

# PERSATUAN GEOLOGI MALAYSIA

# WARTA GEOLOGI

## NEWSLETTER OF THE GEOLOGICAL SOCIETY OF MALAYSIA

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# PERSATUAN GEOLOGI MALAYSIA

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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

### Dispersion of syenitic rock in the microgranitic magma: implication to the relative age between Perhentian Kecil Syenite and Perhentian Granite in the Perhentian Island, Besut, Terengganu

AZMAN A. GHANI, KAMARUL HADI ROSELEE AND AMAN SHAH OTHMAN

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University of Malaya  
50603 Kuala Lumpur

**Abstract:** Irregular syenitic inclusions of various sizes were discovered in microgranitic host at Pasir Patani, southeastern Perhentian Kecil island, Besut, Terengganu. They represent the later stages of mechanical dispersion of the syenitic blocks that fell into the still hot of the younger granitic magma.

#### INTRODUCTION

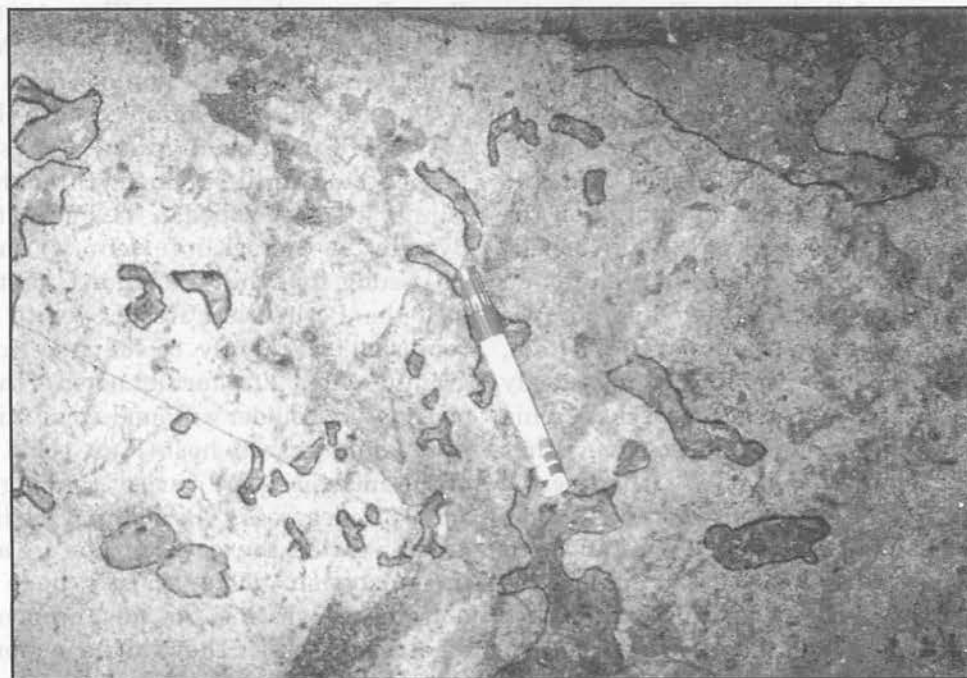
In 1998, Azman and Khoo gave four evidences of the relative age between Perhentian Kecil Syenite and Perhentian Granite in the Perhentian island. They showed that the Perhentian Kecil Syenite is relatively older than the Perhentian Granite in contrast to the Mac Donald (1967) interpretation. The evidences are: (1) occurrence of syenitic blocks in the granitic rock, (2) cross cutting relation of the contact between the rocks, (3) offshoot of microgranite vein from granite to syenite and (4) occurrence of microgranite and porphyritic rocks in the Perhentian granite at the contact, which suggests that the granitic magma quickly chilled against cooled syenitic rocks. This contribution will report new field evidence that will support the relative age. We will describe some new findings obtained from our 2 days visit to the island in April 2000. We discovered irregular syenitic inclusions of various sizes in microgranitic host at Pasir Patani, southeastern Perhentian Kecil island. Detail field relation and geochemistry of the rocks in the study area have been presented by Azman and Khoo (1988), Azman (1999, 2000) and Azman (in press).

#### FIELD DESCRIPTIONS

The contact between Perhentian Kecil Syenite and Perhentian Granite is exposed at Pasir Patani (Azman and Khoo, 1998). Here, the Perhentian Granite intruded the Perhentian Kecil Syenite with the contact dipping 60° to 70° towards the Perhentian Granite. Boundary between them is angular suggesting the Perhentian Granite intruded through an early joint system developed in the Perhentian Kecil Syenite. A microgranite vein (width 10 to 12 cm) issuing from the Perhentian Granite projects into the Perhentian Kecil Syenite and this represents a rapidly cooled injection of the granite. About 20 m further north of the contact, on an *in situ* boulder we found syenitic inclusions in the microgranite host (Figs. 1 and 2). Sizes of the inclusions are varied, ranging from 0.5 cm to 30 cm across. The shape of the inclusions are also varied, the most common are amoeboid-like inclusion. They mostly have rounded margins suggesting the advancement of the digestion process. They can be monomineralic (K-feldspar or hornblende) or consists of typical syenitic material. This syenitic inclusions are easily recognized as the colour and the grain size of the inclusions match exactly to the pink



**Figure 1.** Photograph of irregular ameboid-like syenitic inclusion dispersed in microgranitic rock.



**Figure 2.** Close-up view of the Figure 1.

megacrystic type of the Perhentian Kecil syenite. It is pinkish in colour and consists of coarse grained minerals usually of K-feldspar. Hornblende mono-mineral inclusions occur in smaller size compared to the K-feldspar inclusions.

## DISCUSSION

This paper present another evidence that supports the older age of the Perhentian Kecil Syenite. The syenitic inclusion described in this paper, represent the later stage of mechanical dispersion of the syenitic blocks that fell into the still hot younger granitic magma. The evidence suggests that the syenitic magma already crystallised when the granitic magma intruded. Elsewhere, Azman and Khoo (1998) have reported many angular syenitic 'xenoliths' in the granitic rock (e.g. at Tanjung Batu Nisan and Tanjung Batu Sireh; Figure 6 in Azman and Khoo (1998). Occurrence of the syenitic 'xenoliths' adjacent to the contacts suggests that the granitic magma forced its way up into fractures in its roof and probably helped to detach lumps of overlying syenite. The lumps will slowly dissolved in the granitic magma and the magmatic current will slowly dispersed the syenitic material as irregular shaped inclusions with lobate and cuspsate margins. Occurrence of syenitic inclusions described in this paper together with angular

to subangular syenitic 'xenoliths' suggest that fallen syenitic xenoliths have been digested at different rates by granitic magma. The shape of the syenitic inclusions given in this paper indicates that they have undergone a high degree of digestion (Tindle, 1991).

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## PERTEMUAN PERSATUAN Meetings of the Society

### Ceramah Teknik (Technical Talk)

#### Groundwater study for the Langat Basin

MASAKAZU TAKAHASHI

#### Laporan (Report)

Dr. Masakazu Takahashi, of the JICA Study Team, gave a well-illustrated presentation of his team's groundwater study of the Langat Basin on Tuesday 7th November 2000 at the Geology Department, University of Malaya, at 5.30 pm to an interested audience of 25.



MASAKAZU TAKAHASHI



# REPORT ON FORUM ON YOUNG GEOLOGISTS

**Date: 11 November 2000**

**Time: 9.00 am to 12.00 noon**

**Venue: Geology Department, UM**

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## Foreword

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At first, the forum was designed for all categories of young geologists who work in the private sector. However, due to difficulty in getting representatives from the oil and gas industry, mining industry and others, the forum was finally limited to the engineering industry including environmental and groundwater industries.

As geologists in the engineering sector who have had the least regard from the industry itself compared to those who work in the oil and gas industry, it is time for us to discuss these matters.

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## Introduction

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On 11 November 2000, the Young Geologists' Working Group (YGGWG) of the Geological Society of Malaysia (GSM) organized a Forum on Young Geologists with the theme 'The roles, responsibilities and challenges for Geologists in the Private Sector'. Even though the public sector is very broad for this particular forum, however, it became more focused on the engineering sector as explained by the chairman in his foreword. The forum was divided into two sessions, presentations and discussions.

The purpose of the forum was to gather together all the members or non-members especially the young geologists, graduates or students to discuss and explore further strategies for continuing training, programs and professional development.

### Scope and purpose of this report

This report represents the outcome of the forum. Its findings and recommendations take into account the discussions at the forum as well as further consultations with, and contributions received from the working geologists in the engineering sector, who could not attend the forum.

It is the YGGWG aspiration that this report will be adopted by the Councils of GSM or IGM (Institute of Geology, Malaysia) as the basis for their detailed planning of future activities and priorities. This report and the processes that led to it were never intended to end here. YGGWG wishes to continue to be engaged with geologists in the private sector as well as the students, to hear their ideas, suggestions and constructive criticisms from anyone who cares to contribute.

It is YGGWG's hope that this report will be published in the next *Warta Geologi* or IGM Newsletter or in the form of printed circulation to all GSM/IGM members. The review discussion on this matter shall be carried out annually or biannually.



# FORUM ON YOUNG GEOLOGISTS



## Speakers and Title for Presentations

Four short presentations were given covering the following topics:

- *The geologists' roles in the private sector* by Puan Rozita Musib, Head of Environmental Department, Alam Flora Sdn. Bhd.
- *The geologists' responsibilities in the private sector* by En. Azman Sulaiman, General Manager, TL Geotechnics Sdn. Bhd.
- *The challenges for geologists in the private sector* by Mr. Ng Chak Ngon, Managing Director, Subsurface Engineering Sdn. Bhd.
- *The registration of geologists bill* by Mr. Fateh Chand, Past President, Institute Geology of Malaysia and former Director General, Geological Survey Department, Malaysia.

The presentations at the beginning were designed to set the theme of the forum as well as the objectives of the YGWG.

## Panelists for the Discussion Session

Panelists for the discussion session were as follows:

- Assoc. Prof. Dr. Abd. Ghani Rafek, President of Geological Society of Malaysia.
- Mr. Fateh Chand, Past President of IGM and former Director General, Geological Survey Department, Malaysia.
- Mr. Ng Chak Ngon, Managing Director of Subsurface Engineering Sdn. Bhd.
- Puan Rozita Musib, Head of Environmental Department, Alam Flora Sdn. Bhd.
- En. Abd. Rasid Jaapar, Chairman of Young Geologists Working Group as a forum chairman.

## Participants

62 participants from various backgrounds were able to attend the forum. The participants can be categorized as follows:

- Students from Universiti Kebangsaan Malaysia (15 nos)
- Students from Universiti Malaya (12 nos)
- Lecturers from Universiti Kebangsaan Malaysia (2 nos)
- Lecturers from Universiti Malaya (6 nos)
- Geologists from private sector (27 nos)

Unfortunately, there were no representatives on behalf of the Institute of Geology, Malaysia, the **right** organization to take the lead in issues relating to professional recognition and development.

## Findings from discussion of issues relating to representation and professional recognition

### General

**Q:** Why are geological graduates not interested to join IGM/GSM especially geophysics graduates from USM?

*Arul Mani Shanti*

- Probably due to GSM/IGM being located in the Klang Valley. Therefore, outstation geologists are not interested to join by giving an example based on her experience as a student at UKMS.

*Dr. Abdul Ghani Rafek*

- Did not agree as currently GSM has state representatives.

*Mr. Fateh Chand*

- Suggested that lecturers should play a more active role in encouraging the students to be GSM members. Normally members would ask what GSM/IGM can do for them?

**Q:** Why do many geologists decide not to continue with a geological career?

*Mr. Safarudin Tahir*

- The Government has differentiated between geologists and geophysicists. Therefore, the geological profession has been divided into different categories.

*Mr. Fateh Chand*

- May be due to economic downturn as it not only affects the geological profession but also others such as banking etc. They have to find a job, therefore will join any other profession.

*Ms. Arul Mani Shanti*

- Should not look in the newspapers as jobs in the geological career are normally based on being passed from mouth to mouth or personal contact.
- Proposed industrial training just like other professions such as medical, engineers, lawyers etc.

*Mr. Abd Rasid Jaapar*

- Gave an example of his friend who has a good degree in geology but is now a successful Marketing Manager.
- One of YGWG's objectives is to compile a list of private companies using geologists' services and contact numbers.

*Ms. Gan Lay Chin*

- Most people take geology because it is easy to pass and there is a lot of opportunity to travel.
- Gave example of an Australian mining company that shows you value for money

*Mr. Fateh Chand*

- Malaysian education system limits our choice on subjects that we want to take as well as there are job hunting problems.
- In Japanese companies, they don't care about your first degree as they will provide on-job training. From geology one can switch to become a semiconductor expert.

*Dr. Abdul Ghani Rafek*

- Gave example on Esso that needs someone with little knowledge in geology but will themselves train the person.

## **Recognition by Employers and Other Professions**

**Q:** Are geologists adequately recognized as a separate professional discipline from engineers and does it matter?

*Mr. Tan Boon Kong*

- Yes, many consultation firms require geologists to provide input and the recognition really matters.
- There are two types of graduate geologists, one who only do work when asked and another who will do more than what is required

*Mr. Fateh Chand*

- Local companies do not really appreciate geologists as compared to foreign companies and that goes for the petroleum or mining industry.
- Graduate geologists must do more than what is required by the employers.

*Mr. Ng Chak Ngoon*

- Geologists need to prove themselves that they can do important things. They have to learn as they go along. Geologists should learn engineering then slowly become Engineering Geologists.
- Universities should look into the courses offered, some may have to be revamped. Try to help majority of geological graduates become more useful. Need to share the depression of the lecturer if only 20% of graduate geologists are working in geology related working environment.
- Graduates shall be built in two ways that is by post-graduate courses or short courses. Short courses more relevant in the current situation and should be organised by the GSM/IGM.

*Ms. Rozita Musib*

- Requirements for better career development not only depends on the degree obtained but also on skills and having a positive attitude.

*Dr. Abdul Ghani Rafek*

- Universities should look into possibilities of having post-graduate degree courses and should revise back from the 3 to 4 years to obtain the basic degree.

*Dr. Azhar Hussin*

- Mentioned about weaknesses of the 3-year system which push weaker students to complete the course within the time frame. A lot of programmes have to be compressed and some cannot be done due to the tight schedule.
- Q:** How can we persuade employers and professional colleagues to recognize geologists properly and provide adequate opportunities for professional development?

*Note:*

- This matter was not discussed due to similarity with the above discussion. Majority agreed that graduate geologists should improve themselves first.
- Q:** Should GSM/IGM make a presentation to take around to employers selling the importance of geologists or an information pack sent out by the Society to relevant employers/employers' associations?

*Note:*

- Majority agreed that the above matter need not be discussed as the graduate geologists have to prove themselves.

## **Training**

- Q:** Is the knowledge received from the university enough for geologists to face challenges working in the private sector?

*Note:*

- The above matter was not discussed further as it involved a lot of things beyond GSM's capability such as the education policy, curriculum, etc.
  - Majority agreed that graduates should equip themselves to be more successful.
- Q:** Should we seek to persuade GSM/IGM to organise continuing training or short courses for young geologists?

*Mr. Fateh Chand*

- Short courses will help.
- Should send students for industrial training for at least 3 months. Then, they become marketable

*Dr. Azhar Hussin*

- Private companies in oil and gas industry provide a lot of on-job training for graduate geologists.

*Mr. Tan Boon Kong*

- Difficult to send for industrial training with current 3-year system.
  - IEM organises a lot of courses related to geotechnical engineering and/or engineering geology but the fees are quite expensive. In future, GSM should try to organise the training in house so that the cost can be reduced.
- Q:** Can GSM/IGM have the registration of geologists based on their competency? Should GSM/IGM assess the level of competency based on training or interview? Would this help the employers?

*Mr. Abd Rasid Jaapar*

- Should follow UK Geological Society which has 100 hours of training through a programme called Continuing Professional Development (CPD) and at the end receive Competency Certificate for Chartered Geologist status.

*Dr. Abdul Ghani Rafek*

- May be CIDB can do this. Some of the Australian Universities offer short and compacted courses such as rock mechanics or soil mechanics and the participants received a certificate. Universities together with GSM should look into this matter.

*Mr. Tan Boon Kong*

- Graduate Engineers have points whenever they attend the courses and it benefits them in the pursuit for Professional status.

*Mr. Fateh Chand*

- In the geologists' act, IGM can do a similar thing. Since the act is not in place, IGM cannot do much. However, IGM/GSM/Universities should discuss it if it is necessary.
- GSM is not in any position to issue any competency certificate.

*Mr. Ng Chak Ngoon*

- Training is more important than competency certificate as we cannot judge the participants competency level.

*Mr. Raja Abdul Halim*

- Should have both, that is, training and competency certificate.
- Q:** Should GSM/IGM have ethical code for the members in terms of professionalism? Should this code of ethics be taught in the university? How about project or human management subjects which is commonly one of the geologists' weaknesses?

*Mr. Abd. Rasid Jaapar*

- Code of ethics was not emphasised in universities to the geological students. GSM should have this ethical code and this should be taught in the universities so that the students can be more ethical after leaving universities.

*Dr. Azhar Hussin*

- The right organization for code of ethics is IGM and not GSM as IGM is a professional body while GSM is only a scientific body.
- Q:** Can GSM/IGM make it mandatory for any geologist who wants to specialise in an additional field of geology such as Engineering Geology, Mining Geology, Petroleum Geology, Environmental Geology etc. should have a minimum of 5 years post-graduate experience or 3 years for MSc holders?

*Mr. Fateh Chand*

- Not necessary as geology is a versatile profession. However, geologists should understand that they should not get involved in work beyond their expertise. For example, an Engineering Geologist should not be involved in Petroleum Geology or vice versa.

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## Findings From Questionnaire

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The questionnaire relating to the needs of young geologists in the private sector was passed around during the registration. Out of 27 participants from the private sector, 17 nos had responded and returned the questionnaire duly filled.

The findings from the questionnaire are as follows:

1. 56% respondents from the private sector are between the ages of 25 to 30 years, 38% 30 to 35 years and 6% less than 25 years.
2. 40% respondents had less than 3 years working experience, 38% between 5 to 10 years and 22% between 3 to 5 years.
3. 75% said that their job is partly dependent on their training as a geologist, 19% essentially and 6% said not at all.
4. 38% of respondents working for geotechnical contractors (mainly SI), 31% for engineering consultants, 13% for project management companies, 6% for construction companies and another 6% for environmental consultants.
5. 75% working as permanent staff, 13% contract staff, 6% partnership and 6% own business.
6. 51% had gross salary between RM1,000 to RM2,000, 24% RM2,000 to RM3,500, 19% RM3,500 to RM5,000 and 6% above RM5,000.
7. 56% think their salary will be between RM2,000 to RM3,500 in 5 years time, 31% above RM5,000 and 13% RM3,500 to RM5,000.
8. 56% respondents are grateful to get their current job, 24% happy that their training as geologist is useful to their current work and 20% wish to change to another job not related to geology.
9. 63% said that their bosses and/or colleagues treat them as other professionals in the company, 20% as site supervisor only and 17% as specialist.
10. 63% rate their prospects for professional advancement as geologist as fair (like other professional), 24% good (prospect to be the boss or better position) and 13% bad (shall die a site supervisor).
11. 56% think that the training they received in the universities is not enough, 31% to some extent and 13% enough.
12. 75% wish to continue training for professional development and 25% will depend on the nature of courses offered.
13. 100% of the respondents require training in slope stability analysis/design & foundation engineering, 63% require soil/rock mechanics, environmental geology/geotechnics, interpretation of testing results and project/organization/human management. 56% require groundwater modelling, 38% hydrogeology & engineering geophysics, 25% geological mapping, 13% on sample/geological logging.
14. 40% require training in the form of short courses, 24% night classes, 24% formal courses such as post-graduate diploma and 12% long distance.
15. 44% out of total respondents are GSM members, 38% IGM members, 12% ENSEARCH and 6% IEM.
16. 100% of those who are not GSM/IGM members said that joining GSM/IGM will not benefit them.

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## Recommendations

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Based on the above findings, the Young Geologists' Working Group would like to make the following recommendations:

1. The lecturers at local universities shall ensure their students become GSM members. Students also shall be encouraged to have their own Geological Club at Universities and this club shall have direct connection with GSM. Lecturers must also emphasize the professional ethics to the students so that the graduates can have strong life principles and be a professional with ethics and high morale.
2. GSM should finalize its state representatives fast so that members outside Klang Valley can be more active with their own activities at state level.
3. GSM should prepare a database on private companies requiring geologists as one of their professional staff for undergraduates' references while looking for vacancies.
4. Universities should look into the proposal of sending their students for industrial training as practised by other professional courses.
5. GSM/IGM together with representatives from local universities should form a discussion group to look into the possibility of organising courses for graduate geologists for their professional development. The courses can in the form of short courses or evening classes and the successful candidate may receive a certificate upon completion of his/her courses. A good example is computer courses offered by many institutions.
6. For immediate action, GSM/IGM shall conduct in-house training for graduate geologists especially in the engineering and environmental fields where recognition of the geologists' contributions are much less appreciated.

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## Summary

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YGWG would like to thank those who were involved and have contributed in this forum directly or indirectly.

While more than half of the young geologists say that the universities' syllabus is not enough for them to survive after graduation in the open world, the majority of the participants agreed that young geologists should prove to themselves that they can do more than what their employers or bosses expect.

Finally, there are four challenges for us to face in this new millennium:

1. Challenges for young geologists, to prove that they are capable to go beyond.
2. Challenges for GSM/IGM, to provide training and/or professional development to our members.
3. Challenges for lecturers, to guide students to be more ethical, professional, resourceful and marketable.
4. Challenges for senior geologists, to guide young geologists in all aspects of life especially technical aspects and to create more vacancy for graduate geologists within their organisation (to reduce the number of unemployed geological graduates)

Thank you.

Abd. Rasid Jaapar  
Chairman,  
Young Geologists Working Group 2000/2001

## Malam “Consultancy Practice: Independence, Ethics & Professionalism” — Report

The above “malam” was held on the 15th November 2000 at the Department of Geology, UM. The objective of the event was to provide a forum for the discussion on Consultancy Practice in general, including matters on independence of consultancy reports, ethics and professionalism, etc.

Three panelists presented their views and experience on the above matters, and they were: Mr. Ng Chak Ngoon of Subsurface Engineering, Mr. Koay Leong Thye of Ranhill, and Dr. Gue See Sew of Gue & Partners.

Topics discussed include relevance of geologic reports to engineering projects, the proposed Geologic Act and registration of professional geologists, supervision of site investigation works, legal matters and “expert” witnesses, engineering geology vs. “pure” geology, etc. etc.

Some lively discussions and comments followed the presentations.



Tan Boon Kong  
Chairman  
Working Group on  
Engineering Geology/Hydrogeology

NG CHAK NGOON



GUE SEE SEW



KOAY LEONG THYE



## The world of jade

LAU YIN LEONG

### Laporan (Report)

Mr. Lau Yin Leong of GINN-M Corporation Sdn. Bhd. gave the above talk on Thursday 21st December 2000 at 5.00 pm at the Geology Department, University of Malaya, to an enthusiastic crowd of 30. Mr. Lau is a Graduate Gemologist trained at the famous Geological Institute of America (GIA) in New York City.

