysia.
*rapim@petronas.com.my

The sedimentary successions of the Belait formation exposed across the northern side of the Labuan Island has been studied by various workers such as Hazebroek, 1993; Levell, 1983, 1987; Tate, 1994. Based on his work, Mazlan Madon (1994, 1997) concluded that the basal Belait Formation was deposited in fluvial system developed over an eroded Temburong landscape in an overall transgressive regime. Facies development in the basal Belait reflects a quick change transition from fluvial systems (braided to meandering) to shallow marine successions represented by coarsening-upward offshore shales to shoreface sandstones.

The presence of two (2) new outcrops provide the opportunity to further study the lateral continuity and vertical facies succession within the Belait Formation. A total of nine (9) outcrop sites including two (2) new locations were studied and logged and 142 samples were taken and analysed for biostratigraphic information.

Results showed that the fluvial succession within the Belait Formation is not presence above the Temburong Formation at the new outcrop and replaced by coastal plain, fresh/brackish water estuarine successions. The fluvial succession thickened away from the new outcrop in the direction of Layang-layangan in the west and Tg. Kubong to the east. Furthermore, the fluvial succession in Tg. Kubong is also thinner than previously reported (Mazlan, 1994). Rapid change form fluvial to estuarine environment was observed based on biostratigraphic data. Interms of vertical facies development, we proposed that there are two (2) incised valleys developed where the fluvial succession was deposited and rapidly overlain by brackish water fluvial-estuarine deposits. The new outcrop area is interpreted as an interfluve and appears to be where the center of the anticline is located. The relatively thin fluvial to shallow marine transition above the sequence boundary, implying rapid deepening due to the steepening depositional surface, coupled with rising sea level and uplifting in the new outcrop area. This finding will help us in understanding the relationship between sea level, tectonic activity and vertical/laterar\l facies development.

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GEOLOGY PAPER 22

FABRIC ANOMALY IN MUD CLAST DISTRIBUTION IN THE LAMBIR FORMATION (MID TO LATE MIOCENE), SARAWAK.

E. Padmanabhan[1] & Mohd Pauzi, A.S.[2]

[1]Geoscience and Petroleum Engineering Department, Universiti Teknologi Petronas, Tronoh, Perak;
[2]Petronas Carigali Sdn Bhd, Petronas Twin Towers, Kuala Lumpur.

SUMMARY

There is an increasing interest in the anisotropy of mudstone systems mainly due to seismic anisotropy caused by change in wave velocity and polarization with propagation direction. Therefore, the study was to evaluate the variability in the mud clast distribution in the heterolithic sequences present in the Lambir Formation. Mud clasts show differences in size, shape, thickness, continuity and orientation with respect to the general bedding attitude. The clasts are generally ellipsoidal in shape despite some of them being subrounded. It is evident that the amount of energy needed to transport the larger mud clasts was more than that needed to transport the finer sand grains. The origin of mud clasts remains debatable as the energy setting in which it occurs is generally not in favor of the stability of this feature. Results suggest that size variation of mud clasts with increasing distance from the base could be quite erratic in some places despite a general trend of fining upwards. We introduce the term "fabric anomaly" to describe this feature. The Lambir Formation has tremendous variability at various scales of observation. The fabric anomaly exhibited by mud clasts has the potential to impact critical properties of the clastics.

INTRODUCTION

Currently, there is an increasing interest in the anisotropy of mudstone systems (Schon et al., 2006; Dewhurst and Siggins, 2006) mainly due to seismic anisotropy caused by change in wave velocity and polarization with propagation direction (Valcke et al., 2006) in fine grained rocks. Perhaps the first hint of spatial variability in the Lambir Formation was given by Wilford in the early 60's when he referred to the Lambir Formation as being generally more calcareous at the base and become more clastic towards the upper part. More recent studies have shown tremendous variability in the Formations in the area (Padmanabhan, 2010; Padmanabhan et al., 2010a&b) and that these variations have an impact on critical properties of the rocks. There is still a lack of information and knowledge on the heterogeneity of the sedimentary rocks in this area.

As such, the general objective of this study was to evaluate the anisotropy in the Lambir Formation. The specific objective of this study was to evaluate the variability in the mud clast distribution in the heterolithic sequences present in the Lambir Formation.

MATERIALS AND METHODS

The study area is part of the Lambir Formation and is located approximately 20km south of Miri (Fig. 1). This study is part of a major study initiated in 1997 to evaluate spatial – temporal variability in Borneo. Mud clasts were systematically measured in several outcrops where they occurred. Parameters such as length, width, orientation and density were recorded spatially and temporally.

RESULTS AND DISCUSSION

Field Characteristics

The heterolithic facies present in this Formation has several subfacies of which one is the gray sandstone with flasers of mudstone subfacies (occasionally variants include localized occurrences of laminations of mudstone and sometimes with laminations of coal as well, Fig. 2A). Several types of mud clasts were observed in this subfacies (Fig. 2B). The differences lie mainly in the size, shape, thickness, continuity and orientation of the clasts with respect to the general bedding attitude. Generally, there is a fining upward with regards to the size distribution of the mud clasts suggesting an allochthonous origin (Fig. 2B). The clasts are generally ellipsoidal in shape despite some of them being equigranular and subrounded. These subrounded clasts are usually found scattered throughout the bed (Fig. 3). The size of the subrounded clasts can be variable. The sandy matrix has a consistent texture throughout. However, from an energy point of view, it is evident that the amount of energy needed to transport the larger mud clasts was more than that needed to transport the finer sand grains. Thin laminations of gray mud can occur as parallel or inclined laminations to bedding planes.

The origin of mud clasts remains debatable as the energy setting in which they occur is generally not in favor of the stability of this feature. In addition to this, it can be seen (Fig. 2B) that clasts are ubiquitous on both sides of crests of older clay laminations. Fig. 3 also suggests that size variation with increasing distance from the base could be quite erratic in some places despite a general trend of fining upwards.

Taking into consideration the fact that the presence of clasts is a highly localized feature and the distribution pattern appears unpredictable within the strata in which it occurs, this sedimentary feature is unique and deserves a better recognition that that which has been accorded. As such, we wish to introduce the term "fabric anomaly" to describe this feature. The proposed definition for the term as follows:

Fabric Anomaly: A feature that is part of a fabric and which meets one or more of the following criteria:

(a) (i) It is observable in a rock mass, and
(ii) Designated as a subordinate event, possibly a secondary process, in the chronology of events leading to the development of the strata in question, OR

(b) Constitutes more than 5% by volume but not exceeding 20% of the strata or bed, OR

(c) Does not manifest as a major feature of the entire outcrop or core but is limited in occurrence to less than 5% of the entire outcrop or core in question, OR

(d) Contains in part or whole, material of different origin or mineralogy, OR

(e) May comprise more than one type of fabric feature within a vertical and lateral distance of 25 cm

CONCLUSIONS

The study shows that it is advantageous to link the lithological variations to changes in the energy of deposition rather than to link them to generalized environments of deposition. Vertical variations in the mean dimensions of mudclasts show that there is a possibility that the energy level decreased temporally at a microscale. The spherical and

Figure 1: Location of the study area (red box).

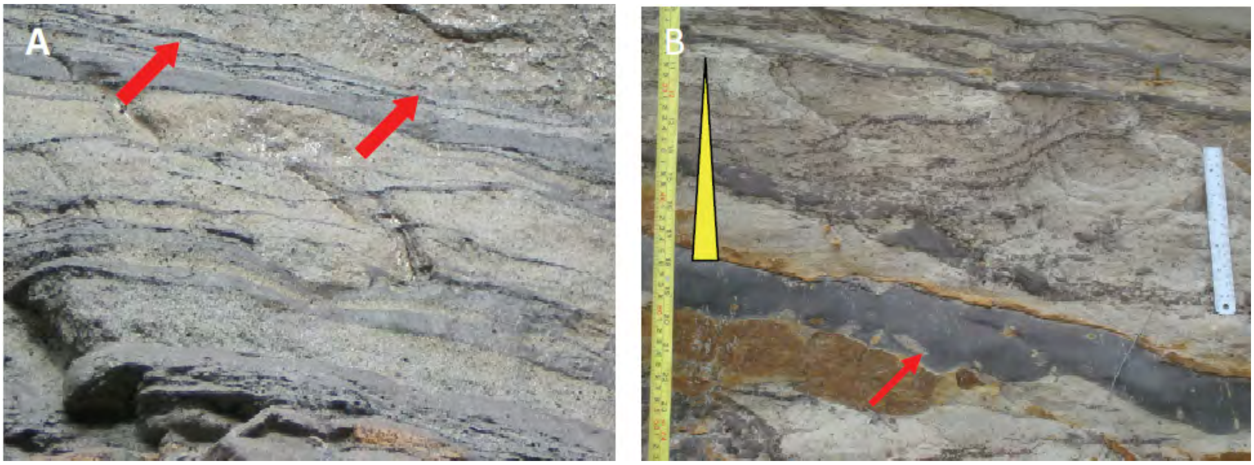

Figure 2: A. Thin laminations (arrows) of carbon (coal) alternating with flasers of gray mud in gray fine sandstone. B. Variations in mud clast size, shape and orientation. (Small lenses of sand present in mudclasts (arrow). Mud in crestal position does not act as a feeder for clasts).

platy morphologies is indicative of progressive changes in transportation distance as well as possibly variations in the degree of erosional processes. The origin of mud clasts remains debatable. Results suggest that size variation of mud clasts with increasing distance from the base could be quite erratic in some places despite a general trend of fining upwards. We introduce the term "fabric anomaly" to cater for this feature.

It is concluded that the depositional processes leading to the development of the Lambir Formation have tremendous variability at various scales of observation. The fabric anomaly exhibited by mud clasts has the potential to impact critical properties of the clastics.

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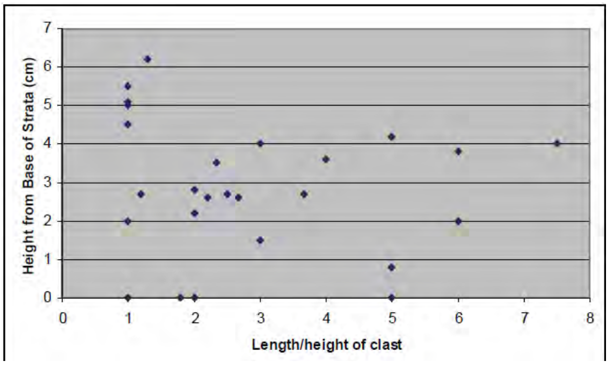

Figure 3: Variations of mean dimensions of clasts as a function of vertical distance from the base of the strata.

GEOLOGY PAPER 23

AN OVERVIEW OF THE PROVEN PRE-TERTIARY KARSTIFIED AND FRACTURED CARBONATE BASEMENT PLAY-TYPE IN THE OFFSHORE NORTHERN VIETNAM

Jamin Jamil Mohd Idris[1], Renato M. Borbajo[2], Herculito Balasbas Caalim[2], Hoang Thuy Lan[2] & Abdullah Dim[2]

[1]PREX, PMU, Level 16, Tower 1, PETRONAS Twin Towers, KLCC, 50088 Kuala Lumpur
[2]PC Vietnam Limited, PETRONAS Tower, Royal Centre, 235 Nguyen Van Cu Street, District 1, Ho Chi Minh City, Vietnam

Over the past 6 years, PETRONAS Carigali Overseas Sdn Bhd (PETRONAS), through its exploration arm in Vietnam, has explored for the hydrocarbon potential of the Pre-Tertiary karstified and fractured carbonate Basement play-type in offshore northern Vietnam (Figure 1). The first encounter of this play type in the subsurface offshore northern Vietnam was in 2004 when severe mud losses were experienced when the A-1X exploration well penetrated 'caves' in the carbonate Basement. Since then, effort was intensified and further technical analysis was carried out until PETRONAS successfully made a commercial discovery in the "D" structure through the D-2X exploration/ appraisal well drilled earlier this year. This milestone discovery has proven the prospectivity of the Pre-Tertiary karstified and fractured carbonate Basement play-type, the first of its kind in the offshore northern Vietnam.

The reservoir penetrated consists of limestone and dolomitic limestone, which can be closely analogue to the similar carbonate formation exposed as 'islands' at Ha Long Bay (Figure 2), located some 100km to the North-Northeast from the discovery. This Carboniferous-Middle Permian dolomitic limestone, interbedded with oolitic limestone and calcaro-cherty shale is referred to as the Bac Son Formation (C-P2), which is about 1000m thick, monoclinal and undulatedly folded, containing foraminifera beds from Chernyshinella, Dainella, etc. to Cancellina, Neoschwagerina, Werbeekina beds gathered with remains of crinoids, brachiopods, bivalves, bryozoa, etc. and corals, conodonts, radiolarians etc. (Tran Van Tri, et al., 2003).

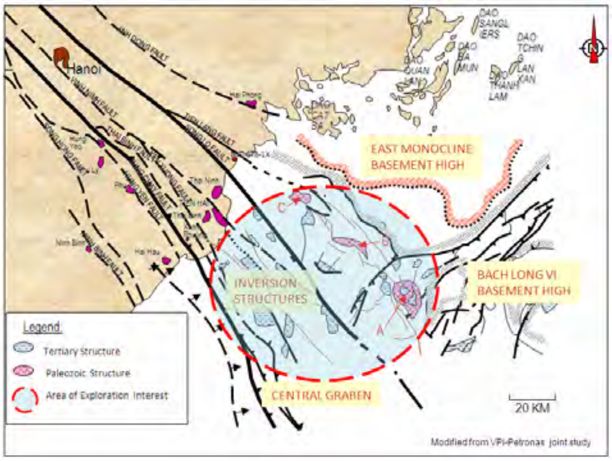

Figure 1: The offshore northern Vietnam area where PETRONAS had explored particularly for the Pre-Tertiary fractured and karstified carbonate Basement is circled in red. This map also shows the main structural element of the area which consists of; i) Central Graben and Miocene Inversion structures to the south of Song Lo fault, ii) A-B-C Ridge extending to B10-STB-1X well onshore, iii) Bach Long Vi Basement High in the east and iv) East Monocline Basement High in the north.

Apart from the cavern system evidence from the outcrop in Ha Long Bay (Figure 3), the carbonate karst-hill and tower karst structures are also fractured, similar to the results from the wells drilled into the Pre-Tertiary carbonate. These faults and fracture sets are believed to have contributed to the increased secondary porosities and permeabilities by acting as the reservoir conduits that connect to the cavern system and matrix (Nelson, 2001).

According to Jamin, et al, 2009, successful hydrocarbon exploration in such play-type offshore northern Vietnam is attributed to a working petroleum system defined by the interplay of the following factors: i) presence of porosities and voids in the carbonate reservoir; ii) increased permeability due to the presence of faults and fractures; iii) presence of a thick and mature lacustrine shaly section which acts both as a source rock and top and lateral seal; and iv) structural formation (Pre-Tertiary) predating oil expulsion and migration. Oil expulsion and migration from this lacustrine source rock began during early-mid Miocene.

The biggest uncertainties and challenges arise from the poor to marginal quality of the current seismic data at the reservoir level which puts a limitation on accurate fractures/lineament and cavern mapping and prediction and also on mapping the base of the carbonate. A much better data quality and more advanced techniques might help to reduce these associated uncertainties.

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Figure 2: The landscape of the Carboniferous-Middle Permian Limestone 'islands' in Ha long Bay, offshore Northern Vietnam showing karst geomorphology and fractures. Ha Long Bay belongs to Quang Ninh Province, adjoining to the Hai Phong City, with an area of 1553 km2 which includes 1,969 islets (Tran Van Tri, et al., 2003).

Figure 3: Modern cave as part of karst system, "Surprise" Cave, Ha Long Bay, offshore northern Vietnam. Clockwise from top left: i) cave opening with cave floor breakdown breccias; ii) pillars set forming a large limestone pillar; iii) cave chamber (over 30 meters high) and passage; iv) pillars and stalagmite with breakdown pile at the base.

GEOPHYSICS PAPER 1

MAPPING REGIONAL SEDIMENTARY HORIZONS IN THE ONSHORE BARAM DELTA, SARAWAK, FROM MAGNETIC AND GRAVITI DATA USING ENERGY SPECTRAL ANALYSIS

Stephen Markham[1], Shiferaw Damte[1], Irena Kivior[1], Simon Randle[1], Masahide Shimada[2], John Jong[2], Hajime Kusaka[2] & Tran Quoc Tan[2]

[1]Archimedes Consulting Pty Ltd 31 Stirling Street, Thebarton, SA 5031, Australia
[2]JX Nippon Oil and Gas Exploration Corporation Lot 1168, 3rd Floor Wisma Interhill, Miri Waterfront Commercial Centre, 98000 Miri Sarawak

SUMMARY

Aeromagnetic and airborne gravity data acquired over the onshore Baram Delta, Sarawak, Malaysia, was used to estimate depth to economic basement that is the Top Cretaceous (Horizon-1), and depth to three intra-sedimentary horizons: Top and Base of Carbonates (Horizon-2 and Horizon-3), and the top of an additional shallower interface (Horizon-4). Depths to these horizons were calculated through the analysis of energy spectra of the observed magnetic and gravity fields, while faults and magnetic lineaments were derived through the application of an automatic curve matching (ACM) method based on the Naudy technique.

The project involved the application of a new spectral technique, termed the Multi-Window-Test (MWT). The application of the MWT allowed quick estimation of depth to multiple horizons (skeleton maps) and also provided a set of optimal window sizes used for detailed mapping. The potential field derived results correlate well with both seismic and well data. Spectral methods have been successfully applied in the study area, and the MWT has proved itself a valuable tool in producing a robust interpretation of potential field data.

INTRODUCTION

Archimedes undertook a study of potential field data covering the onshore Baram Delta for Nippon to map the economic basement, and three sedimentary horizons (Top and Base Carbonates, and an additional shallower sedimentary horizon) and to determine the regional structural trends of the basin. The objectives were achieved by the use of Energy Spectral Analysis 'Multi Window Test' and 'Moving Window' (ESA-MWT and ESA-MW) techniques.

A study of aeromagnetic data was performed (Figure 1a), with the aim of mapping two horizons: Base Carbonate (Horizon-2), and the top of a shallower horizon (Horizon-4). In addition, the MWT procedure was applied to gravity data (Figure 1b) to determine the depth to the economic Basement (Horizon-1), Top Carbonate (Horizon-3), and the top of a shallower horizon (Horizon-4).

The primary tool employed in this project was Energy Spectral Analysis (ESA). A new refinement of the spectral analysis technique was conducted in two stages:

First, to identify magnetic or gravity interfaces, the ESA-MWT was run at stations located on a 4km by 4km mesh over the whole project area. MWT was used to compute the average depths to the targeted horizons and to construct the horizon skeleton maps. MWT was instrumental in overcoming some of the limitations of the spectral method as traditionally employed, by detecting the optimal window sizes required for detailed mapping at every MWT station.

The second stage, the detailed horizon mapping involved an application of the ESA-MW technique. The spectra are computed and interpreted for the optimal window size determined from the MWT 'depth-plateaus' over a dense mesh 1.4 km by 1.4 km for each mapped horizon.

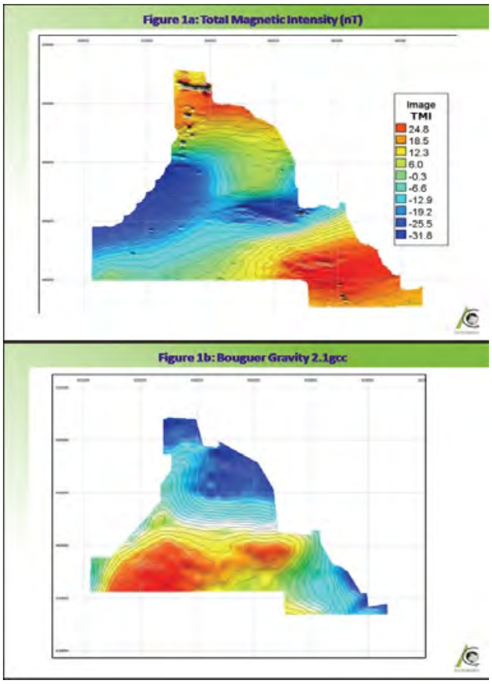
ACM was used along profiles to define major faults and lineaments, and forward modeling undertaken to confirm the interpretations.

ENERGY SPECTRUM ANALYSIS

ESA is a well-established technique for estimating the depth to a (magnetic/gravity) horizon, originally based on the work of Bhattacharyya (1966). Following Spector and Grant (1970), a magnetic/gravity interface is modeled by a statistical layer of magnetized multi-prisms. The logarithm of the radial average spectrum plotted vs. radial frequency produces a curve that has a slope proportional to the depth. In order to obtain an estimate of depth in a localized area, ESA is applied to a windowed sub-region of the potential field data. By performing ESA-MW procedure at multiple locations, a depth map of the interface can be produced (Kivior et al. 1993).

ESA WINDOW SIZE

The most important factor for applying the ESA-MWT procedure is determining the correct window size. If the window is too small, it will not incorporate enough of the data for successful imaging of the horizon; if it is too large, the low frequency spectral decay will be dominated by deeper magnetic/gravity sources. The MWT estimates the depth over a span of window sizes centered over a point of interest (MWT station); estimates that are not sensitive to window size correspond heuristically to magnetic susceptibility or density interfaces.



The MWT procedure consists of calculating energy spectra over a series of increasingly larger windows (Figure 2), all centered over a point of interest. Ranges of window size where the derived depth value is nearly constant, "Depth-Plateaus", indicate both a suitable window size for performing ESA-MW in the neighborhood and the approximate depth to the causative magnetic/gravity interface. Coupled with fast, automatic spectral decay estimation, the MWT can be applied along a profile or over a whole survey area on a regular mesh (Figure3a), to quickly map both depth estimates and stable window sizes for ESA-MW. It is quite possible for each station to have multiple depth-plateaus, and these can often be successfully identified with distinct magnetic susceptibility or density interfaces. At any station, the MWT may identify from the depth-plateau the approximate depth to the mapped horizon and estimate the corresponding optimal window size. Plotting all depth-plateaus along a profile can simultaneously image multiple horizons. Depth-plateaus identified as the same interface, form a coarse image of the detected horizon, called a 'horizon skeleton map' (Figure 3a).

GEOLOGICAL SETTING

The tectonic evolution of the study area is dominated by the interaction between the Eurasian continental plate, the oceanic Indian and continental Australian plates and the oceanic Pacific plate. The interactions between these plates make the region geologically complex with two tectonic models, which show either an extension or subduction of the South China Sea. The major tectonic events that affected the region are the Eocene Sarawak Orogeny and the Eocene-Early Oligocene Sabah Orogeny, with the top of the economic basement corresponds with the Deep Regional Unconformity (DRU), below which lies the Mesozoic Ragang Group, a highly deformed mélange of deeply buried sediments. This accretionary complex is overlain by the Eocene sand-rich West Crocker Formation and the Belait Formation sandstones.

HORIZON MAPPING IN THE ONSHORE BARAM DELTA

We applied the ESA-MWT to magnetic and gravity data sets across the study area at the stations located at 4km by 4km mesh. MWT was used to estimate spectral decay, in order to detect depth-plateaus to obtain an average estimate of the depth to the targeted horizons and to identify optimal window sizes for more detailed horizon mapping (ESA-MW).

Figure 2 shows an example of the MWT graph at one station computed from the gravity data, where the depth-plateaus are showing the stability of the depth solution with respect to window-size. Each depth-plateau represents a density contrast related to the following horizons, economic Basement (Horizon-1), Top Carbonate (Horizon-3) and an additional shallower sedimentary horizon (Horizon-4). Similar procedures have been repeated for each station all over the area. Depth-plateaus were identified and approximate average depths from the plateaus were used to construct a skeleton map of Horizon-1,

Horizon-3 and Horizon-4 from gravity data. The magnetic data was analyzed in a similar manner. The MWT stations were repeated on the same regular mesh over the whole area. The plateaus were identified and skeleton maps were constructed based on approximate average depths for Horizon-2 and Horizon-4. An example of the skeleton map for Horizon-1 is shown in Figure 3a. For both data sets, for each single station, for each separate horizon the optimal window size was determined from the depth-plateaus and used to perform detailed horizon mapping.

The detailed mapping was undertaken using the ESA-MW technique. For each horizon and each data set, spectra of different window sizes were computed at a very dense mesh of 1.4km by 1.4km. The detailed maps of the following horizons were produced: from gravity, economic Basement (Horizon-1), Top Carbonate (Horizon-3), the shallower intra-sedimentary horizon (Horizon-4). From magnetics, Base Carbonate (Horizon-2), and the shallower intra-sedimentary horizon (Horizon-4) from

Figure 2: Multi-Window Test results plotted as Window Size Vs Depth

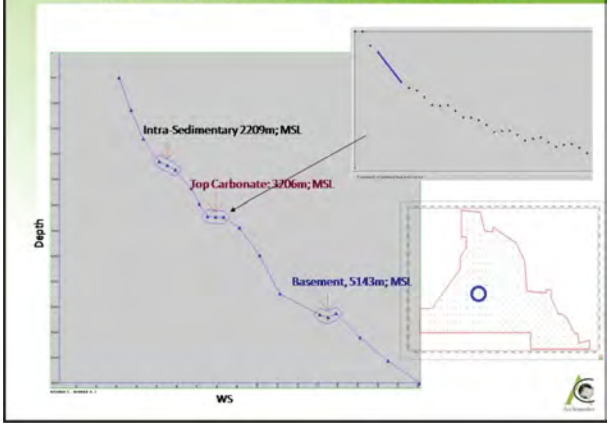


Figure 3a: Gravity Basement Skeleton Map, Datum: MSL (4x4km)

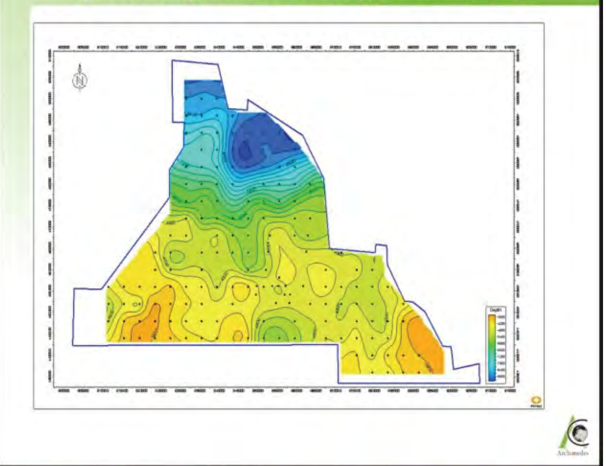
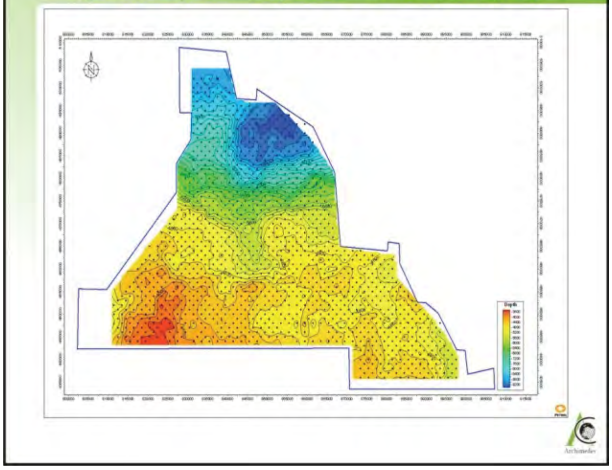


Figure 3b: Gravity Basement Map with location of values (~1.5km spacing)



both data sets. As we analyse potential field data representing different rock properties, the same horizons cannot necessarily be imaged from both magnetic and gravity datasets.

In Figure 3 there is a comparison between the basement skeleton map and the high resolution detailed map. It is clearly visible that detailed mapping highlights many small features and structures which could be of great importance for petroleum exploration. Detailed mapping outlines high resolution details that are not visible on the skeleton maps. Both, the skeleton maps and final detailed horizon maps were QC'ed by comparison with well, seismic data and forward modeling of the magnetic and gravity data using the generated surfaces. As shown in Figure 4, there is a very good correspondence between horizons detected from magnetic and gravity with those derived from seismic.

Figure 4a: Seismic line 23 -Baram Delta Block SK333

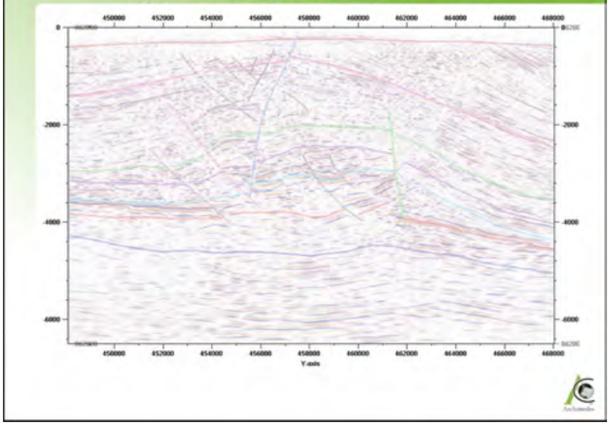
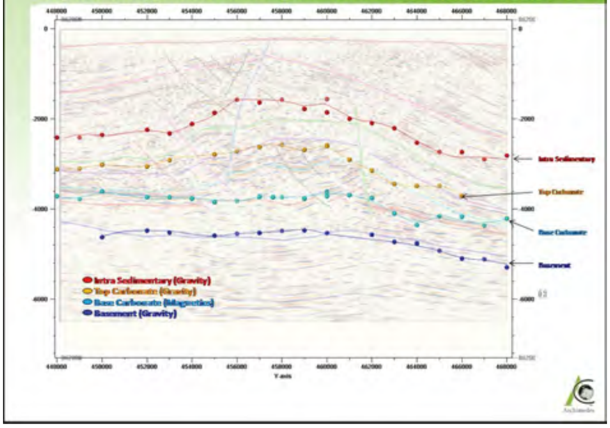


Figure 4b: Mapped Horizons along Seismic line 23 -Baram Delta Block SK333



CONCLUSIONS

We can conclude that in the onshore Baram Delta the analysis of magnetic and gravity data can provide very good estimates of depths to magnetic susceptibility and density interfaces. The MWT technique identifies magnetic susceptibility and density contrasts which can be mapped as continuous surfaces. Further, the ESA-MW technique is a valuable tool for producing detailed images of the sedimentary horizons.

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GEOPHYSICS PAPER 2

EFFICIENCY OF TDEM AND EM-IP METHODS APPLICATION FOR RESERVOIRS EXPLORATION IN SOUTH EAST ASIA

Yuri A. Agafonov[1], Mustapha M. Salleh[2], Sophia V. Kompaniets[1], Olga V. Markovceva[1], Ilya V. Egorov[1] & Igor V. Bouddo[1]

[1]Irkutsk electroprospecting company, Floor 6, Rabochyaya Street, 2A, Business center "Premier", 664011, Irkutsk, Russia.
[2]Onyx Engineering Sdn Bhd, Suites 23A-03 & 04, Floor 23A Plaza 138, 138 Jalan Ampang, 50450 Kuala-Lumpur, Malaysia.

SUMMARY

Application of electromagnetic methods for oil and gas exploration is developing world-wide. Two main types of EM methods are applied: natural source (MT) and methods with artificial source of EM field (TDEM, FDEM) [2]. For hydrocarbon exploration on land high efficiency has transient electromagnetic method in frequency or time domain mode. The role of EM methods is increasing at the areas with poor seismic data quality, non-structural fields and zones with complicated structure of sedimentary cover. Joint interpretation of EM data with seismic or other geological data is a way to reduce the risks and optimize the process of geophysical investigation.

For oil and gas exploration it is possible to study sedimentary layers resistivity at the depth interval from surface to basement and also a lot of information can be received from induced polarization (IP) parameters. The paper is devoted to technique of EM methods combination – TEM and EM-IP for oil and gas exploration, and possible ways of its effective application. Forward modeling results for geoelectric models are shown.

TDEM IN OIL AND GAS EXPLORATION TOOLBOX

The method of near-field transient electromagnetic sounding (TEM) study the EM-components decay after turn off current in transmitter loop. Therefore the observations are performed at the distance to the source not exceeding the depth of key horizon. Stationary source is used with alternate pulsing/receiving. Here we have better resolution due offset, smaller size of sounding set, superior detail and locality of investigations, no influence of lateral near-surface heterogeneity. TDEM effectiveness is confirmed by many years application for solve difficult geological problems across the whole world. EM methods can be used for exploration, studying and characterization of the complex three-dimensional geoelectrical structures typical for ore deposits and hydrocarbon reservoirs [3].

To carry out TEM ungrounded loops are used that enables one to do works all year round and virtually under all climate conditions: permafrost, arctic, deserts, steppe terrains and others.

The investigation depth in TDEM soundings is corresponded with decay time. Measuring time depends on summarized conductivity of sedimentary cover or the average value of electric resistance of layers. TDEM is an induction sounding that's why the square-shaped, non-grounded loops are applied as the sources and receivers of electromagnetic field. For oil and gas exploration usually 500 × 500 m – 800 × 800 m square transmitter loops are applied. Current amplitude can reach 150 – 200 Amps. It depends on resistance of transmitter loop cables and voltage from generator (200 – 400 V). Multi receivers measuring systems with different offset let capabilities to study layers resistivity for all sedimentary cover. TDEM multi-channel telemetric equipment allows to perform field survey with high productivity. Basic specifications of modern EM systems and software for processing and inversion are presented.

The main geological objectives: acquisition of geoelectrical parameters of section that characterize the structure of hydrocarbon promising complexes, estimation of geological section of sedimentary cover, definition of the resistivity of main geological layers based upon the inversion of TEM data, definition of the induced polarization (IP) parameters of the upper layers based upon the inversion in combination with galvanic EM-IP method data, exploration for HC reservoirs in the section of sedimentary cover [1]. Figure 1 illustrates TEM geoelectric section from Eastern Siberia along profile crossing 2 separated HC traps. Blue anomalies indicate presence of reservoirs at the different depths intervals of sedimentary cover – up to 3000 meters.

EM TECHNIQUE FOR INDUCED POLARIZATION STUDY (EM-IP)

To acquire reliable geological results, when using the EM methods with artificial sources at the areas with low-resistivity media, it is demanded to complicate the technology of field works and procedures of data interpretation. The other parameters to gain, in addition to electric resistivity of the target intervals of the section, some researchers apply induced polarization (IP) of shallow layers. However this criterion needs a profound petrophysical research, besides, it cannot be applicable as a reliable criterion in all regions elsewhere.

TEM may be applied for oil and gas prospecting under conditions of low resistivity values, e.g. in sedimentary basins of the «young» Mesozoic section. In this case the geoelectric model is characterized by a high conductivity of host rocks, and target structures-reservoirs with HC have higher resistivity relative to them. The varying rock properties within the discovered fields are responsible for the electric heterogeneity of the media, occurring as noticeable anomalies in electromagnetic fields. As recorded by electric logging, in the hydrocarbon traps and its surroundings, there are regular changes of electric resistivity. The zone of variations, affected by action of hydrocarbons on host rocks, covers the overlying part of the section. Such features commonly cause higher resistivity of the field, as compared to the boundary zone, and increase in resistivity of cover rocks. Besides, the EM survey can also receive induced polarization anomalies associated with the secondary sulfide mineralization in host rocks. The polarization in the anomalous zones may be from 2 to 5 times higher than the depth interval of target reservoirs. Due to seepage of fluids in tectonically active areas, where hydrocarbons migrate through disturbed zones upward, it is feasible to find pyritization aureoles over deep occurrences.

The technique of carrying out of exploration by EM-IP method means use of galvanic type of a current transmitters and receivers – the grounded electrical lines. According to Cole-Cole model EM-IP results are layers resistivity ρ of a sedimentary cover, polarization factor η, relaxation time τ and width of relaxation spectrum c. The complex analysis of the received parameters allows allocating the most perspective zones of reservoirs with hydrocarbons. In this paper combined application of TEM and EM-IP methods considering for oil and gas exploration (Figure 2).

FEATURES OF A SEDIMENTARY COVER GEOLOGICAL STRUCTURE OF SOUTH EAST ASIA REGION

To estimate possible efficiency of application of TDEM and EM-IP methods for exploration of the sedimentary cover typical for region of South East Asia, it is necessary to define physical-geological model. Resistivity models considering in the abstract based on wells data, seismic and geological information.

Sedimentary basins of territory of South East Asia in zones of transition from continent to ocean with an active tectonic mode are extremely various as on a geological structure, and structure of the rocks, capable to contain hydrocarbons. The oil and gas fields are dated not only for deltoid sandstones, coastal-sea genesis, limestones and dolomite rocks, but also to silicate and volcanic rocks. They are opened in a weathering intrusion of granite and metamorphic rocks of the base, crumbling basalts and other magmatic rocks.

Hydrocarbonic fluids are almost nonconducting, the basic contribution to conductivity of sediments is caused by water solutions. TDEM is focused on studying of electrical resistivity of layers. The method is as much as possible effective in the conditions of moderate conductivity of sedimentary cover (up to 200-300 Sim) of ancient platforms.

Considering the region of South East Asia presence of deposits of hydrocarbons both in a sedimentary cover, and in a weathering intrusion of the base is characteristic, it is possible to present the following geoelectric model. The terrigenous and carbonate rocks of Cainozoic age are characterized by low values of resistivity (from units to first tens Ohm·m). The crystal basement, mainly mesozoic age, is combined granite, crystal slates and metamorphic limestones which resistance exceeds 1000 Om·m. In such geoelectric conditions target objects of exploration are reservoirs layers with the raised resistivity in

comparison with bearing strata. Also anomalies of polarizability parameters of near-surface layers can be indicator of HC saturation of reservoirs. For an objective estimation of efficiency of application of TDEM and EM-IP for oil and gas exploration mathematical forward modeling are performed. The purpose is definition of sensitivity of EM decay signals to changes of layers resistivity and anomalies of the induced polarization corresponded with hydrocarbons traps in deep layers.

RESULTS OF MATHEMATICAL MODELING

On the modeling results it is obvious, that even at insignificant difference of resistance of target horizon from containing rocks, on late times of decay curves the difference reaches 2%. For optimum conditions with high contrast of geoelectric properties the difference exceeds 6%.

Results of EM-IP method modeling are represented on Figure 3. In case of presence in sediments of a polarized layer EM-IP signals are changed in comparison with not polarized model more than on 20%. The received results of modeling show about high sensitivity of TDEM and EM-IP methods for hydrocarbons exploration in South East Asia. Paper show modeling results examples and its analysis for estimation of EM methods capabilities.

CONCLUSIONS

Results of mathematical modeling show high sensitivity of EM curves to changes of geoelectric parameters of a sedimentary cover for South-East Asia. Feasibility studies results are presented. It is possible to consider that the joint analysis of resistivity anomalies and the induced polarization parameters increase reliability of oil and gas exploration. TDEM methods also can be successfully applied for geohazards problems, mineral and ground water exploration, 4D monitoring and others.

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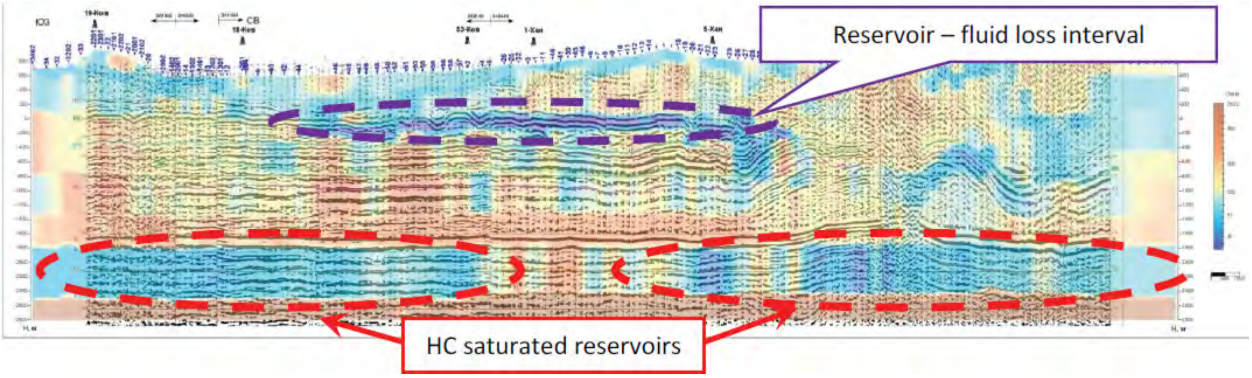


Figure 1: TDEM resistivity section at the gas-condensate field (Eastern-Siberia, Russia).

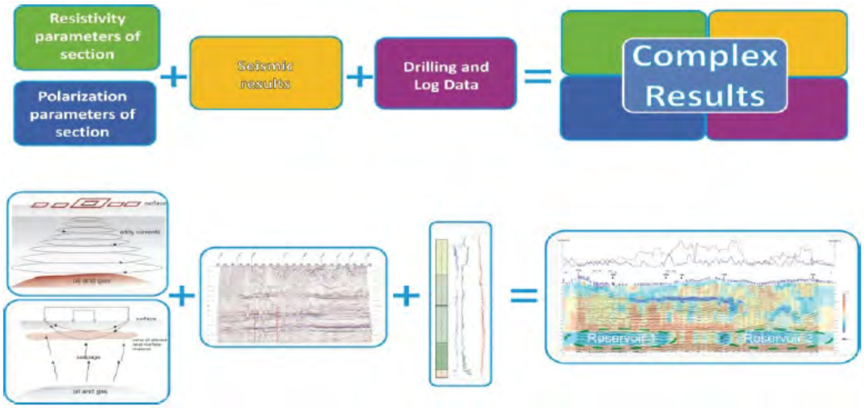
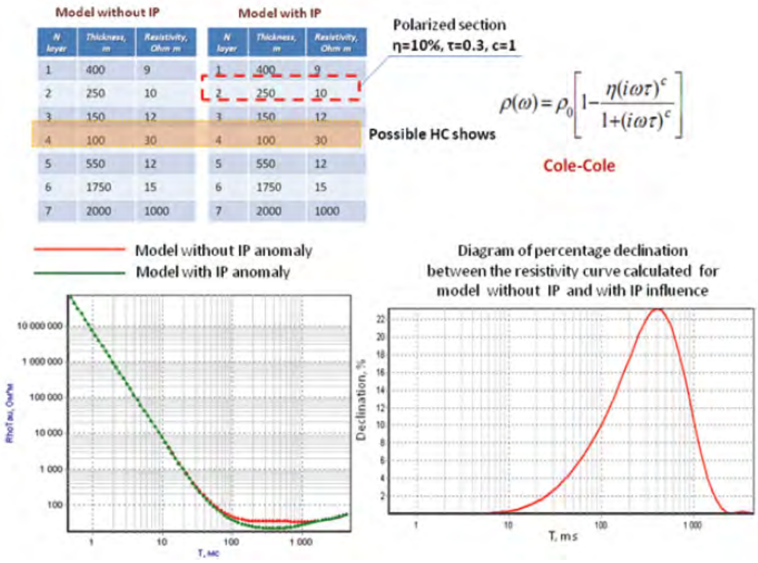


Figure 2: The flow chart of TEM and EM-IP methods application.



Model without IP

N layer	Thickness, m	Resistivity, Ohm m
1	400	9
2	250	10
3	150	12
4	100	30
5	550	12
6	1750	15
7	2000	1000

Model with IP

N layer	Thickness, m	Resistivity, Ohm m
1	400	9
2	250	10
3	150	12
4	100	30
5	550	12
6	1750	15
7	2000	1000

Figure 3: EM-IP method, AB-MN modeling results with IP parameters – HC presence indicator. Geoelectric models with IP anomaly at the 2 layer and without it (above) and apparent resistivity curves for template AB=1200 m, MN=600 m (below).

GEOPHYSICS PAPER 3

ROTATION OF BORNEO REVISITED – NEW INFERENCES FROM GRAVITY DATA AND PLATE RECONSTRUCTIONS

Stan Mazur, Christopher Green, Matthew Stewart, Rkia Bouatmani & Paul Markwick

GETECH Group plc, Kitson House, Elmete Hall, Elmete Lane, Leeds LS8 2LJ, UK; stm@getech.com

Borneo has commonly been considered to have undergone two stages of major anti-clockwise rigid-block plate rotation - 50° between 80 and 30 Ma and 40° between 30 and 10 Ma (e.g. Fuller et al., (1999) and Hall (2002), based on interpretations of palaeomagnetic data from Kalimantan and Sarawak). These interpretations have recently been challenged (Cullen, 2010). Considerations based on gravity data and plate modelling add further concerns.

Cullen (2010) pointed out that the earlier authors had rejected those palaeomagnetic data that did not match their model, using the argument of young re-magnetisation. If those data are taken into account, the 30-10 Ma anti-clockwise rotation must have been restricted to smaller tectonic blocks, with no rigid-plate rotation of Borneo as a whole. It should also be noted that the palaeomagnetic data from

Borneo provide similar results to those for the Malay Peninsula, Sulawesi, the Celebes Sea and parts of the Philippines; this suggests that any rotation should be applied to a block much larger in extent than just Borneo (Fuller et al., 1999).

This suggestion that Sundaland remained a continuous continental shelf - albeit with the formation of deep sedimentary basins due to extension and subsidence processes (Hall, 2002) - is further supported by the lack of evidence for the strike-slip faulting in the Java Sea area that would be required in order to accommodate large amounts of rotation of Kalimantan with respect to a more stationary Java. Large gravity lineaments running east-west through Kalimantan and into the Sea of Kalimantan as well as distinct ENE-WSW gravity anomalies continuing across the Java Sea and into Sumatra are both seen as evidence of crustal continuity. To test the rigid-plate model, the gravity map of the area was reconstructed to 30 Ma according to the rotations of Hall (2002).

The rotation produced a clear misfit along the western coast of Borneo, with the large gravity lineaments that run E-W through central Borneo obliquely overlapping the distinct gravity anomalies trending ENE-WSW in the East Java Sea. The rotation further resulted in significant shortening west of Borneo and substantial extension to the east of the island. However, the Thai and Malay basins preclude compression as late as the Neogene. The implied stretching for the eastern coast of Borneo is far too high compared to our calculations from 2D gravity models and furthermore, sedimentary basins of that area (e.g. Kutai Basin) recorded a phase of inversion in the Early and Middle Miocene. We are therefore in agreement with Cullen (2010) that there is no support for a major (40°) anti-clockwise rotation of Borneo in the period 30-10 Ma.

Based on our results, we propose an alternative plate model that predicts 12-13° of clockwise rotation for Kalimantan and Sarawak relative to South China since 30 Ma. Northern Sabah is separated in our model from Sarawak and Kalimantan by a plate boundary which implies a common tectonic history for northern Sabah and southern Palawan (cf. Cullen, 2010). This history must have been different from the evolution of the remaining part of Borneo up to the Middle Miocene docking of the Palawan Block to the northern margin of Borneo and the Cagayan Ridge.

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GEOPHYSICS PAPER 4

DETERMINATION OF AVO ATTRIBUTES FOR HYDROCARBON RESOURCES REGION OF MALAY BASIN: THE FLUID FACTORS

Goh T. L., Uzir Alimat, Shaidin Arshad & M. Izzuljad Ahmad Fuad

PETRONAS Research Sdn Bhd, Lot 3288 & 3289, Off Jalan Ayer Itam, Kawasan Institusi Bangi, 43000 Kajang, Selangor, Malaysia

Fluid factor is one of the most important AVO attributes in seismic for reservoir hydrocarbon prediction. The typical published fluid factor, ΔF =1.252A+0.580B was derived based on Castagna's mudrock equation (Castagna et al. 1985), Vp=1.16Vs+1360 and Gardner's relation (Gardner el al.1974), Δ=0.23Vp0.25 and was developed based on brine saturated siliciclastics data obtained from Gulf of Mexico. These are true as hydrocarbon indicator for reservoirs of Gulf of Mexico. Since the geological settings for Malay basin are different with Gulf of Mexico, therefore the determination of fluid factor for Malay Basin is very crucial. The respective values of A and B were the intercept and the gradient attribute of reflection amplitude versus sin2Δ plot. Castagna and Smith (1994) reported that the respective value of fluid factors for background (nonpay) and shale/gas-sand interfaces are zero and negative. In this paper, the fluid factor equations based on local mud rock equations as outlined in Table 1 (Vp versus Vs and density versus Vp plot), which were obtained from brine saturated siliciclastics data of 48 wells, were established for respective six petroleum resources regions, Malay Basin. The six petroleum resources regions as illustrated in Figure 1 were divided based on geographical locations and play types, namely region 1 - North Malay Region;

region 2 - West Malay Region; region 3 - South Malay Region; region 4 - Southeast Malay Region; region 5 - Northeast Malay Region and region 6 - Central Malay Region. The rock physical trend lines for region 1, 2, 3, 4, 5 and 6 were established based on 7, 3, 7, 5, 14 and 12 wells data respectively. The respective fluid factor equations for six petroleum resources region 1, 2, 3, 4, 5 and 6 were ΔF=1.235A+0.568B, ΔF=1.219A+0.563B, ΔF=1.238A+0.586B, ΔF=1.222A+0.608B, ΔF=1.228A+0.573B and ΔF=1.263A+0.536B.

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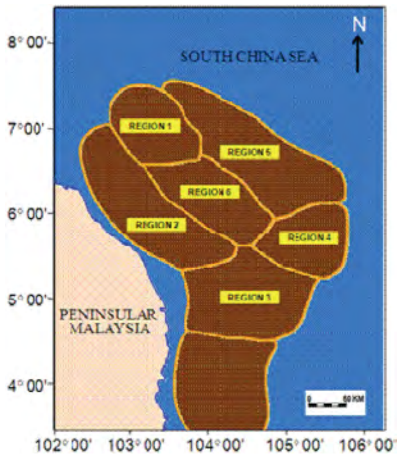

Figure 1: Six petroleum resources regions, Malay Basin

Table 1: Vp-Vs and density-Vp and fluid factor equations for six petroleum resources region.

Region	Number of wells	Vp-Vs equation	Density(Δ)-Vp equation	Fluid factor (ΔF) equation
1	7	Vp=1.1373Vs+1140.6	Δ=0.2141Vp0.2949	ΔF=1.235A+0.568B
2	3	Vp=1.1257Vs+1214.4	Δ=0.1550Vp0.3328	ΔF=1.219A+0.563B
3	7	Vp=1.1720Vs+1133.2	Δ=0.2627Vp0.2689	ΔF=1.238A+0.586B
4	5	Vp=1.2168Vs+1100.7	Δ=0.2491Vp0.2769	ΔF=1.222A+0.608B
5	14	Vp=1.1457Vs+1181.7	Δ=0.1967Vp0.3049	ΔF=1.228A+0.573B
6	12	Vp=1.0720Vs+1250.5	Δ=0.2480Vp0.2768	ΔF=1.263A+0.536B

GEOPHYSICS PAPER 5

SOFT SHALE COMPLICATION IN AVO INTERPRETATION IN SABAH BASIN

Alex Tarang & Yeshpal Singh

Petronas Carigali Sdn Bhd, Level 16, Tower 2, Petronas Twin Towers, KLCC, 50088 Kuala Lumpur, Malaysia.

Field A is a faulted EW trending anticline which has been produced for more than two decades from early Miocene sand. It is very important to understand the rock elastic properties for the purpose of near field wildcat exploration. In Field A, the shale which capped sands is called 'A' shale and roughly 70-100m thick across the field. The upper part of the 'A' shale has Acoustic Impedance(AI) higher than that of the shale, however, the lower portion of the shale is the opposite. Therefore, such a response imposed a challenge to differentiate the sand and shale responses on seismic data set.

Detailed rock physics modeling on petrophysically conditioned logs is a must in order to quantify the elastic properties of the shales with reference to underlying sand reservoir. Figure 1 shows the representative well log response and histograms for shales and sand. Our analysis revealed that soft shale seismic amplitude response is similar to that of the gas sand. The proper AVO/rock physics modeling of the soft and hard shale and the various fluid fill sands responses are necessary in order for us to do correct AVO analysis and thus to be used correctly in the prospect de-risking process. It has been observed that elastic properties like Elastic Impedances, LambdaRho-MuRho are necessary in order to distinguish among them. In addition, proper conditioning of the pre-stack gather is also necessary in order to improve the data quality and enhance the subtle contrast.

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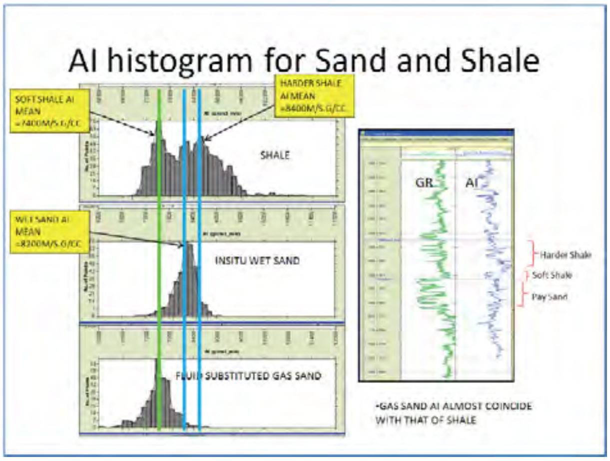


Figure 1: A representative Gamma Ray (GR) and P-Impedance (AI) logs and the AI histograms for shale, wet sand and fluid substituted gas sands over the zone of interest (after Tarang et al, 2010).

GEOPHYSICS PAPER 6

AN INTEGRATED APPROACH TO RESERVOIR APPRAISAL AND MONITORING USING WELL LOG, SEISMIC AND CSEM DATA.

Lucy MacGregor[1], James Tomlinson[2] & Skander Hili[2]

[1]OHM Rock Solid Images, The Technology Centre, Claymore Drive, Bridge of Don, Aberdeen, UK
[2]OHM Rock Solid Images, Level 23, Tower 2, eTiQa Twins, 11 Jalan Pinang, Kuala Lumpur, Malaysia

The controlled source EM method has developed into a tool that is often used in de-risking the exploration process. In this paper we demonstrate how the intrinsic sensitivity of the CSEM method to hydrocarbon saturation can be utilised within a framework of well and seismic data in prospect appraisal and reservoir monitoring applications. This will be illustrated with examples of the rock physics linking elastic and electrical properties along with recent case studies.

CSEM methods use a high powered marine source to generate an electro-magnetic field within the earth.. The detected response of the earth to this electro-magnetic field is recorded by an array of receivers located on the sea-floor. By interpreting the recorded response using forward modelling and inversion approaches, the resistivity structure of the subsurface can be determined. In many situations electrical resistivity is driven by the properties and distribution of fluids in the earth. Resistivity measurements in well logs often show that commercial hydrocarbon deposits may be many times more resistive than surrounding lithologies. In principal, such variations should be readily detected using CSEM receivers. In contrast, seismic data are sensitive to boundaries between lithologic units but are less sensitive to fluid changes within these units. Given high quality seismic data, well logs, sophisticated seismic inversion and rock physics tools, we have the potential to relate changes in seismic rock properties to saturation effects. Nevertheless, the change in resistivity caused by variations in saturation should be much easier to detect.

However, despite the increased sensitivity of resistivity data over seismic data for the determination of saturation, there are two inherent challenges to interpreting CSEM data. Firstly, the structural resolution of CSEM data is poor. Secondly, the cause of resistivity variations "anomalies" (particularly high resistivity features) cannot be uniquely linked to the presence of hydrocarbons in the subsurface when taken in isolation. In many situations these are equally likely to be caused by other highly resistivite material (for example, tight carbonates, salt bodies or volcanics). Both of these limitations must be addressed when considering the applicability of CSEM to answer a specific geophysical question, and as far as possible mitigated by the interpretation approach adopted.

CSEM data can, of course, be interpreted in isolation, and if there were no seismic data or wells in the vicinity of the CSEM dataset (for example if a survey were performed in a frontier area), then this would be necessary. However, with no constraints on this interpretation, the result will suffer from the non-uniqueness and ambiguity which blight unconstrained interpretation approaches. Although resistivity is imaged, the poor structural resolution of the method means that such images are diffuse and difficult to interpret. The uncertainty in the depth of features is large, so that they cannot be unambiguously attributed to a particular stratum. If there are multiple resistive features, these cannot be easily separated, and small resistive bodies are likely to be lost or smoothed into surrounding strata during the inversion process. Even assuming that localized resistivity anomalies can be found, the cause of these anomalies cannot be unambiguously linked to the presence of hydrocarbon.

In the presence of seismic and well information, the question that we are trying to answer with the CSEM data becomes significantly better posed. The question is no longer one addressed at finding a reservoir, but rather one of determining the content of a defined structure. Using seismic information the reservoir structure is known (but potentially not its content or extent), and we have independent constraints on the surrounding strata within which it is embedded. This is therefore a well constrained interpretation problem and one that the CSEM data are in a much better position to answer.

It is clear that a careful combination of all three data types can supply information that is not available, or is unreliable, from any one data type alone. By integrating complementary sources of information and exploiting the strengths of each, estimates of rock and fluid properties such as gas saturation and porosity can be obtained with greater confidence than from any one data type alone.

As we step from an exploration setting though to appraisal and monitoring of a reservoir the level of constraint on the geological model increases, and therefore so does our confidence in the CSEM interpretation. This increased confidence in the result transforms CSEM into a tool that can quantitatively map hydrocarbon distribution and time lapse changes in hydrocarbon saturation away from the well bore.

SEISMIC FACIES ANALYSIS OF GROUP L AND M RESERVOIRS, SOUTHEAST OF MALAY BASIN

Noor Iryani Jumari[1], Hamdan Mohamad[2] & Nasaruddin Ahmad[2]

[1]Petronas Carigali Sdn Bhd, Level 15, Tower 2, Petronas Twin Towers, KLCC, 50088 Kuala Lumpur, Malaysia.
[2]Petronas Carigali Sdn Bhd, Level 16, Tower 2, Petronas Twin Towers, KLCC, 50088 Kuala Lumpur, Malaysia.

