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DIKELUARKAN DWIBULANAN
ISSUED BIMONTHLY

PERSATUAN GEOLOGI MALAYSIA
Geological Society of Malaysia

About the Society

The Society was founded in 1967 with the aim of promoting the advancement of earth sciences particularly in Malaysia and the Southeast Asian region.

The Society has a membership of about 600 earth scientists interested in Malaysia and other Southeast Asian regions. The membership is worldwide in distribution.

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CATATAN GEOLOGI
Geological Notes

The kidney stone from a *bomoh* (Malay medicine-man)

T.T. Khoo
17 Orange St.,
Eastwood 2122
Australia

Abstract: A kidney stone supposedly extracted without surgery by a bomoh from Perak was found to be composed mainly of quartz grains cemented by an organic material, probably glue. A few grains of euhedral zircon accompanied the quartz suggesting that perhaps the provenance of the assemblage is river sand from a granitic terrain.

Reports abound in the media of the miraculous prowess of faith healers in performing surgical procedures on patients even without surgery. In this short note I shall report on the composition of a so-called kidney stone extracted from a patient without surgery by a *bomoh* from Perak.

In 1983 I was persuaded to examine a kidney stone by a staff of the University of Malaya Hospital who told me the history of the stone and that its composition did not fall into any of the types known to medical science. The stone is chocolate brown, smooth, rounded and about the size of a small walnut.

An X-ray diffraction study was made to determine the composition of the stone and indeed the material in it is crystalline yielding 15 reflections in the range from 5 to 90° 2θ angle in the diffractogram. The d-spacing and intensities of all the reflections are those of **quartz (SiO_2)**.

A X-ray fluorescence scan of the inorganic chemical composition of the stone indicated presence of silica (SiO_2) and traces of iron.

Two grain mounts of the stone material in Canada balsam was made and under the polarizing microscope 4 types of grains can be seen. The majority of the grains, more than 80%, are irregularly shaped (no cleavage) with low relief and giving the optical properties of quartz. Some of the quartz fragments contain fluid inclusions and minute, elongate crystallites. The second type of grains are brown thin flakes forming about 20% of the stone. It has low relief and is opaque under cross polars giving an impression that the material is neither crystalline nor mineralogical. This interpretation is reinforced by the lack of any reflections from this material in the X-ray diffraction scan. Most amazingly, in the grain mount there are also three well formed prismatic grains with very high relief greater than balsam. One grain terminates with pyramids at its ends and shows parallel extinction. The other grains are broken each with pyramidal termination. The mineral has all the optical properties determinable of **zircon ($ZrSiO_4$)**. The complete crystal is 0.08 mm long and 0.04 mm in width. Minute grains of opaque iron oxides are present in the grain mount. The X-ray fluorescence study confirms the presence of traces of iron. A photomicrograph of the quartz and zircon grains are shown in Figure 1.

From the study I would think that the so-called kidney stone is perhaps fine quartz sand cemented together by a brown organic glue which contributed the brown opaque flakes in the grain mount. Perhaps the presence of the well formed zircon would suggest that river

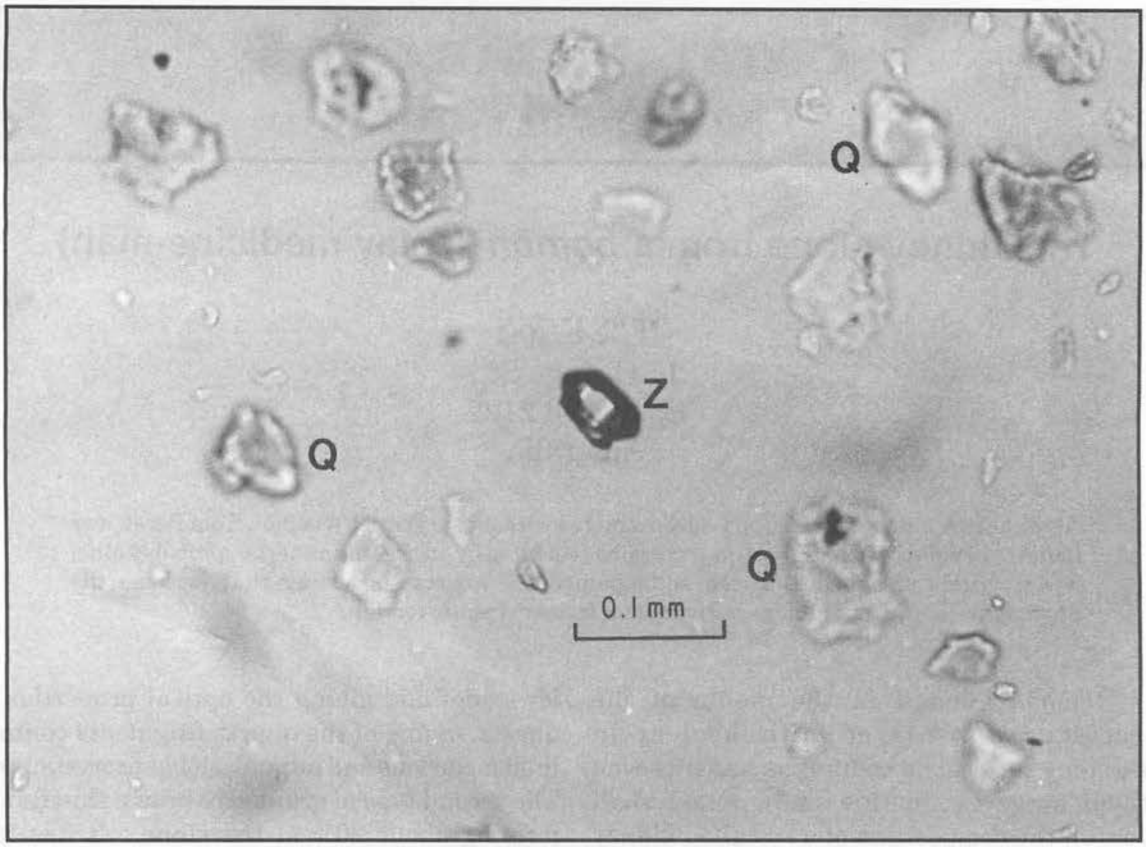

Figure 1. Photomicrograph of grain mount of so-called kidney stone. Q = quartz; Z = zircon.

sand derived from a granitic provenance in Peninsular Malaysia was used to compose the so-called kidney stone.

Kidney stones of various types are known such as uric acid, urates, oxalates and phosphates of lime and ammonium, and layered combinations of the various types (The Concise Home Medical Guide, 1974). Clearly the composition of the so-called kidney stone examined has a composition never before known to medical science. Mineral dust can be inhaled and become embedded in the lungs of humans resulting in pneumoconiosis. The commoner extraneous minerals in the lungs are fibrous asbestos, fine silica or quartz and coal. Lesser known extraneous minerals in the lungs of humans are, for example, fibrous varieties of zeolite such as erionite and mordenite (Casey *et al.*, 1985). However, for extraneous quartz and zircon sand to find their way to the kidney or the *in situ* development of zircon, which needs a high temperature of at least 150°C to synthesize (Deer *et al.*, 1965), in the kidney would have been quite miraculous.

ACKNOWLEDGEMENT

This exercise was carried out using the facilities of the Department of Geology, University of Malaya with which the author has had a long association.

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Manuscript received 28 August 2001

PERTEMUAN PERSATUAN
Meetings of the Society

Ceramah Teknik (Technical Talk)

Diamonds

LAU YIN LEONG

Laporan (Report)

Mr. Lau gave this talk to an audience of about 40 on Friday, 14 September 2001 at 5.30 pm at the Geology Department, University of Malaya.

In this third talk by Mr. Lau, in the series on gemology organised by the Working Group on Economic Geology, he dealt with the following topics; how diamonds form, properties of diamond, the 4C's of diamond (carat weight, colour, clarity and cut), sources of diamond, the De Beers Organisation, synthetic diamonds and stimulants, famous diamonds and pricing.

G.H. Teh

Petroleum exploration highlights in the sedimentary basins of Libya

OMAR S. HAMMUDA

Laporan (Report)

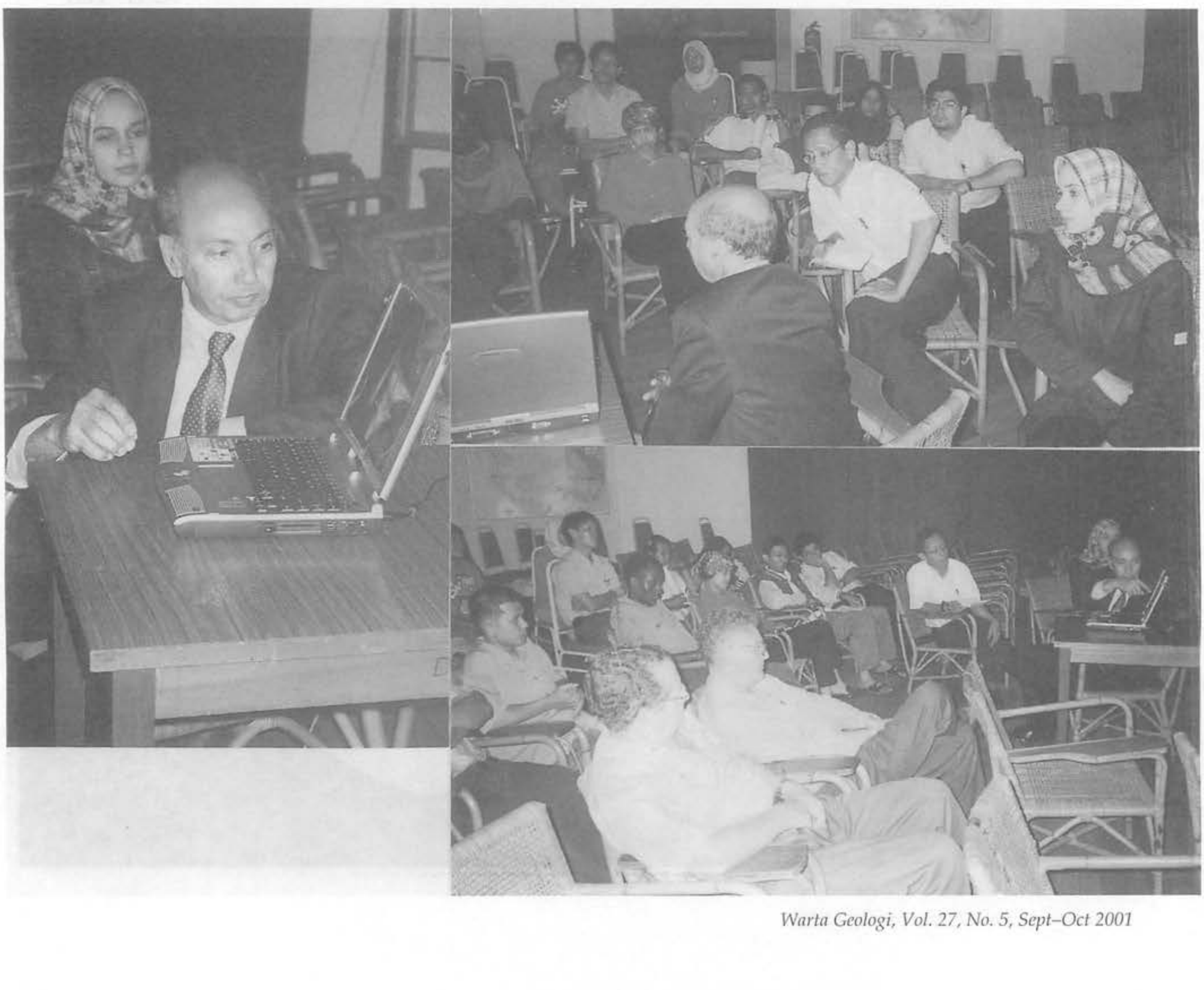
Prof. Omar Hammuda, who is with the Geology Department, Al-Fateh University, Tripoli, Libya, has a Ph.D. from University of Colorado and over 30 years of teaching and research experience in the fields of stratigraphy, biostratigrphy and petroleum geology. He is finishing his tenure as Visiting Professor at University of Malaya.

His talk was held on Monday 24 September 2001 at the Geology Department, University of Malaya at 5.30 pm as a programme of the Working Group on Stratigraphy, Sedimentology and Petroleum Geology.

Due to some default setting on his labtop, the talk could not be projected out from the Society projector. The simple solution was for all the 25 attendees to crow round the labtop.

In his talk, Dr. Hammuda dealt with the geographic location of the Libyan basins, their sizes, shapes and sedimentary thickness, brief exploration history, stratigraphic highlights of the Sirt Basin, comparison with other Libyan basins, ambitious exploration programmes and future discoveries.

G.H. Teh



Disastrous shallow landslide of granite and ignimbrite in Japan

MASAHIRO CHIGIRA

Laporan (Report)

Prof. Masahiro Chigira of the Disaster Prevention Research Institute, Kyoto University, Japan, gave the above talk on Wednesday 17 October 2001 at 10.00 am at Bilik Cempaka, Bangunan Pusat Komputer, Universiti Kebangsaan Malaysia.

Abstrak (Abstract)

Landslide disasters in Japan have been caused by gigantic, deeply extending landslides and by small but enormous number of shallow landslides. My talk will focus on the shallow landslides. Shallow landslides, which caused many of the most severe disasters in Japan, have been occurring in granite and ignimbrite areas, because they move very rapidly for a long distance and occur densely. Most of the shallow landslides of granite have two different types of geological causes. One is the reweathering of paleoweathering material, and the other is the loosening of micro-sheeted granite. Reweathering, of weathered granite occurs on the order of years when it is exposed to ground surface by artificial cutting or natural erosion. Micro-sheeting, microscopic to mesoscopic sheeting made by unloading, occurs in special type of granite. Micro-sheeted granite, even if it is scarcely weathered chemically, is disintegrated near the ground surface with a distinct front on the order of years. These loosened materials slide by the infiltration of water from intense rainfall. Ignimbrite has several types of weathering profiles according to the, intensity of welding, and these types determine the mechanisms of landslide. Non-welded ignimbrite is weathered to form a hydrated and clayey zone, which keeps suspended water above the unsaturated fresh zone. The suspended water increases the weight of the weathering zone by long rainfall rather than short intense rainfall, and leads to their landslide. Moderately welded ignimbrite by vapour-phase crystallization forms a weathering profile with a clearly defined front, which is made mainly by chemical weathering. Permeable, heavily weathered zone above this front finally slides by intense rainfall.

Report on the GSM-IEM Forum *"Engineering Geology & Geotechnics of Slopes"*, 23rd October 2001, held at the Department of Geology University of Malaya, Kuala Lumpur

The GSM-IEM Forum on *"Engineering Geology & Geotechnics of Slopes"* was jointly organised by the Working Group on Engineering Geology & Hydrogeology of GSM, and the Geotechnical Engineering Technical Division of IEM. This forum was the 10th in the series of such forums organised by GSM/IEM, initiated by GSM since 1992.

This 10th forum focussed on slopes, which form a significant component of works tackled by both engineering geologists and geotechnical engineers. Slopes discussed include both soil slopes and rock slopes which, depending on their geology and origin, can pose different engineering problems and challenges in various construction projects.

13 papers were presented at the forum — 5 by geologists and 8 by engineers. Topics range from simple practical slope inspections, slope protection measures, weathering, residual soils, piling, to modelling of rain-induced landslides, and numerous case studies or case histories. The case histories presented include several from Peninsular Malaysia, and one each from Sarawak, Sabah, Hongkong and Wales. The detailed programme is attached.

Response to the forum was overwhelming, with 108 participants. Due to constraints of space at the lecture hall, several requests had to be turned down. Fortunately, extra copies of the proceedings were prepared for the "late comers". Ample time was allocated for discussions, and these were fully utilised, resulting in very lively and fruitful discussions after every presentation.

Tan Boon Kong
Chairman
Working Group on Engineering Geology & Hydrogeology
Dated: 1st November 2001

Footnote: Limited copies of the proceedings are available for sale at RM30 (thirty) only. Please enquire at GSM secretariat (Tel.: 03-79577036, Fax: 03-79563900, E-mail: geologi@po.jaring.my).

Engineering Geology & Geotechnics of Slopes

GSM-IEM Forum
"Engineering Geology & Geotechnics of Slopes",

PROGRAMME

8.15 – 8.45 am	:	**REGISTRATION**
8.45 – 9.00 am	:	**OPENING REMARKS** by Tan B.K., Organising Chairman
9.00 – 9.30 am	:	Mark Wallace & Pang C.H. *(Arup)* Engineer inspections on slopes — methodology & technique
9.30 – 10.00 am	:	John K. Raj *(UM)* Failures at slope cuts in weathered schists of the Kajang area, Peninsular Malaysia
10.00 – 10.30 am	:	Han K.K. *(IKRAM)* Modelling rain-induced landslides
10.30 – 11.00 am	:	***COFFEE BREAK 1***
11.00 – 11.30 am	:	Chow W.S. & Zakaria Mohamad *(JMG)* Terrain mapping for landuse planning
11.30 – 12.00 am	:	Zainab Mohamed *(UiTM)* Challenges and engineering problems related to sedimentary rock slope: a case study
12.00 – 12.30 pm	:	Tan B.K. *(UKM)* Riverbank instability: some case studies in Sarawak
12.30 – 1.30 pm	:	***LUNCH***
1.30 – 2.00 pm	:	Neoh C.A. *(Consultant)* Slope protection: specification, design and construction aspects
2.00 – 2.30 pm	:	Ng C.N. *(Subsurface Eng.)* Some characteristics of tropical residual soils and their engineering significance
2.30 – 3.00 pm	:	Liew S.S. & Gue S.S. *(Gue & Partners)* Massive creep movements of post-glacial deposits in the Kundasang areas, Sabah
3.00 – 3.30 pm	:	***COFFEE BREAK 2***
3.30 – 4.00 pm	:	Wan Zuhairi WY *(UKM)* An investigation of the history and current activity of the Bournville landslide, Blaina Gwent, South Wales
4.00 – 4.30 pm	:	Haryati Awang *(UiTM)* & Mohd. For Mohd. Amin *(UTM)* Uniaxial deformation of unfilled and filled joint under compression
4.30 – 5.00 pm	:	Mokhtar Sheikh Mohamed *(Consultant)*, Azmi Omar & Mohd Zaidi MY *(JPZ)* Complex slope instability: the safe way to retreat
5.00 – 5.30 pm	:	Mun K.P. *(Tesonic)* Some piling problems as viewed by a pile testing professional
5.30 – 5.45 pm	:	**CLOSING REMARKS** by Mun K.P., Organising Co-Chairman

Thinking "Out of the Box" — the role of the geologists in meeting future energy demand

ROBBIE GRIES

Report (Report)

Robbie Gries, President of the American Association of Petroleum Geologist (AAPG) gave the above presentation on Monday 29 October 2001 at 3.00 pm at the Geology Department, University of Malaya. It was attended by about 40 participants.

Robbie has been active in the petroleum industry for 28 years, working initially for Texaco Inc., then Reserve Oil Inc. She is the founder and President of Priority Oil & Gas LLC.

After her talk she met and posed for photographs with members of the local AAPG Student Chapter.

Abstrak (Abstract)

The demand for oil and gas in the next century will greatly increase in the next few decades and reserves are limited. Converting vast amounts of "undiscovered" resources into proven reserves will require geologists "to think out of the box". This means looking at methods no one has tried before, looking for accumulations previously thought unlikely, and looking in places where others have overlooked or thought impossible.

This has never been easy, but it has been the key to giant new reserves being developed. Overturning the "dogma" that is currently favoured by explorationists with a new "heresy" has a history of difficulty. From the "anticlinal theory" in the 1880's to sequence stratigraphy in the 1980's, geologists have had to persevere to get an idea tested. The latest plays that have convincingly converted former "undiscovered resources" into "proven reserves" are basin-centered gas, coal bed methane, and sub-salt exploration. Some plays, like the early offshore Indonesian exploration, required not only creative geology, but unusual deal making.

Buying reserves or increasing reserves by merging with another company does not discover new oil and gas. Taking the risk to develop a new idea, to finance an unusual idea, and to drill is what will provide the supply needed in the next century.

G.H. Teh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5 27'88


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Petroleum Geology Conference & Exhibition 2001

19 - 20 September 2001

Mutiara Hotel, Kuala Lumpur, Malaysia

Laporan

The Petroleum Geology Conference & Exhibition 2001 was held on the 19–20 September 2001 at the Mutiara Hotel (formerly KL Hilton), Kuala Lumpur.