Mr. Lau travels widely in third world countries in search of gemstones. He is a regular bidder for jade and gemstones at the annual auction conducted by the Myanmar Government in Yangon.

As a jade and gemstones dealer for the past ten years, Mr. Lau, is a very qualified speaker in this series of talks organised by the Working Group on Economic Geology.

In his interesting talk, Mr. Lau, gave a brief history of jade, means of identifying jade, colour of jade, sources of jade, jade stimulant and imitations, trade terms of jade and quality factors in determining the price of jade.

After the talk and plenty of questions, the participants were able to view on display Mr. Lau's collection of numerous samples of uncut jadeite, jade blocks, jade stimulants, enhanced jade and also fake jade.

G.H. Teh



## The world of jade



# PETROLEUM GEOLOGY CONFERENCE 2000

22 & 23 November 2000  
Shangri-La Hotel, Kuala Lumpur, Malaysia

## REPORT

The 22nd Petroleum Geology Conference 2000 was held on the 22nd and 23rd November 2000 at the Shangri-La Hotel, Kuala Lumpur. It was attended by well over 300 participants where one keynote paper, 29 technical papers and 10 posters were presented.

The 22nd Petroleum Geology Conference 2000 was declared open by En. Abu Bakar Mohamed, Senior General Manager, Petroleum Management Unit, E&P Business, PETRONAS. In his Opening Address, En. Abu Bakar noted that with the improving economic situation in Malaysia, a preferred more stable oil price would allow us to invest more in the upstream activities in Malaysia. The implementation of new seismic acquisition and processing techniques has helped in gaining better data and more accurate evaluations of our assets. With innovative ideas, the application of leading edge technologies will enable companies to successfully explore and produce substantial amounts of hydrocarbons reservoired in subtle, illusive and deep plays. In the Malaysian exploration scenario, there is an increase in both exploration and development activities. The service sector is increasingly playing a more important role in providing the latest technologies as evidenced in the 24 exhibition booths.

The Organising Chairman of the 2000 Petroleum Geology Conference, En. Yusoff Johari, and his Organising Committee should be congratulated for organising a very successful Conference.

G.H. Teh

# PETROLEUM GEOLOGY CONFERENCE 2000

22 & 23 November 2000  
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## PROGRAMME

### Wednesday, 22 November 2000

- 08.00 : **Registration**
- 08.50 : **Arrival of Invited Guests**
- 09.00 : **Welcoming Address by Prof. Madya Dr. Abd. Ghani Mohd Rafek, President of GSM**
- 09.10 : **Opening Address by En. Abu Bakar Mohamed, Senior Manager, Petroleum Management Unit, E&P Business, PETRONAS**
- 09.30 : **Coffee Break**

### Session 1 : Morning Session

#### Session Co-Chairmen:

**Khairul Anuar Husin (XM, PCSB)**

**Keith Hill (XM, Lundin Oil)**

- 10.00 : **Keynote Address:** Transition into deepwater for South East Asia and Malaysia  
*Mike Shirley (GM, Murphy Oil)*
- 10.30 : **Paper 1:** Exploration during the 1990s in South East Asia: a discussion on activity, the lessons learnt and a glimpse into the future  
*Ian Cross (IHS Energy Group, Singapore)*
- 11.00 : **Paper 2:** Depositional model of Miocene carbonate reservoirs in the F6 Field, offshore Sarawak  
*Matsuda, F. (JNOC), Nakamori, T., Iryu Y. (Tohoku U.), Matsuda, H. (Kumamoto U.) & Chua Beng Yap (PMU)*
- 11.30 : **Paper 3:** Subsurface E&P data management: some recent SSB/SSPC experiences  
*Philip Lesslar (SSB/SSPC)*
- 12.00 : **Paper 4:** Advances in the evaluation of SE Asian Miocene shaly sand reservoirs  
*P.M. Lloyd (Sch), J. Kijam (PCSB), H. Ashraf, & S. Aziz (Sylhet)*
- 12.30 : **Lunch** (sponsored by Schlumberger)

# PETROLEUM GEOLOGY CONFERENCE 2000

22 & 23 November 2000  
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## PROGRAMME

Wednesday, 22 November 2000

### Session 2 : Afternoon Session

#### Session Co-Chairmen:

*Ted G. Zacharakis (XM, Murphy Oil)*

*Denis Tan (XM, SEPM)*

- 13.30 : **Paper 5:** Facies distribution and depositional systems of the modern Baram delta  
*Abdul Aziz b. Abdul Rahim, Cheong Yaw Peng & Joseph J. Lambiase (UBD)*
- 14.00 : **Paper 6:** Palas field integrated depletion plan  
*Ang Duen Woei, Mathis R.S., Mohd Rizam Sarif, Aaron Tee, Yap Kok Thye & Kompanik G.S. (EPMI)*
- 14.30 : **Paper 7:** Fast and slim — Creative development concepts in an oil field, offshore Sabah, Malaysia  
*Philippe Heer (SSPC), Abdul Rahman Yusoff (PMU) & Malvinder Bandal (PCSB)*
- 15.00 : **Paper 8:** Characterizing fractured reservoirs using sonic measurements  
*Aung Than Oo, Amri Amdan & Rokiah Esa (Schlumberger)*
- 15.30 : **Paper 9:** Reservoir characterization of Cycle I and II clastics, offshore Sarawak — a sedimentological investigation  
*M. Johansson (Schl.), Mackertich D., E.S. Swee (A. Hess) & A.T. Oo (Schl.)*
- 16.00 : **Coffee Break**

# PETROLEUM GEOLOGY CONFERENCE 2000

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## PROGRAMME

Wednesday, 22 November 2000

### Session 3 : Afternoon Session

Session Co-Chairmen:

*Kurujit Nakornthap (CEO, MTJA)*

*Hoh Swee Chee (Sen. Mgr, PRAD, PMU)*

- 16.20 : **Paper 10:** Seismic facies analysis of the synrift sediments, in the northeast Malay Basin  
*Robert Wong , Hamdan Mohamad (PMU) & M. Firdaus A. Halim (PRSS)*
- 16.50 : **Paper 11:** Seismically constrained static reservoir characterization and modelling using inverted seismic data  
*Geoffrey Pang (SSB)*
- 17.20 : **Paper 12:** Sand geometry of the deep water Crocker sediments in the Kota Kinabalu area, Sabah  
*Felix Tongkul (UMS)*
- 17.50 : **Paper 13:** 3D seismic interpretation and quantitative fault seal analysis: Muglad Basin, Sudan  
*Azmir B. Zamri (PCSB)*
- 18.20 : **Paper 14:** Geomechanics — its impact on the life cycle of the reservoir  
*Rokiah Esa (Schlumberger)*
- 18.50 : **Paper 15:** Reservoir development and distribution in the deepwater offshore West Sabah  
*Harvey, Mark J. (SSPC)*
- 19.20 : **Evening Cocktail** (sponsored by Teknosif/Western Geophysical/Geco)

# PETROLEUM GEOLOGY CONFERENCE 2000

22 & 23 November 2000  
Shangri-La Hotel, Kuala Lumpur, Malaysia

## PROGRAMME

Thursday, 23 November 2000

### Session 4 : Morning Session

Session Co-Chairmen:

*David Mackertich* (XM, Amerada Hess)

*M. Izham Ismail* (XM, EPMI)

- 08.30 : **Paper 16:** Exhumation of Sabah based on fission-track thermochronology: relevance to the Baram Delta  
*Charles Hutchison*
- 09.00 : **Paper 17:** Source rock characteristics of outcrop samples from Klias Peninsula, Sabah  
*Liaw Kim Kiat (SSPC)*
- 09.30 : **Paper 18:** Sand body character of the modern Baram Delta: implications for petroleum reservoir models in Northwest Borneo  
*Cheong Yaw Peng, Abdul Aziz b. Abdul Rahim & Joseph J. Lambiase (UBD)*
- 10.00 : **Paper 19:** Integrated field depletion study of a complexly faulted field: Irong Barat  
*Chakravarthy Sathasivam, Mohd. Khalid Jamiran & Cheng-Sum Ong (EPMI)*
- 10.30 : **Coffee Break**
- 10.50 : **Paper 20:** Computer simulation of carbonate reservoir model by Facies-3D  
*Yoshida, T., Matsuda, F., Iwahashi, R., Tsukui, O., Ooki, O. & Sato, H. (JNOC)*
- 11.20 : **Paper 21:** Challenges of 4C seismic acquisition and processing, offshore Sarawak  
*Cyril Wong (SSB/SSPC)*
- 11.50 : **Paper 22:** 3D seismic field evaluation — integrated application approach  
*M. Redhani A. Rahman & Ng Tong San (PCSB)*
- 12.20 : **Lunch** (sponsored by Landmark Graphics)

# PETROLEUM GEOLOGY CONFERENCE 2000

22 & 23 November 2000  
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## PROGRAMME

Thursday, 23 November 2000

### Session 5 : Afternoon Session

Session Co-Chairmen:

*Andy Wight* (Acting GM, YPF Malaysia)

*Bill Schaefer Jr.* (GM, Santa Fe Malaysia)

- 13.30 : **Paper 23:** Relationship between biomarker distributions, maceral assemblages and lithofacies in the coal-bearing sequence of Bintulu, Sarawak  
*Ouzani Bachir & Wan Hasiah Abdullah (UM)*
- 14.00 : **Paper 24:** Stress fields of Sundaland during the Tertiary  
*H.D. Tjia (PRSS)*
- 14.30 : **Paper 25:** Pre-stack imaging: time or depth?  
*Carl Notfors, Peter Whiting & Geoff Mansfield (Veritas DGC)*
- 15.00 : **Paper 26:** STRATAGEM — forward stratigraphic modelling for Block E, offshore Sarawak  
*Mark Newall, J. Jong & L.P. Sha (SSB)*
- 15.30 : **Coffee Break**
- 15.50 : **Paper 27:** Geometry and wireline signatures of tidal sandstones reservoirs: outcrop analogus from Brunei Darulssalam  
*Lim Teo Hee, Joseph J. Lambiase & John K. Warren (UBD)*
- 16.20 : **Paper 28:** Seismically constrained lithology modelling  
*Mark Sams (Jason Geosystem)*
- 16.50 : **Paper 29:** Deepwater exploration, offshore NW Sabah: Kamunsu East upthrown drilling success  
*Saiful Bahri Zainal (SSPC)*
- 17.20 : **Closing Remarks and Closing of Conference**



# PETROLEUM GEOLOGY CONFERENCE 2000

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## PROGRAMME

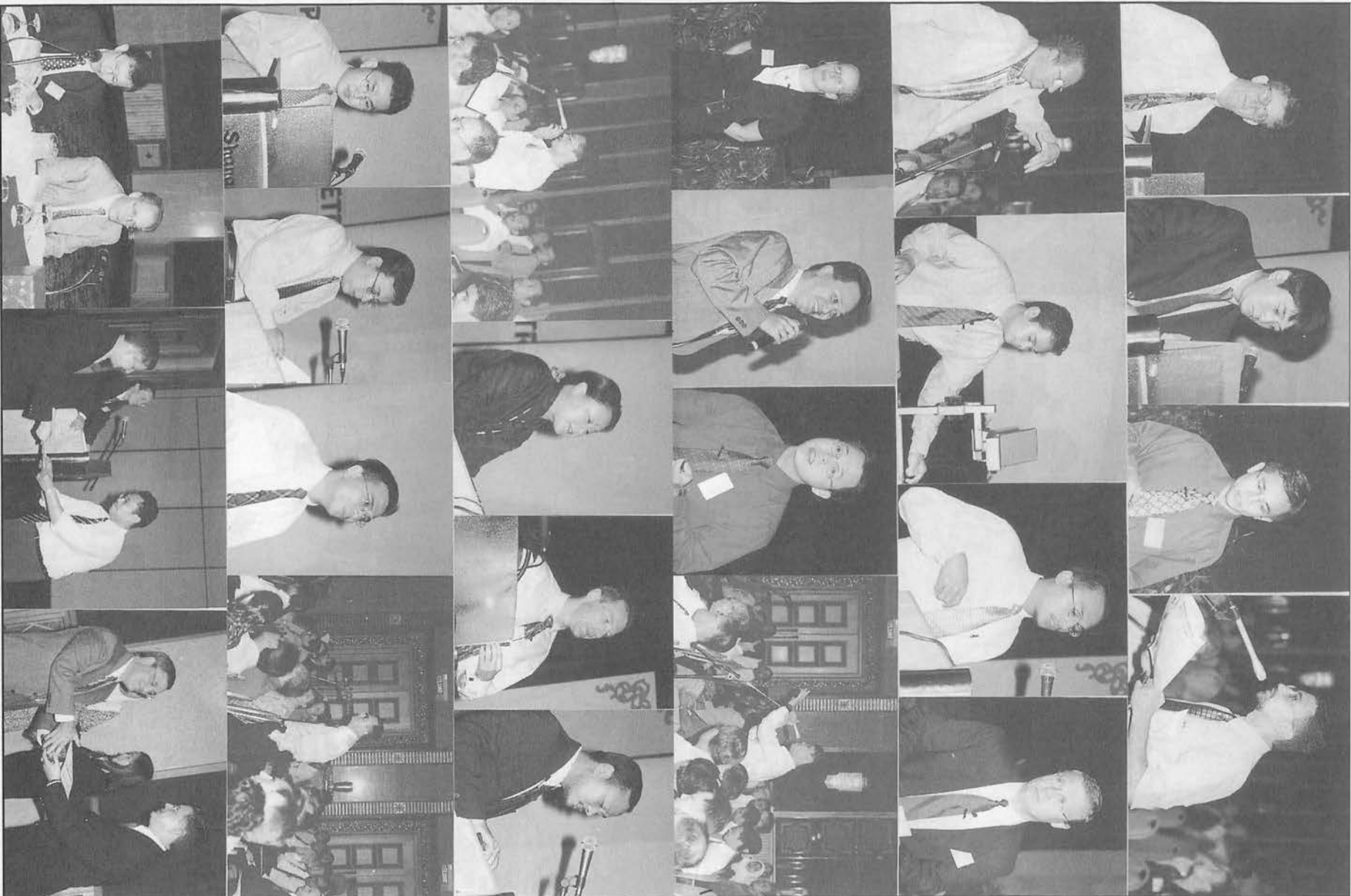
### POSTER SESSION

1. Processing to the limit with SIPMAP, Shell proprietary in-house seismic processing software  
*Khaw Lay Hong and Nazeri Abd Ghani (SSB/SSPC)*
2. The study of overpressures in NW Borneo  
*Yong Boon Teck (SSPC)*
3. The paleogeographic evolution of the NW Borneo margin  
*Francis Ho, Charlie Lee, John Jong, Yong Boon Teck & Mark Newall (SSB)*
4. Source rock evaluation and geochemical characteristics of hydrocarbons from Sabah and Sarawak  
*J. Jong, B.T. Yong & P. Lambregts (SSB)*
5. Preserving our key geological exposures — exploring the realm of geotourism  
*Philip Lesslar and Charlie Lee (SSB/SSPC)*
6. Quantitative modelling and understanding the evolution and distribution of reservoirs in West Sabah continental margin, Malaysia  
*Charlie Lee, Zulkefli Abdul Hamid & Wong Chung Lee (SSPC)*
7. Drastic reduction in commerciality threshold for offshore exploration, Java Sea, Indonesia  
*D. Roger Wall<sup>1</sup>, Andrew W.R. Wight<sup>1</sup>, E.J. Indrawan<sup>1</sup>, Michael E. Ellis<sup>1</sup>, Douglas A. Park<sup>1</sup> & Alan Baker<sup>2</sup> (<sup>1</sup>YPF Maxus Southeast Sumatra BV & <sup>2</sup>PT Schlumberger Indonesia)*
8. Oil-generating potential of the Tanjung Formation coals of South Kalimantan, Indonesia  
*Wan Hasiah Abdullah, Wan Nafiza Wan Jaafar & Rosni Lokmannul Hakim (UM)*
9. Lowering risk in the exploration process: what can we get from basic modeling  
*Jean-Michel Gaulier, Remi Mouchel (Beicip-Franlab), Johannes Wendebourg, Frederic Schneider, Jean-Luc Rudkiewicz & Sylvie Wolf (IFP)*
10. Exploration opportunities in Malaysia  
*Nordin Ramli, Barney Mahendran, Zulkefli Abdul Hamid, Mansor Ahmad, Mohd Adib Abdullah Hudi & Abd Rahman M. Eusoff (PRAD/PMU Petronas)*

# PETROLEUM GEOLOGY CONFERENCE 2000



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## Opening Address by En. Abu Bakar Mohamed, Senior General Manager, Petroleum Management Unit, E&P Business, PETRONAS

*Yang Berusaha Dr. Abdul Ghani Rafiq,  
President of Geological Society of Malaysia,*

*En. Yusoff Johari  
Organising Chairman of the 2000 Petroleum Geology Conference,*

*Distinguished Guests,*

*Ladies and Gentlemen,*

Assalamualaikum 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 ke Malaysia". I am sure you would enjoy the warm weather with clear blue skies offered by 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 22nd Petroleum Geology Conference organised by the Geological Society of Malaysia.

The work put in by the Geological Society of Malaysia and PETRONAS to organise this annual petroleum geology conference 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 is also to transform a good geologist into an astute oil finder 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 where 29 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.

This year, oil prices made an upturn to 10-year highs, surging up to around US\$39 a barrel at one point. Whilst oil prices may be a boom to oil exporting nations, oil importing countries face the risk of escalating inflation, deteriorating trade balances and weaker economic growth. Indeed, higher than expected oil prices is a major threat to the continued strength of global growth. Whatever the scenario, the improving economic situation is our country and a preferred more stable oil price and promising future would allow us to invest more in the upstream activities in Malaysia. 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,*

Technical innovation and 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), have helped us gain better data 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 realistic 3D visualisations of our subsurface geologies. 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, our basins are getting into a mature stage with the opportunity for exploration those obvious structural traps almost closed. 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 and produce these assets. The service sector is increasingly playing a more important role in providing these required technologies. Hence in this Conference, we have some 24 Exhibition Booths (from France, Indonesia and Australia) to display the latest technologies in the market.

*Ladies and Gentlemen,*

In the Malaysian exploration scenario we will see an increase in both exploration and development activities. Our new contractors like Murphy, Amerada Hess, Santa Fe and YPF will be drilling their exploration wells very soon. In addition established players like Carigali, Shell and Esso has made inroads into our new play fairways. It is noteworthy to mention that the Tukai Deep wildcat well, drilled by Carigali opened a "deep reservoir" oil play in the Baram Delta Province. Similarly, Sabah Shell discovered a new play in the turbidites through their appraisal well drilled in the old South Furious field.

As I speaking to you this morning, Murphy Oil is currently drilling their first exploration well in Malaysia and has encountered very encouraging significant oil shows in the previously drilled West Patricia structure.

In our deepwater areas too, Esso has spudded the Lanjak-1 deepwater in Sarawak well just 3 days ago. Hopefully this well add a new "hydrocarbon chapter" to our Deepwater Areas in Malaysia.

*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 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, 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.

It is with great pleasure that I declare the 22nd Petroleum Geology Conference open.

# PETROLEUM GEOLOGY CONFERENCE 2000

22 & 23 November 2000  
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## ABSTRACTS OF PAPERS

*Keynote Address*

### Transition into deepwater for South East Asia and Malaysia

MIKE SHIRLEY

Murphy Oil

*Paper 1*

### Exploration during the 1990s in South East Asia: a discussion on activity, the lessons learned and a glimpse into the future

IAN CROSS

IHS Energy Group

135 Cecil St., 02-01 LKN Bldg.

Singapore 069536

This talk will review the many ups and downs that the nine countries in South East Asia have seen during the past decade. The events covered are deemed important to the industry during the decade and some will have a bearing on the next ten years through the decisions made and lessons learned. Much of the discussion will be focussed on upstream activity with particular emphasis on exploration and appraisal drilling, reserve replacement, and contract and concessional activities.

As we started the decade the herd instinct was in full flow with companies rushing out to acquire acreage in the Far East at highly inflated prices, which, in a large number of cases, they hoped to farm-out to offset costly exploration programmes. 'Hot spots' at the time included offshore Cambodia and Vietnam, onshore Burma (Myanmar), eastern Indonesia, the disputed Spratly Islands and the overlapping zones in the Gulf of Thailand.

The decade started off well with the announcement that Conoco's Indonesian wildcat Alu Alu East #1, which had actually been completed in late 1989, had flowed at very impressive rates from its location in the West Natuna Basin. This was subsequently developed as the Belida Field, and with reserves of around 300 MMBO. Not bad for a gas prospect which was drilled on acreage held since 1968.

There were other successful oil (and condensate) discoveries announced during the decade but overall the amount of gas discovered dominated. The average field size discovered in the 1990s was 24 MMBO and this was still higher than the 18 MMBO recorded in the previous decade but much lower than the 1970s when it averaged 70 MMBO (see below).

In the 1990s the 485 reported discoveries recorded recoverable reserves of just under 25 MMMBOE thus being a more successful decade than the 1980s which recorded some 14 MMMBOE from 476 discoveries. The best year was 1997 when almost 5 MMMBOE were added to the reserves base, largely a result of successful drilling by Arco in the Indonesian province of Irian Jaya in the gas-prone pre-Tertiary where its Vorwata #1 wildcat discovered some 11 TCFG. The figures available show that in 1989 ultimate recoverable reserves in South East Asia totalled 87 MMMBOE and by 1999 this had increased to 112 MMMBOE (or by 29%).

The most successful operator in terms of exploration success was Arco, followed by Unocal, Total, CTOC, Shell, Gulf Canada, Oxy, Esso, and Texaco.

Meanwhile during the 1990s production rose from approximately 2,360,000 barrels of liquids per day (oil and condensate) and 9400 MMCFGD in 1989, to 2,550,000 barrels of liquids per day and 15,800 MMCFGD in 1999. Liquids showed an 8.5% rise with a fall in Indonesian production being countered by a large increase in oil production in Vietnam and increases in condensate in Malaysia and Thailand. Gas production showed a dramatic increase of almost 70% with large increases from all the main producing countries.

In terms of exploration activity Indonesia was the most active country in South East Asia being responsible for almost 60% of the exploration wells completed (see below).

Some of the more important discoveries made during the decade include Total's NW Peciko, Arco's Wiriagar Deep and Vorwata (to be developed as Tangguh), Asamera's Sumpal, Exspan's Kaji-Samoga, Unocal's West Seno and Merah Besar (all Indonesia), Oxy's Malampaya in the Philippines, Texaco's Yetagun in Burma, JVPC's Rang Dong in Vietnam, Shell's Kamansu East and Oxy's Jintan (both Malaysia), and Unocal's Pailin and Pogo's Benchamas (both in Thailand). Interestingly, three of these were made in deep-water areas, four in pre-Tertiary or Basement sequences and several in structures mapped by earlier operators who chose not to drill for various reasons.

