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CATATAN GEOLOGI
GEOLOGICAL NOTES

Surface morphology of glass shards from Late Pleistocene volcanic ash in Perak – A preliminary study

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Abstract — Samples of Late Pleistocene volcanic ash that has been found scattered in Perak were studied under a Scanning Electron Microscope. All of them show distinct characteristics of pyroclastic material of magmatic origin. They consist of glass shards of cuspate and flat-type shapes and also fragments of pumice. Early observation indicates that some of the ash might have gone through some reworking and/or weathering.

Abstrak — Debu gunungapi muda yang dijumpai di Perak telah dikaji di bawah Mikroskop Imbas Elektron. Kesemuanya menunjukkan ciri-ciri jelas bahan piroklastik dari asalan magma. Kandungannya adalah serpihan kaca berbentuk juring dan rata, serta serpihan pumis. Kajian awal menunjukkan sebahagian dari debu mungkin telah mengalami kerjasemula dan (atau) peluluhawaan.

INTRODUCTION

In many parts of Peninsular Malaysia below a comparatively thin soil layer is a white-colored silica-rich acid tuff volcanic ash deposit. Its occurence has been recorded in Sungai Pelus in Perak (Scrivenor, 1931), Sungai Bekok in Terengganu (Tjia, 1976), Kampung Sungai Taling in Kuala Pilah, Ampang and Serdang in Selangor (Stauffer, 1971, 1973, Stauffer & Batchelor, 1978), Padang Terap (Debayeve *et al.*, 1983) in Kedah, Kuala Kangsar (Basir Jasin *et al.*, 1987) and Lenggong in Perak and Dong and Cheroh in Pahang (Law, 1967). Locations of the ash are shown in Figure 1.

Samples from all of the above occurrences have been collected, except from Sungai Pelus, Dong and Cheroh, Pahang. This paper deals with shards from volcanic ash found in a few localities in Perak namely Bukit Jawa, Bukit Sapi, Kampung Kuah, Kampung Pisang in Lenggong and Cegar Galah in Kuala Kangsar. Field photographs of samples from Bukit sapi and Kg Pisang are shown in Figures 2 and 3.

There has been uncertainty whether the ash found in the Malay Peninsular originated from the 75,000 year old Toba eruption or from the 30,000 year old Parapat eruption (Ros & Tjia, 2006). Chemical composition of the glass shards found in Padang Terap corresponds with ash from Toba (Debaveye *et al.*, 1989). According to Stauffer *et al*. (1980) the tephra from both 75,000 year old Toba and 30,000 year Sibuatan eruptions are chemically identical. Samples from Serdang were dated at 68,000 years old and it was concluded that it belongs to the 75,000 B.P. (Westgate *et al*. 1998). The writers are of the opinion that until the result of age-determination of all samples found in Peninsular Malaysia are known, no evidence on the precise date can be given. With these ages, detailed stratigraphic position and relationship of this ash and those from the peninsula can be developed.

Figure 1: Location of volcanic ash found in Peninsular Malaysia and the Late Pleistocene cauldrons in Sumatera.

Figure 2: Field photograph of Bukit Sapi. The volcanic ash is exposed at a roadcut and is estimated to be around 3 m high above the ground.

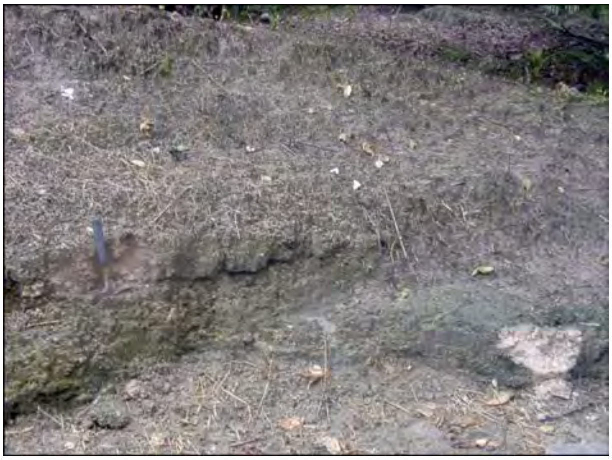

Figure 3: Field photograph of Kg Pisang (Upper Layer) on the left and Kg Pisang (Lower Layer). They are estimated to be around 30 cm and 50 cm thick, respectively.

SURFACE MORPHOLOGY OF GLASS SHARDS

Megascopically, the colour of the ash ranges from almost white, light grey to greyish yellow. The ash appears to be a pure pyroclastic deposit, consisting of pumice fragments and glass shards, with perhaps some crystal fragments including and quartz, biotite, plagioclase, sanidine and hornblende (Basir Jasin *et al*, 1987, Stauffer & Batchelor, 1978, Debaveye *et al*., 1986). The ash found in Cegar Galah contains some organic material in the form of roots and leaves.

Routine procedure in analyzing glass shards from volcanic ash requires the shards to be separated from the ash. Due to constraints in terms of time and research funds, samples of ash were only directly imaged using the Scanning Electron Microscope (SEM) in this preliminary study.

Glass shards in the ash are abundant, easily identified and their surface morphology readily observable in the SEM study. The glass shards are of different sizes and shapes, the majority being of bubble wall junction-type with cuspate, flat or platy shapes, and pumice fragments form cellular networks of parallel elongated vesicles. The cuspate glass shards represent walls of gas bubbles that fragmented during the eruption, while the flat shards are formed by the fragmentation of large flattened glass (Pattan, *et al*., 2002).

U-shaped and Y-shaped ejecta are the most common together with tricuspidate fragments bounded by arcs of circles. As the original glass contained vesicles of different sizes, shapes and thicknesses of bubble walls, there are many variations to the forms described above. The absence of blocky or pyramidal-type morphology of the glass suggest magmatic origin, where shards are formed due to the loss of coherence in frothy magma during its ascent to the ground surface. This is the opposite of glass of phreatomagmatic origin which is formed due to fragmentation of quenched magma as a result of quick chilling through contact with water (Heiken, 1972 in Pattan, *et al*., 2002).

Some samples, from Bukit Jawa (Figure 4), Bukit Sapi (Figure 5), Kg Kuah Upper Layer (Figure 8) and Kg Pisang (Figure 9) appear to be fresh but the others show some indication of having gone through some reworking or weathering. This is indicated by the presence of other elements on the shards surface and also formation of clusters of pieces of shards in samples from Cegar Galah (Figure 6), Kampung Kuah Lower Layer (Figure 7), Kampung Pisang Lower Layer (Figure 10) and Kampung Pisang Upper Layer (Figure 11). However at this early stage of the study, it would be premature to make any conclusion.

The morphology of these ash samples is compared with the ones found in the Central Indian Ocean Basin (from Pattan *et al*., 2002) and the Western Continental Margin of India (from Pattan *et al*., 2001) that have been found in water depths of > 4900 m and 2300 m, respectively.

The glass of the Indian Ocean Basin ash had been separated and cleaned ultrasonically. The shards showed very distinct clean surfaces, and appearance of pyrite framboid is common due to oxidation of some organic material that may adhere to the shards during the fall. This ash is believed to have originated from the 75,000 year old Toba-eruption (Pattan *et al*., 2002) and the age comparison with some sample from Serdang gave a conclusion that both are of the same origin (Westgate *et al*., 1998).

CONCLUSIONS

Conclusions from the preliminary studies are as follows:

a) Glass shards from all the studied ash samples show similar morphology.
b) The presence of some matters on the shard surfaces, also the formation of clusters of pieces of shards may indicate reworking and/or weathering.
c) This ash is of magmatic origin.

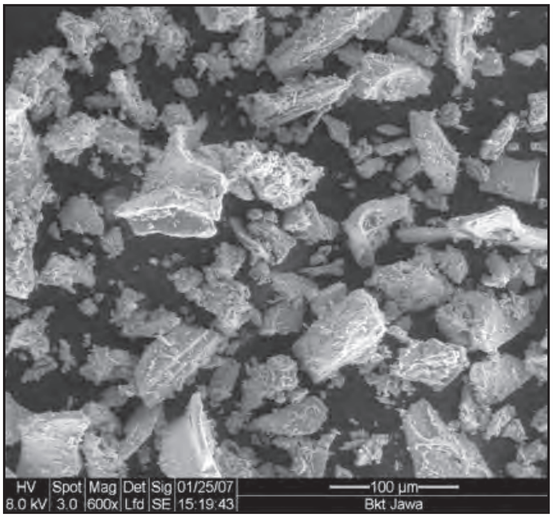

Figure 4: SEM images of the ash found in Bukit Jawa. All three shapes of cuspate shape, flat shape and pumice fragments can be seen.

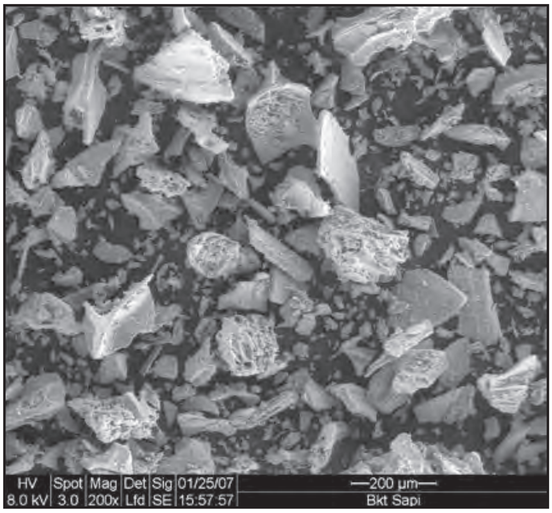

Figure 5: SEM images of ash found in Bukit Sapi. all three shapes were seen, with Y-shaped injecta is common.

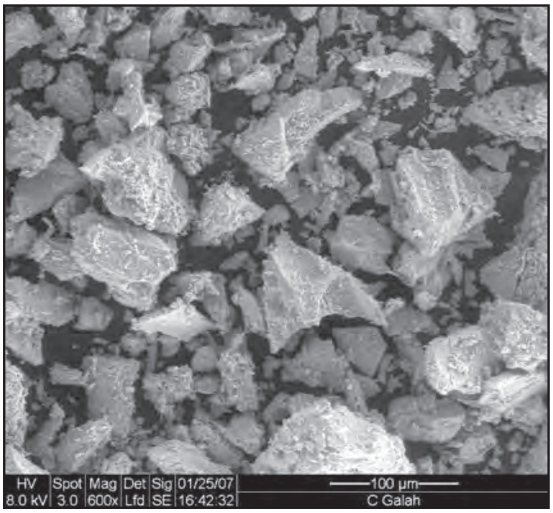

Figure 6: SEM images of ash found in Cegar Galah. All the three major shapes can be seen, however the presence of some growth on the shard surface could be due to reworking and (or) weathering.

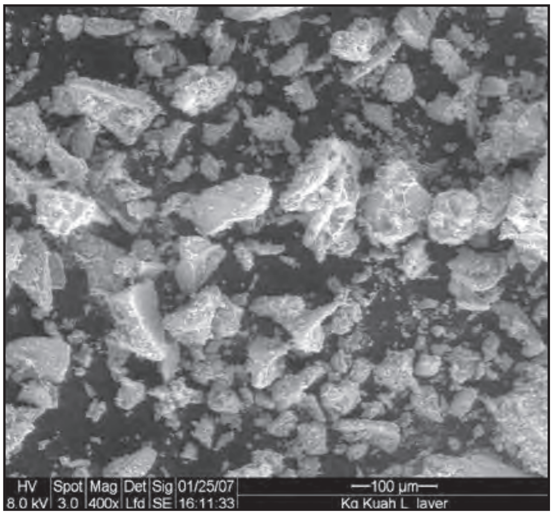

Figure 7: SEM images of ash from Kg Kuah (Lower Layer). Mostly cuspate-type are observed, the growth on the shard surface is also an indication of possible reworking and (or) weathering.

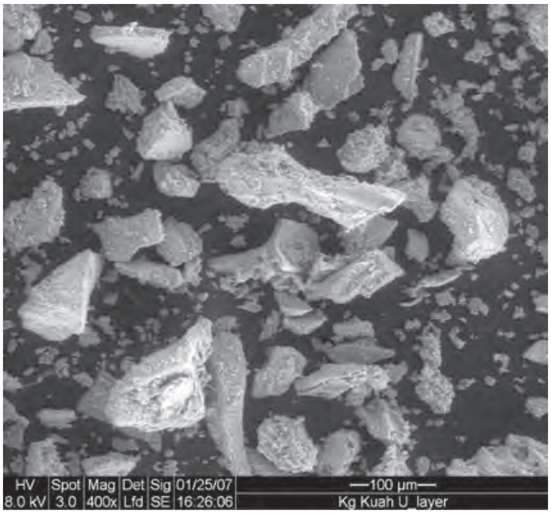

Figure 8: SEM images of ash found in Kg Kuah (Upper Layer). All three types are present, with a Y-shaped shard.

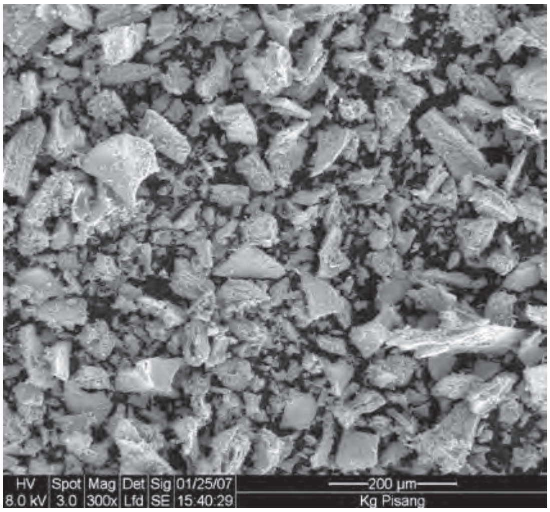

Figure 9: SEM images of ash found in Kg Pisang. All major three shapes are seen.

Future studies will include analysis by EDX, ICP-OES, EPMA for major elements, laser ablation ICP-MS on the minor and trace elements on the separated shards, and also age determination using K-Ar method and also carbon dating on the organic materials. We plan to do some comparison with ash from Sumatera. With this data, we intend to define the stratigraphy of the ash in Peninsular Malaysia.

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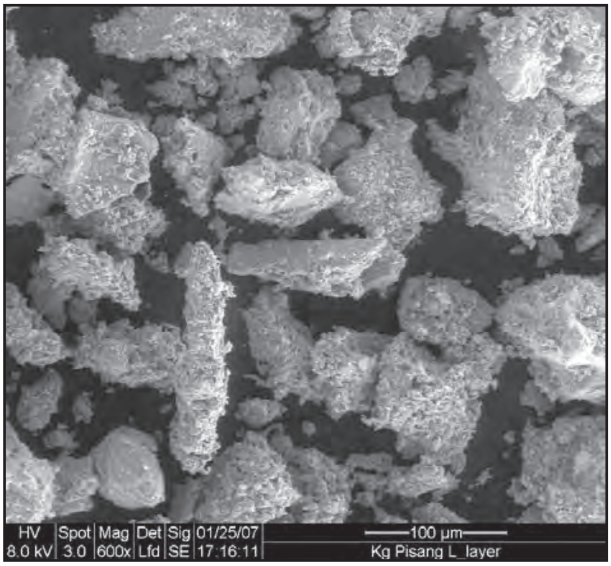

Figure 10: SEM images of ash found in Kg Pisang (Lower Layer). Though cuspate-type can still be seen, the distinct shape is no longer observed due to presence of other elements on the surface.

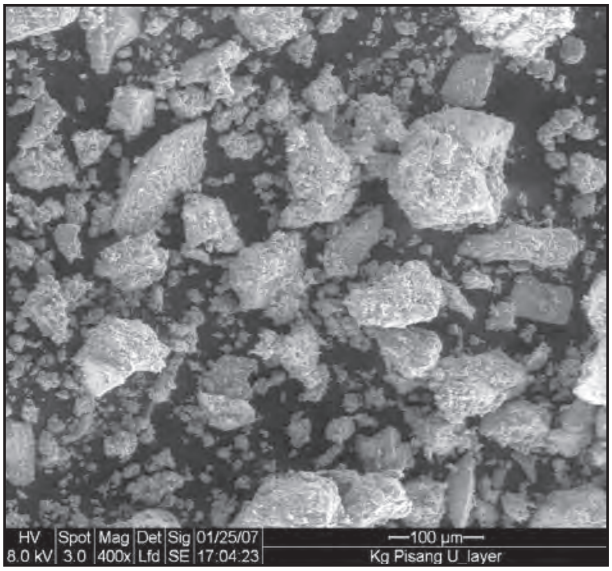

Figure 11: SEM images of ash found in Kg Pisang (Upper Layer). Cuspate and flat-type shards can still be observed, but the appearance of other elements on the surface could be due to reworking and (or) weathering.

A preliminary interpretation of the recent Bukit Tinggi earthquakes using SRTM DEM

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Abstract — This paper presents the preliminary study on the cause of the recent, small intraplate earthquakes, in the Bukit Tinggi area, around the Selangor-Pahang boundary. It discusses the correlation between the earthquake localities and the regional lineaments/structures of the area using relief map generated from SRTM DEM data. The results of the study show that the earthquakes are located at or near to the intersection of three sets of major lineaments trending N-S, NE and NW. This corresponds to the NW Bukit Tinggi and Kuala Lumpur Fault Zones and the N-S and the NE faults mapped in the region. It is interpreted that the earthquakes are due to the reactivation of one of the above faults. The fault reactivation is believed to be the result of stress build-up due to the present-day tectonics in SE Asia (Sundaland).

Abstrak — Kertas kerja ini mengemukakan kajian awal terhadap punca gempabumi intraplat bermagnitud kecil yang berlaku baru-baru ini di sekitar Bukit Tinggi, Dempadan Pahang – Selangor. Ia membincangkan korelasi antara kedudukan gempabumi dengan lineamen dan struktur rantau dengan menggunakan peta jasad timbul yang dihasilkan daripada data DEM SRTM. Hasil kajian menunjukkan gempabumi-gempabumi ini terletak pada atau dekat dengan persilangan antara tiga lineamen major yang menjurus U-S, timut laut, dan barat daya yang menyamai Zon-zon sesar Bukit Tinggi – Kuala Lumpur, dan sesar menjurus U-S, dan timut laut. Ditafsirkan bahawa gempabumi-gempabumi adalah disebabkan oleh pengaktifan semula salah satu daripada sesar-sesar diatas. Pengaktifan semula ini adalah disebakan oleh peningkatan tegasan intraplat berpunca dari aktiviti tektonik kini di Asia tenggara (Sundaland).

Keywords: intraplate, earthquakes, seismicity, lineaments, tectonics.

INTRODUCTION

Peninsular Malaysia is located in the generally stable Sundaland Before the Bukit Tinggi earthquakes occurrences, it was only experiencing low to medium seismic tremors due to seismic waves generated with epicentres located in Sumatra or rarely, the induced seismicity at Kenyir Lake (Raj, 1994; Che Noorliza Lat, 1997, 1999a & b, 2002)). The recent, small intraplate earthquakes, that gave rise to tremors in the Bukit Tinggi area, around the Selangor-Pahang boundary (Figure 1), have been enigmatic. The paradigm of plate tectonics predicts concentrations of earthquakes, volcanism, and other tectonic activity within narrowly defined plate boundaries, but no significant deformation within the rigid plates. Thus the shallow (1.2 to 6.7 km depth), and mild Mw= 1.7 to 3.7 earthquakes (Meteorological Department, Malaysia, 2008) which occurred from November 2007 to January 2008, has stimulated considerable interest and debate (Figure 1). This short paper discusses the correlation between the earthquake localities and the regional structures of the area leading to the interpretation on the probable cause of the earthquakes.

INTERPRETATIONS

Based on field study, existing geological maps and remote sensing analysis using Shuttle Radar Topographic Mission Digital Elevation Model (Figure 2), it is noted that the earthquakes around Bukit Tinggi area were located on granite bedrock, With the available seismicity data from the Meteorological Department, Malaysia, it is difficult to attribute individual earthquakes to a specific structural lineament such as the Bukit Tinggi lineament. The earthquakes are located at or near to the intersection regional lineaments/faults. This corresponds to the NW Bukit Tinggi and Kuala Lumpur Fault Zones and the N-S and the NE faults mapped in the region as shown in Figure 2. A more detail analysis is being carried out and the results will be presented in the near future.

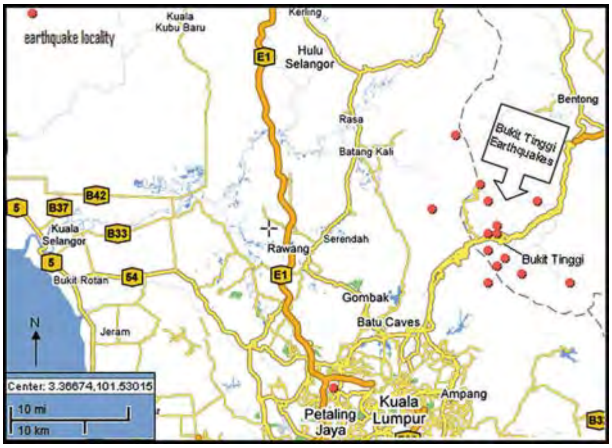

Figure 1: Map showing the earthquake locations.

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Table 1: Suggested mechanism for the Bukit Tinggi earthquakes.

MECHANISM	SOURCE	PRO	CON
Induced seismicity due to Sg. Selangor Dam (Prof Emeritus C.S. Hutchison, The STAR, 7 January 2008)	Nearby major dam	Small, shallow earthquakes	Too far away from major dams.
Intraplate stress build-up leading to reactivation of faults in Bukit Tinggi area (Mustaffa Kamal Shuib, NST, 8 January 2008)	Oblique, north-northeast-oriented subduction of the Indian–Australian plate under the Sundaland.	Close spatial relationship with major fault zones.	No surface rupture and fault slip data
Release of stress (Azlan Adnan, NST, December 2007)	Mounting pressure due to the convergence of the Australian, Eurasian and Philippine plates around Sundaland	Close spatial relationship with major fault zones.	No surface rupture and fault slip data
Stress build-up along Bukit Tinggi fault and consolidation of the geological system (Dr Yap Kok Seng, NST 8 January 2007)	Major earthquakes which rocked Indonesia throughout the years	Close spatial relationship with major fault zones.	No surface rupture and fault slip data

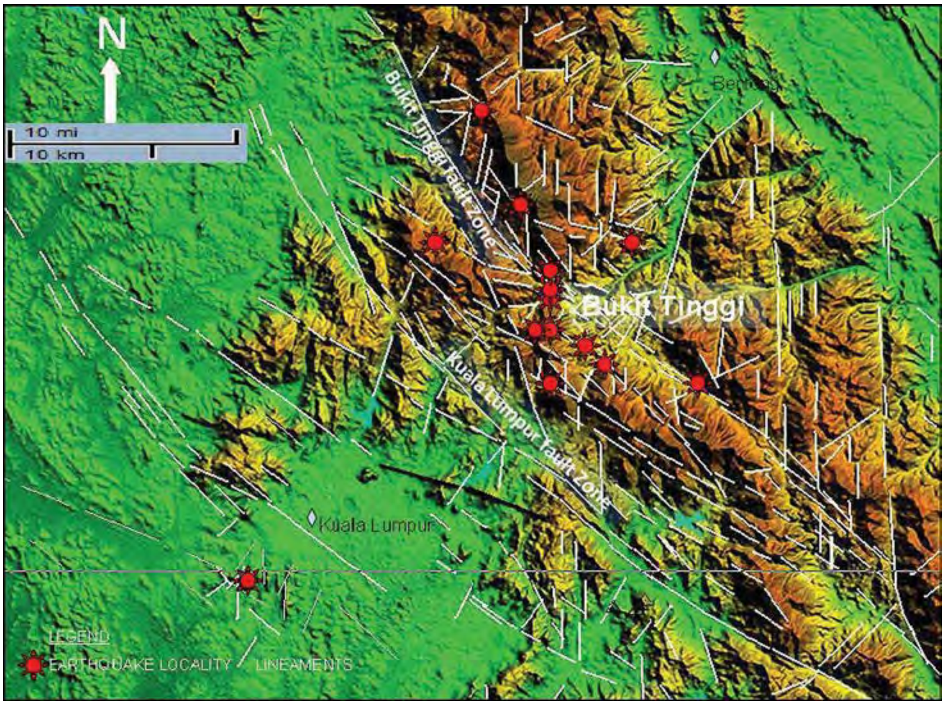

Figure 2: SRTM DEM showing the relationship between the earthquakes and the major structures/lineaments of the region.

DISCUSSIONS

The possible mechanisms that have been used to account for the intraplate earthquakes are given in Table 1.

Induced seismicity can explain small intraplate earthquakes, for example the Kenyir Dam induced seismicity. However, the Bukit Tinggi earthquakes are situated too far away from major dams. But, based on the spatial associations with lineaments and known faults, the earthquakes are ascribed to the reactivation of zone of weakness along the formerly inactive NW Bukit Tinggi (Shu, 1969) and Kuala Lumpur Fault Zones (Stauffer, 1968), NE and the N-S fault zones. No surface rupture was observed nor are data for focal mechanism analysis available to constraint earthquake kinematics.

CONCLUSION

The fault reactivation is the result of intraplate stress build-up due to the present-day tectonics in SE Asia (Sundaland), especially the oblique, north-northeast-oriented subduction of the Indian–Australian plate under the Sundaland. It is suggested that the design of large engineering structures must take into consideration the possible seismicity due to reactivation of ancient major faults zones in addition to the seismicity due to tremors from seismic waves generated with epicentres located in Sumatra or, rarely, the induced seismicity near major dams.

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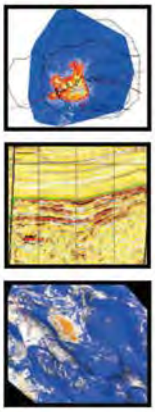

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14th – 15th January 2008 • Kuala Lumpur Convention Center, Kuala Lumpur, Malaysia

WELCOMING REMARKS BY MR. IDRIS IBRAHIM, CHAIRMAN OF THE ORGANIZING COMMITTEE FOR THE PETROLEUM GEOLOGY CONFERENCE AND EXHIBITION, 2008

Yang Berhormat Dato' Sri Azmi Khalid

Minister of Natural Resources & Environment Malaysia

Yang Berbahagia Dato' Fatimah Raja Nasron

Deputy Secretary General 1

Ministry of Natural Resources & Environment

Yang Berbahagia Datuk Dr. Rosti Saruwono

VP, Education PETRONAS

Yang Berbahagia En. Ramlan A. Malek

VP, E & P PETRONAS

Yang Berusaha En. Yunos Abdul Razak

D.G. Mineral and Geoscience Dept, who is also the President of Geological Society of Malaysia, Tan Sri, Tan Sri, Dato', Dato', Distinguished guests, ladies and gentlemen. Assalamualaikum, salam sejahtera and very good morning.

On behalf of the Organising Committee I would like to thank Y.B. Dato' Sri for gracing the occasion of launching the IYPE for Malaysia and opening the annual 29th PGCE 2008. I would also like to welcome to all delegates to PGCE/IYPE. Welcome to Malaysia and enjoy the program and stay in Kuala Lumpur.

Geological Society of Malaysia and PETRONAS have so far co-organise this event, year by year has grown into an important conference for geoscientists in the region. We have organised the PGCE successfully in the past 3 years. The PGCE has attracted more than 1,000 participants and more than 40 exhibitors. This year we have more than 40 papers and about 30 posters.

The PGCE provides a platform for geoscientist to network and exchange ideas, sharing of experiences and lessons learnt; not limiting subject matter confined to local geology but have brought in their respective global experiences.

PGCE 2008's theme "***Discovering New Plays Through Innovative Ideas***" fits very well with the launching of IYPE, as you are aware UN has proclaimed that Year 2008 to be the UN International Year of Planet, amongst other aims at building a wealthier society. New ideas and innovation generated through conference like this would hopefully lead to the discoveries of new oil and gas fields – innovative development program of such fields would certainly contribute to a wealthier society and prosperous nation.

We are fortunate today during the largest gathering of the geoscientist fraternity not only for the PGCE but to witness the launching of IYPE, with a theme of Geosciences for Society and we are those geoscientists to realize such mission.

Finally, I would like to take this opportunity to thank all sponsors, donors, exhibitors and the hardworking committee members to prepare and determine to see these 2 days events to be successful and beneficial to all.

Thank you.

Petroleum Geology Conference and Exhibition 2008

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WELCOMING ADDRESS BY DATO' YUNUS ABD. RAZAK, DIRECTOR GENERAL, MINERALS & GEOSCIENCE MALAYSIA AND PRESIDENT, GEOLOGICAL SOCIETY OF MALAYSIA

Y.B. Dato' Seri Azmi Khalid, Menteri Sumber Asli dan Alam Sekitar Malaysia,

Datuk Fatimah Raya Nasron, Timbalan Ketua Setiausaha, Kementerian Sumber Asli dan Alam Sekitar,

Dato' Rosti Saruwono, Vice President, EducationDivision, Petronas,

En. Ramlan Abdul Malek, Vice President, E&P Division, Petronas

En. Idris Ibrahim, Pengerusi Jawatankuasa Penganjur PGCE 2008

Para tetamu jemputan dan tuan-tuan dan puan-puan hadirin sekelian.

Assalamu 'alaikum dan Salam Sejahtera!

The International Year of Planet Earth (IYPE) is an initiative by the United Nations to appreciate the contribution of geoscience in conserving, monitoring and maintaining the balance of the various processes having an impact on our planet and its inhabitants.

Geoscientists have a crucial role to play together with other professions, in ensuring that all the processes are interwoven harmoniously without affecting the planet's stability and balance, for the benefit of our current and future generations.

As suggested by the IYPE's theme, ***Earth Sciences for Society***, we should grab this once in a life time opportunity, to emphasize the role and importance of geosciences to the society, which encompases and affects the various aspects of life on this planet.

The Malaysia's IYPE National Committee has embarked on several activities extending over the year 2007 to 2009, to fulfill the aims of the IYPE. The activities are led by various Ministries, Government agencies, universities and scientific bodies inconjunction with their existing programmes. Several regional activities also have been planned to highlight the potential use of Earth Sciences for improving the quality of life and safeguarding human soceity.

Ladies and Gentlemen,

The Petroleum Geology Conference and Exhibition 2008 (PGCE 2008) is an annual event organized by the Geological Society of Malaysia (GSM) and PETRONAS. The primary objective of this event is to share expertise and experience in the various aspects of exploration and development in the oil industry.

Petroleum is an essential commodity which is not renewable, once it is exploited. Oil exploration is getting tougher by the day in a more complex geological scenarios and in a much more challenging environment.

It is therefore pertinent to note that, the chosen theme for this year's conference, *Discovering New Plays Through Innovative Ideas*, aptly reflects the current status of the upstream oil industries.

Ladies and Gentlemen,

I would like to take this opportunity to record my sincere thanks and appreciation to Y.B. Dato' Seri Azmi Khalid, Minister for Natural Resources and Environment, for the support given, and the time taken to be with us this morning. I also want to congratulate and thank the Organizing Committees for both of these two events for their hardwork and dedication to ensure the smooth running of both events.

To all invited guests and those attending the launching of the IYPE, I would like to extend my sincere appreciation for fully supporting this event. To all participants, presenters and exhibitors of PGCE 2008, I wish you a very warm welcome. Especially to participants from overseas, I wish you a pleasant stay here in Malaysia and hopefully you will bring back fond memories of your stay here back to you country. I sincerely hope that this conference and exhibiton will be beneficial in bringing a new dimension to the oil industry.

Thank you very much. Sekian. Terima kasih.

OFFICIAL LAUNCH OF THE INTERNATIONAL YEAR OF PLANET EARTH, AND THE OPENING SPEECH OF THE PETROLEUM GEOLOGY CONFERENCE AND EXHIBITION, 2008 BY Y.B. DATO' SERI AZMI KHALID, MINISTER OF NATURAL RESOURCES AND THE ENVIRONMENT, MALAYSIA

BISMILLAHIR RAHMANIR RAHIM

Y. Bhg. Datuk Fatimah Raya Nasron, Deputy Secretary General I, Ministry of Environment and Natural Resources

Y.Berusaha Tuan. Hj. Yunus Abdul Razak, Director General, Department of Minerals and Geosciences Malaysia, and also President of Geology Society of Malaysia,

Y.Berusaha Encik Idris Ibrahim, Chairman of Organizing Committee of Petroleum Geology Conference and Exhibition 2008

Y. Bhg. Datuk Abdullah Karim, Managing Director/CEO, Petronas Carigali Sdn Bhd

Distinguished Guest,

Ladies and Gentlemen

ASSALAMUALAIKUM WARAHMATULLAHI WABARAKATUH DAN SALAM SEJAHTERA

Ladies and Gentlemen,

First of all I would like to thank the organizers of these events, namely the Department of Minerals and Geosciences Malaysia, the Geological Society of Malaysia and PETRONAS for inviting me to share my thoughts and launch these prestigious events. It gives me great pleasure to be here this morning to launch “The International Year of Planet Earth” (IYPE Malaysia), and officiate the Southeast Asia’s premier petroleum event, the “Petroleum Geology Conference and Exhibition 2008”. I am also indeed honoured to be with such a distinguished group of prominent earth scientists and experts from the government sector, oil and gas fraternity, universities and the public who have gathered here this morning to witness and participate in these two events related to Earth sciences.

It is an undeniable fact that Earth scientists assume an important role in the development of any nation because they provide critical inputs for the attainment of the goals of sustainable development. Apart from this, the exploration and development of a country’s natural resources is very much dependent on the knowledge and expertise of earth scientists.

I am also encouraged by the enthusiasm and the participation of students at these events. I hope they will learn valuable lessons from their experience today and become ambassadors in promoting earth sciences in their respective schools.

Ladies and Gentlemen,

We are currently facing major issues that if left unresolved could threaten our very survival on this planet earth. The major issues facing us include climate change, availability of resources such as energy, mineral and water, preservation of wetlands, erosion, waste management, pollution remediation and geological hazards. We have no choice but to collectively confront these issues by taking appropriate measures domestically, regionally and internationally for the benefit of present and future generations. Delay in taking timely and effective measures could have disastrous effects on our livelihood and future.

In this regard, the launching of the International Year of Planet Earth (IYPE) which aims to raise worldwide public and political awareness of the vast potential of Earth sciences for improving the quality of life and safeguarding human society is indeed timely. The outreach and research activities held in conjunction with this programme will run for three years, 2007-2009, with the year 2008 being proclaimed as the International Year of Planet Earth by the United Nations General Assembly. The Year’s ultimate goal is to make our planet a safer, healthier and wealthier place for human societies as encapsulated in its theme ‘Earth Science for Society ’, by ensuring a greater and more effective use of the Earth sciences knowledge.

I would like to take this opportunity to thank and congratulate UNESCO, International Union of Geological Sciences and the IYPE Corporation, for initiating and organising IYPE. We believe their efforts will go a long way toward promoting public understanding of the importance of Earth Sciences, as well as enhancing international awareness on the need to protect planet earth for the present and future generations.

The Malaysian Government is very supportive of the aims set out in the IYPE celebration. We believe IYPE will contribute to sustainable development as it promotes the wise and effective use of Earth materials and encourages better planning and management of these resources to reduce risks to society. Several programmes extending over the period 2007-2009 have been planned to fulfil the aims of the IYPE. Apart from conducting national level activities, the Malaysian Government also supports several international activities to highlight and encourage the effective use of Earth sciences knowledge for the betterment of society. Amongst the activities include seminars, exhibitions, quiz, career talks and contests. These activities will be organised with the co-operation and support of various government agencies, universities and non-governmental organisations. In 2007, Malaysia organised the "International Symposium on Cities and Conservation", "Fifth National Conference on Geological Heritage of Malaysia" and "Regional Conference on Asia-Pacific Geoparks".

Ladies and Gentlemen,

Malaysia is fully committed to sustainable development and has put in place numerous mechanisms and schemes to protect the flora and fauna as well ensure our natural resources are developed and used in environmentally sustainable manner. We also firmly believe in working with the international community to resolve environmental problems such as global warming and climate change that are increasingly threatening nations and societies around the world. Indeed we have been acknowledged and singled out by the World Bank and WWF for our success in managing our forest. Now we are focusing our efforts on the issue of climate change by taking constructive measures including mitigation and adaptation to reduce the effects of global warming on our livelihood and economy.

In this respect, I am glad that the issue of climate change has been identified as one of the key questions outlined in the IYPE with the subtheme "Climate Change – the Stone Tape" with the focus on determining the non-human factor in climate change. I hope the IYPE celebrations worldwide including Malaysia will include programmes and activities that not only enhance awareness of climate change but also stimulate our minds to come up with innovative ideas and methods to combat the issue.

Ladies and Gentlemen,

The Petroleum Geology Conference and Exhibition or PGCE which is an annual event of Geological Society of Malaysia serves as the best forum for the geosciences fraternity to share, build, enhance relationship and network, in the pursuit of sustaining energy resources for the nation and society. It is heartening to note that the Society has organised 27 such conferences since its establishment in 1967, and for being a major contributor to the advancement of knowledge in geosciences in the country.

I am also indeed pleased to note that PGCE has continuously provided the platform for intellectual discourse on geosciences for oil and gas industry in Malaysia in particular, and in South East Asia in general. I would like to take this opportunity to congratulate the Geological Society of Malaysia for their commendable efforts in organising this conference and exhibition annually to promote geosciences and exchange of ideas.

This year's event is the 28th edition of the Petroleum Geology Conference and Exhibition with the theme "Discovering New Plays Through Innovative Ideas". I am happy to know that more than 500 participants are attending this 2 days conference, including university students, with close to 50 scientific papers and dozens of posters being presented and more than 30 exhibition booths being set up. As industry participants and insiders, I am sure there are a multitude of technical issues and challenges to be presented and shared.

Ladies and Gentlemen,

The aims of the PGCE are also in line with the Government's effort to promote the sustainable development and utilisation of natural resources. In this respect, the earth sciences or geosciences fraternity which is at the forefront of the petroleum industry has a major role to assume. The long term sustainability of the industry relies very much on the success of exploration and production efforts amidst global challenges that include depleting resources, increasing demand and the need to balance between economic prosperity and sustainable development.

On one hand, the issue of depleting domestic and regional petroleum reserves reminds us of the urgency to replenish current reserves with new and commercially viable discoveries to meet increasing demand for the resource. I was told that the chances of discovering substantial reserves will be increasingly difficult, as they are located in economically and environmentally hostile environments, such as complex and subtle subsurface geology, remote frontiers and deeper waters. The conventional reserves are in smaller accumulations and widely distributed.

On the other hand, the surge in the price of oil has driven the industry into very costly environments to search and exploit the resources. In view of this, research and development (R&D) as well as better technology and innovation will be critical to enhance the efficiency of the value chain so that discovered resources can be brought to the markets in a more cost effective, efficient and environmentally friendly manner.

I hope the Conference will discuss new and innovative ways to address the issues confronting the oil and gas industry. Innovative ideas coupled with application of new technologies, knowledge sharing and collaboration among oil and gas players in the geosciences fraternity will help increase the success rate by reducing uncertainties in the exploration and exploitation efforts, hence reducing the finding, development and production costs.

It is becoming increasingly evident that there are still substantial amounts of hydrocarbons to be discovered but these are trapped in more challenging environments such subtle traps, deeper sections or basement, under explored onshore and deepwater areas. In this context, I believe the theme of the Conference will challenge the geoscientists to think outside the box in looking at new and more challenging hydrocarbon plays.

I am confident with the expertise and wealth of experience, the conference participants would be able to have useful and constructive exchange of views and work toward achieving the theme of this Conference. I also believe the Conference will be able to generate new knowledge, ideas and best practices pertaining to the development of Malaysian Petroleum Industry, which has played an important role in the socio-economic development of Malaysia.

The Conference should also give particular attention to the issue of sustainable development, especially in view of the fact that oil is a depleting non-renewable resource whose extraction has adverse environmental impact.

I once again express my appreciation and gratitude to geosciences fraternity here and abroad as well as to the oil and gas industry in particular PETRONAS for supporting the launch of IYPE and the PGCE.

Ladies and Gentlemen,

With *BISMILLAHIR RAHMANIR RAHIM* It gives me great pleasure to now launch “The International Year of Planet Earth” (IYPE Malaysia), and officiate Southeast Asia’s premier petroleum event, the “Petroleum Geology Conference and Exhibition 2008”..

Sekian. Wabillahitaufiq walhidayah, Assalamualaikum warahmatullahi wabarokatuh.

Thank you.

planetearth®

Earth Sciences for Society

Petroleum Geology Conference and Exhibition 2008

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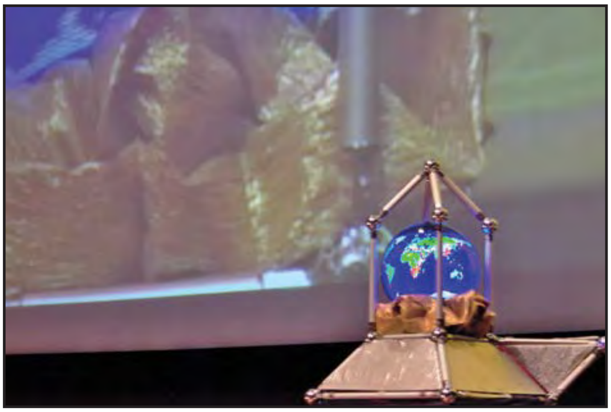

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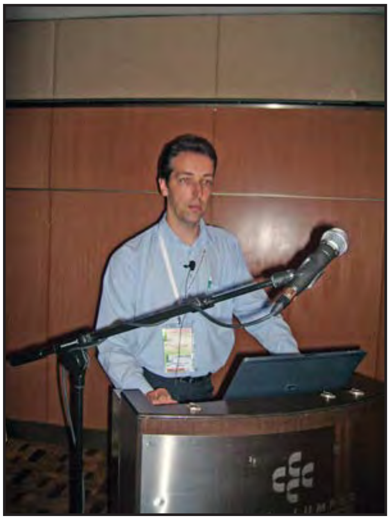

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PROGRAM

Sunday 13 January 2008		
4:00 – 6:00pm	**Registration**	
DAY-1: Monday 14 January 2008		
9:00 – 10:30 am	**Opening Ceremony (sponsored by PETRONAS) Plenary Hall, Ground Floor** **(see previous page)**	
10:30 – 11:00 am	**Coffee Break (sponsored by Orogenic) Exhibition Hall Foyer** **Onsite Registration Begins**	
11:00 – 11:30 am	**Keynote Paper 1 (Plenary Theater)** Oil and Gas Outlook: Acquiring a clear image of the future **Hovey Cox, Sr. Vice President Marketing & US Investor Relations, CGGVeritas**	
Session I	**GEOPHYSICS Rooms 304-305**	**GEOLOGY Plenary Theater**
11:30 – 11:55 am	**Geophysics Paper 1** Marine Acquisition and Processing using Dual Sensor Towed Streamer **Walter Söllner, Andrew Long and Maz Farouki (PGS)**	**Geology Paper 1** Structural controls on hydrocarbon migration and accumulation: An example from the Muglad Basin, Sudan. **James Will Udo Agany (Greater Nile Petroleum Operating Co.) and Hamdan Mohammad (Petronas Carigali)**
11:55 – 12:20 pm	**Geophysics Paper 2** Sub-Basalt Imaging Offshore India. **Tim Bunting (WesternGeco), Tim Brice (Schlumberger), Sean Murray (WesternGeco), and Chris Koeninger (WesternGeco)**	**Geology Paper 2** The prospectivity of stratigraphic traps in Group I interval, Serok – Laba Barat Area, Block PM324, Malay Basin. **Yahya Villareal Basman II (Petronas PMU)**
12:20 – 12:45 pm	**Geophysics Paper 3** Widening the Acquisition Time Window with Swell Noise Attenuation Capability. **George McKinley (ExxonMobil Exploration & Production Malaysia Inc.) and Wayne Zanussi (CGGVeritas Malaysia)**	**Geology Paper 3** Basin modeling and petroleum system analysis of Southern Sulu Sea – East Sabah Basin. **Chan Eng Hoe (Petronas PMU)**
12:45 – 2:00 pm	**LUNCH (sponsored by PETRONAS) Exhibition Hall 5 (Ground floor)**	

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Session II	**GEOPHYSICS** Rooms 304-305	**GEOLOGY** Plenary Theater
2:00 – 2:25 pm	Geophysics Paper 4 Time-domain high-resolution Radon transform. **Michel Schonewille, Peter Aaron, and Carl Notfors (PGS)**	Geology Paper 4 Application of Development While Exploring (DWE) Approach in Marginal Fields Development's Block SK305, Offshore Sarawak. **Foo Wah Yang (Petronas Carigali), Azlan Ghazali (Petronas Carigali), Medy Kurniawan (PERTAMINA), Bui Ngoc Quang (PVEP)**
2:25 – 2:50 pm	Geophysics Paper 5 Imaging of fractures and faults inside granite using controlled beam migration. **Don Pham, Jason Sun, James Sun, and Graeme Bone (CGGVeritas) and Qinbing Tang and Nguyen Triong Giang (Cuulong JOC, Vietnam)**	Geology Paper 5 Utilising sequence stratigraphic concepts to define new plays in NW Sabah Basin. **Edy Kurniawan, Nurita Ridwan, and Robert Wong Hin Fatt (Petronas PMU)**
2:50 – 3:15 pm	Geophysics Paper 6 NMO Application in VTI Media: Effective and Intrinsic Eta. **Joel Starr and Maz Farouki (PGS)**	Geology Paper 6 Using core and log data to link depositional environment with oil system in siliciclastic reservoirs: Case study from Muglad Basin, Sudan. **Yasir M.A. Ghorashi and Saif El Sulaiman (Greater Nile Petroleum Operating Co., Sudan)**
3:15 – 3:30 pm	**TEA BREAK** (sponsored by CGG Veritas) **Exhibition Hall Foyer**	
Session III	**GEOPHYSICS** Rooms 304-305	**GEOLOGY** Plenary Theater
3:30 – 3:55 pm	Geophysics Paper 7 Geophysical Issues and Challenges in Malay and Adjacent basins. **Deva P. Ghosh (Petronas Research)**	Geology Paper 7 Depositional setting and history of cored intervals RS 8 reservoir Block 1, South Caspian Sea, Turkmenistan. **David Ince (Petronas Carigali), Gordon Yeomans (Petronas Carigali Turkmenistan) and Graham Blackbourn (Blackbourn Geoconsulting)**
3:55 – 4:20 pm	Geophysics Paper 8 Exeter Mutineer – Case Study of an Integrated Project from Seismic Survey Design to Inversion. **Tim Bunting, Richard Patternall, and Frazer Barclay (WesternGeco)**	Geology Paper 8 A geocellular modeling approach to characterization of fluvial stacked reservoirs - Northern Fields, Block PM-3 CAA, Malay Basin. **Robert Chatwin (Talisman Malaysia)**

4:20 – 4:45 pm	**Geophysics Paper 9** Comparative analysis of simultaneous inversion result with elastic inversion and AVO envelope in Sumandak Field. **Yeshpal Singh (Petronas Carigali)**	**Geology Paper 9** Sequence of slope instability and healing: Key to predicting deep-water reservoirs distribution in NW Borneo. **Martin Grecula, Senira Kattah, Mark Griffiths, Bill Wilks, Homerson Uy, Kuswadi Hedeir, Hong Chin-Weng, Kelly Maquire, Peter Osterioff, Eleanor Rollet, and Peter Shiner (Sarawak Shell Berhad)**
4:45 – 5:10 pm	**Geophysics Paper 10** 3D Close-the-Loop: Reconnecting Reservoir Modeling to the Seismic Data. **Timothy Barker (Sarawak Shell Berhad)**	**Geology Paper 10** Seismically driven reservoir characterization using and innovative integrated approach: Application to a fractured reservoir. **Abdel M Zellou (Prism Seismic), Soren Christensen (Hess), Tanja Ebbe Dalgaard (Dong), and Gary Robinson (Prism Seismic)**
5.10 - 5.35 pm	**Geophysics Paper 11** Elastic Impedance Inversion for Reservoir Delineation– A Quantitative Interpretation Case Study in the Malay Basin **Cheng N., Bukhari I., Kanok I., Awirut S. and Vitoon C. (CARIGALI-PTTEPI Operating Company Sdn Bhd (CPOC))**	**Geology Paper 11** The West Crocker Formation (Early Oligocene to Middle Miocene) in the Kota Kinabalu area, Sabah: Facies, sedimentary processes and depositional setting. **Nizam Abu Bakar (USM), Abdul Hadi Abd Rahman (Energy Quest), Mazlan Madon (Petronas Research)**
6:30-9:00 pm	**ICEBREAKER (sponsored by Newfield) Exhibition Hall Foyer**	
DAY-2: Tuesday 15 January 2008		
8:30 – 9:00 am	**Keynote Paper 2 Plenary Theater** Geomechanics in Exploration and Development with Examples from NW Borneo **Professor Richard Hillis, University of Adelaide**	
Session IV	**GEOPHYSICS Rooms 304-305**	**GEOLOGY Plenary Theater**
9:00 – 9:25 am	**Geophysics Paper 12** Integrated geological and geophysical analysis by hierarchical classification: combining seismic stratigraphic and AVO attributes. **Alexis Carrillat, Tanwi Basu, Raul Ysaccis, Shye, and Aik Chong (Schlumberger), and Amiruddin Mansor, and Martin Brewer (Petronas Carigali)**	**Geology Paper 12** Structural evolution of Mehar/Mazarani Fold Belt area, Pakistan. **Shamim Haider Ali (Petronas Carigali Pakistan Ltd), Ramly Manja (Petronas Carigali), and Muhammad Adib Abdullah Hudi (Petronas Carigali)**
9:25–9:50 am	**Geophysics Paper 13** Volume blending with directional seismic attributes. **Arthur E. Barnes and Surender S. Manral (Paradigm)**	**Geology Paper 13** Mid-Miocene Unconformity **Charles S. Hutchison (Universiti Malaya)**

9:50–10:15 am	**Geophysics Paper 14** Application of Rock Physics Modelling and Seismic Attribute in Developing the Geological Model – An Example from Eocene Deepwater Turbidite in Block 21/23a, CNS, UK. **Liau Min Hoe (Petronas Carigali), Kester Waters, Howard D Johnson, and Christopher A-L Jackson (Imperial College)**	**Geology Paper 14** The palaeotopographic and palaeodrainage evolution of the South China Sea hinterlands from the Late Cretaceous to Recent. **Paul Markwick and Kerri Wilson (GETECH)**
10:15–0:40 am	**Geophysics Paper 15** The First Mega-merged Seismic Data Processing Project in Malaysia. **Mohd Akmal Affendi Adnan (Petronas PMU)**	**Geology Paper 15** Pore pressure prediction as a prospecting tool, input to risk, volumes and field development. **John P. Brown and Suraini Sulaiman Mustahim (Petronas Carigali)**
10:40–0:55 am	**COFFEE BREAK (sponsored by Murphy) Exhibition Hall Foyer**	
Session V	**GEOPHYSICS Rooms 304-305**	**GEOLOGY Plenary Theater**
10:55–11:20 am	**Geophysics Paper 16** The application of CSEM (Controlled Source Electromagnetic) technology as a tool to complement 3D seismic interpretation and AVO analysis in a deepwater prospect: a case study on Prospect B, Block 2F, offshore Sarawak. **Wong Eng Yao (Petronas PMU)**	**Geology Paper 16** Sedimentology of Cycle II, Balingian Province: An Early Miocene tide-influenced delta system **Meor Amir Hassan (Imperial College), Howard D Johnson (Imperial College), Wan Hasiah Abdullah (Universiti Malaya) and Peter A. Allison (Imperial College)**
11:2011:45am	**Geophysics Paper 17** Recent CSEM learnings in deepwater Borneo. **Matthew Choo, Chester Young, Ling Chin Tiong, James Beer, and Peter Shiner (Sarawak Shell Berhad)**	**Geology Paper 17** Growing evidence of active deformation in the Malay Basin region. **H.D. Tjia (Orogenic Resources and Lestari, UKM)**
11:45–2:10am	**Geophysics Paper 18** CSEM Pilot Survey in Southeast Asia: challenges and takeaways. **Sandeep K. Chandola, Rashidah Karim, Russikin Ismail, Amy Mawarni, Ramlee Rahman, and Paul Bernabe (Petronas Carigali)**	**Geology Paper 18** Climate stratigraphy – A new approach in near-synchronous subsurface correlation. **S.D. Nio (ENRES International)**
12:10–2:35 pm	**Geophysics Paper 19** Channel chasing in Malay Basin using mega-merged data. **Rosemawati Abd Majid (Petronas PMU)**	**Geology Paper 19** Carbon dioxide (CO_2) distribution in the Sarawak Basin and its relationship with entrapment. **Mansor Ahmad and Mohd Irwani Sadi (Petronas PMU)**

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12:35–1:00 pm	**Geophysics Paper 20** Innovative Frontier Exploration Using Seismic and SeaSeepTM Data, Indonesia: Implications for Malaysia. **Peter Baillie (Black Gold Energy), John Decker (TGS-Nopec), Paul A. Gilleran (Black Gold Energy), Dan Orange (TGS-Nopec), Philip A. Teas (TGS-Nopec), and Widjanarko (MIGAS, Indonesia)**	**Geology Paper 20** Geomechanical consideration regarding EOR efficiency and CO_2 sequestration. **David Castillo, David Bowling, and Sunil Nath (GeoMechanics International, Inc.)**
1:00 – 2:00 pm	**Lunch (sponsored by Shell)** **Exhibition Hall 5 (Ground floor)**	
Session VI	**GEOPHYSICS** **Rooms 304-305**	**GEOLOGY** **Plenary Theater**
2:00 – 2:25 pm	**Geophysics Paper 21** Time-lapse seismic modelling in the Malay Basin **Shaidin Arshad, M Firdaus A Halim, M K Sen Gupta, Nor Azhar Ibrahim, and Salbiah Isa (Petronas Research)**	**Geology Paper 21** Sarawak Malaysia deepwater new turbidite play. **Fauzil Fanani Radilas and Sheh Yackop Abdol Karim (Petronas PMU)**
2:25 – 2:50 pm	**Geophysics Paper 22** Permanent Reservoir Monitoring Using Fiber Optic Technology **Steve Maas and Rune Tenghamn (PGS)**	**Geology Paper 22** Play types and hydrocarbon prospectivity in Petronas' Block N44, N45, N50 and N51, Offshore Northwest Cuba. **Othman Ali Mahmud, Salim Sahed, Miguel Guerrero-Munoz, and Salehudin Ujang (Petronas Carigali)**
2:50 – 3:15 pm	**Geophysics Paper 23** Fit for Purpose Time Lapse Seismic at F6. **Elvis Chung and Paul Hague (Sarawak Shell Berhad)**	**Geology Paper 23** The evolution of geological thinking and depositional framework interpretation through the life of a complex reservoir, D35 Field, Offshore Sarawak. **M Ismail B Sahari (Petronas Carigali), David Martyn Ince (Petronas Carigali), Abdul Hadi Abd Rahman (Energy Quest), Samsudin Abdul Hamid (Energy Quest), Jusmila Baharom (Energy Quest) and Abdul Munif Khorani (Energy Quest)**
3:15 – 3:30 pm	**TEA BREAK (sponsored by Nippon Oil)** **Exhibition Hall Foyer**	
Session VII	**GEOPHYSICS** **Rooms 304-305**	**GEOLOGY** **Plenary Theater**
3:30 – 3:55 pm	**Geophysics Paper 24** Large-scale pore pressure prediction after pre-stack depth migration in the Caspian Sea. **Norbert van de Coevering (CGGVeritas), Hazim Hameed Al-Dabagh (Petronas Carigali), Liau Min Hoe (Petronas Carigali), and Tony Jolly (Knowledge Systems, Inc.)**	**Geology Paper 24** More oil from old field. **Noor Azmah Abdullah, Siti Nadia Ameer Hamza, Noor Alyani Ishak, and Wahyudin Suwarlan (Petronas Carigali)**

3:55 – 4:20 pm	**Geophysics Paper 25** Reservoir Characterization and Monitoring Using Multi-Transient ElectroMagnetic (MTEM). **Folke Engelmark (PGS)**	**Geology Paper 25** Pre-Tertiary carbonate play, Offshore Peninsula Malaysia: A revival of forgotten play. **Ogail A. Salam (Petronas Carigali), M Yamin Ali (Petronas Research), and Sahalan A. Aziz (Petronas Carigali)**
4:20 – 5.00 pm	**Closing Ceremony** **Plenary Theater**	

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Poster Sessions (at the Exhibition Booths)

Day 1: 14th January		Day 2: 15th January	
P01	Organic Facies Variation in Lacustrine Source Rocks in the Southern Malay Basin. **Abdul Jalil Muhamad and Awang Sapawi Awang Jamil (Petronas Research)**	P03	Distal Turbidites of the Semantan Formation (Middle-Upper Triassic) in the central Pahang, Peninsular Malaysia. **Hasnol Hady Ismail, Mazlan Madon, Zainol Affendi (Petronas Research)**
P02	Lacustrine Oil Families in the Malay Basin. **Abdul Jalil Muhamad and Awang Sapawi Awang Jamil (Petronas Research)**	P04	Turbidite, debrite or something in between: re-thinking the West Crocker Formation. **Ku Rafidah Ku Shafie and Mazlan Madon (Petronas Research)**
P05	The geographic and stratigraphic distribution of cored sections in the Malay Basin. **Wan M Khairul Anuar Wan Sulaiman, Azmi Mohd Yakzan and Shamsudin Jirin (Petronas Research)**	P07	Condensed section intervals within the Cycle II (Early Miocene) of the D35 Field, Balingian Province, offshore Sarawak: Occurrence and Significance. **Abdul Hadi Abd Rahman (Energy Quest), David Martyn Ince (Petronas Carigali) and Kerrie L. Bann (Ichnofacies Analysis Inc.)**
P06	Temana: Old Field, New Ideas and New Insights. **Johari Jurid, Siti Aishah Osman, Wahyudin Suwarlan, Ali Andrea Hashim, Mohd Al-Amin Abd Mutalib, and Fierzan Muhammad (Petronas Carigali)**	P08	Using gravity data to help identify and differentiate mobile shale bodies, offshore Sabah. **S.J., Campbell (GETECH), M. Lennane and S.E. Pisapia (Murphy Sabah Oil Co. Ltd)**
P11	Two-dimensional stratigraphic simulation of the Malay Basin. **Wan Edani Wan Rashid (UTP), Mazlan Madon (Petronas Research), Ku Rafidah Ku Shafie (Petronas Research)**	P09	Detection of 3D Distribution of Reservoir Sand Bodies by ANN – A Case Study in the North Malay Basin (1). **Toshihiro Takahashi, Jianyong Hou, Arata Kato, Suwit Jaroonsotha and Kazuo Nakayama (JGI/CPOC)**
P12	Advanced mud gas logging technology: Application for fluid identification & characterisation, offshore Sarawak, Malaysia. **Patrick Gou and Sven Scholten (Sarawak Shell Berhad)**	P10	3D Basin Simulation controlled by Capillary Threshold Pressure – A Case Study in the North Malay Basin (2). **Toshihiro Takahashi, Arati Kato, Suwit Jaroonsitha, Jianyong Hou and Kazuo Nakayama (JGI/CPOC)**
P13	Developing remaining oil in K1.1 Sand reservoir with horizontal well in Baram Field, Sarawak Basin. **Nor Azrina M Amin, Noor Azmah Abdullah, Wahyudin Suwarlan, M Elzrey Ab Rahman and M Zamri Wahab (Petronas Carigali)**	P14	Using Acoustic Impedance Data for Tabu Field Subsurface Mapping and Reservoir Characterization. **Fariz Fahmi (ExxonMobil Exploration and Production Malaysia Inc.), Yue Choong Lye (ExxonMobil Exploration and Production Malaysia Inc.), Azlina Ahmad Termizi (ExxonMobil Exploration and Production Malaysia Inc.), Dave Walley (ExxonMobil Indonesia Inc.) and Aniza Yaakob (Schlumberger)**

Day 1: 14th January (cont.)		Day 2: 15th January (cont.)	
P15	Borehole Images and VSPs as Aid to Attribute and Inversion Analysis. **Debnath Basu (Schlumberger), Mark Lamber (Newfield Peninsular Malaysia Inc.), Alexis Carrilat (Schlumberger), Chandra Velu (Newfield Peninsular Malaysia Inc.) and Riasa Hussain (Schlumberger)**	P16	Ichnofossils from the Tertiary sediments of the West Crocker Formation in Kota Kinabalu area, Sabah. **Nizam Abu Bakar (USM), Abdul Hadi Abd Rahman (Energy Quest), Mazlan Madon (Petronas Research)**
P17	Facies characteristics and stratification of debrites within the West Crocker Formation (Early Oligocene to Middle Miocene), Kota Kinabalu, Sabah. **Nizam Abu Bakar (USM), Abdul Hadi Abd Rahman (Energy Quest) and Mazlan Madon (Petronas Research)**	P18	Sedimentary facies characteristics and reservoir properties of Tertiary sandstones in Sabah and Sarawak, East Malaysia. **Teoh Ying Jia and Abdul Hadi Abd Rahman (USM)**
P19	Anding Utara Fractured Basement Modeling an integrated workflow from Seismic-3D Static-Fracture Model. **Siti Zainab Muda, Simon Christian Kurniawan, Siti Sarah Baharuddin (Petronas Carigali)**	P20	Structural style and structural evolution in the Hawke's Bay region, New Zealand. **Nasaruddin Ahmad (Petronas Carigali)**
P21	Controlled-source electromagnetic (CSEM): complementing AVO as prospect qualifier, offshore Sabah, NW Borneo. **Harry Maulana, S.Tanner (Murphy Sabah Oil Co. Ltd), S. Algar (Murphy Oil Co. Ltd) and K Azlan (Petronas PMU)**	P22	The structural and stratigraphic evolution of shale detachment system in the Ceduna Basin, Australia. **M Zaid Jaafar (Petronas Carigali)**
P23	Integrated fracture evaluation of a Malaysian basement well drilled with the oil-base mud. **Edna Malim, Saifon Daugkaew, Steve Hansen, and Aung Than Oo, and Riasat Hussain (Schlumberger), and Simon Christian Kurniawan, and Zairul Asrah Zulkefli (Petronas Carigali)**	P24	Trace Fossil or Soft Sediment Deformation? An enigmatic structure from the Balingian Cycle II Sequence, Offshore Sarawak. **David Ince (Petronas Carigali)**
P26	Application of Walkaway VSP for improved seismic imaging beneath a gas cloud. **Gunawan Taslim (Petronas Carigali), Amy Mawarni M Yusoff (Petronas Carigali) and Teck Kean Lim (Schlumberger)**	P25	Trace fossil assemblages and palaeoenvironmental re-evaluation of Miocene reservoir intervals, Offshore Sarawak, Malaysia. **Kerrie L. Bann (Ichnofacies Analysis Inc.), David M Ince (Petronas Carigali), Abdul Hadi Abd Rahman (Orogenic Resources) & Ahmad Munif Khoraini (Orogenic Resources)**
P28	A comparison of geochemical and petrographic features of oil-prone coals from the Balingian Province with those of the Malay Basin , Malaysia. **Peter Abolins (Petronas Carigali) and Wan Hasiah Abdullah (Universiti Malaya)**	P27	Tectonic Evolution, Sedimentation and Chronostratigraphic Chart of Sabah, Malaysia.. **Allagu Balaguru (Petronas Carigali)**

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ABSTRACT OF PAPERS

Keynote Paper 1

OIL AND GAS OUTLOOK: ACQUIRING A CLEAR IMAGE OF THE FUTURE

HOVEY COX, SR.

Vice President Marketing & US Investor Relations, CGGVeritas

The oil and gas industry, over its history, has seen times of great strength and long periods of weakness. It has also demonstrated a propensity for proving wrong those who try to predict its cycles and peaks.

Over recent history we have experienced one of the greatest, if not the greatest, period of long-term economic growth worldwide. This expansion was literally powered by the relatively clean and inexpensive energy that fossil fuels, oil and gas in particular, provide. Over the past ten years, as economic development strengthened and energy consumption continued to climb, especially in the World's emerging economies, several underlying factors in the energy landscape have started to challenge the oil and gas industry's historic models.

To meet the growing need for energy, E&P budgets increased across the industry focused primarily on production technology to optimize recovery from known assets. This reduced the risks associated with quarterly returns in the capital markets worldwide and at the same time increased depletion rates. When combined with flat-lining exploration spending and the resulting decrease in discovery rates, it also dramatically reduced spare capacity. Together these trends arguably, at least at the current time, moved the oil and gas marketplace from a supply-side to a demand-side driven market.

Changes are needed. When the trends outlined above are compounded with: the growing geological and geopolitical complexities in our business, the rising concern worldwide over increasing energy costs and the industry's environmental impact, it provides a clear opportunity to examine our current business as our historic models may not work as well in the future as the did in the past.

We today, as an industry, sit at a unique place in history that suggests a review of possible directions and decisions. This presentation explores the current state of the industry along with its fundamental drivers to uncover the key challenges companies face today to successfully produce results tomorrow.

Keynote Paper 2

PETROLEUM GEOMECHANICS: FROM THE PLATE-SCALE TO THE RESERVOIR-SCALE

RICHARD R. HILLIS

Australian School of Petroleum, University of Adelaide, Australia

The last 10-15 years have seen an explosion in the application of present-day stress data to petroleum exploration and development-related issues. Borehole breakouts, zones of wellbore where the cross-sectional shape is enlarged and elliptical, were first-named and recognised as being due to present-day stresses in the late 1970s (Figure 1). However, even by the early 1990s, few in the oil industry were familiar with borehole breakouts. Now they are used routinely, along with other present-day stress data, to evaluate fault reactivation and reservoir seals; evaluate naturally fractured reservoirs; assess wellbore stability, and plan fracture stimulation and water flooding operations.

This talk will illustrate how the reservoir geomechanical model (present-day stress and strength data) is determined using logging and drilling data. It will discuss the plate-scale, regional and local tectonic controls on present-day stress with examples from Brunei and the North Sea. Finally it will illustrate the application of the geomechanical model to exploration and development, with examples from Brunei and the North Sea.

Determination of the Geomechanical Model

Most of the data required to determine the present-day stress field and rock strength are routinely acquired by the petroleum industry. The key pieces of data not routinely acquired are an image log, a good quality leak-off test (or preferably extended leak-off test) and laboratory testing of rock strength. The vertical stress magnitude can be determined from density and sonic/check shot log data. The minimum horizontal stress magnitude can be determined from leak-off test data. The orientation of the minimum and maximum horizontal stresses can be determined from the orientation of breakouts and drilling-induced tensile fractures recorded on image logs (Figure 1). The maximum horizontal stress magnitude is the most difficult parameter of the geomechanical model to constrain, but can be derived using various techniques including combining knowledge of rock strength with the occurrence of breakouts and/or drilling-induced tensile fractures or, alternatively, from the orientation of breakouts and drilling-induced tensile fractures, or the variation of leak-off pressures in deviated wells.

Tectonic Controls on Present-Day Stress

Plate boundary forces provide the first-order control on present-day stresses. The World Stress Map project has demonstrated that in many continental areas the orientation of present-day maximum horizontal stress parallels the absolute direction of plate motion. Hence it has been reasonably inferred that the forces driving and resisting plate motion are responsible for the present-day stress field.