The Conference this year was declared open by Yang Berhormat Datuk Lim Haw Kuang, Chairman of Shell Malaysia, the first time a non-PETRONAS or non-Government official is the guest of honour. In his Opening Address, Datuk Lim noted that the challenges facing the oil industry had become more global in nature, where the concept of global teamwork with the mega mergers of former rivals has resulted in the pooling of resources, funds and capabilities to give these giants a competitive advantage over the others. Technical innovation and the application of leading edge technologies, however, remain the key success factor in commercialising Malaysian projects.

In the Malaysia exploration scenario Datuk Lim predicted an increase in both exploration and development activities with the hope of seeing more success and discoveries in the future even though the risk for large hydrocarbon discoveries is increasingly more difficult and illusive.

There were 23 technical papers presented over 4 sessions. The keynote paper was on "A new play type in the Western Malay Basin: the West Malay Basin/J-L/stratigraphic play" by David Abrahamson, General Manager of Amerada Hess. In addition there were 10 posters on display. There were also 23 Exhibition Booths which were well decorated, displaying current and latest technologies available in the market.

This 23rd Petroleum Geology Conference & Exhibition once again turned out to be a very successful gathering of over 300 participants. The Organising Chairman, Nordin Ramli and his Organising Committee should be congratulated for a job well done.

G.H. Teh

Petroleum Geology Conference & Exhibition 2001

19 - 20 September 2001

Mutiara Hotel, Kuala Lumpur, Malaysia

Welcoming Address by Prof. Madya Dr. Abdul Ghani Mohd Rafek, President of Geological Society of Malaysia

Yang Dihormati Tuan Pengerusi Majlis,
Yang Berhormat Datuk Lim Haw Kuang
Pengerusi Shell Malaysia,
Yang Berusaha, En. Nordin Ramli
Pengerusi Jawatankuasa Penganjur,
Persidangan Geologi Petroleum 2001,
Para Jemputan,
Ahli-ahli yang berhormat,
Rakan-rakan Geosaintis,
Tuan-tuan dan Puan-puan para hadirin yang dihormati sekalian,

Assalamualaikum dan Salam Sejahtera,

Saya bersyukur kepada Allah SWT kerana dengan limpah kurniaNya dapat kita bersama pada pagi yang indah ini. Memandangkan penyertaan antarabangsa pada pagi ini, izinkan saya meneruskan ucapan saya dalam Bahasa Inggeris.

A very good morning Distinguished Guests,
Fellow Geologists,
Ladies and Gentlemen,

On this pleasant morning, I would like to wish you all "Selamat Datang" and extend a very warm welcome on behalf of the Geological Society of Malaysia to the 23rd Petroleum Geology Conference & Exhibition, an event which is traditionally held in Kuala Lumpur. I would also like to thank Datuk Lim Haw Kuang, Chairman of Shell Malaysia for taking time from his busy schedule to be with us today morning and to officiate this morning's Conference & Exhibition.

The Petroleum Geology Conference & Exhibition is one of the two major conferences organised by the Geological Society of Malaysia. This Conference & Exhibition is traditionally held in Kuala Lumpur, whereas the Annual Geological Conference is held at different venues throughout the country every year. At this year's Petroleum Geology Conference & Exhibition, a total of twenty-eight (28) papers will be presented, 22 as oral presentations and 6 poster papers. The latest developments in the petroleum industry, in particular exploration and development will be discussed here over the next two days. The exchange of scientific and technical informations, and the sharing of experiences that has become a tradition of the Petroleum Geology Conference & Exhibition is expected to be further enhanced with the excellent papers covering a wide spectrum of topics on Petroleum Geology.

Ladies and Gentlemen,

I would like to take this opportunity to report on some of the latest developments regarding the "Registration of Geologists Bill". This bill is now in its final stages and one of its main aims is the registration of individual geologists and to regulate their activities. A number of meetings have been held by the Council of the Institute of Geology Malaysia, lead by its President Dr. Chu Ling Heng (who is also the Director General of the Department of Minerals and Geoscience, Malaysia) with the legal adviser to the Ministry of Primary, Industries as well as the Attorney General's Chambers to finalise the bill. At the same time, the IGM Council is also drafting the regulations which will be forwarded to the legal adviser of the Ministry. I have been told that the bill itself is in its final stages and is expected to be tabled in Parliament soon.

Ladies and Gentlemen,

Such a Conference & Exhibition is not possible without the involvement and help of many parties. Please allow me this opportunity to thank:-

- Yang berhormat Datuk Lim Haw Kuang, Chairman of Shell Malaysia,
- the organisations and companies who have sponsored or contributed to this Conference & Exhibition,
- the contributors and authors of the technical and scientific papers,
- En. Nordin Ramli and his Committee,
- and to all the participants here.

Lastly, ladies and gentlemen, please accept my most humble apologises for any shortcomings of this Conference & Exhibition, and do also take the time to enjoy some of the sights and pleasant experiences that Malaysia has to offer, particularly those amongst you who are here for the first time or back after some years.

Thank you.

Petroleum Geology Conference & Exhibition 2001

19 - 20 September 2001
Mutiara Hotel, Kuala Lumpur, Malaysia

Opening Address by Y. Bhg. Datuk Lim Haw Kuang, Chairman of Shell Malaysia

Yang Berusaha Dr. Abdul Ghani Mohd Rafek
President of Geological Society of Malaysia,
En. Nordin Ramli
Chairman, Organising Committee
Petroleum Geology Conference & Exhibition 2001,
Distinguished Guests,
Ladies and Gentlemen,

Greetings and a very good morning to all of you.

I would like to extend a warm welcome to all of you. To our foreign guests, I wish you "Selamat Datang" to Malaysia. I am sure you would enjoy the warm weather during your stay in our country. It is indeed my pleasure to be present here amongst prominent geoscientists and experts of the oil and gas industry and to deliver the Opening Address in the Petroleum Geology Conference & Exhibition 2001 organised by the Geological Society of Malaysia. In fact, I feel very honoured to be given the opportunity to be here today because I was made to understand that this is the first time the guest of honour of this event was extended to a non-PETRONAS or non-Government official.

The work put in by the Geological Society of Malaysia to organise this annual petroleum geology conference with the objectives to promote new exploration ideas and geological concepts and even to just share the experiences within the petroleum fraternity is commendable indeed. I hope the aim of this Conference & Exhibition is also to enhance the understanding and increase knowledge of our geoscientists into an astute oil finders that can see much wider, deeper and clearer into the geological subsurface.

It is noteworthy that more than 300 participants are attending this year's Conference & Exhibition where 22 technical papers will be presented, including 10 poster sessions.

I am sure participants will also get the opportunity to listen to the latest technology being used in the search for hydrocarbons which is now extremely necessary in view of the diminishing size of our prospects to be explored.

Ladies and Gentlemen,

The challenges facing the oil industry have become more global in nature. Global competition for exploration and production is increasing as basins become more mature. All these are occurring within a background of increased environmental awareness by the exploration companies as environmental considerations are integrated into all operations. As we go into the new millennium, the concept of global teamwork with the mega mergers of former rivals has resulted in the pooling of resources, funds and capabilities to give these giants a competitive advantage over the others.

Ladies and Gentlemen,

Technical innovation and the application of leading edge technologies remain the key success factors in commercialising our projects. In Malaysia the implementation of new seismic acquisition and processing techniques such as Pre-stack Depth Migration (PSDM), 4-component (4C) and ocean bottom cable (OBC), and 3D visualisations have helped us gain better understanding and more accurate evaluations of our assets. More exciting technologies awaits us in the new millennium with the steady progress of innovative IT technology that will give us a more realistic 3D visualisations of our subsurface geology. Advances in communications and databases will enable us to remotely evaluate and explore prospects from anywhere in the world. In the new millennium, much of this can also be done from the comfort (and safety!) of our homes. Not forgetting peaceful by-products of recent high tech air wars that include airborne aeromagnetic surveys, satellite imagery and terrain mapping radars as they are also being utilised for oil and gas exploration purposes.

Ladies and Gentlemen,

As mentioned earlier, our basins are getting into a mature stage with the opportunity for exploration those obvious structural traps is now very limited. We know there is still substantial amount of hydrocarbons but they are reservoired in subtle, illusive and deep plays. I believe that innovative ideas and the application of leading edge technologies will enable companies to successfully explore, develop and produce these assets. The service sector is increasingly playing a more important role in providing these required technologies. Hence in this Conference & Exhibition, we have some 23 Exhibition Booths to display the current and latest technologies available in the market.

In the Malaysian exploration scenario we will see an increase in both exploration and development activities and we hope to see more success and discoveries in the future even though the risk for large hydrocarbon discoveries is increasingly more difficult and illusive.

Ladies and Gentlemen,

I would like to conclude by reminding my respected audience of geoscientists of that saying "oil is found in the mind of men" and you have to step up the pace of hydrocarbon exploration by using constructive new concepts coupled with technology and synergistic alliances between oil and service companies to ensure success. This Conference & Exhibition, I trust, will provide a sufficient opportunities to review all these. Lastly, I would like to take this opportunity to congratulate the members of the Organising Committee for their efforts in bringing about this Conference & Exhibition.

It is with great pleasure that I declare the Petroleum Geology Conference & Exhibition 2001 open.

Thank you.

Petroleum Geology Conference & Exhibition 2001

Petroleum Geology Conference & Exhibition 2001

Petroleum Geology Conference & Exhibition 2001

Petroleum Geology Conference & Exhibition 2001

19 - 20 September 2001

Mutiara Hotel, Kuala Lumpur, Malaysia

Programme

Wednesday, 19 September 2001

08.00 : ***Registration***

08.50 : Arrival of invited guests

09.00 : Welcoming Address by Prof. Madya Dr. Abdul Ghani Mohd Rafek, President of GSM

09.10 : Opening Address by Y. Bhg. Dato' Lim Haw Kuang, Chairman of Shell Malaysia

09.30 : ***Keynote Address:*** A new play type in the Western Malay Basin: the West Malay Basin/J-L/stratigraphic play
David Abrahamson (GM, Amerada Hess (M) Ltd.)

10.00 : ***Coffee Break****

Session 1 : Morning Session

Session Co-Chairmen:

Kurujit Nakornthap *(CEO, Malaysia-Thailand Joint Authority)*
Hoh Swee Chee *(XM, Petroleum Management Unit, PETRONAS)*

10.30 : ***Paper 1:*** The evolution and prospectivity of the West Luconia Delta, offshore Sarawak, Malaysia
David Mackertich (Amerada Hess (M) Ltd.)

11.00 : ***Paper 2:*** Identifying infill opportunities using time-lapse seismic technology at Irong Barat field: a case study
Lye Yue Choong (Esso Production Malaysia Inc.)

11.30 : ***Paper 3:*** Review of the hydrocarbon potential in Eastern Sabah offshore
Awaludin Harun and A. Rahman b. M. Eusoff (Petroleum Management Unit, PETRONAS)

12.00 : ***Paper 4:*** Borehole image log interpretation: making the most of your data and Realising the limits, an illustration using fluvial, shallow marine and Deep marine environments
Adriaan Bal, Jeremy Prosser and Kenrick van Noord (Baker Atlas GEOScience, Australia)

12.30 : ***Lunch*** *(sponsored by Schlumberger Oilfield Services)*

Petroleum Geology Conference & Exhibition 2001

19 - 20 September 2001

Mutiara Hotel, Kuala Lumpur, Malaysia

Programme

Wednesday, 19 September 2001

Session 2 : Afternoon Session

Session Co-Chairmen:

Martin Stauble *(XM, Sarawak Shell Bhd. / Sabah Shell Petroleum Co. Ltd.)*
Khairul Anuar Hussin *(XM, PETRONAS Carigali Sdn. Bhd.)*

14.00 : ***Paper 5:*** The petroleum system of the Balingian Province, Sarawak Basin
Ouzani Bachir and Wan Hasiah, A. (University of Malaya)

14.30 : ***Paper 6:*** 3D well planning in a collaborative environment: SF30 Field development drilling
Huw A. Davies, Klaas van Luik, Zaal Anuar Alias, Phan Fah Kiong and Richard Ngu (Sabah Shell Petroleum Co. Ltd.)

15.00 : ***Paper 7:*** Stacked hydrocarbon reservoirs in a low relief trap — Baram Delta
Md Yazid Mansor and Nasaruddin Ahmad (PETRONAS Carigali Sdn. Bhd.)

15.30 : ***Paper 8:*** The Malay Basin — play types of the past, present and future
Tan Bee Hoon (Amerada Hess (M) Ltd.)

16.00 : ***Coffee Break****

16.30 : ***Paper 9:*** Fluid inclusion screening of Central Luconia carbonates
Piet Lambregts (Sarawak Shell Bhd.)

17.00 : ***Paper 10:*** Application of high resolution biostratigraphy in the Malay Basin
Shamsuddin Jirim and Azmi Mohd Yakzan (PETRONAS Research & Scientific Services Sdn. Bhd.)

17.30 : ***Paper 11:*** Malaysia's new frontier — the Sabah Trough
Mohd Raji Yaacob (Murphy Sabah Oil Co. Ltd.)

18.30 : ***Evening Cocktail*** *(sponsored by Baker Hughes INTEQ (M) Sdn. Bhd.)*

Petroleum Geology Conference & Exhibition 2001

19 - 20 September 2001

Mutiara Hotel, Kuala Lumpur, Malaysia

Programme

Thursday, 20 September 2001

07.45 : 2nd day convenes

Session 3 : Morning Session

Session Co-Chairmen:

Jack L. Kerfoot *(SXM, Murphy Sarawak Oil Co. Ltd. / Murphy Sabah Oil Co. Ltd.)*

David Mackertich *(XM, Amerada Hess (M) Ltd.)*

08.15 : ***Paper 12:*** Sundaland half-grabens of Sarawak — implications
Charles S. Hutchison

08.45 : ***Paper 13:*** Improved facies and property modelling in Barton 3D static model
Nor Azuairi Che Sidik and Jelani Ranggon (Sabah Shell Petroleum Co. Ltd.)

09.15 : ***Paper 14:*** Stratigraphic framework and paleoenvironment interpretation of PM303 and adjacent areas, North Malay Basin
Azmi M Yakzan, Mahani Mohamed, M. Rapi M. Som (PETRONAS Research & Scientific Services Sdn. Bhd.), Ooi Chit Meng and Anyi Ngau (Shell Exploration and Production Malaysia)

09.45 : ***Paper 15:*** Discriminating hydrocarbons and lithology with seismic data in the Cakerawala Field, Malaysia-Thailand Joint Development Area (MTJDA), Block A18
Cathal Daly (Carigali-Triton Operating Company)

10.15 : ***Coffee Break****

10.45 : ***Paper 16:*** Depth induced impedance variations: implications for predicting lithology and fluid distributions, offshore Brunei Darussalam
Ronghe S. and Pambayuning, S. (University of Brunei Darussalam)

11.15 : ***Paper 17:*** Hydrocarbon discoveries and potential in the Malaysia-Thailand Joint Development Area
Vichai Assavarittiprom, Muhammad Adib Abdullah Hudi and Nuntasak Chenboonthai (Malaysia-Thailand Joint Authority)

11.45 : ***Paper 18:*** Strike-slip structural style in the Sarawak offshore: a case study
Christophe Gonguet (Sarawak Shell Bhd.)

12.15 : ***Paper 19:*** Assessment of fractured reservoirs: an overview
Mohamed Taha (Schlumberger Asia Solutions Center, Kuala Lumpur)

12.45 : ***Lunch*** *(sponsored by Geoeast (M) Sdn. Bhd.)*

Petroleum Geology Conference & Exhibition 2001

19 - 20 September 2001

Mutiara Hotel, Kuala Lumpur, Malaysia

Programme

Thursday, 20 September 2001

Session 4 : Afternoon Session

Session Co-Chairmen:

A. Jalil Mohamad *(Mgr, PETRONAS Research & Scientific Services Sdn. Bhd.)*

Azhar Hj Hussin *(Head of Geology Dept., University of Malaya)*

14.00 : ***Paper 20:*** The Miri Structure — a dextral strike-slip model
Mustaffa Kamal Shuib (University of Malaya)

14.30 : ***Paper 21:*** Sequence stratigraphic study and play fairway analysis of the Lower Goru/Sembar Formations and Mubarak Block, Pakistan
Ramlee Abdul Rahman (PETRONAS Carigali Sdn. Bhd.) and Sahalan A Aziz (PC(P)L)

15.00 : ***Paper 22:*** Formation evaluation in fresh water shaly sands of the Malay Basin
R. Grant Heavysege (Esso Production Malaysia Inc.)

15.30 : ***Paper 23:*** The Kinarut and Kamunsu fans: stratigraphy, architecture and remaining prospectivity in the Greater Kebabangan area
Colin J. Grant, Tim Johnson and John Voon (Sabah Shell Petroleum Co. Ltd.)

16.00 : ***Closing Remarks and Closing of Conference***

16.30 : ***Coffee* & Adjourn***

** Coffee Breaks sponsored by Landmark Graphics (M) Sdn. Bhd.*

Petroleum Geology Conference & Exhibition 2001

19 - 20 September 2001

Mutiara Hotel, Kuala Lumpur, Malaysia

Poster Session

1. Reduction of porosity in Baram sandstones: compaction vs cementation
Abdul Hadi Abd. Rahman (University of Malaya)

2. Migration-progradation tidal succession within the upper Nyalau Formation (Oligocene-Late Miocene) at Tanjong Kidurong, Bintulu, Sarawak
Abdul Hadi Abd. Rahman (University of Malaya)

3. Barton geological modelling: synergies with history matching
Mohd. Reza Lasman and Michael Tayok (Sabah Shell Petroleum Co. Ltd.)

4. SSB/SSPC's geophysics and subsurface IT services
Lee Teck Fui (Sarawak Shell Berhad)

5. Petronas' F38.1 discovery well: a remarkable cost saving and very efficient operational experience
Mohamad Kadir (Carigali-Triton Operating Company) and Abdullah Adli Zakaria (PRSS)

6. Seismic attributes analysis of deep reservoir in Erb West field
Wan Ismail Wan Yusoff, M. Firdaus A. Halim (PRSS) and Juhari Ismail (PETRONAS Carigali Sdn. Bhd.)

7. Sequence stratigraphic study of the Erb West field, offshore Sabah, Malaysia
Wan Ismail Wan Yusoff, Mohd Razali Che Kob (PRSS) and Aladin M. Nor (PETRONAS Carigali Sdn. Bhd.)

8. Suberinite: oil-prone maceral of Borneo coals
Wan Hasiah Abdullah (University of Malaya)

9. Influence of vitrinite types, facies associations and hydrocarbon generation on vitrinite reflectance analysis
Wan Hasiah Abdullah (University of Malaya)

10. Real-time formation evaluation from reliable, repeatable gas in mud analysis
Howard Smith and Yves Martin (Geoeast (M) Sdn. Bhd.)

Petroleum Geology Conference & Exhibition 2001

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Abstracts of Papers

Keynote Paper

A new play type in the Western Malay Basin: the West Malay Basin/J-L/stratigraphic play

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The oil industry and PETRONAS have recognised for some time that stratigraphic plays may exist on the flanks of the Malay Basin. Although the Malay Basin taken in its entirety may be considered a mature area, the western flank of the Basin has seen little drilling activity (Fig. 1). In fact, by the end of 2001 out of a total c. 360 wildcat and appraisal wells in the whole Malay Basin only one or two wildcats have been drilled in the Western Malay Basin J-L play area. This is not particularly surprising as historically the Malay basin has been a structural play.

The first exploration well was drilled in the Malay Basin in 1969. The first significant oil in the basin was discovered two years later in 1971 at both the Seligi and Bekok anticlines. During the 1970s and 80s exploration efforts were targeted at finding the more obvious structural traps, that is, the compressional anticlines. The exploration emphasis in the Malay Basin gradually shifted towards stratigraphic and combination traps. This was especially true on the northeastern flank, or ramp margin, of the basin. This shift in exploration emphasis was highly aided by improving exploration technology and better geologic understanding of the basin.

But what about today now that all the large obvious structures, i.e. the compression anticlines, have been drilled and many of the northeastern basin flank plays have been tested?

In 1997 PETRONAS introduced a new profitability-based PSC fiscal regime to revitalise Malaysian exploration activities. In 1998 the Malaysian government further stimulated the upstream petroleum industry by lowering the export duty on oil from 20% to 10% and the Petroleum Income Tax (PITA) from 40% to 38%. These combined actions by PETRONAS and the Malaysian government were successful in attracting new upstream players to Malaysia. These new entrants to the Malaysian upstream brought new and innovative ideas to exploration. Most of the blocks covered by the R/C PSCs include petroleum discoveries that had not been previously developed. Malaysian exploration activity has significantly increased since the new PSCs were implemented. The increase in exploration activity is already benefiting Malaysia in the short term and is expected to yield long term benefits.