The largest deal made in the South East Asia region during this period was Texaco's purchase of a 45% stake from Shell to join it in the Malampaya Field in the Philippines. This was understood to be a complex deal and press reports indicated that Texaco paid somewhere in the region of US\$1 billion to join the project. Other large deals saw Chevron purchase Rutherford-Moran's stake in B8/32 in the Gulf of Thailand, Premier purchase Texaco's equity in the Yetagun Field offshore Burma and Total buy a stake from PTTEP in the "B" Structure (now Bongkot) also in the Gulf of Thailand. A look at the top ten deals in the region saw only two of these involving Indonesian acreage while eight of them primarily involved the purchase of gas rather than liquids.

As we enter the next decade many changes have occurred in the industry. No longer are we seeing companies using the machine gun approach to selecting acreage. The industry is becoming far more focussed with a great deal of effort being put into buying hydrocarbons in the ground rather than drilling for it. The larger companies, or majors and super majors, seem to be concentrating their exploration efforts on the deep-water areas and unless they become involved in gas in a big way they may choose to leave the region in the near future. We are seeing more and more small companies enter areas where exploration is becoming more and more mature and blocks smaller. However, many of these independent companies are struggling with high funding costs and have little production to benefit from the high oil price following its dramatic rebound in late 1999.

National oil companies are now less dependent on licensing rounds as a means to attract foreign investment and are becoming more realistic about signature bonuses and flexible about fiscal terms. Some have relaxed their rules on viewing and obtaining data, one of the great problems the industry experienced in previous decades.

Many areas do still exist for major hydrocarbon finds however, although these may be gas rather than oil biased. These include several deep-water basins, which are very much in their infancy in terms of exploration, the under-explored Mekong and Eastern basins of Vietnam, the complex onshore pre-Tertiary of Indochina and Eastern Indonesia, and the remote northern onshore basins of Burma.



## Depositional model of Miocene carbonate reservoirs in the F6 field, offshore Sarawak, Malaysia

MATSUDA, F.<sup>1</sup>, NAKAMORI, T.<sup>2</sup>, IRYU, Y.<sup>2</sup>, MATSUDA, H.<sup>3</sup> & CHUA BENG YAP<sup>4</sup>

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Japan

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50088 Kuala Lumpur, Malaysia

The F6 field is located in the offshore Sarawak, east Malaysia. The F6 buildup forming the field consists of the Middle to Upper Miocene reefal carbonates, and developed above the fault block composed of the Lower Miocene siliciclastics (Eping, 1989; Wee and Liew, 1988).

In this study, a total of 1,200 feet of cores from the field was sedimentologically described. Further analyses conducted approximately at every ten feet were as follows; (1) thin-section petrographic analysis, (2) faunal analysis including foraminifers, corals, algae and other fossils, (3) biostratigraphic analysis using benthic foraminiferal fossils and nannofossils, (4) XRD mineral compositional analysis, and (5) carbon and oxygen stable isotope analysis. The following depositional model was reconstructed by integration of these analytical data with results of well correlation using twenty-one electrical log Events including A, A-2, B, E, G and H, and seismic interpretation.

Based on sequence stratigraphic analysis and correlation with third-order cycles of Haq *et al.*, (1988), the reservoir section in the field was subdivided into lower, middle and upper units, which were respectively correlated with the upper 3.2, 3.3 and lower 3.4 third-order global sequences of the Late Miocene. **The lower unit** below Event H mainly consists of a restricted back reef. **The middle unit** between Events A-2 and H comprises an alternation of a shallow fore reef and deep fore reef facies. An extensive exposure surface was recognized in the shallow fore reef facies, on the basis of core observation, evaluation of diagenetic textures and presence of a strong negative anomaly of oxygen and carbon stable isotope data. In the deep fore reef facies with siliciclastic inputs, the results of well correlation and seismic interpretation indicate the presence of major backsteppings, at least, near Events B and G. **The upper unit** between Events A and A-2 is mainly composed of a relatively open marine reef facies. Seismic data show a minor progradation of the reef in its eastern margin. Since no evidence for major subaerial exposures was found in the upper unit, it is considered that the reef growth was terminated with the drowning caused by a major transgression in the third-order global sequence 3.4.

## Subsurface E&P data management: some recent SSB/SSPC experiences

PHILIP LESSLAR

Sarawak Shell Berhad/Sabah Shell Petroleum Co. Ltd.  
Miri, Sarawak, Malaysia

Sarawak Shell Berhad/Sabah Shell Petroleum Company embarked on a company wide subsurface data integration (SSDI) project in early 1997 following an organisational restructuring in 1996. Now, nearly four years later, significant progress has been made in a number of areas. However, there is a continuing drive to identify and resolve areas of weakness and to continue to improve.

This paper discusses the issues and challenges in E&P subsurface data management, approaches taken to address them and experiences to date. In particular it covers the following areas:

- Data ownership and culture change
- Database architecture and data processes
- Data integration and how this can be achieved
- Procedures

In summary, the paper looks at the recognised issues that remain to be tackled and the approaches that are being taken and concludes by taking a look at some of the exciting developments in technology in recent years that may have impact on subsurface data management.

## Paper 4

## Advances in the evaluation of SE Asian Miocene shaly sand reservoirs

P.M. LLOYD<sup>1</sup>, J. KIJAM<sup>2</sup>, H. ASHRAF<sup>3</sup> & S. AZIZ<sup>3</sup>

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<sup>2</sup>PETRONAS Carigali Sdn. Bhd.  
25th Floor Menara 1, Petronas Twin Towers  
Jalan P. Ramlee, off Jalan Ampang  
Kuala Lumpur, Malaysia

<sup>3</sup>Sylhet Gas Fields Limited  
Bangladesh

South East Asian middle Miocene silici-clastic reservoirs are prolific oil and gas producers, but they also present many challenges to log interpretation. The frequently "hot sand" formations typically have a moderate to high silt content, locally developed clay laminations and often fairly fresh or brackish formation waters. The result is what have been referred to as "low resistivity and low contrast" pay zones. These show little variation in the resistivity response between, for example, water filled muddy sands or conversely, thinly interbedded oil bearing sands.

Log analysts have traditionally attempted to solve this low resistivity, low contrast problem by developing increasingly complex variants of the Archie and Dual Water models, as well as by forward modelling techniques. Interpretations are sought by using sophisticated mathematical techniques, with some geological

constraints to counter the risk of non unique solutions.

However, the last 3 years have seen the systematic introduction across S.E. Asia of new generations of logging tools which allow more direct measurement of the petrophysical parameters. This paper will look at two case studies from this region.

In the first, from the Malay Basin, nuclear magnetic resonance is used to distinguish oil bearing "hot" sands (Gamma Ray >120 API) with very similar porosities and clay content, but radically different permeabilities. Electrical images explain how the difference in the depositional setting has resulted in clays being laminated in the more permeable reservoir, but dispersed (a consequence of bioturbation) in the less permeable member.

In the second example, we shall demonstrate how high resolution logging allows quantitative analysis of gas sands developed at the decimetric scale. This analysis is possible because the newer tool sensors benefit from miniaturization technology, and the ability to do real time environmental corrections and speed corrections to compensate for borehole conditions. When integrated with electrical image data the presence (or absence) of gas charge in sands interbedded at the centimetric scale can also be evaluated. Drill Stem Tests confirmed this analysis and a new reservoir was discovered across a previously "thought to be non productive" level in a Bangladeshi gas field.

The authors of this paper would like to thank their organizations for permission to present this data, and recognize their colleagues for help and support and valuable discussions during the course of this interpretation work.

*Paper 5*

## **Facies distribution and depositional systems of the modern Baram delta**

ABDUL AZIZ B. ABDUL RAHIM<sup>1</sup>, CHEONG YAW PENG<sup>2</sup> & JOSEPH J. LAMBIASE<sup>2</sup>

<sup>1</sup>Esso Production M'sia Inc.  
Menara Esso, Kuala Lumpur City Centre  
50088 Kuala Lumpur

<sup>2</sup>Department of Petroleum Geoscience  
Universiti Brunei Darussalam  
Jalan Tungku Link, BE1410  
Negara Brunei Darusslam

The modern Baram delta has long been regarded as an analogue for the highly prolific petroleum reservoirs in northwest Borneo and has been interpreted as a wave dominated delta. However, the depositional system of the delta has not been studied in detail. This study is focuses on the sedimentological characteristics of the modern Baram delta with a view towards determining its depositional systems.

The mouth bar of the modern Baram delta has a semi circular shape that consists of river marginal bars and transverse bar both parallel and perpendicular to the river mouth.

Seven lithofacies have been identified, which are sand facies, sand with organic matter and mud facies, sandy heterolithic facies, muddy heterolithic facies, mud with subordinate organic matter facies, mud facies and highly-bioturbated muddy heterolithic facies.

Sand facies is common on the seaward side of the transverse bar. It consists of relatively clean with parallel lamination, small-scale crossbedding, thinly organic layer and occasionally dispersed mud. Sand with organic matter and mud facies consists of interbedded sand with relatively thick organic layers 1–3 cm), thin layers of mud (1 cm), asymmetrical ripples and burrows. Sandy heterolithic facies consists of 60–80% very fine to fine sand grains, scattered mud and thin layers of organic material. Muddy heterolithic facies conversely characterized by mud of 70–90%, commonly laminated with subordinate thin laminae of organic

matters and scattered sand. Mud with subordinate organic matter facies which tend to occur in the lower deltaic plain consists of >90% soft to consolidated mud, mud pellets, mud laminations and subordinate organic matter. Mud facies is the type of facies, which is common in the prodelta area. It is characterized by homogenous, smooth to consolidated mud and vertical to horizontal burrows. Finally, highly bioturbated muddy heterolithic facies consists of predominantly reworked mud with subordinate very fine sand or silt and organic matter.

Different combinations of depositional processes dominate different part of the delta. Tidal processes dominate on the lower delta plain, inward of the delta front and on the river marginal bars. On the seaward side of the transverse bar and to some extent on both flanks of the delta, waves and tidal processes are important. Waves processes exclusively dominate in the nearshore areas.

Suspension sedimentation is most common in the transition to prodelta areas. They are occasionally affected by storm activity or high energy current. In some areas there are influenced by locally generated currents such as longshore current.

A stratigraphic succession of the modern Baram delta was predicted based on observed facies, assuming the relative sea level continue to rise and sediment supply remains constant. The sands are mostly wave influenced at the base, and gradually replaced by tidal sand. The uppermost sediments are the muddy tidal flat and beach sediments. In this succession, 59% of the sediment is tidal and 41% is wave-generated sand.

In this succession tide generated sediments are much more common than the wave generated sediments. Consequently, the modern Baram delta is not a wave-dominated delta but it should be view as a tide-dominated, wave-influenced delta.

*Paper 6*

## **Palas field integrated depletion plan**

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The Palas field is located approximately 215 km offshore Peninsular Malaysia in the South China Sea. The initial development in 1985 was based on result from five exploration wells. The currently developed reservoirs are the I-100/102 and eleven minor Group I reservoirs. The last exploration well, Palas-6, was drilled in 1993 to delineate the Group K and undeveloped J reservoirs. The Palas-6 results were encouraging and the J reservoirs are planned for development during the upcoming infill drilling program.

This presentation will highlight the technical challenges in redevelopment of I-100/102 reservoirs and the Group J reservoirs development. The I-100/102 reservoirs consist primarily of tidally influenced deltaic deposits and are interpreted to share common original fluid contacts. The I-100/102 infill program will consist of three conventional wells and one horizontal well. The well paths were designed to allow completion in viable Minor I sand targets where possible. The Group J reservoirs are mainly subtidal sand bars with varying levels of bioturbation and can be separated into 3 fluid systems. The Group J reservoirs have thin oil columns and large gas caps. Most of the Group J development will be long reach horizontal wells with multiple reservoir completion.

To facilitate planning of these wells, two detailed 3D geologic models were built, incorporating structural interpretations and seismic attributes (impedance and discontinuity) from a new 3D seismic survey (acquired in 1998), detailed sequence stratigraphic correlation, facies mapping and log analysis. The 3D geologic models were used as the basis for the reservoir simulation studies. A history-matched model of the I-100/102 reservoirs was used to identify infill opportunities.

The drilling is expected to commence soon to develop about 23 MBO of reserves. This integrated approach will optimize overall development and gives maximum economic returns.

*Paper 7*

## **Fast and slim — a creative development concept in an oil field offshore Sabah, Malaysia**

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Shell Malaysia took-up a new challenge when faced with the task of commercialising an oil field recently discovered offshore North Sabah in the South China Sea. The field contains ca. 200 MMstb STOIP, trapped in turbidite deposits within a structurally complex geological setting.

The primary recovery factor assumed for the reservoirs at these shallow depths (1,500–3,000 ft TVss) containing 18 deg API saturated oil, were initially conservative. The reservoir heterogeneity, structural complexity and the likely absence of natural water drive further dictate the need for a creative development concept. Conventional natural depletion and artificial lift development methods alone did not seem to yield maximum life cycle value to the asset.

Based on lessons learnt, SSPC/PN/PCSB jointly has been quick to pull together a fast-track development framework, which ensures application of new technology and full life-cycle development planning for the field. Whilst gaining the advantage of early first oil, this approach will also lead to a scheme with improved recovery and economic robustness.

A phased development is proposed to further pin down the subsurface uncertainties in view of the limited well penetration in the accumulation. A slim jacket with splitter wellhead technology will allow early drilling of a first phase of production-appraisal wells. As well correlation is insufficient, utilising state of the art seismic evaluation methods were used to create realistic static reservoir models to optimally position the first few development and appraisal wells. By making use of ullage in nearby production platform facilities, early oil can be produced within 18 months from field discovery. Utilising novel sand control techniques, it is expected that this early oil productivity will further increased. Meanwhile, first phase development is flexible in design such that facilities could be added to re-inject excess gas back into the reservoir, further increasing the recovery factor.

When more subsurface data is available and uncertainties further assessed and narrowed down after the Phase I development, additional wells will be positioned in areas to further enhance the recovery factor. To tap into all field corners, highly deviated wells are planned. Completions applying SMART well technology to enable increased downhole data gathering and selective production from each of the reservoir sub-units are also being considered.

In the second phase of development, water injection is proposed to arrest the decline in reservoir pressure and further boost the recovery factor. In addition, use of Coiled Tubing (CT) deployed Electro Submersible Pumps (ESP) inside existing wells is proposed to add development flexibility. All these demonstrate a significant paradigm shift in areas of field development concepts, production practices, the need for speed, contracting strategies, drilling practices and cost optimisation etc.

The tremendous effort being put into the proposed development concept has proven that “Bigger” is not necessarily better than adopting a Slim and Phased development approach. It has become symbol for a new

way of teamwork that achieves fast, flexible and robust development results. The benefit of technology application is transparent in delivering maximum business results.

*Paper 8*

## **Characterizing fractured reservoirs using sonic measurements**

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The evaluation of permeable fractures is important in oil and gas exploration in hard rocks where production resulted through fractures. In this case, fracture distribution determines producibility. Therefore fracture characterization is of primary importance for producibility evaluation.

Sonic measurements provide important information on fractures since they have an advantage of showing open permeable fractures, which are the ones from which most of the production occurs. The Stoneley (or tube) wave is a borehole fluid mode that propagates as a pressure wave along the borehole. The Stoneley wave upon passing a fracture that intersects the borehole, applies a pressure to the fluid in the crack. If the fracture is permeable, some of the fluid will flow into it. The net result will be an incremental pressure drop in the borehole. The magnitude of the pressure drop depends on the fracture opening and extent of the fracture. This pressure drop will cause the direct Stoneley wave to attenuate because of the transmission losses and, in turn will generate a reflected Stoneley wave.

Stoneley transmission and reflection analyses, combined with geological image analysis of the wellbore provides a good integration for fracture evaluation. This paper presents examples of fracture characterization using sonic Stoneley measurements and how it can be successfully combined with image data to quantify the fracture width or aperture and subsequently estimate the porosity.

*Paper 9*

## **Reservoir characterization of Cycle I & II clastics, offshore Sarawak — a sedimentological investigation**

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The Sarawak Basin extends 300 km off the Northwest coast of Borneo. The basin can be divided into two sub-basins; one to the east and one to the Northwest, separated by a basement high located towards the southwest. The sub-basin high coincides with a pronounced northwest-southeast structural lineament termed the West Balingian Line (WBL). The area investigated was Balai-1, located within Block SK306, southwest

of the WBL on the basement high. The data set comprised FMS\* data, composite logs and 2D seismic, also available were biostratigraphic, mineralogical and petrophysical results.

The basin comprises Tertiary sediments, composed of interbedded sandstones and mudstones with carbonate mounds located on the highs. The interbedded sandstones and mudstones have been divided into seven stratigraphic divisions (T1S-T7S) based predominantly on unconformities or its correlative conformity (Mat-Zin and Tucker, 1999). An older scheme, divides the sediment into cycles I – VII/VIII, based predominantly on the biostratigraphy and lithology (Ho, 1978; Hageman, 1987). The well in question, Balai-1 has been divided according to the scheme adopted by Sarawak Shell (Hageman, 1987) and exhibits the top of Cycle I and most of Cycle II. The division between Cycle I and II is concurrent with the delineation of T1S and T2S.

Structurally, it was evident from the FMS results that Cycle I displayed dips orientated NNW, striking NNE-SSW and this interval was characterized by much faulting, dipping N (strike E-W). In Cycle II the dips were orientated SW/SE (strike NW-SE or NE-SW, respectively), with faulting only associated with the lower part of the succession. The petrographic results (Hill and Soo, 1991) indicate the sandstones were composed predominantly of litharenite, comprising around 44% quartz, 5% feldspars, 12% rock fragments 16% accessories, framework grains. The rock fragments identified include chert and volcanic fragments. The sandstones are commonly composed of fine to medium grained, moderately well sorted grains. No conclusive, palynological results were recorded in Cycle I to indicate palaeoenvironment, whereas in Cycle II, the presence of foraminifera suggested a marine, inner neritic depositional environment i.e. lower coastal plain (Hulsbos *et al.*).

The stratigraphy in Cycles I and II was analysed using predominantly FMS data, as no core was recovered. In Cycle I, thick units of stacked sandstones (>10 m), displaying erosive basal surfaces, cross-bedding, variable grain-size distributions and divergent palaeoflow patterns were observed. The palaeoflow direction, was predominantly towards the E quadrant, commonly to the NE, with the dominate channel orientated NE-SW. Cycle II, appears similar in nature with only the upper part of the succession exhibiting a more varied sand body characteristic, interpreted as meandering channels and distributary mouth bars.

The thick sandstone units are thought to represent a more fluvial, upper coastal plain environment dominated by anastomosing sandy braided channels possibly laterally constrained i.e. valley-fill. In contrast, the upper part of Cycle II is interpreted to exhibit a more marine, coastal influence depositing as a tide dominated delta front within a lower coastal plain environment.

*Paper 10*

## **Seismic facies analysis of the synrift sediments in the northeast Malay Basin**

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A study of the synrift sediments has been carried out in the northeastern part of the Malay Basin. Two main east-west orientated half-graben systems are located here. The Abu-Lukut Subbasin is the smaller one and it contains partially tested Upper Synrift Basement Drape and the untested stratigraphic trap of Lower Synrift Ponged Facies. The larger Peta Subbasin located southeast of Abu-Lukut Subbasin contains the

untested Lower Synrift Faulted Play. The source rock for both subbasins is envisaged from the Middle Synrift facies comprising the mainly lacustrine shales.

The seismic data of 1988, 1989 and 1990 vintages are mainly utilised for this study as they contain many regional lines useful for correlation purposes. Not many exploration wells penetrated the synrift sediments and when they did, it was not the main target. Out of the 17 wells that had reached the synrift sediments, many of them were bottomed at the upper synrift facies only. Hence, the importance of seismic facies analysis must be emphasized in order to carry out the study of the hydrocarbon potential of the graben plays.

The seismic interpretation is focused more on identifying the play-types using seismic facies analysis.

The Oligocene synrift sediments known as Group M, are divided into lower, middle and upper synrift segments based on their distinct depositional environment which correspond to specific seismic character.

The Lower Synrift sand-prone fluvial/alluvial facies correspond to the high-amplitude, continuous reflectors and also displays a prograding pattern indicating a high sand content. The Middle Synrift shale-prone lacustrine facies is represented by transparent to weak seismic events and can be very thick, providing a good seal for the lower synrift sands. In addition, the Middle Synrift facies constitutes the main source rocks for the synrift plays. The Upper Synrift sand-prone fluvial facies relates to another series of the high-amplitude, continuous reflectors. On the basement highs, they either overlie the Lower Synrift facies/basement or they onlap the rising basement rock as indicated.

So far, only wells drilled in the Abu-Lukut Subbasin did penetrate down to the Lower Synrift facies. A well correlation was constructed tying the Well-1, Well-2, Well-3, Well-4 and Well-5. The Lower Synrift facies is shown to be blocky to coarsening upward sand-prone which is consistent with the seismic facies interpretation. Hardly any sands are deposited in the Middle Synrift facies, again tied to the transparent to weak seismic reflectors. More sands appear in the Upper Synrift facies equivalent to the high-amplitude reflections on seismic data.

Wells in the Peta Subbasin managed to reach the Middle Synrift facies only. Hence, no well correlation was generated for this area. By analogy, the similar seismic facies of the Lower Synrift sediments would yield blocky to coarsening upward sands, suitable for reservoir target. Based on the seismic data, a thicker Middle Synrift lacustrine facies is deposited here which leads to better source and seal potential. The Upper Synrift facies is similar in thickness and character to the other subbasin.

Two play-types in the Abu-Lukut Subbasin emerged from this study. The structural trap of Upper Synrift Drape Over Basement has been partially tested in the Abu oil field. The stratigraphic trap of the Lower Synrift Pondered Facies remains to be tested. The Lower Synrift Pondered facies exhibit a high amplitude, continuous to slightly chaotic events indicating that poor to fair quality reservoir which may not be interconnected and may possess poor to fair sorting. Sealing depends on lateral seals of basement rock and vertical seal of Middle Synrift lacustrine shales. No well has penetrated this facies.

Only one play type could be possible in the Peta Subbasin. The Lower Synrift Faulted Play is still untested. The seismic events shown here are high amplitude, parallel, continuous indicating good quality reservoir of fluvial sheet sands. These sands are sealed laterally and vertically by the Middle Synrift lacustrine facies. Hence, sealing should not be a problem here.

AVO analysis were carried out for the Lower Synrift Pondered Play and also the Lower Synrift Faulted Play to upgrade their prospectivity. The work was carried out by PRSS. A variety of AVO products were analysed including P\*G, P+G, P-G and AVO crossplots. Line 1 AVO response is for the Lower Synrift Faulted Play is positive and points to a Class 2 AVO of oil sands indicating that the Lower Synrift Faulted Play is better ranked than the Lower Synrift Pondered Play.