The Indo-Australian Plate is unusual in that regional directions of maximum horizontal stress are variable and do not parallel the direction of absolute plate motion (Figure 2). However, the Indo-Australian Plate has a uniquely complex convergent northeastern plate boundary. If the nature of this plate boundary (which varies from, for example, Himalayan collision to subduction of Indian Ocean under the Indonesian Sunda Arc) is considered, it can be shown that the regional intraplate stress field is indeed consistent with control by plate boundary forces, as has been inferred in plates with simpler plate boundary configurations. Initial results from several projects undertaken at the University of Adelaide suggest that maximum horizontal stress orientation in the Sunda Plate is also variable and does not parallel the direction of absolute motion of the Plate. Our current interpretation, yet to be fully tested, is that again this reflects the complex configuration of, and forces acting on, the boundaries of the Sunda Plate.

Regional and local structural setting may also impact on the nature of the present-day stress field in the reservoir. This will be illustrated by results from Brunei, where three distinct present-day stress provinces, that are consistent with neotectonic styles apparent in field outcrops and on seismic data, can be recognized: (i) an onshore/inner shelf inversion province; (ii) an outer shelf deltaic extension province, and; (iii) a deepwater compression province (Figure 3). The inversion province exhibits margin-normal, NW-SE oriented present-day maximum horizontal stress, consistent with inverted Miocene-Pliocene extensional deltaic structures in this province. The deltaic extension province is a relatively narrow segment of the outer shelf (a few tens of kilometres wide) with active normal faults striking NE-SW and margin-parallel, NE-SW oriented present-day maximum horizontal stress. The deepwater compression province hosts NE-SW-striking thrusts and present-day maximum horizontal stress is oriented normal to the margin and normal to the strike of the thrusts, i.e. NW-SE. The stress rotation between the deltaic extension and deepwater compression provinces is consistent with margin-normal stresses in the deepwater fold-thrust belt system being generated by up-dip extension of the delta. The stress rotation between the inverted inner shelf province and the deltaic extension province reflects the location of the deltaic system on an active margin subject to ongoing convergence.

The effect of regional and local structural setting will also be illustrated with respect to the North Sea where neither the Northern or Central North Sea areas show the broadly northwest-southeast oriented maximum horizontal stress direction seen onshore North West Europe that results from plate boundary forces. Stresses associated with deglaciation appear to control the east-west maximum horizontal stress direction observed in the Northern North Sea. Maximum horizontal stress orientations are highly variable in the Central North Sea and the stress regime within the sedimentary sequence there appears to be detached from that in the basement.

Application of the Geomechanical Model in Exploration and Development

Both Brunei and the North Sea illustrate that reservoir stresses must be determined from in situ data (as opposed to from regional compilations and offset wells). The recognition of the three present-day stress provinces has major implications for petroleum exploration and development in the Baram Delta-Deepwater Fold-Thrust Belt System. For example, and as will be illustrated in detail in the talk, most stable well trajectories and preferential fluid flow directions in water flooding operations vary over relatively short distances, between Brunei's stress provinces and the 'learnings' from operations in the inner shelf should not be directly translated to the outer shelf, nor to the deepwater.

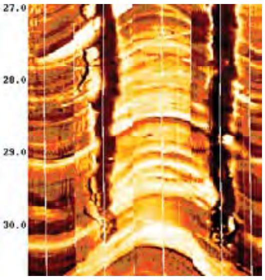

Figure 1: Resistivity image of borehole breakout. Unwrapped view of wellbore wall. Breakout gives direction of minimum present-day horizontal stress.

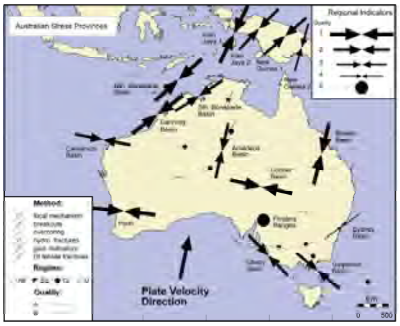

Figure 2: Regional maximum horizontal stress directions and direction of absolute plate velocity for Australia.

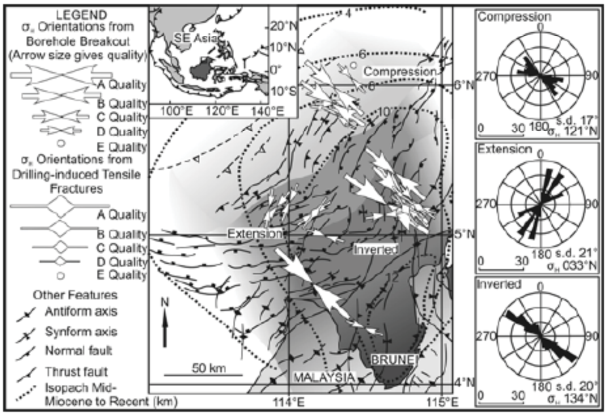

Figure 3: Baram Delta-Deepwater Fold-Thrust Belt System showing present-day maximum horizontal stress directions from petroleum wells (white arrows). Grey shading marks inverted, extension and compression provinces across the delta-deepwater fold-thrust belt system. Dotted lines show isopach of Middle Miocene-Recent deltaic sediments from Morley et al. (2003).

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Geophysics Paper 1

MARINE ACQUISITION AND PROCESSING USING DUAL SENSOR TOWED STREAMER

WALTER SÖLLNER, SVEIN VAAGE, DAVID CARLSON, MARTIN WIDMAIER,
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Introduction

PGS has been developing an entirely new towed marine streamer concept for about five years. The project objective was to engineer a streamer that is capable of recording both the scalar pressure field and the vertical component of the vector particle velocity field. PGS' Next Generation Streamer has accomplished these objectives, and is a step change in streamer technology. This technology overcomes the limitations of hydrophone-only acquisition systems, and allows PGS to separate the up-going wavefield incident upon the streamer from the down-going-wavefield that is reflected from the sea surface. It is thus possible to remove the receiver ghost from the data, at all depths, and thereby recover significant low and high frequency amplitudes normally missing from marine seismic data. It is no longer the case that E&P decision makers must parameterize streamer surveys to maximize data quality at one target depth, whilst sacrificing image quality at shallower or deeper targets.

The PGS Next Generation Streamer uses an extremely quiet, ruggedized solid streamer design to provide enhanced resolution, better penetration, and improved operational efficiency. In fact, the towing depth is typically quite deep, thus increasing the operational window in poor weather or environmental conditions that no other system can handle. PGS experience demonstrates that the technology can deliver deghosted data not just for one depth, but for all depths – in one pass, using one streamer depth. It is also a no-risk technology – PGS can use the dual-sensor information to duplicate the parameters of any existing survey, thus allowing 4D matching plus the benefits of improved image clarity.

PGS has assembled a full acquisition and data processing product range for the Next Generation Streamer. 2D commercial operations are planned to begin in late-2007, followed by 3D commercial operations in 2008.

The Receiver Ghost

Unfortunately, a hydrophone in a towed streamer always records two wavefields that constructively interfere with each other. The up-going pressure wavefield propagating directly to the hydrophone from the earth below, and the down-going pressure wavefield reflected downwards from the "free air" sea surface immediately above the streamer. As the reflection coefficient of a relatively calm sea surface is close to -1, the down-going pressure wavefield has equal amplitude to the up-going pressure wavefield, but opposite polarity. The consequence is that a series of "ghost" notches are introduced into the frequency spectra, and the reflection wavelet is undesirably elongated, reducing temporal resolution. In contrast, velocity sensors are directional, so the down-going velocity wavefield is measured as having equal polarity to the up-going velocity wavefield. Furthermore, the peaks and notches in the amplitude spectra for pressure data are complementary to those for velocity data. Thus, the summation of pressure and velocity data will cancel the amplitude of the ghost event trailing each primary event, and the notches in the amplitude spectra will be removed. This is the case for all angles of incidence and for all source-receiver offsets.

Figure 1 is a simple synthetic example that demonstrates summation of zero-offset stacks for pressure and velocity data. The receiver ghost that complicates interpretation of relatively thick intervals has been removed, and an extremely clear image results.

It follows from simple theory that if the vertical component of particle velocity is known, the total measured seismic wavefield can be decomposed in data processing into the up-going and down-going pressure and velocity wavefields. As the velocity could never historically be measured on towed streamers, however, it was necessary to pursue an estimate of the vertical pressure gradient. One operationally challenging approach to estimate the vertical pressure gradient is to tow two streamers at different depths. It is of course better if the vertical component of the particle velocity can be directly measured – achieved now by PGS..

Next Generation Streamer Operations and Opportunities

The commercial Next Generation Streamer architecture uses densely sampled groups of collocated pressure and velocity sensors in a low-noise solid-fill streamer. An ethernet telemetry system minimizes power consumption for the Next Generation Streamer architecture. The Next Generation Streamer is typically towed at a depth of about 15 m in a quiet and stable environment.

Data processing is relatively straightforward to yield the deghosted and decomposed pressure and velocity wavefields. These wavefields can then be extrapolated to any desired towing depth, if required. Thereafter, the data are passed on to a "conventional" processing flow, modified of course to exploit and preserve the improved frequency and signal-to-noise content of the signal.

Towing a deep Next Generation Streamer allows PGS to operate in a longer weather window, sometimes in scenarios where conventional operations would be shut down. Developmental experience over the past few years demonstrates that weather and operational noise is typically reduced by 3 to 7 dB, dependent upon survey conditions. Efficient acquisition follows from only having to tow all streamers at one depth, exploiting the full streamer width capacity of the vessel, and easily controlling all streamer behaviour.

An advanced implementation of Surface Related Multiple Elimination (SRME) is possible with the Next Generation Streamer. Multiple prediction is based on the up-going pressure wavefield and the down-going velocity wavefield. The key advantage of using the down-going velocity wavefield is that any variations in the sea surface level and reflection coefficient are implicitly included in the implementation. In addition, the use of a velocity field automatically incorporates angle-dependent scaling into the prediction process.

Field Data Example

Figure 2 presents data acquired with a 6100 m Next Generation Streamer towed at a depth of 15 m. Note the significant improvements for the up-going pressure wavefield in terms of event resolution and frequency content on stacked data.

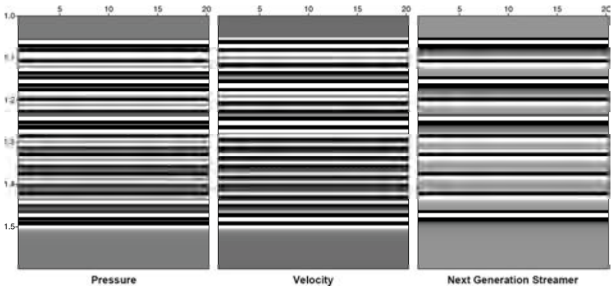

Figure 1. Conceptual synthetic zero-offset stacks for pressure-only, velocity-only, and summation of pressure+velocity. Summation cancels the receiver ghost present in the pressure and velocity data.

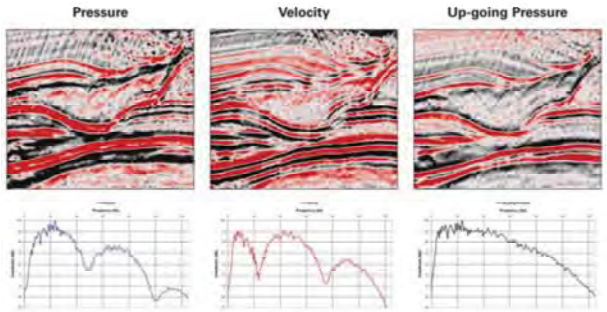

Figure 2. Unmigrated stack comparison. Left: Pressure-only result. Middle: Velocity-only result. Right: Up-going pressure wavefield, derived from the summation of the pressure and velocity wavefields.

Geophysics Paper 2

SUB-BASALT IMAGING OFFSHORE INDIA

Tim Bunting[1], Tim Brice[2], Sean Murray[1] and Chris Koeninger[1]

[1]Western Geco
[2]Schlumberger

The Deccan Trap consists of multiple episodes of lava flows covering large areas onshore and off the West coast of India overlying a number of potential hydro-carbon plays. Due to the high reflectivity of the top-basalt, and the high absorption of the basalt layer, the seismic signal returning from the sub-basalt events is very low amplitude resulting in poor reservoir imaging, with conventional seismic acquisition.

This paper describes a test survey acquired by WesternGeco, to use over-under seismic acquisition to improve image of the intra-basalt and sub-basalt layers. Over-Under acquisition in which sources and or streamers are towed at different depths. Post acquisition wave-field combination techniques take advantage of the change in ghost response, resulting from the different tow depth, to fill of shift the notch resulting in a higher bandwidth image.

Geophysics Paper 3

WIDENING THE ACQUISITION TIME WINDOW WITH SWELL NOISE ATTENUATION CAPABILITY

George McKinley[1]and Wayne Zanussi[2]

[1]ExxonMobil Exploration and Production Malaysia Inc
[2]CGGVeritas Malaysia

Summary

Seasonal timing is a critical factor in the acquisition planning stages of a seismic survey. Once vessel availability has been secured for the desired period, the predicted weather conditions must be considered.

In Peninsular Malaysia it is widely accepted that March through October is the optimum time window for seismic acquisition, as beyond that period monsoon activity causing rough seas can negatively impact the data quality.

Despite the risks associated with the monsoon season it is not uncommon to see seismic vessels operating in West Malaysian waters well into November, as past history has shown periods of breaks in the poor weather allowing for data to be acquired. The survey which forms the basis of this study actually commenced in November and continued to acquire data until the end of January, potentially experiencing the most undesirable of annual weather conditions as it progressed.

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The purpose of this paper is to illustrate that despite the adverse affects of harsh monsoonal weather on the dataset acquired, seismic processing efforts were capable of attenuating the resultant noise to a level which was considered acceptable for further processing.

Introduction

The CGGVeritas vessel Fohn acquired the Larut 3D/4D survey in Peninsular Malaysia (PM) for ExxonMobil from November 2006 through January 2007. Even though the timing of this survey was not optimum due to a delay in arrival of the vessel, given the potentially severe weather that monsoon periods could generate, ExxonMobil decided to attempt to acquire the data even beyond the November timeframe.

The planned acquisition configuration was dual source, 8 streamers with 4500m spread length. After just 28 sequences, as conditions worsened 2 cables were damaged. Following 6 days of downtime for repairs the Fohn re-commenced acquisition with 2 cables less and the remainder of the survey was acquired with a 6 cable layout.

On December 15th 2006 the last sequence of Phase I was completed. Observer's logs on this line reported that swell noise was affecting up to 70% of traces.

The Fohn returned from dry-dock on January 17th and acquired 27 more sequences with a reduced cable length of 3600m.

Typically 15 micro-bars of noise are considered to be the threshold for accepting data for processing. Of the 161 sequences acquired, on average more than one-third of the lines exceeded this level. Average noise levels of each sequence are shown in figure 1. Despite a large part of the survey exceeding the nominally accepted level, ExxonMobil made the decision to process all but 8 of the acquired sequences and most of these 8 lines were not processed due to navigation problems rather than noise issues.

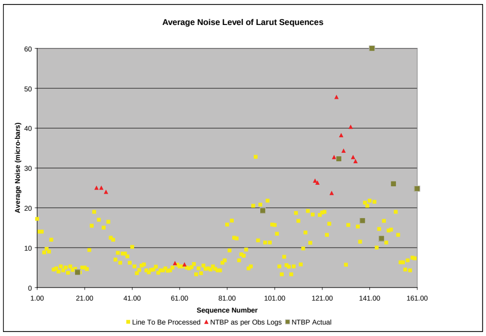

Figure 1 : Average noise levels of the Larut sequences. Of the acquired 161 sequences only 8 were not processed.

Discussion of Methods

The challenge was now left with the CGGVeritas data processing team to formulate a solution to attenuate the noise and improve the data to a level which was acceptable for further high resolution processing including pre-stack time and depth migration and 4D processing. A major factor in the noise attenuation processing involved applying CGGVeritas proprietary swell noise removal techniques, (Guo et al. 2003). These were run in multiple passes in different domains and were successful in reducing the effects of the swell noise.

Swell noise is generally constrained to low frequencies. The proprietary software, FXEdit works on groups of data by transforming a series of user specified time and space windows within the group into the FX domain, identifying spiky traces, editing and interpolating those affected gates prior to transforming the data back. Varying the window dimensions, frequency bands and spike tolerances can have a marked affect on the resultant output.

Typically for Peninsular Malaysia data acquired during the March to October period 2 passes of swell noise removal in the shot record domain is generally sufficient to attenuate the bulk of the swell noise. The first pass targets the low frequency swell, usually 0-16 Hz, while a second pass is used to attack spikes that are usually more sparsely located but higher in frequency. In the Larut project the typical treatment was insufficient. Here 5 passes of FXEdit were required to handle the noise. The first 3 of these were run in channel domain attenuating the bulk of the noise while a further 2 passes were run in the shot record domain with the more typical parameterization.

Figures 2 and 3 show a few shots before and after the full suite of swell noise attenuation has been applied.

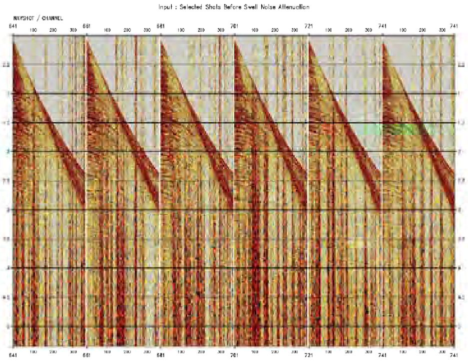

Figure 2 : Selected shotrecords prior to Swell Noise Attenuation.

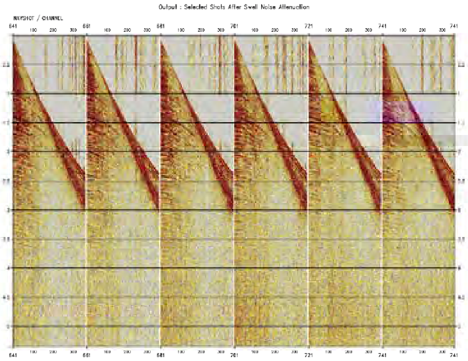

Figure 3 : The same shotrecords after Swell Noise Attenuation.

Conclusions

Our results show that, from a processing perspective, it may be feasible for O&G companies to acquire data beyond the nominally accepted time frame, thus, giving more flexibility in acquisition planning.

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Geophysics Paper 4

TIME-DOMAIN HIGH-RESOLUTION RADON TRANSFORM

Michel Schonewille, Peter Aaron and Carl Notfors
Petroleum Geo-Services (PGS)

Introduction

Multiple attenuation may be classified in two main methodologies; 1) Prediction of multiples from the data itself, and 2) utilizing moveout separation between multiples and primaries. A commonly used version of the prediction approach is the so called SRME technique, where surface related multiples are predicted from the data itself, and at least in principle, does not require any further information. The SRME approach, certainly in its 3D implementation is very computationally intensive, but in recent years with the advent of commodity priced Linux clusters, has become very popular. However, the SRME technique does not work well in shallow marine environments and does not handle interbed multiples, thus there is still a need for approaches based on separation. In this paper we present the method utilizing multiple-primary separation in a tutorial fashion and show its progression from its simplest form in FK space to the latest time-domain Radon high-resolution demultiple.

Multiple attenuation by separation

The early methods utilizing moveout differences were applied in the F-K domain. The procedure was typically to first apply NMO with a velocity slightly slower than the medium velocity positioning primary events in the 2nd quadrant of the F-K domain while multiples which were still undercorrected were located in the 1st quadrant. After zeroing the 1st quadrant the data was inverse transformed. However, decomposing hyperbolic events as dip-components, which is in effect what the F-K transform achieves, does not give good separation, nevertheless the method was used with some success until the mid 80s when Hampson (1986) showed how data could be decomposed efficiently into parabolas. Parabolas are much closer in shape to the hyperbolic shape of events in a cmp gather and after moveout with primary velocity the residual curvature in the data can be described by parabolas very well. In Hampson's method the data is first transformed into the frequency domain and each frequency slice is transformed into the parabolic radon domain. Figure 1 shows the principle of the method, to the left is the data in the time-offset domain, the 2nd frame shows the Fourier transform with the vertical axis being frequency and the horizontal offset, the 3rd frame the parabolic transformation where the vertical axis is frequency and the horizontal curvature while the 4th frame shows the result after the inverse Fourier transform where the vertical axis is now time and the horizontal curvature.

The data in the time-curvature domain clearly shows how the 3 events have been decomposed into their parabolic curvature components and it is clear that the transform has decomposed the data into 3 distinct events which can be muted before the inverse transform. Hampson formulated the parabolic decomposition using least squares, finding the model representation that best match the original data after the inverse transform. In matrix vector notation this may be written as where L is a matrix representing the inverse Radon transform, d is the data and m the model representation. The forward least squares transform is given by: . The matrix L is only dependent on the data geometry and transform parameters, which typically do not change, and so can be pre-computed making this a very fast method.

Although the Hampson method was a vast improvement over the F-K method, Figure 1, frames 3 and 4 demonstrate that events are not distinct and there is a substantial amount of smearing. As long as primaries and multiples are not overlapping this does not present a problem but in geologies where the moveout difference is small between primaries and multiples the smearing will present a problem. In the mid 90s Sacchi and Ulrych (1995) showed how a more high-resolution transform could be computed. The high-resolution Radon transform constrains the inversion by using the inverse of the model space, m, itself as a stabilizing matrix, S, in an iterative fashion: matrix. Since m is the model-space, and it occurs on the right hand side of the equation, it means an iterative scheme must be used.

Figure 2 demonstrates the high-res radon transform. Comparing the 3rd frames in figures 1 and 2 show that the high-resolution transform boosts high amplitudes and suppresses low amplitudes giving better separation in the transform domain.

In the example above there are only 3 events while the example in figure 3 shows 9 events. The 2nd frame shows the standard least squares frequency-curvature space. The nine events are now almost indistinguishable with energy over the entire curvature range making the job of boosting high and suppressing low amplitudes much harder. The 3rd frame of figure 3 shows the curvature-time domain and it is clear that the events in this domain are much better separated, so the idea behind the time-domain high-resolution radon transform is to apply the constraints in this domain rather than the frequency domain. Figure 4 shows the result using the time-domain constraints, the 9 events are now well separated and it would be easy to mute some of them before doing the inverse transform.

Field data example

In Figures 5 and 6 a field data example is shown. The input data has strong aliased multiples, which are a problem for the LS transform. The frequency domain HR transform performs significantly better, but still leaves some aliased energy in the data. The time domain transform removes virtually all aliased multiple energy. The stack is quite effective at attenuating the aliased multiple, but the time domain Radon transform is still visibly better than the frequency domain methods (see Figure 6).

Conclusions

Multiple attenuation using techniques that rely on the move-out differences between multiples and primaries are more effective as the smearing of events in the transform domain is reduced. From the first F-K methods to the Radon transform methods the objective has always been to obtain better separation. The time-domain high-resolution Radon transform presented in this paper shows very good separation and can be a very effective multiple attenuation tool.

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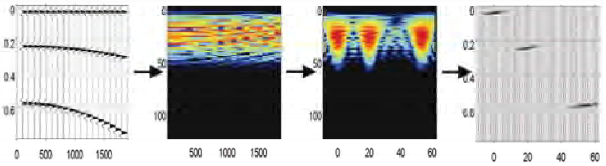

Figure 1. Least squares Radon transform.Frames from left to right shows 1) data in time-offset domain, 2) data in frequency-offset domain, 3) after the curvature transformation in frequency-curvature domain, and 4) after inverse transform in the time-curvature domain..

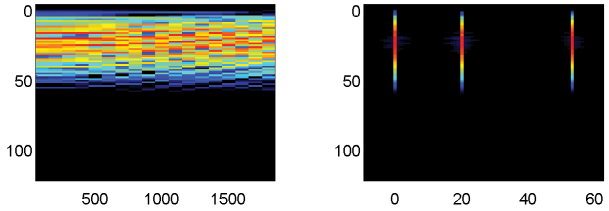

Figure 2. High resolution Radon transform. Frames from left to right shows 1) data in time-offset domain, 2) data in frequency-offset domain, 3) after the high resolution curvature transformation in frequency-curvature domain, and 4) after inverse transform.

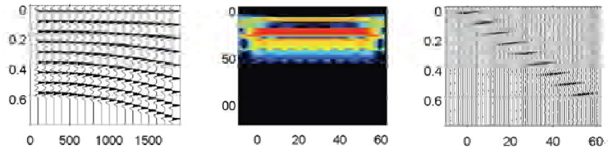

Figure 3. Synthetic with 9 events, the 2nd frame shows the frequency-space domain where much overlap between the 9 events can be seen while the 3rd frame shows the time-curvature domain where the separation is much better.

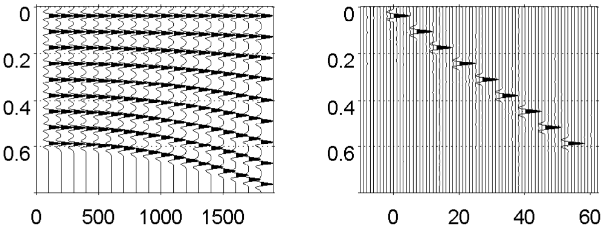

Figure 4. Time-domain high-resolution Radon transform of the 9 event synthetic. Note the very nice separation of curvatures.

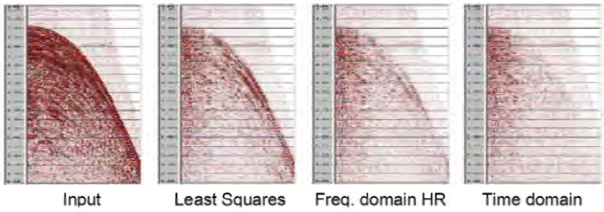

Figure 5. Demultiple results, from left to right: Input CDP gather; least squares Radon; frequency domain high resolution Radon ; time domain high-resolution Radon.

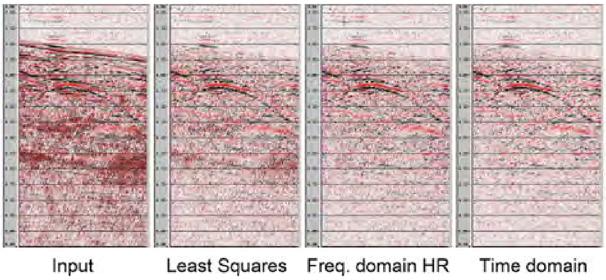

Figure 6. Demultiple results after stack, from left to right: Input CDP gather; least squares Radon; frequency domain high resolution Radon ; time domain high-resolution Radon.

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Geophysics Paper 5

IMAGING OF FRACTURES AND FAULTS INSIDE GRANITE BASEMENT USING CONTROLLED BEAM MIGRATION

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Summary

In this paper, we present a reprocessing case study that applied the latest processing technologies to improve the seismic imaging inside the granite basement reservoir. The highlight of this effort is the application of the latest Controlled Beam Migration (CBM) technology, and a stack sweep method for updating velocity inside the basement.

Introduction

The current study area is in the Cuu Long Basin, offshore Vietnam. In this area, the fractured granite basement forms an excellent reservoir rock, and is the main target of exploration and development activities (Nguyen and Hung, 2004). It is therefore important to image the granite basement with its fractures using seismic methods. However, past effort of imaging has met with difficulties. Two of the main challenges are the poor signal-to-noise ratio inside the basement and the imaging of the steeply dipping fractures. In 2002, a study was carried out in the area using Kirchhoff prestack depth migration, which included horizon-based model building up to the basement and constant velocity sweep below the top of basement. Even with this effort, it was difficult to interpret because the image was contaminated with noise. In particular, it was hard to distinguish the vaguely visible steeply dipping fractures from Kirchhoff migration artefacts.

With recent advances in imaging technology and velocity model building tools, we reprocessed the same data through prestack depth migration, and achieved significant improvements in signal-to-noise ratio and steep dip imaging inside the basement. We present the methodology and results in this abstract.

Methodology

Data preparation

Prior to migration, the acquired seismic data was processed through linear noise removal, demultiple, and fold and offset regularization. It is extremely important to preserve dipping primary energy in data preparation, especially at the stage of linear noise removal. .

Velocity model building and update

Figure 1 shows the lithology and velocity structure of the study area, based on the available information at the start of the project. Water bottom is shallow, approximately 50 meters. For convenience of description, we divide the lithology into three groups. Group one is clastic layers having mostly gradient based velocity, except for a thin layer of velocity inversion that is detectable in sonic logs. Group two is the E sequence, which is also clastic but has a faster velocity. As a consequence, there is a high velocity contrast between group one and group two. Group three is granite. The depth of the top of the granite basement ranges from 2.4 km to 6 km. Sonic log measurements show the granite matrix velocity to be between 5500-6000m/sec. However, the 2002 imaging study found that a velocity of 4600m/sec was more applicable for the migration and stack response of the intra-granite fractures. The initial velocity model was built with the above information in mind.

The velocity update was carried out using tomography that is based on residual curvature analysis (RCA) of Common Image Gathers, in a top-down approach. The method was successful in group one, but met with difficulty on reaching the E sequence. There were two issues. The first was remnant multiples. As the primary reflection was weak below top E, the multiples appeared strong and were the dominant energy (Figure 2). It was therefore impossible to pick the residual curvature correctly. The second issue was in the limitation of RCA tomography itself. The residual curvature of CIG is less sensitive to velocity perturbation at deeper depth.

To continue the velocity update into the E sequence and the granite basement, we resorted to a stack sweep method that was developed for sub-salt velocity update in the Gulf of Mexico. We took the top E horizon as the upper boundary of the stack sweep (Figure 3). The velocity below top E was smoothed and used as the reference velocity, or 100% velocity. Six other velocities were generated by scaling the reference velocity below top E with 83.5%, 89%, 94.5%, 105.5%, 110% and 116.5%, respectively. The seven velocities were used to generate seven CBM (to be introduced later) stacks. We then swept through the seven stacks at each location and depth, and picked the preferred stack (Figure 4). The criterion for picking was based on both the quality of the signal and the geologic plausibility of the structure, so it was necessary to be done by or with the help of an interpreter. After all locations were picked, the picks were smoothed, and then fed into a 3-D tomography program to compute the final velocity (Figure 5).

Migration

Both Kirchhoff and Controlled Beam Migration (CBM) were used in the final migration. Kirchhoff migration was run to image shallow sections and to facilitate the AVO analysis, while CBM was used to image the top of the basement and the fractures inside the basement.

CBM has an advantage of enhancing signal-to-noise ratios and imaging steeply dipping events. In a medium of complex velocity, a subsurface point may have multi-arrivals. A conventional Kirchhoff migration is a single-arrival migration algorithm, representing a high-frequency approximation to the acoustic wave equation. When multi-arrivals occur, it has to select one of the arrivals depending on the specified criteria. This can result in poor imaging. Wave Equation Migration does not use ray paths to represent the propagation of wave fronts, and thus accounts for all arrivals. It produces cleaner images; but it does not image steeply dipping events well. CBM has the advantage of Kirchhoff migration and Wave Equation Migration. It handles multi-arrivals, resulting in a cleaner image than Kirchhoff migration, and preserves the steep dips.

Results and Discussion

The Kirchhoff migration image in the current study is better than the 2002 Kirchhoff image. However, for basement imaging, the major improvement came from CBM. A comparison of 2002 Kirchhoff migration and the current (2006) CBM migration is shown in Figures 6 to 8. The fractures that were barely visible in Kirchhoff migration were clearly imaged with CBM. The top of the basement is also better focused with CBM.

Conclusions

We have presented a case study using Controlled Beam Migration (CBM) to image the top of the basement and the fractures inside the basement. The image quality of CBM is superior to that of Kirchhoff migration.

Acknowledgements

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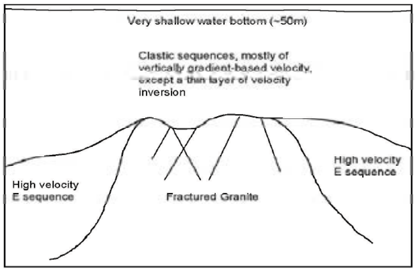

Figure 1: Schematic illustration of lithology and velocity structure.

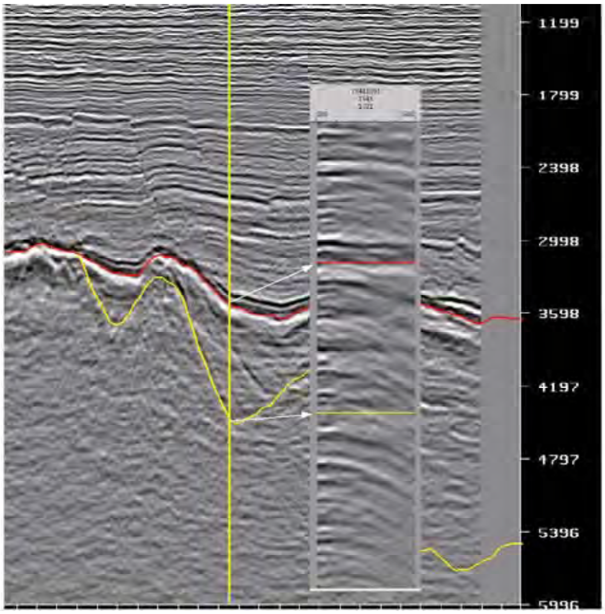

Figure 2: A stack section with a common image gather (CIG) near a highlighted location. Red: top E. Yellow: top of the basement. The multiples are stronger than primaries below top E.

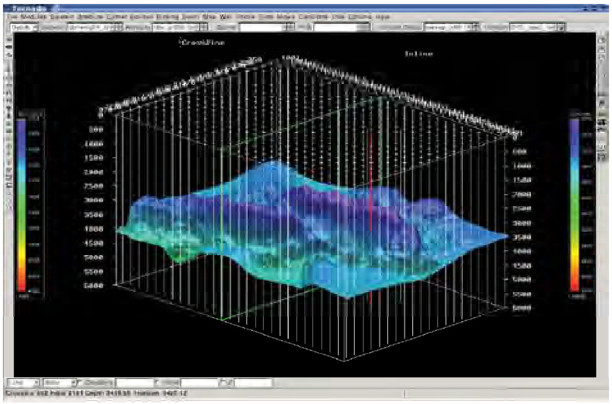

Figure 3: 3D view of the Top E horizon. Stack sweep starts below the top E horizon...

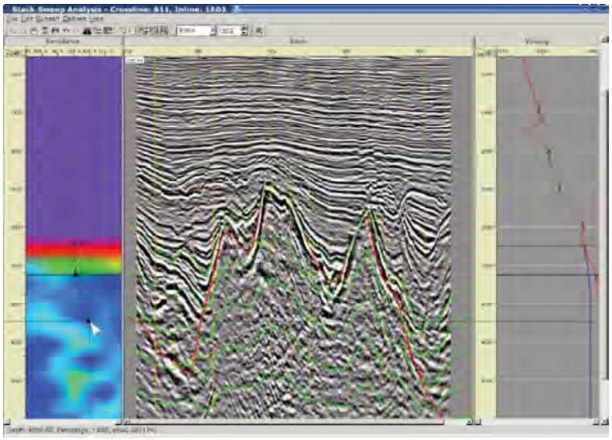

Figure 4: A snap shot of the stack sweep window.

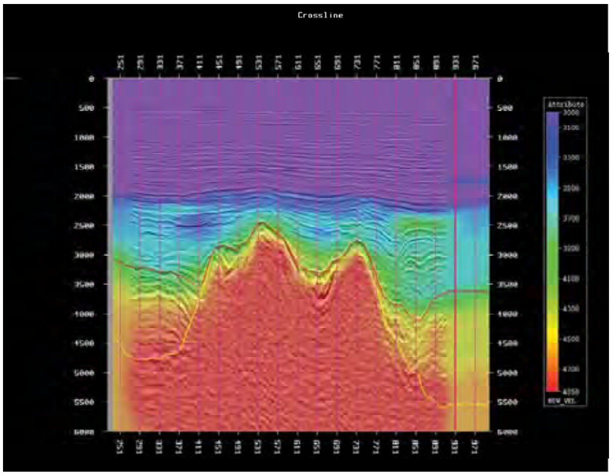

Figure 5: A section of the final velocity model, after stack sweep velocity update.

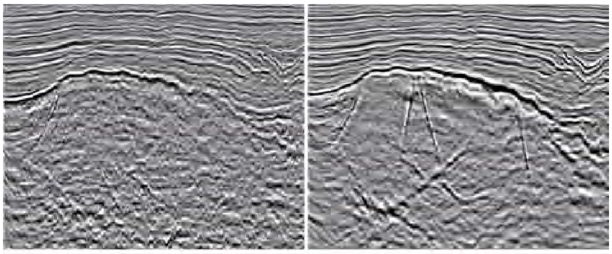

Figure 6: Comparison of 2002 (Left) and 2006 (Right) depth migration on a vertical section.

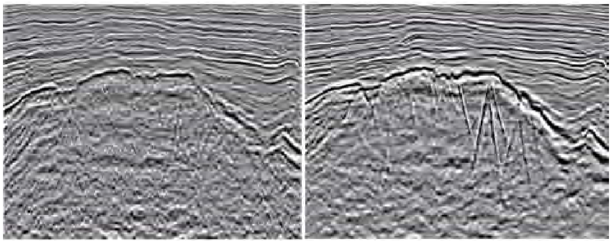

Figure 7: Comparison of 2002 (Left) and 2006 (Right) depth migration on a vertical section.

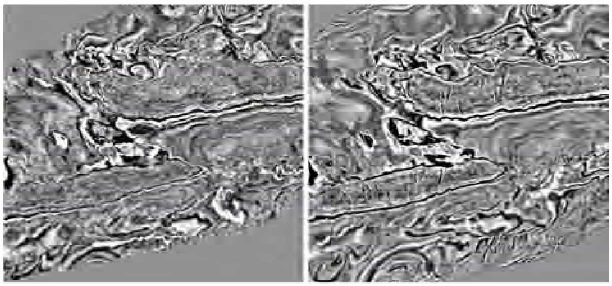

Figure 8: Comparison of 2002 (Left) and 2006 (Right) depth migration on time slices.

Geophysics Paper 6

NMO Application in VTI Media: Effective and Intrinsic Eta

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Summary

NMO or normal move-out is the time shift needed to correct for the effect of offset and velocity in a CMP gather. NMO equations approximate the time shift which would be computed by tracing a ray through a horizontally layered Earth. A few years ago the 2nd order NMO equation, or hyperbolic NMO, was considered adequate in most cases. Today there are many options in the industry to apply higher order NMO which reduces the error in the approximation to the ray traced solution for longer offsets. There are two characteristics which are important when considering the application of a given NMO curve: 1) accuracy, how well the NMO curve approximates the ray traced solution, and 2) stability, how well the curve can tolerate small errors in the estimated velocity field (one would not want small errors in the estimated velocity field to cause large errors in the move-out time calculated).

If the data being processed is isotropic in nature, then the NMO equation will be dependent on velocity, v and offset x. If the data exhibits VTI (transverse isotropy with a vertical axis of symmetry) behavior, where the velocity of acoustic waves traveling horizontally is different from the velocity of acoustic waves traveling vertically, then the parameter η is used in the NMO equation in addition to v and x. Effective η in the NMO equation expressed by Alkhalifah and Tsvankin (1995) is required to correct for both long-offset (non-hyperbolic) and VTI effects in seismic data. Since two effects are being handled by a single parameter, it is difficult to determine if a dataset exhibits VTI behavior solely on the need for an effective η (η_{eff}) parameter to NMO correct the cdp gathers. This leads to ambiguity in the interpretation of η_{eff} when performing velocity analysis and time

imaging. An optimized 6th order NMO equation separates the long-offset terms from the VTI term. The η parameter in this equation is needed only to correct the VTI effects and as such it represents intrinsic η (η_{int}). The use of these two equations has been compared in two case histories. In the first case history, η_{eff} is required but η_{int} is not required. As such, the data exhibits long-offset isotropic behavior. In the second case history, both η_{eff} and η_{int} are required in their respective NMO equations; therefore, the data exhibits VTI.

Introduction

The use of η_{eff} in the NMO equation expressed by Alkhalifah and Tsvankin (1995) to correct for both long-offset and VTI effects in seismic data is well established in the industry. For the purposes of this discussion I will refer to this equation as "Alkhalifah". In cases where VTI exists, the magnitude of η_{eff} required to correct for the long-offset effects versus that needed to correct for VTI cannot be determined. In cases where the data is isotropic (VTI does not exist), η_{eff} is still required to correct for long-offset effects (Alkhalifah 1997). As such, it is difficult to determine if a dataset exhibits VTI behavior solely on the need for an η_{eff} parameter to correct CDP gathers using this equation. The optimized 6th order NMO equation was originally proposed by Sun *et al*. (2002) and can be implemented as an isotropic long-offset NMO correction or a VTI term can be added to correct for VTI effects (Sun and Martinez, 2002). Because the long-offset effects and the VTI effects are handled in separated terms, the η parameter needed for this correction addresses only the VTI and represents η_{int}.

Theory

A ray-traced two-way travel time through a horizontally layered earth can be approximated by Taylor's series expansion (Taner and Koehler, 1969), which, if truncated at the 2nd order term, becomes the familiar hyperbolic NMO equation, equation (1), where x is offset, t_x is the two-way travel time for offset x, t_0 is the zero-offset travel time and v_{nmo} is the NMO velocity.

$$t_x = \sqrt{t_0^2 + \frac{x^2}{v_{nmo}^2}} \qquad (1)$$

Truncating the series at the 4th order term and solving for the coefficients yields the isotropic 4th order NMO equation also known as Long Offset NMO or LNMO.

$$t_x = \sqrt{t_0^2 + \frac{x^2}{v_{nmo}^2} + c_3 x^4} \qquad (2)$$

It is common to say that higher order NMO equations, such as equation (3), handle the "long offset effects" or "ray-bending" which is another way of saying it is a better approximation of the closed form of the Taylor's series expansion.

It is tempting to keep adding terms of the Taylor's series to increase accuracy. While additional terms do increase the accuracy of the equation, they also cause the equation to become unstable. Small errors in the estimation of v and x can cause large errors in tx. This because taking offset, x, to large powers generates very large numbers.

To handle both long-offset errors associated with the truncation of the Taylor series (non-hyperbolic NMO) and errors caused by VTI, Alkhalifah and Tsvankin (1995) use an alternative to the 4th order truncation of the Taylor Series described above, shown here as equation (3).

$$t_x = \sqrt{t_0^2 + \frac{x^2}{v_{nmo}^2} - \frac{2\eta_{eff}\, x^4}{v_{nmo}^2\left[t_0^2 v_{nmo}^2 + \left(1 + 2\eta_{eff}\right)x^2\right]}} \qquad (3)$$

Having offset, x, in the denominator of the 4th order term adds stability to the equation. In equation (3), η_{eff} corrects for errors due to the truncation of the Taylor series (the long-offset effects) and that due to VTI. If η_{eff} were set to zero, equation (4) would become equation (2) as explained in Alkhalifah and Tsvankin (1995). Hence a non-zero η_{eff} would have to be chosen to correct for the long-offset effect irrespective of the existence of VTI. To eliminate this ambiguity and to improve the accuracy of the analytic NMO equation, Sun and Martinez (2002) implemented an optimized 6th order equation with a VTI term, equation (4).

$$t_x = \sqrt{\left(c_1 + c_2 x^2 + c_3 x^4\right)}\left(1 + \frac{C}{2}\,\frac{c_4 x^6}{c_1 + c_2 x^2 + c_3 x^4}\right) - \Delta t_{VTII} \qquad (4)$$

where

$$\Delta t_{VTI} \approx \frac{C_{VTI}\, x^4}{2\sqrt{t_0^2 + \frac{x^2}{v^2}}} \quad \text{and} \quad C_{VTI} = \frac{2\eta_{\mathrm{int}}\, x^4}{v^2[t_0^2 v^2 + (1 + 2\eta_{\mathrm{int}})x^2]}$$

Equation (4) is a 6th order solution to the original Taylor's series where c_k are the coefficients and *CC* is a constant designed to estimate the series' closed form. Like the Alkhalifah NMO equation, optimized 6th order NMO has offset, x, in the denominator of the higher order terms to make it stable. The VTI term is encapsulated in Δt_{VTI}. If we set η_{int} in equation (4) to zero, Δt_{VTI} becomes zero and the equation becomes the isotropic optimized 6th order NMO equation expressed by Sun *et al*. (2002). Hence η_{int} in equation (4) represents intrinsic η and not effective η as in equation (3).

Examples

The first case history is from offshore Brazil in the Santos basin. Here a 3-D true amplitude pre-stack time migration (TAPSTM) was performed using the isotropic optimized 6th order travel time equation described by Sun and Martinez (2002). The isotropic optimized 6th order NMO was removed and a residual velocity analysis was performed using equation (4) and a separate residual velocity analysis was performed on the same data using equation (5). Figure 1 shows a stack of the TAPSTM gathers generated from the velocity analysis using the Alkhalifah equation (equation 4). The stack is overlain by the η_{eff} field determined from the analysis. The magnitude of η_{eff} ranged from 0 to 0.145 with an average of 0.065. The residual velocity analysis using the optimized 6th order NMO equation yielded a null η_{int} field. This would suggest the data is isotropic. A comparison of a single TAPSTM gather moved out with various NMO curves can be seen in Figure 2. Here the gather was first moved out with a 2nd order NMO equation (Alkhalifah NMO with a null η_{eff} field); the classic "hockey sticks" seen on the far offsets might be interpreted as VTI effects. The next gather in Figure 2 is the same gather with an isotropic 4th order NMO applied. Here the data has been corrected and the "hockey sticks" are no longer evident. The 3rd and 4th gather is the same gather moved out with Alkhalifah using the picked η_{eff} field and optimized 6th order NMO using a null η_{int} field respectively. The 4th order NMO, Alkhalifah and optimized 6th order NMO gave commensurate results, which is further evidence that the data is isotropic.

The second case history is from offshore West Africa. As in the example from offshore Brazil, the data was migrated using TAPSTM and then the original velocity function was removed using inverse NMO. A velocity analysis was performed on a single CDP line using both Alkhalifah and optimized 6th order NMO with the VTI term. The results of this analysis can be seen in Figure 3. Figure 3(a) shows the stacked seismic line underlying the picked η_{eff} field using the Alkhalifah NMO equation. The average η_{eff} from this analysis was 0.057. Figure 3(b) shows the same stacked line underlying the picked η_{int} using the optimized 6th order NMO equation. The average η_{int} from this analysis was 0.012. The values of η_{eff} from the West Africa example are larger in magnitude and broader in range than that exhibited by η_{int} for the same data.

Figure 4 shows a single TAPSTM gather from the West Africa example moved out with 2nd order NMO, 4th order NMO, Alkhalifah and Optimized 6th order NMO. The 2nd and 4th order NMO do not adequately correct the gather. Alkhalifah corrects the gathers to a greater extent and the optimized 6th order NMO improves the gather slightly further. An example of this improvement can be seen on the event circled in red in figure 4. The improvement of the optimized 6th order NMO over Alkhalifah is attributed to greater accuracy of the long-offset component of the optimized 6th order NMO equation.

Conclusions

Effective η as required by the Alkhalifah NMO equation is used to address both long-offset effects due to the truncation of the Taylor series expansion and VTI. This leads to ambiguity in the interpretation of η_{eff} when performing velocity analysis and time imaging. The optimized 6th order NMO equation separates the long-offset terms from the VTI term. This allows for intrinsic η analysis in areas exhibiting VTI and isotropic velocity analysis in areas where only the long-offset effects are evident. The η_{int} fields generated from optimized 6th order NMO velocity analysis tend to exhibit smaller values with tighter distributions than that of η_{eff} generated from Alkhalifah NMO velocity analysis. This is due to the separation of the long-offset NMO and VTI effects in the optimized 6th order equation.

Acknowledgments

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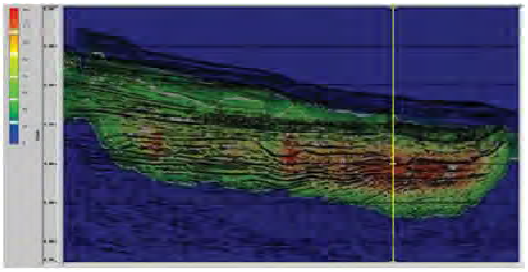

Figure 1: ηeff field underlain by the TAPSTM stacked subline from offshore Brazil. Values of η_{eff} range from 0 – 0.141. The η_{eff} field was determined by residual migration velocity analysis using the Alkhalifah NMO equation.

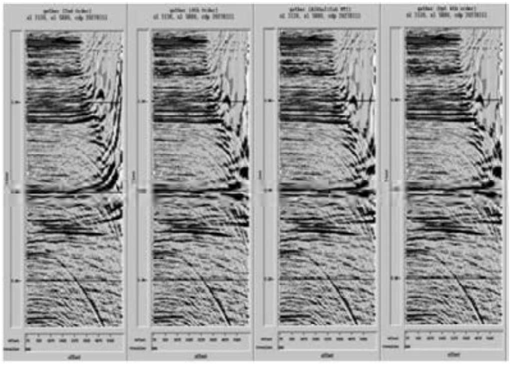

Figure 2: Unmuted TAPSTM gather from offshore Brazil moved out with 2nd order NMO, 4th order NMO, Alkhalifah NMO using ηeff and isotropic optimized 6th order NMO respectively.

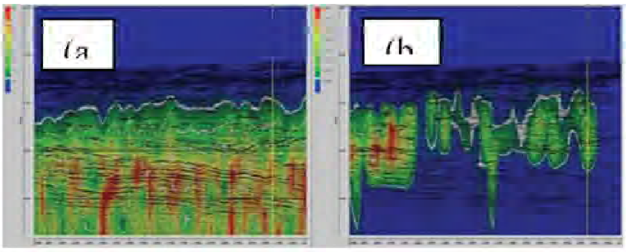

Figure 3: (a) □eff field underlain by the TAPSTM stacked subline from offshore West Africa. The range of □eff values are 0 – 0.125. The □eff field was determined by residual migration velocity analysis using the Alkhalifah NMO equation.
(b) □int field underlain by the TAPSTM stacked subline from offshore West Africa. The range of □int values are 0 – 0.035. The □int field was determined by residual migration velocity analysis using the Optimized 6th Order NMO equation.

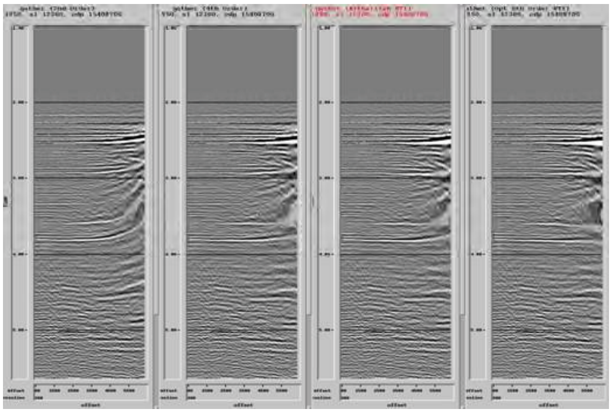

Figure 4: TAPSTM gathers from offshore West Africa moved out with 2nd order NMO, 4th order NMO, Alkhalifah NMO using □eff and isotropic optimized 6th order NMO using □int respectively. The event circled in red shows improved flattening using the Optimized 6th Order NMO correction with the □int.

Geophysics Paper 7

GEOPHYSICAL ISSUES AND CHALLENGES IN MALAY AND ADJACENT BASINS

Deva P. Ghosh
PETRONAS Research Sdn Bhd

Although seismic method has been successfully in the Malay, Sarawak and Sabah basins for quite sometime, there are many geophysical issues that are not well understood or fully resolved. Some of the problems are structurally related whereas the rest are related to interpretation of amplitudes. Of the most complex problem is the gas wipe out issues. Many of our reservoirs suffer from shallow gas leakage and are difficult to image. The easiest way to resolve this problem is the use of shear wave through Ocean Bottom Cable (OBC) technology. However it is quite expensive and most of operators are reluctant to use the technology. An alternative but less effective way is to better focus the P-wave energy by considering approaches like compensation for absorption and or internal scattering within the gas body. Another imaging issue is the fault shadowing problem in many tectonically disturbed areas (Sabah) which gives poor imaging in key zones below the fault. Seismic wave propagation in Malay basin is complicated. In the most cases pay-beds are thin in the seismic tuning range so the earth behaves as an "effective media". Wave propagation in this "media" is different and needs to be understood better. In terms of relationship between amplitude to hydrocarbon prediction certain ambiguities arise from amplitude response caused by lithology or those by pore fill. Further spurious amplitude and AVO responses may come from soft shales and hard shales; coal layers and brine soft sands. Ambiguity of equivalent response in seismic inversion is a very common pitfall. For example: A poor quality sand with gas might give similar response as high quality sand with brine within errors of uncertainties and noise. ome of these issues will be addressed and certain solution suggested.

Geophysics Paper 8

EXETER MUTINEER – CASE STUDY OF AN INTEGRATED PROJECT FROM SEISMIC SURVEY DESIGN TO INVERSION

Tim Bunting, Richard Patternall and Frazer Barclay
Western Geco

In 2006 WesternGeco acquired a seismic survey for Santos, to image the Exeter Mutineer field on the North West Shelf of Australia. Although the field has been in production since 2003, the understanding of the reservoir is limited. Existing seismic was of marginal quality and did not deliver the subtle detail required to understand the complexities of the Exeter Mutineer reservoir. The new seismic has delivered significant up-lift in resolution over the existing seismic. This case study will initially discuss the background and drivers for the new acquisition and then look into how the combination of high end acquisition technology and the integrated approach delivered value to the oil company.

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Geophysics Paper 9

COMPARATIVE ANALYSIS OF SIMULTANEOUS INVERSION RESULT WITH ELASTIC INVERSION AND AVO ENVELOPE IN SUMANDAK FIELD

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Direct hydrocarbon indicators play a very important role for prospect identification. The seismic amplitude based hydrocarbon indicators derived only from seismic information are qualitative and inherited with the tuning and other noise artifacts. There are several techniques to derive hydrocarbon indicators from the integration of well and seismic amplitude information. In the present study, a comparative analysis of Amplitude Variation with Offsets (AVO) envelope, Elastic inversion and Simultaneous inversion results has been carried out in the Sumandak field. The interpretative analysis of simultaneous inversion results indicates that the reservoir can be predicted more accurately with LambdaRho-Vp/Vs attributes volumes in comparison to AVO envelope and EI results. It has been concluded that some of the AVO features are unconformable with structure; however, the simultaneous inversion results are conformable to geological structures which boosts the confidence to use the simultaneous inversion result instead of AVO envelope and Elastic inversion for quantitative interpretation.

AVO envelope

AVO envelope is defined as the square root of the sum of the squares of each data value and its quadrature (the 900 phase shifted version of the recorded signal). It is derived from Hilbert transform of near and far angle stacks and affected due to tuning and other artifacts in the angle stacks and therefore, is phase independent. AVO envelope can provide qualitative information only (Hall et al., 1995) about reservoir properties because it neither integrates well data nor account variation in wavelet/frequency with offset/angle. This is a very common problem which leads to false anomalies associated with AVO tuning. To reduce these artifacts, the seismic data is filtered back to the lowest common denominator, resulting in loss of information. Many AVO failures are largely due to excessive reliance on a single hydrocarbon indicator and lack of proper rock physics understanding in the area.

Elastic impedance inversion

The introduction of the elastic impedance (EI) concept in the late 90's (Connolly, 1999) was a significant improvement in the use of seismic AVO attributes and increased the accuracy of lithology, fluid and porosity prediction in oil exploration and reservoir characterization. In the implementation of elastic inversion, however, severe assumptions were made, such as a constant Vp/Vs ratio and arbitrary scaling factor to match at well location. The elastic impedance derived from inversion of angle stack incorporates several approximations and does not have physical relationship with reservoir properties. Therefore, EI being an angle dependent quantity can not be used directly for quantitative interpretation. Several elastic impedances from more than one partial stacks are combined to estimate angle independent acoustic impedance, shear impedance and Vp/Vs which provides a poor match (large misfit) between seismic data and the synthetic seismic computed from the elastic inversions. It indicates that the seismic data has not been fully utilized in the calculation of the angle independent quantities. This fact almost never displayed or quantified although it is a very important issue.

Simultaneous inversion

In simultaneous inversion all angle stacks are simultaneously inverted to obtain acoustic impedance, shear impedance and density (Pendrel et al., 2000; Ma, 2002). Figure 1 represents the workflow for computation of AVO envelope, elastic inversion and simultaneous inversion. Independent wavelets are estimated for each partial stack to capture the amplitude, frequency and phase between the different angle stacks and therefore, no scaling, phase rotation or frequency balancing is required. Simultaneous inversion has all the advantages of elastic inversion and overcome most of the disadvantages of elastic inversion.

Result and discussion

AVO envelope, elastic inversion and simultaneous inversion analysis were carried out in Sumandak field (Figure 2a) located in the footwall of Morris fault, offshore Northwest Sabah, Malaysia. The producing intervals are Stage IV-C reservoir in the Miocene prograding delta complexes. Figure 2b shows acoustic impedance and Vshale log curves which indicate that low impedance represents sands in the study area. Therefore, high negative amplitude, low impedance, low Vp/Vs and low LambdaRho will represent sands. Figure 3 shows the time structure map of the reservoir top along with amplitude maps (from Full stack and Far stack) and AVO envelope. In present analysis, 80ms down time window from the top of the time structure map (Figure 3a) has been considered for computation of all the attributes discussed herein. It can be noted from Figure 3 that full stack, far stack and AVO envelope shows amplitudes channel features (white polygon) which are not conformable to the structure.

Figure 4 shows elastic inversion and simultaneous inversion result. The channel feature observed on seismic amplitudes AVO envelope (Figure 3) is not there on elastic inversion and simultaneous inversion output. It indicates that inversion results are more reliable in comparison to AVO envelope affected due to tuning. However, shear impedance estimated from elastic impedance inversion indicate high shear impedance (Figure 4d- black ellipse) corresponding to a structural high and low impedance values from simultaneous inversion. There are several disadvantages of elastic inversion in comparison to simultaneous inversion and will be presented in detail. Further attribute analysis of elastic and simultaneous inversion has been carried out. Figure 5 compares Vp/Vs and LambdaRho from elastic inversion and simultaneous inversion. Structural conformable amplitudes validated with well results are more accurate for simultaneous inversion in comparison to elastic inversion. The Vp/Vs ratio from elastic inversion varies from 1.4 to 3.5 in the reservoir interval is not justifiable with rock physics. At the same time, the Vp/Vs ratio does not match with the well data and has very small contrast with the background for one of the structure (Figure 5b: red circle). Similar feature in south-eastern corner of the study area has been observed for Vp/Vs as well as LambdaRho maps. The validation at well locations in the study area indicates that simultaneous inversion results are more accurate in comparison to the AVO envelope and elastic inversion.

Conclusion

The quality check and validation of reservoir property with AVO envelope is very qualitative at well locations; however, it can be done for elastic inversion and simultaneous inversion outputs. Structural conformable flat spots have been observed in the study area and tied with presence of hydrocarbon at well locations through simultaneous inversion. However, it is difficult to correlate the observed AVO effects with reservoir presence or effectiveness. The combination of acoustic impedance and shear impedance, Vp/Vs and the LambdaRho derived from simultaneous inversion of all the angle stacks, has physical relationship with reservoir properties and used for quantitative interpretation for further application.

Acknowledgment

The author thanks the management of PETRONAS Carigali Sdn Bhd (PCSB), Malaysia, for their support and permission. My special thanks go to Ms Rashidah Bt. Karim, Head of XTG Department, PCSB, for her encouragement and continuous support throughout the project work.

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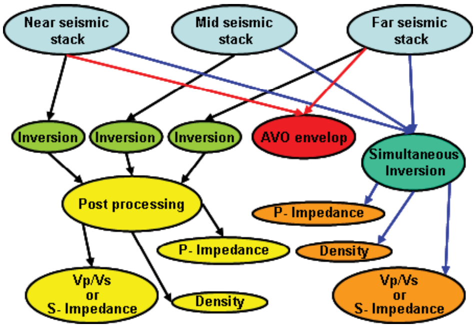

Figure 1: Workflow for AVO envelope, Elastic impedance and simultaneous inversion.

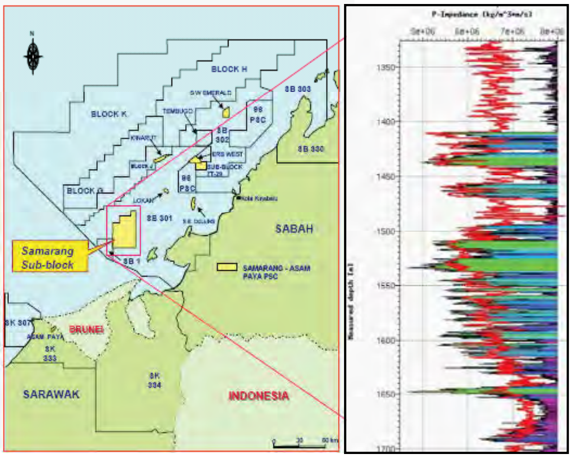

Figure 2: (a) Location map of the study area. (b) Representative well log view shows vshale (black – variable color fill) and acoustic impedance (red) curves. Sands (green) are represented with low acoustic impedance in the study area.

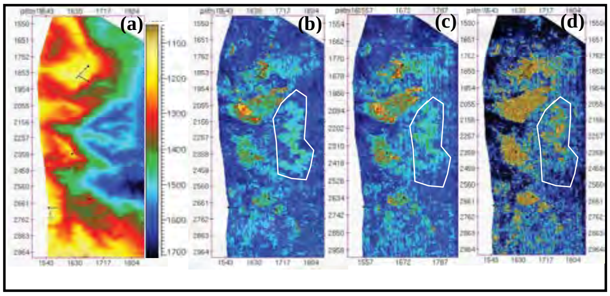

Figure 3: (a) Time structure map at the top of the reservoir. (b) Minimum amplitude map of full stack seismic data. (c) Minimum amplitude map of Far seismic stack. (d) AVO envelop map calculated from near and far seismic. Yellow to blue represents sand to shale correspondence..

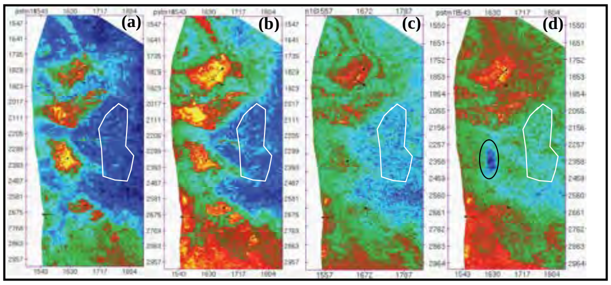

Figure 4: (a) Far angle elastic impedance map from elastic inversion. (b) Acoustic impedance and (c) Shear impedance from simultaneous inversion (d) Pseudo shear impedance calculated from different elastic impedances. Yellow to blue represents low to high impedance values.

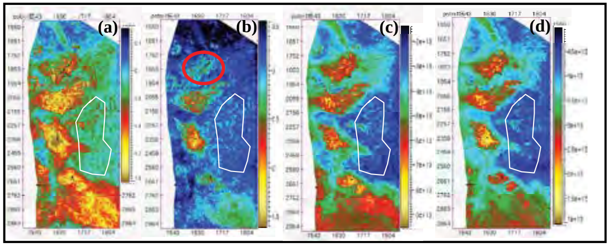

Figure 5: (a) Vp/Vs ratio from simultaneous inversion. (b) Pseudo Vp/Vs from elastic inversion. (c) LambdaRho from simultaneous inversion. (d) Pseudo LambdaRho from elastic inversion

Geophysical Paper 10

3D CLOSE-THE-LOOP: RECONNECTING RESERVOIR MODELING TO THE SEISMIC DATA

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Introduction

Integrated reservoir modeling is a challenging task and in order to ensure the best possible model(s) it must honor all available subsurface data. Successful modeling studies require that all subsurface disciplines are involved throughout the whole process and are QCing the model in the context of all available data.

Good quality seismic data is available for many fields and should be fully used in reservoir modeling. We are proficient in incorporating the interpretation of horizons and faults from the seismic data into the model framework. On many occasions seismic inversion products (for example, acoustic impedance volumes) are used to guide the distribution of reservoir properties, like Porosity or Net-to-Gross, throughout the model. Care is taken to QC the model to ensure consistency with the petrophysical data at the well locations and the geologic concept (distribution of facies, properties, and shapes). But the seismic response of a model was not compared to the actual seismic data.

Discussion

A model must be checked with all the input data to ensure consistency. These checks – the idea behind "Close-the-Loop" – are described for seismic data in Figure 1. The seismic response is a natural integrator of the information contained in a static reservoir model. Models consist of layers of a given thickness. Within these layers a geologic concept is used to determine a distribution of facies. Facies have different reservoir properties, like Porosity or Net-to-Gross. Or an alternative is that these reservoir properties are distributed throughout the model using geostatistical methods. Reservoir properties are related to acoustic properties (Vp, Vs, and Density) based on measured and interpreted well log data. Then, finally, the seismic response can be generated from the resulting layering and acoustic properties for comparison with the actual (measured) seismic data.

The seismic response can be divided into two components – the time thickness (relative time between seismic loops) and the seismic character (waveform shape and amplitude). The time thickness is primarily dependent on the thickness of layers, whereas the seismic character is primarily dependent on the properties. These two components are used when comparing synthetic seismic to actual seismic to determine appropriate updates to the model.

A 3-step approach has been adopted to evaluate the seismic match. Each step requires increased conformance of the model with the seismic and, therefore, can be applied appropriately based on the quality of seismic data.

1. Does the top and base of the model honor the seismic time interpretation and/or actual seismic loops? Does the model fit within the total time thickness allowed? Verify total thickness of model.
2. Do the internal layers of the model honor the seismic time interpretation and/or are aligned with the proper seismic loops? Verify thickness of internal reservoir units.
3. Is the synthetic seismic character (waveform and amplitude) generally consistent with the actual seismic? Verify values and distribution of reservoir properties.

If the appropriate criterion is not met, changes are made to the model and the updated model is checked again. The objective is not a perfect match to the seismic, but to identify and fix the obvious mismatches.

As an example, Figure 2 shows the synthetic seismic generated from a stacked reservoir interval that consists of amalgamated channels and their associated facies. Note the rapid lateral variation in seismic character in the synthetic (right panel) that is not observed in the actual seismic data. It is even difficult to recognize the reservoir units in the synthetic data. After further discussion, it was determined that the clean sand porosity in the different facies does not have as much variability as originally

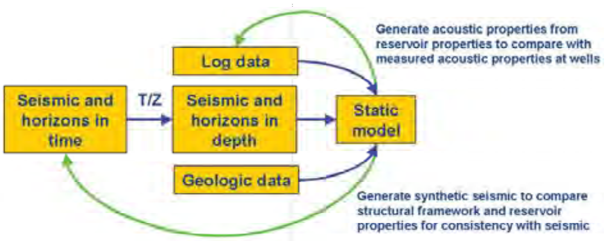

Figure 1. This cartoon illustrates a generic workflow that incorporates seismic, well log and geologic data to build a static model. The resulting model is compared – "Close-the-Loop" – with the data that was used as input. These (green) loops focus on the acoustic properties.