Amerada Hess in early 1998 signed a PSC on Block PM304. During the evaluation of this block it was recognised that a significant portion of the western part of the block lies west of a major hinge line that forms a significant structural feature along a large portion of the western margin of the Malay Basin. The Tertiary units thin rapidly across the hinge line onto the western flank of the basin.

A relatively sparse grid of 2D seismic data existed on the western part of Block PM304 prior to the PSC being signed by Amerada Hess in 1998. Amerada Hess acquired additional 2D seismic data in mid 1998 across PM304, much of it on the western part of the block. It was quickly recognised that an area of 'bright spots' was showing up on several of the 2D lines in the hinge line area. These 'bright spots' appeared to be stratigraphically rather than structurally controlled. Amerada Hess decided to acquire a 3D seismic survey in the hinge line area to cover this, as well as other leads identified on the 2D data. The 3D data was acquired in mid 2000. Mapping of the 'bright spot' anomaly on the 3D data verified that the anomaly was a stratigraphic trap and not structural in nature (Fig. 2).

One possible geologic interpretation of the anomaly is that it is some type of near shore or shoreline lacustrine sand body complex that was deposited against an incised erosional escarpment (Fig. 3). Interpretations of the sand body ranged from it being a palaeo-shoreline beach or barrier bar, an alluvial fan delta, or fluviatile sand. The 'bright spot' anomaly may conform to an embayment in the erosional scarp. It was thought that the anomaly could be charged by hydrocarbons migrating updip out of the more central part of the Malay Basin towards its western margin (Fig. 4).

Based on the results of the 3D survey, this particular 'bright spot' anomaly was upgraded to prospect status and a wildcat well was approved to test the prospect. Amerada Hess drilled a test well on the prospect, in June and July of 2001. The initial results of the wildcat well are encouraging with both oil and gas encountered on test.

Are there other stratigraphic traps of this nature on the western flank of the Malay basin, possibly more subtle than the one recently drilled by Amerada Hess? What new technologies, analyses or ideas will be needed to pursue or define these prospects? These questions can only be answered by more exploration endeavours.

Paper 1

The evolution and prospectivity of the West Luconia Delta, offshore Sarawak, Malaysia

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The West Luconia (Rajang) Delta has seen little exploration activity compared to the other Tertiary Delta systems offshore Borneo. In part this may have been due to its location close to an international boundary but also might be due to a lack of well and seismic data on which to base interpretations. Another reason that it may have been under explored might also have been because of its other name — the 'Rajang Delta'. This implies that it has been solely sourced from the Rajang River which is today a muddy river draining predominantly argillaceous deposits. The name simply does not inspire exploration!

This under-explored delta system has all the makings of a major play fairway offshore Sarawak, sediment source, reservoirs, hydrocarbon source rock and abundant structures. Over the next few years as more seismic data is acquired and interpreted and exploratory wells are drilled we will surely understand more about this potentially prolific province.

Location and structural evolution

The West Luconia delta is considered to lie close to the north-western tip of Borneo (Fig. 1). Most of the published models show a sediment depocentre to the west of the Central Luconia Platform and to the east of the Natuna Arch. There is still debate about the structural evolution of Borneo but most models imply a counter clockwise rotation of Borneo through Miocene times. This coupled with the thought that there is a major lineament passing through this area make unravelling the structural and sedimentological history somewhat difficult.

Hydrocarbon Prospectivity

As with the Baram Delta, the West Luconia Delta is perceived to be a delta system in which the sediment has been derived from the 'highlands' of Borneo (Fig. 2). In the case of the Baram Delta this is the Crocker Range whilst in the West Luconia Delta it is perhaps a mixed sediment source. One of the principal sediment source areas for the West Luconia Delta is considered to have been the Schwaner Mountains or the calc-alkaline West Borneo basement which extends from the western part of Borneo eastwards to the Kutei Basin. Sediment is also likely to have been sourced from reworking of Palaeocene to Early Miocene clastic sediments (e.g. the Kayan Sandstone/Plateau Formation).

There is no shortage of structuration that might give rise to valid traps in the West Luconia province (Fig. 3). On the delta top growth faults forming large tilted fault blocks are abundant (Fig. 4). Deeper offshore, near the delta slope, a combination of sediment loading, listric thrust faulting and compressional inversion has given rise to 'toe thrusts'.

A number of different source rocks exist for the traps seen in this delta province. Like in the Mahakam Delta organic material is considered to have been transported with sediments (rivers, turbidites) into the offshore area. In addition there is the possibility of lacustrine source rocks being present in the area. Early Miocene to Oligocene sub-basins have been described further north in the South China Sea.

All in all the West Luconia Delta has all the makings of a major hydrocarbon province. Exploration to date has been limited (certainly on the Malaysia side of the border) and active operators have recently acquired acreage in the heart of this exciting province.

Paper 2

Identifying infill opportunities using time-lapse seismic technology at Irong Barat field: a case study

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This paper describes the results of a collaborative project between EPMI, Petronas/ Carigali and ExxonMobil Upstream Research Company in Houston. The project investigated the use of time-lapse analysis of legacy 3D seismic data to aid identification of infill opportunities in the Irong Barat field within the Malay Basin. Identification and capture of infill opportunities is critical for maximizing and optimizing reservoir management in this mature field.

The Irong Barat field lies approximately 175 km offshore Peninsular Malaysia in about 60 m of water. The field was discovered in 1979 and began production in September 1983. The first 3D seismic survey was acquired in early 1984 and a repeat survey using both OBC and streamer technologies was acquired in 1998. The main reservoir is the H-50 sandstone, a complex fluvial channel system, of Mid-Miocene age.

The depletion mechanism for the main fault block is gas cap expansion through gas injection. Production is via 3 rows of producers with 2 gas injectors. Gas injection began in late 1984.

ExxonMobil's approach to time-lapse seismic analysis is an integrated model-based approach, where the synthetic seismic response derived from a production history-matched reservoir simulation is compared with the actual seismic response. Before the synthetic and actual seismic response can be compared, the repeatability of the actual seismic data needs to be optimized to take account of differences that are due not to changing reservoir conditions, but to differences in acquisition and processing. In order to minimize these differences, or to improve the repeatability between the two data sets, the baseline survey data is equalized to the monitor survey. The equalization procedure involves several processing steps to balance the amplitude, phase, bandwidth and spatial positioning of the events in the baseline and monitor surveys. Once this is done, the resulting differences between base and monitor surveys can be investigated, compared with the synthetic differences and reconciled via integration with surveillance and production history data. Via this integrated approach between geoscience and reservoir engineering disciplines, updates to the reservoir model can be examined and opportunities identified.

In this project, a number of areas of potential bypassed oil have been identified. Current work is underway to examine these opportunities in line with the ongoing infill-drilling program and with forecast production from the existing production wells.

Paper 3

Review of the hydrocarbon potential in Eastern Sabah offshore

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Sandakan basin is the main sedimentary basin for hydrocarbon exploration in the open block SB305, Eastern Sabah offshore. The total aerial extent of this basin is about 40,000 sq km, with a major portion of it extending beyond Malaysian territory. A total of 12 wells have been drilled in this basin (on the Malaysian side) by various operators since 1970. Many related geological and geophysical studies have been carried out by these operators and a total of about 4,065 line km of seismic have been acquired since then.

Field study of the Dent Peninsula was carried out recently in an effort to further understand the geology of the Sandakan basin. The study emphasize more on the structural trend and reservoir rocks exposed in the Dent Peninsula to compliment the previous studies based on offshore data.

Studies on the seismic lines were carried out focusing on the structure of the prospects in this basin and their associated amplitude anomalies (Fig. 1). Several hydrocarbon indicators were observed and these indicators are correlatable to many of the oil and gas reservoirs identified in the wells. Some flat spots were found in several established structures such as Benrinnes, Dent South, while bright spots were also observed along some of the deep seated faults associated with the structures. Some of the lines with these hydrocarbon indictors were further processed for AVO.

Seismic events at the reservoir intervals from wells with hydrocarbon shows were correlated across the basin to study the distribution of the potential hydrocarbon accumulation. Anomaly distribution maps were generated and the anomaly distribution were compared with the identified reservoir of the prospects. Most of the prospects analysed seem to indicate high potential of hydrocarbon accumulation which were not fully tested by the previous drilling.

Review and integration of the old geological and geophysical data with the findings from the current seismic studies and some new information from the field study indicates encouraging hydrocarbon potential for the Eastern Sabah offshore (Fig. 2). This paper present and discuss these findings which is part of the study to evaluate the hydrocarbon potential of Eastern Sabah.

Paper 4

Borehole image log interpretation: making the most of your data and realising the limits, an illustration using fluvial, shallow marine, and deep marine environments

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The application and development of ichnofabric, architectural elements, and depositional process concepts to petroleum industry core studies is relatively advanced, and has demonstrated its usefulness in correlation, sequence stratigraphy and elucidation of depositional environments. Furthermore, acquisition and development of dipmeter and image log technology is equally advanced. However their usefulness for high level sedimentology remains under utilized. We too often limit our interpretations to locating and quantifying the dip and azimuth of faults and fractures, tectonic tilt, and palaeocurrent directions. Using examples, this paper demonstrates how we can realise the limits.

Fluvial deposits often result in high quality image/dipmeter datasets because of the absence of bioturbation. Therefore surfaces can often be differentiated into bed boundaries, set boundaries, coset boundaries, or cross bedding crucial surfaces that tell us something about bedform and channel geometry. The definition of the geometry of architectural elements in 3-D is crucial to interpretation of fluvial regimes. Depositional elements identified from dip-azimuth vector plots are firstly assumed to be in-channel sandy bars (macroforms), and "upgraded" to higher-orders (e.g. 5th-order main channel or 6th-order channel belt) if they can be convincingly correlated between wells. A geological model of a fluvial reservoir (Yodel-Echo NW Shelf Australia) is developed and subdivided on the basis of image log sedimentology for reservoir modelling (Fig. 1) and placement of development wells.

A shallow marine setting in the China Sea, illustrates the use of image fabric index (IFI), akin to the bioindex, for understanding environmental controls at reservoir and exploration scale. The inverse of the IFI mirrors wave energy. When the wave energy index is displayed opposite sandstone intervals over hundreds of metres, specific packages reflecting high- and low-stand deposition are identified. These indices, when combined with other dipmeter/image log techniques, provide a robust database when integrated with log and core information (Fig. 2).

Deep-marine mass-flow successions pose challenging problems for image-log interpretation due to the wide range of potential causes for sedimentary dips > 10°. Soft-sediment deformation structures, such as slump folds, offer a more reliable alternative to palaeocurrent study through the stereographic analysis of their fold axes (axial trends). In general, the axial trend of the majority of slump-folds are oriented parallel to the slope on which they were emplaced (cf. Woodcock). As such, palaeoslope orientation is merely a bipolar choice perpendicular to the fold axis. Imbrication planes near the base of the slump, filtered palaeocurrents, or other data may help to limit this result to one direction only. In the example shown (Fig. 3), an axial-trend walkout plot has been used to highlight major and minor palaeoslope orientations within a succession from SE Asia. Other than a distinct change in slope orientation, differences in palaeoslope strike may have other causes, such as in-channel slumping, slumping off the levee or simply rotation of the slump axis downslope. It is only by combining sedimentological study of the image with slump-fold analysis that the cause of fold-axis orientations can be better understood (Fig. 3).

Paper 5

Petroleum system of the Balingian Province, Sarawak Basin

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The Balingian Province is a proven petroliferous province with a Tertiary petroleum system (Mazlan and Abolins, 1999). Figure 1 is a schematic representation of the petroleum system of the Balingian Province, Sarawak, proposed in this study based on detailed evaluation of the coaly source rocks and interpreted in combination with published data. The Balingian Province is part of the Sarawak Basin which was a foreland basin during the Oligocene-Early Miocene times, and was subjected to active extensional and strike slip tectonics. During the Middle Miocene, the Sarawak Basin underwent a phase of compression, which resulted in the formation of the Balingian Thrust Belt. Later, the Sarawak Basin saw a coastal shelf progradation and passive continental margin outbuilding during the Middle Miocene to recent.

The Balingian oils are derived from Cycles I/II coal and carbargillite source rocks accumulated within a lower coastal plain deltaic sequences dominated by sandstones, shales, and thinly bedded sands and muds, thereby providing intra-formational source rocks, reservoirs, seals, and carrier beds. The onshore extension of these sequences is known as the Nyalau Formation. The coaly source rocks of Cycles I/II are dominated by higher land plant macerals. They are either vitrinite rich (> 80% vitrinite) or liptinite rich including 80 to 60% vitrinite, 15–25% liptinites such as suberinite, cutinite, bituminite, terpene resinite, sporinite and alginite. The dominance of the higher land plant character is also expressed by the geochemical parameters such as waxyness, widespread occurrence of oleanene, high Tm/Ts ratios, and high C_{29}/C_{30} hopane ratios. The originating flora is presumably a thick mangrove belt similar to that presently fringing the Sarawak coastline, which underwent a suitable burial history and adequate organic matter accumulations under tidal influence.

The coaly source rocks have reached early to mid-maturity with regards to the oil window, which is defined here for coals as being %Ro 0.4–1.2. Several features of early oil generation from coals were reported. Among these features are the occurrence of exsudatinite, micrinite, oil haze, oil droplets, framboids, changes of fluorescence intensity, and the impregnation of the epoxy resin by bitumen. The oil window of the Sarawak coals (%Ro 0.4–1.2) has a peak of generation between 0.5% and 0.7%Ro and is subdivided into two generation phases (i) An early phase %Ro 0.4–0.7 is induced by suberinite, bituminite and terpene resinite, and (ii) the second-generation phase %Ro 0.7–1.2 involves sporinite, cutinite, lipid resinite, alginite and other liptinitic macerals. The first phase of generation is more significant due to the abundance of the macerals suberinite, bituminite, and terpene resinite. By considering this for the Balingian Province a larger volume of source rock will have reached maturity and have generated liquid hydrocarbons.

The extent of primary migration is intimately related to the physical changes of coal during maturation. Primary migration passes through a minimum during the plastic stage. Prior to this minimum the first phase of primary migration is eased through the fabric of coal and by the development of hydraulic fractures (exsudatinite crack network). The increase of porosity and brittleness in the post plastic stage enhances the expulsion or the second phase of primary migration. The second phase of primary migration with a greater tendency for gas release is more considerable than the first one that yielded higher amounts of liquid hydrocarbon. Subsequent to expulsion, secondary migration proceeds through conduits materialised by the mesoscale fracturation. The structural complexity of the Balingian Province, the close association of the oil accumulations with the source rocks, and the lateral continuity of sand bodies seem more likely to favour vertical migration as the most effective charging mechanism with some lateral migration through the thinly bedded sands and muds.

Most of the traps in the Balingian Province are structural traps formed as a result of the Middle Miocene compressional deformation. They are E-W folds and structural highs. However, right lateral movements have influenced the structural trends that are close to the West Balingian Line, or Lines parallel to it (170 and/or 150), resulting in WNW trending anticline structures, which form some of the larger oil fields in the Balingian Province. In the east of the province, the major structures trend NE-SW and seem to be related to left lateral movements along the Anau Nyalau Fault or lines parallel to it (010 and/or 030).

Cycle I/II Balingian sandstones, are considered to be the most important reservoirs. They have porosities ranging between 15 and 32% porosity, which decline rather rapidly due to the basinal related compaction, cementation, and geothermal gradient. Furthermore, an internal shear is recognised in the Bintulu sandstones rich in organic matter that probably reduces their quality. Intraformational shale is considered as efficient cap rocks and seals. Faults cutting through this shale could become effective sealing faults, which lead to highly compartmentalised reservoirs, and therefore increase exploration risks and development costs. Reservoirs in Cycles I/II are oil bearing and those of Cycles III and younger are mostly gas bearing; this is probably due to migration, extent of the source rock, as well as the volume of hydrocarbon generated.

Paper 6

3D well planning in a collaborative environment: SF30 Field development drilling

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In December 2000, a Virtual Reality "jump-start project" was undertaken at a VR facility in Perth by the SF30 Subsurface team supported by SM-EP IT staff, Halliburton directional drilling consultant and Landmark Graphics consultants.

The integrated subsurface team was set the objective of conducting well planning for SF30 Field Phase I development (5 oil producing and 1 gas injection wells). On a broader scale SM-EP organizational objectives were to better understand the value of the immersive technology, as well as 'fast-track' the learning experience needed to support the SM-EP VR facility, which was planned to be opened in 2001.

In January 2001, SM-EP established a Virtual Reality facility formally known as Advanced Collaborative Environment (ACE) centre in Miri to support it's exploration and development efforts in Malaysia. The facility is equipped with a high-resolution projection system and stereoscopic image generator. The ACE centre enables multidisciplinary collaboration in an immersive environment promoting cohesive team decision-making towards a higher level of Operational Integration.

The ACE centre is now an integral part of SM-EP's workflow process and is routinely used to review exploration and production earth models, well objectives and designs, surface facility designs as well as hosting management reviews.

This paper will present the SF30 team learnings of working in a Virtual Reality facility including the need for data preparation, optimising workflows and establishing collaborative work practices to achieve optimal results.

Paper 7

Stacked hydrocarbon reservoirs in a low relief trap — Baram Delta

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The Baram Delta province hydrocarbon exploration began at the turn of 20th century onshore Miri. So far the onshore successful results are from Miri oil field itself and Asam Paya as well as those prolific giants made in neighbouring Brunei. Exploration activities moved offshore in 1957 with Siwa-1 well following the advent of marine seismics. Obviously then all the exploration targets were focused on large rollovers and hanging/footwall closures with large vertical reliefs exceeding 100 m and in some to more than 500 m. After many big oil discoveries, such as Baronia, Baram, Tukau, West Lutong, to name a few, these simple and big structural traps are practically exhausted. Hence, further potential in the delta requires exploring subtle traps.

Tukau Timur prospect is located between the oil producers Tukau and West Lutong (Fig. 1). The prospect was previously identified on vintage seismics by Sarawak Shell Bhd. A large swath of new 3D seismics acquired in 1999 by current operator Petronas Carigali Sdn. Bhd. and partner Sarawak Shell Bhd has further enhanced the trap configuration. The prospect comprises of three mapped culminations, one of which is a low relief fault bounded 3-way dip closure. This easternmost culmination ranked top among the three in terms of its trap integrity, resources volume as well as support of direct hydrocarbon indications. This low relief trap has a maximum vertical saddle-spill closure of less than 70 m and is named the Eastern Culmination.

The exploration well discovered stacks of hydrocarbon reservoirs of well developed sandstones. Down to total depth, 16 reservoirs are found to contain about 200 m nett interpreted hydrocarbons with average porosity and hydrocarbon saturation of 14% and 45%, respectively. A 600 m deeper and possibly overpressured section is expected to contain a further 3 to 6 hydrocarbon reservoirs. These reservoirs were deposited in a coastal fluvio-marine deltaic system within the West Baram Delta (Fig. 2). A majority of the hydrocarbon-bearing reservoirs are filled down to structural spill limit. A thick shaly foreset package in the upthrown fault block is believed to enhance the fault lateral sealing capacity. Excellent vertical retention is provided by intra-formational shales, some at only 2 m thick, within the closure.

The Western and Far-West culminations of the Tukau Timur complex are fault intersection traps with lateral seal risks (Figs. 3 and 4). These geological risks are further reduced based on positive results of the drilled Eastern culmination (Figs. 5, 6 and 7). These traps are expected to be drilling candidates in the nearby future.

Paper 8

The Malay Basin — play types of the past, present and future

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The Malay Basin, located along northeastern part offshore of Peninsular Malaysia, is one of the several hydrocarbon bearing Tertiary Basins discovered in Southeast Asia. Many of the simple anticlinal fields have now been discovered and exploration is starting to concentrate on subtle and/or stratigraphic traps, where the various trap styles become the critical factor on the success of a play.

Hydrocarbons were first proven in the Malay Basin in the early 60's and the first commercial oil discovery was made in 1969 through Tapis-1. The Tapis Field is located in the southeast depocenter of the basin. The field is a simple large inverted anticlinal trap. Following the discovery, other similar inversion features were targeted and a few more major fields such as Bekok and Seligi southeast of Tapis were discovered. A study of 20 fields drilled on the inversion structures indicates that most of these fields are large with a mean field size of approximately 300 MMBOE. In addition, 17 of the fields studied resulted commercial discoveries while the other 3 were sub-commercial, indicating that drilling on the simple inverted anticline has a low commercial risk. The result of this phase of exploration was that the cumulative hydrocarbon reserves in Malay Basin increased from about 1270 MMBOE in 1969 to 3500 MMBOE in 1972 (Fig. 1).