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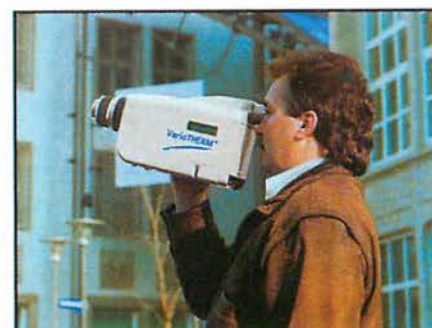
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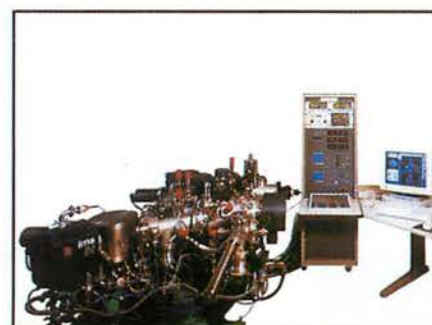
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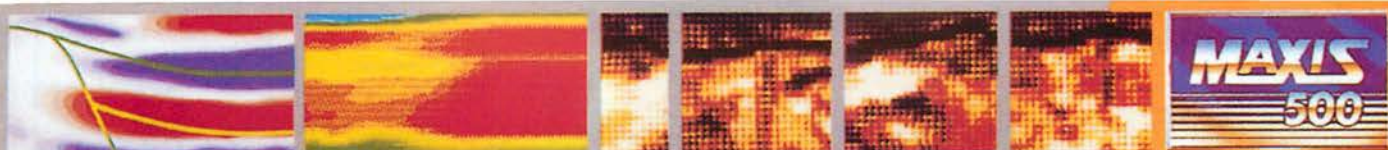
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*People, Knowledge & Technology*

## **Seismically constrained static reservoir characterisation and modelling using inverted seismic data**

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The M3 carbonate, Central Luconia, Offshore Sarawak project executed in 1998 was the first 2D constrained sparse spike inversion (CSSI) project in SSB/SSPC. The Jintan carbonate 3D seismic inversion followed suit, which led to the acquisition of Block SK8. Seismic inversion has since been carried out for both carbonate (F28, B11, E6 and F13 areas) and clastic (D35, Kinabalu and SF30) reservoirs in Sabah and Sarawak. A number of additional projects for CSSI have been identified for 2000/2001.

Traditionally, Sarawak Shell Berhad and Sabah Shell Petroleum Co. Ltd. have been using seismic reflectivity data for seismic interpretation. However, seismic reflectivity data only show the characteristics of the seismic interfaces and not the internal properties of the reservoir. Hence it is difficult to interpret changes within the reservoir itself. This can be resolved by converting the reflectivity data to acoustic impedance (RUNSUM) data. However, this RUNSUM still constitutes uncalibrated bandlimited data, and therefore seismically inverted data using CSSI technique are more superior because it utilises wavelets derived from the seismic and well data as well as incorporating the low frequency component from the well in generating the acoustic impedance.

CSSI has helped to generate acoustic impedance data that represent the near true acoustic reservoir properties of the subsurface. Furthermore, the technological advancement of both Shell proprietary and third party software enables the analysis and display of these attributes and makes seismically constrained near absolute acoustic impedance data easier to produce. The near absolute acoustic impedance data can be directly converted to porosity and permeability of the reservoir. These results can be used as input for reservoir simulation and dynamic modelling.

Reservoir characterisation and modelling using the results of CSSI is becoming a standard procedure in formulating the Field Development Plan for our remaining fields. The presentation will highlight some of these examples and the learning points from using seismic inversion data for reservoir characterisation and modelling.

*Paper 12*

## **Sand geometry of the deep water Crocker sediments in the Kota Kinabalu area, Sabah**

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Deep-water turbidite sands are relatively new exploration targets in Southeast Asia. Recognizing and understanding the geometry of sand bodies in this tectonically active region pose a great challenge. The Paleogene deep-water sediments of the Crocker Formation, partially exposed along the coastal mountain ranges of NW Borneo provides an opportunity to understand turbidite reservoir system. Some of the good outcrops of the Crocker Formation can be found within the Kota Kinabalu area in Sabah.

The Crocker Formation in the Kota Kinabalu area can be divided into two lithological units — a lower sandy and an upper shaly unit. The sandy unit consists predominantly of grey sandstones interbedded with

various colored shales, whereas the shaly unit consists predominantly of shale with thin sandstone interbeds. Based on parameters such as bedding type, internal structures, sand to shale ratio, and grain size, the Crocker Formation can be broadly divided into four main turbidite facies — (i) very thick-bedded Sandstone Facies; (ii) thick to medium-bedded sandstone facies; (iii) thin-bedded sandstone and shale facies; and (iv) red shale facies. The four facies has been interpreted to represent, channels, channel margins and fan lobes, interchannels and basin plain deposits, and pelagic deposits, respectively.

Based on facies and vertical sequence analysis, it can be said that the Crocker sediment is dominantly a sand-rich submarine fan system. The sequence consists of about 500 m stacked channel-levee-fan lobe complex, draped over by about 100 m pelagic and basin plain deposits. The sandy bottom megasequence consists of at least 20 major channel sand sequences that range in thickness from 5–70 meters. Lateral correlation of bedding shows that most of the channel sand sequences could be followed parallel and perpendicular to a northward paleoflow direction. Although there are changes in terms of sand to shale ratio, the overall thickness of the channel sand sequences is generally maintained for several kilometers. The overall good lateral continuity of bedding in the study area suggests that the sands were probably deposited as broad channels and fan lobes over an unconfined basin, at least 50 km wide, producing lenticular and wedge-like sand geometry.

*Paper 13*

## **Quantitative fault seal analysis in Muglad Basin, Sudan**

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The hydrocarbon structural traps in concession areas of Petronas in the Muglad Basin, Sudan are mostly fault-bounded in nature. With the geologic risk associated with hydrocarbon source, reservoir and top seal rocks being well understood, the remaining critical factor that influences the success of finding commercial quantities of hydrocarbon is the lateral fault seal efficiency. Hence the ability to predict the effectiveness of lateral fault seal is crucial in assessing, risking and ranking of prospects.

Traditionally fault seal analysis was carried out in a qualitative manner. This was done normally on paper by constructing a 2-D cross-section of the prospect and analysing the lithological juxtaposition across the fault surface. This qualitative method is quite useful in providing a “quick” prediction of the effectiveness of the fault seal. The result however is difficult to quantify, and thus limiting its uses to single prospect analysis rather than a risking and ranking tool for all the available prospects.

The advancement in computer technology has enabled quantitative fault seal analysis to be performed on workstations. *FAPS*, developed by Badley Earth Science Ltd., is one of the available software in the market that specialises in fault seal analysis.

The first-order fault seal analysis involves identifying lithological juxtaposition across fault surfaces. Detailed seismic mapping and well analysis provide the input required to build the structural and lithological model. 3-D visualisation techniques over fault surfaces reveals areas where sand/shale contacts are occurring.

Consequently after defining areas of sand/sand contacts along fault surfaces, a second-order fault seal analysis can be carried out to determine whether high entry pressure due to shale smearing may arised at fault surfaces to provide lateral seal. The proportion of shale entrained into the fault gouge, termed as *Shale Gouge Ratio*, is an attribute that can be computed by *FAPS* using a specific algorithm. The *Shale Gouge Ratio* can then be used to derive another fault attribute known as *Fault Zone Permeability* using an empirical relationship developed by Badley Earth Science Ltd. A calibration process is important to determine *Fault Zone Permeability* cut-off value to make a fault sealing or leaking.

The study area is covered with 3D seismic and comprises 4 separate geological structures. These structures have been drilled resulting in two discoveries and two dry holes. The area was selected as a pilot area to devise a technique for systematic workstation-based analysis of fault sealing capabilities to be implemented in prospect ranking.

*Paper 14*

## **Geomechanics — Its impact on the life cycle of the reservoir**

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One of the greatest challenges in optimizing the development of a reservoir is maximising hydrocarbon recovery with the minimum amount of drilling. Drilling wells efficiently and placing them in the right location can improve recovery and reduce costs. Ensuring that wells are optimally perforated and stimulated with minimal intervention for sanding dramatically increase the efficiency and cost effectiveness of each well. This paper describes the Mechanical Earth Model concept to the drilling of and production from wells. Through the presentation of case studies this paper explains why this is important, how the model is developed and how it is applied to well construction and field development.

The Mechanical Earth Model (MEM) is a numerical representation of the state of stress and rock mechanical properties for a specific stratigraphic section in a field or basin. The model is linked to the geologic structure through the local stratigraphy and a 3D seismic cube. In its basic form, the MEM consists of depth profiles of the elastic and/or elasto-plastic parameters, rock strength and the earth stresses referenced to the local stratigraphic section. Figure 1 shows a 1-dimensional representation of a Mechanical Earth Model and how it is linked to the stratigraphy and 3D seismic cube. In its most complete form, the MEM consists of a full 3D description of pore pressure, stress and mechanical properties. In practice, the complexity of the model evolves in step with acquisition of new information. From exploration to development, the model evolves from a sparse set of 1-dimensional profiles to a full 3D description of rock properties and stresses. This paper will describe the construction of the MEM and the sources of information used for building it. Examples will be shown on how the MEM can be used for various applications like drillbit selection, cementing, hydraulic fracturing, wellbore instability management, sanding prediction and prevention, well placement and design and enhanced recovery in mature fields.

*Paper 15*

## **Reservoir development and distribution in the deepwater offshore West Sabah**

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Sabah Shell Petroleum Company (SSPC) holds a strong acreage position offshore NW Sabah, with two deepwater blocks J and G approximately 120 km from the coastline. The area encompassed by the 2 blocks is 6,352 km<sup>2</sup> at a water depth of 150 m to 2,000 m. There have been four discoveries to date in the middle to late Miocene turbidite play associated with thrust cored anticlinal traps — Kinarut-1 (Esso, 1972), Kebabangan-1 (SSPC, 1994), Kamunsu East-1 and Kamunsu East Uptthrown-1 (SSPC 1998 and 1999 respectively).

All of these were gas discoveries but Kebabangan and Kamunsu East Upthrown also discovered an oil rim. All of the discoveries are located in the northeast corner of the acreage and now covered by 3D seismic, the remainder of the blocks are covered by a 2D seismic grid. The understanding of the turbidite system, the distribution and reservoir development is key in ranking our portfolio of prospects and in optimal appraisal/development.

SSPC initiated a project with Shell Deepwater Services (SDS) to review the deepwater blocks on a regional scale through the consistent interpretation of the 2D seismic, to determine whether we are able to predict (turbidite) sand quality within the identified leads and prospects. A simple scheme was employed to identify and map seismic facies, which had previously been piloted by SSPC during the Lingan Fan study (Mohamad, M., 1997). Four seismic facies based on high and low reflectivity and continuity were identified and mapped. It is believed that this facies scheme can distinguish sand from shale prone intervals and areas. Tying in of wells in the 3D seismic area broadly confirms this facies scheme and is used to predict facies development in areas of no well control. The results of the Kamunsu East Upthrown well and sidetrack with only 300 m separation at the Kamunsu/Kinarut fan interval encountered highly reflective discontinuous seismic, representing sands, yet the variability in sand distribution within a short distance also demonstrates the challenges for field development in turbidite systems.

Regional well data has been compiled and trend curves developed for reservoir geological parameters e.g. porosity/permeability crossplots, to aid in prospect evaluation. In conjunction with the facies scheme the reservoir property trends are used to predict reservoir development and uncertainties across the prospects in the acreage on a consistent basis. It is this facies scheme and reservoir development prediction that is aiding our prospect analyses and enabling quantification of non-DHI supported leads and prospects.

*Paper 16*

## **Exhumation of Sabah based on fission-track thermochronology: relevance to the Baram Delta**

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A fission-track dating study of Sabah was undertaken to date and quantify the uplift history and indicate the provenance of the Tertiary strata (Hutchison *et al.*, 2000). The results have an important bearing on the sedimentary history of the Baram Delta and basins on the margins of the Sulu and Celebes seas.

### **MOUNT KINABALU GRANITOIDS**

All fission track ages of the Middle Miocene (10–13.7 Ma) igneous rocks of Mount Kinabalu are related to cooling as a result of crustal uplift and unroofing. Apatite fission track ages represent cooling < 80°C (Late Miocene) and zircon < 225°C (Late Miocene). The values are independent of outcrop elevation, indicating very rapid cooling, related to uplift and erosion (exhumation) during the spectacular Late Miocene inversion of the Western Cordillera of Sabah, as recorded in the offshore oilfields as a series of unconformities, dated by detailed oil-field stratigraphy (Hutchison, 1996). They are the Deep Regional (15 Ma), Lower Intermediate (13 Ma), Upper Intermediate (12 Ma) and Shallow Regional (9 Ma). The unconformities are spectacular onland; become less pronounced and die out into conformity towards the outer part of the Inboard Belt. The Late Miocene mountain building event has been named the Sabah Orogeny (Hutchison, 1996).

### **WESTERN CORDILLERA-LABUK HIGHLANDS UPLIFT**

The apatite fission track ages (Middle to Upper Miocene) have been totally reset, suggesting the rocks have been buried by 4 to 8 km of overburden causing heating to > 120°C after deposition (a conclusion supported by vitrinite reflectance) then exhumed and cooled in the Late Miocene. The mean fission track



lengths of 13 to 15  $\mu\text{m}$  characterize rocks which have cooled rapidly, at  $> 10^\circ\text{C}.\text{Ma}^{-1}$  through a temperature range from  $120^\circ$  to  $60^\circ\text{C}$ . The fission track data suggest extremely rapid exhumation rates for the Western Cordillera of  $\sim 600 \pm 100 \text{ m}.\text{Ma}^{-1}$  ( $0.5$  to  $0.7 \text{ mm}.\text{a}^{-1}$ ), comparable to Irian Jaya, New Zealand and the Himalaya.

The zircon fission track ages all pre-date the depositional age of the strata and represent the Cretaceous provenance from which the zircon grains have been eroded and transported, interpreted ultimately as the Mesozoic *Indosinias* terrain of eastern Indochina (Hutchison, 1989), brought to Borneo by the great Mekong River, but the grains have gone through at least one intermediate sedimentary and erosion cycle (The Rajang Group of Sarawak).

The Kulapis and Kuamut Formation blocks in mélangé have re-set apatite fission track ages, that may have resulted from incorporation in the marine mud matrix of the mélangé, which was  $< 100^\circ\text{C}$ . However apatite is partially annealed at  $60^\circ\text{C}$  and completely annealed at  $110^\circ\text{C}$ .

There is strong petrological evidence for uplift. The Chert-Spilite Formation rocks, 5 km N.W. of Telupid, contain porphyroblasts of glaucophane and piedmontite (7–8 kbar at a low geothermal gradient), requiring the Labuk Highlands to have been dramatically inverted and exhumed from a depth of  $\sim 20$  km.

### **ISOSTATICALLY STABLE EASTERN LOWLANDS**

The fission track data, by contrast, indicate isostatic stability. An Oligocene age for the andesite tuff beneath the Sandakan mosque is likely, making it an onshore extension of the NE-SW trending Sulu Sea volcanic Cagayan Ridge.

All the zircon fission track ages are Cretaceous, indicating the provenance of the detrital grains. The apatite fission track ages are all older than the strata and range from Cretaceous to Eocene. They have been only partially or in some cases not reset, showing that the host rocks have remained at a temperature  $< 60\text{--}80^\circ\text{C}$  since deposition. Diagenesis and organic maturity data also support this observation. The apatite fission track data indicate the strata have been buried by less than  $\sim 2$  to 3 km.

It has been concluded that the Late Miocene and younger strata of this terrain have been cannibalized from the exhumed Western Cordillera-Labuk Highlands, which were dramatically uplifted in the Middle to Late Miocene. The zircon fission track ages, consistently Cretaceous, offer support for this.

### **TECTONIC MODEL**

Subduction followed by underthrusting of continental lithosphere, driven by Oligocene-Early Miocene spreading in the South China Sea marginal basin, account for the tectonic features of Sabah. Isostatic rebound then caused Late Miocene uplift of the Western Cordillera. Rapid erosion of the Western Cordillera and Labuk Highlands supplied abundant clastic sediments to the Miocene-Pliocene Baram Delta oil-bearing basin and to the Eastern Lowlands and Sulu and Celebes Seas. The Eastern Lowlands were affected by Miocene rifting of the Sulu Sea marginal basin. The terrain has been isostatically stable; there is no isostatic rebound and hence no underthrust continental crust.

*Paper 17*

## **Source rock characteristics of outcrop samples from Klias Peninsula, Sabah**

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A field study of the Klias Peninsula, the onshore part of SSPC's Block SB-301 PSC, was undertaken in 1998–99. The objectives included:

- An assessment of representative key outcrop sections of their significance as analogues for the various West

Sabah play types;

- Evaluation of the litho-stratigraphic sequences and collection of samples for biostratigraphic determination; and
- Evaluate of the source rock (SR) potential of selected outcrop sections to determine the hydrocarbon characteristics of the oil stains found in tar sands (oil seeps).

This paper discusses only results of the SR characterisation study.

A total of 14 outcrop samples were collected from the following three environments of deposition:

- pre-DRU TB1.3–2.3 deepwater sediments (Stage II/III Crocker, Temburong and Setap Shale formations);
- post-DRU TB2.4–2.5 lower coastal plain sediments (Stage IVA Belait formation); and
- post-DRU TB2.4–2.5 shallow marine sediments (Stage IVA Belait formation).

The samples were sent to Petronas Research and Scientific Services Sdn. Bhd. (PRSS) for geochemical analysis and University of Malaya (UM) for thermal maturity measurements. The analyses included TOC, Rock-Eval pyrolysis, %VR<sub>o</sub> measurement, liquid chromatography, GC (saturates), GCMS (saturates and aromatics), hydrous pyrolysis and hydrocarbon content.

The results of the geochemical analysis indicate encouraging source rock potential. SR quality varies from organic-rich (mixed Type III/II kerogen) to organic-poor (Type III/IV kerogen). Due to prolonged surface exposure and weathering, the SR potential may be under estimated. The samples contain a predominance of higher plant biomarkers in the bitumen characterisation. The SR geochemical parameters indicate a major input of terrigenous (land-plant derived) organic matter from fluvio-deltaic depositional setting. The facies of SR that generated the oil stains on the tar sands are very similar to the source facies of the SR analysed. The SR analysed are not sufficiently mature (immature to very early mature) to have generated significant quantities of hydrocarbon. However, if such rock (SR) is laterally extensive and more deeply buried away from the sample locations, they could have generated oil (stains) similar to those found in the tar sands.

*Paper 18*

## **Sand body character of the modern Baram Delta: implications for petroleum reservoir models in Northwest Borneo**

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The modern Baram Delta has long been interpreted as a wave-dominated delta and extensively used as a modern analogue for the prolific shallow marine sandstone reservoirs in Northwest Borneo, but no detailed sedimentological studies have been completed. Recently, a companion study concluded that it is actually a fluvial and tidal influenced delta, although the sand bodies are influenced by wave energy to a lesser extent.

The deltaic sands include a transverse mouth bar, channel marginal bars and shoreline sands. Mud dominated facies with subordinate organic matter are widely distributed within the very shallow sub-tidal zone all over the delta.

The transverse mouth bar is 3.5 km long, < 2 km wide and 3–5 m thick. On the seaward side, it is parallel laminated and small-scale cross-bedded, moderate to well-sorted fine sand with little interbedded mud and

organic matter. Conversely, the landward side has poorly sorted interbedded fine sand and mud with abundant organic matter, trough cross-beds and is highly bioturbated. The sand has moderate reservoir potential because large parts of the sand body have a moderately high mud content.

The channel marginal bars are situated on both sides of the river mouth with the geometry of 2–3.5 km long, 1 km–< 2 km wide and 2–3 m thick. They are oriented at a high angle to the shoreline sand, and sub-parallel to the river mouth channel. Sand facies on the seaward side tend to be cleaner, better sorted and less burrowed compared to the sheltered parts, which are influenced by fluvial and tidal processes. High angle trough cross-beds and low angle cross-beds with organic matter, mud layers and laminae reduce the reservoir potential to moderate to low.

The shoreline sands are a laterally extensive facies, but the intertidal zone is less than 20 m wide with only 1–2 m thick. Clean shoreface sands are moderate to well-sorted fine sand, but only extend seaward for a few tens of meters. Organic matter, especially plant remnants, is moderately abundant in layers within the parallel and low angle cross-beds. Reservoir potential is moderate to high in the narrow sand bodies.

In general, the depositional setting is unable to generate good quality, wide and laterally extensive reservoir sands. The seaward sides of the sand bodies tends to have better reservoir potential than the sheltered areas due to wave reworking. Most parts of the delta are without wave influence and abundant fine-grained sediment and organic matter derived from river create permeability barriers and reduces the reservoir potential.

Most of the wave-dominated, producing reservoir sandstones in Northwest Borneo vary significantly from the Baram Delta sands in that they are kilometres wide and are parallel laminated, low angle cross-bedded and hummocky cross-stratified, fine to medium grained, moderately to well-sorted and partly bioturbated by vertical and horizontal burrows. Therefore, the modern Baram Delta is an inappropriate modern analogue for the reservoir sands of Northwest Borneo.

*Paper 19*

## **Integrated field depletion study of a complexly faulted field: Irong Barat**

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Irong Barat field is located approximately 170 kilometers offshore Peninsula Malaysia and was discovered in 1997. It is a complexly faulted WNW-ESE trending asymmetrical anticline with a total productive area of about 18 sq kilometers and a hydrocarbon column of about 400 meters for the major H-50 reservoir. Development commenced in 1983.

A comprehensive integrated depletion management study was initiated in early 1999 to maximise ultimate recovery of the remaining developed and undeveloped reserves. Key focus areas include updating the reservoir management strategies, identifying and maturing opportunities to enhance production capacity, optimizing additional development programs, and high grading resource assessments and long-term production forecasts.

A new 3D seismic dataset was acquired in 1998. Significant efforts are being made updating, verifying and integrating geoscience and engineering data. These include geophysical interpretation of the new 3D seismic data, building 3D geological models incorporating latest sequence stratigraphy concepts and improved understanding of facies belts and development of reservoir simulation models.

As a result of the study, two additional drilling programs are planned to further develop the field which involve drilling 18 to 20 new wells from existing Irong Barat-A and new Irong Barat-B platform.

The paper addresses the structural interpretation changes with time, improved stratigraphic definition, production performance implications and new opportunities identification which enable the team to further develop the field.

*Paper 20*

## **Computer simulation of carbonate reservoir model by Facies-3D**

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Facies-3D is a computer simulator for carbonate and siliciclastic sediments, which has been developed by the Technology Research Center of Japan National Oil Corporation. The Facies-3D carbonate model describes three-dimensional carbonate facies distribution based on water depth and current velocity in conjunction with basement (paleo-topography), over a simulation period. The output data at each step include facies and their thicknesses, and porosities, which are modified in meteoric diagenetic environments, for each grid. The Facies-3D carbonate model can be applied as a stratigraphic simulator on a basin scale and as a tool for reservoir characterization on a field scale.