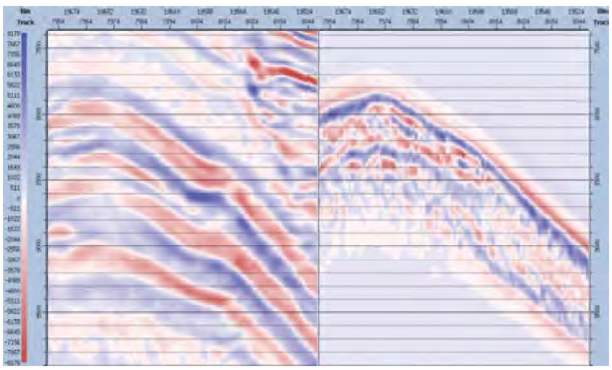

Figure 2. Comparison of synthetic seismic from model with initial facies properties (right) and actual seismic (left) – display is in depth (ft) and the seismic is displayed as pseudo-impedance. This model has a poor character match to the actual seismic.

put in the model. After applying this new geologic concept, synthetics were again generated and they give a better character match as seen in Figure 3. This new geologic concept is more consistent with the measured seismic data.

Figure 4 shows an example of a good match in both time thickness and seismic character. This degree of consistency (in the layering, geologic concept, and reservoir properties) can be obtained when using 3D Close-the-Loop as part of the modeling workflow.

Conclusions

Including 3D Close-the-Loop in the modeling workflow has provided an added dimension of integration that has allowed the identification of modeling inconsistencies that were not caught by other QC steps. The resulting seismic match provides a more realistic view of overall consistency of the model with the input data.

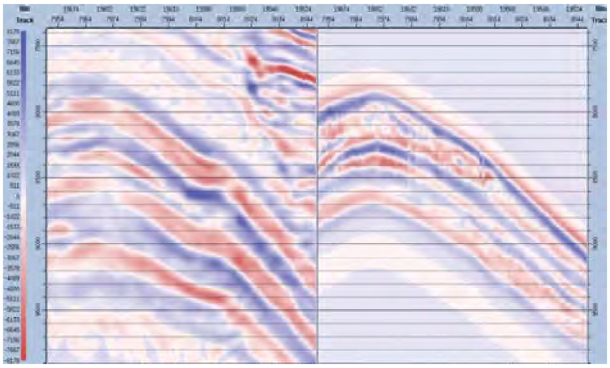

Figure 3. Comparison of synthetic seismic from revised facies properties (right) and actual seismic (left) – display is in depth (ft) and the seismic is displayed as pseudo-impedance. This model gives a much better character match to the actual seismic.

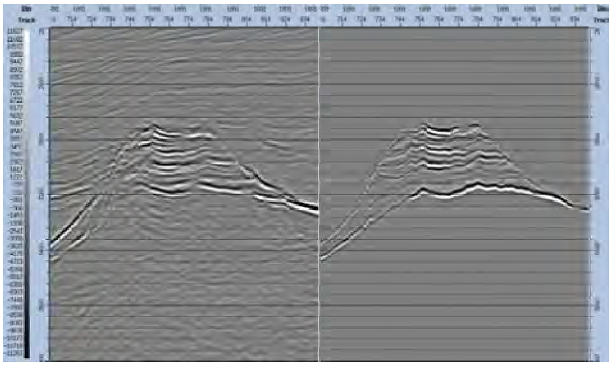

Figure 4. Comparison of synthetic seismic from reservoir model (right) with actual seismic (left). The match is good – though not perfect – providing a more realistic assessment of the reservoir model.

Geophysics Paper 11

ELASTIC IMPEDANCE INVERSION FOR RESERVOIR DELINEATION – A QUANTITATIVE INTERPRETATION CASE STUDY IN THE MALAY BASIN

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CARIGALI-PTTEPI Operating Company Sdn Bhd (CPOC)

This case study focuses on development well targeting using the methodology of elastic impedance inversion to identify effective seismic attributes for delineating thin gas sands formed in a tidal environment with massive coal-beds. The study area is located in the Malaysia-Thailand Joint Development Area (MTJDA) to the north of the Malay Basin. The reservoir sands, statistically are less than 10 meters and inter-bedded with coals (Figure 1). Seismically, the reservoir sands are below seismic tuning thickness resolution and strong coal reflections interfere with the conventional post-stack seismic data.

A comprehensive workflow based on pre-stack elastic impedance inversion was developed to address the aforementioned effects and gain more value from the seismic data. The workflow includes three key steps: modeling, processing and interpretation.

Modeling: Rockphysics and seismic modeling, to understand the reservoir behavior and seismic response

Based on rockphysics and seismic modeling (Figure 1), Vp/Vs related seismic attributes (i.e. Poisson's Ratio) are effective for discriminating gas-sand from coal reflections. Using conventional Amplitude Variation with Offset (AVO) attribute based on seismic reflectivity to interpret thin reservoirs inter-bedded with coals is difficult. Relative Poisson's Ratio (RPR) based on Elastic Impedance (EI) inversion is potentially the most effective attribute (Figure 2).

Processing: Pre-stack seismic data conditioning and elastic impedance inversion, to generate effective "AVO" attributes. Data conditioning processes include unload terabyte pre-stack seismic Normal Move-out (NMO) gathers from tapes to super-gathers for enhancing the signal-to-noise (S/N) ratio; transform super-gathers into angle-gathers for true Amplitude Variation with Angle (AVA) processing; band pass filtering to mitigate noise; trim static to align seismic events; and offset scaling to balance the amplitude. Figure 3 demonstrates the improvement of data quality.

Elastic impedance inversion utilizing the colored inversion methodology (Blache-Fraser, 2004) gives good performance and uses the conditioned pre-stack data as input. Fig-4 shows the dramatically improved seismic resolution and interpretability of elastic impedance inversion stack (i.e. dominant frequency increased from 35 to 60 Hz).

Based on elastic impedance gathers, conventional AVO technology is adopted to generate post-stack attribute volumes. The attributes include Relative Acoustic Impedance (RAI, AVO Intercept, Fig-4b), Gradient Impedance (GI, AVO gradient), Relative Shear Impedance (RSI) and Relative Poisson's Ratio (RPR, Figure 5) etc.

Interpretation: Reservoir interpretation and attribute mapping

Using the elastic inversion results, 38 reservoir horizons were interpreted with volume tracking based on stratal-slices. Horizon attribute maps were extracted using 12 ms window length for reservoir delineation and property prediction. Fig-6a reveals the gas sand distribution using Relative Poisson's Ratio attribute. Fig-6b shows the correlation between RPR attribute and water saturation of 0.65.

The main conclusions from this case study are post-stack seismic attribute indicates strong coal reflections instead of gas sands; Poisson's Ratio is an effective attribute for discriminating gas sands from coal beds; seismic data quality can be improved by conditioning pre-stack gathers; elastic inversion can improve seismic resolution and interpretability; and setail reservoir delineation is feasible by using elastic inversion technology

Acknowledgement to CPOC, Malaysia-Thailand Joint Authority (MTJA), PETRONAS Carigali Sdn Bhd and PTTEP International Ltd. for the support of this study and their permission to present this paper.

Reference

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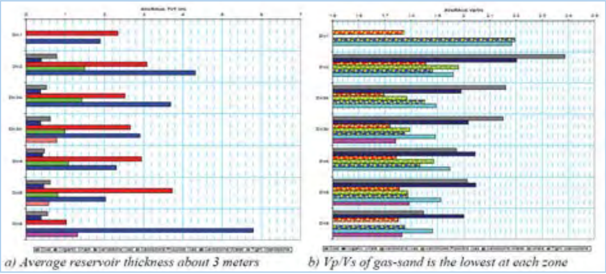
a) Average reservoir thickness about 3 meters *b) Vp/Vs of gas-sand is the lowest at each zone*

Figure 1: Statistics grouped by reservoir zones, showing thin gas sands can be discriminated from others using Vp/Vs ratio.

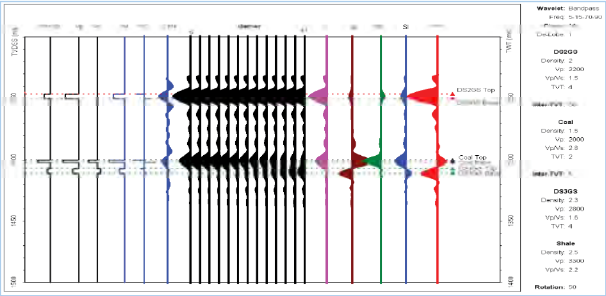

Figure 2: Seismic modeling showing Poisson's Ratio is an effective attribute to identify thin-gas-sands.

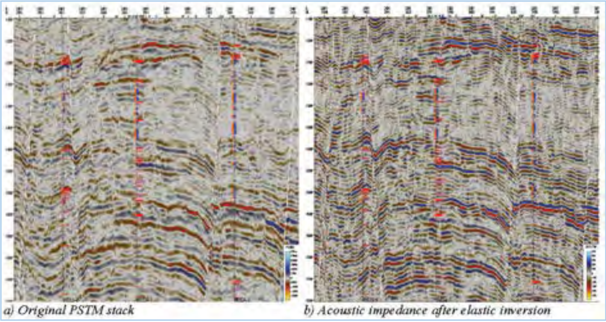
a) Original PSTM stack *b) Acoustic impedance after elastic inversion*

Figure 3: Pre-stack seismic data conditioning and elastic inversion.

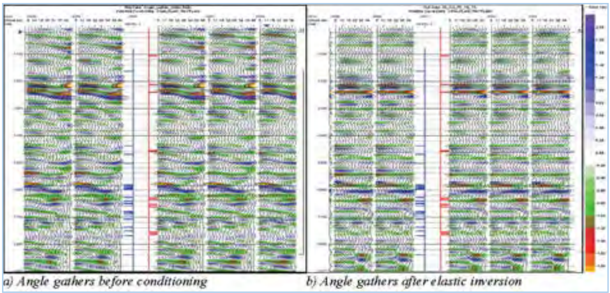
a) Angle gathers before conditioning *b) Angle gathers after elastic inversion*

Figure 4: Data conditioning and elastic inversion improve seismic resolution, S/N ratio and interpretability.

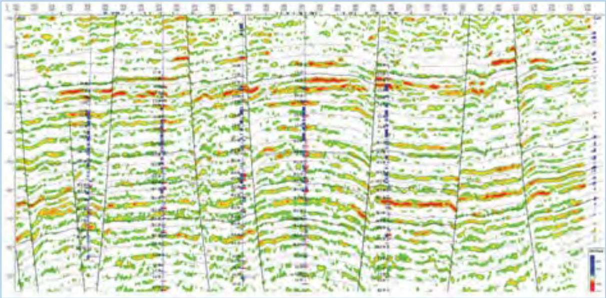

Figure 5: Detailed reservoir interpretation with RPR reveals gas-sands and mitigates coal beds.

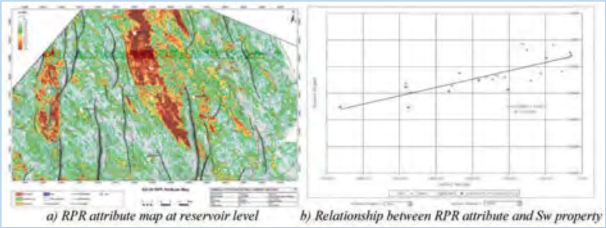
a) RPR attribute map at reservoir level *b) Relationship between RPR attribute and Sw property*

Figure 6: RPR attribute map and reservoir property Sw prediction, correlation at 0.65.

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Geophysics Paper 12

INTEGRATED GEOLOGICAL AND GEOPHYSICAL ANALYSIS BY HIERARCHICAL CLASSIFICATION: COMBINING SEISMIC STRATIGRAPHIC AND AVO ATTRIBUTES

ALEXIS CARRILLAT[1], TANWI BASU[1], RAUL YSACCIS[1], SHYE AIK CHONG[1],
AMIRUDDIN MANSOR[2] AND MARTIN BREWER[2]
[1]Schlumberger, [2]PETRONAS Carigali

Summary

Seismic attributes analysis and classification for exploration and reservoir characterization have been widely published. Applications vary from standard horizon-based facies classification maps to more recent 3D multi-attribute facies classification volumes. The approach is usually the same and run in a two-step procedure. First, an unsupervised classification aims at revealing the natural clustering of the data, and second, a supervised scheme is applied where training and validation data are used to redefine the class cloud point centers based on well log data flagging a specific fluid or lithology.

The limitations of these approaches are that they are focused on one aspect of the seismic response, usually fluid, and tend to neglect the geological framework. In these workflows, more attention is put on the reservoir facies for fluid and potential lithology detection, while the seismic seismostratigraphic signature is overlooked or not used as a constrain in the attribute analysis.

We present a case study in which both texture facies and fluid prediction are linked by performing a hierarchical classification and estimation scheme whereby a multiattributes volume, which captures seismic stratigraphy and texture information, is combined with AVO attributes to map fluid response into a single, coherent seismostratigraphic and reservoir facies volume. This methodology is applied for exploration data screening in offshore Borneo in the Greater Samarang sub-block (East Baram Delta, offshore Sabah, Malaysia). In this case study, geological framework, seismic geomorphology, seismic stratigraphy, and combined fluid response from AVO data calibrated with well data facilitate the development of new play concepts in the highstand system tracts and in the morphology generated by incisions in the shoreface deposits during the low stands.

Introduction

Classification of seismic attributes has been employed in the petroleum industry for about 15 years, using methods either based on artificial neural networks (ANN) (McCormack, 1991) or statistics such as Bayesian classification (Sonneland et al. 1994). Although initially focused on classification of horizon-based attributes derived from the Hilbert's transform of the seismic trace, we have recently seen a growing number of approaches where seismic 3D volume attributes are blended or combined to produce "hybrid," "multiattribute" seismic facies, or "meta-attributes" (e.g., de Rooij and Tingdahl, 2002). In addition, recent 3D applications have been steered towards seismic texture attributes, also called multitrace attributes, for 3D seismic facies characterization. These attributes work regardless of the: dip of the reflectors, data frequency or the rotation, or transition and scale of the attributes (Randen et al. 2000). They allow seismic geomorphology studies and/or supervised 3D seismostratigraphic mapping that fully honor the stratigraphic and geometric data. As a result, these approaches tend to preserve the depositional and structural information captured in the seismic data and, thus, the 3D shape, relationship, and connectivity of the potential geobodies.

There are number of constraints evident when performing classification of seismic attributes, related to inherent limitations of the method. Some of these are addressed in this case study:

1. Seismic facies classification results are generally discrete values.
2. When running seismostratigraphic mapping from 3D stratigraphic or texture attributes, the lithological and fluid response aspect is preferably absent or not fully considered.
3. Conversely, when multiattribute analysis is performed to map reservoir properties, seismic geomorphology and seismic stratigraphic facies are not directly incorporated.

We address these limitations by generating an unsupervised multiattribute volume that captures seismic stratigraphy and texture information as a discrete set of seismic facies. This seismic texture volume is then combined in a systematic way with AVO attributes to map fluid response by a hierarchical classification-estimation scheme based on a relationship identified between the AVO attributes and the water saturation from log data. The final result is a single, coherent volume that incorporates both seismostratigraphic and reservoir facies information.

3D stratigraphic/texture attributes

An important obstacle to automated interpretation of seismic stratigraphy or texture is that it is necessary to overcome the potential impact of local variation in the dip/azimuth of the reflectors. An interpreter would intuitively incorporate this into the interpretation as he/she follows a set of reflectors across a seismic section visually. To automatically replicate this procedure, a computation is made of the dip and azimuth throughout the data volume. This information is incorporated in the multitrace attributes to guide the 3D seismic texture analysis through the data volume (Randen et al. 2000). This approach is comparable to the way in which seismic reflection data is analysed by an experienced interpreter.

There are essentially two main categories of 3D texture attributes (Carrillat et al. 2002). The first includes texture attributes that portray kinematic features of the seismic traces, such as local orientation, signal discontinuity, or unconformity. The second category includes generic texture attributes that capture dynamic features in the seismic signal, such as spectral representations or amplitude behavior.

3D seismic attributes classifications

Unsupervised classification with ANN is performed using both kinematic and dynamic texture attributes to generate the seismic texture volume. The final combination of texture attributes includes chaos, gradient magnitude, flatness, and spectral attributes that capture the main four seismic reflection facies observed in the data (Figure 1):

1. Laterally continuous, parallel seismic reflection facies showing good reflectivity and low heterogeneity of the trace. This class is interpreted as sand-prone (beige class in the texture facies cube).
2. Laterally continuous to subparallel facies with relatively good reflectivity contrast, low frequency, and low seismic heterogeneity of the trace. This class is interpreted as sand-prone (green class in the texture facies cube).
3. Laterally semicontinuous to wavy seismic reflection facies showing poor reflectivity contrast. This class is interpreted as shale-prone (grey class in the texture facies cube).
4. Laterally discontinuous to chaotic seismic reflection facies showing poor reflectivity contrast. This class is interpreted as shale-prone (light blue in the texture facies cube).

The supervised classification of seismic attributes is a natural follow-on step to the unsupervised classification; in which the ANN is guided by training data established from existing well log responses. In this study, we have used a hierarchical supervised classification-estimation scheme to honor the results from the texture volume and combine them with AVO attribute information. Hierarchical means that existing classes defined during the unsupervised classification step are refined by further segmentation (hierarchy) based on a new set of seismic attributes. This hierarchical classification scheme enables the combination in a systematic way of the poststack texture attributes with partial-stack attributes, in our case study with near-stack, far-stack, and scaled AVO cube (far*(far-near scaled).

In other words, the unsupervised multiattribute-based texture facies volume has defined "containers" that are populated with new information derived from the seismic-offset attributes based on a relationship established between seismic AVO attributes and log data.

In this study, crossplot analysis performed at the well locations of the upscaled saturation log versus the near-stack, far-stack, and AVO cube sampled along the borehole trajectory revealed that the best discriminator for change in saturation and hydrocarbon detection was the AVO cube. On the basis of the analysis, the AVO cube is selected as the input attribute for ANN estimation of saturation and for the hierarchical classification step. The hierarchical classification-estimation is based upon a relationship between saturation and a seismic attribute captured by neural network training.

To quantify the prediction error, the estimation workflow has been performed iteratively by changing the input data from different well locations and has been verified with blind well tests not included in the training phase. The final results show that the hierarchical classification preserves the classes defined in the unsupervised seismic texture volume, and then populates the target sand-prone class with a range of values that is derived from the AVO cube response for saturation prediction.

Results and conclusions

The result from the hierarchical classification of texture attributes and AVO attributes is used for interpretation of the sequence stratigraphic framework and depositional environment. . We were able to clearly identify the stratigraphic units from the prograding shoreface and genetically related lower coastal plain stepping basinward, the highstand shore face, lowstand incisions as well as transgressive fills and prograding deltafronts. The fluid response revealed by the hierarchical classification in the texture volume was evaluated versus the lateral and vertical seismic facies associations and the geological framework given by the exploration wells located in the block to identify potential plays.

This combined approach of seismic geomorphology, seismic stratigraphy, and fluid response from AVO data calibrated with existing well data facilitated the development of new play concepts in the highstand system tracts, lower costal plain mouth bars, and in the morphology generated by incisions in the shoreface deposits during the lowstands forming buried hills (Figure 2).

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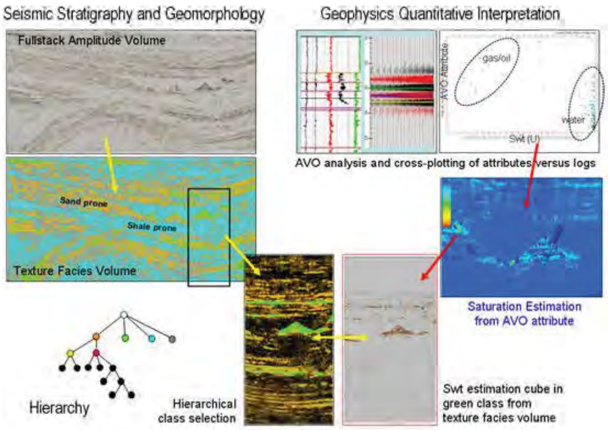

Figure 3: Hierarchical seismic attributes classification workflow. Unsupervised classification of seismic texture attribute produces a texture facies cube (left), which is used as a framework for performing classification-estimation of saturation (Swt) based on AVO attributes and well log responses (right).

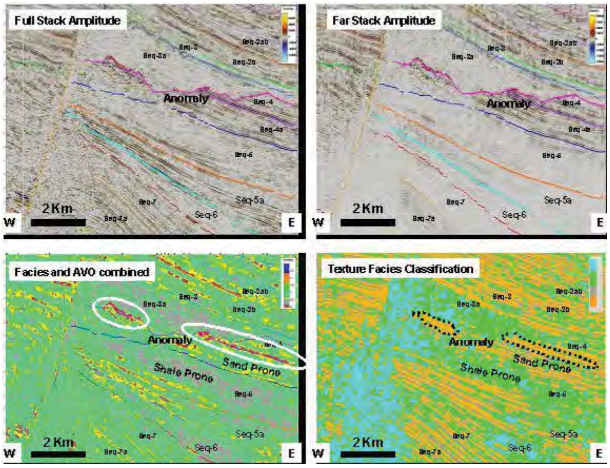

Figure 2: Comparison of seismic sections on full stack and far stack, facies combined with AVO, and texture facies results in prospective zone highlighted by the amplitude anomaly defined as incisions in the shoreface deposits created during the lowstands and forming buried hills plays in various stratigraphic levels.

Geophysics Paper 13

VOLUME BLENDING WITH DIRECTIONAL SEISMIC ATTRIBUTES

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Summary

Multi-attribute analysis through volume blending is a powerful but under-utilized tool for revealing details in seismic data. It is most effective when a seismic attribute that highlights geologic structure, such as discontinuity or lightscape (shaded relief), is displayed in grayscale and combined with an attribute that highlights an element of stratigraphy, such as reflection strength (trace envelope) or average frequency, displayed in color. The directional attributes, lightscape, azimuth, and amplitude gradients, are particularly effective for volume blending. Filtering the structural attributes often greatly improves them for blending.

Introduction

Multi-attribute analysis aids seismic interpretation by highlighting or revealing channels, faults, anomalies, and other features of interest. Four methods are common: volume blending, multi-attribute voxbody detection, attribute cross-plotting, and automatic pattern recognition (see James et al., 2002, for a good review). Of these methods, volume blending is the most popular as it is the easiest to apply and interpret.

While volume blending is widely used, its potential remains under-developed. It is applied largely with seismic discontinuity attributes, as there is a lack of recognition that other attributes are equally suitable and offer complementary information, particularly azimuth, dip, curvature, lightscape, and amplitude gradients. Azimuth, lightscape, and amplitude gradients all involve directional derivatives and so produce displays that appear to be illuminated. Using directional attributes as well as discontinuity produces displays that show more information and provide clearer and more intuitive insights into the geology.

Method

Volume blending combines the information of two or more seismic attributes through opacity or other methods. It is most effective one or more attributes are displayed in grayscale and the original seismic data or another attribute is displayed in color. Attributes that are most effective in grayscale tend to be attributes that highlight geologic structure. These include discontinuity, curvature, dip, azimuth, lightscape, and amplitude gradients. Attributes that are most effective in color tend to be stratigraphic attributes, and include reflection strength, average frequency, phase, interval velocity, and parallelism.

Seismic discontinuity is the most common attribute to display in grayscale for volume blending. It is particularly effective for this purpose when special pre-processing or post-processing filters are applied to enhance its resolution and sharpen details. However, the success of discontinuity for blending overshadows the potential of other useful attributes, particularly the directional attributes, such as azimuth, lightscape, and amplitude gradients. Directional attributes make seismic data appear illuminated by a lightsource. They act like directional filters, and so highlight features that trend perpendicular to the direction of apparent illumination while removing features that trend parallel to the illumination. For this reason, directional attributes should be created in pairs or sets that capture all trends.

Azimuth attributes record the down-dip direction of seismic reflections (e.g., Marfurt and Kirlin, 2000). Careful design of a circular grayscale colorbar allows azimuth to behave like a directional attribute, with different colorbars used to illuminate different directions. Amplitude gradient attributes employ directional derivatives of the reflection strength normalized by the reflection strength, and record either vertical or horizontal gradients. They are well described in the literature though they are not commonly applied (Oliveros and Radovich, 1997; Marfurt and Kirlin, 2000). Amplitude gradients bring out a surprising amount of information hidden in the reflection strength.

Shaded relief is employed throughout geophysics to display digital data as illuminated apparent topography. Such displays aid geologic intuition because apparent topography often suggests true geology. First developed for elevation data, shaded relief has long been used with gravity and magnetic data, it is a natural product of synthetic aperture radar and side-scan sonar, and it is routinely applied to interpreted seismic horizons.

Shaded relief techniques are readily adapted to 3D seismic data to produce lightscape, an attribute that resembles illuminated apparent topography when viewed as time slices or extracted along horizons (Barnes, 2003). The idea behind lightscape is similar to that of a geologist who mentally reconstructs eroded structures through inspection of the strike and dip of small outcrops along the surface (Figure 1). The information in lightscape is the same as that in standard combined dip-azimuth displays, but it presents this information in a way that is more readily understood and interpreted. Lightscape reveals details of geologic structure and indicates the orientation of faults and folds. It is particularly effective when blended with the original seismic data or with discontinuity and amplitude attributes.

Effective stratigraphic attributes for blending include reflection strength, average frequency, interval velocity, acoustic impedance, and parallelism.

Examples

Two examples of the use of the vertical amplitude gradient are shown in Figure 2. In the first of these, the amplitude gradient is blended with the original seismic data. Where the data is coherent and has strong amplitude, the gradient is small, but where the data is noisier or has small amplitude, the gradient acts to show the “roughness” in the data. In the second example of Figure 2, the amplitude gradient is blended with response frequency. The amplitude gradient has the property that it is strongest at troughs in the reflection strength, which is where reflections interfere. These troughs are exactly where the response frequency changes, as the response frequency is constant between consecutive troughs (Bodine, 1984). Thus the amplitude gradient blends well with response frequency to enhance the image. In both examples, the vertical amplitude gradient makes the seismic data appear 3D and illuminated from above.

An example of combining three attributes, the original seismic data, standard discontinuity, and azimuth, is shown in Figure 3. The blending aids structural interpretation by making the major faults stand out clearly. The discontinuity attribute reveals the location of the faults, and the azimuth attribute gives an indication of their throw through illumination. In this example, the azimuth attribute is filtered with vertical median filtering to produce a cleaner and more interpretable image. Such filtering can remove small scale features, but it often produces superior images for blending.

An example of combining three attributes, the original seismic data, standard discontinuity, and azimuth, is shown in Figure 3. The blending aids structural interpretation by making the major faults stand out clearly. The discontinuity attribute reveals the location of the faults, and the azimuth attribute gives an indication of their throw through illumination. In this example, the azimuth attribute is filtered with vertical median filtering to produce a cleaner and more interpretable image. Such filtering can remove small scale features, but it often produces superior images for blending.

Conclusions

Volume blending of two or three attributes produces displays that highlight important elements of geologic structure and stratigraphy, thereby aiding seismic interpretation. It is made more effective by using structural attributes that complement seismic discontinuity. Directional attributes, such as azimuth, lightscape, and amplitude gradients, are quite suited for this purpose. They make seismic data look illuminated topography and act like directional filters. These attributes are often improved for blending through smoothing or median filtering.

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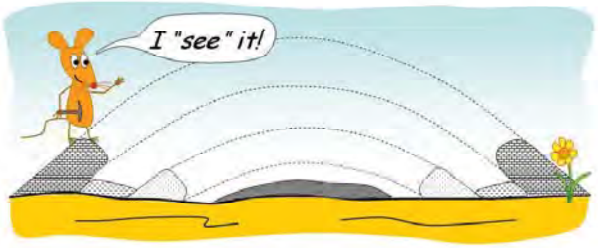

Figure 1: A geologist mentally reconstructs an eroded structure from the dips and strikes of outcrops observed along the surface. This is similar to the way that lightscape reveals details of geologic structure along a time slice.

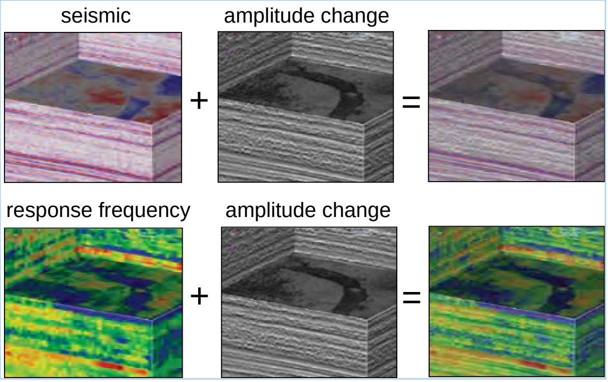

Figure 2: Two examples of blending with vertical amplitude change. In the top example, amplitude change is blended with the original seismic data to show the smoothness and roughness inherent in the data. In the bottom example, amplitude change is blended with response frequency to accentuate the layering in the data.

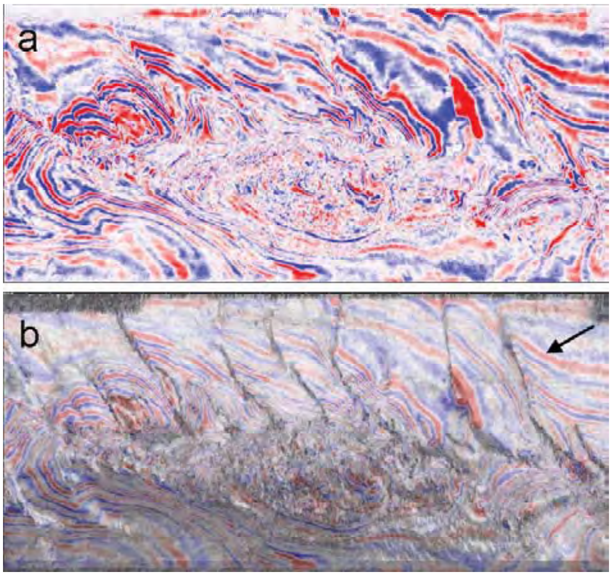

Figure 3: An example of blending to aid structural interpretation. (a) Original seismic data. (b) Original seismic data blended with discontinuity and reflection azimuth to enhance faults. The black arrow shows the effective direction of illumination..

Geophysics Paper 14

APPLICATION OF ROCK PHYSICS MODELLING AND SEISMIC ATTRIBUTE IN DEVELOPING THE GEOLOGICAL MODEL — AN EXAMPLE FROM EOCENE DEEPWATER TURBIDITE IN BLOCK 21/23A, CNS, UK.

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Christopher A-L Jackson[3]

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Block 21/23a is a sub-block of UKCS Block 21/23, which is located within Quadrant 21, Central North Sea, UK. A total of three fields were discovered in Block 21/23, namely the Pict, Saxon and Sheryl fields. The Pict and Saxon fields are located in Block 21/23b and operated by PetroCanada. The Sheryl field is located in Block 21/23a and operated by Oilexco.

The Sheryl field was discovered in year 2006 based on Elastic Impedance anomaly. The discovery was made in the Eocene Tay deepwater turbidite reservoir. This study is based on an integrated approach of utilising the rock physics forward modelling, seismic attribute and geological data in constructing a robust conceptual geological model for the purpose of further prospect evaluations and static model building.

Rock physics forward modelling was conducted prior to seismic data interpretation to build a geophysical database comprising the analogues of seismic responses under different rock properties and pore fluid contents. This database was used to enhance the accuracy in seismic data interpretation. The forward modelling results concluded that the MuRho ($\mu\rho$) dataset can be used as a lithology indicator, while the LambdaRho ($\lambda\rho$) dataset is a fluid type indicator. The AVO modelling showed that brine, oil and gas saturated sands are characterised by Class I, Class II to IIp and Class III AVO responses respectively.

The palaeogeographic map clearly demonstrated that the study area can be divided into four main depositional environments, namely shelf edge, slope, proximal and distal basin floors with increasing relative palaeo-water depth from SW to NE. The shelf edge setting was interpreted based on its thicker Tay stratigraphic unit observed at the proximal part of the canyon system identified on the slope setting. The proximal and distal basin floor settings were differentiated based on the sand geometries, where the former is characterised by channelised sand and the latter contained sheet-like sand geometry that was interpreted to be basin floor fans. Eventually, a conceptual geological model was developed based on the interpretation of all the available geological and geophysical data.

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Geophysics Paper 15

THE FIRST MEGAMERGED SEISMIC DATA PROCESSING PROJECT IN MALAYSIA

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PMU, PETRONAS

In September 2005, Petroleum Management Unit (PMU) embarked on a project to merge all available 3D migrated stack volumes from peninsular Malaysia blocks and output a single volume. The 3D post stack merging program is necessary to provide 3D regional coverage that can be accurately tied to existing wells and with ability to map and track channels and other geobodies that may form traps for Hydrocarbon accumulations. PMU at the time had available 29 surveys in the Malay basin which was each exclusive in its own right. It had its own orientation, as well as 3D numbering system that referred to its own sub-surface inline and crossline spacing. While many of these 3D surveys overlap and as will be shown, often multiple overlaps, prior to this project no two overlapping or adjacent surveys had been merged onto a common platform.

This project made possible an interaction between data from different surveys. By integrating all volumes PMU could have a multi-purpose dataset which could be used to market for potential partnerships by effectively wrapping all 29 surveys into 1. As well as providing a very useful picture of the subsurface on a common grid, it allows key interpretations to be transposed from survey to survey and to sit on a common grid. These were the driving forces behind the project.

In all, this project merged all 29 available surveys using the latest and largest PM309 survey as the base. Each 3D survey had been most recently processed or re-processed between 1992 and 2004, totaling almost 20,000 square kilometers of input data. The output volume after merging totals more than 16,000 square kilometers, sitting on a common 3D grid and can be stored on a single DLT tape.

This paper looks into the method by which the then Veritas team used to re-grid the surveys to a common 'master' grid. This so-called master grid was set up such that future 3D surveys could be incorporated relatively easily into this dataset. The discussion shows how each volume was matched to be of common amplitude, bandwidth and phase and then finishes off by viewing the philosophy behind the merging of the volumes which culminated in a single output dataset.

The 3D seismic mega-merged data would allow the understanding of the regional geology by interpreting and mapping the newly completed 3D seismic mosaic in view of identifying the near field opportunities in the SE Region of Malay basin, which is the main oil-producing province. The seismic interpretation and mapping includes seismic facies modeling of the merged data, as the outcome of this study would allow visualization of the depositional facies in three dimensions. This is a new technology combining the specialized interpretation with the 3D visualization. We would be able to trace the channel system over this area from this sub-surface image and this would help us to identify new reservoirs especially the stratigraphic traps of channel sands and point bar sands that have not been tested.

Examples of the resultant timeslice images taken from the final mega-merged volume can be seen in Figure 2.

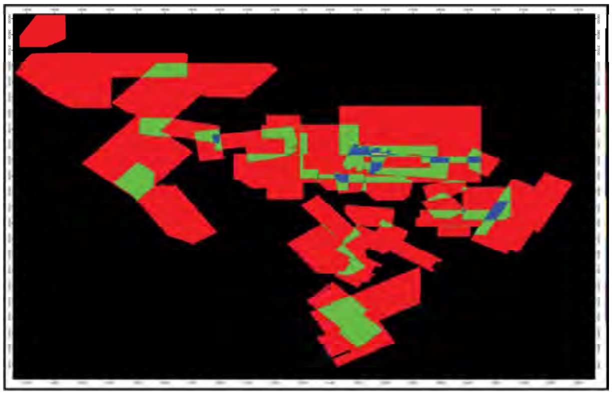

Figure 1. Coverage plot for all 29 surveys before trimming.

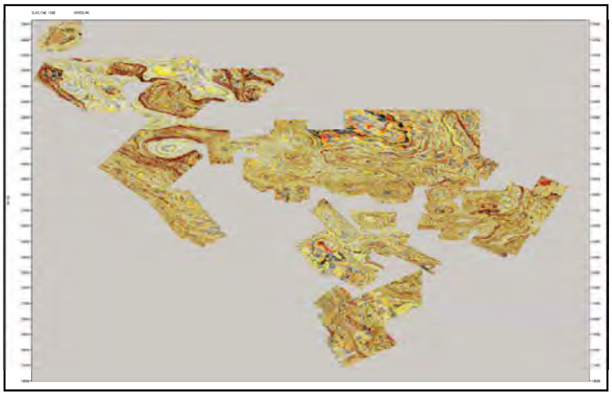

Figure 2. Timeslice through the merged output at 1500ms.

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Geophysics Paper 16

THE APPLICATION OF CSEM (CONTROLLED SOURCE ELECTROMAGNETIC) TECHNOLOGY AS A TOOL TO COMPLEMENT 3D SEISMIC INTERPRETATION AND AVO ANALYSIS IN A DEEPWATER PROSPECT: A CASE STUDY ON PROSPECT B, BLOCK 2F, OFFSHORE SARAWAK.

Wong Eng Yao

PETRONAS Petroleum Management Unit

The Controlled Source Electromagnetic (CSEM) method has emerged into the oil and gas exploration industry, especially in deepwater exploration, and provides geoscientists another tool to assess a prospect by looking at another physical property, i.e. resistivity, besides acoustic properties that can be derived from seismic and AVO analysis.

In this context, CSEM technology is no doubt a tool to complement seismic interpretation and AVO analysis by offering an independent data set to exploration work. However, as the technology is purely based on resistivity contrast down-earth, there is still room for debate as to whether or not the technology is capable enough to help in delineating the true geology of an area.

This paper presents the result of a 2D CSEM survey over Prospect B of Block 2F, Rajang Delta, offshore Sarawak. The 3D seismic of the prospect shows a high amplitude anomaly at both crest and flanks of the structure (Figure 1); while AVO analysis over the crest of the structure gives a Class III AVO response which hints at an existence of a gas cap (Figure 2). The CSEM response displays a positive magnitude build-up which indicates a resistive body lying beneath (Figure 3).

The question left here is the geological model that would explain all the responses obtained whilst honoring the geological (stratigraphic) information from wells drilled in the area before; Whether what lies beneath is truly a sizeable and quality gas reservoir, or, considering the limited resolution of seismic and stacking response of CSEM technology, just thinly-bedded siltstones that wouldn't bring much excitement.

A discussion will be presented in this paper based on the Depth Migration result of CSEM method.

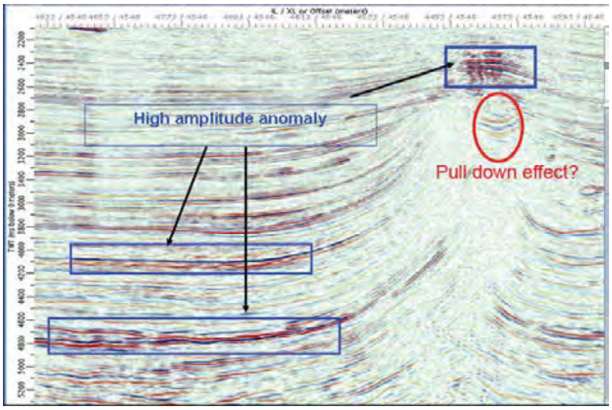

Figure 1: 3D seismic section showing high amplitude anomalies of Prospect B.

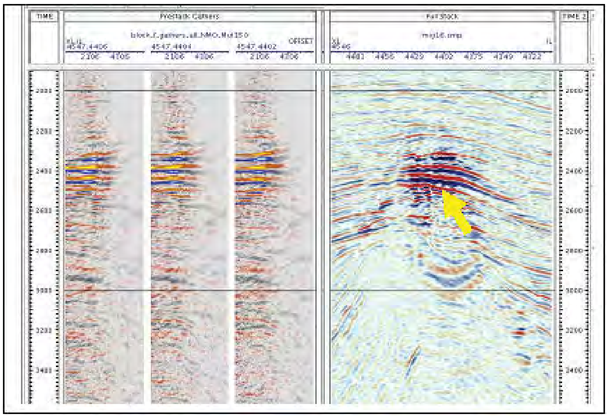

Figure 2: AVO analysis of Prospect B. Note that there's Class III AVO anomaly at the crest of the structure.

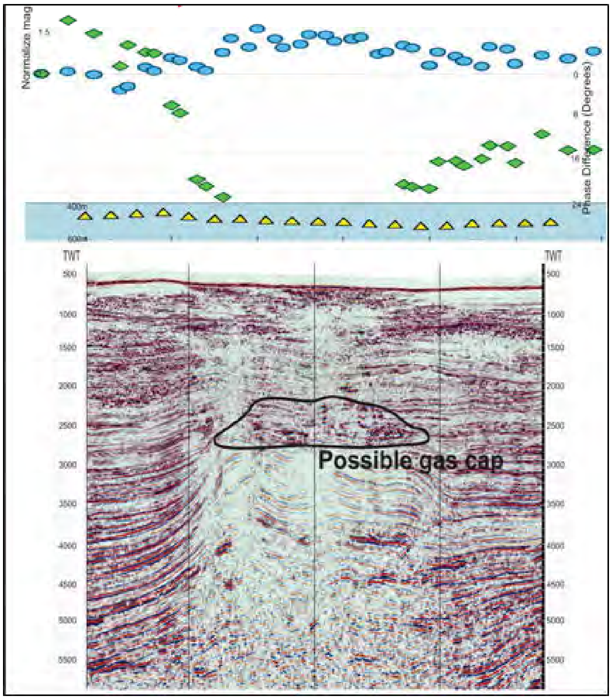

Figure 3: CSEM response of Prospect B. Intermediate offset refers to intermediate depth and the positive magnitude build-up (blue plots) are derived from the high amplitude anomaly seen in seismic.

Geophysics Paper 17

RECENT CSEM LEARNINGS IN DEEPWATER BORNEO

Matthew Choo, Chester Young, Ling Chin Tiong, James Beer and Peter Shiner
Sarawak Shell Berhad

Controlled Source Electromagnetic (CSEM) is an emerging technology with the potential to provide detailed resistivity images of the subsurface. In the context of exploration in DW Borneo, given the potential to directly image the high-resistivity zones associated with hydrocarbon pay, the technology was regarded as the ideal tool to reduce one of the most significant exploration risks in the basin – seal failure. A number of significant early successes over DW Borneo's toe-thrust anticline plays confirmed the potential promise of the technology as an exploration tool in the basin.

Following on this string of successes, CSEM data was acquired over a number of similar structures in 2006. Application of industry-standard processing and interpretive techniques on the data revealed an encouraging CSEM anomaly.

However, proprietary inversion techniques indicated the possible presence of a shallow surface resistive body, while hinting at the presence of slightly elevated resistivities at depth. An exploration well campaign was carried out over the prospect late in 2006, but rather than encountering the expected hydrocarbon pay, the well encountered a near surface and resistive hydrate layer. Good quality but water-bearing reservoir was encountered at the target depth.

This disappointment was the first CSEM negative test in the basin and highlights the need for further development of processing and interpretation methodologies. This paper will present the key CSEM experiences in DW Borneo to date, highlighting on the pros and cons of a still promising and evolving technology in what is still a challenging area.

Geophysics Paper 18

CSEM PILOT SURVEY IN SOUTHEAST ASIA: CHALLENGES AND TAKEAWAYS

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Controlled Source Electro-Magnetic (CSEM) surveys have proved to be useful in de-risking the hydrocarbon prospects in the deep water environment, due to their capability to distinguish between the brine and hydrocarbon saturated reservoirs. However, the interpretation of CSEM response in marginal water depths and complex geological setups remains challenging due to the interference of airwave with electromagnetic field and the background resistivity variations. In the year 2006, PETRONAS conducted a pilot CSEM survey in one of its offshore block in Southeast Asia. The survey was aimed to understand the key risks of the two hydrocarbon prospects identified in the area and to evaluate the strengths and limitations of the CSEM technique for its future application in shallow water depths and complex geological setups.

While one of the prospects had a complex structure and marginal water depths (~150-500m), the other had a conceptual geologic model, with no immediate well control. EM modeling was done to assess the feasibility of the survey. This included 1D modeling and comprehensive 3D modeling based on different background resistivity models and target resistivity values.

CSEM source, a horizontal electric dipole (HED), was towed at 30 meters above the seabed, with a base frequency of 0.15 Hz. emitting a continuous square wave signal. A nominal receiver spacing of 1.5 Km was used with additional receivers deployed inline and azimuthally. Good quality data was recorded up to source-receiver offsets of 10-12 Km.

Data processing sequence consisted of windowing, demodulation, calibration, scaling, channel drop/averaging and inline rotation. Up-down separation was performed to minimize the airwave effect. Depth migration was performed to estimate the depth and lateral extent of the probable resistors.

The measured EM responses were interpreted and compared with the modeled responses using different post-survey resistivity models. For both prospects, resistive anomalies were observed at intermediate offsets. Resistive basement emerges as an important anti-model for one prospect which might moderate a possible reservoir response. For the other prospect, the model having both the reservoir targets explained the response best. Based on the recent results of drilling one of the prospects, 3D forward modeling and 1D inversion are being performed to calibrate the background resistivity model with the well data.

The pilot survey has helped in improving our understanding of the challenges associated with the CSEM surveying in general and shallow water depths and complex geology in particular. Comprehensive modeling, advanced processing and improving inversion algorithms have the potential to address some of these challenges in near future to extend the application of CSEM technology from relatively simple deepwater geologic regimes to relatively complex geologic regimes with moderate water depths.

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Geophysics Paper 19

CHANNEL CHASING IN MALAY BASIN USING MEGA MERGED DATA

ROSEMAWATI ABD MAJID

PMU, Basin Studies, PETRONAS

In 2005, the Basin Studies Group of PRAM, PMU merged 29 3D dataset of the South Eastern part of the Malay Basin. The 3D dataset for the merging ranges from vintage data of 1995 to 2004 covering an areas of approximately of 20,000 sq km with a volume of 1.7 Terra byte of data (Figure 1). The Regional Study of the Malay Basin was carried out by utilizing the 3D Mega Merged Seismic data. With the huge volume of data involved, new technology of hardware and software was applied to handle the data. 3D volume interpretation software and a high end machine (i.e. 128G Machine) is required to do structural and horizons interpretation for the purpose of evaluating any new leads and prospects available in the entire South eastern part of the Malay Basin. By leveraging and integrating the rich information content of geophysical and geological data of the Malay Basin, near field opportunities of new play type and leads/ prospects will be able to be identified/emerged from the study.

Malay Basin is a mature basin in terms of exploration activities in Malaysia and one of the objective of the Mega merge project is to carry out a seismic modeling on regional scale to define regions of common response i.e. channel, point bar. Total of ten (10) horizons tops (D, E, F, H, I, J, K, L, M & Basement) and almost 400 faults were interpreted on the mega merge seismic cube. Forty (40) control wells were also used as formation tops for calibration. Fifteen (15) Regional 2D RC lines were also incorporated in the study for areas where no overlapping of the 3D seismic. Extensive attribute works i.e. Spectral Decomposition, Sweetness, Amplitude Extraction, Reflection Strength has been carried out to identify potential stratigraphic leads and prospect and possible fracture basement. Multiple and stack channels trending from different levels can be observed from the attributes work generated. Most of the channels identified are from Group E, F, I and H of the Lower to Middle Miocene trending NE – SW direction (Figure 2 & Figure 3). Majority of channels presents are observed in Block PM 309 and PM 312 and others are seen in most of the PM Blocks.

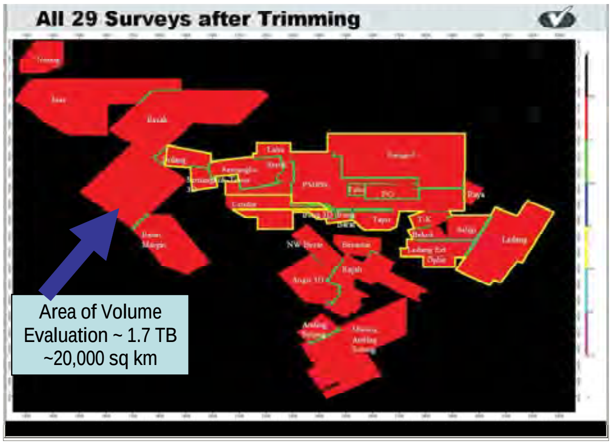

Figure 1: PM Mega-merge area

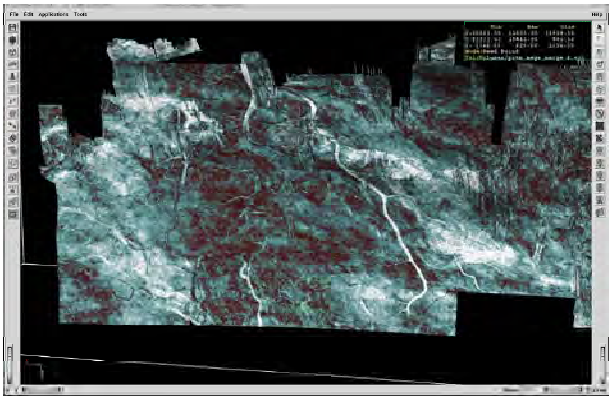

Figure 3: Attributes generation: Spectral decomposition.

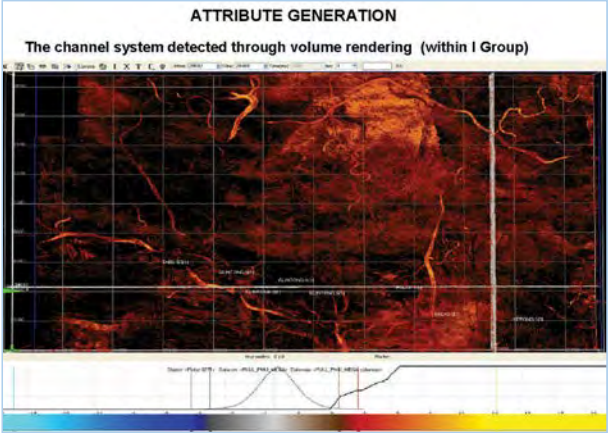

Figure 2

Geophysics Paper 20

INNOVATIVE FRONTIER EXPLORATION USING SEISMIC AND SEASEEPTM DATA, INDONESIA: IMPLICATIONS FOR MALAYSIA

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[3]MIGAS, Indonesia

Most of the world's oil was discovered using onshore surface maps and seeps. Within the past few years, technologies developed for conventional marine hydrographic surveys and anti-submarine warfare have been upgraded, modified, and integrated for offshore petroleum exploration and in particular, deepwater (400–3,500m) exploration.

Very high resolution maps of the sea bottom and zones of oil and gas seepage may be identified using a vessel traveling at 10 knots and surveying a swath of about 4 km. Similar advances in subsea positioning enable accurately-navigated piston-core to sample features we identified on sea-bottom map. These cores can be subjected to modern geochemical analysis and therefore locations of thermogenic hydrocarbon charge may be identified.

In December 2006, TGS-NOPEC commenced the world's largest multibeam and the world's first non-exclusive SeaSeepTM survey as part of an innovative exploration program in the offshore frontier basins of Indonesia. The program was underwritten by Black Gold Energy and co-sponsored by Joint Study partner MIGAS.

SeaSeepTM data comprises:

- Multibeam bathymetry and backscatter data to provide (a) 100% coverage of the sea-floor defining structural trends and modern offsets, (b) location and concentrations of hydrocarbon seeps, and (c) core locations;
- Gravity and magnetic data to provide a regional grid of hi-res profiles to provide first order tectonic fabric and basement architecture and constrain basin thickness and geothermal gradients;
- Navigated piston cores and geochemical analyses; and
- Heat-flow and geothermal gradient data.
- The program will acquire a variety of data to conduct a comprehensive prospectivity analysis over an area of around one million square kilometers. The studies, involving some 30 sedimentary basins, will have available 35,000 km new 2D seismic data
- 400,000 square kilometers of Multibeam SeaSeepTM data including 1,200 sediment cores; 3,600 geochemical analyses; and 120 heat flow probes.

For those who believe that discoveries first start in the mind of the explorationist, perhaps the greatest benefit of the SeaSeepTM exploration program is being able to follow the onshore geology into the offshore with some clarity and confidence. With sea-bottom bathymetric data at almost four times the resolution of onshore shuttle-based topography geological features and trends are easily identified; offshore continuations of major faults are spectacularly displayed and new tectonic models generated. The method facilitates meaningful analysis of areas of complex geology not possible with regional 2D seismic alone.

The presentation will show examples from the survey and discuss possible application offshore Malaysia.

Geophysics Paper 21

TIME-LAPSE SEISMIC MODELLING IN MALAY BASIN

SHAIDIN ARSHAD, M FIRDAUS A HALIM, M K SEN GUPTA, NOR AZHAR IBRAHIM AND SALBIAH ISA

PETRONAS Research Sdn. Bhd.

Time-Lapse seismic has become as an important petroleum reservoir monitoring and management tools since its successful application in 1990s. The fundamental principle underlying the time-lapse seismic is simple, that is, the changes in reservoir parameters or properties are directly related to the differences in seismic response between the monitor and the base surveys. In reality however, the application is not that simple. There are many issues needed to be understood and considered before concluding any differences observed are due to changes in reservoir properties and not due to other factors such as seismic acquisition parameters and seismic processing artifacts.

Feasibility study prior to a full time-lapse seismic project is crucial in providing information that helps guide our expectations. Changes in fluid type and saturation may not necessarily be significant enough to induce a large impedance contrast and consequently detected by seismic signal. The reservoir pore-fluids, rock matrix and frame, and reservoir conditions need to be fully understood to ensure the success of any time-lapse seismic study.

There are many aspects of a time-lapse feasibility study that need to be considered such as seismic acquisition design, processing algorithm and parameters, reservoir production, reservoir fluid properties, reservoir rock properties, reservoir monitoring program, geomechanics, seismic modeling, etc. This paper will focus on the fluid properties and seismic modeling aspects of the feasibility which is thought able to give, if even not full, a sufficient understanding on how pore-fluid type and saturations in the reservoir with varying types and thicknesses of cap rock could affect the resultant seismic amplitude, the fundamental element of any time-lapse seismic study.

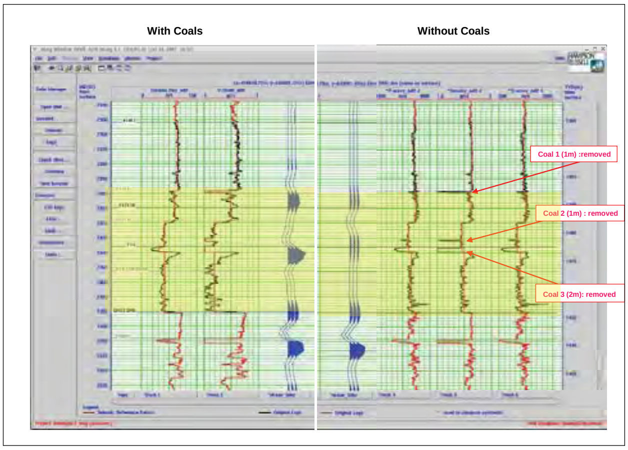

Figure 1: Synthetics traces showing the difference in seismic characters with and without coals on top of reservoirs.

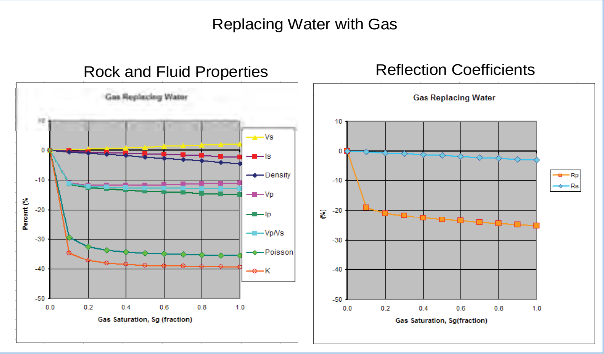

Figure 2: Percentage changes in reservoir seismic properties as reservoir fluid was changed from water to gas.

Geophysics Paper 22

PERMANENT RESERVOIR MONITORING USING FIBER-OPTIC TECHNOLOGY

STEVE MAAS*, BRETT BUNN AND RUNE TENGHAMN

Petroleum Geo-Services (PGS)

Summary

Fiber optic sensor systems have been under development for many years. We have produced prototype seismic equipment to demonstrate the optical technology. 4C seabed systems, streamers and near field airgun recording are a few of the projects under development. A 4C seabed cable has been successfully demonstrated during field operations in the North Sea. Data collected from the field tests have proven the prototype optical system meets the performance required of the deepwater seismic operation. It is an excellent fit for conventional 4C seismic operations and would also be the preferred solution for permanently installed reservoir monitoring systems. Some of the advantages we expect to realize from an optical system include: no in-sea electronics, improved reliability, lighter weight, significantly reduced deployed system cost and improved operational safety.

Introduction

Traditional seismic acquisition hardware relies on sensors that produce an output voltage that is digitized, multiplexed and transmitted up a cable to the recording system. The electronics required to perform this operation are both expensive and unreliable. The passive nature of the optical telemetry system eliminates the need for costly in-sea electronics and the problems associated with them, yielding a system that is more reliable, less expensive and safer to deploy and operate. Optical sensor based systems are beginning to replace the traditional technology in the oil field especially in low channel count high stress environments. The telemetry architecture utilized here provides a system that is expandable beyond the capabilities of current seismic systems.

Optical sensors used in acquiring seismic data are typically constructed from optical interferometers. Many establishments have demonstrated the performance of optical sensors, with the US Naval Research Laboratory leading the technology in the late 70s and early 80s; Giallorenzi (1987) and Dandridge et al (1991). Since then the wide spread availability of fiber optic components and subsystems have helped the optical sensor system evolve into a reality; e.g. Bostick (2000). In this paper we discuss our optical technology and present our forward looking plans for the technology.

Fiber Optic System Architecture

Dense Wavelength Division Multiplexing (DWDM) is utilized in the telemetry scheme to optically power the sensors. An optoelectronic cabinet has been assembled using 10 wavelengths with capability to run 960 sensor or 240 four-component (4C) channels. Multiplexed light is sent into the cable where it is distributed to and from the optical sensors, the light returning from the sensors is then demultiplexed and demodulated. The basics of the system include a phase modulate laser source passing through an interferometer, where stress from the outside world causes a phase shift in the light as it passes through the interferometer. The phase information is extracted from the returning light to output a signal equivalent to the stress input at the sensor. This provides a completely passive in-sea system with no in-sea electronics.

Optical Sensors

We have developed optical sensors for acoustic pressure and shear wave measurements; including an optical hydrophone that has been qualified to operate in 3000 m depths without degradation in performance. The unit was tested to have a scale factor of -140 dB re rad/μPa ±1dB over environmental pressure and temperature. This translates into a noise floor below 1μB. A 3-axis optical accelerometer has become the preferred sensor for shear wave measurement. The 3-axis design measures 30 mm x 50 mm x 75 mm. Like the hydrophone the accelerometer has very good uniformity and performs well. When mounted inside a pressure vessel it is also capable of 3000 m operation.

The Optoelectronic Data Acquisition System

The optoelectronic system generates the optical power for the array and processes the returned optical signals to extract the seismic information. Light returning from the array is routed to a select group of demodulation boards to process the optical data and outputs a 32-bit digital word equal to the seismic data. The data is then sent to a network interface card where it is put into data packets and sent to the recording system over an ATM network. Figure 2 shows the basic optical recording system architecture.

The optoelectronic cabinet with 960 channel capability was assembled in cardfiles, were each cardfile contains four laser boards (2 lasers each), 6 demodulators, one clock reference generator and a network interface card. This is one wavelengths worth of processing or 96 optical channels. Figure 3 shows the cardfile up close and the reduced channel count rack used to test our seabed system. Adding an additional cardfile means you add another 96 channels worth of capability. The optoelectronic system fabricated includes ten cardfiles. Only four cardfiles were used in the reduced channel rack.

Seabed array cable

An array was designed to be used by a 4C exploration crew, being continuously deployed and retrieved in deepwater applications. A steel armored optical cable with the optical fibers inside gel filled stainless steel tubes was used in the construction. A 4C sensor pad was attached to the optical cable every 25 m, the optical fibers in the cable were extracted and fusion spliced to the sensors in the pad. A protective cover and bending strain relief was attached to the entire assembly. 2400 m of array cable plus 4 km of leadin cable were assembled. Mechanical stress test proved the cable assemble can be deployed and retrieved thousands of times without damage to the optical fiber over loads that exceed deepwater deployments of 3000 m. Figure 4 shows the sensor pad assembly.

Field testing

The field test of the Seabed array (Figure 5) was performed onboard the Bergen Surveyor. The optical array was deployed parallel to the PGS FOURcE seabed cable in 300 m of water, 20 miles NW of Marstein, in the Norwegian Trench. The arrays separation was 50 m and the location of the arrays was monitored using external acoustic transponders. The following two figures show the optical array during the checkout and deployment stages. The data was acquired while the gun boat traveled along the arrays firing every 25 m and again while traversing perpendicular across the center of the arrays.

The data shows excellent correlation with that of the electrical system. Figure 6 is a comparison of the hydrophones in the arrays. The data presented shows the corresponding 96 hydrophone channels for the electrical and optical arrays for the same shot in common shot-gathers and the averaged signals from a hydrophone channel, the red trace is the electrical channel and green optical. The low frequency spike seen in the optical channel isn't present in the electrical data because of the roll off filter used in the electrical acquisition system. Finally, the noise response from the two systems is shown. Figure 7 provides the same data for the vertical geophones. Figure 8 is a noise comparison of the hydrophones and geophone group summed over an 8 second shot record.

Near-field airgun recording

With the proven robustness and survivability of the optical system, we have recently integrated the optical hydrophone into a cable and attached to an airgun array to record the near-field signature of the gun array. The optical system has the added advantage of not being susceptible to the switching solenoids and electrical transients created when the airguns are fired.

Optical streamer

We have also developed the optical telemetry and connectors to support 12 km streamer operations. In addition, we have performed vessel handling and tow tests to validate the optical system performance while under tow in a typical seismic operation. The technology developed will be used in the development of a reduced diameter optical streamer for prototype field testing in 2006.

Conclusions

We have successfully demonstrated prototype optical seismic hardware. A DWDM telemetry system allows for the expandability to lengths greater than 12 km with channel counts in excess of 2000 per cable. The optical system has been tested along side conventional cable technology with comparable results. Data collected from the field tests have proven the prototype optical system meets or exceeds the performance required of the deepwater seabed systems. The optical technology offers the advantages of no in-sea electronics, improved reliability, lighter weight, significantly reduced deployed system cost and improved operational safety. Fiber optics is an excellent fit for seismic operations and a preferred solution for permanently installed reservoir monitoring systems.

Acknowledgements

We would like to thank PGS Marine Acquisition for the support and coordination during the tests and most importantly the crews onboard the Bergen Surveyor, Ocean Explorer, Falcon Explorer, American Explorer and the Ramform Viking for their excellent effort supporting the testing. We also thank PGS Marine Geophysical for permission to publish the paper.

Figure 1: Optical hydrophone and accelerometer.

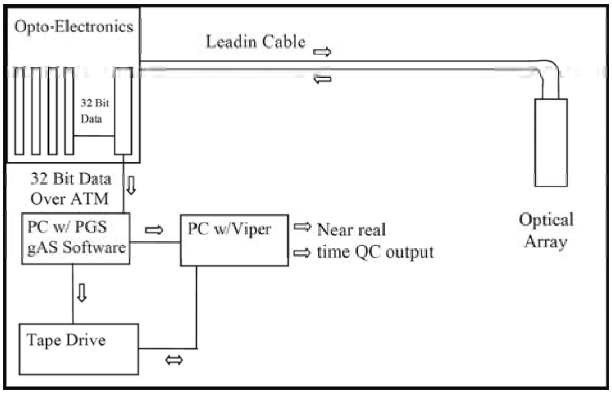

Figure 2: Optoelectronic recording system.

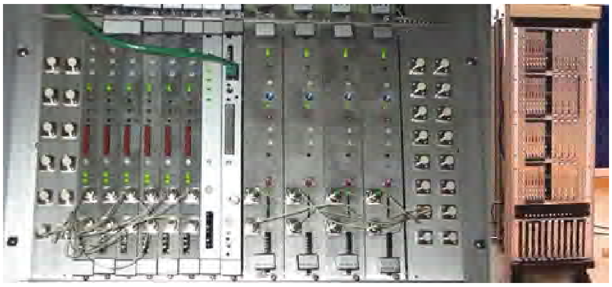

Figure 3: Optoelectronic system cardfile and rack.

Figure 4: Sensor pad assembly showing a side view of geophone housing on sensor pad base (upper), and an end-on photo of the protective housing shows a hydrophone mounted in the pad (lower).

Figure 5: Optical seabed array being prepared in the warehouse (upper), on a deployment reel (lower left), and during deployed (lower right).

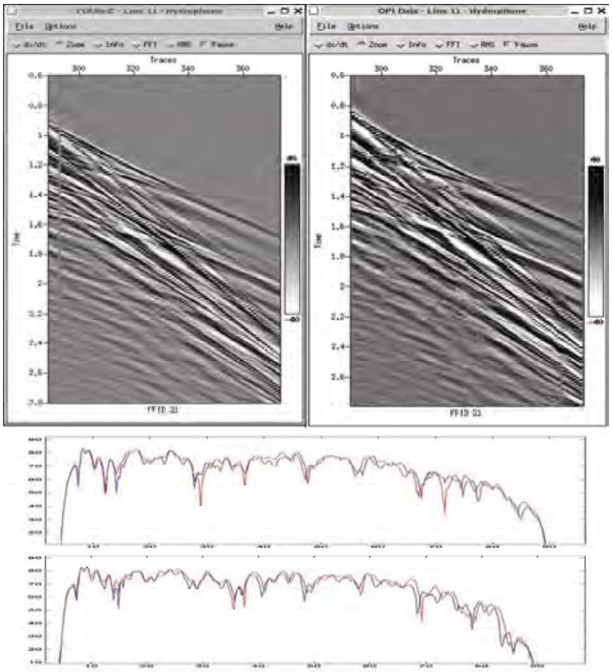

Figure 6: Comparison of electrical vs. optical hydrophones: (upper left) shot gather for 96 electrical channels, (upper right) shot gather for 96 optical channels, (lower) two superimposed amplitude spectra for two of the channels from the FOURcE electrical cable compared to two optical channels.

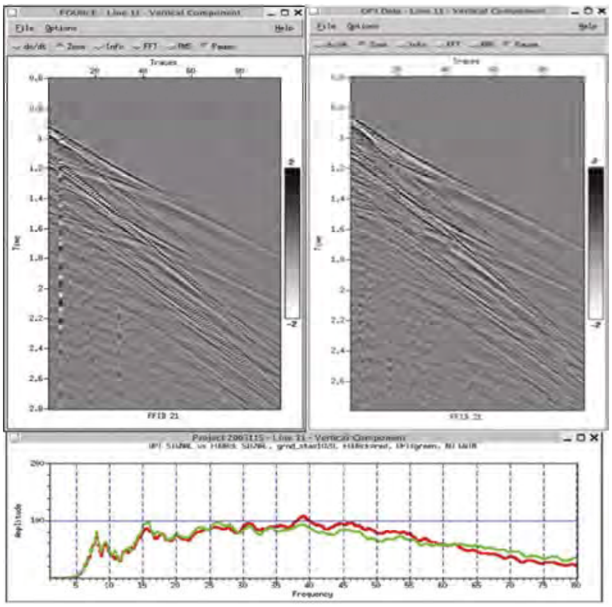

Figure 7: Electrical vertical geophones compared to optical vertical geophones: (upper left) FOURcE electrical shot gather, (upper right) optical shot gather, and (lower) superimposed average amplitude spectra for electrical (red) vs. optical (green) outputs.