SUMMARY

Since PETRONAS Carigali Sdn Bhd (PCSB) has taken over Block XYZ in 2003, 3010 sq km of 3D seismic data were acquired and merged with existing 3D data acquired earlier over the producing fields. Currently, almost 80% of the block XYZ acreage is covered by 3D seismic data. The new data provides an outstanding opportunity to integrate the geology interpreted separately over the producing fields. From the available data on these groups, Group L and M has been identified as a potential new play and enhancing the stratigraphic trap in the south of Malay basin. PCSB has drilled eight wells deep down into the lower Group M, M110 and discovered oil and gas. The new oil and gas discovery in the southeast area of Block XYZ has proved that valid petroleum system is present in the deeper groups.

Group L & M reservoirs have been identified as potential hydrocarbon play in Block XYZ. Seismic facies interpretation is very useful to investigate this concept. Group L and M are deposited in the earlier stage of the basin formation (synrift), which is in fluvial lacustrine environment (EPIC report, 1994). A seismic facies project have been conducted with the aim to describe the seismic facies in the study area and to interpret the depositional setting of these deeper groups in Block XYZ by integrating seismic facies characteristics on 3D seismic data, well log and core data from key wells. It also aims to provide an improved understanding of the local and basin scale distribution of potential reservoir sands in the southeastern part of the Malay basin.

METHODOLOGY

The interpretation of the depositional setting was achieved by integrating the seismic facies characteristics on 3D seismic data, well log, core data and key wells (Fig. 1). The seismic data essentially gives a wide coverage compared to conventional core and core plug measurements. Cores are the most important and high resolution primary data to study the geology of the area. It can provide very detailed information, such as the grain size, stratifications, lithology types, porosity and permeability values and many more.

Thus, core data is given priority in most analyses as it will lead to interpretation on the depositional environment of the cores. However, the seismic data can provide information on the lateral extension and the distribution of the interpreted data as observed from the cores. Seismic is very useful in depicting on the regional picture on a larger scales. The process of palaeogeographic mapping construction must first be consistent with the isochrone maps that were generated at the interested levels. Isochrone map provide stronger evidence of sedimentary facies deposited in different settings represented by the accomodation space available during that particular period of time.

SEISMIC FACIES MAPPING

Seismic facies mapping was definitively explained in Ramsayer's (1979), based on interpreted 2D seismic sections prior to the advent of seismic workstations. This is referred to the "A-B-C" mapping approach, wher observations are made on the upper boundary (A), the lower boundary (B), and internal reflection character (C). As an example, a prograding seismic package with oblique clinoforms, toplap at its upper surface and downlap as its base would be noted as Top-Dwn/Ob (Fig. 2). By using the A-B-C, method, the seismic facies method can be mapped on the basemap.

Base on the seismic characteristics on the seismic sections, the seismic facies can be classified as in the table below (Table 1).

CORE ANALYSIS

From the core studies at well NIJ-17, facies that has been deposited in the braided stream fluvial and distributary mouthbars environment has proved to be potential reservoir in these deeper groups, with porosity ranges from 10%-23%. The core data that were used for the study of Group L and M are from 7 wells namely NIJ-3, NIJ-10, NIJ-27 , NIJ-30, NIJ-33 and NIJ-35. These wells are mostly located in the southeastern part of the study area. The basin deepens towards the northwestern part of the study area with no core control in this part of the block. Sidewalls and core plugs can also be used to complement the analysis. The description of rock characteristics of the sidewall cores and mud log in the upper M group interval were also utilized and these data indicate that there was a gradual evolution of depositional facies from the deeper lake to the shallow lake.

WELL LOG INTERPRETATION

Well log analysis were carried out in this projectis basically on the study of gamma ray (GR) log curves. The interpretation of the GR log curves and the depositional environment were carried out for 6 wells in the L group and

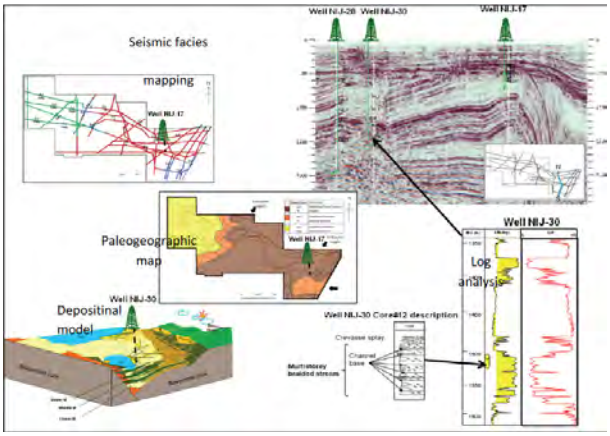


Fig. 1 : Integration of different scale data for paleogeographic map.

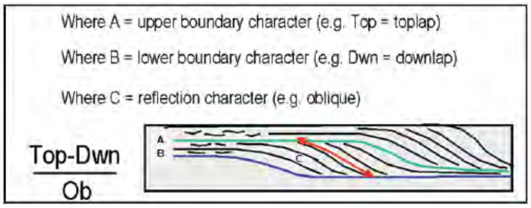


Fig. 2 : A-B-C seismic facies technique of Ramsayer (1979).

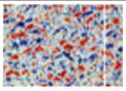
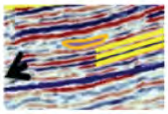
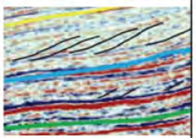
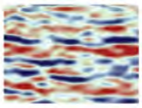
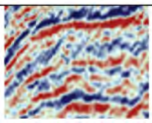
	Seismic facies	Captured image	Probable facies associated	Environment	A-B-C
	Sub-parallel chaotic features		Alluvial deposits	Alluvial deposits	Dwn-C Subp
	mostly parallel reflectors with little downlap, onlap or chanelling		Sandy braidplain : Channel fill Sandy braidplain : Channel lag Lakeplain	Braidstream Fluvial System to lakeplain	C-C P
	Parallel-non parallel, Wavy-hummocky features with some onlap and downlap		Distal distributary mouthbar/ lacustrine shoreface Proximal distributary mouthbar/ lacustrine shoreface	Distributary Mouthbars/ lacustrine shoreface	C-C Si
	Subparallel Low frequency Low-medium continuity		Lacustrine delta front, lacustrine shoreface	Lacustrine shoreface to lacustrine delta front	C-C Subp
	Discontinuity to low continuity reflectors with low frequency		Prodelta muds and sandy events beds Transgressive sands	Lacustrine Pro Delta	C-Di Subp

Table 1 : Seismic facies classification in Block XYZ.

3 wells for the M group. The relationships between facies and facies successions were seen in the gamma ray log. Successions were interpreted by comparison to publish analogue data from similar depositional environment, and general observation of log pattern interpretations. Gamma ray log facies trends generally reflect changes in the proportion of sandstones to shales, which in turn are inferred to record changes in the depositional energy of high to low current flows such as meandering/braided stream channel, floodplain or distributary mouthbars.

EVOLUTION AND DEPOSITIONAL MODEL

Four paleogeographic maps were constructed on top L and 3 levels within the M group (upper M, middle M and lower M) as shown in Fig. 3. The Syn-rift infill consists of fluvial and lacustrine sedimentary rocks (Group L and M). Irregular discontinuous reflectors, rotated by normal faults and increasing thickness towards the north-west, characterize the Oligocene Syn-rift section. The normal faults controlled thickness of the synrift sequence and, in general, the geometry of the structure. These highly influence the direction of sedimentation and the depositional environments for these earlier groups.

The lateral extension of the targeted facies can be observed from the paleogeographic maps produced from this study. These maps are important in the prediction of the deep reservoir potential in Block XYZ. The identification of the palaeoenvironment is based on the integration of seismic facies map, core data and information from wireline logs. The interpretation was made by refering to the model used for the depositional environment of groups K, L and M in the Malay Basin (EPIC report, 1994) which clearly showed that the sediments of groups L and M were deposited in a fluvial lacustrine settings. These comprised of alluvial systems, marginal lacustrine and lacustrine systems.

IDENTIFICATION OF POTENTIAL RESERVOIR DISTRIBUTION

Facies identified in well cores from the study area shows a down current change from fluvial channel deposits (meandering/braided) to stream mouthbars sandstones, delta sandstone, siltstone and claystone and finally into prodelta claystone and siltstone. Laterally adjacent to the braided stream systems are the natural-levee and crevasse splays and siltstone that were changed to flood-plain deposits. Further away laterally to the delta area, sand shoal, sand bar or shallow lake depositional system were deposited. This depositional system was located in shallow lakes, and away from the fluvial distributary mouthbar. Out of all these facies, only the braided-channel and the stream mouthbars are potentially good quality reservoir rock. The sandstone units within the L and M reservoirs are braided and stream mouthbars components and there is potential for future reservoir development in these deeper groups. From the test results, both facies has proven to have good to very good porosities (10%-23%) while the permeability within this facies is slightly low. However, the petrographic analysis results have shown the presence of fractures within the rock, that suggest there are permeability within the reservoirs in these deeper groups.

CONCLUSIONS

The availability of 3D seismic data has allowed for seismic facies analysis of the deeper groups in Block XYZ leading to a new petroleum play and enhancement of production from the block in the future. The findings from this study will serve as a reference for facies distribution, especially the reservoir facies, which would be significant in supporting the exploration and development of associated deep hydrocarbon fields. The integration of various data types has helped the analysis and interpretation of depositional patterns for the reservoir facies across the block. The exploration of new ground from the deeper groups would be beneficial to PETRONAS in the exploration of the deeper prospects. To achieve this, new technology in deep exploration should be implemented in order to overcome certain deep reservoir issues.

ACKNOWLEDGEMENTS

Thanks to PETRONAS Carigali, especially to those who are involved in completing the project, especially to Mr Mazlan

Madon and Tuan Hj. Abdul Rahman Eusoff who kindly shared their knowledge, experience and views on the geology in the study area. And also thanks to the lecturers and friends in the Department of Petroleum Geoscience, Universiti Teknologi PETRONAS.

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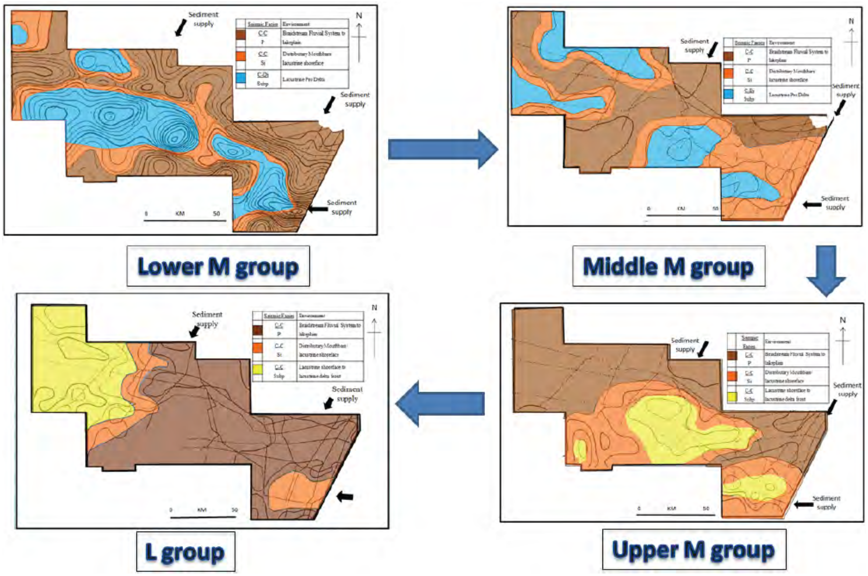

Fig. 3: Palaeogegraphic evolution in Block XYZ area

GEOPHYSICS PAPER 8

THE KARAP MUD VOLCANO IMAGED ON NEW 2D SEISMIC – IMPLICATIONS FOR BASIN ANALYSIS

Franz L. Kessler[1], John Jong[2], Tran Quoc Tan[2] & Hajime Kusaka[2]

[1]Curtin University of Technology, Department of Applied Geology, CDT 250 Miri Sarawak, 98009, franz@curtin.edu.my
[2]JX Nippon Oil & Gas Exploration Corporation (formerly known as Nippon Oil Exploration Limited), Lot 1168, 3rd Floor Wisma Interhill, Miri Waterfront Commercial Centre, Miri Sarawak, 98000

Mud volcanoes can be seen in sedimentary basins, where clay and sand are accumulating within a "geological" short period of time. Several of them were mapped in the NW Borneo Basin, both Sarawak and Sabah (Liechti et al, 1960). In young clastic basins, following rapid burial, clay is liquefied. It moves upwards, intrudes sediment layers, and at times, reaches the surface. The plastic clay extrusions produce volcano-shaped cones than can reach a height of 20 m above area level in Sarawak (Kessler, 2008). The Karap mud volcano (Figure 1) is currently the largest active mud volcano in Northern Sarawak, and located in a hinge area of the "Baram Line". This complex lineament system separates the "Baram Delta", an area of poorly consolidated Mid-Miocene-to-Recent clastic deposits (Kessler 2010), from the more consolidated "Central Luconia" (Figure 2).

Mud volcanoes are complex features. Recent 2D seismic data acquired by JX NOEX, give for the first time insight into the structure of the volcano (Figures 3). The volcano's caldera is asymmetrical, and has formed as a collapse graben array on the tip of a major regional strike-slip fault zone (Figure 4). In the proposed model, the mud-volcanic activity stems from an interaction of surface waters with underlying overpressurized rock. In the funnel-shaped caldera, large quantities of meteoric water are collected, leading to a rise of hydrostatic pressure to a level in the order of 1200 psi. With increasing pressure, water penetrates deeper semi-permeable levels, and interacts with semi-mobile overpressurized pore-space gas.

As the water mud rises, and de-gasses on the way up, gas bubbles are forming that later detonate on the volcano's surface. Arguably, the presence of mud volcanoes points towards compressive tectonism in the sub-surface, strike-slip combined with reverse faulting in the Karap case. Since mud volcanoes depend on overpressured rock, they point towards basin areas

Figure 1: Surface view of the Karap mud volcano, central caldera with center of eruptions.

that are under-compacted. However, a direct link to charge and gas-bearing reservoir can currently not be made. Mud volcanoes also constitute an area of increased drilling risk.

The Karap volcano (triangle, 91; enlarged section) is right in the center of the map. Faults are in red, anticline axis (pink); dip of Baram Delta clastics, yellow arrows. The fault zone responsible for the Karap volcano is covered by alluvials. Insert is the unscaled aerial photo of the volcano.

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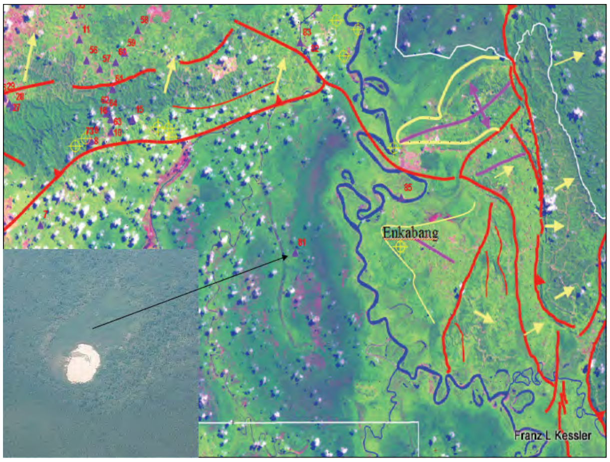

Figure 2: Tectonic (surface) summary map of the Enkabang area (Northern Sarawak, SK 333).

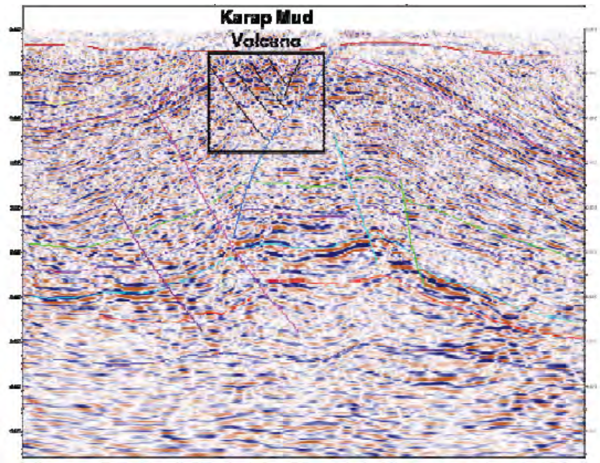

Figure 3: Subsurface image of the Karap mud volcano.

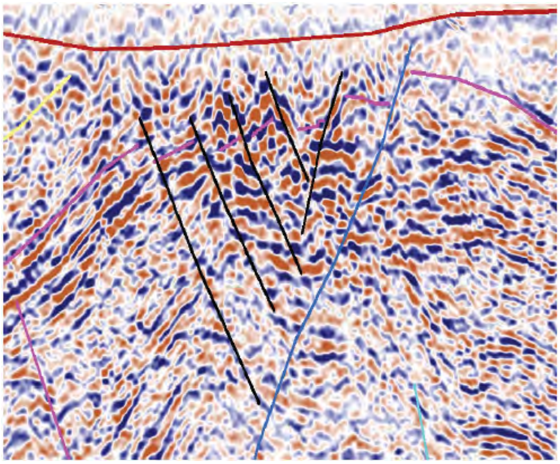

Figure 4: Detailed internal structural overview of the Karap mud volcano.

GEOPHYSICS PAPER 9

LOW RELIEF STRUCTURE, A FAVORABLE HC ACCUMULATION TRAP IN MALAY BASIN

Ji Ping & Norhafizah Mohd

EAP PREX Petronas, Level 16, Tower 2, Petronas Twin Towers, KLCC, 50088, Kuala Lumpur, Malaysia.

Malay Basin had undergone three major vertical structure movements: extension, thermal subsidence and basin inversion. The important result of the inversion is the compressional anticline, include the low relief structure. Exploration activities in recent years demonstrate that low relief structure is a favorable HC accumulation trap.

The discovered low relief structure HC accumulations have the following characters:

- 4 way dip structures (associated with deep seated faults)
- Low HC column (50 to 100 m)
- Large area (up to 60 km^2), and HC filled near to spill point
- Very thick total net pay (over 200 meters)
- Multi layers with different contact systems.
- Low CO2 content comparing to high relief trap.

Coastal plain and deltaic environment deposits match with the low relief structures make them excellent hydrocarbon accumulation traps in Malay Basin.

The possible low relief traps lies between high relief structures or beneath the major gas fields which may be overlooked because they are not obvious in time domain or affected by gas sagging. Hence the comprehensive seismic analysis is needed, especially the 3D seismic velocity model.

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GEOPHYSICS PAPER 10

CONVENTIONAL APPROACH SEEMS TO BE THE BEST!

Hijreen Ismail, M Izham Kassim & Khairul Hamidi Khalid

Petronas Carigali Muriah Ltd.,Level 17-18, Menara Mandiri, Bapindo Plaza,
Jl. Jend Sudirman Kav 54-55, Jakarta 12190- Indonesia.

Lateral and vertical velocity variations are among the key concerns for time to depth conversion especially in carbonate regime. A reliable velocity model should take account of these issues.

The K prospect area is well known of its geophysical and geological complexity. The targeted and proven reservoirs are believed to be a type of platform carbonate. Furthermore, the existence of channel filled by shale throughout the whole K block, in the shallower horizon, i.e. at W level had caused pull down effects until the basement level. The poor seismic data quality and the unavailability of stacking velocities have developed more challenges to the study.

There were three methods had been identified in order to produce a reliable velocity model meant for time to depth conversion purposes. The three methods are; average velocity model, 3D velocity model and conventional layer cake model.

The first model is an application of well average velocity with main focus on the targeted reservoirs. The 3D velocity model had used a 3D grid as a platform to incorporate all TWT surfaces, well and DMO velocities. A statistical concept of modeling had been applied to populate the well (primary trend) and DMO velocities (secondary trend) in a single 3D model. Then, an anisotropy function ({well velocity / DMO velocities} X DMO velocities) had been generated as to integrate the anisotropy factor into this model.

The third model is a conventional method which was generated based on observed velocity changes in sonic data vertically. Whilst, the TWT surfaces had been used as to control for lateral variations. Later, both well velocities and TWT surfaces had been incorporated with utilizing the Vo-K method as the basis of generating this model.

Based on the statistical report of residual errors, the third model turns up to provide the least amount of erroneous.

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GEOPHYSICS PAPER 11

REGIONAL ROCK PHYSICS APPLICATION FOR IMPROVED UNDERSTANDING OF THIEF SANDS IN OFFSHORE SARAWAK BASIN

Yeshpal Singh

PETRONAS Carigali Sdn Bhd, Level 16, Tower 2, PETRONAS Twin Towers,KLCC, 50088 Kuala Lumpur, Malaysia.
yeshpal_singh@petronas.com.my

Seismic data play a crucial role for hydrocarbon exploration. The seal integrity analysis is required for carbonate prospects ranking in Sarawak basin. The overlying capping shale has intercalated sands, which are termed as thief sands. The fluid content of these sands indicates seal breaching. Therefore, fluid characterization of thief sands may help to characterize reservoir seal and in-turn for prospect ranking. . These sands are quite shallow with depth range from 800-1500m. The recorded well logs are quite scarce and never analysed petrophysically in past. Reliable density and sonic(P&S) well logs along with relative amplitude preserved pre-stack data is very crucial to understand the seismic character of thief sands. The shale abundant columns at shallow depth drilled with overbalanced mud weight, induced large washouts and affected recorded well log curves. The density correction for washout zones is a must otherwise misinterpretation of seismic reflectivity may give an AVO pitfall.

In general, conventional petrophysical analysis targeted for reservoir interval. However, to characterize shallower shale sections, a re-look on well logs conditioning is necessary before any further analysis. More than 25 wells widely distributed in Sarawak basin were selected for regional understanding of capping shale characteristics in terms of rock physics analysis. Input logs were quality checked for consistency and necessary corrections applied before putting them as input for rock physics modelling. Suitable rock physics model constructed to synthesized missing logs and poor quality logged interval. Gassmann fluid substitution modelling applied to understand the fluid effect on rock properties. Rock physical analysis for elastic and density logs indicates that brine and hydrocarbon bearing sands are harder than shales in the Sarawak basin.

The well log based forward modelling indicates that the sands always have high P-impedance than shales. The forward modelling results conform to the seismic amplitude variation in sands and shales. The seismic responses of sand tops are represented with positive reflectivity contrast and with dimming amplitudes of angle/offsets. The rock physics modelling and seismic well calibration helped us to delineate thief sands using pre-stack seismic analysis. The workflow and seismic analysis results will be presented in the paper.

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GEOPHYSICS PAPER 12

DELINEATION STRATIGRAPHIC FEATURES USING SPECTRAL DECOMPOSITION AND AVO IN B FIELD, MALAY BASIN

Khairool Anwar B Laksaman, Nguyen Huu Nghi & Goh Sing Thu

Petroleum Management Unit, PETRONAS, Malaysia

SUMMARY

In the search for new hydrocarbon resources to optimize field development plan, delineation of stratigraphic features is becoming an important objective in the oil and gas industry. In the Malay Basin, most of the stratigraphic features are the channel systems which are filled up with either shales or sandstones (Mazlan B.M. et al., 1999). The sand-filled channels are potential targets of hydrocarbon accumulations, while the shale-filled channels can act as trap seal or barriers to fluid flow among reservoirs during field development. Their impacts on exploration and development have been observed from several fields in both northern and southern parts of the basin. Therefore the degree of accuracy in mapping the channel system is crucial to a proper evaluation of the reservoirs, which in turn will help improve the reserves base during the various stages of the field development. In this case study, a suitable methodology and workflow have been applied to address the above challenges for B field development.

METHODOLOGY

An innovative and integrated workflow of Spectral Decomposition and AVO has been applied to delineate the channel systems of the Group H and I sediments. An analogue model, well data, 3D seismic PreSDM stacks, AVO envelop and CMP gathers are the required inputs for this workflow (Figure 1). The Spectral Decomposition application transforms the 3D seismic data from time to frequency domain (Partyka et al., 1999) for mapping channel outlines, while the AVO analysis evaluates the lithology and fluid characteristics. The resultant channel outlines and properties are then incorporated into static and dynamic models.

RESULTS

The Spectral Decomposition allows utilization of the discrete frequency components of seismic bandwidth to interpret and understand the subsurface stratigraphy. This technique is useful to delineate the channel features and also possible hydrocarbon contact (gas) in this study. Figure 2 below shows one example of channel outline delineation from Spectral Decomposition attribute analysis in I sand. Based on log analysis, the sands are interpreted to be a lower coastal plain environment. With support from seismic attributes, the channel outline polygon can be delineated and then used as a channel boundary for facies modeling in static model.

The seismic AVO analysis was conducted with objective to identify the AVO classification (Castagna J.P., Swan H.W., 1997) and also fluid properties prediction in B field. Based on the analysis, H and J sands group in B field have shown the Class I AVO response in general. However one of the sand in lower H Group (channel-like feature) responses as AVO class III (Figure 3). Based on the envelop extraction, the anomaly is similar to the proven gas in F sands (AVO Class III). This hydrocarbon stratigraphic potential need further appraisal to prove up hydrocarbon resource.

CONCLUSION

The study has achieved a significant improvement in identifying the channel bodies and properties, which in turn help improve facies modeling, well placement and optimization of the B field development plan. The work also defined some upside stratigraphic potentials for the future appraisal activities.

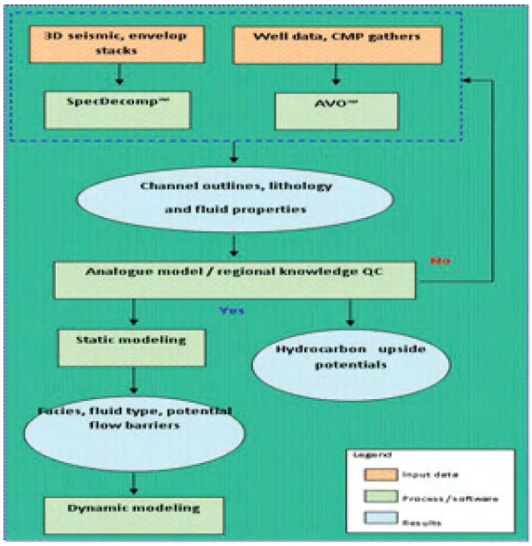

Figure 1: General workflow.

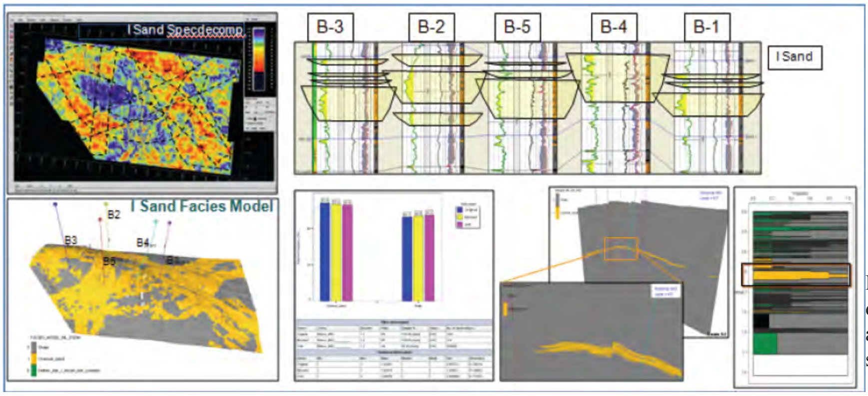

Figure 2: Integration of channel outline delineation from Spectral Decomposition attribute analysis in facies modeling of I sand in B field.

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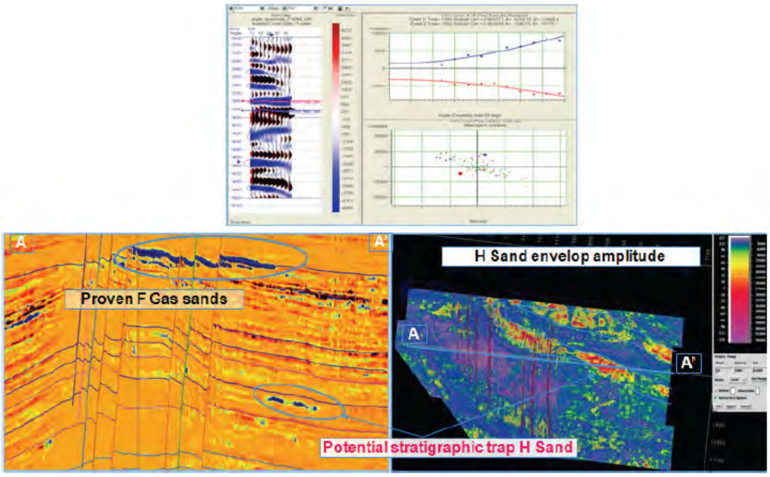

Figure 3: Fluid properties prediction by using AVO analysis has found potential stratigraphic trap in H sand of B field.

GEOPHYSICS PAPER 13

INTEGRATED APPROACH TO IDENTIFY STRATIGRAPHIC PROSPECT FROM SPARSE 2D SEISMIC ATTRIBUTES (AVO), WELL CORRELATION AND GEOLOGICAL MODEL – A SUCCESS CASE FROM GENALE B-2X IN BLOCKS 3&4, OGADEN BASIN, ETHIOPIA

Eadie Noor Fadzly M Salleh, Dodik Suprapto & Amri Shahril Saadudin

PETRONAS Carigali Sdn Bhd, Level 10, Tower 2, PETRONAS Twin Towers, KLCC, 50088 Kuala Lumpur, Malaysia

Genale B-2X is a vertical wildcat exploration well drilled in Blocks 3 & 4 (Genale), Ogaden Basin onshore Ethiopia, 590m above sea level. The well is located approximately 800 km to the southwest of capital Addis Ababa, 15 km northwest of Genale-1 and 40 km southeast of El Kuran-1. It was drilled to evaluate the hydrocarbon potential in the Gumburo and Calub reservoirs.

Geometrically, Ogaden Basin is divided into two sub-basins namely Western sub-basin which was relatively sagged during post Triassic period and Eastern sub-basin which was tectonically active throughout Permian to Tertiary period (as shown in the Figure 1). Prior to drilling, prospect Genale B was identified by bright seismic anomalies, extraction of seismic impedance and AVO seismic attributes from sparse 2D seismic data shot by PETRONAS Carigali Overseas Sdn Bhd (PCOSB) in 2006. The prospect is situated at the western flank of Ogaden Basin that experienced minimal structuration due to its close proximity to Negele Basement which shielded the blocks from intensely being further rifted.

The well was successfully penetrated the Gumburo and Calub reservoirs respectively. Based on the petrophysical evaluation, three gas bearing reservoirs are identified in the Gumburo formation namely Upper Gumburo, Lower Gumburo and Middle Gumburo (Figure 2). High gas reading during drilling was observed in these reservoirs.

Based on the log motif of Genale B-2X and surrounding wells, the log consists of fining upward sequence of Transgressive System Tract (TST) at the base of Gumburo reservoir followed by coarsening upward sequence of Highstand System Tract (HST) and later capped by the TST sequence (Figure 3). The inferred depositional model in Gumburo reservoir consists of progradation of the shoreline with depositional proximal washover fan. Water level rise caused shoreline to retreat with depositional of distal washover fan or lagoon. Results from sample analysis indicate a moderate to low energy deposition environment which may reflect a lagoonal facies between shore and the sandbar. The paleo-depositional environment for Gumburo reservoir is interpreted as sand bar within upper coastal plain (Figure 4).

The workflow involves well to seismic correlation, seismic sequence stratigraphy analysis and extraction of seismic attributes findings combined with the geological model leading to the delineation of prospect. Attributes such AVO and impedance have been extracted within the reservoir level (Figure 5). Positive AVO response represents the minimum and most likely scenario while seismic impedance signifies lithology which is considered as maximum scenario.

As conclusion, exploring a stratigraphic play in frontier area with sparse 2D data is feasible. Integration of seismic attributes with strong geological understanding is very crucial in identifying potential stratigraphic play.

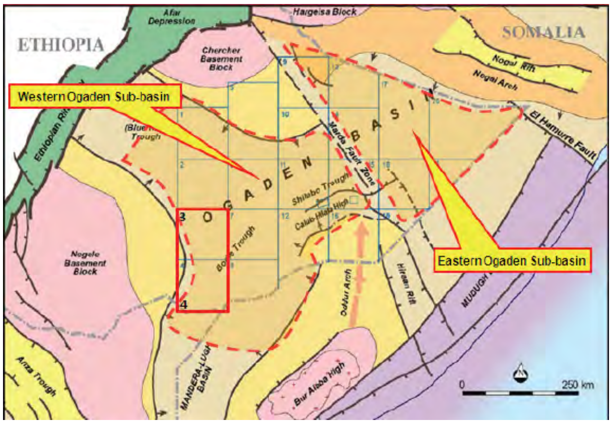

Figure 1: Basin Geometry of Ogaden Basin.

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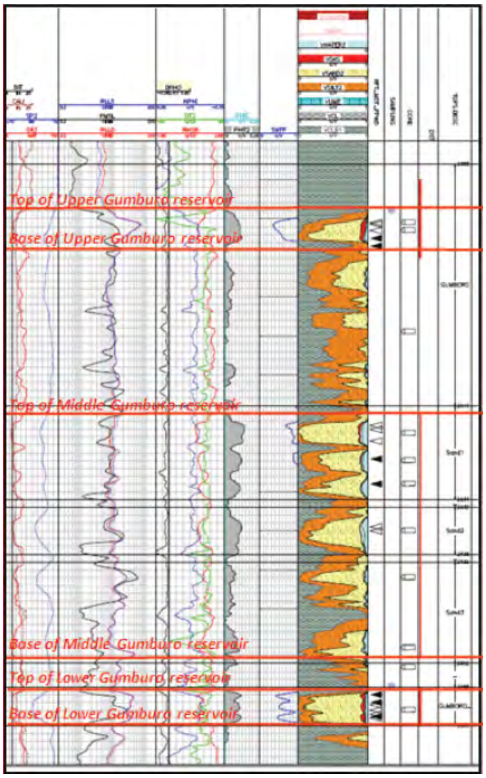

Figure 2: Petrophysical Log Evaluation Genale B-2X.

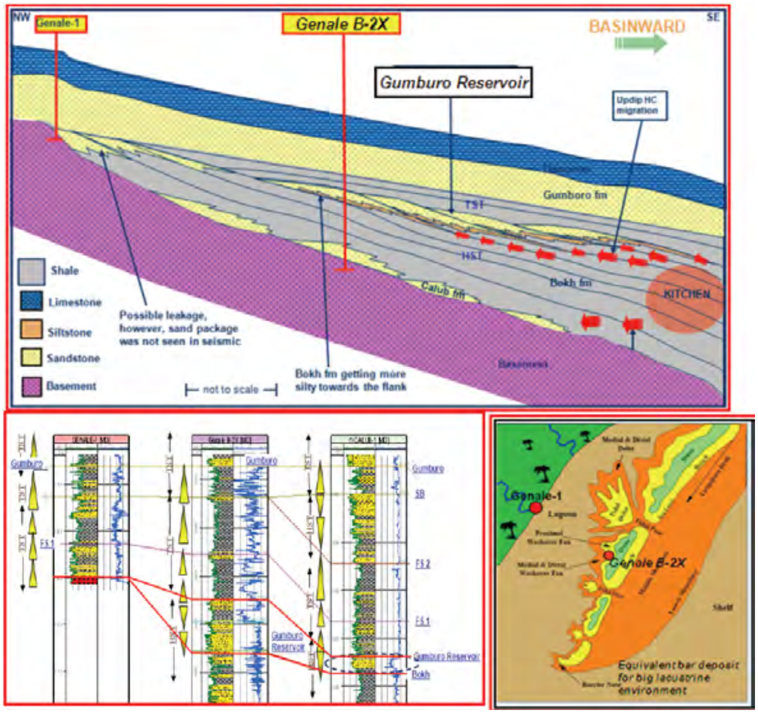

Figure 3: Geological Model and Log Correlation Across Genale area.

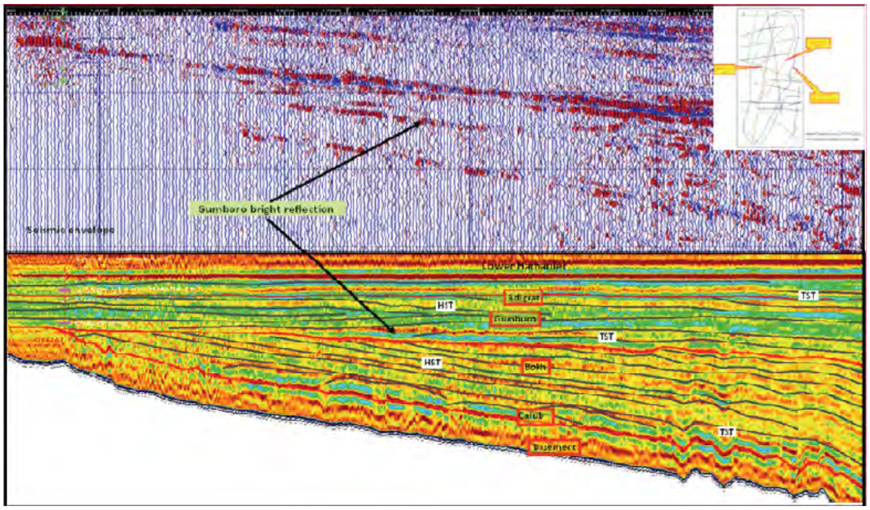

Figure 4: AVO response and Seismic Impedance Analyses.

GEOPHYSICS PAPER 14

SEQUENCE STRATIGRAPHIC STUDY PAVES THE WAY TO THE DISCOVERY OF KINABALU A-1 WELL

Marianny Bt Ismail, Othman Ali Mahmud, Norbashinatun Salmi bt Mohd Nordin, Ummi Farah bt Mohamad Rosli, Yusnizar Bt Julaidi, Myint Win & Narender Pendkar

1PETRONAS Carigali Sdn. Bhd, Level 11 Tower 2, PETRONAS Twin Towers, KLCC, 50088 Kuala Lumpur, Malaysia.

Kinabalu field is located in Sub-Block 6S-23 offshore Sabah, about 61 km to the northeast of Labuan (Figure-1). The field is subdivided into Kinabalu East (East Fault Block), Kinabalu Deep and Kinabalu Ultra Deep (West Fault Block). The Kinabalu field was discovered in 1990 and started production in 1993 (Kinabalu Field Development Plan, 2008).

In late 2008 a regional sequence stratigraphic study of Kinabalu and surrounding areas was carried out to establish correlation of Kinabalu field within the Sabah regional Stratigraphic Framework with emphasis on understanding the stratigraphic location of the reservoir sections. In addition, the study was also aimed to identify upside potential for hydrocarbon exploration for the area. This is the first kind of this study since discovered in 1990 (Othman et al., 2008).

Kinabalu A prospect is located on the upthrown side of Kinabalu East fault (Figure 2). The presence of Kinabalu A prospect was previously reported by the previous operator, but there was no further investigation made to evaluate the potentiality of this prospect (SHELL unpublished report, 2000). The present sequence stratigraphic study has managed to identify and verified the presence of Kinabalu A prospect in the Stage IV C at the 10A reservoir level and deeper section. In the area, where a petroleum system is proven by many discoveries, this potential subtle trap offered an attractive target. Further investigation with detailed structural mapping, resource assessment and seismic attributes studies indicated positive results on the presence of commercial hydrocarbon at Kinabalu A accumulations.

As a follow up to the above studies and findings, Kinabalu A-1 well (KNA-1) was spud on 15 December 2009. The well was drilled to a total depth (TD) of 15, 423 ft MD/10, 023 ft TVD. The well has successfully penetrated hydrocarbon at 10A and 11A reservoir levels and declared as discovery. The KNA-1 well has been suspended for future development. This paper will discuss the workflow used for regional sequence stratigraphic study, which includes the integration of seismic stratigraphy, well log analysis, seismic attributes studies, core analysis and 2D geological modeling leading to the successful discovery of Kinabalu A-1 well.

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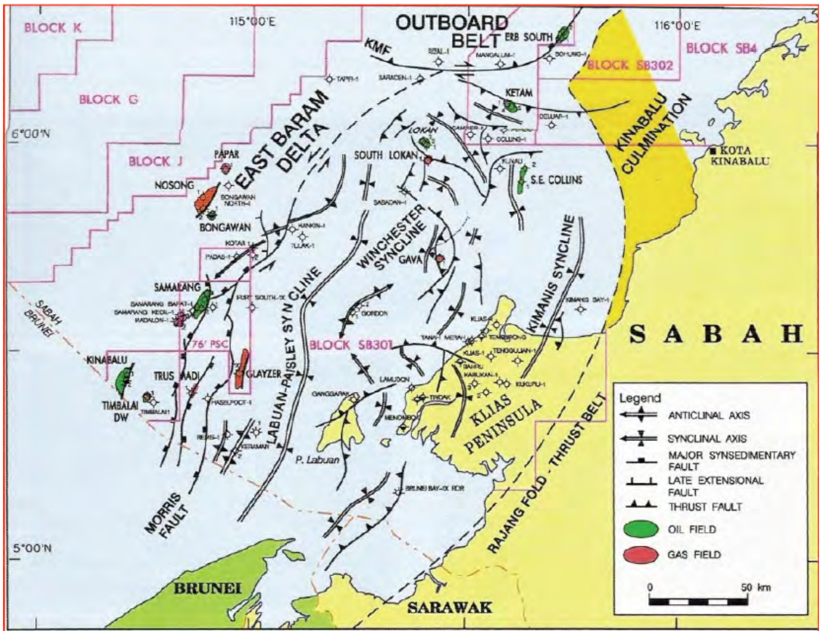

Figure 1: Offshore Sabah map.

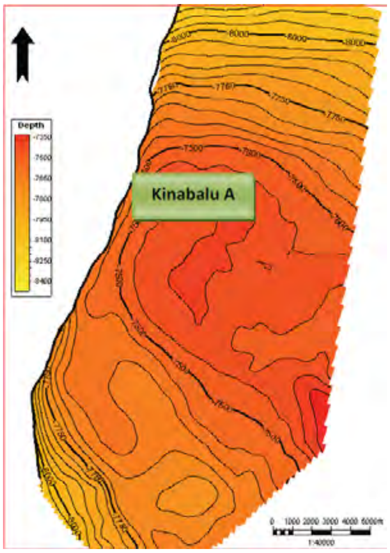

Figure 2: Kinabalu A location at the Top 10A reservoir.

GEOPHYSICS PAPER 15

AZIMUTHAL ANISOTROPIC NMO ANALYSIS FOR AMPLITUDE STRIPPING REMOVAL IN SUMANDAK 3D REPROCESSING

Mazlan Ghazali, Edgardo Padron & Mehmet Ferruh

PETRONAS Carigali, Sdn Bhd, Level 15, Tower 2, Petronas Twin Towers, KLCC, 50088 Kuala Lumpur, Malaysia

Exploration and Production seismic interpretation relies on accurate seismic processing to make a good well proposal.

The removal of amplitude stripping and large vertical discontinuities artifacts, observed in the previous processing (Figure 1), in the crossline direction at the Morris fault down thrown in Sumandak 3D Block, was one of the main objectives of the current PSTM/PSDM reprocessing project.

In this paper, we present a reprocessing case study that applied the Azimuthal anisotropic concept to get a practical solution to this task. In seismic, Azimuthal anisotropic is referred to the apparent velocity dependence upon the azimuth of the shot and receiver geometry (Figure 3).

The study area is in Samarang/Sumandak development block; in a zone with a moderate complex tectonic led by a remarkable normal fault which split two different geological environments.

We will show, how using Azimuthal anisotropic NMO analysis helped to determine the appropriate parameters to correct the velocity field affected by azimuthal velocity anomaly.

Although this correction does not consider the cause of the anisotropy, it produced a good result as the one shown in Figure 2.

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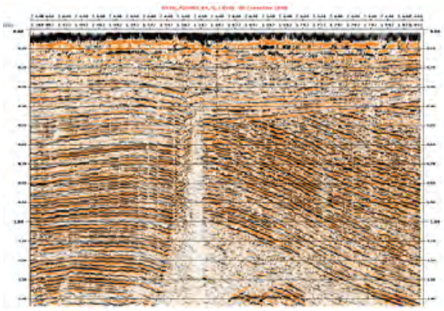

Figure 1: Vertical discontinuities artifacts.

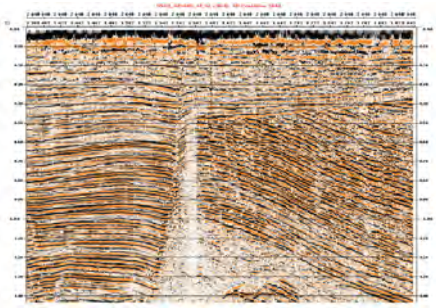

Figure 2: Removal of artifacts using AZNMO.

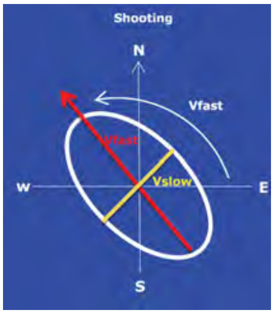

Figure 3: Azimuthal anisotropic analysis

GEOPHYSICS PAPER 16

MULTIPLE, DIFFRACTIONS AND DIFFRACTED MULTIPLES IN THE SOUTH CHINA SEA: HOW DENSE DOES OUR ACQUISITION GEOMETRY NEED TO BE?

Rosemary K Quinn[1] & Lynn B Comeaux[2]

[1] Talisman Energy, Level 33, Menara Citibank, 165 Jalan Ampang, 50250 Kuala Lumpur
[2] PGS Geophysical, Menara Dion, #22-02, 27 Jalan Sultan Ismail, 50250 Kuala Lumpur

ABSTRACT

Multiples, diffractions and their multiples are a common feature of marine seismic data. In some areas of the South China Sea, the residual multiples are a significant problem as they are coincident with the reservoir section. In this instance, we need to devote significant resources to further attenuate the multiples, particularly the diffracted multiples. The challenge is to assess how much effort is sufficient and is that effort required during data acquisition, data processing, or both?

SRME: 2D VS 3D

Verschuur et al (1992) introduced the surface-relate multiple elimination (SRME) method, which is often employed as part of the demultiple strategy in a marine seismic data processing sequence. Authors such as van Borselen et al (2005), Moore and Dragoset (2008) and Hung et al (2010) demonstrate how the method has been developed and refined.

For 2D SRME to work effectively, the structure must be horizontal over the scale of the SRME aperture in order for the model to be predicted accurately. Clearly, this is rarely the case, but as long as the structure does not introduce a substantial timing error or a significant mismatch in the waveform, the adaptive subtraction can compensate for the shift. 3D SRME has the capacity to calculate the shot and receiver pair that would be required to capture the reflection point in a vertical plane linking the two. Hence, in 3D SRME the multiples can be predicted without the timing error. The limitation is the size of the aperture that is available for constructing the source-receiver linkages, which in turn is a function of acquisition geometry.

Van Borselen et al (2005), McHugo et al (2009) and Hung et al (2010) compare the effectiveness of 2D and 3D SRME on seismic data with significant seabed structure. It is generally accepted that in areas of structural complexity, 3D SRME is a more effective demultiple tool than 2D SRME. However, there is rarely a quantitative comparison done to demonstrate the uplift obtained by the application of 3D SRME.

SPATIAL ALIASING

Diffractions are often recorded aliased. They are typically spatially aliased because of the steep diffraction tails, and they are often temporally aliased if generated from a shallow point source. Aliasing makes prediction of their multiples, and hence their removal, impossible using a convolutional method. (See Baumstein et al (2009) for example for a thorough discussion of the subject).

Towing streamers closer together during 3D acquisition or even interleaving the sail lines to improve the spatial sampling of the data are effective, but relatively expensive, ways to reduce spatial aliasing. Interpolation during processing can also be effective at combating spatial and temporal aliasing, and is cost-effective if it can be demonstrated to be an adequate solution to the problem. However, interpolation is rarely effective after more than one pass as data frequently begin to appear artificial.

CASE STUDY EXAMPLE

In this paper, we consider data from the South China Sea. Although there is some structure to the seabed in the cross-line orientation, it is not severe (see Figure 1). The problematic remnant multiples do not appear to be related to seabed dip in this instance. The adaptive subtraction is able to accommodate the small mismatch in timing and waveform that have been introduced to the predicted multiple. Figure 2(top) shows data that have been reprocessed in areas free from diffractions beneath the seabed. The 2D SRME is effective at removing the water borne multiples, regardless of their origin.

However, in areas where there are chaotic reflections in the shallow geology, the remnant multiple is considerable. In this case, because of the complexity of the records and the amount of offset induced by the dipping and broken geology, the predicted multiples are no longer close enough to the real ones for the adaptive subtraction to be able to deal with the mismatch (Figure 2 bottom). The reflections now have such an out of plane component that the only way to correctly predict their reflection points is to use 3D SRME with a large enough aperture to include the necessary source and receiver locations. Baumstein et al (2009) demonstrate on synthetic and real data that 3D SRME is effective at dealing with the multiples of diffractions.

Study of the remnant multiple indicates that it is located beneath areas of highly irregular reflections in the shallow foresets. Since they are shallow events, and the multiples travel primarily through the water column, they suffer very little attenuation. Hence we estimate that they retain frequencies in the range of 80 – 90Hz. Using a water velocity of 1550m/s, we calculate that highest frequency that can be recorded unaliased with a trace spacing of 9.375m (37.5m dual source separation, 75m streamer separation) is 82.7Hz. The impact of this on subsequent demultiple processing is illustrated in Figure 4.

CONCLUSIONS

We conclude that for the study area that we considered in the South China Sea: Remnant multiples on our stacked data can be traced to diffractions originating in foresets; 3D SRME will be required to adequately attenuate multiples related to diffraction; 75m streamer spacing with a dual source array with 37.5m separation plus one pass of interpolation should allow the diffractions to be recorded unaliased and hence attenuated.

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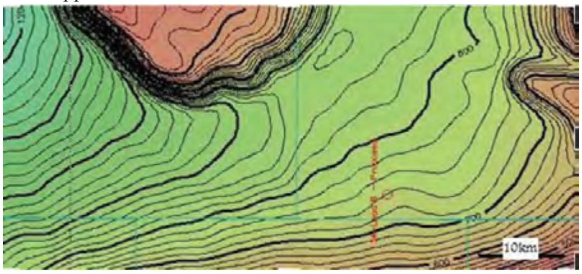

Figure 1: Seabed bathymetry in study area. Water depths range from 550m at the bottom righthand corner to 1200m at the top lefthand corner.

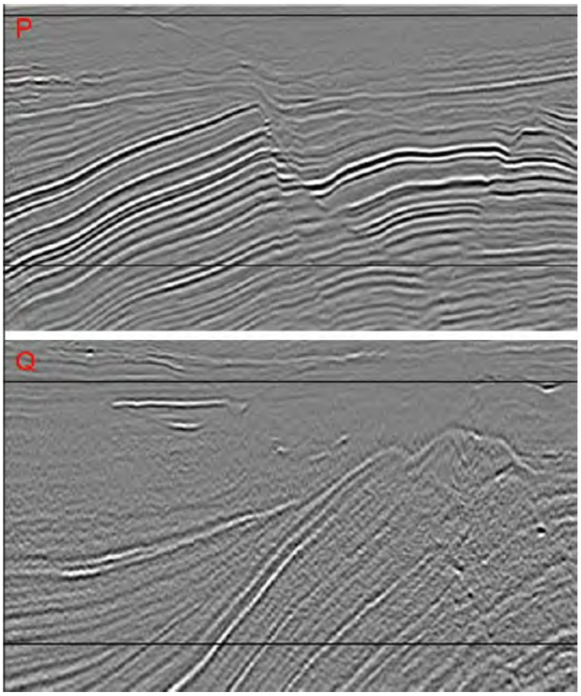

Figure 2: Migrated stacked sections showing structures from South China Sea. Top – 2D SRME has been effective. Bottom – residual multiple of shallow diffractions remains. NB. Data are from the same survey, with the same processing sequence applied and the structures are approximately 30km apart.

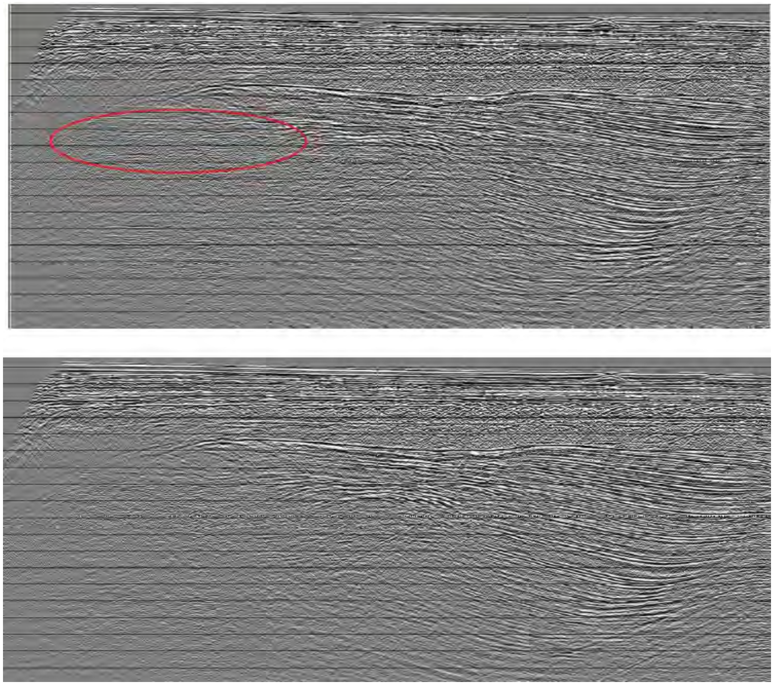

Figure 4: Difference between input stacked section (Figure 3) and stack with 2D SRME applied after trace drop to the annotated trace spacing. A significant deterioration in effectiveness of the multiple attenuation is noted between 18.75m and 25.0m which matches our prediction.

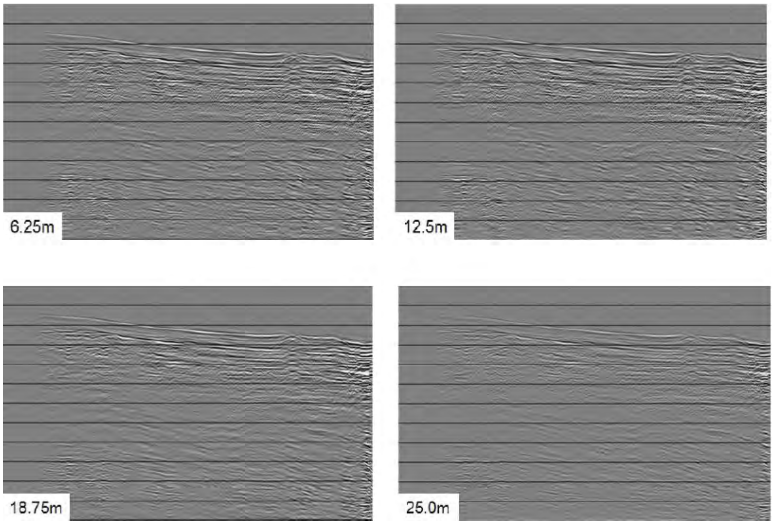

Figure 3: Comparison of 2D line from South China Sea, stacked after ambient noise attenuation; before (top) and after SRME (bottom), no trace drop. Trace spacing in CMP domain is 6.25m. Note the reduction in seabed multiples that are identified by the red ellipse.

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DEGHOST + DENOISE + DEMULTIPLE + VELOCITY & Q INVERSION + DEPROPAGATE = SEISMIC IMAGING

Mehmet Ferruh Akalin

PETRONAS Carigali Sdn Bhd, Level 15, Tower 2, PETRONAS Twin Towers, KLCC, 50088 Kuala Lumpur, Malaysia.

The recent advances in seismic acquisition and processing have made it possible to obtain more accurate representations of subsurface geology than ever before. More accurate and advanced implementations of deghosting, denoise, demultiple and anisotropic velocity inversion and Q-attenuation-factor determination techniques are the fundamentals of high resolution seismic imaging.

Receiver-side deghosting through dual-sensor streamer (PGS), over/under single-sensor streamer (WesternGeco), single-streamer Broadseis (CGGV) or 2C/4C OBC acquisition & processing has become common practice whereby extending usable frequency bandwidth of seismic data. Denoising through filtering in a variety of data domains (shot, receiver, offset, cdp) through XT, FK, TauP, FX, Wavelet-Transform based techniques are very successful and available from all vendors. Effective demultipling through short-period and long-period 2D/3D surface & interbed multiple attenuation techniques are essential for the success of the next steps namely: (1) Velocity & Q inversion and (2) Depropagation (Backpropagation) + Imaging Condition = Seismic Imaging (Migration).

The best subsurface imaging approach PreStack Depth Migration method has to rely on high-frequency accurate background models as compared to earlier approaches which use smooth background models with some hard-boundaries as needed i.e. salt or carbonates. Otherwise, it is unlikely that reservoir imaging below challenging overburden settings will be resolved. To realize the goal of high-frequency accurate background model building, direct-arrival tomography and reflection travel-time tomography, acoustic/elastic inversion, Q-tomography, full-waveform inversion techniques are being utilized to set up the appropriate background model for final imaging.