By the late 1970's and early 1980's, more complex inversion features were drilled with improved 2D seismic resolution, resulting in the discovery of a few large, more structurally complex fields such as Guntong, Tabu and Liang. 37 fields drilled on the faulted structures were studied and 26 or 65% of the fields were found to be commercial. The mean reserve of this trap type is lower, approximately 110 MMBOE, compared to the simple anticlinal traps. The relatively lower reserves of the play is most likely due to limited fault seal which had confined the hydrocarbon column. Despite of the faulted anticlines, fault dependent closures and basement drapes were also the exploration targets throughout late 1970s to 1990s but contribute to a much smaller total reserves (mean value ranges from 30 to 50 MMBOE each). Figure 1 shows the cumulative reserves through time from the beginning of the hydrocarbon exploration in the Malay Basin to recent. Figure 2 summarizes the number of wells drilled on various main trap types through time.

As fewer and fewer undrilled anticline structures were found in the Malay Basin, companies have started to look for new play types. Throughout the 1990's a handful wells have been drilled for pure stratigraphic traps. Most of these early wells were drilled on 2D seismic data where the trap/reservoir was not well understood. In the last few years companies have started to acquire 3D surveys which are permitting the better imaging of stratigraphic traps in areas where they had not previously been identified. The first quality 3D seismic surveys in the mid-late 1980's permitted the identification and exploration of more subtle features such as separate compartments and channels. More recently companies have acquired 3D seismic surveys as an exploration tool. These have been shot prior to any discovery to look for new play types/concepts (Fig. 3). Such surveys are currently being acquired in the Malay Basin.

The exploration history of the Malay Basin has spanned now 3 decades. Stratigraphic traps both within the basin and on its flanks, away from existing discoveries, may well sustain exploration for decades to come (Fig. 4).

Paper 9

Fluid inclusion screening of Central Luconia carbonates

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Fluid inclusion screening is a fast and cost effective technique, which has been used routinely in the oil industry for several years now. With this technique cutting samples are dried and crushed, fluid inclusion volatiles are released and then analysed in a mass spectrometer. This provides a log of palaeofluids and/or present day geochemistry throughout the stratigraphy. This reveals information on hydrocarbon composition, migration, seals and proximity-to-pay zones.

Historically in Central Luconia the Miocene carbonate build-ups have been the main exploration objective. The key risks associated with this play are the charge and retention risks as quite a number of structures were dry and nearby structures, in a similar geological setting, were gas-bearing. For the ongoing carbonate evaluation it is important to know if structures are dry due to "lack of charge" or due to "retention failure". This technique can provide a quick and cheap way to resolve some of these questions.

A pilot study has been carried out using eight wells as a calibration set. Of these wells 4 found a gas column, and one of these is suspected to be a blown trap. The 4 other wells are basically dry.

The results of the fluid inclusion analysis had an excellent fit to the well and seismic data. Clear indications for top seal failure, lateral seal failure and the liquid content of the gas have been observed and reasons for failure of the dry wells were established. As a consequence this dataset provides a good calibration for future work.

This technique can help us to better understand the hydrocarbon habitat of the Central Luconia carbonate play and it is recommended to analyse more (dry) wells in the future.

Paper 10

Application of high-resolution biostratigraphy in the Malay Basin

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High-resolution biostratigraphy is a technique that utilises bioevents of field-wide chronostratigraphic significance. The bioevents reflect the quantitative changes of microfossil assemblages, such as top increases, base increases, and acme events. They are the result of physical and chemical fluctuations in the oceanic water mass through time. Some of them are due to climatic fluctuations and ecological changes in the habitats of upland vegetation. Both marine- and terrestrially-derived microfossil assemblages record these changes in the accumulating sediments as bioevents, which can be interpreted and correlated throughout the field.

By carefully identifying and documenting bioevents, more candidates for correlateable datums can be defined, rather than relying on evolutionary appearance and extinction of certain taxa. This is illustrated in the hypothetical microfossil distribution (Fig. 1) where nine bioevents can be recognised as compared to only two from using a traditional evolutionary or extinction approach. When integrated with wireline logs and seismic data, such bioevents could provide a more accurate stratigraphic framework and allow detailed interpretation of depositional environments.

To illustrate the application of this technique, the results of a high-resolution biostratigraphic study in the JDA Area of the Malay Basin are presented (Fig. 2). The interval of interest consists of approximately 430 m of paralic sediments of Sequence III, II, I and 0. The sediments contain abundant terrestrially-derived palynomorphs, whereas benthic foraminifera and nannofossils are poorly represented.

Each recorded bioevent has enabled further refinement of the earlier regional broad age subdivisions. Three biozones PR13A, PR13B and PR14 of the PRSS Biozonation Scheme (1997) were recognised. These suggest that the age of the studied interval is Middle to Late Miocene. It can be observed that the tops of PR13A and PR13B zones closely coincide with middle Sequence II and lower part of Sequence 0, respectively, in all wells.

By integration of biostratigraphic data with wireline logs, depositional environments can be interpreted and correlated across the wells (Fig. 2). The correlation indicates that the three wells were always within the reach of brackish tidal influence. Development of biofacies seems to be related to eustatic sea level changes. Sequence III and II were interpreted to have been deposited in a predominantly lower estuarine environment, whereas the overlying Sequence I and 0 were deposited in a more distal location in a predominantly distal lower estuarine to shallow subtidal environment. This could have resulted from a widespread marine transgression at the base of Sequence I, marking an extensive drowning of the underlying sequences. A strong fluvial influx is thought to have occurred at the base of Sequence I which led to the establishment of a muddy shallow subtidal environment.

Integration with marine benthonic pulses and wireline logs has identified potential flooding surfaces, which could provide potential correlative datums across the study area. Eight possible marine flooding surfaces, and their correlative surfaces, were identified. Of particular importance are flooding surfaces FS2 and FS3, which are associated with widespread marine transgression over the study area.

From detailed paleoenvironmental interpretation, depositional facies within the lower coastal plain may be differentiated. This permits the recognition of different sand and shale facies from which reservoir compartmentalization could be assessed. Distal lower estuarine to shallow subtidal muddy sands associated with strong fluvial influx are more dominant in Sequence I and 0 as compared to those in the underlying sequences. Shale, associated with widespread marine transgression such as at the base of Sequence I, is likely to be laterally extensive and if preserved could form a potential overhead seal or barrier to reservoir fluid flow. The other potential barriers, are more distal shales such as shallow sub-tidal shale, which have a greater lateral extent than those in an estuarine system. In contrast, shales deposited in an estuarine system may be laterally less extensive, thus acting as less effective baffles to reservoir fluid flow. The results of the study may be used to optimise both exploration and development of oil fields in the area.

Paper 11

Malaysia's new frontier — the Sabah Trough

MOHD RAJI YAACOB

Murphy Sabah Oil Co., Ltd.

Murphy Sabah Oil Co., Ltd. signed the Production Sharing Contract for Block K on 27th January 1999. The block covers an area of 16,496 sq km and it is located approximately 130 km offshore Kota Kinabalu (Fig. 1). It located within the Sabah Trough which is a major northeast to southwest trending bathymetric low with water depths ranging from 1,500 m to almost 3,000 m.

A series of NE-SW trending folds and associated thrusts are present on the continental slope within the block. The folds define the eastern margin of the Sabah Trough with some of the thrust anticlines forming a toe thrust zone. The western margin of the trough is formed by the downfaulted southeastern margin of the Sabah Platform, an area of shallower water depths which extends northwards towards the Dangerous Grounds (Fig. 2).

To the east of the Block K is the Sabah continental shelf which comprises a thick sequence of Neogene clastics which are up to 12 km thick within the Baram Delta. The self has been divided into an Inboard and Outboard Belt. The Inboard Belt is bordered to the east by the outer belt of the Rajang Group Fold and Thrust Belt, comprising a series of imbricated deep water flysch sediments which developed as an accretionary wedge complex during the Palaeogene and earliest Neogene.

Stratigraphy for Block K can be divided into four stages. Stage I (Eocene to Cretaceous Basement), Stage II (Oligocene), Stage III (Lower Miocene) and Stage IV (Middle Miocene to Recent)

Block K is located in a proven petroleum system in the emerging deepwater sector of Borneo, as demonstrated by recent deepwater wells in Sabah and Brunei. One of the significant reservoir potential within the block comprised of Basin Floor Fan turbidite sequences. Thick highstand shale and hemipelagic muds provide an excellent top seal. Migration can occur either cross-strata or via fault deep seated. Structural traps are very obvious on block K that is a key element to prospect definition.

Source rocks can be either from reworked terrestrial sediment or from lacustrine source in the underlying half-grabens. There are few trapping styles within the block, Pop-Up structures formed by movement along back-thrusts due to compression, sub-thrust where sediment traps underneath the thrust and large toe-thrust anticlines.

The seismic database for block K comprised 6,000 line km of 2D seismic lines. This year, Murphy is acquiring more than 3,400 sq km 3D seismic and with onboard processing we believe we can start the drilling program by second quarter 2002.

Paper 12

Sundaland half-grabens of Sarawak — implications

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By end Cretaceous-Palaeocene, Sundaland was a large continental peninsular landmass, which extended from Sumatra, Vietnam, China and the Malay Peninsula as far southward as Java and eastward to Bali and western Sulawesi. It was on this continent that rifting, in the form of half-grabens, progressively developed from the Late Eocene through the Oligocene. These were the important non-marine beginnings of oilfields widely scattered from the Pearl River, Gulf of Thailand and Malay Basin in the north, to the Tanjung of the Meratus and Kangean of the Java Sea in the south.

Sarawak west of the fundamentally important **West Balingian Line** (Fig. 1) was an integral part of this landmass; a fact not sufficiently recognized. The regional significance of this line has been obscured by the over emphasis placed upon the Lupar Line. The region west of the West Balingian Line has inexplicably been named the "Tatau Province" by Petronas. It has no connection with Tatau and should have been named the Mukah Province.

The Penian, Sirik and Patok highs of this province represent an integral part of the Late Cretaceous–Palaeocene Sundaland land surface not inundated by the sea until the Middle Miocene. The cycle terminology of Shell, developed for the Baram Delta, has no relevance for this province, and the stratigraphy cannot be compared across the West Balingian Line: the Balingian Province to its east is a distinct geological terrane of contrasting stratigraphy and tectonic style.

The master faults of the Mukah Province trend NW–SE to WNW–ESE, downthrown to the west and south. These faults developed throughout Sundaland. The Late Eocene to pre-Middle Miocene half-graben fill is non-marine and may be as thick as 5 km. General marine inundation occurred only after Middle Miocene sagging.

Similar half grabens also simultaneously developed upon the uplifted Rajang Group of the Sibu Zone. This was possible because the Late Eocene Sarawak Orogeny uplifted the Rajang Group in a collision zone to become an integral part of the Sundaland landmass. Although the half grabens upon the offshore Sibu Zone (Rajang Group) generally contain less than 1 km of sedimentary fill, the Soikang Basin near Natuna is more comparable to the deeper basins of the Mukah Province. Coal-bearing basins occur upon the uplifted Rajang Group, for example at Merit-Pilah. Their stratigraphy is conventionally assigned to the Oligocene-Lower Miocene Nyalau Formation, but unless palaeontologically proven, they are more likely to be Upper Eocene and to correlate with the Silantek Formation.

The Ketungau Basin of Kalimantan is not unique. The Lupar Fault is its master fault (Fig. 2) identical to the Sirik and S.W. Luconia faults of the Mukah Province and the unnamed faults of the Sibu Zone. To the west of the Lupar Fault is a half graben, which contains the Late Eocene– ?Oligocene non-marine Silantek and Plateau Sandstone formations. The Lupar Fault occurred close to a line of ophiolite within the Rajang Group, causing its prominence in regional syntheses. But we do not know what zone of weakness controlled the geographical position of the other master faults lying beneath the South China Sea. The Ketungau Basin (Mandai and Melawi of contiguous Kalimantan) developed on a region of interior Borneo that, as shown by the Silantek Formation, was uplifted by Early Miocene and never completely inundated by the sea.

It is commonly held that a region such as Sundaland needed to have been reduced to low elevation or peneplained before the extensive development of Late Eocene extension and rifting. A much better terminology for the half-grabens is intermontane basins. They are flat subsiding plains surrounded by mountains, as in northern Thailand. It is preferable to envision the topography of the Basin and Range province of western North America, where basins close to mountains may even subside beneath sea level. The nearby ranges provided the erosional provenance for the sediments that progressively filled the active half-grabens. Long-range transport is a bad concept. Basin formation is a late-stage consequence of orogeny; the mountains are reduced by localized subsidence resulting in steep slopes causing accelerated erosion, a process now already initiated in the Tibetan plateau.

There is no longer a problem of the detrital diamonds (and gold) in western Sarawak and Kalimantan. It is usually stated that major rivers transported them far from China. This is unnecessary and likely to be wrong. The Late Eocene (and ?Oligocene) quartz-rich Plateau Sandstone (and Kayan Sandstone) were provenanced from the **nearby** mountains of Sundaland, such as the Penian, Sirik or Patok highs, that have since been denuded to fill the adjacent grabens.

The Rajang Group is more elegantly regarded as a thick sequence of Late Cretaceous to Lower Eocene turbidite, which filled in a deep marine Sundaland marginal basin. The term 'Proto-South China Sea' gives a false impression when referring to ophiolites of Sarawak (Lupar Line) and Sabah. Ophiolites are nowhere known to represent oceanic lithosphere, but only of uplifted fore- or back-arc basins (which include marginal basins), and those of Sabah have island-arc geochemical signatures. The provenance of the turbidite was from the nearby Sundaland continental landmass (some of which now exists buried under the Mukah Province).

The deeper parts of intermontane basins invariably become filled by turbidite. Marginal basins have an ephemeral existence, and their rocks are eventually squeezed between the bounding continents and sutured into the regional landmass. Although the Mekong River may have partly supplied sediment to the Rajang group, we must remember that the land across which the river system flowed is to be found buried beneath the Mukah province. It is simplistic to deduce that only the Central Luconia Province caused the elimination of the Rajang Basin. Before the Oligocene opening of the extant South China Sea marginal basin, there was no sea here whatsoever and continental Sundaland extended southwards all the way to Sarawak (interrupted only by a Rajang Group marginal basin). Evolutionary tectonic models generally have the weakness of being based upon present-day geography.

Paper 13

Improved facies and property modelling in Barton 3D static model

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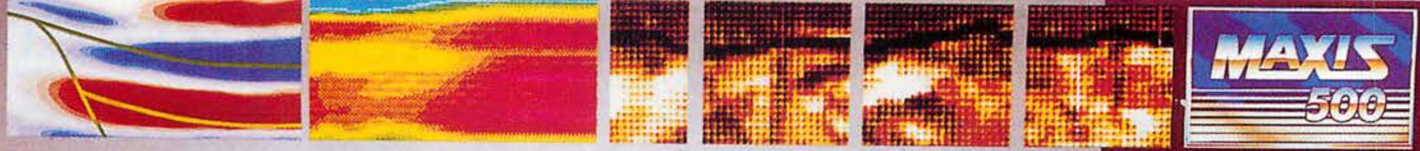
A good reservoir model requires detailed understanding of both structural and sedimentological controls that have impact on reservoir development and distribution. Knowledge of lithology distribution is important in field development planning to predict reservoir property trends. In Barton field where core data is limited, good calibration between lithofacies from core and wireline log properties will allow consistent facies calibration in the uncored wells, thus improved property modelling in the static model.

In Barton 3D static modelling study using GEOCAP, improved core to log facies calibration was carried out using Shell's proprietary neural net software NEUROLOGIC. The software integrates the core lithofacies with log based on a non-liner relation between geological properties and wireline log characteristics. NEUROLOGIC facies calibration showed good correlation between core lithofacies and electrofacies derived by the program, thus providing confidence for predicting facies distribution over the uncored wells.

In this paper, the approach in the use of NEUROLOGIC to perform core/log calibration will be discussed. In addition, key assumptions and results from the study will be highlighted.



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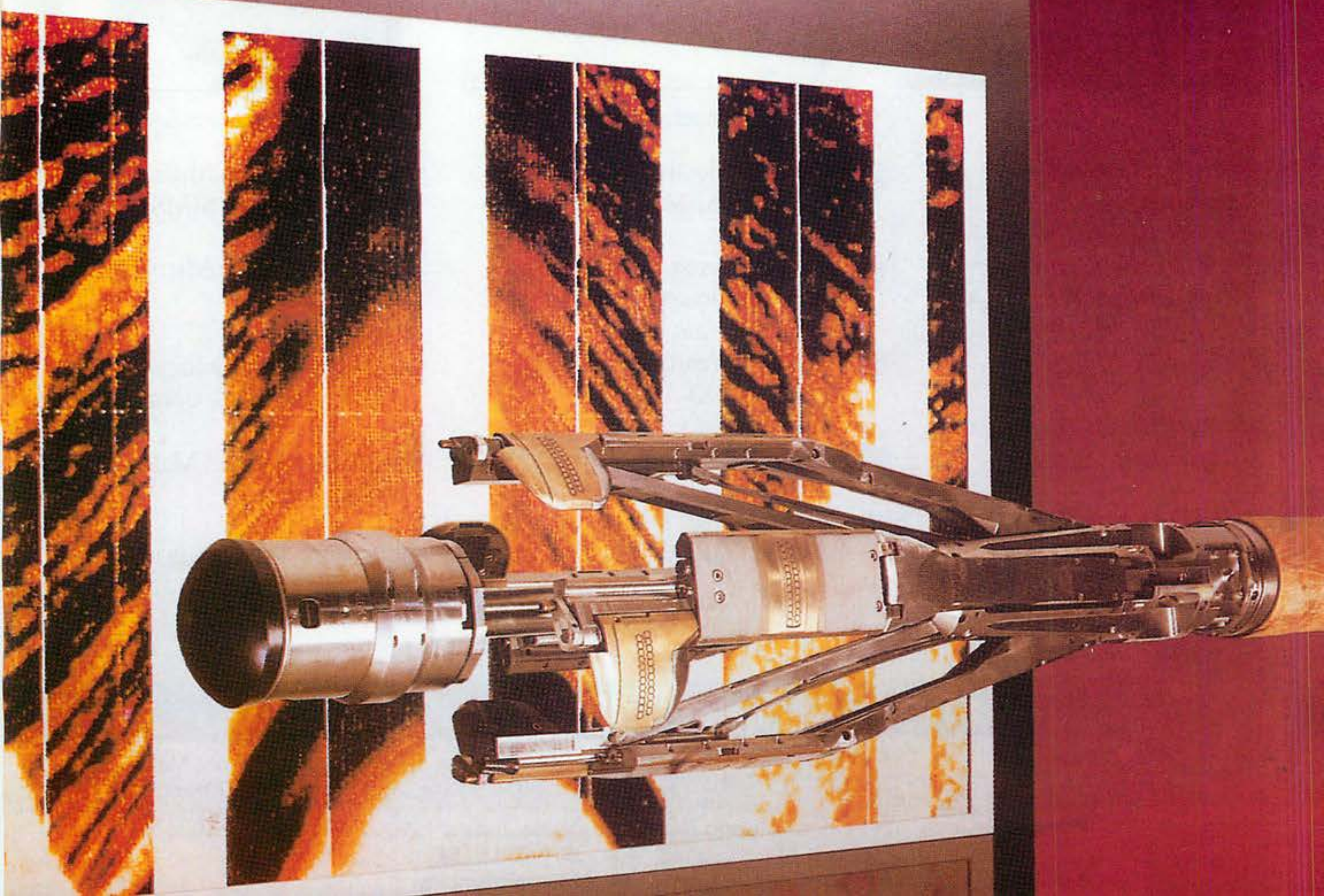

Paper 14

Stratigraphic framework and palaeoenvironment interpretation of PM303 and adjacent areas, North Malay Basin

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The stratigraphic framework and depositional environments of PM303 and its adjacent areas were re-assessed using selected well and regional seismic data, as part of a PRSS-SEPM joint study of the North Malay Basin. This paper presents some of the preliminary results from the joint study. Seismic interpretation was made on multi-vintage 2D data acquired in 1993, 1996 and 1997. Biostratigraphic data were reviewed using multi-source data that were generated in the 1980s and 1990s. In addition, new biostratigraphic data from three wells were also included.