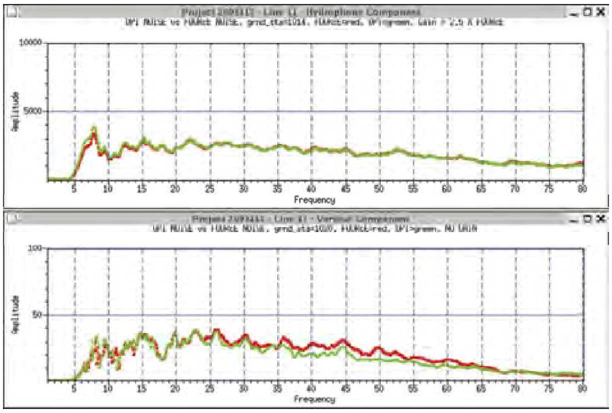

Figure 8: Superimposed amplitude spectra for electrical (red) and optical (green) noise data: hydropohone (upper) and geophone (lower).

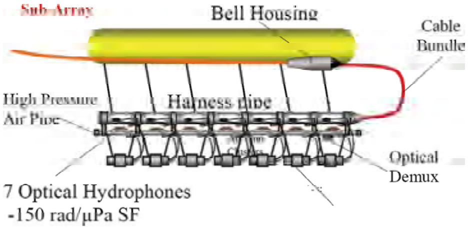

Figure 9: Near field airgun recording system.

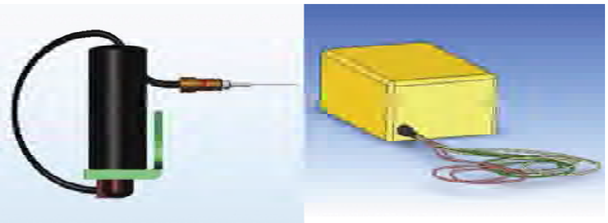

Figure 10: Near-field hydrophone.

Geophysics Paper 23

FIT FOR PURPOSE TIME LAPSE SEISMIC AT F6

Elvis Chung[1] and Paul Hague[2]

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F6 is Shell's largest gas field in the offshore Sarawak, with a GIIP (Gas Initially In-Place) of around 7Tcf (Trillion Cubic Feet). Production commenced in 1987 from a single platform located above the central pinnacle of the carbonate build-up. By 2006, 4Tcf had been produced, but scope for redevelopment still remains in the form of further drilling and late life compression. However, the biggest uncertainty is the strength of the aquifer and the movement of the GWC (Gas Water Contact). Pulsed neutron logging indicates a GWC rise near the main producing area beneath the platform but a large uncertainty remains towards the flanks.

The first 3D seismic survey over F6 was acquired in 2002 (15 years after production start-up), which means there is no suitable pre-production 3D baseline survey. Prior to commitment to the project, a feasibility study was carried out within SSB (Sarawak Shell Berhad) using the 2002 dataset as the 3D baseline. The objectives were primarily, to determine if production-related sweep signals are observable on seismic and if so, when is the ideal time to carry out the monitor survey in order to impact business decisions. The feasibility studies showed that a time-lapse seismic response could be expected in 2006 but highlighted that the time-lapse signals on the flank may be weak to image. This is largely driven by the two different reservoir model inputs in the feasibility study, which could be a uniform rise of the GWC or cone-shape rise of the GWC. Both models also have significant impact on recoverable gas on the flanks as illustrated as in Figure 1. Finally, the changes in the velocity and impedance from both models were found to be small (<5%) and thus, requires good repeatability and good signal-to-noise ratio (S/N) seismic data in order to observe time-lapse signals.

Considering the possibilities from the study and the business impact of additional recoverable volume at the flank, the time-lapse seismic was a timely exercise to help understand the extent of water influx and de-risk future investment on the field.

Seismic Acquisition & Processing : Challenges & Methodology

The key challenge in acquisition of the time-lapse data is to have good repeatability, apart from the common swell noise in marine seismic. The criteria is measured based on the positioning errors in the DSrc (delta/difference of the source position) and the DRec (delta/difference of the receivers position). The overburden in F6 is not complex and is comparable to the northern North Sea fields, where experience shows that good acquisition repeatability, RRR (RMS Repeatability Ratio) of around 0.2 can be achieved for DSrc + DRec of 75-100 metres. This translate into careful navigation and monitoring during the acquisition of the monitor survey to minimise positioning differences.

The base survey was acquired in year 2002, which covers an area of approximately 930 km2 of the F6 and F23 fields. Rather than going ahead with an expensive full-field monitor survey, a fit for purpose narrow swath of 3D data was acquired over the west flank of F6 in September 2006. This was made possible by carrying out an extensive planning exercise, involving the asset team geologist, QI (quantitative interpretation) geophysicist, processing and acquisition geophysicists with support from geomaticians to come up with the survey design. The survey was timely and economical as it was on the back of an on-going seismic acquisition campaign over neighbouring fields and. It took 11 days and repeated 14 seismic lines of the 2002 survey.

Concept Systems Ltd (CSL) in Edinburgh provided the time-lapse pre-plotted shot point positions, which were a repeat of a survey shot by another contractor in 2002. They also provided software to predict streamer feathering matches and measure repeatability of the survey compared to the 2002 base-line. A time-lapse QC (Quality Check/Control) specialist from CSL was riding the vessel for the duration of the survey and provided the real time shooting plan to maximize the feather matching and source positioning. Repeatability plots were also generated for a comparison to the 2002 survey.

The process was performed on 4 offset slots, i.e. 450-550m, 1450-1550m, 2450-2550m, 3950-4150m. The delta receiver and delta source maps were used to identify and prioritise time-lapse reshoot lines. An example of the QC map is shown in Figure 1. The plot shows DSrc + DRec for the offset range 2450-2550m in general falls below 75m and is deemed to meet the repeatability requirement.

Next come the processing challenges which were already foreseen in the feasibility study. The study indicated that the changes in the velocity and impedance from both models were found to be small (<5%). Therefore, time-lapse signals would be hard to picked up without good repeatability and good S/N seismic data. Apart from swell noise, the strong water bottom multiples off the top carbonate have mask the possible time-lapse signals inside the carbonate. The processing was made more challenging due to the fact that the only 3D survey was acquired in 2002, after 15 years of production. Therefore, there is no other time-lapse 3D results for comparison and not much is known about the reservoir dynamic behaviour.

The processing of the base and monitor surveys was carried out using Shell's proprietary processing package in the SSB. The main aim of time-lapse seismic processing is to ensure that the only difference that will result from the final base and monitor seismic volumes will be the production-related signals. To achieve this, both base and monitor were processed identically i.e. the same software, processing flow, parameters and velocities. In order to overcome the challenges mentioned above, careful testing on improving S/N (swell noise attenuation & demultiple) is important and has significant impact to the final result. One key process to optimize repeatability was the time-lapse trace selection process based on DSrc and DRec values. This normally results in the removal of a lot of seismic traces that do not meet the trace selection criteria at the expense of fold-coverage. After the trace selection, big improvement in S/N of the time-lapse signals and RRR values were immediately noticed. Finally, the final pre-stack Kirchhoff 3D time migration volumes of the base and monitor were subsequently used to generate the final time-shift volumes and difference cube (base subtracted by monitor survey after time variant alignment applied)

The key to achieving the objective of the processing was the careful and detail QC work at each crucial step and the regular engagement involving the processing geophysicist, QI geophysicist and the asset team geologist.

The time-lapse Results

The average RRR of the non-time-lapse area obtained from the final migrated seismic volumes was less than 0.2. The compaction-related time-shift on top of the reservoir was in the order of 0-3ms two-way-travel-time (TWT) and the classic stress-arch above the compacting reservoir was also evident as shown in Figure 3. Within the reservoir, the 2002 and the current 2006 GWC were evident on the time-aligned difference volume. This is highlighted by a very clear sweep signal as shown in Figures 4. The observed sweep signal supported and explained the production data and therefore, provided valuable information to enable management to make business decisions on the F6 development plan.

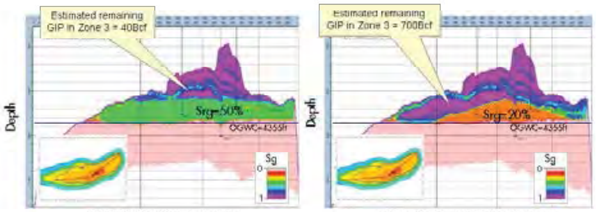
Conclusion

The F6 time-lapse story has been considered as a success and a timely fit-for-purpose project. It demonstrates the need for effective cross-disciplinary integration throughout project execution. The effort put into the feasibility study, acquisition planning and execution, and careful processing paid dividend. The success is also credited to the knowledge transfer of the Shell Group's time-lapse experiences in the North Sea and Gulf of Mexico. Last but no least, the delivery of the technology will not have been realized without management and stake-holders' support.

The time-lapse results are now being used to constrain the dynamic simulation, before forecasts can be produced for a range of potential redevelopment options in F6.

Acknowledgement

The authors would like to thank Ronald Hoogenboom, Lee Bor Seng, Osman Khan, Eng Kia Meng, Khaw Lay Hong, Wong Kah Luk and Tim Barker of Sarawak Shell Berhad who have contributed to the success of this project.



Model 1: Uniform contact rise **Model 2**: Cone-shaped contact rise

Figure 1. Feasibility study models showing remaining gas in-place.

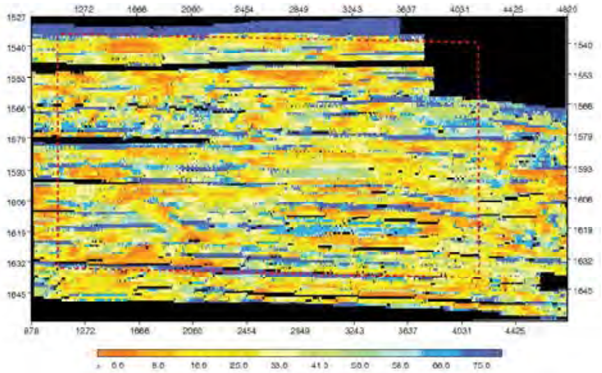


Figure 2. DSrc + DRec map after time-lapse trace selection produced by CSL on offset slot 2450-2550m.

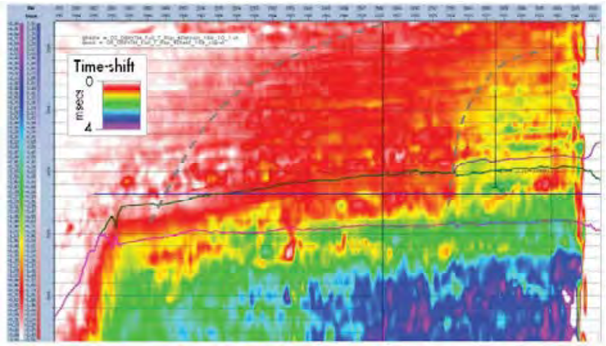


Figure 3. Amplitude difference volume of the F6 time-lapse dataset (2002 vs. 2006)

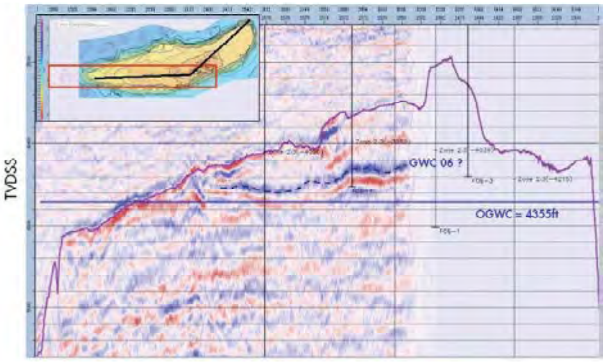


Figure 4.

Geophysics Paper 24

LARGE-SCALE PORE PRESSURE PREDICTION AFTER PRE-STACK DEPTH MIGRATION IN THE CASPIAN SEA

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Introduction

In recent years the prediction of pore pressure has undergone various developments. Geoscientists, such as reservoir and processing geophysicists, are more involved in the application of processes to do predictions based on seismic in 3D. Historically, it was only done on site in 1D. The advancement of seismic processing allows a more and more accurate estimation of the velocities. The combination of the knowledge of the engineers and geoscientists is extremely valuable in trying to predict the pressure cubes. Besides extracting the forecasted pressure profiles at future drilling locations from these volumes, they have an interpretation value. They allow a scanning to provide alternative well locations, see how the pressure regime is distributed with respect to the structure and geology and help with the identification of sealing or leaking faults. This last item is even more facilitated when used in combination with other now standard seismic attribute volumes that help identifying fluids and sands, such as those from AVO and Elastic Inversion.

It is the process of deriving as accurate as possible velocities from seismic processing which is one of the key factors in predicting reliable pressures. Obviously, this is where the processing geophysicists come in. On the other hand, this needs to be combined with an in-depth analysis of the well data, pressure data and drilling data by an experienced person such as a petrophysicist and a pressure engineer. The role of the reservoir geophysicist is to integrate the subsurface information with the specially conditioned seismic data to achieve the most reliable results.

In this article we describe the extensive pore pressure prediction (PPP) processing of 3D marine seismic data acquired over Blocks 01 and AB in the Caspian Sea, Turkmenistan. The data consists of two vintage surveys. The area after the merging of the two surveys covers approximately 1500 km2. It directly follows a pre-stack depth migration (PSDM) undertaken at the first stage of the complete processing project. This makes it a unique case study, but it is proven to be important (Dutta et. al., 2002). In cooperation with the client (PETRONAS Carigali), both a team of processing and reservoir geophysicists (CGG) and drilling experts (Knowledge Systems Inc.) provide the necessary input of disciplines. We would like to stress that it is not the intention of the authors to explain the concepts of pore pressure – there exists extensive literature (see for example Bell, (1998), Bowers, (1999, 2001, 2002), Bruce, Bowers, (2002), Sayers, (2006) and Terzaghi, (1943)).

Initial Well Data Pressure Analysis

An initial pore pressure prediction is undertaken. This is purely based on well and pressure data, and will give an understanding of the behaviour and various responses: do the curves react to varying pore pressure at all? Firstly, the Gamma ray logs are used to construct filtered petrophysical measurements in shales (as predictions are made in shales and measurements are in sands). Subsequently, various effective stress–velocity relationships predict pore pressure, which are refined to calibration data such as mud weight, pressure measurements and drilling events. A second prediction based on resistivity logs is carried out.

First of all, the vertical stress of the overburden needs to be computed, i.e. the Overburden Gradient (OBG), by integrating the composite density function. Most of this composite density function comes from well A, which should be reliable according to the Caliper-Bit Size overlay. The reason for constructing a composite density function is due to missing logging sections in various wells, as well as measurement accuracy errors related to hole enlargement. As Gardner (Gardner et. al., 1974) overestimates the densities in the shallow zone (first ~500 m), Miller's relation, purely based on measurements by Ostermeier et. al. (2001) is used. In this section there are no measured densities, which is very common.

Basic pore pressure gradients (PP) are predicted for the initial input wells using Miller (2002) and Bowers (1994) calibrated pressure models. Both these methods use the sonic log and represent nothing more than a velocity–effective stress relation. For all these wells, some crossing of the PP with the MW (mud weight) curves take place. Also, the match with the MDT measurements is sometimes not good. It should be noted however that pressures are predicted in shales and measured in sands. Some of the mud weight curves were not reliable. In well B, the sonic is estimated, which makes direct quality control comparisons less reliable. The pressure model parameters need to ensure predictions above the hydrostatic pressure (~ 9 ppg). It seems from the analysis however that the sonic logs do detect over pressure, hence it makes sense to use velocities for pore pressure prediction. Eaton's method (1972, 1975) of predicting pressure uses the resistivity logs. With this type of log however, a reliable prediction is not always possible. Some suspiciously low and high values, compared to the Normal Compaction Trend (NCT) were observed. From this, it is decided that the emphasis will be placed on sonic pressure predictions and that the resistivity based pressure predictions are not reliable enough.

For the Fracture Gradient (FG) prediction, normally the matrix stress ratio is determined from LOT measurements. The only data available to use were the LOT (Leak off test) or FIT (Formation integrity test) values, not the pressure vs. time graphs. This makes calibration more difficult (Postler, 1997). As some of the wells had shear sonic available, this could be used in the determination of an Effective Stress Ratio K0=PR/(1-PR) by computing Poisson's Ratio (PR) directly from the Sonic and Shear Sonic. With an average value from the actual PR logs, K0 is derived as being 0.795 (close to a common best experience value of 0.8) and used to predict the FG with the Matthews and Kelly method (Matthews, Kelly, 1967). The FG can also be computed directly using the PR logs (Eaton, 1968, 1997). Subsequently, comparisons with the selected LOT and FIT data points can be made. For a comparison of the individual well FG predictions see Figure 1 (Matthews and Kelly in blue, using PR log in yellow, a 'definitive' pick in greenish colour interpreted by the geomechanical expert).

Analysis shows that one simple NCT most likely does not suffice. Both temporally and laterally there seems to be considerable variation in the compaction trend. This can have various causes, e.g. compartmentalisation or tectonic uplift concentrated in an area. At this stage, it was analysed at what depth the biggest change occurs in the compaction trend for each of the wells. These depths are largely consistent with the depth of the RS4 marker. See Figure 2 for a description of the two Miller models, one above ('Miller 1') and one below ('Miller 2') the RS4 horizon. In Figure 3 it can be seen that the PP prediction based on this multiple NCT gives better results in relation to the MW curves and MDT measurements. There is a danger here to adjust the NCT to predict desired pressures, but thorough analysis has shown the pressure variation exists.

Seismic Processing and Velocities

As this PPP is preceded by a PSDM, we have as input CRP gathers and their associated final velocities. These final RMO velocities have been manually picked on a coarse grid to apply the final RMO correction. The velocity model coming out of the last iteration from the PSDM is used as input to this RMO analysis.

The high-density simultaneous velocity analysis technique used picks a high density VRMS and η (effective eta – this parameter accounts for the anisotropy of the layered rock, i.e. velocity variations with direction) field (Siliqi et. al., 2003). This enables the events to be flattened to higher incidence angle than would be the case with a 2nd order stacking velocity correction. Such an automated velocity analysis was performed using a grid of 8 Inlines x 8 Crosslines (100 m x 100 m), using the RMO velocity analysis as an input guide.

In order to be able to use the seismic velocity field for pore pressure prediction it has to be converted from RMS to interval velocity. Normally, the regularly sampled velocity field (in time) is converted using Dix' approximation (Dix, 1955), but this can lead to some instabilities. Furthermore, we want to preserve as much information as possible, hence a small sample rate has to be used. In order to achieve this goal of a high-frequency, stable velocity conversion, a novel approach has been used:

- ○ The gathers, after removing the RMO correction, are higher order NMO corrected using the new dense velocity and eta field;
- ○ These gathers are stacked to form the highest quality stack as input;

- ○ Based on a user-defined amplitude threshold, the stack is used to form a ‘skeleton’ of values of 1 (elsewhere the values are 0) along coherent events or where there is sufficient signal;
- ○ The RMS velocity field, at seismic sampling, is multiplied with this skeleton;
- ○ In order to get the final interval velocity attribute, the RMS to interval velocity conversion is done using the irregularly sampled RMS velocity field. Because this is done consistent with the geology and along coherent events, the vertical resolution is similar to the seismic resolution. The accuracy of the interval velocity at this resolution depends on the seismic noise level, which generally increases with depth. It is difficult to estimate directly, but it should be higher than with a standard Dix conversion.

To be consistent with the depth conversion decided upon during the PSDM post-processing phase, this new final interval velocity attribute volume in time was converted to depth, using exactly the same average velocity field for conversion of the PSDM seismic imaged volume.

Further Calibration and Compaction Trend

A cross-plot of the new seismic interval velocities along the well tracks against the well sonic velocities shows that for parts the scatter in values is still present. When we leave out wells E and D, this situation readily improves. Even though the correlation is quite good, it was decided to test calibrating the seismic interval velocity field to the well sonic velocities to possibly improve even more on the input to the pore pressure prediction. For this process, the residuals between the seismic and well velocities will be computed and kriged in 3D. These residuals will then be added to the initial seismic velocity field. This method was tested using a kriging radius of 5 km and 10 km. Well A was initially not used in the kriging to serve as a ‘blind well’ test and to provide a validity check for the kriging parameters. The result at this well can be seen in Figure 4, based on which it was decided to apply the kriging step with a radius of 5 km.

Earlier, a calibrated Gardner relation was derived based on the well data to estimate the density from the P-wave velocity (Gardner et. al., 1974). This relation is applied to the new calibrated interval velocity cube. Along the well tracks, this seismically derived density can be cross-plotted against the well density logs. The observed scattering was attributed to the well data quality, as the calibrated Gardner relation purely based on well logs gave a very high correlation between density and velocity. Many observed large differences between the bit-size and borehole-size logs support this argument. This will influence both log measurements. A first order regression inside the cross-plot (excluding outliers) gives an equation that can be applied to the ‘seismic’ density cube to perform a residual calibration. Subsequently the OBG can then be calculated. This OBG volume, computed using the density volume derived from the calibrated interval velocity volume (through kriging) with the additional residual density calibration step was used in the final pressure volume calculations.

It was concluded in the initial well data analysis above that a varying NCT would be used, a shallow zone from the mud-line to RS4 and a second zone below the RS4. In order to see the lateral variations, the interval velocity attribute volume was scanned to establish the spatial variation of the NCT curves on a defined grid of 1 km by 1 km. In order to generate the NCT volume computations, these grid points will be interpolated to cover the final seismic grid. This ‘scanning’ consists of extracting the velocity trace at the selected locations and defining the best lambda parameter for the Miller equation, so that a NCT curve is obtained that fits the respective velocity trace. This is done for the velocity traces between the water bottom and the RS4 horizon and downwards from the RS4 horizon. For both of these zones, there is a distinct difference in the structurally higher eastern area of the seismic data.

Analysis and Conclusion

Now that the OBG and NCT are defined, the PP gradient and the FG can easily be derived with the Miller pressure model. In Figure 5 and 6 the results of the seismic and well pressure prediction are displayed for a few selected old and new wells (these wells were not used in the petrophysical calibration, they became available at the end of the project). Good quality well ties are obtained for the newest wells F and G between the seismic pore pressure prediction and the sonic pore pressure prediction. For the other wells, in general, the ties are fair or reasonable – at least the same trend is present in the sonic PP and the seismic PP. This is proof that the velocity attribute volume is accurate for the pressure estimation, which has achieved good results in the two separate parts of Block 01 and Block AB.

The manual RMO analysis of the PSDM phase of the project does not have sufficient high frequency content to be able to use it successfully in pore pressure prediction. This RMO however provided a good input velocity model for the dense automated velocity and eta analysis.

Furthermore, on the petrophysical model one can conclude that a spatially and vertically varying NCT is required in this area to predict pore pressures. Both resistivity and sonic data responded to pore pressure – seismic velocities should hence show pressure changes in shales. There are non-pressure related effects on the resistivity logs. Normal pressure portions of the well, events and MW logs are mostly used for pressure calibration. For use with seismic data, the Gardner sonic to density transform and the Miller velocity to effective stress transform are calibrated using well data.

Discussion

Shale and sand pressures appear not to be in equilibrium in the study area (concluded through comprehensive investigation of all available well data and geomechanical reports), which is required for calibration of the model (in shales) to measured pressures (in sands). Also, the measured pressures themselves are highly variable: structure, buoyancy and depletion can influence the sand pressures. The temperature differences in the Caspian Sea are expected to have minimum impact on the pressures. Due to the above, it seems that events and MW logs probably provide the most reliable calibration data. The fact that the pressures are not in equilibrium, as well as the high variability of the pressures may be linked to the compartmentalisation. The des-equilibrium means that the uncertainty in the predicted pressures increases. The observation that the two newest wells, F and G, give good ties is noteworthy. As these wells have not been used in the calibration of the petrophysical model (available only towards the end of the project), they serve as so-called 'blind' test wells. These wells are the first wells drilled using synthetic oil-based mud, and there is an uncertainty in the quality and origin of the older well data. With respect to the seismic velocity model, it can be stated furthermore that there is a high uncertainty in the deeper section (~ > 5 km) in the velocities due to the offset limitations. In the shallow zone (up to ~ 1 s, i.e. slightly more than 1 km), due to the limited offsets, no reliable velocity picking is possible.

Despite all the difficulties, it seems that a successful attempt has been made in predicting the pressures in this difficult area. The main challenges are (1) the pressure compartmentalisation, (2) non pressure related influences on resistivity logs, (3) variable pressures, (4) sands and shales often not in pressure equilibrium and (5) an extremely difficult velocity and imaging environment. It is still required to undertake real time prediction of pore pressures while drilling. The current volumes can be used as a reference. Due to the challenges listed and the seismic limitations, there will always be an associated uncertainty and error with respect to the pressure predictions. But the best attempt has been made, and the PSDM has increased the accuracy and reliability of the velocity model. The pressure model used can be updated when new well data becomes available. Of vital importance and value is the combination of well mechanical and operational knowledge and seismic processing expertise.

Acknowledgements

We would like to thank PETRONAS and PETRONAS Carigali for allowing us to present these results and their cooperation. Special gratitude to Mr. Nashrol Ariff Hussain and Mr. Peter Majid in PETRONAS Carigali Turkmenistan for their cooperation. Furthermore, thank you to CGGVeritas and KSI for their support. Personal thanks from Norbert to Chris Manuel for the cooperation during the project.

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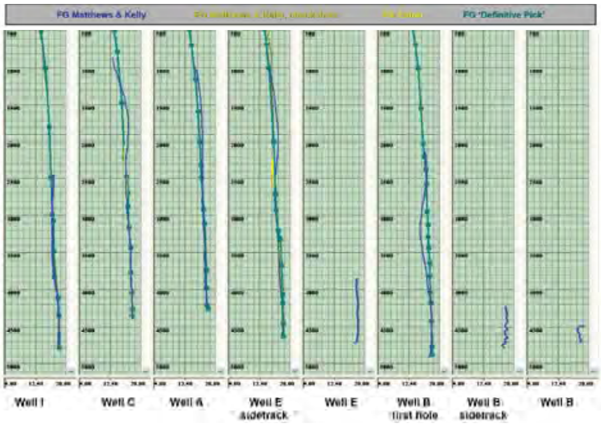
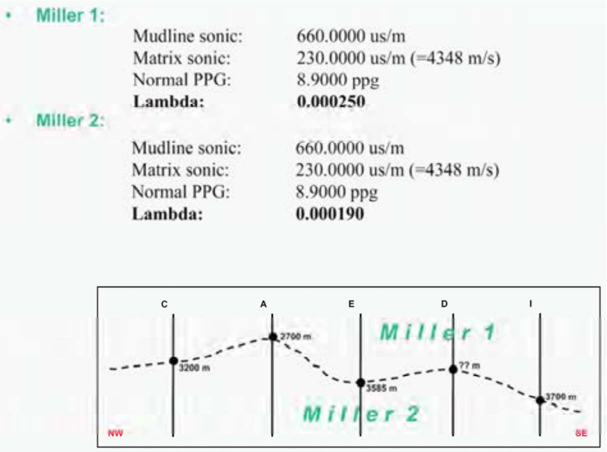


Figure 1: Individual FG comparisons.



- **Miller 1:**

Mudline sonic:	660.0000 us/m
Matrix sonic:	230.0000 us/m (=4348 m/s)
Normal PPG:	8.9000 ppg
Lambda:	**0.000250**

- **Miller 2:**

Mudline sonic:	660.0000 us/m
Matrix sonic:	230.0000 us/m (=4348 m/s)
Normal PPG:	8.9000 ppg
Lambda:	**0.000190**

Figure 2: Initial pore pressure model parameters using a multiple NCT with depth.

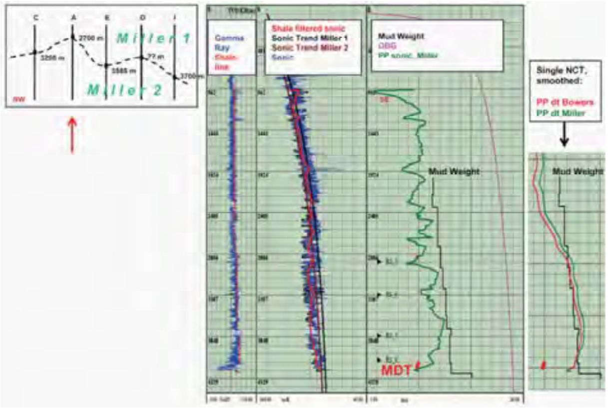


Figure 3: Composite PP results using multiple NCT

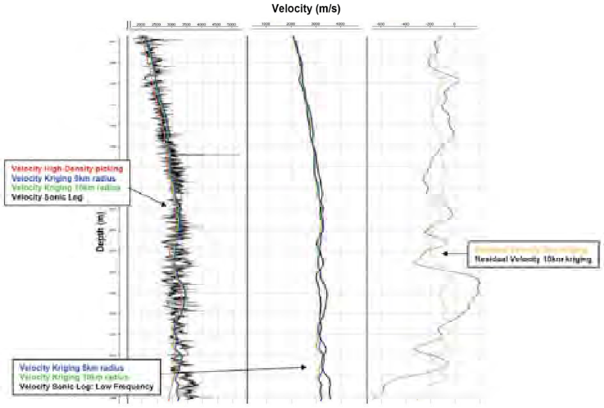


Figure 4: Velocity kriging – test results at blind well A

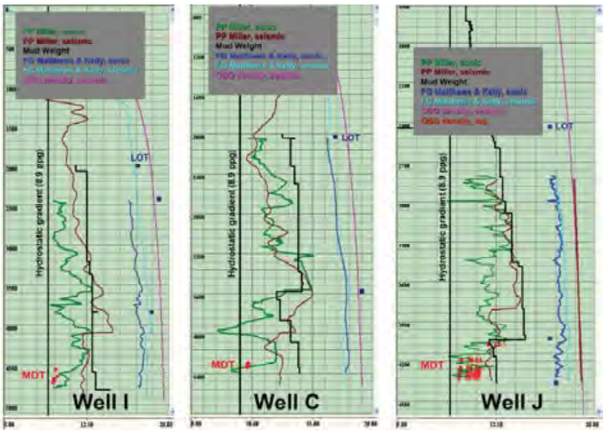


Figure 5: Well vs. seismic based pressure predictions for older wells

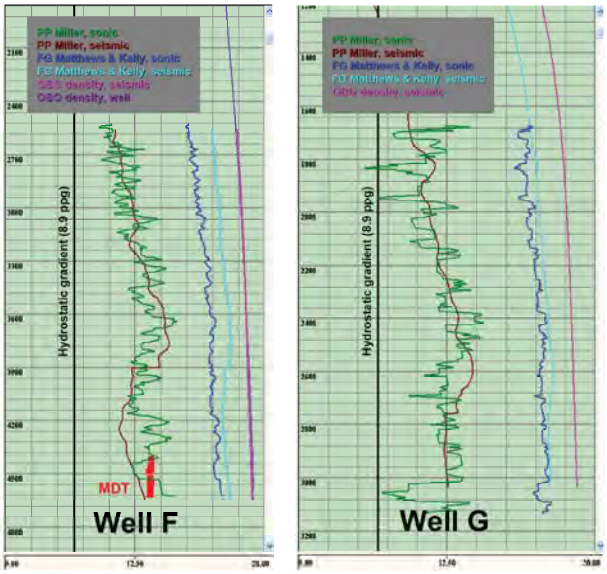


Figure 6: Well vs. seismic based pressure predictions for new wells

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Geophysics Paper 25

RESERVOIR CHARACTERIZATION AND MONITORING USING MULTI-TRANSIENT ELECTROMAGNETIC (MTEM)

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The MTEM method

The Multi-Transient Electro-Magnetic (MTEM) method implements a current bi-pole source with a sequence of receiver stations that measure the resulting voltage. Source and receiver stations are located in a straight line similar to 2-D seismic. Onshore and offshore acquisition systems have been developed providing continuous coverage of the subsurface including the transition zone.

The earth's impulse response is obtained for each source receiver pair by deconvolving the received voltage for the input current. The source signal is a Pseudo Random Binary Series (PRBS) that combined with vertical stacking allows us to maximize S/N. The subsurface resistivity is evaluated from the very shallow sediments down to the target depth by continuously optimizing the acquisition parameters. This involves adjusting the length of the source bi-pole, the bandwidth of the source PRBS, and the sampling rate of the recorded signal to be optimal for each offset range.

The method allows for real time monitoring of the signal and real time assessment of the subsurface resistivity. The final deliverables are 2-D depth sections inverted to resistivity along 2-D profiles.

Reservoir characterization

The MTEM data can be interpreted as a standalone product but the full value is realized when the inversion results are overlain on seismic 2-D depth sections showing the structure and stratigraphy. The reservoir(s) can then be evaluated easily for N/G, thickness and saturation. In well constrained cases where the storage capacity of the reservoir is well known, the STOOIP can be estimated.

Time-lapse monitoring

Seismic has proven the value of time-lapse or 4-D monitoring and is now uniformly recognized as an accepted technique. However, only half of all the reservoirs are suitable for seismic 4-D evaluation, whereas a large part of the remaining half should be well suited for MTEM 4-D. Resistivity monitoring has some significant strengths compared with seismic impedance monitoring. For example, many reservoirs require significant withdrawal of hydrocarbons before a detectable seismic 4-D signal is achieved as seen in Figure 1 below.

On the other hand, the resistivity changes most dramatically at maximum in situ hydrocarbon saturation facilitating 4D evaluation of possible by-passed volumes early in the production cycle, as seen in Figure 2 below. The 4D change in resistivity can cover three orders of magnitude.

Resistivity will then provide a much larger time-lapse change for a given saturation change, but EM suffers a loss of signal when the lateral extent of the by-passed volume is small in relation to depth of burial. Each case has to be evaluated individually by means of modelling, but the signal strength as a function of target size will appear as in Figure 3 below.

Seismic is also sensitive to increased effective stress that results from reservoir pressure draw-down, and the stress effects tend to radiate up into the overburden affecting the velocity field. This makes it harder to equalize time-lapse volumes. Resistivity is not sensitive to stress, only to porosity loss that may affect the reservoir but not the overburden. This combined with excellent repeatability makes constrained MTEM inversion a very sensitive monitoring tool.

In Table 1 below the strengths of MTEM are compared to the strengths of seismic in terms of in situ characterization and 4-D monitoring.

Conclusions

MTEM offers a strong alternative to seismic in many situations where seismic cannot reveal in situ characterization of fluid type and saturation, nor any 4-D changes in saturation. The two technologies complement each other and provide a very strong solution when combined. Seismic can provide the structural and stratigraphic information and MTEM reveal the hydrocarbon saturation, hence de-risking proposed drilling targets.

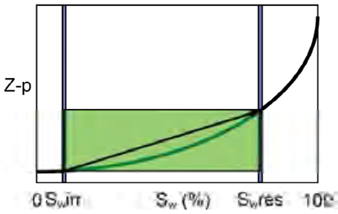

Figure 1: The water saturation (Sw) involved in seismic 4D monitoring ranges from irreducible water (Swirr) at full hydrocarbon charge and Swres at residual hydrocarbon saturation. The trajectory is close to linear and a detectable 4D signal may only be achieved at the later stages of production. The maximum acoustic impedance (Z-p) change is typically less than 20 %..

Table 1: Comparison between MTEM and seismic of in situ characterization of hydrocarbon saturation and 4-D saturation change.

Fluid characterization & 4D	MTEM strengths	Seismic strengths
In situ characterization of economic oil & gas reservoirs	All reservoirs except low resistivity pay	High porosity reservoirs & light fluids
In situ characterization of non-economic HC saturations	Yes	Cannot characterize gas saturation
4-D of high porosity reservoirs	With any hydrocarbon or CO2	Light oil with high GOR & possibly gas
4-D of low porosity reservoirs	With any hydrocarbon or CO2	No
Early 4-D changes	Most sensitive at early times	Linear with weak sensitivity at early times
Stress effects	Not sensitive	Sensitive
Porosity loss	Sensitive	Sensitive
Repeatability	Very good	Poor to fair
Cost of acquisition & processing	Wide range	Wide range
Environmental footprint	Smaller	Larger

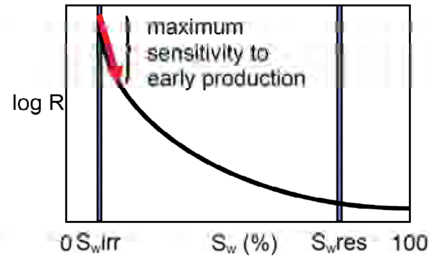

Figure 2: The range of possible water saturations from Swirr to Swres is the same as in the seismic case, but the resistivity is represented logarithmically.

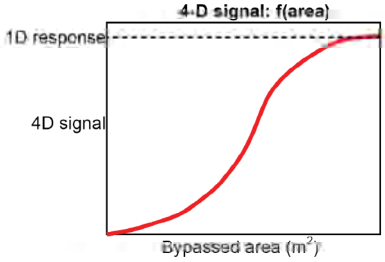

Figure 3: The time-lapse signal from a by-passed area describes an S-shaped curve as a function of area. The exact shape of the curve has to be determined in each individual case, since it is dependent on the entire resistivity depth profile.

Geology Paper 1

STRUCTURAL CONTROLS ON HYDROCARBON MIGRATION & ACCUMULATION: AN EXAMPLE FORM THE MUGLAD BASIN, SUDAN

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The Muglad Rift Basin of the interior Sudan forms an important part of the West and Central African Rift System. It is characterized by thick non-marine clastic sequences of Late Jurassic?/Early Cretaceous to Tertiary age. So far, well penetration is restricted to the Tertiary section in the deepest parts of the basin. However, more than 15 km of sedimentary section have been inferred from seismic data in the main trough.

Three major rifting episodes are documented in the basin. The first rifting event is estimated to have occurred in Late Jurassic?/Early Cretaceous, the second in Late Cretaceous and the third during Tertiary. The structural framework of the basin is controlled by two sets of faults: an approximately north-south trending set of Cretaceous faults and northwest-southeast trending Tertiary faults.

The repeated faults re-activation and, possibly, an oblique extensional stress direction during the Tertiary rifting, generated complex structures. This structural complexity had significantly controlled the generation, migration and entrapment of hydrocarbon. Examples of these controls include: (a) in the highly tilted and truncated parts of the source bed, migration of hydrocarbon is mostly directed into the overlying reservoirs; (b) faults dipping away from the troughs restricted the lateral migration of hydrocarbon; (c) discovered fields are located on well defined trends of gravity anomalies; (d) inter-basinal highs restricted the hydrocarbon migration from one sub-basin to the other; (e) smaller fault throws permit longer distances of lateral hydrocarbon migration.

Geology Paper 2

THE PROSPECTIVITY OF STRATIGRAPHIC TRAPS IN GROUP I INTERVAL, SEROK - LABA BARAT AREA, BLOCK PM 324, MALAY BASIN

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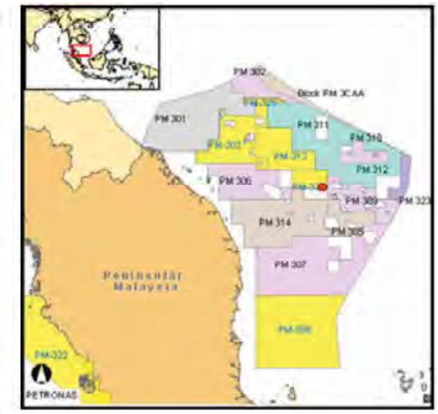
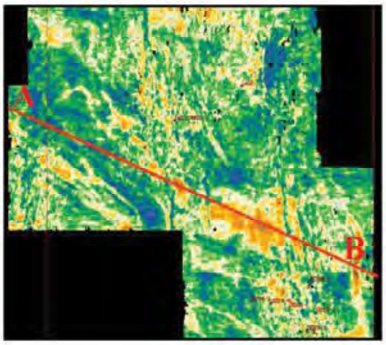
PRAM PMU, PETRONAS

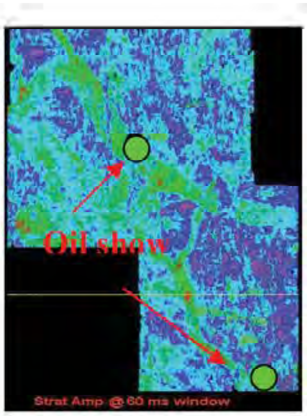
The Serok – Laba Barat area covers 20km x 20km, is located in open block PM 324 and geologically situated in the central part of the Malay Basin. It is made up of two east-west trending main culminations dissected by north-south trending sealing faults which were sites for typical fault-dependent plays exemplified by its three major discoveries: Serok (1979), Laba (1979), Laba Barat (1990). These discoveries proved significant hydrocarbon accumulations at mainly Groups E, F and H intervals. However most, if not all, of the previous wells drilled in the area did not adequately test the Group I section where nevertheless oil shows were observed.

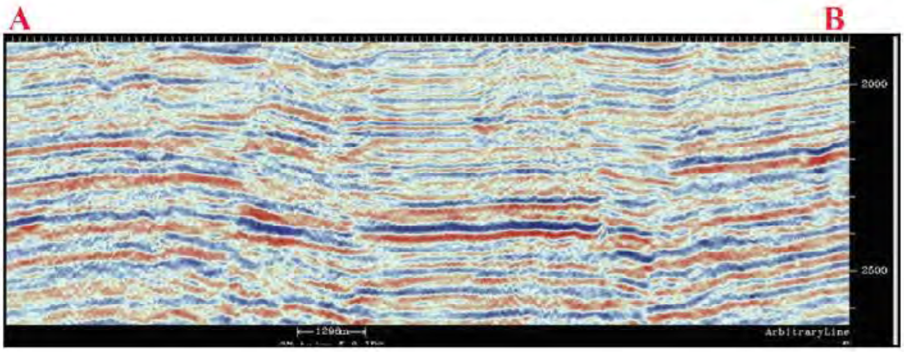
Group I is composed mostly of channel features trending NW-SE thus running parallel to the regional fault ramp margins of the Malay Basin. Locally, most of the individual channels were observed to be either flanking the sides or oriented perpendicular to the culminations. These progradational/aggradational fluvial to tidally dominated estuarine sands, which were deposited in back mangrove to front mangrove environments, are overlain by the predominantly marine to deltaic sediments of Group H & F.

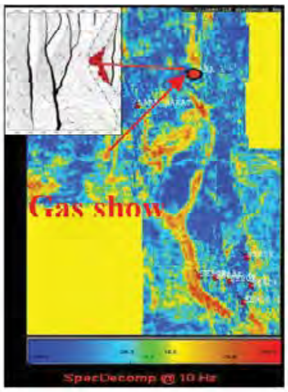
Based on seismic attributes combined with sequence-stratigraphic concepts, there seems a good chance that stratigraphic trapping involving I-channels would be effective.











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Geology Paper 3

BASIN MODELLING AND PETROLEUM SYSTEM ANALYSIS OF SOUTHERN SULU SEA - EAST SABAH BASIN

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This paper presents the results basin modelling work done on the southern portion of Sulu Sea – East Sabah Basin. The study area straddles across the international boundary separating Malaysia and Philippine. A compilation of the seismic data, laboratories data and well data was prepared for the project under the agreement of both sides including but not limited to vitrinite reflectance data, temperature data and lithology data etc.

Comprising predominantly of Neogene sedimentary sequences, the Sulu Sea - East Sabah Basin reflects the complex tectonic history of the region. Portions of the basins have been the target of previous hydrocarbon exploration activities. The presence of several hydrocarbon accumulations and shows through much of the drilled sedimentary section demonstrate that the basin has an active petroleum system. However, the complex geological setting has up to now precluded proper evaluation of any hydrocarbon upside potential in the area.

The database that was used for the present interpretation and review comprised more than 7000 line km of 2D seismic data on the Malaysian side. Eleven wells were used in the study, combined with various reports and publications. Vitrinite reflectance data were collated from the wells data and used as a basis of calibration for the model VR from basin modelling as well as measured porosity and temperature data was obtained from the individual wells as input into the model for calibration.

Hydrocarbon types in the Sulu Sea - East Sabah Basin range from light oil to condensates and gas. The hydrocarbon source in this area is believed to consist of dispersed organic matters ranging in age from Early Miocene to Late Miocene – Pliocene (ISIS, 2005). Similar characteristics were observed in Mahakam delta and Baram delta. There was not any direct correlation between the encountered source rocks and the type of hydrocarbon discovered in the basin; attributed to the lack of biomarker data for the source rocks. The environment of deposition is believed to be within the coastal plain like brackish swamp, lower coastal plain and such (slightly oxidixing deltaic environment). Therefore, Pepper & Corvi's type D/E organofacies were defined as the probable source rocks type. TOC values average around 5%, with the HI value ranging from 50 – 150mgHC/gTOC (100mgHC/gTOC on average and 250 mgHC/gTOC at the extreme end). TOCs from wells in East Sabah Basin present values that are mostly less than 1% at present day with some values of 1 to 3% can be seen in a few wells. Some intervals within the wells displays TOC values up to 10% and they represent coals which are believe to be the active source rock facies as has been demonstrated in Mahakam Delta probably due to their stratigraphic environment. Relatively oil – prone source rocks will be more likely to form in delta margins and estuarines as compared to more gas – prone source rocks in the upper delta plain (ISIS, 2005). The main source rock interval in this area was identified to be the Sebahat Formation (Mid Miocene – Late Miocene). Tungku Formation and Libung Formation from the Segama Group (Early – Mid Miocene) are also the suspected source rock bearing interval.

In the East Sabah Basin, heatflow values have been reported to be between 35 mW/m2 to 64 mW/m2.

The main reservoir sequence within the basin is believed to be the Middle Miocene to Late Miocene Sequence (Sebahat Formation) where the the depositional setting has repeatedly changed from shelfal to upper estuarine. Thus source rock and reservoir are often interbedded; forming stacks of individual reservoir – seal pair. Nymphe-1 that penetrated the synrift section (Early iocene to Middle Miocene sequence) also reported good porosity values at deeper depths. Default values were used for the chosen lithologies like thermal conductivity values, porosity trend with depth and such where the error ranges from 10 to15%.

The basin is believed to be mature at present time with an active petroleum system. The onset of maturity is found to be around 2000m to 3000m (Figure 1). At the flank of the basin, the oil windows are shallower (2000m) due to relatively thinner overburden. Thus, the heat from the basement was able to be transfer thru to shallower levels. Gas window starts around 4000m to 5000m depending on location.

Overpressure could be encountered in some parts of the basin where a thicker overburden and a thicker synrift section exist due to compaction disequilibrium. Seal and reservoir quality poses the highest risks in the basin. Fault sealing capacity analysis and pressure cell mapping might prove crucial to continued exploration effort in the area.

Successful charging to the identified prospects and leads are believed to have been achieved by hydrocarbon migrating through the faults that act as conduits (Figure 2). Even though short distance migration and vertical migration are deem to have charged most of the discovery here, the migration pathways have yet to be understood properly due to the models limitation.

Migration starts as early as Middle Miocene, although the volume expelled will be relatively small at the beginning of the generation period. Active expulsion occurs around Late Miocene during the rapid subsidence period. Charging to the structures occurs between Middle Miocene to Late Miocene (Figure 3). The critical moment was estimated to be around Late Miocene where 50% of the source rocks would have been converted into hydrocarbons (Figure 4).

In conclusion, this area is believed to be mature with an active petroleum system and consists mainly of gas play with some oil plays.

Acknowledgements

The author wish to thank PETRONAS and Department of Energy, Philippines for their permission to publish this paper. He is particularly grateful to the contributions from PETRONAS colleagues: Mr. Robert Wong Hin Fatt, Dr. Peter Abolins, Dr. Allagu Balaguru and Mr. Zulhaimi Abdul Rahman for their advice and help given. He also wishes to extend his gratitude to Mr. Barry Boyce for his help and advice in writing up the paper. All software used in the study is proprietary of IES and the author wish to thank IES for their help rendered, especially Dr. Björn Wygrala.

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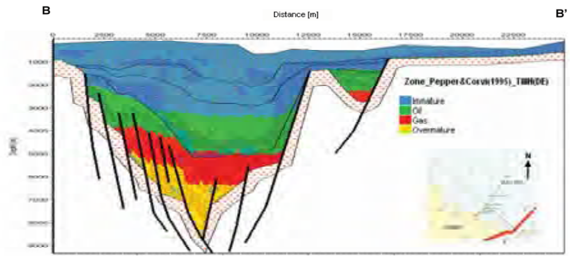

Figure 1: Hydrocarbon Generating Zones in Accordance to Pepper and Corvi

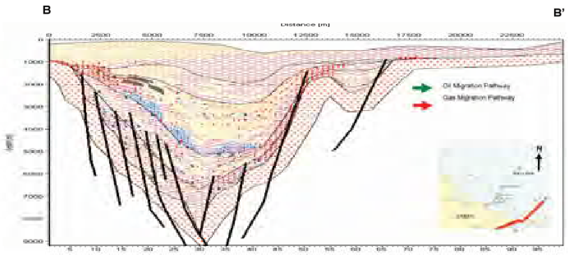

Figure 2: Migration Pathway

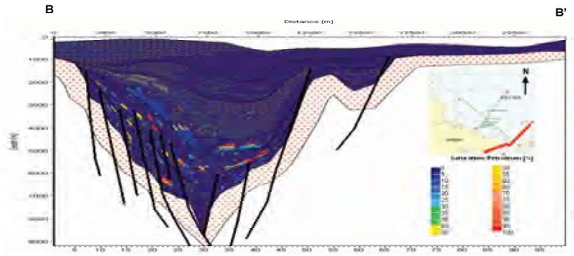

Figure 3: Hydrocarbon Saturation

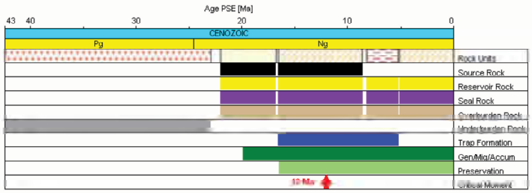

Figure 4: Generalised Petroleum System Chart

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Geology Paper 4

APPLICATION OF DEVELOPMENT WHILE EXPLORING (DWE) APPROACH IN MARGINAL FIELDS DEVELOPMENT IN PCPPOC'S BLOCK SK 305, OFFSHORE SARAWAK, MALAYSIA

Foo Wah Yang[1], Azlan Ghazali[1], Medy Kurniawan[2] and Bui Ngoc Quang[3]

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[2]PERTAMINA
[3]PVEP

PCPP Operating Company Sdn. Bhd. (PCPPOC), the Joint Operating Company of Sarawak Block SK305 PSC, is owned by a Consortium of Tripartite National Oil Companies, namely PETRONAS Carigali Sdn. Bhd. of Malaysia, PERTAMINA of Indonesia and PVEP of Vietnam.

Block SK 305 (16,434 sq.km) is located in the Balingian Geological Province where the main reservoir targets are Late Oligocene to Early Miocene Cycle I &II Sandstones deposited in Lower Coastal Plain to Fluvial- Deltaic environments. In PCSB's D35 Field, which is located in but ring-fenced from the block, oil and gas are currently producing from these Sandstones mainly of fluvial channel origin.

In the Northeast Corner of the Block or "D1" Area which is covered by 3D seismic, there are several marginal oil and gas discoveries with numerous small to medium sized prospects largely grouped in several clusters. Among these clusters, there exist D35 Production facilities with export pipelines to Bintulu oil and gas terminal adjacent to MLNG Complex.

The main economic risks associated with Marginal Field Development are reserves uncertainty and short field life. In order to expedite development and to mitigate such risks at the same time, PCPPOC carries out Development While Exploring (DWE) when the Area Development Plan (ADP) and FDP Studies are still in progress. The drilling program is strategically designed with exploration, appraisal and development in mind to narrow down volumetric uncertainty, firm up reserves, establish fluid contacts and completable oil column for future development. High CAPEX development options such as permanent installations like conventional production platforms and jackets are avoided. Instead, fit-for-purpose technology, low cost, temporary and mobile installations would be applied to expedite development, for example, the choice of Mobile Offshore Production Unit (MOPU) for maximizing the production within short field life. The development strategy would also leverage on existing nearby production, processing and export facilities at D35 to reduce the facility cost to minimum.

In addition, successful exploration/appraisal wells would be suspended for future development as opposed to conventional approach whereby such costly wells would be plugged and abandoned after drilling. Similarly, all development wells could be drilled and suspended ahead of any production installations. It gives the flexibility of completing the development drilling even if any delay in facility fabrication and installation should occur.

Through the smart and innovative application of the DWE approach and cluster development concept leveraging on sharing of nearby production and export facilities, the development project cost and schedule are substantially reduced, hence adding significantly value to the development of Marginal Fields.

Geology Paper 5

UTILIZING SEQUENCE STRATIGRAPHIC CONCEPTS TO DEFINE NEW PLAYS IN NW SABAH BASIN

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PMU, PETRONAS

NW Sabah basin, located in offshore of northwestern Sabah continental margin, is one of the most prolific hydrocarbon producing basins in Malaysia. The basin has been explored the last 110 years since the first exploration well Menombok-1 was drilled in 1897.

The sequence stratigraphic study for NW Sabah Basin was conducted since first March 2007 in conjunction with basin evaluation study for this area. The main objective is to identify new hydrocarbon plays and leads other than the conventional play type in the study area with seismic sequence stratigraphic application.

The regional seismic stratigraphy interpretation was established to identify the regional flooding surfaces and sequence boundaries leading to a regional sequence stratigraphic framework within the study area. The regional cross sections were also constructed to have sequence stratigraphic well correlation framework supported by surface age interpretation based on biostratigraphic data. Most of the interpretation is based on the major sequence stratigraphic event such as flooding surfaces, transgressive surfaces, sequence boundaries and also from genetic reflection packages (top lap, down lap, truncation and baselap), as shown in figure 1.

Some leads have also been identified in Highstand Systems Tracts (HST) prograding sand, Lowstand Systems Tracts (LST) , ponded turbidites, incised valley fill and lowstand delta and also Basal Transgressive Sands (BTS) deposited in a variety of tectonic settings and they will be exhibited in this paper. One example of BTS is shown in Figure 2.

Preliminary conclusion of the study is that the sequence stratigraphic concept can be applied in NW Sabah basin to come up with new play interpretation. The detail mapping and volumetric calculation of the new leads based on the new plays identified will be conducted as the study progresses.

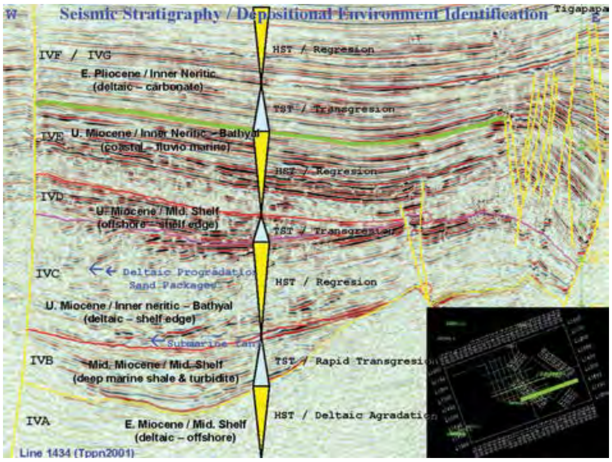

Figure 1: The sequence stratigraphic framework and depositional Environment identification within the study area interpreted based on seismic genetic reflection package.

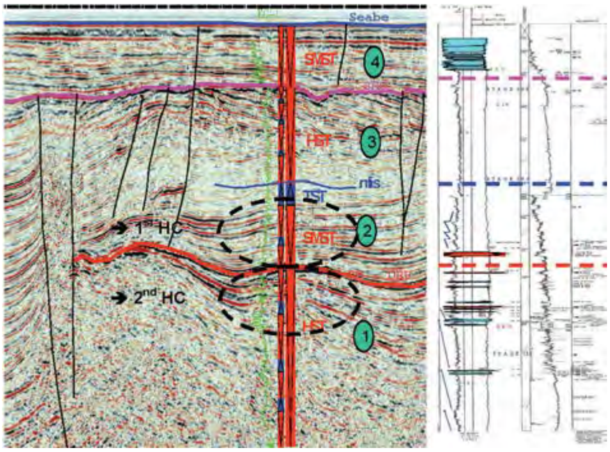

Figure 2: Sequence Stratigraphic Framework Calibration between seismic and well correlation.

Geology Paper 6

USING CORE AND LOG DATA TO LINK DEPOSITIONAL ENVIRONMENT WITH OIL SYSTEM IN SILICICLASTIC RESERVOIRS: CASE STUDY FROM MUGLAD BASIN, SUDAN

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Muglad basin is the major part of Sudan rift system, which in turn, is a main component of West and Central Africa Rift-related System (WCARS). Sedimentary sequences of Muglad rift basin consist of non-marine sequences of lacustrine and fluvial/alluvial facies of early Cretaceous to late Tertiary age directly rested upon the Precambrian basement. Muglad basin had passed through three sedimentary cycles. First sedimentary cycle began from early Cretaceous and its termination is marked, stratigraphically, by basin wide deposition of the thick sandstone of the Bentiu Formation. Second sedimentary cycle, occurred in late Cretaceous and seen in the widespread deposition of lacustrine and flood plain claystones and siltstones. The third sedimentary cycle was associated with the deposition of the Oligocene-Eocene Nayil Formation. These tectono-stratigraphic phases made a geological petroleum conditions, including source rocks, reservoir rocks and seal rocks in the basin. Bentiu and Aradeiba reservoirs, charged by Abu Gabra formation sourced oil, represent more than 80% of oil bearing zones of the Cretaceous oil system in the Muglad basin. Analysis of log and core data from 20 wells revealed that Bentiu formation sand zones represent a meandering and braided stream deposits with possible lacustrine environment. Aradeiba formation has mainly developed as lacustrine shaly deposits, providing efficient seal for underlying Bentiu formation and Aradeiba sands reservoirs.

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Geology Paper 7

DEPOSITIONAL SETTING AND HISTORY OF CORED INTERVALS RS 8 RESERVOIR BLOCK 1, SOUTH CASPIAN SEA, TURKMENISTAN

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PETRONAS Carigali Sdn. Bhd. has been actively exploring and developing the Block 1 area of the Central Caspian Sea, Offshore Turkmenistan for the past 10 years and to date has drilled 16 wells of which five have been cored, providing a near complete coverage of the RS8 reservoir section. The information derived form analysis of the cores provides invaluable control over the static and dynamic models developed to assess reserves and predict likely reservoir behaviour.

The lowermost part of the RS8 B interval is seen in the East Livanov (EL) 3a core and shows a series of units displaying very high dips on originally near horizontal surfaces. These features are considered to represent the results of large-scale slump and water escape processes. The slump units were confined to discrete intervals and in places these were closely associated with, and are probably co-genetic with, water escape features. In other instances water escape features are not clearly associated with slumps and may reflect seismically induced repacking of the sediment.

The overlying section in the available cores shows little in the way of sedimentary features, some burrows are locally developed but in general the very fine-fine grained sandstones show predominantly faint horizontal and low angle lamination with trough and planar cross-stratification only locally developed. In some instances complete bed sets are preserved allowing the recognition of large wave or dune–like bedforms some 1.5-2.0 meters in amplitude. Variably well developed horizons containing mudstone clasts are present. These are variously interpreted as the results of winnowing during storms or as a result of flood processes in the hinterland giving rise to event beds in the shallow lacustrine areas. These facies types are predominant in the majority of cores in the RS8B and RS8A intervals including those from the Oyez and Mashrykov wells some 50km distant to the N.W along the Apsheron structure.

It is worth comparing the lithofacies present in core with those described from outcrop in the Pereriva Suite sections in the Kirmaky valley, Azerbaijan. Here the lower part of the section comprise trough cross-stratified coarse sand to granule and fine to very fine grained sand sized material developed in a channel above an erosional basal contact. No such coarse grained material has been seen in core and similarly the cross-stratification that typifies these deposits is not seen. Stratigraphically equivalent strata have been described during fieldwork carried out by PETRONAS on the Chelekan Suite exposed in the Cheleken anticline in western Turkmenistan. Here well defined channel fill bodies occur, encased within sequences of reddened mudstones and thin bedded sandstones that as a whole are interpreted as floodplain deposits. Clearly there is a different facies assemblage represented in the East Livanov area to that seen in the onshore sections.

The sequence outlined above passes abruptly upward into an interval of dark grey to black mudstones with minor thin beds of siltstone, which locally show slump structures. A thin, 8-10 cm, carbonate horizon occurs at the base of this interval and comprises carbonate grains of probable algal origin as well as other bioclasts. Siliceous grains are present and the top of the unit has a crustose form and again appears to be algal in origin. If in-situ, the carbonate horizon would indicate oxygenated, clear water conditions. The overlying mudstones appear to have been deposited under anoxic conditions for the most part, although TOC analysis shows them to be organically lean. Mudstones in the lower part of the interval contain distinctive 'bladed' or swallowtail anhydrite, the remnants of a gypsum precursor. Similar gypsum crystals have been described from Palaeogene lacustrine sediments from southern France, where they have been interpreted as having grown within the sediment during early/shallow diagenesis.

Above the mudstone dominated section the sequence continues with an interval of sandstones and mudstones. The sandstones are again sharp based and show normal grading, in places passing upwards into an interval showing wave rippled beds. These beds record deposition from single event decelerating flows and may represent the deposits of seasonal flood events accumulating in a shallow lacustrine setting.

The section then passes into a mudstone dominated sequence that shows several horizons characterised by a mottled and vari-coloured appearance with the mudstones showing reddish and purpleish tones and having the typical 'slickensided' appearance of palaeosol horizons. No unequivocal root traces have been observed although a number of near vertical features were noted below the vari-coloured intervals and discussed as possible shrinkage cracks. The associated mudstones are dark grey, with interbedded sandstones that locally show trough cross-stratification. Probable wave generated structures are also developed. The section as a whole is interpreted as having been deposited in shallow lacustrine and lake margin settings. Frequent lowering of lake levels and dessication of the lacustrine mudstones is indicated by the shrinkage cracks and palaeosols, the associated sandstones most probably represent shallow lacustrine deposits. Analogues, at least in part, for the various facies may be found in the present day Caspian Sea and surrounding lake margins.

The following RS8A interval is cored in two wells only but shows essentially similar facies to those seen in the RS8B section. The RS8 sequence as a whole appears to document a progression from deeper water subaqueous lacustrine to shallow lacustrine, subaerial, emergent, conditions. Although no reliable indications of palaeobathymetry are available at present it is possible that the required change in relative lake level could be significant. Possible explanations for these observations are an absolute drop in lake level, possibly climatically driven; shallowing as a result of growth on the Apsheron structure; and mass movement of subaerial deposits into deeper water as a cohesive block

The slump features seen in the lower part of the cored section may reflect either tectonic instability or rapid sedimentation. More core from this section, and into the underlying interval, will be vital to a clearer understanding of the depositional setting.

The availability of cores from these wells has revealed a complex geological history in a highly variable reservoir section. Further understanding of the reservoir will require extensive coring and integration of the data with seismic and well log interpretations. Acquiring core is regarded as a necessity in all key exploration, appraisal and early development wells. This is prudent given the insight the present cores have given into the real complexity of the reservoir, which clearly does not conform to existing simplified depositional models.

Initial interpretation of the facies present indicates that the reservoir sandbodies are likely to have sheet-like architecture, with considerable lateral persistence. The presence of shale interbeds and thicker shale intervals will result in stratification of the reservoir.

In order to confirm the probable geometries of the sandstones and shales that constitute the reservoir section, detailed correlation of the sequences has been carried out. This indicates a high level of lateral persistence of the principal shale intervals. Similarly there appears to be considerable consistency in the development of sandstone packages within the section. Whilst thickness variations do occur, it is still possible to identify consistently developed genetic sequences. On this basis it is felt that the most likely scenario is that the reservoir sandbodies are developed as laterally extensive sheets, having continuity over several kilometres. This is consistent with a situation where a major control over the depositional system is provided by fluctuations in lake water levels.

Geology Paper 8

A GEOCELLULAR MODELING APPROACH TO CHARACTERIZATION OF FLUVIAL STACKED RESERVOIRS – NORTHERN FIELDS, BLOCK PM-3 CAA, MALAY BASIN

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3D geocellular modeling is becoming commonplace in today's sub-surface workflows. This short paper outlines, with examples, an approach to modeling reservoir morphology from seismic data and limited well information in the pre-development phase of a project.

Emphasis is focused on the methods used to integrate seismic attribute information and well data in to the static reservoir model and how Petrel™ is used to assess uncertainties associated with the static and dynamic input parameters. The study also aims to review the geological factors that may effect the flow regime within the reservoirs and ultimately the recoverable reserves.

Reservoirs in the Northern Fields consist of a series of fluvial to deltaic sandstones (figure 1) that vary greatly in lateral extent and thickness. Exploration and appraisal wells drilled to date have encountered over 120 reservoirs in 6 separate accumulations. Seismic data over the upper reservoir sections are of high quality but imaging degrades with depth resulting in a lack of confidence in mapping out reservoir aerial extent. In general, reservoirs are closely stacked on top of each other and all are below the seismic tuning thickness. These factors, coupled with the lack of production information, make estimation of reservoir geomorphology and dynamic behavior challenging.

In the first part of the study, methods are proposed that show it is possible to employ different seismic integration methods during geocellular modelling to help characterize the extent and internal architecture of the reservoirs. In some reservoirs, for example, there is a strong relationship between the seismic amplitude response and the gross sand thickness even below the seismic tuning thickness. A simple decision tree (figure 2) is used to determine the appropriate seismic integration to geocellular modeling methodology.

The second part of the study looks at an example workflow from interpretation through to reservoir simulation. Methods are proposed to streamline the modeling process and evaluate all levels of both static (volumetric) and dynamic uncertainty. Emphasis is focused on facies distribution and connectivity in particular.

Results show that perturbing the seed number in probabilistic facies modeling has a dramatic effect on the in-place volumes and dynamic behavior of the reservoir at this stage in development due to the lack of well control. Moreover, the geocellular modeling workflow coupled with the uncertainty modeling highlights the dangers of running with just one "p50" simulation case when planning the optimal depletion strategy.

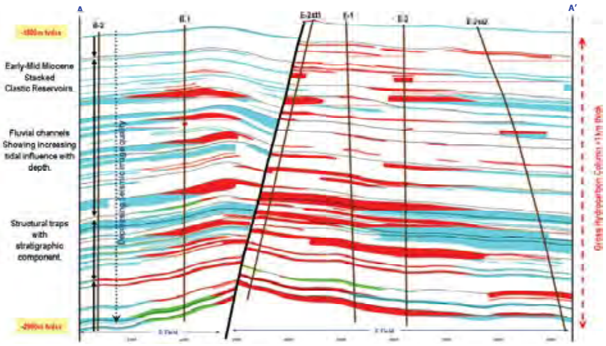

Figure 1: Stratagraphic cross section through Bunga Orkid and East Bunga Orkid.

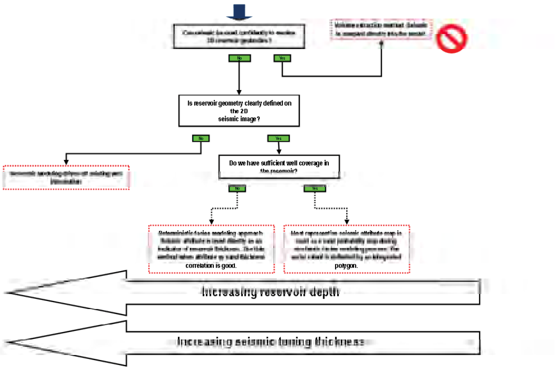

Figure 2: Seismic integration decision tree for geocellular modeling.