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GEOPHYSICS PAPER 18

DIP-DEPENDENT CORRECTIONS FOR DATA RECONSTRUCTION IN TRUE-AZIMUTH 3D SRME

Peter Aaron, Roald van Borselen, Rob Hegge, Simon Barnes & Maz Farouki

Petroleum Geo-Services; maz.farouki@pgs.com

This paper presents a method to apply dip-dependent azimuth, midpoint and offset corrections during the data reconstruction in True-azimuth (TA) 3D Surface-related Multiple Elimination (SRME). The method is applied to synthetic examples and a field dataset. Comparisons are made with a TA 3D SRME which uses a more conventional differential NMO reconstruction, with no additional corrections. Results show that the new method is capable of correcting for primaries, diffractions, multiples and diffracted multiples. It is demonstrated that correcting for azimuth, midpoint and offset effects using geological constraints, during the data reconstruction can significantly improve the prediction of multiples in the presence of complex 3D events, such as diffracted multiples.

TA 3D SRME has already been shown to deliver a significant uplift in de-multiple when compared with 2D SRME and other zero-azimuth forms of 3D SRME (Aaron et al 2008). This is the result of honoring the azimuth of input traces by predicting multiples at the exact input source and receiver locations. However, in order to predict multiples with TA 3D SRME, a large number of traces are needed with a wide array of midpoint, offset and azimuth values. Since it is not feasible to acquire all of the required offsets and azimuths needed at each location, they must be reconstructed from the data that is available.

While the differential NMO in the data reconstruction part of the SRME process attempts to correct for the offset difference between the desired trace and the best fitting trace, it does not correct for the differences in midpoint and azimuth. Our method corrects for the azimuth, midpoint and offset differences between the desired and best fitting trace.

The dip-dependent TA 3D SRME was applied to an offshore field dataset and showed improvement in attenuation of the complex diffracted multiples when the dip-dependent corrections are applied during data reconstruction.

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SEISMIC IMAGING NEAR AND WITHIN THE BASEMENT OFFSHORE MALAYSIA; INCLUDING COMPARISONS OF IMAGING ALGORITHMS

Nabil El Kady[1], M. Shah Sulaiman[1], Zabidi M Dom[1], Tang Wai Hoong[1], Lee Mei Lu1, Pavel Vasilyev[2] & Martin Bayly[2]

[1]PETRONAS Carigali Sdn Bhd, Tower 2, Petronas Twin Towers, Kuala Lumpur City Centre, 50088 Kuala Lumpur, Malaysia.
[2]WesternGeco, 8th floor, East Wing, Rohas Perkasa, No. 8 Jalan Perak, 50450 Kuala Lumpur, Malaysia.

Better 3D acquisition and better imaging have made it possible to explore complex basement plays in Vietnam, Indonesia, and the Malay Basin with some success. It is postulated that oil from adjacent formations may get trapped (under favourable conditions) in vughs and fractures within the basement. Imaging the basement architecture is a key issue (Deva Ghosh et al., TLE, April 2010, also; Areshev, 1992, Reservoirs in Fractured Basement on the continental shelf of Southern Vietnam, Journal of Petroleum Geology, Vol 15, Issue 3, pp 451–464).

In this paper we describe the data preparation; velocity model building and migration methods applied to successfully image the data. The basement fractures are present at a variety of scales but to aid interpretation the larger, seismic scale fractures and faults need to be clearly imaged. In addition to imaging the basement, the seismic data processing flow also was designed to resolve and image shallower clastic horizons. Pre-processing of this data followed a generally industry standard marine data processing flow, however, particular attention was paid to the deep basement events and to the application of multiple attenuation type processes.

This data exhibits a strong vertical compressional acoustic velocity change between the younger clastics and the harder, older basement, with the possibility of intermediate velocity metasediments. Due to the extreme spatial changes in depth of the basement and regional scale faulting there are strong and rapid lateral velocity changes within the dataset. This necessitates the application of pre stack depth migration techniques that can comprehend the lateral changes.

Initially in 2004 a time Migration was run to provide a structural interpretation and asses the gross velocity variability. The subsequent depth migration used a derivation of depth and space varying interval velocities in a "hybrid" model building approach. The shallow clastic overburden model was built using a series of iterative loops of multi parameter reflection based tomography (Woodward et al, 2008, A decade of tomography, Geophysics Vol73, No 5). Shallow sediment velocity updates were based on the residual curvature calculations. In order to overcome the limitation of residual curvature tomography as it becomes less sensitive to velocity perturbation at deeper depth, deeper layers velocity in the metasediments and basement zone were built using a combination of interpretation and Multi-velocity scans.

The progressive model building and checking of the results was performed with intermediate Kirchhoff pre stack depth Migrations. Following the completion of the depth model building the data was fully depth migrated with both Kirchhoff and Adaptive Beam Migration methods. Adaptive Beam Migration (ABM) is an implementation of Pre-stack Depth Migration as described by Ross Hill (N. Ross Hill, 2001, Pre-stack Gaussian-Beam Migration, Geophysics, vol 66, No.4, p1240-1250) and utilises an oversampled range of tapered beams propagated through the subsurface. Upon completion, the two results were compared, The Beam Migration method showed improved focussing and definition of the faults close to the basement.

In an area of the data close to a graben feature, a "curious event" was observed on the stacked depth migrated images. The position of this event was certainly not geologically plausible. Upon inspection of the Common Image Point (CIP) gathers, this data was observed to be poorly moved out, of apparent low frequency, and also appeared only on mid to far offsets. After some analysis and discussion, it was proposed that this data is possibly "duplex wave" or "prismatic wave "energy. That is, a double subsurface reflection. To further investigate this possibility a simple 2D Finite Difference model was constructed with similar reflector geometry and velocities. This model produced a similar event on the raw model gathers as observed in the real data. This implied that it may be possible for this energy to be a" double bounce". To focus such wave phenomena requires an imaging algorithm that comprehends both down going and up going wave propagation, namely a two-way wave equation implementation. Such an implementation is the Reverse Time Migration (RTM) method (Fowler et al, 2010). Consequently, a small subset of the data was run using this depth imaging algorithm to see if the "curious event" energy migrates to a geologically plausible place.

Overall, this case study demonstrated that careful selection of suitable pre-processing processes, depth - velocity model building, and an appropriate prestack depth migration algorithm can assist greatly in improving the image of the top basement and clarify the delineation of fractured basement plays.

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GEOPHYSICS PAPER 20

BROADBAND MARINE SEISMIC – BREAKING THE LIMITS

Robert Soubaras[1] & Carl Notfors[2]

[1] CGGVeritas, 1 rue Leon Migaux, 91341 Massy Cedex, France
[2] CGGVeritas, 9 Serangoon North, Avenue 5, 554531 Singapore

The importance of recording the full range of frequencies (low as well as high) is widely accepted. High-fidelity, low-frequency data provides better penetration for the clear imaging of deep targets, as well as providing greater stability in seismic inversion. Broader bandwidths produce sharper wavelets and both low and high frequencies are required for high-resolution imaging of important features such as thin beds and stratigraphic traps.

The industry has been facing many issues that have limited the performance of marine seismic surveys with respect to bandwidth. Among them, we find mechanical and acoustic noise, source and receiver ghosts and attenuation with depth. Until recently, conventional de-ghosting was found to be sub-optimal. Thanks to recent advances in technology and also in operational capabilities, we have seen several improvements, in particular with the use of solid streamers, deep towing and notch diversity.

We describe a different technique to achieve broadband marine streamer data. The proposed solution is a new combination of streamer equipment, novel streamer towing techniques, and a new de-ghosting and imaging technology. It uses receiver notch diversity to yield a broadband spectrum and takes full advantage of the low noise and low-frequency response of the new generation of solid streamers. As a result, the method creates an exceptionally sharp and clean wavelet for interpretation. It can be tuned for different water depths, target depths and desired output spectra.

A key element of this towed streamer broadband seismic technique is the streamer itself. The new generation of streamer electronics can record hydrophone signal as low as 2Hz, which adds an additional one or two octaves to the low-frequency end of spectrum. Another key element is the design of solid streamers which can significantly reduce noise (particularly sea-state noise) when compared to fluid-based (including gel) streamers (Dowle, 2006).

This combination of low-frequency hydrophone recording and reduced noise make solid streamers an excellent platform for broadband recording. An additional advantage for this technique is that the solid streamer has a uniform density, stable buoyancy and is robust enough to operate at extreme depths (greater than 60m). This deep-tow capability facilitates streamer depth profiles which have significant ghost-notch diversity and optimal low-frequency recording.

Marine receiver deghosting has received renewed interest recently as a key component of broadband imaging. Different approaches for acquiring broadband marine streamer data such as over-under streamers, dual-sensor streamers or variable-depth streamers require their own deghosting methods which may include 2D propagation assumptions method. We introduce a novel approach (Soubaras, 2010) which leads to a deghosting method adapted to any acquisition method and which is optimal in terms of signal-to-noise ratio because it is not performed as a preprocessing stage. It is true amplitude, being able to extract the true deghosted reflectivity, i.e. the reflectivity that would be obtained should the water surface be non-reflecting. The principle of this method is to perform a standard migration together with a mirror migration, and to perform a joint deconvolution using these two images as inputs. We refer to a mirror migration as one which migrates from receivers that are mirrored above the surface.

We will show field data results of the new technology that demonstrates its ability to retain frequencies of up to 6 octaves (Soubaras and Dowle, 2010) and the difference this makes to the resolution as well as deep penetration of the data.

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GEOPHYSICS PAPER 21

SEISMIC IMAGING BELOW SHALLOW GAS CLOUD – A COMPARISON BETWEEN PSTM, PSDM & 4C OBC DATASETS

Tan Boon Hua, Amy Mawarni M Yusoff & Gunawan Taslim

PETRONAS Carigali Sdn Bhd, Level 11, Tower 2, PETRONAS Twin Towers,KLCC, 50088 Kuala Lumpur, Malaysia.

Seismic data degradation due to shallow gas cloud is a common occurrence in the Malay Basin. As with many fields with large structures located in the central axis of the Malay basin, the field under study in this paper is also beset with this issue. This field, which is currently in the development stage, is a 30km long by 10km wide E-W trending elongated four way dip closure intersected by N-S & E-W striking normal faults. Two main structural culminations can be observed on the field. The major culmination lies to the eastern side of the field while a smaller one lies to the western side. The field is found to contain both oil and gas accumulation. A marine streamer 3D seismic survey was acquired over the field in 2002. The survey was acquired with an E-W line orientation.

This 3D survey data was originally processed using Pre-Stack Time Migration (PSTM) in 2002. Amplitude and frequency attenuation of reflectors were particularly severe on the two crestal culminations from approximately 800ms onwards. This problem was attributed to the presence of shallow gas and is further compounded by the presence of multiply stacked gas zones below the shallow gas. As a result, a number of key problems were inherent in the dataset, namely depth uncertainties especially at the crestal zones, fault imaging uncertainties within the gas cloud and also vertical resolution issues.

The 2002 dataset was reprocessed using Pre-Stack Depth Migration (PSDM) in 2009. The aim of this exercise was to improve seismic imaging within the gas cloud, to improve vertical resolution via increased sampling rate, to increase the signal to noise ratio via new processing technologies such as SRME & model based Q and also to reduce depth uncertainty by deriving a high resolution velocity model representative of the changes in geology. Overall, the PSDM data did demonstrate improvements in terms of reflector continuity and frequency content within the gas cloud area. Fault imaging uncertainty, even though still present, has also improved as the fault interpretation within the gas cloud was carried out with greater confidence. Depth prediction at wells based on the PSDM has also shown improvements over the PSTM based prediction. Despite these improvements, the fundamental uncertainties in the dataset remain present as they were inherent to the acquisition process itself.

Also in 2009, a 4-Component Ocean Bottom Cable (4COBC) test line was acquired over the gas cloud zone on the eastern culmination of the field. This operation was carried out to demonstrate two key points. The first was to demonstrate the feasibility of carrying out an OBC acquisition in the studied field while the second and more important point was to demonstrate the data quality improvements of the OBC data over conventional streamer data. The 4COBC test line was acquired in a N-S orientation as opposed to the E-W orientation of the streamer acquisition with the intention to undershoot the gas cloud, and thus give better imaging. Preliminary results from the 4COBC data has shown marked improvements over the streamer data on the particular test line in all imaging and structural aspects which were noted earlier. These results suggest that 4COBC seismic acquisition is feasible in this field and is probably the methodology that will give the best imaging of the field under today's technology.

In summary, this paper has demonstrated that the 2009 PSDM has managed to improve the seismic data processed via PSTM in 2002. However, the problems faced by the 2002 PSTM attributed to shallow gas cloud are still present in the 2009 PSDM dataset as they are inherent to the acquisition process. In order to break away from these problems, a 4COBC survey may be the way to go. Such a survey dataset can potentially enable the many structural & imaging issues of the seismic dataset to be resolved within the development phase of the field.

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GEOPHYSICS PAPER 22

4D SEISMIC ANALYSIS OF RESERVOIR SANDS OVERLYING A SALT STRUCTURE

Haziqah Othman, Shuhadah Basaharudin, Salbiah M Sahad, Salbiah Isa, MK Sengupta & M Firdaus A Halim

PETRONAS Research Sdn Bhd, Lot 3288 & 3289, Kawasan Institusi Bangi, 43000 Kajang, Selangor, Malaysia

PETRONAS Research has recently embarked on a study to determine and understand pressure-saturation variations in a field through the use of 4D seismic technology. Changes in hydrocarbon pressure and saturation due to production produce noticeable changes in amplitude response. 4D seismic or the use of repeated time-lapse 2D/3D seismic surveys enables detection of 4D signal indicative of pressure or saturation changes.

The C field is located some 80 km due east of the coastline of West Africa. Water depth ranges from 739.3 to 823.6 m with area of 60km2. The oil and gas in the field are trapped in Early to Mid-Miocene reservoir sands above a faulted dome caused by underlying salt intrusion. The dome is faulted by low angle (45-60°) radial faults. A dominant east-west fault set subdivides the structure into an uplifted area in the north and a downthrown area to the south, which is itself separated into east and west fault blocks by a large north-south fault. Hence, the faults compartmentalize the field and hydrocarbons into three main fault blocks. The reservoir represents mid-slope turbidites which consist of a series of fining upwards sequences.

Conducting 4D seismic analysis and understanding pressure-saturation variations involve integrating several geophysical technologies. These technologies include well-synthetic-seismic correlation, Rock Physics, Production Scenario Seismic Modeling at selected injector/producer wells, 2D/3D seismic modeling, 4D AVO Modelling/Interpretation and correlating seismic attributes with engineering data, pressure history and saturation measurements.

Figure 1 shows the earth model of the reservoir sand that lies over a salt structure in the C field. The seismic synthetics generated from ray tracing are compared to the seismic section passing through the structure. Figure 2 top panel shows the well-seismic correlation at a selected well in the C field displaying the correlation at the main reservoirs. The bottom panel shows the rock physics analysis in C field.

Figure 3 shows the salt model with three reflectors and the OWC between first and second reflectors. The seismic modelling was conducted using the acoustic elastic finite difference wavefield modeling tool with seismic acquisition parameters applied on the C field. The wave simulation at time 2.1 sec shows the OWC at depth approximately 2000m. This simulation matches with the model where the wave hits the OWC. The generated raw and AGC shot gathers, in the bottom panels, at the source location of distance 1500m shows the three reflectors (R1, R2 and R3) at depth approximately 3200m until 3600m. Figure 4 shows the AVO modeling conducted at a selected well in C field showing a comparison analysis between In situ conditions and after Fluid Replacement Modeling.

Figure 5 shows the Base 1999 and Monitor 2007 RMS Amplitude and Difference Amplitude attribute maps. Yellow color on the RMS Amplitude attribute map indicates high RMS amplitude value. The difference (Monitor – Base) amplitude displays yellow color for high negative and purple for high positive difference amplitude values. Seismic attributes extracted within the major reservoir sands were generated for prediction of hydrocarbon. These attributes and difference maps can be correlated and integrated with pressure and saturation maps for interpretation of the 4D effects.

Figure 6 shows the 3D Inversion Amplitude Envelope attribute map. Orange color indicates high amplitude envelope value indicative of the reservoir hydrocarbon accumulation. The

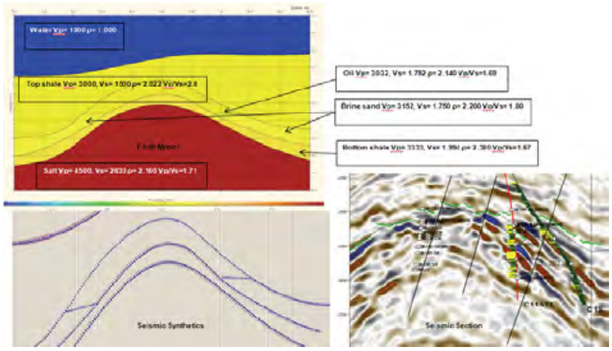

Figure 1: Seismic modeling ray tracing results compared with seismic section in C field.

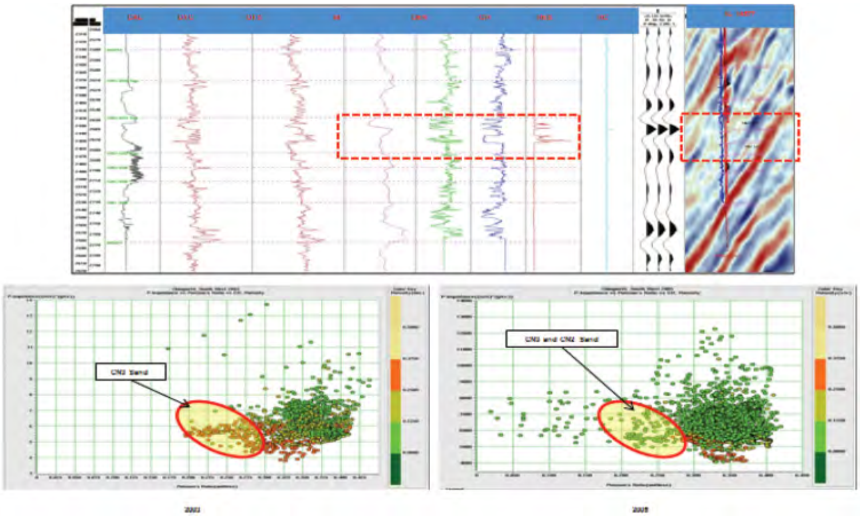

Figure 2: Well-seismic correlation and rock physics analysis in C field.

difference (Base-Monitor) amplitude between base and monitor is most anomalous within the south west region. Purple color indicates small changes in amplitude envelope difference value while yellow color indicates high changes. The 3D Inversion extraction attribute maps can be used for integration with production data.

Improving reservoir monitoring through the effective use of 4D Seismic analysis methods will enable us to more accurately locate bypassed oil and therefore, increase reserves. In addition, 4D seismic can be used to minimize costs by optimally locating development wells even in complex structures.

ACKNOWLEDGEMENT

We would like to thank the management of PETRONAS, PETRONAS Carigali Sdn Bhd and PETRONAS Research Sdn Bhd, for their support and permission. We are grateful to Liau Min Hoe, Lee Chun Ren, Nurhidayah Hutamin and En Abdullah Embong of PCSB, for their support and expert technical advice.

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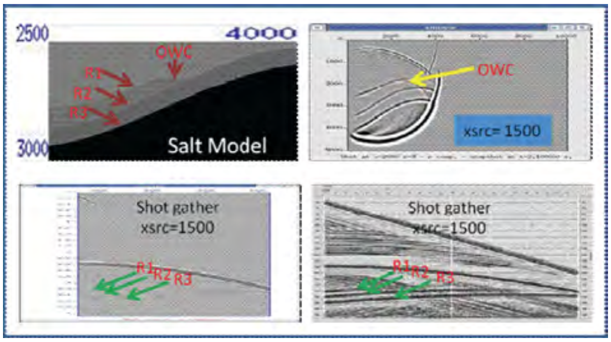

Figure 3: Finite Difference seismic modeling analysis and results.

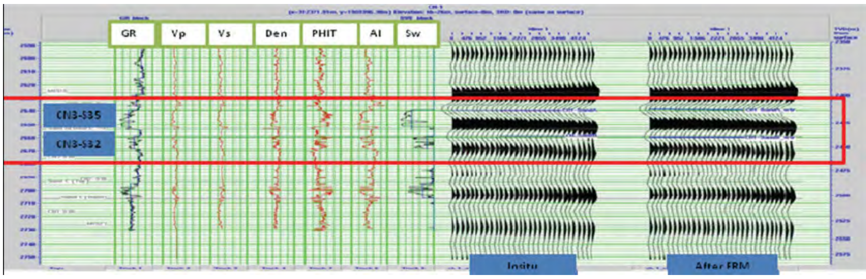

Figure 4: AVO modeling at reservoir sands.

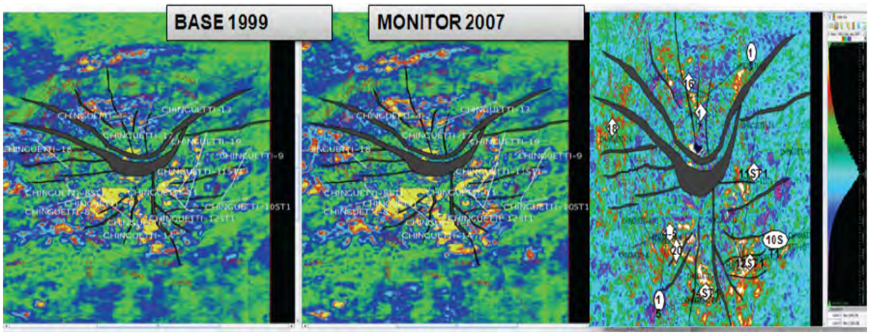

Figure 5: Seismic RMS Amplitude attributes of seismic surveys in 1999 and 2007. Right panel shows the difference amplitude map.

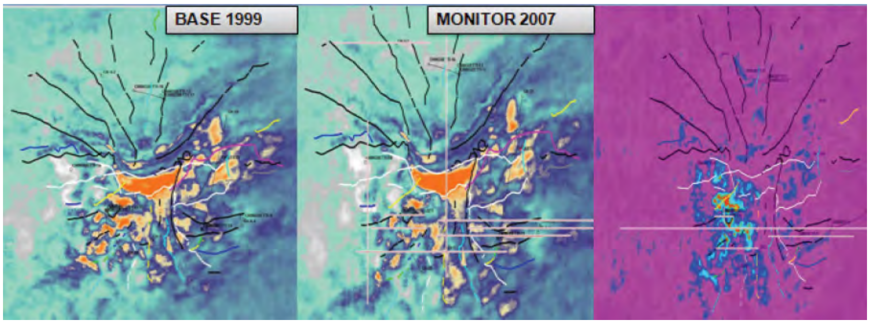

Figure 6: 3D AI Inversion Amplitude Envelope maps of seismic surveys in 1999 and 2007. The difference map is shown in the right panel indicating highest difference amplitudes observed in the southwest region.

GEOPHYSICS PAPER 23

4D SEISMIC INTERPRETATION IN ANGSI FIELD

Tan Chin Kiang[1], Wahyudin Suwarlan[1], Kartina Ali[1] & Fariz Fahmi[2]

[1] Petronas Carigali Sdn Bhd, Level 16, Tower 2, Petronas Twin Towers, KLCC, 50088 Kuala Lumpur, Malaysia.
[2]ExxonMobil Exploration and Production Malaysia Inc

Some brown fields have the 4D seismic technology applied successfully to optimize reservoir production and recovery. This paper describes a case study on Angsi field where by the 4D seismic has contributed significantly as input to the reservoir dynamic model as well as for a deeper understanding of the reservoir behavior.

This paper illustrates key lessons that we have learnt from the 4D application, focusing on feasibility study, QC during interpretation phase and 4D information on the reservoir management.

The Angsi field is located 167 km NNE from Kerteh, offshore of Peninsular Malaysia with average water depth 69m. The depositional environment of Angsi field is fluvial coastal plain environment. The field was discovered in 1974 with exploration Angsi-1 and subsequently followed by 7 appraisal wells. Oil and gas have been produced since 2001. Water injection was the chosen technique to manage the reservoir pressure during depletion. Understanding the water movement and response is the concern in the water injected field.

The base seismic survey was acquired in 1995 while monitor survey in 2006 after 5 years of production. The primary objective of the 4D was to monitor the water movement from the injector wells.

The success story of the technique in Angsi field is the ability to map the water movement in I35L reservoir, understanding the reservoir compartmentalization issues, pattern of preferred water movement and reducing the reservoir quality uncertainty.

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GEOLOGY POSTER 1

MAJOR CONTROLS ON DEEPWATER RESERVOIR DISTRIBUTION, WEST AFRICA

Amita Mohd Ali, Zainol Affendi Abu Bakar, Hasnol Hady Ismail, Redzuan Abu Hassan, Ku Rafidah Ku Shafie & Mazlan Madon

Petronas Research Sdn. Bhd, Kawasan Institusi Bangi, 43000 Kajang, Malaysia

The study of major controls on deepwater reservoir distribution, West Africa was mainly focus on the risk factor associated with reservoir sandstones in the deepwater areas of West Africa covering Cameroon, Equatorial Guinea, Gabon, Congo and Angola. Based on previous unsuccessful exploration results by Petronas up to 2006, it was found that the main factor for this is due to poor understanding of reservoir distribution in the region. This study was carried out to gain a better understanding on the geology of West Africa, particularly with regards to the transport and delivery of sediment from onshore to deepwater areas along the West African margin. This involves a study of the margin evolution both onshore and offshore areas. The primary objective of the study was to improve the understanding of sediment supply to the basins offshore West Africa, with the aim to enhance the prediction of reservoir distribution and quality. Understanding the entire sediment distribution system from source to sink is fundamental to improve models of reservoir distribution and quality. The hinterland analysis allied to a review of offshore data, can significantly enhance the fundamentals of this source to sink sediment distribution system.

The main deepwater reservoirs in the West Africa offshore areas are the Cretaceous and Tertiary turbidite channel and fan deposits. Major controls on deepwater reservoir distribution, are a combination or interplays of regional tectonics, eustasy, sediment supply, climates and intra-basin salt tectonism. West Africa experienced a complex tectonic history from Cretaceous to Tertiary and several important events have been identified to play important roles in controlling the reservoir distributions. The connection of the Congo system to the Ogooue is the most significant event in drainage organisation and long term sediment supply evolution as observed in modern geomorphology. The shelf review identified numerous channels and erosion features which further supported the shelf sediment bypass to the deep water. This explains why most deepwater reservoirs in West Africa are found within Late Cretaceous to Tertiary strata. The most prolific basin for hydrocarbon exploration in West Africa margin is Lower Congo Basin which contains the Tertiary Congo Fan deposits, followed by Gabon Basin. Kwanza and Namibe Basins have many potential occurrences which yet to be proven by major discoveries or development.

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GEOLOGY POSTER 2

SHALLOW SEISMIC: AN ANALOG STUDY OF FLUVIAL DEPOSITIONAL SYSTEMS IN THE MALAY BASIN

W M Khairul Anuar b W Sulaiman*[1], M Rapi b M Som[1] & Faisal A. Alqahtani[2]

[1]PETRONAS Research Sdn. Bhd., Kawasan Institusi Bangi, 43000 Kajang, Selangor, Malaysia
*wanmohdkhairul@petronas.com.my
[2]Department of Earth Science & Engineering, Imperial College, London, SW7 2BP, UK

Lowering and rising of sea levels during the late Pleistocene have greatly influenced the type of topography in the Malay Basin, which are subsequently affect the development of fluvial systems within the region. Availability of shallow, near-subsea three-dimensional (3D) seismic data in the Malay Basin could be utilized to provide analog study of fluvial system of deeper seismic sections. Further understanding of fluvial parameters (length, width, sinuosity, and radius curvature) and their relationship would determine the controlling factors on fluvial patterns.

This study involves 18,000sq km of 3D seismic data and 1600 km length of two-dimensional (2D) seismic lines within the southern half of the Malay Basin. Analysis of high-resolution data (from seabed to 500ms TWT) through combination of seismic attributes and time-slice provides exceptional imaging of channel features and its evolution.

Results indicate that channels tend to be wider, shallower and have an almost straight to low sinuosity at the base of sequences. Channel size would decrease upward within individual sequences, and having deeper incise with higher sinuosity. Channels also tend to cut deeper and have smaller width in high sinuosity and shallower and wider in straight channel.Similar findingswere found by previous works within the region south of the Malay Basin (e.g. Natuna Basin) (Gibling, 2006; Darmadi et al., 2007).This suggests that similar processes affected both areas

Seismic cross sections exhibit different frequency within boreholes in study area to suggest possible lithology variation. However, boreholeslog descriptions indicate that the fills are all mud/shale, irrespective of their location (i.e. point bar, outside channel and inside channel). Therefore, it is possible that different frequency response in seismic could be due to higher density contrast of marine shale compared with lower density contrast non-marine shale.

The wide variation in channel styles and size in the study area is interpreted to be controlled mainly by the sea-level fluctuations (Voris, 2000). However, climate changes may have a significant impact on the channel pattern and sizes by affecting the discharge and the types of sediment load.

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GEOLOGY POSTER 3

AN INTEGRATED APPROACH OF SEDIMENTOLOGY, BIOSTRATIGRAPHY, ORGANIC PETROLOGICAL AND GEOCHEMICAL ANALYSES: A CASE STUDY ON PETROLEUM SOURCE ROCK DEPOSITIONAL ENVIRONMENTS OF SEBAHAT AND GANDUMAN FORMATIONS, EASTERN SABAH

Khairul Azlan Mustapha, Wan Hasiah Abdullah & Ralph L. Kugler

Department of Geology, Faculty of Science, University of Malaya, 50603 Kuala Lumpur, Malaysia

A reconstruction of depositional environment based on integration of sedimentology, palynology, microfossil, organic geochemical and petrological data was performed on the Sebahat and Ganduman Formations. The objective of this study is to characterize the depositional environment and the condition of deposition of organic-rich sediments occurring within these formations that have been identified as probable petroleum source rocks (Khairul Azlan, 2010). Integration of data based on these multidiscipline techniques provides better insights into the depositional control and preservation of organic matter that consequently determine the source rock quality. Six source rocks facies belonging to Sebahat and Ganduman Fomations were identified based on the sedimentologic analyses i.e. grey mudstone (GMd), grey silty sandstone (GSMd), sandy coal (SdCo), black coal (Co), brown coal (BCo) and coaly sandstone (CoSSt). The composite lithostratigraphic log shows the vertical succession of all depositional sequences which are composed of lowstand systems tract, transgressive systems tract, highstand systems tract. The main source rock interval is within the Highstand System Tract (HST) and Trangressive System Tract (TST) (Khairul Azlan, 2010).

The palynomorph data show significant amounts of mangrove pollen that were dominated by Rhizoporacea sp, Bruguera sp, with small numbers of Avicennia sp in both the Sebahat and Ganduman Formations (Figure 1). The significant abundant of mangrove pollen strongly suggest the contribution of mangrove swamp plants, thus indicating a paralic environment of deposition. The foraminiferal assemblages are dominated by benthonic microfossils with a significant number of planktonic microfossils were recorded. The samples from the Sebahat Formation are relatively abundant of benthonic forams with Trochamina sp being the highest. The high numbers of agglutinated forams suggest the depositional environment is a shallow water benthic zone, probably nearby brackish mangroves which received clastic sediments. The presence of floating microfossils such as Globigerina sp and Orbulina sp indicate an open sea area with water depth less than 50 m (e.g. Mazlan et al., 1999). Therefore, the marine environment was limited to an inner neritic zone. The rare numbers of benthonic foram in the Ganduman Formation sediment suggests the water level was slightly shallower than Sebahat Formation. This evidence is supported by the presence of macrofossils of benthic faunas.

Petrographic evidence based on Tissue Preservation Index (TPI) and Gelification Index (GI) values show the analyzed coal samples from the Ganduman and Sebahat Formations were deposited in variable sub-environments, ranging from mangroves to lower delta plain depositional setting (Figure 1). Based on the Groundwater Index (GWI) versus Vegetation Index (VI), the coal seams appear to be scattered in a wide range of environment, although mostly concentrated in swamp that were influenced by mesotrophic hydrologic regime (Figure 2). Geochemical analyses indicate that Sebahat and Ganduman Formations were deposited in a near-marine transitional environment with high terrestrial organic matter influx as supported by a bimodal TIC chromatogram distribution with nC30 being the highest peak. This is suggestive of transitional environments whereby both Sebahat and Ganduman formations were interpreted to be deposited under suboxic conditions as indicated by Pr/Ph ratio ranging from 1 to 3. The high ratio of nC30/nC17 indicates Sebahat and Ganduman formations were deposited under a mixed environment, with both marine and terrestrial input. When there is both marine and terrestrial input to a sediment, the terrestrial condition usually defines the n-alkanes fingerprints, especially in the C25 to C33 range (Tissot and Welte, 1984). A significant presence of oleanane compound in most of the analyzed samples indicates that the organic matter originated from terrestrial angiosperm plant species as commonly noted in Sarawak Basin of Borneo (e.g. Mazlan and Abolins, 1999; Wan Hasiah, 1999).

ACKNOWLEDGEMENTS

We would like to thank PETRONAS (PMU & PRSB) for the support given to the first author when he undertook part of this study during his MSc research project. University of Malaya is acknowledged for the financial support received through PPP Research Grant (PS217/2008A).

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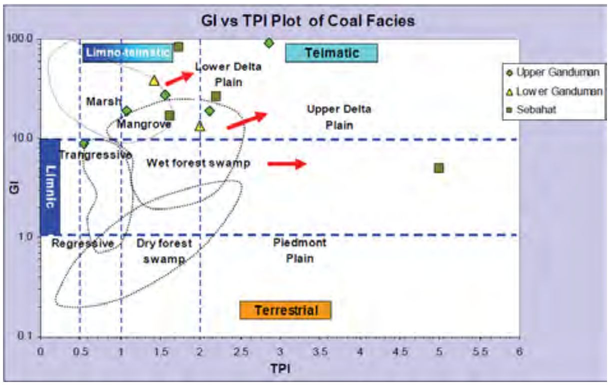

Figure 1. Gelification Index (GI) versus Tissue Preservation Index (TPI) cross plot shows the paleomire of peat swamp of coal (modified after by Diessel, 1986 and Kalkreuth and Leckie, 1989).

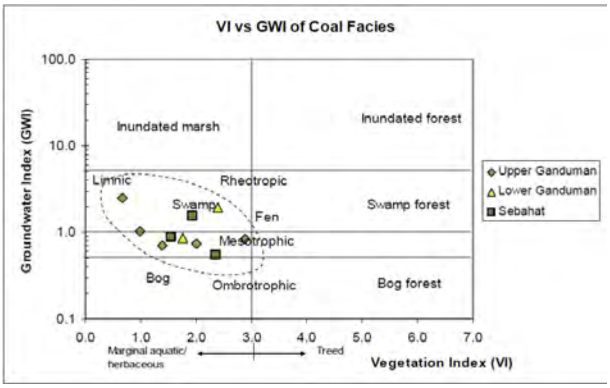

Figure 2. Coal facies diagram of VI vs GWI shows the hydrologic condition during the peat deposition (after Calder et al., 1991).

GEOLOGY POSTER 4

TRANSGRESSIVE-REGRESSIVE CYCLES IN THE MALAY BASIN: THE INTERPLAY OF TECTONICS AND SEA LEVEL CHANGES IN A SILLED BASIN

Mazlan Madon

PETRONAS Research Sdn. Bhd., Kawasan Institusi Bangi, 43000 Kajang, Selangor, Malaysia

Understanding the interplay of tectonics versus sea level changes in sedimentary basins has important economic implications. In rift/extensional basins, stratigraphic onlaps and pinchouts can form important hydrocarbon traps. Onlap plays develop on the basin margins during transgressions, whereas reworked/re-deposited shallow water sands and turbidites deposited during regressive events may form basinal plays. Transgressive-regressive cycles in a deforming rift (extensional) basin are strongly influenced by both eustatic sea level changes and tectonic subsidence/uplift. To explore for such plays it is important to understand how these major factors control sedimentation.

The depositional environments in the Malay Basin during most parts of the Miocene (represented by the stratigraphic intervals I to E) have been interpreted as “brackish” or “lower coastal plain”, implying a restricted marine setting of some sort. The absence of a fully marine faunal assemblage up to the uppermost Miocene does in fact indicate ‘restricted’ marine conditions. Thus, some authors have resorted to terms such as “lacustrine plain” or “lake plain” instead of “lower coastal plain” to denote a coastal plain fronting a lake, as opposed to that of an open sea. This is borne out of the uncertainty concerning the nature of the Malay Basin itself: was it (1) a lake, or (2) a marine embayment or gulf with periodic connection to the ocean?

Seismic data and biostratigraphic analyses carried out since the late 1980s have found evidences for periodic marine transgressions as early as group L time (late Oligocene). Although the Malay Basin did not become fully marine until Pliocene times, the data shows that at least partially marine (“brackish”) conditions were well established by the middle Lower Miocene (J times) (Fig. 1).

Both models have major implications for the development of source rocks as well as reservoir distribution. The major reservoir sands in the basin have been interpreted as tidal or “tidally influenced” deposits, especially in groups E, I, and J, again based on the assumption that there had been a constant connection to the open sea to enable the tides to influence sedimentation. Whether the sands are deposited as fluvial-derived lacustrine deltaic sands or as tidally reworked offshore sands, would significantly impact our reservoir model, and would greatly influence field-wide sand correlation. On the other hand, the glauconitic J sands have been interpreted as storm/wave-generated offshore bars (e.g. Nik Ramli, 1986), possibly under open marine conditions when the basin was connected with the South China Sea. This would have increased the otherwise limited wave fetch in a shallow lake or restricted embayment to have generated large offshore sand bars.

In the Malay Basin, the cyclical pattern of alternating sand-shale units in the K, L, M groups, first reported in an early paper by Armitage and Viotti (1977), is generally attributed to sea level fluctuations. Tectonic controls on transgressive-regressive cycles, however, have not been given due attention. The interpreted sea-level fluctuations in the stratigraphic record bear little resemblance to the often-quoted global eustatic curve of Haq et al. (1987). This suggests that a local or regional, and most likely tectonic or structural, control has had a strong influence on relative sea level in this basin. Many workers have already established that tectonic processes and effects, e.g. lithospheric flexure and thermal subsidence, at evolving rift basin margins exert a strong influence on stratigraphic development (e.g. Watts et al., 1982). Any attempt at force-fitting a global eustatic curve onto the Malay Basin stratigraphy is, therefore, not recommended.

Evidence of tectonic deformation and its effects on the Malay Basin have been reported in many papers (e.g. Ngah et al., 1996, Tjia & Liew, 1996). The main inversion event in Middle-Late Miocene times must have had a big impact on the sedimentation patterns. Most significant is the semi-regional basement high at the southeastern end of the basin, bordering with the West Natuna Basin. The presence of a major structural high in the southeastern end of the basin is well established from seismic data, around the Belumut-Peta area. The basement uplift and inversion of SE Malay and West Natuna basins are also well documented (e.g. Madon, 1997). This basement high,

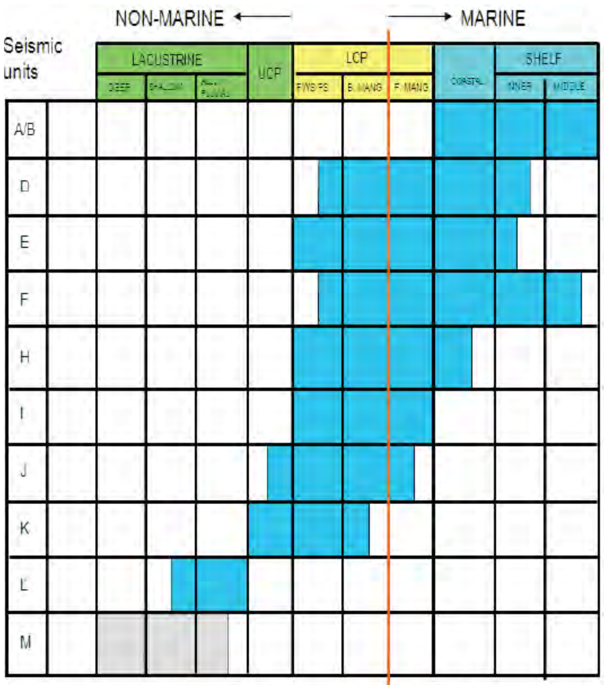

Figure 1: General trend in depositional environments in the Malay Basin.
(Note: UCP; upper coastal plain, LCP; lower coastal plain, FWS/PS; freshwater and peat swamp)

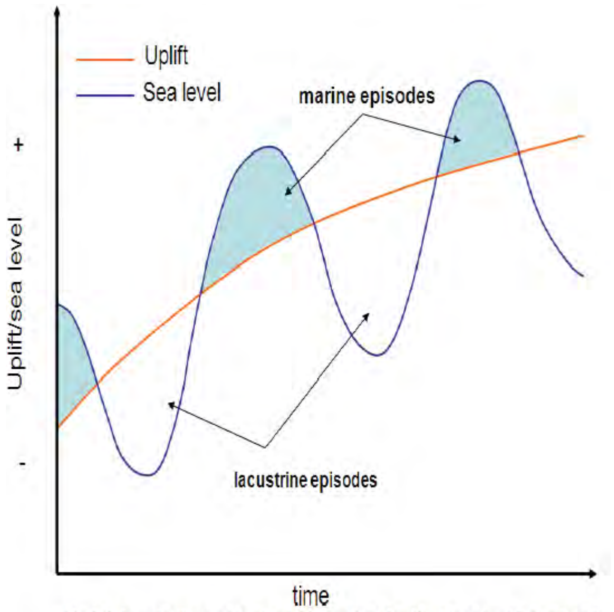

Fig. 2. Schematic diagram showing the interaction of uplift and sea-level fluctuations in creating episodic transgressions in a semi-restricted basin. Assuming a long-term uplift (red), there are times when the sea level will exceed uplift to cause marine influx.

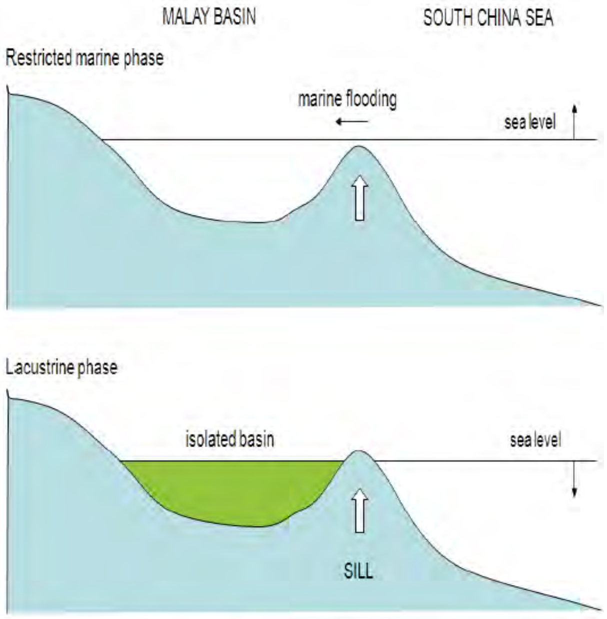

Fig. 3. Schematic of Malay Basin as a semi-restricted basin with a growing structural feature controlling the marine flooding episodes when the rate of sea-level rise exceeds that of the uplift.

or sill, separates the Malay Basin from the West Natuna and the ancestral South China Sea, and must have exerted a strong influence on the relative sea level in the Malay Basin. The diachronous nature of the late Miocene unconformity suggests prolonged compressional uplift since early Miocene times (group H) to late Miocene-Pliocene, with increasing intensity from north to south.

How do subsidence/uplift and sea-level changes in the South China Sea interact and influence sedimentation in the Malay Basin? The long-term uplift of the basement in the south would have been superimposed upon by the higher frequency fluctuations in sea level. There would have been times when the rate of sea level rise exceeded the uplift rate to cause marine flooding into the basins (Fig. 2).

A hypothetical model is envisaged (Fig. 3) in which the basement uplift in the south acts as a "gate" that opens and shuts in response to sea level cycles. At times of high sea level semi-open marine conditions will be established, while during low sea level, the basin behaves like an internally drained lake basin that may be subject to climatically controlled base level changes. It is therefore possible to identify changes in sedimentation patterns associated with these two environmental.

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GEOLOGY POSTER 5

HIGH RESOLUTION BIOMARKER TECHNIQUE FOR SOURCE FACIES INTERPRETATION OF MALAYSIAN OILS

Abdul Jalil Muhamad, Awang Sapawi Awang Jamil, Nurfadhila Mohd Sharef & Farhana Jaafar Azuddin

PETRONAS Research Sdn Bhd, Lot 3288-3289, Off Jalan Ayer Itam, Kawasan Institusi Bangi, 43000 Kajang, Selangor, Malaysia

Malaysian crude oils discovered in the relatively young Tertiary Malay, Sabah and Sarawak basins are generated by variable source facies (PETRONAS, 1999). This is shown by the wide spectrum of biomarkers derived from different precursors present in the oils. Nevertheless, the two main source facies are the fluvial-deltaic, found in great abundance in the Baram Delta and offshore northwest Sabah, and the mixed fluvial-lacustrine found mainly in the Malay Basin. All these oils show presence of, albeit in varied abundance, terrigenous derived biomarkers such as oleanane and bicadinanes, indicating variable contribution from high land plant organic matter into the depositional environments (Awang Sapawi et al., 1991; McCaffrey et al., 1998; Peters et al., 2005). Characterising these oils into oil families based on their biomarker fingerprints is rather time consuming, simply due to the numerous biomarkers present in the samples and extracting the biomarker parameters. Thus, it was thought that a simple, but accurate method is needed to determine their source facies and classify them into oil families.

In this study, an attempt is made to develop a high resolution biomarker technique to provide a quick and accurate method to determine the source facies of oils. This geochemical interpretation tool was developed using a combination of significant biomarker parameters plotted in the form of cross- or ternary-plots. For this purpose, a total of 38 crude oil samples collected from various petroleum basins were selected for this study. Some of these oils were used as end-members for three main source facies, namely, fluvial-deltaic, lacustrine and marine. End-member oils are those oils whose biomarker fingerprints represent a specific source facies mentioned above.

From the numerous biomarker parameters or ratios generated, selected ones were statistically treated using hierarchical cluster analysis (HCA) and principal component analysis (PCA). Parameters with high PCA loadings were then further selected and tested using cross- and ternary-plots to determine the usefulness of the parameters and subsequently select the most significant parameters to be used as source facies interpretation.

Results show that only a few biomarker parameters are essentially needed to distinguish the different source facies into fluvial-deltaic, lacustrine, marine and carbonate when used in appropriate combinations. These parameters are:

Oleanane Index
Homohopane Index
Hopane/Sterane ratio
100*(Ta+Tb)/C27 steranes ratio
C26/C25 tricyclics ratio

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GEOLOGY POSTER 6

CORRELATION OF THE SUBIS LIMESTONES WITH EQUIVALENT LIMESTONE BODIES IN OFFSHORE BALINGIAN PROVINCE, SARAWAK, AND PRUPUH LIMESTONES IN JAVA

Foo Yuan Han

Department of Geology, Faculty of Science, University of Malaya, 50603 Kuala Lumpur, Malaysia

Detailed micropalaeontological studies of the foraminiferal assemblages were carried out to resolve the biostratigraphy correlation and depositional environment of the Subis limestone, the limestone from offshore Balingian Province and the Prupuh limestone.

Most of the foraminifera examined in the samples is consisted of larger benthic foraminifera. Larger benthic foraminifera are important contributors to modern and ancient tropical, shallow-marine sediments. The modern ecological studies of larger benthic foraminifera such as their environmentally sensitive depth distribution, reproductive strategy and morphology and the symbiotic relationship between many larger foraminifera and photosynthetic algae is a powerful tool to develop palaeoecological models of the studied areas.

The Balingian Province lays mainly offshore central Sarawak and is bounded by the west Balingian Line to the west, the Central Luconia Province to the north, and the Tinjar Province to the South. Samples from wells offshore Balingian such as Sompotan-1, Rebab-1, Serunai-1 were studied and can be tied to the Subis location. (Mazlan, 1999).

Subis limestone is a member of the Tangap Formation at Niah. The Tangap formation is composed of calcareous shale, marl, calcareous sandstone and limestone. Limestone is either interbedded with calcareous shale or forms a massive sequence (Haile, 1962).

Prupuh limestone is a member of the Kujung formation. It is located in north-east Java. The Kujung formation is the oldest formation exposed in the East Java area. The age of Kujung Formation has been established as latest Early Oligocene to Early Miocene. (Duyfjes 1941; Najoan 1972; cited in Lunt et al. 2000).

The foraminifera observed in the Subis area and offshore Balingian are free living taxa which are indicative of high energy environment. Miogypsina sp., Nephrolepidina sp. and Amphistegina sp. are mostly confined to shallow warm waters of normal oceanic salinities. Amphistegina in particular are more abundant in shallow, warm, clear waters of high carbonate contents. The calcareous algal assemblage is mostly composed of encrusting forms. Such forms are known to be found in shallow turbulent water, of normal marine salinity and penetrated by sunlight. Thus the foraminiferal and algal assemblages found in the studied area indicate that the Subis limestone and offshore Balingian limestone was formed in a shallow water turbulent environment. The study of the seismic data of the offshore Balingian also indicates that the clastic sediments likely to vary over small distances reflecting changes in depositional energy that occur around coastal to shallow marine settings.

The Subis limestone, limestone bodies from offshore Balingian Province and the Prupuh limestone, Java were developed on various parts of the Sunda plate. The Prupuh limestone is similar in age to the Subis limestone. The limestone from offshore Balingian was the extension of the Subis limestone. The ages of the Java samples have determined by strontium dating.

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GEOLOGY POSTER 7

SALINITY STRATIFICATION AND IT EFFECTS ON THE MALAY BASIN BIOFACIES ASSEMBLAGES

Mahani Mohamed, Shamsudin Jirin & Sanatul Salwa Hasan

PETRONAS Research Sdn Bhd, Lot 3288 & 3289, Off Jln Ayer Itam, Kawasan Institusi Bangi, 43000 Kajang, Selangor, MALAYSIA
Email: mahanmo@petronas.com.my

Salinity stratification usually occurs when tidal currents and waves are not strong enough to mix the water column (e.g. in wave-dominated estuary). Such situation can lead to an anoxic condition because bottom waters can become isolated from dissolved oxygen (source: www.ozcoasts.org.au). Stratified salinity is a feature of partially enclosed seas and paralic environment (Debenay et al., 2000). In a stratified water column, the exchange of water and nutrients between layers is restricted, therefore there can be quite different water quality between the stratified layers; which has direct effect on the biofacies assemblages and distribution. (Debenay and Guillou, 2002). This biofacies event provides a possible explanation that for much of the Miocene, the Malay Basin might have been an enclosed sea, with a limited marine connection at the south to let saline water in.

Over five hundred surface sediment samples were analysed from three selected modern environment namely; Sedili Besar Estuary, Klang-Langat Delta and Pahang Delta (Figure 1). Of all samples analysed, the assemblages from Sedili Besar River Estuary showed domination of Ammonia cf. takanabensis (formerly identified as Ammonia beccarii), (PRSB, 2009). Monospecific assemblage, Ammonia cf. takanabensis dominated within the stratified water column of marine base and freshwater top. (Figure 2). However, in Klang-Langat and Pahang Deltas, the Ammonia assemblages are quite scattered and not confined to only specific area as in the Sedili Besar Estuary. Salinity stratification is very minimal or almost absent in both Klang-Langat and Pahang Deltas. Salinity studies in Sedili Besar Estuary indicates that the areas with abundant A. cf. takanabaensis have strongly stratified salinity, with near normal salinities at the channel floor, and very low salinities at the surface. This concept can be used to explain the high occurrence of Ammonia spp. in the Malay Basin. However, this is still an initial observation, further investigation is needed to firm up the idea.

On the other hand, the agglutinated forms mainly the Arenoparrella group dominates the less stratified water column (freshwater top and base salinity). Benthonic foraminifera live on the water bottom, but mangroves live along coastlines, so when there is a big water body with stratified water, mangroves will react to the fresh/brackish surface layer, whereas the foraminifera will indicate bottom salinities. The two models in Figure 3 help explain many of the foraminifera-palynology associations in the Malay Basin Group E cores. In both instances, the water bodies would retain tidal influence, and respond to sea level change, as the water bodies are virtually always connected to the sea. It can also be used to explain the Ammonia spp. and agglutinated foraminiferal occurrences for biofacies interpretation in the Malay Basin.

Figure 1: Localities of the three modern analogs studied

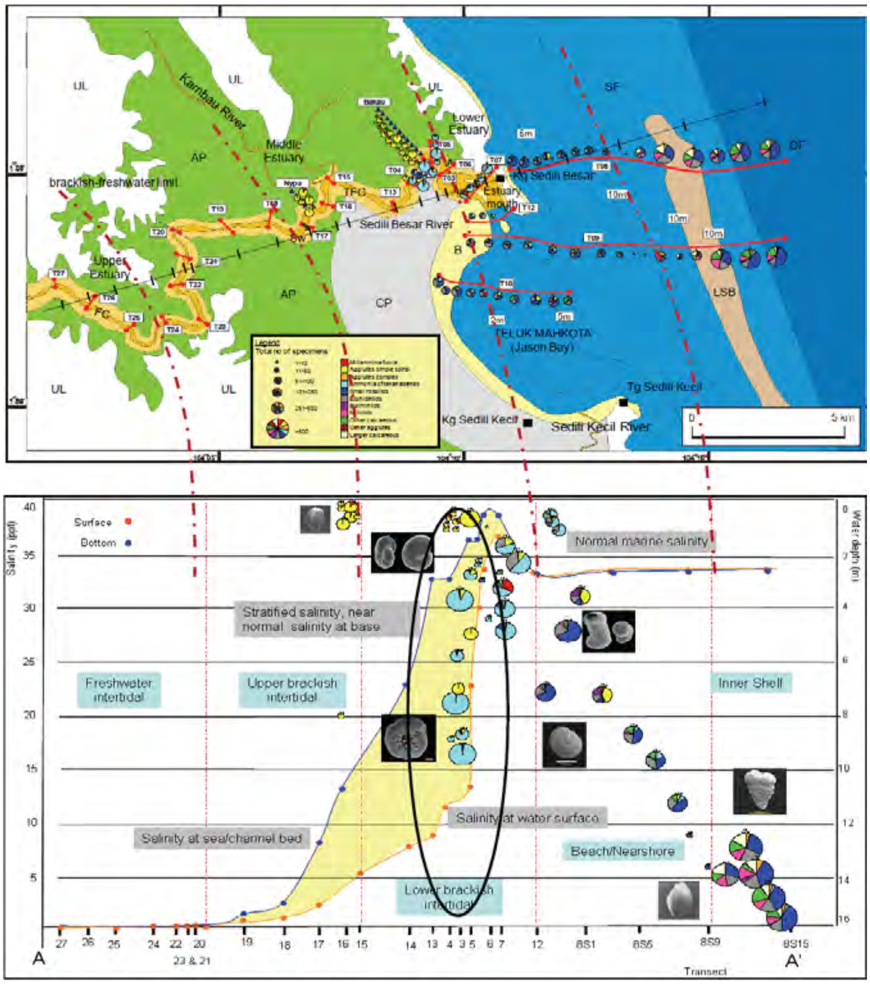

Figure 2: Ammonia cf. takanabensis (light blue) abundance in the stratified water column as observed from Sedili Besar Estuary

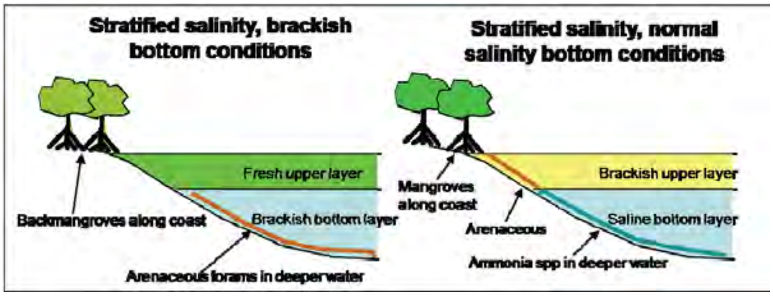

Figure 3: Two models with different stratified salinity

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GEOLOGY POSTER 8

DEVELOPMENT OF NEW CORRELATIONS FOR PREDICTING BUBBLE POINT PRESSURE AND BUBBLE POINT OIL FORMATION VOLUME FACTOR OF MALAYSIAN CRUDE OILS

B. Moradi[1], S.J. Hosseini[1], Birol M.R. Demiral[1] & M.Amani[2]

[1]EOR Center, Universiti Teknologi PETRONAS, Bandar Seri Iskandar, 31750,Tronoh,Perak Malaysia
[2]Petroleum Engineering Department, Texas A&M University at Qatar, 23874, Doha, Qatar

One of the most crucial parts of the input data in petroleum engineering calculations is fluid properties data. From the exploration stage, these properties should be determined either by laboratory experiments or using some empirical correlations.

Although, no one can underestimate the accuracy of the experimental results but these results are highly tied to the quality of the sample taken from the reservoir fluid and also, the condition of the reservoir can affect the quality of the sample.

In addition, sometimes laboratory data is not available or maybe for double checking and comparison purposes, we need another source of dataset rather than experimental data. In this situation, empirical correlations can be a relatively reliable alternative. These correlations can predict physical properties of reservoir fluid under a wide range of pressure and temperature1.

Among the properties of the reservoir fluids, Bubble point pressure (Pb) and oil formation volume factor (Bo) at Pb ,are essential in reservoir engineering calculations, since in improved oil recovery(IOR), if the reservoir pressure reaches to the Pb , the gas will start to evolve in the reservoir and due to the gas bubbles, the oil relative permeability will drastically decrease. Also, estimating Bo at Pb is quite challenging because this point is a inflection point in the curve of Bo vs. pressure and Bo is in its maximum value at Pb .So, it is very important to correctly predict it at Pb2 .

In this study, the new correlations has been developed to estimate bubble point pressure and oil formation volume factor of Malaysian crude oils.

This correlation is applicable for crude oils of ranging between 26 to 54 °API. The comparison of this new correlation with other published ones shows that it is much more accurate than the other ones.