The wells that were used in this study mostly penetrated the Groups A/B, D, E, F and H sediments in PM303. The older stratigraphic intervals were penetrated by several wells outside the block. Lower Group H sediments were deposited during late Early Miocene whilst the upper H was deposited during early Middle Miocene (Fig. 1). This is based on the occurrence of an intra-Group H, NN4/NN5 nannofossil zone boundary, dated as 16.2 Ma. This conclusion has enabled the subdivision of Middle and Lower Miocene sections of Group H in the study area. The Group F sediments were deposited during Middle Miocene. This is based on the recognition of the NN5/NN6 nannofossil zone boundary within upper Group F. The datum is dated as 13.5 Ma. Similarly, deposition of Group E sediments mostly occurred during the Middle Miocene, except for the uppermost part.

Within upper Group E, the last consistent downhole occurrence of the regional palynological marker, *Stenochlaenidites papuanus,* which has been dated as 9.5 Ma elsewhere in this region, suggests that this interval and the overlying Group D sediments are within the Upper Miocene. The age of the overlying Group B ranges from late Upper Miocene to Pleistocene. The base of Group B is bounded by a tectonically-induced regional unconformity, which is estimated to be 7 Ma old. This conclusion is based on the occurrence of N17 planktonic foraminifera zone and NN11 nannofossil zone, immediately above the unconformity. Within the study area, this unconformity represents about 1.5 Ma. These findings imply that the basal Group B Unconformity is an Upper Miocene event rather than Middle Miocene, as previously thought, and may be correlated to similar Late Miocene semi-regional unconformities in the West Natuna Basin, offshore Sabah and southern Vietnam.

Depositional environments in the study area were interpreted using a model that was based on published materials and a modern analogue. By taking into account of the wide, ramp margin nature of the basin, a relatively broad and gently-sloping coastal plain was assumed. The coastal plain bears very distinctive vegetation belts and may be further differentiated on the basis of their microfossil content and lithologic characters. For example, the lower coastal plain may be divided into front mangrove, back mangrove and fresh water/peat swamp, grading laterally in a fluvial system, to lower estuarine, upper estuarine and inter-tidal fresh water, respectively.

Seismic attributes associated with each depositional environment were identified to assist in the seismic facies interpretation. Generally, the coaly sequence in the fresh water swamp/ back mangrove/front mangrove environment is characterised by high amplitudes, high to moderate frequency and continuous seismic reflectors. Seismic reflectors in the coastal environment, however, are rather variable in amplitudes and discontinuous due to channel cuts. The inner shelf is indicated by moderate amplitude, moderate frequency and continuous to moderately continuous seismic reflectors.

Palaeogeographic maps were generated for Groups D to I, based on the integration of biostratigraphy, well sequence stratigraphy and seismic facies interpretation. Deposition of the pre-Group B sediments fluctuated predominantly within the fresh water/back mangrove and inner shelf environments. An inner shelf condition was most extensive laterally during Middle/ Early Miocene upper Group H times (Fig. 2). This is indicated by the widespread distribution of top Group H marine shale. This event is thought to be associated with the high eustatic sea-level phase. In contrast, during the latest part of Middle Miocene (middle Group E), a widespread development of fresh water/back mangrove swamp conditions across the entire PM303 area occurred (Fig. 3). The middle Group E palaeogeographic map indicates that the coastline was at its most distal location. This event is thought to be the result of the Middle Miocene regional sea-level fall.

Although broadly similar to and confirming the existing stratigraphic framework of the Malay Basin, the chrono-stratigraphic framework, established as part of the joint study, provides a better definition of the Base Group B Unconformity and a better understanding of facies distribution in PM303 and the adjacent areas. This chrono-stratigraphic framework and the facies distributions were used in the joint study, and provided better understanding and constraints for:

- The evaluation of the reservoirs and seals distribution,
- The evaluation of potential source rock development and distribution,
- The palinspastic re-construction and forward stratigraphic modelling of the study area, and
- 1D maturity and 2D basin modellings of the study area.

Paper 15

Discriminating hydrocarbons and lithology with seismic data in the Cakerawala Field, Malaysia-Thailand Joint Development Area (MTJDA), Block A18

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The Cakerawala field is located in the Malaysia-Thailand Joint Development Area (MTJDA), Block A18 approximately 150 km off the East coast of Peninsular Malaysia (Fig. 1). As is the case in many other gas fields in the Gulf of Thailand, seismic amplitude anomalies provide a highly effective means of finding hydrocarbons in Block A18. Since 1995, sixteen successful wells have been drilled in the block. In all cases the primary tool for identifying drillable targets has been the presence of seismic amplitude anomalies that have conformed to structure.

For the Cakerawala field development program the use of 3D seismic data has been extended beyond simple mapping of "bright spots" to include the full range of seismic analysis on multiple sub-volumes that is becoming the norm in our industry. Proper integration of well data and incorporation of the depositional model through the use of facies analysis at the well locations and the use of time slices and horizon slices between the wells forms the basis of this approach (Fig. 2). The seismic data provide both the structural framework for the reservoir model and the measurements of reservoir quality that have been tied to amplitude variations and to indicators of the depositional environment such as the horizon slices. In addition, seismic amplitude and estimates of acoustic impedance derived from seismic are used in a visualization environment to select the development drilling targets (Fig. 3). Geostatistical approaches that take account of the uncertainties in the relationships between seismic measurements and lithology and between lithology and both porosity and permeability are also incorporated in the methodology (Fig. 4).

Despite the success experienced with 3D seismic data, a number of significant challenges remain. In particular, success is hampered by the ubiquitous presence of shallow gas, by the limitations imposed by the resolution of the seismic data and by the presence of numerous thin coal beds that produce "false-positive" direct hydrocarbon indicator (DHI) responses.

Paper 16

Depth induced impedance variations: implications for predicting lithology and fluid distributions, offshore Brunei Darussalam

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Acoustic impedance (the product of rock density and the velocity of sonic propagation through rock) is the fundamental property that links together well geology and seismic data. Formation geology and fluid content define acoustic impedance, while seismic data responds to variations in impedance. But formation density and velocity of sonic propagation are affected by pressure and compaction. Hence acoustic impedance is sensitive to depth. With increasing depth, impedance characteristics of the formation change. The seismic response to lithology and fluid therefore changes with depth. Since seismic data and their attributes (including impedance) are often used to extract information regarding reservoir property and fluid distributions, it is important to know which of the fundamental petrophysical properties the seismic data is responding to at any depth. A study of acoustic impedance and its behaviour with depth is therefore crucial in determining what information can be extracted from seismic data.

This research studied the acoustic impedance characteristics of hydrocarbon bearing sheet sand reservoirs at various depths in a field currently under development (Fig. 1). Wireline sonic and density logs (Fig. 2) from this field show (1) trends that increase with depth, and (2) a separation between sand and shale packages. The separation narrows with depth and converges at around the onset of overpressuring, beneath which the sonic trend remains either constant or shows a slight reversal in the overpressured formation. Six hydrocarbon-bearing sand layers were selected for investigation (Fig. 2), chosen so as to sample the various sand intervals and pressure regimes in the formation. Wireline analysis of the sand layers included detailed cross-plots of the sands and surrounding shales (Fig. 3), and calculation of reflection coefficients at their upper interfaces. The wireline impedance logs were correlated with 3D seismic data via synthetic seismograms (Fig. 4). The seismic data volume was inverted into an acoustic impedance volume using the trace based constrained sparse spike inversion algorithm. Impedance maps were extracted for each sand from the seismic-derived impedance volume to study lateral impedance variations.

Integrated evaluation of the wireline, seismic and impedance volume data provided the following inferences. At structurally shallower levels, impedance varies independently and linearly with gamma-ray for sand and shale components. Hydrocarbon (gas) occurrence lowers sand impedance to unique, fluid discriminatory threshold values (Fig. 3, Sand A and Sand B). Overpressured shales occur relatively infrequently and have little or no influence on this impedance threshold. Impedance therefore works as both an indicator of lithology as well as fluid type. Inverse modelling results in pseudo-impedance traces that agree very well with wireline impedances (Fig. 5, impedances below 7e+06 kg/m^3*m/s). At these shallower levels, impedance maps display areas of hydrocarbon occurrence very prominently, and in addition, reveal possible variations in reservoir type and quality, as well as indicate background regional impedance variations (Fig. 6, Sand A and Sand B). Maximum contrasts of acoustic impedance are provided by a normally pressured shale in contact with a gas filled sand. The seismic response to hydrocarbon is therefore a brightening of amplitudes.

With increasing depth, overburden effects reduce the impedance contrast between sand and shale, so that the potential of impedance to act as a discriminator of lithology decreases (Fig. 3, Sand C). Additionally, overpressured shales assume increasing importance. Hydrocarbon occurrence lowers impedance to values that are no longer unique. Low impedance overpressured shales progressively impinge below the gas-sand impedance threshold (Fig. 3, Sand D). The potential of impedance to act as a discriminator of fluid type therefore successively decreases. Inverse modelling still produces a good match between pseudo-impedance traces and wireline impedances (Fig. 5, impedances below 8e+06 kg/m^3*m/s). On impedance maps, areas of low impedance signifying hydrocarbon occurrence are not as prominently displayed as before, and overlap with areas of low impedance shale, thereby creating considerable interpretational uncertainty (Fig. 6, Sands C, D and E). The seismic response to tops of gas sands is marked less by amplitude brightening and more by a reversal in waveform polarity. Overpressured shales in contact with clean sands would create similar seismic responses.

As overpressuring becomes pronounced with increasing depth, the interference between gas-sand and soft shale increases until there is complete overlap in their impedance values (Fig. 3, Sand E). At completely overpressured depths, impedances overlap for all types of lithology and fluid (Fig. 3, Sand F). Impedance responds, not to fluid type, but to fluid pressure instead. The occurrence of overpressuring is unpredictable and discordant to stratigraphic dip. Both seismic and wireline data quality may be adversely affected in overpressured formation. Inverse modelling shows a deterioration in agreement between the derived pseudo-impedance trace and the corresponding wireline impedance log (Fig. 5, impedances above 8e+06 kg/m^3*m/s). Impedance maps provide no indications of lithology or hydrocarbon (Fig. 6, Sand F). The seismic data, at this depth, responds to pressure and not to lithology or fluid type.

This analysis has considerable implications to hydrocarbon production and further exploration in Brunei The focus for further exploration in Brunei is shifting to the deep water environment. The principal data for deep water exploration is seismic. In Brunei, the top of undercompaction related overpressures is encountered at subsequently younger (and therefore shallower) stratigraphic levels from the onshore to the distal offshore. Hence overpressure induced uncertainties will manifest at progressively shallower depths offshore on seismic data. In addition, the onset of overpressuring is lifted to shallower levels along deltaic growth fault associated roll-over anticlines. Where the seismic response to overpressuring is a brightening of amplitude and where this brightening occurs conformable to anticline structures, considerable potential exists for misinterpreting the cause of the amplitude brightening to be the occurrence of hydrocarbon.

This study has demonstrated that the inverse modelling derived impedance volume can, at shallower levels, separate out fluids but has limited potential in differentiating lithology. With increasing depth, the capacity of impedance to separate out both lithology and fluid distributions decreases as a result of overburden effects and overpressure induced uncertainties. Direct hydrocarbon indicators on seismic data change from amplitude brightening at shallower levels to polarity reversals at deeper levels with increasing uncertainty brought about by overpressured shales. Full stack seismic data is increasingly inefficient in differentiating between sand and shale, and between gas-sand and low impedance shale. Alternative data and workflow are required. These may include comparison of Vp/Vs ratios for the different lithology and fluid combinations, analysis of angle dependent impedance (elastic impedance), and stochastic simulations of lithology and porosity distributions using the impedance volume as guide. Impedance, in combination with offset data and/or alternative workflows may still constitute an important tool in obtaining lithology and fluid distributions to build reservoir models that aid development and production.

Paper 17

Hydrocarbon discovery and potential in the Malaysia-Thailand Joint Development Area

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In a unique joint effort to explore and exploit hydrocarbon resources in the overlapping continental shelf claimed by the two countries by the Governments of Malaysia and Thailand, the Memorandum of Understanding between the two countries was eventually signed in 1979 establishing the Joint Authority and designating the Joint Development Area (JDA) concept. This historic event then spurred continuous exploration efforts in the JDA. Since signing the Production Sharing Contracts (PSC) in 1994, a total of 11,910 line km of 2D seismic, 3,104 sq km of 3D seismic were acquired and a total of 29 exploration/appraisal wells were drilled by Carigali Triton Operating Company (CTOC), operator for Block A-18 and Carigali-PTTEPI Operating Company (CPOC), operator for Blocks B-17 and C-19 in the JDA. These exploration efforts by the two operators have resulted in the discoveries of 15 gas fields together with 5 minor oil accumulations.

This paper intends to discuss and review these past discoveries in relation to their geological occurrences and petroleum systems since they are located significantly in the northern part of the oil and gas prolific Malay Basin. In contrast to the central Malay Basin proper where oil and gas are both significant in almost every find, the JDA to date, is believed to be more gas prone. Nevertheless, the fact that some oil has been discovered, has proven generation of oil although small in quantities in the JDA, would warrant a more challenging investigations. Several trap playtypes are prominent in the JDA while some new frontier playtypes would possibly be the next targets of hydrocarbon exploration.

Introduction

The Malaysia-Thailand Joint Development Area is located offshore in the lower part of the Gulf of Thailand and covers an area of approximately 7,250 sq km (Fig. 1). The area consists of three exploration blocks namely Block A-18 which covers 2,940 sq km, Block B-17 covers 3,740 sq km and Block C-19 covers 570 sq km. Block A-18 is currently being explored by Carigali-Triton Operating Company Sdn. Bhd. (CTOC) while Blocks B-17 and C-19 by Carigali-PTTEPI Operating Company Sdn. Bhd. (CPOC).

A Memorandum of Understanding (MOU) was signed on 21 February 1979 between Malaysia and Thailand to jointly explore and exploit the JDA. Subsequently, the Malaysia-Thailand Joint Authority (MTJA) was established, with its Board comprising of equal representatives from both the Malaysian and Thai governments. This authority is vested with the exclusive rights, powers, and privileges of exploring and exploiting the non-living natural resources, in particular petroleum, in the JDA. The MTJA Agreement, 1990 between the two Governments and the enabling Legislation, the MTJA ACT 1990/B.E2533, form the foundation on the powers, functions and responsibilities of MTJA.

In April 1994, MTJA awarded two Production Sharing Contracts (PSC) in the JDA to two groups of contractors i.e. i) Petronas Carigali (JDA) Sdn. Bhd., Triton Oil Company of Thailand (JDA) Ltd. and Triton Oil of Thailand Inc. for Block A-18, and ii) Petronas Carigali (JDA) Sdn. Bhd. and PTTEP International Limited for Blocks B-17 and C-19. Together, the contractors formed a joint-venture company to act as operators in their respective contract areas, Carigali-Triton Operating Company Sdn. Bhd. (CTOC) for Block A-18 and Carigali-PTTEPI Operating Company Sdn. Bhd. (CPOC) for Blocks B-17 and C-19.

Regional Geology

The JDA is located in the northern part of the Malay Basin which is a Tertiary rift basin, elongated in shape, oriented in the northwest-southeast direction. The basin contains thick, in excess of 8 km, sedimentary sequences which were deposited since as far back as Oligocene geological subperiod (or at least 38 million years ago).

The prominent structures in the area are tilted strata against north-south trending transpressional normal faults and listric faults which were related to dextral wrenching deformation from Oligocene and Early Miocene through Late Miocene. The tectonic evolution and basin development are divisible into syn-rift, post-rift and regional sagging periods (Fig. 2).

The sedimentary sequences in syn-rift period were deposited during the initial phase of basin opening by extensional tectonics in Early Oligocene (or Late Eocene) to Early Miocene. These sediments, which floored the basin are believed to be fluvio-lacustrine and lacustrine environments. The sediments change gradually from those of lacustrine to fluvio-lacustrine and to fluvial environments. The fluvial sediments implied the end of the rifting period.

The basin was then subjected to thermal subsidence during the Early to Middle Miocene. As a result, the basin spread and became gentle. The sediments were deposited in the fluvial-tidal-marginal marine complex, which consists of shale, thin laminated sand and coal streaks. During the Late Miocene, the basin depocenter was shifted to a north-south direction due to dextral strike-slip movement. As a result of this movement, several wrench related and inverted structures were formed.

Most of the hydrocarbon fields found in the basin are related to the structural inversion caused by this movement. The inversion also caused the development of a regional unconformity in Late Middle Miocene and marked the end of the Post-rift depositional megasequence.

After the regional unconformity, basin sagging and sediment loading occurred which induced the regional transgressions. The sediment was mainly composed of marine-inner neritic origin, which provided an effective regional top seal for hydrocarbon accumulation. Structuration in the JDA is related to tectonism during the Syn-rift and Post-rift periods. During the Syn-rift, extensional tectonics were predominant whereas transtensional and transpressional tectonics were prevailing during the Post-rift. Pre- Tertiary highs in the blocks generally are related to the rifting. However, structural closures formed during the Post-rift period to become the major traps in the blocks.

Stratigraphy

Stratigraphy in the JDA was established using data from drilling and seismic data, both 2D and 3D. The concepts of sequence stratigraphy combined with lithostratigraphy were generated based on the biostratigraphy, wireline log and well correlations.

Hydrocarbon prospectivity is focused in the Post-rift Megasequence where in Block A-18 thirteen main depositional sequence were identified while in Blocks B-17, six main depositional sequences were delineated (Fig. 3).

The Syn-rift megasequence is very deep and has not been completely penetrated by any wells in the JDA. The sequence, believed to comprise mainly of lacustrine sediments particularly in the deeper part, is Oligocene in age.

Petroleum System

Reservoir

The main reservoirs are sandstones of coastal deposits. For the main reservoirs the effective porosity range from 12% to 28% with respect to depth range of 1,000 m to at least 2,800 m and their thicknesses range from 1–5 m.

Source

Abundant source rocks exist in the area and in the Malay Basin. Shale and coal are the major source rocks in this area and the source rocks can be separated into two major groups as follows:

Intraformational Shale

They are carbonaceous shale and coal within the depositional units. Total Organic Carbon (TOC) range from 0.8–4% and kerogen type III is predominant with minor type II. Gross thickness of the interval ranges from 1.5–3 km and net (source rock) to gross ratio up to 35%.

Synrift Lacustrine

The Oligocene lacustrine shales of the early Syn-rift are probably oil prone source rocks. However, they may have generated significant amount of gas since they are buried at great depth. In general, oil accumulations are likely to be found on the basin flank or the older structure rather than the depocenter.

Seal

Shale and coal play the role of top seal especially the shallow marine shale deposited in the regional sagging period. Intermediate seals are intraformational shale and coal. The seals separate reservoirs into multiple reservoir systems, therefore, numerous hydrocarbon columns are found in the blocks.

Gas Discovery

Since signing of the PSC in April 1994, a total of 5,800 line km of 2D seismic data and 1,166 sq km of 3D seismic data were acquired in Block A-18 while a total of 6,110 line km of 2D seismic data and 1,938 sq km of 3D seismic data were acquired in Block B-17 (Fig. 4). A total of sixteen exploration/appraisal wells in Block A-18 and thirteen exploration/appraisal wells in Block B-17 have been drilled with success. These exploration efforts have resulted in eight gas discoveries in Block A-18 and seven gas discoveries in Block B-17 (Fig. 5). The fields are Cakerawala, Bulan, Suriya, Bumi, Bumi East, Senja, Samudra and Wira Fields in Block A-18 and Muda, Tapi, Jengka, Amarit, Mali, Jengka West and Jengka South fields in Block B-17.

To date a total of about 9 TSCF of gas reserves from 15 fields were discovered in the JDA.

Oil Discovery

Exploration in the JDA has been focused on gas as it was always deemed to be a gas only play. However, it must be pointed out that in addition to the fifteen gas discoveries, minor oil accumulations has also been discovered within the existing gas fields in the JDA. A total of five minor oil accumulations were discovered interbedded within major gas fields i.e. Cakerawala, Bulan, Senja, Samudra and Jengka. The total reserves discovered in the JDA is still small compared to gas but nevertheless the fact that oil is present and generated in the JDA would warrant further investigations.

Current and Potential Playtypes

Based on interpretation and subsequent discoveries, several playtypes are prominent in the JDA.

Structural Trap

Structural trap is the most common trap type in the JDA. Generally this trap type is related to or associated with faulting. Common examples of this traptype are the 4-way dip roll over and 3-way dip fault-bounded closures.

Combination Trap

This trap type is partly bounded by faults and partly by stratigraphic boundary (e.g. facies change). Trap mechanism analysis on gas fields in the JDA indicates that major gas sands penetrated could be categorized into this combination trap type.