Geology Paper 9

SEQUENCE OF SLOPE INSTABILITY AND HEALING: KEY TO PREDICTING DEEP-WATER RESERVOIR DISTRIBUTION IN NW BORNEO

Martin Grecula, Senira Kattah, Mark Griffiths, Bill Wilks, Homerson Uy, Kuswadi Hedeir, Hong Chin-Weng, Kelly Maguire, Peter Osterloff, Eleanor Rollett and Peter Shiner

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Drilling results in deep-water Sabah acreage have proved the presence of sizeable turbidite reservoirs in the NW Borneo basin-slope environment. The reservoir distribution and quality, however, show significant spatial and temporal variation. Spatial heterogeneity is related to different source terrains, shelf dynamics and the location of entry points into the upper slope. The temporal heterogeneity is ultimately linked to the episodes of tectonic deformation and subsequent geomorphologic healing by gravity flow deposition.

The slope accommodation in NW Borneo was episodically created by the thrust-propagation folding as well as by the local extensional faulting, preceding the compression. The instability phase of a depositional sequence is typically marked by the truncation or disconformable surface, overlain by mass-transport deposits (MTDs). These slumps and debris flows were derived either locally, from the growth-anticline limbs, or from the shelf-edge collapses. The healing phase of a sequence contains turbidite aprons and unconfined slope wedge deposits. Depending on the volume and shape of the slope accommodation, the aprons may be vertically stacked above the MTDs or laterally offset. In the former case, the reservoir may show significant thickness variation due to the rugosity of the underlying surface. Presence of reservoir facies in the aprons is dependent on connection between accommodation and an active sand fairway – if the connection is not established, the apron deposits are dominated by muddy turbidites and thin-bedded unconfined sands. The healing phases of the depositional sequences contain several regionally continuous seismic events, which are interpreted as hemipelagic drapes, and thought to represent periods of limited sand supply to the slope environment. The drape-interval recognition is critical for the establishment of regional sequence stratigraphic framework.

The instability events during the deposition of the prospective interval of the NW Borneo slope typically produced relatively subtle syn-depositional topography, which predetermined the character of slope healing. Most of the healing-phase aprons are transient in nature and often bypassed and dissected by later channelised flows. As their thickness is often at the limit of seismic resolution, very detailed seismic mapping is necessary to detect them.

Accumulated learning from the ongoing exploration activity in the region suggests it is necessary to integrate all existing datasets and develop scientifically well-founded conceptual depositional models. It is the recognition of the genetically linked deformation-and-healing depositional sequences, followed by careful reconstruction of the accommodation and its filling patterns, that enables us to increase the chance of finding good reservoirs in this challenging environment. This also opens the way to recognizing and exploiting new stratigraphic play concepts in the NW Borneo basin.

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Geology Paper 10

SEISMICALLY DRIVEN RESERVOIR CHARACTERIZATION USING AN INNOVATIVE INTEGRATED APPROACH: APPLICATION TO A FRACTURED RESERVOIR

ABDEL M ZELLOU[1], SOREN CHRISTENSEN[2], TANJA EBBE DALGAARD[3], GARY ROBINSON[1]

[1]Prism Seismic
[2]Hess
[3]Dong

Summary

This paper presents an innovative integrated workflow applied to the characterization of a fractured chalk reservoir in the Danish North Sea. The methodology uses simultaneous integration of geophysical, geological and engineering data to produce an improved reservoir description. Integrating dynamic flow data with the geophysical and geologic information in 3D, reservoir properties - porosity and effective permeability - are generated using artificial intelligence tools. The strength of this technique lies in the fact that property modeling is not constrained to match upscaled well data and consequently these data serve to validate the outcome.

This workflow builds upon a methodology that has been used successfully for the characterization of fracture distributions. The technique has been extended to include the generation of seismically derived models of porosity and matrix permeability. The objective of the approach is to improve the ability to capture the heterogeneity of key reservoir properties, and thus use the resulting reservoir model to both provide improved predictive ability and identify previously undiscovered development opportunities. The application and outcome of this integrated workflow to the Syd Arne field is presented in this paper.

Introduction

The Syd Arne field, operated by Hess Corporation, is located in the Danish part of North Sea (Figure 1). The field, presently estimated by the Danish Energy Agency at 185 MMstb of oil and 434 Bscf of gas of initial reserves, was originally discovered in 1969 by the I-1X well. However, it was not until 1995 and the drilling of the RIGS-1 well the extension and true value of this accumulation was appreciated. The Field came on production in 1999 and year-to-date a total of 17 development wells have been drilled divided into 11 producers and 6 water injectors.

The Syd Arne field lies approximately 250 km offshore west of Denmark. It is an elongated anticline, 12 km by 3 km, and is one of the Cretaceous) to Danian (Paleocene) chalk of the Tor and Ekofisk Formation (Fm).

In this interval, the late Maastrichtian is the best reservoir layer and there is currently no dedicated development of the Ekofisk Fm. The field lies at a depth of between 2700-2940 m subsea. Over the crest of the field the oil column is restricted to the thickness of the reservoir.

Following the "rediscovery" of the field in 1995 a 3D survey was acquired. This survey is the basis of all geophysical work on the field for the past decade, despite the somewhat poor data quality. In third quarter of 2005 a combined 3D and 4D survey was acquired, but these data were not available for the present study. The 1995 survey has been reprocessed several times with the objective to improve structural imaging and resolution, with the most recent versions being a Pre-Stack Time Migration (PSTM) volume from 2001 and a Pre-Stack Depth Migration (PSDM) volume from 2003. As with most chalk fields in the Danish and Norwegian part of the North Sea, Syd Arne is plagued by a gas cloud in the overburden at the center of the accumulation, causing strong attenuation and poor quality of the seismic data in this portion of the field.

The work presented in this paper was initiated with a 6 month pilot study conducted in a restricted part of the field based on the PSTM data. Following this pilot study, the full field work was initiated using the PSDM seismic data. Although the PSTM volume was considered the preferred volume for mapping of key horizons, major problems in terms of structural imaging were identified during the pilot and consequently the PSDM volume was adopted for the present project. Mapping of key horizons from the PSDM seismic volume was greatly facilitated by taking the second derivative of the seismic amplitude data, especially over the crest of the structure where the target interval in places is very thin and the seismic response over the interval of interest is dominated by tuning.

3D modeling of porosity and permeability in the field has always been very challenging. There are several reasons for this, with the major ones being the adverse effects of the gas cloud in the overburden on the seismic data and a lack of confidence in the ability to map porosity accurately away from the crest of the structure due to changes in the Acoustic Impedance vs. Porosity (AI-PHI) relationship together with a lack of control data for calibration of inversion down flank of the structure.

It is evident from well performance and history matching that the Syd Arne reservoir permeability needs to be enhanced from the matrix permeability derived from core measurements due to the presence of fractures. The permeability enhancement due to fractures in the Syd Arne Field is modelled as a single continuum effective permeability, which is derived from two components:

1. A matrix related permeability considered as the background base permeability
2. Additional permeability from fractures.

The density of larger scale fractures should be correctly modeled vertically and spatially in order to capture the distribution of permeability enhancement due to fractures, which is important for the dynamic behaviour of the field. In this study, the modeling of porosity and permeability will rely on the use of multiple seismic attributes derived from high-resolution inversion and spectral imaging according to the workflow shown in Figure 2.

Previous work (Ouenes et al, 2004) has demonstrated the significant advantages of incorporating multiple seismic attributes in modeling fractured reservoirs using the Continuous Fracture Modeling (CFM) approach. In this approach, two major artificial intelligence tools are used: a fuzzy neural net for ranking the multiple seismic attributes and a neural network to find the potential relationship that may exist between the estimated reservoir property and its drivers. This same approach is extended to porosity estimation.

In addition to the availability of high-resolution seismic attributes, this porosity modeling workflow uses seismic and structural attributes that have a demonstrated geologic meaning. Previous porosity modeling work (Pramanik et al, 2004) has focused mainly on the use of many standard seismic attributes such as amplitude and attributes derived from the amplitude. In the Syd Arne workflow, spectral imaging attributes add information to the modeling process. As evidenced by Kalkomey (1997), adding seismic attributes does not necessarily improve the prediction capabilities of the model. To avoid using spurious attributes, a ranking tool is used to select only the spectral imaging attributes that are truly contributing to improving the modeling of porosity.

Porosity modeling constrained by multiple seismic attributes

Prior to the parameter modeling, a 3D grid was constructed in the depth domain. The grid dimensions are 5 x 18 km and include 42 layers in the Ekofisk and 83 layers in the Tor formation. The cell thickness is 2.5m in the Ekofisk and 3m in the Tor formation. This high-resolution mode (Figure 3) is needed as some of the reservoir features are only a few meters thick. The normal seismic resolution is insufficient for accurate estimation of petrophysical properties at a useful geologic scale; high resolution seismic attributes are key to successful incorporation of seismic data in reservoir modeling.

In addition to the inversion and structural attributes (such as slope, curvature, structure and deformation), other important drivers that might have an impact on the distribution of the porosity were included. Such drivers included spectral imaging attributes like phase and energy at different frequencies, tuning frequency and attenuation frequency.

One of the main reasons for including spectral imaging attributes in the porosity modeling was to investigate if any

of these spectral imaging attributes could compensate for some well known issues/problems seen in the inversion where the inversion model underestimate the AI hence overestimate porosity in some special areas. This is also one of the main reasons why several iterations of the inversion model were made (Figure 5 middle well panel).

Multiple porosity models were generated using eight drivers and the porosity at 15 of the 48 wells available. To evaluate the reliability of the predicted porosity models, the predicted versus actual porosity was compared at wells not used in the modeling (blind wells). Figures 4 and 5 show the comparison between the actual and predicted porosity at various wells. From these comparisons, one can notice the ability of the workflow to capture the vertical heterogeneities along most of the wells.

The influence of parameters other than AI on the porosity was investigated by making comparisons to conventional models using kriging of porosity in wells with AI as secondary volume. The conclusion of this investigation was that the main driver for porosity is acoustic impedance. The influence of the spectral imaging attributes has proven to be minor at the well locations, and it was not possible to compensate for the problems in the AI by adding more geological information. The correlation to acoustic impedance is so strong that it overrules all other parameters. To correct for the overestimation of porosity in certain areas and to capture the log porosity exactly in all the wells the final model was kriged to well data.

The porosity modeling has been an iterative process with several updates of the inversion model reflecting findings and conclusions found in the porosity modeling process. The result of this iterative process is an inversion product with a greater accuracy. This high accuracy and vertical resolution is incorporated in the porosity model.

One main advantage of using the neural network technique for porosity modeling is that it is possible to get a reasonably good match to well data without directly using well data. This allows direct comparison of the model to well data, providing information about uncertainty in different areas of the field. This qualitative information regarding uncertainty in the porosity model is not ovtainable with conventional modeling methods

Conclusions

There are many advantages of this new workflow. The increased and iterative effort in the a prioiri model building translates into an improved inversion result and increased understanding of sensitivities. Furthermore, the established workflow allows multiple inversions carried out in a very short time (i.e. few days), investigating the impact of using different models. Finally, the applied inversion technique, even when provided with a low frequency model (i.e. 1st stage inversion), has proven able to extract more information from seismic data as compared to previous inversions.

The porosity modeling has been an iterative process with several updates of the inversion model reflecting findings and conclusions found in the porosity modeling process. The result of this iterative process is an inversion product with a greater accuracy. This high accuracy and vertical resolution, is incorporated in the porosity model. Many of the added details are validated by well data; some of the most promising prospects identified from the inversion and the subsequent porosity model will be tested in a drilling campaign scheduled for 2007.

In addition to using the seismic data for porosity modeling, multiple seismic attributes are also used in fracture modeling. By using the structural and lithological information available in the seismic data, the fracture modeling software is able to generate models that can capture the complexities of the fracture drivers that determine fracture intensity. These fracture models are then calibrated and translated into an effective permeability model using well test data or/and reservoir simulation. The models derived in this new workflow provide some immediate benefits, as seen in the predicted porosity of the newly drilled wells and the results of the first simulation run.

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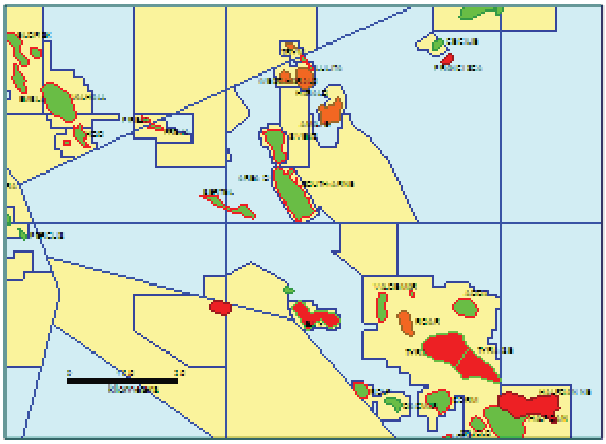

Figure 1: Location Map of the Syd Arne Field

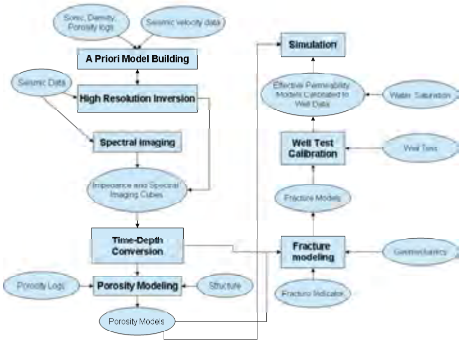

Figure 2: Integrated workflow for the characterization of the Syd Arne field. Methodology Overview

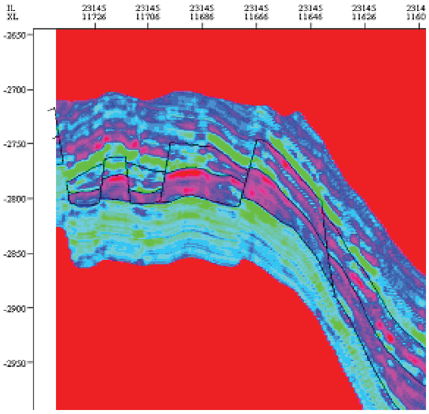

Figure 3: High resolution inversion results with the model framework (horizons and faults) superimposed.

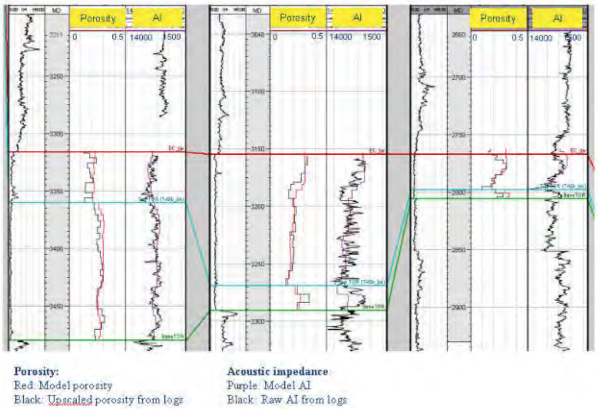

Figure 4: Comparison of model porosity before kriging to porosity from logs and AI.

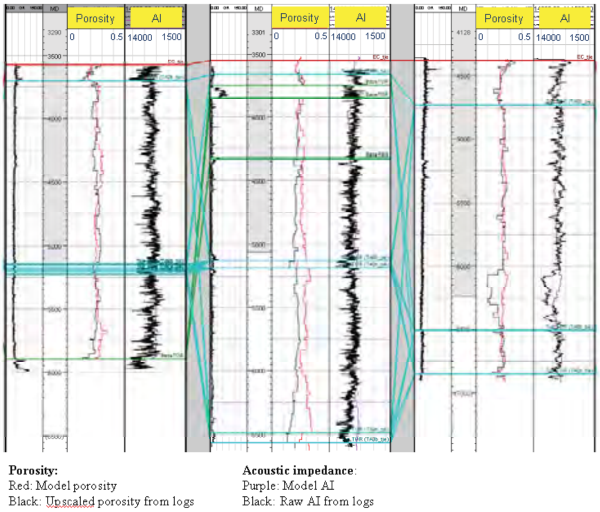

Figure 5: Comparison of model porosity (before kriging) to porosity from logs and AI . The middle well shows the overestimation of porosity from AI.

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Geology Paper 11

THE WEST CROCKER FORMATION (EARLY OLIGOCENE TO MIDDLE MIOCENE) IN THE KOTA KINABALU AREA, SABAH: FACIES, SEDIMENTARY PROCESSES AND DEPOSITIONAL SETTING

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The West Crocker Formation in Kota Kinabalu area in Sabah is one of the best exposed examples of deepwater sedimentary sequence in Malaysia. This paper describes and documents the detailed facies characteristics and sedimentology of outcrops, and proposes a depositional framework for the West Crocker Formation in the Kota Kinabalu area.

Based on lithology, sedimentary structures, geometry, trace fossil assemblages, and paleocurrent data, the sediments are grouped into seven major facies. These are; i) facies A - thick, massive, and structureless sandstone; ii) facies B - thick, and massive sandstone with the presence of post-depositional dewatering structures; iii) facies C - graded sandstone and occasional complete Bouma Sequence; iv) facies D - thin-bedded fine-grained sandstone and siltstone and graded into base-absent Bouma sequences; v) facies E - sandstone and shale interbedding, and frequently marked with lenticular bedding; vi) facies F - slump beds, and vii) facies G - shale. Table 1 summarises the characteristics of the different facies in the study area.

Four deepwater architectural elements had been identified based on the study of vertical successions of facies. These are: i) slopes are made up of turbidite facies F, G, and E; ii) channels are represented by coarse- and medium-grained massive sandstone with predominantly facies A and B; iii) depositional lobes are formed by medium grained sheet sands, made up of facies C and D, and showing a coarsening- and thickening- upward sequences; iv) heterolithic levee-interchannel facies association, predominantly shale with thin, fine-grained sandstone, and siltstone, made up of turbidite facies D, E, F, and G, and showing a coarsening- and thickening- upward succession. Table 2 shows the characteristics and pattern of facies associations in the study area.

This study has shown that the West Crocker Formation, which previously has been referred to as "turbidites", is not composed of solely turbidity current deposits, but includes debris flow, slumps and other submarine mass-transport deposits.

Table 1: Summary of characteristics of the different facies of the study area

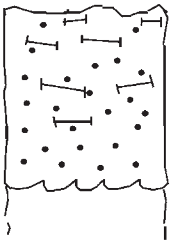
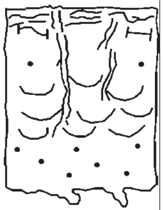
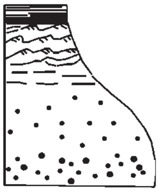
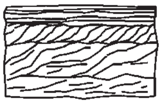
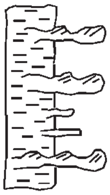
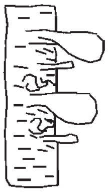
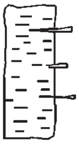
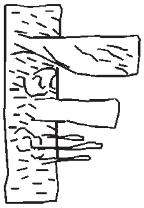
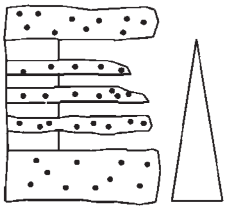
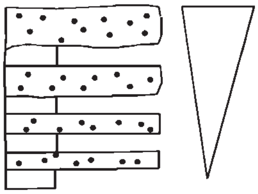
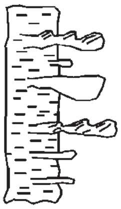
Characteristics	Facies A	Facies B	Facies C	Facies D	Facies E	Facies F	Facies G
Sketch							
Colour	Gray	Light gray	Gray to dark gray	Light gray to light purple	Dark gray (sandstone) to black (shale)	Dark gray (sandstone) to black and red (shale)	Black and red
Thickness	1.0m to ≥ 5.0m	0.5m to 5.0m	≤ 1.0m to 2.0m	≤ 0.5m	Sandstones are ≤ 0.3m	≤ 0.5m to 10.0m	≤ 0.1m to 2.0m
Grain Size	Pebbly and/or gravely medium- to-coarse grained sandstone. Mixture with finer grained beds	Fine- to- coarse-grained sandstone. Gravelly in places	Fine- to- coarse-grained sandstone	Very fine sandstone to siltstone	Very fine sandstone and siltstone, with shale	Very fine sandstone and siltstone, with shale	Shale
Grading/ Sorting	Poorly sorted. Show graded, non-graded or reverse graded	Poorly sorted. Occasionally graded, from gravelly base to silty sands top	Graded. Organized into Bouma sequence that contains Ta division. Ta - Tb division is common	Graded. Organized into Bouma sequence, but Ta division is absent	-	-	-
Geometry	Amalgamated. Continuous sandstone bodies	Continuous sandstone bodies	Amalgamated	Continuous thin siltstone bodies	Heterogeneity	'Chaotic' slump beds. Heterogeneity	Continuous and traceable

Table 1: Continued

Sedimentary Structures	Faint laminations, mud drapes, and flame and load structures	Dewatering structures of dish and pipe marks. Subparallel laminations, cross stratification, and climbing ripples. Flute and tool marks marking the base	Massive graded. Plane parallel laminae, climbing ripples, and upper parallel laminae of siltstone and shale	Cross stratification, climbing ripples, wavy, and convoluted laminae. Upper part normally showing parallel-laminations of siltstone-shale-carbonaceous laminae. Mud drapes	Lenticular bedding. Sandstones showing some climbing ripples, cross-stratifications, and micro cross-laminations. Sole and tool marks marking the base	Slumping. Isolated, connected, folded, or 'floated' of sandstones in muddy matrix	Isolated, few, and very thin layers (mm scale) of very fine sandstone and siltstone (wavy) occasionally associated with this facies in some places
Fossil/Trace Fossil/Coal/Plant Fragment	Mud clasts and intraformational rip-up clasts- high concentrated at the upper part of beds. Coal clasts in places	Mud clasts and intraformational rip-up clasts are common	Mud clasts in some places	Trace fossils exhibit occasionally. Bioturbated at the top part in some places	Bioturbated at the top part of the sandstones in places. Intraformational rip-up clasts display occasionally. Trace fossils are very common; *Nereites, Spirorhaphe, Megagrapton, Paleodictyon, Cosmorhaphe,* and *Helminthoida*	Bioturbated commonly occurred in those sandstones	Mud clasts and coal clasts in places
Top and Bottom Contact	Top irregular. Bottom usually erosional surfaces	Sharp top and bottom. Basal occasionally showing erosional surfaces	Sharp top and bottom. Basal occasionally showing erosional surfaces	Sharp top and basal surfaces	Irregular top and bottom surfaces	Irregular top and bottom surfaces	Sharp and commonly irregular patches. Some rather showing load and flame structures

Table 2: Summary of characteristics and pattern of facies associations of the study area

Characteristics	**Slope**	**Channel and channel-fill**	**Depositional Lobes**	**Levee - Interchannel**
1. Common thickness	0.5m to 10.0m	1.0m to 50.0m	1.0m to 15.0m	1.0m to 15.0m
2. Lithology	Sandstone, Shale	Sandstone (dominant), Shale barriers	Sandstone (dominant), Shale barriers	Sandstone, Shale (dominant)
3. Sedimentary features	Slumping, folding; sandstone bodies floating in muddy matrix	Erosive bases, rip-up clasts, massive, and thick sandstone bodies	Complete and partial Bouma sequences, continuous sheet-like sandstone bodies	Heterogeneity, lenticular bedded. Sandstone marks by climbing ripples, cross-stratification, and micro cross-laminations. Trace fossils are common.
4. Turbidite facies	A, E, F, G	A, B, C, E	A,B, C	D, E, F, G
5. Grain size trend	Chaotic beds. No regular trend	Fining upward	Coarsening upward	Coarsening upward
6. Bed thickness trend	No regular trend	Thinning upward	Thickening upward	Subtle thickening upward
7. Mass transport processes	Rock fall, slump, slide, creep	Debris flows, high density turbidity currents, slump	Grain flows, turbidity currents	Low density turbidity currents, surface currents and pelagic settling
9. Vertical succession trend				

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Geology paper 12

STRUCTURAL EVOLUTION OF MEHAR/MAZARANI FOLD BELT AREA, PAKISTAN

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PCPL is the operator of the Mehar Block since 29th December 1999. The area in geological terms represents the first line of fold belt coming out of foredeep to the east. The current interpretation of the Kirthar Fold Belt (KFB) is of thick-skinned tectonics involving pre-existing extensional faults developed during late cretaceous times (Dr. J Warburton, Nov. 2000)and Mehar - Mazarani Fold Belt (MMFB) is part of the KFB . However, in order to develop a better understanding of the evolution of the MMFB, it is desirable to develop an understanding of the configuration of the basement and overlying sediments through times. An attempt is being made to integrate surface geology, well data, 2D seismic data and other parts of the Pakistan basin as analogue to build a model that would help in understanding the relationship between the structural geology and stratigraphy of area through time. This would eventually help in determining new Play fairway of this area.

As mentioned above,the evolution of MMFB through time has been modelled (Fig 1a & 1b and Fig 2a & 2b) using seismic lines ,surface geology , gravity , magnetic data and available well data.. From Pre-Cambrian to Late Cretaceous, the area experienced extensional /shear tectonic due to Rifting /Drifting of the Indian Plate evolving rifted Trantensional basin consisting of normal extentional /shear faults on a Passive Margin. From Early Palaeocene to Recent is a phase of Ophiolites Obduction and Collision resulting in the Folding, Thrusting and development of foredeep on an active margin.

The pre- existing normal extensional faults are oriented NW –SE nearly parallel to the Jacobabad High and in the foredeep which is manifested by the interpretation of the these faults present on composite seismic lines.The Mehar –Mazarani Thrust Fault (MMT) on the other hand is a west dipping and North South trending thrust fault (Fig 2a) . These re-activated extensional normal faults are also present in the core of the Mehar –Mazarani Fold (MMF) which has been uplifted by MMF thrust fault as seen on North South oriented seismic composite line (Fig 2a). This indicates that the recent thrusting of MMF is not along the pre-existing Extensional Faults, otherwise the orientation of the MMT should have been along the fault plane of the pre-existing extensional fault (NW-SE).

The Gravity (Fig 3) and Magnetic data (Fig 4) indicates that the Basement is dipping to West and there does not appear to be any basement controlled inversion structuring involved. The negative Bouguer anomalies west of the area support the interpretation that sediments including the Infra – Cambrian Salt may be getting deeper and thicker in this area. The presence of Infra Cambrian Salt is supported by Plate Tectonics which suggest that during Infra-Cambrian and Cambrian Indian and Arabian plates were probably part of the same basin (Fig 5) .This support also comes from drilling of Marwi -1 in the south and a number of wells drilled in the northern fold belts and Platform areas.

A model is proposed for the structural evolution of the Mehar –Mazarani Fold Belt. The area has seen continuous episodes of uplift, erosion and rifting /drifting from Infra-Cambrian to Late Cretaceous times. The basement faults have been involved and were re-activated during these tectonic phases. The Cretaceous age, source (Sembar), reservoirs and seals were all deposited in passive margin environment .The late Cretaceous rifting re-activated pre-existing normal faults and also uplifted the area north and east of MMFB (1a & 2b) into what is now called Jacobabad High. The late Cretaceous sediments were eroded from the Jacobabad High as can be seen by the toplap nature of Late Cretaceous seismic reflectors. The Gross Wedge shape nature of Paleocene to Oligocene sediments from MMFB area towards the high indicates that the Paleo high was active during this period. Thick Miocene sediment buried the MMFB area farther as India started colliding with Asian Plate until recent times when the impact of collision inverted the strata into Mehar – Mazarani Fold Belt (MMFB) and Mitto Anticlinal Fold (MAF) (Fig 2c & 1b).

The MMFB appears to have been popped up by deep seated detachment in the Infra Cambrian .This detachment was triggered by the deep seated Basement Wrench faults located west of the foldbelt and are part of the Ornach –Chaman transform fault system (A Kaml, November 1991 and R Ahme, July 1999) . The vertical movement of the MMT is due to the ramping over the faulted and westward tilted basement, and also due to the horizontal shortening created by Jacobabad paleo-high. The ramping phenomenon is similar to the structures like Dhurnal in the Potwar Basin. The Back thrust is also created by the movement of the incompetent Upper Goru Shales into the core of the structures to accommodate space and may also cause shallow secondary detachment. 3D seismic is required to image these complexities and in understanding the implications for the future exploration and development phases.

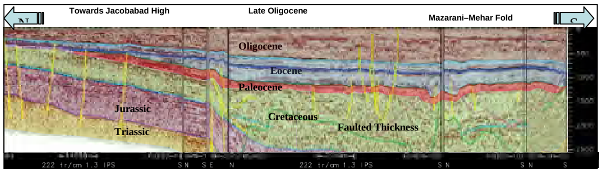


Figure 1a: Oligocene: Marine sedimentation only limited to southern part of the Indus basin, whereas northern part was uplifted due to Himalayan Orogeny and received no sedimentation.

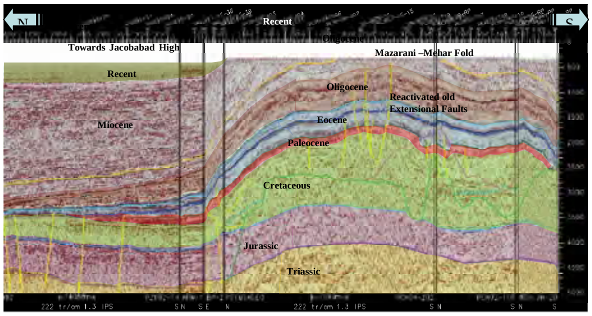


Figure 1b: Recent ; Indian plate continues to converge with Asia @ 2-7 cm /year. In the Mazarani- Mehar area The abnormal thickness of the Cretaceous is due the Mehar-Mazarani Fault . Eocene and Oligocene rocks thin, Paleocene rocks pinch out and thickness of cretaceous rocks decreases towards the Jacobabad High situated in north East of the block.sedimentation.

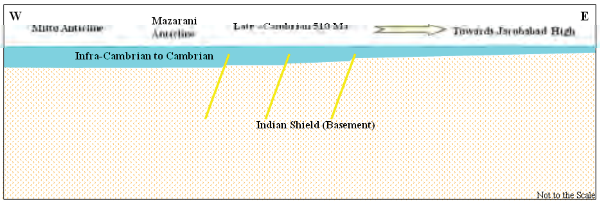


Figure 2a.

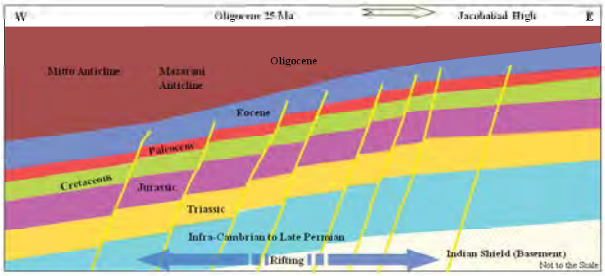
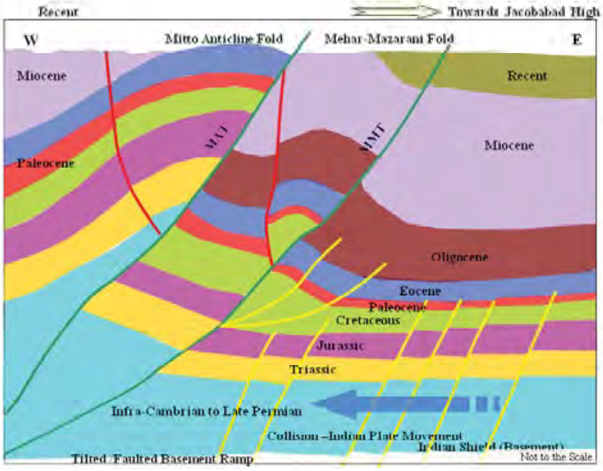


Figure 2b.



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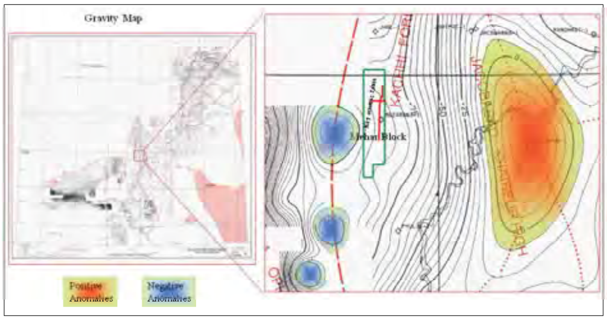

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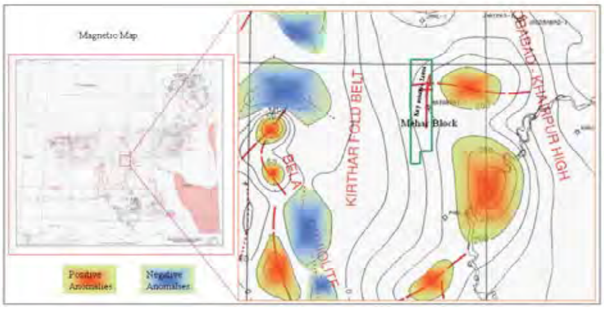

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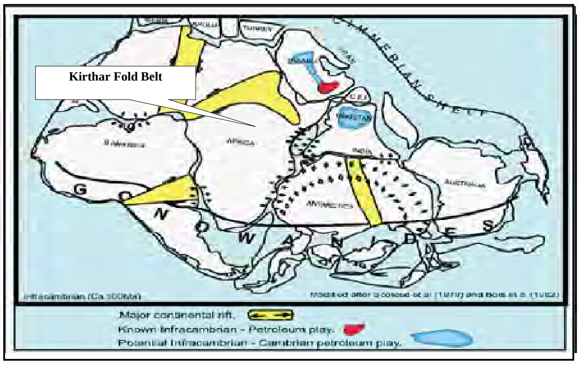

Figure 5.

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Geology Paper 13

MID-MIOCENE UNCONFORMITY

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South China Sea

The Mid-Miocene Unconformity (MMU) is recognized throughout the South China Sea passive margin. It marks the end of rifting that created the marginal basin. It is understood to represent the break-up unconformity when active rifting gave way to sea-floor spreading in the contiguous southwest extension of the abyssal plain. Anomalies are not constrained in this part of the abyssal plain because the oceanic domain is very narrow and the magnetic anomalies not well expressed. However, magnetic anomaly 5c, whose age is estimated at 16.6 Ma, has been identified 300 km NE of the wedge-shaped SW extension of the oceanic area (Huchon et al., 2001). There is no direct drilling evidence of the age of the MMU.

However, south of Hong Kong the break-up unconformity is Oligocene and was drilled through at ODP site 1148 and the micropalaeontology indicated a boundary Upper/Lower Oligocene age of ~28 to 30 Ma for end of rifting and ~24 Ma for beginning of post-rift drape (Clift et al., 2001). The contiguous magnetic anomaly is 11 (32 Ma). The sedimentation hiatus was between 4 and 6 Ma.

The end of rifting and therefore the age of the break-up unconformity are known to be diachronous in passive margins, We should therefore maintain the term MMU for the southern South China Sea until it is drilled through and directly micropalaeontologically determined.

Onland and coastal Sarawak

The Shell drilling-based detailed palaeofacies maps of coastal Sarawak were summarized by Hageman (1987) and given in detail by Hutchison (2005). Throughout most of the Lower Miocene Burdigalian, until about 17 Ma, the coastline was oriented NNW–SSE approximately through Bintulu, with Penian High land on the west and deepening water eastwards towards Miri. Outcrops of Upper Oligocene to Lower Miocene Nyalau Formation (cycles I and II) dominate the Bintulu area and give way eastwards along the coast to the Subis Limestone and then to the Setap Shale. By the beginning of the Middle Miocene (Langhian), 15 Ma, the coastline has re-oriented ENE-WSW parallel to that of the present day. This dramatic change is frequently been referred to as a ‘rotation’, which is clearly impossible. What has happened is a major unconformity (early Mid-Miocene = MMU) in which onland Sarawak has now been uplifted for the first time. A hiatus of ~7 m.y. is followed onland Sarawak by the Upper Miocene Balingian Formation, overlain by the Pliocene Begrih and the Pliocene-Pleistocene Liang Formation. These 3 post-unconformity formations are similar and their outcrops strictly confined to the coastal zone of Mukah-Balingian with extension into Brunei. These formations thicken offshore as cycles V, VI and VII. This coastal zone confinement proves that interior Sarawak was uplifted during the unconformity. The Tatau ‘horst’ can also be accepted within this same timing, but erosion of an anticline, exposing the basement, gives an excessive apparent hiatus.

Onland and coastal zone Sabah

Deep marine sedimentation characterized early Sabah, implying an absence of continental basement, but generally came to an end at 16 Ma (end of Burdigalian). Uplift at this time created land in Sabah for the first time. Tanjong Group very shallow water sedimentation began in the Burdigalian and extended throughout the Langhian. The West Crocker thick sandy turbidite sequence was uplifted before the Middle Miocene (Langhian). Uplift and unroofing of the Western Cordillera (Crocker Ranges) continued throughout the Upper Miocene as shown by apatite fission track data (Hutchison, 2005). This uplift is demonstrated by several unconformities nearshore NW Sabah, beginning with the Deep Regional (DRU) at about 15 Ma, towards the end of the Langhian. Outcropping coal lithologies in the Late Lower to Middle Miocene Tanjong Group of south-west Sabah gave over-mature vitrinite reflectance in the range Ro 0.85 to 0.93% and the Silimpopon coal mine was high rank sub-bituminous. Accordingly it was not only the Crocker Ranges but also southern Sabah that has been strongly uplifted and eroded since the Mid-Miocene.

The Baram Delta began dramatically with the sandy Lambir Formation in the Langhian. The sandy Lambir Formation rests on the Setap Shale that outcrops almost continuously from the Subis Limestone at Batu Niah to the western slope of the Lambir Hills. The cause of the Baram Delta clearly was simultaneous uplift and subsequent erosion of both Sarawak and Sabah. The uplift was remarkably equivalent to the break-up Mid-Miocene Unconformity (MMU) of the South China Sea passive margin. I see no objection to using the same terminology for all, because they are obviously tectonically related.

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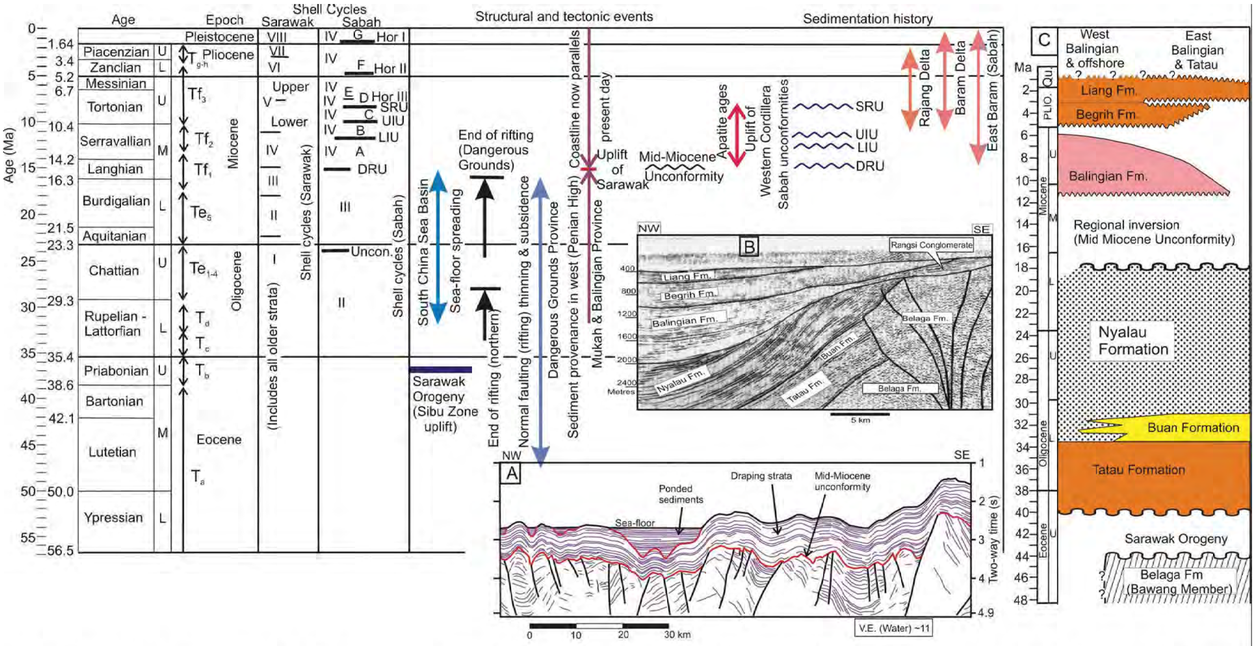

Important geological events in the development of offshore and coastal zone of Sarawak, Brunei and Sabah. Inset: A: seismic section across the Dangerous Grounds to show the end of rifting and beginning of post-rift strata (MMU). B: Seismic section across the Tatau Horst showing the major unconformity (MMU) between the Nyalau Formation and the Balingian Formation. C: Stratigraphy of the Mukah area of coastal and offshore Sarawak..

Geology Paper 14

THE PALAEOTOPOGRAPHIC AND PALAEODRAINAGE EVOLUTION OF THE SOUTH CHINA SEA HINTERLANDS FROM THE LATE CRETACEOUS TO RECENT.

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The tectonic complexity of Southeast Asia is clearly expressed in the modern hinterland topography and drainage of the region. Consequently, as the underlying tectonics has evolved, so to has the landscape. This has had major implications for the character and flux of clastics into downstream basins through time, which in turn affects hydrocarbon potential at the basin to prospect scale.

In order to help understand this complicated history, we have compiled a series of detailed plate tectonic and palaeoenvironmental reconstructions for the South China Sea region. Upon these maps we have built models of the palaeolandscape and palaeodrainage basins and river systems. The methodologies used in the mapping integrate a re-examination of the underlying structure and tectonics using GETECH's in-house gravity and magnetic data and expertise, with detailed palaeoenvironmental mapping that distinguishes between sediment source areas (regions above contemporary base-level, sensu Wheeler, 1964) and depositional sites (areas below contemporary base-level). By mapping regional base-level, we implicitly include an understanding of the dynamics of the landscape and the boundary conditions (climate, vegetation, rock type, etc). The method also provides the means whereby we can link the maps directly to sequence stratigraphy, with the ultimate aim of developing fully dynamic palaeolandscape models. Topography is then added to these maps through comparison with the elevational distribution of comparable Recent tectonic regimes, fission track, hypsometric analysis and other palaeoaltimetry, sedimentological and provenance data where available.

For Indochina and South China, the maps reveal a complicated history of uplift, erosion and river capture that is manifest in the changing sediment fluxes to the offshore basins, with major rivers such as the Mekong, Red and Pearl only developing their modern topology by the Late Miocene.

This talk will discuss the methods used to generate the maps and show some examples of this work. We will also demonstrate how we are developing methods to provide detailed insights into sediment generation and distribution through the petroliferous basins of SE Asia.

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Geology Paper 15

PORE PRESSURE PREDICTION AS A PROSPECTING TOOL, INPUT TO RISK, VOLUMES AND FIELD DEVELOPMENT

John Paul Brown and Suriani Sulaiman Mustahim

Exploration Technology Division, PETRONAS Carigali Bhd Sdn

Traditionally, pore pressure predictions calculated from offset wells and interval velocity data have been used almost exclusively to design well casings and drilling mud weight programs. However, a pore pressure prediction also contains valuable information on how oil, gas and water is behaving in the subsurface and importantly how fluid pressures will effect top seals, fault seals and column heights in hydrocarbon prospects.

PETRONAS Carigali have begun to use pore pressure as a critical input to pre-drill prospect evaluation by combining fault and horizon information, derived from geological maps, with an understanding of how fluid migration and pore pressures, derived from pore pressure predictions, can affect trap risk and volumes.

The use of pore pressure predictions as an primary exploration tool has the advantage that it does not require any additional computational work since a pore pressure prediction must be produced in order to design a well. The key change is a modification to the existing exploration workflow so that pore pressures are calculated during the initial exploration stage which allows them to be combined with mapped horizon and fault data to produce integrated geo-pressure / geometric trap scenarios.

The advantages of the new pore pressure workflow will be illustrated using three exploration / development case studies.

The first, from Sabah offshore Block SB301 illustrates how the centroid concept (Dickinson, 1953 & England et al. 1987) or dynamic capacity model (Finkbeiner et al. 2001) can be used to identify a state of catastrophic seal failure where up dip pore pressure transfer from adjacent synclines has pushed water pressure at the crest of the trap to leak off. This example further highlights how the integration of all available pressure data is vital to produce a geologically valid trap scenario.

The second example, from Sabah offshore Block SB-1 illustrates how pore pressure predictions combining wire line logs and interval velocity data can be used to predict mechanical top seal risk which in turn is used to predict column heights and volumes in an un-drilled down dip fault trap. This type of analysis directly addressed a critical pre-drill risk and was successful in quantifying the risk as well as reducing uncertainty.

The third example is from Central Asia and illustrates the power of combining pore pressure/fluid migration data with structural fault seal and top seal analysis. The approach was used to define a new trap scenario based on "pressure balance" and provided a geological model which tied together several disparate pieces of data. The outcome of the analysis revealed a potentially danger for the position of development wells and the potential for early water break through.

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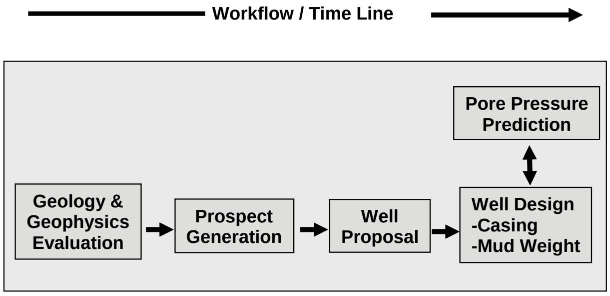

Figure 1: Standard Pore Pressure Workflow.

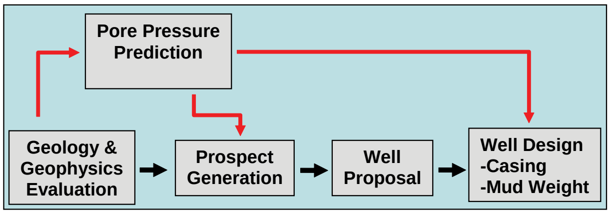

Figure 2: PETRONAS Carigali Pore Pressure Workflow.

Geology Paper 16

SEDIMENTOLOGICAL ANALYSIS OF AN EARLY MIOCENE TIDE-INFLUENCED DELTAIC/COASTAL PLAIN SYSTEM: CYCLE II, BALINGIAN PROVINCE, OFFSHORE SARAWAK

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Introduction

The Balingian Province of northwest Borneo contains a wide range of hydrocarbon-bearing reservoirs, with production dominantly from Early Miocene coastal to lower coastal plain sand bodies. Previous studies have interpreted these deposits as being part of a fluvial-dominated coastal system (Almond et al., 1990). However, this study highlights the widespread occurrence of tidal indicators in the Balingian Province, suggesting a more strongly tide-influenced coastal regime. The occurrence of marine-influenced organic-rich sediments, in particular mangrove-derived coal deposits (Wan Hasiah, 2003), also supports the tide-influenced coastal regime for the Balingian Province.

Facies Associations

The study presented here is a facies analysis based on 1100m of cores from 12 wells, from the Early Miocene Cycle II stratigraphic interval, and onshore outcrops of the equivalent Nyalau Formation around Bintulu, Sarawak. Eight different facies associations are recognized, ie. :-

Offshore facies association

This comprises strongly bioturbated offshore mudstone, with interbedded thin, hummocky cross-stratified sandstone, graded siltstone beds, thin limestone and pebble lag horizons. Bioturbation ranges from moderate to intense (Ichnofabric Index, or II = 2-6), mainly in the form of Ophiomorpha, Thalassinoides, Teichichnus and Glossifungites firmgrounds.

Prodelta – Delta Front facies association

This association consists of 5-20m thick, coarsening upward units composed of structureless mudstone grading upwards into mud and sand-dominated heterolithics. Bioturbation is sparse to absent (II = 1-2) mainly in the form of Planolites.

Mouth bar facies association

This is represented by 3-5m thick coarsening upward units, which are composed of sand-dominated heterolithic facies with intercalated thin cross-bedded sandstone. Tidal indicators present include frequent mud drapes, rhythmic bedding, impoverished marine ichnofauna (II = 2, mainly in the form of small and simple burrows, eg. Planolites and Skolithos), and alternating cross-bedding directions. Thin, hummocky cross-stratified sandstones become more common further upward, indicating more open marine exposure at the distributary mouths.

Tidal Bar/Point bar facies association

This association comprises 3-5m thick packages of sharp-based, blocky or fining upward, sand-dominated heterolithic beds. In outcrop, this is represented by inclined heterolithic stratification, indicating lateral accretion. Tidal indicators present are similar to the ones observed in the Mouth bar facies association.

Bay Fill / Muddy Channel facies association

This consists of 2-12m thick, fining upward sequences, which grade upward from thin sand- dominated heterolithic facies into muddy heterolithics. The succession is typically capped by rooted carbonaceous mudstone and coal. In outcrop this facies association is also represented by channel geometries. Tidal indicators include lenticular bedding with opposing ripple cross-lamination directions, impoverished marine ichnofauna, rhythmic lamination and mangrove deposits.

Channel facies association

This is composed of a variety of facies, but generally characterized by a sharp erosive base, which is overlain by a coarse grain lag overlain by trough cross-bedded sandstones. The succession displays a fining upward grain size trend and an upward decrease in bed thickness Tide-influenced channel fills contain abundant tidal indicators, including frequent mud drapes, paired mud drapes, rhythmic bedding, tidal bundles, bidirectional palaeocurrents, and an impoverished marine ichnofauna. Tidal indicators are absent in fluvial-dominated channel fills, which are coarser grained with conglomerate beds, and include massive sandstone units.

Coastal / Delta Plain facies association

This comprises 5-12m thick successions of palaeosols and rooted mudstone capped by thin, mangrove derived coals (Wan Hasiah, 2003). The palaeosols are commonly dark coloured, with abundant plant debris, though some intervals are light coloured and mottled. Slickensides, siderite nodules and bands, and rooted horizons are abundant.

Shoreface facies association

This is represented by 3-6m thick sand-dominated packages dominated by wave and/or storm-influenced deposits, including laminated sandstone, hummocky cross-stratified sandstone and bioturbated sandstone and minor sand dominated heterolithics. Bioturbation is moderate (II = 2-3) and mainly in the form of Ophiomorpha, Thalassinoides, Teichichnus, and large escape/collapse burrows.

Depositional Model

This analysis recognizes six types of facies successions: (1) Multistorey fluvial-tidal channel successions comprise of up to 30m thick stacked sandbodies, which are interpreted as large, braided, channel complexes; (2) Tide-influenced delta successions comprise of coarsening upward, tens of metres thick heterolithic packages, with associated "delta-top" facies, including single storey fluvial or fluvial-tidal distributaries and tidal bars/pointbars; (3) Tide-dominated delta margin/bay fill successions comprise of thick, mud-dominated packages sometimes capped by thin coals; (4) Wave-storm influenced shoreface successions comprise of coarsening upward packages of planar, hummocky and cross-bedded sandstone; (5) Sharp-based shoreface successions comprise of sharp-based, hummocky cross-bedded or bioturbated sandstone with interbedded bioturbated mudstone; (6) Fluvial-dominated delta successions comprise of coarsening upward prodelta-delta front deposits with associated distributary mouth bars.

The abundance of tidal indicators, which includes heterolithic facies, mangrove swamp deposits, rhythmic interlayering, paired mud drapes and sparse bioturbation (eg. Nio & Yang, 1991) supports the interpretation that the Cycle II deposits of the Balingian Province represents a tide-influenced delta / coastal plain system (Fig.1). This may be analogous to the present-day Mahakam Delta of Kalimantan (Allen & Chambers, 1998), but with stronger wave-storm influence. Another reason for the preference of the Mahakam Delta as a present day analogue for Cycle II compared to previous models based on the Mississippi Delta is the absence of any overbank flood deposits in the form of crevasse splays and channel levees. Our model implies that what has been interpreted as crevasse delta deposits (with lobate geometries and transport perpendicular to main distributary flow) in the fluvia dominated delta model, are actually tidal bar and mouthbar sandbodies, with more elongate geometries perpendicular to shoreline.

Cycle II forms a large scale fining upward sequence reflecting the initial infilling of an incised valley complex followed by gradual transgression marked by tide-infuenced delta progradation and abandonment, and marine incursion.

Acknowledgments

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Table 1: Facies identified in core and outcrop, Cycle II, Balingian Province, Sarawak.

Texture	Facies Codes	Facies
Gravel	Cg	CONGLOMERATE
Sand	Sc	CROSSBEDDED SANDSTONE
	Sl	PARALLEL LAMINATED SANDSTONE
	Sp	PEBBLY SANDSTONE
	Sm	MASSIVE SANDSTONE
	Sb	BIOTURBATED SANDSTONE
	Shc	HUMMOCKY CROSS STRATIFIED SANDSTONE
Heterolithics (>50% sand)	SHh	SAND DOMINATED HETEROLITHICS WITH PLANAR BEDS FLASER AND WAVY BEDDING
Heterolithics (>50% mud)	MHr	MUD DOMINATED HETEROLITHICS WITH CURRENT RIPPLED LENTICULAR SANDSTONE
Mud	Mr	ROOTED MUDSTONE / PALAEOSOL
	Mm	MASSIVE MUDSTONE
	Mb	BIOTURBATED MUDSTONE
	Stg	GRADED SILTSTONE
Chemical sediments	C	COAL
	L	LIMESTONE

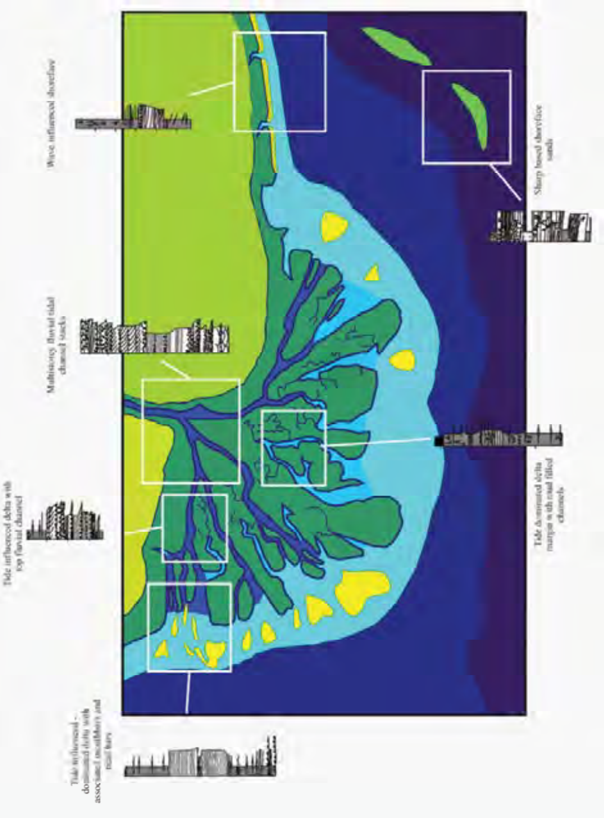

Figure 1: Depositional model for Cycle II, Balingian, Province. Model uses the Mahakam Delta as an analogue, but with a wave / storm dominated coastline at the margins of the delta system. Modified from Allen and Chambers (1998).

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Geology Paper 17

GROWING EVIDENCE OF ACTIVE DEFORMATION IN THE MALAY BASIN REGION

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Very young crustal movements in the Malay basin region point to the possibility of reactivation of regional faults in the basin that may compromise their sealing integrity. In addition, active or reactivated faults that are rooted in the pre-Tertiary basement and reach up close to the base of Quaternary seabed sediments of the basin pose obvious hazards to offshore installations.

The Malay basin originated in the Late Cretaceous as a major aulacogen on the Malay Dome and developed structurally through modifications by differential extrusion of Indosinian crustal slabs. Initially the extrusion imparted sinistral transtensional wrenching on the axial basement fault along the basin length. In post Mid-Miocene, wrench reversal produced transpression, accompanied by general structural inversion. From the Pliocene onward most of basin area has been considered tectonically quiet on the basis of horizontal stratification, absence of volcanic centres, absence of earthquake epicenters, and low relief. However, basement-rooted regional fault zones may reach as high as 150 metres below the shallow seabed and into the Pliocene-Pleistocene strata (Fig. 1) implying structural reactivation in the Quaternary. Onshore Peninsular Malaysia, small Early Tertiary basins hosts lacustrine and fluvial-dominated deposits. These basins appear associated with regional fault zones suggesting structural activity up to that time. Neogene deposits are apparently missing while the blanket of Quaternary sediments only indicates local disturbances associated with base collapse and gravity sliding. On the other hand, an Early Quaternary pillow-basalt flow near Kuantan on the eastern shore of the Peninsula is traversed by long fractures orientated parallel to faults in the pre-Tertiary basement. The fractures in the basalt are vertical to subvertical and are evident manifestations of reactivation of the older faults (Fig. 2). In Southeast Johor at the edge of the Penyu Basin, crustal uplift of 0.5-0.8 m in the past 5000 years is suggested by an abrasion platform that is that much higher compared to the secular Holocene sea-level curve of the Peninsula established from almost one hundred radiometrically determined bio-shoreline indicators. On the shores of Langkawi, in the northwest of the Peninsula, a 2500-year old abrasion platform is cut by long fault zone with associated secondary structures suggesting dextral displacement (Fig. 3). The 26 December 2004 mega-thrust Indian Ocean earthquake is recorded by GPS measurements to have displaced the entire Peninsula laterally in WSW direction by several centimetres. Among relevant findings of ongoing research in the Langkawi islands are geologically very recent crustal uplift of 40-50 cm that manifests as sea-level notches at elevated positions above present mean sea level (Fig.4).

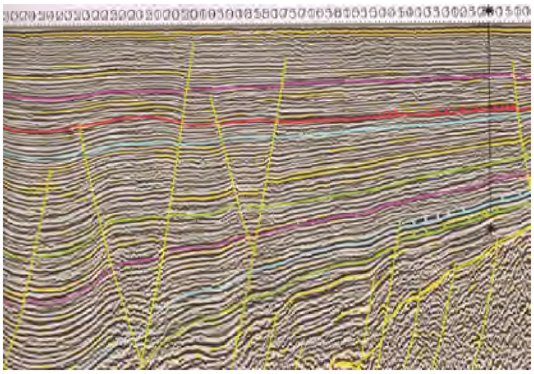

Figure 1: Fragment of a regional seismic line across the Malay basin. Some of the deeply rooted regional faults reach up very close to the sea bed.

Figure 4: The notch corresponds with a mean sea-level now about 0.5 m above the high tide level that is approximately represented by the current water level. Sungai Kilim in the Langkawi Geoforest Park (March 2007). trends N60^{o}E. Pulau Ular, Langkawi.

Figure 2: Flow of Early Quaternary pillow basalt at Pantai Batu Hitam near Kuantan Pahang. Compass points North. The long fractures are parallel to regional faults in the pre-Tertiary of Peninsular Malaysia.

Figure 3: The raised abrasion platform is over a metre above present high tide. This elevation corresponds with 2500 years on the Quaternary sea-level curve of Peninsular Malaysia and Thailand. The young fault across the platform trends N60oE. Pulau Ular, Langkawi.

Geology Paper 18

CLIMATE STRATIGRAPHY – A NEW APPROACH IN NEAR-SYNCHRONOUS SUBSURFACE CORRELATION

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As oil and gas E&P is moving towards more mature phases, innovative new approaches are needed in petroleum geology. To find additional reserves in mature exploration areas and to improve production in existing fields, a better understanding of the spatial distribution and time-stratigraphic framework of the potential reservoirs and seals is needed. To meet these challenges, existing conventional stratigraphic methods have been improved and new stratigraphic concepts have been developed during the last decade. Amongst one of the most important concepts which have been proposed by the Exxon school a decade ago was sequence stratigraphy. Nowadays, sequence stratigraphy is widely applied in subsurface correlations and is becoming a routine practice. Sequence stratigraphy can best be seen as the delineation and correlation of changes in depositional trends that are generated during a base level cycle (see Embry, 2002). Despite the constant modification and improvement of the sequence stratigraphic concept, it did not reach an important objective – the construction of a near- synchronous stratigraphic correlation framework. One of the main reasons is the strongly model-driven approach of sequence stratigraphy which is preventing to construct an objective and reproducible correlation framework.

To resolve this, Climate Stratigraphy and a specially-designed tool have been developed recently and some of its principles and application to the subsurface is presented here. Briefly, the approach comprises two key elements:

1. The Global Cyclostratigraphy model of Perlmutter et al (1990, 1998) – i.e. the theory that climate change is a fundamental control on lithofacies succession – is then applied to the interpretation of this otherwise unexploited information.
2. A facies-sensitive log – normally the GR – is transformed to a spectral trend (or INPEFA™) curve, which shows uphole changes in the waveform properties of the data. The software used for this is CycloLog®, developed by ENRES.

Climate Stratigraphy is basically the science of climate change through geological time and it takes Global Cyclostratigraphy as developed by Perlmutter et al (1990, 1998) as its basic principle. The Global Cyclostratigraphy model was developed as a tool for the prediction of vertical lithofacies succession. The model accepts the control of global climate by changes in the Earth's orbital parameters, through their influence on insolation: this is the Milankovitch model of orbitally-forced climate change. Because climate change is an influence over stratigraphy that is external to the basin, we predict that the pattern of vertical lithofacies change (including any hiatuses and erosion surfaces) will be similar, at least within any latitude-related climatic belt. The vertical stratigraphic succession in a basin is strongly related to climatic change (albeit in the form of a filtered and incomplete record); see Figure 1.

Global Cyclostratigraphy is mainly dealing with basin fill patterns, while Climate Stratigraphy deals with reservoir-scale subsurface correlations. The climate record or more specifically the climate change record is stored in the sedimentary rock record, which again are the "building stones" of the stratigraphic record. This vertical succession is exactly what is sampled by wireline logs. Therefore, an analytical tool that looks at the pattern of vertical lithofacies change (and is also sensitive to breaks in the succession) can potentially reveal the pattern imposed on the depositional system by the succession of climate change. The INPEFA™ curve, with its emphasis on changes in the frequency content, is just such a tool (Nio et al, 2005).

In summary, the method of Climate Stratigraphy allows the development of a framework of near-synchronous well-to-well correlations by identification of (time-)equivalent, primarily climate-controlled, vertical lithofacies changes and trends in wireline log data.

Given our emphasis on climate as the key driver of stratigraphic succession, it might be assumed that we ignore the effects of tectonics. Tectonic processes are, however, not discounted in our approach. The effects of climate change on the lithofacies succession (and hence on wireline logs) are in the order of 10,000s to 100,000s years. The processes of basin subsidence act on a longer time-scale than insolation-driven climatic changes. In terms of their effect on stratigraphy, climate-driven patterns can be considered as superimposed on tectonically controlled patterns that are of longer duration. For instance, an overall increase in sediment-calibre in a given area (as the area becomes more sand-rich) may well be the result of increased tectonic activity, but the shorter term vertical lithofacies variations (as expressed in the changes and patterns of the INPEFA™ curves) are primarily controlled by climatic variations; see Figure 1. In our experience, any effect caused by shorter-term tectonic processes (such as fault movements) do not impact on our ability to interpret and correlate the INPEFA™ patterns.

Although the analysis and correlation of the spectral trend curves of GR logs (INPEFA™_GR curves) is largely a matter of experience, some general principles can be stated. A brief outline will be given here. More detail is available elsewhere (De Jong et al, 2006; Nio et al, 2006).

It is important to realize that the waveform properties can only be analyzed for sections that have been preserved. The INPEFA curves of GR will be identical for different wells only if and when the preserved sections are identical. Practically speaking, this does not occur. The interpretation of INPEFA curves, therefore, focuses on identifying equivalent breaks and trends rather than on finding identical patterns.

Intervals of positive (left-to-right) and negative (right-to-left) trend in the INPEFA™ curve are separated by turning-points

(Figure 2). A positive turning-point is a point at which the trend (in an upward direction) changes from negative to positive (clockwise). A negative turning-point is a point at which the trend (in an upward direction) changes from positive to negative (anti-clockwise). After identification, the turning-points and intervening trends are, firstly, calibrated in lithological terms and, secondly, interpreted in stratigraphic terms. Turning-points that (a) signify changes in depositional trends (Embry, 2002) and (b) are correlatable between wells, are called bounding surfaces. Negative turning-points thus become negative bounding surfaces (NBS), positive turning-points become positive bounding surfaces (PBS). These are our (time-)equivalent, primarily climate-controlled, vertical lithofacies changes. Usually, an NBS marks the base of a trend with a progradational or related component, whereas a PBS represents the beginning of a period of retrogradation or related process.

A hierarchy of change is commonly observable in the INPEFA™_GR curve, indicating a hierarchy of vertical lithofacies trends and changes. StratPacs (stratigraphic packages) are bounded by adjacent negative bounding surfaces of the same hierarchical rank. StratPacs represent systematic changes in (litho)-facies controlled by climatic variations. They are stratigraphically time-synchronous. The lithofacies units within a package are genetically linked: usually, a progradational or related trend is overlain by a retrogradational or related trend.

An example of a time-synchronous correlation is shown in Figure 3.

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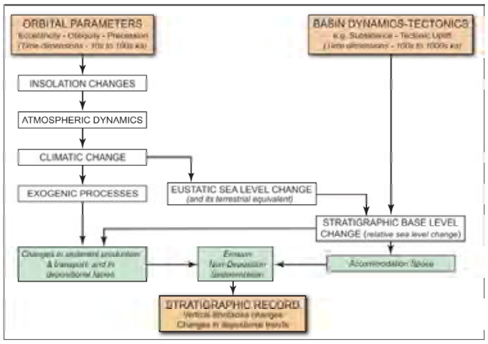

Figure 1: Connection between the orbital parameters and their record in strata.

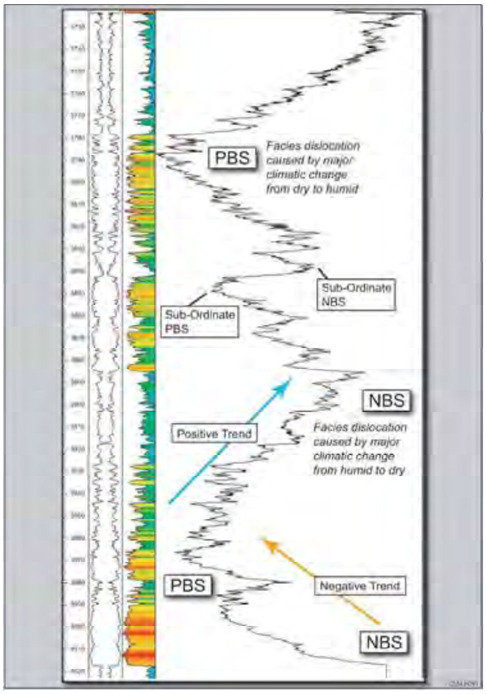

Figure 2: Nomenclature of the INPEFA™ trends and bounding surfaces

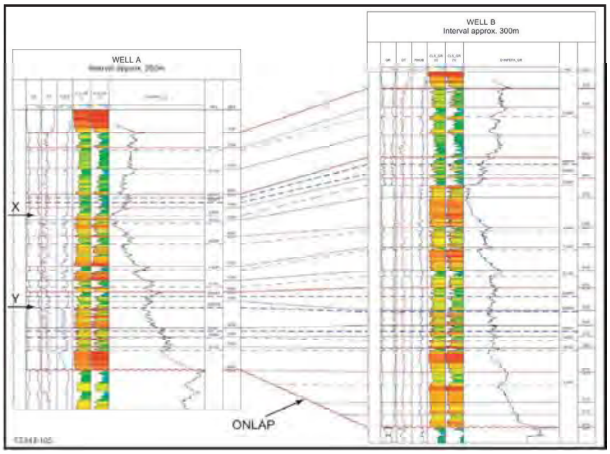

Figure 3: Time-synchronous stratigraphic correlation of two wells within a continental basin setting.