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GEOLOGY POSTER 9

SEDIMENTOLOGY OF CARBONATE BUILDUP IN CENTRAL LUCONIA, SARAWAK, MALAYSIA

Noor Alyani Binti Ishak[1], Zulfiqar Ali[1], Richard Bray[1] & Eswaran Padmanabhan[2]

[1] PETRONAS Carigali Sdn Bhd, Level 11, Tower 2, Petronas Twin Towers, KLCC, 50088 Kuala Lumpur Malaysia
[2]Universiti Teknologi Petronas, Bandar Seri Iskandar, 31750 Tronoh, Perak.

Carbonate rocks are usually complex and difficult to understand, because of the heterogeneity of fabric and depositional setup. Even though the carbonate platforms in the Luconia province contain numerous gas reservoirs; little is published about their geological evolution, lithofacies, depofacies, depositional environment and stratigraphy (Gartner, 2000; Epting, 1980, 1989; Vahrenkamp, 1996, 1998). Alpha and Beta field that are located in Luconia Province are appraisals cum development fields that need a geological study as an input data for the 3D static model. Hence, Alpha and Beta field were proposed by PETRONAS Carigali Sdn Bhd for detailed sedimentological and stratigraphic study based on conventional cores and wireline data.

Three major stratigraphic intervals were defined from the core to well log correlation that was done on the conventional core taken from Alpha and Beta field, which are Lower Transgressive Unit, Middle Aggradational Unit and Upper Drowning Unit. Four lithofacies were identified in well Alpha which are coral floatstone, skeletal packestone, skeletal foraminiferal rudstone and argillaceous limestone; while five main lithofacies were determined in well Beta, which are coral floatstone, skeletal packestone, skeletal rhodolith packestone, skeletal grainstone and skeletal foraminiferal packestone.

From the seismic profile, Alpha and Beta fusiform-shaped isolated carbonate platform shows similar backstepping stratal geometries pattern to other isolated carbonate platform in Central Luconia Province which developed on fault bounded structural highs. The main factor controlling the distribution of stratal geometries within the carbonate across the Central Luconia Province was the sea-level fluctuation and local and regional variations in subsidence.

Based on the observation on both wells Alpha and Beta cores, petrographic analysis and routine core analysis (RCA) results for well Alpha, reservoir quality for both fields are assumed to be primarily shaped by the movement of freshwater in phreatic and vadose environments. Microporosity which is not restricted to any facies occurs through the entire cored section. The distribution of macroporosity however is confined to the carbonate sands, generally packstone and coral floatstone. RCA results in well Alpha indicate skeletal packestone and coral

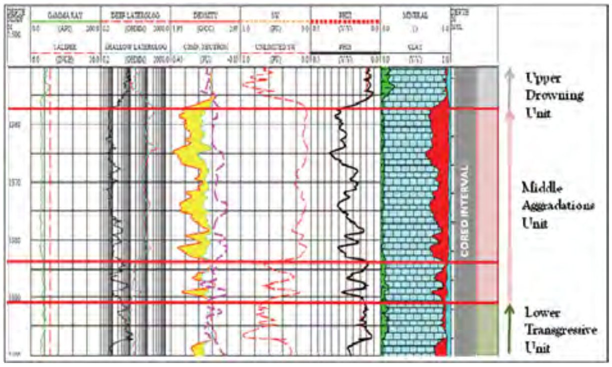

Figure 1. Well Alpha log to core correlation.

floatstone to have a good reservoir quality while well log in well Beta indicate good reservoir quality in skeletal packstone, coral floatstone and skeletal rhodolith packstone.

Based on facies association in core, well Alpha is interpreted to be situated in quiet water inner lagoon environment while well Beta is interpreted to be situated in high energy storm influenced outer lagoon environment. An excellent Holocene analogue is Chinchorro bank off the Yucatan peninsula of Mexico.

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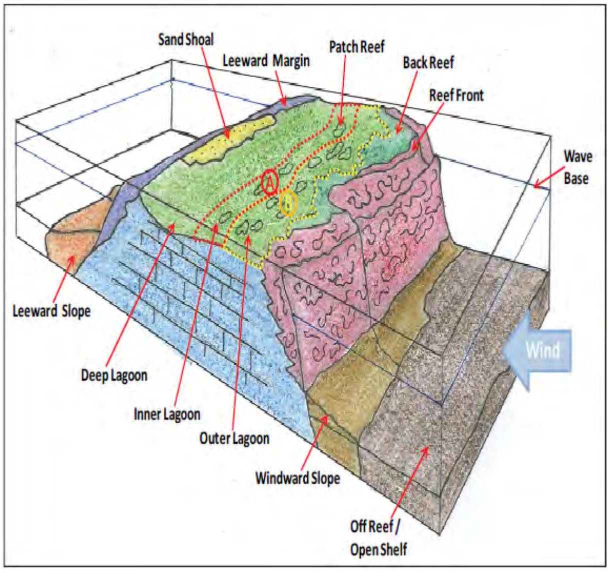

Figure 2. Schematic model of an isolated carbonate platform showing possible depositional environment for well alpha and beta.

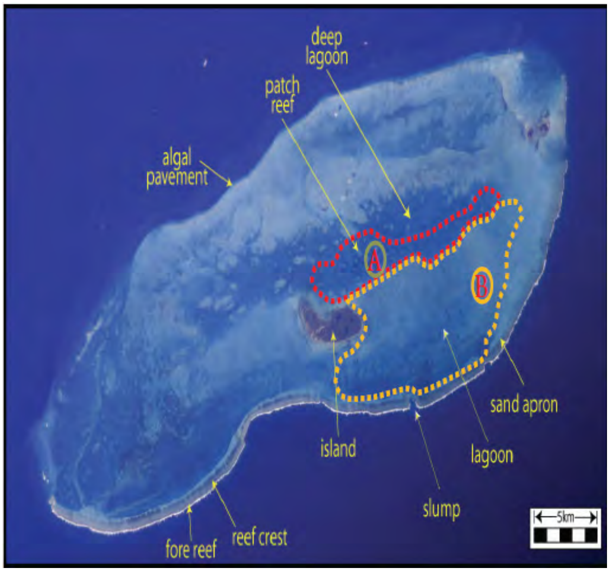

Figure 3. Recent analogues for alpha and beta isolated platforms and possible depositional environments for well alpha and beta. Modified after Bray (2009).

GEOLOGY POSTER 10

SEDIMENTARY FACIES, DEPOSITIONAL ENVIRONMENT AND SEQUENCE STRATIGRAPHY OF MIOCENE WEST BARAM DELTA CORE, OFFSHORE SARAWAK

Ummi Farah Binti Mohamad Rosli, M Amri Bin M Diah & Zulfiqar Ali

PETRONAS Carigali Sdn. Bhd, KLCC, 50088 Kuala Lumpur, Malaysia

Sedimentological and high resolution sequence stratigraphy analysis was conducted on Cycle V Miocene sediment from West Baram Delta, Offshore Sarawak. The analysis focuses on characterizing the different sediment types, investigates the different depositional processes and environments which includes application of high resolution sequence stratigraphy. Seven lithofacies were identified based on the distinct characteristics shown in each facies. Using this lithofacies scheme, eight facies association were interpreted namely upper shoreface, middle to lower shoreface, lower shoreface, offshore, prodelta to delta front, lower estuary, distributary mouth bar and lagoon. It is interpreted that the cored intervals were deposited within a shallow water marginal marine to nearshore setting. Trace fossils are described as it forms an integral part of the main facies scheme and used as an aid to the characterization and interpretation of individual facies. Two parasequence sets were identified: (1) retrogradational parasequence set defined by eight coarsening and fining upwards parasequences; (2) a progradational parasequence set characterized by seven coarsening and fining upwards parasequences. The reservoir quality in the sediment is affected by factors such as clay content, bioturbation, sedimentological controls (lithology and grain size), thin laminations and also diagenetic factor such as siderite and calcite cementation. These factors can highly affect the reservoir properties and may increase or decrease the reservoir quality. Understanding the factors that control the reservoir quality and the heterogeneity of the facies, depositional environment and petrophysical properties is important in assessing the reservoir quality and distribution. This is to ensure a more accurate evaluation of the reservoir architecture, more precise modeling of the reservoirs and better prediction for future development of the field.

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GEOLOGY POSTER 11

A NATURAL LABORATORY FOR FRACTURED GRANITOID AND META-SEDIMENT RESERVOIRS AT REDANG ISLAND, TERENGGANU

Adriaan Bal[1], Hamdan Mohamad[2], Zulkifli A Hamid[2], Garry Malo-Paul[2] & Askury A Kadir[3]

[1] Baker Hughes Inc, Level 25, Menara Tan & Tan, 207 Jalan Tun Razak, Kuala Lumpur
[2] PETRONAS Carigali Sdn. Bhd. (PCSB), Level 16, PeTT-2, KLCC, 50088, Kuala Lumpur
[3] G&P.Eng. Depart. Universiti Teknologi PETRONAS, Bandar Seri Iskandar, 31750 TRONOH, Perak, Malaysia

SUMMARY

There are many classic outcrops that serve as example analogues for clastic and carbonate fields (e.g. Book Cliffs Utah USA or, locally, the Miri to Bintulu road-cut). But in our region there are very few documented fractured basement rock analogues. The Redang archipelago, Terengganu, Malaysia, with excellent granitoid and metasediment coastal outcrops (Khoo et al, 1988), is proposed as a natural laboratory providing excellent examples of meso- and macroscopic scale structural features. This archipelago offers a variety of fracture types of different genesis within a relatively small easily accessible space (45 min flying from KL) located 45km off the coast of Kuala Terengganu (Figure 1). This poster documents the learning from outcrops recently visited by a multidisciplinary team comprising geologists, petrophysicists, reservoir engineers, asset managers, and drillers.

INTRODUCTION

Collectively, the hydrocarbon industry generally understands traditional reservoirs; where depositional environment underpins reservoir architecture and formation evaluation methods and techniques are sophisticated and mature; underpinned by excellent quality outcrop examples used as natural laboratories for training. In contrast, an understanding of structural geology generally and geomechanics specifically is fundamental to understanding any fractured basement reservoir plays.

Any proposed fractured-basement natural laboratory requires good accessible field examples illustrating different fracture types, geomechanical concepts, and evaluation methods relevant to fractured basement plays. Locally, the Redang archipelago shows structural simplicity but also the real complexity of the natural world ideal for appreciating the difficulties associated with formation evaluation of key fractured basement parameters (e.g. porosity, permeability, and productivity).

Fractures

It is very important to recognise that factures are dynamic features that depend on pore pressure and effective stresses. They generate because the stresses and strain exceed the rock coefficient of friction and therefore fails (i.e. fractures). Fracture morphology (open / closed / partly open / vuggy / length / roughness, etc) reflect changes in pore pressure, paleo-effective stress and present day in-situ stresses. All fracture types, tensile, hybrid, and slip (mode-1, mode-2, mode-3) types illustrating these features are well exposed and can be related to basic geomechanical principles (Figure 2).

Fracture Origin

An appreciation of fracture origin models is required to fully evaluate any acquired subsurface fracture data base and differentiate the data into sets and appraise fracture origin. Fractures can be classified into four groups based on origin (Table 1). Differentiation into origin is important because origin has implications for network development and consequently has predictive properties in terms of aerial extent and fracture spacing. Igneous rocks which are emplaced as molten masses do not begin to fracture until they have cooled sufficiently to take on the properties of solids. Once formed they may continue to fracture in different ways as a result of cooling, regional processes, localized tectonic events, and unloading or weathering when near the surface (Price and Cosgrove, 1990). Redang archipelago displays examples of all these fracture origins. Figure 3 illustrates fault related fractures and is placed within a seismic and modeling scale framework.

The basic modes of fracture genesis, ductile, brittle, primary and secondary fractures, regional tectonic and fault related, and surface related fractures can be observed and measured. Cross cutting relationships show age relationships. Description, kinematics, and dynamics related to barren (open) and mineralized (closed) fractures, fracture aperture, along hole fracture density is discussed and illustrated at specific outcrops. Where possible, field examples are related subsurface actual subsurface examples from Vietnam or Malaysia.

Figure 1: Location Map 1

Table 1: Fracture origin and scales over which the origin develop fracture (after Nelson 2001)

Fracture Origin	Feature scale
Tectonic fractures (attributed to local tectonic events and form networks with specific spatial relationships to folds and faults)	9-10 orders
Regional fractures (developed of extremely large areas of crust and have very little change in orientation, simple geometry, and relatively large spacing (1-20 ft). Are unrelated to local structures and are usually developed as orthogonal systems.	5 orders
Contractional fractures (cooling joints)	2 orders
Surface-related fractures (e.g. exfoliation) developed down to about 40 m below the surface.	4-5 orders

Data Collection and Evaluation

Collecting valid fracture parameter data in the subsurface is very difficult. Actually seeing the fractures in the field and attempting to collect and analysis this data provides useful insight and critical discussion about collection and evaluation methods. For example, different groups measuring fracture density along a pseudo-horizontal well (tape measure laid across the outcrop) resulted in different answers.

CONCLUSION

Redang archipelago is an ideal location for a fractured basement natural laboratory. The archipelago provides good analogues of usually difficult to see and appreciate subsurface fractures. The presence of multidisciplinary teams allows for a lively and critical debate on important features and evaluation methods. Field exercises provide hands on experience for data collection and appreciation of uncertainties.

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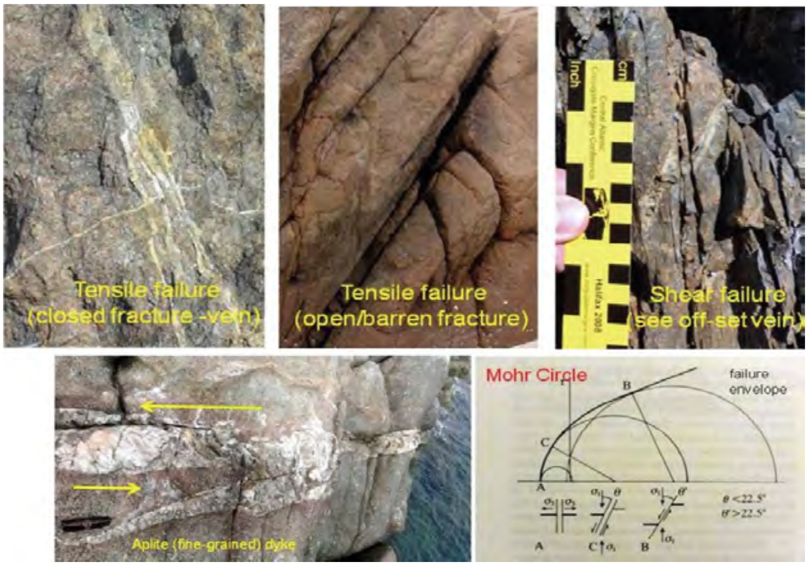

Figure 2: Different fracture types observed in the Redang archipelago. The Mohr Circle, with Navier-Coulomb/Griffin brittle failure envelope, shows stress states that would give rise to extensional (small circle), hybrid (intermediate circle) and shear failure (large circle). Mohr circle from Price and Cosgrove 1990.

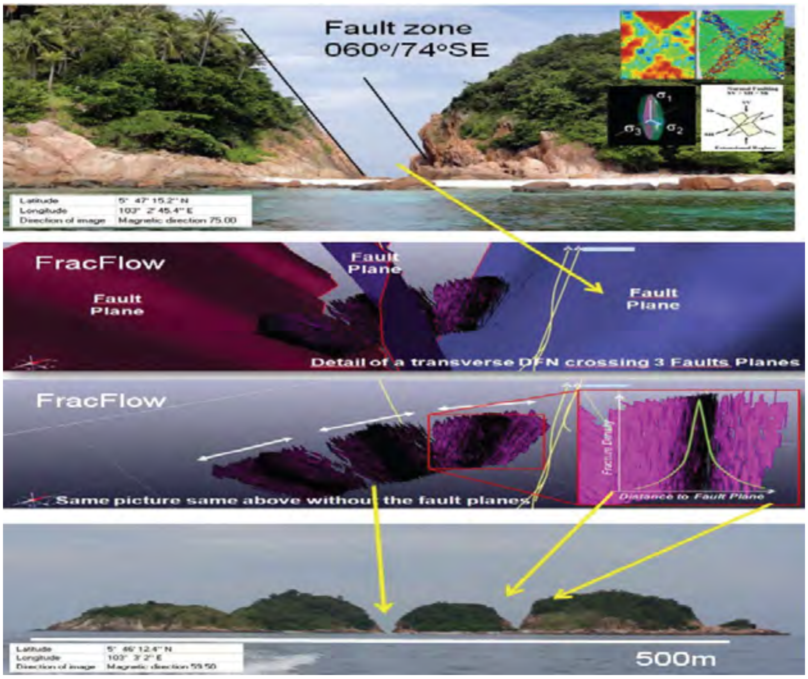

Figure 3: Preferential erosion of shear zones result in development of 5 islands show of shear zones susceptible to weathering due to the high-fracture density characterized by higher porosity and permeability relative to adjacent foot/hanging wall blocks. This location develops appreciation for structures at seismic scale and discrete fracture network (DFN) modelling.

GEOLOGY POSTER 12

THE POSSIBLE SIGNIFICANCES OF COALS ENCOUNTERED IN CORED SECTIONS FROM THE CENTRAL MALAY BASIN; IMPLICATIONS FOR SEQUENCE STRATIGRAPHIC INTERPRETATION AND BASIN CHARACTER

David Ince[1], Mazlan Madon[1], Abdul Hadi A Rahman[2], Ahmad Munif Bin Koraini[2], Mahani Mohamed[1], Sanatul Salwa Hasan[3] & Samsudin Jirin[3]

[1] PETRONAS Carigali Sdn. Bhd, Level 16, Petronas Tower 2, KLCC, 50088, Kuala Lumpur
[2] Orogenic Resources Ltd
[3] PETRONAS Research Sdn. Bhd., Kawasan Institusi Bangi, 43000 Kajang, Selangor, Malaysia

Cores recently acquired from E Group sections from the central Malay Basin, have been the subject of detailed and integrated sedimentological and palaeontogical studies in order to provide the basis for improved understanding of reservoir sequences. These studies have included detailed core description and dense sampling for combined micropalaeontological and palynological analysis. The results of these programs have revealed significant results that allow the coals to be confidently assigned to a particular phase of relative sea level and, furthermore, shed light on the nature of the overall receiving basin. Models have been developed to account for the sequences observed. These may apply more generally to the Malay Basin sections, although variations on this basic theme may occur.

The coals studied have been shown to be of both freshwater and brackish origin, based on the palynological and micropalaeontological content. In all cases they represent phases of drying out of the basin, some being correlatable over wide areas. They are usually underlain by variably well-developed seat earths which show high levels of bioturbation/pedoturbation and also contain marine to brackish microfaunas. As such these seat earths often represent the most saline/marine sediments in a given sequence. This is a feature of many seat earths in the Malay Basin that we have been able to study in addition to those from Sepat. The coals are generally rootleted, and the seat earths are pale grey in colour indicative of the soil zone leaching that creates such deposits. Peat accumulation is invariably terminated by a flooding event, although this may be freshwater, or brackish, based on the palaeontology and level of bioturbation. One of the coals studied occurs as a split seam, with an enigmatic conglomeratic lithology present in the intervening interval.

The conclusion drawn from these observations is that at various stages of the fill of the Malay basin the areas was prone to regular drying out, with the establishment of widespread coal forming peats. River channels formed at the same time as these peats and dissected the area, which is thought to have been low relief, but occasionally flood events breached the channel margins and killing the peat mires, at least locally. Peat accumulation was brought to a close by flooding of the basin, either with fresh or brackish water. This suggests there to have been some form of barrier to the basin, preventing or restricting the ingress of saline water. The presence of brackish water coals may approximately locate the palaeo coastal belt for a given cycle and the upward change in coal character indicates increasingly freshwater conditions. This in turn suggests that peat facies belts may have been migrating basin-wards during phases of falling sea levels, resulting in the establishment of more widespread peats. Reservoir sandstones in the cored sections were most probably deposited within fluvially dominated shallow water deltas or sub deltas in a lacustrine setting.

These observations can be combined to allow a simplified cycle to be developed for the coal bearing intervals in the fill of the Malay Basin. Given that the seat earths appear to be the most marine parts of the section it is considered that the coal forming peats began to form with the onset of falling sea levels, with both the brackish and freshwater peats migrating basin-wards with the coastal belt. Basin-wards migration would have halted at the onset of transgression and thus the S.E. limit of a given coal would delineate the regressive maximum for a particular cycle. Thus the bases of coal beds are likely to be significantly diachronous. The tops of coal beds may also be diachronous. Variations in the make up of sequences occur, probably as a result of subtle interactions between sea level, subsidence in the receiving basin, and the tectonic or sedimentary factors creating a barrier at the S.E. end of the basin. Such short term changes in sea level, and consequently in the geomorphology of the Sunda Shelf, are unsurprising. Recent research (Sathiamurthy and Voris,2006) using Digital Elevation Models has shown the possible response of the area to glacio-eustatic fall in sea level during the Last Glacial Maximum, some 21ka BP, when sea levels were some 116m lower than at present, with the development of former low-lying, potential lake, areas on the exposed shelf which formed Sundaland. Repetition of such changes is considered likely to have resulted in the accumulation of the strongly cyclical sequences typical of parts of the Malay Basin succession.

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GEOLOGY POSTER 13

CALIBRATING CARBONATE CORE DATA TO WIRELINE DATA: SEARCHING FOR A RELATIONSHIP BETWEEN PETROPHYSICAL PROPERTIES AND MAPPABLE DEPOSITIONAL TRENDS

Mehmet Altunbay[1], Adriaan Bal[1], Selim Belhaouas[2], Richard Douglas Bray[2], Gamal Ragab Gaafar[2] & Siti Salwa Bt Sharuddin[2]

[1]Baker Hughes Inc, Level 25, Menara Tan & Tan, 207 Jalan Tun Razak, Kuala Lumpur
[2] PETRONAS Carigali Sdn. Bhd. (PCSB), Level 40, Menara Citibank, 165 Jalan Ampang, 50450 Kuala Lumpur

A common carbonate formation evaluation objective is to define a relationship between petrophysical properties and mappable depositional trends. If such a relationship exists, reservoir simulations and full field development plans are easier to formulate because we can infer petrophysical properties beyond the borehole using the depositional maps as a proxy.

This poster focuses on describing the heuristic process of calibrating wireline logs from an offshore Borneo well that cored carbonate rocks. The process describes the different blind, but necessary, avenues followed to arrive at an optimal facies and petrophysical relationship. One lesson learned in this case study is that multiple methods of inquiry and the integration of different datasets and disciplines are paramount for a more effective understanding of results and the best way forward.

A comprehensive data set was acquired including cores, NMR, full waveform acoustics, borehole images logs, and pressure tests. After data acquisition, a first-pass analysis of reservoir productivity was undertaken using methods outlined in Altunbay, et al (2007). These initial results provided a dataset for work by reservoir engineers. Concurrently, cores are described, plugged for porosity and permeability measurements, acquisition of mini-permeametry data, special core analysis, and thin sections are described.

Borehole image logs suggest there are widely varying facies despite the core being largely uniform skeletal packestone (Figure 1). The resistivity image was unitized according to motif, for example predominately massive conductive or massive resistive, layered, or convoluted (Figure 2). The acoustic image logs were similarly unitized into facies largely reflecting acoustic impedance (Figure 3). Variations in resistivity and acoustic fabrics were expected to relate to vuggy porosity distribution in the core. These image facies were later compared with core facies, logging petrophysical parameters, and when available, the core petrophysical parameters. Surprisingly, resistivity image variation did not reflect vuggy porosity distribution. Acoustic images reflected variations in permeability.

The core was mostly packestone with little variation. Thin section work showed that there was a heavy diagenetic overprint. Consequently, core petrophysical properties largely followed diagenetic trends rather than depositional trends. Ultimately, the first-pass analysis proved to be the best way forward. This is not to say that searching for mappable units is invalid. Ideally, we need mappable units to determine the 3D geometry of the reservoir and must search for these possibilities is a necessary requirement.

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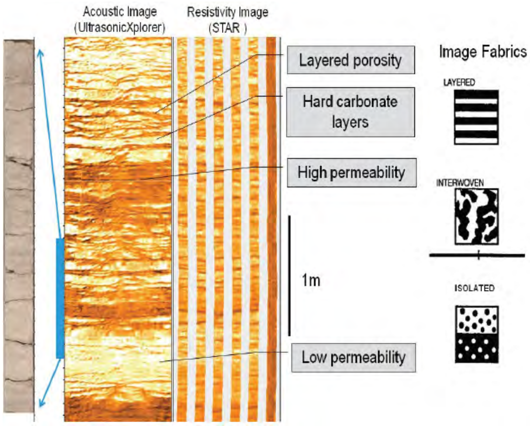

Figure 1: Alonghole view of static image logs showing predominantly layered image fabrics. Corresponding core shows no apparent variation in lithofacies (100% skeletal packestone). Variation in image response relates to changes in permeability and porosity that is not visually apparent in the core.

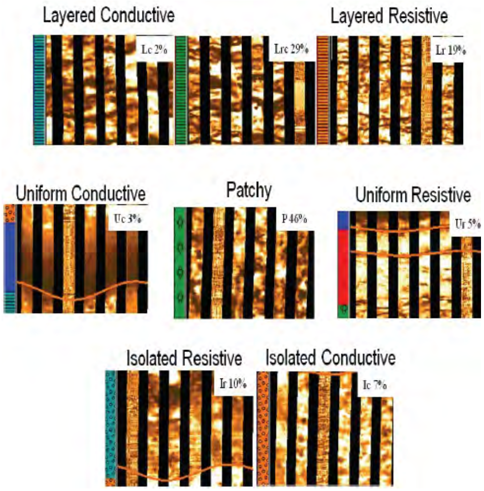

Figure 2: Distribution of resistivity fabrics. Horizontal axis ranges from conductive to resistive. Vertical axis ranges from isolated through to layered fabrics. Percentage quantifies relative proportion in image.

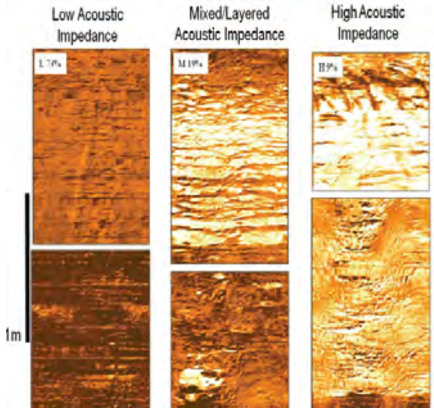

Figure 3: Distribution of acoustic image fabrics. Percentage quantifies relative proportion in image.

GEOLOGY POSTER 14

METHODOLOGY IN SURFACE EVALUATION OF THE FOLD AND THRUST BELT REGION

W Suraya Alssendra, M Hilman B Roslan & Suhaileen Shahar

Global Petroleum System Dept., Basin Analysis & Acreage Evaluation Div.,
PETRONAS Exploration, Level 16, Tower 2, PETRONAS Twin Towers, Kuala Lumpur City Centre, 50088 Kuala Lumpur, Malaysia.

INTRODUCTION

Folded-belt is a distinctively challenging area for all type of E&P activities. Majority of folded-belts on earth are known non- working petroleum system. However some folded-belts are distinctively proven prolific hydrocarbon zone and active E&P area, for example in the Middle East. In areas where accessibility is a challenge, be it geographically or politically, a new method of geological evaluation is needed. There are also times where subsurface data is acquired but due to its low sampling and poor quality this could be a challenge to interpret therefore, a different method is required to assess the area of interest. Moreover, present-day challenging global E&P environment, forced us to look beyond our comfort zone and identify exploration opportunity in areas where we are limited in capability.

This presentation will discuss briefly on workflow and methodology used in evaluation and hydrocarbon prospecting of a folded belt surface evaluation.

WORKFLOW & METHODOLOGY

Prior to the start of any evaluation, a regional study is needed to identify important tectonic events, it's elements and dynamics, structural style and basin evolution which among others include, sediment fill and rock rheology's influence on deformation pattern and regional field excursion is needed to calibrate with desktop evaluation and to confine structural styles.

The satellite based mapping was done by interpreting data from Landsat-7 ETM+ and SRTM (LDCM, 2006). The in house Landsat data has a 30m (Band 1-7) and 15m (Band 8) resolution. SRTM or Shuttle Radar Topography Mission records digital elevation models near global scale from 56 deg S to 60 deg N. The database resolution is 90 m. Google Earth was used as referenced because direct structural interpretation cannot be done on it hence it was used to visualize terrains in 3D. In areas where vegetation is low, lithostratigraphy changes can be easily recognized. However, dipping beds might be a challenge to observe due to dip smearing that occurs in Google Earth images.

Structure pattern identification is done by outlining structural crest using SRTM data (Figure 2). This exercise is done with a lot of iterations as it is not always a straightforward identification process of a fold hinge due to the nature of thrust folds and box folds. The elevation highs on SRTM may also indicate resistive limbs of eroded anticline cores. This process requires iteration mapping using Landsat and Google Earth.

In areas where there is low or no vegetation, lithostratigraphy correlation (Figure.3) is easily carried out using Landsat but it also requires ground truthing as the colours may not indicate lithofacies. This method can be used in areas where lithostratigraphic units are widespread. Lithostratigrahic interpretation will then be used to better define or confirmed the structure interpretation for example in distinguishing between an antiform or synform

PROSPECTIVE CORNERS IDENTIFICATION

Structure and Stratigraphy mapping consists of a set of iterative process as shown in the figure below (Figure.4). It is essential to correlate with other data and information that is available to increase confidence on the satellite interpretation. Ground truthing is a critical process used to prove and identify anticlines and structure styles of the first and second order. The image's resolution does not easily resolve complex structure styles. It is also an essential tool used in calibrating, especially for stratigraphy mapping. In low accessibility areas, where proper field work can't be carried out, geological maps (national geological survey, academia and published maps) and published cross sections can be used. Subsurface information is used to calibrate the type section and thickness of each rock units. The nature of geology and geography of study area controls our confidence in correlation and mapping.

Once completed, the structural and stratigraphy mapping are integrated to produce cross sections of the area. The cross sections are then used to identify structural geometry and trap configuration on the subsurface. The structure model is meant to support the petroleum system concept in the subsurface and define prospective corners for exploration activities.

The main challenge in this method of evaluation is excessive vegetation and information accuracy due to satellite

Figure 1: General workflow of folded belt surface evaluation.

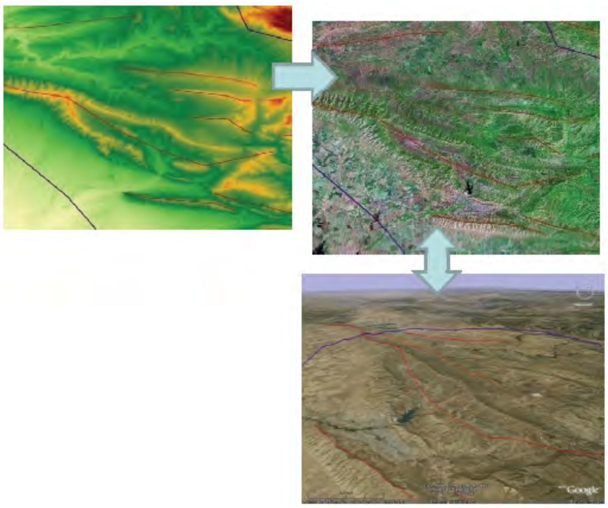

Figure 2: Structural crest identification, (Clockwise : SRTM data, Landsat data & Google Earth image)

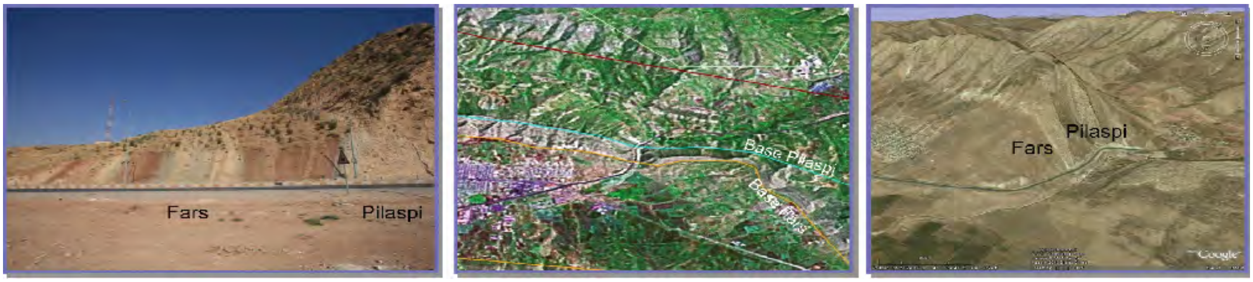

Figure 3: Lithostrastigraphy mapping (L-R: Fieldwork picture, Landsat data, Google Earth Image)

image resolution, poorly georeferenced images, maps and cross sections, confidentiality issues with host government to release subsurface information and oversimplified map sources from publication.

In interpreting structures, where there is an eroded anticline cores, structural crest may not always be the fold axes and this may lead to inaccurate interpretation. Thrust faults are also hard to map as the faults thrust and displacement are not easily observable. In the foreland area, it is a challenge to map due to diminishing observable topography. In stratigraphy mapping, we are mapping lithostratigraphy while in basin evaluation, chronostratigraphy mapping is required to tie to basin evolution and petroleum system study. It is a huge challenge to understand the chronology of basin evolution from lithostratigraphy mapping alone. Various version of interpretation, mainly in stratigraphic terminology across political borders and tectonic models, may complicate accurate identification.

Figure 4: Satellite based evaluation workflow that leads to prospective corner identification.

CONCLUSION

Regional satellite mapping proves to be useful in clarifying areas with potential trap. The workflow and methodology is easily applicable in high terrain, less vegetated onshore area where regional scale geological evaluation is needed. The work platform only requires basic Windows OS, ArcGIS and an Internet connection which is easily available and accessible. This allows abundance of time to be spent on evaluation and interpretation of findings and it also allows documentation in digital and reworkable formats. It has to be noted though, that satellite mapping alone is not adequate for prospect evaluation maturation and should be used as part of regional or semi regional scale petroleum system analysis.

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GEOLOGY POSTER 15

SEDIMENTOLOGY OF LAAYOUNE-DAKHLA AREA WESTERN SAHARA DESERT, SOUTH MOROCCO

Zulfiqar Ali[1] & Zainal Abidin B Juni[2]

[1] Petroleum Geosciences Department, Petroleum Engineering Division,
PETRONAS Carigali Sdn.Bhd, Tower-2, Level-11, Petronas Twin Towers KLCC, 50088 Kuala Lumpur, Malaysia.
[2] Petroleum exploration (XPM) PETRONAS Carigali Sdn. Bhd. Tower-2, Level-10, Petronas Twin Towers
KLCC, 50088 Kuala Lumpur Malaysia.

Direction des Resources Hydrauliques (DRH) drilled water well in Boujdour N° ANGER 1181/120, located at approximately 2.7 km in the North-East of Boujdour and at 50-100 m in the east of the Laâyoune-Boujdour road; Western Sahara Desert, Morocco. On test oil was encountered along with water, as a direct result PETRONAS Carigali Morocco Sdn Bhd. in collaboration with state owned oil company ONHYM decided to evaluate this area geologically for its hydrocarbon potential.

The aims and objectives of the study were to carryout detailed sedimentological and basin modelling study to determine the depositional environment of expected reservoirs, hydrocarbon generation, migration and accumulation within reservoir horizons. But here we will discuss only sedimentology of the basin that will explain reservoir characterisation, distribution and geometry within the study area.

Sedimentological investigation was planned in onshore Laayoune-Tarfaya area, in-order to understand the reservoir distribution, facies interpretation and depositional environment of major synrift and post rift mega sequences.

As a part of sedimentological investigations, reconnaissance geological field trip to Laayoune-Tarfaya area of Western Sahara organised by ONHYM in joint collaboration with PETRONAS

Carigali in May 2006, and a detailed field geological report was submitted to PETRONAS Carigali Morocco exploration team and ONHYM Morocco (Ali. Z, 2006). Drilled well data for study was provided by Geoatlas and ONHYM. Very brief lithological information's were provided but a good attempt is made to utilise all available data in present study, whereas petrographic and palaeontological data was not available.

Detailed stratigraphic and sedimentological analysis of available data reveals that sediment thickness progressively increases from onshore Western Sahara Margin Basin to offshore Western Atlantic of the Laayoune Dakhla Area, which is located both onshore and offshore the passive Atlantic margin of southern Morocco and extends southwards throughout Western Sahara. To the south and southeast area merges with the Senegal Basin and limited to the east by Precambrian basement, to the east by Palaeozoic strata of the Tindouf Basin and to the north and northeast by the Precambrian of the Anti-Atlas Mountains, western limit of the area is considered as the present day shelf break located approximately 20-50 km offshore (Fig-1). These westwards dipping continental to shallow marine sediments of Mesozoic to Cenozoic age are lying on prerift Palaeozoic basement.

Rifting probably commenced in Early Triassic whereas sedimentation begins in Middle to Late Triassic and Lower Jurassic with deposition of continental/lacustrine as major synrift sequence occur in close proximity to provenance in eastern part of the study area. Triassic and Lower Jurassic sandstone can be a possible reservoir as hydrocarbon shows are reported in Triassic from wells (UETAT.A2-41 and UETAT A1-41).

Basin subsidence in Triassic and possibly in Lower Jurassic time makes a way for post rift carbonate deposition. This post rift mega sequence started with the opening of Atlantic during Middle to Upper Jurassic. With the marine transgression, carbonate platform is established in the south-eastern limit of the area whereas more open marine condition is established in north and north western part of the area. Carbonate deposition prograded offshore Western Atlantic probably forming carbonate shoals/reefal build-up that can be a possible reservoir, as Jurassic petroleum system has been proved from onshore PC-1 and off shore Cap Juby wells (MO-2, MO-8 and Cap Juby-1).

Second post rift mega sequence deposited in Lower Cretaceous when the carbonate sedimentation ceased and platform drowned, as a result fluvial system got active over drowned carbonate platform depositing clastic sedimentation of fluvial channel to marginal marine deltaic nature. This post rift sequence is mainly composed of silty-shaly-marly marine sediments to the west offshore Atlantic and sandy to very coarse grained conglomeritic red sandstone in the eastern part of the area. Sediments progressively showing facies variations and prograded from east to west as evident from westwards increase in sediment thickness.

The third major post rift sequence is related to the major transgression that began in the Middle Albian reaching its maximum in the Cenomanian Turonian. This sequence is mainly composed of marls, very calcareous shale that is rich in organic matter and associated by chert and limestone nodules, as has been noticed in outcrops of famous Tarfaya Oil Shale in Laayun-Tarfaya along coastal area of western Atlantic, Sahara Desert. Thickness of these rocks progressively increases from east to west, but in Tarfaya North its erosional limit can be marked along present day shoreline, which shows uplifting and erosion to certain limit possibly at Maastrichtian has been

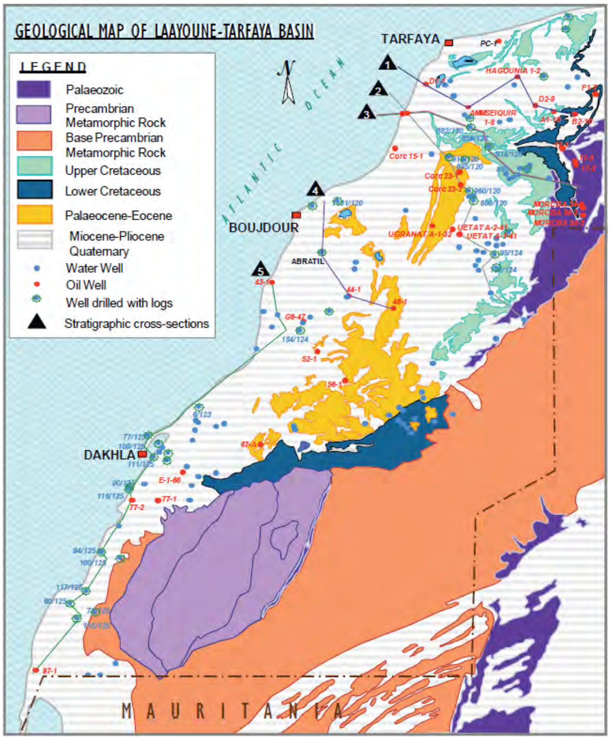

Figure 1: Location and geological map of the area.

uplifted and eroded. These marls are interpreted as possible reservoirs if well developed fractures system and hydrocarbon migration path is established. Oil reported from Cretaceous marl in Boujdour water Well#1181/120, which is most probably assumed as subsurface extension of oil shale horizons exposed in Tarfaya area.

Extensive Tertiary sedimentation in offshore Atlantic is noticed, whereas it is uplifted and eroded in onshore eastern part of the Laayoune-Dakhla Area because most of the cross section reveals thinning of Tertiary sequence towards eastern most limit of the study area. The basin fill was affected by uplift and erosion particularly along the eastern margin between 40 Ma and 20 Ma westward (IHS Energy, 2005). Sediment thickness decrease southward to Dakhla, where only one km of sediments is present onshore. The broadest part of the margin is located between Boujdour and Dakhla, where shelf reach up to 150 km wide in water depth less than 200m. (Ranke et al; 1982, Heyman, 1989, Davidson, 2005).

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GEOLOGY POSTER 16

ECHINODERM PALAEOECOLOGY FROM FRAGMENTS: A TOOL FOR FACIES RECOGNITION IN MESOZOIC CARBONATE SEQUENCES

Aaron W. Hunter

Geoscience & Petroleum Engineering Department, Universiti Teknologi PETRONAS, Bandar Seri Iskandar, Tronoh, Perak, Malaysia
E-mail: aaron_hunter@petronas.com.my

Echinoderms such as crinoids (sea lilies), are a major component of the marine benthos from the late Palaeozoic onwards, where they occurred in such high number so as to be rock forming. On death echinoderms will typically disarticulate into many thousands of ossicles which are considered by many palaeontologists to be indeterminate (Benton and Simms 1995). Research into Mesozoic fossil crinoids has demonstrated that there is currently a lack of understanding of their environmental palaeoecology. This is in part due to taxonomy based soley on exceptionally preserved whole specimens. Thus it has become necessary to consider fragmentary ossicles in defining a more representative palaeoecology.

Bulk sampling (10 to 40 kg) of Middle Jurassic (Bathonian) carbonate and muddy sediments of England, where marine environments ranging from open shelf to lagoon are represented, has yielded numerous crinoid ossicles. Extensive work on exceptionally preserved Middle Jurassic crinoids from northern Switzerland and British Lower Jurassic has enabled identification of crinoid ossicles from the English Bathonian to generic level (Hess 1975).

Results indicate that the colonisation patterns of crinoids are strongly influenced by facies type, allowing the community structure of the crinoids to be clearly defined in ecosystems delineated by substrate type and degree of marine connection. Thus distinct crinoid communities, based on the presence and absence of generic indicators, can be deduced (Hunter & Underwood 2009).

After being successfully developed, the 'crinoid model' was taken a stage further, with its application to three more echinoderm groups: echinoids (sea urchins), asteroids (starfish) and ophiuroids (brittlestars). Previously it was noted that lack of homology in the ossicles made identification beyond family level problematic within these groups. As with the crinoids, examination of complete specimens in museum collections has allowed the recognition of diagnostic ossicles that can identify tests, spines and marginal plates to generic level.

These new data has allowed the construction of a model for echinoderm palaeoecology across marginal marine environments. The application of this model to marine environments outside the British Jurassic, such as the Middle Jurassic of France and the Western Interior, USA, has demonstrated that factors such as substrate and marine connection (salinity) have a greater bias than palaeogeographical and stratigraphic controls.

I propose that the small size of these echinoderm micro-fragments and the large number found preserved, means that they can be used as tool for facies recognition alongside other more traditional fossil groups, such as foraminifera and ostracods and are far more informative than many other macrofossils currently used.

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GEOLOGY POSTER 17

A GEOCHEMICAL OVERVIEW OF SELECTED PALAEOZOIC AND MESOZOIC PETROLEUM SOURCE ROCK ANALOGUES FROM OUTCROP STUDIES, PENINSULAR MALAYSIA

Patrick Gou, Meor Hakif Amir Hassan, Yeow Boon Sim, Wan Hasiah Abdullah & Lee Chai Peng

Geology Department, Faculty of Science, University of Malaya, Kuala Lumpur, Malaysia

With petroleum resources on the decline, oil and gas companies worldwide including Malaysia are on the lookout for unconventional petroleum accumulations. Part of this effort includes looking at older and deeper petroleum source rock intervals that could have generated hydrocarbons earlier that subsequently accumulated in older and deeper reservoir intervals.

In Peninsular Malaysia, two main Tertiary petroleum systems exist (Madon et al., 2006; Tan, 2009). Madon et al. (1999) identified the Groups L and K lacustrine shales (Upper Oligocene-Lower Miocene), and Groups I and H fluvio-deltaic shales and carbonaceous/coaly shales (Lower-Middle Miocene) as the main petroleum source rock intervals for the Malay Basin. Deeper units such as sediments from Group M and pre-Group M (syn-rift) sediments are also believed to contribute to the petroleum system.

The 2005 discovery in the south western part of the Malay Basin by the exploration well Anding Utara-1 penetrated a 220 m oil column in metamorphic rocks (Shahar, 2005). This is significant as it indicates the possibility of having hydrocarbon accumulations in older rocks. Such play is commonly referred to as the fractured basement play. It is believed that the Penyu Basin, which lies to the south of the Malay Basin, could potentially have similar plays as the basement there mainly consists of metamorphosed basalts and weathered tuffs (Fanani et al., 2006). However, the hydrocarbons for these fractured reservoirs, which are on basement highs are thought to be sourced from younger sedimentary rocks that are positioned lower/deeper in grabens.

This study will evaluate the potential of older (i.e. Mesozoic and Palaeozoic) petroleum source rocks based on geochemical analysis of outcrop samples from Peninsular

Malaysia. As the fractured basement play involves reservoir rocks that are of Cretaceous age or older, it is interesting to see if any organic-rich intervals from the Palaeozoic or Lower Mesozoic in Peninsular Malaysia could have contributed to earlier hydrocarbon generation.

The characteristics of these rocks are described based on SRA (Source Rock Analyzer), organic petrography and GC-MS (Gas Chromatography-Mass Spectrometry) analyses. Estimations on the actual hydrocarbon potential in terms of quality and quantity will also be presented, based on the laboratory analyses results and understanding of the regional geology and tectonic history.

Preliminary screening data from SRA-TPH/TOC (Source Rock Analyzer-Total Petroleum Hydrocarbon/Total Organic Carbon) of a black shale sample interpreted to be of Permian age from NW Peninsular Malaysia indicate that the shale has some remaining hydrocarbon potential. This has not been seen in other pre-Tertiary outcrop samples from Peninsular Malaysia. The present-day hydrogen index (HI) of this sample is still quite significant despite its maturity and age. If this is extrapolated back in time, the initial HI would be higher and was probably in the range that favours the generation of significant amounts of liquid hydrocarbons.

The black shale sample was collected from the Kubang Pasu Formation in Beseri, Perlis, and is of probable Permian age. Black shale intervals are common in Palaeozoic rocks worldwide, including Malaysia (e.g. the Detrital Members of the Setul Formation and the black mudstone interbeds of the Kubang Pasu and Singa Formations). The global distribution and correlation of these Palaeozoic black shales indicates that their deposition was controlled by global events. Oceanic Anoxic Events have been suggested to be the main cause, where climate warming and high levels of CO_2 resulted in sluggish ocean water circulation, leading to stratified oceans and oxygen deprivation in deeper waters. Conditions were probably similar to the present day Black Sea, but at a worldwide scale. The high productivity, greater than normal accumulation and preservation of organic material in deep waters produce black shales. Many of these globally distributed black shales are associated with major mass extinctions (Hallam & Wignall, 1997).

A set of samples from younger sediments thought to be of Mesozoic age from Pahang in the central part of Peninsular Malaysia also show signs of remaining hydrocarbon generation potential, especially in the coaly lithologies. The coaly nature of these sediments implies that the type of organic matter is of terrigenous origin, in contrast to the Palaeozoic black shales which are predominantly marine. Such variety is an opportunity and challenge for explorers, as different hydrocarbon types are expected from these source rock analogues.

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GEOLOGY POSTER 18

A NEW APPROACH AND PROSPECTIVITY OF SAND INJECTITE IN MALAYSIA

Askury Abd Kadir & Tengku Amran Bin Tengku Mohd

Geoscience & Petroleum Engineering Department, Universiti Teknologi PETRONAS,31750 TRONOH, Perak

In recent years, there has been increased interest in sandstone injectite features as a significant source for reserve calculation. Sand injectites are classified into 'intrusive' bodies, which result from the remobilization and injection of sand into fractures due to factors such as overpressure, hydrocarbon migration, diagenesis and seismicity. Their occurrences are in the form of sandstone dykes (discordant to bedding) and sills (concordant to bedding) structures. Typically, such fractures are in sedimentary strata. The development of technology and knowledge led the recognition of injectites as an attractive exploration targets with huge significance when planning and optimizing hydrocarbon recovery. They have long been considered mere geological oddities and often being misinterpreted (Figure 1) for insignificant features as their thickness is beyond the resolution of conventional seismic data. Outcrop observation and subsurface exploration including cores, wellbore image logs and seismic sections (Figure 2) are typically utilized to recognize their assemblages and features. The objective of the study is to gain better understanding on the features and characteristics of injected sands as a new prospective fluid conduit in reservoirs as well as their mechanics, implications and challenges. This preliminary study has been conducted based on literature review of published papers, journals, books and other resources, which are gathered, analyzed and revised in accordance to the relevance of the project. Three case studies were analyzed on Gryphon, Volund and Alba Fields highlighting their successful explorations in terms of injectite styles and significance for exploration and production. The results provide better understanding on injectite features which contribute additional reserves, improve the connectivity between reservoir layers and are characterized by chaotically distributed, unconsolidated sands with high porosity and permeability, forming excellent pay zone. Injectite explorations in Gryphon, Volund and Alba fields showed their characteristics as good quality reservoirs which may not be simply ignored for future exploration targets. Do we have sand injectites in Malaysia? Perhaps, we need to re-examine an oil-prune formations in Malaysia which is more emphasis on sand injectite conceptual.

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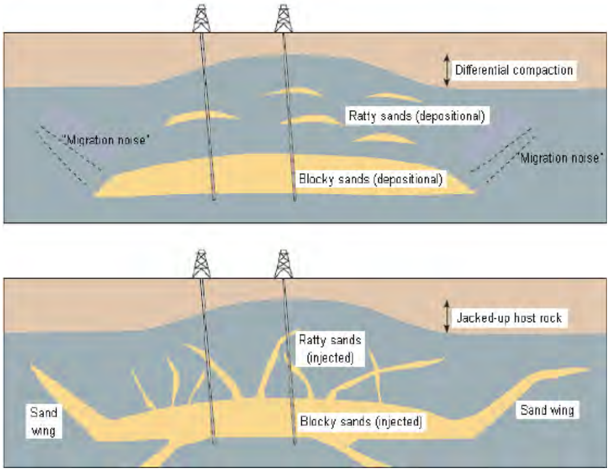

Figure 1: Two models of sandstone distribution interpreted from one set of well data (Source: Braccini et al., 2008)

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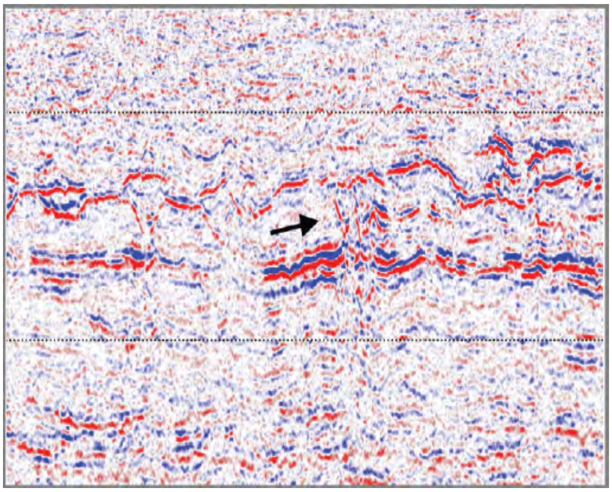

Figure 2: Cross section of seismic migrated stack trace data volume showing steeply dipping events, interpreted as sandstone injectites (arrow), (Source: McHugo et al., 2003)

GEOLOGY POSTER 19

BASIN MODELING OF MALAY BASIN EASTERN FLANK FOR PREDICTION OF SOURCE ROCK POTENTIAL

Ku Rafidah Ku Shafie & Lakhdar Benchilla

Petroleum Resource Exploration, Petroleum Management Unit, Level 16, Tower 1, PETRONAS Twin Towers, KLCC, 50088 Kuala Lumpur, Malaysia.

The offshore eastern flank of Malay Basin is considered a challenging phenomenon for petroleum exploration in the synrift plays. The large amount of quality data from Petronas provides an opportunity to reduce the uncertainty in geological risks to exploration success in these deep plays. The application of basin modeling technique such as PetroMod in petroleum exploration giving us the ability to illustrate petroleum generation history of potential source rocks in our study area. The 1-D basin modeling was carried out on 12 calibration wells in the eastern flank of Malay Basin with an objective to investigate the presence of mature source rock and hydrocarbon charging in the study area. The red-dotted box in Figure 1 shows the location of the study area where the structural setting is severely affected by the tectonic evolution of the basin.

Temperature data for calibration of present-day temperatures in the wells were obtained from the log header and the data were generally of good quality. Those data were corrected using published methods, and results were generally consistent and reasonable. Most of the wells drilled in this block have penetrated the K and L groups and a few wells have penetrated the basement. Models were constructed within the PetroMod software program in the stan¬dard ways. The stratigraphy within each well was constructed as burial history by using the top formation depth and age. The deposition of all the stratigraphy in this area is based on the Regional Malay Basin Stratigraphic Chart (Figure 2).

Two source rocks were considered in this study: the Group L-Shale deposited during synrift episodes are widely interpreted as offshore lacustrine and the Group I that was deposited in the fluvial-deltaic environments (Madon et al., 1999). Hydrocarbon generation in Group L-Shale source rocks was modeled using Pepper and Corvi (1995) _TI(C), which should be appropriate for these source rocks. The Group L-Shale source rock was generated at 12.5Ma and significant oil generation was initiated at around 10.5Ma. The expulsion of large amounts of oil began at about the same time of the oil generation. This has allowed the oil to be trapped in the entire formation group (Epic Study, 1994).

Based on the geological concept, the Group-L source rock are onlapping at the half graben and is believed to be charging the basement laterally. This onlapping attribute can be observed in the seismic section. For the clastic part, most probably the Group K-Shale source rock will charge the K reservoir which is a stratigraphic play type i.e braided stream. In summary, from the perspective of total hydrocarbon generation and expulsion, L-Shale is a potential source rock in this area since most of the wells are discovered within oil zone in the basement play. Figure 3 demonstrated a depositional model of Malay Basin eastern flank with fluvial lacustrine source rocks distributions (Internal Report, 2010).

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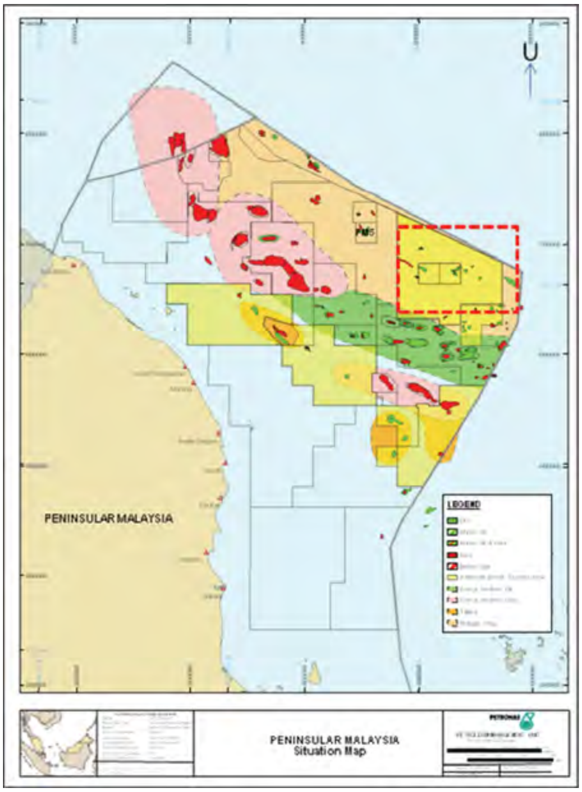

Figure 1: The location of study area in Malay Basin is signified by the red-dotted line. The oil and gas fields are illustrated in green and red colors, respectively (Madon et al., 1999).

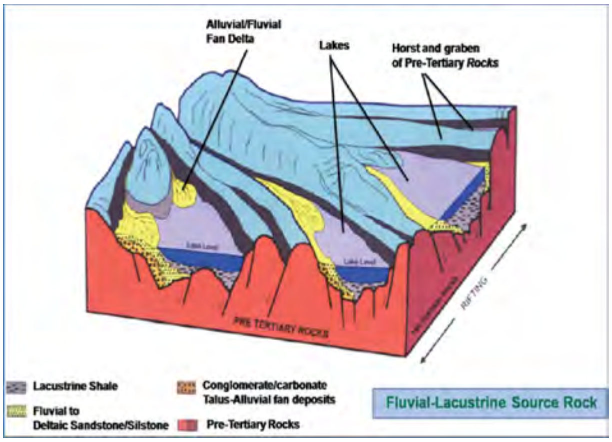

Figure 3: Depositional model for the East flank of Malay Basin displaying the fluvial-lacustrine source rock (Internal Report, 2010).