Stratigraphic Trap

Meandering channel sands on the monocline-dipping flank in the eastern part of JDA can result in a stratigraphic trap. This is evidence in the nearby oil/gas fields in the Malay Basin. There are some channel bodies detected by amplitude anomaly, which could be related to hydrocarbon accumulations in the eastern flank. In all possibility there is a better chance of finding liquid hydrocarbon in this area. In the JDA, this playtype remain to be tested and further investigated.

Pre-Tertiary high

This is a frontier playtype that has been proven success in several Tertiary basins in Thailand and Vietnam. The anticipated Pre-Tertiary lithologies in this area are granite, metasediment and carbonates. It could be a promising potential for future exploration. However currently there is little or no data for further evaluation.

Conclusion

Since signing the first PSC in 1994 in the JDA, active exploration campaigns have resulted in the discoveries of substantial hydrocarbon resources in the form of fifteen gas fields and five oil accumulations. Although gas discoveries may be dominant in the JDA, further investigations indicate that the potential of finding oil is also promising. Understanding more on the petroleum system in the JDA particularly pertaining to the generation and migration of oil and further investigations of new playtypes would certainly open up new horizons in hydrocarbon exploration and exploitation in the JDA.

Paper 18

Strike-slip structural style in the Sarawak offshore: a case study

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In the Sarawak offshore, a deep structure has been mapped in detail from 3D data and has been recognised to exhibit a fault – horizon architecture consistent with left lateral strike-slip tectonics. Furthermore this feature was timed fairly accurately and the main deformation phase was shown to be related genetically to a late event of the Eurasian plate tectonics: the drifting of the Luconia platelet towards the southeast and its rotational collision with the Borneo plate on its Rajang subduction margin.

It will be shown how the characteristic features of a left lateral strike-slip system were identified, then how the cause of deformation was placed in the context of the regional tectonic history. The relation of this structure with neighbouring geological features will be described and a short elaboration will be provided on the hydrocarbon prospectivity of such features.

Paper 19

Assessment of fractured reservoirs: an overview

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Recent hydrocarbon discoveries in Basement rocks over the different parts of the world have demonstrated that fractures can be solely responsible for the making of a producing reservoir (Fig. 1).

Fractured reservoirs are commonly thick, porosity is mainly secondary, the distribution of porosity and permeability is irregular, and production varies greatly. They may or may not have a common hydrocarbon/water contact. Among themselves, they illustrate great differences in their hydrocarbon storage capacity and they may drain juxtaposed hydrocarbon bearing formations.

Effective fracture networks are of tectonic origin (Fig. 2). Different sources of stress often create different types and distribution of fractures (Fig. 3a & 3b). Recognizing the structural style and the stress regimes of sedimentary basins is very crucial to understanding the distribution and intensity of natural fractures. However, in fault related fractures, it is very hard to estimate the width of a fractured zone that is associated to a specific fault. In that regard, it is rather risky to intersect fault planes, as they tend to be open and may result in connecting well bores to aquifers.

The brittleness of host rocks is a function of several factors that include rock type, texture, grain size, porosity, temperature and the effective confining pressure. It controls the density, the morphology and the extension of fractures.

Other than borehole imagery data and oriented cores, most conventional logs are fracture detectors without any capabilities toward defining the hydrodynamic properties and attributes of fractures. Overbalanced drilling and associated deep mud invasion affects the accuracy of open-hole log data, generates pessimistic formation evaluation results and causes sever formation damage.

A proper study of fractured reservoirs begins with recognizing the geometry, origin, morphology, density, width, trace length and porosity of the fracture system. Knowing fracture dips and orientations is very crucial toward setting successful well trajectories in exploring and developing fractured reservoirs.

Assessment of fractured reservoirs requires an integrated effort in order to properly develop and drain these rocks (Fig. 4). Cores, borehole imagery, open-hole logs, well testing and production logging data (Fig. 5) integration are extremely important for thoroughly understanding and modeling fractured reservoirs.

Paper 20

The Miri Structure — a dextral strike-slip model

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Introduction: The Miri Structure

The traditionally accepted structural model for the Miri Structure is that proposed by Von Schumacher in 1941.

Based on previous studies and present field mapping, the structural elements (Fig. 1) associated with the Miri Structure include:

a) an asymmetric slightly overturned south-easterly verging anticline
b) a set of steep north-westerly dipping faults with predominantly normal throws (Shell Hill Faults)
c) a set of conjugate predominantly normal faults arranged in an *en-echelon* manner along the

Shell Hill Fault zone

d) a zone of moderate north-easterly dipping faults with predominant reversed throws but associated with similarly oriented faults with normal throws (Canada Hill Thrusts).

Previous workers recognized that it is not easy to fit all the 4 features into a single deformation mechanism. Therefore based on regional considerations, the Miri Structure was said to be a composite fault system. The Shell Hill faults and an associated normal fault was said to be a growth fault although evidence for a systematic thickening of the hanging wall block is absent. A later compressional event deformed the structure to form the Miri Anticline. It is the objective of this presentation to show that The Miri Structure evolved under a single progressive deformation by dextral strike-slip tectonics (Fig. 1).

The Airport Road Sections (Fig. 2)

Numerous northeasterly striking, steep southeasterly and northwesterly dipping faults with predominant normal throws associated with a series of gentle anticlines and synclines are exposed. On map view this formed a left stepping *en-echelon* arrangement to the Shell Hill Faults and laterally merged as splays to the Canada Hill Thrusts. On vertical sections these faults are conjugate in nature with a predominant normal throws but occasionally accompanied by reverse fault throws and dip reversals. On the fault surface the striations varies from down-dip to oblique to strike. Within the fault zones although normal slip shear planes predominates, reverse slip shear planes are not uncommon without clear-cut crosscutting relationships. Internal deformations within the fault blocks are characterized by small-scale normal faulting but associated with compressional structures such as small-scale thrust related anticlines and gentle synclines. The very small-scale faults predominantly exhibit typical negative flower structure geometry and those that exhibit typical reverse fault geometry are not uncommon.

The geometry of these structures suggests that the strata have undergone an extensional deformation associated with a significant strike-slip component. These structures are not typical of extensional deformation but fit into the geometry of shear fractures related dextral strike slip faulting.

The Hillside Garden Exposure (Canada Hill Thrusts, Fig. 3)

The strata have been deformed into an asymmetric slightly overturned southeasterly verging anticline. This structure is associated with 5 m wide NE trending fault zone exhibiting crosscutting and anatomizing northwesterly dipping faults showing both reversed and normal apparent displacements. The southerly bounding fault show a reverse apparent displacement but the northerly bounding faults shows an apparent normal displacement that gradually changed into reverse faults up section. A rare striation observed on one of the fault shows sub-horizontal striations and there can be no doubt about the strike-slip origin of the faults and anticline. Within the fault zone the strata have been deformed into tight asymmetric folds but outside the fault zone a box-like fold transverse to the fault zone is found.

The associations of minor structures in the exposure suggest that the Canada Hill Thrust is a dextral strike-slip fault zone.

Interpretation

Evidences for strike slip deformation associated with the Miri Structure include the presence of:

1. *En-echelon* normal fault arrangements along a major fault with dominant normal throw (Shell Hill fault), often accompanied by reverse fault throws and dip reversals along individual faults,
    - Conjugate fault systems (synthetic and antithetic)
    - Small-scale faults showing negative and positive flower structures

- Oblique and down-dip striations present

2. Canada Hill Thrust Zone
   - Dextral strike slip fault zone
   - Sub-horizontal striations
   - Fault zone associated with both compressional and extensional structure
   - Thrusts and extensional faults showing cross-cutting relationships
3. Present of push up block/ridge bounded by the Shell Hill fault and Canada Hill Thrust zone
4. Curved horse-tail configuration

Conclusions

The main conclusions from this investigation are as follows:

1. The 4 sets of structural elements associated with the Miri Structure are coeval.
2. They are the result of a progressive NNE trending dextral strike-slip deformational event.
3. Dextral strike-slip movement could have initiated early prior to lithification and continued after lithification.
4. Dextral strike-slip deformation could have commenced from Middle Miocene right up to latest Miocene to Pliocene times.

Paper 21

Sequence stratigraphic study and play fairway analysis of the Lower Goru/Sembar Formations of Mubarak Block, Pakistan

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The Mubarak Block is situated in the Middle Indus basin, about 300 km to the northeast of Karachi, Pakistan (Fig. 1). The main objective for exploration in this block is the Lower Goru/Sembar Formations of Cretaceous age. Sequence stratigraphy approach was used to better understand the depositional history of the Lower Goru/Sembar Formations and subdivide them into sequences and was subsequently used to model the possible play fairway. The study is based on well data, associated biostratigraphy, core reports, well completion report and about 3,000 line-km 2D seismic data of new vintages acquired in 1999, reprocessed and old data over the block area.

After the widespread deposition of the Chiltan Formation platform carbonate in the area, a deepwater basin was developed to the east of the block into which the Sembar Formation and Lower Goru Formation were deposited (Fig. 2). This progressive in-filling of the basin from the east resulted in sedimentary packages that show oblique and sigmoidal clinoform geometries on seismic. Well data corroborates this interpretation of basin in-fill where wells to the east of the block show gross intervals of about 1,000 m whereas the same interval is not seen in well Kandra-1 to the west of the block. In its place the zone is interpreted to be replaced by a thin condensed marine shale. It is then interpreted that sands encased in marine shale encountered in the deeper part of the basin was deposited as part of lowstand fan system and their correlative shallow-marine/non-marine facies was deposited to the east. Subsequent in-filling of the basin from the east to west deposited the majority of the Lower Goru sand in a narrow shallow-marine shelf setting.

Gross Depositional Environment maps were generated. This together with a geological model was used to predict lithofacies and lithologies. From these, a Common Risk Segment map, highlighting areas of common risks was generated. Play Fairway maps can then be constructed from a series of risk maps to show areas or corridors of low risk (Fig. 3).

Some general conclusions that could be reached are: (1) play fairways are relatively narrow and do not always stack vertically, (2) a number of stratigraphic prospects have been identified for different reservoir levels within the block and (3) there are no independent roll-overs in the block so all structural traps requires a minimum of three seals to be successful.

Paper 22

Formation evaluation in fresh water shaly sands of the Malay Basin

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Traditionally, formation evaluation in the Malay Basin focused on the silty nature of the reservoir facies. An assessment of water chemistry and salinity distribution has enabled EPMI to focus on the major cause of the low contrast pay — *fresh water*. This has lead to a systematic assignment of saturation calculation methods. In the easternmost fields, salinities approach that of seawater (30 Kppm). In these fields, most conventional shaly sand equations adequately reduce uncertainty in hydrocarbon saturation estimates.

Some of the largest fields are located in a fairway of fresh water (< 5,000 ppm) in the middle of the basin. At these low salinities, and in the presence of clay minerals, Ro can be completely insensitive to Rw and the excess conductivity term will predominate in all commonly used shaly sand equations. Therefore, there is no reliable way of arriving at accurate fluid saturations with resistivity based methods. Capillary pressure methods have been used increasingly in this interpretation environment.

In the absence of ample, representative, high quality, capillary pressure data, synthetic capillary functions can be developed. Petrographic data (mineralogy, shale distribution, grain-size analysis) and well established surface area concepts can help determine minimum amounts of both clay bound and capillary bound water at irreducible conditions. Clay bound water can be determined from mineralogy, and from routine core/log measurements in shales. Capillary bound water can be measured or estimated from empirical BVWE based on grain size, or analog clean sand reservoirs. NMR data can be used to calibrate the value of BVI.

The low salinity formation water also imposes serious limitations on real time LWD interpretation. In the case of low contrast pay, time lapse LWD logging may be the best way to identify the moveable fluid.

Conclusions/Recommendations

1. The "silt" point at the apex of the N-D boomerang actually represents a poorly sorted siltstone

with a significant amount of clay minerals as a source of excess conductivity.

2. Salinities in the central portion of the Malay Basin are less than 5,000 ppm NaCl equivalent, and therefore resistivity based shaly sand equations are not suitable.
3. Capillary pressure data facilitates robust saturation determinations where resistivity methods are impractical.
4. Synthetic capillary pressure models can extend the applicability to reservoirs lacking the necessary lab data. Results have been compared favourably with CMR data, and applied to a wide range of field studies.
5. Time lapse LWD can improve fluid typing and reduce completion uncertainty in low contrast pays.

Paper 23

The Kinarut and Kamunsu fans: stratigraphy, architecture and remaining prospectivity in the Greater Kebabangan area

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The potential for long term growth of the EP sector within Sabah hinges on the successful exploration and development of the deepwater Middle-Late Miocene turbidite play offshore west Sabah. This play was first tested successfully by the Kinarut-1 well (Exxon, 1972). It has been seven years since Sabah Shell Petroleum Company (SSPC) first ventured into this potentially prolific play with the Kebabangan-1 discovery well in 1994. Currently, SSPC operates two deepwater blocks J and G in this arena in partnership with Conoco and Petronas Carigali.

Between 1997 and 2000, SSPC drilled two wildcat wells in Block G, both discoveries, and appraised the northern Block of the Kebabangan gas field. As well as proving the existence of abundant charge, these wells have enabled the stratigraphy of the Miocene fan systems to be better understood.

One of the keys to further success in this challenging and expensive environment is a thorough understanding of the depositional architecture of the prospective fan systems. Early studies into this were based on the mapping of sequence boundaries from the shelf into the deepwater using 2D seismic data and the employment of a seismofacies scheme to forward predict reservoir distribution (Harvey, 2000). The future is to develop basin-wide 3D reservoir models for each prospective fan that will greatly facilitate both exploration and development well planning.

SSPC has now acquired some 5,500 km^2 of long-cable 3D over its deepwater acreage. Horizon and seismic attribute mapping on this high-fidelity 3-D data set has enabled a more detailed understanding of the complexity of the Kinarut and Kamunsu fans, the primary exploration targets in the greater Kebabangan area. This paper will present the results of recent fan mapping and will discuss the implications with respect to the reservoir distribution and remaining prospectivity around the Kebabangan and Kinarut gas fields.

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Abstracts of Posters

Poster 1

Reduction of porosity in Baram sandstones: compaction vs cementation

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INTRODUCTION

The Baram field is a moderate size oilfield situated in the north-eastern side of the Baram Delta Province, offshore Sarawak, East Malaysia. The field comprises two separate fault-bounded dip closures in the intermediate to deep reservoir levels of Late Miocene age. The cored reservoir intervals of the Baram field (Upper Cycle V ≈ Late Miocene) display successions dominated by thick swaley cross-stratified (SCS) sandstones and other associated shallow marine, wave and storm-dominated facies.

More than seventy core samples from two wells of Baram field were analysed for this study. The descriptions given below are based on thin section analysis using transmitted light microscope. The identification of the different diagenetic cement phases were based on microscopic studies combined with whole rock XRD, clay XRD and scanning electron microscope (SEM). The porosity and permeability values of the cored sandstone intervals were measured at the PETRONAS Petroleum Research and Scientific Services, Kuala Lumpur and the Poro-perm Laboratory, Postgraduate Research Institute for Sedimentology, University of Reading in England. Porosity was measured from coreplugs using a Helium Gas Expansion Porosimeter. The gas permeability was determined from a Nitrogen Gas Permeameter.

The main porosity type in the sandstones of Baram field is intergranular porosity. Some intraparticle porosities in the form of skeletal cavities of forams and microporosities within clay minerals are present in a few samples, but these are of minor importance. The measured coreplug porosity of Baram sandstones ranges from 11.0 to 28.6%. Permeability ranges from 1.125 to 810 mD. Figure 1 shows the plot of permeability against porosity for the whole dataset of Baram field.

OBSERVATIONS AND RESULTS

Mineralogy and Texture of the sandstones

Quartz is the most abundant detrital mineral in all the sandstone samples. Most of the detrital quartz grains are monocrystalline, but a fair proportion (~ 5–10% of detrital quartz proportion) are polycrystalline. Mudstone intraclasts are the second most abundant, occurring as granule to pebble-sized rounded mudclasts and more angular, sand-sized particles. Feldspars, biotite, muscovite, chloritic minerals, heavy and opaque minerals form common accessory detrital minerals. The differentiation between detrital and authigenic quartz using a polarising microscope is difficult. On the basis of their detrital mineralogy, these sandstones are classified as quartz arenite to sublitharenite.

The thick, well sorted, fine to very fine-grained SCS sandstones constitute the principal reservoir units within Baram field. These marine sandstones, with thickness range of 5 to more than 30 ft, commonly show high reservoir quality, with porosities ranging between 20 to 26% and permeabilities between 50 to several hundreds mD. Another distinctive feature of these sandstones is the angularity of the quartz grains. Most of the high porosity and permeability samples show high proportion of angular and elongated grains. The shapes of pores in sandstones are strongly dependent upon the shapes of the grains. Closer and tighter packing in highly spherical grains may reduce porosity and permeability of sandstones (Fraser, 1935) while sandstones consisting of well-sorted angular or subangular grains often show high porosities. The shape of quartz grains for most of the SCS sandstones possibly contributed to their good reservoir qualities.

Porosity Reduction: Compaction vs Cementation

Mechanical compaction is the process of bulk volume reduction that is generally induced by lithostatic stress. This process can reduce primary porosity in quartz-rich sandstones by as much as one third during the initial stages of burial (Houseknecht, 1984). The volume reduction is accommodated by reorientation, cleavage and fracturing of brittle grains, and pseudo-plastic deformation of ductile grains (Houseknecht, 1984; Bjørlykke *et al.*, 1989). The textural criteria exhibited by the sandstones of Baram field suggest that these rocks have not suffered extreme compaction. These criteria include very high cementation (~30% volume intergranular cementation by authigenic siderite), minimum deformation of plastic, ductile and flexible grain and the almost absence of pressure solution (Fig. 2a–d). Grain contacts range from floating to planar; it is not uncommon to have a thin layer of clay in between grains having planar contact. Thin section analyses also show no sutured or concavo-convex grain contacts indicating pressure solution.

Houseknecht (1987) proposed a method of quantifying compaction in sandstones. This technique allows the assessment of the relative importance of compaction and cementation to porosity reduction. Pate (1989) commented that Houseknecht's technique underestimates the importance of mechanical compaction in the reduction of sandstone porosity. Ehrenberg (1989) point to the incorrect formula for the analysis of compactional porosity loss. He also criticises on the oversimplification of the assumption of a 40% value for original porosity. These factors have small effect on the result (Houseknecht, 1989), and for quick comparative purposes, Houseknecht (1987) technique allows an objective assessment of the relative importance of compaction and cementation.

Houseknecht (1987) uses point-counting technique to estimate the intergranular volume (sum of intergranular porosity plus all cements that occupy intergranular space). High values of intergranular volume indicate little compaction, and vice versa. Figure 3 shows Houseknecht's intergranular volume-cement diagram for Late Miocene sandstones from the Baram field. As suggested by Houseknecht (1987), an original porosity of 50% instead of 40% is adopted for the well sorted and angular sandstones of Baram field. The figure shows that intergranular volumes range from 20–50.0%. However, about 85% of the samples plot in the lower left portion of the diagram. A more representative intergranular volume range is 20–35%. This indicates that a larger percentage of the original porosity of these sandstones has been destroyed by compactional processes than by cementation. Very high intergranular volume corresponds to very high percentage of siderite cement in the sandstones. The figure also shows that 10–40% of the intergranular volume has been destroyed by cementation, while compaction have reduced 30–60% of the original porosity.

CONCLUSION

Compaction is the single most important and all prevailing cause for porosity reduction in the Baram sandstones. The Houseknecht's diagram (Fig. 3) for the Late Miocene sandstones of Baram field indicate that a larger percentage of the original intergranular porosity has been destroyed by compactional processes than by cementation. This method of analysis gave an estimate of about 30–60% reduction of original intergranular porosity by mechanical compaction, preserving on average about 20% intergranular porosity (40% of original intergranular porosity). Measured Helium porosity gave maximum porosity values of 28%. The range of measured porosity of non-siderite cemented sandstones range from 15–28%, showing gradual reduction with depth.

Poster 2

Migration-progradation tidal succession within the upper Nyalau Formation (Oligocene-Late Miocene) at Tanjong Kidurong, Bintulu, Sarawak

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A simple, sand-shale 'sandwich' succession belonging to the upper part of the Nyalau Formation (Oligocene – Late Miocene), exposed at the road-cut near the STM Station at Tanjong Kidurong in north Bintulu, display well-preserved sedimentary structures which record the interplay of different processes in a tidal depositional environment.