Facies-3D has been applied to (1) Recent and Pleistocene carbonates in the Ryukyus, southwest Japan (Matsuda *et al.*, 1997), (2) Recent carbonates in the offshore Fraser Island, eastern Australia, (3) Miocene reefal carbonate reservoirs in the Southeast Asia including the Walio (Irian Jaya) and the Arun (North Sumatra), and (4) Cretaceous shallow water carbonate reservoirs in the Middle East. The results of the simulation in the Walio field show that the Facies-3D approximated to a high degree, the distribution of facies and the occurrence of porous intervals (Matsuda *et al.*, 2000).

A simulation case study was conducted using the depositional model of the F6 field located in Central Luconia, offshore Sarawak, Malaysia, including the whole F6 buildup and the reservoir section in the upper part of the buildup. Development of the F6 buildup in the Middle to Late Miocene was subdivided into build-out, build-up and build-in phases (Eping, 1989; Wee and Liew, 1988). The reservoir section in the uppermost part of the build-up phase and the build-in phase was subdivided into the lower, middle and upper units (Matsuda *et al.*, this volume). The lower unit mainly consists of a restricted back reef facies. The middle unit comprises an alternation of a shallow fore reef and deep fore reef facies. Backstepping of the reef occurred in association with siliciclastic inputs. The upper unit is mainly composed of a relatively open marine reef facies. The reef was drowned during a major subsequent transgression.

The F6 reef development and facies distribution in the reservoir section were simulated using Facies-3D. The simulation area size of the whole buildup is 30 km x 17 km with grid size of 500 m x 500 m. The simulation period is 15.2 Ma to 4.6 Ma at every 50,000 years with a total of 212 steps. The simulation area size of the reservoir section is 26.4 km x 14.4 km with grid size of 400 m x 400 m. The simulation period is 6.546 Ma to 5.336 Ma at every 10,000 years with a total of 121 steps. Input parameters for these two simulations were extracted from interpretative geological and geophysical data in the field.

The results of the simulations show that the Facies-3D carbonate model describes the above-mentioned depositional model including (i) the build-out and build-in phases of the F6 reef, and drowning of the reef, and (ii) the distribution of facies in the reservoir section.

## Challenges of 4C seismic acquisition and processing offshore Sarawak

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Marine seismic has so far being dominated by 2D and multi streamer 3D seismic acquisitions. However in recent years it has diversified to include ocean bottom recording. In November 1999 Sarawak Shell acquired six 2D four component (4C) ocean bottom cable (OBC) lines over carbonate fields. In this paper we will describe the acquisition and processing of the survey.

### Acquisition

The acquisition was carried out by Schlumberger Geco-Prakla from 16<sup>th</sup> November 1999 to 26<sup>th</sup> November 1999. Two survey vessels were utilised during the operation, one recording vessel and the other a source vessel. All data were acquired using the Geco-Prakla developed multiwave cable, known as the PXYZ cable. A seismic source is towed over a pre-plotted sail-line by separate source vessel. Each shooting sequence consists of the following: 1) seismic spread (receiver line) move using drop-drag technique, 2) positioning of receivers, and 3) a source vessel shooting pass (shot line). A three km cable with 120 receiver groups at 25 m interval was used. Line length are typically multiple of cable length.

### Processing

The processing was done using Shell's Standard processing package interleaved with specially developed tools for multi component processing. In particular the Hydrophone-geophone combination processing and combined PSDM solution for pp and ps data.

### P and Z component

The main reason for hydrophone-geophone combinations is deghosting. Since receivers are deployed at the sea floor, the spectrum notches caused by receiver ghost and reverberation from water layer generally fall in the signal band. As geophone measures a vector quantity, and can discriminate between up and down going energy. In time domain reflection from sea surface ( $R \sim -1$ ) exhibit a polarity reversal on hydrophone but not on the geophone. In frequency domain, their corresponding spectra are complementary and their combination gives a flatter spectrum. After combination the two components i.e. p and z becomes one which we refer to as PZ.

### PS-X (inline) component

In marine seismic surveys, the initial energy are generated as P waves and are converted to S waves at the interfaces. Here we look at the PS converted waves in the inline direction since they are the dominant S converted energy. The main pre-processing steps in PS data are residual statics and de-reverberation of P-reverberation energy generated at the source. Finally, as ray path of PS data are asymmetric special tools are required to properly image the common conversion point in contrast to common mid point for PP data. The common conversion point varies with both offsets and  $V_p/V_s$  ratio. In our processing we solve this by doing pre-stack depth migration whereby we derived both p and s velocity model in a single step. For the PS data we migrated the positive and negative offsets separately since their ray path are asymmetrical positive and negative imaged would inhibits lateral shifts if the velocity models are not right. Therefore the positive negative PS images are a good quality control of the final PS migrated data.

**PS-Y (crossline) component**

In the 2D survey the Y component of the PS converted energy should consist of noise as the source-receiver azimuth are aligned in the in line direction, no Y signal energy would be generated except for: 1) off plane converted PS energy where there will be PS-Y component, 2) polarisation of S waves. For this component we merely make a common conversion point (assuming a constant  $V_p/V_s$  ratio) stack.

*Paper 22*

## **3D seismic field evaluation — integrated application approach**

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In late 1998 Petronas Carigali Sdn. Bhd. (PCSB) embarked on an Integrated Workflow project as part of it continuous technology improvement bench marking. The Integrated Workflow concept consists of a series of linked domains or components incorporating People, Processes, Data, Software and Infrastructure. This Integrated Workflow was approved as a new benchmark for PCSBs in early 1999 and was used to carry out a technical evaluation of a gas field with 3D seismic data.

As part of the Integrated Workflow, both the business and technical objectives and deliverables were finalised with supervisors and management before the start of project.

This project starts with the loading and quality control of a trusted data set involving 320 square kilometers of 3D seismic data, stacking velocity data and three well data. Proper work plan and technical process were determined upfront base on the best practice that has already been established. Six software that were utilised are Data management software, Seismic interpretation software, mapping software, geological interpretation software, Synthetic seismogram software and time-depth conversion software. The Integrated Workflow will move data form one software to another and incorporated all the interpreted results from different software into a dynamic 'Shared earth model'. The Shared earth model will be demonstrated by a example of generating a geological cross section which integrated lithologies interpretation from wire line logs and geological tops using the main geological interpretation software, 3D seismic data with it interpreted seismic horizons and faults using seismic interpretation software, time to depth conversion calibrated by synthetic seismogram from synthetic seismogram software was performed using time-depth conversion software. The trusted database is managed using data management software that links all the application together.

Large quantity of output were generated which are three synthetic seismograms, eight time structure maps, twenty one depth structure maps, thirty six amplitude attribute maps and two geological cross-sections.

This case study highlight a technical evaluation of a gas field with 3D seismic data using an Integrated Workflow approach to ensure the quality and quantity of the results. Furthermore the cycle time that has been substantially reduced in completing the technical project.

The main factor of the success in implementing the technical project are 1) efficient Integrated Workflow which utilise all the available software, 2) emphasis on the quality control procedure and 3) just in time classroom training and mentoring.

## Relationship between biomarker distributions, maceral assemblages and lithofacies in the coal-bearing sequence of Bintulu, Sarawak

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The coals under investigation are from NW Sarawak and were sampled from the Nyalau Formation (Oligocene-Miocene) which is considered to represent a major transgression over the Eocene landmass. The ideal sequence of the Nyalau Formation, recognised in the Bintulu area, represents a succession of progradational tide dominated sequences which shallow and coarsen upwards from offshore shales into silts. The Nyalau Formation is considered to represent the onshore extension of Cycles I & II of the offshore Balingian Province, which contains important source and reservoir rocks for oil and gas. Petrographic investigation indicates that the liptinitic content of coal is related to associated lithologies and, in turn, to the regime of the peat-forming environment.

Biomarker analyses have shown a similarity between the coals associated with sandstones and those inter-layered in the thinly bedded sands and mudstones. These two facies are classed here as coals associated with sandstones (thick or thin sandstone beds). The other group of coals recognised are those associated with shales.

The Tm/Ts ratio increases with increasing liptinite and mineral matter content. The ratio of Tm/Ts for the coals associated with sandstones decreases with maturity (based on %Ro) and increases with the terrigenous markers Pristane/Phytane (Pr/Ph) and  $C_{29}/C_{30}$  hopane ratios. These are commonly observed for terrestrially-derived oils and/or sediment extracts. However, the variation of Tm/Ts for the coals associated with shales in the samples studied, show a reverse correlation with maturity and terrigenous markers.

The variation of the  $C_{29}$  and  $C_{30}$  hopanes with individual liptinitic macerals shows that Norhopane ( $C_{29}$  hopane) has a proportional correlation with the liptinites. On the other hand,  $C_{30}$  hopane varies independently from liptinitic content, thus  $C_{29}/C_{30}$  hopane is controlled by terrestrial input. In these studied samples, maturity does not seem to control the  $C_{29}/C_{30}$  hopane ratio.

The Pr/Ph ratios measured on the Bintulu coals are in the range of 4–9. Pr/Ph for coals associated with sandstones decrease with maturity and proportionally correlates with the terrigenous markers  $C_{29}/C_{30}$  and Tm/Ts. This situation is reversed for coals associated with shales. However, the Pr/Ph ratios still increase even though the terrestrial markers decrease.

Oleanane (ol) is widespread in the coal extracts. It is identified as two peaks representing a-oleanane and b-oleanane. The ratio of a-ol/b-ol correlates positively with %Ro suggesting that it could be used as a maturity parameter. With the exception of suberinite, oleanane correlates positively with individual macerals as well as with mineral matter. The variation of oleanane with the biomarker ratios Pr/Ph, Tm/Ts and  $C_{29}/C_{30}$  in coals associated with shales is unclear, however, oleanane correlates positively with the biomarker ratios in coals associated with sandstones.

Oleanane and biomarker ratios Pr/Ph, Tm/Ts and  $C_{29}/C_{30}$  hopane are all thought to be primarily controlled by the degree (amount and preferential preservation) of land plant contributions. They are therefore expected to correlate positively with each other. The results show that this is apparently true only for coals associated with sandstones deposited during high-energy periods or alternating energy periods. In contrast, the organic matter within coals associated with shales deposited during calm water periods may have been altered by enhanced microbial degradation in the prevailing bottom water conditions and thus the biomarker ratios show reverse correlation. In calm water conditions in which anoxic conditions prevail, the terrestrial influence is overwhelmed by the microbial activity resulting in biomarker ratios reflecting the depositional environment

conditions rather than the source input. Vitrinite-rich coals associated with sandstones were deposited during high-energy periods or fluctuating energy periods, which drain the environment of deposition. The water is in constant flux allowing the development of oxic conditions and fewer interactions between mineral matter and organic deposits. These conditions of deposition preserve the terrestrial fingerprint of the organic matter. This suggests that high primary productivity of organic matter has a greater influence on the biomarker fingerprints than the depositional condition (such as oxic versus anoxic).

*Paper 24*

## **Stress fields of Sundaland during the Tertiary**

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Sundaland contains the geologically stable Sunda Platform and Cenozoic crustal material that accreted onto it and now forms Sumatra, Java, and Kalimantan/Borneo. Throughout the Cenozoic, changing plate dynamics exerted varying degrees of control onto the stress regime of the region. Partitioning of stress conditions in space and time is most apparent in the Sarawak-Brunei-western Sabah segment, but in other sectors of Sundaland the stress fields appear only to reflect the large-scale plate reorganisations that began in late Early Miocene and in some areas continued until the present. Generally, these changing plate movements resulted in mid-Miocene angular unconformities. In spite of the strong mid-Miocene tectonic disturbances, there are areas where the maximum principal stress (P) orientation persisted across the tectonic event. In the Strait of Melaka, P has remained orientated NE-SW since pre-Oligocene time. The P-orientation is shown by outcropping folds, reverse faults, distribution patterns of depocentres and graben-halfgrabens, en echelon fault zones, and wellbore breakouts. The existing structural database occasionally also provides reliable evidence of significant lateral fault displacements. Current stress fields are indicated by first-motion orientations of shallow earthquakes and are derived from repeated, detailed GPS measurements at about 40 stations distributed throughout the Indonesian and Philippine islands.

During the Cenozoic, Sundaland was subject to the following processes.

- (1) From the Eocene onward, sub-plate India has collided with Eurasia. Its far-field effects in Southeast Asia manifested as SE-ward crustal slab extrusion of Indosinia and part of Sundaland along major NW-trending strike-slip faults such as the Three Pagodas and the Red River zones. Initially this so called model of extrusion tectonics was facilitated by sinistral wrenching on the regional NW faults, but later field work has provided evidence for slip reversals. For instance, the Three Pagodas fault that is believed to extend as the Axial Malay fault zone in the basement of the NW-striking Malay Basin shows such evidence. In pre-Oligocene time, the Axial Malay fault zone moved sinistrally and in the process produced east-west halfgrabens in the basement. Sedimentary fill of these depocentres were later compressed into large E-W anticlines, whose orientations and positions were predestined by those of the halfgrabens. Earlier regional sinistral wrenching was transtensional while subsequent dextral fault slip occurred in a transpressional regime. Proponents of extrusion tectonics believe that as consequence Sundaland rotated clockwise.
- (2) The Indian Ocean-Australian Plate converges onto Sundaland throughout the Cenozoic. Subduction occurs at the Sunda Trench. Along the Sumatra-Java segment the convergence angle has grown more acute by as much as 50 degrees according to some workers, who also proposed that Sundaland achieved this situation by counterclockwise (CCW) rotation. The Sunda backarc basins are thought to be CCW-associated rifts, of which the North Sumatra Basin developed as a pullapart depression. The arcuate distribution of the Sunda backarc basins and their uniform tectonic divisions in sections are difficult to reconcile with the hypothesis. Instead their origin is better explained by crustal thinning when thermal convection patterns of the asthenosphere became disturbed by subduction.



- (3) During the Cenozoic changing plate dynamics of the Pacific, the smaller Philippine, Caroline and South China Sea also significantly influenced the tectonic history of the basins of Sundaland. Until the Middle Eocene, the Pacific Plate proceeded NNW-ward and left the Emperor seamounts in its track. Thereafter, the plate moved WNW which is documented by the Hawaiian chain of seamounts and volcanic islands. The volcanic centres of the island chains all originated above of long-lived mantle plume that currently is under Hawaii Island. The WNW-ward thrust of the Pacific Plate only became effective for Southeast Asia after seafloor spreading ceased in the South China Sea Basin and in the other smaller named basins. Most of the Tertiary stratigraphy of Sundaland is characterised by mid-Miocene unconformities.
- (4) The South China Sea Basin consists partly of oceanic lithosphere and partly of attenuated continental crust. In its northeastern part are East-West magnetic stripes symmetrically arranged about the Scarborough Ridge which is considered the spreading axis. The E-W magnetic lineations indicate spreading activity between 32 Ma and 17 Ma). Magnetic stripes in the SW sector trend SW-NE and probably represent earlier spreading. At the southern margin of the basin, the spreading had been accommodated by subduction beneath Borneo. However, associated volcanism is yet to be reported and the NW Borneo "Trench" is but a downwarp caused by sediment loading according some researchers. On the other hand, structural style that includes imbrication verging NW is consistent with tectonic convergence of Borneo and the South China Sea Basin.
- (5) The central part of the Andaman Sea Basin consists of oceanic crust whose magnetic lineations represent spreading since 13 Ma. The basin is bordered by the active Andaman-Nicobar island arc in the west and by the Mergui Ridge in the east. The latter is the separation with the greater North Sumatra Basin. The rift axis is segmented and forms the connection between the dextral transform Sagaing and Sumatra fault zones.
- (6) The eastern Kalimantan older stress field is associated with opening of the Makassar Strait that probably occurred between early Palaeogene and Early Miocene (44 Ma–34 Ma). The separation is suggested by geological similarities of both sides of the Strait. Upon this tensional regime has become superimposed strong compression that manifests as mid-Miocene and younger fold-thrusts verging towards the axis of Makassar Strait.

*Paper 25*

## **Pre-stack imaging: time or depth?**

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Accurate imaging is obtained by accurate estimation of diffraction surfaces and their subsequent collapse to their point of origin. Conventional processing, with NMO and DMO, only does this approximately. Pre-stack Kirchhoff imaging avoids approximation and can image seismic data more precisely. Real & synthetic examples show the improved resolution that can be obtained with pre-stack Kirchhoff imaging. Pre-stack time and depth imaging only differs in the way they handle lateral velocity variations. The depth algorithm comprehends any lateral velocity variation whereas the time algorithm assumes local invariance. Time versus depth domain output is irrelevant.

### **INTRODUCTION**

The fundamental element of seismic data imaging is the collapse of diffraction surfaces to the point of their origin. Diffraction surfaces are time surfaces that are either created by a point reflector, or would be created by a hypothetical point reflector (a continuous reflection horizon can be equivalently viewed as a collection of point reflectors via Huygen's principle). The shape of the diffraction surface, defined in time, offset (source to receiver) and spatial location, is defined by the interval velocity field of the subsurface. Accurate estimation of this velocity field can lead to accurate estimation of the diffraction surface and hence accurate imaging of the seismic data.

Conventional seismic processing contains a number of elements that prevent accurate estimation of the diffraction surface. Conventional normal-moveout (NMO) is a second-order approximation to the true moveout curve in the offset direction (one component of the diffraction surface). NMO corrected data are often not flattened because the second-order approximation does not predict the offset component of the diffraction surface adequately. The typical effect is the “curl-up” of the farther offsets. Higher order NMO corrections (e.g. fourth-order) can be applied to help improve the accuracy of NMO.

Dip-moveout (DMO) is also part of the conventional processing stream and is applied after NMO correction. The aim of DMO is to predict the component of the diffraction surface in the CMP direction (for each offset) and apply an operator to convert each offsets surface to be equivalent to the zero-offset surface. In general, production applications of DMO are applied with a constant velocity assumption, and hence do not accurately predict the CMP component of the diffraction surface when the velocity is variable. DMO can be applied with a simplistic vertical velocity variation, but more general changes in the velocity cannot be accommodated without significant extra expense, and are hence not often used. For 3D seismic, with vertically varying velocities, it is well known that the DMO operator has a complicated 3D “saddle” shape (Perkins and French, 1990). The application of such an operator is so expensive that it is rarely used in practice, and generally only the 2D component is applied along the source/receiver azimuth.

Pre-stack time migration is commonly used and is close to current “conventional” processing. However, it is often applied using a zero-offset algorithm after NMO and DMO. Also, in the interest of processing speed, it is often applied using a single  $v(z)$  velocity function. This approximation to the velocity field causes further inaccuracies in the prediction of the diffraction surface where the velocities vary laterally.

A combination of the approximations in the NMO, DMO and zero-offset migration steps can lead to poor estimates of the diffraction surface and hence poor imaging of the hypothetical point reflector. More accurate imaging can be obtained through the estimation of the subsurface velocity field and the use of ray-tracing to define the true shape of the diffraction surfaces in offset, time and spatial location. Pre-stack Kirchhoff imaging, either time or depth as required, can accurately define the diffraction surfaces and result in higher resolution, less noisy images.

## **THE SIGNIFICANCE OF NON-HYPERBOLICITY**

Hyperbolic diffraction surfaces are virtually non-existent in seismic exploration. However, diffraction surfaces are often considered to be, or approximated as, hyperbolae. Hyperbolic diffraction surfaces are generated only if the velocity of the medium is constant. In that case, the raypaths are straight and simple triangular raypath geometries are often formed. Hyperbolicity is generated through Pythagoras’ theorem. Whenever the velocity is not constant, the diffraction surfaces will be non-hyperbolic.

In general, when the velocity varies, even if only with depth, it is impossible to write a closed form equation for the diffraction surfaces. It is necessary to effectively trace rays through the velocity field, or solve a recursive equation, to obtain the diffraction surfaces. Algorithms that use the “double-square root” equation (Claerbout, 1985) actually provide hyperbolic approximations to the true diffraction surfaces. The imaging ability and resolution of such an algorithm is therefore compromised.

Hyperbolic imaging techniques have been used for many years in seismic exploration. They have been successful because most diffraction surfaces are approximately hyperbolic for small reflection angles. However, it will be shown that such approximate processing can be significantly improved with pre-stack imaging, especially as the recorded offset range has increased over recent years.

## **SYNTHETIC DATA EXAMPLE**

A synthetic dataset was generated to help analyse the potential improvements of more accurately estimating the shapes of diffraction surfaces. A relatively simple laterally invariant velocity model was used to create two synthetic datasets. One with flat reflection events at each of the interval velocity discontinuities, and a second dataset with a single diffraction source point at each of the interval velocity discontinuities. These synthetic datasets were created using ray tracing. The flat event dataset was processed through conventional imaging and pre-stack Kirchhoff imaging, with the required velocities interpreted by a data

analyst without knowledge of the synthetic velocity model. Subsequently, the diffraction synthetic was processed through the same processing flows, using the same interpreted velocities.

Conventional NMO corrections leave most of the events with residual “curl up” at the far offsets. Fourth order NMO can be used to extend the accuracy of NMO. However, with pre-stack Kirchhoff imaging, rays are traced through the velocity field to obtain the theoretically exact travel times (the diffraction surface) so that, in principle, the events can be flattened exactly. The approach here was to pre-stack migrate the data with the second-order velocities, re-interpret new velocities, iterate migration and interpretation once more, and then migrate for the final time. The events are now close to correctly flattened.

The diffraction synthetic dataset was now processed using the same velocities as interpreted above. First it was processed through a conventional sequence of NMO (fourth-order), DMO, stack and time migration (phase-shift plus stolt algorithm). Next it was processed using pre-stack Kirchhoff imaging, which effectively performs the conventional sequence in one step. The results of these two processing flows are compared in Figure 2. The pre-stack Kirchhoff imaging flow has more accurately collapsed the diffraction events to the point of their source.

### **TIME OR DEPTH?**

There is often confusion about the difference between time and depth migrations. The term “depth” in depth migration is probably the most misleading. Firstly, let us rule out the fact that time migrations commonly output the results in the time domain and depth migrations commonly output the results in the depth domain. For migrated data, only a simple vertical mapping is required to convert between time and depth, so either algorithm could be made to output in either domain. The real difference is how the algorithms estimate the diffraction surfaces.

In the analysis of the synthetic data in the previous section, we obtained optimum results using pre-stack Kirchhoff time migration. The results would not have been improved if we had applied a depth migration. This is because the synthetic velocity model contained no lateral velocity variations. The time migration algorithm assumes that the velocity field is locally laterally invariant. Each trace can have a different vertical velocity function, but it is always assumed to be laterally invariant. Depth migration makes no assumptions about the velocity model and performs detailed raytracing to obtain the exact hypothetical diffraction surface for laterally varying velocity fields. This is effectively the only difference between time and depth migration. Depth migration could be used for all problems, however, since the detailed raytracing and subsequent application are more expensive, depth migration is only used when time migration proves to be inadequate.

### **OFFSHORE THAILAND EXAMPLE**

An example of the improvement possible with pre-stack Kirchhoff imaging comes from the Gulf of Thailand. In this case the water depth is less than 100 metres, and the velocity function varies little in the lateral direction and not extremely in the vertical direction. Figure 3 compares the results of conventional pre-stack time migration (using NMO, DMO and zero-offset migration) and pre-stack Kirchhoff time and depth migrations (mapped back to the time domain). Pre-stack Kirchhoff time migration is a definite improvement over conventional pre-stack time migration, and pre-stack depth migration is only a moderate improvement over that.