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Geology Paper 19

CARBON DIOXIDE (CO_2) DISTRIBUTION IN THE SARAWAK BASIN, AND ITS RELATIONSHIP WITH ENTRAPMENT

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Carbon dioxide content in both associated and non-associated gases in Sarawak Basin fields varies up to a maximum of 90%. High CO2 content in natural gas reduces the economic value by lowering the saleable gas volume, as well as reducing the BTU content. In addition, special infrastructures are required to develop and process gas accumulations containing high CO_2.

Understanding the likely geological parameters that control CO_2 regional distribution patterns will assist explorationist in targeting prospects with a lower CO_2 content. General current understanding on the CO_2 distribution in a basin are, CO_2 percentage increases with depth and high percentage CO_2 accumulation are of inorganic origin and tend to be associated with structures with deep seated faults to facilitate CO_2 migration up dip from basement.

However, we observe that CO_2 percentage varies vertically in a field and does not necessarily increases with depth and could also decreases with depth. CO_2 of same inorganic origin are present in several reservoirs of a field; and yet one reservoir may have very low CO_2 compared to the other reservoirs.

Field observations in the Sarawak Basin CO_2 distribution are the depth of accumulation and origin of CO_2 does not influence the percentage distribution and the geometry of traps and seal effectiveness dictates how much CO_2 the reservoir can hold.

These scenarios are also observed in Sarawak Basin. Major marine transgressive shale provides good and effective top seal. Thus reefal carbonate terminated by drowning can support higher gas column with low CO_2 content.

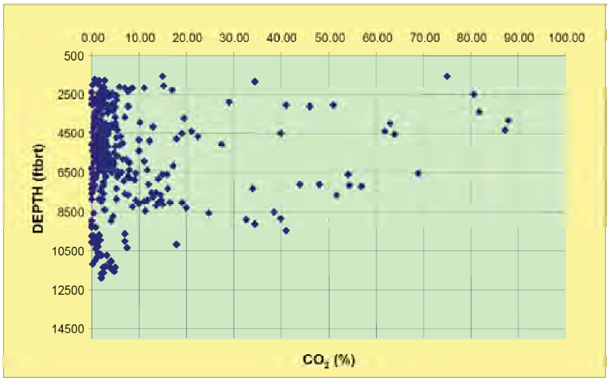


Figure 1: Sarawak Basin, Depth vs Carbon Dioxide (CO_2).

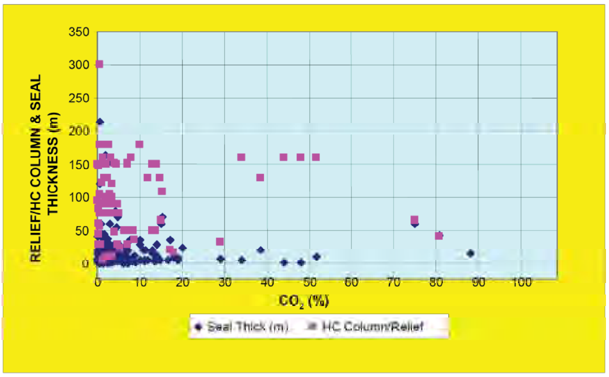


Figure 2: Sarawak Basin, Sandstone Reservoir, Relief/Hydrocarbon Column and Seal Thickness vs Carbon Dioxide (CO_2)

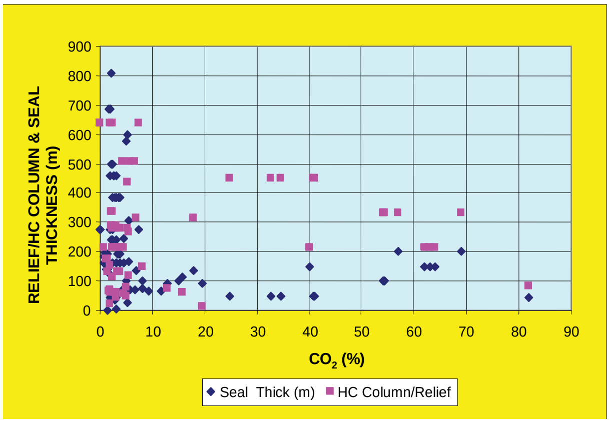
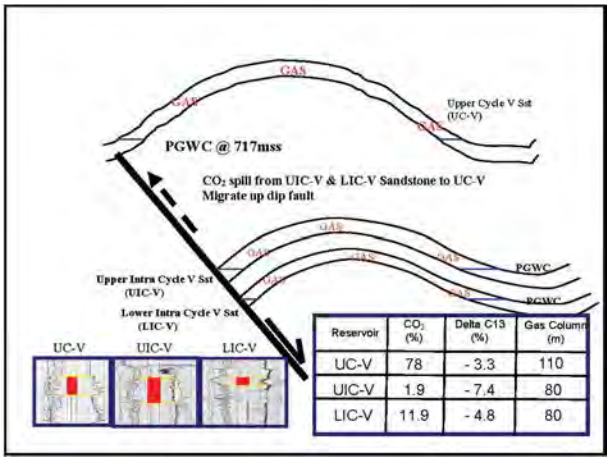


Figure 3: Sarawak Basin, Limestone Reservoir, Relief/Hydrocarbon Column and Seal Thickness vs. Carbon Dioxide (CO_2)



Reservoir	CO_2 (%)	Delta C13 (%)	Gas Column (m)
UC-V	78	- 3.3	110
UIC-V	1.9	- 7.4	80
LIC-V	11.9	- 4.8	80

Figure 4: T3.2 CO2 Distribution

Geology Paper 20

GEOMECHANICAL CONSIDERATIONS REGARDING EOR EFFICIENCY AND CO2 SEQUESTRATION

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An accurate geomechanical assessment of the subsurface is vitally important when designing, executing and monitoring Enhanced Oil Recovery and CO_2 Sequestration Operations. Detailed knowledge of the earth's current stresses and pressures active in the reservoir (and overburden) provides valuable information for understanding how the reservoir (and overburden) will respond to injecting gases or fluids into reservoir rocks.

The stresses operating in the area play an important role in inducing, preventing and controlling hydraulic fracturing (depending on the application). Controlling and containing hydraulic fractures is important for ensuring that the injected gases or fluids are contained within the reservoir during EOR operations. However, in some highly faulted environments, hydraulic fractures have been known to reactivate natural fractures or a faults which has resulted in fluids migrating away from the intended reservoir and minimizing production efficiencies. A case study will be presented in which primary production-induced stress changes were not considered when designing and executing EOR operations which significantly reduced the production performance.

Efficient CO_2 capture and containment will likely produce for our global societies important environmental dividends. Geologic concerns include the selection of a suitable reservoir, the preservation of an impermeable top seal and prevention of fault and/or natural fracture reactivation that could breach the CO_2 reservoir and cause unplanned leakage. Using a well-constrained geomechanical model it is possible to design a CO_2 sequestration program that maximizes the long-term containment of CO_2. Presented is a systematic workflow for analyzing in situ data to constrain the geomechanical model and use it to optimize CO_2 containment in the context of cap rock integrity, fault leakage integrity and natural fracture stability.

Geology Paper 21

SARAWAK MALAYSIA DEEPWATER NEW TURBIDITE PLAY

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Blocks 2A and 2B, located offshore Sarawak in east Malaysia, covers 9000 square kilometers in water depth 150 – 1500 m. Two dry wells were drilled both of which lack post-Middle Miocene Unconformity (MMU) reservoir. Mulu-1 was drilled in 1995 on Block-2B to Cycle 1 at a total depth 5,029 m, and Jelawat-1 drilled 60km SW of Mulu-1 on Block-F encountered significant C1 to C5 gas from MMU sequences. Gas was interpreted from mature post-MMU deep marine sources.

Thousands kilometers of fair to good 2D seismic data over the area indicate the presence of strong, continuous events near top MMU sequence boundary. Post-MMU seismic data is characterized by weak, bluer discontinuous reflectors interpreted as massive deep marine shales.

Several strong seismic anomalies in Post-MMU sequences have been delineated and are interpreted to be sourced from reworked Pre-MMU sequences. Strong amplitude seismic attribute analysis are wide spread and interpreted to be clastic basin floor fan sediments originating from several feeder channel systems. Amplitudes weaken at the fan edges.

Basin floor fans exist in lows and on the flanks of lows. These stratigraphically discontinuous units are enveloped within thick post MMU shales. Sourcing is not considered a problem due to local charging. Risked resources calculated indicate significant hydrocarbon potential is believed to be located in the area.

Geology Paper 22

PLAY TYPES AND HYDROCARBON PROSPECTIVITY IN PETRONAS' BLOCKS N44, N45, N50 AND N51 OFFSHORE NORTHWEST CUBA

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In late 2006, PETRONAS Carigali Overseas Sdn Bhd (PCOSB) was awarded the Cuba's Exclusive Economic Zone (EEZ) offshore blocks N44, N45, N50 and N51. These blocks located to the North West of Cuba are in water depths ranging from 1000 m to 2800 m (Figure 1). The first three-year sub-exploration period calls for a minimal work commitment of 4000 line-km of 2D and 1000 sq km of 3D seismic data.

About 3968 line-km of existing 2D seismic data from the Compagnie Générale de Géophysique (CGG) spec survey and Russian / CubaPetróleo (CUPET) survey were available for PCOSB. Consistent interpretation on the existing seismic data, with proper scientific explanations to the tectonic history of the opening events of the Gulf of Mexico and its sedimentary occurrence have identified various potential play-types in this area (Figure 2).

Remarkable similarities have been found in depositional environments and stratigraphic units between the continental areas from the East Gulf of Mexico and North West of Cuba. An integral knowledge of the geological context is fundamental in order to infer the main analogies in successful hydrocarbon producing areas in the Mexican part of the Gulf of Mexico and the location of potentially new highly productive petroleum systems in the area.

The recently acquired 2D seismic data and the future to be acquired 3D seismic data will further confirm and mature the identified plays and are also crucial to reduce uncertainty and economic risks in this new exploration challenge.

Figure 1: Location map of PETRONAS' blocks in Cuba's Exclusive Economic Zone, offshore Northwest Cuba.

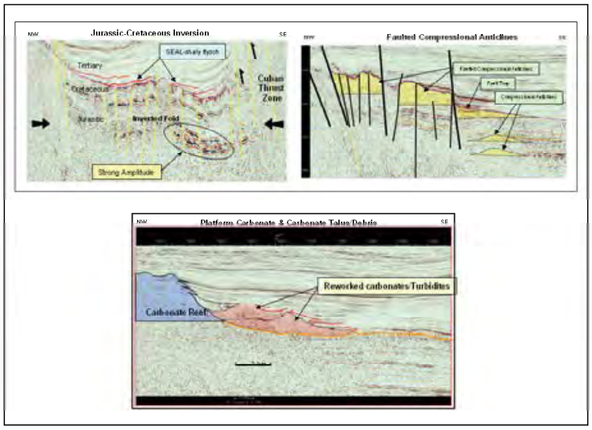

Figure 2: Various play types identified in blocks N44, N45, N50 & N51, offshore NW Cuba.

Geology Paper 23

THE EVOLUTION OF GEOLOGICAL THINKING AND DEPOSITIONAL FRAMEWORK INTERPRETATION THROUGH THE LIFE OF A COMPLEX RESERVOIR, D35 FIELD, OFFSHORE SARAWAK

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The D35 field is a sizeable hydrocarbon accumulation discovered by Shell in 1983, located 135 km north from Bintulu, within the Balingian Province of Offshore Sarawak. Hydrocarbons are contained within the stratigraphically complex Early to Middle Miocene clastic sediments, principally in Cycle II and to a lesser extent in the lower part of Cycle III. Its main hydrocarbon-bearing reservoirs comprise thick, stacked, cross-bedded sandstones, pebbly cross-bedded sandstones, sandy conglomerate and wavy-to-irregularly laminated sandstone. These sediments were initially interpreted by Shell as fluvial channel deposits, a model which was maintained until the relinquishment of the field in 2004.

Recently, an Integrated Study of the D35 cores and well logs has been carried out as part of a Full Field Review (FFR). This involved sedimentological, ichnological, biostratigraphic and coal petrological studies, combined with an extensive well log analysis. The aim was to re-assess the depositional environment and sequence evolution of the D35 reservoir intervals. The study was based on the analyses of cores from six (6) wells, all the available well logs and 3D seismic data

The availability of extensive and well preserved cores was crucial, cores taken in the 1980's and 1990's, largely during the initial appraisal campaign were re-evaluated, documented, sampled and analysed from four different and independent perspectives. This provided significant evidence to support a more robust facies model for static and dynamic reservoir modeling.

Interpretation of coal depositional settings allowed recognition of three sub-environments. based on the GI versus TPI plot i.e. the lower delta plain, mangrove and lagoonal/embayment settings. Biostratigraphic analysis of more than 81 samples yielded moderately rich to very rich sporomorph assemblages. Most samples were either barren of foraminifera, or contain mainly arenaceous or calcareous benthonics which thrive mainly in marginal marine and coastal environments. The results suggest that these samples have been deposited within the brackish realm of the lower coastal plain but with varying degree of fresh water and marine influences.

Physical facies characteristics and ichnological assemblages reveal further evidence that the Cycle II sandstone and mudstone facies were deposited in a marginal marine setting. The thick, conglomeratic/sandy reservoir at the base of Cycle II, which was previously interpreted by Shell as part of a fluvial complex, contains brackish-to-marginal marine trace fossil assemblages precluding a fluvial interpretation.

Evidence from all the studies indicate and support a presence of a barred coastal depositional system which was connected to the sea during Cycle II times.

The following findings are crucial in the reinterpretation of the reservoir interval:

1. Eight environmentally significant facies associations. Facies and facies associations reflects a coastal brackish setting, with marked marine-influenced intervals;
2. The thick, basal conglomeratic sandstones were deposited within a coastal setting possibly representing a prograding mouth bar or barrier bar;
3. The thick mudstones are brackish water estuarine deposits – periodically affected by marine incursion. The presence of these deposits supports a barred coastline interpretation;
4. The base of the the thickest sand body represents a Sequence Boundary formed during a lowstand event, eroding into a brackish water mudstones. The presence of Glossifungites intervals within the Cycle II indicate periods of extended marine flooding. Frequent sea level fluctuations are recognized throughout the Cycle II sequence and provide significant control over facies development;
5. Interpretation of the sequences seen in core together with the mapping of facies types indicates more marine influence towards the north-east of area, consistent with regional palaeogeographic understanding.

This study has allowed further advances in our understanding of the depositional setting, stratigraphic framework and palaeogeography of the Cycle II sequences of the D35 field. A coastal, barred estuarine model, replaces the earlier 'Mississippi delta' model, with a fuller recognition of the importance of repeated sea-level fluctuations. This depositional model predicts a more laterally extensive reservoir, with sheet like rather than channelised sandbodies developed, consistent with the data available from over seventy wells, as well as seismic attributes.

Such an evolution in the geological thinking is to be expected during the life of a major field, as additional data becomes available and advances in technology. However the possibility of such revision is only possible when suitable information is available and in the case of D35 access to core has been crucial to the development of more representative geological model. Gathering key data, cores, oil samples pressure information etc. at an early stage in field life should not be regarded as unnecessary but rather as a wise investment for the future. Additionally it is important to recognize that subsurface models will, and need to, evolve as more data becomes available. Maintaining a model developed early in field life may result in missed opportunities to improve recoveries and asset value.

Geology Paper 24

MORE OIL FROM AN OLD FIELD

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Baram field is located in Sarawak Basin, East Malaysia. The field was discovered in 1963 by Baram-1 well in the down-thrown side of the main growth fault. Six additional appraisal wells including the discovery well for Baram South Fault Block were drilled prior to formulating development plans (Figure 1).

The depositional environment is predominantly fluviomarine-coastal inner nerritic reservoirs from Late Miocene to Early Pliocene in age (Upper Cycle V to Lower Cycle VI). Oil bearing reservoirs occur at depth 2500 to 9000 ft tvdss in the sand-shale intercalation settings.

In recent years, a systematic detail re-evaluation of the field was carried out to identify further development opportunities. For the G&G aspect it covered the re-analysis of the well correlation, seismic interpretation, hydrocarbon fluid distribution, and uncertainties analysis. 3D static model has been used and developed for the analysis. (Figure 2).

Dealing with the multi-stacked with various thicknesses; range around 10 ft to 60 ft tvdss is challenging. But with the effectiveness use of 3D static modeling, state of art drilling technology, challenging the past assumption and maximizing the development of the minor reservoirs have resulted in identification of upside potential and new reserves. (Figure 3).

In 2005 until 2007, 15 wells were drilled from two drilling platforms to further appraise and develop Baram South field, while 4 sidetracks wells, 1 workover & 3 wells were drilled to develop Baram A area, which gave very encouraging results. The overall production of the field has reached the same level as in 1974, i.e 32 years after first field production. (Figure 4).

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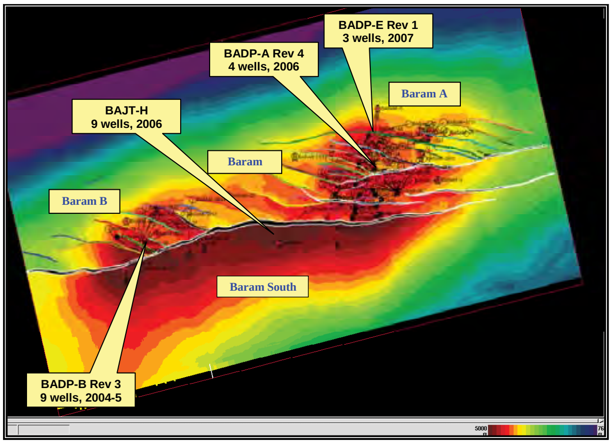

Figure 1: Structure of Baram Field.

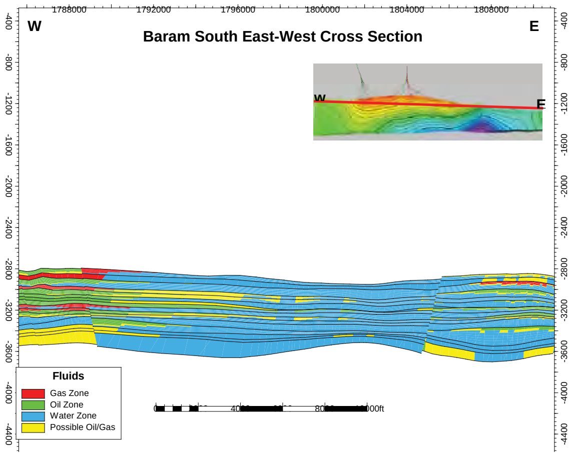

Figure 3: Multistacked reservoirs with various thicknesses in Baram.

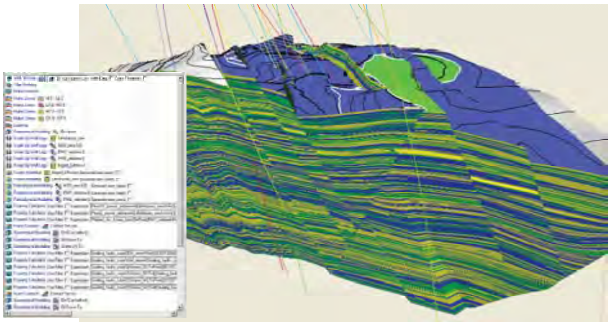

Figure 2: 3D static model that has been used for the analysis.

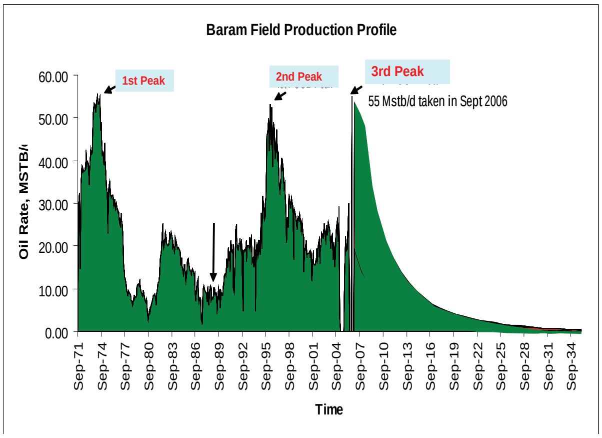

Figure 4: Baram Field Production Profile.

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Geology Paper 25

PRE-TERTIARY CARBONATE PLAY, OFFSHORE PENINSULA MALAYSIA, A REVIVAL OF FORGOTTEN PLAY

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The exploration activities in offshore Peninsular Malaysia have started as early as 1960's. The first well was drilled in 1969 and the oil discovery had made the area as a new petroleum province in Malaysia beside those in the Sarawak and Sabah Basins. It was then followed by several exploration cycles in 1970's and 1980's with many significant discoveries.

Several Tertiary play types were drilled and proved to contain hydrocarbons. The plays include compressional anticline, extensional structural faults, Tenggol Arch basement drape, NE ramp margin, and so on (Figure 1). In early 1970's, the Pre-Tertiary carbonate play was tested at three localities on Sotong and Bunga Raya structures (Figure 2). These wells penetrated between 8 to 492m of limestone formation. However, the three wells proved to be dry. These disappointing results put the exploration of deeper carbonate reservoirs into complete halt as compared to a high success ratio (1 in 4.5 wells) in other overlying Tertiary plays. To date, the only new play type that proved to be successful was the fractured basement play after the discovery of Anding Utara in 2005.

This paper aims to reflect results and findings of most recent geological evaluation and modeling conducted by PETRONAS Carigali in trying to investigate the potential of the Pre-Tertiary carbonate play. Based on onshore regional data, the shallow marine sequences (Lower Carboniferous to the Upper Triassic) cover most of the Sunda shelf area in Peninsula Malaysia, Thailand, and Indochina. Some Pre-Tertiary Formations are outcropping in Peninsula Malaysia as documented by Tija (1985, 1986). The Triassic and older sedimentary formations are mainly marine, while those younger than Triassic are mostly non-marine. The Permian sediments are dominantly calcareous (often reefal) and often associated with volcanic tuffs. Detailed studies in Gua Musang area and the Biostratigraphic study of Sotong-B1 (H. Fontaine et al., 1989) have identified Triassic age fauna in several limestone occurrences.

Recent efforts on identifying new potential plays by PCSB in South Malay Basin indicated the potential of this Pre-Tertiary carbonate play near to Sotong and Tenggol Arch areas (Figure-3). A thorough review of Pari-1 well Penyu Basin, which reached final T.D. in the calcareous siltstone and meta-sediment basement, has indicated the possibility of calcareous shale/carbonate as evident from sample description and seismic data.

Despite the poor quality and old 2D seismic vintages in Tenggol arch and Penyu Basin, some still indicate possible carbonate or reefal build-up reflection patterns. New 3D seismic sections recently acquired in Blocks PM307 and PM308 have clearly indicated 45 deg. dipping beds patterns with circular reefal buildup geometries as seen in time slices (Figure-4). Special seismic attributes e.g. Sweetness, provided further support of possible Pre-Tertiary reefal carbonates overlying the granitic basement at horsts and paleo-highs structures.

The geological model for this play type indicates the source rock is made up of the matured lacustrine facies of Lower-Upper Oligocene often present at deeper grabens and charging updip and vertically along faults. The Pre-Tertiary carbonates (potential reservoir) are present at the paleo-basement highs and horst structures. The cap rock is provided by the massive regional shales that were deposited during the sagging phase and later interformational shales. Deep burial diagenesis of the reservoirs and its proximity to basement mass is believed to enhance the reservoir secondary porosity through dolomitization and dissolution processes.

This Pre-Tertiary play has proved to be successful in southern Thailand when the Nang Nuan oil field was discovered in Permian carbonate by Shell in 1987. This field is located in Chumphon Basin in Southern Thailand where the carbonates extended further south in the central and east coast of the Malay Peninsular. The reservoirs have been strongly affected by karstic features, deep-burial diagenesis and dolomitization by hydrothermal fluids. Good quality 3D seismic and other data will be significantly helpful for better imaging and identifying potential exploration targets in Pre-Tertiary Carbonates. Successful testing and drilling of the play will considerably contribute towards reserve addition.

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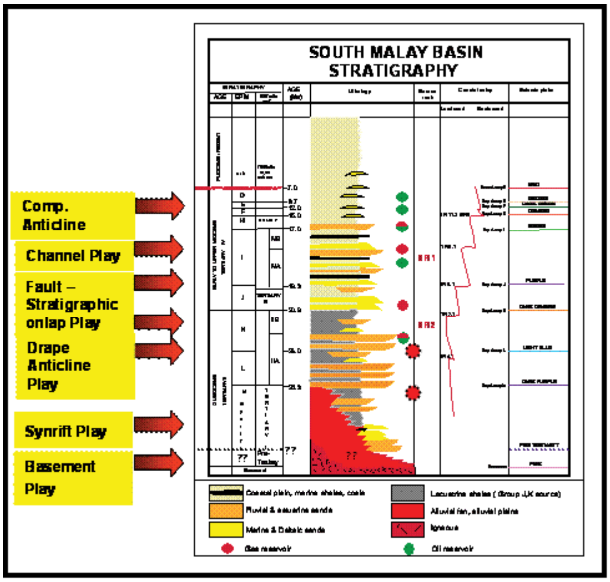

Figure 1: Block PM307 Stratigraphic Column and Play Types.

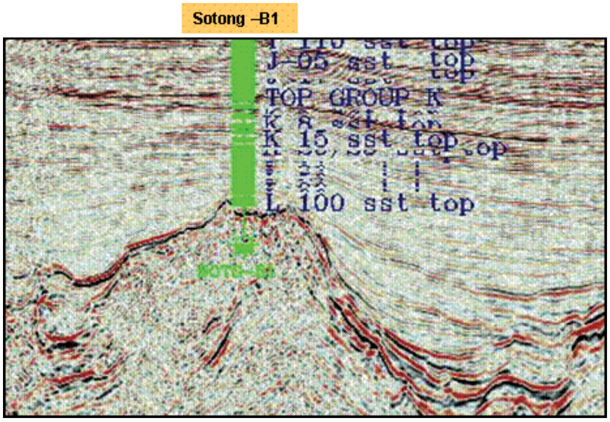

Figure 2: Sotong-B1 Well, drilled about 292 meter of Reefal Limestone (slightly metamorphosed).

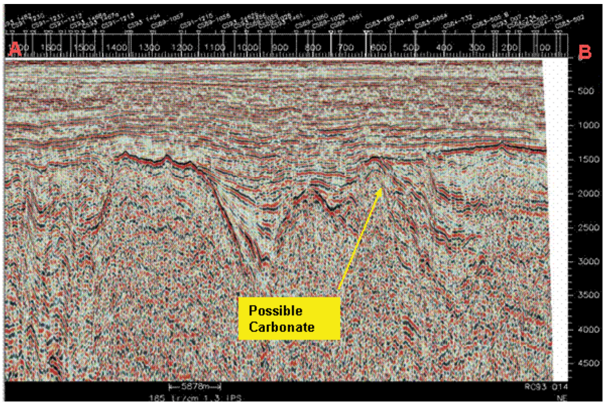

Figure 3: Block PM307- Possible Carbonate Buildup in Tenggol Arch Area.

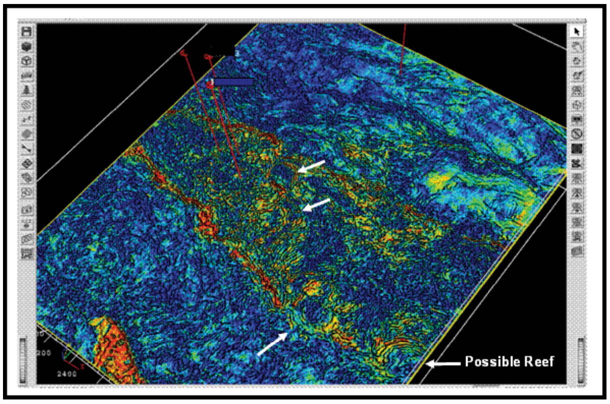

Figure 4: Time Slice 2478 ms, Combo-Mambo Seismic Attribute indicating a possible Reefal Buildup.

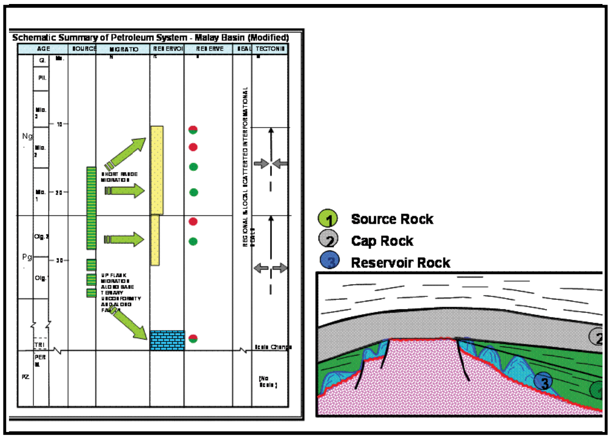

Figure 5: Schematic Summary of Petroleum System, Pre-Tertiary Carbonate Play – Offshore Peninsula Malaysia.

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ABSTRACT OF POSTERS

Poster 1

ORGANIC FACIES VARIATION IN LACUSTRINE SOURCE ROCKS IN THE SOUTHERN MALAY BASIN

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This paper attempts to look at, in more detail, the source rock quality of the lacustrine shales within the Groups K, L and M in the southern flank of the Malay Basin. This study is made possible through the use of state-of-the-art linked-scan gas chromatography / mass spectrometry / mass spectrometry or GCMSMS to provide highly sensitive measurements of biomarkers which are typically in low concentrations in source rock extracts and oils, and especially so in condensates. Since only one well dataset is available, only the vertical variation in the source rock quality of the lacustrine shales is discussed. Stratigraphically, there is a noticeable change in the source rock quality within the three groups. In general, the TOC content of the lacustrine shale sequences in Groups K, L and M range from 0.35 to 2.00 wt% (Fig. 1). Kerogen composition of these shales varies, showing mixtures of Type II and Type III indicating variable contributions from algal, bacterial and higher plant organic matter deposited in a highly to less oxidising environment (Fig. 2). This is indicated by hydrogen index (HI) values ranging from 137 to 403. Group L lacustrine shales seem to provide the best oil-prone source rock with TOC values of 0.45 to 1.95 wt% and HI values in the range of 300 to 400 indicating predominantly Type II kerogens (Fig. 2).

The variation in the source rock quality within the Groups K, L and M may be due to a combination of organic source input and factors controlling the preservation of organic matter within the environments of deposition. This observation is supported by data from screening and microscopic analyses of whole rocks and, alkane and biomarker analyses of source rock extracts. It appears that Groups L and M shales, deposited in a lacustrine environment, received more algal input compared to terrigenous organic matter in a less oxic condition resulting in relatively better organic matter preservation. This is shown by the lower Pr/Ph ratio in the range of 3.1 to 4.0, lower Tm/Ts ratio, moderate to high abundance of C30-diahopane and low abundance of tricyclics and gammacerane (Figs. 3-5). On the other hand, the younger Group K had more fluvial influence and consequently received relatively more terrigenous organic matter input being deposited in a more oxidising environment. This is indicated by the higher Pr/Ph ratio (5.1 to 6.2), higher abundance of oleanane, predominance of C29-steranes compared to C27- and C28-steranes, and trace amounts of tricyclics and gammacerane (Figs. 3-5). It is also observed microscopically that Group K has higher abundance of terrigenous-derived vitrinite particles available for measurements as opposed to Groups L and M. The marked change in organic facies within the lacustrine shales from Groups L and M to Group K is reflected in the evolution of the Malay Basin i.e. the transition from synrift to post-rift phase during the L and early part of K times.

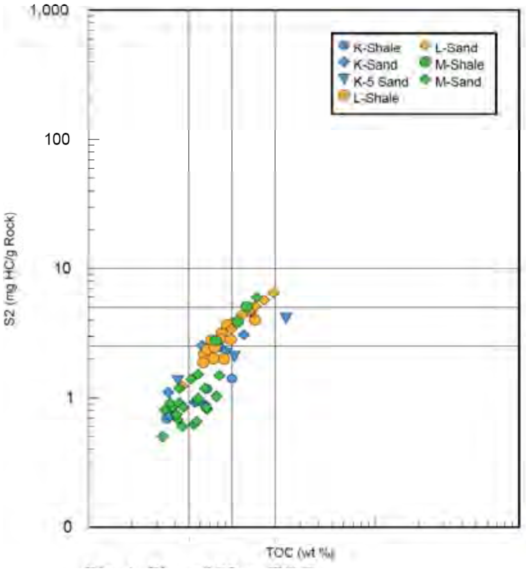

Figure 1: Plot of S2 vs. TOC

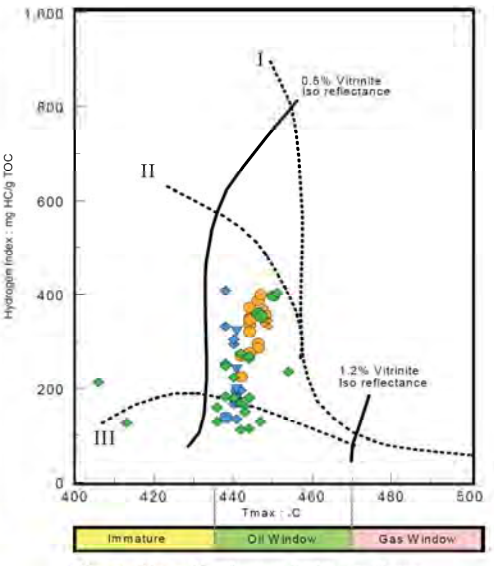

Figure 2: Plot of hydrogen index vs TMax

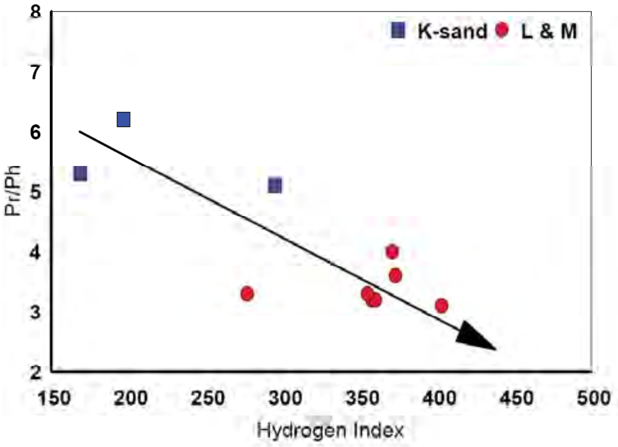

Figure 3: Plot of Pr/Ph vs hydrogen index

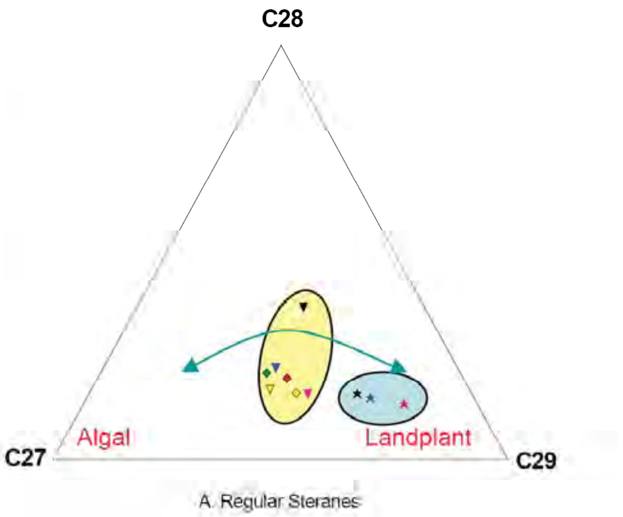

Figure 4: Ternary plot of C27-,C28-, and C29 Steranes

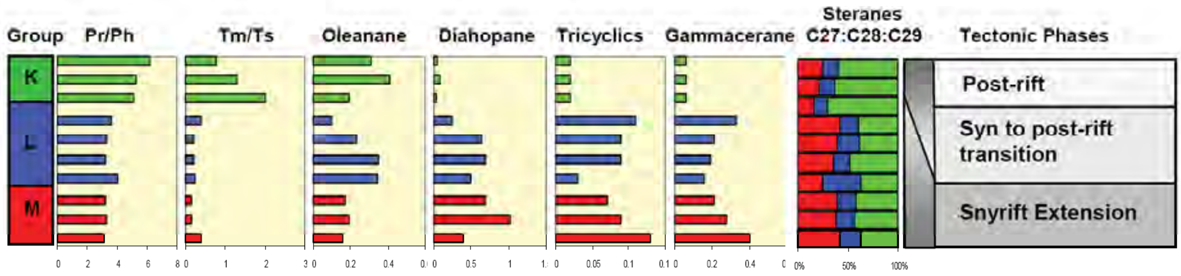

Figure 5: Profiles showing changes in biomarker abundances within Groups K, L and M

Poster 2

LACUSTRINE OIL FAMILIES IN THE MALAY BASIN

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The oils and condensates of the Malay Basin are being generated by two main source rocks - lacustrine and fluvial-deltaic, with varying degrees of mixing between them. In addition, a recent study on the petroleum systems in the northern part of the Malay Basin has also shown that fluvial-marine source rocks could also generate these oils. The focus of this paper is on the lacustrine oils i.e. with respect to their biomarker characteristics and the possibility of grouping them into different oil families. The area of study is the Anding and adjacent fields located in the southern Malay Basin.

The distribution of biomarkers shows that the lacustrine oils were generated from mixed fluvial-lacustrine source facies. This is indicated by the presence of, in varying proportions, algal and terrigenous biomarkers in the analysed oil samples. For comparison purposes, oils from typical lacustrine and fluvial-deltaic source facies were included in the biomarker data analysis. Based on the biomarker distributions (Figs. 1-3) and supported by compound specific isotope ratios (Fig. 4), the oils can be categorised into four oil families, which by chance, are also grouped according to their geographical locations. Possible explanations for these groupings are facies change in the source rocks and factors affecting the oils during migration and post-accumulation. These four oil families and their Pr/Ph ratios are shown below:

1. Anding Oil Family - This oil family can be further divided into two sub-families:
   a. Anding Utara :- Pr/Ph ratio of 4.25 to 4.30
   b. Anding Utara Basement :- Pr/Ph ratio of 3.56 to 3.85
2. Sotong Oil Family :- Pr/Ph ratio of 3.30 to 3.94
3. Malong Oil Family :- Pr/Ph ratio of 2.89 to 3.00
4. Bertam Oil Family :- Pr/Ph ratio of 2.21 to 2.27

Oil-to-source rock correlation between these oils and lacustrine source rocks from the Groups K, L and M was also attempted.

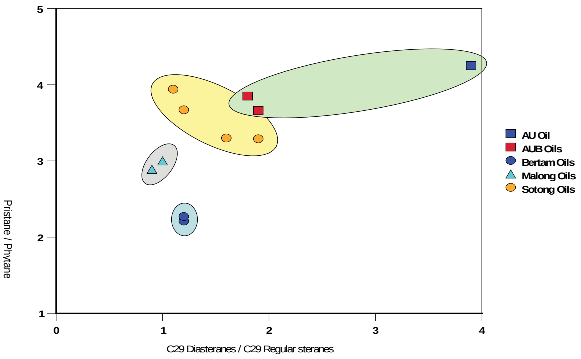

Figure 1: Plot of Pr/Ph vs C29 Diasteranes/Steranes.

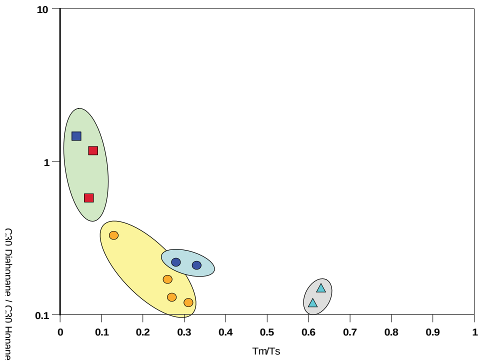

Figure 2: Plot of C30 Diahopane vs Tm/Ts.

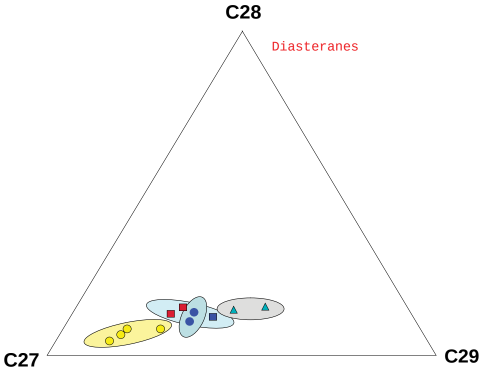

Figure 3: Ternary plot of C27-, C28- and C29 Diasteranes ratios.

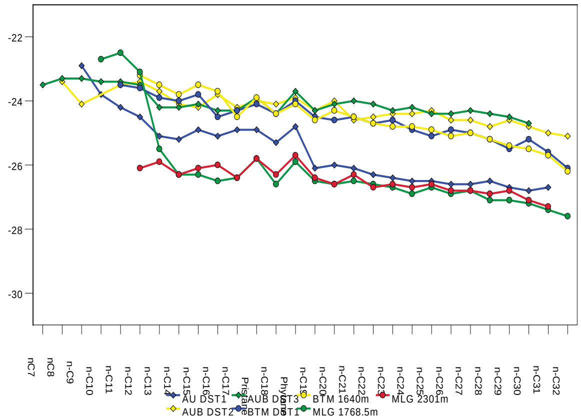

Figure 4: Plot of compound specific isotope.

Poster 3

DISTAL TURBIDITES OF THE SEMANTAN FORMATION (MIDDLE-UPPER TRIASSIC) IN THE CENTRAL PAHANG, PENINSULAR MALAYSIA

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Introduction

The Semantan Formation has been interpreted as deep-marine deposits based on sedimentological and palaeontological studies (e.g. Metcalfe et al. 1982; Metcalfe & Azhar Haji Hussin, 1994; Mohd Shafeea Leman & Masatoshi Sone 2001). Convergence between the Eastmal/Indosinia and Sibumasu blocks during the late Triassic resulted in closure of the Paleo-Tethys Ocean (Hutchison, 1989). Remnants of this ocean are represented by the deep-marine deposits of the Semantan Formation (Middle to Upper Triassic) in the Central Belt of Peninsular Malaysia. Some outcrops of the Semantan Formation at SK Sri Tualang and Taman Mutiara, near Temerloh and along the Karak-Kuantan highway, were studied to gain a better understanding of the deep-marine sedimentary facies and sedimentation processes in the distal parts of submarine fans and basin plain environments (Figure 1).

Lithology

The main facies recognized in the field is shale-dominated heterolithic sand-mud facies, with up to 40 m of composite thickness (Figure 2). The shale is black to dark grey and ranges in bed thickness from few cm to 3 m. It is commonly laminated and interbeds with mudstone, siltstone and thin sandstone. The sandstone, commonly tuffaceous, is light grey, fine grained and medium to well sorted. The beds are either planar or wavy with sharp to gradational contacts. Parallel and cross laminations are common internal structures within the bed.

Depositional Processes and Environment

Turbidity currents triggered by storms or earthquakes are able to carry large amount of sediment from slope to the basinal environment. When the turbidity current energy subsided, the sediment started to settle out of the water mass. Occasionally, thicker sand beds may be deposited by high-energy turbidity flows that were able to travel further out over extremely low gradients into the distal part of the basin. When the energy becomes weaker, turbidity currents are able to spread outwards into the basin and deposit thin sheet-like sandbodies, which typifies the outer fan environment. The shale-dominated heterolithic facies represents the distal parts of submarine fans (outer fan to basin plain) where weak turbidity flows carry silt and fine sand into a predominantly hemipelagic depositional environment. Sedimentary features observed in the outcrops, such as the fine grain size, thin bedded, gradational upper contact, good lateral continuity, normal graded bedding (fining upward) and thin waning-flow sandy layers in shale indicates distal turbidity current processes. In the basin plain, turbidity currents are still able to entrain additional sedimentary particle as they travel. They produced scour features after loose particles are eroded from the sea floor. Low-angle cross, ripple and wavy laminations, resulting from bottom current reworking or weakly turbulent current suspensions, are also quite common features (Figure 3). Some shale and mudstone beds contain Chondrites burrows which are indicative of a quiet environment on the basin plain.

Conclusions

The Semantan Formation in the studied area represents the distal part of a submarine fan or basin plain environment, based on sedimentary facies and structures. The main facies is thick shale-dominated heterolithic sand-mud facies. Sedimentary structures in the thin bedded siltstone and sandstone support the turbidity current as the main depositional process that is responsible for supplying sand and silt to the basinal environment. The Chondrites burrows give evidence for a low-energy environment on the basin plain.

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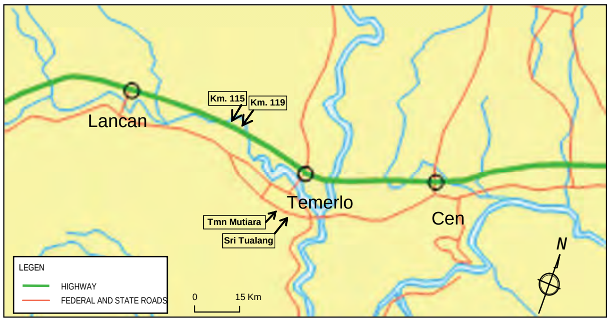

Figure 1 Location map of the outcrop localities.

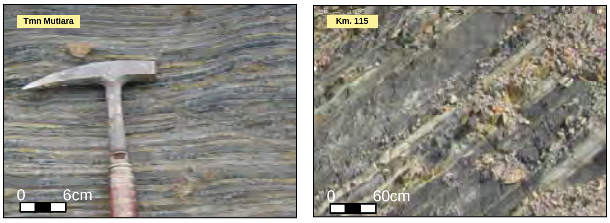

Figure 2: Shale-dominated heterolithic sand-mud facies deposited by weak turbidity flows that carry silt and fine sand to distal parts of submarine fans (outer fan to basin plain).

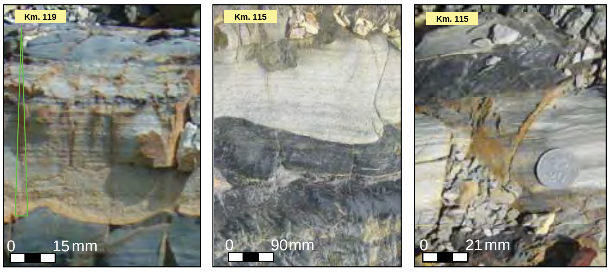

Figure 3: Normal graded bedding, load cast, ripple laminae, scoured structures signified of turbidity current deposits.

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Poster 4

TURBIDITE, DEBRITE OR SOMETHING IN BETWEEN: RE-THINKING THE WEST CROCKER FORMATION

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The Oligo-Miocene West Crocker Formation (WCF) of West Sabah is often referred to as a sand-rich turbidite system, and has been the subject of detailed sedimentological studies during the last few years. The essential features of the WCF sediments can be observed at outcrops scattered within driving distance from Kota Kinabalu (Fig. 1).

For the most part, thickly bedded facies, representing the high-density, sandy turbidites is found in most of the outcrops studied, with the exception of Taman Maju, Sepangar (Fig. 1), where there are more of the "classical" flysch-like, thin-bedded turbidites. In general, the Crocker is sand-rich and very thickly bedded (> 1 m), commonly 1.5-3 m thick, while some may be up to 35 m. Based on the presence of subtle scour and amalgamation surfaces, these thick beds were formed not by a single flow but multiple flow events. Internally, the thick beds, most of which are poorly sorted despite the overall normal grading, are characterized by faint low-angle laminations, resulting from traction, passing upwards into contorted bedding due either to deposition from a slurry, or to soft-sediment deformation and dewatering. Deposition from slurry involves rapid dumping of a dense muddy and water-saturated mass of sediment. Hence, in these types of beds at least, there is strong evidence for some form of high-density (sandy) turbidity flows, slurry, or both. Erosion at base of the flows, indicated by flute casts and various other sole marks are common. Well-developed load structures, including large ball-and-pillow (or "jam roll") structure due to loading and sinking of these dense flows into water-saturated muddy substrate are indicative of the scale and dynamics of these flows.

The turbidites in the WCF are also often characterized by the Bouma-type beds (Fig. 2), passing upward from sharp-based massive sandstone, into low-angle lamination, into convolute lamination, and rippled muddy tops, with floating shale clasts at top of bed. These beds are repetitive vertically, some with well-developed climbing ripples, indicative of rapid deceleration and simultaneous aggradation of flows. Soft-sediment deformation and remobilization is also a common feature of the Crocker – sliding of sandstone beds indicate unstable slopes that resulted in large-scale slumps or slides, possibly triggered by earthquakes in this formerly active margin. Clastic injection structures, predominantly clastic dykes, both of shale and sand are moderately abundant (Madon et al., 2006).

A further facies type frequently interbedded with the thick sand beds is muddy sandstone, with internally structureless or chaotic, and often with shale or heterolithic clasts in them. These overlie the sandstone beds very abruptly, often filling hollows or subtle topographic lows at the top of the massive sands. These muddy facies are probably debris flow deposit laid down soon after the deposition of the massive sand. In most places, the apparent paleocurrent directions measured from the almost vertical beds, generally indicate north to northeasterly directed flows. There is evidence at Lok Kawi Heights, south of Kota Kinabalu (Fig. 1), of southerly directed flows. Whether this is a local phenomenon or is more widespread is being investigated.

Current re-thinking of deepwater depositional process provides better insights into the understanding of Crocker deepwater and turbidite facies in general. In this paper, facies of the West Crocker Formation are described and interpreted in terms of this new model versus the traditional turbidite paradigms (e.g. Middleton and Hampton, 1973 and Shanmugam, 2006). New terms such as high-density and low-density turbidity currents, slurry flow and linked debrite-turbidite systems have been introduced into the literature based on studies in the subsurface of the North Sea together with outcrops in Ireland and Spain (e.g. Haughton et al., 2003; Lowe & Guy, 2000). We show some outcrop examples from the West Crocker Formation to illustrate the different facies that may be interpreted using this new paradigm. While some of the WCF facies may have been formed by turbidity flows (Fig. 2) and debris flows (Fig. 3), there are also other bedding types that represent a different depositional process (Fig. 4), and require re-consideration of the existing models. The ability to discriminate the different types of deposits that result from these various processes is important because of the potential implications for reservoir geometry and heterogeneity.

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Figure 1: Location map of West Crocker outcrops in Kota Kinabalu area.

Figure 4: Sharp-based massive sandstone with internal flow-induced structures, probably indicative of deposition by slurry.

Figure 2: Turbidite bed with Bouma divisions (note book for scale).

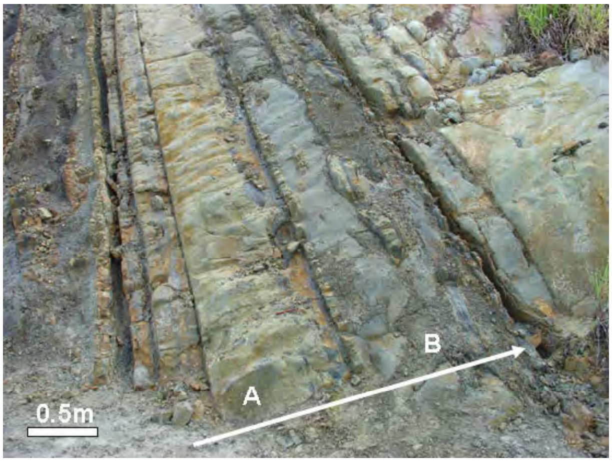

Figure 3: A possible linked turbidite-debrite couplet? Normally graded massive sandstone (A) with floating shale clasts, overlain by muddy sandstone (B) with heterolithic rip-up clasts.

Poster 5

THE GEOGRAPHIC AND STRATIGRAPHIC DISTRIBUTION OF CORED-SECTIONS IN THE MALAY BASIN

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The sediments in the Malay Basin can be seismically differentiated into 'Groups' bearing the alphabets A to M; A being the youngest and M being the oldest. Due to the effects of Middle-Late Miocene tectonic inversion, the area in the south was gradually uplifted, resulting in most of the younger stratigraphic sections to be eroded. Whereas, in the north, where the effect of the inversion is minimal, a thicker sections of younger stratigraphic sections are preserved.

The early phase of exploration activities targeted reservoirs from older stratigraphic sections, mainly located in the south Malay Basin. After 1970, exploration activities gradually shifted towards the north, as more concessionaries open. The main targets are mostly the gas pay horizons from younger stratigraphic intervals. Naturally, the distribution of the cored-sections in the Malay Basin follows this exploration drilling pattern.

This paper shows the geographic and stratigraphic distribution of cored-sections based on the inventory of data from over two hundred wells (Chart 1, 2). These charts provide a quick assessment of the depth of well penetration and length of cored-section, stratigraphic tops, gross lithology and core availability within each stratigraphic unit.

It can be observed that most cored-section in Groups I,J,K,L and M are from wells located in the south. For younger stratigraphic units such as Groups D and E, the cored-sections are available from the wells located in the northern area of the basin. The stratigraphic units having the most cored-section are Groups E, I and J. The least cored-sections are Groups F and M. It can also be observed that approximately one half of the cores was either not described or the data were not available. The deepest cored-section is recorded within Group L at 2783m from Angsi-1, while the shallowest core was cut from Group A/B at 254m in Bekok-4.

The charts also depict the gross lithology of the cored-section. This is represented as colour bars which also reflect the general lithological succession and facies association. They enabled a quick evaluation of gross lithofacies in the cored-section from different stratigraphic units within and across wells. In general, the cores were mostly cut from predominantly sandy lithology associated with the major reservoir pay horizon. The exceptions are in Group D of Noring-2 and 3. In this case, the cored-sections are mainly within clay interval. Some cores cut through several coal horizons. The major ones are in Group J of Bunga Pakma-1 and Group E of Jerneh-3

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Poster 6

TEMANA: OLD FIELD, NEW IDEAS AND NEW INSIGHTS

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Temana Field is located approximately 30km offshore from Bintulu in water depth of about 90 feet and was discovered in 1962 by exploration well TE-1. Development commenced following commercial volume confirmation by appraisal wells TE-9 and TE-10 in 1972. The field is divided into three areas; Temana West, Central and East.

For more than 35 years, the development concept in Temana has been driven by the presence of structural plays. Well locations being placed mostly in the crest of anticlines. Even though there was a belief that a stratigraphic component was involved in the trapping mechanism, the bold move to test this concept was deferred until recently.

Approximately 90% of the field's production is from the H and I series which are characterized by Miocene aged fluvial sands. The I60/I65 series in particular are said to have been deposited in a lower coastal plain environment with tidal influence. Developing the Temana fields entails several challenges, mostly due to the field's rather intricate structure, consisting of over 80 structurally and stratigraphically isolated reservoir compartments. Furthermore, the channelised I60/I65 sands results in several pinch-outs, limiting the sand distribution across the field and resulting in relatively thin reservoirs.

A new appraisal well TE-72 was drilled in 2004 in the Temana Saddle area to test the seismic anomaly on a plunging anticline for the presence of a combination stratigraphic and structural play. This appraisal well was motivated by encouraging results from wells TE-54ST1 and TE-71 for the I60 reservoir, in which a similar amplitude anomaly response was proven as oil bearing (Figure 1). Although the amplitude anomaly was not conformable with the structure at TE-72 well location, the well penetrated 58ft of thick blocky I65 sands, confirmed as hydrocarbon bearing. The sand is observed to be shaled-out in the up-dip offset wells (Figure 2). This pinching-out of the I65 sands towards the northeastern direction gives the reservoir the stratigraphic play needed to act as a trapping mechanism for the hydrocarbon accumulation.

Following the success of TE-72, several geological and geophysical studies were undertaken including a fluid substitution study and a reservoir characterization study on acoustics impedance inversion volumes (Figure 3 & 4). This led to the drilling of three development wells (TE-73ST1, TE-74ST2 and TE-51ST2) in the Temana Saddle area in 2006/07 to delineate fluid contacts and provide drainage points for I65 reservoir. The success of the drilling campaign is reflected in the production figure whereby production from a single well could reach as high as 3600 bopd. The producing wells confirmed the geological model and further established the integrity of the trapping mechanism.

The accomplishment of the Temana Drilling campaign triggered more interest to further dissect the field. Existing seismic cube was reprocessed and subsequently an AVO study was embarked to further delineate the hydrocarbon bearing sands.

The discovery from the appraisal well and the success of the recent development campaign inspire a new paradigm in exploring the Temana Field and opening a new chapter of stratigraphic and structural play concept, hence giving a new direction of exploration towards the flank of the structure.

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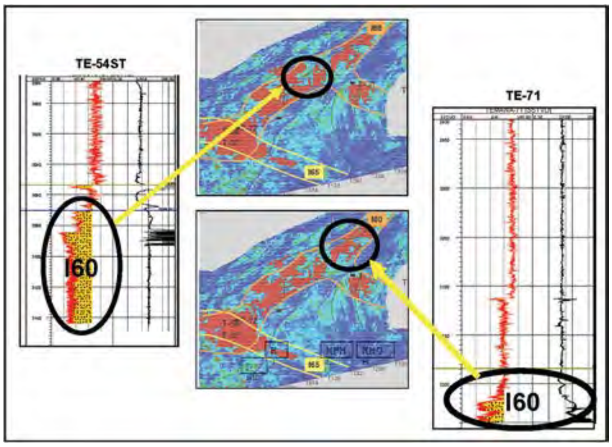

Figure 1. Amplitude Anomaly for I-60 reservoir

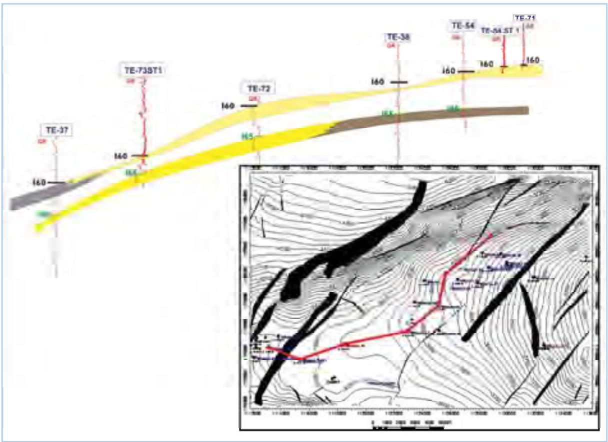

Figure 2. SW to NE schematic cross section of I-60 and I-65 reservoir across Temana Saddle and Central.

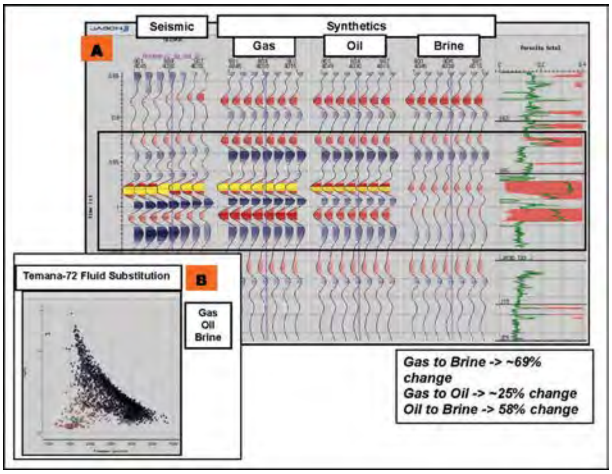

Figure 3. Fluid Substitution Study. A) Temana TE-72 well synthetics for different fluid scenario around I-60/I-65 reservoir and B) Vp/Vs and P-Impedance crossplot of Temana TE-72. Crossplot showing the distribution and movement of the hydrocarbon sands under different fluid scenarios.

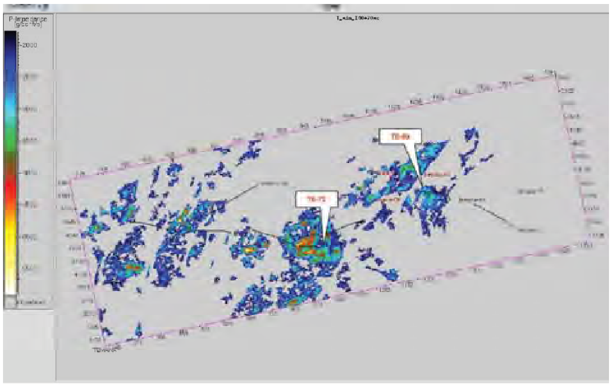

Figure 4. I-65 sand. Minimum P-Impedance distribution for the maximum case.

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Poster 7

CONDENSED SECTION INTERVALS WITHIN THE CYCLE II (EARLY MIOCENE) OF THE D35 FIELD, BALINGIAN PROVINCE, OFFSHORE SARAWAK: OCCURRENCE AND SIGNIFICANCE

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A marine condensed section is a thin stratigraphic interval characterized by very slow depositional rates (<1-10 mm/yr). The interval often comprises fine-grained sedimentary rocks characterized by the presence of highly radioactive and organic rich shales, glauconite, chemical sediments and hardgrounds/firmgrounds. The interval may be thoroughly bioturbated, variably fossiliferous and locally show concretionary cement.

Condensed sections reflect particularly slow accumulation rates and thereby representing a significant span of time within only a thin layer. Condensed sections commonly develop during transgressions, in such cases they may be connected with "maximum flooding surfaces" and form important sequence stratigraphic markers.

The Cycle II (Early Miocene) reservoir intervals of the D35 field in Balingian Province, offshore Sarawak comprises thick, stacked, low-angle to cross-bedded sandstones, sandy conglomerate and wavy-to-irregularly laminated sandstone which are invariably bioturbated. These are interbedded with thick, sparsely bioturbated mudstones and several coal and paleosol horizons.

One major and four minor condensed sections have been identified within the cored intervals. The recognition of these thin but stratigraphically significant intervals is critical in the re-interpretation of the depositional framework of the Cycle II succession of the D35 field. Their occurrences indicate significant episodic marine incursions across the field area and beyond.

A major condensed section (Figure 1) identified within the Basal Interval of Cycle II is correlatable across the D35 field. The interval is complex, and contains a wide variety of trace fossil assemblages. These vary from stressed brackish water suites to very diverse, fully marine suites. Key surfaces, many demarked by palimpsest (time break) assemblages and Glossifungites ichnofacies (indicating firmground development), are closely spaced and commonly amalgamated. These, originally separate, thin intervals of condensed facies were clearly deposited in disparate sedimentary environments. They represent amalgamated, top truncated sequences and reflect maximum flooding intervals deposited during high stand events.

A second, thin, condensed interval has been identified within the Lower Cycle II (LC-II) sub-interval, which is the main hydrocarbon reservoir. The reservoir is interpreted as lobate to sheet-like mouth bars, distributary channels and limited tidal flat complexes. At least four lobes of the mouth bar complexe can be recognized, which are separated by brackish estuarine shale. The thin, Glossifungites interval occurs near the top of LC-II, above an estuary/channel margin sandstone facies. It is in turn overlain by a nine-foot, conglomeratic sandstone representing part of a channelised, mouth bar/distributary channel sandbody. The Glossifungites ichnofacies indicates that a brackish environment was affected b a phase of marine inundation followed by a time break, during which the surface was inhabited by a community of opportunistic organisms. These changes may be related to lobe switching or sediment starvation. The occurrence of this interval indicates that the deposition of the different mouth bar lobes were not continuous, but occurred through time with major breaks.

Near the base of Middle Cycle II (MC-II) two closely spaced and thin condensed intervals are present. These Glossifungites intervals, formed near the top of thick brackish estuarine mudstone and immediately overlain by estuarine channel-bay head sandbodies, represent sediment starvation periods within the isolated basin.

A further condensed section in well D35-5 (6150-6142 ft) is marked by the presence of Ophiomorpha, Zoophycos,

Figure 1: Two core intervals which represent part of the major condensed section identified within the Basal Interval of Cycle II. This condensed interval is correlatable in the cores and well logs across the D35 field. This thick condensed interval is extremely condensed and complex, and contains enigmatic and diachronous stratigraphic stacking and juxtaposition of disparate marine and marginal marine deposits. A wide variety of trace fossil assemblages occur, ranging from stressed brackish water suites to very diverse fully marine suites. They represent amalgamated, top truncated sequences and reflect maximum flooding intervals deposited during high stand.

Scolecia, Chondrites, Teichichnus, Asterosoma, Cruziana, Rhizocorallium, Thalassinoides, Terebelina and Paleophycus, which form a palimpsest. The diverse assemblage is indicative of nearly normal saline conditions.

Stratigraphically higher again, a further condensed section is represented by heavily bioturbated beds, stacked one on top another. The bioturbation is pervasive, with BI of 3-4 grades, and in places reaching 6. Thallasinoides and Diplocraterion are seen below an erosive transgressive surface, pervasive overprinting and stacking of fully-marine and near marine/brackish assemblages is recognised. This condensed section represents an extended period of marine transgression.

The recognition of these marine-influenced condensed intervals has been crucial in the reinterpretation of the environment of deposition of the D35 field reservoir interval. A coastal-estuarine depositional model now replaces the earlier Mississippi-type fluvio-deltaic model, with the importance of sea-level changes being more fully recognised.

Poster 8

USING GRAVITY DATA TO HELP IDENTIFY AND DIFFERENTIATE MOBILE SHALE BODIES, OFFSHORE SABAH

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The reliable identification and definition of shale diapirs is important to reduce exploration risk. This poster describes the work carried out to establish the degree to which these shale bodies can be identified using high resolution gravity data from offshore Sabah.

Test models show that, assuming reasonable density contrasts, mobile shale bodies of a typical size and geometry would give a 2-3 mGal amplitude and 7 to 9 km wavelength gravity low response. Therefore they should be resolvable with good, high resolution gravity data. The picture, however, is complicated in this area by the presence of numerous large bathymetric canyons. The larger of these are shown to yield a similar gravity response as the possible shale diapir bodies, although the gravity effect of these bathymetric canyons can be diminished to some degree by the use of the Bouguer gravity anomaly.

The mobile shale bodies manifest themselves on seismic data as disturbed zones, often with a distinct high impedance contrast on the top. These have been identified on several seismic sections and usually correspond directly with observed 1 to 2 mGal low anomalies in the Bouguer gravity profiles, which can be further highlighted by the use of careful filtering. This gravity response is observed irrespective of whether there is interference from the bathymetric canyons or not. Given that this characteristic gravity response is observed in several places, disturbed areas in the seismic where there is uncertainty can be verified by looking at the Bouguer anomaly profile. The poster shows that such an uncertain zone with this characteristic gravity response is confirmed as a shale diapir by viewing the cross-line trace. For disturbed areas on the seismic data that don't correspond to this same gravity response, alternative explanations might be sought such as the existence of a gas chimney.

Poster 9

DETECTION OF 3D DISTRIBUTION OF RESERVOIR SAND BODIES BY ANN – A CASE STUDY IN THE NORTH MALAY BASIN

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Introduction

Detection of reservoir distribution in 3D is one of the most important tasks for petroleum exploration in the Malay Basin and Gulf of Thailand, where highly stratified thin sand reservoirs are distributed complicatedly. Geology Driven Integration (GDI, developed by dGB Earth Sciences in the Netherlands, is software for attribute analysis by ANN) is one of the most effective techniques utilized to analyze the seismic pattern and to predict reservoir distribution and lithologic change directly from seismic attributes applying Artificial Neural Network (ANN) method. This paper presents the case study in the North Malay Basin which was carried out by JGI and CPOC in 2007.