Four major facies association were identified. These are: i) FA-1 — Trough-to-tabular cross-bedded facies association; ii) FA-2 — Laminated mudstone facies association; iii) FA-3 — Climbing-ripple cross laminated facies association, and iv) FA-4 — Lenticular bedded facies association.

Figure 1 shows the stratigraphical section of the outcrop. A section of the outcrop is shown in Figure 2. The four distinct facies association are informally referred to as FA-1, FA-2, FA-3 and FA-4. The base of FA-1, the trough-to-tabular cross bedded facies association, is not exposed at the outcrop. This strongly indurated unit is transitionally overlained by about 2.5 m of FA-2, a laminated mudstone facies with thin- to medium-thickness silt-sand layers. FA-2 is overlain by FA-3 and this is marked by a sharp and erosive surface of contact, characterised by a thin layer of channel lag deposit. FA-3 is a sandstone unit dominated by climbing-ripple cross-laminations; however, it also display a plethora of other cross-bedded features. Limited horizons of wavy cross-bedding, flaser bedding, tabular cross-bedding and trough cross-bedding are not uncommon. This unit is characteristically and transitionally capped by a small-scale, well-draped tabular cross-bedded unit with pronounced downstream troughs. FA-4 which overlies FA-3 is a muddy heterolithic facies of wavy- to lenticular bedded layers.

The detail description and interpretation of the different facies follows.

Facies Association 1 — Trough-to-tabular cross-bedded facies association

The base of this facies is not exposed. The maximum measured thickness of the unit at the outcrop is about 4.0 m. This fine- to medium-grained, well-sorted sandstone unit is characterised by medium- to large-scale trough cross-bedding structures (> 5 cm thick layers), chaotically distributed (Fig. 3). The troughs wavelengths range between 0.5–2.0 m. Most of the troughs show thin mud-drape lining, and many are accompanied with rounded mud chips. The upper part of this unit gradually changes into megaripple bedding, mud-draped, sigmoidal foresets and tabular cross-bedded layers. Limited zones of draped wavy-bedding can also be seen within the unit. The top part of FA-1 transitionally merged into the overlying laminated mudstone facies. The transitional zone is characterised by thin, inclined sand lenses interbedded in mudstones.

Facies Association 2 — Laminated mudstone facies

Facies assocaition FA-1 transitionally grades into this laminated mudstone facies association. This dark gray shaly unit is finely laminated with intercalations of thin silt and sand layers (Fig. 4). Thin sandy layers are more common at the base and the top of this unit.

This unit is interpreted as a channel-fill deposit. During the early stages of the abandonment of the channel fill, sedimentation is rather rapid, and this resulted in the introduction of coarser material during overbank flows or very high tide. These coarser sediments form the thicker sand lenses at the base of the unit.

Interpretation FA-1 and FA-2

Since FA-1 and FA-2 displayed pronounced transitional/gradational contact, they must have intimate genetic origin. Collinson and Thompson (1982) suggested that trough-shaped cross-bedded sets are produced by the development of sand dunes, while tabular cross-bedded sets are related to sandwaves. Dunes and sandwaves are structures formed when sand beds responded to currents more powerful than those that generate ripples. These features are common in medium- to coarse-grained sandstones. The cross-bedding here are similar to Allen (1980) Class V and VI sandwave models, which are thought to form under bidirectional, rectilinear tidal currents (Johnson and Baldwin, 1996). The structures displayed here are referred by other authors as megaripple bedding. Megaripple bedding, produced by migrating megacurrent ripples (Reineck and Singh, 1975), may be produced in rivers or tidal channels. Reineck and Singh (1975) also suggested that fine sand megaripples are caused by higher velocity flow compared to megaripples in coarser sand.

Terwindt (1981) argued that features like mud-draped foresets can only be produced and preserved in sheltered estuaries. Wavy bedding requires conditions where both sand and mud can be deposited and preserved (Reineck and Singh, 1975). Tabular cross-bedding are formed from straight crested dunes migrating downcurrent, where the stoss side erosion is less than sedimentation of the foreset.

The laminated mudstone facies of FA-2 is interpreted as a channel fill deposit deposited due to the cutting-off of the channel flow.

The vertical, fining-upward succession showed by FA-1 and FA-2 closely resemble a channel bar deposits. However, the assemblage of sedimentary structures present suggest that this facies association is the result of the interplay of fluvial and tidal processes. The diagnostic tidal indicators within this facies are: i) the sigmoidal mud-draped foresets; ii) the mud-draped wavy bedding. The fining-upward succession of FA-1 and FA-2 is thus interpreted as a tidal channel fill deposit.

Facies Association 3 — Climbing-ripple cross laminated facies

This facies association is dominated by the climbing-ripple cross-lamination structures; however, it also displays a plethora of other cross-bedded features.

The overall thickness of the unit is about 1,200 cm. The base of this unit is distinctly mark by intraformational lag conglomerate horizon, bearing large rounded shale pebbles (Fig. 5A and B).

The most dominant type of climbing-ripple cross lamination displayed within this unit is ripple laminae-in-drift, as described in Reineck and Singh (1975) and Collinson and Thompson (1982). These are cross-laminated sand bed deposited on the lee sides of migrating climbing ripples. Individual cross-bedded set thickness range from 15.0 cm to 30.0 cm. Most of these cross-bedded layers are without any clay laminae; however some horizons are strongly draped with carbonaceous detritus. Cosets of these ripple-laminated layers are separated in places by thin, wavy-bedded and in-phase ripple lamination layers, sometimes with continuous clay-drape. Sparsely distributed small pebbles of clay and lignite clasts can also be observed. Restricted horizons of flaser beds were also recorded within this unit.

Two horizons of distinct, small-scale mud-draped cross-bedded layers can be found in the middle part of the unit and the topmost level (Fig. 6). Most authors refer to this sub-facies as another variety of trough cross-bedding, some referring to it as sigmoidal mud-draped foresets. The writer however felt that the term applied by Ramos *et al.* (1986) is the most descriptive and appropriate. They termed this facies as tabular cross-bedded layers with downstream troughs. The thickness of this coset displayed at Tanjong Kidurong is less than 90 cm.

Interpretation

Ripples, which results in cross-lamination, form due to water movement over a sand bed, either as unidirectional currents, oscillatory waves or a combination of both (Collinson and Thompson, 1982). Climbing ripple cross-lamination – signify variable current velocities and sediment supply. This type of cross-lamination is thought to be rare in tidal environments; however, Wunderlich (1969) have recorded these structures from tidal flats with high sedimentation rates (Reineck and Singh, 1975).

The tabular cross-bedded layers with downstream troughs are interpreted as shallow, surface channel deposit. Similar small-scale, mud-draped cross-bedded layers (sigmoidal mud-draped foresets) at the top of this unit have been reported by Dalrymple (1984) and interpreted to represent shallow ebb-flow runoff on muddy tidal flat, which indicate periods of emergence. FA-3 is thus interpreted as a depositional product of a sand flat with notably high sedimentation rates.

Facies Association 4 — Lenticular bedded facies

This is a lenticular bedded unit with mainly connected sand lenses (Fig. 7). Lenticular bedding developed due to the formation of incomplete sand ripples on muddy substratum (Reineck and Singh, 1975). As the formation of these structures requires conditions of current or wave action depositing sand, alternating with slack water conditions for the deposition of mud, the most suitable environments are the subtidal and intertidal zones (Reineck and Singh, 1975). Within these zones, changes take place between slack water and turbulent water, and sediment supply is good.

The overall stratification of the Nyalau formation rocks at the STM Station in Tanjong Kidurong can be interpreted to represent two fining-upward sandstone-shale successions produced by the combined action of lateral migration of tidal channels and creeks (the transition of FA-1 into FA-2), and progradation of sandy tidal flats as a result of high amount of sediments supplied from the sea, due to tidal action (FA-3 and FA-4).

Poster 3

Barton geological modelling: synergies with history matching

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Barton field is located within the structurally complex in-board area, offshore North Sabah. The hydrocarbon is contained within a ca. 1,500 ft thick sequence of Lower Coastal Plain sandstones and shales, belonging to the Middle Miocene, Stage IVA. The main reservoir bodies comprise channel, crevasse splay, mouthbar with minor shallow marine incursion, whereas floodplain shale forms reservoir seals and barriers.

The field commenced production in 1981. To-date some 28% of the field reserve has been produced and reservoir pressure is observed to decline rapidly. Based on material balance studies, the "do nothing option" resulted in this field quitting economic production in 2012. Reservoir management studies into optimising oil recovery and identifying means to sustain economic production beyond 2012 to maximise the profitability of the venture are ongoing. This work involves 3-D static and dynamic simulation modelling studies.

This paper presents the static modelling aspect of the modelling study. The model is primarily aimed to (1) generate a detailed description of the reservoir geometry and properties of Barton Main reservoirs (Stage IVA, F/G/H/I sands), (2) validate field STOIIP and (3) identify key subsurface uncertainties that could have adversely impact the Enhanced Oil Recovery schemes.

The main features of this static modelling study is the identification sand packages, which were used to assist in the correlation and the use of neural net approach to identify lithofacies from wireline log. Although sand-to-sand correlation is generally problematic for these channelised bodies in Barton, sand packages which is characterised by sand-rich at top and shale at base can generally be correlated with ease. These sand-rich intervals represent channel complexes and are extensive fieldwide. Likewise, the shale layers at the base of unit are also extensive. Within the channel complex, however, the geometry of the intra-shales is less predictable. As these intra-shales can form barrier/baffles to fluid flow and may have detrimental impact field performance, they were modelled as sensitivities.

Overall, the Barton rock model shows complicated reservoir development. The top of the model comprises succession of poor net-to-gross unit (F sand) overlying relatively high net-to-gross reservoir packages (channel complexes of the G and H2 sands). A shale dominated layer which appear to be present fieldwide (H1 sand) separate the sand-rich G and H2 reservoir packages. The base of the model is dominated by low net-to-gross I sand. Within the I-sand, two sand-rich layers (channel complexes) is also present.

This paper outlines the various aspects of the modelling study, key assumptions and also the outcome of the model.

SSB/SSPC's geophysics and subsurface IT services

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In Sarawak Shell Berhad/Sabah Shell Petroleum Company Limited, IT services are organised into portfolios that are combined with appropriate business areas. This organisation has been seen over the years to be an effective way to work towards developing IT-smart E&P workers as well as Business-smart IT staff. There are 4 portfolios: The Subsurface, Surface, Business and Corporate.

This poster session covers the Subsurface Portfolio and depicts the close linkage and synergy between Seismic Acquisition, Processing, IT Project Management Support, Application Support, Portfolio Management and Data Management. Briefly, the following aspects are covered in each section:

Seismic Acquisition

The various processes that are carried through and the uncompromising emphasis that Shell places on HSE considerations.

Seismic Processing

The tools of the trade are discussed as well as key processes and workflows that provide a glimpse of some of Shell's leading edge technology.

IT Projects Management and Application Support

The wide range of tools available in the subsurface realm as well as relentless and rapid pace of IT developments both within the Shell Group and by vendors are just some of the challenges faced in this area.

Portfolio Management

This aspect of our services looks at rationalisation of products and licences against business requirements, constraints, work processes and strategy directions.

Data Management

Against the technology backdrop above, the requirement for easily accessible, timely and quality data is even more pressing than ever before while at the same time the emphasis has shifted from mere provision of data to one of management of this valuable resource as a long term asset.

Poster 5

Petronas' F38.1 discovery well: a remarkable cost saving and very efficient operational experience

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F38 structure is a pinnacle-typed carbonate built-up on the Central Luconia Platform in a water depth of 95 m. It is located about 160 km north of Bintulu and 120 km west of Miri, Sarawak (Fig. 1). The nearest discovered gas fields of F38 are B11 and Cili Padi, located about 17 km northeast and 23 km west respectively. The F38 structure is within 15 km to the existing gas pipeline offshore Sarawak, Malaysia.

F38.1 well was drilled as a vertical exploration well in the open acreage block SK310 by semi sub rig, Hakuryu-III which used a slim-hole well design and the method enabled PETRONAS to significantly reduce both drilling time and cost by about 20% (Fig. 2). The well was spudded on the 7th February 2001 and reached at its final total depth (TD) on the 25th February 2001. The objectives of this well were to test the gas potential in the reefal carbonate build-up in the Central Luconia Province, offshore Sarawak.

The Top Carbonate was penetrated at 2,515 mRKB and the well was drilled to its final TD in carbonate at 3,000 mRKB without encountering any operational problems or abnormal pressure. The top target and final TD were shallower by 42 m and 17 m respectively from prognosis. This is contributed by the fact that the actual velocities in the F38.1 are faster than predicted.

The well encountered about 436 m (as high as Cili Padi) gas column (down to the GWC) in the Mid-Miocene Cycle IV carbonate with a total net pay of 310 m, average porosity of 17% and average water saturation of 20% (Fig. 3). The results indicate an additional 136 m of gas column from expectation, making the degree of hydrocarbon fill in F38 is approximately 80% (the highest structural fill so far in Central Luconia Province).

The pressure data demonstrated that the gas accumulation was in one system with the Gas-Water-Contact at 2,951 mRKB. During drilling in the target zone, high gas readings and resistivity up to 2,000 ohm were recorded.

Two production tests were conducted in the carbonate reservoir to confirm the fluid type, evaluate the well deliverability and obtain the reservoir data (Fig. 4). The cumulative flow using 1" choke was 50.5 MMscf/d of gas and 224 bbl/d of hydrocarbon liquid (condensate) with API gravity of 32 degree and with some amount of inert gas.

A significant amount of gas reserves was confirmed from the F38 Carbonate.

The well was plugged and abandoned on 14th March 2001 and had taken about 36 days (vs 44 AFE days) to complete the full drilling operations at a total cost of approximately RM18.2 million with two production tests (vs RM21.9 million AFE cost with one production test). Overall, the F38.1 gas discovery well drilling operations saved PETRONAS almost 20% of the original budget and time. But most importantly the results of the well have upgraded the hydrocarbon prospectively in the open acreage Block SK310, Offshore Sarawak.

Sequence stratigraphic study of the Erb West field, offshore Sabah, Malaysia

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The Erb West field in the offshore Sabah, comprises a NE-SW trending, dome-shaped anticline terminated by a major NW-SE trending normal faults in the NE sector. The crestal part of the field is virtually unfaulted whereas the southern flank is dissected by several E-W trending normal faults. The structural configuration is believed to be the result of deep seated wrench faulting which characterised the Sabah area during Miocene and Pliocene (Fig. 1).

The sequence stratigraphic study of the field was conducted using well data and 3D seismic. The high resolution sequence stratigraphic correlation of the well logs was done using the technique described by Van Wagoner (1995) and formed the basis for the sequence stratigraphic concept adopted in this study. The conceptual model proposed by the "Exxon" group (Mitchum, 1977; Vail, 1987; Van Wagoner, 1990) is employed with slight modification to obtain a better understanding of the geology and a realistic perspective of the reservoir facies distribution within the field. The seismic facies analyses was done using a modified technique from Vail *et al.* (1977) and Brown and Fisher (1977). The new stratigraphic scheme for the Erb West field is proposed (Fig. 2).

The Upper Miocene Stage IVC and IVD of the Erb West field strata can be divided into four stratigraphic units namely, P, N, M and L. These units can be grouped into different system tracts, with reference to Exxon's third order sequence model. The P unit is the lowstand system tract (LST), M and N is the transgressive system tract (TST). The TST can be subdivided into Early TST (N unit) and Late TST (M unit). The highstand system tract (HST), is believed to be the L unit.

During the deposition of the Unit P, N and M, the paleo-high was located to the East of the Erb west field and is known as the Erb High. It was separated from the Erb West field by the N-S fault system. To the north of the field is a SE-NW trending fault zone. This fault system is mostly a series of normal faults with the down-thrown side to the N and NE. To the S and SW sector, the field is cut by a series of faults making a fault zone trending in the E-W to SE-NW direction. This faulted zone, appears as a trough feature which is bounded by normal faults.

The faults system and the arrangement of the fault blocks dictated the highs and lows in the Erb West field. The regional high is in the southern and southeastern part of the field. It is related to the Erb High further to the east. The siliciclastic sediments of the Erb West field was derived through or from this high.

The faulted zone in the SW part, provide a major passage for sediments discharge. This low, which is bounded to the south and north by high relief zone, received the sediments from both sides, the south and the north. The northern high, where the major portion of the field is situated, is referred to as the central high. The low faulted zone area is then called the central low. Beyond the main SE-NW trending fault system is a low relief area which is dipping towards the NE (Fig. 3).

The depositional system of the studied Erb West field's strata, ranges from the incised-valley fill, deltaic, and coastal to shallow marine systems. The incised-valleys and delta systems is common in the LST strata (P unit). However, during the TST (N and M units), other coastal and associated systems were developed due to increased accommodations for sediments dispersal. The estuarine and coastal to shallow marine system has been identified from these units.

The fairly consistent facies type, size and orientation within the Erb West field indicates the consistent position of the paleogeographic elements, like highs and lows, orientation of the regional dip and faults throughout the deposition of the studied units. Even though, there is a slight difference, it is only minor variances. Its distribution reflect the fluctuation of sea levels record and preservation from the erosional processes.

The fluctuation of sea level due to either, eustatic or tectonic or both is apparent in the Erb West field. The shifting of coastal and associated facies as seen on the seismic sections, is used to delineate the sea level position and characterise the sea level changes. This can be seen from the sedimentary facies distribution of each stratigraphic unit. The facies distribution for each stratigraphic unit with emphasis on the sand facies, is illustrated.

Poster 7

Seismic attributes analysis of deep reservoir in Erb West field

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A seismic attribute analysis of deep reservoir in Erb West field was carried out to re-evaluate and determine its prospectiveness. The 3D seismic attributes, well data and facies maps were incorporated to develop a geologic framework for predicting the reservoir properties. The study contributed also to the delineation of the reservoir within the complex fault zone in the southwest region of the field. The database included 3D seismic data volume, interpreted seismic horizons, well logs, log correlations and various well and seismic reports.

3D Seismic Attributes Extraction and Analysis were first applied on the shallower proven reservoirs M4, N2 and N7. A deeper reservoir was then identified based on a sequence stratigraphic study conducted by PRSS. The potential reservoir was called the P reservoir. A similar 3D Seismic Attributes Analysis was later applied to the P reservoir. The geologic depositional model derived from the sequence stratigraphic study developed by PRSS was correlated with the seismic expressions. Several seismic attributes, such as RMS Amplitudes and Mean Amplitudes, were extracted and analysed for the respective fluid and facies responses in comparison with the conventional seismic amplitudes. The more generalized Energy Half Time seismic amplitude was found useful to delineate sequence stratigraphic facies distribution within the field and hence formed the basis of the seismic attribute interpretation.

The seismic attribute map for the P reservoir basically describes the sequence stratigraphic configuration where strong-continuous-high-amplitude features were observed in the South-Southeastern zone where shorelines are interpreted. Strong features indicate sediment deposition direction to the North-Northwest. A channel feature can be seen flowing through the high-amplitude event and ends in a zone of discontinuous-medium-to-high-amplitude-anomalies interpreted as deltaic facies. These facies are spread out over the western part of the field encompassing the southwestern complex fault zone.

A relationships between reservoir properties and seismic amplitudes were derived for all the main reservoirs which generally shows a trend of high net sand and porosity values with high RMS amplitudes. These relationship of the reservoir property to the RMS amplitude were used for predicting the deeper P reservoir's properties. Potential leads are interpreted to be within these delta sands and relative sand quality can also be inferred from the reservoir properties and seismic amplitudes relationships developed.

Poster 8

Suberinite: oil-prone maceral of Borneo coals

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The coals currently investigated are of Tertiary age, collected from areas of Sarawak, Brunei and Kalimantan. Tertiary coals of Southeast Asia are known to be effective source rocks in the prolific gas- and oil-producing basins of the region (e.g. Todd *et al.*, 1977; Mazlan and Abolins, 1999). Much of the petroleum in the region was generated from organic matter of higher plant origin that was deposited within a lower delta plain to prodelta setting. The nature and origin (other than being 'higher plant') of the organic matter, however, has not previously been specified. In this study, the maceral suberinite and the associated macerals bituminite, liptodetrinite/fluorinite and phlobaphinite have been recognised as the most oil-prone macerals of the Borneo coals. The depositional setting of coals with adundant suberinitic components appears to be mangrove swamps. As mangrove paleo-belts are known to be widespread between latitudes 30°N and 30°S (Morley, 2000), it seems apparent that oils within these regions, particularly Southeast Asia, are sourced from mangrove-derived coaly constituents of which suberinite is the dominant component.