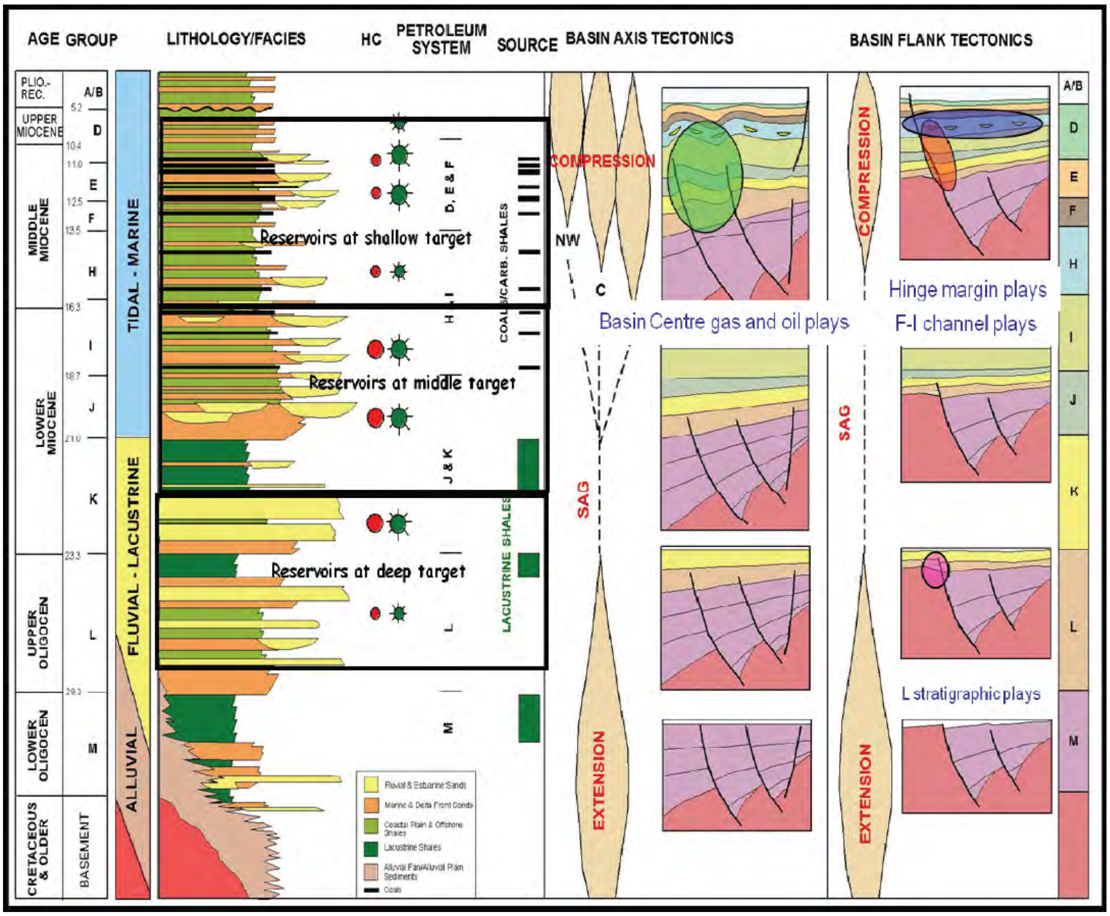

Figure 2: The regional stratigraphic chart of Malay Basin with tectonic events through geological time (EPIC, 1994).

GEOLOGY POSTER 20

PROSPECTIVITY IN THE SLOPE BREAK BELTS OF MALAY BASIN WESTERN MARGIN

Ji Ping & Zuliyana Ibrarim

EAP PREX Petronas, Level 16, Tower 2, Petronas Twin Towers, KLCC, 50088 Kuala Lumpur, Malaysia.

Malay Basin Western margin covers about 5000 km2, mainly with the steep monocline (up to 6 degree) tectonic background, which is different from other area of Malay Basin. In the Late Oligocene to Early Miocene syn-rift extension phase, Groups M, L and K were deposited in an alluvial-lacustrine setting. The slope break belts associated with fan system deposits make them a promising exploration area.

The slope break belt consists of three main parts: slope, slope break and slope-toe. It can be originally because of tectonic, deposition and erosion. There are multi belts in the Western margin. And the results of the deposition are the basin floor fan, slope fan, subaqueous fan and other gravity flow fans.

Lacustrine shales of M, L and K Groups are the main source rock in the area. The sandy fan bodies consist the high quality reservoirs. Lacustrine shales provide the top seal. Up-dip seal can be controlled by juxtaposition of sand against incised valley, palaeo-cliff, fault and sand pinch out. The key element and the risk is the up-dip sealing of the trap.

Exploration history demonstrates the slope break belt is a good prospective area in Malay Basin. The exploration approach is also discussed, especially the geophysical studies.

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GEOLOGY POSTER 21

SOME DIFFERENTIATING FIELD CHARACTERISTICS BETWEEN THE BELAIT & LAMBIR FORMATIONS, NORTH SARAWAK

Mohd Syamim Ramli & E. Padmanabhan

Geoscience & Petroleum Engineering Department, Universiti Teknologi PETRONAS, Perak

SUMMARY

Similarities between the general appearances of the Belait and Lambir Formation in the field have led to difficulties in distinguishing one from another. This differentiation is important as there is an ongoing E&P in this part of Sarawak. Selected outcrops from the northern and central Sarawak have been analyzed in the field to evaluate the difference between these Formations. Field observation suggested that there are at least eight differentiating characteristics between these Formations. In terms of sedimentary features, presence of asymmetrical ripple marks on the Belait Formation indicates a fluviatile environment whereas on the Lambir Formation, symmetrical ripple marks are much more common features. Cross-beddings on the Lambir Formation are also abundantly found but it is not encountered in the Belait Formation. Fossil burrows of Ophiomorpha Nodosa are also common in the Lambir Formation but to a lesser extend in the Belait. Flow patterns features such as mud- and/or sand-filled channels are also a characteristics of the Belait Formation. Conglomerates of the Belait Formation can be found on the southern part of Sarawak. In terms of bedding and stratigraphy, heterolithics sequences are widely encountered in the Belait Formation outcrops, but rarely in the Lambir Formations. Observations on the proportions of sand and clay in these heterolithics sequences between the two Formations suggest that the Belait Formation possess a much sandier sequence. Presence of carbonaceous shales are also common in the Belait Formation whereas massive sandstones are more often encountered in the Lambir Formation. Despite these general differentitating characteristics, distinguishing some of the outcrops are still difficult as these features may not be present in all outcrops.

INTRODUCTION

The Belait Formation found in the North-eastern Sarawak is Lower – Upper Miocene in (Hutchison, 2005). The Formation comprises alternating sandstone, sand and clays in varying proportions and thickness (Liechti et. al., 1960; Tate, 2001; Hutchison, 2005). Liechti et al. (1960) interpreted the environment of Belait Formation as partly deltaic particularly to the south and gradually to the coast merges with the more marine Lambir Formation. Recent paleocurrent analysis by Padmanabhan (2010b) reveals that the massive sandstone facies and dark grey massive shale facies of the Belait Formation were part of a deltaic system with flow directions between 40° to 180°.

The Lambir Formation (Middle – Upper Miocene) occupies about 220 square miles in the Lambir Hills, Bakong area, Teraja

Table 1: Simplified checklist for distinguishing characteristics between the Belait and Formations (note: * refer to less common/rare and ***** refer to as common features otherwise stated).

Type	Feature	Belait Formation	Lambir Formation
Sedimentary features	Ripple mark	Asymmetrical	Symmetrical
	Cross-bedding	NIL	******
Fossils	*Ophiomorpha Nodosa*	*	*******
Flow pattern	Channels	*****	*
	Conglomerate	****	NIL
Bedding/Stratigraphy	Heterolithics secquence	****** Mud-dominated sequence	* Sand-dominated sequence
	Carbonaceous shale	******	***
	Massive SST	**	******

area and south-east of Marudi (Haile, 1957). The Formation consists predominantly of sandstones and alternating shales with minor limestone and marl in some places (Haile, 1957; Liechti et al., 1960; Tan et. al., 1999). This Formation has been interpreted as marine in origin.

It is difficult to distinguish between both Formations in the field. Criteria that will assist to distinguish these Formations will be very useful as there are renewed interests in oil and gas exploration in this part of Sarawak. As such, the objective of this paper is to develop a list of distinguishing criteria that will assist in the differentiation between the Lambir and closely related Belait Formations in the field.

MATERIALS & METHODS

A few outcrops were studied in each Formation in North-eastern Sarawak (Belait Formation) and South of Miri area, North-Western Sarawak (Lambir Formation). This study is solely based on field observation from selected outcrops and some literature review. New outcrops of the Belait Fm (Northern Sarawak) have been studied recently (Padmanabhan, 2010a & b).

RESULTS & DISCUSSIONS

Field observations from the selected outcrops suggest that there are some differentiating characteristics between these two Formations. These differentiating characteristics are as follows and summarized in Table 1.

Sedimentary Features

Ripple marks are quite common as sedimentary features in the Belait Formation (Padmanabhan, 2010a). Asymmetrical ripple marks found in the Belait Formation are characteristic of fluviatile environment (Padmanabhan, 2010a). The symmetrical shape ripple marks in the Lambir Fm indicate a near-shore environment (marine) (Padmanabhan, 2010a). Presence of cross-beddings which point out to near-shore environment are also commonly found within the Lambir Formations but not in the Belait Formation (Padmanabhan, 2010a).

Fossils

Burrows of Ophiomorpha Nodosa are quite common in the Lambir Formation (Hutchison, 2005) but to a much lesser extend in the Belait Formation (especially in North-western areas adjacent to the Lambir Fm) (Padmanabhan, pers. comm.).

Flow Pattern

Features such as mud- and/or sand-filled channels are also found within the Belait Formation. Channels are very rare in the Lambir Formations (Padmanabhan, 2010a). Conglomerates in the Belait Formation are found in the south-eastern parts of Sarawak. These were intially classified as a older and subrecent terrace materials (Liechti et. al., 1960) but reclassified as conglomerate (Padmanabhan, 2010a). These patterns suggest a fluviatile environment for the Belait Fm.

Bedding / Stratigraphy

Heterolithic sequences are attributed to changing environments. The Belait Formation is believed to have been deposited as an isolated basin infilling oscillating between littoral and deltaic-paralic settings (i.e. lagoon, protected inlet) (Liechti et. al., 1960; Padmanabhan, 2010a).

Observation on the proportions of sand and clay in these heterolithics sequences suggests that the Belait Formation possess a higher clay content compared to the Lambir Formation. Presence of carbonaceous sandstone is found more commonly in the Belait Formation as opposed to the Lambir Formation (Fig 1a). Occurrences of massive sandstone facies (Fig. 1b) are much more common in the Lambir Formation rather than in the Belait Formation (Padmanabhan, 2010a).

CONCLUSIONS

Based on these observations, it is concluded that despite identifying some differentiating characteristics between both Formations, there will still remain some outcrops where such characteristics are absent. Linking such outcrops to these Formations mentioned earlier will remain a challenge.

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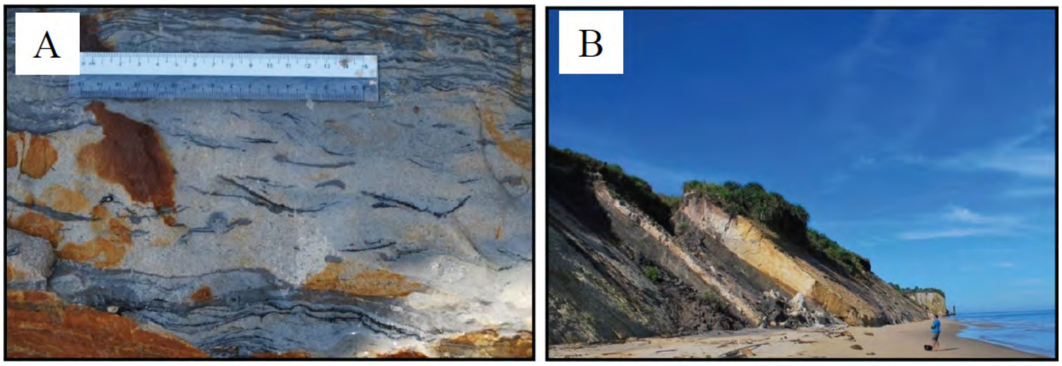

Fig 1: Distinguishing features in the Belait and Lambir Formations on field. 1A - Very fine-grained carbonaceous sandstone from the Belait Formation. 1B – Massive sandstone facies from the Lambir Formation, Southern Sarawak.

GEOLOGY POSTER 22

DEEP OVERPRESSURED PLAY: SECOND LIFELINE FOR WEST BARAM DELTA, EAST MALAYSIA

M Hafizan Abdul Wahab[1] & Jennifer Chin Li Yen[2]

Sarawak Exploration, PETRONAS Carigali Sdn Bhd, Level 10, Tower 2, PETRONAS Twin Towers, 50088 Kuala Lumpur, Malaysia
[1] hafizan_wahab@petronas.com.my; [2] jenniferchin@petronas.com.my

Year 2010 marks 100 years of exploration activities in the West Baram Delta offshore Sarawak, one of the most prolific deltas in Southeast Asia. Ever since, a total of more than 50 exploration wells have been drilled targeting the conventional Middle Miocene Topset Clastic Play. The declining trend in both exploration success and production rates in recent years is alarming, hence the increased urgency of testing a new play concept.

The deepest well drilled recently entered an overpresurred zone at depth of about 4km, with hydrocarbons still being encountered at the last penetrated reservoir. This success has triggered numerous ideas for the new potential hydrocarbon play type in the much deeper and severe overpressured reservoirs.

At these depths reservoir quality is the main risk associated with this new play. The biggest challenge for the exploration is associated with predicting the onset and magnitude of the overpressures as these have direct impact on in-place gas volumes, well design, and well deliverability.

This paper will discuss the new ideas behind evaluating the trap effectiveness, seal capacity, and reservoir quality of this overpressured play.

With a renewed exploration campaign targeting the deep overpressured play it is believed the West Baram Delta HC province can be rejuvenated.

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GEOLOGY POSTER 23

STRUCTURAL STYLES OF THE NORTH WEST SABAH AND WEST SULAWESI FOLD THRUST BELT REGIONS AND ITS IMPLICATION TO THE PETROLEUM SYSTEM – A COMPARISON

Nor Farhana Nor Azidin[1], Allagu Balaguru[2] & Nasaruddin Ahmad[1]

[1] Petronas Carigali Sdn Bhd, Level 16, Tower 2, Petronas Twin Towers, KLCC, 50088 Kuala Lumpur, Malaysia.
[2] Brunel Energy

SUMMARY

Offshore North West (NW) Sabah and West Sulawesi are located in highly complex fold and thrust belts within the Sundaland plate. NW Sabah hydrocarbon exploration started in 1897 with the drilling of the Menombok-1 well. The first seismic data in the West Sulawesi were acquired in 1968. In term of geological structural evolutions in NW Sabah and West Sulawesi both areas have experienced several phases of deformation from Paleocene until Pleistocene.

The structural styles in NW Sabah and West Sulawesi regions can be divided into deformed and undeformed zones. The NW Sabah region is deformed by thin-skinned tectonic style (Figure 1) while the West Sulawesi region has both thin and thick-skinned tectonic style (Figure 2). Thin-skinned tectonic style is derived from gravitational induced compression while thick-skinned deformation is caused by thrusting within the basement. The thin-skinned tectonic style deformation zone can be divided into three structural provinces of growth faults (extensional) at the proximal area, translation/raft in the middle and toe-thrusts at the frontal area (Figure 3 & 4). Thick-skinned tectonic style forms basement high and mountain building during which the crust is shortened horizontally and thickened vertically.

Fault propagation fold geometry analysis shows that fault propagation fold at the landward area are characterized by bigger fold geometry compare to front and middle at the seaward area. Within these regions two distinct structural styles have been identified. The NW Sabah has a wider fold thrust and higher mobilized shale volume compared to the West Sulawesi region (Figure 3 & 4).

Palaeogeographic study by Balaguru et al. (2008) in NW Sabah indicates that its decollement zone is dominated by hemipelagic shales deposited during Lower Miocene whereas Fraser et al. (2003) suggested that West Sulawesi is controlled by mud-rich sediments during Upper Miocene. The differences in lithology, perhaps one of the elements, effected NW Sabah to have lower height and wider width folds due to the less resistance ductile decollement. The West Sulawesi fold thrust styles are relatively showing higher height and narrower width which signifies brittle decollement with more resistance, that allowed the deformation wedge to glide tightly overridding the older layer.

Taper wedge is the sum of bathymetric slope (α) and the decollement dip (β). It is a function of the relative strength of the wedge and the strength of the decollement; the weaker the decollement and the stronger the wedge material, the smaller the wedge taper. The wedge strength is defined by frictional coefficients and fluid-pressure values for both the internally deforming wedge and its decollement (Bilotti et al., 2005). Taper wedge analysis at study areas show that NW Sabah has low β

and high α whilst West Sulawesi shows relatively high β and low α. Thus, lower β is resulted from a weak decollement induced by ductile mobilized shale that deformed the toe-thrust system.

PETROLEUM SYSTEM

Based on the structural style evaluation, petroleum system elements of trap and reservoir in NW Sabah and West Sulawesi have been identified. The main structural traps in both study areas are fault propagation folds and fold thrust anticlines. Structural deformation in NW Sabah were formed during Upper Miocene whereas in West Sulawesi were occurred during Middle Miocene. More structure traps of fault-related closures can be observed within the undeformed zone (Figure 3 & 4).

Hydrocarbons in NW Sabah are found mainly in stage IV (Middle Miocene to Pleistocene). Stage III (Lower to Middle Miocene) potential has not been fully explored. Southern part of West Sulawesi is expected to have better reservoirs with dominant sand-rich sediments filling the basin. Reservoirs are comprised of syn-kinematic depositional and carbonate build-up from Lower Miocene to Pleistocene (Figure 4).

The source rock of NW Sabah is rich in terrigenous organic matter from land plant with coals occurring only as transported fragments (Azlina Anuar et al., 1997). These are most likely occur within the Stage III and IV sequences, which are Lower to Middle Miocene age, interbedded with sand-prone reservoir facies. West Sulawesi morphology during the Neogene indicates substantial elements of confinement, with postulated occurrence of anoxic, deep-restricted marine shales in the central basin axis throughout Miocene to Pliocene (Fraser et al., 2003).

The hydrocarbons migration in NW Sabah and West Sulawesi are generally through faults and intrabedding movement. The seal in NW Sabah is mainly provided by intraformational shale and mudstone with effective top and flank seals in many proven accumulations. In some places, shale-filled slump scars and shale diapirs act as seal. The seal in West Sulawesi is the mudrocks within the fold belt of Upper Eocene to Lower Miocene age.

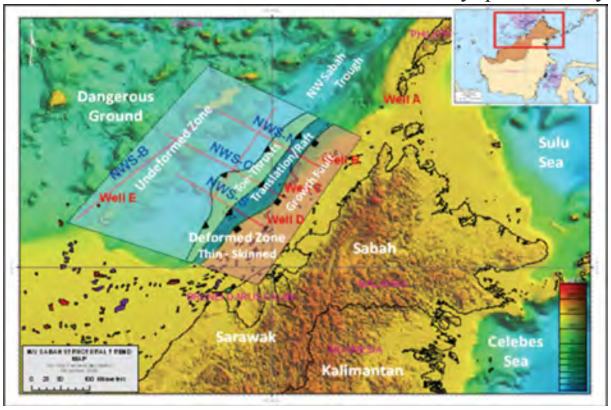

Fig. 1: Structural trend map of NW Sabah.

CONCLUSION

The weak decollement zone has a significant influence on the structural styles where mobilized shales deformed the deformation wedge, leading to the development of fault propagation folding and fold thrust anticlines that form the main structural trap in NW Sabah and West Sulawesi.

RECOMMENDATION

Mature exploration area like NW Sabah requires new thinking in enhancing future hydrocarbon potential. Deepwater areas of Outboard Belt are still relatively unexplored particularly in the Sabah Trough and Toe Thrust Sheet Zone. Based on the palaeogeographic study, better reservoir potential is located at the southern part of West Sulawesi compare to the northern part of the region.

ACKNOWLEDGEMENT

Thank you to Nasaruddin Ahmad, Dr Allagu Balaguru, AP Askury A Kadir, Prof Dr Alain Mascle, Ani Aiza Asha'ari, Phillip Gordon Cassidy and Abdullah Dim for facilitating the study. Further thanks to PCSB, UTP and IFP for giving the opportunity to publish the results of the project. Special thanks to my family and friends for their love and support.

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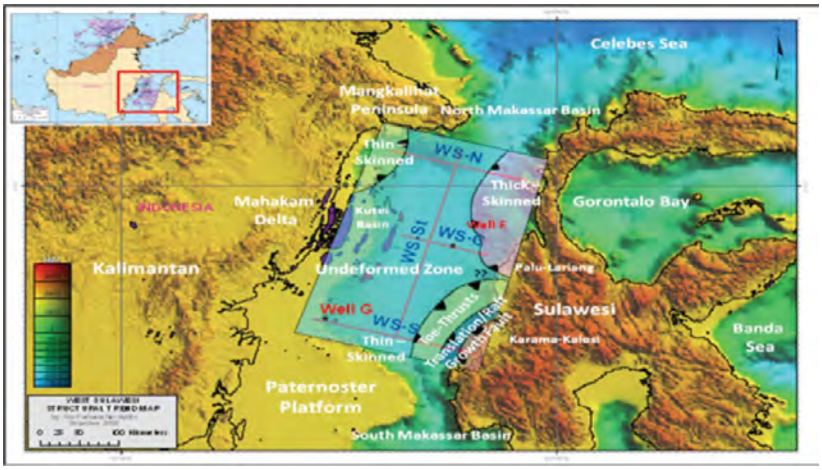

Fig. 2: Structural trend map of West Sulawesi.

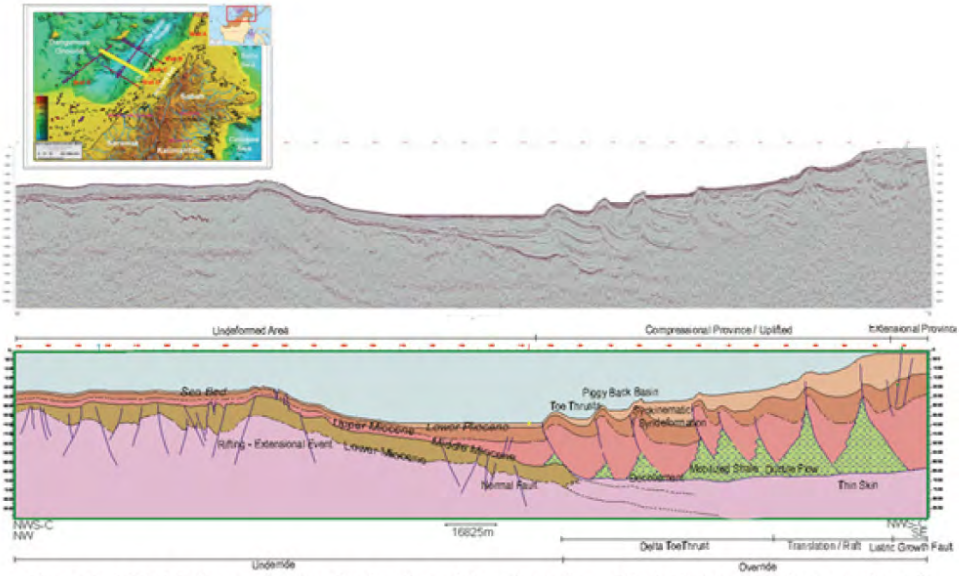

Figure 3 : NW Sabah map showing the location of the seismic lines (Top). Uninterpreted seismic line of NWS-C (Middle). Interpreted and labelled seismic line of NWS-C (Bottom).

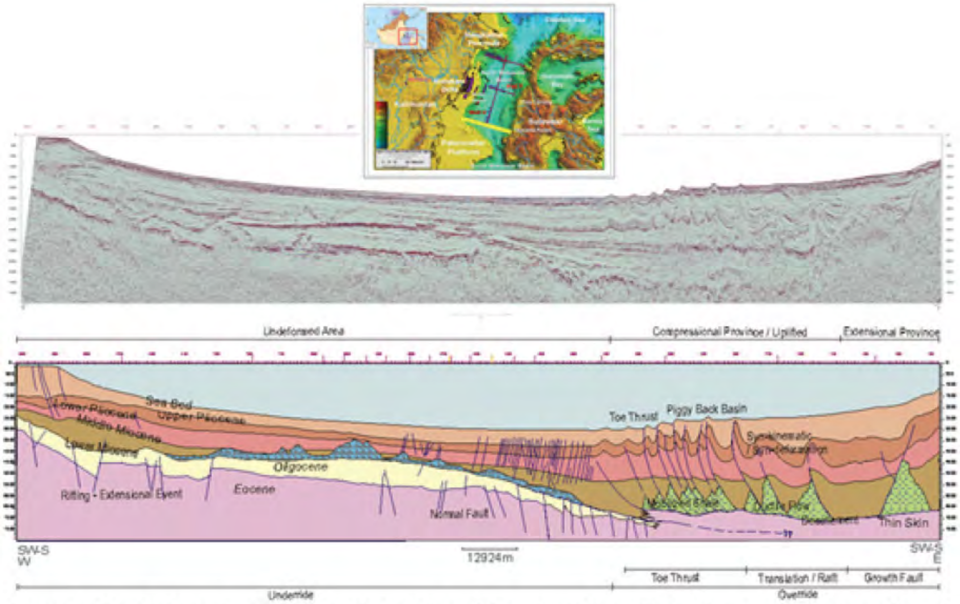

Figure 4 : West Sulawesi map showing the location of the seismic lines (Top). Uninterpreted seismic line of WS-S (Middle). Interpreted and labelled seismic line of WS-S (Bottom).

GEOLOGY POSTER 24

STUDY OF UPSCALING PERMEABILITY FROM THIN SECTIONS USING 3D PORE SPACE IMAGE AND PORE NETWORK MODELING

Luluan A. Lubis & Zuhar Zahir Tuan Harith

Geosciences and Petroleum Engineering Department, Universiti Teknologi PETRONAS, 31750 Tronoh, Perak, Malaysia.
luluan.lubis@gmail.com and zuharza@petronas.com.my

SUMMARY

Digital rock physics technology has effectively proved in reducing time and cost to predict physical properties of reservoir rocks. However, most of the predictions are at pore-scale level. In this study we address our research on predicting permeability at core-scale. The study carries out numerical simulation on three-dimensional (3D) pore space images to predict permeability at pore-scale. A digital volume required for this numerical simulation is obtained from thin section images. From these images we reconstruct 3D pore space images using multiple-point statistics (MPS). Permeability from several pore space images are used to predict permeability at core-scale by using upscaling methods (arithmetic, geometric and harmonic method). The results from these predictions are expected to match well with the experiment.

INTRODUCTION

Porosity and permeability are the key of physical properties in petroleum. These properties usually obtained by applying standard experimental tests on rock samples collected along selected depths of petroleum well. In addition to sampling costs, laboratory routine includes the manufacture of thin plates for petrographic analysis and the measurement of porosity, permeability, which are, presently laborious, time consuming and high cost procedures. Not only are such experiments lengthy and expensive but also there is often a lack of rock material to conduct these experiments i.e. core hardly extracted and the only material left from the well are sidewall plugs and drill cuttings which cannot be measured by experiment. In such situations, digital rock physics can be an alternative (Dvorkin et al., 2008; Touati et.al., 2009).

Numerical simulations of fluid flow through 3D pore space can provide accurate estimations to predict physical properties. A digital volume can be obtained from CT-scan. However, the device still prohibitively expensive and the scanning time is too long to be practically useful in massive numerical experimentation. An alternative is a statistical reconstruction of 3D volume from a 2D image (thin section). Thin sections are relatively easy and cheap to prepare.

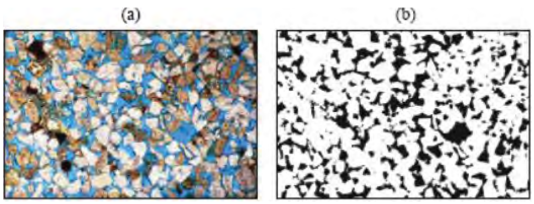

Fig. 1. (a) Scanned image from an epoxy-saturated thin section. Blue color denotes pores. (b) Binary image after image processing. The pore space appears in black.

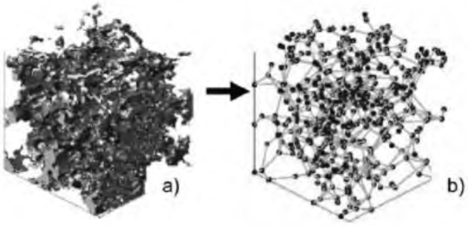

Fig. 2. (a) Binarized 3D image; (b) a topologically equivalent network of pores connected by throats. Each pore and throats has a volume, shape and cross-sectional area derived from the 3D image.

The goal of this study is to predict permeability at core-scale (experiment scale) using information from thin sections. Specifically, we carried out simulation of viscous fluid flow through a realistic pore space. A realistic pore space can be reconstructed based on statistical information from two-dimensional (2D) images (thin sections or SEM images) (Keehm et.al., 2006; Okabe and Blunt, 2004). MPS was used to obtain 3D pore space images. Once a 3D image is reconstructed, the pore network will be extracted and physical properties will be simulated by solving relevant transport equations from the pore network modeling. The permeability from 3D pore space images are used to predict permeability at core scale using simple upscaling methods.

METHODOLOGY

Thin Section Data And Image Processing

Thin sections saturated by epoxy, so the pore space is clearly distinguishable. From the color image of the thin section, a binary image can be obtained using simple image processing. We converted the true color image into an index image, and selected proper indices for grains and pore space. Then the binary image can be represented by indicator function f(r) (Keehm et al., 2006),

$$f(r) = \begin{cases} 1 \text{ if } r \text{ belongs to pore space} \\ 0 \text{ otherwise} \end{cases} \quad (1)$$

r denotes a spatial location within the binary image.

2D To 3D Porous Media: Multiple-Point Statistics

Binary images used as an input to reconstruct porous media. In this study, we used MPS to reconstruct 3D pore space images. This method has been used by Okabe and Blunt, (2004) to reconstruct carbonate rock and has been developed by Tang et al., (2010)

First step, a 2D cross section used as an original training image is scanned by 2D multiple-grid data templates to build search trees. From this search trees the conditional probability distribution function (cpdf) information can be stored. Second step, by using the extracting template, sample points are extracted from the training image and then these sample points used as original conditional data. Third step, draw a simulated value from the previous cpdf using Monte Carlo Methodology. Then simulated value is then added to the conditional data for the simulation at all subsequent. Fourth step, Loop step 3 until all grid nodes are simulated. Then one simulated image has been generated, which will be used as a new training image for next simulation.

To generate a 3D structure from 2D image, loop step 1-4 until N-1 new 2D simulated images are generated. Stacking the original training image and those N-1 image successively. A 3D image of porous media with N layers is generated. Each pixel in those layers corresponds to a voxel in 3D pore space.

Permeability Estimation: Pore Network Modeling

To simulate accurately transport phenomena in porous media, a detailed description of the pore space is needed. In this study, a digital three-dimensional representation of the pore space is constructed by using MPS method. Binarized 3D images (where 1 and 0 represent void and grain respectively) were used as input data for network extraction. From this, a topologically equivalent network model is built with pore sizes, shapes and connectivity based on the three-dimensional representation (Dong and Blunt, 2009; Oren and Bakke, 2002).

Permeability, k, in 3D images is computed as the mean of directional permeabilities. This is calculated by applying macroscopic pressure gradient,

$$Q = \frac{K(p_1 - p_0)A}{\mu L} \qquad (2)$$

Q is the volume of fluid flowing per unit time, is viscosity of the fluid and A is the cross sectional area in the direction. The fluid flow is assumed to be governed by steady state Stokes equations for an incompressible Newtonian fluid subject to a no slip boundary condition at the solid wall. Permeability is also calculated in the network equation (2); (p1-p0/L) is then applied macroscopic pressure gradient accross the network while Q is the total single-phase flow rate which is found by solving for pressure everywhere and imposing mass conservation at every pore. From this equation we can calculate the permeability. We used open source software from Imperal College London to calculate the permeability.

UPSCALING PERMEABILITY

(Keehm et al., 2006) used simple upscaling methods to predict permeability at core scale. He speculate that the possible reason why the computed permeability values from 3D pore space images overestimated lab-measured permeability values is because its heterogeneity.

To combine the permeability building blocks (each permeability that obtained from 3D pore space images) to arrive at the absolute permeability on the core-plug scale, we used the same upscaling method which the aritmatic mean is used to average permeability values parallel to the bedding (horizontal) direction, while the geometric or harmonic mean is used to average permeability perpendecular to the bedding.

CONCLUSIONS

Keehm et al., (2006) was using the same concept as we did to predict permeability at core-scale. However, the method to reconstruct 3D pore space image by Keehm has limitation and lacking through-going connectivity. Because of these reasons, this method works best on high porosity clastic rocks. To calculate permeability, Keehm used Lattice Boltzmann Method (LBM), which is robust enough to simulate fluid flow. However, this method is still very computational intensive for single/multiphase flow through porous media.

For these reasons, we use the methods to predict permeability at core-scale (experiment scale). We modify the method to reconstruct 3D pore space image by using MPS (Tang et al., 2010). This method was improved and can be used (even) to reconstruct carbonate rock at pore scale (Okabe and Blunt, 2004). Replacing LBM, we used pore network modeling software from Imperial College London which practical enough to calculate permeability at pore scale (Dong and Blunt, 2009).

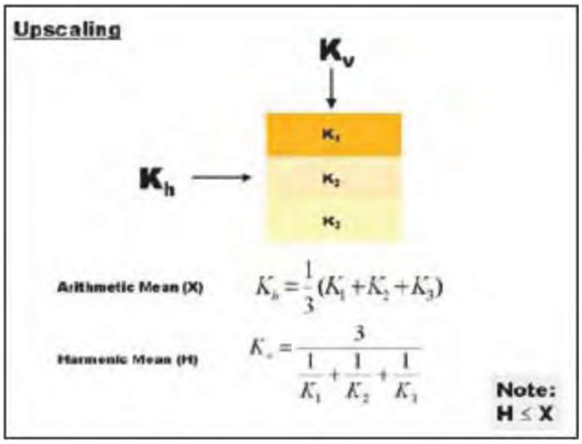

Fig. 3. Schematic figure showing the difference between arithmetic (X) and harmonic (H) mean, which are used to average permeability measurements in the horizontal (parralel to bedding) and vertical (perpendicular to bedding) directions, respectively.

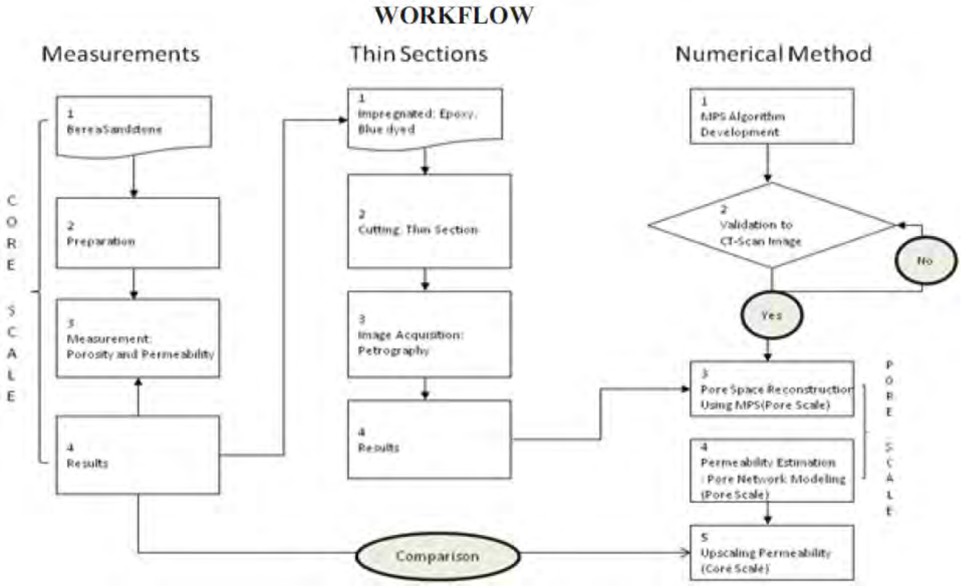

Fig. 4. Integrated workflow to predict permeability at core-scale.

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GEOLOGY POSTER 25

KEROGEN KINETICS IN PETROLEUM SYSTEMS ANALYSIS: A CASE STUDY USING COALY SOURCE ROCKS FROM MALAYSIAN ONSHORE BASINS

Peter Abolins[1] & Wan Hasiah Abdullah[2]

[1]PETRONAS Carigali Sdn Bhd, Level 16, Tower 2, PETRONAS Twin Tower, KLCC, Kuala Lumpur, Malaysia
[2]Department of Geology, University of Malaya, 50603 Kuala Lumpur, Malaysia

Kerogen kinetics, when incorporated into a petroleum systems model, play a key role in defined the timing of hydrocarbon generation, the composition of hydrocarbons generated, and hence the phase of hydrocarbons in the subsurface. Such roles and applications are discussed in various papers such as Pepper and Corvi (1995), di Primio and Horsfield (2006), and Stainforth (2009).

In this study, bulk kerogen kinetics were derived for a selection of coal samples from the Malaysian onshore Tertiary basins of Batu Arang, Bintulu, Merit-Pila and Mukah-Balingian. These coals possess % vitrinite reflectance (%Ro) in the range of 0.42-0.60% thus are thermally immature to early mature for hydrocarbon generation. These coals are expected to have fair to good petroleum generating potential based on the HI values that ranges from about 100 to 500 mgHc/gTOC. Petrographically, these coals are observed to be dominated by vitrinite macerals with common occurrence of liptinitic kerogen (10-40% by volume).

The aim of this study is twofold. Firstly to compare the personalised bulk kinetics acquired here with those currently available from published literature. Secondly is to illustrate the impact of different kerogen kinetics and geochemical parameters in the context of petroleum system analysis that is commonly used in oil and gas exploration, specifically on the timing, quantity and type of hydrocarbon generated. This is achieved by incorporating the personalised kinetics and other geochemical parameters acquired here into simple generic 1D and 2D basin models constructed using the PetroMod software suite.

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GEOLOGY POSTER 26

CONTINUOUS ISOTOPE LOGGING IN REAL TIME WHILE DRILLING

Martin Niemann[1], Jerome Breviere[1] & Shell FEAST Team[2,3]

[1] Geoservices S.A., 127 Avenue du Bois de la Pie, Paris Nord II, BP 67049 Roissy en France, 95971 Roissy CDG CEDEX, France
[2] Shell International E&P B.V., Rijswijk, The Netherlands
[3] Shell International E&P Inc., Houston, USA

Stable carbon isotope (δ13C) values for light hydrocarbons (HC) are routinely used to characterise both the geochemical and geological systems encountered in the sub-surface; providing information on the HC source, thermal maturity and the occurrence of in-reservoir secondary processes (Whiticar, 1994) . Until now δ13C ratios of light HC's are obtained from spot samples collected at the well site (Isotubes, gas bags, Vaccutainers, etc.) and analyzed off line. Depending on the geographic location of the well the reporting of gas isotope data might occur either weeks or months after samples are collected. In the latter instance the usefulness of the data for field development decisions is significantly reduced. Recent improvements in mud logging techniques now provide a tool for the continuous logging of methane (C1) stable carbon isotope values in real time while drilling. Such data provides a much higher vertical resolution with measurements every second with a typical accuracy of ±1‰. It is anticipated that δ13C measurements of ethane (C2) and propane (C3), as well as δD-C1 in real time will follow in the near future.

Geoservices Isotope Logging is coupled with the Geoservices FLAIR system that provides quantitative analyses of C1 to C5 (HC's from formation) and semi-quantitative analyses of HC's up to octane and light aromatics (Breviere et al., 2002; McKinney et al., 2007) in order to enhance the interpretational potential of stable isotope values .

The extraction of gaseous HC's from the drilling fluid takes place as close to the bell nipple as possible under fully controlled conditions, including stable mud and air flows, stable temperature and stable pressure. The compositional analysis (FLAIR) is performed with a gas chromatograph-mass spectrometer (GC-MS), whereas the isotopic analysis is performed simultaneously by near infrared absorption spectroscopy. The application of this technology on a drilling site is new and field tests have shown that this technology is extremely robust and stable and performs well under the harsh conditions on an offshore drilling site.

Field tests have been performed throughout the world in order to test performance for different geological systems and especially different drilling conditions (encompassing variations for both oil and water based drilling muds, as well as differences in drill bit types). Results were compared with both Isotube data and WFT/DST gas samples. Comparison of Isotube and WFT/DST data revealed a good match, within the accuracy limitations of the Isotope Logging equipment.

Further comparison indicated that the continuous character of Isotope Logging data reveals a much higher variability and complexity of δ13C-C1 depth profiles than previously observed with Isotube or Vaccutainer samples. These latter samples are only spot samples with an insufficient depth resolution to detect small scale variations and features. The high resolution of Isotope Logging real time data provides the means for in depth analysis of encountered fluids and their geological habitat, but also represents an interpretational challenge.

Isotope Logging was successfully applied to delineate reservoir connectivity and compartmentalization, provided information about possible biodegradation processes within an oil-column and provided successfully real time information to decipher the nature of HC's encountered in the subsurface. This presentation will provide an overview about this new well site service and discusses case studies focussing on reservoir compartmentalization and fluid separation based on δ13C-C1 where compositional data are inconclusive.

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GEOLOGY POSTER 27

LITHO-FACIES MAPPING FOR QUALITATIVE EVALUATION OF CAPROCK SEAL CAPACITY IN NORTHEAST CENTRAL LUCONIA PROVINCE, OFFSHORE, SARAWAK

Shakila Mustaffa[1], Che Shaari Abdullah[2] & Hamdan Mohamad[1]

[1] PETRONAS Carigali Sdn Bhd, Level 16, Tower 2, Petronas Twin Towers, KLCC, 50088 Kuala Lumpur, Malaysia.
[2] PETRONAS Management Unit, Level 16, Tower 1, Petronas Twin Towers,KLCC, 50088 Kuala Lumpur, Malaysia.

SUMMARY

The Miocene age Cycle IV equivalent carbonate pinnacles in Central Luconia Province Offshore Sarawak are very prolific hydrocarbon play type. However the petroleum system elements effectiveness for such play type proved highly variable for different pinnacles. The caprock facies identification and mapping highlighted in this project is an attempt to relate qualitatively the sealing rock facies type to the hydrocarbon column length preservation within the pinnacles. Interpreting seismic reflection pattern and calibrating with the well lithology profile are techniques used to classify the facies types and delineate the area of occurrence. The interval defined as caprock in this project is restricted to the stratigraphic interval spanning Cycle IV to Cycle VI (Figure 1). The relative spatial distribution of the pinnacles encapsulated by distal pro-delta facies of hemi pelagic fine detritus indicated high likeliness of having hydrocarbon pool with significant column height compared with the pinnacles encapsulated by proximal delta facies.

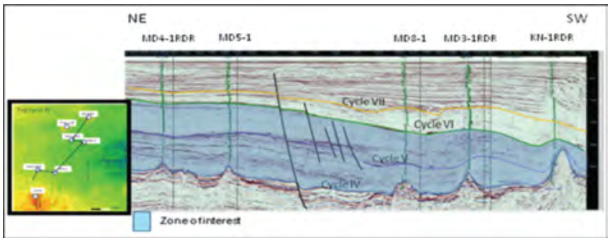

Figure 1: Section of zone of interest (Cycle IV – Cycle VI).

SEAL STUDY

Data of five drilled wells which had penetrated on carbonate pinnacles were used in this study. Seismic and well logs characters are relatable and show progradation pattern along NE-SW direction (Figure 2). Seismic sequence analysis was done to verify the depositional environment system. A seismic reflections, well logs and drilling result of these five wells have been observed and evaluated collectively to produce a facies map.

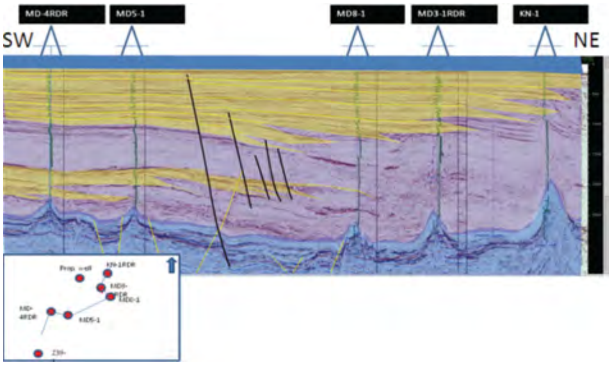

Figure 2: Progradation pattern in study area.

CONCLUSION AND RECOMMENDATION

Qualitatively, Central Luconia Province caprock has different effectiveness caprock seal quality from SW-NE direction which higher quality to the northeastward. The differences are related to the litho-facies of the seal. Produced base map shows that distal fan facies is very effective seal, followed by mid fan facies and lowest effectiveness seal quality is proximal fan facies (Figure 3).

It is recommended that a more comprehensive similar study over an extended area of Central Luconia region be carried out to improve our understanding of seal facies. It is suggested to conduct more studies on the northern part of the study area because there were expect thicker seal in the deeper carbonate area. In view of the economic value of hydrocarbon in the Cycle IV carbonate build ups, directly comparable with the SE-NW Luconia province and more surveys and samples on the clastics surrounding these reefs, to evaluate their caprock value and the nature of their lateral continuity.

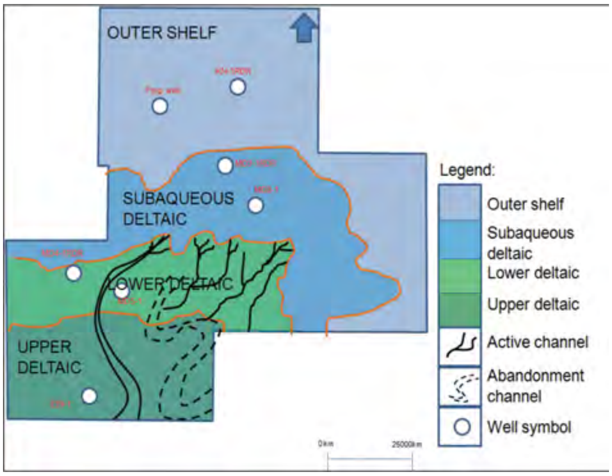

Figure 3: Facies map of study area.

GEOLOGY POSTER 28

INTEGRATION OF FLUID INCLUSION STRATIGRAPHY (FIS) IN THE PETROLEUM SYSTEM ANALYSIS OF A FRONTIER AREA IN SARAWAK OFFSHORE BASIN, MALAYSIA

Ong Swee Keong, S.R. Iyer, Satyanarayana Yelamanchi & Fatma Nazihah Bt M Khatib

Petronas Carigali Sdn Bhd, Level 10, Tower 2, Petronas Twin Towers, KLCC, 50088 Kuala Lumpur, Malaysia.

SUMMARY

The present study integrates the results of FIS into the petroleum system analysis of the North Luconia province and brings out a better understanding of the hydrocarbon generation and migration. FIS results also serves as a calibration to supplement the 3D geochemical basin modeling of the frontier deepwater offshore Sarawak basin.

FIS technology is a rapid geochemical analytical technique that involves the automated analysis of volatile compounds trapped within micron-sized cavities in rock material taken from well cuttings, core or outcrop samples. These “fluid inclusions” are representative samples of subsurface fluids and are not subjected to fractionation during sampling or evaporative loss during sample storage for any length of time. Drilled cutting samples at equally spaced intervals from five offset wells analyzed to identify for any hydrocarbon presence.

The FIS results in general indicate dry gas and some intermittent wet gas response anomalies in most of the wells. Anomalies are stronger in the pre-MMU section compared to the weak anomalies observed in post-MMU sequence in the wells.

Well B shows gas-range hydrocarbon through most of the section with some intermittent wet gas spectra at several intervals. Thin sections show rare, blue-fluorescent, moderate gravity light oil inclusions in carbonate. Well C data reveals hydrocarbon anomalies in several zones with dry to wet gas responses, which is also proven by analysis of MDT gas samples. Well D indicates notable wet gas spectra near the bottom of the section with no visible liquid hydrocarbon inclusions or stain. Well E shows dry gas responses through most of the section with intermittent thin wet gas. Thin section of rare, blue blue-fluorescent, moderate gravity light oil inclusions is identified in sandstones. Well A contains very scarce low gas anomalies throughout the whole section and thin sections contain no visible liquid hydrocarbon inclusions or stain.

Post-drill analysis of offset wells indicated hydrocarbon charge as one of the key risks in the study area. 3D basin modeling using regional 2D sequence maps was carried out to mitigate the hydrocarbon charge risk. Modeling results suggest adequate generation and migration in the area. However, late deposition of the regional top seal has resulted in few small accumulations in the area with significant loss of hydrocarbon charge.

Dry gas with intermittent wet gas FIS anomalies in the pre-MMU section of the offset wells suggest presence of migrated hydrocarbon in the drilled structures and corroborate the basin modeling results. This enhances the confidence on the presence of a working petroleum system in North Luconia province which is also proved by recent discovery.

FIS results are direct evidence of the presence of working hydrocarbon charge system and have helped in better understanding of the prospectivity of the study area.

INTRODUCTION

The study area is located in North Luconia offshore Sarawak basin which is a major petroleum habitat hosting many oil and gas fields (Fig.1). Exploratory efforts in a frontier area of this basin met with varied success and efforts are on to bring out a better understanding of the petroleum system to reduce exploration risk related to the hydrocarbon charge. This study is based on the integration of FIS geochemical results and regional petroleum system analysis to give a better insight into the hydrocarbon presence, generation and migration in the area.

METHODOLOGY

FIS technology is a rapid geochemical analytical technique that involves the automated analysis of volatile compounds trapped within micron-sized cavities in rock material taken from well cuttings, core or outcrop samples. These “fluid inclusions” are representative samples of subsurface fluids and are not

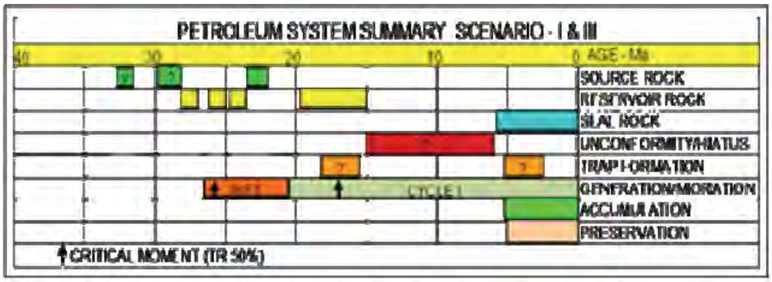

Table 1 : Petroleum System summary chart based on the 3D basin modeling results

subjected to fractionation during sampling or evaporative loss during sample storage for any length of time. Drilled cutting samples at equally spaced intervals from five offset wells analyzed to identify for any hydrocarbon presence. The objective section of the FIS wells results was interpreted together with other geological data. The results were then integrated with the petroleum system analysis to define the hydrocarbon presence, generation and migration in the area as well as the possible reasons for the dry wells.

GEOLOGICAL BACKGROUND

North Luconia province is located in the northernmost part of Sarawak offshore which forms an integral part of the South China Sea basin. The offshore Sarawak basin initiated as intracratonic rifts due to crustal extension during Late Eocene to Early Oligocene (Hutchison, 2004; Mazlan Madon et. al., 2007). The extensional phase continued up to Late Early Miocene to Middle Miocene with deposition of progressively shallowing up marine to marginal marine sequence, designated Cycle-I to Cycle-III. These Cycles hosts the source, reservoir and seal elements of the petroleum system. Regional uplift in the area due to plate convergence resulted in a major unconformity, designated Middle Miocene Unconformity (MMU), which is widespread throughout the basin. The post MMU sequences are characterized by hemipelagic and mass transport sediments, deposited in a deep water environment during Late Miocene to Recent. The objective reservoirs in the area are primarily in the Cycle-I to Cycle-III sequences dominated by clastics sediment. Occasional limestone stringers below the MMU may also form potential reservoir targets.

DISCUSSION OF RESULTS

The FIS results in general indicate dry gas and some intermittent wet gas response anomalies in most of the wells. Anomalies are stronger in the pre-MMU section compared to the weak anomalies observed in post-MMU sequence in the wells.

Well B shows anomalous concentrations of largely gas-range hydrocarbon through most of the section with some intermittent wet gas spectra at several zone intervals (Fig. 2). Thin sections show rare, blue-fluorescent, moderate gravity light oil inclusions in carbonate and sandy carbonate (Fig. 4). Well C data reveals hydrocarbon anomalies in several zones with dry to wet gas responses, which is also proven by analysis of MDT gas samples. Well D indicates notable wet gas spectra near the bottom of the section with no visible liquid hydrocarbon inclusions or stain in the thin sections. Well E shows dry gas responses through most of the section with several intermittent thin wet gas zones. Thin section of rare, blue blue-fluorescent, moderate gravity light oil inclusions is identified in sandstones. Well A contains very scarce low gas anomalies throughout the whole section and thin sections contain no visible liquid hydrocarbon inclusions or stain (Fig. 3).

Fig 1 : Regional geological map showing study area wells location

Post-drill analysis of offset wells indicated hydrocarbon charge as one of the key risks in the study area. 3D basin modeling using regional 2D sequence maps was carried out to mitigate the hydrocarbon charge risk. Modeling results suggest adequate generation and migration in the area (Fig. 5). However, late deposition of the regional top seal has resulted in few small accumulations in the area with significant loss of hydrocarbon charge (Table 1).

Dry gas with intermittent wet gas FIS anomalies in the pre-MMU section of the offset wells suggest presence of migrated hydrocarbon in the drilled structures and corroborate the basin modeling results. This enhances the confidence on the presence of a working petroleum system in North Luconia province which is also proved by recent discovery.

CONCLUSIONS

- FIS data clearly indicates presence of migrated hydrocarbon in most of the drilled wells.
- FIS results are direct evidence of a working hydrocarbon charge system within the study area.
- FIS anomalies corroborates well with the hydrocarbon generation and migration from the 3D geochemical basin modeling.

ACKNOWLEDGEMENTS

The authors are grateful to PCSB for permission to publish the results of the study. The authors also thank Mr. Jamlus B Md Yassin, Mr. Mazman B Abu Bakar, and Mr. Shahrul Amar B Abdullah for their support. Thanks also to the Technical professionals-PCSB for their review and criticism.

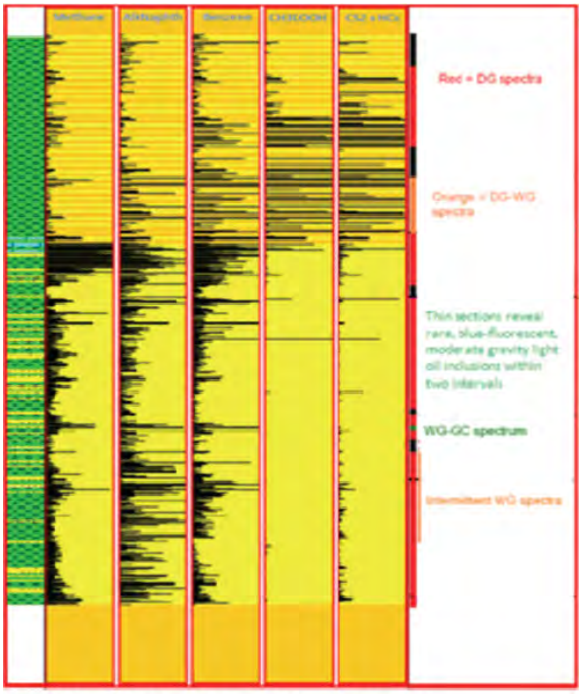

Fig 2 : Well B FIS response summary tracks

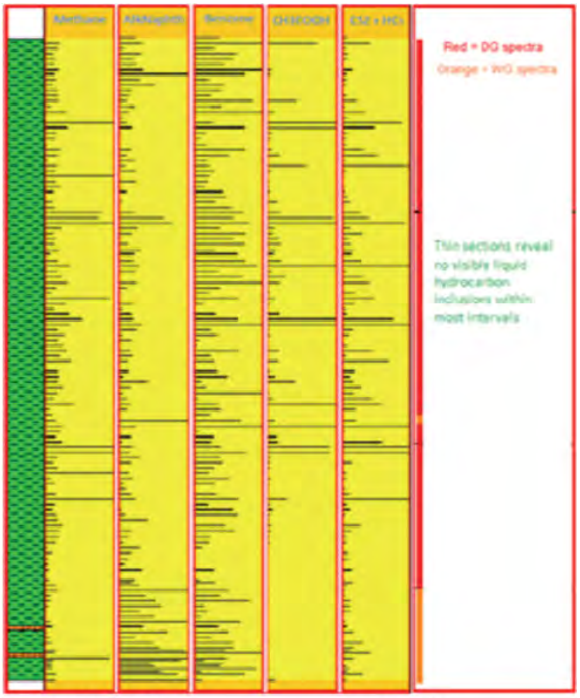

Fig 3 : Well A FIS response summary tracks

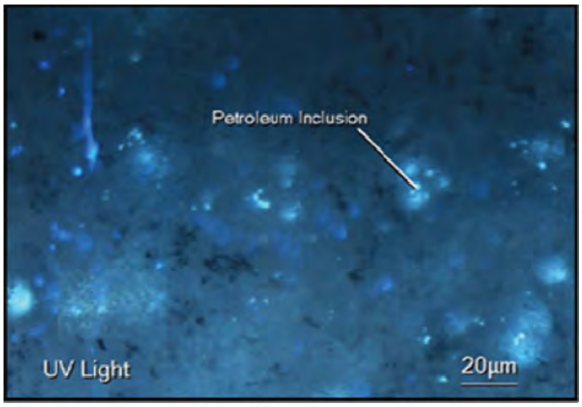

Fig 4 : Thin section showing rare, blue-fluorescent, moderate gravity light oil inclusions in Well B

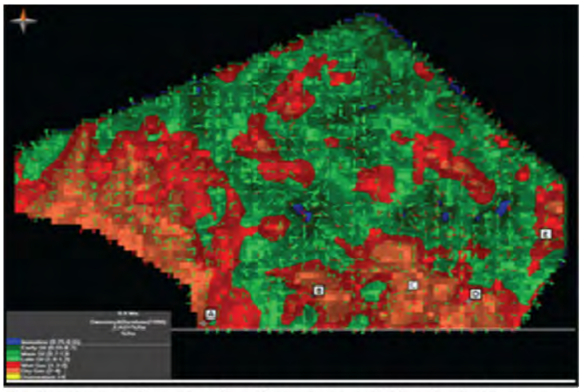

Fig 5 : Generation & migration vector of the Cycle-I source rock sequence around the offset wells in the study area

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GEOLOGY POSTER 29

EFFECTIVE RESERVOIR FLUID SAMPLING SUPPORTS RESERVOIR CHARACTERIZATION

Rahimah Abd Karim[1], Pedro Elias Paris Acuna[1], Wa Wee Wei[2] & Sammy Haddad[2]

[1]Petronas Carigali Sdn Bhd, Level 9, Tower 2, Petronas Twin Towers, KLCC, 50088 Kuala Lumpur, Malaysia.
[2]Schlumberger, 18th Floor, East Wing, Rohas Perkasa, No.8, Jalan Perak, 50450 Kuala Lumpur, Malaysia.