Concept and Theory of GDI

Both of well logs and seismic records reflect the changes of material properties, such as porosity, lithology, fluid content and bed thickness. ANN method gives the solution to establish the mathematical relationship between some seismic attributes extracted from seismic records and rock properties from well logs. However, only a few available well data prevents from establishing the reliable relationship. To compensate a limited number of well data, a method of Monte Carlo Simulation is applied to generate pseudo wells based on the stratigraphic-geological model based on the real log data, geological information and geological knowledge in GDI (Figure 1).

Application of GDI to build up the 3D lithology cube

Main target is "Z" sands in the Zone "AB" and three real wells are selected to establish the integration framework which is a generic description of stratigraphy, lithology and geological knowledge of study area (Figure 2). Sand-shale lithologic units are set as a lithology code to classify the lithology with seismic attributes. Each lithology code for sand and shale is defined as 1 and 0 respectively. 200 pseudo wells are generated with various combinations of stratigraphic frameworks based on well log responses within given ranges of distribution and geological constraints. The synthetic seismograms corresponding to 200 pseudo wells are constructed by convolving the generated reflection coefficients series with a zero-phase wavelet. Two kinds of correlative feature data sets, the pseudo wells and the synthetic seismograms feature sets are given by this way.

ANNs are generated to establish the relationship between lithology (sand/shale) and seismic attributes. A series of amplitude values with 2ms sampling internal, or "Sample", within -20ms to 20ms are input into ANN. As the volume transformation, the lithologic change within the time window from -150ms to 120ms referring to the "Z" sands (Figure 3). ANN establishes the relationship between lithology and seismic attributes, and the normalized RMS is about 0.8 which indicates reasonable training results. The trained ANN is applied to 3D seismic records in the study area to predict the sand probability distribution in "AB" zone.

Conclusions

The predicted distribution of sand body at main reservoir "Z" sands and channel-fan shaped features are detected clearly in 3D lithology cube (Figure 4a) comparing with the sand distributions estimated by other attribute analyses (Figure 4b). To confirm the reliability of expected distribution of sand bodies, the predicted lithologies from the 3D lithology cube are extracted at the well locations and the GR log from the real wells. Then, the predicted lithology and GR log are compared. As a result, the predicted alternation of sand and shale at well locations coincides with GR-based lithology. The results from this study indicates that 3D lithology cube is very effective to detect the reservoir distribution and to identify the relationship between traps and reservoirs in the North Malay Basin, where traps are faulted anticlines with low relief in height and where highly stratified thin sand reservoirs are distributed complicatedly.

Acknowledgement

We would like to thank CPOC for giving permission to publish this work.

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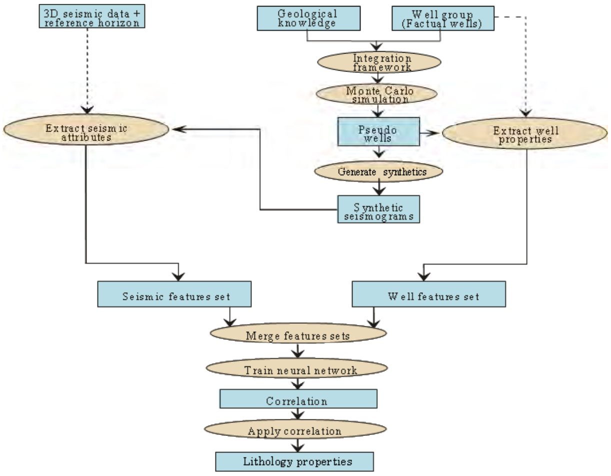

Figure 1 Flow chart of GDI analysis for the lateral prediction of reservoir properties

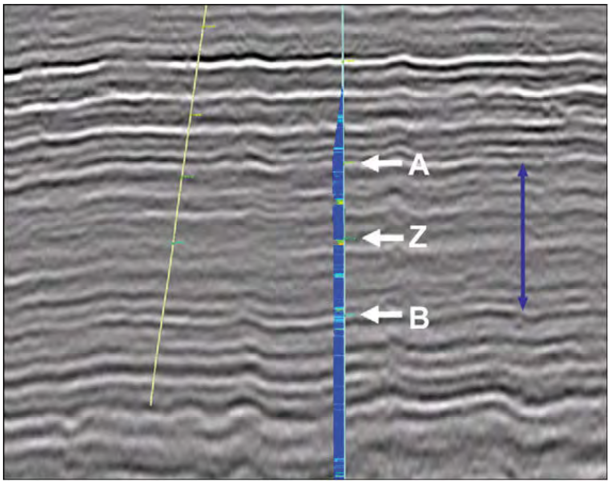

Figure 2 The target horizon of Z sands on the seismic section

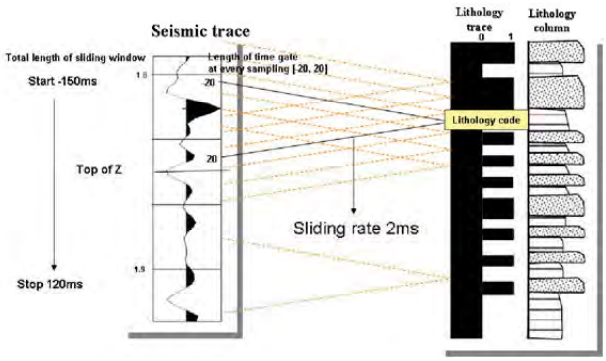

Figure 3: Extraction of seismic attributes and lithology codes within a sliding window for volume transformation in GDI.

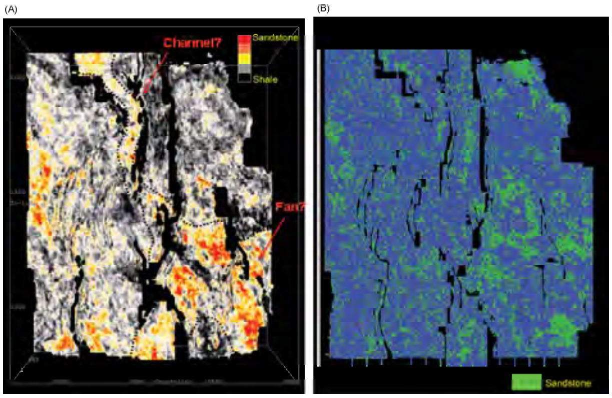

Figure 4: Predicted lithology distribution at the horizon at the Z sands by GDI, (b) predicted sand distribution at the same horizon by another attribute analysis method.

Poster 10

3D BASIN SIMULATION CONTROLLED BY CAPILLARY THRESHOLD PRESSURE – A CASE STUDY IN THE NORTH MALAY BASIN

Toshihiro Takahashi[1], Arata Kato[1], Suwit Jaroonsitha[2], Jianyong Hou[1] and Kazuo Nakayama[1]

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[2]CPOC, KL, Malaysia

Introduction

The relationship between capillary threshold pressure of seal formations and buoyancy of hydrocarbons is considered as one of the most important aspects for petroleum exploration (Sales, 1997; Nakayama and Sato, 2002). As high quality 3D seismic data is acquired in common, high resolution 3D basin simulation of capillary-dominated, multi-phase flow regimes is the effective technique to realize the generation, migration and accumulation of hydrocarbons in basin scale. This paper presents the case study of 3D basin simulation in the North Malay Basin which was carried out by JGI and CPOC in 2007.

Concept and Theory of MPath

Significant recent progress has been made in basin modeling based on multi-phase hydrocarbon migration process, however, most of previous basin simulations are adopted by Darcy's low (Carruthers and Ringrose, 1998). In geologic time scale, flow of secondary migration of hydrocarbon is controlled by capillary (resistive) and buoyancy (driving) forces (Schowalter, 1979). MPath enables to simulate the hydrocarbon migration and accumulation controlled by capillary-buoyancy forces by inversion percolation method. This method assumes that hydrocarbon migration occurs at a moment in geologic time scale and the migration speed is not calculated in this model. Therefore the migration volume of hydrocarbon is dominated by expulsion rate from source rocks.

Application of MPath

3D probability cube of sandstone in AB Zone is made from 3D seismic lithology cube which is prepared by GDI (Takahashi et al, 2008). This 3D sandstone cube has 938, 776 and 201 cells in x-axis, y-axis and z-axis, respectively. Cell sizes of each axis are 25m, 37.5m and 4msec in x-axis, y-axis and z-axis, respectively. The total cell number is around 146.3E+06.

Capillary threshold pressure for shale is defined as normal distribution with a mean of 10,000 (KPa) and that for sand is defined as normal distribution with a mean of 100 (KPa) with a standard deviation of 50 for both cases. Geochemical data indicates the kerogen may have gererated mainly gas as minor oil is expected to be generated below horizon B.

20 realizations of migration and accumulation of gas are expected in Zone AB (Figure 1) based on 3D sandstone cube, definition of capillary pressure and expulsion rate of gas. One of realization is shown in Figure 2, and numerous gas pools are expected. The advantage of MPath is much shorter calculation time compared with other software which is controlled by Darcy's low. In this study, one of the 3D high resolution geologic models has more than 140E+06 cells, but it takes about just 3 hours for calculation of the one realization.

Conclusions

3D basin simulation reveals that migration and accumulation system of hydrocarbon is controlled by structural spill-point in the study area, because most of accumulated hydrocarbons spill out through not only structural/cross fault spill-point but also stratigraphic spill-point. To confirm the results of 20 realizations, comparison between actual gas reservoir and gas accumulation probability at well locations is carried out, and these predicted accumulations are coincide with real gas reservoirs (Figure 3). Two new prospects with multiple accumulations are detected, whose pore volumes are larger than those of discovered gas accumulations

(Figure 4). 3D basin simulation by MPath gives us huge information of hydrocarbon migration & accumulation into reservoir. It also contributes to detect the new prospects as the most effective way.

Acknowledgement

We would like to thank CPOC for giving permission to publish this work.

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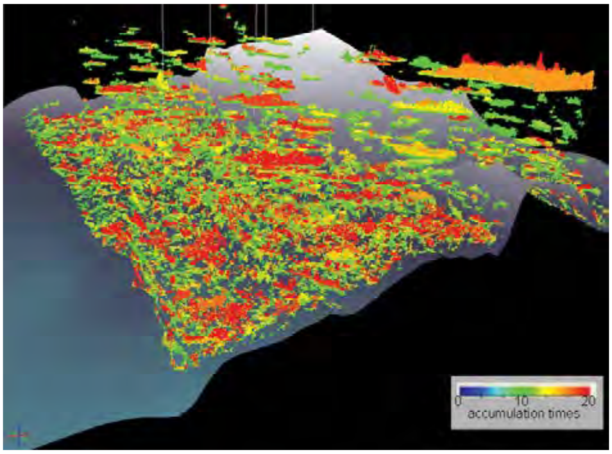

Figure 1: Result of risk analysis from 20 realizations in AB zone.

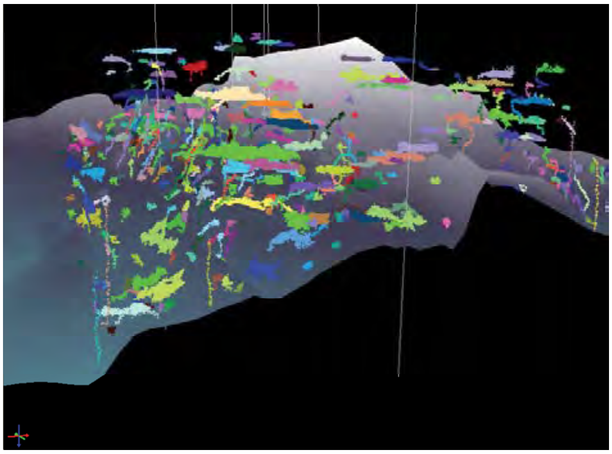

Figure 2: One of realization (11th) of migration and accumulation of gas in AB Zone.

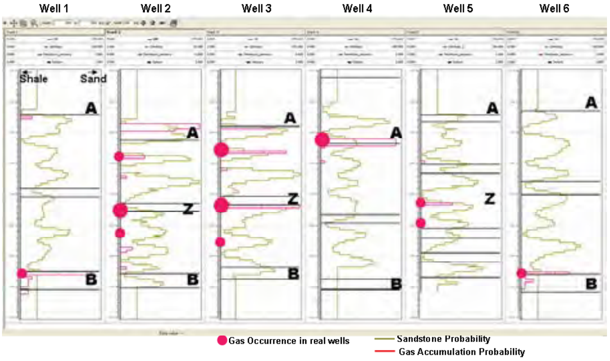

Figure 3: Comparison with petroleum presence from risk analysis and gas occurrence in real wells.

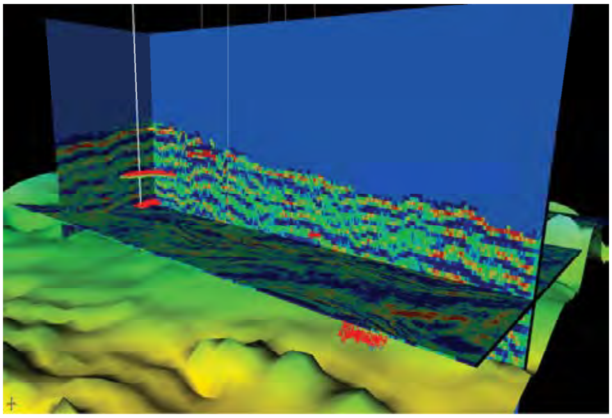

Figure 4: One of the new exploration prospects by 3D basin simulation.

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Poster 11

TWO-DIMENSIONAL STRATIGRAPHIC SIMULATION OF THE MALAY BASIN

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Stratigraphic simulation is a computer modelling technique that can be applied in petroleum exploration to understand the depositional geometries and architecture of a sedimentary basin. By making geologically reasonable assumptions about certain process parameters (e.g. sediment supply and tectonic subsidence rates), realistic stratigraphic geometries and attributes of sedimentary basins can be replicated by forward modelling. There are a number of proprietary and a few commercially available stratigraphic simulation packages designed for this task; ranging from simple 1D to more sophisticated 3D techniques (Ku Rafidah & Mazlan Madon, 2007). In this study we have used SEDPAK™, a 2D modelling package developed by the Stratigraphic Modelling Group at the University of South Carolina (Kendall et al., 1991), to simulate the stratigraphic evolution of the Malay Basin, offshore Peninsular Malaysia. The objective of the study is to investigate the relative influence of the main factors that controlled sedimentation in the basin. In a previous study of overpressure development in the basin (Madon, 2007), subsidence and sedimentation (burial) rates were found to be the main controlling factors in overpressure development. In this study, SEDPAK™ was used to reconstruct a depositional history of the basin by varying the rates of tectonic subsidence, sediment supply and eustatic sea-level change. We have used an interpreted seismic section across the basin as a starting model (Figure 1) and, upon applying a time-depth conversion, constructed a geologic cross-section to be simulated. Based on the published geologic ages of the seismic horizons and the measured thicknesses of the stratigraphic units, their average sediment accumulation rates were derived along the profile as input to the simulation. Figure 2 shows the three main input parameters. The input value for the modelling parameters is varied by trial-and-error iteration until there was agreement between the model result and the observed geometries in the seismic depth-section.

The results of the simulation are shown in Figure 3, where the stratal geometries obtained by the simulation are comparable to the observed seismic section (cf. Figure 1). We investigated two cases: one in which there was simple subsidence without faulting, and another with a major fault on the eastern margin (representing the Bergading Fault in Figure 1). The results show a difference in the subsidence pattern due to the activity on the normal fault, which has created accommodation space for deposition of a thicker wedge of sediment basinwards. This type of fault-controlled sedimentation is of interest, as it may result in deposition of reservoir facies across the fault, perhaps during falling sea level (lowstand). This study demonstrates the potential application of stratigraphic simulation techniques in predicting the controls on stratigraphic development and, hence, the distribution of reservoir, source and seal facies.

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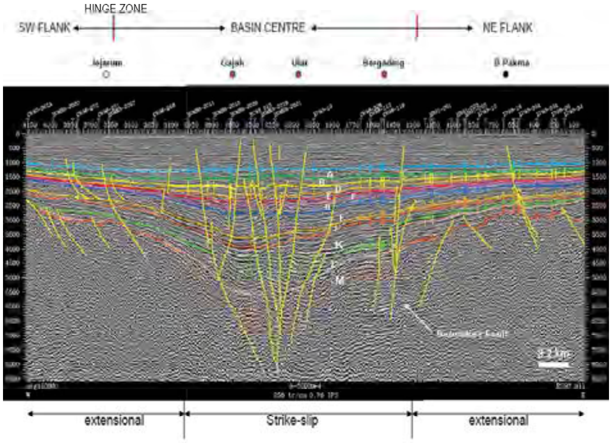

Figure 1: North Malay Basin regional seismic line (RC93-011) showing the main structural elements and architecture of the basin. This seismic line was used to reconstruct the basin model

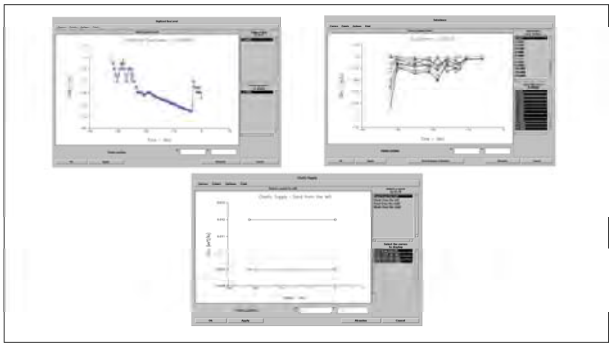

Figure 2: Input parameters for simulation of the northern Malay Basin. These parameters are the main controlling factor in development of the stratal pattern in this basin. (A) Sea level fluctuation in Malay Basin, based on the eustatic curve by Haq et al. (1987) which estimated sea-level oscillations within 100m, (B) Subsidence at 16 different locations in northern Malay Basin were assumed to be influenced by sedimentation accumulation rate, which was estimated by dividing the thickness of the unit by the time interval of deposition from observed seismic line (RC93-011). (C) Sediment supply was assumed to be constant and from both sides of the basin. The sediment is assumed to be 55% shale and 45% sand throughout the simulation..

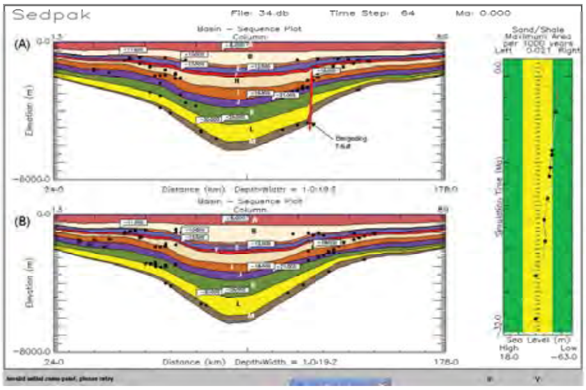

Figure 3: Modelled stratigraphic pattern of northern Malay Basin displayed in sequences (colour-coded) at present day. (A) Modelled basin with influence of normal fault (Bergading Fault) (B) Modelled basin without influence of the fault. Differential subsidence due to the fault has produced different system tracts as shown in Fig 2(A), and resulted in different stratal architecture..

Poster 12

ADVANCED MUD GAS LOGGING TECHNOLOGY: APPLICATION FOR FLUID IDENTIFICATION AND CHARACTERISATION, OFFSHORE SARAWAK, MALAYSIA

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Conventional mud gas data has been available for a long time from mudlogging operations. For several reasons, it has been under-utilised for fluid characterisation, although still acquired routinely in the drilling of oil and gas wells. However, the introduction of some advanced mud gas logging methods like FLAIR (Fluid Logging and Analysis in Real-Time) by Geoservices have made near real-time geochemical analysis of mud gas data possible. Advanced mud gas logging is also referred as Gas While Drilling (GWD) in some literature.

This article will describe how such mud gas data are utilised to identify and characterise different fluid types encountered by wells drilled in Shell operations. Two wells drilled offshore Sarawak in 2006-2007 are presented as examples (see Figure 1). The first example is an appraisal well while the second is a development well. The appraisal well was drilled to appraise the stacked sand reservoirs of Late Miocene age within the Baram Delta Province while the development well was drilled to produce gas from a sour (high H2S and CO2) carbonate reservoir in the eastern part of Central Luconia Province.

Corrected FLAIR data are analysed in-house by Shell geochemists in a data analysis package called Spotfire DecisionSite. Typically, n-alkanes (C1, C2, C3, iC4, nC4, iC5, nC5, nC6, nC7), aromatics (benzene, C6H6 and toluene, C7H8) and cyclo-hexane (methylcyclohexane) components are measured. The geochemist has to be aware of the type of drilling mud used to identify possible contamination from hydrocarbons from the mud itself. In the development well example, a pilot attempt was also carried out to measure mercaptanes to indirectly detect H2S in the carbonate reservoir. The mercaptanes measured were methyl mercaptane (CH4S), ethyl mercaptane (C2H6S), and propyl mercaptane (C3H8S).

Data interpretation is carried out by plotting various geochemical cross-plots and depth plots (see Figure 2). Hydrocarbon zones are identified by certain methane (C1) cut-off values, usually at 10,000 ppm. Hydrocarbon and water-bearing zones clearly show different trends on C1/C2 vs. C1/C2+ plots. Oil-bearing zones have relatively higher toluene/nC7 and methylcyclohexane/nC7 ratios compared to gas-bearing intervals. Biodegraded oil can be identified where sudden increases or spikes in iC5/nC5 ratios are observed; bacteria preferably consume the normal alkanes first (nC5), thus the sudden increase in this ratio.

A very useful geochemical plot that we created from our Sarawak experience is the log balance vs. log wetness plot (see Figure 3). Plotted on logarithmic scales for both axes, this plot would enable the different fluid types (dry gas, wet gas, oil, biodegraded oil or water) to be distinguished when properly calibrated. This plot is first applied in Sarawak as the conventional wetness-balance cross-over plot used in the Gulf of Mexico is not locally applicable.

In the case of the appraisal well example, the analysis of the mud gas data using methods described earlier helped the asset team pick fluid sampling points of different fluid types in various intervals. Several fluid types were identified from the mud gas data; wet gas/condensates, oil, biodegraded oil and water. Gradational changes in fluid character can be clearly observed in the various plots. Good data was also obtained within the cored intervals. It was later revealed that 4 out of 4 the fluid types interpreted from the mud gas data match the PVT analysis results.

In the development well example, the pilot attempt to measure mercaptanes (to indirectly measure H_2S) and CO_2 failed due to the use of H^2S scavengers in the drilling mud. However, ratios of the heavier to lighter n-alkane components decrease with increasing H_2S levels (see Figure 4). These ratios include (C4+C5+C6)/(C1+C2+C3) and (C2+C3+C4+C5+C6/C1). This is probably because H_2S preferentially reacts with heavier n-alkanes first, thus lower heavier n-alkane/lighter n-alkane ratios are observed where H_2S is higher in concentration. This behaviour still needs further investigation, as more data is required to further validate this observation. The mud gas data, together with LWD data can also be used to identify possible baffles/tight zones within the carbonate reservoir.

In summary, advanced mud gas logging has proven to be valuable as a first pass/initial fluid characterisation tool. Continuous fluid identification and characterisation from the mud gas data will provide up-to-date fluid data throughout the drilling operations up to target depth, and serve as a practical back-up when other fluid characterisation methods fail

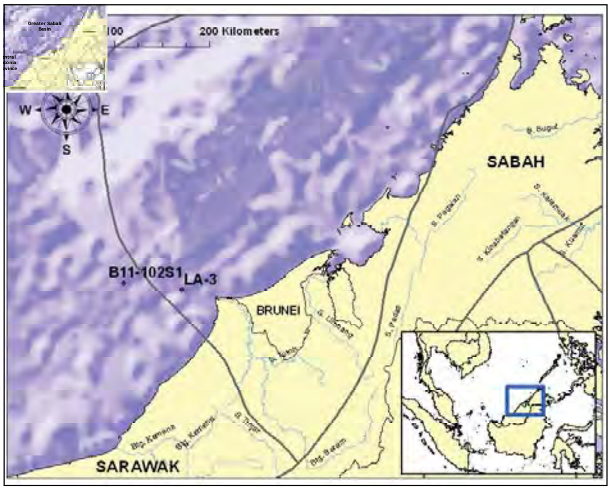


Figure 1: Location of the development and appraisal wells in Central Luconia and West Baram Delta Provinces (western part of the Greater Sabah Basin) respectively, offshore Sarawak, Malaysia.

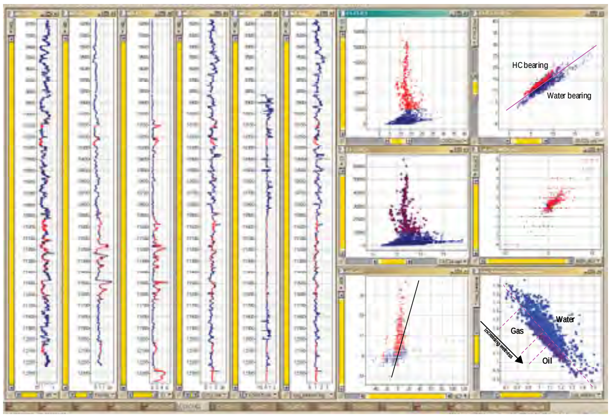
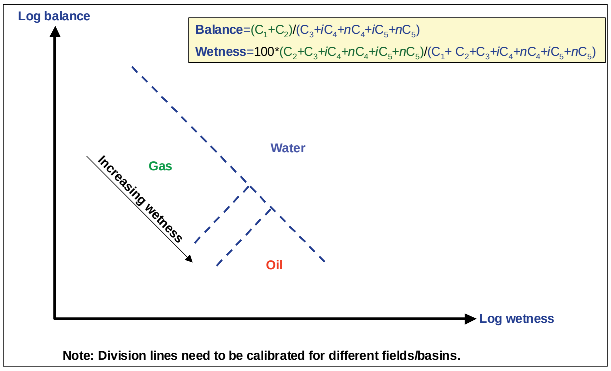


Figure 2: Mud gas data interpretation plots used by Shell geochemists. Analysis/interpretation is done in Spotfire.



Balance=$(C_1+C_2)/(C_3+iC_4+nC_4+iC_5+nC_5)$

Wetness=$100*(C_2+C_3+iC_4+nC_4+iC_5+nC_5)/(C_1+C_2+C_3+iC_4+nC_4+iC_5+nC_5)$

Note: Division lines need to be calibrated for different fields/basins.

Figure 3: Log balance vs. log wetness plot used to aid the geochemist to distinguish different fluid types from mud gas data. The plot needs to be calibrated first before being applied to a particular well/field/basin.

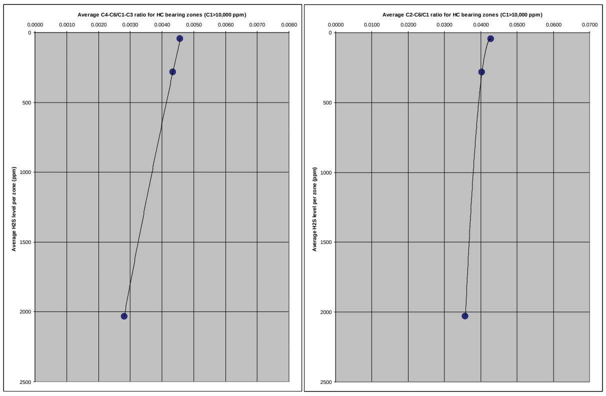


Figure 4: Changes in hydrocarbon ratios with increasing H2S levels in the reservoir.

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Poster 13

DEVELOPING REMAINING OIL IN K1.1 SAND RESERVOIR WITH HORIZONTAL WELL IN BARAM FIELD, SARAWAK BASIN

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Baram field is located in Miri Sarawak Basin, East Malaysia. (Figure1).The field was discovered in 1963 and brought into production in 1969. In it's nearly 40 year production period, optimal well placement is critical for drainage of the remaining reserves.

The field was developed with 8 drilling platform, three surface facilities, and two compressor platforms. STOIIP was estimated at 1400 MMSTB with a EUR of 390 MMSTB from more than 170 wells. Some of the remaining reserves are left behind in the oil column <60 ft, reservoir thickness <20 ft, and dipping angle >4deg which was economically unattractive to be developed.

This study is mainly focused on how to maximize oil recovery with respect to horizontal well in thin reservoir by using azimuthal geosteering technology. (Figure 2)

BADP-E Rev 1 project successfully drilled a 2000 ft horizontal section in Baram-E111S1 well to drain the remaining oil from K1.1 reservoir in Block 3. The horizontal section was drilled at +3800 ft TVDSS within 1-5 feet below the ceiling and without exiting the reservoir. (Figure 3) Thereby allowing the well to attain maximum distance from oil-water contact and ensuring no attic oil was left behind.

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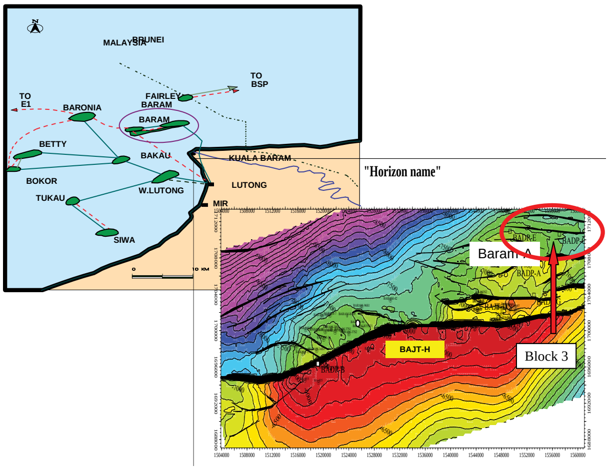

Figure 1: Baram Field Location.

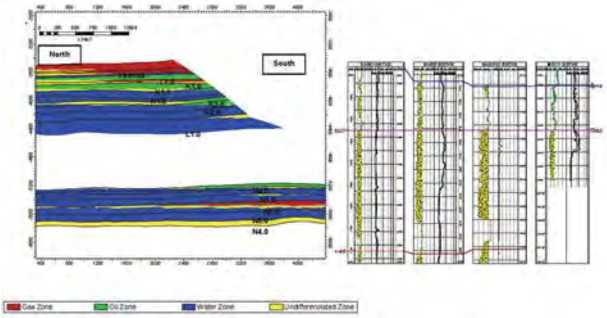

Figure 2: Horizontal well in thin reservoir (K1.1 sand).

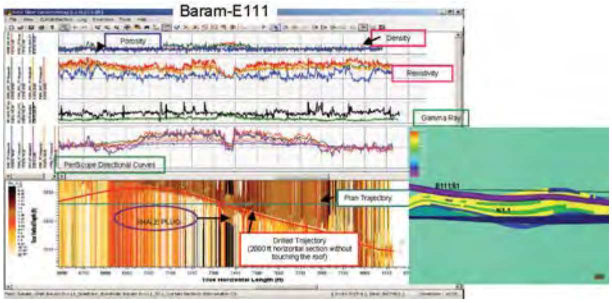

Figure 3: The horizontal section was drilled 1-5 feet below the ceiling and without exiting the reservoir.

Poster 14

USING ACOUSTIC IMPEDANCE DATA FOR TABU FIELD SUBSURFACE MAPPING AND RESERVOIR CHARACTERIZATION

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The Tabu oil and gas field, located in the southeast part of the Malay basin, was discovered in 1978 by Esso Production Malaysia Inc with the drilling of the Tabu-1 well. Oil production commenced in 1986 and is currently producing from Tabu-A and Tabu-B platforms. A field study was conducted from 2004-2006 utilizing a recently acquired 3D seismic survey to exploit the non-associated gas (NAG) and gas-cap blowdown (GCBD) resource at Tabu.

Accurate reservoir characterization is required for a successful development. For Tabu field, seismic inversion was carried out with the objective of improving reservoir characterization. Acoustic impedance inversion is a process of generating an acoustic impedance volume from the seismic reflection data. It has several advantages over a seismic reflectivity volume. The acoustic impedance data has improved resolution due to the contribution of very low frequencies from the well log data. Representing the subsurface as layers instead of layer interfaces by removing the complexity caused by the seismic wavelet, results in an improved link to the petrophysical properties of the subsurface formations.

Seismic inversion was carried out using the JASON Constrained Sparse Spike inversion (CSSI) algorithm. High quality well ties are important for determining the low frequency acoustic impedance trend, seismic wavelet extraction, and inversion of the seismic trace. Careful selection of CSSI parameters and the merge point between the low-frequency model and the inverted band-limited acoustic impedance are required for a successful inversion.

The results of the acoustic impedance volume have had a significant impact on the interpretation of the Tabu Lower "J" reservoirs, one of the key gas reservoirs. Improved reservoir characterization, including geometry and reservoir properties has resulted. Based on the results of the interpretation a seven well development of the reservoir was initiated. Initial drilling has confirmed the validity of the interpretation model.

Poster 14

BOREHOLE IMAGES AND VSPS AS AID TO ATTRIBUTE AND INVERSION ANALYSIS

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Borehole images have inherent information on sedimentary structure and lithofacies that are typically used qualitatively. There are ways of unlocking this potential by doing a comprehensive facies analysis and obtaining quantitative outputs with new applications like neural network or multivariate histogram techniques. However even with these approaches the high-resolution quantitative facies data is still only at the borehole, capturing near-wellbore characteristics which are difficult to translate and propagate into the interwell space. Needed at this critical barrier, is a tool to tie-in high-resolution borehole image and log derived facies with something that will also have a correlation with attributes that characterize the interwell and 3D-space. We test rock-physics attributes like acoustic impedance and Poisson's-ratio and attributes generated from vertical seismic profiles (VSP) as being the likely links between high-resolution near-borehole information and interwell/3D space represented by seismic data.

Borehole seismic data in logs and VSPs capture seismic reflection and rock-physics characteristics at a high-resolution and VSPs have a higher frequency content than 3D seismic. These datasets (rock-physics and VSPs) may have a bearing on the lithofacies contrasts seen at the borehole, at a higher-resolution than 3D seismic. However VSPs and rock-physics approaches are typically underutilized for facies analysis and only used for checkshot time-depth conversions, velocity modeling and as calibration for AVO inversion.

This paper addresses the feasibility in an actual dataset, to correlate and test whether facies driven contrasts from the borehole have any response in rock-physics and VSP data. If this is possible then the propagation of image-derived near core-like high-resolution facies, across domains (quantitatively between geology to geophysics) may be possible. This by way of using the geophysical data as the initial tie-in point with borehole image facies that enables cross-domain collaboration whereby lithofacies information from the borehole can be propagated into 3D seismic, albeit at a coarse scale.

In this case-study on the West Belumut-3 well from Newfield in Peninsular Malaysia, facies analysis was performed using a neural network approach. The inputs were density, neutron, gamma-ray and lamination density (a textural attribute log derived from the FMI) which was trained to estimate the four lithofacies (Figure 1): massive thick-bedded sandstone; sandy heterolithics; shaly heterolithics; and massive shale.

The lithofacies represents a braided channel fluvial system in the lower reaches of the borehole below the K-20 marker. The intermediate interval, between the J-15 and K-20 markers (Middle J and Upper K Group), represent a shallow marine shoreface/sub-tidal bar environment. The upper interval above the J-15 marker (Upper J Group) represents a lower coastal-plain predominantly comprising of tidal flats. This depositional facies trend shows a progressively lower net:gross trend captured in the lithofacies, from bottom to top.

The VSPs inherently have a higher frequency content (around 100-120 Hertz) than the corresponding seismic data. In this case the acoustic impedance and poisson's ratio in association with the migrated zero-phase vsp trace displayed a secular trend that matched very well with the the progressively lower net:gross upsection.

The geological facies derived from log data (GR, TNPH, RHOZ and Lamination Density) can be predicted with high confidence (corr. coeff: 0.80) by combining rock physic properties i.e. acoustic impedance (AI) and poisson's ratio. Cross-plotting of AI versus Poisson's ratio overlaid with color-coded lithofacies reveals well defined facies clusters (Figure 2). The two intermediate classes being heterolithics, has some overlap in attribute space. This suggests that lithofacies as defined in this well, can be predicted from geophysically derived rock physical properties (Figure 3) away from the well via prestack inversion and could be used to map geobodies using a quantitative interpretation scheme.

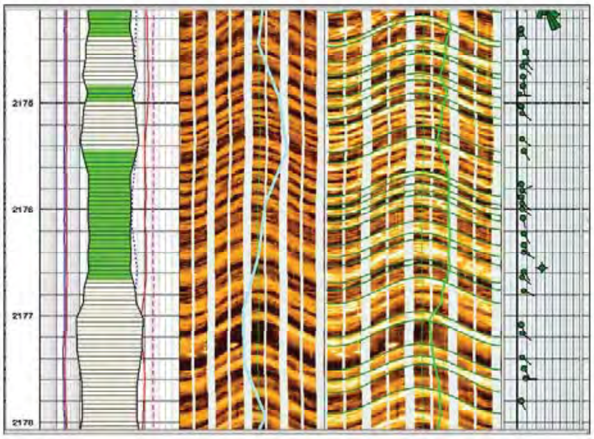

Figure 1: Borehole image with estimated neural-net facies, picked feature tadpoles and logs

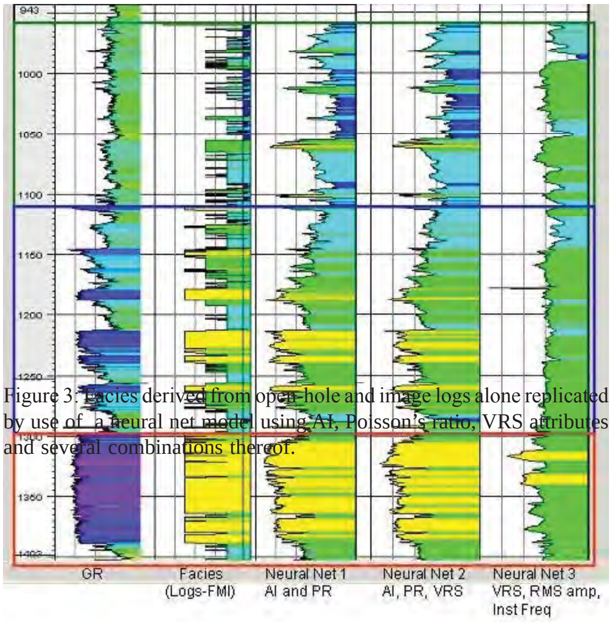

Figure 3: Facies derived from open-hole and image logs alone replicated by use of a neural net model using AI, Poisson's ratio, VRS attributes and several combinations thereof.

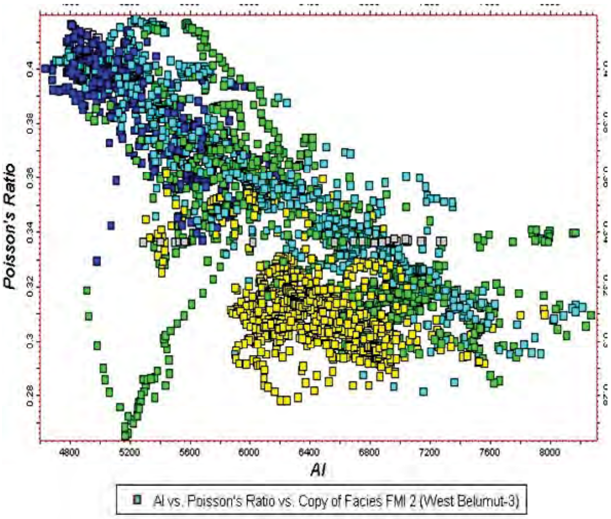

Figure 2: Crossp-plot of AI versus Poisson's ratio overlain by color-coded geological facies

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Poster 16

ICHNOFOSSILS FROM THE TERTIARY SEDIMENTS OF THE WEST CROCKER FORMATION IN KOTA KINABALU AREA, SABAH

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Detailed facies analysis on several well-exposed successions belonging to the West Crocker Formation reveals well-preserved trace fossils, which has not previously described. The ichnofossil assemblage in this area is associated with turbidite deposits, which indicates benthic or deep marine environments. They can be grouped into two different ichnofacies namely Zoophycos and Nereites.

Traces of Zoophycos ichnofacies include Chondrites, Cosmorhaphe, Phycosiphon, Planolites Protopaleodictyon,, Thalassinoides and Zoophycos. Zoophycos ichnofacies appears in all the various types of facies associations. They are common within heterolithic beds of predominantly shale, with minor fine-grained and thin bedded sandstones, and siltstones. These beds are interpreted to be deposited in the levee-interchannel areas that indicate quiet water settings (Nizam et.al 2006, 2007). Some Zoophycos ichnofacies such as Chondrites and Protopaleodictyon are common within the thin muddy sandstone that formed depositional lobes association (Figure 1). Their distribution suggests that there is no specific environmental constraint for Zoophycos ichnofacies.

Due to the broad paleobathymetric range of Zoophycos ichnofacies (Pemberton, 1992) facies-crossing elements by Cosmorhaphe, Thalassinoides, and Zoophycos with Nereites ichnofacies are portrayed in the study area. The widespread distribution of these ichnofossils may be due to the variable food resources, numerous substrate types, and different energy and oxygen levels (Pemberton, 1992; Paolo Monaco, 1995).

Nereites ichnofacies are sub-divided into pre-turbidite and post-turbidite suite. Pre-turbidite ichnofossils includes Helminthoida, Lorenzinia, Nereites, Paleodictyon, Spirodesmos, Spirophycus, Spirohaphe (Figure 2), Urohelminthoida, and Megagrapton. They are also found within heterolithic beds of shale and sandstone/siltstone that formed levee-interchannel association. They represent the quiet environments where the substrate is free from turbidity currents influence (Pemberton, 1992; Paolo Monaco, 1995). Post-turbidites ichnofossils includes Ophiomorpha, Skolitos, and Diplocraterion. They are found within the laminated sandstones in the fining-upward sequences of channel fill association (Figure 3). These ichnofossils represents less stable community and very much influenced by turbidity activities. They may also be derived from shallower environments (Pemberton, 1992; Tchoumatchenco, 2001).

These traces are preserved as complex horizontal grazing traces and patterned feeding/dwelling structures, numerous crawling and/or grazing traces and sinuous faecal casting. These structures are produced by deposit feeders and scavengers, and possible structures associated with trapping or farming microbes within essentially permanent open domiciles. These traces are later filled-in by sediments transported by the low density turbidity currents.

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Figure 1: Characteristics trace fossils of Chondrites-Protopaleodictyon assemblage. (a) Chondrites isp.; resembles meandering and branching style. (b) Protopaleodictyon isp.; less meander, shows branching from the apex of the meander. They are found on bedding plane of thin muddy sandstone in Taman Maju, Sepanggar.

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Figure 2: Pre-turbidite Spirohaphe ichnofossil of Nereites ichnofacies. This spiral-shaped ichnofossil represents crawling or grazing trace is found on bedding planes of heterolothic beds in Taman Warisan, Inanam..

Figure 3: Post-turbidite Ophiomorpha ichnofossil occurs in laminated sandstone of channel-fill succession. It represents vertical burrowing traces in a less stable environment. This spectacular 3-dimensional trace exhibits in Bantayan outcrop, Inanam.

Poster 17

FACIES CHARACTERISTICS AND STRATIFICATION OF DEBRITES WITHIN THE WEST CROCKER FORMATION (EARLY OLIGOCENE TO MIDDLE MIOCENE), KOTA KINABALU, SABAH

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The West Crocker Formation in Sabah has always been referred to as sediments of turbidite systems. However, field observations have revealed the presence of thick sandstone bodies which display distinct facies characteristics such as very thick beds, poor sorting, lack of internal layering and sedimentary structures, randomly distributed mudclasts, loadcasted bases and irregular tops. These features reflect deposition by debris flow; hence, these deposits are debrites.

The debrites of West Crocker Formation show average thickness of around 2.0 m. However, in places, they may reach 38.0 m. They are commonly structureless and may amalgamate to form thick sandstone masses. The amalgamation surfaces are marked by remnant mudstone partings which form load and flame structures at their bases. These debrites can be differentiated into two types: muddy debrites; and massive debrites.

Muddy debrites are relatively thinner than massive debrites. They are fine to medium grained and are poorly sorted. They are internally non-graded. The presence of dispersed mud within this facies gives them a darker colour, which is commonly dark gray. Organic materials and plant fragments are common, and in certain area coal clasts are present. One distinct characteristic of this facies is the great quantity of intraformational rip-up clasts. The clasts are scattered within this facies, and their proportion is high at the upper part of beds. The top surfaces muddy debrites often show great irregularities (Figure 1).

Massive debrite comprises pebbly and/or gravelly medium to coarse grained sandstone, gray to light gray in colour, and poorly sorted. They are normally non-graded, but may show some grading in places. Faint lamination and mud drapes are present within this facies. Massive debrites are always more than 2.0 m thick. Their top surfaces are slightly irregular. Those extremely thick (more than 10.0 m) sandstone bodies are grouped into this facies.

Facies analysis shows the occurrence of debrites in slump and channel facies associations. Debrites in slump association are represented by large blocks of massive debrites floating in muddy matrix, such as at Kingfisher Sulaman outcrop (Nizam et.al 2007). These large blocks may be travel in debris flow and become grounded, even though the rest of the flow continued into the basin. Channel association in the study area contains the two types of debrites. These associations generally show a fining- and thinning-upward trend of 1.0 to 50.0 m of successions (Nizam et.al 2006, 2007) (Figure 2). Massive and thick debrites are common features within channel association throughout the study area (Figure 3).

According to Weimer and Slatt (2004), this kind of thick deposits may be formed by different processes. These includes; a) rapid sedimentation, b) the formation of submarine canyons from retrogressive slides, c) earthquakes, d) deep ocean currents, and e) meteorite impacts. A catastrophic submarine debris flow may carry a huge amount of sediments up to 2300 million kg (Marjanac, 1985), could be deposited in several tens of thousands of km2 in aerial extent, with an enormous thickness (Pickering & Corregidor, 2005; Amy & Talling, 2006).

The occurrences of such thick debrites suggest that these sediments were deposited within the tectonically active areas. This agrees with the fact that deformation, uplift and erosion of the Rajang Fold-Thrust Belt during Oligocene-Early Miocene were linked to the opening of the South China Sea, resulted to the formation of West Crocker sediments.

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Weimer, P., and Slatt, R.M., 2004. Petroleum systems of deepwater settings. Soc. of Exploration Geophysicists, 410p.

Figure 1: Dark gray muddy debrites with high proportion of intraformational mud clasts and irregular top. Bed thickness is 1.0 m. Locality: Bantayan, Inanam.

Figure 2: Thick, massive and structureless debrites show a fining- and thinning-upward of channel-fill association. Locality: Warisan, Inanam. Geologist for scale is 1.6 m height.

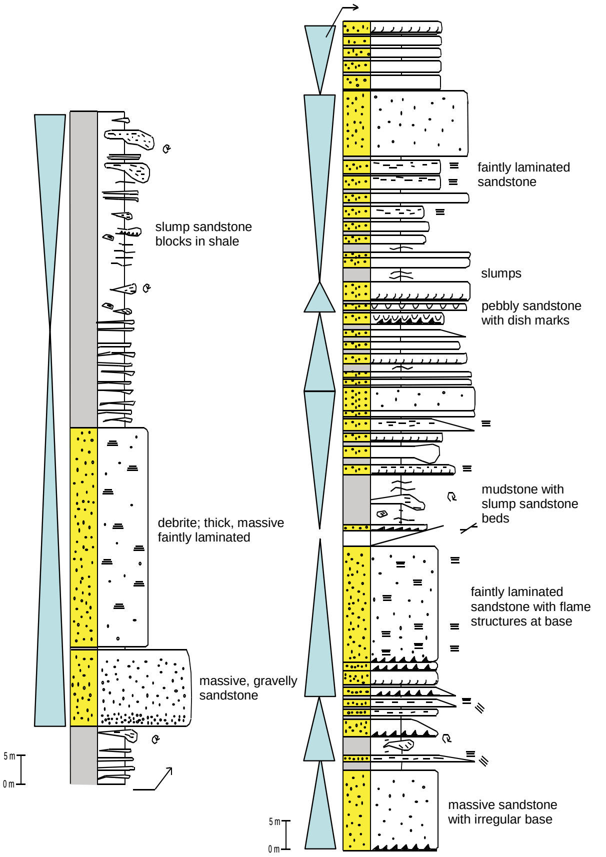

Figure 3: Sedimentary log of Kingfisher Sulaman outcrop shows the occurrences of debrites in the lower to upper succession. Thick massive debrites, representing upper fan to slope channel facies associations, occur in the lower and upper parts.

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Poster 18

SEDIMENTARY FACIES CHARACTERISTICS AND RESERVOIR PROPERTIES OF TERTIARY SANDSTONES IN SABAH AND SARAWAK, EAST MALAYSIA

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Sandstones are very important as reservoirs for oil and gas; more than 50% of the world's petroleum reserve is estimated to occur in sandstones. Depositional environments, and thus facies characteristics, determine the overall reservoir properties of sandstones. The purpose of studying the reservoir sedimentological characteristics and petrophysical properties of Tertiary reservoir quality sandstones from Sabah and Sarawak is to investigate and determine the relationships between sedimentological and facies characteristics, and reservoir properties of the different types of sandstones.

Sandstones from Sandakan Formation (Sandakan, Sabah), Miri Formation (Miri, Sarawak), Nyalau Formation (Bintulu, Sarawak) and West Crocker Formation (Kota Kinabalu, Sabah) were investigated and analysed in this study. The sedimentary sections represent a variety of rock types in terms of depositional facies and ages.

The Sandakan, Miri and Nyalau sandstones exhibit strong depositional facies control on their poro-perm properties. Many previous studies have shown that the reservoir quality (porosity and permeability) of sandstones are strongly influenced by their depositional facies (Scherer, 1987; Ramm, 1999; Sylvia et.al., 2000). The sandstone lenses (gutter casts) from Sandakan recorded the highest poro-perm (Φ :> 20%; k :> 10md), but with very limited lateral and vertical continuity. The HCS and SCS from Sandakan show moderate poro-perm (Φ: ~20%; k: 1-10md) and good lateral continuity. HCS and SCS sandstones from Miri recorded better poro-perm values than TCB sandstones because they are generally better sorted, fine average grain size and lack muddy laminations or drapes. Bioturbated sandstones from Miri are with low porosities due to the poor sorting caused by infiltration of silty or muddy particles. The high density values (d: ~2.3g/cm3) for Nyalau sandstones reflect a higher degree of compaction and cementation than Sandakan and Miri sandstones. The lower porosities of Nyalau sandstones (Φ: ~15%) reflects their burial history/ compaction.

The sandstones of West Crocker Formation show close relationships between diagenesis and poro-perm values, because these sandstones have undergone higher degree of compaction and cementation (geologically much older than Sandakan, Miri and Nyalau Formations). These sandstones recorded high densities (d:2.3-2.8g/cm3), high velocities (v: 4500-7500m/s) and low poro-perm values (Φ: <10%; k: <1md). Many studies have shown that diagenesis tends to accentuate the influence of depositional factors on the reservoir quality of sandstones (Wilson and Stanton, 1994; Nagtegaal, 1979; Weber, 1980). However, diagenesis may also influence reservoir properties in an irregular manner or even reverse depositional controls (Wescott, 1983; Stonecipher et. al., 1984).

HCS sandstones of Miri Formation show high reservoir qualities (Φ :> 20%; k :> 10md) with good lateral extent and uniform thickness (Table 1). The HCS and SCS sandstones of Sandakan show moderate reservoir qualities. They are fine grained, moderately sorted and with occasional mud lamination. The reduced sorting and the presence of mud laminations must have contributed to the slight reduction in reservoir quality. Low poro-perm values, high densities and high velocities Crocker sandstones are tight, non-reservoir quality sandstones because they have been cemented and compacted. Different phases of structural deformation and diagenetic modifications may further complicate the porosity and permeability evolution of these sandstones (Carpenter et al., 2006; Collins et al., 2006).

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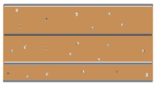
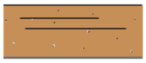
Table 1: Geometry, sandstone facies and reservoir quality of the different sandstones investigated in this study.

Geometry Sketch	Type of sandstone	Formation	Quality of Reservoir
	Gutter cast (Trough cross-bedding)	1.Sandakan	Non-reservoir quality
	Hummocky cross-stratified	1.Sandakan 2.Miri 3.Nyalau	Moderate quality High quality Low quality
	Swaley cross-stratified	1. Sandakan 2. Miri	Moderate quality Scatter?
	Bioturbated	1.Miri	Low-Moderate quality
	Trough cross-bedding	1.Nyalau 2.Miri	Low quality High-moderate quality
	Parallel to massive (Compacted, cemented)	1.Crocker	Non reservoir quality

Poster 19

ANDING UTARA FRACTURED BASEMENT MODELING AN INTEGRATED WORKFLOW FROM SEISMIC-3D STATIC-FRACTURE MODEL

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[1]PETRONAS Carigali Sdn Bhd, PETRONAS Twin Towers, Kuala Lumpur
[2]Schlumberger, Rohas Perkasa, Kuala Lumpur

The Anding Utara Field located in PM 12 Block in production sub-block of Malong-Anding-Sotong within the Angsi-Duyong sub-basin of the South Malay Basin, offshore Peninsular Malaysia in area of water depth approximately 74 m with 4 wells drilled (Figure 1.0). The productive reservoir in Anding Utara Field is a fractured Jurassic Metamorphic Basement High within a pull-apart basin formed by extensional faulting during basin development. It is about 12 km long and 7 km wide.

Correlation indicated that Anding Utara Jurassic Metamorphic Basement underlain by very thick Oligocene shale as a cap rock (Figure 2.0). The 3D fractured modeling was created using by collaborating well log, well tests, seismic attributes and outcrops analogs. The shared knowledge and flexible workflows have been conducted to get the best-fit model, manageable data and easier-way to be re-run.

Dual Porosity and permeability modeling was generated for fracture and matrix properties (Figure 3.0). The fracture properties are divided into 2 major fracture sets; Distance to fault fracture set as representative for tectonic mechanic and bed contained fracture set as representative for stratigraphic mechanic (Figure 4.0). The matrix properties are developed in weathered basement. The matrix becomes the major oil storage, while the open fracture becomes the oil flow conduit.

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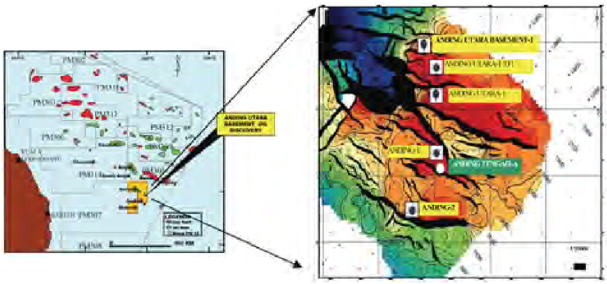

Figure 1: Location Map for Anding Utara.

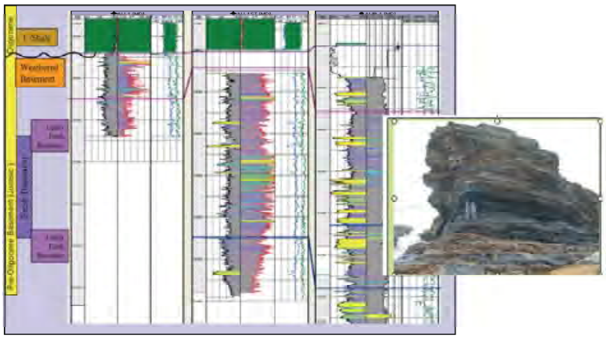

Figure 2: Stratigraphy correlation between Anding Utara-1, AUST-1 and AUB-1 and basement outcrop.

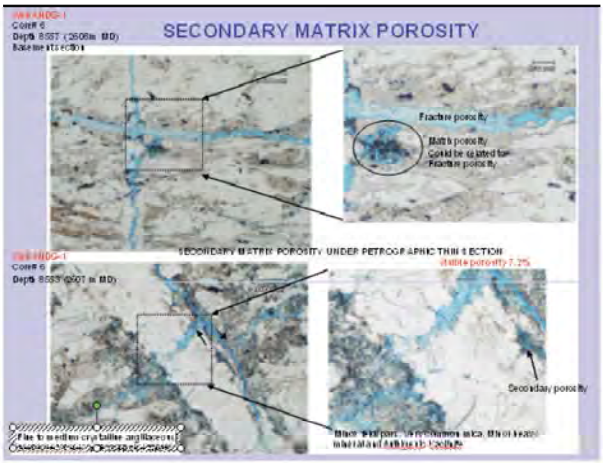

Figure 3: Secondary matrix porosity under thin section.

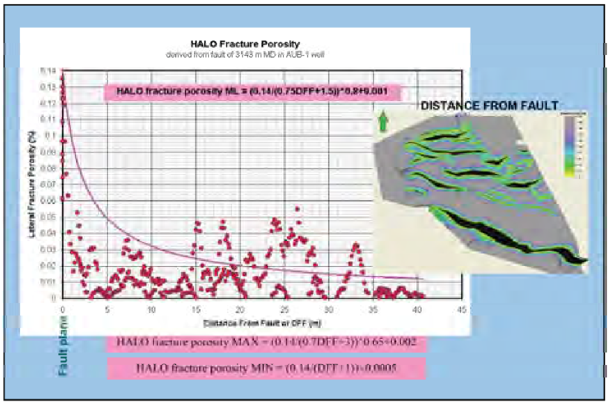

Figure 4: Fault (Halo) fracture porosity model for 3 cases (Max, ML and Min).

Poster 20

STRUCTURAL STYLE AND STRUCTURAL EVOLUTION IN THE HAWKE'S BAY REGION, NEW ZEALAND

Nasaruddin Ahmad

PETRONAS Carigali Sdn Bhd, PETRONAS Twin Towers, Kuala Lumpur

This poster presents the analysis of regional 2D seismic lines across the Hawkes Bay region offshore east coast of the North Island of New Zealand. The study area is located in the outer forearc and contractional domain of the Hikurangi subduction complex. Detailed intrerpretation of long regional 2D seismic lines has indicated that the area underwent rifting in the Cretaceous, thermal sag and subsidence in the Paleogene, followed with contraction and thrusting in the early Miocene, extensional faulting in middle to late Miocene together with continued thrusting and inversion in the Pliocene to Present Day. Within the Neogene section three principal depositional sequences were identified representing growth strata deposited during different deformational phases - a syn-thrusting sequence, a syn-extensional sequence and a syn-inversional growth stratal sequence.

Within the study area three tectono-sedimentary domains were identified based on the difference structural styles and sedimentary architectures. In the north the Raukumara Shelf is characterized by thrust fault-related folds, inverted extensional faults and gravitational sliding structures. In the central domain of Hawkes Bay itself, a series of Present Day active thrust faults occur associated with folds and inverted extensional faults. The southern structural domain, the North Wairarapa Shelf, is characterized by thrust related folds and gravitational sliding structural elements.

Fold amplification characteristics, overall shortening and thrust fault spacings indicate that the shortening rates were relatively higher towards southwest of the study area. The extensional faulting in the Raukumara Shelf may indicate that subduction underplating and gravitational collapse of a supra-critical Coulomb wedge in this region.

Poster 21

CONTROLLED-SOURCE ELECTROMAGNETIC (CSEM): COMPLEMENTING AVO AS PROSPECT QUALIFIER, OFFSHORE SABAH, NW BORNEO

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Amplitude versus Offset (AVO) analysis has been utilised to evaluate potentially hydrocarbon-induced seismic amplitude variation with offset. One major uncertainty is that reservoirs with 10% gas saturation will have similar AVO responses to commercially saturated reservoirs (>60% hydrocarbon saturation). In frontier deepwater areas that lack of well control, an independent, non-seismic method like marine controlled-source electromagnetic (CSEM) survey becomes an important technique to assess the risk of low saturation gas reservoirs.

The CSEM measurement is sensitive to resistivity contrasts, it can potentially differentiate hydrocarbon saturated reservoirs (highly resistive) and the surrounding conductive sediments. Furthermore, it may also be able to discriminate reservoirs with commercial saturation (tens-thousands Ωm resistivity) from those with residual saturation.

Stochastic AVO modelling performed on Prospect X in Offshore Sabah, NW Borneo, indicates the presence of hydrocarbons as well as a chance of having low saturation gas. The CSEM interpretation on the Prospect X, however, reveals a 20-60% electric magnitude increase of the target response over a chosen background, which indicates a hydrocarbon-related resistive body. Further interpretation suggests that significantly thick sand with resistivity of 100Ωm is the most likely cause for the CSEM anomaly; hence, it derisks the possibility of low saturation gas being present in the prospect.

The combined AVO-CSEM interpretation is a compelling prospect qualifier in the Sabah deepwater setting, where (1) drilling an expensive deepwater well is not justified based on amplitude anomaly alone, particularly when gas-charged siltstone and "fizz" gas reservoirs are common, (2) the absence of non-hydrocarbon highly resistive lithologies such as salts, volcanics, and thick limestones avoids misleading resistivity interpretations, (3) the water depth is sufficient to suppress the air-wave effect that might otherwise mask any potential highly resistive anomalies, and (4) the reservoir depth below seabed is suitable for this combined interpretation to be successful in finding commercially saturated hydrocarbon reservoirs.

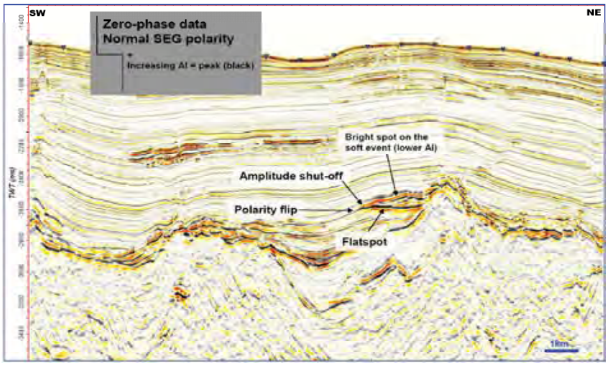

Figure 1: DHI elements of Prospect X on conventional stacked seismic

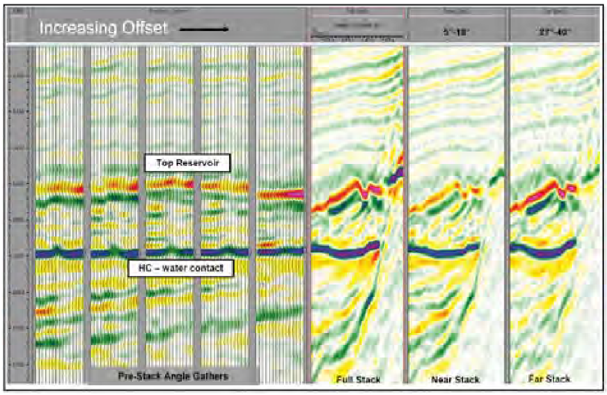

Figure 2: Pre-stack gathers in Prospect X exhibits class III AVO anomaly

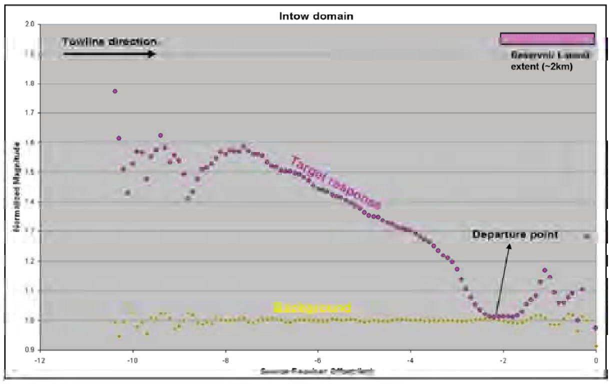

Figure 3: Normalised magnitude plot of Rx06

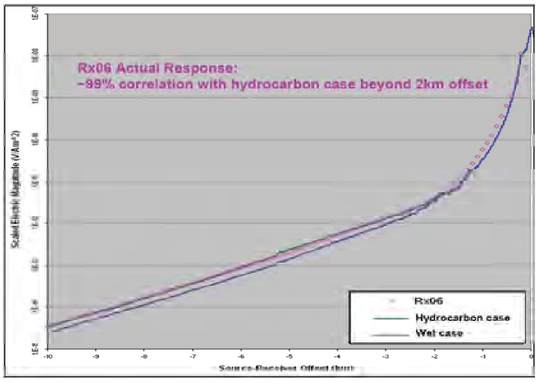

Figure 4: Synthetic curves against Rx06 response

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Poster 22

THE STRUCTURAL AND STRATIGRAPHIC EVOLUTION OF SHALE DETACHMENT SYSTEM IN THE CEDUNA BASIN, AUSTRALIA

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The Ceduna sub basin, part of the Bight basin, covers an area of 95,000 sq. km and is located at the southern margin of the Australian continent. The basin was formed by the Mid-Late Jurassic to Early Cretaceous separation of southern Australia from Antarctica.

Four principal tectono-stratigraphic phase have been identified in the Ceduna Sub-Basin. Mid-Late Jurassic rifting was followed by two phases of post-rift thermal subsidence in the Cretaceous with southern margin breakup occurring in the Late Santonian. From the Late Cretaceous through the Cenozoic the passive margin phase was characterized by progradational sediment deposition from a major delta system – the Ceduna delta. Four episodes of thermal subsidence have been identified and these events are related to a massive sediment influx into the passive margin basin. Two major delta complexes have been identified..

Rapid progradation of Turonian –Santonian and Campanian –Maastrictian deltas on the unconsolidated Albian deep marine shale have produced series of syn –depositional listric faults and shale detachment systems. Two episode of shale detachment systems have been recognized - a Mid Albian and a Late Santonian detachment systems. The Mid Albian event is more widespread than the late Santonian event which only dominated the outer margin of the delta. The Mid-Albian event produced a series of southward dipping listric fault systems which are associated with syn depositional growth sequences and contractional toe- thrust systems.

The Ceduna sub-basin shale detachment systems are characterized listric extensional growth faults and roll–over anticlines. Sediment depocentres are controlled by the syn–depositional fault structures with the initial sedimentation infilling the basin center followed by a shift to the outer delta margin after the basin center has been filled, together with reactivation of the fault along the delta margin. Sediment accumulation in the fault hanging-walls caused the propagation of growth faults, hanging wall rotation and the development of roll–over anticlines. Small scale roll-over anticlines dominate the western part of the study area and large scale anticlines dominate the middle sector of the basin.

Poster 23

INTEGRATED FRACTURE EVALUATION OF A MALAYSIAN BASEMENT WELL DRILLED WITH THE OIL-BASED MUD

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Simon Christian Kurniawan[2], Zairul Asrah Zulkefli[2]

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[2]PETRONAS Carigali Sdn. Bhd.

Hydrocarbons discovered in the naturally fractured basement reservoir around the Malay basin are being explored for additional reserves for the Malaysian oil and gas industry. The fractured basement reservoirs are much more difficult and expensive to evaluate when compared to a conventional reservoir due to its challenging environment. Many new technology tools are target s for such reservoirs. However, the optimized formation evaluation program is required to obtain as much reservoir information to enable an estimation of the most prospective hydrocarbon bearing intervals in this reservoir. This information is essential for field development decision in fractured basement reservoirs.