Suberinite, derived from suberin-impregnated cell walls of cork tissue (Fig. 1), is a maceral that is almost exclusively known to Tertiary coals and a few Mesozoic coals. It occurs mainly in bark but may also be found in the stems and roots of woody and herbaceous plants. *Rhizophora sp.*, in particular, contains abundant suberinitic and the associated phlobaphinitic cell fillings (Teichmuller, 1982). Suberin and subereous components are waxy constituents, considered to be predominantly polymers containing polyesters and aromatics (Kolattukudy, 1980).

Organic geochemical evaluation performed on the coals that are rich in suberinite and/or bituminite yielded HI values in the range of 250–400 mgHC/gTOC. The S2 Py-GC pyrograms of these coals are dominated by n-alkane/alkene doublets as well as aromatic components, thus supporting the oil-prone nature of these suberinitic macerals. Saturated hydrocarbon fractions of these coals are dominated by higher molecular weight n-alkanes and display waxy appearances.

The generation of fluvio-deltaic oils has been associated with terrestrially-derived organic matter of mangrove origin (e.g. Brown, 1989, Wan Hasiah 2001). Mangrove pollen, particularly of Rhizophoraceae, are known to have been widely distributed within the Sunda region since early Tertiary times (Morley, 2000).

Under the microscope, liquid hydrocarbons generated occur in the form of an oil haze or oil globules, while solid hydrocarbon occurs in the form of exsudatinite which was seemingly soft and mobile when exuded from the precursor material. The texture of the coal fabric and the association of the macerals present are expected to govern the mode of hydrocarbon generation and the expulsion pathways (Wan Hasiah, 1999, 2000).

As could be observed petrographically, subsequent to hydrocarbon generation, the suberinite-phlobaphinite framework breaks down, giving rise to liptodetrinite, fluorinite, vitrodetrinite and exsudatinite (Fig. 2). Accumulation of disordered or disintegrated suberinitic constituents subsequently forms bituminite (Fig. 3). Thus, bituminite (as defined by ICCP, 1975) is recognised here as a secondary maceral (an intermediate stage) which represents a transformation product from the precursor maceral suberinite during hydrocarbon generation.

The hydrocarbon material directly associated with suberinite and bituminite began to generate at about 0.4%Ro and was exhausted by 0.7%Ro. This early generated material is believed to play a significant role in saturating the source rock pore system and deactivating adsorptive sites. Upon reaching a saturation threshold, materials that are expelled should be able to leave the coaly source rock without being held back within the pore systems. Incorporation of remnant suberinitic material within the vitrinite fabric, however, is still apparent in higher maturity coals of about 1.0%Ro (Fig. 4) suggesting that suberinite-derived components, such as fluorinite/liptodetrinite, also possess good oil generating potential and expel their hydrocarbon components at a higher maturation level (> 0.7%Ro). The inclusions of hydrocarbon generating material and suberinitic components appear to be responsible for the perhydrous nature of the coaly source rocks and for the fluorescence phenomena of the vitrinitic coal fabric.

Poster 9

Influence of vitrinite types, facies associations and hydrocarbon generation on vitrinite reflectance analysis

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Vitrinite reflectance (VR) analysis is the most widely used technique for the assessment of thermal maturity. The maturity is a measure of the degree of chemical and physical changes experienced by coal and dispersed organic matter with increasing depth of burial. VR is a measure of the proportion of light reflected from the polished surface of a sample compared to that of a standard. This technique, however, tends to be taken for granted. The numbers generated, more often than not, are accepted unquestioned. This is a mistake as the technique, if not carefully managed, is open to several sources of error. This study discusses a number of factors that are found to be most critical and most likely to influence vitrinite reflectance measurement. These include:

1. Vitrinite types: Tertiary coals, in contrast to Carboniferous coals, contain a wide range of vitrinite types. Although measurements should be performed on telocollinite (or collotelinite)

type of vitrinite, this is not always the case and as such variations in the values obtained may be significant. Which is the correct virinite to measure is therefore a fundamental question.

2. Inter-maceral facies effects: The presence of certain macerals, notably alginite, and also suberinite, can suppress vitrinite reflectance measurement. Vitrinite in close association with such macerals should be avoided.
3. Lithofacies association: Different lithologies enclosing the organic matter, may exert a partial control on the measured vitrinite reflectance. This may be ascribed to the varying thermal conductivities (for example of a sandstone compared to a shale). Also needed to be taken into consideration is the ease of escape of the coalification products such as volatile matter, and bitumen (or hydrocarbons) that may have impregnated the organic matter.
4. Hydrocarbon impregnation: Soaking of vitrinite in hydrocarbon leads to a lowering of its reflectance. This phenomenon is not all-pervading and can be avoided once recognised.
5. Plastic deformation: As a consequence of hydrocarbon generation, the vitrinitic coal fabric may undergo plastic deformation which subsequently alters the physical-chemical state of the coal and causes the reflectance to increase.

Besides these main factors listed, reasons for variation in vitrinite reflectance values may also be attributed to factors related to conditions of deposition such as microbial alteration and other biochemical influences within the coal depositional environment. All of these factors will effect VR measurements and need to be highlighted.

Poster 10

Real-time formation evaluation from reliable, repeatable gas in mud analysis

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Real-time Surface Monitoring of the Gas in drilling mud is a common practice throughout the Upstream Petroleum Industry and has been used for generations in the oil industry. Typically, hydrocarbon gas monitoring was measured with the primary objective of indicating, in real-time, hydrocarbon bearing formations, and as a safety factor to assist the companyman to make real-time decision making related to the rig operations and downhole reservoir conditions. Several criteria related to the inefficient degassing of the drilling mud, did not encourage any objective, quantitative measurement and analysis of the acquired real-time gas in mud data, and was rarely used for formation evaluation.

Recent improvements in the design and operation of the real-time degassing and gas detection systems have significantly improved the quality of the real-time gas in mud data acquisition, which is then available for real-time analysis. These technical improvements of the mudlogging degassing and gas detection system include:

- Mud Suction Probe design to allow sampling of drilling fluid very close to the bell-nipple.
- True constant volume, constant mud rate GAS TRAP, unaffected by mudflow variations in the well.
- Efficient transport gasline from the Gas Trap to the mudlogging gas detection system.

- High Accuracy, High Sensitivity and fast computation of the gas composition (C1 to nC5).
- Independent determination of total hydrocarbon gas and its individual components.
- Ability to detect recycled hydrocarbon gases pumped down back into the hole, with a second independent gas trap located in the pump suction mud tank. And constantly correct the drilled gas results, from the recycled, injected gas.
- Real-time Integration of all available data acquired whilst drilling, allowing the detection, processing, analysis and evaluation of gas measurements related to any drilling actions or reservoir event.

These practical technical improvements allow the geologist and reservoir engineer, real-time quantitative, detection and analysis of the gases released by the formations during the drilling operations. Further near real-time analysis of the gas data at the rigsite, often provide determination of specific reservoir characteristics, which are critical to the decision making process during drilling operations, and enhance the reservoir modelling characteristics. Recent examples of successful use of these modern mudlogging mud degassing and detection systems include:

- Successful characterisation and identification of *In-situ* Reservoir Fluid Composition in real-time, during drilling when using Synthetic-Oil Based Mud (SOBM). Including condensate-rich or oil bearing zones, dry gas bearing zones, depleted (water swept) zones, water bearing zones.
- Optimisation of future well operations (logging, testing, perforations, etc.)
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1. Ciceron A. Angeles
   38 Lemonwood St, Phase 2 Greenwoods Executive Village Cainta, Rizal 1900 Philippines.

2. Richard A.S. Cayzer
   P.O. Box 509, Lutwyche, Brisbane, Qld 4030 Australia.

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The GSM is seeking the address of the following members. Anyone knowing the new address please inform the Society.

1. Mohd. Zainudin Badarudin
   Dames & Moore, Phileo Damansara 1, 1209, Block B, 9 Jalan 16/11, 46330 Petaling Jaya, Selangor D.E.

2. Malek Musa
   43, Jalan Impian Jaya, Saujana Impian, 43000 Kajang, Selangor D.E.

3. Muhad Saleh Ambong Bolong
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Southeast Asian Basins: Oil and Gas for the 21st Century

August 21-24, 1994
Kuala Lumpur, Malaysia

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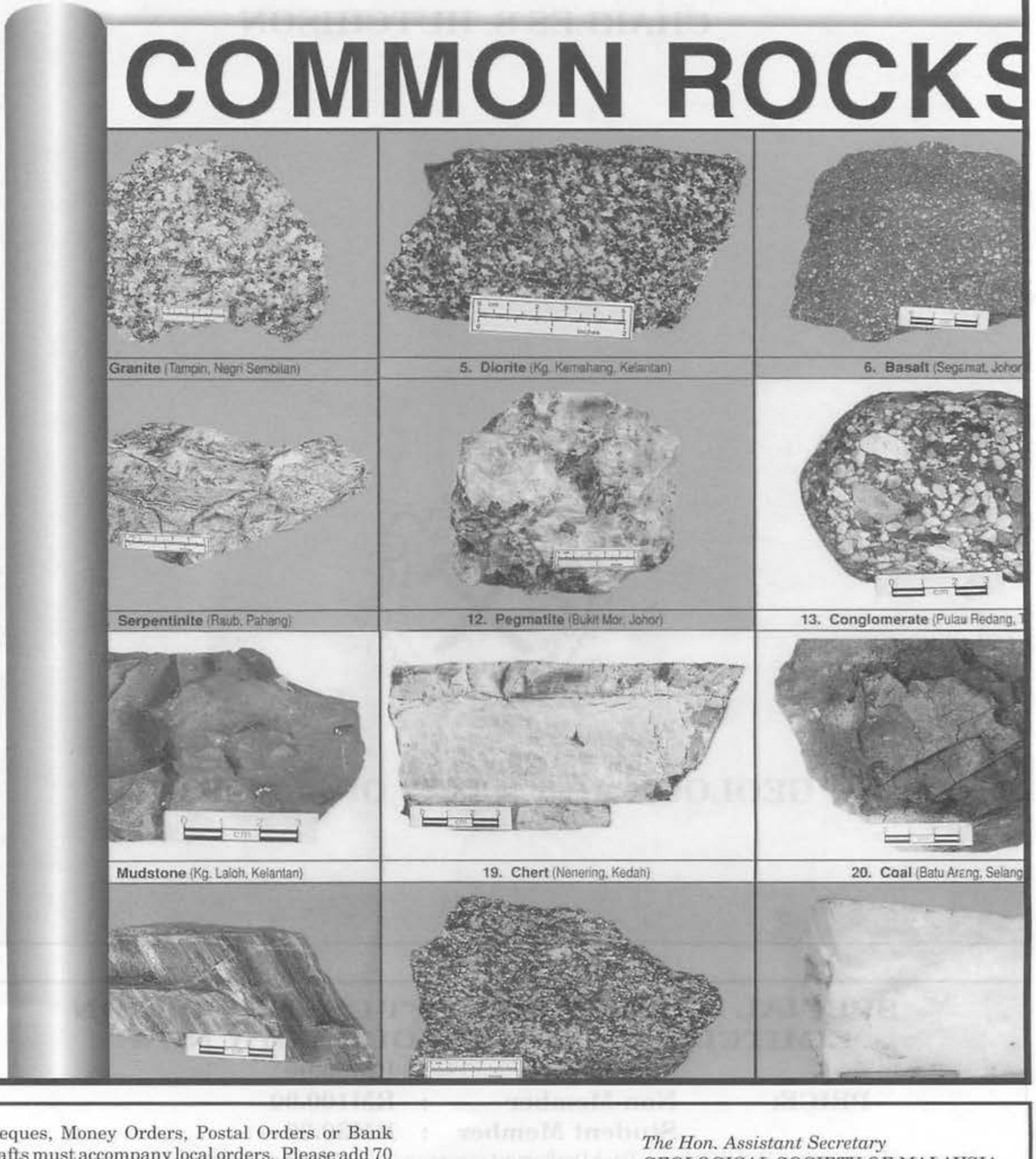

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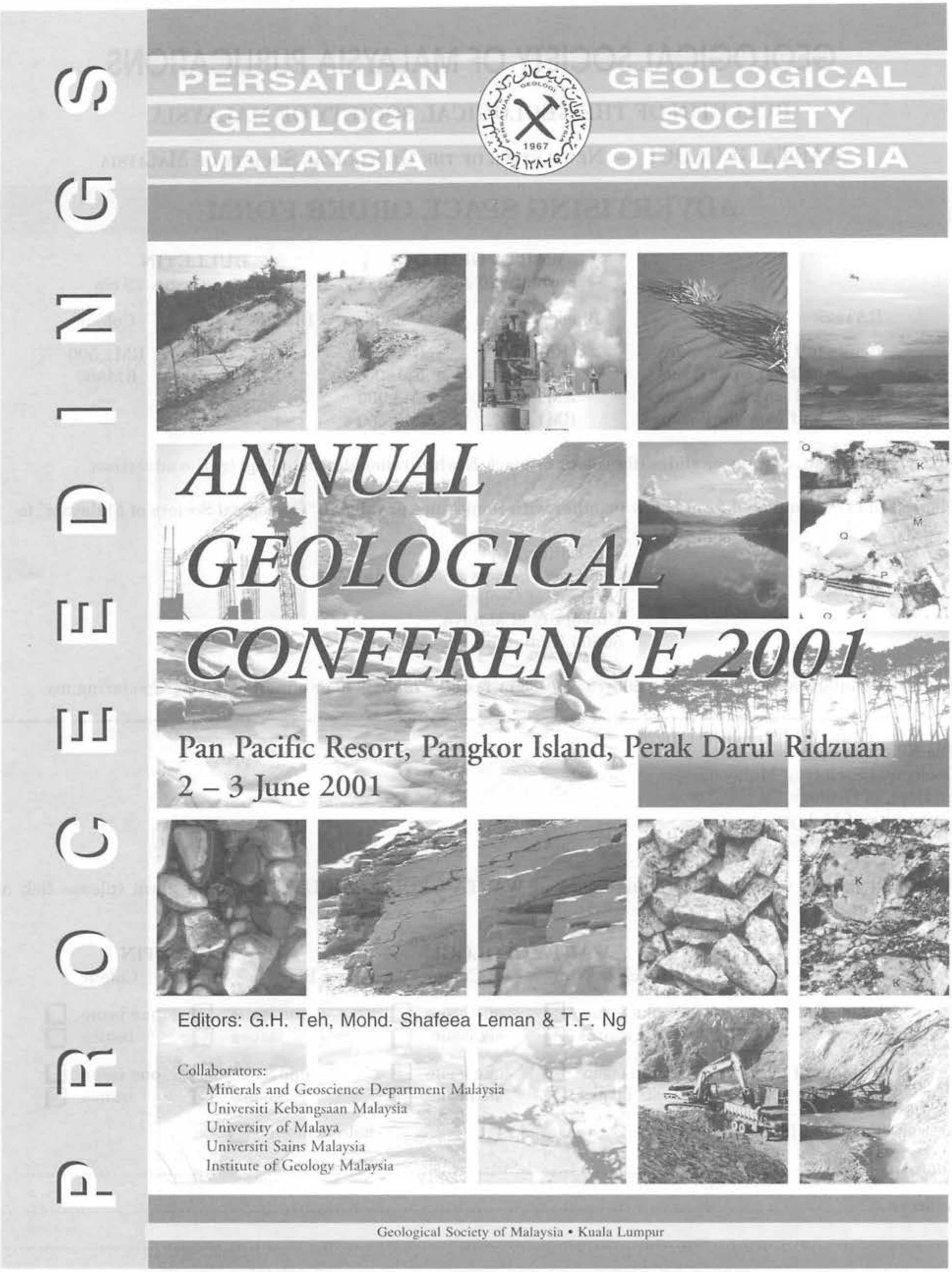

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2002

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March 10–13
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May 27–30
EUROPEAN ASSOCIATION OF GEOSCIENTISTS AND ENGINEERS (63rd Conference & Technical Exhibition), Florence, Italy. (Contact: Website: http://www.eage.nl/)

July 7–12
16TH INTERNATIONAL SEDIMENTOLOGICAL CONGRESS, Auckland Park, Gauteng, South Africa. (Contact: Bruce Cairncross, Department of Geology, Rand Africans University, P.O. Box 524, Auckland Park, 2006, South Africa. Tel: +27 11 489 23 13; Fax: +27 11 489 23 09; E-mail: bc@na.rau.ac.za; Website: http://general.rau.ac.za/geology/announcement.htm)

September 16–20
INTERNATIONAL ASSOCIATION OF ENGINEERING GEOLOGY AND THE ENVIRONMENT (IAEG), "Engineering Geology for Developing Countries" (9th International Congress), Durban, South Africa. (Contact: South African Institute for Engineering and Environmental Geologists, P.O. Box 2812, Pretoria, 0001, South Africa. E-mail: saieg@hotmail.com; Website: home.geoscience.org.za/saieg/2002.htm)

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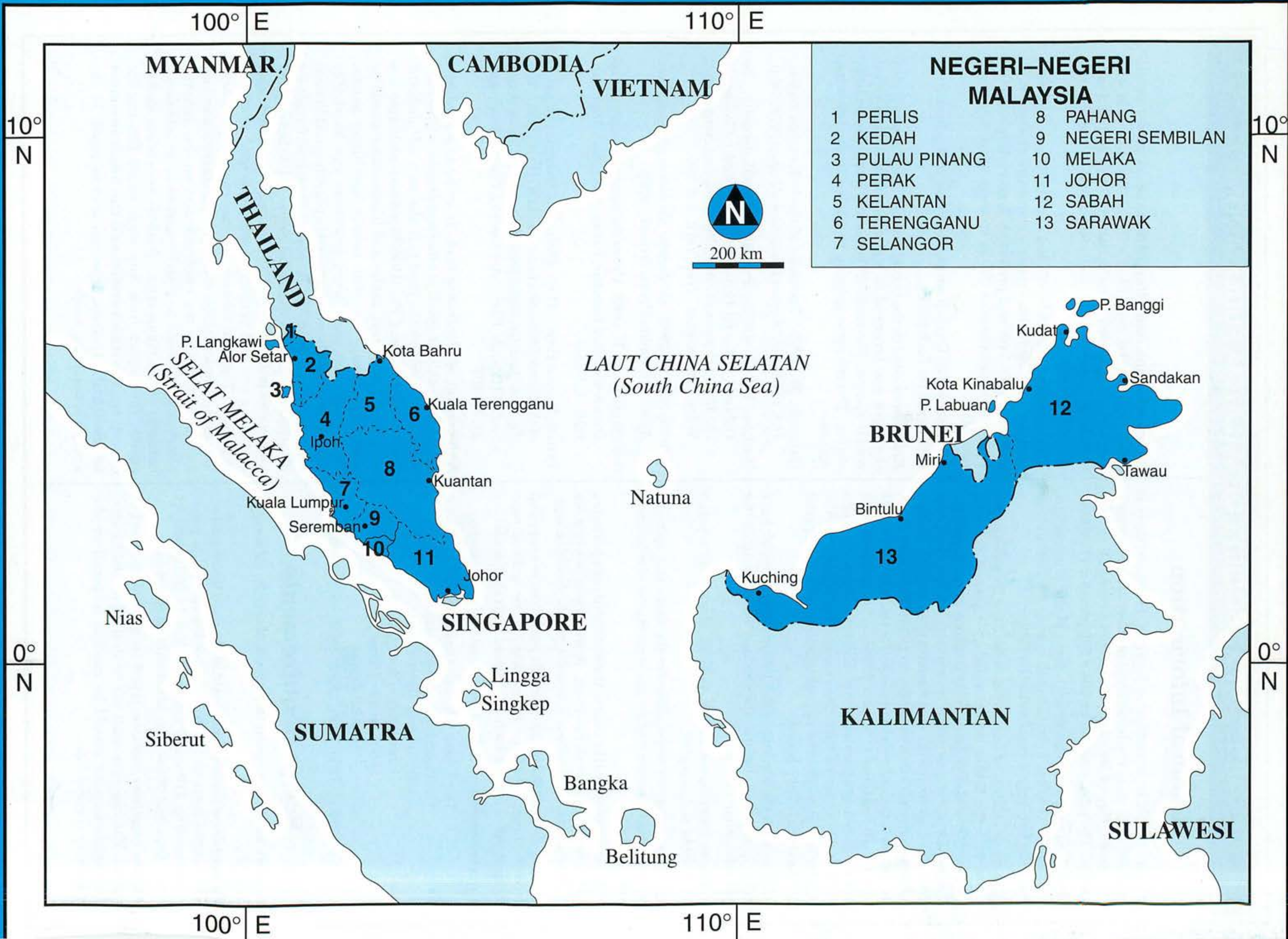

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