The velocity model for pre-stack depth migration was generated using reflection tomography which uncovered some lateral velocity variations, but not enough to make major changes to the seismic image. The improvement obtained by pre-stack Kirchhoff migration is obtained by its superior ability to estimate the slowly varying diffraction surfaces.

### **CONCLUSIONS**

Conventional processing is characterised by the processes of NMO and DMO. These processes are only exact for constant velocity or straight raypaths. Whenever the velocity varies, even vertically, NMO and DMO result in inaccurate focusing of the final migrated data. The recent trend towards the acquisition of longer offsets increasingly exacerbates the difference between conventional and pre-stack Kirchhoff imaging.

The imaging of seismic data can be described as the correct estimation of hypothetical diffraction surfaces and their subsequent collapse to their point of origin. Even for relatively simple vertical variations, it is not a simple procedure to correctly estimate the diffraction shapes. Pre-stack Kirchhoff migration estimates the diffraction shapes by raytracing through the interval velocities of the medium.

If the velocity field varies slowly in the lateral direction, then the diffraction shapes can be adequately estimated by assuming that the velocity field is locally laterally invariant. In this case we have pre-stack time migration. If the velocities vary too much in the lateral direction for this approximation to be adequate, then more detailed raytracing is required to estimate the (now more complex) diffraction surfaces. In this case we have pre-stack depth migration. This is the only difference between pre-stack time and depth migrations. The fact that time migration generally outputs images in the time domain and depth migration generally outputs images in the depth domain is irrelevant.

Synthetic datasets have shown that processing with better estimates of the diffraction surfaces improves processing results. The typical higher-order NMO "curl-up" on a cdp gather can be eliminated and the focusing of diffractions can be much more accurate. Conventional processing, with NMO and DMO, can only create relatively smeared, blurry results upon the collapse of the diffractions.

Many real datasets have confirmed that pre-stack Kirchhoff imaging do indeed provide superior resolution when compared to conventional processing. A dataset from the Gulf of Thailand has shown that pre-stack Kirchhoff time migration resulted in obvious improvements over conventional processing with NMO and DMO. Also, there proved to be insufficient lateral velocity variations for pre-stack depth migration to create any major improvement over pre-stack time migration. These results help show how similar pre-stack Kirchhoff time and depth migrations really are. The only real difference is the raytracing employed by the different algorithms for the estimation of the diffraction surfaces.

*Paper 26*

## ***STRATAGEM*** — **forward stratigraphic modelling for Block E, offshore Sarawak**

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*STRATAGEM* is a Shell proprietary software package that simulates stratigraphic patterns in both clastic and carbonate depositional environments. The 2D forward modeling requires input data on subsidence history, sediment supply, eustatic sea-level variations and some other parameters. The predicted stratigraphic patterns are thus the results of the inter-relationship of sea-level variations, type and rate of sedimentation and tectonic history of the study area. The modeling can be calibrated with imported seismic and well data to allow a qualitative test of conceptual models of the geological evaluation of the basin.

As part of Block E evaluation, *STRATAGEM* modeling was carried out on selected regional seismic lines. The main aims of this modeling are: 1) to test the validity of seismic interpretation, 2) to compare sediment supply patterns from different directions 3) to investigate the potential existence of turbidite reservoirs, and 4) to help identify areas of potential source rock development.

These regional seismic lines, located in various geological provinces, were selected to review the input parameters from different directions. Subsidence data was derived from palinspastic reconstruction of interpreted lines and Haq sea-level curve was used for eustatic sea-level change (Haq *et al.*, 1988). The sediment input was varied for each line to mimic the seismic geometry observed. The outcomes of *STRATAGEM* modeling can be summarised as follows:

- In terms of stratigraphic patterns, the models illustrate the clear difference between mainly rapid progradational/

retrogradational in the stable Central Luconia Province and relatively aggradational patterns in the West Baram Delta, controlled by high subsidence rate and active growth-faulting.

- The simulations indicate a steady increase of sediment supply since the Middle Miocene with a few fluctuations. The supply patterns generally reflect the relative sea-level variations with sediment sourced from the Southwest.
- The models suggest the presence of two main phases of turbidite development; an older ponded turbidite package, probably associated with a major lowstand in the Late Miocene (Cycle V), in the southern part of Block E and a Late Pliocene and younger turbidite system, which progressively shifted from southern Block E to the Northwest Sabah Trough. This development coincides with the migration of the depocentre, which was probably located in the southern part of Block E during the Late Miocene to Early Pliocene times to the current deep-water depocentre, the Northwest Sabah Trough (Jong and Sha, 1999).
- Source rock depositional modeling of the regional lines suggests the presence of both land plant-derived and marine kerogens. In general, the source richness (TOC) is low indicating mainly lean source rock. The models also show a slightly higher concentration of TOC and relatively higher percentage of oil-prone kerogen (higher Hydrogen Index values) within the foreset depositional environment.

In summary, *STRATAGEM* forward stratigraphic modeling of Block E generated a realistic geometry of sedimentary successions. It can be used as a sensitivity tool in estimating potential reservoir and source rock development.

*Paper 27*

## **Geometry and wireline signatures of tidal sandstone reservoirs: outcrop analogues from Brunei Darussalam**

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Traditionally, the petroleum reservoirs in Brunei Darussalam have been interpreted as wave-dominated delta deposits but recent studies show that a significant number of the producing reservoirs are tidal sandstones. The reservoir properties and geometries of these two reservoir types are significantly different, therefore it is important to be able to distinguish them. To date, the characteristics of the tidal reservoirs have not been described in detail. Consequently, the objective of the study is to determine in outcrop the reservoir properties and geometry of tidal sandstones and to recognise equivalents in subsurface.

The outcrop facies include tidal channel sands, tidal sand flats, tidal mud flats, embayment mudstones and coaly shales. Tidal channel sands are dominated by fine clean sandstones. Individual channels are typically 3 to 4 m wide and range from 0.5 m to 1.0 m in thickness. Sedimentary structures consist of high angle cross beds, mud clasts at the base of channels, asymmetrical wave ripples and bioturbated bedding surfaces.

Tidal channel units are laterally continuous for at least the 230 m lateral extent of the outcrop with only minor variation in thickness. There is a consistent net to gross of 90% and channel sand units are ~3 m but can be stacked to much greater thicknesses (up to 19 m in the outcrop). Reservoir quality can be reduced somewhat by lateral variability in sandstone thickness and the presence of mud-filled channels.

Tidal channels have minor vertical permeability barriers caused by mud laminae capping most channel sets. However, successive sands remain connected and lateral continuity is preserved because the mud caps are discontinuous. Porosities are typically higher in the tidal channel sands (~20%).

Tidal sand flats consist of thin fine sands interbedded with muds. The sands typically contain organic matter as laminae with occasional coal clasts. Sedimentary structures consist of lenticular bedding, wavy bedding, flaser bedding and reactivation surfaces.

Tidal sand flats have lateral continuity in the order of tens of metres and a highly variable net to gross (ranging from 90% to 60% in sections 90 m apart) due to rapid lateral changes in the thickness of muds. Tidal sand flats are typically less than 1 m thick, which limits the volume of the potential reservoir. Porosities are relatively low to medium (~12%~15%), because intergranular porosities are clogged by clay pellets. Major vertical permeability barriers occurred due to laterally extensive muds within the unit. Horizontal permeability is controlled by the lateral continuity of individual sandstone packages.

A portable gamma ray spectrometer was used to create a synthetic outcrop gamma log. The tidal channel sands show a tabular signature with sharp contacts. Subsurface successions that have been interpreted as tidal sandstones have a similar gamma signature, suggesting that it is possible to identify tidal successions with wireline data. Higher resolution tools such as FMI and OBDT logs may be required to confirm a tidal genesis.

*Paper 28*

## **Seismically constrained lithology modelling**

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Quantitative reservoir characterisation often requires that the lithology distribution is described in detail. For example, in carbonates variations in the porosity versus permeability relationships can be associated with different rock fabrics, which can be defined as lithology types. Therefore in order to build models of permeability of the reservoir for flow simulation we must first not only build models of porosity but also associated models of lithology.

There are many techniques to build lithology models. Many of these techniques are based on geostatistics in order to ensure that the models honour the well data and to incorporate the inherent uncertainty in constructing such models. In the absence of tight well control the uncertainty in the lateral distribution of lithology can be very high. In many environments seismic data respond to variations in lithology. Since seismic data sample the subsurface densely, the seismic data can be used to help constrain the distribution of lithology during modelling and thereby reduce uncertainty.

This paper demonstrates through the presentation of a number of examples from the SE Asia region a technique called geostatistical inversion with lithology simulation. In this approach models of lithology are constructed geostatistically in such a way that they explicitly match the seismic data. Models can be constructed with detail beyond the seismic bandwidth. The practical steps in the implementation of the technique are shown along with techniques to analyse the multiple realisations that result from this method.

The examples presented are from both clastic and carbonate environments and show the importance of lithology modelling to quantitative reservoir characterisation.

*Paper 29*

## **Deepwater exploration, offshore NW Sabah: Kamunsu East upthrown drilling success**

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A window of opportunity came to SSB/SSPC to utilise the semi-sub rig suitable for deepwater drilling that had successfully drilled Kamunsu East-1 when the rig was available again at very short notice in November 1999. At that time a potential large oil prospect named Kamunsu East Upthrown (KMEU) in a water depth of 3,500 ft was just ready to be tested.

In order to realise this opportunity SSB/SSPC had to face the main challenges of planning, preparing and executing a deepwater well within four weeks and limited budget.

The solutions to these challenges was handled by SSB/SSPC in the following forms: (1) Strike alliances with the key providers based in Singapore so that deepwater project materials were kept within reach for quick mob but without any commitment from both parties (2) Discounted rate to contract the rig into Malaysia in Q4 99 from Shell Philippines Exploration (3) Best practices from other wells were built upon and adapted for KMEU-1 well. Drilling the limit initiatives were adopted such that they could match and improve on the achievements from the previous Kamunsu East-1 well.

A fit for purpose data acquisition programme was proposed with the objective to acquire only the essential data to minimise up-front expenditure.

No high-resolution digital and side scan survey was acquired as the available 3D seismic data is of high quality and did not indicate any obvious shallow gas risk at the proposed well location.

Kamunsu East Upthrown prospect had several potential hydrocarbons bearing fan levels within the Miocene turbidite sandstones. This drilling opportunity was maximised by combining exploration and appraisal multi-objectives in the vertical and geological sidetrack holes.

The vertical exploratory well was designed test the hydrocarbon potential and fluid type of the Pink, Kinarut and Keabangan fan levels each exhibited clear flat spot at each levels that were interpreted as fluid contacts. The sidetrack was planned to appraise the up-dip Pink and Kinarut fan levels seen in the vertical hole and also to drill a deeper Keabangan exploration target.

Geophysical modelling predicted the primary Kinarut fan level to have a high probability of being oil-bearing whilst the Pink level as likely gas-bearing. No clear prediction could be made on the likely hydrocarbon type at Keabangan level.

The results of the vertical and sidetrack wells verified the presence of gas and oil in the Pink and Kinarut fan respectively. At the Keabangan level it was gas and oil-bearing in the vertical hole and sidetrack respectively. The wells proved some 200 ft oil column, the longest oil column so far found in SSPC deepwater acreage but also discovered gas at a previously unpenetrated Pink turbidite fan.

The vertical well confirmed that the flat spots penetrated in the Pink and Keabangan levels were indeed associated with the fluid contacts. However, the flat spot at the Kinarut level proved to be a paleo-contact. At the Kinarut level the oil saturation is low at 45% probably due to poor reservoir quality. Interbedded thin oil and water columns were detected in the sidetracked Keabangan exploration objective.

Strong changes in net-to-gross at the Pink fan level were observed between the vertical and geological sidetrack over some 50 ft distance. Oil was found in the poorer net-to-gross upper Kinarut level but the good quality blocky sand at lower Kinarut was water-bearing.

The main learning points that will be incorporated into future deep water well planning are: (1) MDT samples proved crucial in evaluating reservoir fluid types as hydrocarbon differentiation was sometimes difficult on wireline logs. (2) The shearlog data acquired with the Baker Hughes MAC tool was adversely

affected by the tool mode problem especially in slow formations. It is recommended to use XMAC tool. (3) SSB/SSPC had demonstrated the ability to drill cheaply (US\$9.3 M for vertical and sidetrack) by taking rig opportunity at discounted rate, fastest (12 days from spud to TD at 10,300' in vertical hole) and deepest water depth location drilled in Malaysia with a planning lead time of just four weeks.

The continuous and successful exploration efforts have increased the probability of success for both oil and gas plays in Sabah deepwater outboard acreage. SSB/SSPC have proven the ability to deliver low cost deepwater wells that will allow smaller reserves cut-off and a promise of lower development expenditure. These combined factors provide the stimulus for SSB/SSPC to launch an aggressive campaign for the search of oil and gas whilst commercialise the proven gas in the deepwater acreage.



# PETROLEUM GEOLOGY CONFERENCE 2000

22 & 23 November 2000  
Shangri-La Hotel, Kuala Lumpur, Malaysia

## ABSTRACTS OF POSTERS

Poster 1

### Processing to the limit with SIPMAP, Shell proprietary in-house seismic processing software

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Sarawak Shell Berhad EPT-GPA, the Seismic Processing and Archiving group has been in the business of producing quality seismic data in production mode for a number of years now. Starting with the first inhouse 3D in 1996 with the first installation of an initial 4-160 MHz CPU IBM SP2s. The center has now grown to a massive 24-400 MHz CPU Sun-E450s with total storage of 1.2 Terrabyte disk space.

With the recent upgrade, processing capability has increased from a 1,000 kms conventional 2-Ds and 3Ds to full blown Pre Stack Time and Pre Stack Depth Imaging in-house projects. The biggest 3D to date clocked 1,400 sq km just last year.

#### SIPMAP Processing Power

IBM SP2s & Sun E450s. Increased processing capability as well as speed with the recent installation of the new Suns. More value added processing are being carried out in-house on top of SIPMAP quality conventional 2D and 3D projects.

#### What can SIPMAP bring into the picture from your seismic dataset?

##### *Conventional Processing & Reprocessing: 2D & 3D Marine*

The center is fully equipped to carry out 2D/3D Marine new processing as well as reprocessing work. Dedicated machines as well knowledgeable trained staff ensure you will get the most from your seismic data.

##### *Special Processing: Pre Stack Imaging, PreStack Depth Migration, 4C, Timelapse*

Expertise in value added processing above made the SIPMAP center your ideal partner in discovering the immense benefits of new technology in your field.

#### Some notable SIPMAP data examples are categorized as follows:

- a. 2D & 3D Conventional Processing: Baronia, Baronia Timurlaut, Baram
- b. PSI Processing: Timbalai, Winchester
- c. PSDM: Keabangan, SBG, Barton South Furious
- d. 4C: SK308

## **The study of overpressures in NW Borneo**

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A study of pressure data from exploration and appraisal wells from across the NW Borneo Margin has been part of a Regional Study undertaken by SSB/SSPC over the last year. The study of the relationship between formation strength, aquifer overpressure and hydrocarbon column length provides important information for the prediction of the presence of oil and gas accumulations.

During the course of the study, some 106 RFT data from Sabah and 225 RFT data from Sarawak have been compiled. In addition leak-off pressure data from some 111 exploration, appraisal and development wells have been compiled. The formation pressure data and LOT data have been analysed to determine regional pressure trends in the geological provinces of offshore NW Sabah and Sarawak.

These trends are used in the following way:

- ¥ Estimating the maximum hydrocarbon column length in prospect volumetric calculation. This is easily achieved by extrapolating a hydrocarbon gradient from the base of the formation pressure until it intersects the lower bound envelope. Moreover the comparison between aquifer overpressure and minimum horizontal stress in discovered fields can demonstrate the dependency of hydrocarbon column length on aquifer overpressure and minimum horizontal stress within individual provinces.
- ¥ Predicting trap integrity. A prospect having higher predicted formation pressure than the lower bound envelope would indicate that the trap has been breached. In this case the formation pressure is greater than the seal strength of the overlying seal thus fracturing it. In contrast, prospects with predicted formation pressures lying below the lower bound envelope would have pressure space to accommodate hydrocarbons. The closer the fluid pressure is to the minimum in-situ stress, the greater the likelihood that a prospect will not be hydrocarbon bearing. Consequently the prediction of the level of aquifer overpressure is of considerable importance in hydrocarbon exploration.

In general the deeper the exploration target the higher the probability that overpressures will be encountered. In Tertiary deltas, rapid sedimentation is considered to be the chief cause of overpressures (undercompaction overpressures). In this regard it is interesting to note the relationship between porosity trend across different provinces with depth. The deviation of observed porosity from those expected for a hydrostatically pressured rock would mark the first onset of overpressures. Overpressures are quite common throughout offshore NW Borneo especially in Inboard Belt, Outboard Belt, Champion-Timbalai Trend, Padas-Tulak trend and Nosong-Tapir trend in the East Baram Delta. Integration of analyses of regional pressures against depth in other offshore areas of the margin is ongoing.

*Poster 3*

## **The palaeogeographic evolution of the NW Borneo margin**

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A Regional Study Team has been compiling and integrating results of a number of studies carried out over the last decade in Sabah and Sarawak by SSB, SSPC, PRSS and PCSB. Coupled with developments in sequence stratigraphic understanding and recognition of new play concepts, the work has resulted in a set of maps that depict the palaeogeographic evolution of the NW Borneo Margin from Miocene to the Recent.

The maps are based on the integration of well and seismic data. The interpretation of regional seismic lines supported by modern biostratigraphic interpretation of some 184 key wells across the NW Borneo Margin has resulted in a consistent framework of seismic horizons. Environments of deposition interpreted from well data were correlated with seismic facies which, in turn, were used to predict the distribution of reservoirs in those areas where there is poor well control.

The maps have been produced for chronostratigraphic intervals that correspond to the global sea level sequences. A number of key maps and correlation panels will be presented in the poster session highlighting the value of regional studies in the prediction of source rock/reservoir and seal distribution.

*Poster 4*

## **Source rock evaluation and geochemical characteristics of hydrocarbons from Sabah and Sarawak**

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As part of NW Borneo regional review initiative, a study is carried out to compile and review all available geochemical data of evaluated source rocks, hydrocarbons and source rock extracts from Sabah and Sarawak. Preliminary results from this study indicate that:

- Based on VR analysis, source rocks from Sabah are generally immature and only attain early maturity at around 6,000'. On the other hand, source rocks from Sarawak reach early maturity at around 4,000', with samples at greater depths entering the oil generating window around 6,000'. The difference in source rock maturity could be due to different tectonic and geothermal regimes in these areas.
- Source rocks in Sabah are generally poorer in quality in comparison to those from Sarawak, where coaly samples are common (high TOC). In general, higher TOC reflects better generating potential (S2).
- Rock-Eval pyrolysis data suggest the presence of predominantly gas-prone Type III, land plant derived kerogen with some mixed oil- and gas-prone Type II/III kerogen. The presence of Type II/III kerogen is commonly attributed to bacteria reworking/marine influence of terrigenous organic matter. However, the potential presence of marine organic matter cannot be dismissed
- Isoprenoid/n-alkane ratios (Pr/C17 vs Ph/C18) infer source rock deposition and preservation occurred mainly in oxidising environment. However, there are a number of samples from Sarawak exhibiting mixed organic sources.
- Stable carbon isotope ratios for saturated vs aromatic hydrocarbons also show mainly terrigenous organic matter, albeit the ratios for some samples also indicate significant presence of marine organic matter.
- Similarly, predominance of C29 steranes relative to C27 and C28 steranes suggest the existence of mainly terrigenous organic matter, with insignificant contribution from marine organic matter in Sabah, whilst samples from Sarawak show significant marine influence, especially for those from the Central Luconia Province.

In general, the above observations confirm the common knowledge of hydrocarbons in the study area being derived mainly from higher plants, land derived organic matter. However, recent studies by other researchers using the advance GCMS(MS) finger-printing technique have shown the existence of marine source rocks in Sarawak (e.g. Scherer and Abolins, 1999), although little is yet known of the geological controls on their distribution and extent. It is hoped that by year-end, additional oil samples that are selected for detailed biomarker analysis, which are currently being analysed will provide some insights into the potential presence of marine source rocks in the study area.

## **Preserving our key geological exposures — exploring the realm of geotourism**

PHILIP LESSLAR & CHARLIE LEE

Sarawak Shell Berhad/Sabah Shell Petroleum Co. Ltd.  
Miri, Sarawak, Malaysia

Miri town is the locality of Malaysia's first commercial oilfield, discovered in 1910. It is also a locality rich in geological exposures that exhibit a wide range of features. This poster session summarises efforts to date made by a group of volunteers to preserve a selected number of these exposures as permanent geological exhibits that also support educational and eco-/geo-tourism efforts.

The Airport Road outcrop in Miri, located about two kilometers from the town center along the way to Miri Airport, is one of the most outstanding geological exposures in the region. In particular, it has been hailed by some as one of the best outcrops in the world for the observation of faults in three dimensions. Many geological field trips to the site have been made by the various petroleum companies operating in the area. In addition, the site has attracted scholars from Universities in the region and from Europe. Its location on one of the highest points in Miri town also offers visitors a panoramic view of Miri and its surroundings.

In pursuing logistics aspects, linkage to development aspirations of the community and the Government has been a key area of focus as is maintenance of the exhibit over time. Early efforts have therefore been made to present results of the effort to local dignitaries and the Miri Council and to secure support which has proven to be extremely positive.

This poster session depicts the progress and experiences to date, outlines future plans and looks at a range of synergy areas e.g. tourism industry, education, geological survey, local university.

## **Quantitative modelling and understanding the evolution and distribution of reservoirs in West Sabah continental margin, Malaysia**

CHARLIE LEE<sup>1</sup>, ZULKEFLI ABDUL HAMID<sup>2</sup> & WONG CHUNG LEE<sup>3</sup>

<sup>1</sup>Sabah Shell Petroleum Co. Ltd.  
Miri, Sarawak, Malaysia

<sup>2</sup>PETRONAS  
Kuala Lumpur, Malaysia

<sup>3</sup>SIEP  
The Hague, The Netherlands

The evolution and distribution of reservoirs in the West Sabah Continental margin, in particular the deepwater area, is not well understood. This paper presents the results of recent attempts in quantitative modelling of the study area.

Quantitative stratigraphic modelling, based on regional 2D seismic lines from the West Sabah continental margin area, adequately modelled the stratigraphic and structural geometries of the continental margin and deepwater basins. Good match between modelled and observed stratigraphy based on seismic and well data has enhanced the current understanding of the evolution and distribution of both shallow water and deepwater reservoirs in the area.

Tectonically induced subsidence/uplift is found to be the main controlling factors on reservoir evolution and distribution. Thrust-sheet piggy-back basins and associated thrust ridges form an ideal trap for the ponding of turbidites on the shelf, slope and basin by the fill-and-spill mechanism. In addition, eustatic sea level changes have major impact on the rate of sediment supply, accommodation space and environment of deposition, and often enhanced the effects of tectonic activity.