Good quality reservoir fluid samples are critical to ensure the accuracy of the captured fluid composition and thus accurate key reservoir fluid properties' description, namely GOR, saturation pressure, density, and viscosity. Reliable characterization of reservoir fluid properties during the early stages of exploration and development is critical for understanding fluid composition, estimating reserves, and optimizing production or completion strategies.

Miscibility and time limitation allocated by the drillers have been the main challenges in the open-hole sampling. A quick cleaning process and real time monitoring of contamination level are essential in assuring clean reservoir samples. Fluid cleaning process using conventional openhole sampling technique1 (see Figure 1) typically required long pumping times to reach acceptable contamination level.

This work presents an optimized wireline sampling technique with full utilization of downhole fluid analysis applications to address the open hole sampling challenges in an offshore Malaysia field. High quality reservoir oil and water samples were required for detailed PVT and flow assurance analyses. The mud type used was water-based mud, which posts a great challenge particularly for water sampling since the fluids are easily miscible. A focused sampling technique2 (see Figure 2) was used to accelerate the mud filtrate cleaning process. Different downhole fluid analysis approaches were applied at water and oil sampling station to monitor the reservoir fluid contamination level. At water sampling stations, pH measurement3 (see Figure 3) helped to discriminate the clean reservoir water and water based mud filtrate. While at oil sampling stations, flowing fluid optical density differences4 (see Figure 4) was monitored to ensure clean formation oil sample. The methodology and applications of all the techniques are discussed in detailed in this work and documented with actual field data and PVT laboratory results.

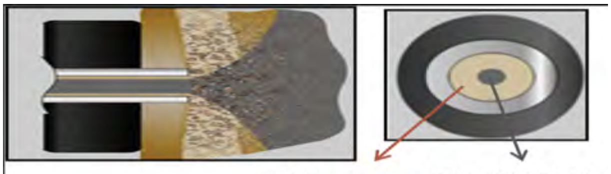

Figure 1: Conventional Sampling Probe was based on single pump and single flowline concept. The amount of filtrate entering the probe is controlled by the formation anisotropic, viscosity differences and invasion profile.

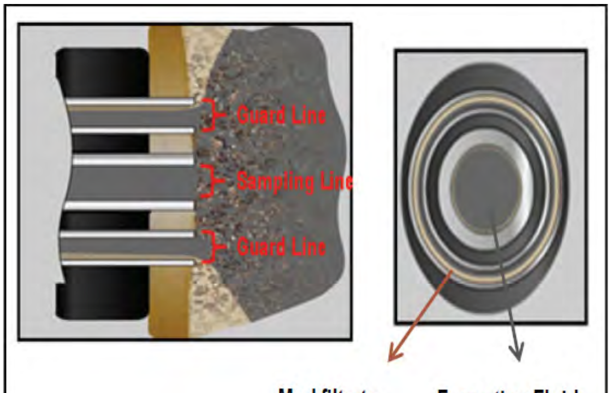

Figure 2: Focused Sampling Probe concept – the filtrate is guarded away using the concentric probe design, only clean fluid is entering the sample line.

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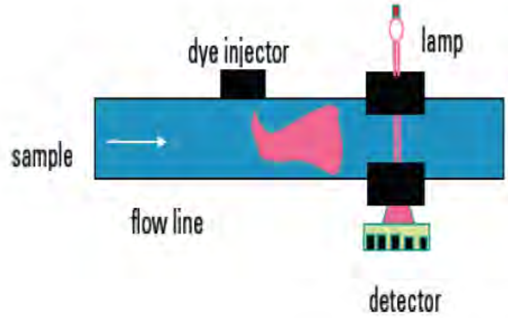

Figure 3: pH sensitive dye is injected into the Wireline Formation Tester (WFT) flowline (only when a pH measurement is made).

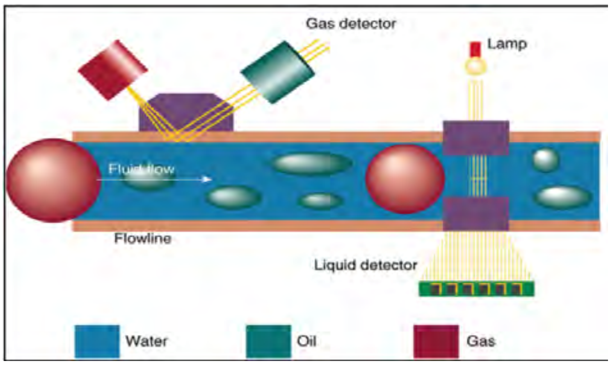

Figure 4: Live Fluid Analyzer (LFA) employs an absorption spectrometer that utilizes visible and near infrared light to differentiate water and oil in WFT flowline.

GEOLOGY POSTER 30

GEOCHEMISTRY OF GAS AND CONDENSATE IN THE SURMA BASIN, BANGLADESH

Nobuyori Takeda[1], Susumu Kato[1], Masashi Fujiwara[2], Md. Noor Alam[3], Md. Mosharraf Hossain[4], Md. Ashif Eqram Kahn[4], Md. Mashiur Rahman[4] & Md. Anisul Haque Sarker[5]

[1]JGI, Inc., Meikei building, 1-5-21 Otsuka, Bunkyo-ku, Tokyo 112-0012, Japan
[2]Mitsui Oil Exploration Co., Ltd.(MOECO), Hibiya Central Bldg. 12FL. 2-9 Nishi-Shimbashi 1-Chome, Minato-ku, Tokyo 105-0003, Japan
[3]Bangladesh Petroleum Institute (BPI), Sector #8, Plot 5A, Uttara Model Town, Dhaka-1230, Bangladesh
[4]Bangladesh Petroleum Exploration & Production Co., Ltd. (BAPEX), Shahjalal Tower, 80A/B Siddhewari Circular Road Malibagh, Dhaka-1217, Bangladesh
[5]Bangladesh Oil, Gas and Minerals Corporation (PETROBANGLA), Petrocentre, 3 Kawaran Bazar C/A Dhaka-1215, Bangladesh

INTRODUCTION

The Surma basin, which contains very thick Cenozoic sediments more than 20km, produces more than 95% of gases and condensates in Bangladesh. The producing reservoirs of gases and condensates are fluvial deltaic to estuarine sandstones in the Middle to Late Miocene Bokabil and Bhuban Formations of the Surma Group, which are located below the regional seal in anticlinal structures formed in the late Pliocene and Pleistocene age. To understand the petroleum system in the Surma basin more clearly, we performed geochemical analysis for condensate and gas samples which are taken from wells in the major fields in the Surma basin. Collected samples and the analytical items are shown in Table 1.

ANALYTICAL RESULTS

The condensates show relatively low API gravity values ranging from 26.2 to 48.3 degree, and very low sulfur content (<0.01 - 0.2%). Lower API values are attributed to rich aromatic hydrocarbons. Condensates from Rashidpur and Habiganj (samples No. 6, 7, 8 in Table 1) are medium oil (26.2 - 29.2 API degree), and are biodegraded due to lack of normal- and iso- alkanes. The condensate from Sylhet (No.1) shows high Pristane/Phytane ratio and contains abundant bicadinanes, indicating that it is originated from terrestrial source, which is concordant with the results by Curiale et al. (2002).

The result of light fraction analysis (C3 -C8 gaschromatography) is shown in Fig. 1 and 2. The n-heptane/1tr3dimethylcyclopentane - toluene/methylcyclohexane(n-C7/1tr3DMCP - Tol/MCH) plot (Fig. 1; Kato, 1993) indicates that condensates from the Surma basin, except samples from Fenchuganj (No. 4, 5), are plotted in the area rich in n-heptane and poor in toluene, in contrast with the maturation trend of oils and condensates from Niigata district, Japan, suggesting the effect of vertical migration from deeper part of the basin. The Titas condensates are most mature, and followed by Kailash Tila , Beanibazar, Fenchuganj, and they seem to have vertically migrated for longer distance than others. Further, samples from a single field show subtle variations. One sample from Titas (No. 13) is different from others, and samples from Kailash Tila show wider variations.

The n-heptane/methylcyclohexane (F, in Fig. 2, Thompson, 1987) indicates that condensates are originated from the Cenozoic coaly source rocks. Samples from the Surma basin are plotted along the trend of evaporative fractionation in the toluene/n-heptane-n - heptane/methylcyclohexane plot (B - F plot), whereas oils and condensates from the Niigata district are plotted along the maturation trend. The degree of fractionation of samples is Fenchuganj, Kailash Tila, Titas, Beanibazar, and samples from Kailash Tila varies with wells and reservoirs.

The alkylphenanthrene maturity (Fig. 3) indicates that maturity from MPR looks higher than that of MPI-1, suggesting that samples are within the process of condensate formation. That is, high maturity and influenced by upward migration (Kato and Nishita, 2010). Maturity seems to be highest in samples from Kailash Tila, followed by Sylhet, and samples from Titas seems to be the lowest maturity. Two samples from Fenchuganj showed different phenanthrane composition.

Gases from the Surma basin showed low wetness (0.08-5.2%) except one sample from Kailash Tila (No. 12), and relatively high (over 1) i-butane/n-butane ratio. Their methane

No.	Well name	Depth (m)	Formation	Condensate						Gas	
				API (°)	Sulfur (wt%)	Light fraction	GC/MS				
							Alkanes	Aromatics		Composition	δ13C
1	Sylhet-7	1874-1908	Bhuban	43.1	<0.01		○	○			
2	Beanibazar-	3452-3467	Bokabil							○	○
3	Beanibazar-	3457-3466	Bokabil	48.3	<0.01	○		○			
4	Fenchuganj-	2768-2781	U. Bhuban	41.1	0.01	○		○		○	○
5	Fenchuganj-	2579-2582	U. Bhuban	42.4	0.02	○		○			
6	Rashidpur-1	1445-1511	Bokabil	26.2	0.02					○	○
7	Habiganj-1	1417-1483	L..Bokabil	29.2	0.01					○	○
8	Habiganj-3	1328-1487	L..Bokabil	29.1	0.01					○	○
9	Habiganj-4	1363-1489	L..Bokabil							○	○
10	Titas-1	2617-2769	U. Bhuban	40.0	0.02	○		○		○	○
11	Titas-5	2922-3052	Bhuban	38.8	0.02	○		○		○	○
12	Titas-8	3293-3551	Bhuban	42.9	<0.01	○		○		○	○
13	Titas-10	3473-3680	Bhuban	39.7	0.02	○		○		○	○
14	Kailash Tila-1	2941-2948	Bhuban	44.8	<0.01	○		○		○	○
15	Kailash Tila-2	2252-2265	Bhuban	46.4	<0.01	○		○			
16	Kailash Tila-2	2797-2938	Bhuban	39.7	0.01	○		○			
17	Kailash Tila 3	2724 2731	Bhuban	43.4	<0.01	○		○			
18	Kailash Tila-2	2252-2264	Bhuban	43.2	0.02	○		○		○	○
19	Kailash Tila-4	2930-2958	Bhuban	44.8	<0.01	○		○		○	○

Table 1. Samples from the Surma basin and the list of analysis.

carbon isotope composition (δ^{13}C1, -37 to -44.7‰) implies that gases from the Surma basin are of thermogenic origin. In the C1/(C1+C2) - δ^{13}C1 plot (Bernard diagram), gas from Rashidpur (No.6) is dry and show the effect of migration. Gases from Habiganj (No.7, 8, 9) indicate mixing with small amount of microbial gas. The maturity evaluation of gases by means of δ^{13}C1 - δ^{13}C2 plot (Fig. 4) and δ^{13}C2 - δ^{13}C3 plot (Waseda et al., 2002) indicate that gases are generated at boundary region of oil window and condensate window (around 1%Ro) except one sample from Kailash Tila (No. 14) and one sample from Fenchugonj (No. 4). The reason for these exceptions is thought to be of high maturity when looking at δ^{13}C3. Gas from Rashidpur (No.6) is biodegraded, due to heavy δ^{13}C2 (-13‰). The maturity of gases from Titas seems to be lower than others. There is variation in the maturity of samples from Kailash Tila and Titas, suggesting some differences among wells and reservoirs. One sample from Titas shows light δ13C1 than others, suggesting slight addition of microbial methane.

DISCUSSION: IMPLICATIONS FOR PETROLEUM SYSTEM

The composition of gases and condensates in the Surma basin looks fairly uniform, and suggests that those are generated from a similar type of source rock. High pristane/phytane, abundant bicadinanes, low F value indicate that those are generated from coaly or terrestrial source rocks.

Most of maturity parameters indicate that gases and condensates from the Surma basin are generated and expelled from source rock at relatively high maturity, around the beginning of condensate generation. The maturity of samples from Titas on the n-C7/1tr3DMCP - Tol/MCH plot differs from the maturity on the MPR - MPI-1. The low maturity in MPR - MPI-1 plot can be explained that Titas samples contain aromatic hydrocarbons of much higher maturity (experienced cracking), probably migrated from deep part of the basin. Further, the maturity of gases for Titas samples seems to be lower than other samples. The addition of some immature gases, microbial gases or cracked gas with lighter δ^{13}C are the possiblities.

When looking at data from a single field, some compositional variations are recognized. This means that fluid in a single field is not homogeneous, and some complicated processes such as differences in timing of migration, fluid mixing, re-migration etc. have occurred during the accumulation into the present reservoir.

The n-C7/1tr3DMCP - Tol/MCH plot and B - F plots suggest that condensates have experienced evaporative fractionation. This means that condensates and gases have experienced pressure and temperature changes, and those are probably the result of vertical migration. The fact that gases and condensates are of similar origin and maturity, in spite of different molecular size distribution and physical property, seems to support the scheme of vertical migration and phase separation, or fractionation of petroleum fluid during the development of the present day structures, with the deposition of the late Pliocene to Pleistocene Dupi Tila Formation.

Before the deposition of the Dupi Tila Formation, source rocks were several thousand meters shallower than the depth at present time, and the place of generation and expulsion in the kitchen area might be different from that today. Consequently, the Oligocene and the Miocene source rocks may have generated hydrocarbons before the deposition of the Dupi Tila Formation, and migrated and trapped elsewhere in the Surma basin. By the deposition of the Dupi Tila Formation, a drastic changes occurred both in the structure and the burial depth, and as a result, a considerable change must have occurred to the petroleum system in the Surma basin, such as destruction of formerly accumulation, changes in the location of traps, additional oil/gas generation with increasing burial depth etc. This means that a significant re-migration, addition and mixing of fluids, and resulting in the similar composition and maturity among condensates and gases in the Surma basin.

As some compositional variations are observed within a single field, it is necessary to perform a more detailed study of each field to explain the petroleum system of the Surma basin minutely.

ACKOWLEDGEMENT

The authors acknowledge the Government of Bangladesh for giving permission to present paper. We are also thankful to ICEP for providing necessary funds for the joint research between Japan and Bangladesh.

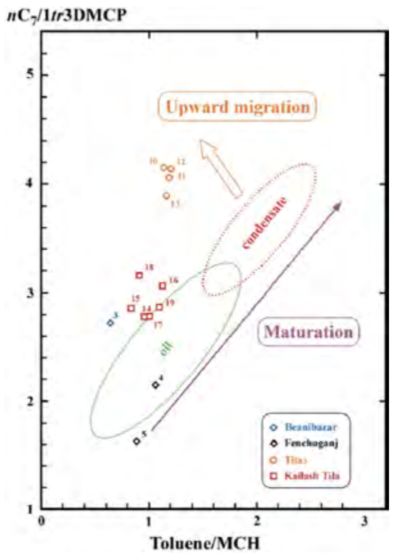

Fig. 1: Heptane/1tr3dimethylpentane-toluene/methylcyclohexane (n-C7/1tr3DMCP-Tol/MCH) plot. Circles in the diagram indicate the average composition of oil and condensates in Niigata, district, Japan.

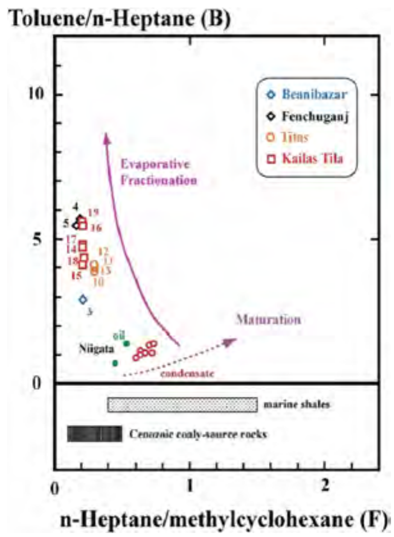

Fig.2: Toluene/n-heptane-n-heptane/methylcyclohexane (B-F) plot by Thompson (1987)

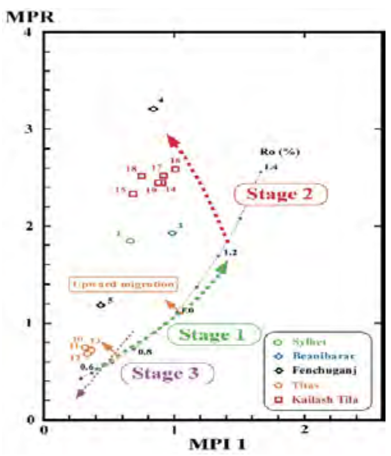

Fig. 3: MPR-MPI 1 plot (Stage 1: oil; generation, Stage 2: condensate, Stage 3: Cracking)

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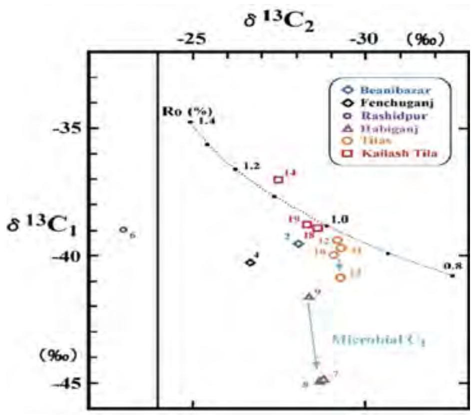

Fig. 4: $\delta^{13}C1-\delta^{13}C2$ plot.

GEOLOGY POSTER 31

REPRESENTATIVE FLUID SAMPLES FOR RESERVOIR FLUID EVALUATION AND FLOW ASSURANCE ANALYSES: SOUTH EAST ASIA FIELD

Michael Tighe[1], Sammy Haddad[2] & Lee Chin Lim[2]

[1] Carigali-PPTEPI Operating Company Sdn. Bhd., Level 8, Tower 2, PETRONAS Twin Towers, KLCC, 50088 Kuala Lumpur, Malaysia.

[2] Schlumberger, 18th Floor, East Wing, Rohas Perkasa, No.8 Jalan Perak, 50450 Kuala Lumpur, Malaysia.

Representative fluid samples are essential to achieving high quality PVT and flow assurance lab analyses. This is especially important when downhole samples are acquired in an oil base mud (OBM) environment. These high quality samples are also needed to better understand reservoir and fluid behavior throughout the field life.

This work presents a case study of an offshore field in East Asia that required high quality reservoir oil fluid samples for detailed PVT and flow assurance analyses. An oil bearing sand was discovered during the development drilling phase of a predominantly gas bearing reservoir environment. It was required to take low contamination samples from this zone during the development drilling phase without compromising the primary well objective of completion as a gas producer. As such, samples had to be taken on wireline in an oil based mud (OBM) environment. Accordingly a carefully planned methodology and technology was planned and used to achieve the goal of obtaining reservoir fluid samples.

Samples acquired from a previous well in the field using traditional openhole wireline formation testing technology and methods resulted in relatively high contamination levels. High levels of OBM filtrate contamination typically have detrimental effects on the PVT analyses quality for both gas and oil samples. Rig time, cost and sticking risk also limited the time allowed for the wireline formation tester to stay stationary at a sampling depth. As a result, a decision was made to utilize a new sampling technology that allows the obtaining of low level contamination while minimizing sampling station and rig time. To achieve this goal, the job was carefully designed and monitored by operating company and service company experts in real time to ensure the required results. The sampling technology, method and field and laboratory results are presented in this work.

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GEOLOGY POSTER 32

A COMPARISON BETWEEN 1D AND 3D BASIN SIMULATIONS OF THERMAL EVOLUTION AND HYDROCARBON GENERATION A CASE STUDY IN THE SOUTH MALAY BASIN, OFFSHORE PENINSULAR MALAYSIA

Azlina Anuar[1] & M Jamaal Hoesni[2]

[1] Petronas Carigali Sdn Bhd, Level 16, Tower 2, Petronas Twin Towers,KLCC, 50088 Kuala Lumpur, Malaysia.
[2] PETRONAS Research Sdn Bhd, Lot 3288 & 3289, Off Jalan Ayer Itam, Kawasan Institusi Bangi, 43000 Kajang, Selangor, Malaysia

One of the first steps when undertaking a basin modeling project is to define the thermal evolution of the study area via 1D thermal calibration. The resulting thermal model, often defined by heat flow maps, is then applied to subsequent 2D and 3D simulations. This study offers a comparison between 1D and 3D thermal modelling of the South Malay Basin and illustrates the need to re-calibrate the 1D thermal model before its application to a full 3D block simulation.

A systematic approach towards determining the top-of basement heat flow in the South Malay Basin was adopted, taking into account the three main heat sources of the basin: asthenospheric heat (β-factor dependent in rift settings) and radiogenic heat production from the crust as well as the sediments. Using basin modeling software, the heat flow variations through geologic time were determined by means of vitrinite reflectance (from standard measurement and FAMM methods) and measured present-day temperature data (from drill stem and production tests) as the main calibration points. Three top-of-basement heat flow maps for the different stages of the South Malay Basin development, namely the pre-rift, post rift, and the pre-inversion and folding phases were initially defined via 1D thermal calibration (Anuar et al, 2009). Having established the 1D-heat flow distribution patterns through time by incorporating the relevant stretching factors as determined by Madon & Watts (1998), these maps were then used as input for the 3D maturity modeling.

Calibrated heat flow values derived from the 1D models were applied to the 3D block. Resulting calculated and measured temperature and maturity data, however, highlighted noticeable differences between the modeled and observed temperature and maturity values in a number of wells (Figure 1). This illustrates the need to recalibrate the 1D-derived heat flow maps as they gave lower predicted bottom-hole temperatures and vitrinite reflectance values when applied to the 3D block model despite having been calibrated in 1D. It is concluded that, because 1D models do not capture the full basin geometry to enable complete thermal and fluid transport in space, they would often underestimate (although sometimes also overestimates) the observed temperature and pressure data. Throndsen & Wangen (1998) have shown considerable variations observed between

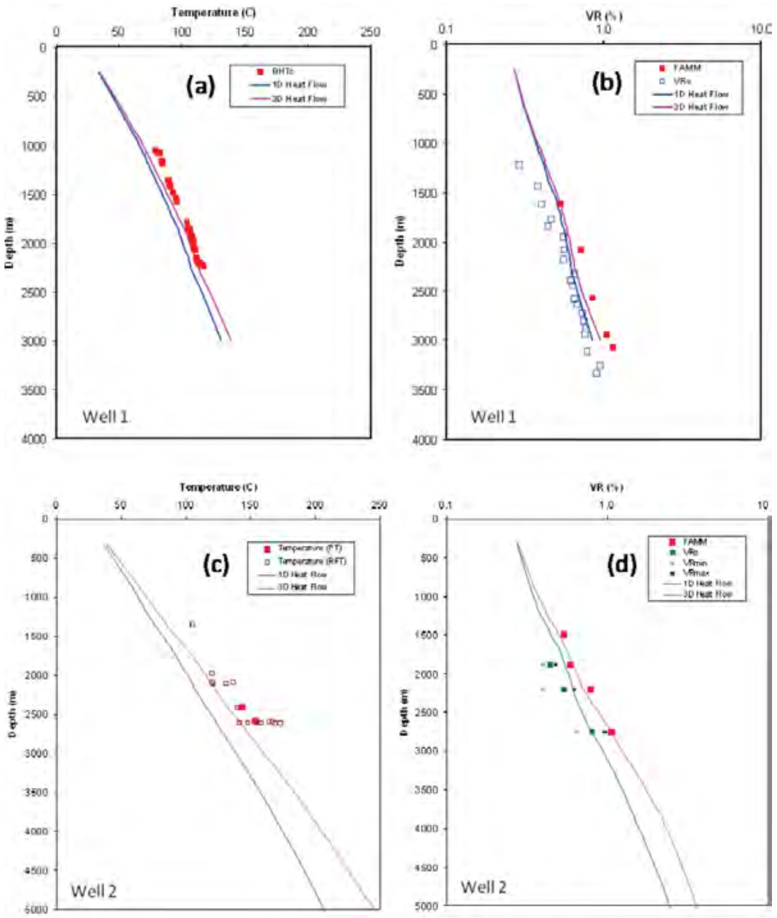

Figure 1. Temperature and maturity calibrations for Well 1 (a & b) and Well 2 (c & d) wells using the 1D derived heat flow maps (blue line) and the 3D-based corrected heat flow maps (red line). It is clearly shown here that the matching between calculated and measured data is better with the 3D-based corrected heat flow maps. FAMM data is considered as more reliable due to the vitrinite suppression phenomenon in the Malay Basin.

1D, 2D and 3D thermal models. The differences, among others, can be attributed to heat focusing, heat transfer through fluids, lateral variation in lithological properties and overpressure.

An optimisation was done by analysing the magnitude of differences between the modelled and actual temperature and vitrinite trends. Adjustments to the heat flows were necessary in order to match the modelled temperature and vitrinite reflectance values to those measured at the well locations. Subsequent shifting of individual heat flow values up and down, guided by the results at the calibration well locations, allowed a best fit scenario to be determined. The new and updated heat flow values were re-contoured and the revised maps (Figure 2) were then re-assigned to the corresponding time steps within the 3D model so that the temperature-dependent parameters, such as source rock maturation and hydrocarbon generation, can be calculated in the final simulation.

The establishment of the three new base-of-sediments heat flow models (present day and 16 Ma, 25 Ma and 40 Ma) enables all future thermal modelling work in the study area to be conducted with a higher degree of confidence, as these maps have been calibrated by the 3D basin modelling method. Corrections and further refinements can be made to these maps as more work is carried out in the study area.

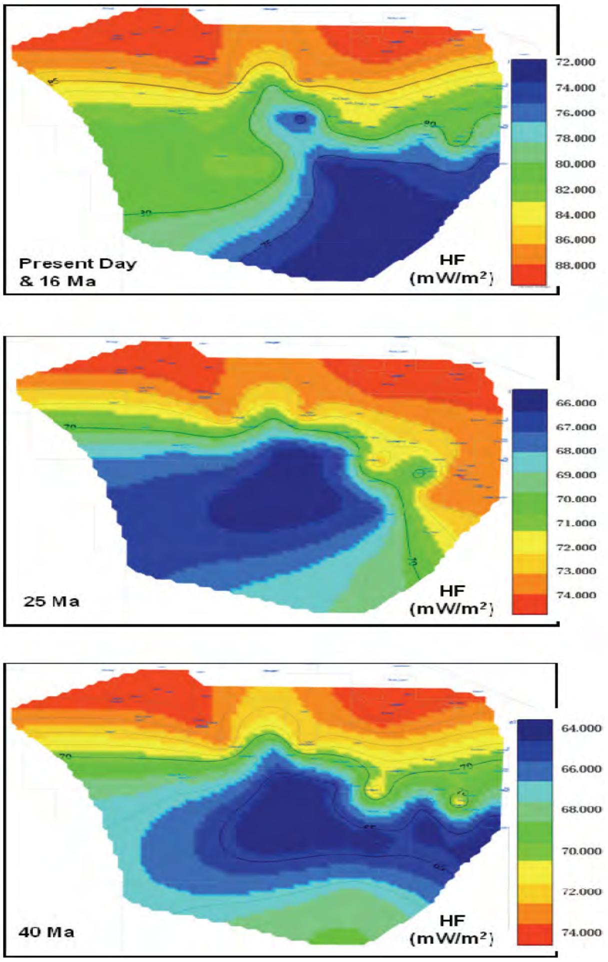

Figure 2. Final heat flow maps applied to the study area following adjustments of the initial maps derived from the earlier 1D thermal calibrations - present day & 16 Ma, 25 Ma and 40 Ma.

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GEOPHYSICS POSTER 1

4D EFFECT FROM SATURATION VARIATION DUE TO FLUID MOVEMENT USING 4D SEISMIC ACOUSTIC IMPEDANCE INVERSION METHODS FOR RESERVOIR MONITORING

Shuhadah Basaharudin, Nor Azhar Ibrahim & M Firdaus A Halim

PETRONAS Research Sdn Bhd, Lot 3288 & 3289, Kawasan Institusi Bangi, 43000 Kajang, Selangor, Malaysia

SUMMARY

Inversion method is the process of extracting the acoustic impedance (AI) profile for each seismic trace. The AI property is related to the layer properties of the reservoir-density and velocity. Meanwhile, velocity and density data can be obtained from well logs. Therefore the impedance inversion relates the seismic data with the well log data. The purpose of this study is to understand the changes in reservoir properties that could be predicted from the changes in P-impedance between the two surveys (base and monitor) and to obtain a time-lapse impedance model that can predict changes in fluid distribution that is due to production of hydrocarbons and also due to water injection (EOR) over the well X.

All inversion algorithms suffer from non-uniqueness because there could be more than one possible geological model consistent with the seismic data. However, we can include the low frequency model (LFM) to constrain the final result and give a reliable and accurate inversion output. Low frequency information can be derived from well logs information or from the stacking velocities.

The benefits of seismic inversion are numerous such as the broader bandwidth of the impedance data maximizes the vertical resolution and minimizes the tuning effects, interpreting volumes rather than surfaces is geologically more meaningful, removes the effects of the wavelet from the seismic bandwidth, reservoir properties are separated from the overburden, may provide quantitative predictions on the reservoir properties and possibility of extending the layer features beyond the seismic bandwidth.

Figure 1 is the inversion fundamental concept of inverting the seismic data to impedance data. Figure 2 shows the result of inversion on Base (left) and Monitor (right) within the A sand

reservoir. The purple colour indicates the low impedance area (reservoir) and the red indicates the high impedance area (non-reservoir). The A sand reservoir was highlighted in the ellipses.

Figure 3 display the Difference (Monitor-Base) result within the A sand reservoir in percentage value of 0-18%. The purple colour represent the low changes value(less than 4%) while the green represent the highest changes value (more than15%). The red arrows are the injector wells and the yellow are the producer well that show changes in the impedance between the surveys.

From the study, 3D Seismic Acoustic Impedance Inversion is sensitive to the fluid changes in the reservoir and the AI differences at the production wells are possibly indicative of production (pressure\saturation changes), whereas at the injector wells, these inversion AI difference may be the result of water injection for the EOR program in A sand reservoir. These inversion results can help to make decision on where to place better injector and producer wells locations in the future.

ACKNOWLEDGEMENT

We would like to thank the management of PETRONAS, PETRONAS Carigali Sdn Bhd and PETRONAS Research Sdn Bhd, for their support and permission. We are grateful to En Wahyudin Suwarlan of PCSB, for his geological seismic interpretation expert advice on the study field.

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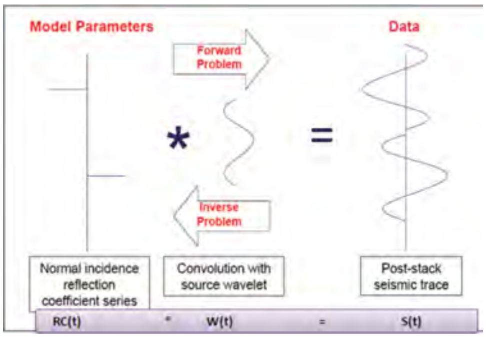

Figure 1: The fundamental concept of Seismic Acoustic Impedance Inversion.

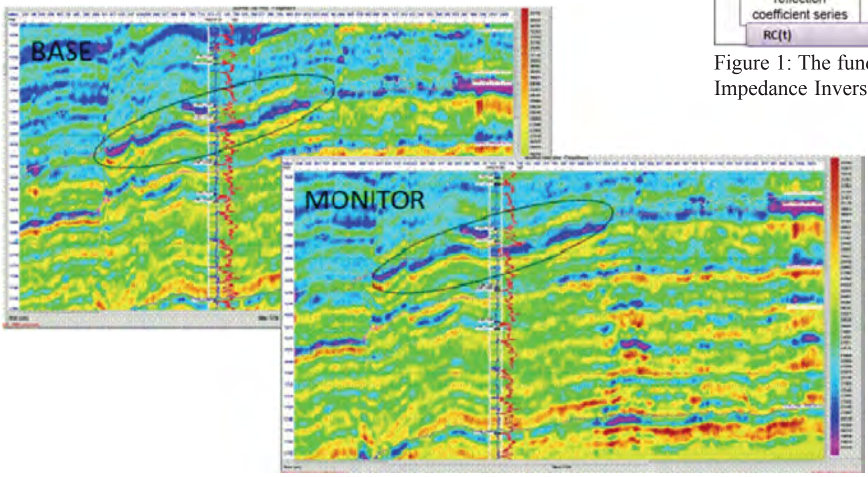

Figure 2: The inversion result on Base (left) and Monitor (right) seismic data.

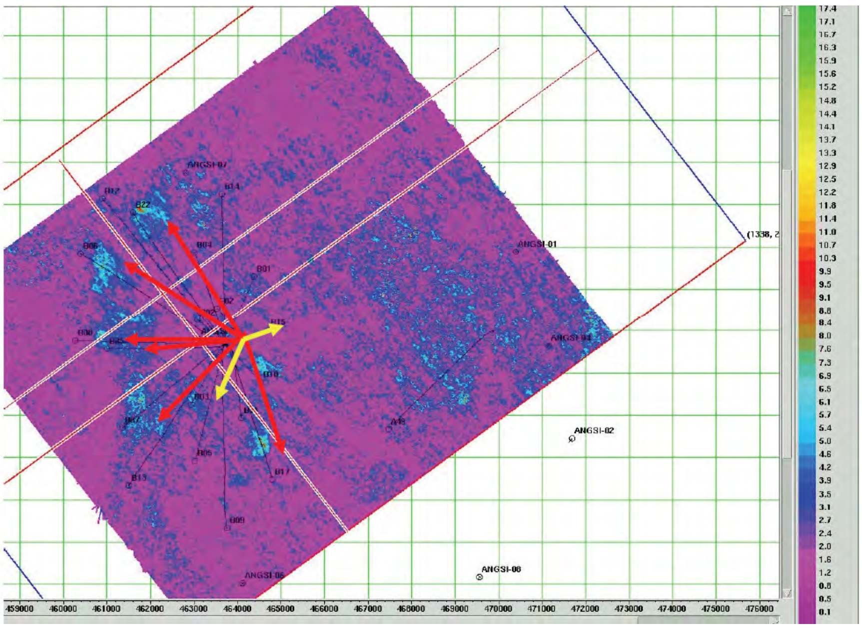

Figure 3: The Difference (Monitor-Base) result within A sand reservoir.

GEOPHYSICS POSTER 2

CHANNEL THICKNESS ESTIMATION USING SPECTRAL DECOMPOSITION

Nora Aida Ramly[1], Nor Azhar Ibrahim[1], M Rapi M Som[1], Wan M. Khairul[1], Siti Syareena Ali[1] & M Raisuddin Tajuddin[2]

[1]PETRONAS Research Sdn. Bhd, Lot 3288 & 3289 Off Jalan Ayer Hitam, Kawasan Institusi Bangi, 43000 Kajang, Selangor
[2]Energy Quest Sdn. Bhd.

The Spectral Decomposition provides a new, non-traditional approach to seismic interpretation and attributes analysis. This technique is used for imaging and mapping temporal bed thickness, channel and geological features over 3D volumes where the samples are subdivided into different frequencies ie; 10 Hz, 15 Hz, 20 Hz, etc (Kishore, 2006) . Different materials in the rock strata resonate at different frequencies, and therefore can be distinguished from one another by their frequency response.

The Spectral Decomposition techniques is widely used and successfully done for channel thickness estimation in a field scale (Partyka et al., 1999, Hall, 2004). However, channel thickness estimation in a regional scale has not been widely done. This study is the first attempt in applying this technique in the Malay Basin with regards to the I group channel. This study covers an area of 40,000 km2 located in the southern half of the Malay Basin. As a control parameter the top I and top J were interpreted and 20 proportional slices were defined by using stratal slicing technique. For each interval the RMS amplitude was carried out to produce a channel map.

The spectral decomposition technique was performed to estimate the channel thickness. 20 Spectral decomposition volume attributes were generated at each interval to estimate the channel thickness for I010 to I140 channels. The frequency range from zero to Nyquist frequency (125 Hz) was generated. In addition the frequency slice animator was used to review the Frequency tuning map to determine the Optimum Frequency (Fo). Subsequently, average velocity was utilized to calculate the channel thickness.

As the conclusion it can be deduced that the Spectral Decomposition technique worked well in the study area where the results were found to be quite matched with the channel thickness value stated in the well information. For that reason, this technique was confidently applied to some areas that do not have any well control in order to perform the channel thickness estimation.

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GEOPHYSICS POSTER 3

ESTIMATING POISSON'S RATIO FROM ELASTIC IMPEDANCE: A CASE STUDY FOR HYDROCARBON PLAYS IN MALAY BASIN

Ang Chin Tee & Shaidin Arshad

PETRONAS Research Sdn Bhd, LOT 3288 & 3289, Off Jalan Ayer Itam, Kawasan Institusi Bangi, 43000 Kajang, Selangor, Malaysia

It is now common for a 3D datasets to be processed as partial offset volumes to exploit the AVO information in the data. The amplitudes of near-offset stack relate to changes in acoustic impedance (AI) and can be tied to well logs using synthetics. Unfortunately, there have been no simple equivalent processes for far-offset stacks. However, the symmetry can be recovered using the elastic impedance (EI). EI provides a consistent and absolute framework to calibrate and invert non-zero offset seismic data just as AI does for zero-offset data (Connolly, 1999).

An EI log acts as a platform to calibrate the inverted data to any desired rock property (SI, σ, μ, λ etc) with which it correlates (Connolly, 2010). Many studies on EI have been done on Gulf of Mexico, and a strong correlation was found between EI at 30° and hydrocarbon pore volume. This relationship was then used to estimate the in-place volumes for the field from the inverted 30° seismic volume. EI is also widely used to discriminate lithology and to distinguish fizz water from commercial gas concentrations (Gonzalez, 2004).

Estimating the Poisson's ratio from seismic is also crucial. Theoretically, one can invert a 90° angle stack which has amplitude that is proportional to changes in Poisson's ratio. However, this approach is difficult due to the sensitivity to residual moveout and bandwidth variations.

On the other hand, EI has values equal to AI at normal incidence. If K = 0.25, then EI is equal to (Vp/Vs)2 at 90° which is closely related to Poisson's ratio. This allows the construction of high angle stack, and then being calibrated and inverted using the equivalent EI log.

Since the absolute level of EI(90°) is depending on the value of K being used, one should study for the optimum angle of EI that correlates with Poisson's ratio at well locations. In this paper, we will perform this study for hydrocarbon plays in Malay Basin and validate the result by estimating the correlation coefficient. With the known optimum angle, we can estimate Poisson's ratio from seismic with the information from EI.

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GEOPHYSICS POSTER 4

CHALLENGING VIEWS TOWARDS MINIMIZATION OF MULTI-COMPONENT DATA COMPLEXITIES

Amar Ghaziah, Riaz Alai & Hafizal M. Zahir

PETRONAS Research Sdn Bhd, LOT 3288 & 3289, Off Jalan Ayer Itam, Kawasan Institusi Bangi, 43000 Kajang, Selangor, Malaysia

The acquisition of seismic multi-component data and the application of various multi-component processing technologies have shown observable benefits in more accurate imaging of the earth's subsurface. Although many successful and advanced technologies have been applied in the oil and gas industry with compressional waves alone, the help of shear waves in addition to existing methodologies has opened new opportunities to many oil and gas companies in finding new reserves. In addition to improved subsurface imaging using shear wave information, they are also inevitable in optimal characterization of reservoirs.

Complexities in multi-component data occur when the wave front suddenly gets distorted due to sudden subsurface velocity changes. An increase of velocities corresponds to waves reaching subsurface salt bodies or hard volcanic rocks. On the other hand, lower velocities are directly related to waves passing through gas clouds, which is characteristic in Malay Basin environments. In this abstract, some challenging views will be discussed for waves passing through gas clouds and some examples will be shown on field data from the Malay Basin. The critical observations include lower amplitude reflections and minimal propagation of compressional waves, which create serious complexities and challenges in optimal illumination and imaging within these environments.

In this abstract, we review existing efforts and important characteristics of compressional waves as well as shear waves related to data from the Malay Basin emphasizing the added value of shear wave energy towards enhanced understanding and characterization of oil and gas reservoirs.

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GEOPHYSICS POSTER 5

A SHALLOW WATER CSEM CASE STUDY: QUALITATIVE AND QUANTITATIVE ANALYSIS

Mazlan Md Tahir[1], Azani Abd Manaf[1] & Siti Hassulaini Abdul Rahman[2]

[1]BAP, PREX, Petroleum Management Unit, PETRONAS, Level 16, Tower 1, PETRONAS Twin Towers, KLCC 50088 Kuala Lumpur, Malaysia

[2]EMGS AP SDN BHD, Unit E-15.2-4, 15th Floor, East Wing, Wisma Rohas Perkasa, No: 8 Jalan Perak 50450 Kuala Lumpur, Malaysia

Controlled Source ElectroMagnetic (CSEM) has been proven to be a valuable tool for remotely detecting and mapping offshore hydrocarbon reservoirs. The method, described by Eidesmo et al. (2002), measures the electrical properties of the subsurface where replacement of saline pore fluids by hydrocarbons influences the resistivity of reservoir rocks.

A CSEM survey was conducted in shallow water area (~90 m depth) where is located at the depocenter of the late tertiary west Luconia delta (Rajang delta), west of the Central Luconia Province, Offshore Sarawak, Malaysia. Generally, geological setting of the area is a regressive, prograding deltaic sequence interrupted by regional transgressive events Earliest Pliocene, Late Early Pliocene and Early to Mid-Pleistocene (Robertson Research, 1989). The basin deepened to the north-western part of the survey area, where thick marine sequences were deposited during Neogene to recent.

Receivers were deployed in two 3D grids to allow for inline and wide azimuth data covering two main prospects which are 12 km apart. In addition, a single receiver line was deployed almost perpendicular to these grids to cover an elongated target not covered by the grids.

The first pass analysis of the resistivity distribution was obtained through a qualitative approach (attribute analysis). This approach is limited to denoting one area more resistive than another, excluding actual resistivity values and accurate depth investigation. In shallow water, the measured data is dominated by an electromagnetic (EM) signal that has propagated along the air/water interface, commonly known as the airwave effect. The airwave effect in the data was reduced by decomposing the EM field into down going and up going component and removing the latter (Amundsen et al., 2006). After the airwave removal, the attributes obtained anomalous features over the prospect area, however this analysis is inconclusive.

A quantitative (inversion) approach was later adopted, which can both account for the airwave and assign resistivity values in depth where sensitivity is provided. Anisotropic 2.5D and 3D inversion was applied and supported that the anomalous features observed in the qualitative approach coincide with high resistivity within the seismic prospect outlines. Even though both inversion schemes (2.5D and 3D) reconstructed the resistive features, it is important to recognize the limitation of 2D data. A 2.5D inversion relies on a 2D approximation of the subsurface, rendering geometry changes orthogonally to the towline unresolved. A grid survey resolves 3D effects and anisotropy by combining inline and azimuth data, i.e. data from receivers both on and off the source towline (Morten et al., 2009).

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GEOPHYSICS POSTER 6

METHODS IN ESTIMATING VISCO-ELASTIC PROPERTIES FOR GAS CLOUD IMAGING : A MULTICOMPONENT SEISMIC AND ROCK PROPERTIES ANALYSIS

Ang Chin Tee & M Hafizal Mad Zahir

PETRONAS Research Sdn. Bhd, Lot 3288 & 3289 Off Jalan Ayer Hitam, Kawasan Institusi Bangi
43000 Kajang, Selangor, Malaysia

The presence of gas cloud in the Malay Basin has always been a topic to be discussed when it comes to imaging the subsurface. Gas cloud has caused compression (P-waves) data acquired to suffer from poor data quality due to higher attenuation of P-waves, wavefront distortion which caused by low velocity distribution within the gas bodies and transmission losses. Converted shear wave (P-S waves) data from multicomponent acquisition allows images to be obtained that are unobstructed by the gas and/or fluids (Thomsen et. al 1997, Granli et. al 1999). In addition, rock properties can be uniquely determined from the compressional and shear data, allowing for improved reservoir characterization and lithologic prediction. This paper will discuss method for determining the optimal parameters of the velocity (V) and density (ρ) within the gas cloud for further input into P-S waves imaging.

One of the methods in determining the parameters is by the generation of rock properties models to understand how the gas cloud modifies the visco-elastic properties of rocks such as Vp, Vs, ρ, Qp and Qs (Chaveste, 2007). This method starts with well log modeling and inversion to estimate moduli of rock constituents that incorporates Batzle, Wang and Gassmann equations (Kumar, 2006). It then can be used to model logs for different rock conditions such as porosity (Φ), lithology and fluid saturation (see Figure 1). Through Athy's equation, the reconstruction of P-wave and S-wave velocities and density trends can be done to predict the normal compaction trends and quality factor (Q).

Through rock properties model, the Vp/Vs ratio can be estimated for both measured and modeled logs (Figure 2). The estimation of Vp/Vs is crucial in order to predict the Common Conversion Point (CCP) of the P-S waves. This information can be used to QC the P-S data processing by migrating the CCP; updip if the ratio is low, or downdip if the ratio is high. Figure 3 illustrates the positioning of the CCP events and Figure 4 shows its respective P-S impulse response.

The absorption parameters of the gas cloud could also be estimated through attenuation modeling. Well-log information in addition to VSP-data, could be used for quality factor (Q-factor) estimation. Sonic velocities measured at frequencies above the seismic signal band, usually around 12 kHz, when computed together with synthetic seismogram, and adjusting the time shift between the two type of data, can be used to estimate the Q-factor (Arnim, 2003). The estimation of Q-factor is important in determining if the multicomponent acquisition and processing of PS data would result in better imaging of the reservoirs. The smaller absorption of the S-wave, the higher resolution and better quality P-S waves data can be recorded.

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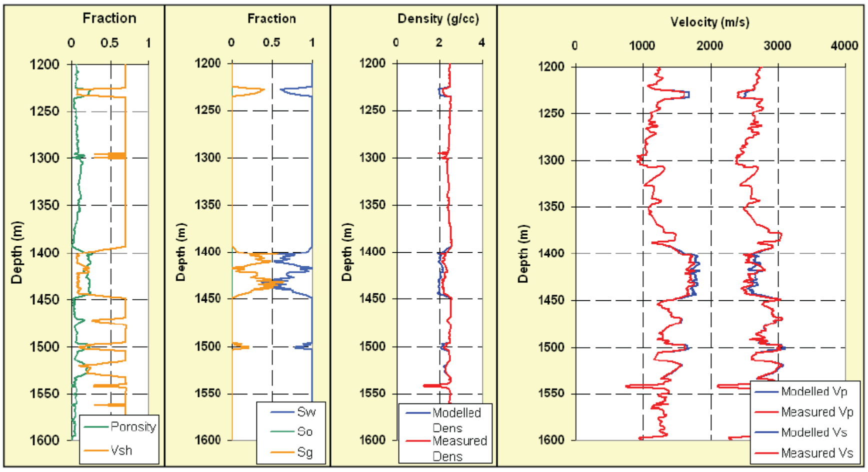

Figure 1: Petrophysical evaluations and the modeling of visco-elastic properties.

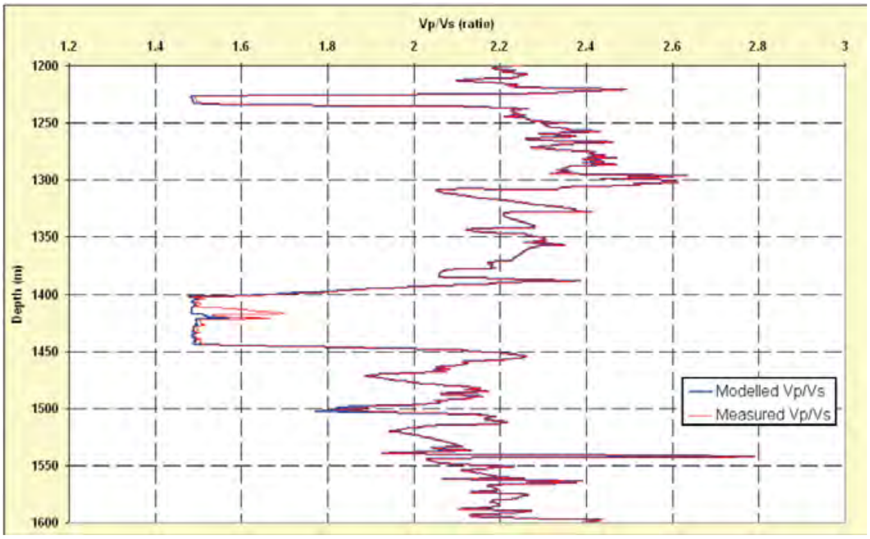

Figure 2: The measured and modeled Vp/Vs ratio.

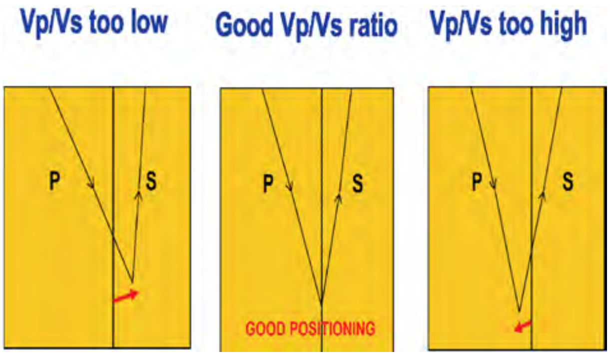

Figure 3: Estimating the position of Common Conversion Point (CCP) from Vp/Vs ratio.

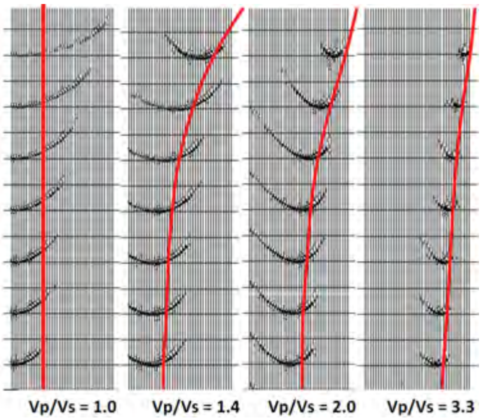

Figure 4: P-S impulse response.

GEOPHYSICS POSTER 7

INTEGRATING SEDIMENTOLOGICAL CORE STUDY AND SEISMIC ATTRIBUTES TO DEFINE FLUVIAL CHANNEL CHARACTERISTICS IN THE MALAY BASIN.

Putri Yunalis M Yunos, Siti Syareena M Ali, M Rapi M Som, Nor Azhar Ibrahim & W M Khairul Anuar B W Sulaiman

PETRONAS Research Sdn. Bhd., Kawasan Institusi Bangi, 43000 Kajang, Selangor, Malaysia

The integration of sedimentological core study and seismic attributes to define the fluvial channel characteristics has been carried out within the 3D seismic megamerge, in the seismic Group I, Malay Basin. The main objective of the study is to characterise the geometries, heterogeneities, properties, and classification of fluvial channel reservoirs in Group I.

The study were carried out by utilizing the available cored intervals, biofacies analysis, wireline logs, seismic, and well data. The method used in this study is based on the core review program by evaluating the core-based results and integrating with the RMS seismic attributes results. The core review program utilizes both previous investigations as well as conducting new study on the cored sections. The cored interval included cores taken from the I-25, I-50, I-68, I-80, I-85, I-90, I-100, and I-110 reservoirs, which were discovered from year 1978 to 2002. The depositional environments of the cored intervals were then interpreted based on the core lithofacies associations integrated with biofacies characters from palynological and foraminiferal analyses.From the results of the core study, only cores from 3 wells have been identified as potential fluvial channel sandbody. The identified potential fluvial channels core data were later validated and verified with the available seismic data. The study has established new insights with implications on the understanding of the paleogeography of the Malay Basin for the I group.

Based on the core facies analysis there are five main sandstone lithofacies identified from the fluvial channel facies of I25, I80, and I100 in Group I, Malay Basin. These are trough cross-bedded sandstone, massive sandstone, cross laminated sandstone, parallel laminated sandstone, and ripple laminated sandstone lithofacies. The best reservoir characteristics for the fluvial channels are shown by trough cross-bedded sandstone lithofacies.

The core based characterization and classification of Group I have identified three key wells from reservoir I25, reservoir I80, and reservoir I100 as potential fluvial channel sand bodies.

Specifically, comparisons are made as to properly integrating the core-based and seismic-based information from horizon strata slice of RMS amplitude maps. The integrated study approach concludes that only two cored wells have been interpreted to penetrate fluvial channel sand bodies while other cores from Group I which were thought to be fluvial in nature based on previous work or their log profiles however indicate that they were deposited in more marine environments. The integration of sedimentological core study and seismic attributes has defined the fluvial channel classification in the Group I in the Malay Basin, capable of improving reservoir understanding.

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GEOPHYSICS POSTER 8

AN APPRAISAL WELL, FROM GEOPHYSICAL POINT OF VIEW: DO NOT SIMPLY CALL IT A FAILURE!

Hijreen Ismail[1], Prama Arta[2] & Bernato Viratno[2]

[1]PETRONAS Carigali Muriah Ltd.,Level 17-18, Menara Mandiri, Bapindo Plaza, Jl. Jend Sudirman Kav 54-55, Jakarta 12190- Indonesia.

[2]PETRONAS Carigali Sdn Bhd, Tower 2, Petronas Twin Towers, Kuala Lumpur City Centre, 50088 Kuala Lumpur, Malaysia.

The field is located around 148 km from Bintulu, Offshore Sarawak. This field was discovered in March 2006 by Z-1 exploration well. The type of reservoir is a carbonate pinnacle.

The recently drilled appraisal well X-ST1, has opened various perspectives. The production tests in the three different zones failed to prove the availability of a significant amount of hydrocarbon in the northern part of the field structure. However the successful VSP operation, manage to provide a new time depth relationship at the well location. The success also offered velocity control at the northern area and allowed reinterpretation works. The latest well correlation sets a new geological marker, whereby the Top of carbonate was found to be ~26 m shallower when compared to prognoses. Five horizons were reinterpreted. They are Top of carbonate and Top of zone 4, 5, 6, and 7. Using the new generated 3D velocity model, all the TWT maps were then converted to depth structure maps. When the generated depth structure map of Top of zone 6 was overlaid with gas water contact as found in Z-1 well, a saddle, which separates the southern pinnacle from the northern area carbonate platform in this zone, appeared to be suggested. Hence new resource assessment exercises had been conducted based on the new gross bulk volume (GBV). Consequently, it was gladly found out that there are 69% increase of volume in terms of calculated 2P GIIP. The drilled X-ST1 well also provided input on the quality of the carbonate in the northern area. The porosity observed in this well is totally different from the Z-1 exploration well. In conclusion the X-ST1 appraisal well did provide noteworthy inputs to the understanding of the field structure and economic values to the company.

RECOMMENDATIONS

- Regenerate inversion cube based on the latest data
- Acquire 3D seismic at non-3D seismic area, especially at the northern area of the structure.
- Carry out advance reservoir characterization analysis such as AVO model.

GEOPHYSICS POSTER 9

FIT FOR PURPOSE SEISMIC RESERVOIR CHARACTERISATION

Troy Thompson[1], Matthew Lamont[1], Carlo Bevilacqua[2] & Natasha Hendrick[1]

[1] DownUnder GeoSolutions Pty Ltd, 80 Churchill Avenue, Subiaco, WA, Australia 6008

[2]Apache Energy Limited

Quantitative seismic interpretation utilises seismic amplitude behaviour in conjunction with well log data, petrophysics and rock physics to make quantitative predictions about lithology and fluid away from well locations. Seismic reservoir characterisation in general cannot follow a one-size-fits-all approach – it is critical to consider local geological insight. It is also essential to determine the appropriate quantitative interpretation (QI) workflow based on available seismic and well data, and the desired outcome. Together, this will ensure robust and reliable characterisation of the hydrocarbon reservoir is achieved.