This paper presents the challenges and results of the formation evaluation program in the fractured basement reservoir in Malaysia. This particular well example is a highly-deviated well drilled with oilbased mud (OBM) as it was believed that the borehole wall failures, formation damage and fracture damage which occurred in previous wells was due to being drilled with a water-based mud (WBM). Current image-based fracture evaluation techniques were developed for water-based mud systems. However, a comparatively limited fracture analysis can still be done with the Dual Oil-base MicroImager (OBMI2) in oil-based muds.

There are inherent limitations that prevent interpreters from performing a full fracture analysis beyond fracture identification, orientation and fracture density quantification in OBMs. OBM makes differentiating between open and closed/healed fractures impossible as both appear as resistive events although one is filled with the OBM and the latter with resistive cement. This in turn prevents the calculation of fracture aperture and fracture porosity. This uncertainty can be fulfilled by combining the borehole image results with dual packer wireline formation tester (WFT), Sonic Scanner reflection imaging and Stoneley data.

The borehole image was crucial in selecting testing zones for the dual packer WFT, and in turn the WFT results were especially helpful in determining whether fractures within a certain zone were open or healed (productive or not). Reservoir parameters and fluid sampling were obtained using the WFT. In addition, the combination of the borehole image and Stoneley was an important factor in reducing uncertainties. The Stoneley fracture analysis is intended to detect open fractures with significant fluid flow in/out of them. Also Borehole Acoustic Reflection Survey imaging delivers highresolution acoustic images around the wellbore to identify sub-seismic inter beds, faults or fractures far beyond the resolution obtained from any seismic surveys. Using a combination of data from all of these disciplines, the uncertainties of fracture analysis in OBM can be lessened and the resulting integrated solution giving significant value to the characterization of complex fractured reservoir.

Poster 24

TRACE FOSSIL OR SOFT SEDIMENT DEFORMATION? AN ENIGMATIC STRUCTURE FROM THE BALINGIAN CYCLE II SEQUENCE, OFFSHORE SARAWAK

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The Early Miocene Cycle II interval in the D35 field contains the principal hydrocarbon bearing reservoirs. The majority of the Cycle II section however comprises a variety of mudstone facies and minor coal horizons. Recent analysis of the sedimentology and ichnology of these rocks has revealed a variety of distinctive trace fossil assemblages that reflect variations in salinity of the water column. As detailed in a parallel poster presentation the predominant facies is interpreted as having been deposited under brackish water conditions with somewhat restricted ichnofaunas reflecting this environmental stress. As well as the readily identified trace fossils that can be assigned to known Ichnogenera, there are structures of unknown origin that, to date, have not been recognized as trace fossils but are not satisfactorily explained by physical processes. The presentation describes these structures and presents the suggestions that have so far been advanced to explain their origin. A physical process involving loading of starved ripples has been put forward, however the viability of this process is unclear. An alternative interpretation is that the structure represents an organic trace reflecting an aspect of animal behaviour previously unrecognised in these sections. Evidence is presented and the reader is encouraged to weigh and debate the options for interpretation.

Poster 25

TRACE FOSSIL ASSEMBLAGES AND PALAEOENVIRONMENTAL RE-EVALUATION OF MIOCENE RESERVOIR INTERVALS, OFFSHORE SARAWAK, MALAYSIA.

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This study integrates ichnology and sedimentology to re-define the palaeoenvironmenal and sequence stratigraphic interpretation of Miocene reservoir intervals in the D35 Field in Offshore Sarawak, Malaysia. The succession has been interpreted previously to reflect predominantly fluvial and lacustrine environments of deposition. Analysis of the trace fossil assemblages throughout the succession strongly suggests, however, that it is exceedingly difficult to reconcile the majority of these units with a fluvial and fresh water interpretation. Instead, the interval reflects a variety of lower coastal plain deposits, most of which were moderately to significantly affected by marine influence.

Sandstone-dominated facies contain ichnological suites that exhibit low to moderate levels of bioturbation, with assemblages consisting of structures indicative of opportunistic feeding behaviors. Stacked or "re-equilibrated" Rosselia (many of which are truncated and are preserved as allochthonous mud clasts Figs 1-2) and large, spiral-form Ophiomorpha irregulare are common. Thin mudstone interbeds and drapes within the sandstone units contain suites of opportunistic trace fossils consisting of Thalassinoides, Chondrites and Planolites.

Mudstone-dominated facies exhibit variable but moderate to low degrees of bioturbation intensity, pronounced variability in ichnogenera distributions, and the predominance of simple forms representing the simple feeding strategies of resilient trophic generalists. Ichnogenera include Planolites, Teichichnus, Thalassinoides, Chondrites, Lingulichnus and Gyrolithes. Intervals that contain higher diversity assemblages, reflecting the periodic establishment of impoverished marine suites, contain more complex structures such as diminutive Zoophycos, Phycosiphon and Siphonichnus.

The trace fossil assemblages in the sandstone- and mudstone-dominated facies represent a variety of stressed expressions of the Cruziana Ichnofacies with less common occurrences of impoverished examples of the Skolithos Ichnofacies and characterize brackish-water environments that experienced periodic, increased levels of marine influence.

Poster 26

APPLICATION OF WALKAWAY VSP FOR IMPROVED SEISMIC IMAGING BENEATH A GAS CLOUD

Gunawan Taslim[1], Amy Mawarni M Yusoff[1] and Teck Kean Lim[2]

[1]PETRONAS Carigali, Kuala Lumpur
[2]Schlumberger Oilfield Services, Kuala Lumpur

The Vertical Seismic Profiling technique (VSP) has been widely used in oil and gas exploration in Malaysia over recent years. During 2007, a well was drilled to access the hydrocarbon prospect within a gas cloud area by Carigali and a walkaway VSP acquired over the area to delineate reservoirs underneath the gas cloud. VSP utilizes the advantage of placing the receivers in the ground that are close to the target reflectors and thus reduce seismic signal attenuation by half of that encountered by conventional surface seismic acquisition. The results show a much clearer image enabling the interpreter to define the top reservoirs which were not possible to track on the surface seismic. Based on these findings, the PCSB team decided to re-evaluate the technical and economic impacts to the initial field development plan (FDP).

Poster 27

TECTONIC EVOLUTION, SEDIMENTATION AND CHRONOSTRATIGRAPHIC CHART OF SABAH, MALAYSIA

Allagu Balaguru

Sabah Exploration Projects, Exploration Division, PETRONAS Carigali Sdn. Bhd.

A stratigraphic chart incorporating all the Tertiary tectonic evolution and sedimentation phases of the Sabah Basins (North Borneo) was constructed based on onshore and offshore exploration data. This chart reflects the most recent interpretations of Sabah stratigraphy and correlations of onshore and offshore areas of Sabah. It includes major lithostratigraphic units and biostratigraphic markers.

The diverse structural trend and depositional framework of Sabah (North Borneo) were contributed by several regional tectonic events occurred since the early Tertiary. At least three major episodes were linked to NW-SE compressions coinciding with the ongoing subduction of the proto-South Chine Sea during the Late Eocene (Sarawak Orogeny), middle Early Miocene (22-20Ma, Sabah Orogeny-BMU) and early Middle Miocene (15.5Ma, MMU/DRU).

The Late Eocene tectonic deformation is characterized by folding and thrusting of basement rock and older paleogene sediments i.e. Rajang-older Crocker fold-thrust belts. The Paleogene regional tectonic setting of Sabah seems to be very complex with southeasterly subduction in the NW Borneo, and extension in the SE in the Celebes Sea and Makassar Strait (Hall 1996, 1997). The Paleogene appears to be a period of continued deposition of deep marine turbidites. The probable Late Eocene regional uplift was suggested by Hutchison (1996) as the Sarawak Orogeny which is related to the collision of the Luconia Continental Block. The palaeontologically dated Upper Eocene unconformity is found only in the onshore Sarawak area (Tatau Horst) between the Tatau and Belaga Formations (Wolfenden 1960, Haile and Ho 1991, Hutchison 1996).

The Early Miocene (BMU, 22-20Ma) deformation is interpreted to mark a major tectonic event, causing formation of the mélanges, major uplift and erosion which produced the Base Miocene Unconformity (BMU). This was followed by a change in depositional environment from deep-water to a shallow deltaic setting (Balaguru 2001, Balaguru et al. 2003, Van Hattam 2005). Patches of limestone (Burdigalian age) formed during this uplift. This tectonic event is related to subduction and collision of the Dangerous Ground Continental Block to the NW Borneo and referred as the 'Sabah Orogeny' (Hutchison 1996). This uplift has particular significance since it provided a nearby and abundant sediment source from the Middle Miocene onwards which explains the tremendous thickness of rapidly deposited Middle to Upper Miocene sediments found in the surrounding basins. This unconformity which should be the real deep regional unconformity is here been referred as pre-DRU (Deep Regional Unconformity) to avoid any confusion.

The Late Early Miocene (~19-20Ma) marked the NW-SE direction of rifting of the Sulu Sea interpreted to have rejuvenated the Central Sabah Basin with regional extension and subsidence, and initiated rift basins as part of the formation of the Sulu Sea in a back arc setting (Balaguru et al. 2003 and 2004, Nichols et al. 1990). The rift basin with coeval onshore extension became depocentre for the Stage III deltaic-shallow marine deposition of the Tanjong Formation in the east and Meligan/Setap Shale Formation in the west of Sabah.

Middle Miocene collision of another arc-continent collision in the northern Borneo between the Cagayan Arc and Palawan micro continental block (Rangin 1991) caused another Middle Miocene Unconformity (MMU, 15.5Ma) has been referred to mark the Deep Regional Unconformity (DRU) in Sabah. This deformation caused inversion of the early Middle Miocene sediments.

The early Late Miocene Kinabalu emplacement plausibly marks the Intermediate Regional Unconformity (IRU, 10.6Ma) in Sabah.

The Late Miocene (SRU, 8.6Ma) tectonic event marks another major folding and uplift which can be correlated as the Shallow Regional Unconformity (SRU) of this region (Bol and Van Hoorn 1980, Levell 1987). This latest phase of major tectonic event most probably caused by NW-SE trending strike-slip faulting and transpressional fault movement in this region (Balaguru et al. 2003). Continuous transpressional movement resulted in major structural inversion and uplift most of the southern and eastern parts of Sabah where the Miocene strata now are exposed onland with a highest point at 1500 m (Gunung Lotung) above the sea level. This event is here termed the Meliau Orogeny (Balaguru 2001).

The transpressional movement along the major strike-slip faults in this region would better explain the structural development in these areas. It probably continued during the Late Pliocene and another unconformity can be picked at 5.5Ma, and is possibly related to propagation of deformation from Sulawesi towards NW Sabah. The Late Pliocene strike-slip deformation is regionally significant and occurred at similar time as important deformation in NE Kalimantan, Sulawesi and NW Sabah. This transpressional movement is interpreted to be the cause of the major orogenic deformation, uplift and final structural development in Sabah region and possibly continued to the present day.

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Poster 28

A COMPARISON OF GEOCHEMICAL AND PETROGRAPHIC FEATURES OF OIL PRONE COALS FROM THE BALINGIAN PROVINCE WITH THOSE OF THE MALAY BASIN, MALAYSIA

PETER ABOLINS[1] AND WAN HASIAH ABDULLAH[2]

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The role of coal as a source for oil continues to be debated in geochemical circles. This paper attempts to present the case for Malaysian Tertiary aged coals as a source rock for oil, as well as for gas.

The Malay Basin of offshore Peninsular Malaysia and the Balingian Province of offshore Sarawak, are petroliferous Tertiary basins. Both basins are known to contain coal-bearing sequences of Lower Miocene age (Group I in the Malay Basin; Cycle II in the Balingian Province.)

This paper compares and contrasts the respective geochemical and petrographic characteristics of the Balingian and Malay Basin coals with the purpose of assessing their oil generating capability and their source facies.

The oil-prone nature of these coals can be envisaged visually under reflected light microscope, in particular using fluorescence mode visualization, and by evaluating their chemical composition in terms of hydrocarbon content. Based on the current investigation, it is most apparent that both sets of coals possess many similar oil-generative features, such as the extensive development of exsudatinite crack network, common occurrence of oil haze, significant occurrence of oil-prone liptinite macerals e.g. suberinite, including its derivatives, and show some common biomarker distributions. The use of biomarker distributions as an aid to correlating the coals to the oils of the respective basins is also demonstrated. Combined use of biomarker assemblages, calibrated with biostratigraphic data, helps constrain the source facies of produced oils.

The application of detailed maceral analysis is described and is shown to be able to categorise the coal depositional settings of these basins into diferent sub environments.

CERAMAH TEKNIK TECHNICAL TALK

GSM Chairman's Lecture No. 12
On Limestone Hills, Rockfalls and the Developers

TAN BOON KONG

25 January 2008,
Geology Department, University of Malaya

REPORT

The 12th GSM Chairman's Lecture was given by the Mr. Tan Boon Kong, the Chairman of the Working Group on Engineering Geology and Hydrogeology to an audience of about 15 people at the Department of Geology, University of Malaya.

In his talk, Mr. Tan gave an overview on the potential geohazards related to development near limestone hills and a brief review on the past and current guidelines related to development of such sites. The talk has generated heated discussion, especially on the implication of current guideline on proposed developments around limestone hills.

Ng Tham Fatt

Abstract — Limestone hills provide scenic or picturesque settings. However, hidden amongst these limestone hills are potential geohazards in the form of rockfalls. Therein lies the dilemma faced by the submitting engineer for the developer who might want to carry out development projects in areas close to or in the vicinity of limestone hills.

Guidelines have been drawn up by the Department of Minerals and Geoscience Malaysia (JMG) with respect to the various buffer zones around limestone cliffs vis-à-vis construction within these buffer zones. For example, JMG stipulates a safety buffer zone of 2 x "cliff height" within which buildings would not be allowed. This requirement results in loss of large tracts of land around limestone hills for development and is an economic loss to developers and authorities alike.

The speaker presented his proposed detailed assessment of individual cliff stability incorporating mapping of geological structures and solution features as a realistic and practical approach to the problem of developing in the buffer zones. This approach ranks individual limestone cliff with respect to degree of hazard by considering the cliff profile, all geological structures and solution features encountered at each cliff, Tan (1998). These data and analysis are important for the submitting engineer to consider and assess the associated geotechnical risks of developing within the buffer zones.

Some local case studies from the Kinta Valley area in Ipoh and the Klang Valley area in Batu Caves are provided as illustrations.

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CERAMAH TEKNIK TECHNICAL TALK

Estimating Remaining Oil Saturations (ROS): Methodologies & Challenges

MOHAMED R. SALEH EFNIK

25 January 2008,
Geology Department, University of Malaya

A technical talk entitled Estimating Remaining Oil Saturations (ROS): Methodologies & Challenges had been presented by Mr. Mohamed R. Saleh Efnik, Senior Petrophysicist, Research Development Division Abu Dhabi Company for Onshore Oil Operation (ADCO). Mr Mohamed experience includes working as Development Geologist, Wellsite Geologist, Petrophysicists, Senior Log Analyst and Lead Petrophysicist

The talk was presented on the 29th Jan 2008 at Gelolgy Lecture Hall, University Malaya. The attendance to the presentation was good. The talk starts with the speaker defining ROS then describe the different methodologies available to extract the remaining oil. These was then followed on problems and difficulties face particularly on estimating and getting the remaining oil from limestone.

Samsudin Hj. Taib

CERAMAH TEKNIK TECHNICAL TALK

Trace element analysis by laser ablation ICP-MS and its application to tephrochronology

NICK PEARCE

Senior Lecturer in Geochemistry, Institute of Geography and Earth Sciences,
Aberystwyth University, Aberystwyth, Wales, UK SY23 3DB

31 January 2008
Department of Geology, University of Malaya

Abstract — Tephra deposits are widely used in correlation and provenance studies, which often rely on accurate chemical analyses of material from the deposit. Many large magnitude eruptions are broadly rhyolitic, and major element analyses of glass shards by EPMA may not identify these unequivocally. Trace element analyses of the juvenile glass component can help to distinguish or correlate individual deposits, although preparation of sufficient material for bulk analysis from distal deposits may be difficult. ICP-MS, a highly sensitive trace element analytical technique which requires only small amounts of sample, offers possibilities for the analysis of distal tephra deposits by either solution digestion methods (around 25mg of sample) or by laser ablation analysis of individual (around 40 microns) grains of material.

Solution ICP-MS analysis of glass separates weighing as little as 0.025g, and digested in $HF/HClO_4$ are accurate (typically better than +/-5%) with precisions (1 s.d.) of about +/- 3% for most trace elements, although this deteriorates to about +/-20% for rare elements in small samples (e.g. HREE in a 25 mg sample). Some examples of solution ICP-MS analyses of glass will be presented to illustrate both the application and some of the problems of bulk analysis.

Laser ablation (LA) ICP-MS has been used to determine the trace element composition of very small volumes of bulk glass, and also of individual glass shards from tephra deposits. Here a powerful UV laser vapourises the sample, and use of an internal standard (usually 29Si) accounts for variations in the volume of ablated material and calibrates the analyses. For single shard analyses, the EPMA mount is used and the same grains are analysed for their trace element content. Despite spatial resolutions around 5µm, at present reliable trace element data can be produced from shards about 40 microns across, with 30 elements determined in a 45 s analysis. Laser ablation methods are less accurate (around +/-5-10%) than solution ICP-MS analyses, and precision decreases from around +/- 3% at a few hundred ppm (e.g. Zr, Rb, Sr) to about +/-10% at 1 ppm, and about +/-30% at 0.05 ppm (e.g. HREE). Detection limits vary with tuning and operating conditions, but are typically around 0.5-0.05 ppm. Recent improvements in both ICP-MS and laser instrumentation enable smaller shards to be analysed, and the potential for this will be discussed. Whilst unlikely ever to challenge ion probes for spatial resolution, material from cryptotephras and ice cores is coming into the size range possible for analysis using newer ICP-MS and laser instrumentation, although issues such as the quality of the mounting resin become very important. A series of examples of the application of both LA-ICP-MS data to tephra studies from North America, Santorini and New Zealand will be presented to illustrate the potential of this powerful analytical technique.

CERAMAH TEKNIK TECHNICAL TALK

Retirement Lecture No.2

The Seismic and Tsunami Hazards and Risks Study in Malaysia

P. LOGANATHAN

20 February 2008
Department of Geology, University of Malaya

REPORT

Sdr. Loganathan, formerly of Minerals & Geoscience Department (JMG), gave the second Geological Society of Malaysia Retirement Lecture entitled: "The seismic and tsunami hazards and risks study in Malaysia" on 20th Feb. 2008 at the Department of Geology, University Malaya, Kuala Lumpur.

This study was initiated soon after the infamous 26 December 2004 Sumatra earthquake and tsunami event. The study was undertaken jointly by several local universities and government agencies, including JMG and Akademi Sains Malaysia. The scope of the study was rather wide and multi-faceted, including tectonics, earthquake/tsunami hazards and risks, marine and coastal studies, impacts on aquaculture, engineering of infrastructures and highrise buildings, etc.

Some lively discussions and interesting remarks followed the presentation.

Tan Boon Kong,
Chairman W/G on Engineering Geology & Hydrogeology

Abstract — The Academy of Sciences Malaysia was appointed on 13th December 2005 with the signing of an agreement with the Malaysian Meteorological Department representing the Government of Malaysia, to be the lead organization in the "Seismic and Tsunami Hazards and Risk Study in Malaysia". The Academy was to manage and coordinate the implementation of the two-year Study. The participating organisations are the Minerals and Geoscience Department Malaysia (MGDM), Malaysian Meteorological Department (MMD), Putra University of Malaysia (UPM), Science University of Malaysia (USM) and the Technological University of Malaysia (UTM) and an individual, Mr. Leyu Chong Hua.

The objectives of the Seismic and Tsunami Hazards and Risks Study in Malaysia are as follows:

(i) To assess the seismicity in Malaysia;
(ii) To evaluate the seismic risk in and tsunami risk towards Malaysia;
(iii) To develop macrozonation map of Malaysia;
(iv) To develop microzonation maps for several major cities in Malaysia;
(v) To assess and review the adequacy of existing monitoring/data collection system and need for any improvement;
(vi) To assess the need for seismic factors in planning and design of major structures in Malaysia involving ground acceleration map and design response spectrum; and
(vii) To identify areas in Malaysia vulnerable to earthquakes and tsunamis.

The Study is to be completed by end September 2008. Among the deliverables of the study are:

(i) Seismotectonic Map of Malaysia
(ii) Macroseismic (Observed Intensity) Map of Malaysia
(iii) Macrozonation map of Malaysia, and
(iv) Microzonation Maps of selected cities of Malaysia.

CERAMAH TEKNIK TECHNICAL TALK

Transverse Segmentation of the Baram Basin and Northern Borneo: An Alternate Model for Oligo-Miocene Subduction

ANDREW B. CULLEN

21 February 2008
Geology Lecture Hall, University of Malaya
(in collaboration with Department of Geology, University of Malaya and UM AAPG Student Chapter)

REPORT

On Thursday 21 February 2008, the Department of Geology welcomed a visit by Dr Andrew Cullen, AAPG Regional Lecturer. Andrew currently works in the Global New Ventures Team for SIEP in Rijswijk, The Netherlands. He has over 20 years experience in the oil and gas business, including 16 years with Shell in roles ranging from production seismology to frontier exploration. In addition to his experiences as a petroleum geologist, Andrew has also worked as a gold prospector, asbestos petrographer, and industrial minerals geologist. His present research focuses on the geological history of Borneo and includes regional tectonics, the palaeogeography of the Crocker fan, palaeomagnetism of the Nyalau Formation, and the petrogenesis of the Usun Apau Volcanics. Andrew is a member of the Geological Society of America and the American Association of Petroleum Geologists. He has served an advisory board College of Geosciences for the University of Oklahoma and currently serves on AAPG's Grants-In-Aid Committee.

In the morning, Andrew gave a lecture on "The Kinabalu Fault and Its Influence of the Distribution of Hydrocarbons in the Greater Kinabalu Field, Sabah, Malaysia" to about 60 undergraduate and post-graduate students of the Department of Geology. In the evening, Andrew gave a thought-provoking and interesting lecture on "Transverse segmentation of the Baram basin and northern Borneo: an alternative model for Oilgo-Miocene subduction" to about 40 students and geoscientists, including some from the oil and gas industry. Andrew offered an alternative model to the tectonic evolution of NW Borneo, challenging the more widely-accepted model of the rifting, drifting and subduction of the South China Sea beneath Borneo. His model showed a series of NW-SE trending transverse zones cutting across Borneo. The talk was followed by active and, at times, rather heated arguments and discussions. The abstract of the talk is given below.

Abstract — The West Baram Line separates the two petroleum systems of NW Borneo. Oligocene sandstone and Early Miocene carbonate reservoirs of the gas-prone Luconia system lie to the SW. This talk examines the oil-rich Baram Basin to the NE, which produces from Middle Miocene to Early Pliocene sandstones. Extensional and inversion structures dominate the shelf where exploration activities spans nearly four decades. Recent discoveries prove this petroleum system extends into deepwater where an active fold-thrust belt has formed above a "lower plate" of attenuated continental crust. New regional structural mapping (~100,000 km2) integrating seismic and well data shows the Baram Basin is segmented into 4 structural domains whose boundaries trend NW-SE similar to the West Baram Line. The basin's largest fields lie on or near domain boundaries indicating they exert fundamental control on the petroleum system. Two domain boundaries project across Borneo as broad zones that correlate with contrasting elements of the onshore geology. When these observations are examined in light of gravity, tomographic, and GPS data, current models for the region's tectonic evolution are called into question. In these models, collision of the Dangerous Grounds following Eocene to Early Miocene SE-directed subduction under NW Borneo drives the Sabah Orogeny. An alternative model is proposed. In this model northern Borneo is largely underlain by attenuated crust, Oligo-Miocene subduction is minimal, and the Sabah Orogeny reflects initiation of NW-directed subduction beneath the Semporna-Dent Peninsula. In this context the Baram Basin is a retro arc foreland basin underlain by a mosaic of deep crustal blocks that partition deformation driven by far-field tectonic stress.

CERAMAH TEKNIK TECHNICAL TALK

AAPG VISITING GEOSCIENTIST TALKS

PETER LLOYD

The Quest for Energy

26 February 2008
Geology Lecture Hall, University of Malaya
(in collaboration with Department of Geology, University of Malaya and UM AAPG Student Chapter)

Chasing Channel Sands in SE Asia

28 February 2008
Geology Lecture Hall, University of Malaya
(in collaboration with Department of Geology, University of Malaya and UM AAPG Student Chapter)

REPORT

Mr Peter Lloyd, AAPG Visiting Geoscientist, gave two talks to students and members of the GSM on Tuesday 26 February and Thursday 28 February 2008.

Peter spent more than 30 years working as a geoscientist with BP, Deminex and Schlumberger in Europe, North and South America, the Middle East and Far East, and is very active in professional organisations and their activities. Although he is happily retired in France, he keeps busy as a Tutor and Honorary Lecturer for Heriot Watt's Master Programme in Petroleum Engineering, and gives courses in various parts of the world.

On Tuesday 26 February, some 30 students and academic staff attended the talk on The Quest for Energy. The talk was followed by some 20 minutes of Q&A covering oil prices, factors affecting oil prices, environment, etc.

On Thursday 28 February, Peter gave his talk on Chasing Channel Sands in SE Asia to some 60 students, academic staff and geoscientists from the oil and gas industry. The discussion after the talk covered not just chasing channel sands, but also field development, appraisal of discovery, and how to join AAPG as a student member and how to set up a Student Chapter.

The abstracts of the two talks are given below.

The Quest for Energy

Abstract — This comprehensive introductory treatment of the Oil & Gas industry starts off by looking at world energy needs, worldwide oil and gas reserves and the challenging careers that are offered as those reserves are found and developed. The importance of technology advances is highlighted.

Different inter-related disciplines in the oil and gas industry will be discussed; geophysics, stratigraphy, sedimentology, geochemistry, petrophysics and reservoir engineering. The importance of data integration will be highlighted.

Petroleum Systems will then be examined with a discussion of source rocks, reservoirs, seals and traps as well as the processes of oil and gas generation, migration and entrapment. The drilling and production of hydrocarbon accumulations will also be presented.

The presentation concludes with a review of the importance of professional society involvement in ones career.

Chasing Channel Sands in SE Asia

Abstract — With technical advances in surface seismic and downhole electrical imaging techniques, it is now possible to not only map the distribution of reservoir sandstones in the subsurface, but to accurately define the orientation of productive fairways, or "sweet-spots", within the sequence.

Channel sands frequently have favourable reservoir characteristics. Having often been laid down in higher energy settings, they commonly have coarser and better sorted grains, less clay and improved poroperm characteristics. However, they often have limited lateral extent and shoe-string geometries which make them more difficult to predict in the subsurface.

This paper will summarize the results of four case studies and some additional examples of how channel sands, laid down in different depositional settings, have been recognised with borehole imaging. From sedimentary features and palaeocurrent directions within the sands it has been possible to determine their orientation.

Further complexities in reservoir characterization, caused by thin beds or bioturbation; and how these effects can be recognized on the images, and quantified using other electric log data, will be discussed.

A sound understanding of the depositional model and the integration of all the available data (outcrop studies, seismic attributes, cores, logs and downhole imagery) allows channel sands to be identified in a wide range of environments. The ability to orient the channels and so map them in the subsurface provides the basis for reducing risk and optimizing the success ratio of both appraisal and development wells. Because of their potential as stratigraphic traps and production fairways, they offer good prospects for increasing recoverable reserves.

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NEWS OF THE SOCIETY

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ANNOUNCEMENT

Eleventh Regional Congress on Geology, Mineral and Energy Resources of Southeast Asia

Kuala Lumpur, Malaysia • 1 – 3 June 2009

GEOSEA XI
Kuala Lumpur

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GEOSEA XI

The Geological Society of Malaysia is organising the GEOSEA XI in Kuala Lumpur from 1st to 3rd of June 2009 to mark the closing of the United Nations International Year of Planet Earth, 2007-2009. The GEOSEA Congress will be held parallel to the Petroleum Geology Conference and Exhibition 2009, a premier Oil and Gas event of Southeast Asia. The Congress offers an excellent opportunity to exchange scientific and technical information and advancement in geoscience, mineral and energy resources among geoscientists. The GEOSEA Congress is a premier geoscientific event in the region and has been well attended by the geoscientific community world-wide.

The technical program of GEOSEA XI consists of oral and poster presentations on geoscience and related aspects of the GEOSEA core region of Southeast Asia as well as East Asia. Papers covering the 10 themes of the International Year are welcome. For more information on the themes please check www.yearofplanetearth.org or contact the GEOSEA XI secretariat.

Other related activities include pre- and post-conference workshops, short courses and geological fieldtrips. Social events and tours for delegates are also planned.

National collaborators of GEOSEA XI are the Minerals and Geoscience Department Malaysia, Universiti Kebangsaan Malaysia, University of Malaya and PETRONAS. Regional collaborators from the GEOSEA core region have also been invited.

Make a note in your diary and join us in Kuala Lumpur for GEOSEA XI.

For further information and to receive a copy of the GEOSEA XI circular please contact:

The Organising Committee, GEOSEA XI
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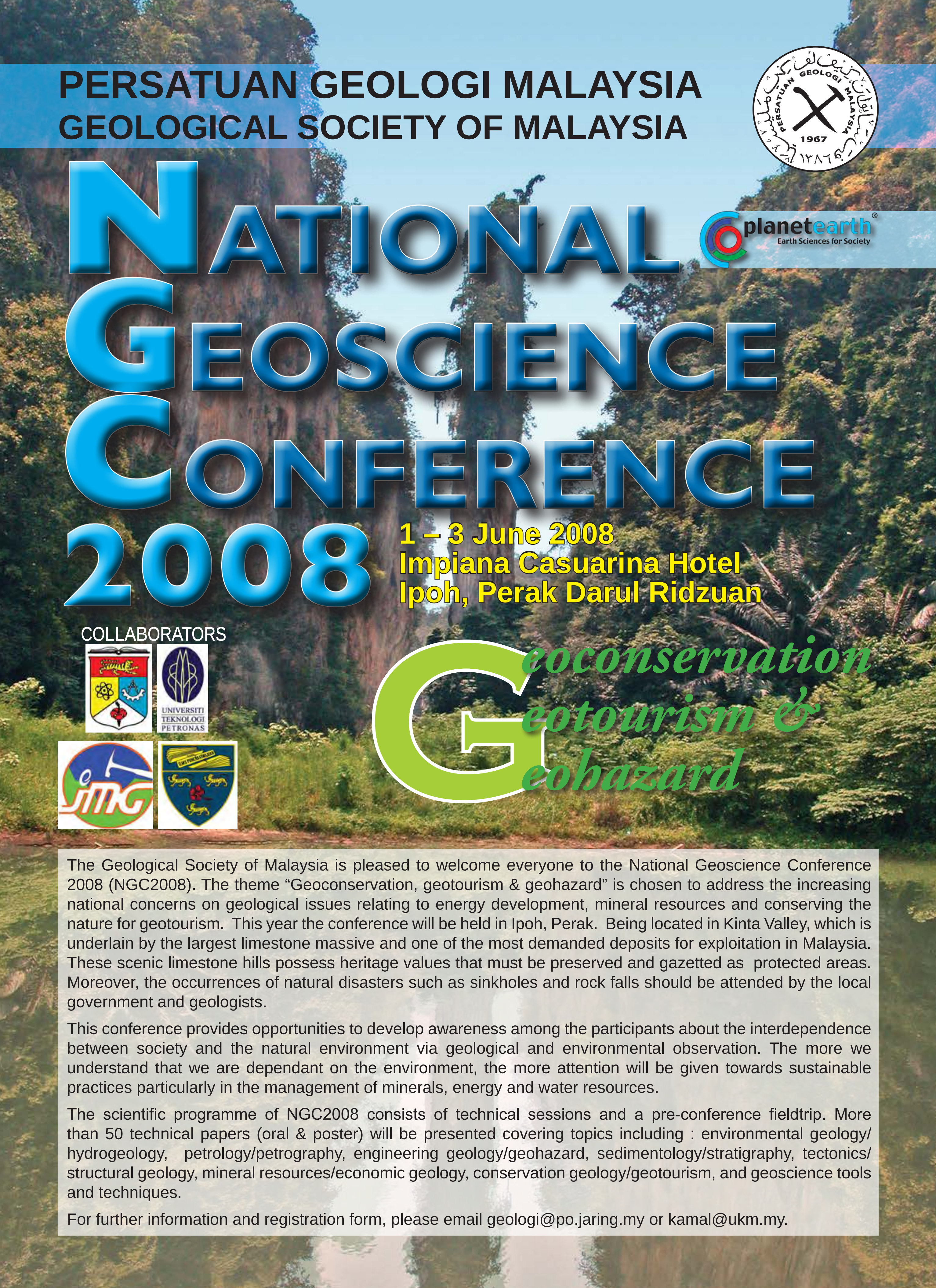

PERSATUAN GEOLOGI MALAYSIA
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Geoconservation Geotourism & Geohazard

The Geological Society of Malaysia is pleased to welcome everyone to the National Geoscience Conference 2008 (NGC2008). The theme “Geoconservation, geotourism & geohazard” is chosen to address the increasing national concerns on geological issues relating to energy development, mineral resources and conserving the nature for geotourism. This year the conference will be held in Ipoh, Perak. Being located in Kinta Valley, which is underlain by the largest limestone massive and one of the most demanded deposits for exploitation in Malaysia. These scenic limestone hills possess heritage values that must be preserved and gazetted as protected areas. Moreover, the occurrences of natural disasters such as sinkholes and rock falls should be attended by the local government and geologists.

This conference provides opportunities to develop awareness among the participants about the interdependence between society and the natural environment via geological and environmental observation. The more we understand that we are dependant on the environment, the more attention will be given towards sustainable practices particularly in the management of minerals, energy and water resources.

The scientific programme of NGC2008 consists of technical sessions and a pre-conference fieldtrip. More than 50 technical papers (oral & poster) will be presented covering topics including : environmental geology/hydrogeology, petrology/petrography, engineering geology/geohazard, sedimentology/stratigraphy, tectonics/structural geology, mineral resources/economic geology, conservation geology/geotourism, and geoscience tools and techniques.

For further information and registration form, please email geologi@po.jaring.my or kamal@ukm.my.

BERITA-BERITA LAIN
OTHER NEWS

GEOINTRO 2008: A GLIMPSE OF GEOLOGY

23 February 2008
Department of Geology, University of Malaya

REPORT

GeoIntro 2008: A Glimpse of Geology was organized by the members of American Association of Petroleum Geologists (AAPG) Student Chapter University of Malaya and generously sponsored by Murphy Oil Corporation, Schlumberger and Shell. The objective of the event was to promote geology to Matriculation and Form 6 students. Through this event, we hope to raise these students' awareness on geology and cultivate their interest in this field, as well as expose them to this course in which they can pursue their further studies in the near future.

The event was held successfully on 23 February 2008 from 9.00am till 4.30pm and was attended by about 80 students from University Malaya Matriculation Centre, SMK La Salle and SMK Bukit Bintang.

AAPG Advisor, Prof. Denis N.K Tan started off the event by giving a very inspiring opening speech. He gave a brief introduction on the AAPG Student Chapter University of Malaya. In his speech, he pointed out that generally students nowadays are not familiar with geology and therefore he hoped that GeoIntro 2008 will influence more students to take up geology. According to him, geology is full of adventures and it is a lifelong learning process. Besides that, he also added that, to fully benefit from the event, participants should take this opportunity to ask questions regarding studies and career prospects in geology as there is a high demand in oil and gas and mining geologist within these 5-10 years.

Next, Pebrina Puspa Sari, the Organizing Committee Director gave a short speech about GeoIntro 2008 and its objectives. She explained that the objectives of GeoIntro is reflected in the tagline, A Glimpse of Geology, which is to briefly expose students to the interesting world of geology and to give them an idea on what geology is all about. She urged the participants to grab this opportunity to learn and gain as much knowledge as possible.

The first talk of the event was given by Geology Department of University Malaya Senior Lecturer, Dr. Nuraiteng Tee Abdullah. She started off by sharing her study background and a brief introduction on geology. She also touched on the various fields related to geology such as geophysics, sedimentology, structural geology, paleontology, environmental geology etc. Apart from that, she also introduced the course structure for Bsc in Geology and Applied Geology. She ended her talk by sharing the interesting history of the Geology Department which started in 1955 in Singapore, to the present one in Kuala Lumpur, University Malaya.

Following that, Mr Muzli Hussain, a Senior Manager of Exploration with Petronas, took his turn to talk on the career prospects of geology undergraduates in Petronas and the work responsibilities and working life of a geologist. He also introduced the background of Petronas as a national oil and gas company as well as touched on Petronas as a business entity and a petroleum producer. According to Mr. Muzli, Petronas plays a good role in contributing to the well-being of the nation and its people.

The next speaker was Mr. Govan Gangatharan, a Production Geologist with Shell. His talk revolves around his interesting work experience in Shell. He started his talk by sharing about his days as a geology undergraduate in the Geology Department of University Malaya right up to his working experience in Shell. He also mentioned about Shell training programs, the benefits of working in Shell and the working environment in Shell, which includes lots of traveling to beautiful destinations, and has captured the attention of the participants. In his talk, he also urged students to take up geology as it offers a very rewarding career.

For the Student Sharing Session, Ong Hock Kim, the Geology Department student representative and President of American Association of Petroleum Geologists (AAPG) Student Chapter University of Malaya, presented a very lively and interactive session. The presentation was more informal in nature so as to encourage the students to interact and take part in the presentation. He included short video clips in his presentation and shared his experience as a geology undergraduate so far. He also presented on fieldwork and the facilities and study environment in Geology Department. During this session, the students interacted by asking lots of questions.

After the Student Sharing Session, a movie titled "Living Rock" was played. The movie showed the various types of rocks and phenomenon that makes up the Earth. The movie provided an enlightening visual stimulation to the students and it made them better understand the whole concept of geology.

Last but not least was the speaker from Jabatan Mineral & Geosains Malaysia (Mineral & Geoscience Department), Tuan Hj Zainol b. Husin. The focus of his talk was career prospects other than in the oil and gas industry. He mentioned careers in the Mineral & Geoscience Department which will need geologists in the near future. He also talked about the work scope of a geologist and his own experience as geologist after he joined the Minerals & Geosciences Department.

After all the talks by various speakers were delivered, the students proceeded with the Tour and Exhibition Session. During this session, students were guided on a tour of the Geology Department and were brought to the exhibition halls. There were 4 exhibition halls set up for this purpose. One was in the Main Hall of the department where Petronas displayed posters on the career prospects and introduction to Geology. Another exhibition hall is set up in the Mineralogy and Petrology Lab which displayed the various hand specimens such as rocks, minerals and fossils. The next exhibition hall is in the Paleontology and Stratigraphy Lab which displayed microscopic specimens and incorporated the use of microscopes. The Mineralogy Lab is turned into another exhibition hall which displayed fieldwork gears and a mini presentation on geology fieldwork. Throughout this session, the students were given brief explanations on the displayed objects and they were encouraged to touch and play with those objects to satisfy their curiosity. This session is more like a fun and interactive session between the student participants and the geology undergraduates to encourage communication between them. The session aimed to provide a thorough understanding about geology by displaying and explaining geologically related objects. This also provided the students with a hands-on experience in geology course.

GeoIntro 2008 ended at 4.30pm after a group photo-taking session.

As a conclusion, GeoIntro 2008 managed to deliver its objectives of exposing the Matriculation and Form 6 students to geology and instill their awareness and interest in this field. The students left not only with GeoIntro 2008 t-shirts but also with a whole new understanding and knowledge in geology, which we hope will benefit them and encourage them to take up geology as their course of choice in the future. We would like to thank all our sponsors; Murphy Oil Corporation, Schlumberger and Shell for their generous support to this event. We also extend our gratitude to PETRONAS and JMG for their participation and assistance.

Wong Yien Lim
Organizing Committee Secretary

ORBITUARY

Dr. Chu Ling Hing

1948 – 2008

The untimely demise of Dr Chu Ling Heng, former Director General of the Department of Minerals and Geoscience, Malaysia, after a sudden illness while on vacation in Beijing, China, has come as a shock to the geoscience fraternity.

Dr Chu is best remembered for his role in the successful merger of the Geological Survey Department Malaysia and the Mines Department Malaysia into the Minerals and Geoscience Department of which he was the second Director General.

Born in Kota Bharu Kelantan, he had his early education in Kelantan and went on to earn a B. Sc. Hons (Geology) in 1972. He joined the then Geological Survey Department Malaysia upon graduation and during his 31 years in service carved out an illustrious career culminating in his appointment as Director General of the Minerals and Geoscience Department. During this period the ever-hardworking Dr Chu managed to work on and obtained an M. Sc. from the University of Malaya (MU) and a Ph. D. from the National University of Malaysia (UKM). Those who have worked with him know that he was a cooperative subordinate, helpful colleague and an approachable and caring boss.

Dr Chu has an excellent knowledge of geoscience and tirelessly promoted it through presentation of technical papers and participation at conferences, excursions and fieldtrips. His participation in geoscience activities locally and overseas has won him many friends and admiration all over the world. He was an active Member of the Institute of Geology Malaysia, serving as its President until his retirement from the MGDM. As the DG of MGDM, he played a vital role in the preparation of the Geologists Bill.

Upon his retirement in 2004, Dr Chu was appointed as a member in the Elections Commission of Malaysia and remained as a member until his untimely death.

Socially, the ever affable Dr Chu loved his pint and a karoke session and is always a pleasure to have in any party. He has been a great friend to many and saying no to friends who needed help was never in his vocabulary. All of us who knew him well have lost a great friend and colleague.

Dr Chu is survived by his wife, Madam Song Sai Kow, sons Chu Voon Fui and Chu Yoon Fui, a daughter-in-law and daughter Chu Sook Peng and daughter-in-law Hoh Huey Jiu

Teoh Lay Hock.

UPCOMING EVENTS

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2007–2009: The International Year of Planet Earth (IYPE). Contact: website: http://www.esfs.org/index.htm or www.yearofplanetearth.org.

March 17-21, 2008: Basic Drilling, Completion and Workover Operations, Kuala Lumpur, Malaysia. Contact: Petroskills, P.O. Box 35448, Tulsa, Ok 74153-0448, USA. Tel: +1 918 828 2500; Fax: 918 828 2580; email: training@petroskills.com

March 31-April 4, 2008: Basic Geophysics, Miri, Malaysia. Contact: Petroskills, P.O. Box 35448, Tulsa, Ok 74153-0448, USA. Tel: +1 918 828 2500; Fax: 918 828 2580; email: training@petroskills.com

April 01-04, 2008: The 3rd International Conference on Geotechnical & Geophysical Site Characterization, Taipei International Convention Center, Taiwan. Contact: Ms. Zoe Chang, 10F-2, No. 51, Sungjiang Road, Taipei, 104 Taiwan. Tel: +886 2 2504 4338 ext 15; Fax: +886 2 2504 4362; email: zoe329@elitepco.com.tw

April 7-11, 2008: Avo, Inversion and Attributes: Principles and Applications, Kuala Lumpur, Malaysia. Contact: Petroskills, P.O. Box 35448, Tulsa, Ok 74153-0448, USA. Tel: +1 918 828 2500; Fax: 918 828 2580; email: training@petroskills.com

May 22, 2008: Hydrogeology meets Hydroecology, Burlington House, London, UK. Registration details obtainable from www.geolsoc.org.uk

May 27-29, 2008: 32nd Annual IPA Convention & Exhibition, Jakarta Convention Center, JCC, Indonesia. Contact: 32nd Annual IPA Convention & Exhibition, Wisma Kyoei Prince, 17th Floor (Suite 170), Jl. Jendral Sudirman Kav. 3, Jakarta 10220, Indonesia. Tel: 62 21 5724161; Fax: 62 21 5724159; email: tpc_ipa@biz.net.id

May 30-June 2, 2008: The 2nd International Conference on Geotechnical Engineering for Disaster Mitigation and Rehabilitation (GEDMAR08), Nanjing, China. Contact: Dr. A. Deng, Dr. T. Zhang, GeoHohai, Hohai University, 1 Xikang Road, Nanjing 210098, China. Tel: +86 25 8378 7917; Fax: +86 25 8371 3073; email: GEDMAR08@hhu.edu.cn; web: www.GeoHohai.com/GEDMAR08

May 12-13, 2008: Exploiting Geoscience Collections. A joint meeting between the Geoscience Information Group and the Geological Curators Group. Contact: Jeremy Giles, National Geoscience Data Centre, British Geological Survey, Keyworth, Nottingham NG12 5GG, UK. Tel: +44 (0) 1159363220; email: jrag@bgs.ac.uk

May 27-29, 2008: 32nd Annual IPA Convention & Exhibition, Jakarta Convention Center, JCC, Indonesia. Contact: Technical Committee Secretariat, Wisma Kyoei Prince, 17th Floor (Suite 1701), Jalan Jendral Sudirman Kav. 3, Jakarta 10220, Indonesia. Phone: (62-21) 5724161/4282/4285/4286; Fax: (62-21) 5724159/ 4259; email: tpc_ipa@biz.net.id

May 30-June 2, 2008: 1st International Conference on Long Time Effects and Seepage Behavior of Dams (LTESBD08), Hohai University, Nanjing, China. Contact: Dr. Domenico Gallipoli, Tel: 44 141 330 3927 (direct); 44 141 330 4077 (secret); Fax: 44 141 330 4557; email: Gallipoli@civil.gla.ac.uk; website: http://LTESBD08.hhu.edu.cn

June 1-3, 2008: National Geoscience Conference 2008: Geoconservation, Geotourism and Geohazard, Ipoh, Perak, Malaysia. Contact: Geological Society of Malaysia, c/o Dept. of Geology, University of Malaya, Kuala Lumpur, Malaysia. Tel: 603 79577036; Fax: 603 79563900; email: geologi@po.jaring.my.

June 9-13, 2008: Mapping Subsurface Structures, London, U.K. Contact: Petroskills, P.O. Box 35448, Tulsa, Ok 74153-0448, USA. Tel: +1 918 828 2500; Fax: 918 828 2580; email: training@petroskills.com

June 16-20, 2008: Structural Styles in Petroleum Exploration, London, U.K. Contact: Petroskills, P.O. Box 35448, Tulsa, Ok 74153-0448, USA. Tel: +1 918 828 2500; Fax: 918 828 2580; email: training@petroskills.com

June 30-July 4, 2008: 10th International Symposium on Landslides & Engineered Slopes, Xi'an, China. Contact: website: www.landslide.iwhr.com

July 2-3, 2008: International Conference on Flood Recovery Innovation and Response, FRIAR 2008, Institution of Civil Engineers, London, UK. Contact: Kimberley Robberts, Conference Secretariat, FRIAR 2008, Wessex Institute of Technology, Ashurst Lodge, Ashurst, Southampton SO40 7AA, UK. Tel: 44 238 029 3223; Fax: 44 238 029 2853; email: krobberts@wessex.ac.uk

July 7-11, 2008: Operations Geology, Kuala Lumpur, Malaysia. Contact: Petroskills, P.O. Box 35448, Tulsa, Ok 74153-0448, USA. Tel: +1 918 828 2500; Fax: 918 828 2580; email: training@petroskills.com

July 14-18, 2008: Basic Petroleum Engineering Practices, Kuala Lumpur, Malaysia. Contact: Petroskills, P.O. Box 35448, Tulsa, Ok 74153-0448, USA. Tel: +1 918 828 2500; Fax: 918 828 2580; email: training@petroskills.com

July 21-25, 2008: Introduction to Seismic Stratigraphy: A Basin Scale Regional Exploration Workshop, Kuala Lumpur, Malaysia. Contact: Petroskills, P.O. Box 35448, Tulsa, Ok 74153-0448, USA. Tel: +1 918 828 2500; Fax: 918 828 2580; email: training@petroskills.com

July 21-25, 2008: Sandstone Reservoirs, Kuala Lumpur, Malaysia. Contact: Petroskills, P.O. Box 35448, Tulsa, Ok 74153-0448, USA. Tel: +1 918 828 2500; Fax: 918 828 2580; email: training@petroskills.com

August 4-8, 2008: Well Log Interpretation, Kuala Lumpur, Malaysia. Contact: Petroskills, P.O. Box 35448, Tulsa, Ok 74153-0448, USA. Tel: +1 918 828 2500; Fax: 918 828 2580; email: training@petroskills.com

August 5-14, 2008: 33rd International Geological Congress (IGC), Lillestrom, Oslo, Norway, on behalf of five Nordic countries (Norden) – Denmark (including the Faeroe Islands and Greenland), Finland, Iceland, Norway and Sweden. Website: www.33igc.org

August 11-15, 2008: Shaly Sand Petrophysics, Kuala Lumpur, Malaysia. Contact: Petroskills, P.O. Box 35448, Tulsa, Ok 74153-0448, USA. Tel: +1 918 828 2500; Fax: 918 828 2580; email: training@petroskills.com

August 25-28, 2008: Carbonate Petrophysics, Kuala Lumpur, Malaysia. Contact: Petroskills, P.O. Box 35448, Tulsa, Ok 74153-0448, USA. Tel: +1 918 828 2500; Fax: 918 828 2580; email: training@petroskills.com

August 25-29, 2008: Advanced Drilling Engineering, Kuala Lumpur. Contact: HOT Engineering GmbH, Roseggerstrasse 17, A-8700 Leoben, Austria. Tel: +43 3842 43053-33; Fax: +43 3842 43053-1, email: training@hoteng.com; website: www.hoteng.com

September 1-4, 2008: XIIIth IWRA World Water Congress, Montpellier, France. Contact: email: wwc2008@msem.univ-montp2.fr; website: wwc2008.msem.univ-montp2

September 3-5, 2008: 2nd International Workshop on Geotechnics of Soft Soils: Focus on Ground Improvement. Contact: AMGISS Secretariat, c/o Dept. of Civil Engineering, John Anderson Building, University of Strathclyde, Glasgow G4 0NG, Scotland, UK. Tel: 44 141 548 3277; Fax: 44 141 553 2066, email: amgiss@strath.ac.uk; web: www.iwgss.org/ or www.cc.strath.ac.uk/amgiss/

September 15-19, 2008: Carbonate Reservoirs, London, U.K. Contact: Petroskills, P.O. Box 35448, Tulsa, Ok 74153-0448, USA. Tel: +1 918 828 2500; Fax: 918 828 2580; email: training@petroskills.com

September 17-19, 2008: PUrE Conference 2008: International Conference on Impacts of Pollution in a Changing Urban Environment, The University of Manchester, UK. web: www.pureconference.org.uk

September 22-26, 2008: Sequence Stratigraphy: An Applied Workshop, London, U.K. Contact: Petroskills, P.O. Box 35448, Tulsa, Ok 74153-0448, USA. Tel: +1 918 828 2500; Fax: 918 828 2580; email: training@petroskills.com

September 29-October 3, 2008: Petroleum Geochemistry: Tools for Effective Exploration and Development, London, U.K. Contact: Petroskills, P.O. Box 35448, Tulsa, Ok 74153-0448, USA. Tel: +1 918 828 2500; Fax: 918 828 2580; email: training@petroskills.com

October 1-6, 2008: 12th International Conference: Computer Methods & Advances in Geomechanics, Goa, India. Contact: email: dns@civil.iitb.ac.in; website: www.12iacmag.com/

October 6-10, 2008: Turbidite Sandstones, London, U.K. Contact: Petroskills, P.O. Box 35448, Tulsa, Ok 74153-0448, USA. Tel: +1 918 828 2500; Fax: 918 828 2580; email: training@petroskills.com

October 6-10, 2008: Foundations of Petrophysics, Kuala Lumpur, Malaysia. Contact: HOT Engineering GmbH, Roseggerstrasse 17, A-8700 Leoben, Austria. Tel: +43 3842 43053-33; Fax: +43 3842 43053-1, email: training@hoteng.com; website: www.hoteng.com

October 8-10, 2008: 8th International Hydrogeological Congress of Greece, Athens, Greece. Contact: email: hydrogeology@aua.gr; website: http://iah-hellas.geol.uoa.gr/

October 20-22, 2008: Characterisation of Oil and Gas Reservoirs with Neural Network Technology, Kuala Lumpur, Malaysia. Contact: HOT Engineering GmbH, Roseggerstrasse 17, A-8700 Leoben, Austria. Tel: +43 3842 43053-33; Fax: +43 3842 43053-1, email: training@hoteng.com; website: www.hoteng.com

October 21-23, 2008: 3rd International Conference on Remediation & Management of Contaminated Land: Focus on Asia, Kuala Lumpur, Malaysia. Contact: Brownfield Asia 2008, c/o The Institution of Engineers, Malaysia, P.O. Box 223 (Jalan Sultan), 46720 Petaling Jaya, Selangor D.E., Malaysia. Tel: +603 79684001/4002; Fax: +603 79577678; email: brownfieldasia@gmail.com

October 27-31, 2008: Production Logging and Reservoir Monitoring, Kuala Lumpur. Contact: HOT Engineering GmbH, Roseggerstrasse 17, A-8700 Leoben, Austria. Tel: +43 3842 43053-33; Fax: +43 3842 43053-1, email: training@hoteng.com; website: www.hoteng.com

November 10-14, 2008: Seismic Interpretation, Kuala Lumpur, Malaysia. Contact: Petroskills, P.O. Box 35448, Tulsa, Ok 74153-0448, USA. Tel: +1 918 828 2500; Fax: 918 828 2580; email: training@petroskills.com

November 10-14, 2008: Fundamentals of Petroleum Geology, Kuala Lumpur, Malaysia. Contact: HOT Engineering GmbH, Roseggerstrasse 17, A-8700 Leoben, Austria. Tel: +43 3842 43053-33; Fax: +43 3842 43053-1, email: training@hoteng.com; website: www.hoteng.com

November 24-27, 2008: The Pacific Rim: Mineral Endowment, discoveries & Exploration Frontiers (PACRIM Congress 2008), Gold Coast, Queensland, Australia. Contact: Gideon Rosenbaum – g.rosenbaum@uq.edu.au or David Giles – david.giles@adelaide.edu.au; website: www.ausimm.com.au/pacrim2008/pacrim2008_v4.pdf

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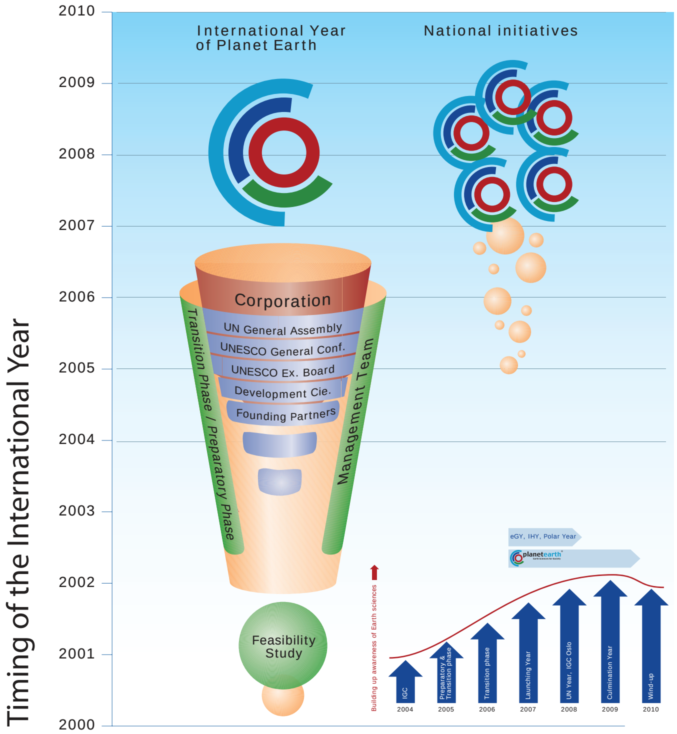

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Outreach
Examples

- Top Conferences in all continents
- Conference on indigenous geo-knowledge vs geosciences
- Balloon launches
- Geo-buses
- World Ministries of Mining Forum (2008)
- Exhibitions
- Popular books and articles
- Tours and excursions
- Teaching teachers
- TV Documentaries
- DVD on sustainable extraction
- Youth and the Earth
- Geoparks
- Olympic Games
- Stamps
- New Year Concert
- Music Symphony
- Art Competitions
- Planet Earth ringtones

Science Activities
Examples

- Google Earth 3D
- Transparent Earth: 1:1M digital map of the world
- International Science Congresses
- Wikipedia Quality label for Medical Geology
- International Consortium on Urban Geoscience
- Design for underground cities
- Research grants for students in LDC's
- New member in Nature family: Journal on Earth Sciences

PERSATUAN GEOLOGI MALAYSIA

GEOLOGICAL SOCIETY OF MALAYSIA

PP 3279/2/2007 ISSN 0126-6187

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"Fold Mullion in the Mersing Beds, Tanjung Balau, Johor."

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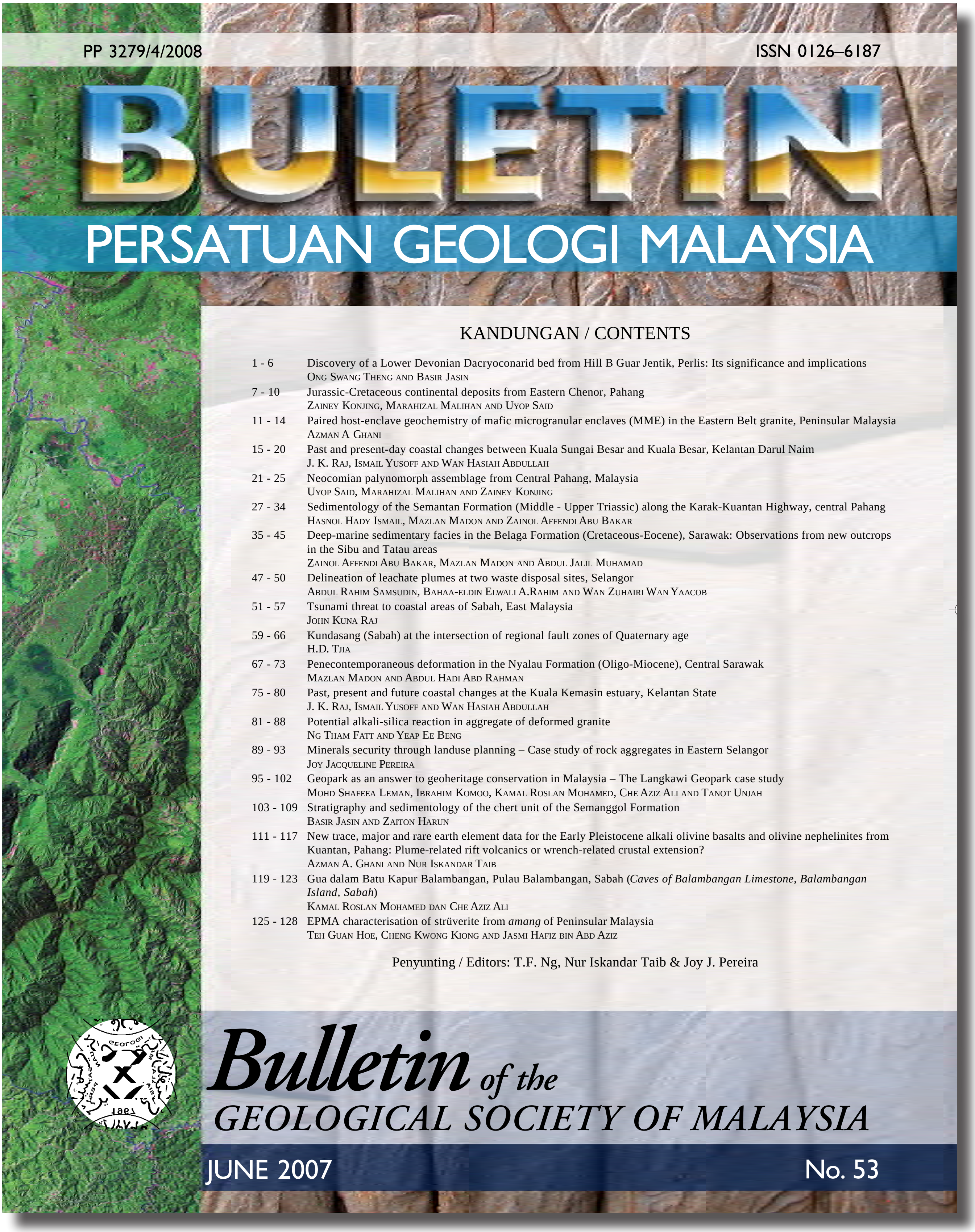

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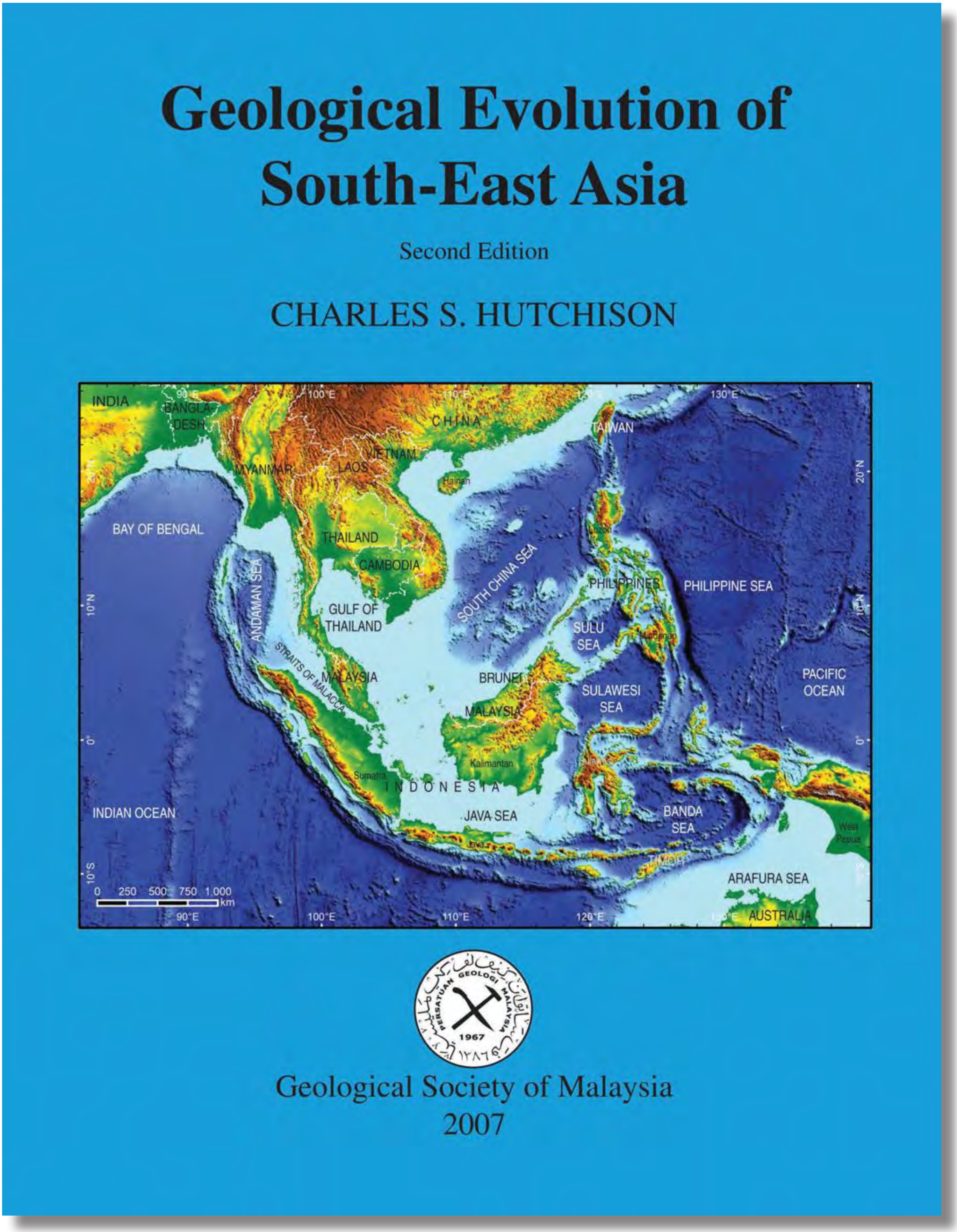

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Bulletin 2 (Dec 1968). 152 p. Bibliography and Index of the Geology of West Malaysia and Singapore by D.J. Gobbett. Price: RM5.00.

Bulletin 3 (Mar 1970). 146 p. Papers in Geomorphology and Stratigraphy (with Bibliography supplement). Edited by P.H. Stauffer. Price: RM5.00.

Bulletin 4 (Jun 1971). 100 p. Papers in Petrology, Structure and Economic Geology. Edited by P.H. Stauffer. Price: RM5.00.

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Bulletin 13 (Dec 1980). 111 p. A collection of papers on geology of Malaysia and Thailand. Edited by G.H. Teh. Price RM5.00.

Bulletin 17 (Dec 1984). 371 p. A collection of papers on geology. Edited by G.H. Teh. Price: RM10.00.

Bulletin 18 (Nov 1985) 209 p. Special issue on Petroleum Geology. Edited by G.H. Teh. & S. Paramanathan. Price: RM15.00.

Bulletins 19 (Apr 1986) & **20** (Aug 1986). GEOSEA V Proceedings Vols. 1 & 11. Fifth Regional Congress on Geology, Mineral and Energy Resources of SE Asia. Kuala Lumpur, 9-13 April 1984. Edited by G.H. Teh & S. Paramanathan. Price for both bulletins 19 & 20: Members: RM30.00: Non-members: RM60.00

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Bulletin 29 (Jul 1991). 255 p. A collection of papers presented at GSM Annual Geological Conference 1990 and others. Edited by G.H. Teh. Price: RM10.00

Bulletin 30 (Apr 1992). 90 p. Annotated bibliography of the geology of the South China Sea and adjacent parts of Borneo by N.S. Haile. Edited by G.H. Teh. Price: RM10.00.

Bulletin 31 (Jul 1992). 176 p. A collection of papers presented at GSM Annual Geological Conference 1991 and others. Edited by G.H. Teh. Price: RM10.00.

Bulletin 32 (Nov 1992). 283 p. Special issue on Petroleum Geology Vol. VII. Edited by G.H. Teh. Price: RM30.00.

Bulletin 33 (Nov 1993). 419 p. Proceedings Symposium on Tectonic Framework and Energy Resources of the Western Margin of the Pacific Basin. Edited by G.H. Teh. Price: RM40.00.

Bulletin 34 (Dec 1993). 181 p. Bibliography and Index – Publications of the Geological Society of Malaysia 1967-1993. Compiled by T.F. Ng. Edited by G.H. Teh. Price: RM20.00.

Bulletin 36 (Dec 1994). 186 p. Special issue on Petroleum Geology Vol. VIII. Edited by G.H. Teh. Price: RM50.00.

Bulletin 37 (Jul 1995). 506 p. Proceedings AAPG-GSM International Conference 1994. Southeast Asian Basins: Oil and Gas for the 21st Century. Edited by G.H. Teh. Price: RM60.00.

Bulletin 38 (Dec 1995). 190 p. A collection of papers presented at GSM Annual Geological Conference 1994 and others. Edited by G.H. Teh. Price: RM30.00.

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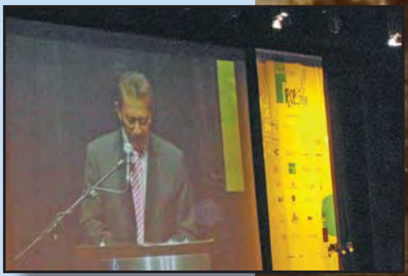

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