*Poster 7*

## **Drastic reduction in commerciality threshold for offshore exploration (Repsol-YPF-Maxus-Schlumberger, Java Sea, Indonesia)**

**D. ROGER WALL<sup>1</sup>, ANDREW W.R. WIGHT<sup>1</sup>, E.J. INDRAWAN<sup>1</sup>, MICHAEL E. ELLIS<sup>1</sup>,  
DOUGLAS A. PARK<sup>1</sup> & ALAN BAKER<sup>2</sup>**

<sup>1</sup>YPF Maxus Southeast Sumatra BV  
Jakarta, Indonesia

<sup>2</sup>PT Schlumberger Indonesia

The Offshore SE Sumatra PSC in Indonesia's Java Sea has been explored for over thirty years, finding 30 commercial oil fields having cumulative production exceeding one billion barrels. In such a mature phase, exploration appeared unattractive owing to prohibitively high cost for apparently low reward. A strategy was needed to balance the risk:reward ratio (cost:risk:reserve potential) to encourage the exploration drilling necessary to maintain reserve growth.

This was solved by an expendable, 'slim-hole' drilling programme (dubbed 'MX'). A ten-well programme was designed that on a probabilistic risk analysis basis provided attractive net present value and rates of return. Costs were halved by utilizing three concepts; slim-hole, a built-for-purpose rig and truly integrated contractor services, using Schlumberger's new 'Bima', a highly-automated, self-propelled, self-elevating vessel designed for efficient moving, pre-loading, rig up/down operations. Economics were further improved by integrating with innovative production technological advances such as 'Guardian' monopod caissons. Close co-operation with Pertamina, in terms of 'streamlining' the approval process and allowing marginal field incentives on a case-by-case basis, was a key element to the success of the project.

To end 1999, seven exploration wells (and 13 development/delineation wells) had been drilled, in record time and with extremely reduced costs. In addition the performance exceeded predicted limitations on depth and other factors. Three of the exploration wells have so far encountered significant oil pay. If these prove commercial, the programme may be extended to larger-reserve, riskier ventures in the new Millennium.

*Poster 8*

## **Oil-generating potential of the Tanjung Formation coals, Barito Basin, South Kalimantan, Indonesia**

**WAN HASIAH ABDULLAH, WAN NAFIZA WAN JAAFAR & ROSNI LOKMANNUL HAKIM**

Department of Geology  
University of Malaya  
50603 Kuala Lumpur

The Barito Basin lies on the southeastern edge of the continental Sundaland plate. The Basin contains sediments of Tertiary age, the coal measures of which are found around the margins of the Meratus Range. The

Tanjung Formation forms the basal Tertiary section and is widely accepted as Eocene in age. The formation is named from its occurrence within the Tanjung oilfield. The discovery of Tanjung-1 was made in 1938 within the Lower Tanjung Formation sandstones in the northeastern part of the Barito Basin.

In this study, fifteen coal samples were analysed by means of organic petrological and organic geochemical *methods* with the aim of evaluating their oil-generating potential. Ten of the coal samples are from the basal thick (C) seam while the remaining five samples are from the (B) seam above. The upper (B) seam splits incorporating about 60 cm of silty mudstones, several samples of which were also analysed.

The petrological analyses performed in this study include petrographic description and maceral analysis in reflected white light and under blue light excitation, and vitrinite reflectance (% Ro) measurement in white light using oil immersion. The geochemical analyses carried out include determination of total organic carbon (TOC) content, bitumen extraction, Rock-Eval pyrolysis and gas chromatography-mass spectrometry (GC-MS). Both the petrographic and geochemical data indicate that the coals possess very good oil generating potential. This is a consequence of their being rich in liptinitic material of up to 40% by volume of whole rock. This good source rock potential is supported by moderate to high hydrogen indices (HI) of 242–436 mgHC/gTOC and high extractable organic matter and hydrocarbon yields exceeding 10,000 ppm. All of the coal samples analysed are early to mid mature based on vitrinite reflectance values of 0.52–0.66%. This is supported by Tmax values of between 424 and 436°C. Based on petrographic observation, the organic matter that is recognised to be the most oil-prone within these coals is the maceral suberinite. This maceral is seen to expel oil-like material and is associated with other common liquid hydrocarbon generative features often considered to be indicative of oil generation from coals, such as the occurrence of exsudatinite and oil haze.

*Poster 9*

### **Lowering risk in the exploration process: what can we get from basic modeling**

JEAN-MICHEL GAULIER, REMI MOUCHEL<sup>1</sup>, JOHANNES WENDEBOURG, FREDERIC SCHNEIDER, JEAN-LUC RUDKIEWICZ & SYLVIE WOLF<sup>2</sup>

<sup>1</sup>Beicip-Franlab  
232, Av. Napoleon Bonaparte  
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<sup>2</sup>IFP

*Poster 10*

### **Exploration opportunities in Malaysia**

NORDIN RAMLI, BARNEY MAHENDRAN, ZULKEFLI ABDUL HAMID, MANSOR AHMAD,  
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- |   |  |
|---|--|
| <p>1. Liau Min Hoe<br/>Petronas Carigali, Level 26 Tower 1,<br/>Petronas Twin Towers, Kuala Lumpur City<br/>Center, 50088 Kuala Lumpur.</p>         | <p>3. Abdul Hadi Abdul Rahman<br/>Jabatan Mineral &amp; Geosains Malaysia,<br/>Tingkat 9, Wisma Persekutuan, 20200<br/>Kuala Terengganu.</p> |
| <p>2. Daniell Lewis<br/>Geocrete Laboratory Sdn. Bhd., No. 26,<br/>Jalan P2/4 Seksyen 2, Bandar Teknologi<br/>Kajang, 43500 Semenyih, Selangor.</p> | <p>4. Mohamed Tiher A. Taha<br/>Schlumberger Asia Solution Center, 18th<br/>Floor, Rohas Perkasa, 8 Jalan Perak, 50450<br/>Kuala Lumpur.</p> |

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#### PERTAMBAHAN BAHARU PERPUSTAKAAN (New Library Additions)

The Society has received the following publications:

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| <p>1. Tin International, vol. 73, nos. 10 &amp; 11,<br/>2000.</p>              | <p>Exploration Production, vol. 22, no. 2, 1998.</p>                                   |
| <p>2. American Museum Novitates, nos. 3301,<br/>3302 &amp; 3303, 2000.</p>     | <p>7. AAPG Bulletin, vol. 84, nos. 9 &amp; 10, 2000.</p>                               |
| <p>3. Acta Palaeontologica Sinica, vol. 39, nos. 2<br/>&amp; 3, 2000.</p>      | <p>8. AAPG Explorer, Nov. &amp; Dec. 2000.</p>   |
| <p>4. Acta Micropalaeontologica Sinica, vol. 17,<br/>nos. 2 &amp; 3, 3000.</p> | <p>9. Monthly statistics on mining industry in<br/>Malaysia, July 2000.</p>            |
| <p>5. Palaeontological Abstracts, vol. 15, nos. 2-<br/>3, 2000.</p>            | <p>10. Scripta Geologica, no. 120, 1999.</p>   |
| <p>6. Bulletin du Centre de Recherches Elf</p>                                 | <p>11. Bulletin of the National Science Museum,<br/>vol. 26, nos. 1 &amp; 2, 2000.</p> |
|  | <p>12. USGS Prof. Paper: 2000: nos. 1618, 1615.<br/>1999: no. 1616.</p>                |

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# Common Rocks of Malaysia

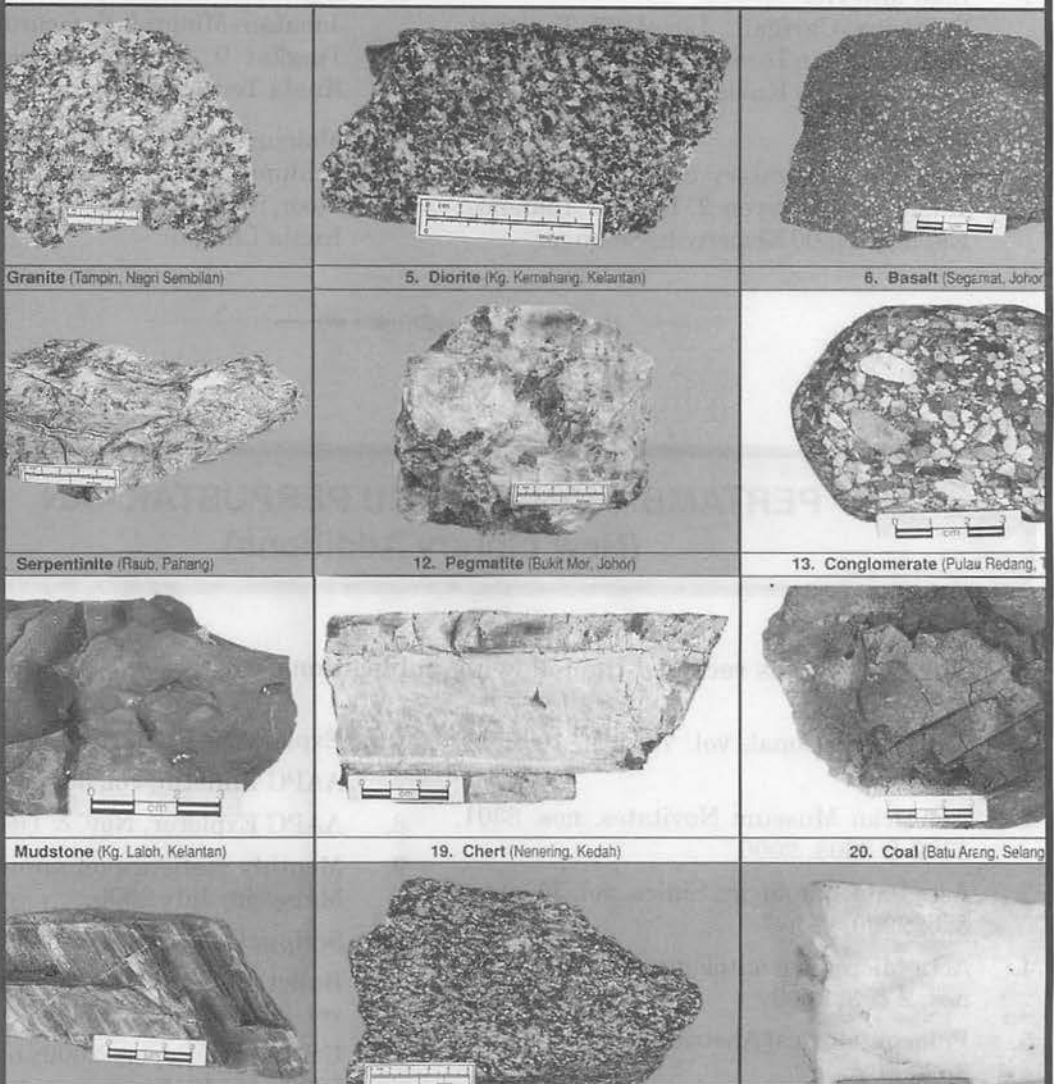
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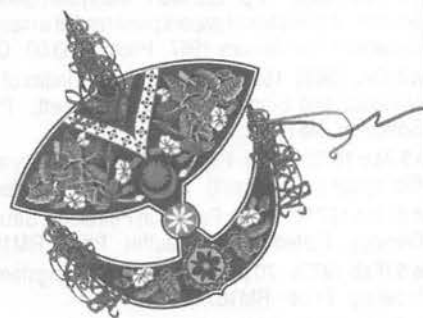
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#### January 12-16

*SYMPOSIUM PANGAEA*, Muscat, Sultanate of Oman. (Contact: Aymon Baud, Musée Géologique, UNIL-BFSH2, CH-1015 Lausanne, Suisse. Tel: 0041 21 692 4471; Fax: 0041 21 692 4475; E-mail: aymon.baud@sst.unil.ch; Website: <http://www.geoconfoman.unibe.ch>)

#### January 25-26

*SPATIAL METHODS FOR SOLUTION OF ENVIRONMENTAL AND HYDROLOGIC PROBLEMS: SCIENCE, POLICY AND STANDARDIZATION — IMPLICATION FOR ENVIRONMENTAL DECISIONS (INTERNATIONAL CONFERENCE)*, Reno, Nevada, USA. (Contact: Dr. Vernon H. Singroy, Canada Center for Remote Sensing, 588 Booth St., Ottawa, ONT K1A 0Y7, Canada. Tel: +1-613 947 1215; E-mail: vern.singhroy@geocan.nrcan.gc.ca)

#### March 13-15

*3RD SEMINAR ON ANALYSIS, METHODOLOGY OF TREATMENT AND REMEDIATION OF CONTAMINATED SOILS AND GROUNDWATERS*, Paris, France. (Contact: Howard Hornfeld, programme coordinator for the chemical industry, United Nations Economic Commission for Europe, Palsis des Nations 429-3, Ch-1211 Geneva 10, Switzerland. Tel: +41 22 917 3254; Fax: 41 22 917 0178; E-mail: chem@unece.org)

#### March/April 2001

*1ST INTERNATIONAL CONFERENCE ON SALT WATER INTRUSION AND COASTAL AQUIFERS*, Essaouira, Morocco. (Contact: Prof. Driss Ouazar, Ecole Mohammadia d'ingénieurs, B.P. 765, Agdal Rabat, Morocco. Tel: +212-7-670579; Fax: +212-7-778853; E-mail: ouazar@emi.ac.ma; Website: [www.ce.udel.edu/cheng.saltnet/swica.html](http://www.ce.udel.edu/cheng.saltnet/swica.html))

#### April 8-11

*AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS*, Denver, Colorado, USA. (Contact: AAPG Conventions Dept., P.O. Box 979, 1444 S. Boulder Ave., Tulsa, OK 74101-0979; Fax: 1 918 560 2684; E-mail: [dkeim@aapg.org](mailto:dkeim@aapg.org))

#### May 2001

*ANATOMY OF CARBONATE BODIES*, Marseilles, France. (Contact: M. Floquet and J.P. Masse, Centre de Sédimentologie-Paléontologie, Université de Provence, Case 67, 13331 Marseilles Cedex 03, France. E-mail: reef@newsup.univ-mrs.fr)

#### May 2001

*GEOCHEMICAL EXPLORATION* (20th International Symposium). (Contact: Association of Exploration Geochemists. Website: [www.aeg.org/](http://www.aeg.org/))

#### May 5-12

*PHODOPE GEODYNAMIC HAZARDS, LATE ALPINE TECTONICS AND NEOTECTONICS*, International Conference with extensive field trip in SW Bulgaria. Sofia, Bulgaria. (Contact: Website: [http://www.geology.bas.bg/Rhodope\\_conference](http://www.geology.bas.bg/Rhodope_conference); E-mail: [Zagor@router.geology.bas.bg](mailto:Zagor@router.geology.bas.bg))

#### May 11-21

*MID-PALAEOZOIC BIO- AND GEODYNAMICS: THE NORTH GONDWANA-LAURUSSIA INTERACTION*, Joint meeting of the 'International Geological Correlation Program

(IGCP) 421' and the 'Subcommission on Devonian Stratigraphy (SDS)' hosted by the 'Senckenbergische Naturforschende Gesellschaft', Frankfurt am Main at the 'Forschungsinstitut und Naturmuseum Senckenberg' Frankfurt am Main, Germany. (Contact: G. Plodowski, Forschungsinstitut Senckenberg, Senckenberganlage 25. D-60325 Frankfurt am Main. Tel: ++49-69-97075127; Fax: ++49-69-97075137; E-mail: gplodows@sngkw.uni-frankfurt.de)

#### May 27-30

*GEOLOGICAL ASSOCIATION OF CANADA-MINERALOGICAL ASSOCIATION OF CANADA* (Joint Annual Meeting), St. John's, Newfoundland, Canada. (Contact: Newfoundland Geological Survey, E-mail: dgl@zeppo.geosurv.gov.nf.ca; Website: www.geosurv.gov.nf.ca/)

#### June 3-6

*AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS* (Annual Meeting), Denver, Colorado, USA. (Contact: AAPG Conventions Department, P.O. Box 979, 1444 S. Boulder Ave., Tulsa, OK 74101-0979, USA. Tel: +1 918 560 2679; Fax: +1 918 560 2684; E-mail: dkeim@aapg.org)

#### June 6-8

*SEDIMENT 2001*, Jena, Germany. (Contact: Organisationskomitee Sediment 2001, Institut für Geowissenschaften, Universität Jena, Burgweg 11, D-07749 Jena, Germany. Tel: +49 3641 948 621; Fax: +49 3641 948 622; E-mail: sediment2001@geo.uni-jena.de; Website: http://www.uni-jena.de/chemie/geowiss/tagungen/tagungen.html)

#### June 10-15

*WATER-ROCK INTERACTION* (10th International Symposium, Sponsored by Working Group of the International Association of Geochemistry and Cosmochemistry), Sardinia, Italy. (Contact: Rosa Cidu, Dipartimento di Scienze della Terra, via Trentino 51, I-09127 Cagliari, Italy. E-mail: cidur@unica.it)

#### June 11-16

*63RD EUROPEAN ASSOCIATION OF GEOSCIENTISTS AND ENGINEERS CONFERENCE & TECHNICAL EXHIBITION*, Amsterdam, The Netherlands. (Contact: EAGE

Conference Dept., P.O. Box 59, 3990 DB Houten, The Netherlands. Tel: +31 30 6354055; Fax: +31 30 6343524)

#### June 18-21

*GROUNDWATER QUALITY 2001. NATURAL AND ENHANCED ATTENUATION OF GROUNDWATER POLLUTION*. Organised by IAHS, Sheffield, U.K. (Contact: David Lerner, University of Sheffield, Tel: +44 114 222 5743; Fax: +44 114 222 5701 or 5700; E-mail: d.n.lerner@sheffield.ac.uk)

#### June 24-28

*EARTH SYSTEM PROCESSES* (International Meeting sponsored by the Geological Society of America and the Geological Society of London), Edinburgh, Scotland. (Contact: Ian Dalziel, University of Texas at Austin; E-mail: ian@utig.ig.utexas.edu)

#### June 25-27

*3RD INTERNATIONAL CONFERENCE OF FUTURE GROUNDWATER RESOURCES AT RISK*, Lisbon, Portugal. (Contact: FGR'01 International Conference, CVRM Geosystems Center, Instituto Superior Técnico, Av. Rovisco Pais, 1049-001 Lisbon, Portugal. Tel: +351 21 841 72 47; Fax: +351 21 841 74 42; E-mail: fgr@alfa.ist.utl.pt; Website: www.alfa.ist.utl.pt/~cvmr/FGR)

#### July 3-8

*CLIMATE AND BIOTA OF THE EARLY PALEOGENE*, Plowell, Wyoming, USA. (Contact: Scott Wing, Dept. of Paleobiology, Smithsonian Inst., Washington, DC 20560, USA. Tel: (202) 3578 2649; E-mail: wing-scott@nmnh.si.edu)

#### July 17-20

*OIL AND GAS MALAYSIA 2001: THE 9TH MALAYSIAN OIL, GAS AND PETROCHEMICAL ENGINEERING EXHIBITION*, Kuala Lumpur, Malaysia. (Contact: Overseas Exhibition Services Ltd., 11 Manchester Square, London W1M 5AB, Angleterre. Tel: +44 (0) 207 862 2000; Fax: +44 (0) 202 862 2078; E-mail: pmckean@montnet.com)

#### July 29 - August 2

*BIOGEOCHEMISTRY OF TRACE ELEMENTS* (6th International Conference, University of Guelph, Guelph, Ontario, Canada. (Contact: ICOBTE Secretariat, Department of

Land Resource Science, University of Guelph, Guelph, Ontario, Canada N1G 2W1. Tel: +1-519 829 4120 ext. 2531; Fax: +1-519 823 1587; E-mail: icobte@lrs.uoguelph.ca; Website: icobte.crle.uoguelph.ca)

#### July 29 – August 4

**12TH INTERNATIONAL CLAY CONFERENCE**, Bahía Blanca, Argentina. (Contact: Fernanda Cravero, Secretary-General 12 ICC, Departamento de Geología, Universidad Nacional del Sur, 8000 Bahía Blanca, Argentina. Tel: +54 291 459 51 01 ext. 30 41; Fax: +54 291 459 51 48; E-mail: 12icc@criba.edu.ar; Website: <http://www.12ICC.criba.edu.ar>)

#### July 30 – August

**INTERNATIONAL ASSOCIATION OF ENGINEERING GEOLOGY AND THE ENVIRONMENT (IAEG), "Engineering Geological Problems of Urban Areas"** (International Symposium), Ekaterinburg, Russia. (Contact: Secretariat, "EngGeolCity-2001, UralTISIZ 79, Bazhov str., Ekaterinburg, Russia 620075. Tel: +7 3432 559772; Fax: +7 3432 550043; E-mail: UralTIS@etel.ru)

#### August 6–10

**7TH INTERNATIONAL CONFERENCE ON FLUVIAL SEDIMENTOLOGY**, University of Nebraska-Lincoln, USA. (Contact: Mike Blum, Department of Geosciences, 214 Bessey Hall, University of Nebraska-Lincoln, Lincoln, NE 68588-0340, USA. Tel: +1 402 472 78 72; Fax: +1 402 472 49 17; E-mail: mblum@unl.edu; Website: <http://www.unl.edu/geology/icfs.html>)

#### August 6–10

**AGGREGATE 2001 — ENVIRONMENT AND ECONOMY**, Helsinki, Finland. (Contact: Tampere University of Technology, Lab. of Engineering Geology, P.O. Box 600, FIN-33101 Tampere, Finland. Fax: +358 3 3652884; E-mail: kuulavai@cc.tut.fi or pekka.ihalainen@luyv.fi)

#### August 10–13

**THE INTERNATIONAL SYMPOSIUM ON THE GLOBAL STRATOTYPE OF THE PERMIAN-TRIASSIC BOUNDARY AND THE PALEOZOIC-MESOZOIC EVENTS**, Changxing, Zhejiang Province, China. (Contact: Dr. Tong Jinnan, Faculty of Earth Science, China University of Geosciences, Wuhan 430074, China. Tel: +86-27-8748 2031; Fax: +86-

27-8780 1763; E-mail: jntong@public.wh.hb.cn)

#### August 20–24

**PALEOFORAMS 2001** (International Conference on Paleozoic Benthic Foraminifera), Middle East Technical University, Ankara, Turkey. (Contact: Demir Altiner, Department of Geological Engineering, Middle East Technical University (ODTÜ), 06531 Ankara, Turkey. Tel: +90-312-2102680, +90-312-4275195; Fax: +90-312-2101263; E-mail: <altiner@tubitak.gov.tr><demir@metu.edu.tr>)

#### August 23–28

**INTERNATIONAL CONFERENCE ON GEOMORPHOLOGY** (5th), Tokyo, Japan. (Contact: Prof. K. Kashiwaya, Dept. of Earth Sciences, Kanazawa University, Kanazawa, 920-1192 Japan. E-mail: kashi@kenroku.kanazawa-u.ac.jp)