There is an array of QI workflow options for reconnaissance, exploration and reservoir-appraisal applications. Typically reconnaissance workflows must be utilised when no wells are available within the seismic survey area. In this instance, amplitude variation with incident angle (AVA) attributes can be used to identify exploration targets. AVA stack rotations are one powerful attribute to highlight potential anomalies when minimal or no well log data are available within the seismic survey area. AVA stack rotations are equivalent to the well-known extended elastic impedance (EEI) attribute (Whitcombe et al., 2002), and can be thought of as weighted stacks designed to enhance or suppress particular AVA responses. EEI is typically computed in intercept-gradient space, however stack rotations can also be computed using near and far (angle stack) attributes. Near and far AVA attributes have both high signal-to-noise ratio and statistical independence (Herrmann and Cambois, 2001). A simple scan through rotation angles can then be undertaken to quickly highlight interesting anomalies.

When well log data are available, statistical rock physics can be undertaken to quantify the geophysical signatures of all rock and fluid types of interest. Subsequent forward modelling facilitates the understanding of how seismic responses will change as a function of key variables such as depth, fluid content, and reservoir quality. In addition to enabling the prediction of the most likely seismic response, statistical rock physics enables the prediction of the range of possible responses. Capturing this population behaviour results in a more realistic evaluation of any seismic anomalies.

With access to statistical rock physics and forward modelling results, it becomes possible to calibrate variations in AVA stack rotations to known rock and fluid properties, and maximise the discrimination of fluids relative to lithology. More comprehensive exploration and appraisal QI workflows are also possible with access to well log data. Seismic-to-well ties can be made, and relative AVA inversion products can be generated. AVA stack rotations can be applied following simultaneous relative inversion – this largely removes the effect of the seismic wavelet and enhances the interpretability of the data. Note that, it is important to appreciate that stack rotation angles are depth dependent. For example, AVA responses can change with depth as a function of different compaction gradients between sands and shales. It is necessary to take this into consideration when doing exploration work over large time windows.

Where well control is sufficient, it becomes possible to construct low-frequency models and generate absolute rock property derivatives. These inverted rock properties can then be integrated with depth-dependent, stochastic rock physics models using a Bayesian classification scheme to make quantitative predictions about lithology and fluids away from well locations (Lamont, et al., 2008). When multiple wells have penetrated a known reservoir, more focussed reservoir characterisation is possible, and stochastic inversion can be utilised to understand key characteristics and uncertainties in important reservoir parameters such as net sand, porosity, fluid saturation etc. (Glinsky et al., 2005).

Seismic reservoir characterisation must be approached on a case-by-case basis. An integrated workflow that is optimised to take advantage of all available geological and geophysical data is essential. Statistical rock physics is important for understanding seismic responses and their uncertainty, but also for implementing the appropriate workflow and interpretation model. The 'degree' of quantitative interpretation must be a function of the available data and the job at hand.

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GEOPHYSICS POSTER 10

APPLICATION OF SEISMIC ATTRIBUTE FOR CHANNEL IMAGING IN THE MALAY BASIN

Nor Azhar Ibrahim[1], M Raisuddin Tajuddin[2], M Rapi M Som[1], M Fauzi A Kadir[1], Wan M Khairul W Sulaiman[1], Putri Yunalis M Yunos[1], Siti Syareena M Ali[1] & Nora Aida Ramly[1]

[1] PETRONAS Research Sdn Bhd, Lot 3288 & 3289, Off Jalan Ayer Itam,
Kawasan Institusi Bangi, 43000 Kajang, Selangor; azharir@petronas.com.my
[2] Enerqy Quest Sdn Bhd, 7th Floor, Menara KH, Jalan Sultan Ismail, 50250 Kuala Lumpur

A seismic attributes is any measure of seismic data that help us visually enhance or quantify features of interpretation interest (Chopra and Marfurt, 2007). Amplitude, Frequency and Phase represents different aspect of a seismic reflection that brings outs different aspects of geologic features.

The purpose of this paper is to document the application of seismic attributes for channel imaging in the Malay basin at basin wide scale. Presently, channel characteristic in the I-Group has not been fully understood. Therefore, the utilization of mega merged data for this project is to help us better understand of channel morphology/characteristics in the Malay basin through the application of seismic attributes.

The area coverage of this study is approximately 40,000km2 which includes the 3D mega merged volume in the southern half of the Malay basin and fifteen (15) individual 3D seismic volumes. Two (2) major horizons, I-TOP and J-TOP were interpreted for basin-wide interpretation of I-Group interval as shown in Figure 1. From this, twenty (20) strata/proportional slices were generated using stratal slicing techniques that were associated to I010 to I140 sands of the I-Group.

Seismic attributes analysis on a small volume was carried out to identify the best attribute for channel imaging. The result shows that Root Mean Square (RMS) attributes reveals the anomalous amplitudes which represent channels outline (Figure 2) while frequency volume created from Spectral Decomposition has further enhanced the channel images (Figure 3). Future similar works could be expedited using this methodology and better define the channel outline.

Results from this regional study shows that a combination of RMS amplitude and Spectral decomposition is the effective seismic attributes that reveals channel feature which were calibrated with core and well logs data for validation. As a conclusion, combination of multi-attributes and geological concept is a powerful aid to seismic interpretation and geomorphology interpretation that could lead us to better prospect identification and contributed to exploration success

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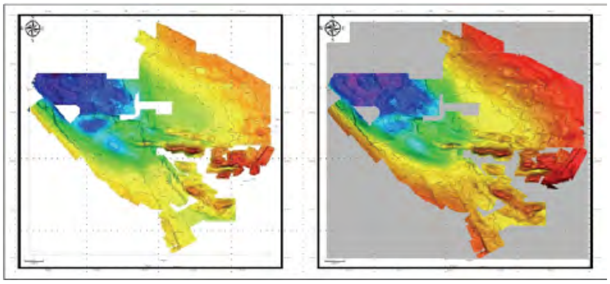

Figure 1: Interpreted time structure map of H and J TOP across the study area.

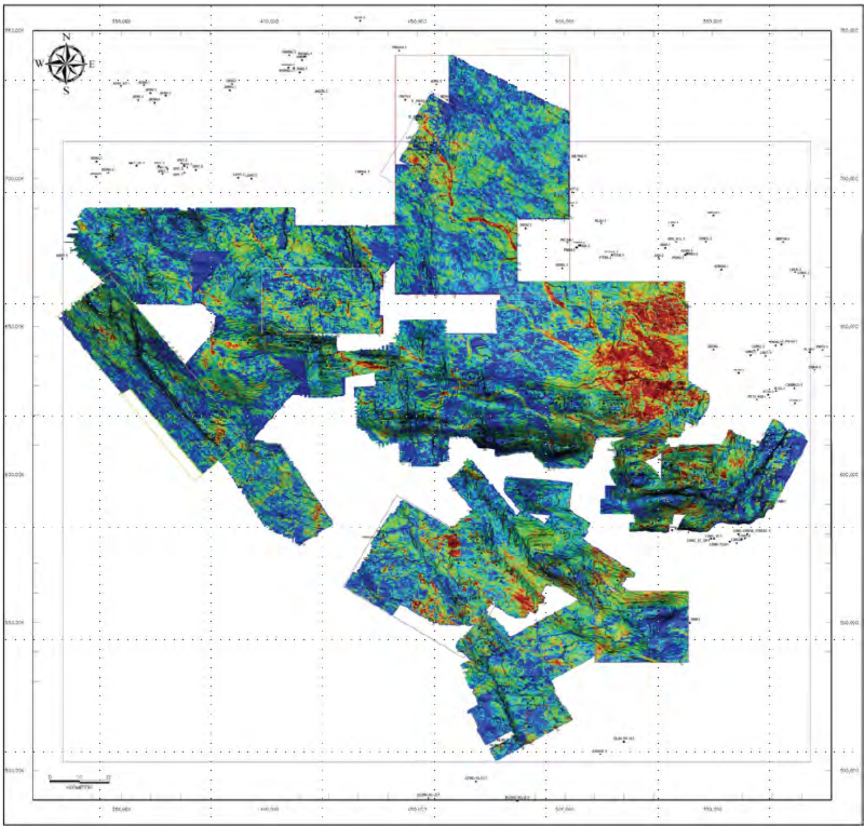

Figure 2: RMS amplitude map revealing channel features of Group I Interval.

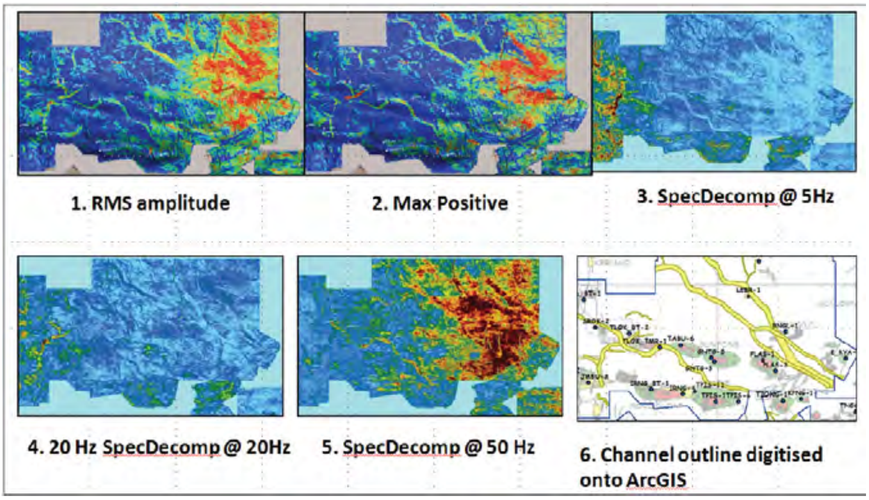

Figure 3: Spectral Decomposition technology for Imaging channel below coal layer.

GEOPHYSICS POSTER 11

GRAVITY AND MAGNETIC SIGNATURES, DERIVED CRUSTAL STRUCTRE AND TECTONICS OF SIRT BASIN, NORTHERN CENTRAL PART OF LIBYA

Ahmed. S. Saheel[1], Abdul Rahim Bin Samsudin[2] & Umar Bin Hamzah[2]

[1] Libyan Petroleum Institute (LPI), Triploi-Libya,P.O.Box 6431.
[2] School of Environment and Natural Resource Sciences, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor.

The Sirt basin is located in the north central part of Libya within the bounder's 270N-330N and 160E-220E. This study involves analysis of gravity and magnetic data to delineate structures and faults and to locate any major structures. The produced Bouguer gravity map shows prominent NW-SE and N-NW trends. Isostatic residual map is characterized by a dominant NW– SE trend in the study area. This is clearly evident in the isostatic residual. The main trending anomalies are in the northern and southeastern parts of the study area with NW-SE orientation. A strong NW-SE trend is truncated by E-W trending in the southeastern and southwestern parts of the area. This is consistent with change of tectonic zones (Duronio and Colombi, 1983). The magnetic expression in the northern part of Ajdabiya trough is characterized by NW-SE trending structures which coincide with late Cretaceous structures of the Sirt basin, while the southern part is characterised by NE-SW trending features which coincide with a late Paleozoic trend (Goudarzi, 1970, 1980). The northern part of the Ajdabiya trough is separated from the southern part by a prominent NE-SW lineament that is expressed in both the gravity and magnetic data. It is interpreted as a basement fault, which separates a thicker southern crust from a thinner northern crust. The high gravity anomaly within the northern part of the Ajdabiya trough is interpreted as a result of mantle upwelling which caused thinning of the continental crust beneath the northern part of the Ajdabiya trough. The Total horizontal derivative results of Gravity and Magnetic data (Cordell, 1979) ,(Cordell and Grauch, 1985), 3D Euler Deconvolution of gravity and magnetic data magnetic anomalies produced features trending similar to the positions of tectonic and geological information from the Sirt basin. High gradient values delineate NNW-SSE to N-S and NW-SE trends which mark the faulted southwestern, southern, northern and central boundaries of the basin, respectively. New faults with orientations NNW-SSE trends along the southwestern flank of the Sirt basin and is truncated by E-W faults dividing it into segments. Strong N-S lineaments occur over the southern and central part of study area and are well indicated by the 3D Euler Deconvolution. From this study the 3D Euler Deconvolution provides very useful information of the rift structures. Predictive modelling (2-1/2D) of gravity profiles was carried out for northern and southern parts of Sirt basin. Two profiles were controlled by wells. The deepest part of the northern profile is in the Ajdabiya and Al Jahamah platform and approximately depth from 3-6km. The deepest part along the southern profile is approximately 4.88 km in the Zallah and Hameimat trough.

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GEOPHYSICS POSTER 12

SEISMIC IMAGING AND VELOCITY MODELLING OFFSHORE MYANMAR (ANDAMAN SEA BASIN)

Farhan Ahmed Khan, M Hakimey Hashim, Azlan Mohd Sabirin, Goh Leong Kee & Garry Malo Paul

PETRONAS Carigali Sdn Bhd, Level 15, Tower 2, PETRONAS Twin Towers, KLCC, 50088 Kuala Lumpur, Malaysia.

All Geophysical Data Analysis/Processes are basically solving the inverse problem. One of the inversion methodologies is to derive Structure & Velocity via Seismic Imaging. The proper seismic imaging workflow is crucial in attenuating multiples and optimally images the seismic feature. This will further enhance the confidence level during interpretation and mapping and might all the way lead toward seeing flares. From pre-analysis/data preparation/data stabilization, analysis/data processing to deliverable of Pre-Stack Time Migrated Gathers require detail and precise technical analysis. The testing of 2D seismic line no. A, Offshore Myanmar, Andaman Sea Basin through PSTM has shown optimized subsurface imaging and better attenuation of multiples, which can be seen in target zone from 3000ms to 4000ms TWT.

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GEOPHYSICS POSTER 13

POST-STACK CROSS EQUALIZATION FOR TIME-LAPSE SEISMIC

Tan Chin Kiang[1], Wahyudin Suwarlan-PCSB[1], Kartina Ali[1] & Fariz Fahmi[2]

[1]Petronas Carigali Sdn Bhd, Level 16, Tower 2, Petronas Twin Towers, KLCC, 50088 Kuala Lumpur, Malaysia.
[2]ExxonMobil Exploration and Production Malaysia Inc

Successful 4D imaging requires high repeatability. Repeatability is a measure of similarity of two or more vintages of seismic data and is a function of acquisition geometry, ambient conditions and processing similarity. This paper illustrates a case study to cross equalize two 3D datasets acquired in 1995 (base) and 2006 (monitor) in a field with pressure maintenance support to analyze whether technology can be used for reservoir monitoring purposes.

Prior to the cross equalization effort, the base and monitor surveys were processed together using a 4D co-processing workflow. Co-processing is done with careful choice of parameters to maximize repeatability and optimize production-related 4D responses. The cross-equalization process is done after co-processing to minimize any seismic differences unrelated to production (improving repeatability) and enhancing the interpretability of the real 4D signal. This is also the process that generates the final 4D volumes and 4D attributes for the interpretation analysis.

The key steps in the cross equalization workflow include residual phase matching, static time shift, matching filter, amplitude normalization and time varying time shift. The accuracy of co-processing and consistent acquisition minimized the level of required cross equalization. Appropriate QC at each stage of cross equalization ensures that the desired 4D effect is preserved as the two datasets become increasingly comparable and look alike in the non-reservoir zones where ideally no change is expected. The final differences after cross equalization clearly shows high amplitude 4D anomalies around injector wells.

The overall improvement of 4% repeatability was achieved through the cross equalization process. The 4D data successfully imaged both water and gas movement throughout the major reservoir and results are currently being used to update the geologic and reservoir simulation models as well as to support a drilling campaign.

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GEOPHYSICS POSTER 14

SEISMIC FACIES CHARACTERIZATION OF THE CENTRAL NORTHWEST SABAH BASIN

M. Farizanuddin Jaapar, Ahmad Fahrul Januri, Harminzar Mansor, Mazlan Md. Tahir, Robert Wong & M. Razali Che Kob,

1BAP, PREX, PMU, PETRONAS, Level 16, Tower 1, PETRONAS Twin Towers, KLCC, 50088 Kuala Lumpur, Malaysia

The presence of reservoirs especially at the outboard of NW Sabah Basin is one of the major issues for the explorationist. Some of the wells were drilled targeting turbidites were unfortunately not successful.

A total 15 regional 2D seismic lines from different vintages have been chosen as key lines for seismic facies description and facies mapping in order to established regional correlation from inboard to outboard Sabah and identify new hydrocarbon play, leads & prospects.

The study area is located at the centre of NW Sabah Basin, which covered from inboard to outboard area. Generally the basin is bounded to the west by the West Baram Line & to the east by the Balabac Strait Fault. The Sabah Basin is a structurally complex basin that was form on the southern margin of a foreland basin that resulted from the collision between the NW Sabah Platform and western Sabah during the early Middle Miocene. Its complex syn-tectonic sedimentary history resulted in the recognition of major unconformity-bounded sedimentary packages Stages IVA to IVF (Mazlan Hj. Madon et al., 1999).

There are 4 major seismic facies characters had been identified, which displayed strong amplitude with wormy reflector, weak amplitude with wormy reflector, strong amplitude with parallel reflector and weak amplitude with parallel reflector. Turbidite environment can be interpreted by identifying wormy reflector which usually represents channelized activity and also deepwater evidence such as gull wing character. Parallel reflector represents more quite and calm environment. (Walker and James, 1992). Integration of seismic characters with sequence stratigraphy approach will facilitate to interpret DOE and to produce paleo-environment map (Emery and Myers, 1996).

This paleo-environment map will contribute to the petroleum system analysis within the area especially in term of presence and reservoir distribution prediction. Ultimately, this map would be able to explain why certain well is successful or vice versa.

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GEOPHYSICS POSTER 15

GEOLOGICAL MAPPING USING REMOTE SENSING AND MAGNETIC DATA

Nurdalila Binti Tazaruddin1, Khiruddin Bin Abdullah2, Nur Azimah Binti Hussin2, Ashkan Mohajerin2 & Farahida Binti Suradi1

1Efogen Sdn Bhd, Kuala Lumpur, Malaysia.
2School of Physics, Universiti Sains Malaysia, Penang, Malaysia.

In this project, Thematic Mapper (TM) and Digital Elevation Model (DEM) images, as well as magnetic data, were used to study the geological features of Kuh-e-Djahan Bin in Iran. Scanned geological map which was geometrically corrected was then used with TM and DEM images to extract geological information. Several analyses have been done to the images such as colour composite, principal component analysis, ratio and supervised classification. In order to evaluate the classification process, accuracy assessment was done to the classified images. The accuracy statistics was the measuring scale of the classification. In addition, contour and drainage patterns analyses were also done to extract elevation, flow direction and flow accumulation data to provide further information. Magnetic modelling with a small degree of unsuitability (misfit) between the model and the geological data was employed in order to compensate the subsurface interpretation. In a nutshell, these few named analyses were flawlessly facilitated in interpreting lithologic and structural geological features which was the interest of this study.

INTRODUCTION

Kuh-e-Djahan Bin is situated in the province of Chaharmahal va Bakhtiary. This province has a total area of 14820 km2 which is surrounded by the provinces of Esfahan, Khuzestan and Kohkiluyeh va Boyerahmad. Its capital is Shahr-e-Kord and this province is in the central part of the Zagros Mountain range between internal forelands and the Esfahan province. The structural pattern of this region mostly consists of numerous ground drifts that lead to the elimination of repetition of some geologized layers. The minerals mostly found in this small area are sedimentary rock types such as limestone, sandstone, conglomerate, shale, marls and quaternary deposits. The temperature is semi - humid cold with little vegetation coverage in the area (http://www.ngdir.ir/States/StateDetail).

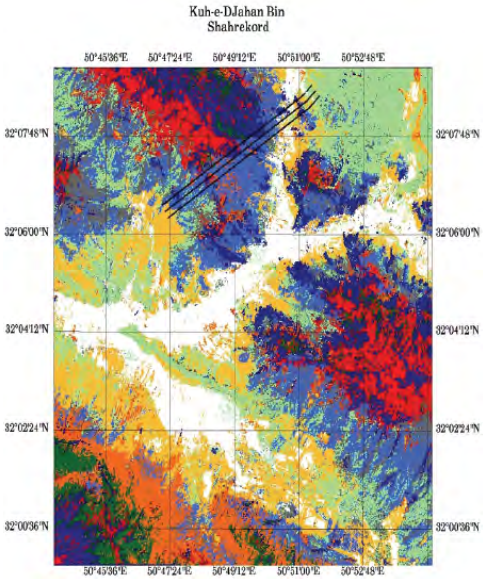

Figure 1: Supervised classification image with input TM4, TM5, TM7, RTR 4/2, RTR 3/1 and DEM

The objectives in this study are (i) to map the distribution of rock types, (ii) to determine contour and drainage patterns from DEM image and (iii) to correlate magnetic model with the geological interpretations. To ensure the efficiency of lithologic interpretations, the classified image was analysed carefully with the supervised classification method. The pre-processing step involves geometric corrections of geological map, a crucial step, since this yielded corrected image with the highest practical geometric integrity. For competence structural interpretation, the analyses extracted from DEM image by using certain algorithms were combined with geological map. Hence, a very excellent correlation and interpretation could be made. All the lithologic and structural interpretations were processed with the PCI Geomatica V.9.1 (PCI Geomatics, Ontario, Canada, 2003). In a magnetic model, the magnetic data were analysed by using two-dimensional extrapolation also known as contours at first. Then, it was followed by two-dimensional smoothing of the noise introduced by the extrapolation by using a low pass filter. One-dimensional profiles were extracted from the smoothed two-dimensional contour maps with profile selections based on magnetic line surveys and anomaly patterns. Finally, the forward modelling process for magnetic data was carried out by Mag2dc software (Cooper, 2003).

RESULTS

Supervised Classification Image

In this particular area, there were 9 types of rocks classified, identified as K (limestone), K8 (shale & marls, interbedded with marly limestone), EO (white limestone, marly & dolomitic limestone), OM2 (fossilliferous marly limestone), Q (quaternary), E (red conglomerate, sandstone, siltstone), P1 (hard conglomerate, sandstone, gritstone), K3 (thin gray argillaceous limestone), and K7 (marly fossilliferous limestone & thin sandy argillaceous limestone).

Figure 1 shows the supervised classification image by using TM4, TM5, TM7, RTR 4/2, RTR 3/1 and DEM input channels. Based on this figure, the most precise distribution of rocks is Q, followed by K and EO. The least precise is E and K8. Since Q rock is the most exposed from the image classification, it may be the most easily detected rock compared to other materials. Q rock, which belongs to the fourth age of geology, is considered a younger rock compared to other rocks. For the case of K rock, belonging to the third age of geology, which is older than any other rocks, it still can be classified well enough. Supposedly, K rock should not be revealed at all due to its age, but with the presence of a fault along the area, the K rock is exposed perfectly. Several types of rocks which are not revealed or cannot be classified at all such as K8 may be due to the effect of shield. In addition, the presence of vegetation, for example, may account for younger rocks to not be seen.

Drainage Patterns

The elevation contour (Figure 2 (i)) shows several colours indicating the elevation levels with yellow to white representing

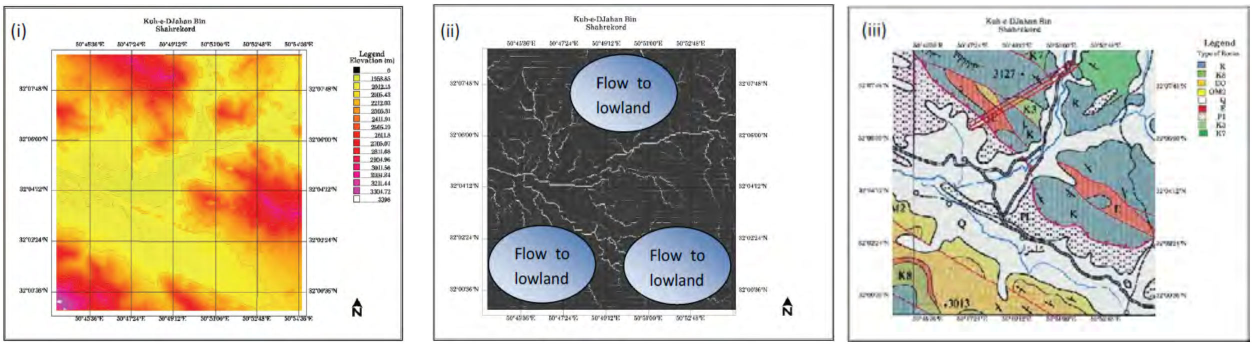

Figure 2: (i) Elevation contours, (ii) Flow direction, (iii) Geological map of Kuh-e-Djahan Bin.

increased elevation. There are three high elevation areas and drainage naturally flows to the low elevation areas, as marked in the flow direction image (Figure 2 (ii)). This flow eventually connects with the stream at the lowlands. Based on this figure, the drainage pattern is dendritic. The interpretation depends on the condition for the pattern to show up which is on homogeneous, uniform soil and rock materials mostly in sedimentary rocks. It consists of a network of channels resembling tree branching (Monroe et al., 2007). From the geological map (Figure 2 (iii)); high elevation areas are dominated by limestone and sandstone rocks. These types of rocks have medium to coarse drainage density which indicate good permeability. This indirectly leads to a less dense integrated drainage network.

Magnetic Modelling

As illustrated in Figure 3 (i), the model has two bodies. The first polygon (red in colour) has 13 corners with susceptibility of 0.0030 CGS. These are known as alluvial deposits or Q rock with respect to the geological map. The second one (blue in colour) has 19 corners with susceptibility of 0.0010 CGS. These are known as limestone or K rock with respect to the geological map. This model represents one possible interpretation of the subsurface configuration as many different models can produce similar magnetic anomalies. Therefore, no unique solution exists (Burger, 1992). However, from the variation of the magnetic intensity in the magnetic model profile line, it can be interpreted that the fluctuation actually indicates a fault zone. Furthermore, the model also corresponds to the orientation of fault. Since the magnetic survey detects variation between two different rocks, it additionally supports the idea of a fault zone at the fluctuation segment. This can be further supported by the geological map which indicates the variation encloses a fault zone.

The magnetic model can be correlated with the magnetic profile which is obtained from DEM image. The magnetic profile (Figure 3 (ii)) which corresponds to the line magnetic being modelled is actually the elevation profile. Hence, area with distance from 1000 to 2000 meters (fluctuation segment in the magnetic model) is actually a high elevation area. Thus, it can be distinguished indirectly that Q rock increases in elevation from the left and K rock gradually decreases in elevation to the right.

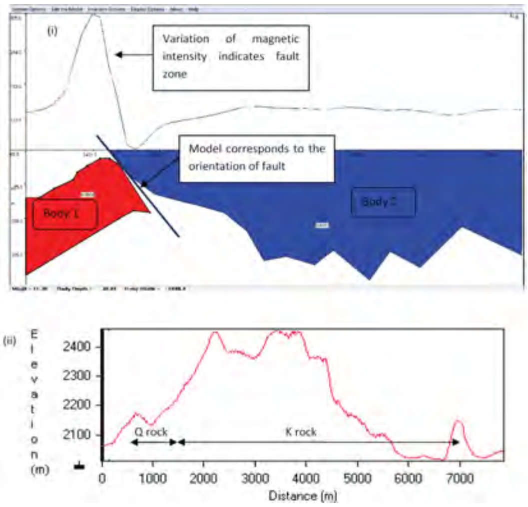

Figure 3: Compilation of (i) magnetic model (ii) elevation profile for line survey starts from 50051'28"E 32008'37"N until 50047'18"E 32006'24"N.

CONCLUSIONS

The purpose of the study was to use a methodology that as much as possible interpreted and analysed both TM and DEM images of an area namely Kuh-e-Djahan Bin for studying geological features. Supervised classification was employed to determine the distribution of rock types. The classification for the area to a certain extent was quite good. It can partially map the distribution of rock types as in the geological map. Automated extraction of contours and drainage patterns from the DEM image was also employed. These two extractions were mutually related to each other since a drainage system usually finds equilibrium state where it flows from high elevation to low elevation area. In addition, magnetic modelling methodology was also integrated in the study. The model actually responded to the structural interpretations where it has indirectly mapped the fault zones. The elevation for model or rocks can be identified since the model was correlated with the elevation profile as well.

The methodology applied here remarkably supports the geological interpretation from TM and DEM images. The methodology enabled remote sensing facilities to locate lithologic and structural geological features and undertake interpretation in an easier way. With the integration of the magnetic method, the interpretation becomes useful since this method actually gives specific information for particular areas while remote sensing methods correspond to large scaled areas.

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SEISMIC ATTRIBUTES FOR RESERVOIR PROPERTY PREDICTION— A REVIEW

Muhammad Sajid & Zuhar Zahir Bin Tuan Harith

Geosciences and Petroleum Engineering Department. Universiti Teknologi PETRONAS
geosajid@hotmail.com and zuharza@petronas.com.my

Seismic attributes are extensively used in prediction of reservoir property, such as morphology Properties and petrophysical properties of the reservoir. There is no direct relation exist between most of the calculated attributes and the measured reservoir property but still we can use these seismic attributes by statistically correlating them with the measured reservoir property at the well location. In this paper we will review the correlation of some of the important properties of the reservoir with the seismic attributes and how these attribute should be used to predict the reservoir desired property of investigation. We will describe how to select the different attributes to produce a meta-attribute (hybrid attribute) and how to use THESE META-ATTRIBUTES to map the reservoir property. We will discuss how other branches of geophysics (AVO, Rock-Physics) help us in more reliable reservoir property prediction.

INTRODUCTION

According to oxford dictionary, attribute is defined as "a quality or feature regarded as a characteristic or inherent part of someone or something", so the Seismic Attributes are all the information obtained from seismic data, either by direct measurements or by logical or experience based reasoning (Taner, 2001).There are basically two types of seismic data interpretation, first in the seismic interpretation is tied with the geologic analog, principals of structural deformation and sedimentary deposition. The interpreted geological model is iterated till it ties with the observed geological model. This type of interpretation is called as phenomenological interpretation. The second type of seismic data interpretation is called as probabilistic interpretation, in this type of interpretation, patterns are extracted from the seismic data and correlated with the measured property at the know locations like wells sites. These extracted information could be raw seismic observation or mathematically calculated seismic attributes. Probability can then be assigned to observation or potential observation. (Wallet, et al., 2009)

The term "seismic attributes" were introduced in the geophysics literature and vocabulary in late 1970 and the application of analytic signal analysis to seismic interpretation was introduced in the geophysical literature by Taner et al 1970(Taner, et al., 1979). Seismic attributes can be classified in many ways, several authors have their own classification, Taner 2001(Taner, 2001) classified seismic attributes in to seven groups on the basis of domain characteristic of the attributes. S. Chopra and K. J. Marfurt 2008(Chopra and Marfurt, 2008), Classified seismic attributes into two classes, reflectivity attribute and morphology attribute. Reflective attribute group contains those seismic attributes which helps in predicting the petrophysical property of the reservoir like porosity, reservoir thickness, presence of hydrocarbon etc, whereas the morphological attributes help to predict the fault, fractures, dip, azimuth, termination, gas chiminy, reservoir dimention etc. we will go with this latter classification of seismic attributes.

LIQUID AND GAS PREDITION

Low frequency attribute play important role in identification and monitoring of pore fluid in the reservoir. In most of the cases, water bearing reservoir reflectivity increases with the decrease of frequency and increase with water saturation, usually the low frequency anomaly is associated with the fluid in the reservoir whereas high frequency anomaly is associated with the gas or clay content in the reservoir.(Goloshubin and Silin, 2005)

But how we know about which frequency correspondes to which property of the reservoir, Goloshubin and Bakulin 1998; Goloshubin, Korneev et al. 2002 used the field experiment, physical model and mathematical model to describe the use of low frequency as a good indicator of gas-oil contact. Although the seismic definition decreases with the filtering of high frequency but the low frequency bright spot can be easily identified, which otherwise will be difficult to see. From physical model it was observed that for identification of gas, h/λ should be greater than 1, for water $1 < h/\lambda > 0.2$, for oil $h/\lambda < 0.2$, where h is the thickness of the water bearing reservoir, and λ is the spectrally decomposed low frequency wave length. (Goloshubin and Bakulin, 1998; Goloshubin, et al., 2002)

Wave let extraction technique is also suggested for predicting the reservoir property. Which correlated energy loss from zero- to dominant-frequency range is responsive to the presence of fluid whereas the energy loss from dominant to Nyquist-frequency range is correlated with the gas in the reservoir (Lichman and Goloshubin, 2003).

Amplitude verses offset (AVO) is extensively used for fluid identification in the reservoir. AVO type two environment, where there is increase in amplitude of gas bearing reservoir with increase of offset can be used together with the spectrally decomposed low frequency data. The cross plot of far offset with respect to near offset of spectrally decomposed seismic data by using the peak amplitude frequency of far-offset seismic data can be a good indicator of reservoir property which could be more reliable than using these attribute individually(Ren, et al., 2007).

PERMEABILITY,COMPACTION PREDICTION

Ren, Goloshubin et al. 2009 (Ren, et al., 2009) suggested that the frequency depenedent variation of amplitude and phase can be a good source for identification of lithology, permeability of the reservoir. He suggested that in deep seated resevoir with low permeability, high compaction and having impidence high from overlying layer shows reflection dimming effect with decrease of frequency whereas the reservoir with high permability, low compaction and having low impidence from overlying layer shows reflection brighting effect with decreas in frequency. The reservoir with intermediate permeability, compaction and having slightly low impidence form overling layer shows change in phase from low to high frequency(Walls, et al., 1999), Walls used the seismic attributes correlated through Neural network with the lithology interpreted at the well location to predict the lithology though out the survey area.

Phase time delay, decrease in Quality factor (Q) and high frequency shadow in observed in the water bearing reservoir (Goloshubin, et al., 2002; Korneev, et al., 2004). but before to use of increase in amplitude with decrease in frequency as attribute, it must be bear in mind that low frequency could be introduce in seismic data due to Normal Move Out (NMO) stretching or Common Mid Point (CMP) stacking. It's also observed that there is 12% decrease in trace frequency when the reflector depth equal to the far-offset trace to stack (Goloshubin, et al., 2006). One way to use this attributes for fluid prediction in reservoir is to correlate the low frequency amplitude with the measurement at the well data.

For the correlation of seismic attribute with the measured property of the reservoir at the well location, well logs must be upscale to the seismic attributes points; secondly the seismic attributes should be average by selected traces surround the well (Walls, et al., 1999). Well logs are considered to be the direct measure of the sub-surface lithology property but their response is also affected by the invaded drilling fluid(Walls, et al., 2004). This invaded fluid affects both the sonic and density log measurement so this error should also be considered and removed before to be used in correlation with the seismic attributes.

META-ATTRIBUTE GENERATION

We can extract thousands of seismic attributes from seismic data, but most of the calculated attributes have no direct relationship with the measured property of the reservoir. Still we can use these calculated seismic attributes to predict the reservoir property by correlating them at the well location with the actual measurement of the formations.

Each seismic attribute provides one dimension of the reservoir property of investigation so to proper prediction of the reservoir property we need more than one seismic attribute for each property of the reservoir. Figure.1 shows that the fault interpreted my human brain can equally accurately interpreted by the meta-attribute produced for deform zone identification.

Different methods are used for selection of seismic attributes for each specific property of the reservoir.

- Knowledge based expert systems.
- Statistical attributes geostatistical.
- Linear discrimination analysis, PCA.(Taner, 2001)

After selection of seismic attributes for specific property of the reservoir these attributes are mapped to lower dimension to produce meta-attribute (hybrid attribute), some of the methods are

- Data Clustering.(Yang, et al., 2006)
- Probability Density function. (John, et al., 2008)
- Abductive Network.(Ahmed, et al., 2010)
- Regression Analysis.(John, et al., 2008)
- Artificial Neural Network. (Supervised or unsupervised). (Walls, et al., 1999)

But the problem is that, even if we find good correlation between the selection seismic meta-attributes and the reservoir property, how can we know that the relationship is true or spurious? There is always a probability to get the spurious correlation between them, and the spurious correlation probability increases

- With the decrease of independent well measurement.
- With the increase of independent attributes.
- With the decrease of sample correlation.(Kalkomey, 1997)

DISCUSSION AND SUGGESTIONS

Seismic attributes are most important tool of seismic data interpretation. Tomorrow will the world of Geo-expert systems, in this Geo-expert system we will just have to import the raw data, rest of the job will be performed by these intelligent system on the basis of information we want to extract from the data. These Geo-expert system will used 3D/4D seismic data, well logs, production data, rock-physics templates, etc to interpret the large volume of data and will support the Geoscientist to focus of more potential zones for reservoir property of investigation. Similar to the search engine of Google we will ask the Geo-expert system to locate the fault zones/OWC/Gas zone/Water Zone etc from more than tetra bytes of geosciences data. In these Geo-expert Systems, one of the important functions of interpretation will be performed by these seismic attributes.

Seismic attributes are providing good support to geoscientist in their interpretation. Their performance can be increase by integrated study with rock-physics, AVO, Sequence Stratigraphy etc. Before the implementation of these seismic attribute as the predictor of reservoir property of investigation,

These attributes predictability must be confirmed on the Rock-Physics forward modeled synthetic seismogram.

During the Neural Network training, all those well should be selected which define the whole survey area and all those well logs should be selected which have full depth coverage of the reservoir under Investigation.

Separate meta-attribute should be created for each property of reservoir. Some desired property of investigation requires the combination of meta-attribute, so for them we can create the mathematical attribute from the relevant meta-attributes or can get the support form Color blend RGB for 3D map presentation.

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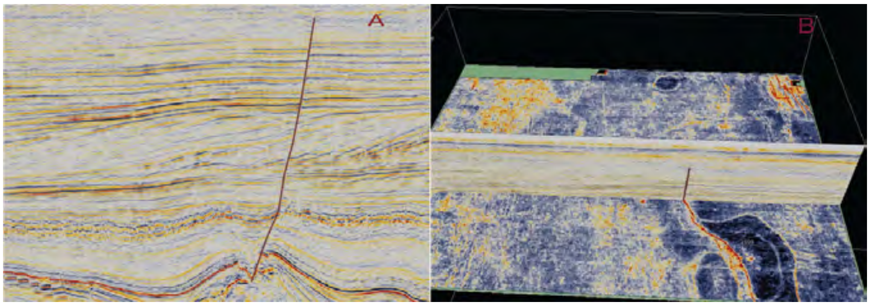

Figure 1: 1(A) shows the fault mark by the interpreter. 1(B) shows the same interpreted seismic section together with the time slice attribute map.

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GEOPHYSICS POSTER 17

A LOW FREQUENCY SEISMIC SURVEY IN AN EXPLORATION ENVIRONMENT

Paul West1, Konrad Cieślik[1], Shamim Haider[2], Abdul Aziz Muhamad[2], Sandeep Kumar Chandola[2] & Awalludin Harun[2]

[1] Spectraseis AG, Giessereistrasse 5, Zurich, 8005, Switzerland
[2] Petronas, Level 15, Tower 2, Petronas Twin Towers, KLCC, 50088 Kuala Lumpur, Malaysia.

Spectraseis and PETRONAS acquired a low frequency (LF) passive seismic survey over a producing field and a series of leads and prospects in south-Asia. Efficient field operations and close coordination among all involved parties provided a good quality dataset with minimal environmental impact and HSE exposure in only 9 days of recording. Despite the presence of high levels of noise from exploitation activities and interference from a strong near surface effect, detailed analysis and careful processing returned results that are reliable and consistent. The LF results show a good correlation to well results, with both productive and dry areas correctly identified. The survey also extended over undrilled prospects. Good quality results over the known areas extends the usefulness of the survey, adding information to the body of geophysical and geological knowledge for ranking further exploration and appraisal prospects in the area.

INTRODUCTION

The LF method analyses the recorded spectrum of the ambient seismic wave field to test for spectral signatures that may be indicative of hydrocarbon accumulations in the subsurface. Observations at different locations around the world have shown that local variations in the spectral energy content of the ambient wave field correlate with the presence of subsurface hydrocarbon accumulations (van Mastrigt & Al-Dulaijan, 2008). The presence of a secondary wave field due to modifications of the regional background by a reservoir can be expected to result in locally increased energy content.

The primary objective of this survey is to assess the ability of the LF method to identify a producing field and evaluate its strengths and limitations under the given geological setting. The performance of the method over known reservoirs establishes the potential of the survey over undrilled prospects to add value to the exploration workflow for ranking prospective locations within the block. Figure 1 is a vertically exaggerated regional cross section; the survey was completely within the shallow regional syncline. Gas reservoirs sealed by the fault planes of the wrench fault structures are the targets. These are expected to be ~15-20m thick at ~3200m depth. The two highlighted accumulations east of the centre are both drilled and proven. The fault structure in the centre of the figure (without dashed circle) was drilled, but encountered no hydrocarbons. To the west is an undrilled prospect. The LF survey was designed to include the known well results as calibration by which the untested prospects could be evaluated for charge.

DATA ACQUISITION

Data acquisition was over nine days in March 2009; 245 locations were occupied for 24 hours by broadband seismometers with flat response from 40s to 50Hz. The lines were oriented mainly along dip (east-west) and strike (north-south) directions. Four reference stations were deployed and recorded for the full duration of the survey to monitor temporal variations in the ambient wave field. The very sparse population in the area means that the main noise sources are associated with exploration and production activities. Three producing wells, an active exploration well and a gas processing plant lie within the bounds of the survey area. These noise sources pose significant challenges for the processing and analysis of the data. However, these activities provide the benchmark information of known hydrocarbons in place by which other areas of the survey can be measured against.

DATA CHARACTERIZATION

Understanding what constitutes the regional background ambient wave field is critical to allow the identification of additional body-wave energy emitted from or scattered by the reservoir. Figure 2 shows the power spectral density (PSD) for two example stations. A strong peak is seen between 2.5-3.5Hz which falls in the frequency range where previous LF studies have identified spectral features relating to subsurface hydrocarbons. The red spectrum in Figure 2 is from a known hydrocarbon bearing location, while the blue spectrum is from a location over a dry well. The amplitude of the two spectra at 3Hz is similar, but the shapes are very different. A narrow peak above low background energy characterizes the dry-well location, while the successful well location has a wider feature and more energy between 2.0 and 4.5Hz. These differences need to be evaluated and captured in attribute calculation and hydrocarbon potential maps of value.

Anthropogenic noise is evident in all recorded data, although usually minor due to the sparse local population. Broadband, transient noise bursts (often from passing vehicles, people or animals) are relatively easy to identify and remove (Goertz et al, 2009). Coherent noise generated by hydrocarbon exploitation activities is almost continuous in time and can not be removed by time windowing. Three locations worst affected by this type of noise were omitted from further analysis. The use of three-line swaths proved beneficial in this case for spatial redundancy.

Near surface studies using the horizontal to vertical energy (H/V) spectrum can determine shallow velocity structures (Fäh et al, 2001). The fundamental Raleigh wave mode peak was identified at 1.3-1.9Hz and its secondary zero at 2.5-3.7Hz. This secondary zero gives rise to the strong spectral peak on the vertical component data in Figure 2. Therefore, this narrow band of energy is a near surface resonance effect rather than associated with a secondary wave field from depth. Some correlation was made between client provided refraction statics map and uphole survey reports and a calculated map of the peak frequency of the narrow spike. This again suggests a relationship between the 2.5-3.5 Hz energy feature and the near surface.

RESULTS

The primary attribute calculated from the LF data was PSD-IZ (described by Saenger et al, 2009). This is a quantifiable measure of the energy contained on the vertical component by integrating the PSD spectra. After noise removal, a frequency band for integration is selected to best quantify spectral features of interest and exclude remnant stationary noise. Here, the maximum frequency is set to 4.5Hz to minimize the effects of production noise. The minimum for integration is the natural energy trough between 0.6-1.2Hz. Energy between 2.25-3.75Hz was notch-filtered out after the above analysis confirmed that the energy is a near surface resonance feature.

Figure 1: Schematic geologic cross section across the survey area. Target reservoirs highlighted in circles. Vertical exageration ~25:1. Upper strata is not the topographic surface.

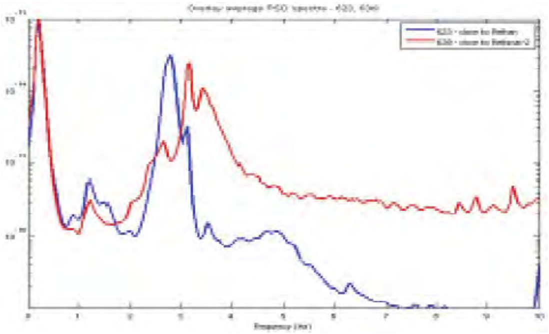

Figure 2: Mean spectra at locations above known gas reservoir (red) and near a dry well (blue)

Figure x shows the map of PSD-IZ attributes for all points. After detailed analysis and thorough noise removal, higher PSD-IZ attribute values can be indicative of energy from a secondary wave field traveling from the subsurface. In general, the results are temporally and spatially consistent, with little variation based upon day of recording. The north-south trending swath to the east of the survey shows low values to the south, high values through the central section, and a slight decrease to the north. Similarly the western of the two north-south swaths shows high values at its centre and trends down to medium values to the north. The long west-east swath ties well at the intersection points and shows very clear zones of low values either side of the central north-south lines. Further to the west is a significant clustering of medium-high values.

INTEGRATION OF WELL RESULTS

The consistent patterns, temporal stability, and cross-line ties of the results give confidence in the quality of the processing. By introducing the results of the exploration and production wells drilled to date, it is possible to both evaluate the results of the survey against known calibration points and make statements about potential areas for drilling in the exploration program.

Two of the three producing wells along the easternmost swath are within the areas of highest attribute values while the third one is at the edge of this zone. The discovery well to the centre of the survey is centered in a zone of high attributes at the tie point of two swaths. To the north lies a tight, uneconomic gas discovery located within a zone of medium attribute values. The well that encountered no hydrocarbon at the target depth falls in a clear zone of the lowest attributes. Four wells drilled to date show good correlation to the results of the LFPS survey. The other two well locations show middle attribute values, though still exhibit charge. These ambiguities could relate to subsurface complexity, resolution, or incorrect results. A more detailed understanding of how the signal relates to the hydrocarbon system and reservoir parameters would provide further understanding of these two locations.

The LFPS method in this area successfully identifies the known reservoirs and an unsuccessful well. This indicates that the dataset contains valuable information for undrilled areas. Further, it suggests a high potential for hydrocarbons in the western part of the survey area indicated by a large clustering of high attribute values.

CONCLUSIONS

Despite the presence of high levels of noise from exploration and production activities during the survey and interference from a strong near surface effect, detailed analysis and careful

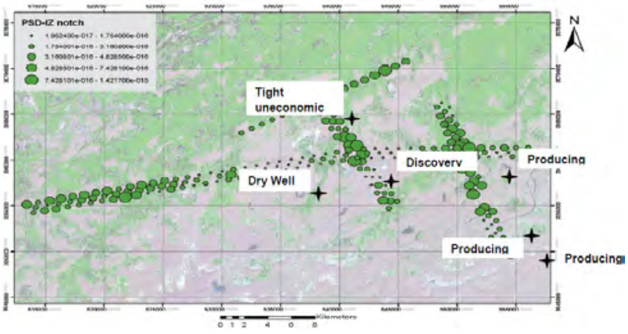

Figure 3: Final PSD-IZ map with well results. Bubbles are 5 energy bins. Values are consitent with interpretation as hydrocarbon potential.

processing of the dataset returned a set of results that are reliable and consistent. The LF survey results show a good correlation to the well program undertaken to date. Both productive and non-hydrocarbon bearing areas were identified by the LF method. Given the success of the results compared to drilling information, the method provides information in support of other geophysical and geological datasets to assist in the ranking of prospects for continued drilling efforts in this area.

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GEOPHYSICS POSTER 18

3D COIL SHOOTING SURVEY ON TULIP FIELD: DATA PROCESSING OVERVIEW – PLANNING, CHALLENGES AND OPPORTUNITIES

Michelle Tham[3], Michele Buia[1], Riccardo Vercesi[2], Swee Leng Ng[3], Andreas Tyasbudi Waluyo[3] & Suyang Chen[3]
[1]ENI E&P, [2]ENI Indonesia, [3]WesternGeco

The Tulip 3D survey is a single-vessel Coil Shooting project east of Kalimantan, offshore Indonesia. The coil geometry is very different to the conventional race-track towed streamer approach. Whilst it results in many acquisition and imaging benefits, the circular geometry introduces several differences, a number of new challenges and opportunities in data processing. A fit for purpose processing workflow was tailored to address the challenges, and at the same time taking advantage of the opportunities provided by the circular geometry.

The Tulip survey area is geophysically very complex due to the presence of several unfavourable geological factors, especially in the near surface. In particular the rough sea bottom and very bright Bottom Simulating Reflectors (BSR) below the seabed generate several orders of multiples and degrade the subsurface illumination. The presence of free gas below the BSR causes a sudden frequency and amplitude decay of primary reflections. Complex subsurface geology further complicates the scenario. All these conditions when combined result in very strong and high orders of surface multiple reflections, diffracted multiples, absorption, scattering and poor transmission of seismic signal energy. The consequences of these complexities is overall poor seismic response, very low acoustic impedance contrast at the reservoir level and therefore extremely low amplitude or near invisible target reflections, very low signal-to-noise ratio (S/N), poor imaging and poor illumination of the reservoirs. In order to achieve a better imaging of the zone of interest and for the appraisal campaign, eni successfully acquired a Coil shooting (French, Cole, 1984; Durrani et al, 1987) survey on the Tulip discovery. The acquired data was processed through to depth imaging utilizing multi-azimuth tomography velocity model building.

The circular geometry introduces several differences and new challenges in survey design, modeling, acquisition and processing workflow (Reilly, Hird, 1994; Reilly, 1995). For Tulip survey, a careful pre-survey modeling and processing simulation was critical to evaluate the feasibility of future post-acquisition processing of the survey, with respect to both the geophysical challenges and the geometry induced constraints and opportunities. Prior to the commencement of the acquisition, a subset volume of 3D synthetic data with coil geometry was generated to assess the application of 3D processing algorithms. When processing a Coil shooting survey, the first difference, compared to the conventional data, is the presence of the turn noise due to acquiring data while the vessel and cables were tracking continuously in circles. The level of noise is inversely proportional to the curvature radius of the circles being acquired and proportionally related to any apparent crossflow of currents. The second aspect and very different to the conventional processing is related to the spatial sampling, with the Coil shooting geometry, the trace offset distances are not regularly spaced in the shot or midpoint domain. This result in the midpoint/offset clustering inside the circles and inducing some apparent geometrical or moveout distortion in the seismic reflections, which makes the application of conventional straight sail line based processing methods unsuitable. The third and perhaps the main challenge related to the Tulip's geometry is the although very high, but irregular fold of coverage, resulting in amplitude footprints, which change position as a function of the incidence angle, and require proper treatment in order to avoid amplitude inconsistencies and migration artifacts.

On the advantages and opportunities aspects, the circular geometry allows the full 3D processing algorithms to work at their best. The true-azimuth 3D demultiple tools work very well for the Tulip survey. The same conclusion is valid for velocity model building and migration algorithms due to the large azimuthal content.

This paper will discuss some of the pre-emptive measures taken during the survey design stage prior to both acquisition and processing as well as the overview of the processing experience of the Tulip project and some relevant results.

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GEOPHYSICS POSTER 19

RECENT TRENDS IN OFFSHORE EXPLORATION: MORE DATA, LESS MODEL

Guillaume Cambois &Maz Farouki

Petroleum Geo-Services; maz.farouki@pgs.com

New marine acquisition techniques – such as wide- and multi-azimuth, over-under and dual-sensor – provide additional data that complement conventional narrow-azimuth towed streamer data. These new data help reduce uncertainties in velocity model building and ultimately lead to a more accurate image of the subsurface.

It is a well-known aspect of the general inverse theory that ill-posed problems need additional constraints to be resolved. These constraints often take the form of an a priori model from which the solution is required not to differ too much. This model represents an initial guess that must obviously be close to the exact solution if we want the correct answer. An alternative approach is to collect more independent data to reduce the under-determination of the system.

Imaging in complex geology where pre-stack depth migration is required to correctly reveal the subsurface structure is such an ill-posed problem. Common exploration targets include sub-salt, sub-basalt, and beneath gas plumes. The complex structures and the high velocity contrasts in these regimes combine to diffract seismic waves in all directions. The little energy that gets recorded by the relatively small streamer spread does not contain enough information to fully reconstruct the complex structures. In addition, noises (such as multiple reflections) further distort the already weak signals. Consequently, imaging in these complex geology regimes leaves a lot to interpretation.

To reduce under-determination more independent data must be collected. The industry started to gradually increase the streamer spread, reaching typically 9km in length and up to 1.3km in width. This comparatively small width was first addressed by acquiring surveys in multiple directions. Later techniques extended the width using additional source vessels. An alternative approach is to acquire ocean-bottom seismic, which provides wide-azimuth as well as potentially multi-component data, but at a significantly higher cost.

Recent developments, such as dual-sensor streamer and 3D over-under gather more independent data and offer a no-compromise bandwidth extension on the receiver side. On the source side, over-under and multi-level arrays also increase low-frequencies without loss of high-frequencies.

The methods listed above will be further developed and illustrated with various examples from around the world.

GEOPHYSICS POSTER 20

A TOWED EM SYSTEM TEST SURVEY

Johan Mattsson, Lena Lund, Jostein Lima, Marit Ronæss, Folke Engelmark & Maz Farouki

Petroleum Geo-Services; maz.farouki@pgs.com

A newly developed towed EM system has been tested offshore in the North Sea. We show that the measured electric field data are of sufficient quality and signal-to-noise ratio for successful detection and inversion of the high resistivity reservoir area including distinction of some of the shallow gas accumulations above the reservoir. 1D inversion in the frequency domain is performed on individual common mid points (cmps) along a survey line across the reservoir with robust results as well as 2.5D inversion. A 3D resistivity model is also built from seismic data and interpreted horizons. This model is manually fine-tuned by comparing resulting 3D forward modeling data with the measured data. Finally, the estimated resistivity structure is investigated with respect to available vertical resolution from the data. This is accomplished by reformulating the inverse problem to a boundary value problem with solutions that approximately give the vertical resistivity structure at each cmp.

The motivation for developing a towed EM system is to significantly increase the acquisition efficiency compared to existing stationary systems. Efficient EM data acquisition increases the range of applications as better spatial coverage can be achieved at lower cost. In the test survey, an electric current dipole source and an EM streamer were simultaneously towed along a 12km long survey line from one vessel in a speed of 4 knots.

1D and 2.5D inversions are performed on the frequency response data along the survey line. In both cases, the reservoir is clearly observed, which agrees well with the seismic information. At shallower depths, there is an increase in resistivity above the reservoir, which probably originate from the thin gas pockets above the reservoir. This is also supported by the 3D modeling. The estimated sea-water resistivity also agrees well with the values from in-situ measurements.

The EM towed system has provided electric field data of sufficient quality and signal-to-noise ratio for successful detection and inversion of the highly resistive reservoir area, including distinction of some of the shallow gas accumulations above the reservoir, using an acquisition method of significantly greater efficiency than stationary systems.

GEOPHYSICS POSTER 21

SEPARATION OF SEISMIC DIFFRACTIONS AND SPECULAR REFLECTIONS: A TOOL FOR IMPROVED PROCESSING, IMAGING AND INTERPRETATION

Riaz Alai[1], M Hafizal Mad Zahir[1], Amar Ghaziah[1] & Eric Verschuur[2]

[1]Petronas Research Sdn. Bhd., Lot 3288 & 3289, off Jalan Ayer Itam, Kawasan Institusi Bangi, 43000 Kajang, Selangor Darul Ehsan, Malaysia.

[2]Delft University of Technology, Department of Applied Physics, Lorentzweg 1, 2628 CJ, Delft, The Netherlands.

Complex subsurface structures often generate complex seismic data that may produce inaccurate seismic images affecting the risk factor and success in exploration of oil and gas reservoirs. Therefore, it is important to analyze the character of seismic reflection data and to facilitate this analysis; we can divide the total recorded data into suitable sub-components. As seismic waves reach local discontinuities in the subsurface, new energy is initiated and waves are generated as if a pseudo secondary point source is buried in the subsurface and is emitting diffracted energy. On the other hand, when there is a change of rock type in the subsurface giving an impedance contrast, waves will be partly reflected back at the interface and partly transmitted further into the subsurface.

In detailed seismic reflection data studies in the search for coherent energy, one can observe two kinds of "seismic data events" that are generated in the subsurface and being recorded during seismic data acquisition: 1) seismic diffractions and 2) specular reflections. For better identification and understanding of recorded seismic data, it is beneficial to categorize the effect of subsurface discontinuities into these two categories and process them separately (several researchers have developed methods for this separation). Seismic interpretation is often done on specular reflection data and the effect of diffractions might be neglected in many cases, especially when they are not separated from the data and conventional seismic data processing is applied on the total recorded data. On the other hand, the diffraction energy can be instrumental in fault and fractures identification and characterization.

In this abstract we review a method and implementation for the separation of diffracted energy from specular reflections and illustrate the successful application on a deepwater marine data with a complex seabottom surface. The field data example illustrates improved velocity picking on specular reflections in comparison with velocity analysis on the total recorded data (without separation). The examples confirm that a systematic methodology to separate seismic diffractions from the total recorded wave fields is essential and provides better control of locating faults and fractures optimally.

GEOPHYSICS POSTER 22

DETERMINATION OF AVO ATTRIBUTES FOR ACOUSTIC IMPEDANCE ZONES OF MALAY BASIN: FLUID FACTORS

Uzir Alimat, Goh T.L, Shaidin Arshad & M. Izzuljad Ahmad Fuad

Integrated Seismic and Imaging Technology, PETRONAS Research Sdn Bhd

Based on previous study on Acoustic Impedance (AI) characteristics of the end member of two clastic rocks i.e. sandstone and shale, the Malay Basin can be generally divided into 2 major zones (Uzir et. al, 2009). It was observed in that study that the similar AI characteristic was displaying distinct distribution pattern, which later was postulated to be much related to the tectonic setting and depositional environment (Figure 1). Changes in AI pattern will directly affect the AVO response and its attributes. This paper is analyzing one of the most important AVO attributes which is the fluid factor and it is highly desirable for a hydrocarbon indicator (Smith and Gidlow, 1987). The typical published fluid factor ($\Delta F = 1.252A + 0.580B$) was derived from the combination of two well known equations i.e. Castagna mudrock equation and Gardner equation. The indicator should be negative for shale over gas-sand interfaces and significantly more negative than for shale over brine-sand interfaces (Castagna and Smith, 1994). The respective values of A and B were the intercept and the gradient attribute of reflection amplitude versus $\sin 2\theta$ plot. The A and B values can also be calculated from Shuey Approximation equation (Shuey, 1985). In this paper, the fluid factor equations were derived based on rock physical trend lines of Vp versus Vs plot and density (ρ) versus Vp plot, which were obtained from 48 well logs data that have been rigorously conditioned (Table 1).

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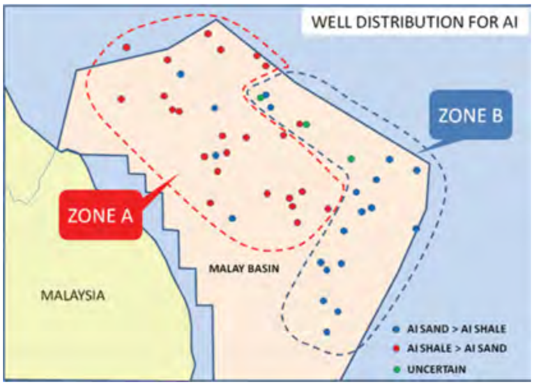

Figure 1: Subdivision of Malay Basin into 2 major zones based on the AI characteristics of sand and shale end member.

Table 1: Fluid factor derived from V_p-V_s and density-V_p relationships for both Zone A and B

Zone	Number of wells	V_p-V_s empirical equation	ρ-V_p empirical equation	Fluid factor (ΔF) equation
A	27	$Vp=1.1469Vs + 1590.3$	$\rho=0.2134Vp^{0.2944}$	$\Delta F=1.231A+0.574B$
B	21	$Vp=1.1962Vs + 1123$	$\rho=0.2254Vp^{0.2884}$	$\Delta F=1.222A+0.598B$

GEOPHYSICS POSTER 23

THE DISCOVER WAY TOWARDS MORE REALISTIC ENHANCED RESOLUTION SEISMIC INVERSION – A FIELD TEST

Dominic Lowden[1], Bruce Webb[2], Jennifer Graham[3] & Vincent W.T. Kong[4]

[1] WesternGeco Inversion Services, Schlumberger House, Buckingham Gate, Gatwick Airport, West Sussex RH6 0NZ, UK; DLowden@exchange.slb.com
[2] WesternGeco Inversion Services, Schlumberger House, Buckingham Gate, Gatwick Airport, West Sussex RH6 0NZ, UK; BWebb@exchange.slb.com
[3] WesternGeco Inversion Services, Schlumberger House, Buckingham Gate, Gatwick Airport, West Sussex RH6 0NZ, UK; JGraham@exchange.slb.com
[4] WesternGeco Geosolutions, L5, 256 St Georges Terrace, Perth WA 6000, Australia; wkong@exchange.slb.com

Optimum seismic inversion requires that the input data have the broadest possible frequency bandwidth coverage. Normal seismic data generally lack the low frequencies, and these are then usually augmented by low frequency models derived through various forms of spatial Well log interpolation. However, the low frequency models do not sufficiently represent in detail localized geological variations.

In the pursuit to acquire broader bandwidth seismic data, Hill & Bacon, 2006 [a] wrote about the Over/Under acquisition and processing technology, following which, Özdemir et al, 2008 [b] described the optimized deghosting of Over/Under lowed streamer data in the presence of noise. Krach et al, 2010 [c] further elaborated on the technique for improved resolution and deep imaging.

The DISCover method is a new modified Over-Under technique in seismic acquisition to yield a seismic dataset that is richer in the low frequencies without loss of high frequent content. These seismic spatially-sampled low frequencies do carry important smaller scale geological variations within the subsurface, and together with a minor contribution of the ultra-low frequencies from the Well log data, greatly improve the seismic inversion results.

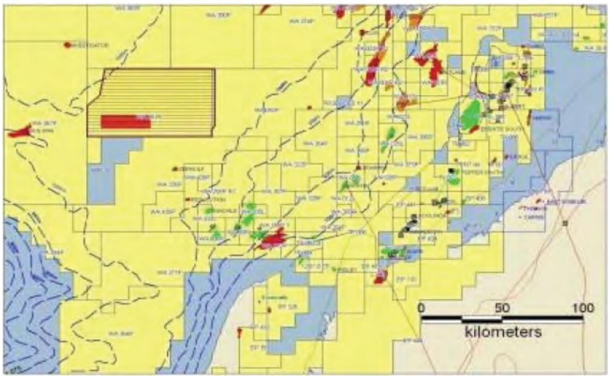

Figure 1: Location of the DISCover Field test data.

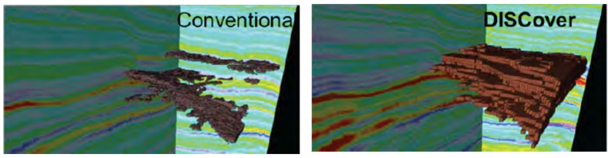

Figure 3: Post seismic inversion pay geobody extraction

The Field test was conducted at the NW Shelf of Australia (Fig 1). The DISCover operation technique is discussed. The seismic data from the DISCover method is compared with that from a conventional survey technique (Fig. 2A and 2B). The implication for seismic inversion is demonstrated, with results for a more consistent pay geobody extraction made possible by using the DISCover dataset (Fig. 3).

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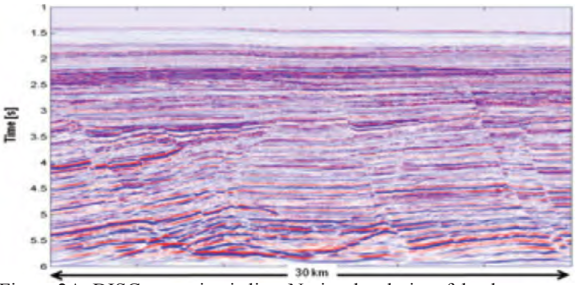

Figure 2A: DISCover seismic line. Notice the clarity of the deeper events.

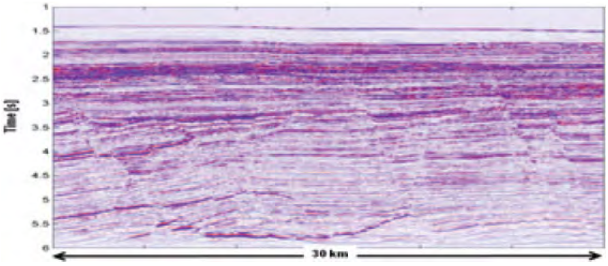

Figure 2B: Conventional seismic line.

GEOPHYSICS POSTER 24

FAN MODE SHOOTING TO REDUCE INFILL RATES FOR MARINE SEISMIC ACQUISITION IN AREAS OF STRONG AND UNPREDICTABLE SEA CURRENTS

Budi Priasati* & Stephen Elliott

WesternGeco Support Services, Kuala Lumpur; *priasati@slb.com

Conventional towed marine seismic reflection surveys are typically designed to acquire a uniform surface coverage across the area of interest. However, given that the streamer spread is anywhere between 200 and 1000m wide and generally between 3000 and 10,000m long, sea currents often force the streamer to divert significantly from the vessel path or modify the streamer shape. This results in reduced coverage for some offsets or offset ranges, or in an extreme case, a complete lack of coverage or "hole" in the data.

Such coverage holes can vary in size, regularity, and sample density leading to problems in the processing of the seismic data and ultimately degrade the quality of the final image. As a result it is necessary to acquire a program of infill to ensure that the survey is properly sampled. This is typically between 15 and 30% of the total kilometers of the survey, resulting in a proportional increase in costs and survey time.

Recent deployments of streamer steering devices have shown great value in mitigating this effect by maintaining streamer shape and matching adjacent line feather. However, it is also possible to actively steer the streamer to acquire a larger sub-surface swath at the tail. Fan Mode Shooting is a 3D marine acquisition technique where the streamers are deployed with variable separation with offset (Figure 1). Since the high frequencies are attenuated at longer offset and depth, the bin size can be increased with offset and depth, without damaging the quality of the final data. Monk (2010) has recently shown that adopting this methodology dramatically reduces the amount of infill required and produces significant cost savings.

This paper will present a regional case example of how 'Fan Mode Shooting' was successfully used to reduce the infill requirement during a marine seismic acquisition in South China Sea between June and August 2010 (Figure 2).

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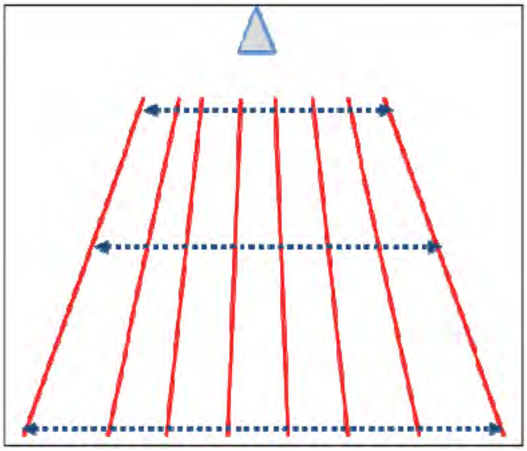

Figure 1: Cartoon shows Fan Mode Shooting with streamer interval were varies over offset, typically 25% to 50% wider at for offset compared to near offset

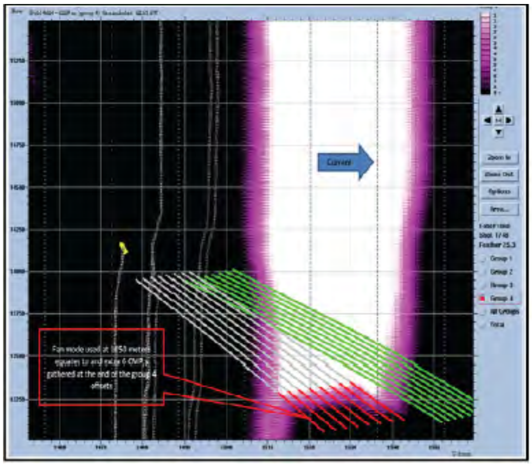

Figure 2: Active sail line(grey) feather is greater than the previous sail line (green) and not overlapping, therefore fan mode is used to compensate for the feather mismatch.

GEOPHYSICS POSTER 25

ANALYSIS OF STRESS CONDITION OF FAULTS IN OIL-GAS-BEARING AREAS USING GIS AND REMOTE SENSING DATA

Michail Vakhnin

Institute of Geology of Komi SC UB RAS, Pervomajskaya 54, 167000, Syktyvkar, Komi Republic, Russia; oilkominc@mail.ru

SUMMARY

The lineaments have been determined for the North-East of the European platform (the Timan-Pechora oil-gas-bearing province) using remote sensing data. The obtained data were combined with the geological-geophysical information into the geoinformation system for further processing and analysis.

GIS technologies allows integrating all the variety of available data on the structures into a uniform system and enables carrying out of researches in the view of all possible data (DeMers Michael, 1999).

The work used space images taken by satellites Landsat-7, which provided imaging of the Earth's surface with application of six channels with resolution 30 meters, and one IR-channel with the resolution 60 meters with simultaneous panochromatic imaging with resolution 15 m. The width of the review for all channels made 185 km.

The data were geopositioned in Gauss-Kruger projection on Krasovsky ellipsoid in the system of coordinates SK-42, the tenth zone. Then rectilinear sites (lineaments) were determined by the elements of landscape. Lineaments are generally understood as linear heterogeneities of the earth's crust and lithosphere. They can be of a various rank, extent and depth. They can develop on surface directly or as geological and landscape anomalies. Lineaments are caused by latent breaks of basement, fracture zones in sediments, etc.

Lineaments and lineament zones are zones (channels) of the raised permeability of the Earth's crust. They serve as transiting ways for solutions and gases, which generally possess higher temperature in comparison to the surface of the Earth (Kats Y.G., 1986). Also in fracture zones, especially sedimentary basins, the fluid system is constantly present and redistributed. It results in intensive deformations in fracture zones, and, hence, in their expression in the landscape attributes reflected on space images in the form of lineaments (Kuzmin Y.O., 2004). Therefore, the shape of lineaments on space images is a generalized reflection on the surface of both deformations and fluid mode of near-surface areas of the Earth's crust.

Lineaments are possible to divide into several types by their extent: transcontinental, transregional, regional, local.

Lineaments, resulted from various discontinuous dislocations, have characteristic features.

Faults result from stretching of the Earth's crust, incline toward deeper rocks. Lineaments, formed by the given type of dislocation, are characterized by linearity, frequently with offsets, which divide blocks with various geological structure and type of relief.

Thrusts are a little bent, round and formed as a result of literal compression.

Shears are characterized by horizontal displacement of rocks. Lineaments near them are developed along unidirectional curvatures of riverbeds, slopes, watersheds and other various forms of relief.

Overthrusts are resulted from longitudinal compression with formation of folds. Lineaments in this case are developed in the form of complex scalloped pattern of displaced masses.

The form of the lineaments, their pattern can help to define kinematic and geodynamic conditions of formations of faults and conditions of their formation.

The intensity and width of lineaments depend on the depth of occurrence of a fault and its activity. The account of all these data by the form, sizes, intensity allows considering faults and geodynamic conditions of the studied area.

DATA ANALYSIS

Lineaments are described by a set of quantitative characteristics: orientation, length, density. In the given work lineaments were visually determined from several kilometers to several tens kilometers, which could be related to local category, comparable to the size of local structures. Digitalizing was carried out using the geoinformation system ArcGIS 9.3. In total about 5000 lineaments of various orders were determined in the investigated territory.

GIS was used for analysis, which was realized on the basis of ArcGIS 9.3 and included the following maps: maps of local structures, seismic and drilling maps, maps of deposits, structural maps. The map of structures incorporated digitized contours of structures with data about the depth, horizon (supposed age), morphological characteristics, condition of structures (revealed, prepared for drilling, explored by drilling). The map contained major tectonic boundaries and oil-gas-bearing areas and regions and deposits (Fig.1).

After digitizing of lineaments, calculation of lengths and strikes the tables of lengths and strikes of the lineaments for various tectonic elements and the whole territory of the Timan-Pechora oil-gas-bearing province was made. Additionally the value of anisotropy was calculated, where the criterion of anisotropism of lineament distribution was their vector sum. In the case of isotropic (disordered) distribution of lineaments, their vector sum was equal or close to zero, whereas the vector sum of anisotropic (ordered) distribution significantly deviated from zero (Ul'masvai F.S., 2005)

The revealed lineaments were compared to the faults established by seismic prospecting and other geophysical methods.

Regularities between the presence of structures with deposits of hydrocarbons, deep faults and density of lineaments were established. The significant amount of deposits is located in immediate proximity to deep faults.

Lineaments have generally a dominating southwestern and northeastern direction, well conformable to planetary fracturing caused by rotational stress of the upper cover of the Earth.

Stability of this lineament network seems to be connected to the fact that the reanimation of already existing faults is energetically more favorable. The greatest density was observed along such deep faults, as East-Timan, Peri-pechora, East-Kolva, Ilych-Chiksha, Varandey Shapkinsky deep faults, which were considered as discontinuous-continuous faults. Also the increase of lineament density was confined to the crossing areas of deep faults.

The faults with maximal newest tectonic activity were determined after the comparison with lineament density map, e.g. the northern part of the East Kolva abyssal fault. The

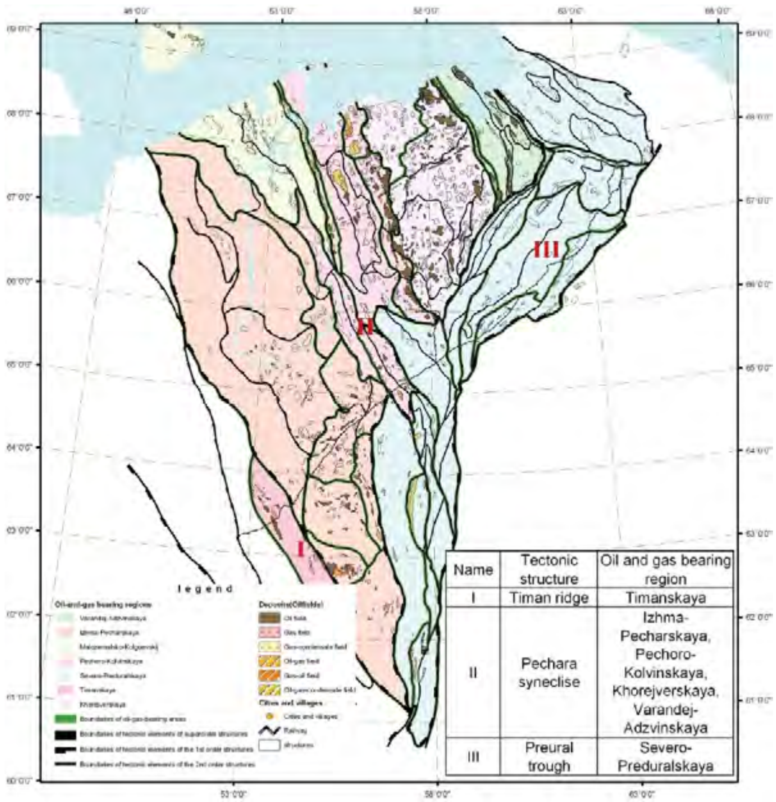

Figure 1: Scheme of functionality operation.

influence of this fault on oil-gas content of the local structures was analyzed.

CONCLUSIONS

The rose-diagrams of parameters of specific density and anisotropy of the chosen lineaments on the unit of area in the territory of the Timan-Pechora oil-gas-bearing province allowed revealing area of the Earth's crust differing by block divisibility, more dislocated and, hence, more permeable. The given areas coincide with the most perspective oil-gas-bearing areas of the province.

Proceeding from the above-stated, it is possible to conclude that many oil-gas-bearing structures are reflected in modern neotectonics and spatially connected with lines of the global fault network (lineaments). The consideration of the regularities in regional and exploration works will allow a more effective investigation of hydrocarbon deposits.

The data of the analysis of fault strike and density were laid into basis for the reconstructions of stress-deformation condition of rocks at the North-East of the European platform.

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GEOPHYSICS POSTER 26

AVO APPLICATION FOR CARBONATES RESERVOIR CHARACTERIZATION IN SARAWAK BASIN

Noreehan Shahud & Yeshpal Singh

Petronas Carigali Sdn Bhd, Level 16, Tower 2, Petronas Twin Towers, KLCC, 50088 Kuala Lumpur, Malaysia.

Recent development in geophysics technology keeps improving to fulfill the need of energy resources. Geoscientists have to think out of box and be creative to come out with ideas on how to fully utilize all available data to find more hydrocarbons within specify budget. In order to provide optimum analysis, a proper feasibility analysis shall be carried out to set some expectation before embarking for full project. In reservoir characterization analysis integration of both geophysical and geological data is a must for quantitative seismic interpretation. This paper will focus on the application of Extended Elastic Impedance (EEI) attributes for characterization of carbonate reservoir heterogeneities in the study area.

The study field is located in the Central Luconia Province which forms part of Sarawak Basin of Northwest Borneo. The carbonate build-up in this field overlies Cycle III mixed clastics and carbonates. As a result to the extensional tectonics at the end of Cycle III, submarine topographical highs were formed, where reef growth took place during Cycle IV/V. The middle Miocene Carbonates are hydrocarbon bearing and is the main reservoir interval seismic characterization. In the study area, the major challenge is the very small carbonate interval (~65-95m) and imposes a major constraint for seismic-well integration for reservoir characterization. Rock physics analysis based regional trends have been utilized for characterization of deeper interval.

Prior to EEI feasibility study, all input data are quality checked. In general, both seismic and well data are prone to operational issues, which may affect the data quality and quantity. Nevertheless, with proper planning and better understanding on the technical parameters needed for optimum reservoir characterization, modeling and analysis could benefit in achieving the objectives. A high correlation coefficient of elastic parameters with optimum "chi" angle provides "tuned" results to the desired output. The EEI were used to separate lithology and fluid effects.

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GEOPHYSICS POSTER 27

MULTI-DISCIPLINARY PORE PRESSURE PREDICTION : RECONCILIATE GEOPHYSICS AND BASIN MODELING TO CONTROL RISKS AND UNCERTAINTIES IN DRILLING OPERATIONS

Lecante, G., Wojciak, P. & Bianchi, N.

BEICIP-FRANLAB, E&P Consultancy, 232 Av. Napoléon Bonaparte, 92500 Rueil Malmaison, France.

According to many operating companies, a very large part of unscheduled downtime during drilling is related to pore pressure and fracture gradients. In that respect, the ultimate objective of pore pressure prediction is to control the risks and uncertainties related to drilling operations.

Anomalous pressures in geological formations can originate from many physical phenomena – such as: sedimentation rates, fluid expansion mechanisms, etc. – which can be accurately modeled using advance 3D Basin Modeling Techniques, applied at local scale. Thanks to their ability to rigorously simulate the multiple phenomena occurring within a geological basin (especially compaction disequilibrium, hydrocarbon generation, fluid buoyancy), basin modeling tools can be applied for modeling the coupling effect of pressure, overburden, effective stress, fracturation gradient, porosity, fluid density, temperature, permeability.

On the other hand, pore and confining pressure generally have opposite effects on acoustic elastic properties of the rock (compressional velocity in particular): velocity generally increases with confining pressure and decreases with pore pressure. Consequently the joint analysis of interval velocity variations and compaction trends gives allows assessing pore pressure. Geophysics has therefore been widely used over the past decades for predicting over-pressured zones. Such zones are detected with seismic (interval velocity) and sonic transit time. In most cases the strong increase in transit time in the over-pressured interval indicates the degree of overpressure. This change in the transit time is generally detected in the seismic interval velocity also.

In practice, pore pressure predictions are performed using one of these two independent approaches without any attempt to combine them, while their combined used would gives a better confidence in the predicted pore pressure values, despite the high uncertainty due to lack of data.

The objective of the study presented in this paper is to reconcile these two complementary approaches. It shows one way of integrating the two techniques throughout the prediction process.

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CERAMAH TEKNIK TECHNICAL TALK

Mineralogy and Geochemistry of Volcanic Ash from Mount Merapi Eruption in 2010

Hamzah Mohamad & Wan Zuhairi Wan Yaacob
Program Geologi,
Pusat pengajian Sains Sekitaran dan Sumber Alam, Fakulti Sains dan Teknologi,
Universiti Kebangsaan Malaysia, 43600, Bangi, Selangor

12 Januari 2011

Bilik Mesyuarat Program Geologi, Universiti Kebangsaan Malaysia

Satu pembentangan ceramah teknik yang bertajuk "Mineralogy and Geochemistry of Volcanic Ash from Mount Merapi Eruption in 2010" telah diadakan pada 12 Januari 2011 di bilik Mesyuarat Geologi, UKM. Ceramah ini disampaikan oleh dua pembentang. Prof Madya Dr Wan Zuhairi Wan Yaacob membentangkan fenomena dan kesan yang dihadapi oleh penduduk sekitar hasil daripada letusan ini dan diikuti oleh pembentang oleh Prof Dr Hamzah Mohamad yang membentang hasil analisis petrografi, geokimia dan tafsiran suhu dan sekitaran pembentukan Gunung Merapi daripada sampel-sampel yang telah dianalisis. Ceramah ini adalah anjuran bersama Persatuan Geologi Malaysia dan Program Geologi, UKM. Ia dihadiri oleh kira-kira 60 orang ahli geologi daripada UKM, UM, MINT, UNITEN dan IKRAM. Yang Berbahagia Dato Yunus Abd Razak, Ketua Pengarah Jabatan Mineral dan Geosains, juga mantan Presiden Persatuan Geologi Malaysia turut hadir mendengar ceramah teknik ini.

Resolving the architecture of the Ngalia Basin in central Australia from gravity and magnetic field interpretation – A component of a Uranium minerals system study

Clive Foss
Senior Research Geoscientist
CSIRO Earth Science & Resource Engineering
Australia

18 January 2011

Geology Lecture Hall, Department of Geology,
University of Malaya, 50603 Kuala Lumpur

Abstract: The Ngalia basin of the Northern Territory, Australia has proven uranium deposits and is an active area of uranium exploration. The uranium is believed to have been derived from surrounding basement rocks and to have been initially deposited in sedimentological and diagenetic processes before being repeatedly mobilised and redeposited in subsequent thermal and tectonic events. A full understanding of these processes is hampered by the limited knowledge of the structure and evolution of the basin as derived from sparse outcrop, limited vintage seismic and just two wells to basement. To improve understanding of the basin as required to support exploration for blind mineralisation, CSIRO is undertaking an integrated geochemical, sedimentological, structural and geophysical study funded by a consortium of uranium exploration companies. This talk focuses on the task of mapping the three-dimensional structure of the basin, which has been undertaken with inversion and modelling of regional gravity and aeromagnetic data.

Kajian kestabilan potongan cerun batuan metasedimen di Bukit Chendering, Kuala Terengganu

Hamzah Hussin & Tajul Anuar Jamaluddin
Pusat Pengajian Sains Sekitaran dan Sumber Alam,
Fakulti Sains dan Teknologi
Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor

19 Januari 2011

Bilik Mesyuarat Program Geologi
Universiti Kebangsaan Malaysia

Abstrak: Bukit Chendering terletak kira-kira 5 kilometer dari bandar Kuala Terengganu. Litologinya terdiri daripada selang lapis batuan syis, filit, kuarzit dan sabak yang berusia Karbon. Terdapat juga daik dolerit yang berkelebaran sehingga 5 meter dan terluluhawa sepenuhnya di kawasan ini. Batuan di kawasan ini telah mengalami sekurang-kurangnya dua kali canggaan tektonik menyebabkan batuannya menjadi hancur dan mudah terurai apabila terdedah ke permukaan. Disebabkan ciri batuannya yang hancur, cerun potongan yang dibina menjadi tidak stabil dan mudah mengalami kegagalan. Ketakselanjaran pada jasad batuan di kawasan ini dibentuk oleh satah-satah perlapisan, kekar, sesar, foliasi, dan zon sesar. Pemetaan geologi struktur yang dilakukan pada 9 buah cerun potongan dilakukan dengan mengambil data-data struktur dan struktur relikta yang tersembunyi pada singkapan yang terluluhawa teruk. Analisis kestabilan kinematik telah dilakukan dengan membuat andaian data struktur dan struktur relikta yang diambil adalah sama dari segi gaya dan orientasi seperti pada batuan segar. Hasil analisis mendapati bahawa kebanyakan cerun di kawasan kajian mempuyai berbagai potensi kegagalan cerun dalam bentuk baji, satah dan terbalikan. Untuk mengurangkan risiko kegagalan, pemotongan cerun perlu dibuat mengikut orientasi dan sudut cerun yang disyorkan. Selain itu, penggunaan sistem jaringan yang disokong dengan pepaku tanah "soil nail" adalah sangat penting bagi menstabilkan cerun disamping dapat mengurangkan kadar penguraian jasad batuan pembentuk cerun yang terdedah di permukaan.

CHAIRMAN'S LECTURE No 16: Geology and Tunnelling in Malaysia

Tan Boon Kong

21 January 2011

Geology Lecture Hall, Department of Geology,
University of Malaya, 50603 Kuala Lumpur

Sdr Tan Boon Kong gave the lecture entitled Geology and Tunnelling in Malaysia on Friday 21st January 2011 at 5.30pm at Geology Department, University of Malaya. The talk was well attended by an audience of 20. In introducing the speaker, the Chairman, Dr Teh Guan Hoe, praised Sdr Tan for keeping the tradition of the Chairmans Lecture Series going. Incidentally this is Sdr Tans nth talk in the series. It is hoped that other Chairmen of the Societys various Working Groups will follow Sdr Tans good example and come forward with their talks in the near future. Sdr Tan highlighted the 3 types of tunneling techniques practised in Malaysia and followed that up with colourful and informative slides of the various aspects of the various tunnels. A very stimulating question time followed and the enthusiastic audience definitely benefitted from the talk.

Penerbitan sudut geseran puncak satah ketakselanjaran daripada penentuan kekasaran permukaan

Abdul Ghani Rafek,Goh,T.L.,Mohd. Hariri Ariffin & Nurul Baizura M. Yunus
Program Geologi,
Pusat pengajian Sains Sekitaran dan Sumber Alam, Fakulti Sains dan Teknologi,
Universiti Kebangsaan Malaysia, 43600, Bangi, Selangor
aghani@ukm.my

9 Februari 2011

Bilik Mesyuarat Program Geologi, Universiti Kebangsaan Malaysia

Abstrak: Kekasaran permukaan satah ketakselanjaran memainkan peranan penting dalam mempengaruhi kestabilan jasad batuan. Beberapa pendekatan boleh digunakan untuk penentuannya. Pembentangan ini mempersembahkan suatu pendekatan mudah di mana dua persamaan polinominal telah diterbitkan untuk mengkorelasikan sudut geseran puncak θ_{puncak} satah ketakselanjaran dengan Pekali Kekasaran Kekar, PKK batuan syis segar dan terluluhawa sedikit. Untuk satah ketakselanjaran batuan syis segar, sudut geseran puncak θ_{puncak}= -0.022PKK2 + 3.21PKK + 28.1°, manakala θ_{puncak}= -0.025PKK2 + 3.24PKK + 26.6°, bagi satah terluluhawa sedikit, dengan koeffisien penentuan (R2) bernilai 0.98 untuk kedua-dua kes. Pendekatan ini memberi satu pilihan penganggaran sudut geseran puncak, θ_{puncak} dengan pengukuran nilai PKK di lapangan dan aplikasi persamaan ini untuk penentuan sudut geseran puncak.

Abstract: The surface roughness of geological discontinuities plays an important role in influencing the stability of rock masses. Several approaches can be adopted for its determination. This presentation puts forward a simple approach whereby two polynomial approximations have been derived to correlate the peak friction angle, θ_{peak} of discontinuity planes of fresh as well as slightly weathered schist with the Joint Roughness Coefficient, JRC. These polynomial approximations are θ_{peak}= -0.022JRC2 + 3.21JRC + 28.1° for fresh discontinuities and θ_{peak}= -0.025JRC2 + 3.24JRC + 26.6° for slightly weathered discontinuities, both with coefficient of determination (R2) of 0.98. These results offer an alternative method for estimation of the peak friction angle, θ_{peak} by measuring the JRC values in a field survey and employing these equations for the estimation of the peak friction angle of the discontinuity planes.

Magnetotelluric survey in some active tectonics areas

Toru Mogi
Insitutue of Seismology and Volcanology
Hokkaido University, Japan

28 January 2011

Geology Lecture Hall, Department of Geology,
University of Malaya, 50603 Kuala Lumpur

Abstract: The magnetotelluric (MT) method is an electromagnetic method based on the joint analysis of electric and magnetic fields through their ratio that define the MT impedance. This method has been intensively used in mineral exploration and crustal studies because of its sensitivity to conductivity contrast of rocks. The MT method is useful for delineating large-scale conductive and resistive zones within the earth. It is used for identifying structure related to juxtaposed rocks with differing resistivities, caused by differing rock types, fluid content or alteration within relatively uniform strata, and representing significant features such as partial melts, feeder dykes, structural features like faults and shear zones, magma chambers, etc. Because the method is sensitive to electrical resistivity, it offers an alternative and complementary exploration tool to seismic and gravity surveying and can be used for identifying structures that are generally undetectable by other techniques.

I will talk about resistivity structure sections obtained by MT surveys in some tectonic areas such as:

1. Arc-arc collision area in Hokkaido, Northern Japan.
2. Crust strain concentration area in Central Japan.
3. Three types of tectonic areas in Indonesia.

The heterogeneous electrical features in tectonic areas show a close spatial relationship with the distribution of the displacement rate and with seismicity. This suggests that the resistivity structure can be used as an index from which to evaluate the deformation characteristics of the crust.

Geological hazards assessment on the Wadi Dayqah Dam, the Sultanate of Oman

Tajul Anuar Jamaluddin[1], Steven Chong Fook Loy[2] & Arulgnanam V. A.[3]

[1]SEADPRI, Universiti Kebangsaan Malaysia, 43650 Bangi Selangor
[2]SC Geoconsult, 61 Jalan BU6/9, Badar Utama, 47800 Petaling Jaya, Selangor
[3]Euroculture (M) Sdn. Bhd. Suite 6G UBN Towers Jalan P. Ramlee 50250 Kuala Lumpur

16 February 2011
Bilik Mesyuarat Program Geologi, Universiti Kebangsaan Malaysia

Abstract: Having been devastated by the recent tropical cylone events, Cyclone Gonu in June 2007 and Cyclone Phet in June 2010, the government of the Sultanate of Oman recognizes the need to study the impending natural/geological hazards associated with the mountainous terrain in Oman in order to prevent disaster in the future. With this vision in mind, a Consortium led by Consultant HSS (CHSS) Dubai, in collaboration with Euroculture (M) Sdn. Bhd., SC Geoconsult, SEADPRI (South East Asia Disaster Prevention Research Institute, UKM) and the Department of Earth Sciences, Sultan Qaboos University of Oman, has carried out an initial study to identify the pertinent and potential hazards on important major infrastructures. Amongst them is the newly built Wadi Dayqah Dam, which is the largest dam in Oman located in the Qurayat Wilayat.

This paper presents some of the major findings of the initial field study in the Wadi Dayqah Dam site. This study has found that the slopes, notably along the access roads leading to the various sections of the dam are in unsatisfactory conditions. Slopes were cut too steep and without due consideration given to the geological structures and geomechanical properties of the rock mass condition. Most of the slopes are unprotected, too steep, lacking in drainage control systems and erosion protection measures. Some of the slopes have already failed. Detailed studies should also be carried out on the natural slopes which formed the right abutment of the main dam. There are indications that the foot slopes have been badly scoured by the sudden rise of water levels in the downstream river due to overflows from the reservoir brought on by Cyclone Phet. Toe undercutting of the slope can lead to slope instabilities, and the resulting progressive failures may jeopardise the stability of the entire hill slope and consequently, the main dam itself. Another serious problem that needs immediate/urgent attention is the seepage that developed in the lower rock slope on the left abutment of the main dam.

The evidences presented show that the ever presence of inherent hazards and risks pertaining to precipitation-induced landslides and slope failures in the dam site. Therefore, it is vital and imperative that a concerted effort is undertaken by Government of Sultanate of Oman to implement a comprehensive mitigation and management plan to address and overcome such hazards.

Radiolaria Kapur di Kunak, Sabah
(Cretaceous Radiolaria at Kunak, Sabah)

Junaidi Asis
Program Geologi, Pusat pengajian Sains Sekitaran dan Sumber Alam,
Fakulti Sains dan Teknologi, Universiti Kebangsaan Malaysia,
43600, Bangi, Selangor

23 hb Febuari 2011

Bilik Mesyuarat Program Geologi, Universiti Kebangsaan Malaysia

Abstrak: Rijang yang terdapat di singkapan baru di kilometer 20 Jalan Kunak – Semporna mengandungi kelimpahan radiolaria. Rijang ini berwarna merah keperangan dan berselang lapis nipis dengan syal bersilika serta sering berasosiasi dengan batuan mafik seperti spilit, basalt, peridotit dan serpentinit. Asosiasi batuan ini telah dikelaskan sebagai Kompleks Teluk Darvel. Kompleks ini merupakan satu unit lithodem bagi menggantikan Formasi Chert-spilit yang mana penggunaannya tidak sesuai dan mengelirukan. Sebanyak 8 sampel telah diambil pada singkapan tersebut, kemudian diproses mengikut kaedah mikropaleontologi. Spesimen yang baik pengawetannya diambil gambar foto dengan menggunakan mikroskop pengimbas elektron. Didapati sebanyak 37 spesies daripada 24 genera telah dikenalpasti dan sebanyak 26 spesies pilihan telah digunakan untuk menentukan usia batuan rijang. Antara fosil indeksnya ialah *Dictyomitra gracilis, Dictyomitra farmosa, Dictyomitra obesa, Dictyomitra montisserei, Dictyomitra multicostata, Dictyomitra koslovae, Pseudodictyomitra languida, Tugurium pagoda, Xitus spicularius, Xitus Mclaughlini, Torculum coronatum, Stichomitra simplex , Stichomitra communis, Stichomitra stocki, Phalangites perspicuous, Rhopalosyringium fossile, Pseudotheocampe tina, Pseudoaulophacus sculptus, Pseudoaulophacus putahensis, Alievium superbum, Patelulla helios, Godia concava, Patulibracchium grapevinensis, Pessagnobrachia fabianii, Crucella messinae, Crucella cahensis,* dan *Acaeniotyle rebellis*. Himpunan fosil ini menunjukkan usia batuan rijang tersebut ialah Kapur iaitu sekitar Aptian hingga Turonian. Asosiasi batuan mafik dan rijang ini merupakan jujukan ofiolit yang mewakili kerak lautan yang terbina di kawasan pemuaian.

Abstract: A new chert outcrop exposed at kilometers 20 Kunak-Semporna road contains abundant radiolaria. The chert is brownish-red in colour. It is interbeded with thin layers of siliceous shale, and usually associated with basalt, spilite, peridotite and serpentinite. The rock association is known as the Darvel Bay Complex. This lithodemic complex replaces the Chert-Spilit Formation. Eight samples were collected from the outcrop and processed for micropaleontological study. Well preserved specimens were photographed by scanning electron microscope. A total of 37 species from 24 genus were identified and about 26 selected species were used for the age determination of chert. The index fossils consist of *Dictyomitra gracilis, Dictyomitra farmosa, Dictyomitra obesa, Dictyomitra montisserei, Dictyomitra multicostata, Dictyomitra koslovae, Pseudodictyomitra languida, Tugurium pagoda, Xitus spicularius, Xitus Mclaughlini, Torculum coronatum, Stichomitra simplex , Stichomitra communis, Stichomitra stocki, Rhopalosyringium fossile, Pseudotheocampe tina, Pseudoaulophacus sculptus, Pseudoaulophacus putahensis, Alievium superbum, Patelulla helios, Godia concava, Patulibracchium grapevinensis, Pessagnobrachia fabianii, Crucella messinae, Crucella cahensis,* and *Acaeniotyle rebellis*. A Cretaceous age, which range from Aptian to Turonian is suggested by this fossil assemblage. The association of mafic rocks and chert represents part of an ophiolite sequence of the oceanic crust that was formed at the spreading center.

Cretaceous Flower Hunting in Eastern Asia

Masamichi Takahashi
Department of Environmental Sciences
Niigata University, Japan.

15 March 2011

Geology Lecture Hall, University of Malaya, Kuala Lumpur

Abstract: Flowering plants (angiosperms) consisting of more than 350,000 living species dominate the vegetation of most terrestrial ecosystems. The origin and early evolution of angiosperms had remained as an abominable mystery in evolutionary biology in the last twenty-five years. Recent paleobotanical studies of the early fossil history of angiosperms have, however, been revolutionized with the discovery of small and well-preserved three-dimensional fossil flowers (mesofossils) from Cretaceous between 125 and 65 million years before present. The mesofossils that are usually preserved as charcoal from ancient forest fires provide unrivalled insights into the structure, biology and evolutionary relationships of ancient angiosperms. The paleobotanical studies have greatly increased the quantity and quality of information available about the structure and relationships of Cretaceous flowers.

Our research is documenting the early evolutionary history of flowering plants through the study of fossil flowers, fruits and seeds that are preserved as charcoal in some Cretaceous fossil localities in Japan and Mongolia. For the past ca. 15 years we have been studying small Cretaceous fossil flowers, fruits and seeds using scanning electron microscopy and synchrotron radiation X-ray microtomography (SRXTM). SRXTM is an important new tool that we can use to study fossil plants to obtain data on internal structure without destroying the specimens. The goal of this research is to document the early fossil history of flowering plants and investigate how flower structure and plant diversity has evolved through time.

The Kamikitaba plant mesofossil assemblage, the first and unique record of mesofossil preservation from eastern Asia, was isolated from carbonaceous, black, poor-sorted sandy siltstone (Late Cretaceous; early Coniacian, ca. 89 million years before present) in Fukushima Prefecture, Japan. The assemblage includes well-preserved angiosperm flowers, fruits, seeds, leaf fragments and wood. We are now extending the Cretaceous Flower Hunting Project to Mongolia and Southeastern Asia.

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1. Sriyanee De Silva, Mitra Energy Ltd., Suite 24.3, Level 24, Menara IMC, 8 Jalan Sultan Ismail, 50250 Kuala Lumpur
2. Mazlan Madon, Petronas Research Sdn Bhd., Lot 3288 & 3289, Off Jalan Ayer Itam, Kawasan Institusi Bangi, 43000 Kajang
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Dear Members

Please update your contact details by sending your email address, telephone no. and fax no. to : geologicalsociety@gmail.com

PERSATUAN GEOLOGI MALAYSIA

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NATIONAL GEOSCIENCE CONFERENCE 2011

The Puteri Pacific Johor Bahru &
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NGC2011

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For further information please contact:

National Geoscience Conference 2011
Geological Society of Malaysia
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University of Malaya
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Tel: (603) 7957 7036 Fax: (603) 7956 3900
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First Circular can be downloaded at
http://geology.um.edu.my/gsmpublic/NGC2011/first_circular.pdf

GSM Photographic Competition 2011

1st Prize: RM1,000.00
2nd Prize: RM 500.00
3rd Prize: RM 300.00
5 consolation prizes of RM100.00 each

Deadline: 31 September 2011

Email your entry to gsmphotocompetition@gmail.com

Please read the Rules and regulation.

Geological Society of Malaysia
Persatuan Geologi Malaysia
Photographic Competition 2011

Rules and regulations:

1. This photographic competition is open to all members of the Society, as well as the general public.
2. The purpose of the competition is to promote interest in the geology of Malaysia. We are especially interested in photographs that showcase the beauty and uniqueness of Malaysian geology, including geological landscapes, outcrops, specimens and photomicrographs of rocks, minerals and fossils. The subject matter and scene should be directly related to the geology of Malaysia, and located within Malaysia.
3. Judging will be based on artistic merit, originality and quality, as well as geological content.
4. Entries are to be submitted in the form of digital images in JPEG, TIFF, PSD or PNG file format. Maximum file size is 15 Mb and it is recommended that the image size be no smaller than 5 megapixels.
5. The subject matter and scene should be accurately depicted in the photograph. Limited digital adjustments (dust removal, cropping, level, saturation, colour balance and contrast, etc.) and black & white conversion are acceptable. Montages or blending of multiple photographs is not allowed, with the exception of panorama, HDR and DOF stacking.
6. Each contestant may submit up to ten entries, and multiple entries are encouraged. However, each contestant will be limited to winning two prizes.
7. The prizes are as follows:
   - 1st Prize: RM1,000.00
   - 2nd Prize: RM 500.00
   - 3rd Prize: RM 300.00
   - 5 consolation prizes of RM100.00 each

   Each prize winner will also receive a certificate
8. By submitting the entry, the contestant acknowledges that he/she is the photographer, and sole owner of the photograph. By submitting the entry, you also grant the Geological Society of Malaysia the non-exclusive right to use your photographs. The winning photographs will become the property of the Society.
9. Closing date: All entries must reach the Geological Society of Malaysia before the 31st of September, 2011.
10. The decision of the judges is final. The organizers reserve the right to make adjustments to these rules and regulations if deemed necessary.
11. Entries in CD should be carefully packed and mailed to: The Organizer, GSM Photographic Competition 2011, c/o Department of Geology, University of Malaya, 50603 Kuala Lumpur, or email to gsmphotocompetition@gmail.com

Each entry must be accompanied by the following information in a text file:
1. Name
2. Address
3. Profession
4. Affiliation/Institution
5. Telephone & fax
6. Email address
7. Image file name
8. Title of photograph
9. Description/Geological information
10. Locality
11. Camera & setting
12. Digital adjustment (if any)

Petroleum Geoscience Research Group

Department of Geology,
University of Malaya

Petroleum Geoscience provides the knowledge, understanding, and assessment of how hydrocarbon resources are formed and where they occur. This provides key information and direction for the design of cost-effective, successful exploration and production projects. This requires fresh ideas regarding depositional systems and the petroleum systems they contain, particularly with regard to the distribution of source rocks and reservoir rocks. The major disciplines of Petroleum Geoscience are Petroleum Geology, Petrophysics, Geophysics, Sedimentology, Stratigraphy, Structural Geology and Petroleum Geochemistry. The integration of these various disciplines is presently in place at the Department of Geology, University of Malaya, under two working sub-groups i.e. PEAK (Petroleum Exploration Advanced Knowledge) and SEARCh (Source Evaluation And Reservoir Characterisation) units. The Source-Evaluation component of the SEARCh unit is well established, with a productive history of research and publication.

The Reservoir Characterisation component of SEARCh represents a new advanced, long-term, multidisciplinary research initiative within the Petroleum Geoscience Group. This programme provides a support framework for the new MSc in Petroleum Geology by 70% research as well as the existing postgraduate research programmes. The programme builds on the technical expertise represented by the recent expansion of petroleum

Group Leader:
Professor Dr. Wan Hasiah Abdullah (Petroleum Geochemistry)
Email address: wanhasia@um.edu.my

Members:
Dr. Ralph L. Kugler (Reservoir/Development Geology)
Emeritus Professor Dr. Charles Hutchison (Regional Geology)
Professor Dr. Lee Chai Peng (Sedimentology)
Assoc. Prof. Dr. Samsudin Hj Taib (Geophysics)
Assoc. Prof. Dr. Ng Tham Fatt (Structural Geology)
Assoc. Prof. Mustaffa Kamal Shuib (Structural Geology)
Dr. Meor Hakif Amir Hassan – (Sedimentology)
Dr. Mohamed Shalaby (Petrophysics)
Dr. Md Aminul Islam (Seismic Interpretation)
Ms. Nur Huda Mohd Jamin (Geophysics)
Mr. Nur Islami (Seismic Interpretation)
Mr. Khairul Azlan Mustapha – (Petroleum Geology)
Ms. Wong Yien Lim (Sedimentology)

Collaborators:
Professor Dr. Howard D. Johnson (Petroleum/Development Geology)
Professor Dr. Harry Doust (Basin Analysis/Exploration Geology)
Dr. Muhamad Pedro Barbeito (Biostratigraphy)

Petroleum Geology MSc students at the Shell core storage facility in Miri.

geology staff. Components of the programme will include quantitative digital outcrop modeling of reservoir analogs pertinent to Malaysia, particularly heterolithic clastic reservoirs and naturally fractured reservoirs, as well as investigations in reservoir quality/diagenesis. Thus, issues from field-scale to pore throats will be addressed in an integrated manner to provide relevant results that can aid planning of improved and enhanced hydrocarbon recovery projects by the local petroleum industry. The capabilities of this research component are enhanced by the recent acquisition of state-of-the-art SEM, XRD and XRF. Acquisition of additional analytical instrumentation (CT scan, LiDAR, various types of porosimeters/permeameters, etc.) is an ongoing goal in support of the programme. This programme will lead to increased support by the local and international petroleum industry as well as collaboration with international academic research consortia.

The main accomplishment of PEAK has been the establishment of the capability to provide advanced applied knowledge through teaching, training and field guides/seminars to postgraduates and offering consultancy services to oil/service companies through specifically designed training programmes and tailored projects for local and overseas participants and companies. For example, a comprehensive, multi-month geology and geophysics training programme was conducted for professional personnel from the Equatorial Guinea Energy Ministry. Among SEARCh unit main accomplishments is the ability to obtain oil companies grant and sponsorship of their staff to undertake research at Geology Department, University of Malaya. Members of the unit are embarking on integrated research under Borneo Project, the findings of which would benefit the ever challenging oil and gas exploration activities within the surrounding region. The new, collaborative initiatives of the Reservoir Characterisation component of SEARCh further benefit the Malaysian petroleum industry by addressing topical issues pertinent to production and field development. Advanced software such as Petrel, PetroMod, Roxar RMS, Petrosys, etc is used in combination with advanced source rock evaluation techniques (e.g. GC-MS, Py-GC, SRA, VR analyses) and reservoir characterisation methodologies (e.g. Interactive Petrophysics, Norsar SeisRox, Midland Valley MOVE, etc). Studies and characterisation of major source rock types of NW Borneo basins, facies analysis, analogue studies, and stratigraphic correlation between onshore and offshore petroleum province has been carried out by the group.

Training for geologists and engineers from the Equatorial Guinea Energy Ministry.

PROFILE

The PROFILE section will make a regular appearance in Warta Geologi starting from this issue. This section highlights institutions, programmes, research groups and researchers in the field of geoscience.

If you wish to have your institute or research featured in the PROFILE section, please email geologicalsociety@gmail.com

UPCOMING EVENTS

May 2-6, 2011: Petroleum Geostatistics – Integrating Data for Reservoir Modelling and Simulation , Vienna, Austria. Contact: HOT Engineering GmbH, Parkstrasse 6, A-8700 Leoben, Austria; Tel: +43 3842 43053-33; Fax: +43 3842 43053-1; email: training@hoteng.com

May 2-6, 2011: Analysis of Structural Traps in Extensional Settings, Kuala Lumpur, Malaysia. Contact: Tel: 603 2168 4751; email: ap-enquiries@petroskills.com

May 2-6, 2011: Foundations of Petrophysics, Vienna, Austria. Contact: HOT Engineering GmbH, Parkstrasse 6, A-8700 Leoben, Austria; Tel: +43 3842 43053-33; Fax: +43 3842 43053-1; email: training@hoteng.com

May 6-10, 2011: Mapping Subsurface Structures, London, UK,Contact: Tel: 603 2168 4751; email: ap-enquiries@petroskills.com

May 16-20, 2011: Petroleum Systems Modelling for Exploration Risk Assessments, Vienna, Austria. Contact: HOT Engineering GmbH, Parkstrasse 6, A-8700 Leoben, Austria; Tel: +43 3842 43053-33; Fax: +43 3842 43053-1; email: training@hoteng.com

May 17-21, 2011: Basin Analysis with Fugro Robertson, Kuala Lumpur, Malaysia. Contact: Caroline at Tel: +65 6741 9749; email: caroline@asiaedge.net

May, 23-26, 2011: The interrelations between deformation and metamorphism, Granada, Spain. Contact:Domingo Aerden (University of Granada): aerdenaugr.es

May 23-27, 2011: Sequence Stratigraphy: An Applied Workshop, Kuala Lumpur, Malaysia. Contact: Tel: 603 2168 4751; email: ap-enquiries@petroskills.com

May 23-27, 2011: Image Log Interpretation, Kuala Lumpur, Malaysia. Contact: Caroline at Tel: +65 6741 9749; email: caroline@asiaedge.net

May 24-26, 2011: Trouble Free High Angle, Extended Reach Drilling & Complex Wells, Kuala Lumpur. Contact: Caroline at Tel: +65 6741 9749; email: caroline@asiaedge.net

May 30-31, 2011: Introduction to Exploration and Production for New Engineers and Non-Technical Professionals, Singapore. Contact: Caroline at Tel: +65 6741 9749; email: caroline@asiaedge.net

May 30-Jun 3, 2011: Introduction to Petrophysics – Log Analysis, LWD & Wireline, Kuala Lumpur, Malaysia. Contact: Caroline at Tel: +65 6741 9749; email: caroline@asiaedge.net

June 6-10, 2011: Geochemical Techniques for Solving Reservoir Management and Field development Problems, Houston, USA. Contact: Tel: 603 2168 4751; email: ap-enquiries@petroskills.com

June 6-10, 2011: Fundamentals of Petroleum Geology, Vienna, Austria. Contact: HOT Engineering GmbH, Parkstrasse 6, A-8700 Leoben, Austria; Tel: +43 3842 43053-33; Fax: +43 3842 43053-1; email: training@hoteng.com

June 11-12, 2011: National Geological Conference 2011, Johor Baru, Malaysia. Contact: Geological Society of Malaysia, Tel: 603 79577037; Fax: 603 79563900; email: geologicalsociety@gmail.com

June 13-17, 2011: Operations Geology, Kuala Lumpur, Malaysia.Contact: Tel: 603 2168 4751; email: ap-enquiries@petroskills.com

June 20-24, 2011: Surface Production Operations, Kuala Lumpur, Malaysia.Contact: Tel: 603 2168 4751; email: ap-enquiries@petroskills.com

June 20-26, 2011: Deep-water Turbidite Depositional Systems and Reservoirs, Nice, France. Contact: Tel: 603 2168 4751; email: ap-enquiries@petroskills.com

June 27-29, 2011: Upstream Petroleum Economics and Risk Analysis with Fugro Robertson, Kuala Lumpur, Malaysia. Contact: Caroline at Tel: +65 6741 9749; email: caroline@asiaedge.net

28 June-7 July 2011: XXV IUGG General Assembly "Earth on the Edge: Science for a Sustainable Planet". Melbourne, Australia. The program will include an International Tsunami Symposium. Details: www.iugg2011.com/default.asp

June 30-Jul 1, 2011: Economic Aspects of Production Sharing Contracts with Fugro Robertson, Kuala Lumpur, Malaysia. Contact: Caroline at Tel: +65 6741 9749; email: caroline@asiaedge.net

July 4-8, 2011: Development Geology, Kuala Lumpur, Malaysia.Contact: Tel: 603 2168 4751; email: ap-enquiries@petroskills.com

July 4-8, 2011: Carbonate Geology for Oil and Gas Exploration & Development, Vienna, Austria. Contact: HOT Engineering GmbH, Parkstrasse 6, A-8700 Leoben, Austria; Tel: +43 3842 43053-33; Fax: +43 3842 43053-1; email: training@hoteng.com

July 10-15, 2011: 17th European Symposium on Organic Chemistry (ESOC2011), Crete, Greece. Contact: Michael Orfanopoulos, email: info@esoc2011.com; website: www.esoc2011.com

July 11-15, 2011: Clastic Sedimentology for Exploration and Development, Vienna, Austria. Contact: HOT Engineering GmbH, Parkstrasse 6, A-8700 Leoben, Austria; Tel: +43 3842 43053-33; Fax: +43 3842 43053-1; email: training@hoteng.com

July 11-15, 2011: Basic Petroleum Engineering Practices, Kuala Lumpur, Malaysia. Contact: Tel: 603 2168 4751; email: ap-enquiries@petroskills.com

18-19 July 2011: 2nd Asia-Pacific GeoParks Network (APGN) Symposium. Hanoi, Vietnam. Theme "Geopark and Geotourism for Regional Sustainable Development". Details: vckg.vigmr.vn/

July 25-29, 2011: Basic Petroleum Geology, Kuala Lumpur, Malaysia.Contact: Tel: 603 2168 4751; email: ap-enquiries@petroskills.com

July 25-29, 2011: Naturally Fractured Reservoirs: Geologic and Engineering Analysis, London, UK. Contact: Tel: 603 2168 4751; email: ap-enquiries@petroskills.com

July 25-29, 2011: Introduction to Seismic Stratigraphy: A Basin Scale regional Exploration Workshop, Kuala Lumpur, Malaysia. Contact: Tel: 603 2168 4751; email: ap-enquiries@petroskills.com

August 1-5, 2011: Advanced Seismic Stratigraphy: A Sequence – Wavelet Analysis Exploration – Exploitation Workshop, Kuala Lumpur, Malaysia. Contact: Tel: 603 2168 4751; email: ap-enquiries@petroskills.com

August 5-15, 1012: 34th International Geological Congress, Brisbane, Australia. Contact: Dr. Ian Lambert, Geoscience Australia. Tel: +61 2 62499556; Fax: +61 2 62499983; email: ian.lambert@ga.gov.au; website: www.ga.gov.au/igc2012

August 8-12, 2011: Basin Analysis Workshop: An Integrated Approach, Singapore. Contact: Tel: 603 2168 4751; email: ap-enquiries@petroskills.com

4-7 September 2011: FRAGILE EARTH International conference: Theme "Geological Processes From Global to Local Scales, Associated Hazards & Resources". Munich, Germany. Details: www.geosociety.org/meetings/2011munich/

September 5-7. 2011: Volcaniclastic Rocs – Classification, Properties, Genesis and Depositional Settings, Vienna, Austria. Contact: HOT Engineering GmbH, Parkstrasse 6, A-8700 Leoben, Austria; Tel: +43 3842 43053-33; Fax: +43 3842 43053-1; email: training@hoteng.com

September 12-16, 2011: Carbonate Reservoirs, London, UK.Contact: Tel: 603 2168 4751; email: ap-enquiries@petroskills.com

September 12-16, 2011: Seismic Interpretation, Kuala Lumpur, Malaysia.Contact: Tel: 603 2168 4751; email: ap-enquiries@petroskills.com

3 – 9 October 2011: The Second World Landslide Forum – Sponsored by the IUGS And The International Consortium On Landslides, Rome, Italy. Details: www.wlf2.org/home/home-page

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PP2509/07/2011(028111) ISSN 0126-5539

WARTA GEOLOGI PERSATUAN GEOLOGI MALAYSIA

Newsletter of the Geological Society of Malaysia

Jilid 37, No. 1 • Volume 37, No. 1 • January–March 2011

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Department of Geology, University of Malaya, 50603 Kuala Lumpur, MALAYSIA
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