#### August 24–27

**1ST INTERNATIONAL CONFERENCE ON SUSTAINABLE DEVELOPMENT IN KARST REGIONS**, Beijing, China. (Contact: Prof. Yuan Daoxian, E-mail: dxxyuang@osmanthus.gxnu.edu.cn)

#### August 27–29

**SOCIETY FOR GEOLOGY APPLIED TO MINERAL DEPOSITS "Mineral Deposits at the Beginning of the 21st Century"** (6th Biennial Meeting), Kraków, Poland. (Contact: 6th Biennial SGA Meeting, Dr. Wojciech Mayer, University of Mining and Metallurgy, Faculty of Geology, Geophysics & Environmental Protection, av. Mickiewicza 30; 30-059 Kraków, Poland. Tel: +48-12 617 2385; Fax: +48-12 633 2936; E-mail: wmayer@geol.agh.edu.pl; Website: <http://galaxy.uci.agh.edu.pl/~sga>)

#### September 3–5

**21ST IAS MEETING OF SEDIMENTOLOGY**, Davos, Switzerland. (Contact: Haruko Hartmann, IAS-2001, Institute of Geology, ETH-Zentrum, 8092 Zurich, Switzerland. Fax: +41 1 632 1080; E-mail: info@ias-2001.ethz.ch; Website: <http://www.ias-2001.ethz.ch>)

#### September 6–12

**IAMG2001 (THE ANNUAL CONFERENCE OF THE INTERNATIONAL ASSOCIATION FOR MATHEMATICAL GEOLOGY)**, Cancún, Mexico. (Contact: IAMG2001 Conference Secretariat, c/o Jorgina A. Ross, Kansas



Geological Survey, 1930 Constant Avenue, Lawrence, KS 66047-3724, USA. Tel: +785-864-3965; Fax: +785-864-5317; E-mail: [aspiazu@kgs.ukans.edu](mailto:aspiazu@kgs.ukans.edu); Website: <http://www.kgs.ukans.edu/Conferences/IAMG/index.html>)

#### September 8-15

*MAEGS-12 (12TH MEETING OF THE ASSOCIATION OF EUROPEAN GEOLOGICAL SOCIETIES)*, "Carpathians Palaeogeography and Geodynamics: Multidisciplinary Approach", Kraków, Poland. (Contact: Polish Geological Society, MAEGS-12, Oleandry 2a, PL 30-063 Kraków, Poland. Fax: +48 12 6332270; E-mail: [ptg@ing.uj.edu.pl](mailto:ptg@ing.uj.edu.pl))

#### September 9-14

*SOCIETY OF EXPLORATION GEOPHYSICISTS* (71st Annual Meeting and International Exposition), San Antonio, Texas, USA. (Contact: SEG Business Office, Tel: +1-918 497 5500; Fax: +1-918 497 5557; Website: [seg.org/](http://seg.org/))

#### September 9-15

*INTERNATIONAL ASSOCIATION OF HYDROGEOLOGISTS*, "New Approaches to Characterising Groundwater Flow" (31st International Congress), Munich, Germany. (Contact: Munich 2001, Institute of Hydrology, GSF National Research Centre of Environment and Health GmbH, Ingolstädter Landstr. 1, D-85764 Neuherberg, Germany. Tel: +49 89 3187 2585; Fax: +49 89 3187 3361; E-mail: [seiler@gsf.de](mailto:seiler@gsf.de); Website: [agh.iaag.geo.uni-muenchen.de/](http://agh.iaag.geo.uni-muenchen.de/))

#### September 17-21

*7TH INTERNATIONAL CONFERENCE ON PALEOCEANOGRAPHY*, Sapporo, Japan. (Contact: Prof. Helmut Weissert, Geological Institute, ETH-Zurich, CH-8092 Zurich, Switzerland. Tel: +41 (0)1 632 37 15; Fax: +41 (0)1 632 10 30; E-mail: [helmi@erdw.ethz.ch](mailto:helmi@erdw.ethz.ch); Website: <http://www.ijnet.or.jp/jtb-cs/icp7/>)

#### September 24-26

*ARCHEAN SYMPOSIUM* (4th International), Perth, Western Australia. (Contact: Website: [redback.geol.usa.edu.au/~ias/](http://redback.geol.usa.edu.au/~ias/))

#### September 25-29

*SIXTH INTERNATIONAL SYMPOSIUM ON LAND SUBSIDENCE (SISOLS 2000)*, Ravenna, Italy. (Contact: Dr. Laura Carbognin,

CNR-ISDGM, S. Polo 1364, 30125, Venezia, Italy. Tel: +39-041 5216826; Fax: +39 041 5216892; E-mail: [jane@isdgm.ve.cnr.it](mailto:jane@isdgm.ve.cnr.it))

#### November 5-8

*GEOLOGICAL SOCIETY OF AMERICA* (Annual Meeting), Boston, Massachusetts, USA. (Contact: GSA Meetings Dept., P.O. Box 9140, Boulder, CO 80301-9140, USA; Tel: +1 303 447 2020; Fax: +1 303 447 1133; E-mail: [meetings@geosociety.org](mailto:meetings@geosociety.org); WWW: <http://www.geosociety.org/meetings/index.htm>)

## 2002

*INTERNATIONAL ASSOCIATION ON THE GENESIS OF ORE DEPOSITS (11th International Symposium)*, South Africa. (Contact: Dr. Erik Hammerbeck, Geological Survey, Department of Mineral and Energy Affairs, 280 Pretoria Street, Private Bag X112, Silverton, Pretoria 0001, South Africa. Tel: +012 841 1130; Fax: +012 841 1203; E-mail: [ehammerb@geoscience.org.za](mailto:ehammerb@geoscience.org.za))

#### March 10-13

*AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS* (Annual Meeting), Houston, Texas, USA. (Contact: AAPG Conventions Dept., P.O. Box 979, Tulsa, OK 74101-0979, USA. Tel: +1-918 560 2679; Fax: 1-918 560 2684; E-mail: [convene@aapg.org](mailto:convene@aapg.org); Website: <http://www.aapg.org/>)

#### April 7-10

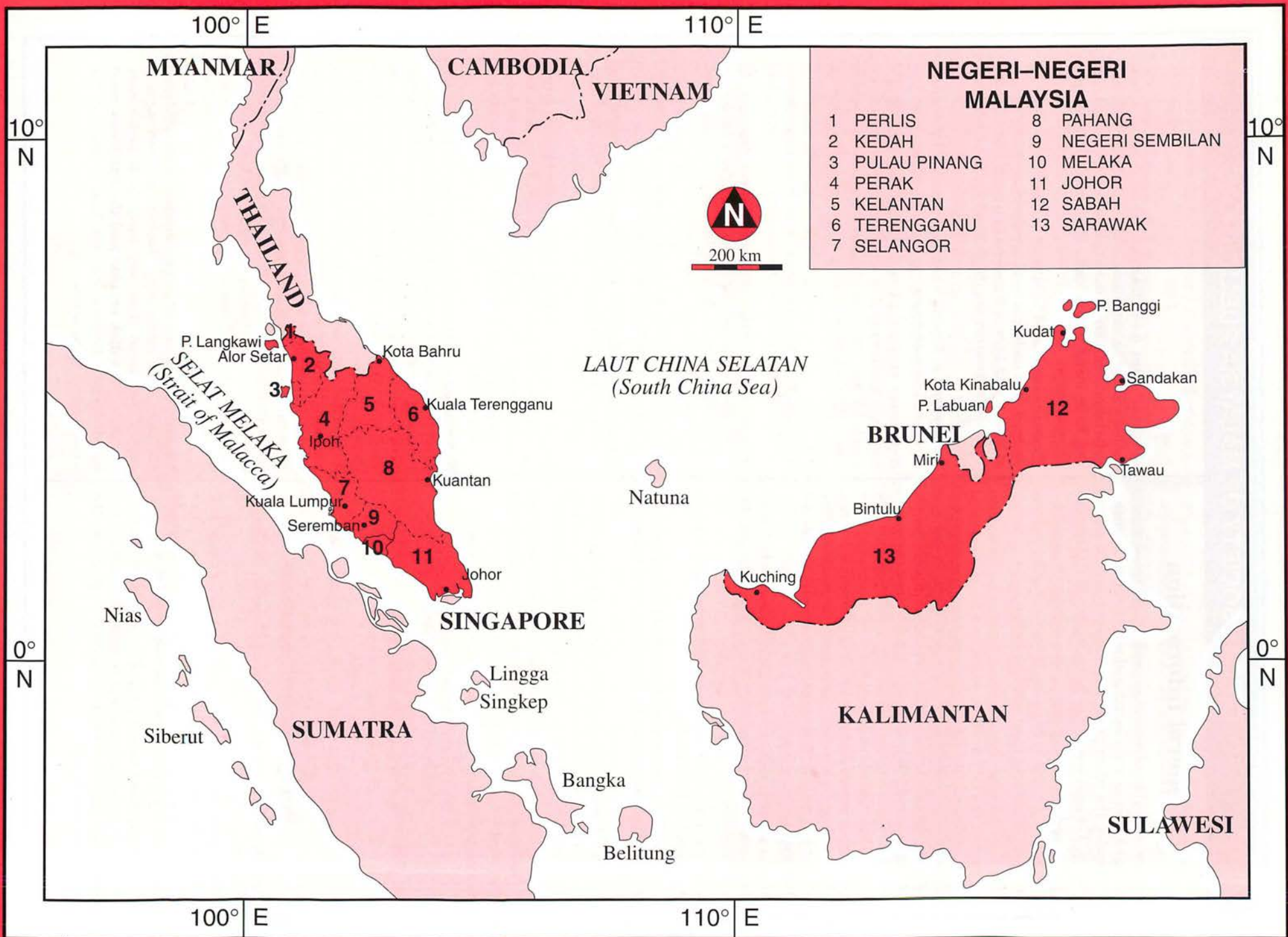
*AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS* (Annual Meeting), Houston, Texas, USA. (Contact: AAPG Conventions Department, P.O. Box 979, 1444 S. Boulder Ave., Tulsa, OK 74101-0979, USA. Tel: +1 918 560 2679; Fax: +1 918 560 2684; E-mail: [dkeim@aapg.org](mailto:dkeim@aapg.org))

#### 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



**NEGERI-NEGERI MALAYSIA**

- |                |                   |
|----------------|-------------------|
| 1 PERLIS       | 8 PAHANG          |
| 2 KEDAH        | 9 NEGERI SEMBILAN |
| 3 PULAU PINANG | 10 MELAKA         |
| 4 PERAK        | 11 JOHOR          |
| 5 KELANTAN     | 12 SABAH          |
| 6 TERENGGANU   | 13 SARAWAK        |
| 7 SELANGOR     |                   |



MYANMAR

CAMBODIA

VIETNAM

THAILAND

SELAT MELAKA  
(Strait of Malacca)

LAUT CHINA SELATAN  
(South China Sea)

BRUNEI

KALIMANTAN

SULAWESI

SUMATRA

SINGAPORE

Nias

Siberut

Lingga  
Singkep

Bangka

Belitung

P. Langkawi  
Alor Setar

Kota Bahru

Kuala Terengganu

Ipoh

Kuantan

Kuala Lumpur  
Seremban

Johor

P. Banggi

Kudat

Kota Kinabalu  
P. Labuan

Sandakan

Miri

Tawau

Bintulu

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Geological Survey, 1930 Constant Avenue, Lawrence, KS 66047-3724, USA. Tel: +785-864-3965; Fax: +785-864-5317; E-mail: [aspiazu@kgs.ukans.edu](mailto:aspiazu@kgs.ukans.edu); Website: <http://www.kgs.ukans.edu/Conferences/IAMG/index.html>

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#### September 24-26

*ARCHEAN SYMPOSIUM* (4th International), Perth, Western Australia. (Contact: Website: [redback.geol.usa.edu.au/~ias/](http://redback.geol.usa.edu.au/~ias/))

#### September 25-29

*SIXTH INTERNATIONAL SYMPOSIUM ON LAND SUBSIDENCE (SISOLS 2000)*, Ravenna, Italy. (Contact: Dr. Laura Carbognin,

CNR-ISDGM, S. Polo 1364, 30125, Venezia, Italy. Tel: +39-041 5216826; Fax: +39 041 5216892; E-mail: [jane@isdgm.ve.cnr.it](mailto:jane@isdgm.ve.cnr.it))

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*GEOLOGICAL SOCIETY OF AMERICA* (Annual Meeting), Boston, Massachusetts, USA. (Contact: GSA Meetings Dept., P.O. Box 9140, Boulder, CO 80301-9140, USA; Tel: +1 303 447 2020; Fax: +1 303 447 1133; E-mail: [meetings@geosociety.org](mailto:meetings@geosociety.org); WWW: <http://www.geosociety.org/meetings/index.htm>)

## 2002

*INTERNATIONAL ASSOCIATION ON THE GENESIS OF ORE DEPOSITS (11th International Symposium)*, South Africa. (Contact: Dr. Erik Hammerbeck, Geological Survey, Department of Mineral and Energy Affairs, 280 Pretoria Street, Private Bag X112, Silverton, Pretoria 0001, South Africa. Tel: +012 841 1130; Fax: +012 841 1203; E-mail: [ehammerb@geoscience.org.za](mailto:ehammerb@geoscience.org.za))

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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](http://home.geoscience.org.za/saieg/2002.htm))

#### September 22–27

**SOCIETY OF EXPLORATION GEOPHYSICISTS** (72nd Annual Meeting and International Exposition), Las Vegas, Nevada, USA. (Contact: SEG Business Office, Tel: +1-918 497 5500; Fax: +1-918 497 5557; Website: [seg.org/](http://seg.org/))

#### October 21–25

**INTERNATIONAL ASSOCIATION OF HYDROGEOLOGISTS**, "Groundwater and Human Development" (32nd International Congress), Mar del Plata, Argentina. (Contact: Dr. Emilia Bocanegra, Centro de Geología de Costas y del Cuaternario, Facultad de Ciencias Exactas y Naturales, Universidad Nacional de

Mar del Plata, Casilla de Correo 722, 7600 Mar del Plata, Argentina; Tel: +54 223 475 4060; Fax: +54 223 475 3150; E-mail: ebocaneg@mdp.edu.ar; or download Circular)

#### October 28–31

**GEOLOGICAL SOCIETY OF AMERICA** (Annual Meeting), Denver, Colorado, USA. (Contact: GSA Meetings Dept., P.O. Box 9140, Boulder, CO 80301-9140, USA; Tel: +1 303 447 2020; Fax: +1 303 447 1133; E-mail: [meetings@geosociety.org](mailto:meetings@geosociety.org); Website: <http://www.geosociety.org/meetings/index.htm>)

## 2003

#### 28 September – 3 October

**SOCIETY OF EXPLORATION GEOPHYSICISTS** (73rd Annual Meeting and International Exposition), Dallas, Texas, USA. (Contact: SEG Business Office, Tel: +1-918 497 5500; Fax: +1-918 497 5500; Fax: +1-918 497 5557; Website: [seg.org/](http://seg.org/))

#### November 2–5

**GEOLOGICAL SOCIETY OF AMERICA** (Annual Meeting), Seattle, Washington, USA. (Contact: GSA Meetings Dept., P.O. Box 9140, Boulder, CO 80301-9140, USA. Tel: +1 303 447 2020; Fax: +1 303 447 1133; E-mail: [meetings@geosociety.org](mailto:meetings@geosociety.org); Website: <http://www.geosociety.org/meeting/index.htm>)

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Papers should be as concise as possible. However, there is no fixed limit as to the length and number of illustrations. Normally, the whole paper should not exceed 30 printed pages. The page size will be 204 x 280 mm (8 x 11 inches).

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c/o Geology Department  
University of Malaya  
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MALAYSIA

Tel: (603) 7957 7036 Fax: (603) 7956 3900

## Script Requirements

**Scripts** must be written in Bahasa Malaysia (Malay) or English.

**Two copies** of the text and illustrations must be submitted. The scripts must be typewritten double-spaced on paper not exceeding 210 x 297 mm (or 8.27 x 11.69 inches, A4 size). One side of the page must only be typed on.

**Figure captions** must be typed on a separate sheet of paper. The captions must not be drafted on the figures. The figure number should be marked in pencil on the margin or reverse side.

**Original maps and illustrations** or as glossy prints should ideally be submitted with sufficiently bold and large lettering to permit reduction to 18 x 25 cm: fold-outs and large maps will be considered only under special circumstances.

**Photographs** should be of good quality, sharp and with contrast. For each photograph, submit two glossy prints, at least 8 x 12.5 cm and preferably larger. Use of metric system of measurements (SI) is strongly urged wherever possible.

**An abstract** in English which is concise and informative is required for each paper.

**References** cited in the text should be listed at the end of the paper and arranged in alphabetical order and typed double-spaced. The name of the book or journal must be in *italics*. The references should be quoted in the following manner:

HAMILTON, W., 1979. Tectonics of the Indonesian region. *U.S. Geological Survey Professional Paper 1078*, 345p.

HOSKING, K.F.G., 1973. Primary mineral deposits. In Gobbett, D.J. and Hutchison, C.S. (Eds.), *Geology of the Malay Peninsula (West Malaysia and Singapore)*. Wiley-Interscience. New York, 335-390.

HUTCHISON, C.S., 1989. *Geological Evolution of South-east Asia*. Clarendon Press, Oxford. 368p.

SUNTHARALINGAM, T., 1968. Upper Paleozoic stratigraphy of the area west of Kampar, Perak. *Geol. Soc. Malaysia Bull. 1*, 1-15.

TAYLOR, B., AND HAYES, D.E., 1980. The tectonic evolution of the South China Sea basin. In: D.E. Hayes (Ed.), *The Tectonic and Geologic Evolution of Southeast Asian Sea and Islands, Part 2. Am. Geophy. Union Monograph 23*, 89-104.

**Submission of electronic text.** In order to publish the paper as quickly as possible after acceptance, authors are requested to submit the final text also on a 3.5" diskette. Both Macintosh and PC (DOS/Windows) platforms are supported. Main text, tables and illustrations should be stored in separate files with clearly identifiable names. Text made with most word processors can be readily processed but authors are advised to provide an additional copy of the text file in ASCII format. Preferred format for illustration is Encapsulated PostScript (EPS) but authors may submit graphic files in their native form. It is essential that the name and version of softwares used is clearly indicated. The final manuscript may contain parts (e.g. formulae, complex tables) or last-minute corrections which are not included in the electronic text on the diskette; however, this should be clearly marked in an additional hardcopy of the manuscript. Authors are encouraged to ensure that apart from any such small last-minute corrections, **the disk version and the hardcopy must be identical**. Discrepancies can lead to proofs of the wrong version being made.

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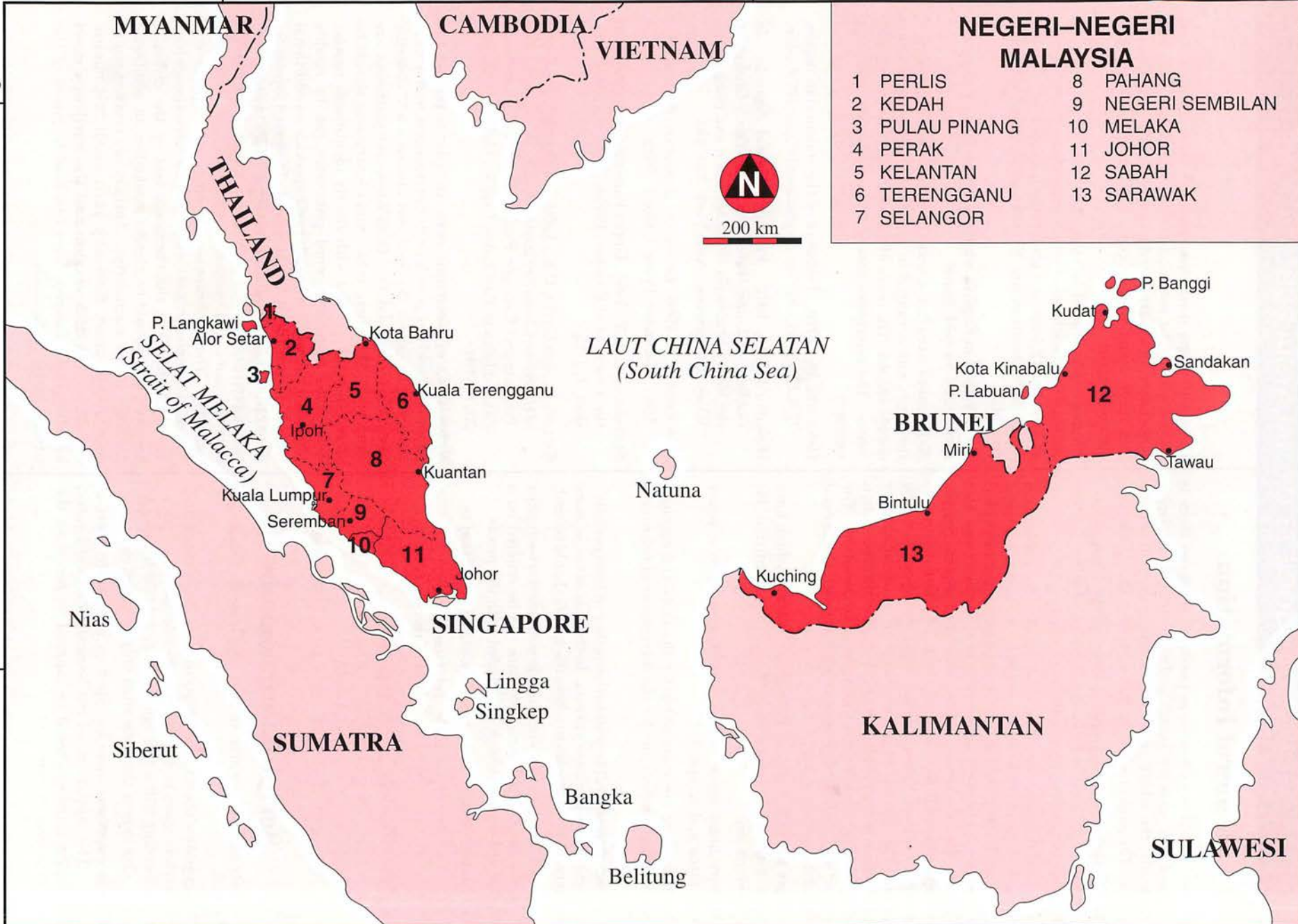
VIETNAM

THAILAND

SELAT MELAKA  
(Straits of Malacca)

LAUT CHINA SELATAN  
(South China Sea)

NEGERI-NEGERI MALAYSIA	
1 PERLIS	8 PAHANG
2 KEDAH	9 NEGERI SEMBILAN
3 PULAU PINANG	10 MELAKA
4 PERAK	11 JOHOR
5 KELANTAN	12 SABAH
6 TERENGGANU	13 SARAWAK
7 SELANGOR	



Nias

Siberut

SUMATRA

SINGAPORE

Lingga  
Singkep

Bangka

Belitung

Natuna

Kuching

Bintulu

BRUNEI

Miri

P. Labuan

Kota Kinabalu

Kudat

SULAWESI

KALIMANTAN

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